Department
for Environment
Food & Rural Affairs

fera

FIELD GUIDE TO INVASIVE ALIEN PLANT PESTS IN THE CARIBBEAN UK OVERSEAS TERRITORIES

PART 4 – HEMIPTERA (Bugs)

Chris Malumphy, Sharon Reid, Rachel Down, Jackie Dunn
and Debbie Collins

FIELD GUIDE TO INVASIVE ALIEN PLANT PESTS IN THE CARIBBEAN UK OVERSEAS TERRITORIES

Part 4 Hemiptera (Bugs)

Chris Malumphy, Sharon Reid, Rachel Down, Jackie Dunn and Debbie Collins

Second Edition

Fera Science Ltd., National Agri-food Innovation Campus, Sand Hutton, York, YO41 1LZ, United Kingdom

https://fera.co.uk/

Published digitally: April 2018.

Second edition published digitally: April 2019.
Divided into 6 parts to enable easier download

Suggested citation: Malumphy, C., Reid, S., Down, R., Dunn., J. & Collins, D. 2019. Field Guide to Invasive Alien Plant Pests in the Caribbean UK Overseas Territories. 2nd Edition. Part 4 – Hemiptera (Bugs). Defra/Fera. 43 pp.

Frontispiece

Top row: Giant African land snail *Lissachatina fulica* © C. Malumphy; Mediterranean fruit fly *Ceratitis capitata* © Crown copyright; Sri Lankan weevil, *Myllocerus undecimpustulatus undatus* adult © Gary R. McClellan. Second row: Cactus moth *Cactoblastis cactorum* caterpillar © C. Malumphy; Cottony cushion scale *Icerya purcashi* © Crown copyright; Red palm mite *Raoiella indica* adults © USDA. Third row: Tomato potato psyllid *Bactericera cockerelli* © Fera; Cotton bollworm *Helicoverpa armigera* © Crown copyright; Croton scale *Phalacrococcus howertoni* © C. Malumphy. Bottom row: Red palm weevil *Rhynchophorus ferrugineus* © Fera; Tobacco whitefly *Bemisia tabaci* © Crown copyright; Brown marmorated stink bug *Halyomorpha halys* © David R. Lance, USDA APHIS PPQ, Bugwood.org.

Contents

PART 4 – HEMIPTERA (Bugs)

PART 5 – HEMIPTERA (Scale insects)

HEMIPTERA

6.20 Solanum or Pepper Whitefly

Order: Hemiptera
Family: Aleyrodidae
Species: *Aleurotrachelus trachoides* (Back)

	Present l	Threat		
	Absent ¡	Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	l			
Cay	l			
Mon	¡			ü
TCI	l			

Figure 6.20.1 Solanum whitefly, *Aleurotrachelus trachoides* adults and larvae infesting American black nightshade (*Solanum americanum*), British Virgin Islands © C. Malumphy

Background

The Solanum or Pepper whitefly *Aleurotrachelus trachoides* was described from specimens collected on Brazilian nightshade (*Solanum seaphorthianum*) in Cuba and has since been found to occur widely in the Neotropical Region. In recent decades it has significantly increased its geographical distribution due to being spread by man with international trade (EPPO, 2015a). It now occurs in North America, the Pacific, West Africa and South-East Asia. Within the UK Overseas Territories, *A. trachoides* has recently been found in the British Virgin Islands, Cayman Islands and Turks and Caicos Islands, mostly on pepper (*Capsicum* spp.) and tomato (*Solanum lycopersicum*). It poses a potential economic plant health risk to all the UKOTs with tropical climates.

Geographical Distribution

Solanum whitefly is native to the Neotropical region but has a history of moving internationally in trade. It was introduced to Tahiti in the 1930s or earlier but has only become widespread in the Pacific over the last 30 years. It was reported from Florida (USA) in 1994 *(*Mead, 1994). It has also been introduced to West Africa (Malumphy, 2005), India and South-East Asia.

Figure 6.20.2 *Aleurotrachelus trachoides* adult female on pepper (*Capsicum annuum*), USA © Vivek Kumar, University of Florida

Figure 6.20.3 *Aleurotrachelus trachoides* puparia on sweet potato (*Ipomoea batatas*), Gambia; the puparia are black but are often hidden beneath a layer of wax © Fera

Figure 6.20.4 *Aleurotrachelus trachoides* on tomato (*Solanum lycopersicum*), TCI © C. Malumphy

Figure 6.20.5 Capsicum crop damaged by *Aleurotrachelus trachoides*, Martinique © Philippe Ryckewaert – CIRAD, Martinique

Figure 6.20.6 Pepper plant infested with *Aleurotrachelus trachoides* exhibiting poor growth, chlorosis and leaf curling, TCI © C. Malumphy

Figure 6.20.7 Solanum whitefly, *Aleurotrachelus trachoides* adults and larvae infesting an outdoor pepper crop (*Capsicum annuum*), TCI © C. Malumphy

Figure 6.20.8 Solanum whitefly *Aleurotrachelus trachoides and tobacco whitefly Bemisia tabaci, infesting* tomato (*Solanum lycopersicum*), BVI © C. Malumphy

Figure 6.20.9 Tomato (*Solanum lycopersicum*) foliage showing chlorosis and necrosis due to infestation of solanum whitefly *Aleurotrachelus trachoides and tobacco whitefly Bemisia tabaci, BVI* © C. Malumphy

In the Caribbean it has been recorded from Antigua and Barbuda, Bahamas, Barbados, British Virgin Islands, Cayman Islands, Cuba, Dominica, Dominican Republic, Guadeloupe, Haiti, Jamaica, Martinique, Netherlands Antilles (Curaçao), Puerto Rico, Saint Lucia, Trinidad and Tobago, Turks and Caicos Islands and the US Virgin Islands.

Host Plants

Solanum whitefly is broadly polyphagous, feeding on plants belonging to at least 33 families, and exhibits a preference for plants in the family Solanaceae. Hosts include nine major crop hosts: celery (*Apium graveolens*)*;* sweet pepper (*Capsicum annuum*)*;* chili pepper (*Capsicum frutescens*); sweet potato (*Ipomoea batatas*)*;* tobacco (*Nicotiana tabacum*)*;* avocado (*Persea americana*)*;* rose (*Rosa* sp.); tomato (*Solanum lycopersicum*); and eggplant (*Solanum melongena*).

Description

Aleurotrachelus trachoides adults (Fig. 6.20.2) are white, covered with a white powdery wax, and 1-2 mm in length. The puparia (fourth-larval instar) are elliptical, black (Fig. 6.20.3), about 1.0 mm in length with a long marginal white wax fringe and they are often covered by the first, second and third-instar exuviae (Fig. 6.20.3). The puparia occur in dense colonies that smother the under surfaces of the foliage with puparia, wax secretions and honeydew, on which sooty moulds grow. Although the puparia are black, infestations appear white due to a covering of cottony wax (Figs 6.20.1, 6.20.3 and 6.20.7). *Aleurotrachelus* is one of the largest genera of whiteflies and currently contains 74 species (Evans, 2008; Martin & Mound, 2007). There is no comprehensive key for their identification. The black puparia need to be bleached and slide mounted before they can be identified (Walker, 2008b).

Biology

Like all whitefly, the development of *A. trachoides* involves six stages: egg, four larval instars and the adult. Females lay tiny, translucent, oblong eggs on the undersides of leaves (Fig. 6.20.2), which turn yellow to greyish-brown as they mature. The life cycle (egg to adult) takes approximately 29 days at 25±1°C; eggs take an average of eight days to hatch, seven days for first instars to moult into second instars, six days for second instars to moult into third instars, four days for third instars to moult into fourth instars (puparium), and four days for the adult to emerge (Kumar *et al*., 2016).

Dispersal and Detection

The main natural dispersal stage is the winged adult although they are relatively weak fliers and can only fly over short distances. They readily fly when disturbed and are easily transported by air currents or on workers clothes. Long distance dispersal is by infested plants being moved in plant trade. Infestations of *A. trachoides* are highly conspicuous due to the cottony wax and are easily detected by examining the lower surfaces of the foliage. Infested plants exhibit chlorosis, poor growth and leaf curling (Fig. 6.20.6) and severe infestations can cause significant necrosis and leaf loss (Fig. 6.20.5-6.20.9). It is however, very difficult to detect the eggs and early instars during phytosanitary inspections.

Economic and other Impacts

Solanum whitefly feeds on leaves and young shoots, but fruit can also be attacked. Direct damage is caused by larvae and adults removing large quantities of sap. Symptoms may include plant stunting, leaf loss, and lower fruit production. Indirect damage is caused by sooty moulds developing on honeydew egested by the insect. This may reduce photosynthesis and gas exchange, as well as the aesthetic and economic value of the plants. It is an economic pest of chillies, peppers, sweet potatoes, tomatoes and yams but is not known to be a virus vector.

6.21 Tobacco or Sweet Potato Whitefly

	Present l / Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	l			
Cay	l			
Mon	l			
TCI	¡			ü

Order: Hemiptera
Family: Aleyrodidae
Species: *Bemisia tabaci* (Gennadius) species complex

Figure 6.21.1 Tobacco whitefly *Bemisia tabaci* puparium (left) and adult (right) © Fera

Background

Tobacco whitefly, *Bemisia tabaci* (Fig. 6.21.1) is one of the most economically important agricultural and horticultural pests in the World, due in part to its broad polyphagy, prodigious reproductive capacity, adaptability, and ability to vector more than 110 plant pathogenic viruses (Global Invasive Species Database, 2017, and references cited therein). It has many common names including Tobacco whitefly, Silver leaf whitefly and Sweet potato whitefly. It is not a single species but a complex of many morpho-cryptic taxa that are only distinguishable at the molecular level and the taxonomy has not yet been resolved. This is significant because different 'biotypes' or 'species' within the complex vary in biological characteristics such as host preferences, ability to vector viruses and pesticide resistance. Until recently, *B. tabaci* was considered to only be a pest of field crops in tropical and sub-tropical regions, but is now widely distributed under glass in temperate areas.

Bemisia tabaci poses a significant economic plant health risk to all the UKOTs. It has the potential to have a highly detrimental impact on vegetable production because of the risk of virus transmission, for example, Tomato yellow leaf curl virus (TYLCV) (Fig. 6.21.2) on tomato and Cucurbit yellow stunting disorder virus (CYSDV) (Fig. 6.21.3) on melon.

Geographical Distribution

Bemisia tabaci is suspected of being native to India but the evidence is inconclusive, and it now occurs worldwide in tropical and subtropical regions, and on indoor or protected plantings in temperate regions (CABI, 2017; Evans, 2008).

Figure 6.21.2 TYLCV symptoms on tomato © D. Blancard, INRA

Figure 6.21.3 CYSDV symptoms on melon © http://www.nacaa.com

Figure 6.21.4 *Bemisia tabaci* eggs © Fera

Figure 6.21.5 *Bemisia tabaci* pupa © Fera

Figure 6.21.6 *Bemisia tabaci* adult © Fera

Figure 6.21.7 Mixed population of whitefly on tomato**:** *Trialeurodes vaporariorum* puparia and one *Bemisia tabaci* puparium (indicated by the arrow) © Fera

Host Plants

Bemisia tabaci feeds on an extremely wide range of host plants (800+ species assigned to 90+ families), and the number of recorded hosts is continually increasing. They include crops grown outside in the tropics and sub-tropics e.g. cassava (*Manihot esculenta*), cotton (*Gossypium* spp.), sweet potato (*Ipomoea batatas*), tobacco (*Nicotiana* spp.), pepper (*Capsicum* spp.) and tomato (*Solanum lycopersicum*), and numerous ornamental plants.

Description

Bemisia tabaci adults (Figs 6.21.1 and 6.21.6) are about 1 mm long; males are slightly smaller than females. The body and both pairs of wings are covered with a white, powdery, waxy secretion. The wings are held tent-like above the body and slightly apart, so that the yellow body is apparent. The eggs (Fig. 6.21.4) are oval, pale brown in colour, with a stalk at the base, approximately 0.2 mm long. They are usually laid randomly on the under-surface of leaves, either singly or in scattered small groups, although they may form partial circles on smooth leaves, e.g. on *Ficus*. The early larval-instars are yellow-white scales, 0.3-0.6 mm long. The fourth-larval instar (Figs 6.21.1 and 6.21.5), known as the puparium or pupa, is oval, narrowing posteriorly, and about 0.7 mm long. On a smooth leaf the puparium lacks enlarged dorsal setae, but if the leaf is hairy or densely covered in whitefly, two to eight long dorsal setae are present. *Bemisia tabaci* is frequently found in with other whitefly species such as glasshouse whitefly (*Trialeurodes vaporariorum*) (Fig. 6.21.7).

Biology

All whiteflies have six developmental stages: egg, four larval instars, and the adult. Each female lays up to 160 eggs. Hatching occurs after 5-9 days at 30°C, depending on host species and humidity. The first instar or 'crawler' is flat, oval and scale-like, and is the only mobile larval stage. It moves to a suitable feeding site where it moults and becomes sessile throughout the remaining larval stages. The first three nymphal stages last 2-4 days each whereas the fourth larval stage or puparium lasts for about 6 days, depending on the temperature. The adult emerges through a 'T'-shaped rupture in the pupal case and expands its wings before powdering itself with wax from glands on the abdomen. Mating begins 12-20 hours after emergence and takes place several times throughout the life of the adult. Female adults may live for 60 days, males live for 9 to 17 days. Up to 15 generations can occur within one year.

Dispersal and Detection

Adult *B. tabaci* do not fly very efficiently but once airborne, can be transported quite long distances by the wind. All stages of the pest are liable to be carried on planting material and cut flowers of host species. The international trade in poinsettia is considered to have been a major means of dissemination of *B. tabaci* within Europe. Detecting the eggs and larval stages of *B. tabaci* at low densities can be very difficult due to their small size and cryptic habits. The white waxy adults may be observed on the upper surfaces of foliage or on the growing points. The larvae, particularly the yellow puparia may be observed on the lower surface of the foliage. The adult whitefly can be readily caught on yellow sticky traps and this is the main tool for monitoring outbreaks of *B. tabaci*.

Economic and other Impacts

Bemisia tabaci is one of the most economically important agricultural and horticultural pests in the world. It causes damage directly by feeding and indirectly by honeydew egestion and virus transmission. Feeding by adults and larvae causes chlorotic spotting, growth distortion, and premature leaf drop. The honeydew egested by the feeding larvae covers the surface of the foliage and fruit and serves as a medium for the growth of sooty moulds. This reduces the photosynthetic potential of the infested plant. Honeydew and moulds also disfigure and lower the market value of fruit and flowers. However, it is the viruses vectored by *B. tabaci that have the greatest economic impact. Bemisia tabaci* vectors plant viruses in the genera *Geminivirus*, *Begomovirus*, *Closterovirus*, *Nepovirus*, *Carlavirus*, and *Potyvirus*. These can cause total failure of susceptible crops.

6.22 Cardin's Whitefly

Order: Hemiptera
Family: Aleyrodidae
Species: *Metaleurodicus cardini* (Back)

	Present l Absent ¡	Threat Bio	 Hlth	 Econ
Ang	¡			ü
Ber	l			
BVI	¡			ü
Cay	l			
Mon	¡			ü
TCI	l			

Figure 6.22.1 *Metaleurodicus cardini* colony on *Erithalis fruticosa* in the Turks and Caicos Islands © C. Malumphy

Background

Cardin's whitefly, *Metaleurodicus cardini*, is a polyphagous pest that damages plants both directly by its feeding and indirectly due to the associated sooty moulds that grow on the honeydew egested by the insect. It was originally described from specimens collected in Cuba and has been recorded from several islands in the Caribbean. It has been introduced to the USA (Florida, Hawaii) where it is an occasional pest on guava (*Psidium guajava*). Hamon *et al.* (2011) produced a datasheet on this whitefly and much of the information presented here is adapted from their work.

Within the UK Overseas Territories, *M. cardini* has been recorded from Bermuda, the Cayman Islands and the Turks and Caicos Islands. Cardin's whitefly poses a plant health risk to all the UKOTs in the Caribbean.

Geographical Distribution

Metaleurodicus cardini is native to the Neotropical region although its precise origin is unknown. It has been introduced to North America and the Pacific (Evans, 2008). In the Caribbean it has been recorded from the Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, Turks and Caicos Islands and the US Virgin Islands.

Figure 6.22.2 *Metaleurodicus cardini* adults and larvae on *Psidium* © Lyle J. Buss, University of Florida

Figure 6.22.3 *Metaleurodicus cardini* adult showing a distinct characteristic spot on each wing © Lyle J. Buss, University of Florida

Figure 6.22.4 Fluffy wax trails deposited by adult females of *Metaleurodicus cardini* © Lyle J. Buss, University of Florida

Figure 6.22.5 Single egg of *Metaleurodicus cardini preserved in ethanol* © C. Malumphy

Figure 6.22.6 *Metaleurodicus cardini* puparia showing wax filaments emerging from the dorsum ©Lyle J. Buss, University of Florida

Figure 6.22.7 *Metaleurodicus cardini* puparium with most of the dorsal wax removed © C. Malumphy

Host Plants

Metaleurodicus cardini is polyphagous, feeding on host plants assigned to 14 plant families, including some crop and ornamental plants (Evans, 2008; Mound & Halsey, 1978). It shows a preference for Mrytaceae and is most frequently recorded on guava (*Psidium guajava*).

Description

The adult whiteflies are yellow with a fine dusting of white wax (Figs 6.22.1-3). Their wings are cream-coloured with a conspicuous dark spot near the centre of each wing (Fig. 6.22.3), which are easily visible with a x10 hand lens. As the adult female deposits eggs on the lower surfaces of the foliage, a fine trail of fluffy white wax (Fig. 6.22.4) is rubbed from tufts of wax on the underside of the abdomen. This wax trail is very similar to wax trails left by other whitefly species and by flatid bugs. The eggs are elongate, oval, cream, and attached to the host plant by a thin stalk (Fig. 6.22.5). The puparia (Figs 6.22.6-7) are oval, yellow, with five pairs of long wax filaments emerging from the dorsum. These wax filaments easily break off and cover the colony, giving a somewhat messy waxy appearance (Fig. 6.22.6).

Metaleurodicus is a Neotropical genus containing 11 species which can be identified using the key by Evans (2008). The puparia need to be slide-mounted first and examined under a high-power microscope. *Metaleurodicus cardini* is easily separated from other species in the genus by the presence of only four pairs of compound pores on the abdomen, whereas the other species bear five or six pairs of abdominal compound pores. Walker (2008c) provides pictures of a slide-mounted puparium of *M. cardini* showing the diagnostic characters.

Biology

All whiteflies have six developmental stages: egg; four larval stages, the fourth larval stage being known as the puparium; and the adult. There appears to be little information specifically published on the biology of *M. cardini. Several natural enemies have been recorded including hymenopterous parasitoids (Hymenoptera,* Aphelinidae*), ladybird larvae and adults (Coleoptera, Coccinellidae), hoverfly larvae (Diptera,* Syrphidae), *and lacewing larvae (Neuroptera,* Chrysopidae).

Dispersal and Detection

Adult whiteflies are winged and capable of flight, but they are poor fliers and natural dispersal is limited. The eggs and larvae may be distributed over long distances in plant trade.

Metaleurodicus cardini is most likely to be detected by inspecting the undersides of leaves for white fluffy wax trails, puparia, and adult whiteflies with a dark spot on each wing. Even low-density populations smother the lower surfaces of leaves with white wax and are highly conspicuous. The adults may also be observed on the upper surfaces of leaves, particularly at the growing tips.

Economic and other Impacts

Metaleurodicus cardini is not usually an economic pest, but occasionally huge populations develop, and it can become a serious problem, most notably on *P. guajava*. These situations usually occur when something has disrupted the complex of natural enemies that normally supress the whitefly numbers. Large populations may also be found on native plants in natural habitats, for example, on *Brysonima lucida, Erithalis fruticosa*, *Mosiera longipes*, and *Tabebuia bahamensis* in the Turks and Caicos Islands. However, the environmental impact is unknown.

6.23 Ficus Whitefly

Order: Hemiptera
Family: Aleyrodidae
Species: *Singhiella simplex* (Singh)

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	l			
Mon	¡			ü
TCI	¡			ü

Figure 6.23.1 *Singhiella simplex* adult female (left), with a dark yellow body and faint greyish bands on the wings, and mature fourth-larval instar or puparium (right), with red eye spots, on *Ficus* © C. Malumphy

Background

Singhiella simplex is an Asian whitefly that feeds exclusively on figs (*Ficus* spp.), causing damage to plants both directly by its feeding and indirectly due to the associated sooty moulds that grow on the honeydew egested by the larval stages. It is commonly known as Ficus whitefly or fig whitefly. It was originally described from specimens collected from *Ficus bengalensis* in India and has recently been introduced to North and South America, the Caribbean, and the Mediterranean. It can cause complete defoliation and dieback of branches of ornamental figs. The literature pertaining to this whitefly was recently reviewed by Kondo & Evans (2013) and much of the information in this fact sheet is based on their work. Ficus whitefly poses a plant health risk to all the UKOTs in the Caribbean.

Geographical Distribution

Singhiella simplex is native to Southeast Asia and has recently been introduced to the Americas (first recorded in Florida in 2007) and the Mediterranean. In the Caribbean it has been recorded from the Cayman Islands, Jamaica and Puerto Rico (Kondo & Evans, 2013).

Host Plants

Singhiella simplex is oligophagous on *Ficus* and exhibits a preference for weeping fig (*F. benjamina*). Host plants include: strangler fig (*F. aurea*), council tree (*F. altissima*), Indian banyan (*F. bengalensis*), *F. benjamina*, long leaf or sabre fig (*F. binnendijkii*), fiddle-leaf fig (*F. lyrata*), Cuban laurel (*F. microcarpa*), banana-leaf fig (*F. maclellandii*) and *F. racemosa* (Kondo & Evans, 2013). It has also been recorded on *Rhododendron indica* (Ericaceae) but this needs confirmation.

Figure 6.23.2 *Singhiella simplex* eggs © Fera

Figure 6.23.3 *Singhiella simplex* fourth-larval instar or puparium © Fera

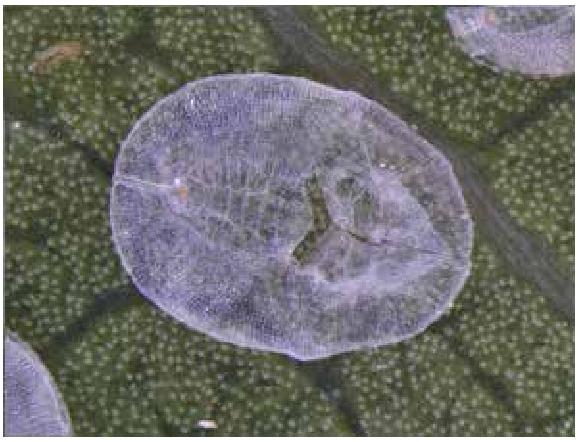

Figure 6.23.4 *Singhiella simplex* empty pupal case © Fera

Figure 6.23.5 *Singhiella simplex* pupal cases on *Ficus* © Fera

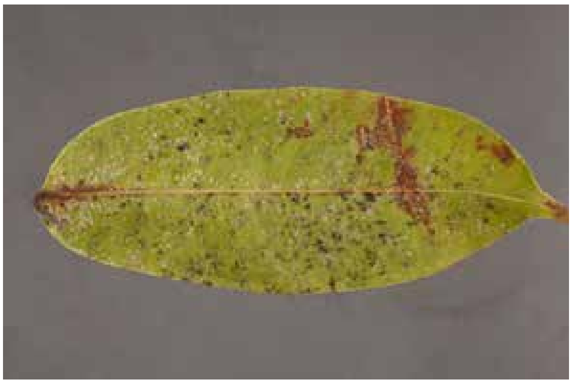

Figure 6.23.6 *Ficus binnendijkii* leaf infested with *Singhiella simplex* showing sooty mould growing on egested honeydew © Fera

Figure 6.23.7 *Ficus* hedge in Florida defoliated by *Singhiella simplex* © 2011 JP Miller & Sons Services

Description

The adult whiteflies (1.4-1.6 mm) (Fig. 6.23.1) are a deep yellow with conspicuous red eyes. Their wings are cream-coloured with faint grey bands on each wing, which are easily visible with a x10 hand lens. The adults are very active and readily fly when disturbed. The eggs are 'kidney' shaped in lateral view, yellow to light brown, and attached to the host plant by a thin stalk (Fig. 6.23.2). The eggs are laid in dense groups, mostly adjacent to the mid vein and near the base of the leaf. The first, second and third larval instars are almost translucent and difficult to spot. The puparia (1.3 mm long and 1.0 mm wide) (Figs 6.23.1 and 6.23.3-5) are oval, translucent to pale yellow, with the adult red eye spots becoming conspicuous with maturity (Figs 6.23.1 and 6.23.3). One unusual feature is that the eggs and larval stages occur on both the lower and upper surfaces of the foliage (the larval stages of most whitefly species only occur on the lower surface).

Several other whitefly species may also be found on *Ficus* in the Caribbean but none in such large populations or with the puparia on the upper leaf surface, nor with adults bearing grey bands on their forewings (Fig. 6.23.1).

Biology

All whiteflies have six developmental stages: egg; four larval stages, the fourth larval stage being known as the puparium; and the adult. The biology of *Singhiella simplex* has been recently studied by Legaspi *et al*. (2011). The total duration of the immature stages varies from 97.1 days at 15°C to 25.2 days at 30°C the adults live 8 days at 15°C, 4.2 days at 25°C, and 2.5 days at 30°C. A large number of natural enemies have been recorded for *S. simplex* including: the parasitoids *Encarsia tricolor* (Hymenoptera: Aphelinidae) (Evans, 2008; Hodges, 2007), *Encarsia protransvena* and *Amitus bennetti* (Platygastridae); the lacewing predators *Chrysopa* spp. (Neuroptera: Chrysopidae): and the ladybird predators *Harmonia axyridis* (Coleoptera: Coccinellidae), *Olla-v-nigrum*, *Exochomus children*, *Chilocorus nigritis*, and *Curinus coeruleus* (Mannion, 2010). Various enzootic pathogenic fungi have also been isolated from *S. simplex* in Florida, namely *Isaria fumosorosea*, *Paecilomyces lilacinus*, and *Lecanicillium* sp., *Fusarium* sp., and *Aspergillus* sp. (Avery *et al.,* 2011).

Dispersal and Detection

Adult whiteflies are winged and capable of flight, but they are poor fliers and natural dispersal is limited. The eggs and larvae may be distributed over long distances in plant trade.

Infestations of *S. simplex* are likely to be easy to detect since severely infested *Ficus* plants shed many of their leaves and appear defoliated (Fig. 6.23.7). They also exhibit significant chlorosis (yellowing of the leaves) and the leaves may be spotted with black sooty mould growing on the egested honeydew (Fig. 6.23.6). There may also be small clouds of tiny white, gnat-like adult whiteflies flying from the foliage which are easily observed when branches of infested plants are shaken.

Economic and other Impacts

Singhiella simplex is an economic pest of *Ficus* spp. in the USA (Florida), India, Brazil and Israel (Kondo & Evans, 2013). Feeding by the whitefly causes yellowing of leaves, severe defoliation and branch dieback, and high populations can stunt the growth of young trees. Repeated defoliation and re-growth reduces plant health. The impact in the Caribbean is potentially large due to the abundance of *Ficus* as ornamental plants. However, it is important to note that there are no published records of the whitefly attacking the edible fig *Ficus carica*.

6.24 Black Citrus Aphid

Order: Hemiptera
Family: Aphididae
Species: *Aphis* (*Toxoptera*) *citricidus* (Kirkaldy)

	Present l Absent ¡	Threat Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	l			
Cay	l			
Mon	¡			ü
TCI	¡			ü

Figure 6.24.1 Adult black citrus aphid *Aphis citricidus* on *Citrus* sp. in India © Poorani Janakiraman

Background

The black citrus aphid, brown citrus aphid or tropical citrus aphid, *Aphis* (*Toxoptera) citricidus*, is one of the world's most serious pests of citrus. Published literature on the pest frequently refer to it under the synonym, *Toxoptera citricida*. The aphid causes feeding damage to citrus, living in ant-attended colonies on young growth (unexpanded and young expanded leaves and flower buds) of host plants, rolling leaves and stunting shoots. More significantly, it is even more of a threat to citrus because it is the most efficient vector of citrus tristeza virus (CTV). One of the most devastating citrus crop losses ever reported followed the introduction of black citrus aphid into Brazil and Argentina: 16 million citrus trees on sour orange rootstock were killed by CTV (Carver, 1978).

Geographical Distribution

Aphis (*Toxoptera*) *citricidus* is native to southern Asia but spread to many tropical and subtropical parts of the world with the movement of Citrus plants or leaves. In the early 20th century it was known to be widely distributed in India, New Zealand, Australia, the Pacific Islands, Africa south of the Sahara, Madagascar, the Indian Ocean Islands and South America. In the mid-1990s and early 2000s it spread to North America (Florida), Central America and the Caribbean Basin (Yokomi, 1994), and Europe (Madeira, Portugal and north-western Spain). It thrives in a moist warm climate, but it is not found in regions with long hot dry seasons (Blackman & Eastop, 2006).

Figure 6.24.2 Adult *Aphis citricidus* apterous viviparous female, slide mounted © Brendan Wray, AphID, USDA APHIS ITP, Bugwood.org

Figure 6.24.3 Adult *Aphis citricidus* apterous viviparous females and nymphs © Poorani Janakiraman

Figure 6.24.4. Alate and apterous *Aphis citricidus* © Bayer Pflanzenschutz, Bayer Pflanzenschutz, Bugwood.org

Figure 6.24.4 Citrus tristeza virus symptoms on Citrus sp. © Florida Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Bugwood.org

Host Plants

The primary hosts of black citrus aphid are *Citrus* species and related hosts in the family Rutaceae. While commercial *Citrus* varieties and rootstocks are the preferred hosts, other common hosts include calamondin (x *Citrofortunella microcarpa*), orange jessamine (*Murraya paniculata*), rough lemon (*Citrus jambhiri*), sour orange (*C. auranticum*), box orange (*Severinia buxifolia*) and lime berry (*Triphasia trifolia*) (CABI, 2017). The aphid can survive on some non-rutaceous hosts temporarily as they migrate away from a crowded food source. Although Rutaceae are the preferred hosts, large colonies of apterae are often found on very different plants including *Pyracantha* in Malawi and Zimbabwe; *Cudramia* in China and Australia; *Camellia sinensis* in the Seychelles; and *Maclura* in Java (Blackman & Eastop, 2006). A detailed host list is provided in a review by Michaud (1998).

Description

Adults are shiny-dark brown to black and nymphs are brown. Winged adult females (alates) are 1.1-2.6 mm in length. Wingless adult females (apterae) are 1.5-2.8 mm in length. Detailed morphological descriptions are provided by Blackman & Eastop (2013) and CABI (2017). They are very similar in appearance to other *Aphis* species found on *Citrus* and mixed colonies of two or more species may occur. Adult specimens should be slide mounted for accurate determination.

Biology

In most parts of the world, black citrus aphid is permanently anholocyclic, meaning that there is no sexual cycle and thus, no males, no oviparae, and no eggs. All individuals throughout the year are viviparous parthenogenetic females. Japanese populations are an exception, as there is a recorded sexual phase on *Citrus* (Komazaki, 1988). Populations of black citrus aphid increase very rapidly under favourable conditions, nymphs mature in six to eight days at temperatures of 20°C or higher (Komazaki, 1982). Biology studies conducted under field conditions showed that the black citrus aphid development time was 8-21 days, and there were about 30 generations per year in southern Zimbabwe (Symes, 1924).

Disease vectoring

Black citrus aphid is the most important vector of CTV, the most economically damaging disease of citrus. The aphid can acquire the virus after feeding on infected plants for 5-60 minutes; but loses the ability to transmit the virus after 24 hours (CABI, 2017).

It is also a vector of Papaya ringspot virus, Watermelon mosaic virus (CABI, 2017); Citrus vein enation (woody gall) virus, a probable luteovirus (da Garta & Maharaj, 1991); Cowpea aphid-borne mosaic virus, a potyvirus affecting groundnut in Brazil (Pio-Rebeiro *et al*., 2000); Celosia mosaic virus, a potyvirus affecting *Celosea argentea* in Nigeria (Owolabi *et al*., 1998); Chilli veinal mottle virus (Blackman & Eastop, 1984) and Soybean mosaic virus in China (Halbert & Brown, 1996).

Dispersal and Detection

Field infestations are best detected by regular visual inspections of new shoot growth of host plants and monitoring with yellow sticky traps, water traps and suction traps. Winged morphs develop when populations become crowded, and/or food source declines in quality, and disperse in search of new hosts to begin new colonies. Black citrus aphids are not strong fliers and few fly far from their parent colony (Gottwald *et al*. 1995), but can be carried long distances with wind assistance (Cabi, 2017). The most likely means of dispersal is through trade of ornamental Rutaceae and orchard stock.

Economic and other Impacts

Black citrus aphid is the most important aphid vector of CTV, a phloem-limited closterovirus. It is particularly efficient at transmitting the two most severe strains: one can cause rapid decline and death of citrus trees planted on *C. aurantium* rootstock, and the other can cause stem pitting in twigs, branches and trunks of grapefruit and sweet orange regardless of rootstock. Stem pitting CTV weakens a tree and reduces fruit size, quality and quantity.

Citrus fruits are the most important fruit tree crop in the world, with an annual production of over 120 million tonnes. Florida is a major producer of citrus, the industry is worth US$ 8.6 billion a year and generates roughly 45,000 jobs (Anon, 2018). Since the black citrus aphid was first discovered in Florida in 1995, it has posed a real and serious threat to the citrus industry (Tsai *et al*. 2009).

Disastrous epidemics of CTV have occurred in Argentina, Brazil, Colombia and Peru, more than 50 million trees on sour orange rootstock have been killed (Rocha-Pena *et al*. 1995). Garnsey *et al.* (1996) estimated that 200 million citrus trees on sour orange rootstock occur worldwide and were at immediate risk of CTV decline.

6.25 Cypress aphid

Order: Hemiptera
Family: Aphididae
Species: *Cinara cupressi* (Buckton) sensu lato

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.25.1 Cypress aphid *Cinara cupressi* apterous viviparous female on *Cupressus* spp., UK © Influentialpoints.com

Background

The cypress aphid occurs in Europe, Asia, Africa and the Americas. Commonly found on *Cupressus* spp. it can cause severe direct feeding damage resulting in dieback and sometimes death. It is highly invasive, and according to International Union for the Conservation of Nature criteria, is one of the world's 100 worst invasive alien species (*Lowe et al., 2000). The taxonomy of Cinara cupressi sensu lato is not straightforward*, Watson *et al.* (1999) observed that *C. cupressi* appears to belong to a species complex and certain populations of *C. cupressi* may in fact be distinct species (e.g. *C. sabinae* in North America and *C. cupressivora* in Africa and Western Europe). However, they cannot be satisfactorily distinguished morphologically and require molecular study to characterize the number and identities of distinct species (Remaudière & Binazzi, 2003).

Geographical Distribution

Populations of *C. cupressi* s.l. are thought to have originated from North America and the Middle East (Watson *et al.*, 1999). It spread west into Europe and later south into Africa (1980's) where it is recorded from twelve countries on the continent and Mauritius. It arrived in South America pre-1991 and is reported from Argentina, Brazil, Chile and Colombia (Fig. 6.25.2) (CABI, 2017).

Figure 6.25.2 *Cinara cupressi sensu lato* distribution map © CABI

Figure 6.25.3 Alate cypress aphid on *Xanthocyparis nootkatensis,* UK © Influentialpoints.com

Figure 6.25.4 Cypress aphid colony on a branch *Cupressus* spp., UK © Influentialpoints.com

Figure 6.25.5 Mould growing on honeydew deposited by cypress aphid on *Xanthocyparis nootkatensis* in the UK © Influentialpoints.com

Figure 6.25.6 Twig withering resulting from phloem necrosis induced by cypress aphid on *Xanthocyparis nootkatensis* in the UK © Influentialpoints.com

Host Plants

Found most commonly on *Cupressus* spp. (Fig. 6.25.4) but also on other Cupressaceae, different populations within *C. cupressi* s.l. appear to have different host preferences, for example *C. sabinae* is known almost exclusively from *Juniperus scopulorum* whereas *C. canadensis* was described on *J. virginiana*. A combined host list includes Chilean cedar (*Austrocedrus chilensis*), black cypress pine (*Callitris calcarata*), Leyland cypress (*Cupressocyparis*), Arizona cypress (*Cupressus arizonica*), gowen cypress (*C. goveniana*), Mexican cypress (*C. lusitanica*), Monterey cypress (*C. macrocarpa*), Mediterranean cypress (*C. sempervirens*), Himalayan cypress (*C. torulosa*), Patagonian cypress (*Fitzroya cupressoides*), Bermuda cedar (*J. bermudiana*), prickly juniper (*J. oxycedrus*), African pencil cedar (*J. procera*), Rocky Mountain juniper (*J. scopulorum*), eastern redcedar (*J. virginiana*), juniper gum (*Tetraclinis articulata*), Eastern white cedar (*Thuja occidentalis*), western redcedar (*T. plicata*), sapree wood (*Widdringtonia nodiflora*) and Yellow cedar (*Xanthocyparis nootkatensis*) (CABI, 2017; Montalva *et al.*, 2010; Influential Points, 2018).

Description

Cinara cupressi wingless apterous viviparous females (Fig. 6.25.1) are orange-brown to yellowish-brown and covered with fine pale hairs. The dorsum is dusted with pale grey wax making a pattern of cross-bands: two dark wavy longitudinal stripes which are close together on the thorax and diverging on the abdomen, where they merge with a broad brown-black cross-band at the level of the siphunculi. The whole aphid is clothed with fine hairs. Legs are yellowish with distal parts of the femora, knees and tips of the tibiae dark brown to black. The body length of apterae is 1.8-3.9 mm. (Blackman & Eastop, 2006; Heie, 1995).

The winged alatae (Fig. 6.25.3) have a dark thorax, and abdomen very similar to the apterae. The oviparous females are much like the apterae, they are 3.7-3.9 mm, brown and shiny. Hind tibiae are slightly thickened from base to apex and have more than 100 small scent plaques (Heie, 1995).

Biology

In temperate climates, populations of cypress aphid produce sexual females and winged males in the autumn in order to produce egg laying females (oviparae); the eggs overwinter on cypress foliage and stems and hatch the following spring. During the warmer months only wingless females are present, which reproduce asexually (by parthenogenesis) giving birth to live young. Populations found in milder climates reproduce asexually all year round. Host quality and environmental conditions determine the number of generations produced per year, with up to 11 or 12 generations per year recorded in Italy (Binazzi, 1997) and eight to ten generations in Jordan (Ciesla, 1991). In parts of Africa, the wingless females, often referred to under the synonym *C. cupressivora,* tend to aggregative in dense colonies on shady parts of the plant, and on a wide range of feeding sites from young green branches to woody stems (Kairo & Murphy, 2005). Sooty mould (Fig. 6.25.5) often develops on the honeydew they egest, which coats the foliage and nearby surfaces inhibiting photosynthesis (CABI, 2017).

Cinara cupressi, along with other *Cinara* spp., vectors a fungal disease known as Cypress Canker or Cypress Dieback, caused by one or more species of *Seiridium*. Cypress canker attacks at least 25 conifer species of the Cupressaceae family in many parts of the world, including Australia, the United States and Europe (Agriculture Victoria, 2017).

Dispersal and Detection

The natural dispersal of cypress aphids is through the flight of the winged forms, which are produced a few times each year in response to crowding and environmental cues. The winged aphids are strong fliers and may be carried for long distances by the wind (CABI, 2017). Ants feed on the honeydew produced by the aphids and have also been observed transporting the aphids from one part of the tree to another, thus creating new areas of infestation (Influential Points, 2018).

The aphids are difficult to detect as they are very well camouflaged against the tree bark and are therefore easily transported on plants for planting and missed during quarantine inspections (Ciesla, 1991; Remaudière & Binazzi, 2003). The inner and lower parts of the canopy should be examined for signs of sooty mould growth, which develops near colonies of the aphids (CABI, 2017).

Economic and other Impacts

The cypress aphid can cause severe direct feeding damage resulting in dieback and sometimes death of host conifers with associated economic, environmental and aesthetic costs. The saliva they produce is phytotoxic and leads to necrosis in the phloem subsequently resulting in the twig withering (Fig 6.25.6) Dieback usually occurs from the inner crown outward and from the lower crown upwards (Influential Points, 2018; Ciesla, 1991). Unless infestations are treated promptly, death of trees that are sensitive to the feeding of the cypress aphid will be imminent (Ciesla, 1991).

In southern and eastern African, the cypress aphid killed a total of US$ 27.5 million worth of cypress trees in 1991 and was causing a loss in annual growth increment of US$ 9.1 million per year (Murphy *et al.*, 1996). The loss of commercial plantations *C. lusitanica* in Kenya has had a serious effect on the domestic wood supply, and the presence of a large number of dead trees in rural and urban areas provides a large volume of fuel that can increase the destructive potential of wildfire (Ciesla, 1991). In Malawi, cypress aphid damages the endangered national tree, *W. nodiflora* (Ciesla, 1991) and in Chile, it is damaging endemic forest species including *A. chilensis* and *F. cupressoides* (Montalva *et al.*, 2010).

The host species most vulnerable to attach from cypress aphid in the Caribbean region is Bermuda cedar (*J. bermudiana*). Bermuda Cedar was the most dominant tree on Bermuda before the 1940s when 95% of the trees were killed by the accidental introduction of two scale insects, *Carulaspis minima* (main pest – see fact sheet 6.26) and *Lepidosaphes newsteadi*, leading to serious social, economic and ecological implications. The cedar was a valuable timber resource and of great cultural value to Bermudians, it is also a nesting habitat for birds and homes of insects and other species. Many species that were adapted to life in the cedar-dominated forest also seriously declined, such as the native bluebird and the endemic cicada, which is now extinct (D.E.N.R, Unknown). Absence of natural enemies, has allowed cypress aphid populations to increase rapidly in countries where the species has been introduced.

6.26 American Palm Cixiid

Order: Hemiptera
Family: Cixiidae
Species: *Haplaxius crudus* van Duzee

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	l			
Mon	¡			ü
TCI	¡			ü

Figure 6.26.1 *Haplaxius crudus* adult © J.D. de Filippis, University of Florida, Bugwood.org

Background

Haplaxius crudus, commonly known as American palm cixiid, is still widely known by its junior synonym *Myndus crudus*. It is native to the American tropics and subtropics and is expanding its range in the Caribbean. The adults feed mainly on palms, particularly commercially important species such as the coconut and date palms, while the nymphs feed mainly on grasses. *Haplaxius crudus* is an economically important pest as it is a vector of coconut lethal yellowing caused by *Candidatus* Phytoplasma palmae, a highly destructive disease that affects at least 37 species of palms (CABI, 2017).

Geographical Distribution

Haplaxius crudus, first described from Jamaica in 1907, is native to the American tropics and subtropics. Its current range is from northern South America, Central America, certain islands of the Caribbean, Mexico, and Florida and southern Texas in the USA. In the Caribbean it is reported native to Cuba, the Cayman Islands, Jamaica and Trinidad, and has been introduced to the Bahamas, Dominican Republic and Haiti, and to Puerto Rico as recently as 2013 (CABI, 2017).

Figure 6.26.2 Leaf yellowing symptoms of lethal yellowing on coconut palms, *Cocos nucifera* © N.A. Harrison, University of Florida

Figure 6.26.3 Coconut palms, *Cocos nucifera*, in various stages of lethal yellowing © N.A. Harrison, University of Florida

Host Plants

The adults of *H. crudus* feed predominantly on the foliage of various palm trees (Arecaceae). The major host of *H. crudus* adults is coconut palm (*Cocos nucifera*). It is also very common on Sabal palm (*Sabal palmetto*) and Manila palm (*Andonidia merrillii)*. Minor hosts include Fiji fan palm (*Pritchardia pacifica*), *Pritchardia thurstonii*, date palm (*Phoenix dactylifera*), Canary Island date palm (*Phoenix canariensis*), *Trachycarpus fortunei*, *Veitchia merrillii*, *Washingtonia robusta*, *Roystonea regia* and *Dypsis lutescens*.

Adults less commonly feed on grasses (Poaceae), for example Saint Augustine grass (*Stenotaphrum secundatum*), *Paspalum notatum, Cynodon dactylon* and *Eragrostis curvula*. Adults have been observed to visit other monocotyledonous plants e.g. *Pandanus utilis* (Pandanaceae) and *Heliconia bihai* (Heliconiaceae).

The nymphs are subterranean and develop on the roots of certain species of grasses and weeds, a few species of sedges (Cyperaceae) and one Portulacaceae growing in the vicinity of palms. Their hosts include grasses cultivated as turf or forage, particularly *S. secundatum*, but also *Andropogon bicornis*, *A. virginicus*, *Brachiaria decumbens*, *B. humidicola*, *B. mutica, Cenchrus ciliaris*, *Chloris barbata*, *Cynodon dactylon*, *Cynodon nlemfuensis*, *Cyperus esculentus*, *Cyperus ligularis*, *Digitaria eriantha*, *Digitaria abyssinica*, *Distichlis spicata*, *Eremochloa ophiuroides*, *Eustachys petraea*, *Fimbristylis cymosa*, *Leersia hexandra, Panicum laxum, Panicum maximum*, *Panicum bartowense*, *Panicum purpurascens, Paspalum notatum*, *Portulaca pilosa*, *Setaria* spp. and *Zoysia* spp. (CABI, 2017; Hernández *et al.,* 2018).

Description

Adult *H. crudus* are 4.2-5.1 mm long, with females slightly larger than males. The head and thorax of adults vary in colour from straw-coloured to light brown, and the abdomen has a greenish tinge in the pale forms. The wings are hyaline with pale veins. The eyes of the adult are light sensitive, being maroon-coloured at night and becoming straw-coloured during the day (Howard, 1981). Spines occur in clusters on the ends of the hind leg segments. There are three parallel ridges that divide the prothorax longitudinally (CABI, 2017).

There are five nymphal instars, 0.64-2.68mm long. Nymphs are light brown to grey, red on the front of the head and rostrum. The legs are also reddish, grading to bright red distally. The fore tibia are flattened, a modification for digging. The eyes are maroon and do not change colour with light intensity. The nymphs produce wax threads from glands on their abdomen and other parts of the body (CABI, 2017). Eggs are white, averaging 0.54 mm in length and 0.17 mm in width, with the anterior end asymmetrical and pointed, and the posterior end rounded (Wilson & Tsai, 1982). A key to the nymphal instars of *H. crudus* is provided by Wilson and Tsai (1982) and keys to the adult males of of *Myndus* (= *Haplaxius*) are provided in Kramer (1979). *Haplaxius crudus* is currently the only species of the family Cixiidae commonly found on palm foliage in the Caribbean region, aiding its identification in the field.

Biology

Haplaxius crudus is heterovoltine, the number of generations being affected by temperature (Halbert et al., 2014). Mature adults fly to palm foliage and feed by penetrating the tissue of the frond with their stylet and sucking the phloem. Mating occurs on the palms, and the females return to grasses to lay eggs, singly or in rows of up to five eggs on the lower fronds of grasses, near to the root collar (Howard & Wilson, 2001). Once hatched, the nymphs move underground, feeding on the roots of grasses. They exude a cottony wax which they deposit along the roots and use to form 'nests', in which they live, usually in groups of 2-10 individuals (Tsai & Kirsch, 1978). The wax is thought to protect them from moisture, disease and predators, and may also be used to coat their toxic excrement (CABI, 2017; Sforza *et al.*, 1999). When disturbed, nymphs become active and can jump about 5-10 cm (Howard and Wilson, 2001). In southern Florida, *H. crudus* adults are found throughout the year, with population peaks in March, May, September and November (Woodiel & Tsai, 1978). *Haplaxius crudus* is as a vector of coconut (or palm) lethal yellowing, '*Candidatus* Phytoplasma palmae'.

Dispersal and Detection

*A*dults disperse naturally through flight and with wind assistance, although information regarding flight ability is lacking. There are some suggestions that jump spread outbreaks of coconut lethal yellows disease occur following severe weather events such as hurricanes, which would infer log-distance movement of the vector. Smith (1997) suggests that the most likely way *H. crudus* could be spread is by the international trade of plant material. Lethal yellowing infected vegetative plant material, including ornamental species, could carry the pathogen in international trade. The vector is less likely to be carried by palms, which are infested only by the actively mobile adults, but could possibly be moved in international trade as nymphs in soil accompanying palms and grasses. *Haplaxius crudus* is a very inefficient vector of lethal yellowing, but is so abundant that a very low transmission rate is sufficient to spread the disease (Purcell, 1985).

Symptoms of the coconut lethal yellowing disease include premature drop of fruits, and the calyx end of coconuts will turn brown to black and have a water-soaked appearance. Yellowing of the foliage occurs, beginning with the oldest leaves and progressing upward through the crown. In some cases, this symptom is exhibited as a solitary, yellowed leaf ("flag leaf") in the middle of the leaf canopy. Leaves turn brown, desiccate, and hang down forming a skirt around the trunk for several weeks before falling. These symptoms coincide with death of the root tips. Death occurs in *C. nucifera* about 4-6 months after the initial symptoms appear (CABI, 2017). Since the phytoplasma is not culturable, a molecular diagnostic test is used to confirm the presence of the pathogen.

Adults cixiids can be trapped using rotary flight traps, yellow sticky traps, collected using a D-vac, or by sweeping vegetation with a net (Sforza, 1999). The adults are active during the day and night day (Howard, 1981).

Economic and other Impacts

Although the American palm cixiid does not appear to cause visible damage to its host plants, *it is considered a major pest of palms due to its* importance as a vector. The main economic impact of *H. crudus* is as a vector of coconut lethal yellowing, a highly destructive disease that affects at least 37 species of palms, including many palms that are important as ornamental plants or as local sources of food or fibre in the tropics. Since the 1980s the disease has practically eliminated coconut palms from the Caribbean coast of most of southern Mexico and much of Central America (Howard, 2015). The disease has also destroyed ornamental palms in Florida, USA (Smith *et al.*, 1997). Although Florida is not a coconut-producing area, it has suffered a socio-economic loss as a result of a destruction of hundreds of thousands of *C. nucifera* palms, an important and valuable feature of the amenity vegetation (Smith *et* al., 1997).

Texas Phoenix palm decline, similar to but genetically distinct from the phytoplasma that causes lethal yellowing, is another disease transmitted by *H. crudus.* It is a fatal, systemic disease that kills palms relatively quickly and most severely affects *Phoenix sylvestris*, *P. dactylifera*, *P. canariensis* and *S. palmetto* (Harrison & Elliott, 2015). *Haplaxius crudus* has also been implicated as a possible vector of coconut foliar decay virus (Wilson, 2005).

Economic losses include loss of markets, as international trade in palms from lethal yellowing -infected areas is prohibited because of the threat of the disease and vector spreading (CABI, 2017).

6.27 Asian Citrus Psyllid

Order: Hemiptera
Family: Liviidae
Species: *Diaphorina citri* Kuwayama

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	¡			ü
BVI	l			
Cay	¡			ü
Mon	¡			ü
TCI	l			

Figure 6.27.1 *Diaphorina citri* adult © Pest and Diseases Image Library, Bugwood.org

Background

Asian citrus psyllid, *Diaphorina citri*, is widely distributed in southern Asia and began invading the Americas in the 1940s. It was discovered for the first time in the Caribbean Basin in 1998 and has since spread widely. It is the most serious pest of citrus worldwide, primarily due to its role as a vector for the bacterium '*Candidatus* Liberibacter asiaticus', that causes the highly destructive Asian huanglongbing or citrus greening disease. The disease has severely impacted US orange production, and threatens to destroy the US$ 3.3-billion industry entirely.

Asian citrus psyllid and citrus greening disease are a major plant health risk to all the UKOTs in the Caribbean, wherever citrus is grown.

Geographical Distribution

First described from Taiwan, *D. citri* is widespread throughout Asia and in parts of the middle east and has been present in the western Hemisphere for several decades. It was first detected in Brazil in the 1940s (Costa Lima, 1942) and since then has spread slowly through South America. In 1998, it was discovered for the first time in the Caribbean Basin both in Guadeloupe and in Florida. It has spread widely among islands and adjacent mainland countries, including Antigua and Barbuda, Bahamas, Barbados, Belize, the Cayman Islands, Cuba, Dominica, Dominican Republic, Haiti, Jamaica, Puerto Rico, Mexico, the US Virgin Islands and is now well established in citrus producing regions of the United States (CABI, 2017; Halbert & Núñez, 2004). It spread to the African island nations of Mauritius and Réunion and reached East Africa (Tanzania) in 2014 (Shimwela *et al.*, 2016).

Figure 6.27.2 *Diaphorina citri* nymph © Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org

Figure 6.27.3 *Diaphorina citri* adult feeding © Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org

Figure 6.27.4 *Diaphorina citri* eggs © David Hall, USDA Agricultural Research Service, Bugwood.org

Figure 6.27.5 Citrus greening (*Candidatus Liberibacter asiaticus*) © Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org

Host Plants

Diaphorina citri is restricted to the Rutaceae, occurring on wild hosts as well as on cultivated *Citrus*, especially lemon (*C. limon*), rough lemon (*C. jambhuri*), sour orange (*C. aurantium*), grapefruit (*C. paradisi*) and lime (*C. aurantiifolia*). *Murraya paniculata*, a rutaceous plant often used for hedging, and curry leaf or curry tree (*M. koenigii*), used in Asian cuisine, are both preferred hosts (CABI, 2017).

Description

Martin *et al*. (2012) provide a good description of the various life stages. The eggs (Fig. 6.27.4) are approximately 0.01-0.15 mm long, elongate, almond-shaped, thicker at the base, and tapering towards the distal end. Newly laid eggs are pale, but then turn yellow and finally orange before hatching. There are 5 nymphal instars which are 0.25-1.7 mm long, light yellow to dark brown in colour with red eyes, and with well developed, large wing pads (Fig. 6.27.2). The adults (Fig. 6.27.1) are 3.0-4.0 mm long with a mottled yellowish-brown body, light brown head and brown legs. The underside of the body is greenish-white. The abdomen of females turns bright yellow-orange when ready to lay eggs. The wings are transparent with white spots, or light-brown with a central beige band. Forewings widest near tip. The body appears dusty due to a whitish, waxy secretion.

Biology

Asian citrus psyllid has a short life cycle and high fecundity. It may have up to 10 generations per year under favourable conditions, the optimum range of temperatures for population growth is 25-28°C. Up to 800 eggs are laid by each female on the tips of growing shoots, in leaf crevices, or at the base of leaf buds (CABI, 2017). Nymphs feed on newly emerged or flushing vegetation and population densities are lower when active growth is not occurring. In southern Florida, peak psyllid densities occur in May, August, and October through to December. Adults exhibit a distinctive feeding stance by lowering their head and elevating their body to a 45-degree angle (Fig. 6.27.3) (Martin *et al*., 2012).

Diaphorina citri vectors the bacterium '*Candidatus* Liberibacter asiaticus' causing the Asian form of citrus huanglongbing (greening) in Asia. It has been shown experimentally that it can also transmit the African form, '*Candidatus* Liberibacter africanus'. In Mauritius and Réunion, where both forms occur, *D. citri* probably transmits both (CABI, 2017).

Dispersal and Detection

Several studies have suggested that adult Asian citrus psyllids can fly several kilometres. Under laboratory conditions *D. citri* can fly continuously up to 2.4 km without wind assistance (Martini *et al.*, 2014). Gottwald *et al.* (2007) suggested that wind-assisted *D. citri* dispersal in Florida ranges from 90–145 km, and Sakamaki (2005) suggested that *D. citri* could have dispersed up to 470 km, throughout the Okinawan islands (Japan) with wind assistance. In Florida, long distance dispersal is thought to be a combination of both natural adult psyllid movement and human-assisted transportation. The unregulated movement of bulk citrus and infested nursery stock is thought to have contributed to the rapid distribution of *D. citri* in Florida (Bayles *et. al.,* 2017). Immature stages are relatively immobile, but can, along with eggs and adults, disperse widely through movement of host plants and crops.

Citrus plants showing disease symptoms may be observed before the psyllid. The symptoms include: yellowing of the leaf veins, mottling of the entire leaf (Fig. 6.27.5), premature defoliation, dieback of twigs, decay of feeder rootlets and lateral roots, misshapen and bitter fruit, decline in vigour, and ultimately the death of the entire plant. In addition, *D. citri* feeding typically causes severely curled leaves, defoliation and dieback. Serious damage to growing points can occur, which can lead to dwarfing as well as lack of juice and taste in fruit. Heavy *infestations* can cause blossoms and young fruit to drop (Martin *et al*., 2012; Cabi, 2017). Monitoring of psyllid populations is most commonly done using double-sided yellow panel traps or sweeping vegetation with a net.

Economic and other Impacts

Asian citrus psyllid is a significant economic pest as it is the most efficient vector of the bacterium which causes the disease huanglongbing (citrus greening), regarded as one of the most important threats to global commercial citrus production. It is estimated that globally more than 60 million trees were destroyed by the disease by the early 1990s. In Asia alone, approximately 100 million infected citrus trees have been destroyed by this disease since 1960. There are also reports that 1 million trees were eliminated in Brazil in 2004 (CABI, 2017). Ledford (2017) reports that the disease has slashed US orange production in half over the past decade, and threatens to destroy the US$ 3.3-billion industry entirely. The citrus industry in Florida has been hit particularly hard. Honeydew egested by *D. citri* promotes the growth of sooty mould which makes the fruit unattractive, affects the photosynthetic activity of the tree and attracts ants which fend off natural enemies of *D. citri*, resulting in additional pest damage (CABI, 2017).

6.28 Brown Marmorated Stink Bug

	Present l Absent ¡	Threat Bio	Threat Hlth	Threat Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Order: Hemiptera
Family: Pentatomidae
Species: *Halyomorpha halys* (Stål)

Figure 6.28.1 Adult brown marmorated stink bug *Halyomorpha halys* © Hectonichus, Wikipedia

Background

The brown marmorated stink bug *Halyomorpha halys*, native to East Asia, is an invasive species that is expanding its range in North America (first detected 1996) and in Europe (first detected 2004) (Hoebeke & Carter, 2003; CABI, 2017). It is highly polyphagous, damaging numerous crops. It has not been recorded in the Caribbean but there is a risk of introduction due to the large volume of trade and tourism that occur between North America and the Caribbean. The bug poses a potential plant health risk to all the UKOTs in the Caribbean.

Geographical Distribution

Halyomorpha halys is native to Asia and has been introduced into Europe and North America (USA) (CABI, 2017). It has not been recorded in the Caribbean to date.

Host Plants

Halyomorpha halys is a highly polyphagous pest attacking more than 100 plant species, primarily fruit trees and woody ornamentals, but also field crops (CABI, 2017). The majority of crops affected are temperate/subtropical crops, such as *Malus, Prunus* and *Vitis*, but it also attacks *Citrus* and *Ficus* spp. Field crops include bell pepper (*Capsicum annuum*) soybean (*Glycine max*), tomato (*Solanum lycopersicum*) and maize (*Zea mays*). Ornamental trees/shrub hosts include: *Aralia*, *Cryptomeria*, *Cupressus*, *Hibiscus* and *Rosa*. In Asia, *H. halys* has also been found on weeds (e.g. *Actrium* spp.) (CABI, 2017). It is not known what native plants in the Caribbean *H. halys* could feed on.

Figure 6.28.2 Brown marmorated stink bug eggs © D. Lance, USDA, APHIS, PPQ

Figure 6.28.3 Brown marmorated stink bug hatched eggs and first instar nymphs © D. Lance, USDA, APHIS, PPQ

Figure 6.28.4 Brown marmorated stink bug third instar nymphs © D. Lance, USDA, APHIS, PPQ

Figure 6.28.5 Group of brown marmorated stink bug fourth and fifth instar nymphs © G. Bernon, USDA, APHIS

Figure 6.28.6 Brown marmorated stink bug adult © S. Ellis

Figure 6.28.7 Brown marmorated stink bug adult on a peach © G. Bernon, USDA, APHIS

Description

Hoebeke & Carter (2003) provide detailed morphological descriptions. The eggs are elliptical (1.6 x 1.3 mm) and light green in colour. They are attached side by side in groups of 20 to 30 on the underside of leaves (Fig. 6.28.2). There are five nymphal instars which range in size from 2.4 mm at the first instar to 12 mm in length at the final instar. Deep-red eyes characterize the immature stages. The abdomen is a yellowish-red in the first instar (Fig. 6.28.3) and gradually turns to off-white with reddish spots in the latter instars (Figs 6.28.4-6.28.5). The pronotum of the nymphs is armoured with spines, and a white band is present on the tibiae of the third to fifth nymphal instars. Adults are approximately 17 mm long and are generally brown in colour (Figs 6.28.1 and 6.28.6). Distinguishing characteristics found on adult *H. halys* include lighter bands on the antennae and darker bands on the membranous, overlapping part at the rear of the wings. They also have patches of coppery or bluish metallic-coloured punctures on the head and pronotum. The scent glands are located on the dorsal surface of the abdomen and the underside of the thorax. It is these glands that are responsible for producing the pungent odour that characterize "stink bugs."

Biology

In the USA, one generation per year has generally been reported however, during hot summers more than one generation per year is possible. In its native range five to six generations per year have been reported. It overwinters in the adult stage. During the summer, adult females lay on average 50-150 eggs, but can produce up to 400 eggs each, clustered in groups of 20-30 on the underside of the leaves. *Halyomorpha halys* has a high minimum threshold for development (over 14°C).

Dispersal and Detection

Halyomorpha halys is a strong flyer and can move from host to host during the growing season. Over long distances, the pest can be disseminated by trade of host plants but also by movements of goods or vehicles. The pathways of introduction for *H. halys* into North America and Europe remain uncertain but it is suspected that the pest was introduced either as a hitchhiker or via plant imports.

Economic and other Impacts

Halyomorpha halys feeds by sucking plant juices. Adults generally feed on fruit (Fig. 6.28.7), whereas the nymphs feed on leaves, stems and fruit. The most serious crop damage results from the insect feeding on pome and stone fruits, and on seeds inside legume pods. Leaf feeding is characterized by small lesions (3 mm diameter) which may become necrotic and coalesce. Fruit that has been fed on by may have small necrotic spots or blotches, grooves and brownish discolorations. In cases of heavy infestations, fruit are severely disfigured and unmarketable. In Asia, *H. halys* causes significant damage to soybean and various horticultural crops. In Northern Japan, apple crops have increasingly been damaged by *H. halys*. In Asia, no damage has been reported to forestry trees. However, in Japan *H. halys* is considered a pest in nurseries producing seeds of cedar (*Cedrus* spp.) and cypress (*Cupressus* spp.) because it can feed on the cones. In the USA, *H. halys* damages woody ornamentals and fruit trees, peach (*P. persica*), pear (*P. communis*) and apple (*Malus* sp.), in urban environments and commercial fruit orchards. *Halyomorpha halys* is considered a vector of Paulownia witches' broom phytoplasma in Asia. It can also be a nuisance to humans because at the end of autumn, adults can aggregate in buildings and houses seeking overwintering sites. When disturbed or crushed they discharge a characteristic pungent odour, which is unpleasant and long lasting (CABI, 2017).

6.29 Avocado Lace Bug

Order: Hemiptera
Family: Tingidae
Species: *Pseudacysta perseae* (Heidemann)

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
Ang	¡			ü
Ber	l			
BVI	l			
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figure 6.29.1 Avocado lace bug *Pseudacysta perseae* adults © 2016 Masumi Palhof, BugGuide.net

Background

The avocado lace bug, *Pseudacysta perseae*, was first described from specimens collected in Florida (USA). For most of the twentieth century it was regarded as having a restricted distribution, primarily to peninsular Florida, and being only an occasional minor pest. However, during the last 20-30 years it has become a more frequent and damaging pest of avocado (*Persea americana*) and dramatically expanded its geographical distribution in the Caribbean and spread to northern areas of South America (Peña *et al*., 2012).

Avocado lace bug was recently recorded from the British Virgin Islands and poses a plant health risk to all the UKOTs in the Caribbean wherever avocado is grown.

Geographical Distribution

Pseudacysta perseae occurs from northern South America northwards to southern USA (Humeres *et al*. 2009). In the Caribbean Region it has been recorded from Bermuda, British Virgin Islands, Cuba, Dominican Republic, Guadeloupe, Martinique and Puerto Rico.

Figure 6.29.2 Avocado lace bug adult (centre) and nymphs © James Castner, University of Florida

Figure 6.29.3 Avocado lace bug eggs showing their distinct circular lids © Adrian Hunsberger, University of Florida

Figure 6.29.4 Colony of avocado lace bug with adults, eggs, nymphs, exuviae and black faecal spots © David Rosen, 2005 Regents, University of California

Figure 6.29.5 Avocado lace bug colony on the underside of a leaf and damage on the upper side of adjacent infested leaves © David Rosen, 2005 Regents, University of California

Figure 6.29.6 Avocado leaf with damage to the upper surface caused by avocado lace bug © James Castner, University of Florida

Figure 6.29.7 Avocado leaf with damage to the upper surface caused by avocado lace bug © www.californiaavocadogrowers.com

Host Plants

Pseudacysta perseae is oligophagous on Lauraceae, including avocado (*Persea americana*), camphor (*Cinnamomum camphora*), red bay (*Persea borbonia*) and swamp bay (*Persea pallustris*).

Description

The adults are oblong-oval and about 2 mm long. They appear distinctive with their lace-like wings, which are yellowish white and bear a transverse black bar, the head and prothorax (section of body behind the head) are black (Fig. 6.29.1). The wings are sometimes darker, being brownish and/or orange. The legs and antennae are pale yellow, with blackish tips. The nymphs are blackish with paler wing buds, and blunt spine-like projections emerging from the body (Fig. 6.29.2). The eggs are oval, black and have a characteristic circular lid (Fig. 6.29.3). The eggs are often hidden beneath black blobs of tar-like excrement.

Pseudacysta perseae is the only species in this genus, so identification to genus is tantamount to specific level. Blatchley (1926) described the genus *Pseudacysta* and provided keys to the Tingidae of eastern USA. Hurd (1946) provided a key to the lace bug genera of North America. Heidemann (1908) provided a detailed description of adults and late instar nymphs.

Biology

Pseudacysta perseae is sexually reproductive, lays eggs and has five nymphal instars. It can take from three weeks, in warm weather (Abud Antum, 1991), to several months, in cooler conditions, to complete its development from egg to adult. It has several generations a year and all developmental stages can be found living together throughout the year. The lace bugs live in colonies, depositing eggs upright in irregular rows in groups on the lower leaf surface. The nymphs and adults only feed on the lower surface of the foliage (Moznette, 1922), causing gradual local destruction of the plant cells, resulting in chlorotic and necrotic patches (Figs 6.29.4-6.29.5). The lower surface of the leaf becomes covered in exuviae (cast skins), spots of frass, and mould (Fig. 6.29.3), and the upper leaf surface develops yellow patches that eventually turn brown or bronze (Figs 6.29.6-6.29.7).

The natural enemies of avocado lace bug have been studied in detail by Peña *et al*. (1998, 2012, and references cited therein).

Dispersal and Detection

The winged adults are the main natural dispersal stage. The eggs, nymphs and adults may also be dispersed over long distance in plant trade.

The bug is likely to be first detected because damage is observed on the foliage. However, similar symptoms (chlorotic and necrotic patches) may be caused by thrips, mites, and certain diseases (for example anthracnose fungus, *Colletotrichum gloeosporioides*) and disorders. The leaves therefore need to be examined carefully with a X10 hand lens to confirm the presence of the lace bug which are found on the lower surface of the foliage together with small droplets of black tar-like excrement and exuviae.

Economic and other Impacts

Infestations of the lace bug result in distinct brown necrotic patches on the foliage (Figs 6.29.6-6.29.7). Heavily damaged leaves become dry, curl up, and drop prematurely. Leaf photosynthesis is reduced by 50% when the leaves sustain 40% damage of the foliar area (Peña *et al.,* 1998). The avocado lace bug has been particularly damaging in the Dominican Republic, where it has caused complete defoliation of avocado trees. Defoliation stresses the trees, which have reduced fruit yields.

6.30 Tomato potato psyllid

Order: Hemiptera
Family: Triozidae
Species: *Bactericera cockerelli* (Šulc)

	Present l / Absent ¡	Threat: Bio	Threat: Hlth	Threat: Econ
Ang	¡			ü
Ber	¡			ü
BVI	¡			ü
Cay	¡			ü
Mon	¡			ü
TCI	¡			ü

Figures 6.30.1 Adult *Bactericera cockerelli.* Newly emerged adult female (left) detected on aubergine from Mexico by UK Plant Health Service © Fera; Mature adult female (right) © Pest and Diseases Image Library, Bugwood.org

Background

Bactericera cockerelli, commonly called the Tomato potato psyllid, Potato psyllid or Tomato psyllid, is one of the most destructive potato pests in the western hemisphere. As well as the direct feeding by the psyllid having harmful effects on its Solanaceous hosts, in 2007 this species was linked as the main vector of the bacterium '*Candidatus* Liberibacter solanacearum', which has caused serious damage to the potato and tomato industries in the Americas and New Zealand, and the carrot industry in Europe (EPPO, 2013).

Geographical Distribution

Bactericera cockerelli is native to the Great Plains region of North America but has over time colonised much of the western USA and southern Canada. It also occurs in Mexico and Central America, reported from Guatemala, Honduras, Nicaragua and El Salvador. The species was introduced to New Zealand in 2006 and is now widespread there (CABI, 2017).

Host Plants

There are at least 64 confirmed host plant species of *B. cockerelli* (Biosecurity Australia, 2009; Martin, 2008). In a literature review by Davidson *et al.* (2008) it is recorded from over 160 plant species, but many of these finds are based on the presence of adults and no other life stage.

Figure 6.30.2 Fifth nymphal instar *Bactericera cockerelli* detected on aubergine from Mexico by UK Plant Health Service © Fera

Figure 6.30.3 Fourth nymphal instar *Bactericera cockerelli.* detected on aubergine from Mexico by UK Plant Health Service © Fera

Figure 6.30.4 Second nymphal instar *Bactericera cockerelli* detected on aubergine from Mexico by UK Plant Health Service © Fera

Figure 6.30.5 Leaf curl and discoloration on potato caused by '*Candidatus* Liberibacter solanacearum' © Joe Munyaneza USDA/ARS

Bactericera cockerelli is mainly a pest of Solanaceous plants including several commercially grown hosts: peppers (*Capsicum annuum*); chilli (*Capsicum frutescens*); tamarillo (*Solanum betaceum*); tomato (*S. lycopersicum*); aubergine (*S. melongena*); potato (*S. tuberosum*); and tobacco *(Nicotiana tabacum*). It is also a pest of sweet potato (*Ipomoea batatas*: Convolvulaceae) and several weeds and non-crop species in the Solanaceae and Convolvulaceae.

Description

Yen and Burckhardt (2012) give a detailed description of all the life stages of the psyllid. The eggs are white-yellow, semi-transparent, almond-shaped, elongate with a broadly rounded base, attached to the long, thin petiole, and narrowed towards the apex; 0.32 mm long and 0.18 mm wide. There are five nymphal instars (Figs 6.30.2-6.30.4) which are all strongly dorso-ventrally flattened, whitish or yellowish in colour, with red compound eyes. All instars bear marginal setae surrounding the entire body. The 4th and 5th instars have two grey longitudinal bands bearing brown dots on abdomen dorsally; 5th instars with scattered brown dots on thorax and on wing pads dorsally. They vary in size from 0.40 mm long, 0.21 mm wide (1st instar) to 1.65 mm long and 1.23 mm wide 5th instar). Newly emerged adults are pale yellow or green, but they become dark brown with maturity (Fig. 6.30.1). Body length (including forewings) of the male is 2.8–2.9 mm, and female is 2.8–3.2 mm.

Biology

Adults feed on leaves and can mate more than once. A female can lay up to 500 eggs over a 21-day period, but in the field it is more likely to be around 200 eggs, depending upon the host plant. Once emerged, nymphs settle on the underside of young leaves, and feed on the plant sap. The rate of nymphal development is dependent on temperature. The psyllid develops between 15°C and 32°C with optimum development at 27°C. In a greenhouse with an average temperature of 18°C psyllids take 33 days to complete their life cycle. A single generation may be completed in three to five weeks. The number of generations per year varies, usually ranging from three to seven in the Americas and up to 7-8 generations per year in Auckland, New Zealand (Martin, 2016; CABI, 2017).

Bactericera cockerelli causes 'Psyllid yellows', a disease of potatoes and tomatoes, thought to be a physiological reaction to feeding and salivary secretions from the psyllid. On tomatoes, the disease symptoms are the yellowing and stunting of the growing tip and a cupping or curling of the leaves. Many flowers may fall off the trusses of infected plants and fruit that develop may be small and misshapen. On potatoes, the foliar symptoms are a stunting and yellowing of the growing tip and the edges of the curled leaves often have a pink blush or purple colour. Tuber initiation and growth of potatoes is also affected (Cabi, 2017).

More significantly, the pest is the primary vector of a bacterium, '*Candidatus* Liberibacter solanacearum', which causes the disease 'zebra chip' in potatoes. The disease weakens plants and reduce yields and quality of crops. Symptoms of zebra chip in aerial parts of the plant include stunting, chlorosis and purpling of foliage (Fig. 6.30.5), upward rolling and scorching of leaves and the production of aerial tubers. On cutting, there may be patchy discolouration of tuber tissue, but this is often indistinct or absent. Characteristic symptoms can often be seen in fried potato tubers. (Martin, 2016; Defra, 2017). The pathogen also causes a very similar disease in tomatoes and capsicum. As well as yellowing and deformation of the leaves mature fruit is very much smaller, tends to have a pointy end, and frequently they occur in larger clusters of fruit than normal. In severe cases, the yellowing progresses to plant death.

The bacterium is also transmitted transovarially in the psyllid, meaning the infection is maintained by each life stage as they develop and moult. This is thought to impact upon the spread of the disease between geographic regions by dispersing psyllids and helps maintain the bacterium in geographic regions in the overwintering stage (CABI, 2017). There are at least four known biotypes of the psyllid in the Americas which differ in overwintering, dispersal and disease transmission capabilities (CABI, 2017).

Dispersal and Detection

Adult *B. cockerelli* are strong fliers and can disperse over long distances, especially with the assistance of wind and warm temperatures. Adults in the Americas migrate en masse to northern feeding sites in the spring, a distance of several hundred kilometres. Immature stages of *B. cockerelli* are immobile, but can, along with eggs and adults, disperse widely through movement of host plants and crops. The movement of eggs on plant material is thought the most likely pathway of introduction of the pest into New Zealand (CABI, 2017). The eggs and early instars are very small and cryptic and could easily missed during quarantine inspections.

Adult psyllids are easily collected by sticky traps, water traps, can be hand collected, vacuum collected or swept from foliage with a net, or shaking foliage over beating trays (Yen & Burckhardt, 2012).

Economic and other Impacts

In recent years, potato, tomato, and pepper growers in a number of geographic areas have suffered extensive economic losses associated with outbreaks of potato psyllid (CABI, 2017). Zebra chip has caused millions of dollars (US) in losses to the potato industry as plant growth, yields and export markets are severely affected by the disease Munyaneza (2012).

There are quarantine and trade implications for countries where the psyllid is present because some countries may require that shipments of potatoes from certain growing regions be tested for the disease before the shipments are allowed entry (CABI, 2017).

In New Zealand, *B. cockerelli* has colonised both islands and has vectored '*Candidatus* Liberibacter solanacearum' in potato, tomato and capsicum crops causing serious economic damage; losses in glasshouse tomato and capsicum crops are estimated at up to US$ 1 million (Liefting, 2008). Australia put in place additional quarantine requirements for the importation of fresh tomato and pepper from New Zealand after 2006, where growers need to ensure that crops for export have been produced in areas free of *B. cockerelli* or the exported produce must be free of the psyllid (EPPO, 2013).