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FIELD GUIDE TO INVASIVE ALIEN INVERTEBRATES IN THE SOUTH ATLANTIC UK OVERSEAS TERRITORIES

PART 4 – INSECTS (bugs, ants, wasps, moths)

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

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Frontispiece
Top row: Asian Tiger Mosquito *Aedes albopictus* adult © Susan Ellis, Bugwood.org; Fall armyworm *Spodoptera frugiperda* adult © Fera; Pumpkin fly *Dacus bivittatus* adult female © Fera. Second row: Sheep tick *Ixodes Ricinus* adult © Fera; South American tomato moth *Tuta absoluta* larvae © Fera; European earwig, *Forficula auricularia* adult male © Pudding4brains. Third row: Big-Headed Ant *Pheidole megacephala* worker © Alexander L. Wild; Brown soft scale *Coccus hesperidum* adult female © C. Malumphy; Fall armyworm *Spodoptera frugiperda* larva © Fera. Bottom row: Oriental Fruit Fly *Bactrocera dorsalis* adult © Fera; Harlequin ladybird *Harmonia axyridis* adults © Bugwood.org; Red Imported Fire Ant *Solenopsis invicta* worker © April Noble, Bugwood.org.

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PART 3 – INSECTS (termites, beetles, earwigs, flies)

6.13 Black bean aphid

Order: Hemiptera
Family: Aphididae
Species: *Aphis fabae* Scopoli

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
SH	¡			
Asc	¡			
Tris	¡			
FI	¡			ü
SG	¡			
BAT	¡			

Figure 6.13.1 *Aphis fabae* (black bean aphid) adult with nymphs © Influentialpoints

Background

The black bean aphid (*Aphis fabae*) complex is a group of related species or subspecies. These individuals are superficially identical (University of California Agriculture and Natural Resources, 2008). *Aphis fabae* is one of the most widely distributed and polyphagous aphids, present throughout the world and presently absent from Australasia (CABI, 2019).

Black bean aphids cause direct damage by phloem feeding, resulting in significant impairment of plant growth and yield (Shannag and Ababneh, 2007). They can also cause indirect damage by acting as vectors for plant viruses (University of California Agriculture and Natural Resources, 2008).

Aphis fabae has a heteroecious and holocyclic lifecycle. It exhibits host plant alternation between primary hosts on which the aphids reproduce sexually in the autumn, overwinter as eggs and then in the spring and summer it has several parthenogenetic generations on secondary hosts (Douglas, 1997). The life cycle therefore involves seasonal migration between unrelated winter (woody or primary) and summer (herbaceous or secondary) host plants (Fischer et al., 2005). The main means of dispersal is through migratory flight (CABI, 2019a). In the tropics the aphid, which is most likely to be the subspecies *A. fabae solanella*, does not overwinter as an egg stage. It is anholocyclic, breeding parthenogenetically throughout the year (CABI, 2019a).

Figure 6.13.2 *Aphis fabae* adult winged viviparous female © Fera

Figure 6.13.3. *Aphis fabae* adult wingless viviparous female © Fera

Figure 6.13.4 *Aphis fabae* nymphs on spindle *Euonymus europaeus* © Influentialpoints

Figure 6.13.5 *Aphis fabae* on broad bean (*Vicia faba*) © RHS.org

Geographical Distribution

Aphis fabae is widely distributed throughout the world (Miller & Stoetzel, 1997). It is present in Asia, Africa, North America, Central America and the Caribbean, South America and Europe (CABI, 2019a). It is predominantly a crop pest in temperate and Mediterranean climates. It is uncommon in most tropical regions and is presently absent from Australasia (CABI, 2019a).

Hosts

The primary host is usually spindle (*Euonymus europaeus*), however *A. fabae* is highly polyphagous on secondary hosts, it has one of the broadest host ranges, having been recorded from nearly 120 plant families (Favret & Miller, 2012), which include many crop plants. In temperate regions its main host crops are broad bean (*Vicia faba*) and sugar beet (*Beta vulgaris*), while at high altitudes in the tropics its main host is the common bean (*Phaseolus vulgaris*) (CABI, 2019).

Description

Aphis fabae is a dark brownish to matt black aphid, sometimes with a distinct greenish hue with fairly short, dark, tapered siphunculi and a dark cauda. Wingless adult (apterae) (Figs 6.13.1, 3 and 4) range in size from 1.2-2.9 mm, and have a variable abdominal sclerotic pattern confined to abdominal tergites 6-8 in smaller apterae, but broken bands are present in larger ones. Marginal tubercles are protuberant but small. The antennae usually have segments III-IV and the base of V quite pale. The longest femoral and tibial hairs are longer than the least width of the tibia. The black bean aphid immatures (Fig. 6.13.1 and 4) often have discrete white wax spots, as do sometimes the adults (InfluentualPoints, 2019).

Winged adults (alatae) (6.13.2) are1.3-2.6 mm, Alatae have secondary rhinaria distributed III (3-)7-33, IV 0-14, V 0-3. They are dark like the apterae and arevariably striped withdorsal white wax markings. The femora bear fine, long hairs on all surfaces and the cauda has 10-19 hairs (Influentialpoints, 2019).

Biology

Aphis fabae has a heteroecious and holocyclic lifecycle in much of Europe, alternating between its primary host spindle (*E. europaeus*), where it overwinters as an egg stage, and a wide range of secondary host plants. Eggs can also be laid on guelder rose *(Viburnum opulus*), mock orange (*Philadelphus cornarius*) and some other species of *Euonymus* (CABI, 2019a).

In the temperate climate of Northern Europe, eggs are laid on spindle between October and December. From late February to April eggs hatch into nymphs which go through four instars to become parthenogenetically reproducing apterous females. About three generations occur on spindle, until alates (spring migrants) are produced between mid-May and early June. The spring migrants colonize a wide range of secondary hosts on which apterous females are produced which reproduce parthenogenetically. Dense colonies are produced due to rapid population growth. One female may produce up to 100 young. Alates are produced on secondary hosts throughout the summer (summer migrants), partly in response to overcrowding. These alates colonize fresh herbaceous secondary hosts plants (CABI, 2019a).

Around September in Northern Europe, gynoparae (autumn migrants) and males are produced. Gynoparae undertake migratory flights to relocate spindle (Nottingham & Hardie, 1989). Once on spindle they produce the apterous oviparae or sexual females. Several weeks after the gynoparae start appearing, the sexual males are produced on the secondary host plants. They locate spindle independently and find the oviparae using sex pheromone cues. After mating, the oviparae lay their eggs in bark crevices on the stem or on the winter buds of the spindle trees. Each oviparae lays around four to six yellow-green eggs, which darken with time to a shiny black. Before the embryos hatch, they need to go through a cold spell and enter diapause (CABI, 2019a).

In Southern Europe *A. fabae* may reproduce parthenogenetically on secondary hosts throughout the year. In the tropics the aphid is most likely to be a subspecies, *A. fabae* solanella. It does not overwinter as an egg stage, but breeds parthenogenetically throughout the year, with alate forms being produced in response to overcrowding (CABI, 2019a).

Dispersal and Detection

The main means of dispersal of *A. fabae* is through migratory flight. The winged forms of this aphid disperse very effectively, and a long-distance spring migration takes *A. fabae* from its primary host to secondary herbaceous hosts, including many crops. It is highly polyphagous, with many wild species potentially acting as reservoirs for crop infestation (CABI, 2019a).

The aphid can also be carried in trade on planting material and some vegetable products (CABI, 2019a). The plant parts liable to carry both adults and nymphs of *A. fabae* in trade/transport are flowers, inflorescences, cones, calyx, fruits (including pods), leaves, stems (above ground), shoots, trunks and branches (CABI, 2019a).

Dense colonies of *A. fabae* can be detected on upper stems and the underside of leaves, in beans and other crops. Young colonies consist of matt black aphids on younger shoots, while older colonies spread over most aerial plant parts. Alates can be detected with suction traps, yellow water traps and yellow sticky traps (CABI, 2019a).

Economic and other Impacts

Direct feeding damage by *A. fabae* is caused by phloem feeding, resulting in loss of sap and injury to plant tissues. Young plants are particularly vulnerable. Under heavy attack plants may be stunted and may die. Seed formation is subsequently reduced (CABI, 2019a).

It is particularly important on beans, peas, beets, crucifers, cucurbits, potato, tobacco, tomato, and tulip (Favret & Miller, 2012), causing direct or indirect damage through the spread of viruses. The following viruses can be vectored by *A. fabae* (CABI, 2019):

Bean common mosaic necrosis virus;

Bean common mosaic virus (common mosaic of beans);

Bean leafroll virus (pea leafroll virus);

Bean yellow mosaic virus (bean yellow mosaic);

Beet mosaic virus (spinach mosaic virus);

Beet yellows virus (beet yellows);

Cowpea aphid-borne mosaic virus;

Faba bean necrotic yellows virus;

Maize dwarf mosaic virus (dwarf mosaic of maize);

Pea seed-borne mosaic virus;

Plum pox virus (sharka);

Potato leafroll virus;

Potato virus S;

Potato virus Y (potato mottle);

Soybean mosaic virus (soybean mosaic);

Tobacco etch virus (tobacco etch);

Tulip breaking virus

6.14 Mealy Cabbage Aphid

Order: Hemiptera
Family: Aphididae
Species: *Brevicoryne brassicae* (Linnaeus)

	Present l / Absent ¡	Threat		
		Bio	Hlth	Econ
SH	¡			
Asc	¡			
Tris	¡			
FI	¡			ü
SG	¡			
BAT	¡			

Figure 6.14.1. Adult Mealy Cabbage Aphid, *Brevicoryne brassicae* © InfluentialPoints.com

Background

Mealy cabbage aphid (*Brevicoryne brassicae*) occurs throughout all the temperate and warm temperate parts of the world in colonies that can contain thousand densely packed individuals (Gabrys, 2008; Pal & Singh, 2013). They are monecious, feeding primarily of plants in the family Brassicaceae. In cold climates oviparae and small thin winged males occur in autumn and the population overwinters as eggs. Where winters are mild *B. brassicae* overwinters parthenogenetically as nymphs. *B. brassicae* is considered a key agricultural pest of Brassicas (which includes the mustards and crucifer) as the aphids not only deteriorate the quality of the crop but also its yield and are known to vector at least 20 viral pathogens (Chan et al., 1991). Both wingless (apterae) and winged (alate) forms are capable of transmitting viruses.

Geographical Distribution

Brevicoryne brassicae, is a cosmopolitan species native to Europe, but now has a worldwide distribution (Gabrys, 2008; Gill *et al*., 2013; Pal & Singh, 2013) and is thought to have been found on Saint Helena in the 1960's but it's current status in unknown (CABI 2018; Varnham, 2006).

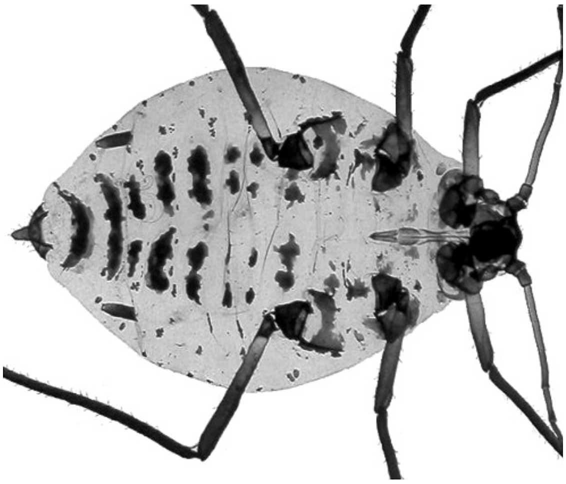

Figure 6.14.2 Mounted apteral form of *Brevicoryne brassicae* with nymphs © InfluentialPoints.com

Figure 6.14.3 Alate form of *Brevicoryne brassicae* with offspring © InfluentialPoints.com

Figure 6.14.4 *Brevicoryne brassicae* infestation on wild garlic mustard © InfluentialPoints.com

Figure 6.14.5 *Brevicoryne brassicae* colony late in season with a predatory cecidomyiid larva © InfluentialPoints.com

Hosts

Brevicoryne brassicae feed primarily on plants in the family Brassicacea including important crops such as oilseed rape (*Brassica napus*) and cabbage vegetables such as head cabbage, Brussel sprouts, cauliflower, kale, collards (*B. oleracea*, *B. oleracea* var. *gemmifera*, *B. olerace*a var. *botrytis, B. oleracea* var. *sabellica*) (Gabrys, 2008). The host plants can be divided into three groups depending on their ability to support aphid populations: permanent, temporal and accidental. Permanent host plants such as all those in the Brassicacea support the aphid population throughout the whole vegetation period. Temporal host plants such as cress (*Lepidium sativum*) or woad (*Isatis tinctoria*) support 2-3 aphid generations and accidental plants such as Penny Cress (*Thlaspi arvense*), Shepherd's Purse (*Capsella bursa-pastoris*), honesty (*Lunaria annua*), wallflower (*Erysimum cheiranthoides*) the aphids may have less than one generation (Gabrys, 2008).

Description

Adult *B. brassicae* can take on two forms: winged (Fig. 6.14.3) and wingless (Fig. 6.14.1 and 6.14.2). Wingless females (apterous females) are oval shaped, green yellow or greyish green in colour, with a darker head and two rows of dark spots dorsally on the thorax and abdomen (Fig. 6.14.2). These spots increase in size towards the posterior end. Their bodies are covered with a thick greyish-white or bluish mealy wax and are about 1.6-2.6 mm long and their siphunculi (cornicles) are small and dark (Gabrys, 2008; Hines and Hutchison, 2013; Natwick, 2009). Winged females (alate females) are smaller and lack the waxy covering of wingless females (Natwick, 2009). They are green in colour with a yellow abdomen with two dark spots on the dorsal anterior segments which merge into a dark band across the last abdominal segment (Fig. 6.14.3) (Kessing and Mau, 1991). All adult males are winged.

In temperate climates, eggs overwinter in plant debris near the soil surface (Hines & Hutchinson, 2013). Eggs are not laid in warm climates; females produce female nymphs directly which remain on her back until they are large enough to survive on their own (Kessing and Mau, 1991). Nymphs are similar in appearance to apterous adults (Fig. 6.14.2 and Fig. 6.14.5) but differ in having less developed caudae and siphunculi. The nymphal period varies from seven to ten days. Winged forms develop and start migrating to new host plants only when plant quality deteriorates or when a plant becomes overcrowded or from seasonal changes (Gill et al., 2013).

Biology

The type of life cycle of *B. brassicae* depends on the climatic conditions during winter. In colder regions winged males and apterous oviparous females appear in autumn and after mating they lay overwintering eggs. In warmer regions they reproduce parthenogenetically throughout the year. Parthenogenetic females are viviparous (i.e. they give birth to nymphs). Depending on the temperature and humidity conditions, one cabbage aphid generation can develop in 7-10 days (Hafez, 1961; Pal & Singh, 2013) and they can complete up to 15 generations (often overlapping) during the growing season (Hines & Hutchison, 2013). Older nymphs and adult apterae leave plants in response to over-crowding and decline in plant quality. Winged morphs also appear following overcrowding and decline in plant quality or in reaction to environmental factors such as seasonal reduction in temperatures and day length. Overcrowding alone is not responsible for the appearance of winged forms in *B. brassicae* colonies (Gabrys, 2008).

Dispersal and Detection

Dispersal to new locations is most probably due to movement of plants, machinery, infested produce etc. however winged morphs are also able to fly relatively long distances to find suitable host plants.

To detect cabbage aphids, look for dense waxy colonies on growing points of plants. Aphids may be hidden within newly furled leaf growth and often feed on the underside of leaves and in the centre of cabbage heads (Hines and Hutchison 2013). They prefer feeding on young leaves and flowers and often go deep into the heads of Brussels sprouts and cabbage (Natwick 2009). Colonies of aphids can be found on upper and lower leaf surfaces, in leaf folds, along the leafstalk, and near leaf axils. Severely infested plants can be detected by a mass of small sticky aphids from honey dew secretions which can attract ants (Gill et al., 2013).

Economic and other Impacts

The cabbage aphid, *Brevicoryne brassicae* is one of the most destructive pests in Cruciferaceae or Brassicaceae plant family around the world. It is of agricultural concern because it deteriorates crop quality and yield and is a vector of at least 20 viral pathogens that can cause diseases in crucifers and citrus. Both wingless (apterae) and winged (alate) forms are able to transmit viruses, but the wingless aphids demonstrate a higher rate of transmission (Gill et al., 2013).

6.15 Brown Soft Scale

Order: Hemiptera
Family: Coccidae
Species: *Coccus hesperidum* Linnaeus

	Present l / Absent ¡	Threat		
		Bio	Hlth	Econ
SH	¡	ü		
Asc	¡	ü		
Tris	l			
FI	¡	ü		
SG	¡			
BAT	¡			

Figure 6.15.1 Brown soft scale *Coccus hesperidum* adult females on *Laurus nobilis*, Gibraltar © C. Malumphy

Background

Brown soft scale, *Coccus hesperidum* (Fig. 6.15.1), is one of the most polyphagous and widely distributed species of scale insect in the world. It is a serious pest of citrus, various fruit trees, ornamentals and of indoor plantings. It damages plants both directly by removing plant sap and indirectly by egesting large quantities of honeydew which serve as a medium for the growth of black sooty moulds. In the Tristan du Cunha archipelago, large populations of *C. hesperidum* are causing decline and mortality of the endemic Island Cape Myrtle *Phylica arborea*. This threatens the survival of native finches that depend on the *P. arborea* fruit.

Coccus hesperidum is one of the most common scale insects on ornamental indoor plantings and is therefore a potential threat to all the UKOTs where indoor plants are grown.

Geographical Distribution

Coccus hesperidum is one of the most widely geographically distributed of all scale insect species and its native range is unclear. It has been recorded from more than 140 countries throughout the tropics, subtropics and temperate areas of the world. In cooler areas, it is often restricted outdoors to plants growing in sheltered situation, urban heat islands and/or indoor plantings (García Morales *et al.*, 2016).

Figure 6.15.2 *Coccus hesperidum* on *Laurus nobilis* growing outdoors in the north of England © C. Malumphy

Figure 6.15.3 *Coccus hesperidum*, Scotland © Crown copyright

Figure 6.15.4 *Coccus hesperidum* on *Cephalotaxus*, Scotland © Crown copyright

Figure 6.15.5 *Coccus hesperidum* on *Hedera*, Scotland © Crown copyright

Figure 6.15.6 Coccus hesperidum © C. Malumphy

Figure 6.15.7 *Coccus hesperidum* attended by *Lasius grandis*, Gibraltar © C. Malumphy

Figure 6.15.8 Iridaceae in a glasshouse dying due to a large infestation of *Coccus hesperidum*, Scotland © C. Malumphy

Figure 6.15.9 Orange tree dying due to large infestation of *Coccus hesperidum* and other hemipterans. Note the black mould on the ground growing on egested honeydew, Gran Canaria © C. Malumphy

Host Plants

Coccus hesperidum is one of the most polyphagous of all scale insects feeding on several hundred-plant species assigned to 125+ families. Preferred families that include numerous host species include: Anacardiaceae, Apocynaceae, Araceae, Araliaceae, Arecaceae, Asparagaceae, Asteraceae, Bignoniaceae, Fabaceae, Malvaceae, Moraceae, Myrtaceae, Pinaceae, Rosaceae, Rubiaceae and Rutaceae. It is very common on *Citrus*, wherever it is grown. Other common hosts include olive, avocado, cotton, mango, cocoa, Ficus, Hibiscus, holly, ivy, bay laurel, oleander, palms, ferns and orchids.

Description

The adult female body is broadly oval to round; flat to slightly convex in lateral view; body yellow-green to yellow-brown, usually with small brown flecks scattered on dorsum, frequently coalescing to form bands that may resemble a cross (Fig. 1); body turning brown with age; without an obvious wax covering; ovisac absent. They occur on arboreal parts of plant, including foliage, bark and fruit. Males are extremely rare and appear to have only been recorded in the UK and Russia. The immature female scales are elongate oval, flat and yellow.

Biology

Coccus hesperidum is parthenogenetic in most areas although males have been reported. It will breed continuous, producing overlapping generations, if environmental conditions are suitable. It develops six generations per year in Israel and 3-5 generations per year in southern California. The eggs hatch within the body of the adult female (*ovovivipary*) and there are three nymphal stages.

Dispersal and Detection

The main natural dispersal stage for *C. hesperidum* is the first nymphal instar or crawler. They have a relatively low natural dispersal potential as most crawlers tend to settle to feed within a short distance of their parent, if there are suitable feeding sites. Crawlers may also be dispersed over longer distances by air currents or be transported on other animals. Dispersal is likely to be more rapid and over longer distances by the movement if infested plant material in trade.

Detection involves close visual inspection of the host plants. Large infestations are relatively easy to detect but low-density populations and early nymphal instars can be difficult to detect. The foliage of infested plants becomes black due to the moulds growing on egested honeydew. Ants, and less frequently wasps and flies, are attracted to the scales to feed on the honeydew.

Economic and other Impacts

Coccus hesperidum can be a serious pest of citrus, various fruit trees, ornamentals and of indoor plantings (Fig. 6.15.6*)*. Large populations cause chlorosis, premature leaf loss and dieback. Susceptible plants can be killed although this is uncommon outdoors due to the large number of natural enemies (mainly parasitoid wasps) that suppress the populations to below damaging levels. *Coccus hesperidum* can become a major problem if biocontrol is disrupted by use of broad spectrum, non-selective pesticides. Sooty moulds (6.15.7) growing on the honeydew egested by the scales inhibits photosynthesis and gas exchange and can lower the aesthetic appearance and market value of ornamental plants. In addition, sooty moulds can reduce the size of fruit (yield) and cause them to be downgraded unless efficiently washed.

6.16 Greenhouse Orthezia or Jacaranda bug

Order: Hemiptera
Family: Ortheziidae
Species: *Insignorthezia insignis* (Browne)

	Present l Absent ¡	Threat Bio	Hlth	Econ
SH	l			
Asc	¡	ü		
Tris	¡	ü		
FI	¡			
SG	¡			
BAT	¡			

Figure 6.16.1 Greenhouse orthezia *Insignorthezia insignis*; colony infesting a shrub in Saint Lucia (left); closeup of adult females bearing ovisacs on *Ilex* sp. in the Bahamas (right) © C. Malumphy

Background

Greenhouse orthezia, *Insignorthezia insignis* (Fig. 6.16.1), has spread throughout the world in tropical and subtropical countries. It also occurs in botanical collections grown in heated glasshouses in temperate regions. It is an occasional pest and has the potential to damage a wide range of crops, ornamentals and native plants. For example, it was introduced into Saint Helena in the late 1980s where, in the absence of any natural enemies, the pest was destroying the last remaining stands of the endemic gumwood, *Commidendrum robustum* (Booth *et al.,* 1995).

Geographical Distribution

Insignorthezia insignis is reported to be native to the Neotropical region, probably to Guyana and neighbouring countries, and has spread throughout the world in tropical and subtropical countries. It occurs widely in the Caribbean region (Garcia *et al.,* 2016). It also occurs in temperate regions in botanical collections with heated glasshouses. Ezzat (1956) provides a world map showing isotherms defining areas of the world where conditions exist in which he considered *I. insignis* could survive.

Figure 6.16.2 Adult female *Insignorthezia insignis* with ovisac, collected in 1930 from Royal Botanic Gardens, Kew, UK © Crown copyright

Figure 6.16.3 *Insignorthezia insignis* adult found in the UK on fresh herbs imported from Uganda © Crown copyright

Figure 6.16.4 Adult and immature *Insignorthezia insignis* on *Plocama pendula*, Canary Islands © Crown copyright

Figure 6.16.5 Colony of *Insignorthezia insignis* on Asteraceae, Canary Islands © C. Malumphy

Figure 6.16.6 Large infestation of *Insignorthezia insignis* on ornamental Citrus, UK © Crown copyright

Figure 6.16.7 Young orange *Citrus sinensis* plant covered in sticky honeydew egested by *Insignorthezia insignis* which serves as a medium for black sooty moulds, UK © Crown copyright

Host Plants

Insignorthezia insignis is broadly polyphagous, feeding on plants assigned to more than 119 genera in 45 families (Garcia *et al.,* 2016). It appears to prefer woody hosts, occurring mainly on the shoots and twigs. It is most often found on trees and shrubs of the Verbenaceae (especially *Lantana*, *Clerodendron* and *Duranta* species), Solanaceae (especially *Capsicum* and *Solanum*), Acanthaceae, Asteraceae (especially *Eupatorium* and other ornamentals) and Rubiaceae (including *Coffea*). In Egypt it has been recorded damaging a wide range of crops and utility plants such as sugarcane, *Citrus*, potatoes, tomatoes, chrysanthemums, shade trees such as *Jacaranda*, and windbreaks such as *Casuarina* (Ezzat, 1956).

Description

Adult female body is about 1.5 mm long and 1.3 mm wide, brownish olive green; dorsum mostly bare of wax except for two narrow longitudinal rows of 12 small white wax processes, these rows situated on either side of the mid-line; the dorsal wax processes fairly short, the longest and most curled occurring towards the posterior end (Figs 6.16.1-6.16.3). Ovisac up to 3.5 mm long, of brittle wax plates, nearly parallel-sided, curving slightly upwards posteriorly (Ezzat, 1956). Immature females resemble smaller versions of the adult. Males are rarely present.

Biology

The biology has been studied by Green (1922) and Ezzat (1956). There are three immature instars in the female and reproduction is parthenogenetic. Males do occur, but are very rare. Females lay between 58-95 eggs. There are up to three overlapping generations each year. The minimum and maximum critical temperatures for successful survival of colonies are 14° and 34° C, respectively.

Dispersal and Detection

The main natural dispersal stage is the first instar or crawler. They can disperse either by walking, by being blown by the wind, or by hitch-hiking on other organisms. Long distance dispersal and accidental introductions to new countries occur on infested planting material.

Insignorthezia insignis may be detected by careful examination of shrubs or trees. Sooty mould or sticky honeydew on leaves and stems, or ants running about may indicate the presence of the scale insect. The insects may be found attached to twigs and stems (and sometimes on the underside of leaf midribs).

Economic and other Impacts

Insignorthezia insignis is rarely damaging in the Caribbean region, although large populations may develop on and damage stressed plants. It is primarily a glasshouse pest in subtropical and temperate regions. Over much of its geographical range it is regarded as a minor pest, but in Hawaii, East Africa and South and Central America it has at times become a severe problem on *Citrus*, coffee, olive, *Jacaranda*, *Lantana* and other ornamental plants (CABI, 2017).

6.17 Yellow Crazy Ant

Order: Hymenoptera
Family: Formicidae
Species: *Anoplolepis gracilipes* (Smith)

	Present l Absent i	Threat		
		Bio	Hlth	Econ
SH	i	ü		
Asc	i	ü		
Tris	i			
FI	i			
SG	i			
BAT	i			

Figure 6.17.1 *Anoplolepis gracilipes* worker © Erin Prado, from www.antweb.org

Background

Anoplolepis gracilipes, are commonly known as ‘yellow crazy ants’ because of their erratic movements when disturbed, or ‘long-legged ant’. Like several other invasive ants, it is a tramp ant, a species that easily becomes established and dominant in new habitat due to traits such as aggression toward other ant species, little aggression toward members of its own species, efficient recruitment, and large colony size (Kirschenbaum & Grace, 2008). Native to South East Asia, it is considered one of the world's top 100 worst invasive species (GISD, 2013) and has spread throughout the tropics where it has invaded continental and island ecosystems and caused environmental damage. *Anoplolepis gracilipes* has the potential to devastate native 'keystone' resulting in a rapid alteration of ecosystem processes and negative effects on endemic species. In the past few decades, *A. gracilipes* has been brought to world attention due to its deadly attacks on nesting birds in the Seychelles and on the endemic crabs of Christmas Island (Wetterer, 2005).

Figure 6.17.2 *Anoplolepis gracilipes* worker head front profile© Erin Prado, from www.antweb.org

Figure 6.17.3 A dead gecko being dragged by yellow crazy ants in India ©Dinakarr

Figure 6.17.4 *Anoplolepis gracilipes* workers in Hawaii ©Forest & Kim Starr (USGS)

Figure 6.17.5 The Christmas Island forest skink (*Emoia nativitatis*), extinct in part due to the actions of *A. gracilipes* © Harold G. Cogger

Geographical Distribution

There is much disagreement concerning the geographical origin of *A. gracilipes.* Some authors consider *A. gracilipes* to be native to Africa, as the genus is almost exclusively African, others believe it is native to South East Asia where it is widely distributed (Wetterer, 2005). It is widespread in the tropics. It has been introduced into parts of Africa (including South Africa), Asia, South America (including Brazil) and Australia. It has been introduced into a wide range of tropical and subtropical islands including Caribbean islands, some Indian Ocean islands (Seychelles, Madagascar, Mauritius, Réunion, the Cocos Islands and the Christmas Islands) and some Pacific islands (New Caledonia, Hawaii, French Polynesia, Okinawa, Vanuatu, Micronesia and the Galapagos archipelago), (*Holoway et al., 2002).* A CLIMEX study by Jung *et al.* (2017) showed that the yellow crazy ant's distribution is greatly influenced by climatic conditions (particularly high temperature and humidity), somewhat limiting it to tropical and subtropical regions. They noted that it can survive in low temperatures (approximately 5°C) and dry conditions (e.g., Punjab in India, Baja California in Mexico). As temperature has a substantial effect on the development and activity of this species which could limit its spread into the natural environment of the southernmost UKOTs in the South Atlantic.

Foraging and Feeding

The yellow crazy ant is a scavenger and preys on a variety of litter and canopy invertebrates, such as small isopods, myriapods, molluscs, arachnids, land crabs and insects (O'Dowd *et al*. 1999). In addition to protein-rich foods *A. gracilipes* may rely heavily on carbohydrate-rich nutrient sources, such as plant nectar or honeydew-producing scale insects

Yellow crazy ant forage extremely competitively over every surface within its territory, and its ability to forage throughout the day and night, and over a wide range of temperatures allows it to rapidly alter invaded ecosystems. High temperatures and surface ground temperatures of 44°C may prevent workers from foraging. Ant activity begins to decline from around 25°C and foraging may be limited by rain. Researchers have reported an increase in both foraging activity and nest size in the dry season (O'Dowd, 2009).

Description

Anoplolepis gracilipes is one of the largest invasive ants and range from 1- 5mm, with remarkably long legs and antennae. Workers (Fig 6.17.1 & 4) are monomorphic, displaying no physical differentiation. It has a yellow-brownish body colour and is weakly sclerotized. Workers have a long slender gracile body, with the gaster usually darker than the head and thorax (GISD, 2019c). A full description and aid to identification can be found at www.antweb.org.

From Antweb: Among introduced ants, *Anoplolepis gracilipes* might be mistaken for *Paratrechina longicornis* (the Black Crazy Ant), which also has very long antennae and legs and eyes that break the outline of the head in full face view. In addition to the difference in colour, *A. gracilipes* can also be distinguished by the lack of erect hairs on the mesosoma, petiole and gaster. Anoplolepis gracilipes can also be mistaken for species of *Leptomyrmex* and *Oecophylla* because of their similar sizes and very long limbs. *Anoplolepis* can be distinguished from *Leptomyrmex* by the presence of an acidopore. *Anoplolepis* can be distinguished from *Oecophylla* by the more compact petiole.

Biology

Anoplolepis gracilipes colonies are polygynous. Worker production fluctuates but is continuous throughout the year. Sexual offspring may occur year-round but are generally produced seasonally (prior to the rainy season) (O'Dowd *et al*., 1999).

The life cycle of *A. gracilipes* has been estimated to take 76-84 days. Eggs hatch in 18-20 days, and worker larvae develop in 16-20 days. Pupae of workers require around 20 days to develop while those of queens develop in 30-34 days.

They inhabit disturbed habitats such as urban areas, forest edges or agricultural field and has been known to successfully colonise a variety of agricultural systems, including cinnamon, citrus and coffee crops and coconut plantations, and on banana, rambutan, mango, durian, sugarcane and langsat (references in O'Dowd, 2009). It is also able to inhabit human dwellings or human-frequented areas has meant it has become a serious pest in many households and buildings (O'Dowd, 2009).

Yellow crazy ants are also recorded invading undisturbed forest habitats, such as the drier monsoon forests on Christmas Island, where the ant takes advantage of crab burrows, the woody debris of the forest floor, tree hollows and epiphytes and the hollows created at the base of palm leaves (O'Dowd, 2009). They typically nest leaf litter or in cracks and crevices and in agricultural regions it is typically found nesting at the base, or even in the crown, of crop plants (O'Dowd, 2009)

Dispersal and Detection

Crazy ant colonies disperse naturally by nest fission (budding) whereby when mated queens and workers leave the nest to establish in new areas, only rarely do they disperse through flight via female winged reproductive forms. Generally, colonies that disperse through budding have a lower rate of dispersal and need human intervention to reach distant areas. It has been recorded that *A. gracilipes* moves as much as 400 m (1,300 ft) a year in Seychelles. A survey on Christmas Island, however, yielded an average spreading speed of three meters a day, the equivalent of one kilometre a year (O'Dowd, 1999).

Accidental dispersal is by human activities via general freight and household movements and the ants can also be potentially introduced through nursery stock from infested areas, as ants can easily escape detection in soil and plant material.

Economic and other Impacts

On Christmas Island in the Indian Ocean, land crabs are a keystone species in the forest ecology, they dig burrows, turn over the soil, and fertilize it with their dropping (Anon, 2017). *Anoplolepis gracilipes* have formed multi-queen supercolonies which are decimating the red land crab (*Gecarcoidea natalis*) populations and are having an impact on robber crab and blue crab numbers. Crazy ants do not bite or sting, they spray formic acid as a defence mechanism when disturbed. In areas of high ant density, the movement of a land crab disturbs them, leading them to spray formic acid, which at high levels can overwhelm the crabs. The crabs are usually blinded and eventually die from dehydration and exhaustion, as they decay, they provide food for the ants (Hoskin & Lach, 2015). Seedlings and weeds that are usually eaten by crabs start to grow, changing the structure of the forest. They crazy ants were on Christmas Island for over 50 years before they started showing a noticeable impact, this coincided with the arrival of a lac scale insect from southern Asia which produces copious honeydew, suggesting that availability of sugar fuelled a population explosion (Hoskin & Lach, 2015). The scale insects farmed by yellow crazy ants have increased in numbers and killed mature trees (Davis et al, 2008). The ants have thought to have played a role in the extinction of the Christmas Island pipistrelle (*Pipistrellus murrayi*) and Christmas Island forest skink (*Emoia nativitatis*) (Fig 6.17.5) in the past decade (Hoskin & Lach, 2015). There is concern that that endangered birds such as the endemic Abbott's booby (*Sula abbotti*), could eventually be driven to extinction through habitat alteration.

Crazy ant invasions on islands across the Pacific and Indian Oceans have reduced populations of native ants and other invertebrates (Hoskin & Lach, 2015). Populations of other ground and canopy dwelling animals, such as birds, reptiles (Fig 6.17.3) and other leaf litter fauna, have also decreased.

Crops, including sugarcane, macadamia, mango, and coconut, are also affected, due to the ants tending sap-sucking insects and killing the predators of crop pests (Hoskin & Lach, 2015). In Java, the scale insect *Coccus viridis* flourished in the presence of crazy ants, with an average of 1,057 scales per coffee bush, compared to 70 on ant-free bushes (Van der Groot, 1916).

In Australia, where the pest is present and under eradication in a number of areas, the Queensland Government, found that costs would range from AUS$115 million to over AUS$3 billion if the ants were not treated, this analysis only considered only limited impacts on agriculture and domestic dwellings however, not environmental impacts (Hoskin & Lach, 2015).

6.18 Argentine Ant

Order: Hymenoptera
Family: Formicidae
Species: *Linepithema humile* (Mayr)

	Present l Absent ¡	Threat Bio	 Hlth	 Econ
SH	l	ü		
Asc	¡	ü		
Tris	¡	ü		
FI	¡	ü		
SG	¡			
BAT	¡			

Figure 6.18.1 *Linepithema humile* adult worker ant © Eli Sarnat, PIAkey/Invasive Ants of the Pacific Islands/USDA APHIS ITP/Bugwood.org - CC BY-NC 3.0 US

Background

The Argentine ant, *Linepithema humile*, is one of the most invasive and problematic ant species in the world according to the Invasive Species Specialist Group (www.issg.org/database). Their invasion is of particular concern on oceanic islands due to the vulnerability and endemism typical of island ecosystems (Wetterer *et al.*, 2001). *Linepithema humile* invasions displace, through competition, almost all native ant species and native arthropod fauna which in turn affects several ecological processes (Suarez *et al.*, 2001; Wetterer *et al.*, 2001; Carpintero *et al.*, 2005; CABI, 2019.) Its presence can also have an economic effect, such as damage to infrastructure, and negative effects on crops and plantations due to its mutualistic interactions with hemipterans, which can affect the growth and production of the host plant (CABI, 2019).

Geographical Distribution

The Argentine ant is native to northern Argentina, southern Brazil, Uruguay and Paraguay (Suarez *et al.*, 2001; Tsutsui & Case, 2001) and was first recorded in North America in 1891 (Foster, 1908). Spreading primarily via human mediated transport, the Argentine ant is now found on six continents and numerous oceanic islands (Suarez *et al.*, 2001). *Linepithema humile* is most successful in Mediterranean and subtropical climates where it is usually associated with disturbed habitats as a result of human commercial activities. However, these ants can tolerate a range of abiotic conditions by their close association with humans (Suarez *et al.*, 2001).

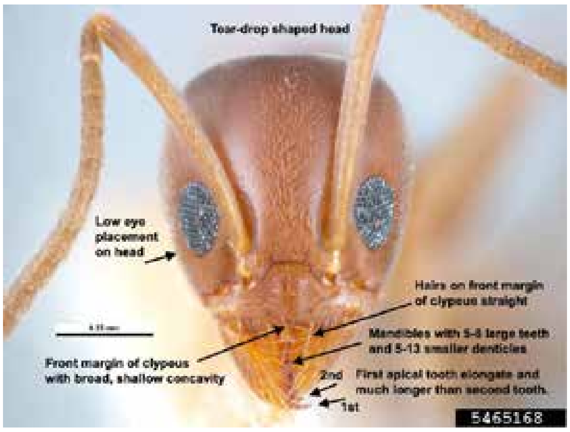

Figure 6.18.2 Head diagram of *Linepithema humile* © Pest and Diseases Image Library, Bugwood.org

Figure 6.18.3 *Linepithema humile* adult alate and worker © Pest and Diseases Image Library, Bugwood.org

Figure 6.18.4 *Linepithema humile* adult workers collecting honeydew from mealy bugs © Phil Lester

Figure 6.18.5 *Linepithema humile* queen (bottom centre) and workers © Phil Lester

Geographical Distribution

The Argentine ant is native to northern Argentina, southern Brazil, Uruguay and Paraguay (Suarez *et al.*, 2001; Tsutsui & Case, 2001) and was first recorded in North America in 1891 (Foster, 1908). Spreading primarily via human mediated transport, the Argentine ant is now found on six continents and numerous oceanic islands (Suarez *et al.*, 2001). *Linepithema humile* is most successful in Mediterranean and subtropical climates where it is usually associated with disturbed habitats as a result of human commercial activities. However, these ants can tolerate a range of abiotic conditions by their close association with humans (Suarez *et al.*, 2001).It is reported as common in St Helena (Pryce & Key, 2018).

Feeding and Foraging

Linepithema humile is omnivorous. Its diet is basically composed of liquid food (Abril *et al.*, 2007), but also contains a small percentage of solid food, mainly comprising of insects (Abril *et al.*, 2007). The collection of liquid food is related to the feeding of males and workers which feed mainly on carbohydrates, the principal nutrient of the liquid food collected. This, for the most part, consists of honeydew from scale insects (Fig. 6.18.4) or nectar from flowers. The collection of solid food is linked to the feeding of larvae and queens. Due to its high protein content, this is the main nutrient consumed by these individuals for their development and egg-laying, respectively (Abril *et al.*, 2007).

Description

Argentine ant workers are small (2.0-3.0 mm long) and uniformly light brown in colour (Fig. 6.18.1 and Fig. 6.18.3; Newell & Barber, 1913). The males are also small (2.8-3.0 mm long), winged and dark brown in colour (Newell & Barber, 1913). The queens are larger (4.5-5.0 mm long; Fig. 6.18.5), dark brown with a large thorax, as broad as the head (Newell & Barber, 1913). Morphological characteristics of the head are shown in Fig. 6.18.2. The eggs are elliptical, pearly white with an average size of 0.3 mm long by 0.2 mm wide (Newell & Barber, 1913).

Biology

In its native range *L. humile* are unicolonial but form polygynous (multi-queened) colonies when introduced into new areas (Holway *et al.*, 2002; Buczkowski *et al.*, 2004). These populations produce large numbers of offspring that dominate over other ant species (Holway *et al.*, 2002), these unicolonies can consist of cooperative interconnected nests forming supercolonies, e.g. the so-called European supercolonies (Giraud *et al.*, 2002). Supercolony formation results in no behavioural aggression (fighting) between different colonies and populations; this trait is greatly advantageous and allows for the ant colonies to attain high local densities and dominate ecosystems rapidly (McGlynn, 1999). Nests may be found under piles of wood, stones, under or amongst rubbish, under buildings, in potted plants or in piles of leaves or other organic debris. These ants mostly nest outside but may move into houses or other buildings if their outdoor nests are disturbed.

Linepithema humile workers move steadily in defined continuous trails and can exploit a wide range of habitats and food sources (Suarez *et al.*, 2001).

Dispersal and Detection

Natural dispersal is by nest fission (budding) whereby inseminated queens leave established nests on foot along with a group of workers and form new nests nearby (Suarez *et al.*, 2001; CABI, 2019).

Accidental dispersal is via human mediated transport. This means of dispersion is commonly known as long distance jump dispersion (Suarez *et al.*, 2001) and allows dispersion from a few kilometres to thousands of kilometres worldwide.

The easiest way to detect *L. humile* on the crop is by searching for foraging workers on the trunk or stems of plants because they associate closely with honeydew producing hemipterans. The Pacific Invasive Ant key (Sarnat, 2008) and Pacific Invasive Ants Taxonomy Workshop manual (Gunawardana & Sarnat, 2007) are useful tools for identification.

Economic and other Impacts

Linepithema humile is an economic pest in tropical and warm temperate regions around the world as it invades crops and plantations for honeydew by creating mutualistic interactions with hemipterans, which in turn affect the growth and production of the host plant (Suarez *et al.*, 2001; CABI, 2019). *Linepithema humile* invasions also affect essential ecological processes (Wetterer, *et al.*, 2001). They displace native ant and arthropod species which alters several ecological processes such as ant-mediated seed dispersal and/or plant pollination and can reduce the available nectar for bees to forage on (Wetterer *et al.*, 2001; Holway *et al.*, 2002).

6.19 Singapore Ant

Order: Hymenoptera
Family: Formicidae
Species: *Monomorium destructor* (Jerdon)

	Present l	Threat		
	Absent ¡	Bio	Hlth	Econ
SH	¡	ü		
Asc	¡	ü		
Tris	¡			
FI	¡			
SG	¡			
BAT	¡			

Figure 6.19.1 *Monomorium destructor* adult alate and worker © Pest and Diseases Image Library, Bugwood.org

Background

Monomorium destructor is known as a ‘tramp ant’ as they have been transported around the world via human commerce and trade. They can be found in tropical, semitropical or temperate regions and are a nuisance in urban environments as they can cause extensive damage by gnawing holes in fabric and rubber goods, remove rubber insulation from electric and phone lines and damage polyethylene cable (Wetterer, 2009; CABI, 2019; Hoffman, 2019a).

Geographical Distribution

Monomorium destructor probably originates from India but there are subsequent reports that it is native to all of Asia (Wetterer, 2009; CABI, 2019). The species has subsequently been introduced throughout tropical and semitropical zones of the world and is being increasingly spread into the temperate zones where it survives in heated buildings (Harris, n.d.; Wetterer, 2009).

Foraging and Feeding

Monomorium destructor is a relatively slow-moving ant that forages along narrow trails with a broad diet of living and dead insects, insect eggs, carbohydrates from tending sap-sucking insects, nectar and seeds. In households they will feed on almost any food available (Harris, n.d.; Deyrup *et al.*, 2000; CABI, 2019).

Figure 6.19.2 *Monomorium destructor* major worker adult showing mandibles © Eli Sarnat, PIAkey: Invasive Ants of the Pacific Islands, USDA APHIS PPQ, Bugwood.org

Figure 6.19.3 *Monomorium destructor* dorsal view of adult worker © Pest and Diseases Image Library, Bugwood.org

Figure 6.19.4 *Monomorium destructor* workers © Eli Sarnat, PIAkey: Invasive Ants of the Pacific Islands, USDA APHIS PPQ, Bugwood.org

Description

The length of workers is highly variable (polymorphic) from 1.8-3.5 mm and they are uniformly light yellow to dull brownish yellow in colour (Figs 6.19.1-4). The gaster (swollen part of abdomen) is always darker (Figs. 6.19.1 -4). The antennae have 12 segments including a 3-segmented club. The mandibles have 3 strong teeth the fourth (topmost) is minute (Fig. 6.19.2; Harris, n.d.; Wetterer, 2009; CABI, 2019).

Biology

The Singapore ant forms large colonies with multiple queens. They nest outdoors in trees or in soil, or in buildings, depending largely on whether they occur in tropical, semitropical or temperate zones (Harris, n.d.; Smith, 1965; CABI, 2019). For example, they nest predominantly in trees in Sri Lanka (e.g. in coconut plantations), soil in tropical regions and are mainly associated with urban areas in Australia's Northern Territory (Harris, n.d.; CABI, 2019).

Dispersal and Detection

Natural dispersal is by nest fission (budding) whereby queens walk on foot accompanied by workers to establish new nests (Harris, n.d.; CABI, 2019).

Accidental dispersal is by human-mediated dispersal, without which the ant may never have reached its current locations. *Monomorium destructor* is a tramp ant, renowned for transportation *via* human commerce and trade. It is associated with a wide range of freight types, making it difficult to target any particular pathway (Harris *et al.*, 2005).

These ants have been detected at borders on a range of commodities and can be identified using the Pacific Invasive Ant Key (Sarnat, 2008) and the Pacific Invasive Ants Taxonomy Workshop manual (Gunawardana & Sarnat, 2007).

Economic and other Impacts

In the natural environment *M. destructor* may have some effect on other ant species but is not generally a major component of ant communities, however it has been documented as displacing native invertebrate fauna through aggression, and as such can be a threat to biodiversity (Harris *et al.*, 2005). It is not recorded as a horticultural or agricultural pest but there are many documents on its ability to be a major urban pest. Foragers gnaw holes in fabric and rubber goods, remove insulation from electric and phone lines etc. Cars parked overnight in infested areas can have their ignition systems shorted. They forage for sugars, fats and proteins in houses resulting in costly property damage and treatment (e.g. cars, televisions, phones etc.). Several house and car fires have also been attributed to this ant species (Harris *et al.*, 2005) and people have been bitten in bed (Harris, n.d.; Harris *et al.*, 2005; CABI, 2019).

6.20 Tawny Crazy Ant

Order: Hymenoptera
Family: Formicidae
Species: *Nylanderia fulva* (Mayr)

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
SH	¡	ü		ü
Asc	¡	ü		ü
Tris	¡	ü		ü
FI	¡			
SG	¡			
BAT	¡			

Figure 6.20.1 *Nylanderia fulva* female worker © Mike Quin, BugGuide

Background

Nylanderia fulva is a species of ant within a group of ants referred to as "crazy ants", named because of their quick and erratic movements. Their colonies consist of many ants with more than one queen and display supercolony characteristics. It is an invasive species and considered a serious agricultural, urban, and ecological pest in its native and introduced regions (Hill *et al.*, 2016; Wang *et al.*, 2016). Hemipteran population increase due to the tending by these ants, leading to increased damage to fruit crops (Hill *et al.*, 2016; Wang *et al.*, 2016); they cause electrical damage to phone lines, air conditioning units and computers etc. (Meyers, 2008); and are known to displace native ant species (Hill *et al.* 2016; Sharma *et al.*, 2017).

Geographical Distribution

Nylanderia fulva is native to South America, especially southern Brazil and northern Argentina along the border of Uruguay and Paraguay. It has become established in Anguilla, Bermuda, Colombia, Cuba, Guadeloupe, Martinique, Mexico, Panama, Puerto Rico, St. Vincent and the Grenadines, and the US Virgin Islands (Gotzek *et al.*, 2012; Hill *et al.*, 2016; Wang *et al.*, 2016).

Foraging and Feeding

Nylanderia fulva is omnivorous, feeding on sweet liquid exudates for carbohydrates (Fig 6.20.2) from plant nectaries and from honeydew produced by various hemipteran insects (e.g. aphids, mealybugs, scale insects, etc.), and protein from predation and scavenging of arthropods, insects, including other ant species, and small vertebrates (Wang *et al.*, 2016; Sharma *et al.*, 2017).

Figure 6.20.2 *Nylanderia fulva* on passion fruit vine © Mike Quin, BugGuide

Figure 6.20.3 *Nylanderia fulva* male ©John Schneider, BugGuide

Figure 6.20.4 *Nylanderia fulva* workers with brood © Blake Layton

Figure 6.20.5 An army of *Nylanderia fulva* ants © Fudd Graham, Auburn University, Bugwood.org

Description

Nylanderia fulva ants are monomorphic and golden-brown to reddish brown in colour Figs. 6.20.1 and 6.20.3). The workers are 2-2.5 mm in length, males are slightly larger (2.4-2.7mm) and queens are ~4mm longer (MacGowan, 2016). Their body surface is smooth and glossy and covered with dense pubescence (hairs). After feeding, the rear portion of the abdomen appears striped (Fig. 6.20.1) due to stretching of the light-coloured membrane connecting the abdominal segments (Sharma *et al.*, 2017). The workers have 12 segments on their antennae and the males have 13, neither have a club (Sharma *et al.*, 2017).

The queen lays single white ovoid eggs (0.4 mm in length) which are then attached to the egg mass (17-25 eggs) using saliva from the workers (Wang *et al.*, 2016). The egg stage hatch into hymenopteriform larvae (Fig 6.20.4) which pass through three instars for workers and four instars for males (Wang *et al.*, 2016).

Biology

Nylanderia fulva colonies often consist of many ants with more than one queen and display supercolony characteristics – i.e. individual colonies do not exhibit mutual aggression towards one another, and multiple interconnected nests can be hundreds of kilometres long. The nests are usually found in leaf litter, rotten logs, in and under various types of debris, soil, under potted plants and along underground electrical conduits etc. (MacGowan & Layton, 2010; Sharma *et al.*, 2017). They are less active during the cooler months, but populations rapidly increase with increase in temperature during spring and summer. Alate males (Fig 6.20.3) actively fly throughout the year with a peak abundance in summer whereas the alate queens are produced just once a year in late summer (Wang *et al.*, 2016).

Dispersal and Detection

Natural dispersal is by nest fission (or budding), where queens establish new nests with the help of workers within walking distance of the natal nest (Wang *et al.*, 2016). Invasive populations have been reported to spread at a rate of approximately 20 – 30 m per month in Texas (Meyers, 2008) and approximately 100 m per month in Columbia (Wang *et al.*, 2016).

Accidental introductions are from human activities which has led to its successful invasion into the United States and the Caribbean etc. from South America. However, *N. fulva* has a lower critical thermal limit of » 7°C (Bentley *et al.*, 2016) which could limit its spread into the southernmost UKOTs in the South Atlantic.

Accurate identification of this species has been problematic as there is a lack of distinctive characteristics between species, especially in the workers, which has led to misidentification as *N. pubens* in the past (Gotzek *et al.*, 2012; Wang *et al.*, 2016) and proper identification is often limited due to a lack of taxonomic resources. In addition, this species has several different common names including Rasberry crazy ant (named after its discoverer Tom Rasberry), hairy crazy ant and Caribbean crazy ant but its official common name is the tawny crazy ant (Entomological Society of America, 2016).

Economic and other Impacts

This species forms huge supercolonies and can dominate over native ant species due to its aggressive and competitive nature and could have a cascading ecological impact if left unchecked (LeBrun *et al.*, 2013). It is a serious urban pest due mainly to the sheer volume of ants within a colony which often infiltrate homes and businesses (Fig 6.20.5), sometimes causing power shortages due to their attraction to electrical systems (Meyers, 2008; MacGowan, 2016). At high densities, *N. fulva* can also be an agricultural pest due to its enhancement of phloem-feeding hemipteran insects (Wang *et al.*, 2016) and they been reported to destroy honey bee hives in Texas by consuming the brood and then colonizing the hives (Harmon, 2009).

6.21 Big-Headed Ant

Order: Hymenoptera
Family: Formicidae
Species: *Pheidole megacephala* (Fabricius)

	Present l Absent ¡	Threat Bio	 Hlth	 Econ
SH	l			
Asc	l			
Tris	¡	ü		
FI	¡			
SG	l			
BAT	¡			

Figure 6.21.1 *Pheidole megacephala* adult major worker © Alexander L. Wild

Background

The big-headed ant is a very successful invasive species and is an urban, agricultural and environmental pest (Wetterer, 2007; CABI, 2019). They form large colonies with multiple nests and have multiple fertile queens spreading throughout the colony (CABI, 2019). *Pheidole megacephala* is an exotic ant species that can severely affect native invertebrate biodiversity (Hoffmann *et al.*, 1999) and although climate limits its geographical spread it can be easily introduced into greenhouses and other climate-controlled facilities, as reported in England and Denmark (Collingwood, 1979).

Geographical Distribution

Pheidole megacephala is presumed to be native to Africa because of the extensive geographic variation there. It appears to have then spread rapidly to all parts of the tropics and subtropics beginning in the colonial period and was already widespread by the 1800s. Temporary infestations can occur in temperate regions when colonies are accidentally introduced to greenhouses and other climate-controlled facilities (Collingwood, 1979; CABI, 2019).

Foraging and Feeding

Pheidole megacephala is an omnivorous scavenger, feeding on honeydew from aphids and other hempiteran insects (Fig. 6.21.4), dead insects, soil invertebrates and small vertebrates (e.g. bird hatchlings) (Wetterer, 2007; Hoffmann, 2019b). Foragers will quickly recruit nest mates to a food source using foraging tunnels that have numerous entrances and can be seen along the soil surface. Arthropod prey items are dissected by workers and brought back to the nest. Trophallaxis is often observed between minor workers or a minor and a major worker (Dejean *et al.*, 2005).

Figure 6.21.2 *Pheidole megacephala* minor (small heads) and major (large heads) adults © Western Australian Agriculture Authority

Figure 6.21.3 *Pheidole megacephala* workers with their much larger queen © Alexander L. Wild

Figure 6.21.4 *Pheidole megacephala* minor workers tending aphids © Alexander L. Wild

Figure 6.21.5 Soil displaced by *Pheidole megacephala* digging around a water pipe © R.H. Scheffrahn, University of Florida

Foraging and Feeding

Pheidole megacephala is an omnivorous scavenger, feeding on honeydew from aphids and other hempiteran insects (Fig. 6.21.4), dead insects, soil invertebrates and small vertebrates (e.g. bird hatchlings) (Wetterer, 2007; Hoffmann, 2019b). Foragers will quickly recruit nest mates to a food source using foraging tunnels that have numerous entrances and can be seen along the soil surface. Arthropod prey items are dissected by workers and brought back to the nest. Trophallaxis is often observed between minor workers or a minor and a major worker (Dejean *et al.*, 2005).

Description

Pheidole megacephala are dimorphic. The major workers (or "soldiers") have large heart shaped heads, hence its common name, the big-headed ant, and are 3 – 4 mm in length and remain primarily inside the nest (Figs 6.21.1-2). The minor workers (Fig. 6.21.2) are small (2 mm) and do most of the foraging. The petiole (waist) of both worker forms are two-segmented and the post-petiolar node is conspicuously swollen, they are yellow to reddish brown in colour with the head and abdomen somewhat darker than the mesosoma (Wetterer, 2007).

Biology

The big-headed ant is holometabolous (undergoes complete metamorphosis), and like other dominant invasive ant species, forms unicolonial supercolonies (i.e. multiple queen aggregations of interconnected nests that lack colonial boundaries and intraspecific aggression and act as a single cooperative unit (Hoffmann *et al.*, 1999). New colonies are commonly formed through budding with one or more queens accompanied by a group of workers (Fig. 6.21.3) splitting off from the main colony, however single alate queens are also known to found new colonies (Wetterer, 2007). It has been reported that an individual queen can lay up to 292 eggs in a month (Wetterer, 2007). Their nests can be found in disturbed soils, lawns, flowerbeds; under objects e.g. bricks, cement slabs; around trees or water pipes (Fig. 6.21.5) and along the base of structures and walkways.

Dispersal and Detection

Natural dispersal is by nest fission (budding) whereby populations establish in new areas by creating new nests and displacing other ant species in the process; this can be rapid (Hoffmann, 2019b).

Accidental dispersal is by human activities via general freight and household movements and the ants can also be potentially introduced through nursery stock from infested areas. However, temperature has a substantial effect on the development and activity of this species which could limit its spread into the natural environment of the southernmost UKOTs in the South Atlantic as they are not active outside the nest at temperatures below 5°C (Wetterer, 2007). However, they can be introduced into climate-controlled greenhouses via nursery stock.

These ants can easily escape detection in soil and plant material.

Economic and other Impacts

This invasive ant displaces most native invertebrate fauna directly through aggression, and as such is a serious threat to biodiversity (Hoffmann *et al.*, 1999; Vanderwoude, 2000; Wetterer, 2007; CABI, 2019). Evidence also exists of reductions in vertebrate populations where this ant is extremely abundant. Effects on plants and horticultural crops can be direct through the likes of seed harvesting, or indirect through the likes of harbouring phytophagous insects which reduce plant productivity. This ant is also known to chew on irrigation, telephone cabling and electrical wires (CABI, 2019).

6.22 Red Imported Fire Ant

Order: Hymenoptera
Family: Formicidae
Species: *Solenopsis invicta* Buren

	Present l Absent ¡	Threat		
		Bio	Hlth	Econ
SH	¡	ü	ü	ü
Asc	¡	ü	ü	ü
Tris	¡	ü	ü	ü
FI	¡			
SG	¡			
BAT	¡			

Figure 6.22.1 *Solenopsis invicta* adult red imported fire ant © April Noble, Bugwood.org

Background

The red imported fire ant, *Solenopsis invicta* (Fig. 6.22.1), also known as the fire ant or RIFA, is an aggressive omnivorous forager that occurs in high densities. *It* is highly invasive and destructive due to its high reproductive capacity, large colony size, ability to exploit human disturbances, wide food range and ability to sting (CABI, 2019). If disturbed, it can relocate quickly, ensuring survival of the colony.

Infestations can impact households, humans, livestock, crop production, flower/nursery production, infrastructure, wildlife, recreation, tourism and businesses. Worker ants respond rapidly and aggressively to disturbances and bite and sting repeatedly with a painful burning sting. *Solenopsis invicta* venom forms a white fluid-filled pustule or blister at the red sting site, a symptom characteristic only of fire ants (Fig. 6.22.2). *Solenopsis invicta* can also attack livestock and wildlife. They are attracted to mucous membranes in the animals' eyes and nostrils, and their stings cause blindness and swelling, which may cause suffocation. Immobilized animals, such as penned or new born livestock, are at greatest risk.

Geographical Distribution

Solenopsis invicta is native to tropical areas of Central and South America (CABI, 2019). It is an invasive pest that has become widespread in the southern USA and Caribbean (Morrison *et al*., 2004; ISSG, 2014). It has also spread to China, Malaysia, Singapore, Australia and New Zealand, although it has been successfully eradicated from New Zealand (Pascoe, 2001; CABI, 2019).

Figure 6.22.2 Reactions to stings from *Solenopsis invicta*, British Virgin Islands © C. Malumphy

Figure 6.22.3 *Solenopsis invicta* – multiple life stages © Imported Fire Ant Station, USDA APHIS PPQ, Bugwood.org

Figure 6.22.4 Mound of *Solenopsis invicta*, British Virgin Islands © C. Malumphy

Figure 6.22.5 Colony of *Solenopsis invicta*, British Virgin Islands © C. Malumphy

climates are unsuitable for the ant's successful establishment although it may survive in heated structures. It is estimated that continental areas receiving more than 510 mm of rainfall a year will support *S. invicta* whereas continental areas receiving less rainfall will only support populations near sources of permanent water or in regularly irrigated areas (Morrison *et al*., 2004).

Host Plants

Fire ants can cause significant damage to a number of crops, including soybean (*Glycine max*), citrus (*Citrus* spp.), eggplant (*Solanum melongena*), okra (*Abelmoschus esculentus*), sweet potato (*Ipomoea batatas*), cabbage (*Brassica* spp.), cucumber (*Cucumis sativus*), sunflower (*Helianthus* spp.) and watermelon (*Citrullus lanatus*) with ants feeding on the buds and fruits. The ants also feed on the branches, new terminal growth, flowers, young fruit, bark and sap of tree crops. *In citrus orchards, S. invicta* tunnels through roots and tubers, feeds on plants, fruit and seeds and can girdle young trees (Stewart & Vinson, 1991). As well as causing direct damage to plants, *S. invicta* also aggravates populations of other insect plant pests such as Hemiptera (e.g. aphids, scale insects and mealybugs), with the ants consuming the honeydew produced by these pests.

Description

The life cycle of the ant has four stages: egg, larva, pupa, and adult (Fig. 6.22.3). The eggs are spherical and creamy-white, and the larvae are legless, cream-coloured and grub-like with a distinct head capsule (CABI, 2019). The pupae resemble the worker ants and are initially creamy-white but turn darker before the adult ants emerge (Fig. 6.22.3). The eggs, larvae and pupae are referred to as a brood.

Worker ants are females and do the work of the colony, with larger individuals functioning as soldiers who defend the colony. Worker ants are wingless, dark reddish-brown with black abdomens, have a two-segmented antennal club and range from 1.5 to 5.0 mm long (Fig. 6.22.1). Workers in the genus *Solenopsis* are polymorphic, meaning they are physically differentiated into more than two different body-forms (Vinson, 1997). A new colony's first workers, called minims, are smaller than those of later generations. Minors are slightly larger, and medias larger still (Taber, 2000). The largest is the major worker, which (in later generations) can reach lengths of up to 5.0 mm (Taber, 2000).

At certain times of the year, winged males and queens are produced. The queen ants are reddish-brown and larger than the worker ants (9.0 mm), whereas the males are shiny and black with a smaller head.

Biology

A general overview of the biology and ecology of *S. invicta* can be found in Vinson (1997). *Solenopsis invicta* is a social insect with colonies producing hills, nests or mounds where they reside (Figs 6.22.4-5). *Solenopsis invicta* can live in a wide range of habitats and is able to dominate altered habitats. The mounds generally occur in open, sunny areas for purposes of brood thermoregulation (Porter & Tschinkel, 1993) and are especially common in disturbed and irrigated soil. The ant is also well adapted to opportunistic exploitation of disturbed habitats (Morrison *et al*., 2004). The colonies can occasionally occur indoors, within electrical equipment and tree trunks (Vinson, 1997). In disturbed and developed forested areas, *S. invicta* nests are abundant along roadsides and trails near buildings, but it is not abundant in densely wooded areas. Colonies also occur in lawns, gardens, school yards, parks, roadsides and golf courses. A fully developed colony can contain over 200,000 to 400,000 ants.

Mounds may reach 30 to 40 cm high and 30 to 50 cm in diameter in clay-type soils. The mounds have no entrance holes or central entrance hole on the surface, instead foraging worker ants enter and exit through tunnels radiating up to 5 to 10 m away from the mound. Inside, the mounds have interconnecting galleries that may extend 30 to 40 cm deep, although some tunnels can penetrate to the water table. The disturbance of mounds results in a rapid defensive response by the worker ants, which quickly run up the vertical surfaces to bite and sting any objects that are encountered. Under extremely hot, dry conditions, colonies may live underground and not develop surface nests or mounds.

Fire ants are omnivorous, but a large portion of their diet are invertebrates which they sting and kill (Holway *et al*., 2002; Ness & Bronstein, 2004). They also feed on dead animals, plant tissues, seeds, fruits and are attracted to honey dew and sap flows (Vinson, 1997). There are four larval instars which are fed only a liquid diet by the workers until they reach the third instar (Vinson, 1997). When the larvae reach the fourth instar, they can digest solid foods. Worker ants will bring solid food rich in protein and deposit it in a depression in front of the mouth of the larvae (Vinson, 1997). The larvae will secrete digestive enzymes that break down the solid food and regurgitate it back to worker ants.

The queen spends her life laying eggs. At certain times of the year, winged males and queens are produced that fly into the air, where they mate. The males die soon after wards and the mated queens form new colonies. Newly-mated *S. invicta* queens often move to pastures (Taber, 2000). The mated queens find suitable nesting sites, shed their wings, and begin digging underground chambers in which to lay eggs. The first eggs and larvae, which emerge as minims, are cared for by the queen. The workers then care for the queen and subsequent brood, forage for food, and expand the nest.

Dispersal and Detection

The spread of *S. invicta* has been aided by humans via the shipment of infested articles such as nursery potting media, sod, bales of hay and soil *(*CABI, 2019*)*. Objects contaminated with soil pose a high risk *(CABI, 2019)*. Infestations recorded from Aruba and Jamaica have only been found on golf courses that import sod from Florida, indicating an important potential means of spread (Wetterer, 2013). Interspecific competition with resistant native ant fauna may limit its spread (Porter *et al*., 1997).

Electrical equipment e.g. air conditioning units, power company transformers, traffic signal control cabinets, electrical pumps and car electrical systems can also attract infestations seeking warmth and shelter, but also provide a means of spread (CABI, 2019).

Early detection by active surveillance followed by nest treatment is critical to any eradication attempt. Although expensive, it is nothing compared to the economic costs of permanent infestations. Pitfall traps and attractant baits are both methods that can yield good results (Stringer *et al.*, 2011). Fire ants are significantly more attracted to baits containing mixed proteins (hotdog or ground meat combined with sweet peanut butter) compared to sugar or water baits. Baited pitfall traps are better than non-baited pitfall traps and food baits at detecting incipient ant colonies, whereas food baits perform well when trying to detect large colonies (Stringer *et al.*, 2011).

Economic and other Impacts

Solenopsis invicta is a major pest to various economic sectors costing an estimated $6 billion annually in the USA (Drees & Lard, 2006). Infestations can impact households, humans, livestock, crop production, flower/nursery production, infrastructure, wildlife, recreation, tourism and businesses. If not treated immediately, infestations of new areas by *S. invicta* are likely to be expensive or even impossible to eradicate. Infestations covering several hectares may cost thousands of US dollars to eradicate, whereas infestations covering several hundred hectares could cost tens of thousands of dollars to eradicate (Drees et al., 2002). In Hawaii it is estimated that the potential cost of *S. invicta* infestations could total $2.5 billion over a 20-year period following introduction and minimal government response (Gutrich et al., 2007).

6.23 Little Fire Ant

Order: Hymenoptera
Family: Formicidae
Species: *Wasmannia auropunctata* (Roger)

	Present l Absent ¡	Threat Bio	Hlth	Econ
SH	¡	ü	ü	ü
Asc	¡	ü	ü	ü
Tris	¡	ü	ü	ü
FI	¡			
SG	¡			
BAT	¡			

Figure 6.23.1 *Wasmannia auropunctata* adult © Eli Sarnat, PIAkey: Invasive Ants of the Pacific Islands, USDA APHIS PPQ, Bugwood.org

Background

Wasmannia auropunctata, known as 'the little fire ant', is an invasive pest blamed for reducing species diversity, reducing overall abundance of flying and tree-dwelling insects, and eliminating arachnid populations. It is also known for its painful stings. On the Galapagos, it reportedly eats the hatchlings of tortoises and attacks the eyes and cloacae of the adults (Holway et al; 2002). It is considered one of the 100 worst invasive species of the world by the IUCN due to its negative impact on natural ecosystems, agriculture and human health (CABI, 2018; Chifflet, 2018).

Geographical Distribution

This species originated from Central and South America and has successfully spread throughout the tropics since the beginning of the last century. Its introduced range now encompasses many Caribbean islands, Florida, several West-African countries, North America (including Canada), South America and a large number of Pacific islands (Holway et al., 2002; Wetterer et al., 2003). It also recently established populations in the Mediterranean zone, in Israel, which is raising concerns about its potential distribution range outside the tropics (Vonshak et al. 2009).

Figure 6.23.2 *Wasmannia auropunctata* adults at bait © Eli Sarnat/PIAkey: Invasive Ants of the Pacific Islands/USDA APHIS ITP/Bugwood.org - CC BY-NC 3.0 US

Figure 6.23.3 *Wasmannia auropunctata* adults attending scale insects © Forest & Kim Starr-2012 - CC BY 4.0

Figure 6.23.4 Adult *W. auropunctata* dorsal view © Pest and Diseases Image Library, Bugwood.org

Figure 6.23.5 Adult *W. auropunctata* lateral view © Pest and Diseases Image Library, Bugwood.org

Description

Wasmannia auropunctata workers are monomorphic, i.e. they display no physical differentiation (Holway et al., 2002), small to medium-sized, with the workers ranging from 1-2 mm (Holway et al., 2002) and are light to golden brown in colour. The gaster (abdomen) is often darker. The pedicel, between the thorax and gaster, has two segments; the petiole and postpetiole (Figures 6.23.4 and 6.23.5). The petiole is 'hatchet-like', with a node that is almost rectangular in profile and higher than the postpetiole. The antenna has 11 segments, with the last two segments greatly enlarged into a distinct club. The antennal scape (the first segment) is received into a distinct groove (scrobe) that extends almost to the posterior border of the head. The propodeum has long and sharp epinotal spines (propodeal spines). The body is sparsely covered with long, erect hairs (Figure 6.23.5). This species is well-known for a painful sting, seemingly out of proportion to its size (Wetterer et al. 2003)

Queen *W. auropunctata* are much larger (approximately 4.5 mm) and darker than the workers. In dense colony aggregations, the multiple queens are quite conspicuous peppered among the lighter-coloured workers.

Biology

Wasmannia auropunctata form both polygenous (multi-queened) and monogenous (single-queened) colonies, have generalist feeding and nesting habits and thrive in a wide range of conditions (Wetterer et al., 2003). They do not excavate nests deep under ground but instead exploit an extremely broad array of superficial cavities both natural and man-made, e.g. under rocks, under or within logs, plant debris, cavities within human products etc. (Wetterer et al, 2003). They are not able to establish in cold climates but can survive in human habitations or infrastructure including climate-controlled buildings and greenhouse e.g. it has known to be a pest in greenhouses in England and Canada (Holway et al, 2002; Wetterer, et al., 2003)

Dispersal and Detection

Natural dispersal is by nest fission (budding) whereby queens walk on foot accompanied by workers to establish new nests (CABI, 2019; Wetterer et al., 2003). They are also known to spread via floating vegetation or debris, particularly on logs (CABI, 2019).

Wasmannia auropunctata have an affinity for nesting at the base of trees and so are easily spread locally and globally in potted plants nurseries, fruit produce, ornamental plants etc and also by the movement of logs and lumber products (CABI, 2019; Holway et al., 2002). Military and commercial activity may have also facilitated the spread of these ants in the Pacific region (GISD, 2019) so added checks should be extended to these activities with the South Atlantic UKOTS.

Intentional introductions from its use as a biological control agent has occurred Gabon and Cameroon because it preys on, and therefore helps control, certain herbivorous cocoa pests (CABI, 2018; GISD, 2019a).

Detection can be by conducting surveillance programs in high risk areas with favourable ant habitats, by visual inspection, vial baiting or by chop stick baiting with lures such as peanut butter.

Economic and other Impacts

In its native range in South America, *W. auropunctata* is a pest in disturbed forests and agricultural areas, where it can reach high densities. They are also a nuisance to plantation workers and horticulturists due to their painful sting (CABI, 2019; Wetterer et al., 2003).

W. auropunctata may have negative impacts on biodiversity of vertebrates and invertebrates. They compete for food and cause a decline in numbers of small vertebrates. In Colombia, a high abundance of this ant in forest fragments has been linked with low ant diversity. It efficiently exploits resources including nectar, refuges within vegetation and honeydew residues (of Hemipteran insects), and it may out-compete and displace native myrmecofauna (Armbrecht and Ulloa-Chacón, 2003). In human habitations this species may sting, and even blind, domestic pets (cats and dogs) (Romanski, 2001). It is believed to have caused a decrease in reptile populations in New Caledonia and in the Galapagos archipelago, where it eats tortoise hatchlings and attacks the eyes and cloacae of the adult tortoises. *W. auropunctata* is probably the most aggressive species that has been introduced into the Galapagos archipelago, where a marked reduction of scorpions, spiders and native ant species in infested areas has been observed (References in CABI, 2019).

6.24 German wasp

Order: Hymenoptera
Family: Vespididae
Species: *Vespula germanica* (Fabricius, 1793)

	Present l Absent ¡	Threat Bio	 Hlth	 Econ
SH	¡	ü	ü	
Asc	l			
Tris	¡	ü	ü	
FI	¡	ü	ü	
SG	¡	ü	ü	
BAT	¡	ü	ü	

Figure 6.24.1. German wasp, *Vespula germanica* adult © Fir0002/Flagstaffotos

Background

The German wasp (*Vespula germanica*) is a wasp species of Palaearctic origin within the family Vespidae. This species is commonly known as the 'European wasp' in Australasia, South Africa and South America, and the 'German wasp' or 'yellowjacket' elsewhere. It occurs naturally in Europe, northern Africa and Asia, and has been introduced into North and South America, Iceland, Ascension Island, South Africa, Australia and New Zealand. It can sometimes be difficult to distinguish *V. germanica* from another invasive Palearctic wasp, *V. vulgaris*, which can have forms which look extremely similar. German wasp can have significant negative impacts on horticulture, apiculture, tourism and outdoor social activities, as well as animal health and biodiversity.

Geographical Distribution

The German wasp is present throughout Europe, northern Africa and parts of the Middle East and Asia. The wasp has been introduced to the USA, New Zealand, Australia, Canada, Chile, Argentina and Iceland. It has been established on Ascension Island since the early 1960's (Yarrow, 1967), presumably by accidental introduction from Europe. It has been recorded in Chile and Argentina since the 1970's. In Chile, *V. germanica* has been recorded from Punta Arenas in the southern tip of South America to Coquimbo in the north. In Argentina, the species is present throughout Patagonia (CABI, 2019). A German wasp was intercepted by the Falkland Islands Department of Agriculture in 2015, it was discovered in a trailer from either the UK or the Netherlands and sent to Fera for identification.

Figure 6.24.2 German wasp, *Vespula germanica* adult face with black dots © Pest and Diseases Image Library, Bugwood.org

Figure 6.24.3 Common wasp, *Vespula vulgaris* adult face with anchor mark © Pest and Diseases Image Library, Bugwood.org

Figure 6.24.4 *Vespula germanica* queen constructing a nest © Gary Alpert, Harvard University, Bugwood.org

Figure 6.24.5 Queen and workers of *Vespula germanica* in nest © Phil Bendle

Description

Adult German wasps are 12 to 17 mm long (queens may be up to 20 mm long) with a blackish brown pedunculate abdomen and bright yellow stripes (Fig. 6.24.1). They have strong black markings including an arrow-shaped mark down the middle of the abdomen and black spots on either side. Wings are long and translucent, legs are yellow and antennae black. Antennae are divided into 12 (females) or 13 (males) segments and the abdomen is divided into 6 or 7 segments also depending on gender (males have 7). Queens are equipped with an ovipositor (GISD, 2019b). German and common wasps (*V. vulgaris*) are very similar in appearance. The dorsal markings on the abdomen have shown to be variable, the marking on the side of the head and face are more reliable to distinguish between these two species (Figs 6.24.2 and 6.24.3)

Biology

Vespula germanica is a social wasp with a typically annual life cycle. Mated queens overwinter in leaf litter, crevices in tree bark and also buildings. In spring, the queens emerge, feed at nectar sources and begin searching for suitable nesting sites. She will choose secluded sites, either underground, behind retaining walls and rockeries in gardens, in sheds or in cavity walls or roof spaces in buildings. The founding queen builds her golf ball sized 'embryo' nest (Fig. 6.24.4) mixing saliva with wood fibres collected from dead trees, wooden poles and fences. Adult worker wasps (females) reach maturity and assume all foraging and nest-building duties while the queen remains within the nest.

By late summer the nest is about the size of a football with several thousand adult workers in the colony. At this time, queen-rearing cells, which are twice the volume of the worker cells, are constructed and the new queens and males are produced (Fig. 6.24.5). In most of their native range the young queens leave the nest, mate and find and find shelter to overwinter, however in warmer regions they have the capacity to overwinter by re-queening, remaining in the nest, developing their ovaries and laying eggs. This is a very common phenomenon in Australasia where about 10 per cent of colonies of *V. germanica* continue for 12 months or more (CABI, 2019).

Vespula germanica is polyphagous, with the adults feeding on carbohydrates in the form of sugars, such as nectar, tree sap, fruit and honey dew. Workers collect protein for the developing larvae, such as arthropod prey and carrion. Due to their scavenging behaviour, they are often found in association with human food sources and can become a nuisance, especially when they become aggressive and sting.

Dispersal and Detection

Masciocchi *et al* (2016) studied the flight behaviour and dispersal of V. *germanica* queens in laboratory conditions. They discovered that the main queen dispersal events occur before queens enter hibernation and showed that queen dispersal by flight is likely to contribute proportionately less to population spread than human-aided factors. When searching for suitable nest sites in the spring, queens of *V. germanica* can probably disperse several km but no confirmed distances have been determined (CABI, 2019).

Introductions to countries in the southern hemisphere and North America with a similar climate to their endemic range in the northern hemisphere, such as Australia, New Zealand, South Africa, United States, Canada, Chile and Argentina are all highly likely to be due to movement of hibernating queens via sea or air travel. It is thought to have invaded New Zealand in the 1940's by the arrival of hibernating queens in crates of aircraft parts from Europe after the Second World War.

Economic and other Impacts

Vespula germanica can have significant negative impacts on horticulture, apiculture, tourism and outdoor social activities, as well as animal health and biodiversity, primarily in countries where the wasp has been accidentally introduced (CABI, 2019). Beekeepers in New Zealand and Tasmania, Australia, suffer significant losses to *V. germanica* predation of adult bees and invasion of hives.

They also cause problems in orchards and vineyards where they feed on and spoil fruit, they also intimidate and sting human workers, especially at harvest (de Villiers *et al.*, 2017). Due to their scavenging behaviour and aggressive nature, they can become a nuisance at picnic sites and other public places where food is consumed. For most people, a sting means initial pain followed by localised swelling and itching. However, 2–3% of the general population may be at risk of systemic hypersensitivity reactions to insect stings. Hypersensitivity reactions range from large localised swelling to sudden death from anaphylaxis. Studies have shown that about 10% of people stung more than once become allergic to wasp venom (WaspWeb, 2019).

German wasps are known to attack domestic pets and livestock. In Israel, they were found to damage the udders and teats of dairy cows (Braverman *et al*., 1991). In Australia, wasps kill livestock when animals such as goats eat fallen fruit containing foraging wasps (CABI, 2019).

Vespula species can impact tourism when they are present in large numbers and foraging aggressively for food. For example, on the Greek island of Skopolos where *V. germanica* occasionally overwinters, "populations of social wasps in some years reach such numbers that they pose a definite risk to the future of tourism and agriculture on the island" (CABI, 2019).

Biodiversity is threatened in regions where German Wasp has become invasive, it preys upon and competes with a range of arthropods and birds. In New Zealand's *Nothofagus* beech forests the breeding success of birds such as the endangered kaka parrot (*Nestor meridionalis*) is adversely affected due to the invasion of this wasp. Plagues of *V. germanica* compete with the parrots for food, the honeydew produced by scale insect, *Ultracoelostomaa assimile* (Beggs & Wilson, 1991).

6.25 Fall Armyworm

Order: Lepidoptera
Family: Noctuidae
Species: *Spodoptera frugiperda* (Smith)

	Present l Absent ¡	Threat Bio	Hlth	Econ
SH	¡			ü
Asc	¡			ü
Tris	¡			ü
FI	¡			
SG	¡			
BAT	¡			

Figure 6.25.1 *Spodoptera frugiperda* larva (left) and adult (right) © Fera

Background

The fall armyworm, *Spodoptera frugiperda*, is a lepidpopteran pest that feeds in large numbers on leaves and stems of more than 180 plant species, causing major damage to economically important cultivated grasses such as maize (*Zea mays*), rice (*Oryza* spp.), sorghum (*Sorghum bicolor*) and sugarcane (*Saccharum officinarum*) but also to other vegetable crops and cotton. It has been repeatedly intercepted at quarantine in Europe and was first reported from Africa in 2016 (Goergen *et al*., 2016) where it is causing significant damage to maize crops (Fig. 6.25.2) and has great potential for further spread and economic damage. The term "armyworm" can refer to several species, often describing the large-scale invasive behaviour of the species' larval stage. *Spodoptera frugiperda* poses a significant economic plant health risk to all the UKOTs with tropical and subtropical climates.

Geographical Distribution

Spodoptera frugiperda is native to tropical and subtropical regions of the Americas. In 2016 it was reported for the first time from the African continent and has now been confirmed in 45 African countries (CABI, 2019). In 2018, *S. frugiperda* was reported from the Indian subcontinent, it has also been recorded in Thailand, Myanmar and Sri Lanka (CABI, 2019).

Host Plants

Spodoptera frugiperda is a polyphagous pest reported to infest 186 host plant species in North and Central America (Casmuz *et al.*, 2010). It has a preference for wild and cultivated grasses, maize, rice, sorghum, millet and sugarcane (Poaceae). Other hosts from 27 families include *Allium* (Liliaceae), *Brassica* spp. (Brassicaceae), *Capsicum* and other Solanaceae including aubergine (*Solanum melongena*), potato (*S. tuberosum*) and tomato (*S. lycopersicum*), *Cucumis* (Cucurbitaceae), *Gossypium* (Malvaceae), *Phaseolus* (Fabaceae) and *Ipomoea* (Convolvulaceae) as well as various ornamental plants (chrysanthemums, carnations and *Pelargonium*) (Smith *et al.*, 1997; CABI, 2019).

Figure 6.25.2 *Spodoptera frugiperda* larval damage on maize © University of Georgia, Bugwood.org

Figure 6.25.3. *Spodoptera frugiperda* egg mass © Fera

Figure 6.25.4 *Spodoptera frugiperda* larva © Fera

Figure 6.25.5 *Spodoptera frugiperda* adult at rest, lateral view © Mark Dreiling, Bugwood.org

Description

The eggs (Figure 6.25.3) are dome shaped measuring about 0.4 mm in diameter and 0.3 mm in height. The number of eggs per mass varies considerably but is often in the range of 100 to 300. The eggs are sometimes deposited in layers, but most eggs are spread over a single layer attached to foliage. The female also deposits a layer of greyish scales between the eggs and over the egg mass, imparting a furry or mouldy appearance (Capinera, 2017)

Young larvae are greenish with a black head, the head turning an orange colour in the second instar. In the second, but particularly the third instar, the dorsal surface of the body becomes brownish, and lateral white lines begin to form. In the fourth to the sixth instars the head is reddish brown, mottled with white, and the brownish body bears white subdorsal and lateral lines (Figs 6.25.1 and 6.25.4). Elevated spots occur dorsally on the body; they are usually dark in colour, and bear spines. The face of the mature larva is also marked with a white inverted "Y" and the epidermis of the larva looks rough or granular in texture when examined closely.

The adult moths (Figs 6.25.1 and 6.25.5) have a wingspan of 32 to 40 mm. In the male moth, the forewing is generally shaded grey and brown, with triangular white spots at the tip and near the centre of the wing. The forewings of females are less distinctly marked, ranging from a uniform greyish brown to a fine mottling of grey and brown. The hind wing is iridescent silver-white with a narrow dark border in both sexes (EPPO, 2015).

Biology

Eggs are laid at night on the leaves of the host, stuck to the under surface of the lower part of the lower leaves in tight clusters of 100-300, sometimes in two layers, and usually covered with a protective layer of abdominal bristles. Total egg production per female averages about 1500 with a maximum of over 2000. Hatching requires 2-10 days (usually three to five days; two to three days in the summer months). There are usually six larval instars. The young larvae feed deep in the whorl; the first two larval instars feed gregariously on the underside of the young leaves causing a characteristic skeletonizing or 'windowing' effect, and the growing point can be killed. Larger larvae become cannibalistic and thus one or two larvae per whorl is usual. The rate of larval development through the six instars is controlled by a combination of diet and temperature conditions, and usually takes 14-21 days; 14 days in the summer and 30 days during cool weather. Larvae tend to conceal themselves during the brightest time of the day. Larger larvae are nocturnal unless they enter the armyworm phase when they swarm and disperse, seeking other food sources. Pupation normally takes place in the soil inside a loose cocoon in an earthen cell, or rarely between leaves on the host plant, and 9-13 days are required for development. Adults emerge at night, and are most active during warm, humid evenings. After a preoviposition period of three to four days, the female normally deposits most of her eggs during the first four to five days of life, but some oviposition occurs for up to three weeks. Females typically use their natural pre-oviposition period to fly for many kilometres before they settle to oviposit, sometimes migrating for long distances. On average, adults live for 10-14 days, ranging from about seven to 21 days (EPPO, 2019)

A threshold temperature of 10.9 °C and 559 day-degrees C are required for development. Sandy-clay or clay-sand soils are suitable for pupation and adult emergence, and emergence in these soil types is directly proportional to temperature and inversely proportional to humidity. Above 30 °C the wings of adults tend to be deformed. Pupae require a threshold temperature of 14.6 °C and 138 day-degrees C to complete their development (Ramirez-Garcia *et al.*, 1987).

Spodoptera frugiperda is a tropical species adapted to the warmer parts of the New World; the optimum temperature for larval development is reported to be 28°C, but it is lower for both oviposition and pupation. In the tropics, breeding can be continuous with four to six generations per year, but in northern regions only one or two generations develop; at lower temperatures, activity and development cease, and when freezing occurs all stages are usually killed. In the USA, *S. frugiperda* usually overwinters only in southern Texas and Florida. In mild winters, pupae survive in more northerly locations (Capinera, 2017).

Dispersal and Detection

Spodoptera frugiperda is a regular annual migrant in the Americas, dispersing throughout the USA and flying into southern Canada virtually every summer. It is suggested that, in this species, migration has evolved as a major component in the life history strategy. The use of the pre-oviposition (maturation) period for widespread dispersal seems to be very effective. In the USA, adult moths have been recorded using a low-level jet stream, which took them from Mississippi to Canada in 30 hours (CABI, 2019). Larvae frequently exhibit armyworm behaviour in late summer or early autumn and local dispersal is thus successfully accomplished, helping to reduce larval mortality.

In most years larvae arrive in Europe carried by air-freight on vegetables or fruit from the New World; sometimes they are also intercepted on herbaceous ornamentals (Seymour *et al.*, 1985).

Spodoptera frugiperda can be detected by searching fields for leaf feeding damage and by using pheromone traps.

Economic and other Impacts

Spodoptera frugiperda is found widely throughout the warmer parts of the New World. Damage results from leaf-eating and healthy plants usually recover quite quickly, but a large pest population can cause defoliation and resulting yield losses; the larvae then migrate to adjacent areas in true armyworm fashion. Caterpillars of *S. frugiperda* appear to be much more damaging to maize (*Z. mays*) in West and Central Africa than most other African *Spodoptera* species. The overall costs of losses for maize, sorghum (*S. bicolor*), rice (*Oryza* spp.) and sugarcane (*S. officinarum*) in Africa are estimated to be approximately $13,383m (Abrahams *et al.*, 2017). This does not take into account up to 80 other crops the insect has been known to feed on, as well as subsequent seed lost for the following growing seasons.

6.26 South American tomato moth

Order: Lepidoptera
Family: Gelechiidae
Species: *Tuta absoluta* (Meyrick)

	Present l / Absent ¡	Threat		
		Bio	Hlth	Econ
SH	¡			ü
Asc	¡			ü
Tris	¡			ü
FI	¡			
SG	¡			
BAT	¡			

Figure 6.26.1 *Tuta absoluta* larvae showing the patterned prothoracic shield just behind the head © Fera

Background

Tuta absoluta, commonly known as South American tomato moth, or South American tomato pinworm, is a highly destructive insect pest of tomato (*Solanum lycopersicum*) also known to attack other cultivated solanaceous plants. Originating in South America, this pest has quickly invaded Central America, Europe, the Middle East, and parts of Asia and Africa. It is a pest of both field and glasshouse crops therefore is a pest relevant to all UKOTs that cultivate solanaceous plants.

Tuta absoluta has reached economic pest status in most invaded areas around the world because of its high demographical potential, which is mainly due to a short generation time, a relatively wide host range, a good thermal adaptability and its aptitude to develop insecticide resistance (Mansour *et al.*, 2018).

Geographical Distribution

The pest is native to South America, were it is believed to have originated in Peru, and is found in regions less than 1000 m above sea level. It has since been introduced into Central America and Europe, where it was first detected in Spain in 2006 from a single Chilean population (Guillemaud *et al.*, 2015). Despite plant protection efforts it spread rapidly in Europe and despite being a tropical-to-subtropical moth, it has invaded greenhouses in Northern Europe where it is a major pest. It spread further East into the Middle East and Asia and is present in almost all the Central and South west Asian countries neighbouring China. The pest first reached North Africa in 2008, from where it rapidly spread south and has now been recorded in 41 countries on the African continent (Mansour *et al.*, 2018).

Figure 6.26.2 Tomato fruit showing holes created by *Tuta absoluta* larvae © Fera

Figure 6.26.3 Adult *Tuta absoluta* on a sticky trap © Fera

Figure 6.26.4 Leaf mines created by *Tuta absoluta* on a tomato plant © Fera

Figure 6.26.5 Tomato cut open to show the internal feeding damage and secondary rot caused by *Tuta absoluta* larvae © Fera

Host Plants

South American tomato moth feeds on Solanaceae and to a lesser degree also Amaranthaceae, Convolvulaceae and Fabaceae. It is a serious pest of tomato (*Solanum lycopersicum*), the leaves, stems and fruit are attacked by the larvae. It is also known to attack leaves of cultivated solanaceous plants such as aubergine (*S. melongena*), pepino (*S. muricatum*), potato (*S. tuberosum*), pepper (*Capsicum annuum*), tobacco (*Nicotiana tabacum*), solanaceous weeds and garden bean (*Phaseolus vulgaris*) (EPPO, 2019).

Description

The following is partially based on a description of *T. absoluta* by (Imenes *et al.*, 1990). Their eggs are very small (< 0.4 mm long), elliptical, and their colour varies from oyster-white to bright yellow, darkening in the embryonic phase and becoming almost black near eclosion. The first-instar larvae are whitish soon after eclosion, becoming greenish or light pink in the second to fourth instars according to food (leaflet or ripe fruit, respectively) (Fig. 6.26.1). There are usually four larval instars. The pre-pupae are lighter than the feeding larvae (first to fourth instars) and develop a distinguishing pink colouration on the dorsal surface. They leave the mines and build silk cocoons on the leaflets or in the soil, according to habitat. When pupation occurs inside mines or fruit the pre-pupae do not build cocoons. Pupae are < 6 mm long, greenish in colouration at first, turning chestnut brown and dark brown near adult emergence. Adult moths are about 10 mm long, with silver-grey scales, filiform antennae, alternating light or dark segments and recurved labial palps which are well developed (CABI, 2019).

Biology

The female of *T. absoluta* lays more than 200 eggs during its life time, usually on the underside of leaves, on buds, or on the calyxes of green fruit. Eclosion of eggs (at 26-30°C and 60-75 % RH) occurs at about five to seven days. The larvae under these conditions pass through four instars which are completed in around 20 days, after which the larvae form a cocoon for pupation. Pupation lasts about 10-13 days and under laboratory conditions, the adults will live for 30-40 days (CABI, 2019). Generations overlap, and there may be over 10 generations in a year if conditions are favourable in Europe, although only five generations per year have been observed in Argentina. *Tuta absoluta* can overwinter as eggs, pupae or adults. Caparros Megido *et al.* (2012) reported laboratory evidence of deuterotokous parthenogenesis in this species, an asexual reproduction where both males and females are produced from unfertilized eggs

Korycinska & Moran (2009) provided a summary of the biology. Larvae are commonly associated with leaves, creating blotch leaf mines that are visible on both sides of the leaf (Fig. 6.26.4). There can be several mines on a single leaf. The mines have dark frass (excrement) visible inside, and over time the mined areas will turn brown and die. The larvae also mine apical buds and stems, and at high densities the larvae will attack both green and red fruit. The larvae can tunnel into the fruit and leave only a surface hole visible (Fig. 6.26.2), and/or may mine just below the surface, creating a yellow-coloured fruit mine. Pupation may take place on the surface of the leaf, within the mine or tunnel, or the final instar larva may exit the plant and pupate in the soil, where detection is very difficult. Adult moths are nocturnal, spending the day resting between leaves, and are unlikely to be seen.

Dispersal and Detection

Short-distance dispersal (adjacent field to field or field to tunnels) of *T. absoluta* is known to be facilitated by wind especially soon after introduction (Desneux *et al.,* 2011), with moths capable of active flights of up to 100 km (Ferracini *et al.,* 2012*),* a characteristic that may aid the species' dispersal. Long-distance dispersal of the pest is likely to be through movement of infested plants, soil and fruits. Production greenhouses that repack and distribute tomato fruits produced in infested countries are a proven pathway for the spread.

The pest has spread rapidly in Europe since its introduction, despite efforts by plant protection agencies. Estimations show that the pest has increased its range radius by an average of 600 km per year (Campos *et al.*, 2017).

Management of the pest with insecticides has led to the widespread development of insect resistance (Siqueira, 2000). A variety of specialist traps are available for trapping adult moths (Fig 6.26.3). Pheromone traps are considered as the first line of defence against this moth both in open fields and in greenhouses as they are used for monitoring and male annihilation purposes (Cabi, 2019).

Tuta absoluta is easily found on tomato plants because it prefers the apical buds, flowers or new fruits, where the black frass is visible. When there is a severe attack it colonizes the leaves on the other parts of the plant. Mines are evident on attacked leaves. *Tuta absoluta* damage could easily be confused with that of another Gelechiid, *Keiferia lycopersicella* (tomato pinworm), a pest of tomato in the USA.

Economic and other Impacts

In Latin America, *T. absoluta* is considered a key pest of tomato both in the field and under protected conditions. Both yield and fruit quality can be significantly reduced by the direct feeding of the pest and the secondary pathogens which may then enter through the wounds made by the pest (Fig. 6.26.5). Following its introduction into Europe, Africa and the Middle East, *T. absoluta* has already caused extensive economic damage. The impact of the pest includes severe yield loss reaching 100%, increasing tomato prices, bans on the trade of tomato including seedlings, an increase in synthetic insecticide applications, disruption of integrated management programmes of other tomato pests, and an increase in the cost of crop protection. In addition, the outbreak of this pest led to a significant augmentation of risks for growers, consumers and the environment associated with the blind use of chemicals (CABI, 2019).