Sustainable Farming Fund
Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

Horticulture New Zealand
FRESH TOMATO PRODUCT GROUP

Whitefly: identification and biology

in New Zealand greenhouse tomato crops

Factsheet 1, 2009

Edited by Peter E. Smith

Two species of whitefly that are significant pests in greenhouse tomato crops worldwide are found in New Zealand. Greenhouse whitefly (*Trialeurodes vaporariorum*) has long been a problem for New Zealand growers and sweet potato whitefly[1] (*Bemisia tabaci*), also referred to as tobacco whitefly, poinsettia whitefly or silverleaf whitefly, has potential to become a significant pest due to virus transmission and pesticide resistance development.

This is the first in a series of four factsheets dealing with whitefly as a pest. While other crops are mentioned in passing, the key focus is on New Zealand greenhouse tomato crops.

Other factsheets in the series are:

Factsheet 2—Whitefly: natural enemies
Factsheet 3— Whitefly: integrated pest management
Factsheet 4— Whitefly: spray options

Note: Whitefly management is a rapidly changing scene. These factsheets summarise current knowledge and best management practice gleaned from literature searches and according to leading New Zealand industry consultants. Members of the consultancy group were: Stephen McKennie, Terril Marais, Roelf Schreuder, John Thompson and Bruce Chapman.

Fig. 1. Greenhouse whitefly (*Trialeurodes vaporariorum*) on the back of a young tomato leaf.

Fig. 2. Sweet potato whitefly (*Bemisia tabaci*) on the back of a young tomato leaf.

What are whitefly?

Whitefly adults are tiny white insects about 1.0 mm long. They are often described as moth-like in appearance, but they have piercing, sucking mouthparts and are related to plant hoppers, scale insects, mealy bugs, psyllids and aphids (Figs 1 & 2). Their whole body, including wings, has a bright white powdery appearance.

Adult whitefly are usually found on the undersides of tomato plant leaves[2] where they feed and lay eggs. Large numbers are obvious to the naked eye. They fly when disturbed[3].

1. Sweet potato whitefly appears to mutate readily into different variants. The first recognised form overseas, 'strain A' (or cotton strain) was not a significant pest, but in the 1980s a new far more damaging strain arose, which was called 'strain B' (or poinsettia strain). The latter has since been shown to be genetically different and so has been named silverleaf whitefly (*Bemisia argentifolii*). By the 1950s it was clear that strains of sweet potato whitefly differed in plant host range, ability to adapt to plant hosts and virus transmission capabilities. It is therefore now considered to be a complex of differing biotypes.

2. Adult greenhouse whitefly tend to be on young leaves towards the top of the plant, whereas sweet potato whitefly may be found all over the plant.

3. Other identifying features of whitefly include: their wings are held over their body when at rest; they have two forward-pointing antennae on their head; they have long mouthparts used to pierce plants and suck their juices; and, males are often seen next to females fluttering their wings.

Why are whitefly pests?

Both greenhouse whitefly and sweet potato whitefly infest a very wide range of economically important crops worldwide[4]. Greenhouse whitefly, a species found throughout New Zealand wherever greenhouse crops are grown, is a particularly important pest of tomato plants, New Zealand's largest greenhouse crop by area and value.

Sweet potato whitefly is not yet widely established throughout New Zealand, but overseas experience shows it has potential to devastate many different greenhouse crops and has an enormous range of host plants, including weeds[5]. Thus, there is strong potential for re-infestation to occur from crop to crop and from nearby weeds to crop.

Both nymph (juvenile stages) and adult whitefly cause direct damage when they suck plant juices[6]. As a result, infestations of both whitefly species can give tomato plants a yellow, mottled look, stunting their growth, causing wilting and defoliation and thereby seriously reducing crop yield. Heavy feeding by whitefly can eventually kill plants.

Indirect damage occurs when their sticky honeydew secretions grow sooty moulds that block photosynthesis (Fig. 3). Any sooty mould on fruit has to be washed off before sale (Fig. 4).

Nymphs of sweet potato whitefly inject enzymes that cause changes in the plant's chemistry. The result can be irregular ripening of fruit which remain hard and sour tasting, with retarded internal colour. Physiological symptoms like these can occur at very low whitefly densities and are one of the main problems caused by sweet potato whitefly worldwide.

Adult whitefly[7] also have the potential to cause crop losses indirectly by transmitting plant viruses (see below), although this is not yet an issue in New Zealand tomatoes.

Whitefly may be present in greenhouses year round, but most growers report that infestations are worst in summer[8], especially when it is hot and dry, or sunny. (In contrast, winter life cycles are longer, making whitefly easier to control[9].)

Both species can reproduce and disperse rapidly. They also adapt to new host plant species and may rapidly develop insecticidal resistance if repeated spraying of insecticides from one chemical group occurs.

Fig. 3. Tomato leaf showing sooty mould growing on honeydew deposited by whitefly. The sooty mould blocks out light thereby reducing photosynthesis.

Fig. 4. Tomatoes showing sooty mould growing on honeydew deposited by whitefly. The sooty mould has to be washed from fruit before sale.

4. Examples of greenhouse crops attacked by greenhouse whitefly include: eggplant (aubergine), cucumber, gerbera, sweet pepper, tomato and capsicum. They are also pests on pumpkins, beans and many other outdoor plants, especially during hot seasons. One New Zealand strain of greenhouse whitefly is now a major pest on tamarillo. Sweet potato whitefly infest an enormous range of plants worldwide, especially in tropical and sub-tropical areas, thus they have the potential to become a problem in New Zealand greenhouses.
5. Host weeds vary from one district to another and property to property. They include sow thistle (puha), milkweed, dock, black nightshade, redroot, chickweed and mallow.
6. Their mouthparts are used to suck food sap from phloem vessels.
7. Adult whitefly, because they are mobile, are responsible for spreading viruses. In contrast, juvenile stages remain on the same leaf throughout their development.
8. Some growers report infestations are worst during spring-summer, others in late summer.
9. Although whitefly is easier to control with chemicals during winter, the biological control agent *Encarsia formosa* is less effective at this time of the year.

Because of the potential for transport in imported fresh produce, whitefly and the diseases they transmit are no longer restricted by natural geographical barriers.

Viruses

Overseas, greenhouse whitefly transmits tomato chlorosis virus, tomato infection chlorosis virus and strawberry virus. In New Zealand it has spread beet pseudo-yellow virus (BPYV)[10] in cucumber crops.

Sweet potato whitefly is known to transmit many viruses, especially geminiviruses, to several hundred plant species, causing severe damage to many economically important plants (Fig. 5). This is a key reason why sweet potato whitefly is now considered one of the most invasive and economically damaging insects in horticulture and agriculture worldwide. Currently, abutilon mosaic geminivirus[11] is in New Zealand, while sweet potato whitefly transmit the important tomato yellow leaf curl virus in Queensland, Australia. In 2008 the presence of tomato torrado virus (ToTV) that damages tomatoes and other solanaceous plants was confirmed in South Australia. It is spread by both greenhouse and sweet potato whitefly. So, there is real risk of other viruses arising in New Zealand due to accidental introductions of whitefly from overseas.

Both nymphs and adults can pick up viruses, which are then transmitted from plant to plant by the adults.

Greenhouse whitefly

Greenhouse whitefly (*Trialeurodes vaporariorum*) is the species most commonly found on greenhouse tomato crops in New Zealand. However, it has a host range of several hundred plant species and can easily spread from one crop or weed species to another.

Identification

Several features distinguish greenhouse whitefly from sweet potato whitefly (see page 6)[12]:

- egg—in the first 1–2 days is white, then later brown to black (Fig. 6)
- pupa—an oval, white case with a fringe of white threads projecting outwards around the body (Fig. 9); when attacked by *Encarsia formosa*, pupa is black, not transparent
- adult—has pure white wings held flat over its body at rest, so the body has a triangular shape when viewed from above (Fig. 10); larger than sweet potato whitefly[13].

Biology

All life cycle stages of the greenhouse whitefly tend to be found on the undersides of tomato plant leaves.

Fig. 5. A pepper (*Capsicum* sp.) plant showing symptoms caused by a geminivirus transmitted by sweet potato whitefly (*Bemisia tabaci*). Photo by David Riley, University of Georgia, www.ipmimages.org.

Fig. 6. Mature greenhouse whitefly (*Trialeurodes vaporariorum*) eggs on the underside of a tomato leaf.

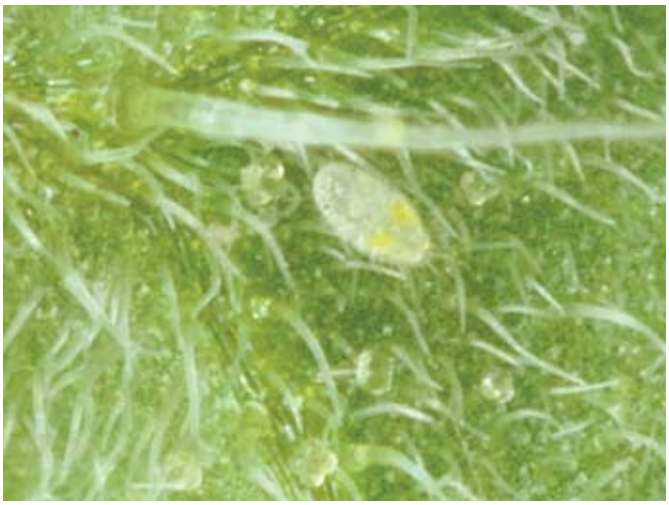

Fig. 7. Greenhouse whitefly (*Trialeurodes vaporariorum*) crawler (first nymph stage) on the underside of a tomato leaf.

10. Also called bean pseudo-yellow virus.
11. The virus causes bright yellow variegation in *Abutilon* species leaves.
12. Nymph stages are barely distinguishable from sweet potato whitefly.
13. Contrast with moth fly, a true fly that has a body about 3 mm long with greyish scaly wings that have a dark fleck. Moth fly is not a pest. Its larva feeds on dead and decaying plants.

Egg

Adults lay their elongated oval eggs on the undersides of the youngest tomato plant leaves towards the shoot tips. For the first couple of days the eggs are transparent to pale cream-yellow, then after a day or two they begin to turn brown-black (Fig. 6).

Greenhouse whitefly lay eggs on end[14] fixed to the leaf with the help of a short stalk. They are about 0.25 mm long and oval in shape. On smoother leaf surfaces, as with some varieties of tomatoes, the eggs are laid in circles, but on hairy leaves, as with other varieties, the eggs are laid randomly across the leaf surface. Females may produce up to 300 eggs in their lifetime[15].

Crawler (first nymph stage)

The egg hatches into the near-transparent first nymph stage called a crawler (Fig. 7). It is flat, oval, almost transparent and only 0.3 mm long with tiny legs that allow it to move across the leaf surface. After hatching it may travel a short distance until it successfully probes the leaf to obtain sap, where it then settles to feed. It remains at this location until it turns into an adult. Before moulting into the next nymph stage, the body swells to become more rounded.

Scale (second to fourth nymph stages)

When the crawler moults, it turns into a legless, 0.3–0.4 mm long, scale-like creature that is fixed to the leaf surface (Fig. 8). If the plant is growing quickly, older nymphs are therefore found several leaves lower than young nymphs (since eggs are continually being laid towards the top of the plant).

The body is oval and almost transparent, although some yellow internal organs may be visible, and is surrounded by a short, see-through fringe[16]. There are longer hairs on top of the body.

It remains immobile, feeding off sap and moulting between nymph stages.

Pupation

The fourth nymph stage starts off flat and oval[17]. At the end of this stage it stops feeding, swells, becomes denser and forms waxy, spiny rods over its body (which can be seen with a hand lens). As a result it is creamy white in appearance and about 0.7 mm long. It has a distinct body wall giving it greater height off the leaf surface. This is the 'pupa' stage[18] (Fig. 9).

14. Contrast with cabbage whitefly that lay eggs on their sides.
15. The host plant species influences the number of eggs laid. It also influences the duration of the life cycle and survival through to the adult stage.
16. In the early nymph stages the fringe lies against the host plant.
17. In the fourth nymph stage the fringe of hairs is raised up from the surface of the plant.
18. Pupation occurs within the skin of the fourth nymph stage.

Fig. 8. Greenhouse whitefly (*Trialeurodes vaporariorum*) nymphs, called scale, on the underside of a tomato leaf.

Fig. 9. Greenhouse whitefly (*Trialeurodes vaporariorum*) pupae on the underside of a tomato leaf.

Fig. 10. Newly-emerged greenhouse whitefly (*Trialeurodes vaporariorum*) adult alongside its empty pupa skin. Note the insect's triangular shape when viewed from above.

Sometimes the pupa turns black, indicating it has been attacked by the parasitic wasp *Encarsia formosa*[19] (refer to Factsheets 2 and 3). It may also turn grey, brown or yellow due to attack by other parasitic wasps.

Shortly before it emerges parts of the adult, especially its eyes, can be seen through the pupa skin.

Adult

When the adult emerges its wings are clear at first (Fig. 10), but in time become covered in white wax. An adult can fly within a few hours and begins feeding by piercing leaves and sucking out plant sap, which it continues for the rest of its life.

During the first few days adults move from old leaves to younger leaves on the same or different plant. Thereafter they spend most of their time on the undersides of the topmost leaves, but will fly when disturbed. Males are about 0.9 mm and females are about 1.1 mm long. Females begin egg laying in 1 to 3 days, depending on temperature[20].

Length of life cycle

The time taken for greenhouse whitefly to progress through their development stages depends on the temperature and host plant on which they are feeding. The optimum temperature range for development is 20–25°C. For example, at 22°C the egg-to-adult development on tomatoes takes about 28 days to complete, with the duration of each stage as follows:

Egg — 8 days
First nymph — 6 days
Second nymph — 2 days
Third nymph — 3 days
Fourth nymph — 4 days
Pupa[21] — 5 days
Adult — life span 10 to 40 days
(Female starts laying 2 days after emerging)

Development ceases below 8°C and egg laying stops below 7°C. Temperatures above 30°C are not favourable for whitefly development and all development ceases above 35°C.

19. When *Encarsia formosa* attacks a whitefly nymph, it lays an egg within the nymph's body that soon hatches into a grub. The grub feeds off the nymph's tissues (it is said to parasitise it) and eventually emerges as an adult *Encarsia,* killing the whitefly nymph in the process.
20. After emerging, adult female greenhouse whitefly take two days at 22°C to start egg laying.
21. The pupa forms inside the skin of the fourth nymph stage.
22. Survival at lower temperatures will depend on the host plant having cold-hardy leaves on which the whitefly can survive.
23. Currently, twenty four biotypes of *Bemisia tabaci* are recognised worldwide, and two polyphagous biotypes, B and Q, have spread rapidly in many countries. Biotype Q was first detected in 2006 on greenhouse capsicum, South Auckland and there is suspicion that biotypes A and B are also present in New Zealand. Biotype Q is especially capable of developing resistance to a range of insecticides.

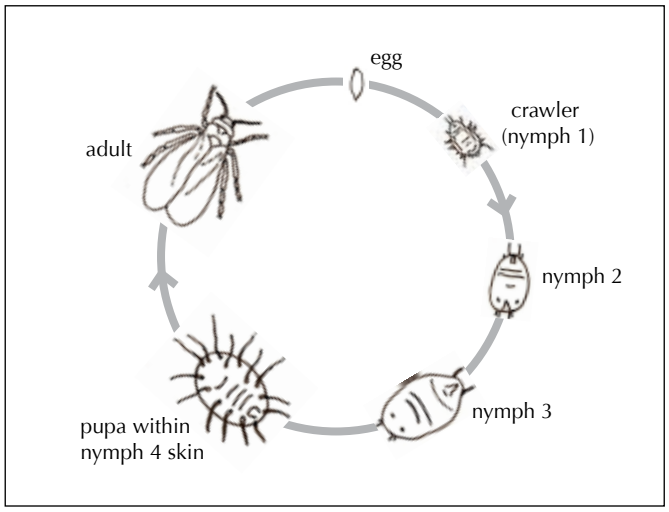

Fig. 11. Life cycle of greenhouse whitefly (*Trialeurodes vaporariorum*).

In heated greenhouses and in warmer parts of the country the life cycle continues throughout the year, with all stages being present at any one time. The life cycle is shown in Fig. 11.

There is no overwintering or resting stage, but greenhouse whitefly adults can overwinter on weeds or cultivated plants in greenhouses or other protected sites[22]. Scales and pupae survive short cold periods in favourable microclimates such as areas next to greenhouses or where the winters are mild. Eggs are able to survive -3°C for more than 15 days.

The optimal humidity is 75–80%, so normal greenhouse conditions are ideal for rapid whitefly development.

Sweet potato whitefly

Sweet potato whitefly (*Bemisia tabaci*) was first found in New Zealand in the early 1990s. Overseas it is a significant pest on a wide range of tropical and subtropical crops including tomatoes and in the UK it has achieved the status of a notifiable pest. Many different strains exist around the world[23], each having a different range of hosts, each producing different plant disorders and each having different abilities to transmit viruses.

The predominant strain found in New Zealand is Biotype Q, but Biotypes A and B may also be present. Here, sweet potato whitefly is found on poinsettias, begonia, hibiscus and many greenhouse vegetable crops. Elsewhere in the world Biotype B, often considered to be a different species (*Bemisia argentifolii*), infests tomatoes, brassicas and cucumbers and causes silver leaf symptoms in pumpkins and squash (which is why it is called silverleaf whitefly).

In Europe, when temperatures are suitable, sweet potato whitefly has been found to coexist with greenhouse whitefly.

Identification

Several features distinguish sweet potato whitefly from greenhouse whitefly (see page 3)[24]:

- egg—light yellow-green, then later light brown (Fig. 12)
- pupa—broad, flat and transparent or yellow in colour; pointed at one end; few hairs or setae; adult's red eyes and white wing buds are visible through the body wall; when attacked by *Encarsia formosa* the pupa is brown and the colour of the parasite is visible inside
- adult—smaller, yellower and flies less often than greenhouse whitefly; holds its wings vertical and parallel to (more alongside) the body when viewed from above.

Biology

The life cycle and behaviour of greenhouse whitefly and sweet potato whitefly are similar (Figs 12–14). However, unlike greenhouse whitefly, sweet potato whitefly lays its eggs widely over the whole plant, so that all stages of the life cycle can be found on the same leaf.

Life cycle

Sweet potato whitefly prefers warmer temperatures than greenhouse whitefly. Development occurs in the range 14–35°C, but optimally at 25–30°C. On tomatoes at 30°C the time from egg to adult is as short as 18 days. Adult sweet potato whitefly live for 10–15 days at 28–30°C.

On tomatoes at 25°C a female produces around 195 eggs in her lifetime.

At 16–19°C development is very slow, with the life cycle taking 140–70 days respectively, and death rates are high. At 9°C and low humidity the nymphs die. During winter adults can survive several weeks without a host plant, i.e. in an empty greenhouse. In the United Kingdom sweet

24. Nymph stages are hardly distinguishable from greenhouse whitefly.

Key differences between greenhouse and sweet potato whitefly

	Greenhouse whitefly	Sweet potato whitefly
Optimum temperature	20–25°C	25–30°C
Adults found	Near top of plant.	All over plant.
Type of damage	Honeydew and feeding damage cause lower yields and aesthetic damage to fruit; some plant viral diseases (overseas).	Honeydew and feeding damage cause lower yields and aesthetic damage to fruit; viruses and physiological changes lead to serious plant disease symptoms (overseas).
Insecticide resistance	Some resistance.	Potentially highly resistant.

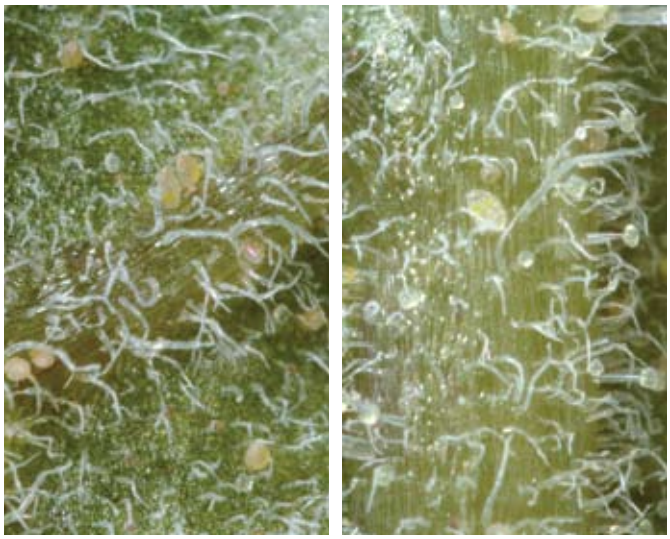

Fig. 12. Sweet potato whitefly (*Bemisia tabaci*) eggs (left) and crawler (centre right).

Fig. 13. Sweet potato whitefly (*Bemisia tabaci*) scale. Photographer: Charles Olsen, USDA APHIS PPQ, www.ipmimages.org.

Fig. 14. Sweet potato whitefly (*Bemisia tabaci*) male (smaller) and female adults. Note their yellow bodies and how their wings lie parallel to their sides.

potato whitefly have a low chance of survival outside a greenhouse and this is probably also the case in cooler parts of New Zealand.

Other things that look like whitefly

Whitefly can be difficult to identify. If you are in doubt about what you have found, send leaves with pupae to AsureQuality Plant Pest and Disease Testing (see page 8 for details).

Other insects in New Zealand that look like greenhouse and sweet potato whitefly include:

- cabbage whitefly (*Aleyrodes proletella*)—adult is about 1.5 mm long, has a black fleck on each wing and is found on brassicas and sow thistles
- moth fly—a non-pest species of fly; adult is about 3 mm long with greyish wings with a dark fleck.

Behaviour and population biology

Dispersal

Greenhouse whitefly tend to remain in groups until the population becomes dense. This means infestations stay concentrated in a few places, especially during the earlier stages of the crop. Later as temperatures rise, they become more active and spread widely over the whole crop. Adults are the most important dispersal stage.

Distribution

Only the first nymph (crawler) stage of greenhouse whitefly is capable of movement, and this is limited to short distances, usually on the same leaf on which it hatched.

Adults of greenhouse whitefly only lay eggs on the young leaves at the top of the plant, so as the plant grows, younger nymphs are found on the upper parts of the plant and older ones are found lower down.

In contrast, sweet potato whitefly adults tend to lay eggs over the entire plant, so all life cycle stages can be found on the same leaf.

Population build-up

Population growth is influenced by both the host plant type and temperature. For example, at 25°C, during her lifetime a female greenhouse whitefly will lay over 600 eggs on cucumber, but only around 200 eggs on tomato. At 22°C she will lay around 150 on cucumber and around 50 on tomato.

Different plant varieties can affect population growth. For example, greenhouse whitefly population growth is faster on beef tomatoes than on round tomatoes. A population can also adapt to its host plant, so one that originates on tomatoes will develop better on another tomato crop than a population originating from a different type of crop such as cucumber.

Poor cultural management techniques often encourage build-up and spread of whitefly. If plants are stressed by under-watering, extremes of temperature, poor fertility, low light, incorrect pH of growing media, or crowding, they may be more susceptible to whitefly. High nitrogen nutrient levels have also been linked to spikes in whitefly population growth. Whereas higher nitrogen levels may be unavoidable, most other factors can be manipulated in favour of optimum plant vigour thereby reducing the effect of whitefly infestations.

Integrated crop management

As with any pest or disease, whitefly should not be considered in isolation of other crop management practices. Many factors contribute to their dispersal and population growth. Amongst others, failure to prevent new introductions of the pest, failure to eradicate them between crop cycles, poor weed control in and around the greenhouse, poor crop waste disposal techniques, failure to understand pest and natural enemy life cycles and behaviour, inappropriate insecticide use that adversely affects natural enemies and many other factors increase pest pressure by favouring whitefly. Later factsheets will address these issues in more detail and suggest practical solutions.

Because whitefly control often involves a complex set of interactions, you may wish to seek further information and assistance from your local advisor.

Further reading and web sites

The following references and web sites have been useful for compiling the material in this factsheet and offer information over and above what is supplied here:

Australian Pesticides and Veterinary Medicines Authority www.apvma.gov.au/permits/permits.shtml

Biobest www.biobest.be/

Ferguson C M, Moeed A, Barratt, B & Kean J M 2007. *BCANZ—Biological Control Agents introduced to New Zealand*, www.b3nz.org/bcanz/index.php

Koppert biological systems www.koppert.com/

Llewellyn, R (ed.) 2002, *The Good Bug Book*, 2nd edition, Integrated Pest Management Pty Ltd, Queensland.

Malais, M H & Ravensberg, W J 2003, *Knowing and Recognizing: The Biology of Glasshouse Pests and Their Natural Enemies*, revised edn, Koppert Biological Systems, PO Box 155, 2650 AD Berkel In Rodenrijs, The Netherlands. 288 pp.

Martin N A (ed.) 1999, *Whitefly: biology, identification and life cycle*. Crop & Food Research, Broadsheet No. 91: 1–8.

Martin N A (ed.) 1999, *Whitefly: how to avoid whitefly and control them: the principles*. Crop & Food Research, Broadsheet No. 93: 1–8.

Martin N A (ed.) 1999, *Whitefly: how to reduce your risk from whitefly: crop-specific strategies*. Crop & Food Research, Broadsheet No. 94: 1–8.

Martin N A (ed.) 1999, *Whitefly: natural enemies of whitefly and their biology*. Crop & Food Research, Broadsheet No. 92: 1–8.
New Zealand Plant Protection Society www.nzpps.org
Tomatoes New Zealand www.tomatoesnz.co.nz

Identifying unknown organisms

AsureQuality Plant Pest and Disease Testing
Address: PestLab, AsureQuality Ltd, 131 Boundary Road, Blockhouse Bay, Auckland 0600
Free phone: 0800 PESTLAB (0800 737852)
Email: pestlab@asurequality.com
Web site offers Pest and Disease Diagnostic Order Form, Lab Sampling Instructions and Price List at:
www.agriquality.com/laboratory_testing/plant_pest_and_disease_testing.cfm

Factsheet updates
These factsheets and any updates can be found at: www.tomatoesnz.co.nz

Photographs
Except where specifically mentioned, all photographs by Peter E. Smith.

Consultancy Group
John Thompson, Bioforce Ltd, PO Box 73, Drury 2247, South Auckland, NZ.
Stephen McKennie, Horticentre, PO Box 547, Drury 2247, South Auckland, NZ.
Terril Marais, Zonda Resources Ltd, PO Box 756, Pukekohe 2340, NZ.
Roelf Schreuder, NZ Gourmet, PO Box 53028, Auckland International Airport, NZ.
Bruce Chapman, Insect Science Ltd, 830 Selwyn Rd, RD8, Christchurch, NZ.
Peter Smith, Educational Solutions Ltd, PO Box 100, Lincoln 7640, NZ.