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

Horticulture™ New Zealand
FRESH TOMATO PRODUCT GROUP

Whitefly: spray options
in New Zealand greenhouse tomato crops

Factsheet 4, 2009

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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 (*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 last in a series of four factsheets dealing with whitefly as a pest. Its key focus is on management of greenhouse whitefly using insecticide sprays as a *last line of defence* in an integrated pest management (IPM) programme. The programme employs *Encarsia formosa* (for simplicity called *Encarsia* throughout the rest of this factsheet) as the primary means of control. By using insecticides sparingly and only when needed, this will minimise the risks of resistance development in whitefly populations that has already occurred, especially overseas and to some extent in New Zealand.

Spraying topics are only discussed as they relate to whitefly control. It is left to other publications to deal with detailed aspects of spraying such as equipment maintenance and calibration, sequence when mixing, worker safety, maximum residue limits (MRLs) and withholding periods.

Other factsheets in the series are:

Factsheet 1—Whitefly: identification and biology
Factsheet 2—Whitefly: natural enemies
Factsheet 3—Whitefly: integrated pest management

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.

Spraying considerations

Why spray?

Spraying can be a highly effective control method but should only be used as a *last line of defence* as part of an IPM programme for greenhouse whitefly control (Fig. 1). Before spraying, the following options, outlined in Factsheet 3 *Whitefly: integrated pest management*, should have been tried:

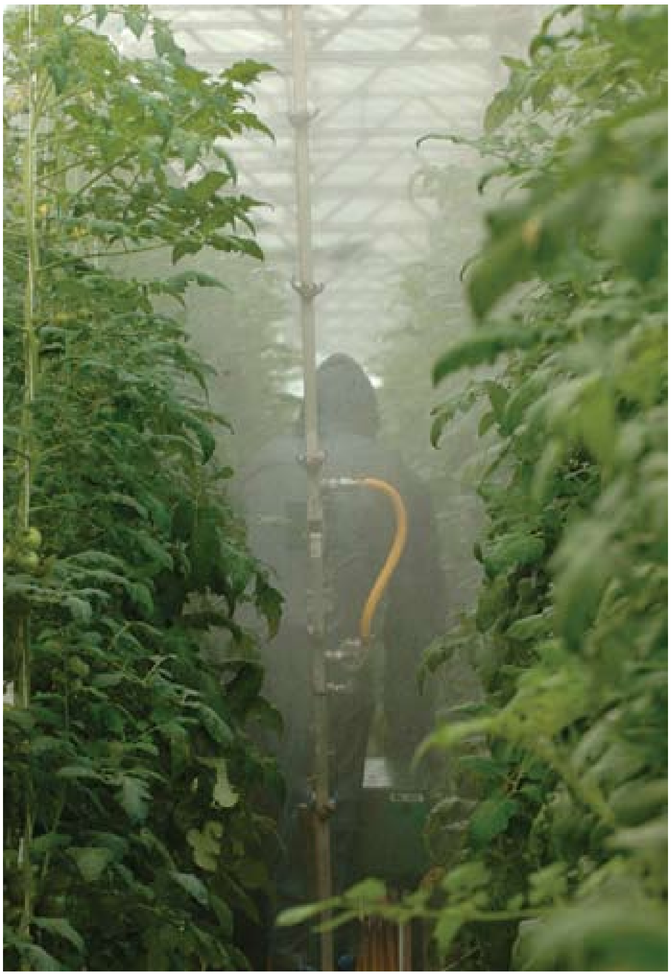

Fig. 1. Spraying for whitefly using a vertical pipe-rail boom sprayer, considered the best option for most greenhouse tomato spray applications.

- prevention strategies to minimise the chances of infestation
- cultural techniques such as adjusting planting times to avoid summer and early autumn
- optimal use of the natural enemy *Encarsia,* involving amongst other things careful monitoring and tomato plant de-leafing strategies
- environmental manipulation, e.g. maintaining temperatures to best suit *Encarsia*.

If spraying seems the only choice, and given *Encarsia* is being employed, then first consider the following options in order, keeping in mind the aim is to manage the pest problem, not necessarily to eradicate it:

1. a consultant's advice may be useful in determining options that are least harmful to the *Encarsia* population
2. selectively applying spraying oils or horticultural soaps beneath leaves towards the top of the plant will check the adult whitefly population while minimising the impact on *Encarsia*
3. if monitoring shows the pest is localised, spot spraying a few plants or rows with spraying oils or horticultural soaps may suffice to keep whitefly under control
4. whole crop applications of spraying oils, horticultural soaps or entomopathogenic fungal formulations and other 'soft' sprays may suffice to control whitefly (but note that when used on the whole crop, spraying oils and horticultural soaps may have some negative effects on the *Encarsia* population)
5. use selective sprays such as Neem, Pymetrozine, Buprofezin or Spiromesifen that are effective against whitefly, but have minimal or only slight negative effects on *Encarsia* (see Table 1 for spray persistence and toxicity with respect to *Encarsia*)
6. use broad spectrum sprays that are effective against whitefly, but have the least negative effects on *Encarsia* (see Table 1 for spray persistence and toxicity with respect to *Encarsia*)
7. rotate between different insecticide modes of action (M.o.A.) groups to minimise resistance build-up in the whitefly population (see 'Resistance management' later in this factsheet).

Take into account potential issues when applying chemical controls including: their effects on bumble bees; the resistance of whitefly populations to many types of sprays; potential resistance build-up due to poorly managed spray programmes; the effectiveness of chemicals; the effectiveness of the application equipment being used; the need to match the chemical mode of action to the pest life cycle stage present (e.g. some chemicals might only kill juvenile stages and not adults); residue build-up in the crop and fruit; side effects on natural enemies; other pests and diseases that need to be controlled; and, safety for workers by adhering to contact and non-contact re-entry periods.

If sprays are used, all regulations, guidelines and requirements outlined in the current *New Zealand Standard Management of Agrichemicals NZS 8409:2004* manual and all label and manufacturers' instructions should be adhered to. Whatever is applied to the crop must comply with the limits stated in the current New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards 2007. There may be export market residue limits to consider too.

When to spray

In a properly managed IPM programme, the only time to spray is when monitoring shows it is necessary, that is, when the threshold level for spraying whitefly is reached. Spraying should not be done on a regular calendar basis. There are several monitoring techniques, employed by the grower or worker, that can help determine if the pest is getting out of hand. For example, if monitoring method 4 'Instant assessment of whitefly numbers' from Factsheet 3 shows that in a mature crop there are hotspots where the number is rising above 20 adult whitefly per square metre (in the heads of the plants) and *Encarsia* black scale make up considerably less than 80% of the total scale, it is probably necessary to spray. Whatever spraying method is used, aim to *prevent* pest outbreaks, crop damage and harm to *Encarsia* or other biological control agents and beneficials including bumble bees. (Note that if *Encarsia* were not being employed, a spray dependent strategy would normally involve spray applications earlier in the crop cycle. This however is not the approach being considered here.)

Target pest stage

Spraying can be used to selectively target the adult greenhouse whitefly stage. This is achieved by applying spraying oils or horticultural soaps under the uppermost 3–4 leaves where adults congregate. *Encarsia* adults and black scale, found lower down on the plant, remain relatively unaffected. This strategy is one of the more environmentally sound and effective on-going means of controlling whitefly. Important benefits of spraying oils and horticultural soaps are their physical mode of action (which is unlikely to lead to resistance build-up in whitefly populations) and their low risk to workers. A key disadvantage is that they provide no residual action, so regular, thorough spray coverage is essential. However, care must be taken to adhere to label guidelines to avoid overuse, resulting in damage to the plants. It is strongly advised to test the spraying product on a few plants growing under the same conditions as the main crop, then waiting a few days to check that no harm is done, before applying it more extensively.

If monitoring shows it is necessary to spray the whole plant, again the first choice is to use spraying oils and horticultural soaps, but also consider using beneficial entomopathogenic fungi. Apply in repeat, spaced applications in order to kill all whitefly life cycle stages. Like spraying oils and horticultural soaps, entomopathogenic fungi have low toxicity and short persistence times with respect to *Encarsia*. Alternatively, use selective sprays such as Buprofezin, Pymetrozine, Neem or Spiromesifen. Always base the number and spacing of applications on the manufacturer's specifications. The disadvantage of spraying the whole plant with these is the possible loss of some of the *Encarsia* population, which then requires boosting with new introductions after the appropriate time. See Table 1 for a list of sprays showing their persistence and toxicity with respect to re-introduction of *Encarsia*.

The use of broad spectrum sprays should be a last resort as these can kill all life cycle stages of *Encarsia* and residues can remain for some time (up to months) after the initial application. If the tomato plants are already large it may be too late to re-establish the *Encarsia* population during this crop cycle and a new *Encarsia* programme may have to wait till the beginning of the next new crop.

Table 1. New Zealand registered (mostly, see footnote) crop protection products used for pest and disease control on greenhouse tomatoes shown within their categories and IRAC[a] or FRAC[b] mode of action groups, along with their target pests, withholding periods, persistence times (when used as a spray) and toxicity with respect to *Encarsia formosa*. Values are based on a one-time application at the recommended rate. More concentrated doses, repeat applications and different means of delivery such as via irrigation may result in different withholding periods, persistence times and levels of toxicity. (+) Sprays with label claims for whitefly control in greenhouses. Note that non-whitefly protection products are included because of their potential effects on *Encarsia formosa*.

Crop protection categories, common names and IRAC[a] or FRAC[b] mode of action groups	Product / Trade name	Target pests	Label claims for whitefly in greenhouses	Withholding period (relating to picking)	Persistence in weeks (before it is safe to re-introduce *Encarsia*)	Toxicity to *Encarsia* at application time. 4 very harmful — 1 harmless
Parasitoids (parasites)						
*Encarsia formosa**	En-force, En-strip	Whitefly	+	0 days	—	—
Biologicals, horticultural soaps, plant-based spraying oils & botanical IGRs						
Bacillus thuringiensis (Bacterial pathogen)	E.g. Agree WDG, Delfin WG, Dipel ES, Dipel DF	Looper caterpillar, tomato fruitworm on tomato		0 days	0 weeks	pupa 1 adult 1
Beauveria bassiana (Entomopathogen)	Beaugenic	Thrips		1 day	0 weeks	pupa 1 adult 1
Lecanicillium longisporum (Entomopathogen)	Vertiblast	Aphids		1 day	0 weeks	pupa 1 adult 1
Lecanicillium muscarium, previously known as *Verticillium lecanii* (Entomopathogen)	Vertikil	Whitefly, thrips and aphids	+	1 day	0 weeks	pupa 1 adult 1
Horticultural soaps (Potassium salts of fatty acids)**	E.g. PS1, PS2	Whitefly, psyllids		0 days	0 weeks	pupa 1 adult 1
Plant-based spraying oils	Eco-oil	Whitefly, spider mite	+	0 days	0 weeks	pupa 1 adult 1
Botanical IGRs	Neem 600WP	Greenhouse whitefly	+	0 days	0 weeks	pupa 2 adult 1
Crop protection chemical subgroups — Insecticides						
Carbamates (IRAC) 1A						
Methomyl	Lannate L	Whitefly	+	2 days	6–10 weeks	pupa 4 adult 4
Organophosphates (IRAC) 1B						
Pirimiphos-methyl	Actellic smoke generator	Greenhouse whitefly	+	3 days	6–8 weeks	pupa 4 adult 4
Organophosphates (IRAC) 1B + Pyrethroids (IRAC) 3A						
Pirimiphos-methyl + Permethrin	Attack	Whitefly, aphids, caterpillars	+	3 days	12 weeks	pupa 4 adult 4
Avermectins (IRAC) 6						
Abamectin	E.g. Avid	Mite pests		3 days	3–6 weeks	pupa 1 adult 4
Pymetrozine (IRAC) 9B	Chess	Whitefly and aphids	+	3 days	0 weeks	pupa 1 adult 2
Buprofezin (IRAC) 16	E.g. Ovation, Applaud	Greenhouse whitefly	+	3 days	0.5 weeks	pupa 2 adult 1
Tetronic and Tetramic acid derivatives (IRAC) 23						
Spiromesifen	Oberon	Whitefly, spider mites, psyllids	+	1 day	0 weeks	pupa 1 adult 1
Crop protection chemical subgroups — Fungicides						
Thiophanates (FRAC) 1 Thiophanate-methyl	Topsin M	Botrytis. powdery mildew		3 days	0 weeks	pupa 1 adult 1
Dicarboximides (FRAC) 2 Iprodione	E.g. Rovral, Defence	Botrytis		3 days	0 weeks	pupa 1 adult 1
Piperazine (FRAC) 3 Triforine	Saprol	Powdery mildew, *Fulvia fulva* (ex *Cladosporium fulvum*)		3 days	0 weeks	pupa 1 adult 1
Chloronitriles (FRAC) M5 + Thiophanates (FRAC) 1 Chlorothalonil + Thiophanate-methyl	E.g. Taratek	Botrytis		3 days	0 weeks	pupa 1 adult 1

Data collated from Biobest web site www.biobest.be, Koppert Biological Systems web site www.koppert.com, the New Zealand Novachem Agrichemical Manual 2009, The Good Bug Book, the IRAC Mode of Action Classification Aug. 2008, the FRAC Code List 2007, and personal communication with industry consultants.

* No registration needed.

** No horticultural soap products are registered for use in greenhouses. However, they are used as aduvants. Care must be taken to apply at label rates and to follow label instructions in order to avoid phytotoxicity effects.

a. IRAC is short for the Insecticide Resistance Action Committee, a group who developed the Insecticide Mode of Action classification system to guide growers and consultants on the selection of insecticides and acaricides in an effective and sustainable pest resistance management strategy.

b. FRAC is short for Fungicide Resistance Action Committee, a group who developed the Fungicide Mode of Action classification system to guide growers and consultants on the selection of fungicides in an effective and sustainable pest resistance management strategy.

Minimising effects on *Encarsia*

Many insecticide sprays have negative effects on *Encarsia*. However, application techniques and spray formulations can be employed to reduce damaging effects to acceptable levels, including:

Spot spray: Only spray hot spots of infestation, e.g. worst affected plants or rows, rather than make blanket applications to the whole crop. *Encarsia* is then able to re-colonise from adjacent unsprayed plants. It is better to use horticultural soaps and spraying oils for this so whitefly resistance doesn't build up.

Target spray parts of the plant: Use horticultural soaps or spraying oils to spray the undersides of leaves in the top portions of plants where adult greenhouse whitefly are found, leaving the rest of the plant unsprayed. This checks adult whitefly numbers, while leaving *Encarsia* adults and black scale that occur lower on the plant relatively untouched. Note that this strategy will not be as effective against sweet potato whitefly as the adults are distributed over the whole plant.

Use 'soft' sprays first: As the first line of defence, employ horticultural soaps, spraying oils and beneficial entomopathogenic fungi since these have minimal impact on *Encarsia*. These alone may be sufficient to keep whitefly below harmful levels.

Use selective sprays: Aim to use sprays that have a strong impact on the pest species, but little impact on *Encarsia.* Some sprays for example are very harmful to *Encarsia* adults, but have minimal impact on pupae (black scale). This means there will still be *Encarsia* ready to emerge quite soon after the spray's residual effects have subsided.

Broad spectrum sprays: Employ broad spectrum sprays only as a last resort. These generally have long persistence times and/or are highly toxic to pupa and adult stages of *Encarsia*. Their use may effectively negate the re-introduction of *Encarsia* for the rest of the crop cycle.

Fewer spray applications: Keep the number and scale of spray applications to the minimum required to kill the targeted life cycle stages, as extensive and repeated spraying over and above this increases the accumulation of toxic chemicals on plants and in the greenhouse environment and therefore increases the chance of disrupting the *Encarsia* life cycle.

Minimising effects on bumble bees

Because bumble bees can be harmed by some sprays, it is important to check their potential effects (see Koppert and Biobest web sites) and seek expert advice before spraying.

Note: Use chemicals legally. Users of sprays must follow label instructions, manufacturer's recommendations and adhere to their legal responsibilities. They are not absolved from compliance by reason of any statements made or omitted in this publication. Labels may have warnings to prevent inappropriate tank mixes, to avoid phytotoxicity and to avoid hazardous working conditions for employees. Some products may need to be managed by an Approved Handler.

Resistance management

Overseas, whitefly has become resistant[1] to many chemical products, including organochlorines, organophosphates, carbamates, pyrethroids and specific insect growth regulators like Buprofezin and Teflubenzuron. Resistance to Buprofezin has been demonstrated in New Zealand and there is suspicion of resistance to carbamates in some parts of the country. So, it is very important to use pest management strategies that aim to reduce or prevent resistance so that existing sprays remain effective into the future.

It is important to note that whitefly do not appear to build resistance to horticultural soaps and spraying oils. While these products may have a short term effect, they are none-the-less valuable tools in whitefly control.

When poor control by an insecticide becomes evident, it is important to determine what factors may be responsible, e.g. wrong rate used, poor coverage, high spray water pH (greater than 6.5), unfavourable conditions, etc. If such factors are considered not to be the cause, an advisor should be contacted to determine the best control strategy to follow. Under no circumstances should the manufacturer's recommended label rate be exceeded, as this will only make worse any developing resistance episode.

Apply insecticides in clusters

The most vulnerable stages of the whitefly life cycle are the young nymphs and adults, while eggs and pupae are least susceptible to many insecticides. One application of spray is thus rarely effective as it only kills off parts of the life cycle, leaving others relatively untouched. It is therefore best to use the same insecticide in a cluster of applications spaced to catch whitefly at its most vulnerable stages (except for Buprofezin which should be used no more than twice on the same crop in a 12 month period). The timing of all products should be based on manufacturer's recommendations, temperature and close observation of the insect to identify the presence of the vulnerable stages. So during mid-summer when whitefly develop quickly through the stages, several spray applications should be more closely spaced—for example only a few days apart—compared with several applications applied perhaps a week to 10 days apart during cooler conditions. The exact spacing is dependent on the mode of action of the product, its persistence and the pest pressure at the time.

Apply insecticides from different IRAC[2] chemical groups

The common practice employed by many growers in recent times of using the same active ingredient spray routinely applied once a week or fortnight throughout the growing season is highly conducive to building a resist-

1. Resistance is the ability of a proportion of the pest population to survive applications of a chemical at a rate that formerly would have killed them. Because resistance is inherited, once it has developed it is largely irreversible. A New Zealand developed resistance management strategy for whitefly can be found on the website www.nzpps.org/resistance/whitefly.php
2. IRAC is short for the Insecticide Resistance Action Committee, a group who developed the Insecticide Mode of Action classification system to guide growers and consultants on the selection of insecticides and acaricides in an effective and sustainable pest resistance management strategy.

ant whitefly population. By contrast, applying a spray in a cluster of several applications, then changing to a spray from a different IRAC mode of action group for the next cluster of applications means there is less chance of building resistance in the pest population.

Sprays are categorised according to their chemical structure and mode of action. Different commercially available formulations of sprays that belong to one IRAC chemical group have similar mechanisms by which they kill (see Table 1). As a general rule therefore, it is very important to select sprays from different groups for each successive cluster of applications. First, by doing this, whitefly have a low chance of surviving applications of sprays from one group (because several applications kill whitefly as they pass through their most vulnerable early nymph and adult phases). But second, if any do survive and again require control, they are killed by the next cluster of applications of a spray from a different group which has a different mode of action. (Note, it is also possible for cross-resistance to occur between chemical groups with a similar mode of action, e.g. carbamates (1A) and organophosphates (1B) in some pests.)

Because there is evidence for whitefly resistance to Buprofezin in New Zealand, it should not be used more than twice in any one crop per 12 month period and it should always be used in conjunction with another insecticide from a different chemistry (IRAC) group.

Application rates and coverage

It is important to ensure application rates and their associated water rates are correct according to the label. Train and de-leaf plants before sprays are applied and ensure that spray coverage, especially of the undersides of leaves, is thorough to optimise its effectiveness. Ensure that chemicals with short storage lives are not used after their expiry dates.

Mode of action

Physical mode of action (M.o.A) chemicals: Because of their mode of action — suffocation, adhesion and disruption — sprays such as horticultural soaps and spraying oils are unlikely to select for resistance in insect populations. This means they can be safely used to spray portions of the crop where hot spots of infestation occur, or parts of plants such as their heads, without fear of leaving some whitefly alive to breed and build a resistant population. Regular systematic monitoring allows these hot spots to be pinpointed. To ensure thorough coverage of the pest, apply these products as a coarse mist at low to medium pressure, to the undersides of leaves. With these products it is especially important that the plant dries quickly after spraying to minimise damage to the leaves.

Systemic chemicals: For the most part of their life, whitefly nymphs are protected by a shell-like covering that makes chemical control difficult. So, an effective means of killing them is by the use of systemic insecticides. When applied, the chemicals penetrate through the leaf surface and travel in the sap stream to the leaves and are taken up during feeding. Sometimes they are applied as a drench or via the irrigation system in which case they are taken up by the roots and travel in the sap stream to the leaves. (Note that these methods require a good working knowledge of the system so as to ensure the chemical is delivered to the root zone within the last 1–2 irrigations of the day and not left sitting in the system overnight. This practice is also only as good as the uniformity of the irrigation delivery. Seek advice from an expert before implementing.) Pymetrozine is an example of a systemic chemical. When applied as a foliar spray it has little effect on *Encarsia* pupae, but has some harmful effects on adults (see Table 1). It is not recommended for use via irrigation.

Residual chemicals: These may be taken up by the leaf tissue but are not transported within the plant, leaving a residue in or on the leaf to extend pest control. Examples include Spiromesifen and Buprofezin. Both have little impact on *Encarsia* (see Table 1).

Contact / fumigant chemicals: Some chemicals are effective in killing whitefly adults by direct contact, for example via vapour activity or by the chemical's presence on the leaf. Examples include products like Pirimiphos-methyl, and Pirimiphos-methyl + Permethrin. These chemicals are very harmful to *Encarsia* (and other beneficials including bumble bees) and are likely to negate any effective use of this biocontrol agent for the whole crop cycle.

Product choice

Only a small selection of New Zealand registered insecticides have label claims for whitefly control in greenhouses. These and other chemicals registered for pest control or otherwise permitted on greenhouse tomato crops are listed in Table 1. Note that some insecticides that control whitefly are specifically registered for use on field crops only and should not be used in greenhouses.

New Zealand insecticide products with label claims for whitefly control were registered for greenhouse whitefly (*Trialeurodes vaporariorum*). It is unknown how effective they are against strains of sweet potato whitefly (*Bemisia tabaci*) in New Zealand.

To ensure crop safety when any new product is used, it is important to apply it to a few plants at label recommended rates and number of applications (in the crop and growing situation). Then, wait for a few days to ensure there are no phytotoxicity effects before committing the product to the whole crop.

Spraying oils

Some spraying oils have been shown to increase insecticide efficiency by improving their spread and their penetration of the insect exoskeleton and therefore the likelihood of making contact with and improving their control of whitefly scales. There are two types of spraying oils on the market, mineral oils and plant-based oils like canola oil. In many cases mineral oils have caused severe crop damage in greenhouse crops and so should not be used. For crop safety, always ensure that the spraying oils are plant-based.

'Soft' pest control products
These products, often referred to as biorational or reduced-risk chemicals, are considered ecologically sustainable with low toxicity towards humans, other mammals and non-target species. They may also have short residual presence on leaves. Examples include spraying oils, horticultural soaps and entomopathogenic fungi. They should be used as the first crop protection line of defence in an IPM programme using *Encarsia*.

Off label use
Chemical products registered for greenhouse use will have predetermined MRLs. The use of a product for purposes or at rates other than indicated on the label is therefore not recommended. This is because, without prior testing, residues remaining in fruit at the time of harvest will not be known by the grower, so they may accidentally exceed maximum residue limits, for example, the default MRL value of 0.1ppm, allowed in their produce. This is relevant to both local and export markets — and export markets often have very strict requirements for residues in produce.

Method of application
The great majority of insecticides used for whitefly are applied as foliar sprays. To ensure they are effective and to minimise resistance (particularly when spraying synthetic broad spectrum chemicals), it is essential to achieve thorough coverage of both sides of all leaves within the crop canopy with a pH adjusted spray solution. Poor coverage, which may arise from inaccurate sprayer calibration and/or application technique, is a common reason for failing to control a pest. In most greenhouse tomato cropping systems the best method of delivery uses vertical pipe-rail boom sprayer units set up to deliver high volume wet sprays. Their use is discussed in detail below, along with some discussion of less preferred application methods.

Achieving effective coverage
Good spray coverage is essential. To assist this:

- manage plants to allow easy spraying access (that is, create adequate paths and ensure sufficient, even spacing between plants) and ensure all plants are layered to the same height
- use spray pressures sufficient to penetrate into the canopy and move the leaves
- for foliar sprays, apply between 500 and 2500 L of water / ha depending on the size of plants and plant density of the crop being treated
- check spray coverage by attaching water-sensitive paper to the undersides of leaves or use UV-fluorescent tracers to detect spray deposits
- tag selected leaves, check the number of whitefly scale on those leaves, then re-check the tagged leaves after spraying to evaluate its effectiveness (taking into account the product mode of action and the life cycle stage the product targets).

Equipment options

High volume (HV) sprayers
These usually deliver up to 2500 L (although sometimes up to 2800 L) of spray per hectare of varying droplet size between 100 and 700 microns in diameter. (As an indication of size, a dot on this page is approximately 500 microns diameter, and 1000 microns equals one millimetre.) They are the most common spraying system and preferred choice of equipment, with most pesticide labels being written for HV application. Two types are discussed here.

Vertical pipe-rail boom sprayers
These spraying units, employing a fixed vertical boom on a pipe-rail cart, are the regarded as the best commonly used spray systems available to tomato growers (Fig. 3). They are moved backwards through the rows to minimise chemical contact with the person applying the spray.

In high wire layered tomato crops, the following recommendations give best spray penetration and coverage of inner and outer leaves for the full height of the plant (Fig. 4). They can be used for any spray formulation.

Nozzles types: 80° angle, flat fan (Fig. 2)

Nozzles directed: 45° upwards from the horizontal in order to increase deposition of droplets on the undersides of leaves where whitefly live

Fig. 2. 80° flat fan nozzles facing upwards at a 45° angle.

Fig. 3. Vertical pipe-rail boom sprayer. When travelling down rows the spray boom follows the person, thereby minimising worker contact with chemicals.

Number of nozzles: up to 9 on each side of the boom (the number dependent on the height of the plants), 300 mm apart, directed outwards so both sides of the row are sprayed at once

Nozzle flow rate: 1.2 L / min

Pressure: 250–300 kPa (2.5 to 3.0 bar) at the boom

Boom movement speed: 1 m / sec (normal walking speed) giving an average coverage of 2,200–2500 L / ha

Boom height: For good coverage in the canopy, match the boom height with the height of the crop, which may require layering the crop before spraying. Some lower nozzles may be shut off when the crop is de-leafed higher up the stems at certain times of the season[3].

Hand guns
These produce a similar type of droplet to vertical pipe-rail boom sprayers. They are good for treatment of hot spots, but it is difficult to achieve even, consistent coverage over wide areas of application with this type of equipment.

Ultra low volume (ULV) and low volume (LV) sprayers
ULV systems like thermal foggers, pulse foggers and low volume misters deliver tiny droplets as small as 30 microns diameter at rates of 100 L per hectare, while LV systems deliver 30–100 micron droplets at rates of 100–400 L per hectare. They enable easy and quick treatment, but are only suitable for delivery of some chemicals (those with a 'vapour activity'). They are not recommended for whitefly as they give greater distribution of spray on the tops of leaves and poor penetration within dense tomato canopies resulting in poor whitefly control. They are not suitable for spot treatments and are not suited for delivering physical mode of action sprays such as spraying oils and horticultural soaps to run-off.

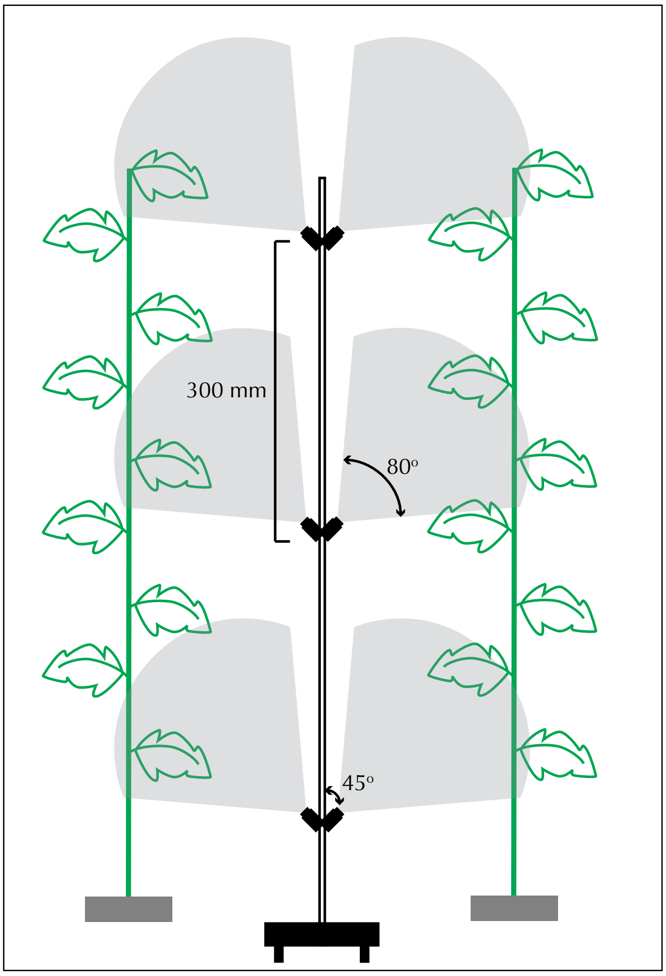

Fig. 4. Stylised vertical pipe-rail boom sprayer set-up showing 80° flat fan nozzles directed upwards at 45º towards the crop. Nozzles are positioned 300 mm apart (the number employed being dependent on the height of the plants).

Mist blowers or motor blowers
These are low volume blowers that produce small droplets of 10–60 microns diameter. They enable quick delivery of spray over a considerable distance with good mixture deposition, but can be clumsy, inaccurate and produce inconsistent canopy penetration.

Drenching and via irrigation
There are no products registered for application as a drench or via irrigation for tomato crops in New Zealand. Because there are issues relating to correct delivery rate, over- or under-dosing, residues, the effects on MRLs, seasonal variations in uptake; timing of dose and dilution caused by irrigation cycles following application, these methods are not generally recommended.

Separate sprayers
It is recommended that a separate spraying unit is used for 'soft' sprays to avoid toxic residues from previous use of broad spectrum sprays harming *Encarsia*. If this is not possible, ensure the spray unit is thoroughly cleaned, decontaminated and flushed before use.

Maintenance of sprayers
Regular maintenance of sprayers is very important because blocked or partly blocked nozzles affect the spray pattern and leave some areas of the crop untreated. Experience has shown that a poorly maintained spray boom can reduce chemical control efficacy by 50%. Check the nozzle output and clean nozzles at least twice a year, a job that is best done when a new crop is planted and shortly before the main 'spraying season'. A spray boom maintenance check should include the following:

- clean all nozzles and filters behind the nozzles
- check the pressure at the spray boom by filling the tank with clean water and switching the pump on.

3. Notes on vertical pipe-rail boom sprayers: Fan nozzles give better penetration than cone nozzles and 80º nozzles give greater spray velocity and therefore better penetration than wider angle nozzles. The international code for these nozzles is 03F80 (03 = flow rate; F= flat fan; 80 = 80° spray angle). Volumes greater than 2500 L/ha may lead to excess spray run-off. Information collated from various sources, including *Tomatoes: effective use of pipe-rail boom sprayers*, Fact sheet 20/00 Project No. PC 136, Horticultural Development Council, UK.

The pressure at the boom should be 250–300 kPa (2.5–3.0 bar) when the boom is spraying (if needed, reduce or increase the pressure at the pump)

- check that all nozzles have a similar spray pattern; if not, debris may still be in the nozzle so check again or replace the nozzles
- check that all the nozzles give equal output by collecting the output of each nozzle individually over a set time such as one minute.

In case of intensive use, nozzles should be replaced once a year (although ceramic nozzles may last longer) due to excessive nozzle wear caused by some crop protection products. Checking a spray boom may take time, but can save significant labour and chemical costs, and improve spaying effectiveness.

Horticultural suppliers may also offer sprayer maintenance services.

Correcting pH

New Zealand bore and town supply water often has a pH that is higher than 6.5, but the optimum range for a spray mix is generally 5.5–6.5 (pH 6.0 being a good value to target). Sprays mixed at a higher pH can have greatly reduced effectiveness due to alkaline hydrolysis (and at a lower pH can cause crop damage). To lower the pH it is best to use a commercial spray tank buffer — which is safer than other options — to achieve the optimal pH level.

Plant leaf management

Whitefly eggs, scales and pupae lie flat against the undersides of leaves. This makes them more difficult to target by spraying. To improve coverage, reduce the density of foliage by removing selected leaves. However, attempt to minimise the quantity of *Encarsia* black scale lost in the process. Do this by checking the percentage of scale that are black. If this value is 80% or greater, consider retaining some leaves on the lower shaded side of the plant, or, drop those leaves that have been removed onto the floor and leave them there for at least two weeks to allow time for adult *Encarsia* to emerge.

Spray diary

Records of chemical applications are vital documentation for present and future decision-making in an IPM programme and in case problems are encountered. It is important to record: what was applied, how much per 100 L and the spray volume (litres per area); what disease or pest was targeted; what area(s) of the greenhouse were sprayed; the application method; who did the spraying; date and time of day; greenhouse temperature and humidity; and, *Encarsia* release dates, rates and locations. There are many electronic spray diaries available now, e.g. SprayLog which is available free from the web site www.spraylog.hortplus2.com.

Other pest and crop disease considerations

For simplicity, this factsheet has only considered control of whitefly. When other pests and diseases are present, decision-making is more complex, requiring greater levels of experience. An advisor's input may be invaluable in developing a more sophisticated IPM programme for these circumstances.

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/

ERMA Registers http://www.ermanz.govt.nz/search/registers.html

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

Whitefly insecticide resistance management strategy 2005 www.nzpps.org/resistance/whitefly.php

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.

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