New Zealand Code of Practice for the Management of the Tomato/Potato Psyllid in Greenhouse Tomato and Capsicum Crops

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1. Introduction

The tomato/potato psyllid, *Bactericera cockerelli* is a relatively new pest to New Zealand (confirmed present by Biosecurity NZ May 2006) and is the vector for Candidatus *Liberibacter* a plant disease of tomato, capsicum and other solanaceous crops including potato. This document is the industry's Code of Practice for its greenhouse tomato and capsicum growers. For further information contact:
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1.1 Objective

The objective of this Code of Practice is to provide guidance to growers and others in the industry for the effective, safe and responsible control of the tomato/potato psyllid in order to minimise the impact of Liberibacter on production and export market access.

1.2 Scope

The Code of Practice is aimed at all producers of greenhouse tomato and capsicum crops. Use of this Code will result in a number of benefits for this industry group and consumers alike. Implementation of the Code will ensure:

a. Damage to individual crops will be minimised
b. Control of the pest will be effective and sustainable
c. Management of other pests of significance in these crops will not be unduly affected
d. Current IPM practices in place remain functional and the continued supply of high quality low residue fruit to the NZ public and our export customers is not compromised.
e. Resumption and continuation of export of these crops will be facilitated

1.3 Relevant legislation and industry standards

All relevant legislation and industry standards should be followed or adhered to in the control of the tomato/potato psyllid. For further information refer to the following:

- New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards 2008 (http://www.nzfsa.govt.nz/policy-law/legislation/food-standards/nz-mrl-fs-2008-consolidation.pdf)
- New Zealand GAP or GLOBALGAP
- GROWSAFE®
- Other Approved Supplier or Produce Trading Partners programmes

1.4 Information on the tomato/potato psyllid

The tomato/potato psyllid is a small phloem-feeding, winged insect about 3mm in length and resembles a miniature cicada. This pest can sometimes vector 'psyllid yellows' disease to a number of host plants. Recently, a new species of bacterium causing this disease in solanaceous plants has been described as belonging to the genus *Candidatus Liberibacte*r. A description of the insect is found in Appendix 1 along with additional sources of information and photos of life stages, characteristic excreta and typical host plant damage. Horticulture New Zealand has published sets of identification cards and a poster, and MAF Biosecurity New Zealand has a pamphlet with further information and images. Refer to Appendix 1 for the relevant web links.

2. Responsibilities, training and planning

2.1 Monitoring Duties and Responsibilities

Greenhouse growers or managers should:

- Identify a suitably trained person (or persons) to scout the crop on at least a weekly basis (shorter interval during periods of high pest pressure).
- Establish a crop monitoring plan based on the requirements of section 3.3. Make maps of the greenhouse unit in which row numbers and bays can be easily identified.
- Set up a pest monitoring records system, and record pest numbers, life stages, location, and actions taken.
- Undertake monitoring at least weekly, increasing in frequency to daily monitoring during periods of high pest pressure.
- Ensure that monitoring is consistent between plants and between monitoring personnel.
- Make all greenhouse staff aware of Psyllid and Liberibacter symptoms and encourage reporting to the crop scout of any unusual or unhealthy symptoms in the greenhouse.
- Make identification cards and posters available to all staff.

2.2 Training requirements

- Crop monitoring personnel must be familiar with monitoring techniques and of Psyllid/Liberibacter symptoms or identification.
- All greenhouse staff should be familiar with the potato/tomato psyllid and the symptoms of the disease that it can sometimes cause.
- Quality images and easy to understand descriptions of the disease vectored by the psyllid facilitates more informed feedback from staff because symptoms of feeding damage may resemble other disorders.
- Ensure sufficient copies of the psyllid field identification cards are available.

2.3 Pre-planting requirements

- Only source seedlings from a supplier implementing psyllid control measures during the nursery phase:
    - Psyllid control on young plants can be achieved by spraying or drenching with an IPM compatible insecticide. Abamectin or spinosad sprays are options. For drenching, Calypso (Thiacloprid) in the irrigation water at a rate of 20ml per 1000 plants has been effective. Avoid substantial run off in the days following application. Repeat if required.
- Inspect the area surrounding the greenhouse for host plants, both weeds and ornamentals (see Appendix 2). Remove and destroy host plants where possible.

2.4 Planting

- Only plant seedlings that are free of pests. If psyllids are found on seedlings, destroy infected seedlings before they are introduced into the greenhouse.
- Check all other seedlings in the batch to ensure they are not infested.
- Psyllid control on young plants can be achieved by spraying or drenching with an IPM compatible insecticide. Abamectin or spinosad sprays are options. For drenching, Calypso (Thiacloprid) in the irrigation water at a rate of 20ml per 1000 plants has been effective. Avoid substantial run off in the days following application. Repeat if required.

2.5 Crop removal and actions between cropping cycles

- Before the end of a crop, pests should be contained within the building and eliminated before the old plants are removed. This prevents pests from being spread into the environment around the outside of the greenhouse. Apply a high volume pesticide spray of, for example, abamectin together with triple rate surfactant or mineral spraying oil. Keep the greenhouse closed for 24 hours before plant removal.
- Remove the plants in a secure manner such as in covered bins to land fill or covered composting.
- Clean and disinfect the greenhouse ensuring all plant material including weeds and volunteer plants are removed and destroyed.
- Check all flying insect pests have been eradicated by hanging yellow sticky traps (at least 10/ha) and inspect daily. Fog or spray insecticide if pests are present. Close the greenhouse ventilators and doors and allow a period for warming to accelerate pest eradication.
- Where possible, set up a double door system at the greenhouse entrance using insect mesh. This is to prevent flying insects from easy access to the crop. Hang one yellow sticky trap at least every $10m^2$ in this area.

3. Key aspects of crop protection

To successfully control the tomato/potato psyllid over an extended period, various methods must be employed or control will not be reliable.

3.1 Control Methods

3.1.1 Cultural practices

Cultural aspects of crop protection involve considering all of the basic growing best practice concepts to ensure optimum growing conditions for maintaining a healthy crop which has maximum resistance to pests and diseases. Attend to as many of these as possible; e.g. temperature, irrigation, pH and fertility, plant spacing.

3.1.2 Hygiene

Preventing pests from entering the crop should always be a key consideration in crop management. This commences before the end of a crop to ensure low carry over of all pests and diseases refer sections 2.3-2.5, above). All crop debris should be removed from the greenhouse and immediate environment. Weed and volunteer plant removal is required to ensure no green bridge remains for hosting pests. Adequate sanitation is essential before the new crop arrives. During the cropping period ensure good hygiene practices are observed at all times. Infestations must be dealt with promptly and appropriately, and diseased plants should be removed promptly and disposed of in a secure manner.

3.1.3 Biological agents

Research on a number of new natural enemies of the psyllid is underway. Some beneficial insects and mites are found in the crop without being introduced. If agrichemicals are carefully managed, predatory mites, lacewings, ladybirds, parasitic wasps and other beneficial arthropods and entomopathogenic fungi will contribute to controlling pests (their impact on Tomato/potato psyllid is not extensively researched at this stage). Refer to Appendix 4 on side effects of chemicals on natural enemies and identify the least damaging options if it is determined that spraying is required.

3.1.4 Physical methods

Exclusion of pests by screening vents and doors is not practical for many properties at present. However certain spray options with a physical mode of action should be considered whenever possible. Soaps; e.g. dish washing liquids, and compounds that are sticky or have deterrent properties; e.g. certain spreader and sticker adjuvants, can be employed to prevent pests from visiting plants and/or laying eggs. Several essential oils; e.g. cedar wood and neem, deter psyllids from selecting plants for egg laying. Care should be taken when trialling oils as many are phytotoxic. Yellow sticky traps placed near vents and entranceways can be used to reduce psyllid populations migrating into the greenhouse.

3.1.5 Chemicals

Chemicals registered for use in tomato and capsicum crops are listed in section 3.5. Care is required in selecting chemicals so that a minimum of damage is done to beneficial organisms and resistance to the pesticide is prevented. Most chemicals should only be used 2 – 3 times per season. Adhere strictly to specific product advice at all times to ensure pesticide resistance is minimised. Consult crop protection specialists for advice on selection, application guidelines and rotation of products with different modes. Always ensure compliance with New Zealand Maximum Residue Limits.

3.2 Management of alternative host plants

Check plants in the area surrounding the greenhouse are not hosting tomato/potato psyllids. Remove known host plants where possible. The host range of the tomato/potato psyllid is said to include the plants listed in Appendix 2.

Check regularly to ensure a buffer zone remains free of host weeds. If the pest psyllid lays eggs on desirable ornamentals that cannot be removed or replaced, control these populations by selecting sprays from the list in section 3.5. Continue the practice of rotating pesticides by their mode of action groups.

3.3 Crop monitoring

It is necessary to monitor psyllid populations in order to make informed decisions for their control. Monitoring psyllid populations on the plants in the greenhouse is the most reliable and effective way to monitor psyllid populations at the moment. Yellow sticky traps may give some indication of psyllid activity but currently there is insufficient information to relate trap catches with psyllid populations in greenhouse crops. Yellow sticky traps however can give background information on psyllid activity. Yellow sticky traps if hung near vents can be used to reduce psyllid populations migrating into the greenhouse.

3.3.1 Monitoring for tomato/potato psyllids

(a) Scheduled crop scouting

The method outlined below is based on a 4m x 8m structural module common in many multispan Venlo style glasshouses, but can readily be adapted to suit other structures. The 4m sections between poles along the row are a designated sampling unit. Each sampling unit will contain approximately 15 tomato stems or >40 capsicum stems.

Monitoring is based on searching for psyllid sugars as a way for homing in on psyllid infestations:

- Monitor at least weekly – more frequent monitoring is recommended during times of high pest pressure.
- Each week, sample 1 row per 8 metre bay and alternate the rows (1 through to 5) between weeks so that all rows are monitored over a 5 week period.
- Monitor the plant between poles which is showing the most psyllid sugars.
- If no sugars are seen, monitor a plant at random within a 4m bay.

- Concentrate on monitoring the top section of capsicum plants and middle section of tomato plants.
- Score the psyllid infestation:
  - 0 no psyllids present
  - 1 adults only
  - 2 adults and eggs
  - 3 adults, eggs and nymphs (on 1 -5 leaves)
  - 4 adults, eggs and nymphs (on > 5 leaves)
  - 5 psyllid infestation on adjacent plants
- Using the 4 metre section method approximately 1 in 60 - 65 plant stems should be examined in each monitoring period.
- Not all plants infected with Liberibacter show disease symptoms, however these may be detected during scheduled crop monitoring.
  - Record and then remove all plants showing yellowing symptoms associated with the Liberibacter disease in each sampling section.
  - Any plants showing Liberibacter symptoms anywhere in the greenhouse should also be removed.
- If the symptoms are not expressed strongly, plant samples may be sent for testing for Liberibacter.
- Make control action decisions as described in section 3.2.2.

(b) Monitoring yellow sticky traps

Yellow sticky traps are not a formal part of the monitoring programme, as there is currently not enough information to relate trap catches with action thresholds. However they can be useful for giving a quick assessment of comparative psyllid activity in greenhouses for given periods.

It is suggested that sticky traps are monitored and replaced weekly inside and outside the greenhouse in north, south, east and west positions (See Sections 2.5 & 3.5). Caution is required in interpreting results from sticky yellow traps from outside the greenhouse as other psyllid species may also be present and these may be difficult to distinguish from the tomato/potato psyllid adults.

(c) Monitoring by staff while working the crop

In addition to specific crop scouting activities, described in 3.3.1. (a), all greenhouse staff should be trained to look for and recognise psyllids and their symptoms while working the crop. It is suggested that a reward system be instigated as an incentive for extra vigilance.

All staff working in the crops must be able to recognise all the life cycle stages of the tomato/potato psyllid and to report suspected psyllid infestations to crop monitors. This is extremely important at the initial stages of the psyllid infestation when numbers of psyllids in greenhouses may be very low.

This informal monitoring by crop working staff is a very important component of crop monitoring and should be incorporated into the monitoring programme.

(d) Monitoring other pest and diseases

Psyllid monitoring can be incorporated into the other pest and disease monitoring. It is suggested that each plant that is selected to be monitored for psyllids is also used for monitoring whitefly and other pests and biological control agents.

3.3.2 Guidelines for Action Thresholds for Psyllid control

The guidelines for action thresholds are described below and are only indicative – they are based on grower experience and have not yet been scientifically validated.

Monitoring will give growers two values: the proportion sample infested with psyllids and a value from 1 - 5 indicating the severity of the infestations. Both values need to be taken into account when defining the required action. In general growers should take the action that applies to the highest of the value or percentage. For example, if the percentage value is <1% but the level of infestation is >1.8, then a full insecticide application should be made.

Table 1: Suggested action thresholds

Percentage of sample infested with psyllids	Value indicating level of psyllid infestation	Action
0	0	No action
<1%	<1.5	Remove infected leaves
1-2%	1.5-1.8	Spot spray insecticides
>2%	>1.8	Full insecticide application

These guidelines are only indicative and will require adjustment by individual growers to meet their particular requirements.

3.3.3 Control actions

Removal of infected leaves

At very low infestation levels, psyllids may be controlled by removing infested leaves. These leaves should be placed directly into plastic bags, sealed and disposed of in a safe manner.

Spot spraying

When spot spraying is to be undertaken further monitoring of plants and rows around the identified infested area should be undertaken to more accurately define the section of greenhouse that needs to be treated by spot spraying.

Monitoring hot spots

Experienced growers can often determine areas in their greenhouse where the initial psyllid infestations occur. Extra monitoring in these areas will give additional information. It has been reported that psyllids preferentially attack plants that have previously been infested with psyllids. Marking and monitoring these plants may also give additional information.

3.3.4 Records - Monthly Tomato/potato/psyllid/Liberibacter summary sheet

Monthly data sheets can be used to summarise psyllid monitoring, control actions and Liberibacter infestations (see Appendix 3 for the layout of the monthly recording sheet). A separate sheet should be used for each greenhouse on the property.

This summary sheet records:

Weed Hosts:

Surveying the property for weeds that are host plants for the tomato/potato psyllid and recording actions to remove these alternate host plants (See Appendix 2 for list of weed host plants).

Neighbouring crops:

The location of neighbouring crops that host the tomato/potato psyllid and control strategies.

Yellow sticky traps:

Total tomato/potato psyllids caught on sticky traps inside and outside the greenhouse.

Plant monitoring for psyllids

Weekly counts of the number of plants monitored, percent of plant infested with psyllids, the mean psyllid score and the control actions taken in response to the monitoring for each week.

Plant monitoring for Liberibacter

Weekly counts of the number of plants showing Liberibacter symptoms and the response including the number of plants removed.

Insecticide application

Record all insecticides applied each week for both the control of psyllids and other pests. This data will include product used, active ingredient, concentration, water rate and method of application.

3.4 Consideration of other pests, pollinators and natural enemies.

Many methods of controlling plant pests are not selective to the pest and can kill beneficial insects. Consideration must to be given to the role pollinators need to play in a crop and the importance of maintaining populations of natural enemies such as parasitic wasps and predators. If bumblebees or biological control agents are being caught on yellow sticky traps in substantial numbers, either reduce trap density or change the trap position relative to the height of the crop.

Sprays with a contact mode of action should also be used with care as these can also reduce the role beneficial organisms' play in the control of psyllids and other important pests (See Appendix 4).

3.5 Plant protection products

The tomato/potato psyllid is a relatively new pest in tomato and capsicum crops in New Zealand, and is not currently covered by any New Zealand agrichemical registrations.

Fortunately many agrichemicals registered for controlling pests such as greenhouse whitefly and mites also have activity against the tomato/potato psyllid. While optimum application rates have not been set, concentrations listed on labels for similar insect pests should be regarded as appropriate rates when a product is used to target psyllids.

At all times adhere to pest management best-practice including:

- Seek up-to-date advice on pest management options.
- Implement cultural and biological control options where available.
- Utilise non-chemical methods to suppress pests as part of the management.
- Use sound scouting procedures and action thresholds.
- Apply insecticides only when necessary.
- Use appropriate, adequately maintained spray equipment.

- Spot spray infested areas whenever feasible. Commence spraying from a low infestation area and progress towards the 'hot spot' or towards a greenhouse wall to avoid dispersing the pest.
- Preserve natural enemies of plant pests by using selective products when possible. Refer to Appendix 4 for side effects of chemicals on beneficial organisms.
- Report poor control of an insecticide to a crop protection advisor.
- Do not use the same spray on successive generations of the pest.
- Rotate active ingredients with different Mode of Action Classifications.
- Ensure that the relevant MRL is not exceeded at time of harvest (Table 2).

Many insecticides act on the nervous system of the pest but do not necessarily target the same site within the nervous system. Thus there are different groups affecting the nervous system, some inhibiting metabolic processes, others are feeding blockers or inhibitors of cuticle synthesis. For more detailed information refer to IRAC website: www.irac-online.org.

Active ingredients reported to give control of this pest both locally and in other countries include the following chemicals:

Table 2: Spray Options Information Summary

Group	Active Ingredient	Chemical Trade Name	Mode of Action	NZ Registration (MRL) *	Pre-harvest Interval
1A	Methomyl	Lannate L	Contact and Ingestion	Tom (0.3 mg/kg) Cap (0.3 mg/kg)	Tom – 2 days Caps – 2 days
1A	Oxamyl	Vydate L	Contact Ingestion Plant systemic	Not Registered (0.1 mg/kg)	Unknown
1A	Pirimicarb	Pirimax 500 Pirimor 50 Pirimisect Prohive ™	Contact Fumigant Trans laminar	Tom (1.0 mg/kg) Cap (1.0 mg/kg)	Tom – 3 days Caps - unknown
1B	Diazinon	Dew 500 Diazinon 800/W Diazonyl 60 EC	Contact Ingestion Respiratory	Tom (0.5 mg/kg) Cap (0.5 mg/kg)	Tom – 3 days Caps – 14 days
1B	Dichlorvos	Dichlorvos	Contact Ingestion Fumigant	Tom (2.0 mg/kg) Cap (2.0 mg/kg)	Tom – 3 days Caps – 3 days
1B	Malathion	Maldison	Contact Ingestion	Tom (8.0 mg/kg) Cap (8.0 mg/kg)	Tom – 3 days Caps – 3 days
1B	Methamidophos	Metafort 60 SL Monitor Tamaron	Contact Ingestion Plant systemic	Tom (0.1 mg/kg) Cap (0.2 mg/kg)	Tom – 3 days Caps - unknown
1B	Pirimiphos methyl	Actellic SG	Contact Ingestion Fumigant	Tom (1.0 mg/kg) Cap (1.0 mg/kg)	Tom – 3 days Caps – 3 days
3A	Alpha-cypermethrin	Bestseller 100EC Cypher Dominex 100 Fastac	Contact Ingestion	Tom (0.1 mg/kg)	Tom – 3 days
3A	Deltamethrin	Ballistic Decis Forte Deltaphar 25 EC Cislin Insectigone	Contact Ingestion	Tom – outdoor (0.05 mg/kg)	Tom – 3 days

Group	Active Ingredient	Chemical Trade Name	Mode of Action	NZ Registration (MRL) *	Pre-harvest Interval
3A	Lambda-cyalothrin	Karate-Zeon	Contact Ingestion	Tom – outdoor (0.1 mg/kg)	Tom – 3 days Caps - unknown
3A	Taufluvalinate	Mavrik	Contact Ingestion	Tom – outdoor (0.2 mg/kg)	Tom – 3 days Caps - unknown
4A	Imidacloripid	Confidor	Contact Ingestion Plant systemic	Not registered (0.1 mg/kg)	Tom – unknown Caps - unknown
4A	Thiacloprid	Calypso	Contact Ingestion Plant systemic	Not registered (0.1 mg/kg)	Tom – unknown Caps - unknown
4A	Thiamethoxam	Actara, Cruiser	Contact Ingestion Plant systemic	Not registered (0.1 mg/kg)	Tom – unknown Caps - unknown
5	Spinetoram		Contact Ingestion	Not registered (0.1mg/kg)	Tom – unknown Caps - unknown
5	Spinosad	Success Naturalyte	Contact Ingestion	Tom - Outdoor (0.01mg/kg) Cap – not registered (0.1 mg/kg)	Tom – 3 days Caps - unknown
6A	Abamectin	Abamax Apostle Avid Verdex	Contact Ingestion	Tom (0.1 mg/kg)	Tom – 3 days Caps - unknown
9A	Pymetrozine	Chess WG	Feeding inhibitor	Tom (0.5 mg/kg)	Tom – 3 days
15	Novaluron	Rimon	Chitin Inhibitor	Not registered (0.1 mg/kg)	Tom – unknown Caps - unknown
17A	Buprofezin	Mortar Ovation 50WDG Pilan	Insect growth regulator	Tom (0.5 mg/kg) Cap (0.5 mg/kg)	Tom – 3 days Caps – 3 days
21A	Fenpyroximate	Fenamite	Contact	Not registered	Tom – unknown Caps - unknown
23	Spiromesifen	Oberon	Inhibits development and fecundity. Ovicidal	Tom (0.5 mg/kg) Cap (1.0 mg/kg)	Tom – 1 day Caps – 1 day
23	Spirotetramat	Movento	Inhibition of lipid production	Not registered (0.1 mg/kg)	Tom – unknown Caps - unknown
28	Chlorantranilipro le	Coragen	Nerve & muscle action	Not registered (0.1 mg/kg)	Tom – unknown Caps - unknown

* Maximum Permitted Residue Level in Food– "NZ Food Standards 2008"

Some of these active ingredients are also effective when applied as a drench. The side effects on beneficial organisms can be reduced when systemic active ingredients are applied in this manner. Consult your insecticide supplier for details.

Extracts from the neem tree contain many chemicals with insecticidal properties. The most commonly researched extract is azadirachtin which is reported to have useful activity against the tomato/potato psyllid. The mode of action on psyllids is unknown but researchers have reported disruption of feeding and growth along with prevention of settling and egg laying. Neem extracts and other botanical products could play a useful role in repelling or deterring the pest from using the plant as a host.

Further spray options that are compatible with biological control agents and pollinators are soaps, oils and naturally occurring fungi, the latter being pathogenic to many insects. Soaps and oils can sometimes be used with selected agrichemicals to gives dual modes of action when spraying. Plant damage can result from such mixtures so small scale trials should be carried out first.

Two of the most commonly used insect pathogens are *Beauveria bassiana* and *Verticillium lecanii*. Under favourable conditions these fungi can give good control of psyllid nymphs but environmental conditions may limit the useful life of these organisms.

The tomato/potato psyllid has numerous natural enemies in New Zealand in the form of predators, parasites and pathogenic fungi. Long term control of this pest will be best accomplished by utilising as many deterrent options as possible and supported by chemical use when required.

3.6 Advice on effective application of insecticides

Whenever insecticides are applied attention to equipment set up is crucial to achieving good control. For targeting both sides of the leaf surface a boom spray with fan nozzles (03F80) 30cm apart, 45 deg upward from horizontal at a pressure setting of 2.5 – 3.0 bar and ground speed of one metre per second is efficient. For targeting underside of leaves only, a cone nozzle angled under the leaf may be more appropriate. Use spray sensitive paper placed in target ones to confirm adequate insecticide coverage.

3.7 Insecticide application records

Record all details of spray applications in a spray diary. This includes the operator's name, dilution rates of active ingredients and additives, total volume, spray speed, pressure, temperature and climate data (Refer Appendix 5). Obtain comments from the crop scout after spraying, on efficacy of each spray and be guided by past results when deciding on conditions for a repeat spray if required.

3.8 Best practice where vectors are involved

- Work with neighbours to achieve low tomato/potato psyllid numbers in the greenhouse vicinity.

- Control pest psyllids in the crop to low levels using IPM best practice.

- Aggressive management of infected plants reduces the risk of disease spread within the crop. Rouge out infected plants, place in plastic bags and bury or burn them promptly.

4. Summary of recommendations for minimising psyllid and other insect levels in crops

- Ensure all staff and visitors are instructed in compulsory growing-site hygiene practices.
- Plant good quality pest-free seedlings.
- Use pest resistant cultivars where possible.
- Ensure growing best practice in plant care, irrigation, plant nutrition and environmental control.
- Use biological control options for pest and disease management whenever possible.
- Choose spray options that have a non toxic physical mode of action where available.
- Ensure as many staff as possible can recognise key pests and diseases so that prompt remedial actions can be taken to minimise impact on yield and quality.
- Maintain robust crop scouting procedures with strict routines and evaluation of records.
- Take pest control actions in accordance with pest monitoring records and recommended thresholds
- Choose agrichemicals with care targeting least side effects on beneficial insects including bumblebees and adequate rotation of classes of mode of action to prevent insecticide resistance. Ensure with holding periods can be realised before the next harvest day. Keep records of all treatments.
- Check the selection of spray equipment is appropriate, settings, calibration and active ingredient dilution rate. Ensure good target coverage is achieved during each spray session. Moisture sensitive paper can be used to confirm coverage.

Appendix 1: Life cycle and pest ID

The potato/tomato psyllid, *Bactericera cockerelli* (Homoptera: Psyllidae) is a hemipteran insect measuring 2-3 millimetres (mm) with piercing-sucking mouthparts that enables this pest to feed on the phloem of its host plants. It undergoes incomplete metamorphosis: egg, nymph and adult.

Eggs are oval, small and attached to the leaves by a short stalk which would require magnification for identification but quite noticeable when on the leaf edges. Eggs are yellow when first laid and turn orange prior to eclosion or emergence to the first nymphal stage. Eggs are hatched between 4 to 5 days after being laid.

The nymph passes five scale-like nymphal stages requiring between 12-21 days. The nymph looks much like a scale insect or a large whitefly scale and grows to 2 mm. It is flat and has a fringe of spines around the edges. With in this stage, it changes from light yellow to tan then to greenish brown. However, wing buds appear at the 3rd nymphal stage and becomes very apparent at the 4th and 5th stages. The wing buds of the psyllid nymph distinguish it from the whitefly nymph.

Adult psyllids are winged and resemble tiny cicadas. They are yellowish or greenish as they emerge and turn dark green or brown as they mature with white stripes on the thorax and head after 5 days. The psyllids are seen in aggregates feeding and mating on the leaves of host plants and mate more than once. After mating, female psyllids lay eggs on any part of the leaves. A single female is capable of laying up to 510 eggs in its lifetime.

Psyllid total development occurs between 15.5^{o}C and 32.2^{o}C with optimum development occurring at 26.6^{o}C. In a greenhouse environment averaging at 18^{o}C, psyllid takes 33 days to complete its life cycle.

Sources of additional information:

http://www.biosecurity.govt.nz/pests-diseases/plants/potato-tomato-psyllid/photos.htm

http://www.biosecurity.govt.nz/pests-diseases/plants/potato-tomato-psyllid.htm

http://www.tomatoesnz.co.nz/research_reports_public.htm

http://www.freshvegetables.co.nz/research/reports_public.html

Appendix 2. Host plants for the tomato/potato psyllid

Adult potato/tomato psyllids can be found on many plants, especially in summer when they are migrating. Although they may be able to feed on a wide range of plants they can only reproduce only on some members of the Solanaceae and Convolvulaceae families.

In addition to the host plants listed in the table, the psyllid probably breeds on Chilli. Overseas it has been found breeding on field bindweed (*Convulvulus arvensis*) and morning glory (*Ipomoea purpurea*) (Convulvulaceae) and tobacco and black nightshade (*Solanum nigrum*) (Solanaceae). However, overseas information must be confirmed locally. For example we have found that black nightshade (sometimes called deadly nightshade) in not a breeding host plant in New Zealand. Adults may lay eggs on the plant, but all nymphs die.

Table: Plants on which potato/tomato psyllid can breed in New Zealand. Plants that support large populations of the psyllid are indicated with an asterisk.

Family Name	***Crop/weed***	***Common name***	***Scientific name***
Convulvulaceae	Crop	Kumara	*Ipomoea batatas*
Solanaceae	Crop	Capsicum*	*Capsicum annuum*
	Crop	Egg plant*	*Solanum melongena*
	Weed	Poroporo	*Solanum aviculare* and probably *S. laciniatum*
	Crop	Potato*	*Solanum tuberosum*
	Crop	Tamarillo	*Solanum betaceum*
	Crop	Tomatoes*	*Solanum lycopersicum*
	Weed	Thorn apple	*Datura stramonium*
	Weed	Apple of Peru	*Nicandra physalodes*

Appendix 3. Monthly tomato/potato psyllid / Liberibacter Record Summary sheet

Date	
Greenhouse/unit	
Size	
Crop	
Cultivar	
Number of plants	
Planted	
Pull out	
Export/no export	

Weed host survey		
	Found	Action
Apple of Peru		
Thorn apple		
Bindweed		
Nightshade*		
Other host		

Presence of alternative crop host in locality			
Crop	Stage	Location	Strategy
Potatoes			
Tomatoes			
Capsicums			
Tamarillo			
other			

Yellow sticky traps			
Outside	Total 1-4	Inside	Total 1-4
	psyllids		
Week 1		Week 1	
Week 2		Week 2	
Week 3		Week 3	
Week 4		Week 4	

Plant monitoring for psyllids								
	Number sampled	% plants infested	Total score	Mean score per Plant sampled	Response		Spray action	
					No action	Leaf cull	Spot	House
Week 1								
Week 2								
Week 3								
Week 4								

Plant monitoring for Liberibacter			
	Number plants showing symptoms	Response	
		Plants removed	Other
Week 1			
Week 2			
Week 3			
Week 4			

Full house insecticide applications							
	Applied for psyllids	Applied for other pests	Product	Active ingredient	Concentration	Water rate	Application method
Week 1							
Week 2							
Week 3							
Week 4							

Appendix 4. Toxicity of selected Chemicals to Natural Enemies

Insecticide active ingredient	Bumble Bees (2)		Predatory Mites (1)						Parasitoids (1)			
			Amblyseius cucumeris		*Phytoseiulus persimillis*		*Hypoaspis miles*		*Aphidius* spp.		*Encarsia formosa*	
	Tox	Per	Tox	Per	Tox	Per	Tox	Per	Tox	Per	Tox	Per
Abamectin	B	72 h	2	5d	4	1w	2	5d	4	1w	3	5d
Acetamiprid	B	24 h	3	5d	3	1w	4	1w	3	-	4	2w
Alphacypermethrin	C	-	4	>8W	4	>8w	3	-	4	-	4	>8w
Buprofezin	A	-	1	-	2	-	1	-	1	1w	1	-
Chlorantraniliprole	-	-	-	-	-	-	-	-	-	-	-	-
Deltamethrin	B	72h	4	>8w	4	>8w	4	>8w	4	>8w	4	>8w
Diazinon	C	-	4	3w	4	1w	2	-	4	-	4	4-6w
Dichlorvos	B	36h	4	3d	4	1w	4	-	4	-	4	1w
Dinotefuran	-	-	-	-	-	-	-	-	-	-	-	-
Fenpyroximate	B	36h	4	-	4	>8w	3	>8w	3	-	1	-
Flonicamid	A	-	1	-	1	-	1	-	1	-	1	-
Imidacloripid	C	-	4	-	3	-	4	-	4	-	4	-
Lamba-cyalothrin	C	-	4	>8w	4	>8w	4	>8w	4	>8w	4	>8w
Malathion	C	-	4	>8w	2	1w	1	-	4	>8w	4	>8w
Maldison	-	-	-	-	-	-	-	-	-	-	-	-
Methamidophos	C	-	4	-	4	6w	4	-	4	>4w	4	>4w
Methomyl	B	72h	4	-	4	1w	4	-	4	-	4	-
Oxamyl	C	-	4	8w	4	>8w	3	-	4	>8w	4	>8w
Novalorun	B	72h	2	-	1	-	2	-	-	-	-	-
Permethrin	C	-	4	>8w	4	>8w	4	>8W	4	>8w	4	>8W
Pirimicarb	B	24h	3	3d	2	3d	1	-	1	-	2	3d
Pirimiphos-methyl	C	-	3	3d	2	3d	1	-	1	-	2	3d
Pymetrozine	A	-	1	-	2	-	2	-	2	-	1	-
Pyriproxifen	A	-	1	-	2	-	1	-	1	-	1	-
Spinetoram	-	-	-	-	-	-	-	-	-	-	-	-
Spinosad	B	24h	1	-	1	-	1	-	3	-	3	1w
Spiromesifen	A	-	2	-	3	-	1	-	-	-	-	-
Spirotetramat	-	-	-	-	-	-	-	-	-	-	-	-
Taufluvinate	B	72h	4	-	4	-	4	-	4	-	4	-
Thiacloprid	B	24h	-	-	3	2w	3	-	3	-	3	-
Thiamethoxam	C	-	-	-	4	>2w	2	-	4	-	-	-

Note 1: The side effects of insecticides are classified into four categories according to IOBC/WPRS classification:

Class	Toxicity	Percentage death or reduction of parasitism capacity
1	Non-toxic	<25 death
2	Slightly toxic	25-50% death
3	Moderately toxic	50-75 death
4	Toxic	> 75% death

Pesticides residual effects:
For beneficial organisms, the residual period or persistence (Per) is given in days (d), weeks (w), or Hours (h). A hyphen (-) signifies that the information is not available. "More than" (>) signifies that the indicated residual period is a strict minimum.

Note 2: The side effects on bumblebees (*Bombus spp*.) are described in 3 classes:

Class	Advice
A	Can be used in combination with bumblebees
B	Remove the bumblebees hive before product application and until after the indicated persistence period
C	Do not use in combination with bumblebees

Bumblebee hives must be removed from the greenhouse before the application and not returned until after the indicated persistence period for class B. Hives can be removed for a maximum period of 72 hours before tomato pollination is affected.

Sources of additional information:

www.iobc.ch/2005/IOBC_Pesticide Database_Toolbox.pdf
www.koppert.nl/e0110.html
www.biobest.be
www.goodbugs.org.au

Appendix 5: Spray Record

SPRAY RECORD													
Block ID____							Crop Variety____________________________						
Date	Time Start	Time Stop	Operator Name	Chemical plus other Additives	Dilution rate liters/100L or grams/100L	Spray Rate (L/ha)	Nozzle Selection & set up	Spraying Speed (m/sec)	Spray Pressure (kPa)	Air Temp (°C)	Air Humidity (%RH)	Solar Radiation (J/cm²)	Effect on Pest