Psyllid News
Tomato & Capsicum edition

February 2013

Welcome

Welcome to the Tomato & Capsicum edition of Psyllid News. This issue contains a wealth of psyllid related information generated from the 3 year SFF funded Sustainable Psyllid Management research programme.

This publication summarises some of the research highlights of interest to the tomato & capsicum industry, as well as providing a review recent research published on psyllid both in New Zealand and overseas.

In this issue

Highlights of the Psyllid research programme

The 3 year Sustainable Farming Fund research programme (SFF 09/143: Sustainable Psyllid Management) was completed in June 2012. Research highlights included:

- BotaniGard ® ES and Met52®EC entomopathogen treatments were found to be suited to greenhouse use and should be considered for inclusion in future IPM programmes.
- Soft chemicals (e.g. mineral oils, horticultural soaps & oils, plant extracts) were not found to be sufficiently effective for TPP control under greenhouse conditions.
- Host range testing of the psyllid biocontrol agent *Tamarixia triozae* predicts that some non-target parasitism of NZ psyllid species may occur. Climate modelling has demonstrated that *T. triozae* will survive in NZ's growing regions. Industry will now have to decide whether to proceed with an application to import and release this BCA.
- Psyllid control studies (on potted capsicum) in NZ indicated that abamectin (Group 6), bifenthrin (3A) were effective at reducing TPP (>80%) up to 3 days after treatment. Abamectin, bifenthrin, spiromesifin (23) and spirotetramat (23) gave effective control of TPP nymphs over a 6 week period.
- Highlights of international psyllid research in 2011/12:
  - A single adult psyllid is capable of transmitting Liberibacter (to potato) over a 6hr feeding period.
  - Liberibacter disease symptom development is retarded at temperatures below 17°C and above 32°C. Cool temperatures (15-21°C) slow psyllid reproduction (on potatoes).

A full summary of the research from this SFF programme can be found on the Tomatoes New Zealand website. The research having most relevance to the Greenhouse industry, specifically testing of Entomopathogens; *Tamarixia* host range testing to establish potential as a biological control agent; and evaluation of soft chemicals for psyllid control is summarised in the next few pages.

Use of Entomopathogens for control of TPP

Entomopathogens are microorganisms that infect and kill insect hosts. Entomopathogens could provide feasible integrated pest management options for control of tomato potato psyllid (TPP), particularly under greenhouse conditions.

Research to investigate the efficacy of entomopathogens for psyllid control was conducted by Plant & Food Research Ltd under the Sustainable Farming Fund research programme; SFF 09-143 Sustainable Psyllid Management. This research indicated that entomopathogens show some promise for controlling TPP. The outcomes of this research are summarised in the following report.

Bioassay screening:

To select suitable entomopathogen candidates for larger scale greenhouse trials, an initial series of laboratory and greenhouse bioassays were conducted. Six entomopathogen products, four fungal isolates (Table 1), a microbial standard (eNtocide L™), a conventional standard Oberon®, and a water control were applied to adult TPP using an immersion assay and to TPP nymphs using a detached leaf bioassay.

The bioassays showed that TPP adults and nymphs were susceptible to a number of entomopathogens. Under laboratory conditions (25°C ± 1.1°C), BotaniGard® ES andMet52® EC outperformed the conventional insecticide standard, Oberon®, and all other entomopathogens screened.

BotaniGard® ES, BotaniGard® 22WP, Mycotrol® O and Met52® EC, and the three *Lecanicillium* isolates resulted in adult TPP mortality above 90% within 72 h of application.

BotaniGard® ES, BotaniGard® 22WP and Met52® EC, and the *Lecanicillium* isolates gave greater than 55% nymph mortality five days after application. Younger nymphs succumbed more quickly to the treatments than older nymphs. *Isaria* -based products and isolates were less successful at killing both adult and nymph TPP, with the application of NoFly™ WP, PreFeRal® 20WG and isolate F129 resulting in less than 90% mortality of adults and less than 60% mortality of nymphs.

BotaniGard® ES and Met52® EC were selected as the best potential candidates for subsequent greenhouse trials based on overall efficacy and obtaining a rapid solution for industry.

Table 1: Commercial entomopathogen products (yellow rows) and fungal isolates (blue rows) evaluated against TPP.

Product/ Isolate	Active Ingredient	Manufacturer/Supplier	Country
BotaniGard® ES	*Beauveria bassiana* (GHA strain)	BioWorks Inc.	USA
BotaniGard® 22WP	*Beauveria bassiana* (GHA strain)	BioWorks Inc.	USA
Mycotrol® O	*Beauveria bassiana* (GHA strain)	BioWorks Inc.	USA
NoFly™ WP	*Isaria fumosorosea* (FE 9901 strain)	Natural Industries, Inc.	USA
PreFeRal® 20WG	*Isaria fumosorosea* (Apopka 97 strain)	BioBest	Belgium
Met52® EC	*Metarhizium anisopliae* (F52 strain)	Novozymes Biologicals Australia Pty, Ltd	Australia
Isolate F421	*Lecanicillium muscarium*	AgResearch	New Zealand
Isolate F425	*Lecanicillium muscarium*	AgResearch	New Zealand
Isolate F426	*Lecanicillium muscarium*	AgResearch	New Zealand
Isolate F129	*Isaria fumosorosea*	AgResearch	New Zealand

Use of Entomopathogens for control of TPP

Impact of environmental conditions on fungal isolate growth and germination:
Conditions such as temperature and light can influence the germination, growth, therefore the pathogenicity of fungal entomopathogens. All isolates (*Lecanicillium* and *Isaria*) had high rates of germination at 20°C and 25°C, and showed consistent growth at 15°C, 20°C and 25°C. In contrast, all isolates had either limited or no germination or growth at 30°C or within the greenhouse (Figure 2). Light had no effect on germination. These results are consistent with most fungal entomopathogens in New Zealand.

Caged greenhouse trials:
Candidate treatments identified from the adult and nymph bioassays (BotaniGard® ES and Met52® EC) were used for greenhouse trials on capsicum and tomato plants. All trials received 2 applications 1 week apart and were compared against a water control.

Capsicum trials: TPP mortality was significantly greater with BotaniGard® ES (overall reduction of 88%) than with Met52® EC (66%) or Oberon® (49%) ($P < 0.0001$). BotaniGard® ES resulted in the greatest reduction in adults (75%).

Tomato trials: TPP mortality was greatest with BotaniGard® ES (overall reduction of 83%), followed by eNtocide L™ (63%), Oberon® (40%) and Met52® EC (33%), ($P \leq 0.0001$).

Environmental stability of entomopathogens:
Temperature and humidity can significantly affect germination, infection, and survival of entomopathogens. Variable differences in mortality between entomopathogenic treatments at different times of the year in the greenhouse were evident.

The mortality of TPP when treated with BotaniGard® ES and Met52® EC was 88% and 66%, respectively, in March to April (average temperature 19.4°C and relative humidity 80%), and 82% and 33% respectively, in April to March (average temperature 14.3°C and RH 83%). The performance of BotaniGard® ES was not influenced by changing environmental conditions unlike Met52® EC.

Summary

Fungal entomopathogens have demonstrated efficacy against TPP and should be considered for inclusion in future IPM programs.

The results presented provide an indication of product and isolate efficacy under specific environmental greenhouse conditions. Both BotaniGard® ES and Met52® EC are suited to greenhouse temperatures, but the activity of these will be dependent on the amount of time environmental conditions are optimal, that is 23 –25°C and 25–30°C, respectively.

Timing spray applications to correspond to periods in the growing season when higher

Figure 1. Mycosed adult and nymph tomato potato psyllid following application of entomopathogen products and isolates. (Source: Plant & Food Research Ltd.)

Use of Entomopathogens for control of TPP

greenhouse temperatures are maintained is likely to maximise the effectiveness of these entomopathogens.

In greenhouse environments where environmental conditions are not controlled, the use of these entomopathogens would be best suited to early spring, early and late summer and autumn.

Future directions

Candidate entomopathogens require testing under a broader range of environmental conditions on targeted crops throughout a growing season. Such work could be performed within a controlled environment facility, with results validated within commercial greenhouses.

The effects of candidate entomopathogens on non-target organisms, such as predators and parasitoids of TPP, should also be examined prior to the inclusion within an IPM programme.

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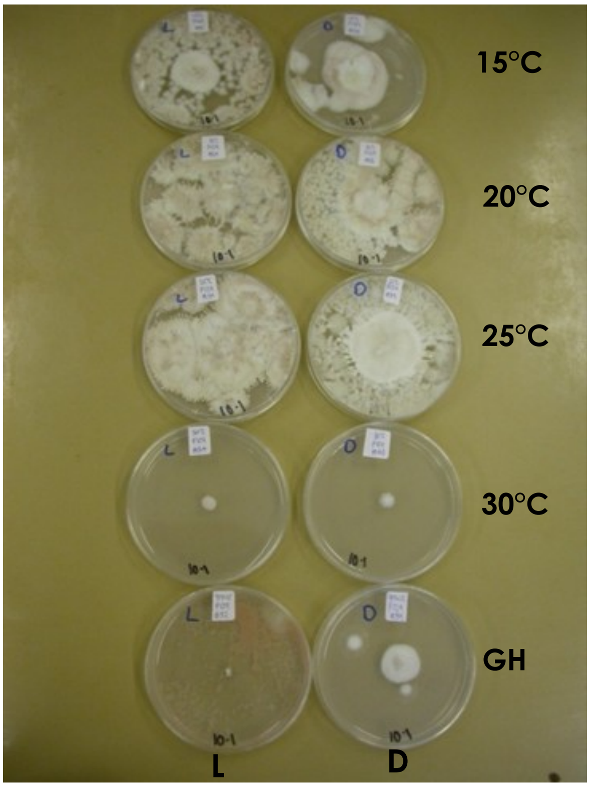

Figure 2. The growth of *Isaria fumosorosea* (isolate F129) under different temperature and light regimes. Temperatures include 15°C, 20°C, 25°C, 30°C and held under variable conditions within a greenhouse (GH) (average temperature 20.3°C, with 24% of the time above 25°C . L = light, D = dark.

Evaluation of soft chemicals for psyllid control in the greenhouse industry

A series of research trials were conducted by Plant and Food Research Ltd. to investigate the efficacy of soft chemicals against TPP for the greenhouse industry. This research formed one of the milestone research objectives under the Sustainable Farming Fund research programme; SFF 09-143 Sustainable Psyllid Management.

Under this milestone the efficacy of essential oils as repellents, and soft chemicals as possible control options for TPP were investigated. The outcomes of this research were presented in 2 research reports:

Walker MK, Butler RC, Berry NA 2010. Evaluation of selected soft chemicals as potential control options for tomato/potato psyllid. A Plant & Food Research report prepared for Horticulture New Zealand. SPTS No. 3937. 12p.

Walker MK, Butler RC, Berry NA 2011. Evaluation of selected essential oils as potential repellants for tomato/potato psyllid control. A Plant & Food Research report prepared for Horticulture New Zealand. SPTS No. 5617. 19p.

Preliminary results obtained from these studies indicated that some essential oils retain repellency effects after 48 hours, while soft chemicals were less effective at providing psyllid nymph control. Applications of 4 soft chemicals; Eco-oil, PS2, Excel Oil and Agri-50NF resulted in low mortality rates of TPP nymphs (up to 58% mortality for Eco-oil after 168 hours).

A review of this Soft Chemical research by the greenhouse industry in October 2011 identified that a continuation of the soft chemical research would be of little commercial benefit. Consequently this line of research was terminated and resources re-allocated to support the Entomopathogen research programme.

Host Range Testing of BCA (*Tamarixia triozae*)

In 2009 a North American parasitoid, *Tamarixia triozae*, was imported by Plant and Food Research Ltd. into quarantine facilities for assessment as a biological control agent. Prior to this, searches conducted between 2006 and 2008 had failed to identify any natural enemies within New Zealand that were likely to control TPP on tomatoes.

Research to investigate possible non-target impacts of *T. triozae* on New Zealand psyllid species was conducted by Plant and Food Research Ltd. under the Sustainable Farming Fund research programme; SFF 09-143 Sustainable Psyllid Management.

In New Zealand the importation and release of new organisms (including biological control agents) is regulated by the Hazardous Substances and New Organisms (HSNO) act (1998), administered by the Environmental Protection Authority (EPA). The EPA is required to consider the effects that the release of a new organism is likely to have on native species (and on valued introduced species). Given this regulatory framework, assessment of potential non-target impacts is an important part of any application for release of a new organism in New Zealand.

In this study *T. triozae* was exposed to a range of psyllid species that occur in New Zealand to determine what, if any, non-target impacts *T. triozae* are likely to have if released into the New Zealand environment.

Host range testing:

Host-range testing was carried out to evaluate the potential for *T. triozae* to impact negatively on non-target psyllid species in New Zealand (Table 1). Eight psyllid species were tested, including an exotic psyllid BCA agent, the Broom psyllid (*Arytainilla spartiophila*). A range of tests were undertaken to determine if parasitism and subsequent development was likely.

Tamarixia triozae did not oviposit on six of the eight non-target psyllid species it was exposed to in no-choice screening tests (Table 1).

Tamarixia triozae did oviposit on two native psyllid species, *Trioza curta* and *Trioza panacis* (Table 1). However the oviposition rate on both was lower than the oviposition rate on the target pest TPP. In addition, no *T. triozae* adults emerged from parasitized *T. curta*, suggesting that *T. triozae* would not be able to maintain itself over time in situations where *T. curta* was the only host available.

Tamarixia triozae did emerge from parasitized *T. panacis* nymphs but the first generation female

Host Range Testing of BCA (*Tamarixia triozae*)

parasitoids from *T. panacis* had reduced ability to produce further offspring compared with parasitoids that emerged from their usual host (TPP).

Testing indicates that *T. triozae* may attempt to use novel species as hosts, and that *T. triozae* is capable of developing in at least one of these novel species.

Future directions

Test results indicate that some non-target parasitism is likely if *T. triozae* encounters novel psyllids in its new environment, so it is important to have a better understanding of the potential distribution of *T. triozae* in New Zealand. Therefore the ability of *T. triozae* to survive in the New Zealand environment has now been assessed through climate modelling. This research is funded by SFF and industry co-funding (Potatoes NZ, Tamarillos NZ, Heinz-Watties).

Climate modelling predicts that *Tamarixia* will survive and establish in regions of NZ where tomatoes, tamarillos and potatoes are grown. Areas of the east coast of the South Island and the east coast of the North Island (particularly the Hawke's Bay) and areas around Auckland, Waikato, and the Manawatu/Wanganui. Now that this distribution and host range testing has been conducted the industry needs to determine whether to proceed with a release application. This is a process that will evaluate whether *T. triozae* will "significantly displace native species" and whether such a release can be approved.

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Table 1: Host range testing of *T. triozae* against New Zealand psyllids

Family	Species to test	Parasitoids lay eggs in no-choice test?	Parasitoids lay eggs in choice tests?	Parasitoids emerge from eggs?	Emerged parasitoids lay eggs?	Parasitoids lay eggs in large-scale choice tests?
Triozidae	*Trioza panacis*	Yes	Yes	Yes	Yes	Yes
	Trioza vitreoradiata	No	-	-	-	-
	Trioza curta	Yes	Yes	No	-	-
	Trioza "Ohumata"	No	-	-	-	-
Psyllidae	*Ctenarytaina clavata*	No	-	-	-	-
	Acizzia dodonaeae	No	-	-	-	-
	Psylla apicalis	No	-	-	-	-
	*Arytainilla spartiophila** (Broom psyllid)	No	-	-	-	-
TOTAL		**6/8**	**2/8**	**1/8**	**1/8**	**1/8**

*Exotic species imported as a BCA

International Research

Psyllid International Literature Review (June 2011 – August 2012)

One of the outputs of the Sustainable Farming Fund psyllid research programme is an annual scan of the scientific literature which has been published on the tomato potato psyllid and Liberibacter. This review summarises the psyllid research highlights published from New Zealand and around the world. Much of the research is focused on potatoes, but information such as psyllid behaviour and distribution, and psyllid control is of relevance to the Greenhouse industry.

If you would like more information on any of the research, please refer to the list of references at the end of this review. Your local library should be able to arrange an interloan of the scientific journal.

Reports of Liberibacter around the world:
'*Candidatus* Liberibacter solanacearum' has been reported from a number of countries and crops over the period from June 2011 to August 2012.

- Naturally infecting greenhouse tomato plants in Mexico (Ling et al., 2011).
- Commercial fields of carrots in southeastern Norway and in southern Sweden, in association with the carrot psyllid (*Trioza apicalis*) (Munyaneza et al., 2012b, Munyaneza et al., 2012c).
- Zebra chip disease of potatoes was observed for the first time in the states of Idaho, Oregon, and Washington State (Crosslin et al., 2012a; Crosslin et al., 2012b).
- Spain has recently confirmed the detection of '*Ca* L. solanacearum' on carrot crops (Alfaro-Fernandez et al., 2012a).
- Liberibacter was reported in association with *Bactericera trigonica* in the Canary Islands (Alfaro-Fernandez et al., 2012b)

Review articles:
Two excellent review articles were published by US researchers in 2012. The first, by Casey Butler and John Trumble provides an update on the life history, relationship to plant diseases, and management strategies against TPP (Butler & Trumble, 2012).

The second review, recently published by Joe Munyaneza (Munyaneza, 2012), provides a comprehensive discussion of the causative agent of ZC disease, '*Ca*. Liberibacter solanacearum', the geographic distribution, hosts, and biology of TPP (*B. cockerelli*) is also described. In this review, Munyaneza has noted that the recent expansion of ZC into the Pacific Northwest was a major threat to a significant portion of the potato production area in the USA. Approaches for psyllid and Liberibacter management are also reviewed including chemical, biological, and cultural controls.

Psyllid control studies:
Some research highlights include:
- Electrical penetration graph (EPG) methods were used by Butler et al. (2012) to investigate the effects of imidacloprid (IRAC group 4a – neonicitinoid) on the feeding behaviour of adult TPP. This study demonstrated that imidacloprid can significantly decrease salivation and ingestion from the phloem, and hence reduce the likelihood of Liberibacter transmission.
- In a New Zealand study, the efficacy of 11 insecticides from several resistance groups was tested against adult and nymph stages of TPP in a series of potted capsicum plant trials (Page-Weir & Jamieson, 2011).
    - ◊ Residues of abamectin (group 6) + oil, and bifenthrin (group 3A) were most effective at reducing TPP (>80%) up to 3 days after treatment.
    - ◊ Thiacloprid and imidacloprid (group 4A), spiromesifen (group 23), spinetoram (group 5), and azadirachtin (botanical) exhibited slight toxicity.
    - ◊ Residues of buprofezin (group 16); pyrethrin (3A), and mineral oil had no effect on adult mortality.
    - ◊ Abamectin, bifenthrin, spiromesifen, and sprirotetramat (group 23) gave effective control of TPP nymphs over a 6 week period.
- An on-line tool developed by Christian Nansen and co-authors (Nansen et al., 2011) predicts the effectiveness of insecticide spray applications under a series of

environmental conditions. This on-line tool (available at: http://pilcc.tamu.edu/) predicts % leaf coverage based on the variables of canopy, plant height, temperature, wind speed, and spray volume.

Psyllid behaviour and distribution:
Several studies were published over 2011/12 that investigated the occurrence, behaviour and distribution of TPP in crops:

- Studies of TPP distribution in potato has confirmed that psyllid life stages (eggs and nymphs) were not evenly distributed but instead were clustered and aggregated through a crop (Ramirez-Davila et al. 2012; Workneh et al. 2012).
- Aggregated distribution of psyllids is not just limited to potato crops, studies of TPP distribution on green tomato plants (Physalis ixocarpa) in Mexico (Crespo-Herrera et al., 2012) indicated that all life stages (nymphs and eggs) were aggregated in the crop.
- Butler and Trumble (2012) observed an aggregated distribution of psyllid in potato fields. Significantly more potato plants were infested with psyllid on the top and middle of the plant, and on the undersides of the leaves.
- It was also noted by researchers that Zebra Chip intensity in potato fields was significantly greater on the edges than in the infields. This has significant implications for psyllid management as greater emphasis on control should be directed toward the edges of plots (Henne et al., 2012; Workneh et al. 2012)

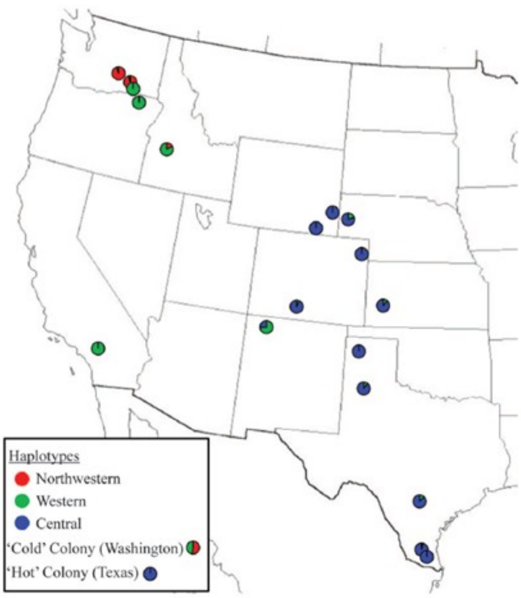

Figure 1: Geographical distribution of three psyllid haplotypes in the Central and Western United States. Individual pie charts depict the haplotypes identified by HRM analysis at each location throughout the Western and Central United States (*source*: Swisher et al. 2012).

Psyllid distribution through the USA:
Considerable variability was found in the abundance of psyllids across the US growing regions surveyed (Goolsby et al., 2012). The percentage of psyllids infected with Liberibacter was consistently highest in the Lower Rio Grande Valley (LRGV) of Texas, supporting indications of an overwintering reservoir of Liberibacter infected psyllids in this area.
Using a molecular genetic approach Swisher et al. (2012) showed that at least three psyllid haplotypes (haplotype = a group of heritable genes) correlating to geographical regions exist in the United States (Figure 1). These haplotype regions are:

- Western haplotype (New Mexico, California, Oregon, Washington, Idaho)
- Central haplotype (Texas, Kansas, Nebraska, Wyoming, Colorado, New Mexico)
- Northwestern haplotype (Washington, Idaho).

The question of whether these distinct psyllid populations are migrating or overwintering, particularly in the upper Northwestern area of the United States has yet to be determined. TPP tested from NZ have been of the Western haplotype.

Psyllid in New Zealand:
Graham Walker and colleagues from Plant & Food Research published the results of studies on psyllid numbers in Pukekohe (Walker et al., 2011). Monitoring has shown that TPP adult, egg and nymph numbers were absent or low until mid-December with numbers increasing rapidly in mid-January, with a peak in nymph numbers in early February. Studies by Plant & Food Research on alternative hosts has shown that there is a high abundance of TPP before December but the TPP is not on the crop. The most common predators were brown lacewing

(*Micromus tasmaniae*) and small hover fly (*Melanostoma fasciatum*). While these predators were abundant during spring and early summer, from mid-February predator populations declined while TPP populations remained at high levels. From this study it would appear that naturally occurring predators provide some control of TPP early in the season in Pukekohe, but were not able to control TPP populations in mid and late summer.

Trials in Pukekohe investigating psyllid damage to early potatoes in Pukekohe were reported by Walker et al. (2012). Using 4 treatments, (insecticide drench at planting; insecticide drench and weekly foliar sprays; insecticide drench and threshold foliar sprays; and no insecticides), researchers determined that based on the low level of ZC from all treatments, early insecticide applications were not required for 'early crop' potatoes at Pukekohe.

Liberibacter genetics:
Isolates of Liberibacter sourced from North America (USA and Mexico) and New Zealand were examined to better understand their genetic relationships and the possible origins of this pathogen. Glynn et al. (2012) detected two sequence types (ST-1 and ST-2). Both sequence types were found to be present among US isolates while only ST-1 was detected from Mexico and ST-2 from New Zealand sourced isolates. These results agree with other recent studies (Lin et al., 2012; Nelson et al., 2011) where two Liberibacter haplotypes were reported in the USA. The development of these markers will enable researchers to conduct wider epidemiological studies of Liberibacter disease.

Psyllid feeding and disease transmission:
- Psyllid adults are more efficient vectors of Liberibacter than nymphs (Buchman et al., 2011b).
- Exposure of a plant to 20 adult psyllids for as little as 1 hour resulted in ZC symptom development and a single adult psyllid was capable of transmitting Liberibacter to potato within a 6 hour access period.
- This represents a challenge to control the psyllid vector, as psyllid feeding for only a short period could result in substantial spread of the disease.

Disease symptom development:
Laboratory studies demonstrated that temperatures below 17°C appeared to retard the development of Liberibacter and ZC symptoms (Munyaneza et al. 2012a), while temperatures over 32°C were detrimental to Liberibacter and no ZC symptoms occurred. Workneh et al. (2011) have also reported that cool temperatures (15 to 21°C) slowed psyllid reproduction and the build-up of Liberibacter in potato tubers.

Psyllid fitness:
High levels of Liberibacter can negatively affect psyllid fitness (fitness = growth rate and longevity). Alvarado and colleagues (Alvarado et al. 2012) suggested that this might explain observed seasonal variations of ZC incidence in the field. For example, there may be high numbers of uninfected psyllids or those with low levels of Liberibacter, resulting in low ZC incidence in plants and tubers.

Research articles

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Arras, J.; Hunter, W.; Bextine, B. 2012. Comparative analysis of antennae sensory arrays in Asian citrus psyllid, *Diaphorina citri*, and potato psyllid, *Bactericera cockerelli* (Hemiptera). *Southwestern Entomologist*. 37, 1: 1-12. DOI: 10.3958/059.037.0101.

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Butler, C. D.; Trumble, J. T. 2012. The potato psyllid, *Bactericera cockerelli* (Sulc) (Hemiptera: Triozidae): life history, relationship to plant diseases, and management strategies. *Terrestrial Arthropod Reviews*. 5, 2: 87-111.

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Reports & Resources

A number of research reports have been produced by Plant & Food Research Ltd as outputs from the SFF funded Sustainable Psyllid Management research programme. For copies of these reports contact John Seymour (Vegetables New Zealand) or Helen Barnes (Tomatoes New Zealand).

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