Project Objectives

The overarching objective for this project was to develop sustainable management systems for Tomato Potato Psyllid (TPP) for the potato, tomato, capsicum and tamarillo industries. To achieve this, a series of research themes were identified to encompass all aspects of TPP including; monitoring TPP distribution throughout NZ, assessment of the impacts of TPP on the potato industry, insecticide trials to assist with the development of spray programmes, alternative control strategies such as biological control, soft chemical trials, and entomopathogens. Additionally, the development of diagnostic tools to detect Liberibacter (the bacterial pathogen vectored by TPP) to better understand the distribution of Liberibacter in plant tissue and in TPP was developed through this project.

These project objectives were developed into a series of research milestones:

- MS 1-3: Insecticide field trials
- MS 4: National psyllid monitoring
    - *Extension activity* (June 2010): TPP monitoring
- MS 5: Liberibacter diagnostics
- MS 6: Evaluation of soft chemicals
- MS 7: Biological control agent development
- MS 8: Entomopathogens for TPP control
- MS 9: Tamarillo insecticide trials and effects of antifeedants on TPP activity
- MS 10: Tamarillo monitoring for TPP
- MS 11: Annual literature scan of TPP research
- MS 12: Information transfer to industry
- MS 14: *Extension activity* - Assessment of economic impact of TPP

During the course of the project a review of the Soft Chemical milestone (Milestone 6) by the tomato and capsicum industry prior to the October 2011 project planning meeting identified that a continuation of the soft chemical research would be of little commercial benefit. As a result, the project team agreed to terminate the soft chemical research milestone and redirect the remaining budget to support the Entomopathogen research (Milestone 8).

Approach

At its outset, the project identified several areas of research to specifically address the concerns of the potato, tomato, capsicum and tamarillo industries around the future management of TPP in New Zealand. In formulating the project objectives and milestones each industry sector (potatoes, tomatoes capsicums and tamarillos) was widely consulted to ensure that industry priorities were captured in the final work-plan. The objectives were a mixture of cross- sector and sector-specific research. Although some objectives were targeted towards providing information for a specific sector the intention was that the information resulting from the work would be available for all groups.

The approach was to undertake work that would add to the understanding of TPP and Liberibacter biology, and develop a range of monitoring and control tools that could move the industries away from using non-selective synthetic pyrethroid or organophosphate insecticides towards more targeted agrichemical products, oils, and entomopathogenic fungi.

The main findings from this project

Milestones 1, 2 and 3 - Tomato-Potato Psyllid Insecticide Trials (2009–12): Milestones 1, 2 and 3 of this SFF project were to undertake 3 years of main crop insecticide trials at Pukekohe Research

Station to test different insecticides and action thresholds and their impact on TPP populations and damage to potato crops.

Three to five treatments were used: insecticide drench and weekly foliar sprays (i.e. 'standard' spray programme); insecticide drench and different threshold-based foliar sprays (i.e. reduced spray programmes); and no insecticides (i.e. control). Reduced spray programmes were based on nominal action thresholds utilising either the number of TPP nymphs per middle leaf or the mean number of TPP adults per yellow sticky trap. Thresholds based on infestations of TPP nymphs on plants led to a range of 5–8 applications of insecticides, approximately half the number applied in the weekly spray programme.

The incidence of Zebra Chip (ZC) damage in treatments triggered by nymph thresholds were unacceptable, ranging from 5 to 27% ZC. However, thresholds based on sticky trap catches led to a 50% reduction in sprays with <1% ZC when the 'standard' sequence of insecticides was applied. The sticky trap action threshold gave promising results that deserve further investigation to assess if this method may be used as an economic action threshold, being an economic injury level (EIL) 'trigger'. Also, the 'standard' sequence of blocks of Avid®, Movento® and Sparta® gave the best results of all the insecticide rotation strategies tested in these 'insecticide' trials.

Milestone 4 - Psyllid National Monitoring: The seasonal abundance and distribution of the TPP was assessed using weekly sticky trap monitoring in commercial potato, field tomato and tamarillo crops during the 2009-10, 2010–11 and 2011-12 growing seasons. At an additional two sites, weekly sticky trap and plant assessments were performed.

The most important findings and conclusions were:

- TPP numbers were highly variable between sites and regions. Generally, the North Island had higher TPP numbers than the South Island.
- In general, for both the North and South Islands, the abundance of TPP appeared to peak between early February and late March, with declining numbers towards mid-April. This means that early potatoes in the North Island may escape TPP/*Candidatus* Liberibacter solanacearum (Lso) damage and could be grown without chemical psyllid control.
- The monitoring (both sticky trap and plant assessment) was influenced by crop management and local climate.
- Greater TPP numbers were generally found on the edge of a crop rather than in the middle. This is a similar observation to that reported from TPP monitoring programmes in the USA.
- The sticky trap monitoring programme is most useful at the beginning of the cropping season, providing an indication of when TPP could be expected to arrive in the crop. Sticky trap monitoring should be accompanied by actual plant assessments throughout the growing season to give a true indication of pest infestation in the crop.
- Sticky traps recorded psyllids 1-4 weeks earlier than plant assessments did.

Further studies should include trapping and plant assessments in unsprayed crops and development of a less labour-intensive weather-based supervised control system for TPP. In addition, this study has shown that in many cases, the first one or two insecticide applications can be omitted, as they were applied too early in the season. Education of growers regarding this would increase profits and decrease TPP insecticide resistance.

***Milestone 4 Extension activity* (June 2010): TPP monitoring.**
Retrospective analysis of the Liberibacter status of psyllids collected during national monitoring of the 2009-2010 growing season demonstrated that Liberibacter was present at all sites at most monitoring periods. This result suggested that Liberibacter incidence is very high in the New Zealand psyllid populations. The results also suggested that there is no disease-free period when psyllids are present in a crop. Therefore the potential for infection with Liberibacter is very high whenever psyllids are present.

Milestone 5 - Improved Liberibacter Diagnostics: A DNA extraction protocol has been developed and successfully optimised for the detection of Liberibacter in psyllids and plant tissue. This method uses a single-step semi-nested SYBR Green qPCR targeting the Lso 16S rRNA gene. Ring testing against USA samples indicates that this methodology is more sensitive than the USA methodology.

A study was undertaken to characterise the distribution of '*Candidatus* Liberibacter solanacearum' (Lso) in infected potato plants over time. Results from this study showed that the distribution of Lso within plants was uneven, with spatial and temporal differences. Titre was also variable between plant tissues. These results lead to recommendations for field sampling of Lso in potato crops. First, samples should be collected from mid-point stem or stolon tissue, not foliar material or upper stems. Second, testing should be delayed until 2-3 weeks after recognised exposure to TPP. These guidelines are designed to avoid the generation of false-negative test results. PCR testing of TPP collected from crops may provide a more practical approach than testing plant material. TPP can be processed immediately after collection and testing TPP for Lso could provide information about the infective potential of the TPP population.

Milestone 6: Soft Chemicals in the Greenhouse Industry: The aim of this milestone was to evaluate the efficacy of soft chemicals (essential oils) for the control of TPP in the greenhouse industry. The repellency of 10 essential oils was investigated using a no-choice laboratory assay. From this testing the essential oils Neem and Cederwood were found to produce the most significant response after 1 hour. After 48 hours, Neem and Patchouli reduced oviposition and significantly repelled adult female TPP.

A review of the Soft Chemical milestone (Milestone 6) by the tomato and capsicum industry prior to the October 2011 project planning meeting identified that a continuation of the soft chemical research would be of little commercial benefit. As a result, the project team agreed to terminate the soft chemical research milestone and redirect the remaining budget to support the Entomopathogen research (Milestone 8).

Milestone 7 - Host Range Testing of BCA (*Tamarixia triozae*): Searches conducted between 2006 and 2008 failed to identify any natural enemies within New Zealand that were likely to control TPP on tomatoes, so in 2009 a North American parasitoid, *Tamarixia triozae*, was imported into quarantine facilities at the Mt Albert Research Centre, Auckland, for assessment as a biological control agent.

Host-range testing has been carried out to evaluate the potential for *T. triozae* to impact negatively on non-target psyllid species in New Zealand. *Tamarixia triozae* did not oviposit on six of the eight non-target psyllid species it was exposed to in no-choice screening tests. *Tamarixia triozae* did oviposit on two native psyllid species, *Trioza curta* and *Trioza panacis*. 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 parasitoids from *T. panacis* had reduced ability to produce further offspring compared with parasitoids that emerged from their usual host (TPP).

Milestone 8 – Entomopathogens: Seventeen commercial entomopathogen products and isolates were identified as candidates for screening against TPP in New Zealand. Due to importation, legal and time constraints, 12 of the 17 candidates were successfully sourced, and 11 were evaluated, including seven entomopathogen products and four fungal isolates. These were evaluated in the laboratory and greenhouse using adult (immersion) and nymph (detached leaf) bioassays as a means of selecting suitable candidates for larger scale greenhouse trials.

- *Screening of entomopathogens:* All entomopathogens screened using a leaf bioassay showed varying degrees of activity against nymphs and adults. K4B3, BotaniGard® ES and Met52® EC outperformed the conventional insecticide standard, Oberon®, and all other entomopathogens screened, and were therefore selected as the best potential candidates for subsequent greenhouse and host plant trials based on overall efficacy and obtaining a rapid solution for industry.

- *Impact of environmental conditions on isolate growth and germination*: All isolates 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 limited or no germination or growth at 30°C or within the greenhouse in February. Light had no effect on germination. These results are consistent with most fungal entomopathogens.
- *Effect of host plant on the susceptibility to entomopathogens:* Host plant (capsicum, tomato and potato) had no effect on the observed efficacy of selected entomopathogens against TPP.
- *Caged greenhouse trials:* performed on capsicum and tomato confirmed the efficacy of BotaniGard® ES and Met52® EC. BotaniGard® ES demonstrated more consistent efficacy in response to changes in environmental factors.
- *Environmental stability:* performance of the greenhouse tested entomopathogens was influenced by temperature and relative humidity.

The results presented provide an indication of product and isolate efficacy under specific environmental conditions. Both BotaniGard® ES and Met52® EC are suited to greenhouse temperatures, but the activity of these fungi will be dependent on the amount of time conditions are optimal, that is 23–25°C and 25–30°C, respectively. As such, timing spray applications to correspond to periods in the growing season when higher greenhouse temperatures are maintained is likely to maximise the effectiveness of the spray. 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.

Milestones 9 and 10: Tamarillo insecticide trials and Orchard monitoring: The aim of this work was to determine the seasonal abundance of the different life stages of TPP on tamarillo trees through field monitoring (MS 10), and to relate this information to results from the potted plant insecticide trial (MS 9) to determine the optimum timing of insecticide applications to control TPP.

Milestone 10: Orchard monitoring.

The main findings of the orchard monitoring work are as follows:

- TPP in Northland have multiple overlapping generations
- TPP appears to overwinter as late instar nymphs in tamarillo orchards
- There is low survivorship of TPP from young nymph to older nymph in tamarillos
- There appears to be a constant migration of adult TPP into the orchards (this is based on monitoring and on grower observation)
- The new spray program has likely made an impact on the number of TPP found in the tamarillo orchards that were monitored.
- Disease symptoms progressed quickly over the summer months, with some trees showing severe symptoms within 6 weeks.

These results may be influenced by seasonal difference (e.g. dry summer (drought) vs. wet summer), and as unmanaged solananaceous crops die from TPP burden, there may be less sources of TPP to infest tamarillo orchards. Disease symptoms progressed quickly over the summer months, with some trees showing severe symptoms within 6 weeks. Early results have indicated that TPP were not found on plants with disease symptoms, indicating a reduced attraction of these plants for feeding or laying eggs. There is significant crop loss due to Liberibacter infection which has a detrimental effect on orchard production.

Milestone 9 - Tamarillo Insecticide Trials:

- Insecticide testing – susceptibility of different life stages of TPP to insecticides:
  - Of the 11 products tested, Avid + oil, Talstar, Oberon, and Movento gave effective control of TPP nymphs over a 6-week period.
  - Avid + oil and Talstar had good knockdown effect against TPP nymphs, while Oberon and Movento took a couple of weeks to become effective.
  - Oberon + oil and the mineral treatment controlled TPP nymphs for up to 2 weeks.
- Testing efficacy of spray residues:
  - Laboratory trials tested the residual activity of 5 insecticides against TPP nymphs at 1, 3, 7, 17, 21 and 28 days after treatment.
  - Compared to untreated plants, Avid, Movento and Oberon treated plants had significantly fewer nymph numbers with 21 day old residues.
  - 28 day old residues did not result in a significant reduction of TPP on plants
  - The percent mortality of TPP adults exposed to residues of Sparta (up to 28 day old residues), Avid (17 day old residues), and Movento, Oberon, and Neemazal (1 and 3 day residues), was significantly higher compared to controls.
  - Fewer eggs were laid by adults exposed to 1 and 3 day old residues of each insecticide treatment compared to controls.
- Testing antifeedants against the tomato potato psyllid (TPP) using EPG technique: Tomato plants were sprayed with one of four treatments: Neemazal (Neem Oil), Surround (Kaolin Clay), DC-Tron (Mineral Oil) or Tap Water (Control). Using the EPG method, the treatment of tomato plants with Neemazal, Surround or DC-Tron did not deter TPP feeding enough to prevent phloem feeding and therefore probable Liberibacter transmission.

Milestone 14: Extension activity - Assessment of economic impact of TPP: A survey of the potato industry was undertaken by Alan Kale (ELAK Consultants) commissioned by Potatoes NZ with funding from SFF. It covered forty-two (42) growers from all sectors of the potato industry as well as five (5) Processors and three (3) Seed Merchants. A survey of the tomato/capsicum industries for the economic impact of TPP was completed by Market Access Solutionz.

Regional grower costs were broken into three categories: crop impacts, control costs, and other costs (such as extra compliance costs, other production and management costs). This survey (Kale, 2011) reported that the economic impact across the potato industry in the 2010-11 growing season was $28 million. These impacts were most severe in the North Island where process grower costs increased by up to an additional $5,600 per hectare, compared to $540 in the South Island. Costs included crop impacts (yield and quality), control costs and other costs (management, research, market access and compliance). In 2011, approximately $5 million of losses was reported in the capsicum and tomato industries combined as a result of TPP (MAS, 2011). In addition to yield impacts due to TPP, these losses were incurred as a result of increased insecticide applications, additional crop monitoring and costs of compliance for export produce.

Differences this project made to your group / community of interest / industry

The project provided an early foundation for ongoing and improved communication and collaboration between industry groups (Potatoes New Zealand, Tomatoes New Zealand, Vegetables New Zealand, and NZ Tamarillos Growers Assn.), the processing industries (Heinz Watties, Mr Chips, McCain Foods, Bluebird Foods), agrichemical companies, and the research community. By bringing these groups together, and all parties becoming aware of the magnitude of the problem and the research challenge, an integrated research programme has been developed to find answers to the underlying biological questions in the longer term.

The project has provided information that is of direct benefits to growers:

- Insecticide trial work has demonstrated that there are many agrichemicals that are effective for TPP control which can be used in conjunction with organophosphate insecticides in a resistance management programme.
- Guidelines have been produced on obtaining optimum spray coverage to make best use of these products.
- In areas such as Pukekohe where early season TPP pressure is low it is possible to reduce insecticide inputs in early potato crops.
- Having collected three years of national monitoring data the tamarillo, field tomato, and potato industries have a good knowledge of the timing of TPP population increases. This knowledge can be combined with climate data to anticipate population peaks.
- Accurate diagnostic methods are now available to confirm Liberibacter infections or for screening of potato tubers or TPP.
- The efficacy of entomopathogenic fungi for TPP control has now been verified and the greenhouse industry can make informed decisions about the use of these products for TPP control.
- The tamarillo industry now has a good base of knowledge of insecticides that are effective for TPP control in their crops.

Perhaps the biggest difference that the project has made is that, in additional to these additional tools, all industry participants are much better informed about TPP and Liberibacter and have the confidence to continue producing these crops while longer term solutions are developed.