Monitoring *Bactericera cockerelli* and associated insect populations in potatoes in South Auckland

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Abstract *Bactericera cockerelli* (the tomato-potato psyllid; TPP) and associated insects were monitored weekly in unsprayed potatoes at Pukekohe by using yellow sticky traps and sampling plants from late July 2009 until mid March 2010. TPP adult catches and egg and nymphal infestations were absent or low until mid December. Other exotic and native psyllid species dominated trap catches until TPP populations increased markedly in mid January and peaked at 120 adults per trap in late February, with egg numbers reaching 520 per plant a week later. TPP nymphs peaked at 260 per plant in early February. *Micromus tasmaniae* (brown lacewing) was common in spring and summer, but *Melanostoma fasciatum* (small hover fly) became the dominant predator, peaking at 162 eggs and 35 larvae per plant in mid January. Naturally occurring predators appear to be important biological control agents of aphids, small caterpillars and probably TPP on potatoes at Pukekohe.

Keywords tomato-potato psyllid, *Bactericera cockerelli,* sticky traps, plant sampling, potatoes, *Melanostoma fasciatum, Micromus tasmaniae.*

INTRODUCTION

Bactericera cockerelli (Sulc) (Hemiptera: Triozidae), most commonly known in New Zealand as tomato-potato psyllid (TPP), is a new invasive pest of vegetable and fruit crops in New Zealand (Teulon et al. 2009). TPP is also considered the major vector of the newly discovered pathogen '*Candidatus* Liberibacter solanacearum' (Liefting et al. 2008) that is associated with zebra chip disorder in potato (*Solanum tuberosum* L.) crops. Damage/foliage symptoms can also occur in plants where *Candidatus* Liberibacter solanacearum has not been detected. Psyllid yellows has also recently been recorded in potatoes in New Zealand (Liefting et al. 2009). It has been associated with foliar symptoms similar to those of zebra chip but the insect vector in potatoes is unclear.

Industry initiatives for control of TPP in potatoes in New Zealand began in November 2008 with the publication of an interim insecticide resistance management strategy for insect pests in potatoes (Walker & Berry 2009). Anderson (2008) considered that an early start (when plants emerge from the ground) may be needed for control options for TPP in potatoes, including insecticide applications. Major yield losses have been attributed to TPP in the southern

US (Munyaneza et al. 2007) and in New Zealand (J.A.D. Anderson, Plant & Food Research, pers. comm.), and management of TPP in New Zealand has relied heavily on insecticides to date. In Texas, low populations of nymphs have been associated with economically acceptable levels of zebra chip disorder (Goolsby et al. 2007), but it is not known for how long these low population levels need to be maintained.

Prior to the arrival of TPP in New Zealand, insecticides were applied to potatoes mainly for control of *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) (green peach aphid) and *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) (potato tuber moth; PTM). Insecticide resistance has been reported for green peach aphid from potatoes from Pukekohe (Cameron & Walker 1988) and for PTM from Pukekohe and Waikato potato crops (Walker et al. 2008a). With these resistance issues and the threat that TPP may also become resistant to insecticides, increasing the applications of insecticides appears to be an unsustainable control option for insect pests in potatoes.

The importance of natural enemies in suppressing potato pests has been emphasised in Australia (Horne & Page 2009). However, some of the key natural enemies differ between countries and Australia has no psyllid pests in potato crops. The appearance of TPP in New Zealand now requires a re-evaluation of natural enemies. Therefore, as part of developing a more robust pest management programme for all pests in potato crops, and in particular for TPP, pest monitoring techniques and impacts of natural enemies are being investigated in trials at Pukekohe, South Auckland. Sweep nets, vacuum sampling, yellow sticky traps, plant symptoms and plant sampling methods (Cranshaw & Hein 2004; Goolsby et al. 2007) have been used to monitor TPP overseas, but it is recognised that monitoring populations and establishing thresholds is difficult (Wright et al. 2006). Yellow sticky traps have been used in New Zealand (Cameron et al. 2009) to monitor TPP adult populations but plant sampling techniques for nymphs have not previously been described. This paper reports on the use of sticky traps and plant sampling to improve understanding of TPP and other insect infestations, seasonal trends and interactions of populations of insect pests and naturally occurring predators in unsprayed potatoes growing in the Pukekohe area.

MATERIALS AND METHODS

Potato plants growing at Pukekohe Research Station (174° 55’ E, 37° 10’ S) were monitored weekly from late July 2009 to mid March 2010. Initially, volunteer potatoes were monitored at two adjacent sites. Then, from 23 November, an untreated planting of 0.3 ha of ‘Moonlight’ potatoes immediately adjacent to one of the volunteer areas was monitored.

Sticky trapping

Two double-sided yellow sticky traps (Biobest, Belgium), each side measuring 100 × 250 mm, were placed in the volunteer potatoes. Then, from 23 November, four traps were placed among the untreated crop, one trap in each quarter of the crop, 5 m in from the half-way point of each side. All traps were attached at canopy height and secured to a metal stake. The traps were replaced weekly and stored in plastic A4 file copy pockets at ambient temperature to allow identification and counting of TPP and other psyllid species through the clear plastic.

Plant sampling

Ten volunteer plants were sampled initially and, once insects were found (from 18 August to 23 November 2009), 30 volunteer plants were non-destructively sampled at weekly intervals by assessing and recording all insect life stages of all species present on the whole plant. In the untreated crop, whole plants were assessed initially, but as plants grew bigger (after 3 weeks), only single stems were assessed. Eight plants were randomly selected from each of the four quarters in the crop and whole plants or single stems were destructively sampled. Each stem was sub-sampled, with all insects counted on (1) the first, oldest (bottom) leaf, (2) a middle leaf (the first leaf closest to the mid-point of the stem length), (3) the first (bottom) half of the stem and (4) the second (top) half of the stem. Individual results are not presented (G.P. Walker, unpublished data), but results from all four sub-samples were pooled and multiplied by the number of stems on the particular plant to give estimated numbers of insects per plant.

A sub-sample of small insects (mainly aphids and thrips) was collected every week and stored in 75% alcohol for later identification. Psyllids were identified following Dale & Nielson (2009). A sub-sample of lepidopteran eggs and larvae was collected and reared individually in tubes containing a general-purpose insect diet (Singh 1983) to determine their identity and fate (reared to adult moth, parasitoid adult, etc.). Also, approximately every month a sub-sample of psyllid eggs and nymphs was collected and reared to adulthood at Mt Albert Research Centre to confirm identities.

Statistical analysis

For each insect life stage the sticky trap counts and individual plant counts were analysed separately by fitting generalised linear models with Poisson error variance and a logarithmic link function using GenStat Release 11.1. Sticky trap counts varied significantly between positions within the untreated crop (deviance ratio=3.06, residual df=57, P=0.035) and, although these made very little difference to predicted means for each week, the position effect was included for trap catches. For plant sampling, because the residual variance for any particular insect stage generally varied between volunteer plants and those sampled from the trial crop, being smaller for the former often by a factor of 10, the two sampling phases were kept separate. Standard errors of weekly sample means (SEMs) were calculated, and used to confirm that sample size was adequate. These SEMs were approximately constant over time on the square root scale, as predicted by Poisson distribution theory, so the median SEM for each life stage from the crop sampling has been used to provide an indication of sampling precision for population fluctuations over the growing season. Volunteer plants, which were sampled prior to 23 November, had only 1–2 stems, so were recorded as whole plants; populations of all insect species on them were very small compared with those on the untreated crop later in the season, so SEM bars are shown for the crop sampling only.

RESULTS

Sticky trapping

Figure 1 shows the trends in trap catches of TPP and other psyllid species captured on the sticky traps from mid August 2009 to late April 2010. In late winter and spring, catches were dominated by a *Ctenarytaina* sp. that had previously been found on several *Eucalyptus* tree species (P.J. Dale, Auckland, pers. comm.), with a peak of 40 per trap in late August. There was another peak in catches of this species in early December. An undescribed exotic species (Casuarina psyllid, an *Acizzia* sp. that has been recorded from *Casuarina* host trees) and a native species (*Trioza vitreoradiata* (Maskell) (Hemiptera: Triozidae) described from *Pittosporum* plants) were occasionally captured (Figure 1; Dale & Nielsen (2009); F.H. MacDonald, unpublished data; P.J. Dale, Auckland, pers. comm.). Two other adult psyllids caught were not able to be identified. TPP adult catches were zero or very low until mid December (Figure 1). Catches increased in mid January and there were two peaks through the summer period, with >60 adults captured per trap each week for a 3-week period from mid January and another peak reaching 121 per trap on 24 February (Figure 1).

Plant sampling

Ten plants only were assessed on the first two sampling occasions on 28 July and 11 August, but after that period monitoring was weekly and consisted of sampling 30 or 32 plants or stems.

TPP was the only psyllid species identified from the potato plant samples. TPP egg and nymphal infestations were absent or low until mid December (Figure 2) and during this period infestations were located mainly in clusters on individual leaves or stems. There were two peaks in egg infestations related to trends in adult sticky trap catches. Egg numbers first peaked at 244 per plant on 26 January, 1 week after the first peak in adult sticky trap catches commenced (Figure 1). The second peak in egg numbers (520 per plant on

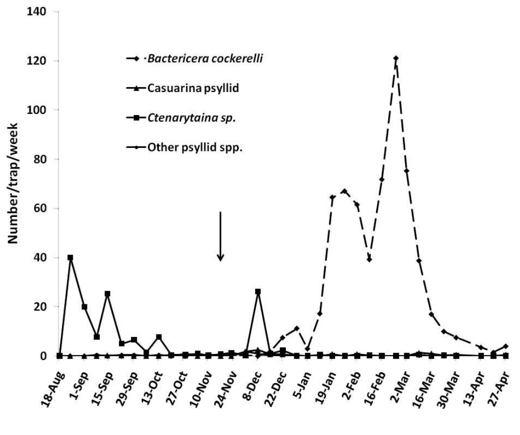

Figure 1 Mean number of adult psyllid species captured per sticky trap per week from August 2009 at Pukekohe, New Zealand. The arrow indicates when monitoring switched from volunteer potatoes to the potato crop.

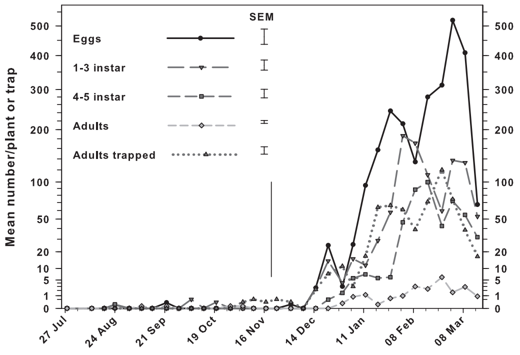

Figure 2 Mean number of tomato-potato psyllid (TPP) life stages per plant (square root scale) on unsprayed potato plants at Pukekohe, New Zealand and of TPP adults captured per sticky trap per week on traps. Error bars are median SEM bars for the planted crop over the sampling period from 20 November 2009 (as marked by the vertical line on the figure at this date).

2 March) occurred 1 week after the highest peak of adult sticky trap catches. Increases in numbers of 1st to 3rd instar TPP nymphs occurred 1–2 weeks after the peaks in adult sticky trap catches. The increase in 4th and 5th instar TPP nymphs was 2–3 weeks after the first peak in adult sticky trap catches but only 1 week after the second peak in adult sticky trap catches. It is likely that the destructive sampling method dislodged adult TPP, so the numbers recorded on plants would be an under-estimate of the actual infestation.

Aphids were not common on potato plants and usually only young instars were found. In spring, populations peaked in September, ranging from 0.5 to 0.7 aphids per plant, and there was a peak in aphid populations in autumn of 1 aphid per plant on 20 March. Species identified were *M. persicae* (green peach aphid) and *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae) (potato aphid). *Thrips tabaci* Lindeman (Thysanoptera) (onion thrips) was the only thrips species identified from samples and populations were low, never more than a few per plant (data not presented).

Lepidopteran species identified on potato plants were PTM and the noctuid species *Chrysodeixis eriosoma* (Doubleday) (green looper), *Thysanoplusia orichalcea* Fabricius (soybean looper) and *Helicoverpa armigera* (Hübner) (heliothis), all identified from collected eggs and larvae, plus *Agrotis ipsilon* (Hufnagel) (greasy cutworm) reared from collected eggs. Noctuid eggs were common on potato plants but few small caterpillars and very few large caterpillars were located. There was a lot of evidence of minor leaf damage (chewing) caused by small caterpillars, although the insects themselves were rarely observed. The absence of the causal agents of this minor leaf damage may have been due to predation. PTM located in leaf mines peaked at 25 per plant on 12 January and were present throughout the sampling period, but final tuber damage was minimal (data not shown).

The most common life stages of insect predators found on plants during this study were eggs of *Micromus tasmaniae* (Walker) (Neuroptera: Hemerobiidae) (brown lacewing) and eggs and larvae of *Melanostoma fasciatum* (Macquart) (Diptera: Syrphidae) (commonly known as small hover fly). Brown lacewing eggs were the most common life stage of any insect found on the volunteer potatoes in winter and early spring, reaching >5 per plant in late September (Figure 3). In the untreated crop, lacewings increased to be the most abundant insect until 22 December with an average of 19 eggs per plant. There was another peak of 26 lacewing eggs per plant in mid February. Lacewing larvae, pupae and adults were much less abundant (data not presented). Small hover fly became common in mid December, becoming the dominant predator found on foliage by 30 December. Small hover fly appeared to respond to the small increase in TPP infestations in late December and populations increased markedly, peaking at an average of 162 eggs and 35 larvae per plant on 12 January (Figure 3). Small hover fly larval numbers ranged from 13–35 per plant over a 6-week period from the start of January to mid February. It is noteworthy that over this period insect infestations on most plants consisted almost exclusively of TPP eggs and nymphs, lacewings, and small hover fly eggs and larvae. Small hover fly larvae were the major foliage-dwelling predaceous life stage present during this period, and may have contributed to the delay in build-up of late instar TPP nymphal populations that occurred after the first peak of infestations of TPP (Figure 2). However, from mid February onwards, predator populations declined while TPP nymphal populations remained above 80 per plant.

Sheetweb spiders (Linyphiidae) were commonly found on small plants and appeared to be the most common ground predator. Other foliage-dwelling insect predators located during the sampling were *Coccinella undecimpunctata* L. (Coleoptera: Coccinellidae) (11-spotted ladybird), *Harmonia conformis* (Boisduval) (Coleoptera: Coccinellidae) (large spotted ladybird), *Nabis kinbergii* Reuter (Hemiptera: Nabidae) (damsel bug), *Oechalia schellenbergii* (Guerin) (Hemiptera: Pentatomidae) and the predatory thrips, *Aeolothrips fasciatus* (L.) (Thysanoptera). All these predator species were relatively rare, particularly when compared with the abundance of brown lacewing and small hover fly.

The parasitoid *Cotesia subandinus* (Hymenoptera: Braconidae) Blanchard was reared from PTM larvae collected in leaf mines throughout the whole period of the trial (reared

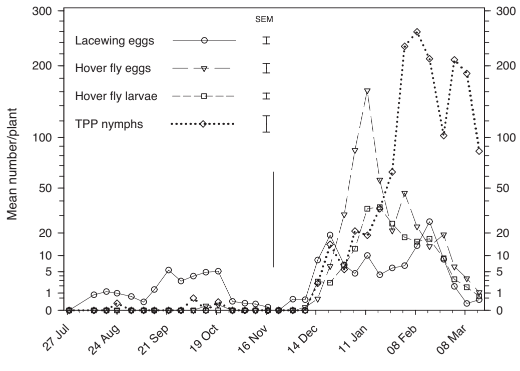

Figure 3 Mean number per plant (square root scale) of brown lacewing eggs, eggs and larvae of small hover fly and tomato-potato psyllid nymphs (all instars) on unsprayed potatoes at Pukekohe. Error bars are median SEM bars for the planted crop over the sampling period from 20 November 2009 (as marked by the vertical line on the figure at this date).

from every weekly collection of mined leaves), with levels of parasitism ranging from 29 to 100%. Also, *Cotesia kazak* Telenga (Hymenoptera: Braconidae) was reared from a larva of *H. armigera*. No entomopathogens or other parasitoids were found attacking any other insects, including TPP and the predator species, reared from collections during this study.

DISCUSSION

In spring the most common insect species located was lacewing eggs, and larvae and adults of this predator would be expected to control aphid populations, which remained very low throughout the survey period. *Micromus tasmaniae* has previously been observed to be an abundant predator of aphids in lucerne (Cameron et al. 1983) especially in spring. It has also been noted to feed on a wide range of species including the psyllid *T. vitreoradiata* (Valentine 1967). Small hover fly became common in January and it appeared that the only abundant pest prey, apart from neonate or small caterpillars, was TPP. Larvae of *M. fasciatum* are known to feed on aphids, eggs, small caterpillars and thrips in lettuce (Walker et al. 2008b). They are also cannibalistic and will eat other predators (G.P. Walker, unpublished data). Results from on-going laboratory no-choice studies show that larvae of small hover fly and larvae and adults of brown lacewing, 11-spotted ladybird, large spotted ladybird and damsel bugs can all feed on all life stages of TPP (MacDonald et al. 2011; G.P Walker, unpublished data). The delay in increases in numbers of large TPP nymphs may be partly attributed to predator activity, in particular small hover fly larvae, and possibly spiders (Boase 2010; MacDonald et al. 2011). It is noteworthy that a large proportion of the small hover fly larvae located on plants in January and February were late instars, capable of consuming large numbers of insects. However, predators were not able to control TPP populations in mid and late summer (Figure 3). Infestations of all insect species declined from late February, particularly predator populations, and this may have been partly due to the unattractiveness of the potato crop, which was showing a lot of foliage damage from psyllid yellows symptoms from early February.

The present results confirm that sticky traps are a good predictor of crop infestations by immature stages of TPP. The two peaks in trap catches of adult TPP also indicate two separate summer generations of TPP (Figure 2; G.P. Walker, unpublished data). Any interpretation of trap catches of psyllids for pest management of TPP needs to include species identification of adult psyllid catches, particularly in spring when other psyllid species may be much more common than TPP. The present results are similar to the studies reported by Cameron et al. (2009), which were mainly conducted in the same localised area the previous year.

The results of the present study indicate that early season crops grown in this area may avoid damaging infestations of TPP, as was concluded by Cameron et al. (2009). Increases in both trap catches and crop infestations in January in both studies indicate a rapid increase in risks of damage by TPP from that time on. Symptoms of psyllid yellows and crop deterioration appeared about 3 weeks after the first increase in TPP flights and plant infestations in mid January. Subsequently, more than 700 tubers from the untreated crop were tested for infection by *Candidatus* Liberibacter solanacearum, with results indicating that about 58% of tubers were infected (N.A. Berry, Plant & Food Research, unpublished data).

Naturally occurring predators were abundant enough in the present study to potentially be important biological control agents of aphids, small caterpillars and probably TPP on potatoes at Pukekohe. It will be a challenge to both researchers and industry to incorporate natural enemies into a sustainable pest management programme for potatoes. For example, further studies are needed to understand the reasons for declines in predator numbers prior to the decline in numbers of TPP. Also, a pest management programme based around calendar spraying is unlikely to be sustainable due to reported insecticide resistance in key pests (Cameron & Walker 1988; Walker et al. 2008a) and the threat of resistance developing in TPP. Further research is planned to determine the potential of these natural enemies and their impacts on TPP. Strategies for using natural enemies need to be developed, in conjunction with informed use of selective insecticides, to develop a sustainable pest management programme for potatoes grown at Pukekohe.

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