A field trial to assess damage by *Bactericera cockerelli* to early potatoes at Pukekohe

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Abstract An early season potato trial at Pukekohe assessed the damage caused by *Bactericera cockerelli*, tomato-potato psyllid (TPP), and investigated the need for insecticide treatment. Four treatments were used: insecticide drench at planting; insecticide drench and weekly foliar sprays; insecticide drench and threshold-based foliar sprays; and no insecticides. TPP and associated insects in the trial were monitored weekly using yellow sticky traps and sampling plants from mid-October until mid-December 2011. TPP adult catches remained very low, reaching 1.5 per trap per week in December, and egg and nymphal infestations were absent or very low. Other exotic psyllid species dominated trap catches in December. The predator, *Micromus tasmaniae* (brown lacewing) was the most common insect, present throughout the trial, peaking at a combined total of 6.6 eggs and adults per plant. No damage was caused by TPP in any treatments indicating that insecticides may not be required to produce healthy 'early crop' potatoes at Pukekohe.

Keywords tomato-potato psyllid, *Bactericera cockerelli*, sticky traps, plant sampling, early potatoes.

INTRODUCTION

The tomato-potato psyllid (TPP), *Bactericera cockerelli* (Sulc) (Hemiptera: Trioziidae), and its associated bacterial pathogen, *Candidatus Liberibacter solanacearum*, are associated with zebra chip (ZC) disorder in potato (*Solanum tuberosum* L.). The most characteristic symptom of ZC is the production of dark flecking concentrated in the perimedullary tissue within the tuber. This defect becomes more pronounced when tubers are fried, producing regular striped patterns in latitudinal tuber slices

and giving the disease its name (Buchman et al. 2011). The psyllid is estimated to have cost the potato industry around \$60 million since it was first found and that figure is expected to grow (Anonymous 2011). Most of this cost is due to crop impacts (yield and quality) and control costs (additional insecticides and spray applications). Past experience in New Zealand suggested that the only effective way to minimize the impacts of TPP and ZC is the careful application of well timed agrichemical sprays (Anonymous 2009).

Prior to the arrival of TPP in New Zealand, insecticides were applied to potatoes mainly for control of aphid and moth pests. The main aphid species in potatoes are *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) (green peach aphid) and *Macrosiphum euphorbiae* (Thos.) (potato aphid), and the main moth pest is *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) (potato tuber moth (PTM)).

Insecticide resistance has been reported for green peach aphid on potatoes from Pukekohe (Cameron & Walker 1998) and for PTM from Pukekohe and Waikato potato crops (Walker et al. 2008). With these resistance issues and the threat that TPP may also become resistant to insecticides, plus considering the increased costs of control of TPP, it is important to define periods when insecticides may not be required, both to minimise resistance and to reduce costs of controls. This paper reports on an early season trial in 2011 to assess the need for insecticides to produce a healthy crop grown at Pukekohe.

MATERIALS AND METHODS

Crop management

The trial was conducted in spring/early summer 2011 at the Plant & Food Research Pukekohe Research Station (PRS) (174° 55' E, 37° 10' S). Potato seed tubers 'Ilam Hardy' (certified PT 2nd generation 50–100 g seed) were planted on 6 September 2011 at an inter-row spacing of 300 mm and a depth of ca 250 mm. The soil type at PRS is described as a Patumahoe mottled clay loam and has a pH of 6.1. Soil fertility was

amended with an application of 2.5 t/ha "Potato Mix" (N:P:K = 6:6:6) at planting. Metribuzin and linuron were applied prior to crop emergence for weed control, and mancozeb was applied for blight control at recommended rates at 7–10 day intervals throughout the growing season.

Trial layout

The trial utilised a fully randomised block design of four treatments using four replicates each. Plots were 12 m long and 6.2 m wide, with eight rows of potatoes spaced 750 mm apart. Each plot comprised about 320 tubers and plots were separated by non-planted buffers, 3.1 m wide.

Treatments

The treatments are shown in Table 1. Actara was applied by backpack sprayer (single nozzle) at planting as an in-furrow spray over the tubers at 4 g/100 m row applied in 50–100 litres water/ha. The foliar insecticides were applied with a tractor-mounted plot sprayer using hollow-cone, non-drip nozzles at a water rate of 500 litres/ha at a pressure of 8 bar (120 psi). Foliar applications were made to the 'Weekly' treatment from 100% emergence of plants and applied in a sequence of blocks of different mode of action insecticides as in Table 1.

Sticky traps

At plant emergence, double-sided yellow sticky traps, measuring 100 × 250 mm (Biobest, Belgium), were placed in the middle of each of the four 'Untreated' plots. Each trap was attached

Table 1 Insecticide treatments for an early potato trial at Pukekohe Research Station, 2011.

Treatment name	Insecticide treatment
Actara	Actara® (thiamethoxam 250WSG) in furrow at 1 g ai/100 m row only
Threshold	Actara & action (foliar spray) threshold of 0.1 TPP nymph per middle leaf (or equivalent infestation for stem or plant)
Weekly	Actara & weekly foliar applications from 100% emergence. Blocks of three Avid® (abamectin 18EC) at 10.8 g ai/ha plus Eco-oil® at 1 ml/litre tank mix, two Movento® (spirotetramat 240SC) at 84 g ai/ha, four Karate® Zeon (lambda-cyhalothrin 250CS) at 30 g ai/ha and four Tamaron® (methamidophos 580SC) at 580 g ai/ha.
Untreated	Untreated

just above canopy height and secured to a metal stake. The traps were replaced weekly and stored in plastic pockets to allow identification and counting of TPP and other psyllid species. Sticky traps were maintained from 6 October to 16 December 2011.

Plant sampling

Initially eight plants were sampled weekly from each of the four plots in each treatment (32 plants per treatment), non-destructively, by assessing and recording all life stages of all relevant insect species present on the whole plant. As plants grew bigger, only single stems were assessed. After 3 weeks, partly because of time constraints, sampling changed to 100 middle leaves, being 25 middle leaves per plot (2 middle leaves from separate stems from 12 plants, plus 1 more middle leaf per plot). Previous research (Walker et al 2011a; G.P. Walker, unpublished data) has focussed on determining a practical, cost-efficient method for sampling potato plants, and analysis demonstrated that assessing a middle leaf is a reliable indicator of the actual infestations on a whole plant (G.P. Walker, unpublished data). Middle leaf counts were used for the action threshold and counts for middle leaves were multiplied by the leaves per stem and number of stems on the particular plant to give estimated numbers of insects per plant.

Tuber yields and specific gravity

Senescing plant tops were mown off on 16 December. The trial was machine harvested on 20 December 2011 and tuber yields and size-grades were assessed. For tuber yield and quality assessments, the two middle beds from each plot were dug and a 5 m length defined in the middle of each plot. All tubers within this area were graded visually into 'marketable (undamaged and >60 g) or reject (<60 g, green, diseased or damaged by PTM) categories. The weights of the two grades were recorded. A representative sub-sample of ≥ 30 tubers (approximately one tuber chosen from each plant) was also picked from this area in each plot for assessment of specific gravity and ZC. This method of sub-sampling

was used to minimise variations within a plot, because plants within a plot may exhibit different symptoms of TPP damage (G.P. Walker, personal observation). Tuber specific gravity was assessed on 22 December and determined by calculating the difference in weight of these ≥ 30 marketable tubers in air and in water.

Cooking tests for 'zebra chip'

On 22 December, within 1 week of harvest, 30 of these marketable tubers were randomly selected for cooking tests ('crisping') to determine the incidence of ZC. A single crisp slice of around 2 mm thickness was cut from the centre of each tuber with a stainless steel mandoline slicer and crisps were then fried in canola oil in batches of ten for 3 to 3.5 minutes at 180°C. Each individual crisp was then assessed on a 0–9 scale for symptoms of ZC where 0 = no browning and 9 = dark brown (Walker et al. 2011b). The percentage of crisps in each scale was assessed for each treatment.

Statistical analysis

The means of weekly sticky trap catches were calculated but differences between counts due to the position of the four traps were not assessed. The numbers of TPP located in the trial were so low that differences in these insect numbers between treatments were not analysed. Tuber yields and specific gravity were compared using analysis of variance using Genstat Ver 13 (VSN International Ltd.) but ZC scores had no differences to compare. Least significant differences (LSDs) were calculated to allow comparisons of means. Where the significance of the difference was borderline, the Tukey's adjustment for multiple comparisons was made before concluding whether the difference was sufficiently large to allow for the fact that there are six possible pairs of comparisons.

RESULTS

Threshold

The 'Threshold' treatment was based on the use of a nominal action threshold of 0.1 TPP nymphs per middle leaf. This threshold was not reached

so no foliar insecticides were applied. Therefore, this treatment was considered equivalent to the Actara-only ('Actara') treatment.

Sticky trapping

Figure 1 shows the trends in trap catches of TPP and other psyllid species captured on the sticky traps. In October and November psyllid catches were low and in December catches increased, with a *Ctenarytaina* sp. dominating the trap catches, peaking at 24 per trap on 13 December. This species has previously been found on several *Eucalyptus* tree species (Walker et al. 2011a). TPP adult catches were zero or below 1 per trap throughout most of the trial, increasing to a peak of 1.5 per trap in the last 2 weeks of the trial (Figure 1).

Figure 1 Mean number of adult psyllid species captured per sticky trap (placed in untreated plots) per week at Pukekohe from 13 October to 16 December 2011.

Pest species on plants

TPP eggs and nymphs were absent or rarely located and no adults were located on any plants in any treatment during this trial (Figure 2; G.P. Walker, unpublished data). Two TPP eggs were located in an 'Untreated' plot on 23 November and one TPP egg in an 'Actara' plot on 13 December, plus two small TPP nymphs were located in a 'Threshold' plot on 15 November. Aphid numbers were low, peaking over a 3-week period in late October at 0.5 to 0.6 per plant in the 'Untreated' plots; these numbers were similar to those reported over this period in the previous year (Walker et al. 2011a). Aphids in the other treatments reached a peak

of 0.25 aphids per plant on 2 November in the 'Actara' plots. The main aphid species identified was the potato aphid. The presence of PTM was first recorded on 29 November (one mined leaf) and numbers of mined leaves were very low. Apart from locating the occasional *Thrips tabaci* Lindeman (onion thrips), no other relevant pest species were located during this trial.

Figure 2 Mean number of aphids, tomato-potato psyllid (TPP) nymphs, brown lacewing (eggs and adults) and small hover fly (eggs and larvae) per potato plant (in untreated plots) compared with mean number of TPP adults per sticky trap per week at Pukekohe from 13 October to 16 December 2011.

Natural enemies on plants

The most commonly located foliage-dwelling predators during this trial were eggs and adults of *Micromus tasmaniae* (Walker) (Neuroptera: Hemerobiidae) (brown lacewing) and eggs and larvae of *Melanostoma fasciatum* (Macquart) (Diptera: Syrphidae) (commonly known as small hover fly) (Figure 2). Brown lacewing eggs were the most common life stage of any insect found in the trial and most predators were located in the 'Untreated' plots (data not presented). In the 'Untreated' plots, numbers of lacewing eggs and adults increased to >3.2 per plant on two occasions during the trial and increased to 6.6 per plant at the final assessment (Figure 2). Numbers of lacewings in the other treatments were initially low, and peaked at 3.24 per plant in the 'Actara' plots on 23 November, being at the same level as in the 'Untreated' on this date (Figure 2). Hover fly eggs and larvae were not located until late November and increased to reach about 4 per

plant at the end of the trial in the 'Untreated' plots (Figure 2), peaking in the other treatments at 3.3 per plant in the 'Actara' plots.

Tuber yields, specific gravity and cooking tests for zebra chip

A summary of the average weights, specific gravity and ZC scores for the four treatments is presented in Table 2. There were no statistically significant differences in either marketable yield or reject yield between the treatments. Symptoms of ZC were not found in any tubers assessed by cooking tests and there was no statistically significant difference in specific gravity between treatments.

DISCUSSION

Results from the present study indicate no meaningful differences between treatments and therefore no advantage from foliar-applied insecticides for pest control on early potatoes. Zebra chip symptoms were not detected in any treatments and there was also very little difference in specific gravity between treatments. The results indicate no ZC but this is no guarantee that all tubers from all plants would not display ZC symptoms. This is because results from previous trials by potato breeders indicate that individual plants in crops grown early at Pukekohe for harvest before January may express ZC symptoms: 2-5% in 2010 but 0% in 2011 (J.A.D. Anderson, unpublished data). However, the present results are strong evidence that the incidence of ZC would be very low and within industry standards (industry feedback suggests acceptable levels of ZC range from <0.5 to 3% rejection rate). The only noticeable difference in

tuber quality was slightly more reject-sized tubers in the 'Untreated'; overall there were more small tubers in the 'Untreated' plots than the 'Actara' plots. Observations from the trial indicated that tubers were mainly rejected due to being slightly under-size. If the crop had been allowed to mature for a slightly longer period, most of these tubers would have been of marketable size (G.P. Walker, personal observation).

During this trial, TPP populations were very low or absent, even in the 'Untreated' plots, and ZC was not detected (Table 2). Having 'zero ZC' made it impossible to compare between treatments in this trial, but it does reinforce results from previous research trials undertaken at PRS. Cameron et al. (2009) and Walker et al. (2011a) reported that studies conducted in the previous 2 years indicated that early season crops grown in this area may avoid damaging infestations of TPP. Buchman et al. (2011) report that adult TPP are highly efficient vectors of *Candidatus Liberibacter solanacearum* (the causal agent of ZC) and that nymphs are less efficient than adults at transmitting this bacterium. The data from monitoring sticky traps during the present trial indicate that flights and numbers of TPP invading these potato crops may be below an economic injury level. Trap catches during the trial peaked at 1.5 per plant (Figure 1). Cameron et al. (2009) reported that trap catches in two commercial crops harvested before 23 December 2008 exceeded 2 TPP per trap on only one occasion, that being the final week, while showing no discernable effects on crop yield and quality. This is in agreement with a two-treatment early trial conducted in 2010 that showed that trap catches up to 3 per trap resulted

Table 2 Summary of average weights (kg/10 m²), specific gravity (with standard errors) and zebra chip score of harvested potatoes from an early trial at Pukekohe, 2011.

Test	Actara only	Threshold	Weekly	Untreated
Marketable weight	37.2 ± 1.05	36.5 ± 0.67	37.7 ± 0.65	35.5 ± 0.65
Reject weight	1.4 ± 0.19	1.3 ± 0.10	1.5 ± 0.17	2.3 ± 0.39
Specific gravity	1.080 ± 0.001	1.079 ± 0.002	1.078 ± 0.001	1.079 ± 0.002
ZC symptoms ¹	0	0	0	0

¹100% of tested tubers had a ZC score of 0–1 (scores of 0 or 1 are assessed as having no ZC symptoms).

in no ZC in harvested tubers (Walker et al. 2011a; G.P. Walker, unpublished data). It is concluded from these 3 years of trials that low trap catches (<3 TPP adults per trap) may indicate that invading populations are below an economic threshold up until about mid-December, or in crops close to harvest in December. However, as reported previously (Walker et al. 2011a), 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.

In this trial the most common insects located on plants were lacewing eggs, and larvae and adults of this predator appeared to control aphid populations in the 'Untreated' plots. These data are similar to results reported by Walker et al. (2011a) from monitoring untreated potatoes at PRS in the previous year. Small hover fly was not recorded in the trial until late November, with numbers increasing at the end of the trial (Figure 2). Observations from this trial and results published by Walker et al. (2011a) confirm that predators are the dominant insects on potato plants from spring through to mid-December and that naturally occurring predators may control foliage-dwelling pest species during this period.

There is a critical need to determine the economic threshold in potatoes for TPP and the subsequent decision of whether to spray an insecticide (Butler & Trumble 2011). In the present trial, plant infestations of TPP were very low or absent. Currently there is no reliable sampling protocol for TPP nymphs in potato crops and consequently both the economic injury level and action thresholds for plant infestations are unknown (Cameron et al. 2009; Martini et al. 2011). Sub-sampling methods in potatoes have been compared and it was found that sampling a middle leaf gives a reliable estimate of the actual infestations (Walker et al. 2011a; G.P. Walker, unpublished data), and this system of sub-sampling was used in the present trial. Martini et al. (2012) reported that plant stem mid-portion TPP counts show the strongest correlation with total counts of TPP, while Trumble et al. (2011)

recommend sampling the underside of leaves in the middle or top of a plant. It is suggested that assessing 100 middle leaves per treatment is an effective method of estimating the actual infestations on plants for spray decisions.

The challenges ahead are to define better these economic injury levels and relate them to crop monitoring tools such as sticky traps and plant sub-sampling systems to minimise the use of insecticides and make potato production in the region more sustainable. In conclusion, 3 years of early trials at PRS demonstrate that insecticides may not be required for growing healthy early potatoes at Pukekohe. However, it is recommended that growers regularly monitor their crops in case of unusually high early season invasions of TPP.

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