BACTERICERA COCKERELLI: INCURSION, DISPERSAL AND CURRENT DISTRIBUTION ON VEGETABLE CROPS IN NEW ZEALAND

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ABSTRACT

The tomato potato psyllid (*Bactericera cockerelli* (Sulc)) probably invaded New Zealand in the summer of 2005-06. The first authenticated records from May to June 2006 indicated that it was widely distributed in the Auckland area with a further record from Taupo so that no attempt was made to eradicate it. By April 2009 records indicated that it had spread throughout much of New Zealand. Its spread within New Zealand is likely to be from a combination of natural and human mediated dispersal. The psyllid, and the liberibacter it transmits, will provide a serious challenge to the ongoing development of Integrated Pest Management in greenhouse crops (especially tomato and capsicum), outdoor tomatoes and potatoes. The economic impact of this insect and disease in the 4 years it has been in New Zealand has been in millions of dollars in terms of increased management costs, crop losses and loss of export markets.
Keywords: tomato potato psyllid, *Bactericera cockerelli*, spread, distribution, economic impact.

INTRODUCTION

Bactericera cockerelli (Sulc) (Hemiptera, Triozidae) (Burckhardt & Lauterer 1997), or the tomato-potato psyllid (TPP), as it is commonly referred to in New Zealand, is a newly invasive pest species of vegetable and fruit crops in New Zealand.

TPP females lay small (less than 0.2 mm) oblong eggs that are attached to host plant foliage by a short stalk. TPP pass through five nymphal stages before emerging as initially light yellow to pale green adults. The adult colour gradually darkens to a grey or black colour with distinctive white markings on the dorsal side of the abdomen. The general appearance of the darker adults has been described as resembling miniature cicadas, with an average body length of less than 3 mm (Pletsch 1947). Faeces (honeydew) resulting from the psyllid nymphs and adults feeding on the phloem contents of a plant is covered in a wax as it exits the insect's anus, resulting in a white granular substance referred to as psyllid sugars (Compere 1916). The majority of host plants that TPP are able to breed on belong to the Solanaceae (Wallis 1951; Martin 2008).

The potato psyllid is thought to have originated in North America, where it is found in Mexico, the United States west of the Mississippi, and southern areas of the Canadian provinces of British Columbia, Alberta, and Saskatchewan (Wallis 1951), and more recently in glasshouses in Ontario (Ferguson & Shipp 2002). Historically in North America, infestations of this psyllid have been associated with outbreaks of a putative physiological disorder caused in response to the feeding secretions of TPP (Eyer & Crawford 1933; Eyer 1937) referred to as psyllid yellows (Richards 1928; Richards & Blood 1933; Wallis 1951). More recently (since the mid-1990s to early 2000s) TPP

has been associated with the zebra chip disorder, which has become a major problem for potato growers in Central America, Mexico (Secor & Rivera-Varas 2004) and the southern United States (Munyaneza et al. 2007). The zebra chip disorder reduces potato yield and quality, and some outbreaks have been so severe that entire potato fields have been abandoned (Munyaneza et al. 2007). TPP is considered to be the main vector of the newly discovered pathogen '*Candidatus* Liberibacter solanacearum' (Liefting et al. 2008) or '*Ca*. L. psyllaurous' (Hansen et al. 2008), which is associated with zebra chip and possibly psyllid yellows.

This paper documents the incursion and subsequent dispersal and current distribution of TPP in New Zealand, the detection of *Ca*. L. solanacearum (hereafter referred to as liberibacter) and implications for TPP management in New Zealand.

METHODS

Psyllid distribution

Data to establish the distribution and spread of TPP in New Zealand were collected from four sources, phone/web surveys, crop surveys, sticky traps and suction traps.

Phone surveys were carried out by Plant & Food Research (PFR) staff in April 2007 and January 2009. Selected growers (18 in 2007, 10 in 2009) of solanaceous crops (especially tomato, capsicum and potato), horticulture consultants (3 in 2007, 2 in 2009) and other industry representatives (3 in 2007, 2 in 2009) were called and questioned about their knowledge of the presence and distribution of TPP. In June 2007 an internet site (www.InsectWatch.com) was created to illustrate the distribution of TPP in New Zealand to interested parties and to encourage them to report suspected occurrences of TPP in their crops. However, no new locational reports came from this source.

Commercial and domestic properties (capsicums, tomatoes, potatoes and tamarillos: 17 different sites in total) in the Auckland and Canterbury region were examined visually for TPP by PFR staff between April 2006 and January 2009. TPP samples were collected and identified.

As part of ongoing research to assess the seasonal flight activity of the TPP, yellow sticky traps (Biobest, Belgium) were placed in and around several crops (capsicums, tomatoes and potatoes: 26 different sites in total) throughout New Zealand over the 2008/2009 summer season. The traps were replaced weekly and the number of TPP recorded. Data collected from sticky traps in potato fields in Canterbury (28 January–12 March 2009) and South Canterbury (28 November 2008–25 February 2009) were used for this paper.

Weekly insect trap catches from 7.5 m high suction traps (Stufkens et al. 2000) at Lincoln (Canterbury Agricultural Science Centre) (02 April 2007–16 March 2009), Pukekohe (Pukekohe Research Centre) (02 January 2006–28 May 2007, 13 October 2008–16 Mar 2009) and Hawke's Bay (Ngatarawa, west of Hastings) (04 December 2006–18 June 2007, 12 May 2008–09 Mar 2009) were examined for the presence of TPP. Trapping dates reflected periods when suction traps were operating (they were primarily used for aphid monitoring). Trap analysis for TPP was retrospective from January 2006 until August 2008 and thereafter trap contents were examined weekly until April 2009. Psyllid samples were collected and TPP identified according to the characters described in Dale et al. (2009).

As part of a wider liberibacter detection survey programme, MAFBNZ conducted a phone survey of 29 tomato and capsicum growers in June 2008 to assess common factors associated with the distribution of TPP and liberibacter at that time.

RESULTS AND DISCUSSION

Psyllid distribution

Figure 1 illustrates distributional records for TPP in New Zealand for each growing season (July to June inclusive) since its discovery in New Zealand in March 2006. Crosby area codes (Crosby et al. 1976) are used to illustrate the psyllid's regional spread.

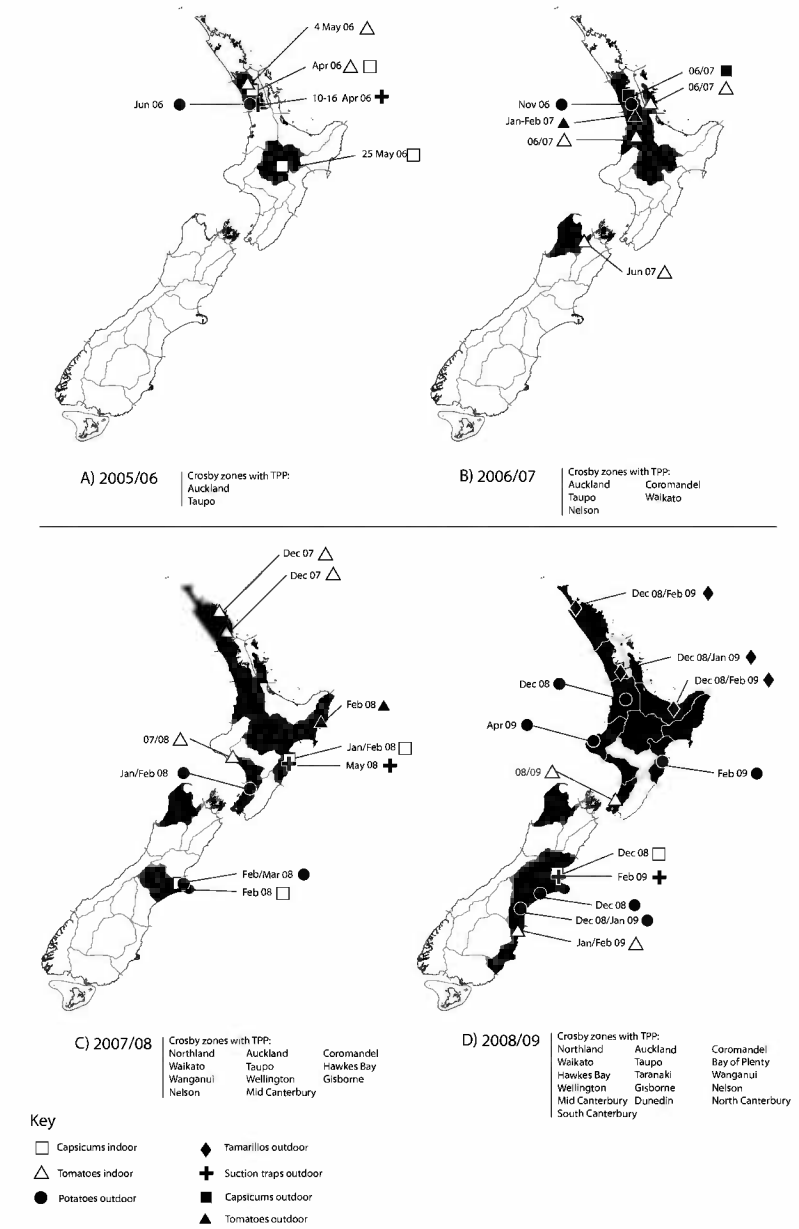

FIGURE 1: Tomato potato psyllid distribution in New Zealand with respect to Crosby locality zones in (A) 2005/06, (B) 2006/07, (C) 2007/08 and (D) 2008/09. See text for collection methods.

March to June 2006

Several authors have suggested that TPP was in New Zealand in 2005 (Robertson 2006a; Workman & Pedley 2007a; Robertson 2008d) but the first authenticated record was from a tomato plant in Clevedon (Crosby code: AK) in March 2006. This sample was not submitted for identification until May 2006 (J. Richmond, MAFBNZ, unpubl. data). Psyllid samples from tomatoes were collected by staff from Investigation and Diagnostic Centres, MAF Biosecurity NZ (MAFBNZ), from inside a greenhouse complex in Kumeu, north west Auckland (AK), on 4 May. MAFBNZ staff identified TPP and this was later validated by US Department of Agriculture Systematic Entomology Laboratory scientists (Gill 2006). A delimiting survey in the Auckland region showed that TPP was present in several glasshouse facilities around Auckland, including Karaka south of Auckland (Gill 2006). Retrospective examination (in November 2008) of insect samples from a 7.5 m high suction trap at the Pukekohe Research Centre indicated the presence of TPP outside in Pukekohe, South Auckland (AK), in the week ending 18 April 2006 (M-C. Nielsen, unpubl. data). Additionally, an examination of volunteer potato plants remaining in a field in South Auckland (June 2006) also confirmed this crop to be infested with TPP (Gill 2006). TPP was also collected and identified from greenhouse capsicums near Taupo (TO) in May 2006 (Gill 2006).

The wide distribution, lack of linkages between infested sites, and the unknown pathway of entry into New Zealand for TPP led MAFBNZ to conclude that this pest was well established in New Zealand and eradication was not feasible (Gill 2006). This decision was made before the discovery of the liberibacter vectored by TPP (see below) and the subsequent understanding of its potential negative impact on a range of solanaceous crops in New Zealand and elsewhere.

July 2006 to June 2007

Records of TPP in this season confirmed its widespread distribution in the Auckland area, as far north as Warkworth, both in greenhouse crops and outdoors. TPP was also recorded from regions neighbouring Auckland, including Coromandel (CL) and Waikato (WO). In addition, the first South Island record of TPP was reported in June 2007 from a tomato greenhouse crop in Nelson (NN) (J. Thomson, BioForce, pers. comm.) (Fig. 1).

July 2007 to June 2008

Reports of TPP in this season indicated that its distribution had extended to include Northland (ND), Wellington (WN), Wanganui (WI), Hawke's Bay (HB) and Gisborne (GB) in the North Island and mid Canterbury (MC) in the South Island (Fig. 1).

July 2008 to April 2009

Additional regional records for TPP in this season included Bay of Plenty (BP), Taranaki (TK), north Canterbury (NC), south Canterbury (SC) and Dunedin (DN) (Fig. 1). Lack of reports of TPP from other localities does not necessarily mean that TPP was not present there, just that it has not been reported. Indeed, it is likely that TPP is more widespread than reported here.

Dispersal within New Zealand

In June 2008 a number of features common to TPP-infested tomato and capsicum greenhouses were identified as a result of the grower phone survey. These features included their proximity to other infested greenhouses or infested outdoor crops, common sources of seedling nursery stock, and common interactions with other greenhouse growers, biological control specialists and horticultural experts (e.g. onsite visits). At least one grower reported seedling tomatoes arriving at their property infested with TPP. The discovery of TPP in Nelson in the South Island in June 2007, far from any other know sources of TPP, suggested spread by means other than long distance or localised flight. Thus, the spread of TPP within New Zealand is likely to have occurred by a combination of natural and human mediated dispersal. Possible conveyances of TPP were likely to have included infested host plant material and inanimate goods (e.g. clothing), highlighting the need for strict hygiene measures to minimise the spread of this and similar unwanted organisms within New Zealand.

***Candidatus* Liberibacter identification**

From January to May 2008, disease symptoms similar to 'psyllid yellows' were observed in several TPP-infested commercial glasshouse tomato crops in Auckland with associated crop losses of up to NZ$1 million (Liefting et al. 2009a). Initial extensive diagnostic testing of symptomatic plants for a range of known plant pathogens (i.e. fungi, bacteria and viruses) all proved negative (Liefting et al. 2009a). However, in April 2008, similar symptoms appeared in a glasshouse capsicum crop on the same property as one of the infected tomato crops (Liefting et al. 2009a). Capsicum is not usually known to be susceptible to psyllid yellows (Liefting et al. 2009a). Additional investigation using transmission electron microscopy, polymerase chain reaction (PCR) and sequence analysis led to the discovery of a bacterium new to science that was named '*Candidatus* Liberibacter solanacearum' (Liefting et al. 2009a,b).

Hansen et al. (2008) had also reported *Candidatus* Liberibacter psyllaurous on potato and tomato with 'psyllid yellows' in the USA and shown TPP to be its vector. The 16S rRNA sequences of the '*Candidatus* Liberibacter' species from USA (Hansen et al. 2008) and New Zealand (Liefting et al. 2009a,b) are thought to be identical (L.W. Liefting, MAFBNZ, pers. comm.).

Samples from potato tubers harvested from a breeding trial in May 2008 at Pukekohe showing symptoms of zebra chip (see below) also tested positive for liberibacter (Anderson 2008; Liefting et al. 2008). Subsequently, Abad et al. (2009) found the same liberibacter species in potato plants infected with zebra chip disease in the United States.

A survey of tomatoes, capsicums, potatoes and tamarillos by MAFBNZ in July 2008 confirmed the establishment of liberibacter in Northland, Auckland, Waikato, Nelson and Canterbury. This distribution matched the known general distribution of TPP, although the bacterium was not detected in all the regions known to have had psyllids in the previous summer such as Gisborne and Hawke's Bay (MAF 2008c). The southernmost detection of liberibacter was in table potatoes south of Christchurch (Robertson 2008d).

Impact on greenhouse crops

The potential for TPP to become a major pest in greenhouse crops was realised early by industry leaders (Robertson 2006a,b,c; Ivicevich 2006) and it became a major feature of greenhouse crops research initiatives at Crop & Food Research (now Plant & Food Research) and Horticulture New Zealand (Whiteman 2006; Robertson 2006c, 2007). The research emphasis has been on the effective use of insecticides (van Toor et al. 2007; Berry et al. 2009) and exploration for biological control agents within New Zealand (Workman & Pedley 2007a, b; Anon. 2008a) and overseas (Workman & Whiteman 2009). Psyllid management has become critical for maximising crop production and quality and to ensure market access for export fruit (Robertson 2008e). TPP became a major problem in some tomato and capsicum greenhouse crops (Robertson 2008b), with many growers forced to use pesticides toxic to beneficial insects (Workman & Pedley 2007a), thus jeopardising the ongoing development of Integrated Pest Management and biological control in New Zealand greenhouse crops. However, non-IPM focused controls have generally been successful, as only one TPP has been found on tomato and capsicum fruit being exported from New Zealand (Robertson 2007; Robertson 2008f).

Impact on potato crops

In retrospective analysis of trial data, Anderson (2008) attributed poor potato seedling establishment in potato breeding trials at Pukekohe in March 2007 and March 2008 at least in part to psyllid damage. Additionally, potatoes from main-crop trials harvested in late May 2008 at Pukekohe had extremely poor tuber quality, yields, dry matter levels and a range of symptoms, including indications of zebra chip, typical of psyllid infestation (Anderson 2008). Only one Pukekohe grower reported having had major yield loss due to psyllids (Anderson 2008). In the 2007-08 season, Anderson (2008) considered that potato growers may have been protected from serious psyllid damage by regular applications of insecticide to control tuber moth, but if early season psyllid infestations develop, an early start will be needed for control options, including insecticide applications (Anderson 2008).

Industry initiatives for sustainable psyllid control began in November 2008 with the publication of an interim resistance management strategy (Anon. 2008).

In the 2008-09 season, symptoms including leaf curling, purpling and stunting of potato crops in the presence of psyllids were common in some North Island potato crops, but these symptoms were not seen in South Island crops even with psyllids present (J.D. Fletcher, Plant & Food Research, unpubl. data). There have been anecdotal reports of increased use of insecticides for psyllid control. Additionally in French fry potatoes in the North Island there have been reports of low yields, small size, low dry matter and dark fries attribute to TPP/liberibacter but there is no clear pattern to their distribution (J. Anderson, Plant & Food Research, pers. comm.). Some of these symptoms may be associated with '*Candidatus* Phytoplasma australiense', which was discovered in some potato crops in February 2009 (L.W. Liefting, MAFBNZ, pers. comm.).

Impact on outdoor tomato crops

During 2007-08 major problems with TPP were first noticed on outdoor tomatoes in Hawke's Bay, with severe yield effects (Robertson 2008a, b; G.P. Walker, Plant & Food Research, pers. comm.). Significant impacts on yields and production costs have also been observed in the process tomato industry in 2008-09 (B. Snowdon, Heinz Watties, pers. comm.). Full agrichemical control programmes that may be needed for TPP on outdoor tomatoes, at least until new biocontrol practices have been developed, are likely to severely disrupt the very effective IPM programmes established for this crop in New Zealand (Cameron et al. 2009).

Impact on export trade

After the discovery of liberibacter in greenhouse tomatoes and capsicums in New Zealand, MAFBNZ withdrew its phytosanitary certification for New Zealand fresh tomatoes and capsicums on 4 June 2008. This resulted in the immediate cessation of trade for these and other solaneceous fruits to key export countries such as Japan, Australia and the Pacific Islands (Robertson 2008c). On 17 July 2008, MAFBNZ reinstated its phytosanitary certification for New Zealand-grown tomato and capsicum export produce (MAF 2008c). Japan reopened its market for New Zealand export tomatoes and capsicums on 12 August 2008 (MAF 2008e, Robertson 2008d) but the Australian market was not opened until early December 2008 and then with a range of new requirements to ensure that TPP did not enter Australia (MAF 2008f). Access for tomatoes and capsicums was still closed for Fiji in March 2009 (Robertson 2009b).

With the discovery of the liberibacter in potato in New Zealand, MAFBNZ continued to issue phytosanitary certification (with the exception of French Polynesia) for potatoes, citing a greater understanding of the risks associated with TPP/liberibacter on potato (MAF 2008a). Fiji suspended import permits for potatoes from New Zealand for most of July 2008 subject to New Zealand potatoes meeting their specified conditions to ensure TPP did not enter Fiji (MAF 2008a,d). Additionally, exports of potatoes to French Polynesia were halted for just over 1 week (MAF 2008a,b).

Reduced export receipts of New Zealand capsicums of around $NZ5.22m in 2008 (2008 FOB value: $28.38 m cf. 2007 FOB value: $33.6 m) were attributed primarily to the effects of the psyllid/liberibacter incursion on (1) closing the main export markets and (2) the time needed to regain access to them (Robertson 2009a). Additionally, Robertson (2009b) considered that the 2008 closure of New Zealand's principle export markets as a result of TPP/liberibacter cost the greenhouse tomato industry in the order of $NZ3 million in lost exports alone.

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