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A review of the potato psyllid (*Bactericera cockerelli*); a new insect pest of potato in New Zealand

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KNOWLEDGE AND VALUE FROM SCIENTIFIC DISCOVERY

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1 Executive summary

The potato psyllid, a pest of potatoes and other solanaceous crops in North America, has become established in New Zealand. This pest is believed to cause psyllid yellows and zebra chip, both of which have cost North American potato producers and processors millions of dollars due to damaged crops.

The following is a summary of a larger literature review (in progress), funded by Horticulture New Zealand and Crop & Food Research, describing what we know about this insect pest.

2 New potato pest found in New Zealand

The potato psyllid, *Bactericera cockerelli* Sulc, was first recorded in New Zealand in 2006 (Gill 2006) and has now become established in most parts of the country. Initially it was mainly a pest of solanaceous greenhouse crops, but more recently it has had a major impact on outdoor tomatoes and has also been found in potatoes.

The potato psyllid is thought to have originated in North America where two biotypes have been identified, the native and invasive biotypes (Liu et al. 2006). Figure 1 is a map of the countries/states/provinces (shaded in grey) where the psyllid has been confirmed present (Wallis 1955; Ferguson & Shipp 2002; McGuire 2002; Liu et al. 2006). There is no reference as to what the latitude is for the northern limit of the potato psyllid's distribution, so the shaded areas in Figure 1 of the Canadian provinces, British Columbia, Alberta, Saskatchewan, and Ontario are arbitrarily chosen.

The native biotype overwinters in Mexico and Texas and is believed to migrate in spring and summer to northern regions such as Colorado, Nebraska and Montana, and possibly even into southern parts of British Columbia, Alberta and Saskatchewan, in Canada (Wallis 1955). The invasive biotype is associated with a western expansion of the species' distribution in North America, and is now commonly present in California (where previously it was reported as only an occasional pest) and Baja (Mexico) (Liu et al. 2006). There is also an unconfirmed report of the psyllid being present in Guatemala.

The invasive biotype has higher LC_{50} doses (i.e. it is less susceptible) for some insecticides than the native biotype (Liu & Trumble 2007).

Figure 1: Map of North America showing the regions where the potato psyllid has been confirmed present (shaded grey).

Historically in North America, infestations of this psyllid have been associated with outbreaks of psyllid yellows in potatoes (Richards 1928; Richards & Blood 1933; Wallis 1955). This was thought to be a physiological disorder caused in response to the feeding secretions by the potato psyllid (Eyer & Crawford 1933; Eyer 1937). More recently (since the mid-1990s, early 2000s) the potato psyllid 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 states of the 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).

It is not yet known if psyllid yellows and zebra chip are one and the same, as their symptoms are very similar. In potato plants the common symptoms include yellow, red, or purple shoots, and curled and leathery leaves. As the symptoms progress, enlarged nodes produce clusters of abnormally shaped leaves or small aerial tubers. Plants infested early produce few or no tubers, while plants attacked later produce numerous small poor quality potatoes. Other potato diseases in North America also have very similar symptoms, such as potato purple top (Munyaneza et al. 2007).

The main difference between zebra chip and psyllid yellows symptoms is that tubers with zebra chip have necrotic flecking (discontinuous dark flecks) throughout the tuber. When infected potatoes are fried the necrosis becomes more prominent, resulting in chips with a burnt appearance, and hence the term zebra chip (Munyaneza et al. 2007). Tubers with the psyllid yellows disorder have generally not had this symptom, either because researchers reporting psyllid yellows failed to notice or report this necrotic flecking, or because these disorders are different.

In New Zealand, a crop of potatoes was recently found to have zebra chip symptoms in the tubers. Psyllid yellows has been reported from a range of solanaceous crops, including potatoes, infested with potato psyllids.

3 New pest spreads bacteria

It has recently been discovered that potatoes in New Zealand (MAFBNZ) and the United States (APHS) exhibiting zebra chip symptoms were infected with a bacteria, *Candidatus*[1] Liberibacter. Studies in the United States have found that the potato psyllid can vector a Liberibacter species new to science, L. psyllaurous, into potatoes and tomatoes, resulting in psyllid yellows type symptoms (Hansen et al. 2008). It has yet to be confirmed that the Liberibacter found in tubers with zebra chip symptoms is the same species, L. psyllaurous, described by Hansen et al. (2008). In New Zealand, a Liberbacter bacterium (possibly L. psyllaurous) was first found in greenhouse tomatoes and capsicums where it was also thought to be spread by the potato psyllid.

MAF BNZ confirmed the presence of the bacterium from 14 commercial tomato and capsicum glasshouse sites in the Auckland, Northland, Waikato, Taupo, Mid Canterbury and Nelson regions as of 24 July 2008 (www.biosecurity.govt.nz/pests/surv-mgmt/resp/tom-cap-bacterium/update-24july).

In the United States, researchers thought psyllid yellows/zebra chip may be caused by phytoplasmas (mycoplasma-like organisms), since symptoms appear similar to potato purple top wilt syndrome caused by the Columbia Basin potato purple top phytoplasma (Secor et al. 2006). Although up to three different phytoplasmas have been detected in potato plants with zebra chip symptoms in the United States (Secor et al. 2006), these micro-organisms have not been detected in plants exhibiting psyllid yellows or zebra chip in New Zealand (20/6/2008 communication from IDC-PHEL MAFBNZ to Sonia Whiteman, HortNZ).

The psyllid yellows disorder was previously attributed to a physiological reaction to secretions injected into the plant by the potato psyllid during feeding (Eyer & Crawford 1933; Richards & Blood 1933), but it may be that these symptoms were caused by Liberibacter bacteria. Recent advances in molecular microbiological techniques have allowed the detection of the Liberibacter bacterium, so there is still a great deal to learn about its association with zebra chip and psyllid yellows.

[1] *Candidatus* is used before the genus and species name of bacteria-like organisms to indicate the organism has “candidate” status rather than full taxonomic status.

4 The purpose of this study

This literature review on the potato psyllid on potato crops was prepared for Horticulture New Zealand to provide growers with a comprehensive source of information on this pest, its associated disorders, and potential implications for potato pest and disease management in New Zealand.

After its first discovery in New Zealand in 2006, and subsequent spread throughout the North Island and parts of the South Island, the potato psyllid was primarily viewed as a pest of greenhouse crops (especially capsicums and tomatoes). However, with its spread into outdoor tomato areas in Hawke's Bay in 2008 and observations on unsprayed potato crops at Pukekohe in 2008, it became apparent that the potato psyllid posed a serious threat to these outdoor crops in New Zealand as well. Additionally, crop loss and market access issues surrounding the discovery of Liberibacter and its putative relationship with the potato psyllid have heightened the importance of these issues.

We used the library and internet facilities available at Crop & Food Research to undertake this literature review. The main electronic database used was CAB (containing more than 4.9 million records dating back to 1973), and a 50-page bibliography compiled by Cranshaw (1993) for references prior to 1973. Due to the paucity of recent published literature, and the recent discovery linking Liberibacter with the psyllid and their host plants, the internet (Google search engine) was also used to search for additional information.

5 Background information

The majority of published literature comes from the United States, where the potato psyllid and psyllid yellows were first described (Sulc 1909; Richards 1928).

5.1 Psyllids

- The potato psyllid was first described in 1909 from specimens collected from capsicum growing in a home garden in Colorado (Sulc 1909).
- Life stages include eggs, five larval instars, and adults (Pletsch 1947).
- In an earlier laboratory study (temperature not specified), the life cycle (egg to adult) of the potato psyllid was found to take between 15 and 30 days (Knowlton & Janes 1931). In a laboratory study at 26°C the developmental time took, on average, 29 days (Abdullah 2008).
- In the United States, three to five generations have been recorded on potato crops per year (List 1939b; Pletsch 1947).
- Temperatures above 30°C markedly reduce larval and adult survival (List 1939a).
- In the laboratory, some females were found to lay over 1000 eggs in their lifetimes and were recorded to live up to 189 days (Knowlton & Janes 1931).
- Adult longevity and female fecundity were found to depend on the host plant (Knowlton & Thomas 1934; Pletsch 1947).
- Of the more than 160 plant species that psyllids have been found on, 46 were recorded as having all life stages (eggs, nymphs and adults) present in the field, suggesting these plant species are potential breeding hosts (Pletsch 1947; Wallis 1955). Most (42) of these putative breeding host species belonged to the Solanaceae family.

5.2 Psyllid yellows and potatoes

- The first report of psyllid yellows symptoms in North America was made in 1928 (Richards 1928).
- It was believed to be caused by a toxin injected by the potato psyllid during feeding on the phloem of the plant (Richards 1928; Eyer & Crawford 1933).
- High numbers of psyllids and increased duration of psyllid feeding increased the psyllid yellows symptoms in potato plants (Richards & Blood 1933).
- Some solanaceous host plant species showed psyllid yellows symptoms more readily than others (e.g. symptoms on potato and tomato were more apparent than with capsicum) (Pletsch 1947).
- Psyllids have been found to develop on all potato cultivars, but psyllid yellows symptoms may vary between cultivars (i.e. some cultivars displayed symptoms with fewer psyllids feeding for less time than other cultivars) (Babb et al. 1944).
- The environmental conditions, in particular light intensity and duration, may increase psyllid yellows symptoms (Richards & Blood 1933).
- Psyllids removed from plants displaying mild symptoms of psyllid yellows (e.g. discolouration, cupping or rolling of leaflets) may lose their symptoms and resume ‘normal’ growth (Richards & Blood 1933).

- Plants around the field margins were found to be the first to exhibit foliage symptoms of psyllid yellows (Blood & Richards 1933; Babb et al. 1944; Wallis 1955; Cranshaw & Hein 2004).

These findings were compiled from studies undertaken prior to the recent discovery of Liberibacter in solanaceous crops.

5.3 Zebra chip and potatoes

- The association of the potato psyllid with zebra chip was only made within the past few years, therefore much less is known about factors affecting its spread and occurrence. For example, it is not known how many psyllids can cause symptoms to appear in the foliage or tubers, or if the brown flecking can occur in tubers where the foliage has not exhibited any symptoms.
- Zebra chip was first reported in potato fields in the United States in 2000. It was only occasionally important economically until the growing seasons of 2004, 2005 and 2006, when it caused millions of dollars of damage to both potato producers and processors, even resulting in entire potato crops not being harvested (Munyaneza et al. 2007). Potato growers in the United States have reported that processors have rejected potatoes from an entire field, even when the proportion of tubers with the brown flecking symptom was low.
- Potato plants displaying zebra chip foliage symptoms (e.g. discoloured leaves, leaf roll) have generally been found scattered throughout the crop, and in some cases have been observed to cause clusters of collapsing plants that senesce earlier than neighbouring plants (Gudmestad & Secor 2007).

6 Monitoring and management

6.1 What does this pest mean for New Zealand potato growers?

Given the potential impact that this insect and its associated pathogen(s) can have on potato yields, the potato psyllid needs to be monitored and managed.

6.2 Monitoring for the psyllid or Liberibacter

6.2.1 Psyllid

Thresholds or intervention. Despite the long history of psyllids in the United States, there was no information in the literature (published or unpublished) regarding action thresholds. This has been attributed to the difficulties in sampling for psyllids and the severe impact psyllids can have on yield.

Presence/absence. To assist in determining the presence/absence of adult potato psyllid populations, yellow pan traps (used to monitor winged aphid populations) (Cranshaw 1994) or yellow sticky traps (Goolsby et al. 2007) have been suggested. However, these methods do not indicate if psyllids have established populations on a crop. Indicator plants that psyllids may colonise before the main crop (e.g. pepper plants) have also been recommended (Cranshaw & Hein 2004).

Scouting. Examining leaf samples regularly for eggs and nymphs, although it is difficult and time-consuming to see the eggs and nymphs, can provide information on whether a population has established or not (Cranshaw & Hein 2004; Goolsby et al. 2007). If it can be established that psyllids have colonised a potato crop then there is a strong chance that there could be yield loss (Cranshaw & Hein 2004).

6.2.2 Liberibacter

In New Zealand, sampling protocols for establishing presence/absence of this bacterium and extent of the infection in a potato crop are being developed.

6.2.3 Recognising the potato psyllid

Pictures and descriptions of the life stages of the potato psyllid, and the by-product of psyllid feeding, psyllid sugars, can be found at:

www.biosecurity.govt.nz/pests-diseases/plants/potato-tomato-psyllid.htm
www.nzpotatoes.co.nz/user_files/PDF/Psyllid_Poster.pdf
www.nzpotatoes.co.nz/user_files/PDF/Psyllid_cards.pdf

The following is a brief description of the life stages, psyllid sugars and psyllid yellows/zebra chip symptoms, adapted from Pletsch (1947) and Richards & Blood (1933).

- **The eggs** (attached to leaves by short stalks) and first two instars are very small (less than half a millimetre) and therefore difficult to see on foliage in the field.
- **The nymphs** look like scale or whitefly nymphs, but are more mobile (will move when disturbed) than scale or whitefly nymphs. In the field it may be possible to see 3^{rd}, 4^{th} and 5^{th} instars on foliage, although they are less than 2 mm long, and the green colour of 4^{th} and 5^{th} instars can make them difficult to detect.

- **The adults** look similar to aphids, but with markings on the body and wings similar to cicadas, hence their description as ‘miniature cicadas’ (Pletsch 1947). Adults are around 3 mm long. When disturbed, adults may rapidly jump or fly away, making them difficult to see on a plant.
- **Psyllid sugars and psyllid yellows symptoms.** The difficulty in seeing eggs, nymphs and adults on plants may mean the first indication of their presence will be through (1) psyllid sugars, which look like granulated sugar on the foliage, or (2) the first symptoms of psyllid yellows/zebra chip, where the leaves have an upward rolling appearance, possibly with some discolouration of the foliage (yellow, red or purple depending on the cultivar).

6.3 Resistant cultivars

No potato cultivars are known to be resistant to psyllids.

6.4 Biological control

Although experience in the United States suggests that populations of natural enemies in potato crops have not been large enough to suppress psyllid populations to below damaging levels (Cranshaw & Hein 2004), biological control agents may have a part to play in reducing potato psyllid populations in the general environment and thus reduce pest pressure.

6.5 Cultural control

It has been considered important to reduce overwintering potato psyllid populations by removing volunteer potato plants, controlling weed hosts (apple of Peru, thorn apple nightshade) and burying waste potatoes (Wallis 1946; Hill 1947).

6.6 Insecticides

A few of the insecticides recommended for the management of potato psyllids in potato crops in the United States (Cranshaw & Hein 2004) are also listed in the Novachem Agrichemical Manual (2008) to manage aphids and potato tuber moths in potato crops in New Zealand (Table 1). There are reports that carbamates do not suppress psyllid populations (Cranshaw 1985, 1989), so they have not been included in the table. Also, as mentioned previously, the invasive biotype may be less susceptible to some insecticides than the native biotype (Liu & Trumble 2007); both biotypes may be present in New Zealand.

Table 1: Insecticides listed for control of aphids and potato tuber moth (PTM) in potato crops in New Zealand, and for control of potato psyllid on potato crops overseas.

Insecticide group	For aphids and PTM on potatoes in New Zealand (Novachem Manual 2008)	For potato psyllid on potatoes grown overseas (Cranshaw & Hein 2004)
Organophosphate	Acephate, Dimethoate, Methamidophos, Phorate	Methamidophos, Phorate, Disulfoton
Neonicotinoid	Imidacloprid (seed treatment)	Imidacloprid (± synthetic pyrethroid [cyfluthrin]), Thiamethoxam (both for soil and foliar treatments)
Neonicotinoid + synthetic pyrethroid		Imidacloprid + cyfluthrin (foliar application)
Synthetic pyrethroid	Cytokinin, Deltamethrin, Lambda-cyhalothrin	
Pyridine azomethine	Pymetrozine	
Macrocyclic lactone	Spinosad	
Benzotriazine organothiophosphate	Azinphos-methyl	
Organochlorine	Endosulfan	Endosulfan

6.7 What further research could be done and why?

6.7.1 Current research

Currently, studies are being undertaken in New Zealand by CFR and MAF to:

- Confirm the transmission of Liberibacter by the potato psyllid (CFR);
- Establish colonies of potato psyllids that are Liberibacter-positive and Liberibacter-negative (CFR);
- Establish the proportion of potato psyllids that are infected with Liberibacter in psyllid populations (CFR);
- Investigate whether Liberibacter can be seed-transmitted (MAF);
- Investigate whether the potato psyllid can transmit Liberibacter infections from infected tomato fruit to uninfected plants (MAF, CFR);
- Establish the potato psyllid biotype(s) present in New Zealand (CFR);
- Test the effectiveness of insecticides on the NZ potato psyllid populations (CFR);
- Identify effective potato psyllid natural enemies (CFR).

6.7.2 Future work

Future studies and plans could include:

- Investigate whether other pest species such as aphids, thrips and whitefly can vector Liberibacter . **Rationale:** Establish the extent that the bacterium can be spread (i.e. will managing the psyllid be enough to limit the spread of the bacterium?)
- Establishing effective action thresholds – within a sector (i.e. for potato growers) and across sectors (i.e. on a regional basis). **Rationale**: Markets are unlikely to tolerate continued prophylactic use of insecticides. This is also a critical step toward including the psyllid in an IPM programme.

- Establishing the breeding and feeding host plants in New Zealand to minimise build up of psyllid populations.
- Identifying environments and conditions suitable for the psyllid to overwinter in New Zealand (links with host plants). **Rationale**: As with breeding hosts, this is important in understanding how to minimise build up of psyllid numbers.
- Development of the psyllid (individuals (i.e. lifecycle) and populations) in laboratory studies (lifecycle, minimum and maximum temperature developmental thresholds), field crops and greenhouses. **Rationale**: This links with overwintering above, providing us with important information on where the psyllid may overwinter in New Zealand, what climatic conditions lead to outbreaks, how many generations would be expected each year, how soon a population could re-infest or build up from low numbers (e.g. after spraying), etc.
- Identifying the host plant range of Liberibacter. **Rationale**: Provides important information as to what cultivated plants may be impacted by this bacterium and which plant species may act as a reservoir for the bacterium.
- Determining which potato cultivars in New Zealand are more tolerant (or if any are resistant) to psyllid infestations. **Rationale**: Reduce insecticide use.
- Developing an insecticide resistance management programme for potato psyllids. **Rationale**: The potential exists for the psyllid to develop resistance to insecticides.
- Coordinate research efforts across produce sectors potentially impacted by the psyllid. **Rationale**: The potato psyllid not only attacks potatoes but is a pest of many important solanaceous crops, including tomatoes, peppers, eggplant, and tamarillos. It will be important to work co-operatively with these sectors to maximise research initiatives.

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