Investigation into the entry pathway for tomato potato psyllid *Bactericera cockerelli*

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Abstract The tomato potato psyllid (TPP) *Bactericera cockerelli* (Hemiptera: Trioizidae) was first notified to the New Zealand Ministry of Agriculture and Forestry (MAF) in May 2006, although it has been suggested by several authors to have been present in New Zealand in 2005. MAF undertook an entry pathway analysis during the initial investigation into TPP in 2006. TPP is a vector of the bacterium-like pathogen *Candidatus Liberibacter solanacearum* ('liberibacter') and MAF further analysed the entry pathway of TPP during the liberibacter incursion response in 2008. This paper summarises the data and reasoning behind the conclusion that TPP was most plausibly introduced to New Zealand as a result of smuggling, rather than through slippage on regulated pathways.

INTRODUCTION

Tomato potato psyllid (TPP) *Bactericera cockerelli* (Sulc) (Hemiptera: Trioizidae) was first reported in New Zealand in May 2006 and is now established throughout the North Island and in most regions of the South Island, including Southland. TPP is a natural vector of the bacterium-like pathogen *Candidatus Liberibacter solanacearum* ('liberibacter'), which was first detected in New Zealand in May 2008 (Liefting et al. 2009). The TPP and liberibacter complex affects the potato, tomato, capsicum and tamarillo industries in New Zealand. It causes significant yield losses, plant mortality, decreased quality of tubers and fruit, and increased control-related costs (Teulon et al. 2009; Potatoes New Zealand 2010). The rapid spread of TPP within New Zealand is likely to be the result of a combination of natural and human-mediated dispersal (Teulon et al. 2009).

Overseas, TPP is found in the USA (Pletsch 1947), Canada (Pletsch 1947; EPPO 2009) and the Central American countries of Mexico, Guatemala and Honduras (Pletsch 1947; Abdullah 2008). Abdullah (2008) considered the presence of the crystalline honeydew, excreted in copious quantities by immature psyllids, provided an excellent indicator of psyllid infestations. Due to this readily detectable indicator of TPP presence, this insect is unlikely to remain undetected and unreported in other countries for considerable periods of time.

Candidatus Liberibacter solanacearum co-occurs with TPP in Canada, USA, Mexico, Guatemala and Honduras (EPPO 2009). However, it may also be found in the absence of TPP, for example, in carrots in Finland (Munyanza et al. 2010).

The presence of two haplotypes of TPP was suggested by Liu et al. (2006) and Jackson et al. (2009) after comparing the inter-simple sequence repeat (ISSR) markers, mitochondrial gene cytochrome oxidase I (COI) and internal transcribed spacer 2 (ITS2) of TPP from the United States, Mexico and Guatemala. During the 2008 liberibacter response, the mitochondrial gene COI sequences of five TPP specimens from New Zealand were compared with GenBank sequence data, and found to correspond with the populations of TPP from western USA rather than those of central USA and eastern Mexico (L. Kumarasinghe, MAF, unpublished data). Nelson et al. (2011) found three haplotypes of *Candidatus Liberibacter solanacearum* by analysing single nucleotide polymorphisms on the 16s rRNA, 16s/23s ISR and 50s rplJ and rplL ribosomal protein genes in 80 isolates from USA, Mexico, Guatemala, Honduras and Finland. The two liberibacter haplotypes from North and Central America were found to have a geographical distribution pattern that was segregated into the 'a' haplotype found in western USA, Mexico, Honduras and Guatemala and the 'b' haplotype found east of the Cascade mountains in the USA and east of the mountain divide in eastern Mexico. Some overlap of the two haplotypes distribution occurred, especially in Texas. Nelson et al. (2011) considered this geographical distribution pattern to be similar to the segregation and distribution of the two TPP haplotypes into (1) western USA and (2) central USA and eastern Mexico reported in Liu et al. (2006) and Jackson et al. (2009). On the basis of the limited evidence available, Nelson et al. (2011) proposed that the New Zealand liberibacter sequences were consistent with its introduction, probably with the psyllid, from the western range of the psyllid in North and/or Central America.

Since the discovery of TPP and liberibacter in New Zealand there has been considerable speculation about both the method and pathway of their introduction. The incursion of TPP in New Zealand is particularly perplexing in light of the geographical distance between New Zealand from all other known distributions of the insect,

and an apparent mismatch between movements of potential risk goods (host material) and the insect's distribution.

TPP is recorded as being able to feed, shelter or overwinter on species from over 20 plant families (Knowlton & Thomas 1934; Pletsch 1947; Wallis 1955). Some plant species within the families Solanaceae, Convolvulaceae and Lamiaceae are able to support the normal development of TPP from eggs through to adults (Wallis 1955). This wide host range greatly increases the number and type of potential incursion pathways into New Zealand. For the purposes of this paper, importation pathways were assessed for risk, based on the 'unregulated' good or event status, where no intervention to limit presence or movement of TPP has occurred. This approach is similar to the assessment method in international pest risk assessments, such as the Biosecurity Australia (2009) report on *Candidatus Liberibacter solanacearum*. This paper documents the New Zealand Ministry of Agriculture and Forestry's (MAF) investigation and analysis to date of potential incursion pathways for TPP.

METHODS

Location analysis of positive sites in 2006

During the MAF investigation into TPP in 2006, the location of infested sites, the distribution and relative population size of TPP within these sites, and the species and age of infested host plants were recorded. From these data, modes of domestic spread and timeframes of introduction could be hypothesised. The justification for this analysis is that newly introduced species may continue to achieve domestic spread by the same or similar means as the original pathway of establishment.

Pathway analysis of TPP introduction

A risk matrix was developed from published data on preferred hosts and internationally accepted risk pathway categories (FAO 2003) to analyse the 'likelihood of exposure' risk in New Zealand. The following pathways of introduction have been considered in this paper: infested primary host nursery stock or fresh produce, casual or

hitchhiker transport on other nursery stock or fresh produce, casual or hitchhiker transport on inanimate or non-plant material, natural long distance dispersal by wind or flight and accidental or intentional release of a TPP population on smuggled plant material.

All nursery stock and fresh produce legally imported into New Zealand are required to undergo prescribed mitigation measures to reduce the likelihood of new insect species entering New Zealand. These measures are verified by MAF on arrival in New Zealand.

Different pathways will have different levels of probability of subsequent establishment of TPP in New Zealand and this was assessed qualitatively. 'Nursery stock' is defined as all plant material that forms a propagative unit, including whole plants or parts of plants, for example, cuttings, scions, budwood, marcots, off-shoots, root divisions, bulbs, corms, tubers, rhizomes and plants *in vitro* (tissue culture), or viable laboratory specimens. All fruit, vegetables, edible tubers and bulbs that are imported for consumption, cut flowers or foliage of plant material imported for fresh use by the florist industry are defined as 'fresh produce'.

Risk goods

Goods that may provide refuge for TPP or effect the movement of TPP from one location to another are termed 'risk goods'. Plant species (hosts) or produce originating from these species (goods) were grouped according to their taxonomic classification of plant family and assigned to one of four categories in the following order of precedence: (1) Plant families that contain any species reported as able to support the development of TPP eggs through nymphal development to fecund adulthood are described as 'primary or breeding hosts'. (2) Plant families that contain any species where TPP is observed to feed and lay eggs, but young fail to mature, are described as 'secondary hosts'. (3) 'Tertiary hosts' are plant families on which TPP has been observed as feeding or overwintering on any species. (4) All other plant families were classified as having 'no known association' with TPP.

Assumptions

In evaluating these potential pathways and risk goods, a number of assumptions were made: (1) New Zealand has suitable climatic conditions for the rapid increase of TPP populations. (2) Because the TPP populations were largely confined to equally favourable controlled environments in the Auckland region at the time of first reporting in May 2006, TPP is unlikely to have been introduced prior to 2002. (3) Because of the observed rapid rate of establishment in glasshouses and outdoor crops as TPP has spread southwards since 2006, it is considered most likely that TPP was introduced during the period 2004 to 2005. (4) Based on the limited genetic analysis of *liberibacter* and TPP to date, the source of the New Zealand incursion of TPP was most likely western USA. (5) Other countries receiving risk goods from North and Central America will have quarantine intervention strategies similar to those of New Zealand. (6) Although TPP eggs and nymphs are difficult to detect, the waste sugars produced by both the adults and nymphs, and the adults themselves are readily detected visually and by trapping of adults. (7) The combination of rapid population increase in favourable climates (including glasshouses) and the relative ease with which TPP is detected suggests that a TPP presence in susceptible countries would become apparent within a short period of time and this would be reported through official channels.

There were five assumptions around nursery stock and fresh produce. (1) TPP adults demonstrate host preferences among primary host plant species. (2) Nursery stock represents a higher risk than fresh produce, as nursery stock of primary host species supports all life stages of the psyllid. (3) The conditions (temperature and humidity) during transportation of either nursery stock or fresh produce are unlikely to adversely affect TPP survival (eggs, nymphs or adults). (4) TPP eggs are stationary and nymphs have very limited mobility. Eggs and nymphs on secondary nursery stock host material, or on the fresh produce from either primary or secondary host plants, would need to be placed directly on primary host plants to be able to transfer to

and establish in the new habitat. (5) TPP adults are highly mobile and could readily find new hosts, although this is balanced by fresh produce packing and handling procedures that encourage adults to move off host material prior to export. Natural dispersal assumptions included (1) Dispersal through natural flight or wind will result in a sequence of detections that correlates with meteorological and/or geographical information, and (2) Recently established populations of TPP would be readily detected by the presence of psyllid sugars and observation of nymphs and adults on host plants.

There were two assumptions relating to accidental release from smuggled plant material. (1) There was/is no incentive or driver to intentionally introduce TPP to New Zealand. (2) There was/is limited incentive or driver to intentionally smuggle these specific types of primary host plant material as nursery stock, seed and fresh produce are routinely imported through standard legal pathways. In addition, systems exist to assess and regulate individual importation requests.

New Zealand fresh produce and nursery stock importations from the USA

Data on consignments of fresh produce and nursery stock imported to New Zealand from the USA between 2002 and 2005 were extracted from NZ MAF QuanCargo database and compared to known host association records. Because volume information was not able to be converted into a standard measure, and/or the value information was not available for some records, the data were collated as the indicative only value of 'consignments'. When examining the results for importation data, the treatments and risk mitigation measures that were applied to these goods at the New Zealand border are discussed.

Fresh produce and nursery stock export data from the USA

To assess pathways for fresh produce and nursery stock, USA agricultural export data and New Zealand fresh produce and nursery stock import data were analysed. The data set of the United

States agricultural product exports was obtained from the United States Department of Agriculture (USDA) Foreign Agricultural Service Global Agricultural Trade System (GATS) (www.fas.usda.gov/gats/default.aspx). The data were retrieved using the USA Foreign Agricultural Trade System (FATUS) categories for fresh fruit, fresh vegetables and nursery greenhouse (cut flowers and nursery stock) commodities, either in metric tonnes or thousand units, for the calendar years 2002–2005. The quantity values for exports to New Zealand were compared with exports to other world regions including Oceania, where TPP is not established.

RESULTS AND DISCUSSION

Location analysis of positive sites in 2006

The investigation following the discovery of TPP in 2006 found that the insect was present in high numbers, distributed in random, isolated clusters within tomato glasshouses at a number of Auckland sites. Within 1 month, one plant in a well-established capsicum crop in a large Taupo glasshouse and two locations in a 3 ha paddock of 'volunteer' potatoes in south Auckland were found to be infested. The presence of TPP in the latter was suggestive of natural spread, whereas the former suggested a very recent introduction, most likely resulting from human assisted dispersal. Within a short period of time, an anecdotal report of the inadvertent movement of TPP on New Zealand produced tomato seedlings was received. With multiple domestic modes of spread occurring at the time of, or soon after discovery, no obvious pathway of TPP entry into New Zealand could be inferred.

As a contrasting example, the now eradicated Florida red scale, *Chrysomphalus aonidum* (Hemiptera: Diaspididae), was first detected in Auckland in a public garden. From tracing information and further finds at other nursery sites in Auckland, it was concluded that the scale insect was being distributed to these sites through imported glasshouse-grown subtropical plants. Although no relative risk analysis was conducted, it is considered most likely that Florida red scale was introduced through imported nursery stock

(K. Thomas, MAF, unpublished data). In this case, the pattern of distribution within New Zealand and the direct link with an overseas source enabled a likely importation pathway to be identified, but in the TPP case it is not nearly so clear-cut.

Pathway analysis of legal and illegal imported risk material

Primary host nursery stock material in the absence of quarantine intervention (i.e. insecticide treatments, quarantine, and inspections) is considered to have the highest likelihood of introducing TPP. In this scenario, some proportion of primary host plants arriving in New Zealand would be infested. On receipt of the goods, the importing company or individual may then rapidly disseminate the goods throughout the country, from which there would be little impediment to TPP being able to multiply and disperse. In New Zealand, nursery stock and the plant pests that may be on such material are rapidly distributed by vehicle to a large network of plant nurseries and outlets throughout the country (McNeill et al. 2006).

Fresh produce represents a slightly less probable introduction pathway for TPP for two reasons. First, eggs and nymphs tend only to occur on fruit when pest population numbers are high (Pletsch 1947). Second, the highly mobile adults would likely move off fresh produce during normal harvesting, grading and packaging procedures (Robertson 2008). However, fresh produce may still be considered a moderate risk, as evidenced by TPP-infested consignments of yellow and red capsicums being intercepted in Hawaii from Los Angeles (HDOA E-News 2004). Similarly to nursery stock, rapid distribution of fresh produce on arrival is assured by virtue of the perishable nature of the goods. Once at the final site of consumption or waste disposal, any remaining TPP adults would readily disperse, but may find it difficult to locate new primary hosts for oviposition.

The risk of TPP establishment from non-primary host nursery stock and fresh produce is lower due to TPP's preference for primary host

material and the inability of TPP to successfully complete its lifecycle on these non-primary hosts.

Wallis (1955) reported that TPP could survive for 1-2 months (depending on the occurrence of subzero temperatures) on evergreen trees (cedar, pine, spruce). It is possible that TPP might survive on inanimate goods for a similar period of time. However, TPP adults are not likely to occur in association with inanimate objects unless the goods are in close proximity to host material or TPP adults were present in very high numbers. Once again, TPP would readily move away from such goods onto primary or other host material, particularly if packaging or handling was involved.

The factors considered in assessing the relative likelihood of natural spread and deliberate or accidental transportation of insects on smuggled material are discussed within the relevant sections later in this paper. A summary of assumed relative likelihood of TPP establishment, if unrestricted trade of defined risk goods from a country where TPP is present occurred, is shown in Table 1.

Nursery stock and fresh produce

When the imports of nursery stock are analysed according to known TPP host association, four categories of risk goods were identified based on host status of the commodity. New Zealand did not import any nursery stock of the families Solanaceae or Convolvulaceae nursery stock over the period in question (2002-2005), but did receive 12 consignments of nursery stock of the family Lamiaceae, a family known to contain a host species. All 12 primary host consignments were imported as tissue culture material. There were 59 consignments of nursery stock from plant families that act as secondary hosts (Asteraceae, Fabaceae, Malvaceae, Polygonaceae, Ranunculaceae and Scrophulariaceae) on which TPP may oviposit without successful maturation of nymphs. These secondary host consignments were tissue culture plantlets, bulbs, laboratory specimens or whole plants that were placed in post entry quarantine (eight consignments). There were a further 59 consignments of tertiary

Table 1 Assumed relative likelihood of tomato-potato psyllid (TPP) establishment in New Zealand if unregulated¹ trade occurred through various pathways.

Pathway or risk goods	Arrival in New Zealand	Distribution through network	Reproductive ability ²
Primary host nursery stock plant material	High	High	High
Primary host fresh produce	Moderate	High	Moderate
Other nursery stock species	Low	High	Negligible
Fresh produce from other species	Low	High	Negligible
Non-plant material and inanimate goods	Negligible	Low	Negligible
Natural dispersal by wind or flight directly from countries where TPP is known to be present	Negligible	High	High
Deliberate or accidental release on smuggled material	High	Low	High

¹To estimate greatest possible probability, risk goods were assessed based on the 'unregulated' good or event status, where no intervention to limit presence or movement of TPP, has occurred. The impact of quarantine measures that all nursery stock and fresh produce are required to undergo on importation to New Zealand is discussed in the text.

²Ability of TPP to produce successive fecund generations on the risk good or immediate surrounds.

hosts (Rosaceae, Salicaceae and Pinaceae) on which TPP have been recorded as feeding or overwintering. These tertiary host consignments consisted of either budwood or cuttings placed into post entry quarantine, or tissue culture material. Finally, 445 consignments of nursery stock that have no known host association with TPP (61 plant families represented) were imported during this time period. This consignment group contains lab specimens (six consignments), tissue culture and bulbs (282 consignments) and budwood or plants directed to post entry quarantine (157 consignments). The total number of consignments was 575.

If the officially required risk mitigation practices of elimination, minimisation and isolation are applied to primary host nursery stock then the risk of TPP introduction on nursery stock should be eliminated or minimised by being imported in an insect-proof manner such as tissue culture. All imported nursery stock is required to undergo one or more treatments or measures designed to minimise pest survival. For example, whole plants and cuttings or budwood must be treated with insecticide dips at the

border and subjected to post entry quarantine containment for a minimum of 3 months, during which routine inspections occur. Bulb or rhizome nursery stock is considered very unlikely to harbour TPP, while laboratory specimens are directed to containment facilities.

Analysis of the fresh produce imports received from the USA shows the risk rating for this pathway could be further lowered (Table 2). No fresh produce from the families Solanaceae, Convolvulaceae or Lamiaceae were imported from the USA over the period 2002-2005. Of the 20 plant families in which TPP associations have been recorded, only the tertiary host families Rosaceae and Fabaceae are represented in the importation data. The heavy representation of produce from the Rosaceae family (stonefruit, pipfruit and strawberries) and the associated risk of introducing TPP are negated by the high degree of quarantine scrutiny that is applied to those products because they are hosts of fruit fly (Tephritidae). The sole Fabaceae consignment was green peas, which were sampled and inspected on entry as per the routine protocol. No species from the plant families from which imported

'floral greens' are classified have been recorded as supporting the breeding, feeding or overwintering of TPP. These fresh plant products are inspected on arrival and treated if any pests are detected. For the reasons given above, the probability of TPP introduction through nursery stock and fresh produce from the USA to New Zealand is considered very low. This reasoning is similar to the findings of Frampton & Nalder (2009).

Although the comparison of general nursery stock and fresh produce export data from the USA is a relatively crude measure of the proportion of risk goods and risk of TPP introduction, it is nevertheless a useful yardstick of comparative exposure between geographical regions. By comparison with the total volume of fresh produce and nursery stock being exported from the USA between January 2002 and December 2005, the proportion directed to New Zealand is very small (0.4% fresh produce

and 0.07% nursery stock). The EU (5.5% of nursery stock, 4.1% of fresh produce), East Asia (1.5% of nursery stock, 23.5% of fresh produce), Caribbean (2.6% of nursery stock), South America (1.5% of nursery stock), South East Asia (4.8% of fresh produce) and Middle East (1.1% of fresh produce) regions all receive more than three times the volume of nursery stock and/or fresh produce than New Zealand (data source: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics). None of these countries have records of TPP presence.

The low proportion of nursery stock and fresh produce from the USA directed to New Zealand where TPP is now present, compared to the higher proportion of nursery stock and/or fresh produce directed to other regions where TPP is absent suggests there is no relationship between the volume of nursery stock or fresh produce traded from the USA and global TPP

Table 2 Consignments of fresh fruit and vegetables entering New Zealand from the United States of America, between 2002 and 2005.

Fresh produce type	Plant family	Number of consignments
Citrus	Rutaceae	1881
Stonefruit, pipfruit and strawberries	Rosaceae ¹	1353
Floral greens	Arecaceae, Elaphoglossaceae, Ericaceae, Equisetaceae, Melanthiaceae, Ruscaceae and Xanthorrhoeaceae	510
Grapes	Vitaceae	257
Asparagus	Liliaceae	169
Allium	Alliumaceae	144
Mango	Anacardiaceae	30
Pomegranate	Lythraceae	28
Dates	Arecaceae	11
Kiwifruit	Actinidaceae	9
Other vegetable	Discoreaceae and Fabaceae ¹	2
Pawpaw	Annonaceae	1
Tomatoes, capsicums etc.	Solanaceae ²	0
Mint leaves	Laminaceae ²	0
Kumara	Convovulaceae ²	0
Total		4397

¹Tertiary hosts.

²Primary hosts.

distribution. Given the limited volume of primary host plant family material and the risk mitigation measures placed on all nursery stock and fresh produce imported into New Zealand, it seems unlikely that either of these controlled pathways represented a substantial risk of introduction of TPP into New Zealand.

Natural spread as a pathway

Prior to the New Zealand incursion of TPP, this insect had not expanded its geographical range beyond Northern and Central America since the 1900s. Within that region, TPP is reported as a migratory insect, a strong flyer and able to utilise the Gulf winds and abundant host availability in North America to move from Mexico and southern USA to infest the Canadian summer crops annually (Wallis 1946; Pletcher 1947). Although this behaviour helps to explain the rapid colonisation of New Zealand once it arrived, it is inadequate to account for the natural dispersal from North and Central America across the equator to New Zealand while bypassing all countries in between.

In contrast, the leucaena psyllid (*Heteropsylla cubana*) is native to Central America and the Caribbean. Gutteridge & Shelton (1994) documented this insect's progression from 1983, when the psyllid was recorded in large numbers in Florida, on to Hawaii (April 1984), Western Samoa, Fiji (February 1985), Phillipines (October 1985), Papua New Guinea and Indonesia (March 1986), Australia (April 1986), Thailand (November 1986), India and Sri Lanka (1988), Mauritius (1991) and Reunion and coastal East Africa (1992). The authors suggested that where the rapid spread of this species was not attributable to identified human-mediated movements, air currents (high level, equatorial and/or storm related) were involved in this insect's dispersal.

Deliberate or accidental transportation of insects on smuggled material

New Zealand, like other countries, is no stranger to attempts by people to circumvent our biosecurity system. Border statistics show that passengers do not declare risk goods as required on the arrival declaration. In 2005-06, undeclared risk goods

were seized from four out of every one thousand arriving passengers (Waite 2006). Furthermore, although tools such as searching, X-rays and dogs are used to detect these undeclared risk goods, there are low levels of undeclared and undetected risk goods (slippage) through the system (Taulau & Rowsell 2010).

The likelihood of accidental or intentional introduction on host material (smuggling) can again be assessed by an examination of the potential plant families imported. Two of the primary host plant families, Lamiaceae and Convolvulaceae, may be propagated from either negligible-risk seed or high-risk vegetative material, whereas the main primary host plant family, Solanaceae, is most likely to be propagated by the low risk material of seeds or tubers. If the smuggled goods are small volumes for personal use, the immediate widespread distribution of these risk goods is likely to be low.

Within the primary host plant families, it is speculated that chilli peppers are the most likely plant material to be smuggled, as enthusiasts may be fixated on particular fruit characteristics. Smuggling is expected to be confined to the easy to conceal items of either fruit for consumption or seeds for sowing, rather than seedlings, cuttings or whole plants. Again, the considerations given to fresh produce apply: fruit are unlikely to be contaminated with eggs or nymphs unless sourced from a heavily infested parent plant and the highly mobile adults are likely to disperse prior to packaging. This scenario is considered a possible pathway if smuggled material came into close proximity to the affected glasshouses and multiple domestic distribution networks as identified by the MAF investigation in 2006.

Although there was very low awareness of this insect in New Zealand prior to its first report in May 2006, TPP is not a "collectable" species (such as a butterfly) or a beneficial insect of the kind that a person would deliberately import for economic gain. TPP could however, have been introduced into New Zealand accidentally or as a case of mistaken identity. The eggs are very small, difficult to detect and appear similar to those of lacewings (a valuable pest predator), and the early nymphal stage of TPP is similar to

the nymphs of other insects, including whitefly. New Zealand has several previous instances of individuals or groups of individuals illegally introducing new biocontrol agents. For example, in 1997 rabbit calicivirus was illegally introduced into Central Otago, while in 2010, a New Zealand company supplying biocontrol insects and a New Zealand tomato glasshouse company were convicted and sentenced for the deliberate importation, breeding and distribution of the predatory mirid bug, *Macrolophus pygmaeus* (Heteroptera: Miridae). Given the presence of related commercial interests in the Auckland region and proximity to associated distribution networks, this is a possible entry pathway.

CONCLUSIONS

Although a definitive pathway of entry for TPP could not be explicitly identified, this paper has documented the current assessment that (1) New Zealand's TPP originated from western USA, (2) the original site of establishment in NZ is unclear, (3) the likelihood of introduction on legally imported nursery stock is unlikely, (4) the likelihood of introduction on fresh produce is unlikely, (5) the likelihood of introduction by natural dispersal is negligible, and (6) TPP might plausibly have been introduced by the smuggling of primary host material.

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