Prevalence of tomato potato psyllid (*Bactericera cockerelli* Sulc) on red capsicum fruit in choice and no-choice tests

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Abstract Tomato potato psyllid (TPP; *Bactericera cockerelli*) was first recorded in New Zealand in 2006. Exports to Australia must be fumigated with methyl bromide (MB) to comply with New Zealand's phytosanitary export certification requirements. Fumigation reduces the quality of the capsicums. In tests using high densities of TPP adults, TPP laid eggs mainly on the top of the calyx and the stem and some on the body of the fruit, although far fewer eggs than were laid on tomato or capsicum leaves. Given the choice between capsicum fruit body, stem and calyx or capsicum leaves, 99.2–99.5% of eggs were laid on leaves. Nymphs that hatched from the few eggs laid on the calyx and stem did not survive, indicating that capsicum fruit are a poor host for TPP. No eggs were laid beneath the capsicum calyx. Some exported capsicums are washed using high pressure washing equipment, which might dislodge TPP eggs. The very low incidence and survival of TPP on capsicum fruit could result in this fruit already meeting or exceeding the phytosanitary requirements of the importing country.

Keywords *Bactericera cockerelli*, risk assessment, oviposition, methyl bromide fumigation, capsicum, quarantine.

INTRODUCTION

New Zealand fresh capsicum (*Capsicum annuum* L.) exports were valued at NZ\$32 million in 2014. Exports to Japan and Australia comprise 98% of all capsicum exports (Market Access Solutionz 2014; Aitken and Hewett 2014). Tomato potato psyllid (*Bactericera cockerelli*; (Sulc) Hemiptera: Trioziidae, TPP) is a quarantine pest in both of these major markets as it is a serious pest of solanaceous crops around the world (Liu & Trumble 2004) and, since its arrival in New Zealand, it has resulted in more stringent phytosanitary export certification requirements (Teulon et al. 2009). Capsicums exported to Australia must be fumigated in New Zealand with methyl bromide (MB) prior

to export to control TPP (MPI 2016), which can reduce the quality of capsicums on arrival in Australia (E.M. O'Donoghue, Plant & Food, Palmerston North, personal communication). Capsicums exported to Japan must be inspected and found free of TPP (MPI 2015). If TPP is intercepted during inspection on arrival in Japan, the consignment must be fumigated with MB, destroyed or re-shipped. MB has been phased out globally for most of its uses, although quarantine and pre-shipment (QPS) uses are currently exempt phase out under the Montreal Protocol (UNEP 2012), while some regions such as Europe have banned all uses of MB including those used for QPS.

Alternative methods of meeting the stringent phytosanitary requirements for TPP on exported capsicums are currently being considered. Ethyl formate is effective against nymphs and adults. However, the fumigant concentrations and exposure periods required to control eggs significantly reduced capsicum quality (Jamieson et al. 2015). High pressure washing (HPW) has also been shown to remove mealybugs and aphids artificially-infested on capsicums (Jamieson et al. 2010; Page-Weir et al. 2015). In general, in cases where an export commodity is not a preferred host for the pest, it is possible that a further disinfection may not be required when the exports already meet or exceed the phytosanitary standard.

Growers, researchers and industry representatives have not observed TPP on the fruit, stem and calyx of capsicums. However, TPP infestations were frequently observed on the leaves of capsicum plants. There appears to be no published records of TPP on capsicum fruit. The objective of this research was to determine the propensity of TPP to lay eggs on capsicum fruit, calyx and stem when no other material is available for oviposition and, if so, to compare the oviposition potential and nymph survival of TPP on the capsicum fruit, calyx with eggs laid on capsicum leaves.

MATERIALS AND METHODS

In all experiments, fresh capsicums were obtained over an 8-month period from commercial growers that infrequently exposed the growing fruit to insecticides. The capsicums were grown in glasshouses and processed through a HPW system after harvest.

Potential for TPP to lay eggs on capsicum fruit, stem and calyx

To determine if TPP lays eggs on capsicum fruit body, calyx and stem, 20 groups of 50 TPP adults were placed with 20 red capsicums i.e. 50 TPP per capsicum. The TPP were obtained from a colony maintained on capsicum plants at Plant & Food Research, Auckland. TPP (sex ratio 50:50) on capsicums were contained in individual cages

made of a fine mesh fabric with the fruit supported by a plastic container (10 cm height, tapering from 10.5 cm diameter at the top to 8.5 cm at the base). All cages were closed with a twist tie and stored at 20°C, 16:8h light:dark cycle. The TPP were left for six days which was considered sufficient time for adults to lay eggs. The total number of adults and eggs on each fruit were counted on the seventh day. The number of the eggs laid on the fruit body, stem or calyx were recorded. Fruit with TPP eggs were kept at 20°C for a further nine days after which the number of eggs that had hatched and the number of live nymphs were recorded.

No-choice tests: Oviposition and survival of hatched nymphs on capsicum fruit, stem or calyx or tomato leaves

The number of eggs laid on capsicum fruit body, stem and calyx was compared with the number of eggs laid on tomato leaves. Tomato leaves were chosen because they last longer than capsicum leaves once excised from the living plant. The survival of nymphs that hatched from eggs laid on capsicum fruit and tomato leaves was also compared. At least 60 TPP were collected from a TPP colony and placed with each of 107 freshly harvested capsicum fruit. TPP on capsicum fruit

Figure 1. The number and location (stem, top of calyx, body of fruit) of tomato potato psyllid eggs found on each of the 20 capsicums after six days exposure to 50 TPP adults (approx. 50:50 sex ratio) at 20°C.

were contained as described above, then placed at 20°C for 7 days to allow sufficient time for the adults to lay eggs. At least 60 TPP adults were similarly collected and placed with an excised tomato leaf as described by Jamieson et al. (2015). At the end of seven days, adults were removed and counted and any eggs counted. Capsicums with eggs were kept for a further two weeks and the number of hatched eggs and living nymphs recorded and monitored daily until they died.

Choice tests: Oviposition on capsicum fruit, stem and calyx or capsicum leaves

To determine TPP oviposition preference, TPP were given a choice of laying on excised capsicum fruit, or capsicum leaves growing on a small capsicum plant kept in a vented plastic cage (30 cm high, 22 cm diameter). A small capsicum plant was placed inside each cage next to an upturned pot with a capsicum fruit on it, so that the fruit was at a similar height to the living plant. Twenty adult

TPP were placed into each cage. Twenty cages containing a capsicum fruit, a capsicum plant and TPP adults were established. Cages were placed at 20°C for seven days which was sufficient time for the adults to lay eggs. Adults were then removed and sexed and the number of eggs laid on capsicum leaves of the plant and capsicum fruit were recorded as eggs per female. Capsicums with eggs were kept for a further 7-9 days weeks. During this time the number of nymphs was recorded and the nymphs monitored daily until they died.

RESULTS
Potential for TPP to lay eggs on capsicum fruit body, stem and calyx

Of the 20 capsicums exposed to a total of 1000 TPP, a total of 109 eggs were laid on 14 capsicums over the six day exposure to TPP adult females (Figure 1). The total number of eggs on each fruit ranged from 1 to 38, with most fruit having

Table 1 A comparison of the number of tomato potato psyllid eggs laid on either tomato leaves or capsicum fruit, (including stem and calyx) in no-choice tests after a 7 day exposure to at least 60 TPP adults and the average egg hatch and survival of hatched nymphs.

Substrate	Total no. eggs laid	Total number of leaves or capsicums	Mean no. eggs laid per leaf or capsicum	Mean no. eggs/female adult ¹	Mean percentage egg hatch	Mean percentage nymph survival 2 weeks after adults removed
Tomato leaves	7940	20	397.0 ± 43.2	7.94 ± 0.91	80.3 ± 5.5	72.2 ± 5.9
Capsicum supply* 1	1085	25	43.4 ± 4.3	0.61 ± 0.07	61.6 ± 2.4	0
Capsicum supply* 2	61	35	1.7 ± 0.4	0.03 ± 0.01	87.2 ± 6.7	0
Capsicum supply* 3	559	23	24.3 ± 2.5	0.60 ± 0.06	73.4 ± 7.8	0
Capsicum supply* 4	591	22	26.9 ± 3.1	0.85 ± 0.10	54.4 ± 2.7	0

¹Estimated 50:50 sex ratio; *Commercial suppliers

Table 2 Mean number of tomato potato psyllid eggs laid on capsicum fruit (including stem and calyx) or capsicum leaves growing on a small capsicum plant when exposed to 20 TPP adults for 7 days.

	Total no. eggs laid	Mean no. eggs laid per cage	Mean no. eggs laid per female ¹	Mean no. eggs laid per fruit	Mean no. eggs l aid per plant	Mean % eggs aid on plant
Trial 1	2103	105.2 ± 23.2	12.1 ± 2.1	0.3 ± 0.3	104.9 ± 23.3	99.2 ± 0.8
Trial 2	2196	109.8 ± 20.7	11.0 ± 1.7	0.7 ± 0.4	109.2 ± 20.7	99.5 ± 0.4

¹Estimated 50:50 sex ratio

1–3 eggs after six days’ exposure to a high density of 50 TPP adults. The preference for oviposition location was stem>calyx>body of fruit, with only a single egg found on the body of one of the 20 fruit. No eggs were found under the calyx of any fruit. Seven to nine days after the first assessment, all nymphs that had hatched were dead.

No-choice tests: Oviposition and survival of hatched nymphs on capsicum fruit body, stem and calyx or tomato leaves

Female TPP laid 10–234 times more eggs on tomato leaves (mean of 397 eggs per leaf, mean of 8 eggs per female) than on the stem and calyx of capsicum fruit (means of 2–43 eggs per capsicum, means of 0.03–0.85 eggs per female) over a 7-day period (Table 1). No eggs were laid on the body of the capsicum fruit. The mean percentage egg hatch from eggs laid on either capsicum leaves or fruit ranged from 54–87%. No nymphs survived from hatched eggs laid on the capsicum stem and calyx, when assessed two weeks after the adults were removed, compared to 72% of the nymphs surviving from eggs that hatched on capsicum leaves.

Choice tests: Oviposition on capsicum fruit body, stem and calyx or capsicum leaves

When TPP female adults were given the choice of laying eggs on either capsicum fruit body, stem and calyx, or leaves growing on capsicum plants, 99.2–99.5% of the eggs were laid on the capsicum leaves (Table 2). Of 4,299 eggs laid, only 19 of them were on the capsicum stem and calyx. All of these eggs were laid on the top of the calyx and stem of the capsicum. No eggs were

laid under the calyx or on the body of the fruit.

DISCUSSION

In tests using high densities of TPP adults, TPP oviposited mainly on excised tomato leaves or growing capsicum leaves and rarely on the stem and calyx of capsicum fruit. No eggs were laid on the body of the fruit. Nymphs that hatched from eggs laid on the stem or calyx did not survive, indicating that exported capsicum fruit are unlikely to support TPP survival. We conclude that capsicums are a poor host. The prevalence of TPP on commercially-grown capsicums, with much lower densities of TPP than tested here, is likely to be extremely low or even negligible.

No eggs were laid beneath the calyx of fruit, where it is very difficult to remove pests. It is likely that the tight space under the calyx restricts TPP access for oviposition. Since all TPP eggs were laid on the top of the calyx and on the stem of fruit, mechanical disinfestation such as HPW has the potential to remove TPP eggs (Jamieson et al. 2010; Page-Weir et al. 2015).

Our results indicate that capsicum fruit are a poor host for TPP, which could be taken into account when considering the export certification requirements for this pest on capsicums exported to Australia. Occasional insecticide use combined with HPW has the potential for a systems approach, which will reduce the already low risk of TPP on export capsicums. Trials are currently underway to determine the efficacy of HPW in removing TPP eggs and nymphs.

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