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Efficacy of ethyl formate against tomato/potato psyllid

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August 2013

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Background

In 2006 tomato/potato psyllid (TPP; *Bactericera cockerelli*) was first recorded in New Zealand and subsequently mandatory fumigation with methyl bromide for crops such as capsicums and tomatoes was required for export to Australia. This was later removed for loose tomatoes with no calyx; however, truss tomatoes and capsicums still require methyl bromide fumigation before export, which detrimentally affects the quality of the product because of increased rots and the browning of the green stems. Many exporters are simply no longer exporting capsicums and truss tomatoes, as the quality impacts of methyl bromide means that export is no longer economically viable. Therefore, alternative treatments that maintain good fruit quality are required.

Alternative treatments might be in the form of a single treatment or a systems approach using multiple independent risk reduction measures. There are a range of potential options (e.g. high pressure water-washing, heat, cold), but fumigation of the final packed product is a preferred option for the capsicum and tomato exporters. Ethyl formate (EF) is a ‘generally recognised as safe’ (GRAS) compound which is being developed to disinfest a range of fresh produce from a range of pests.

This report outlines the initial trials to develop EF + CO_2 as a postharvest disinfestation treatment for capsicums and truss tomatoes, by determining which life stage of TPP is the most tolerant to EF + CO_2 and what lethal EF concentrations are required to control TPP.

Methods

Two trials were carried out, In the first preliminary unreplicated trial, TPP eggs, nymphs and adults were exposed to a range of concentrations of EF + CO_2 for 1, 2, 3 or 4 hours using the volatile treatment facility at PFR Auckland. A 1-hour exposure time was chosen and all life stages were exposed to a range of concentrations of EF to determine the lethal concentration required to control TPP.

Results

Eggs were the most tolerant life stage to ethyl formate treatment. Complete prevention of egg hatch (100% mortality) was achieved using a 1-h exposure to 1.19% EF. Adults and nymphs were more susceptible and were killed after a 1-h exposure to 0.06% and 0.12% EF, respectively. Calculated mean lethal concentrations for 99% mortality (LC_{99}) for eggs and nymphs were 0.81% and 0.07% EF, respectively. LC_{99}s were not calculated for adults, as there were not enough mortality points below 100% to provide a statistically robust value.

Conclusion and recommendations

TPP are susceptible to ethyl formate treatment and after the fruit quality trials are completed and reported, a decision needs to be made whether to proceed with the development of ethyl formate as a disinfestation treatment for capsicums and truss tomatoes.

The next steps include:

- Complete fruit quality and EF sorption studies
- Conduct TPP mortality trials using selected EF concentrations and treatment times required to achieve the required mortality (TBD by AQIS/MPI) in the presence of fruit (using commercial load factors), to demonstrate required treatment efficacy and maintenance of acceptable fruit quality
- Scale up treatment to semi-commercial volumes to demonstrate treatment efficacy on a larger scale
- Demonstrate the low prevalence occurrence of TPP life stages on the fruit and stem of capsicums and truss tomatoes.

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1 Introduction

In 2006 tomato/potato psyllid (TPP; *Bactericera cockerelli*) was first recorded in New Zealand and subsequently mandatory fumigation with methyl bromide for crops such as capsicums and tomatoes was required for export to Australia. This was later removed for loose tomatoes with no calyx; however, truss tomatoes and capsicums still require methyl bromide fumigation before export, which detrimentally affects the quality of the product because of increased rots and the browning of the green stems. Consequently many exporters are simply no longer exporting capsicums and truss tomatoes, as the quality impacts of methyl bromide means that export is no longer economically viable. Therefore, alternative treatments that maintain good fruit quality are required. The value of an alternative treatment to the industry is outlined in Appendix 2.

Alternative treatments might be in the form of a single treatment or a systems approach using multiple independent risk reduction measures. There are a range of potential options (e.g. high pressure water-washing, heat, cold), but fumigation of the final packed product is a preferred option for the capsicum and tomato exporters. Ethyl formate (EF) is a 'generally recognised as safe' (GRAS) compound and is therefore considered safe for use with human food and may be excluded from mandatory premarket approval. It is being applied commercially as a disinfestation treatment for fresh produce, such as bananas and pineapples, and has been identified as a promising methyl bromide replacement for fresh produce. EF is flammable and explosive when mixed with air at concentrations required to be introduced into an area to kill pests. However, formulations in CO_2 (commercially available as VAPORMATE™) or delivery systems using other inert gases such as nitrogen reduce this risk to an acceptable level.

To add EF + CO_2 as an approved treatment for fresh produce export pathways such as capsicums and truss tomatoes to Australia, New Zealand MAF and Department of Agriculture, Fisheries and Forestry (DAFF) require an extensive, scientifically robust pest mortality dataset that shows that ethyl formate + CO_2 treatment is as effective as methyl bromide fumigation.

This report outlines the initial trials to develop EF + CO_2 as a postharvest disinfestation treatment for capsicums and truss tomatoes, by determining which life stage of TPP is the most tolerant to EF + CO_2 and what lethal EF concentrations are required to control TPP.

Further trials to determine the tolerance of capsicums and truss tomatoes to EF + CO_2 and the sorption of ethyl formate by capsicums and truss tomatoes were undertaken in PFR CORE projects and will be reported separately (Woolf et al. in prep).

2 Methods

An initial small-scale trial found that tomato/potato psyllid (TPP) survived well on tomato leaves and laid high numbers of eggs when adults were placed into containers with a single leaf.
An additional benefit was that the cut tomato leaves lasted longer than capsicum leaves. The decision to use leaves instead of plants was made because of: 1) control of plant material quality; 2) control of TPP numbers v. simply collecting infested leaves from a colony; 3) ease of replication v. growing large numbers of plants.

2.1 Establishment of insects prior to treatment

Tomato leaves (‘Moneymaker’) were collected from 8-week-old plants. Leaves that were 3-4 nodes below the growing tip were selected. The cut end of each leaf was then placed in a 5 mL glass vial of water and the top enclosed with cotton wool. Each leaf was then placed within a graduated plastic pottle (10 cm L x 8-11 cm W), with mesh at each end to allow for ventilation and later for fumigation (Figure 1).

Figure 1. An excised tomato leaf within a plastic pot with mesh ventilation at the base and lid.

Since eggs and early nymphs cannot be transferred onto leaves without causing damage, the following method was used. Pots were set up with a single tomato leaf as described above. Fifty adult TPP of mixed sex were collected and placed in each pot with a single tomato leaf to lay eggs for 7 days. After 7 days, all adults were removed and the leaves placed at 20°C. Pots set up in this way 2 weeks before treatment had egg hatch resulting in early instar nymphs at the time of treatment. Pots set up 7 days before treatment had eggs of various ages for treatment. Before treatment, each leaf was assessed to ensure that there were 100+ nymphs, or eggs, on each leaf.

Late nymphs can be easily transferred by hand using a fine-tipped paintbrush. Using this method, 100 late instar nymphs were placed on each leaf in a pot.

A vacuum aspirator was used to collect 100 adults of mixed sex. The adults were then placed into each pot with a single tomato leaf.

Each pot contained one of the following TPP life stages (Figure 2):

- Eggs (32 pots; 100+ eggs each)
- Early nymphs (first, second, third instar; 32 pots; 100+ nymphs each)
- Late nymphs (fourth, fifth instar; 32 pots; 100 nymphs each)
- Adults (32 pots; 100 adults each).

Figure 2.Tomato/potato psyllid nymphs (left) and adults with eggs (right).

All infested leaves were placed at 20°C, 16:8 h (light:dark) until treatment.

2.2 Treatments

The EF treatments were carried out in the Volatile Treatment Facility (VTF) at Plant & Food Research in Auckland. Fourteen identical 76.8-L steel gas-tight chambers were used for this trial in a controlled temperature room. The amount of EF and CO_2 delivered to each chamber was controlled by the user input into the computer program. A CO_2 gas stream (10 L/min) was passed through a heated bead bath (75°C) and liquid EF was delivered using a micro-dispenser into the heated gas stream. The gas was again passed through the heated bead bath to volatilise the EF before delivery to the chamber. The chambers filled automatically consecutively and were purged of EF once the treatment time was completed. EF was monitored in each chamber, with 50-µL samples taken from the chamber and injected into a gas chromatograph unit. The measured concentrations of EF, O_2 and CO_2 during the treatments are presented in Table 1.

2.2.1 Trial 1: TPP life stage tolerance trial

A preliminary single replicate trial was carried out to define the mortality response of various life stages of TPP exposed to six concentrations of EF + CO_2 (EF) for each of four durations (1, 2, 3, 4 h) at 13°C in 76-L chambers. This was to enable an appropriate duration and range of concentrations to be selected for the TPP life stage tolerance test.

All life stages of TPP were set up in the same method as described above. After treatment insects were held at 20°C, 16:8 h (light:dark) until assessment.

2.2.2 Trial 2: Replicated trial

Based on the results from the preliminary trial, all life stages of TPP were exposed to a 1-h treatment of one of 10 concentrations of EF + CO_2 at 13°C in 76-L chambers. Nymphs and adults were exposed to targets of 0.05, 0.1, 0.15, 0.2% EF and the more tolerant egg stage was exposed to targets of 0.5, 0.8, 1.0, 1.3, 1.6, 2.0% EF (Table 1). Four replicates (i.e. chambers) of each treatment were carried out. After treatment, the TPP were held at 20°C and the number of live and dead recorded.

2.3 Mortality assessment

All nymphal life stages and adults were assessed 1 day after treatment. Any nymphs or adults that had movement when gently prodded with a fine-tipped paintbrush were classified as live. Those that showed no movement were classified as dead.

Leaves with treated and untreated TPP eggs were kept at 20°C for 14 days before assessment. During that time the water in the vials was replenished as needed, and fresh non-infested leaves provided in each pot for any hatching nymphs to feed upon. Egg assessment was classified as hatched if a newly emerged nymph was present, or unhatched if an entire egg remained.

2.4 Statistical analyses

The TPP mortality data were analysed and presented in figures based on actual EF concentrations rather than target concentrations. The effect of EF on the mortality of TPP was analysed using a robust version of the Generalized Linear Model (GLM) capabilities (Hastie et al. 1992) in R version 2.15.2 (R Core Development Team 2013). Variance was assumed proportional to that for a binomial distribution. The analysis assumed that the form of dependence of mortality on concentration was that given by a complementary-log-log model, with concentration as the explanatory variable. The assumed form of response was log(-log (1-p)) = a + bc, where p = expected mortality, and c = concentration of EF.

From the derived coefficients, the LC_{99} (calculated lethal concentration) or the concentration required to produce a mortality of 99%, was calculated with adjustment for sources of mortality other than EF. Two possible sources of extraneous mortality were considered: handling, and treatment with CO_2. The mortalities attributed to these sources were compared using a simpler binomial GLM and found not to be significantly different. Therefore, the handling control and treatment control mortality data were combined and used as the control mortality, cm, in the calculation of the LC_{99} values, cm + (1 - cm) x 0.99. The geometric means of the four replicates for each life stage were calculated along with a 95% confidence interval.

For mortality response figures (Figures 3 and 4), non-parametric loess fits (Cleveland et al. 1992) were calculated and plotted on an arcsine scale in R. Smooth lines were drawn through the mean percentage mortality points for each TPP life stage-treatment duration combination after exposure to EF + CO_2, at each concentration. The error bars represent the root-mean-square of the errors of the fit and are applicable over the entire mortality range, which would not be the case if calculated on a binomial scale.

3 Results

3.1 Treatment conditions

The measured EF concentrations were less than the target. This is probably because of EF condensing in pipes and in the chamber, loses through exhaust while introducing EF (which is required to avoid pressurisation), and sorption of EF by contents of chamber (plant material and containers). Actual EF measured was used when comparing mortality/dose responses of TPP.

Table 1: Target and measured treatment conditions for tomato/potato psyllid: ethyl formate (EF), carbon dioxide, oxygen concentrations, and temperature.

%EF target	Mean %EF initial (SEM)	Mean %EF final (SEM)	$\%CO_2$ (SEM)	$\%O_2$ (SEM)	Mean temp (SEM)
0.05	0.04 (0.003)	0.04 (0.009)	0.82 (0.158)	21.50 (0.204)	14.69 (0.006)
0.1	0.06 (0.003)	0.05 (0.005)	1.06 (0.008)	21.87 (0.172)	14.69 (0.006)
0.15	0.09 (0.003)	0.08 (0.005)	1.52 (0.021)	21.42 (0.233)	14.69 (0.006)
0.2	0.12 (0.005)	0.10 (0.003)	1.82 (0.021)	20.92 (0.115)	14.69 (0.006)
0.5	0.35 (0.015)	0.30 (0.035)	3.31 (0.109)	20.36 (0.448)	14.69 (0.006)
0.8	0.59 (0.029)	0.49 (0.048)	5.45 (0.119)	19.38 (0.842)	14.69 (0.006)
1.0	0.75 (0.040)	0.65 (0.050)	6.97 (0.109)	19.62 (0.675)	14.69 (0.006)
1.3	0.85 (0.052)	0.54 (0.081)	7.76 (0.747)	19.25 (0.665)	14.69 (0.006)
1.6	1.19 (0.041)	0.90 (0.108)	10.15 (0.186)	18.83 (0.325)	14.69 (0.006)
2.0	1.51 (0.019)	1.22 (0.055)	12.20 (0.103)	17.85 (0.437)	14.69 (0.006)

3.2 Preliminary trial

In the preliminary trial all 3253 adults, 2116 late nymphs and 4931 early nymphs were killed by treatments between 0.15 and 2.55% EF (Appendix 1). Eggs were the most tolerant life stage to ethyl formate treatment. Complete prevention of egg hatch (100% mortality) was achieved using a 1-h exposure to 1.8% EF, a 2-h exposure to 1.1% EF, a 3-h exposure to 1.7% and a 4-h exposure to 0.6% EF (Table 2, Figure 3). Calculated lethal concentrations for 99% mortality for a 1- to 4-h treatments were between 0.51 and 1.87% in the single replicate preliminary trial (Table 3). A 1-h treatment time was selected for the replicated trial.

Table 2. Percent mortalities of tomato/potato psyllid (TPP) eggs treated with 0.15-2.60% ethyl formate (EF) for 1, 2, 3, or 4 h in preliminary trial.

Treatment Time (h)	Measured EF conc. (%)	% mortality	n
1	Handling control	0	50
	CO_2 control	2.63	76
	0.15	7.21	111
	0.29	20.62	97
	0.61	86.67	60
	1.20	98.38	185
	1.81	100	239
	2.54	100	137
2	Handling control	16.56	157
	CO_2 control	4.39	205
	0.16	4.26	94
	0.31	18.75	128
	0.58	95.00	20
	1.08	100	72
	1.70	100	51
	2.30	100	82
3	Handling control	0	190
	CO_2 control	7.88	165
	0.15	21.74	69
	0.32	61.54	221
	0.58	97.59	166
	1.23	99.42	171
	1.70	100	131
	2.60	95.24	63
4	Handling control	4.35	69
	CO_2 control	6.4	125
	0.22	58.62	29
	0.27	50	32
	0.58	100	144
	1.24	100	328
	1.77	100	61
	2.55	100	165

Table 3. Estimated lethal concentration calculated to achieve 99% mortality (LC_{99}) of tomato/potato psyllid eggs using concentrations between 0 and 2.6% ethyl formate (EF).

Treatment time	LC_{99}	n
1	1.15	955
2	0.62	809
3	1.87	1176
4	0.51	953

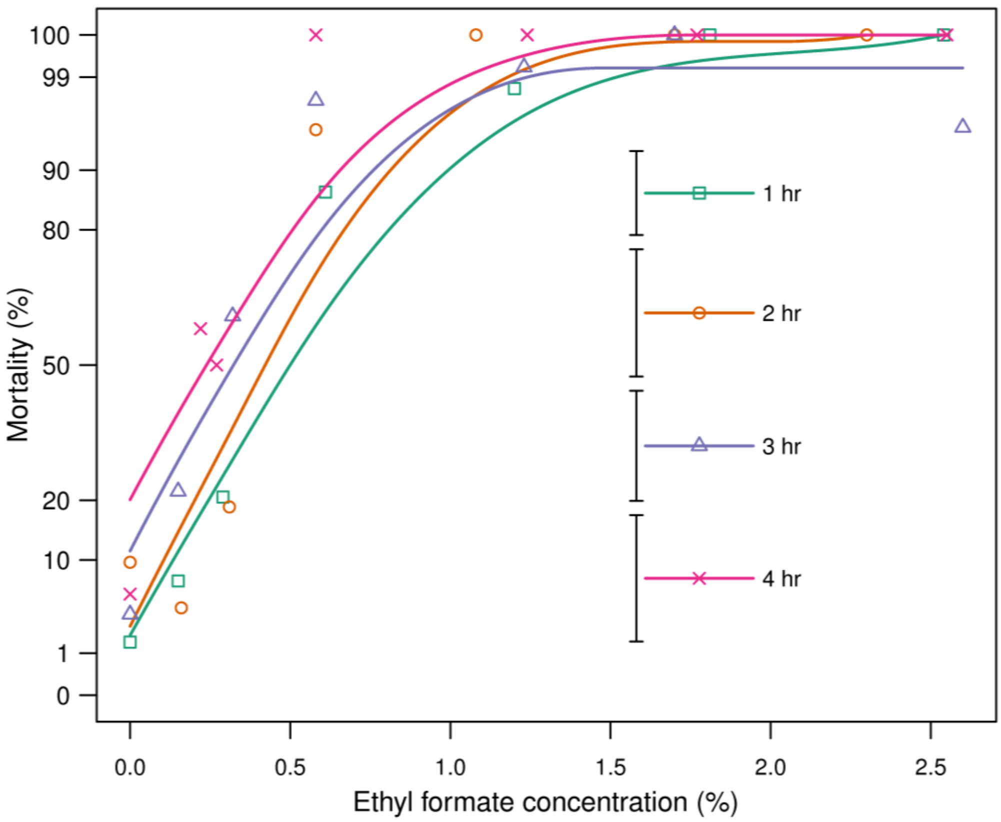

Figure 3. Dose mortality response of tomato/potato psyllid eggs to ethyl formate treatment in a preliminary trial. For each point n=20-328.

3.3 Replicated trial

The replicated trial confirmed the egg stage was the most tolerant life stage to EF treatment. Complete kill of eggs was achieved after a 1-h exposure to 1.19% EF (Table 4, Figure 4). However, all nymphs and adults were killed after a 1-h exposure to 0.12% 0.06% EF, respectively (Table 5, Figure 4). Calculated mean lethal concentrations for 99% mortality (LC_{99}) for eggs and nymphs were 0.81% and 0.07%, respectively (Table 6). LC_{99}'s were not calculated for adults, as there were not enough mortality points below 100% to provide a statistically robust value.

Table 4. Percent mortalities of tomato/potato psyllid (TPP) eggs treated with 0.35-2.51% ethyl formate (EF) for 1 h in replicated trial.

Days after treatment	Measured EF conc. (%)	Mean % mortality	SEM	n
7	Handling control	5.84	1.76	1357
	CO_2 control	4.26	2.86	757
	0.35	73.15	11.50	474
	0.59	95.23	3.63	441
	0.75	98.20	1.31	918
	0.85	99.60	0.40	679
	1.19	100.00	0.00	813
	1.51	100.00	0.00	637
14	Handling control	10.11	3.57	771
	CO_2 control	6.21	3.76	838
	0.35	52.93	21.41	379
	0.59	95.02	2.62	602
	0.75	96.18	1.92	733
	0.85	99.59	0.41	806
	1.19	100.00	0.00	845
	1.51	100.00	0.00	916

Table 5. Percent mortalities of tomato/potato psyllid (TPP) adults, early and late nymphs treated with 0.04-0.12% ethyl formate (EF) for 1 h in replicated trial.

Life stage	Measured EF conc. (%)	Mean % mortality	SEM	n
Adults	Handling control	7.16	1.58	443
	CO_2 control	7.22	1.27	439
	0.04	66.55	11.55	423
	0.06	100.00	0.00	499
	0.09	100.00	0.00	509
	0.12	100.00	0.00	382
Early nymphs	Handling control	2.02	1.33	894
	CO_2 control	1.69	0.84	1193
	0.04	73.66	14.03	1116
	0.06	95.82	2.06	949
	0.09	99.21	0.79	916
	0.12	100.00	0.00	664
Late nymphs	Handling control	7.17	1.08	365
	CO_2 control	8.89	1.55	373
	0.04	59.85	13.44	353
	0.06	95.46	1.35	399
	0.09	99.03	0.97	330
	0.12	100.00	0.00	529

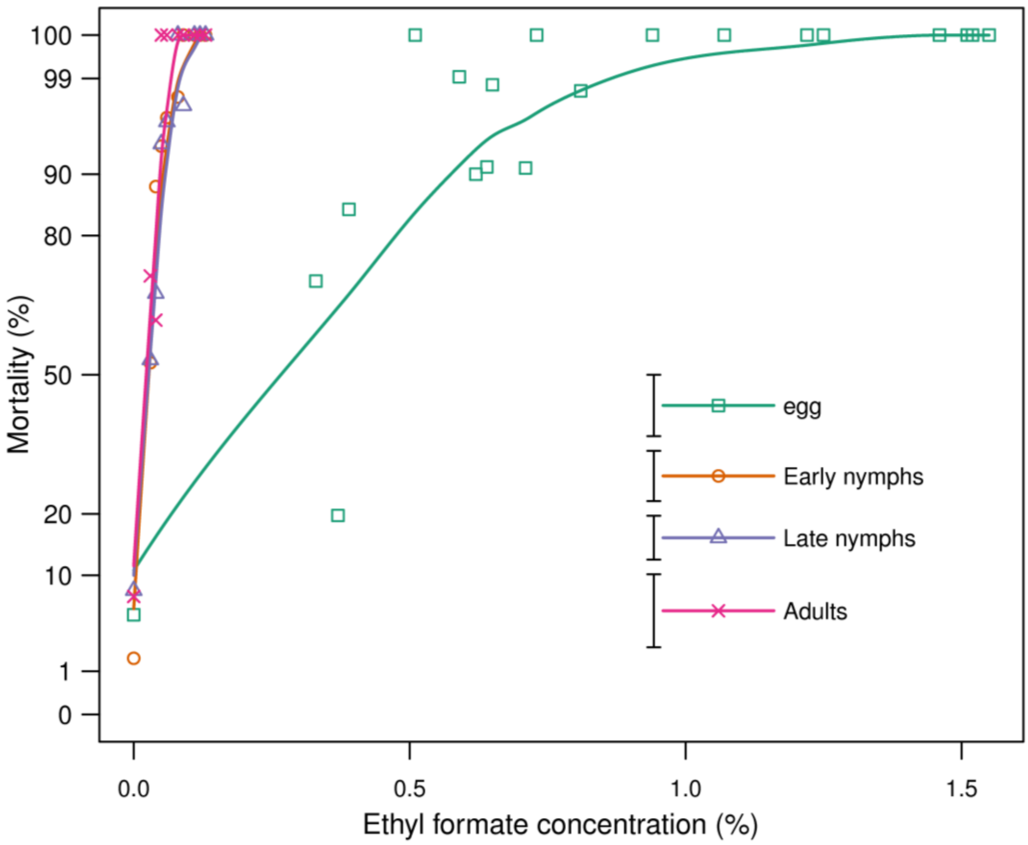

Figure 4. Dose mortality response of different life stages of tomato/potato psyllids after a 1-h exposure to different concentrations of ethyl formate.

Table 6. Calculated lethal concentrations of ethyl formate to achieve 99% mortality (LC_{99}) of different life stages[1] of tomato/potato psyllid.

Life stage	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Mean	95% CI	SEM
Eggs	0.845	1.009	0.824	0.620	0.812	0.666-0.991	0.082
Early nymphs	0.059	0.057	0.081	0.073	0.067	0.055-0.082	0.005
Late nymphs	0.094	0.069	0.067	0.069	0.074	0.061-0.090	0.006

[1] LC_{99} estimates could not be calculated for adults, as there were not enough mortality points below 100%.

4 Discussion

Results from this study show that EF+CO_2 is a promising postharvest treatment to control TPP on capsicums/tomatoes in New Zealand. The data show that a treatment of 0.09% (~2.8 g/m^3) EF at 13°C will achieve 99% mortality of TPP nymphs and adults, whereas a higher concentration (1% EF or ~31.5 g/m^3 EF) at 13°C will achieve 99% mortality of TPP eggs with 95% confidence.

Other pests that may cause market access issues for export capsicums and truss tomatoes, such as species of mites, mealybugs, thrips and spiders, will need to be considered when developing EF treatment protocols for New Zealand export capsicums and truss tomatoes. TPP can be considered among the more susceptible pests to EF + CO_2, along with mixed thrips species, greedy scale and obscure mealybug (Griffin et al. 2013). These susceptible species were generally controlled (99% mortality) by a 0.33-1.16% (10.5-36.6 g /m^3) EF (+ CO_2) treatment for 1-2 h. Lepidopteran species tend to be more tolerant to EF + CO_2 treatments (Griffin et al. 3013) along with Fuller's rose weevil and redback spider (De Lima 2006, 2009, 2010). Eggs are often the most tolerant life stage to EF treatment (Simpson et al. 2007; van Epenhuijsen 2007; De Lima 2009; De Lima 2010; Griffin et al. 2013). Often concentration/time recommendations based on laboratory studies vary because of the presence/absence of fruit and other materials in bioassays, which enable EF to be hydrolyzed into formic acid and ethanol (Desmarchelier 1999). Chhagan et al. (2013) found that EF concentrations reduced by 70% in chambers with apricots and/or apricot boxes over a 1-hour exposure period; therefore, determining the sorption rates of capsicums and tomatoes is important and will be reported by Woolf et al. (in prep.).

Initial fruit quality trials indicated that both tomatoes and capsicums can tolerate 0.4-0.8% EF + CO_2; however, ≥1.2% EF resulted in a significant reduction in fruit quality (Woolf et al. in prep). These early results indicate there may be a window of opportunity between concentrations of EF high enough to cause high TPP mortalities, and concentrations low enough to result in commercially acceptable fruit quality. This in turn, with sufficient data to demonstrate the low prevalence of TPP on the fruit and stem part of the plant, could achieve sufficient quarantine control to replace methyl bromide as a quarantine treatment.

5 Further Research

Future research should focus on determining the mortality rates of TPP and other pests of quarantine concern in presence of capsicums and truss tomatoes at concentrations below 1.2% EF (+ CO_2). The sorption rates of commercial fruit load factors and the influence of packaging on EF concentrations available to kill TPP and other pests should also be determined. Then larger-volume EF treatments in semi-commercial trials should be carried out to demonstrate final EF application dose. Along with this, it would be prudent to begin accumulating data to demonstrate the low occurrence of TPP life stages on the fruit and stem of capsicums and truss tomatoes.

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Appendix 1. Percent mortalities of tomato/potato psyllid (TPP) adults, early and late nymphs treated with 0.57-2.60% ethyl formate (EF) for 1, 2, 3, or 4 h in preliminary trial.

Treatment Time (h)	Measured EF conc. (%)	Adults		Early nymphs		Late nymphs	
		Mean % mortality	n	Mean % mortality	n	Mean % mortality	n
1	Handling control	1.1	91	3.85	182	10.39	77
	CO_2 control	5.261	114	2.80	107	0	69
	0.15	100	136	100	117	100	86
	0.29	100	111	100	237	100	86
	0.61	100	91	100	165	100	93
	1.20	100	114	100	113	100	107
	1.81	100	106	100	228	100	92
	2.54	100	81	100	190	100	115
2	Handling control	10.88	147	15.76	330	6.54	107
	CO_2 control	10.76	158	16.45	310	8.55	82
	0.16	100	165	100	116	100	74
	0.31	100	156	100	161	100	93
	0.58	100	242	100	155	100	103
	1.08	100	151	100	223	100	84
	1.70	100	194	100	116	100	98
	2.30	100	195	100	326	100	85
3	Handling control	5	160	2.86	489	7.61	92
	CO_2 control	25.56	133	3.191	595	10.59	85
	0.15	100	125	100	421	100	95
	0.32	100	139	100	347	100	96
	0.58	100	203	100	158	100	81
	1.23	100	201	100	393	100	103
	1.70	100	180	100	239	100	77
	2.60	100	158	100	230	100	86
	Handling control	11.90	84	5	366	6.33	79
	CO_2 control	24.75	101	2.222	315	14.29	84
	0.22	100	97	100	93	100	86
	0.27	100	110	100	46	100	83
	0.58	100	68	100	229	100	77
	1.24	100	91	100	255	100	72
	1.77	100	68	100	87	100	71
	2.55	100	71	100	286	100	73

Appendix 2. Value of effective postharvest disinfestation treatment to the New Zealand capsicum and truss tomato industries (L Fung, HortNZ)

A meeting on 20 February 2012 with five truss tomato and capsicum producers/exporters, BOC Gases and Plant & Food Research considered a range of treatment options as an alternative to methyl bromide. This proposal was developed as a result of discussions at the meeting as it was considered that ethyl formate + CO_2 offered the best potential replacement thereby allowing access to Australia as well as use as a “clean-up treatment” for exports to Japan.

Subsequent enquiries with several major exporting companies of truss tomatoes and capsicums have provided the following estimates of commercial and economic impact that this project could achieve (assuming a successful outcome):

Product	2011 market value	Australia	Japan
Truss tomatoes	Existing	$1.5 million	
Capsicums	Re-entry	$3-5 million	
	Existing	$10 million	$20 million

Economic impact can be viewed as creating value be allowing re-entry into the market as well as safeguarding existing market share which is currently achieved under difficult entry requirements.

Commercial impacts that are had to quantify include:

Overall improvement of fruit quality

Longer window for sale (extended shelf life so more likely to maximise sales

Potential use of sea freight to Australia (lower costs of production). This would significantly extend the “window” into Australia allowing New Zealand fruit to compete in the marketplace for a much longer timeframe

Export enables volume adjustments of the domestic market so that value does not drop steeply (more applicable to truss tomatoes) – the value lost to growers by an over supply is at least a 50 % reduction in price paid to the grower

Truss tomatoes are a higher value product than the current majority of tomatoes sent to Australia as "loose rounds", an effective alternative treatment to methyl bromide could add significant value to exports by allowing producers to switch production to the higher value product for that market.

All the companies (six) spoken to that grow and export truss tomatoes or capsicums considered that developing an alternative to methyl bromide that was “softer” and more benign to the environment and human health was worthwhile.

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