

**Note: Only 1 spray applied for all treatments at this point in time. Plants assigned to this column are the plants that were to receive a second spray on 24 May.

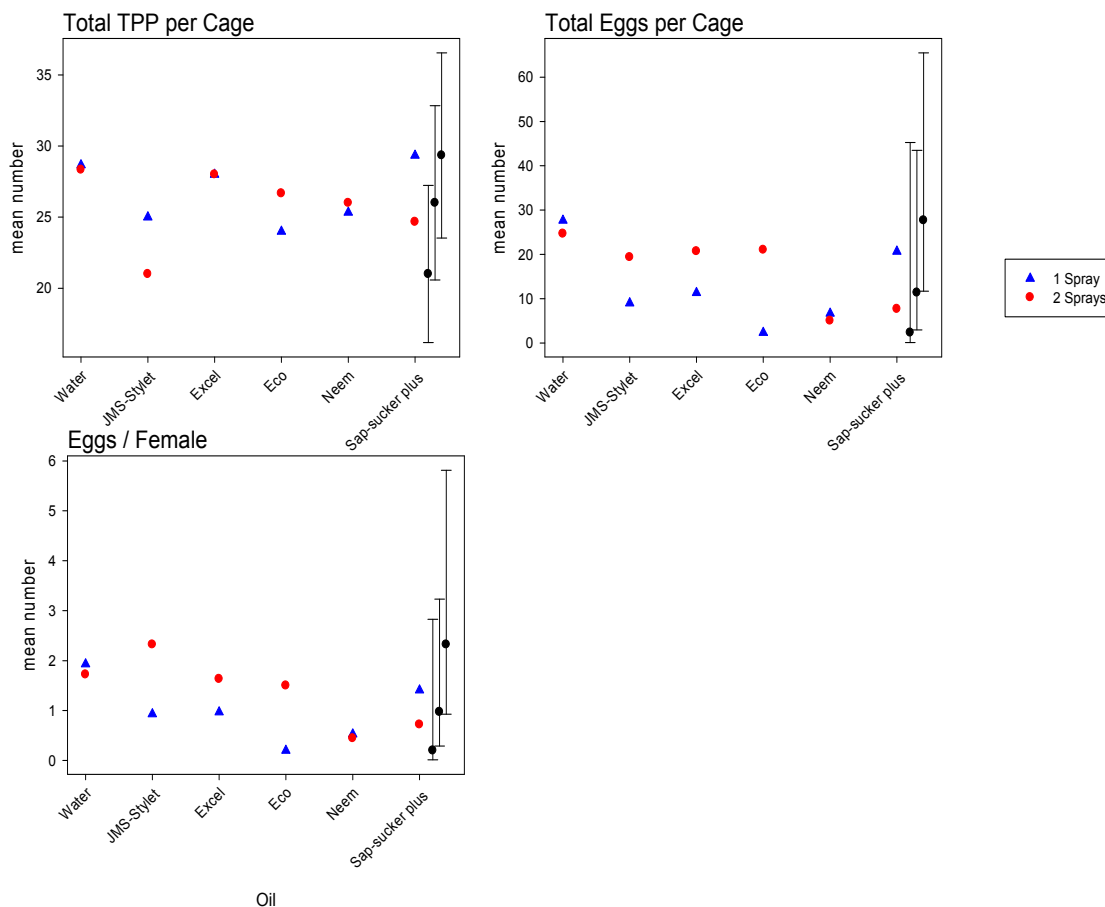


Figure 10: 4th May, Mean total TPP and eggs per cage and eggs per female. Error bars show 95% confidence limits for the highest, a mid-range, and a small mean.

Note: Only 1 spray applied for all treatments at this point in time. “2 sprays” indicates the plants that were to receive a second spray on 24 May.

3.2.2 Second assessment: TPP egg and nymph mortality

On the second assessment day (14 May) (1 spray applied), there was no substantial variation between the treatments in the number of eggs remaining ($P > 0.28$ for all effects). Variation in the number of nymphs on each plant ranged from 0 to 50 per cage and varied strongly with soft chemical ($P = 0.003$ for the main effect). Nymph numbers were highest for water (mean = 36.5/cage) and lowest for JMS Stylet (mean = 2.0/cage; $P = 0.006$). Numbers for the other soft chemicals were also lower than for water, varying from 4.3/ cage for Neem 600 WP ($P = 0.004$) to 17.8 for Eco-Oil[®] ($P = 0.09$) (Table 6, Figure 11).

Table 6: 14th May, Mean eggs remaining, and live nymphs per cage (95% confidence limits).

Oil	Eggs Remaining		Nymphs	
	1	2**	1	2**
W	1.9 (0.9,4.2)	1.7 (0.8,3.9)	41.0 (21.0,79.9)	32.0 (15.0,68.1)
J	0.9 (0.2,3.6)	2.3 (0.9,5.8)	4.0 (0.5,33.9)	0.0 (0.0,*)
X	1.0 (0.3,3.2)	1.6 (0.7,4.0)	9.0 (2.2,37.4)	14.0 (4.5,43.9)
C	0.2 (0.0,2.8)	1.5 (0.6,3.6)	16.7 (5.8,47.5)	19.0 (7.1,50.7)
N	0.5 (0.1,2.5)	0.4 (0.1,2.7)	5.0 (0.7,33.8)	3.7 (0.4,34.2)
S	1.4 (0.6,3.4)	0.7 (0.2,3.1)	17.3 (6.2,48.4)	1.3 (0.0,54.1)

*Cannot be estimated

**Note: Only 1 spray applied for all treatments at this point in time. Plants assigned to this column are the plants that were to receive a second spray on 24 May.

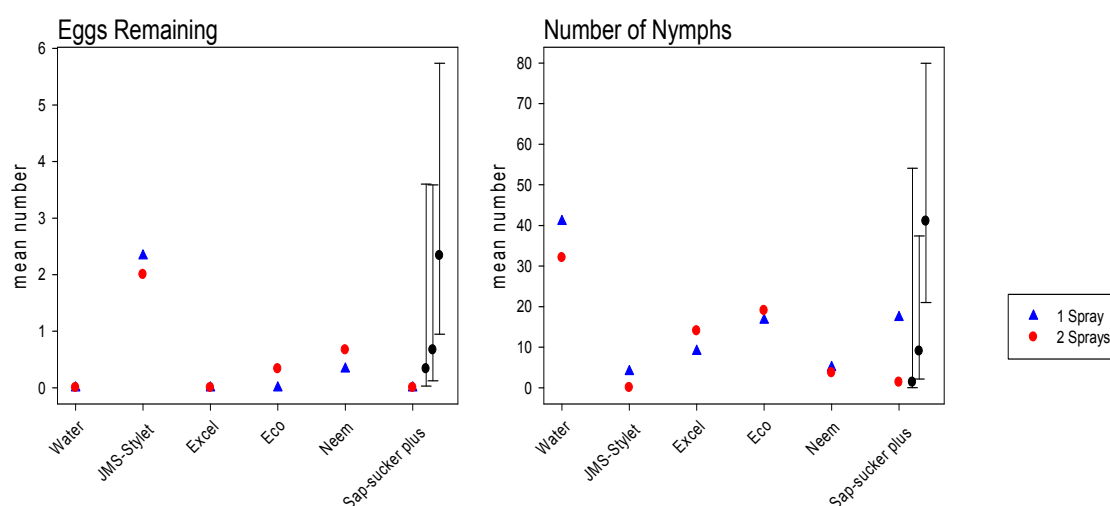


Figure 11: 14th May, Mean eggs remaining, and live nymphs per cage. Error bars show 95% confidence limits for the highest, a mid-range, and a small mean.

Note: Only 1 spray applied for all treatments at this point in time. “2 sprays” indicates the plants that were to receive a second spray on 24 May.

3.2.3 Third assessment: TPP nymph mortality, nymph size and adult emergence

On the third assessment day (24 May) (2 sprays applied to half of the plants), numbers of live nymphs varied with soft chemical ($P = 0.008$ for the main effect) and number of sprays ($P = 0.004$). However, the difference between 1 and 2 sprays was relatively similar for all soft chemicals ($P = 0.580$). This non-significant interaction means it is not entirely legitimate to make the comparisons between 1 and 2 sprays, and therefore further analyses used averages for 1 and 2 sprays combined. On average, numbers of nymphs were reduced by the second spray to only $\frac{1}{4}$ of those found with 1 spray (Table 7, Figure 12). However, the reduction in total nymphs compared with water was only significant for Organic JMS Stylet Oil® and Excel Oil® ($P < 0.001$; $P = 0.035$). Numbers of emerged adults varied between all treatments ($P < 0.001$), but was relatively unaffected by the number of sprays ($P = 0.517$ for the main effect). Adult numbers were lower for all soft chemicals than for water ($P < 0.001$ for all) (Table 7, Figure 12).

Table 7: 24th May, Mean total Nymphs and Adults emerged per cage (95% confidence limits).

Oil	Nymphs Alive		Adults Emerged	
	1	2	1	2
W	19.3 (8.3,44.9)	10.3 (3.3,32.7)	16.0 (10.0,25.7)	14.3 (8.7,23.6)
J	0.0 (0.0,*)	0.0 (0.0,*)	0.0 (0.0,*)	0.0 (0.0,*)
X	2.7 (0.3,25.8)	0.3 (0.0,203.8)	0.0 (0.0,*)	0.0 (0.0,*)
C	23.7 (11.1,50.7)	1.3 (0.1,33.0)	0.7 (0.1,6.8)	2.0 (0.5,7.6)
N	15.3 (6.0,39.5)	5.3 (1.1,26.5)	5.3 (2.3,12.1)	2.7 (0.8,8.5)
S	8.7 (2.5,30.5)	0.0 (0.0,*)	2.0 (0.5,7.6)	1.0 (0.2,6.6)

* Cannot be estimated

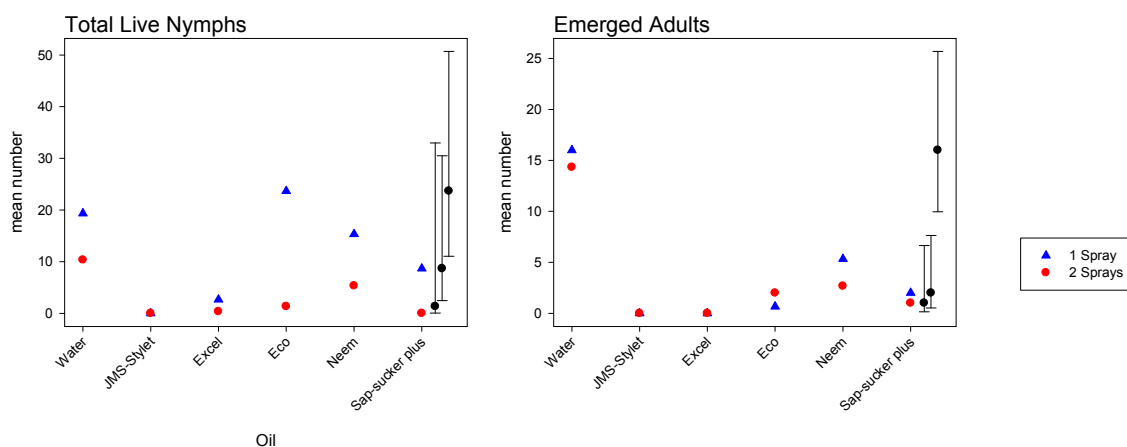


Figure 12: 24th May, Mean total Nymphs and Adults emerged per cage. Error bars show 95% confidence limits for the highest, a mid-range, and a small mean.

Numbers of large, medium and small nymphs varied between soft chemicals ($P = 0.004$, 0.028 , 0.008 respectively) and with the number of sprays ($P = 0.014$, 0.001 , 0.007 respectively). Numbers of large nymphs were reduced by more than half with the application of the second spray, and numbers of small nymphs by almost 90%. Large nymphs were most numerous with water for both 1 and 2 sprays followed by Neem 600 WP and Eco-Oil[®]. No large nymphs were found with Organic JMS Stylet Oil[®]. Mean small nymphs were below 1 per cage for all soft chemicals except Eco-Oil[®] and Neem 600 WP at 1 spray only. No small nymphs were found with JMS Stylet. For medium nymphs, the spray effect varied noticeably between the soft chemicals ($P = 0.046$ for the soft chemical by Number of sprays interaction). This is primarily because for almost all soft chemicals, numbers were higher with one spray than with two, but for Neem 600 WP, the numbers were slightly higher with two sprays (2.3 v. 1 per cage). The largest numbers of medium nymphs were for Eco-Oil[®], one spray (6.7), followed by Sap Sucker Plus, one spray (3.0). Once again, no medium nymphs were found with JMS Stylet Oil[®] (Tables 8 & 9; Figures 13 & 14).

Table 8: 24th May, Mean number of large, medium and small nymphs per cage (95% confidence limits).

Oil	Large		Medium		Small	
	1	2	1	2	1	2
W	17.0 (7.8,37.2)	9.7 (3.4,27.3)	2.3 (0.8,7.0)	0.3 (0.0,6.0)	0.0 (0.0,*)	0.3 (0.0,12.2)
J	0.0 (0.0,*)	0.0 (0.0,*)	0.0 (0.0,*)	0.0 (0.0,*)	0.0 (0.0,*)	0.0 (0.0,*)
X	0.7 (0.0,34.9)	0.0 (0.0,*)	1.7 (0.5,6.1)	0.0 (0.0,*)	0.3 (0.0,12.2)	0.3 (0.0,12.2)
C	9.0 (3.1,26.4)	1.0 (0.0,25.3)	6.7 (3.5,12.7)	0.0 (0.0,*)	8.0 (3.8,16.7)	0.3 (0.0,12.2)
N	12.0 (4.7,30.5)	2.7 (0.4,19.3)	1.0 (0.2,5.3)	2.3 (0.8,7.0)	2.3 (0.6,9.1)	0.3 (0.0,12.2)
S	5.3 (1.3,21.6)	0.0 (0.0,*)	3.0 (1.1,7.9)	0.0 (0.0,*)	0.3 (0.0,12.2)	0.0 (0.0,*)

* Cannot be estimated.

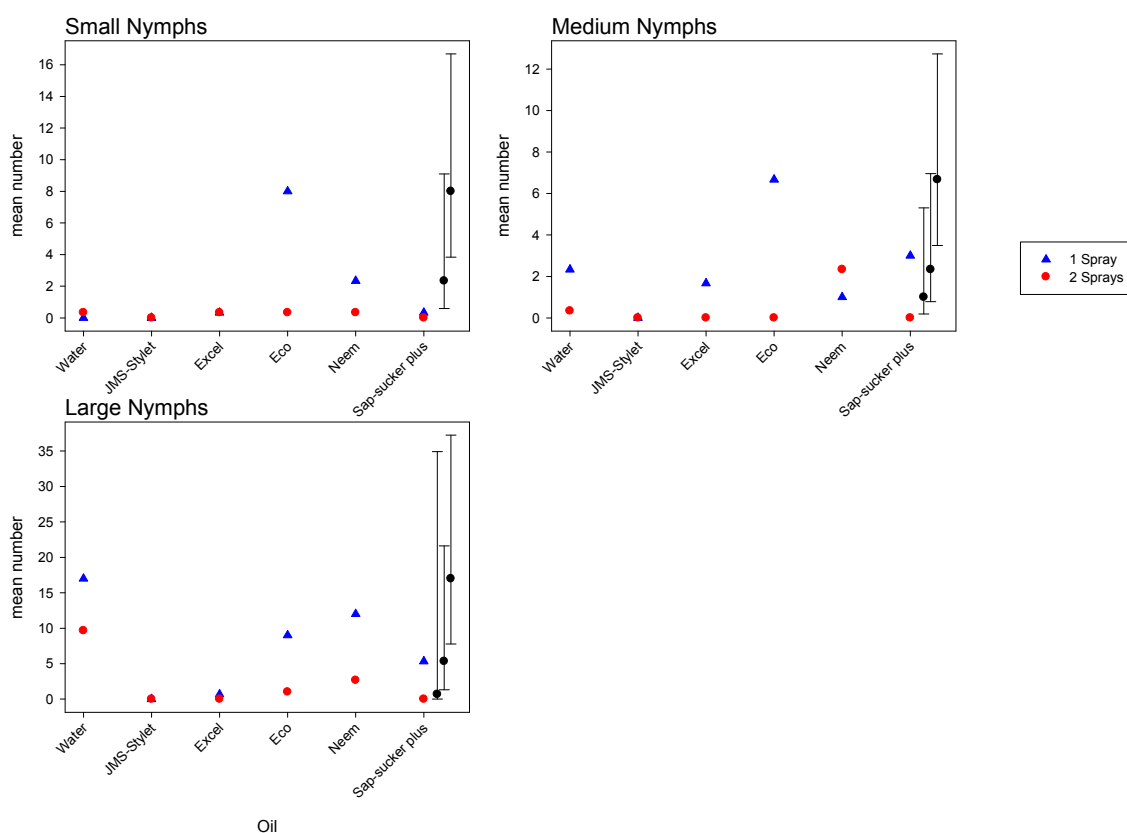


Figure 13: 24th May, Mean number of large, medium and small nymphs per cage. Error bars show 95% confidence limits for the highest, a mid-range, and a small mean.

Table 9: 24th May, Mean percentage of large, medium and small nymphs per cage (95% confidence limits).

Oil	Large		Medium		Small	
	1	2	1	2	1	2
W	87.9 (73.8,95.0)	93.5 (72.1,98.8)	12.1 (5.0,26.2)	3.2 (0.3,26.8)	0.0 (0.0,*)	3.2 (0.3,26.8)
J	-	-	-	-	-	-
X	25.0 (4.6,69.6)	0.1 (0.0,*)	62.5 (22.9,90.3)	0.0 (0.0,*)	12.5 (1.1,64.0)	100 (*,100.0)
C	38.0 (25.6,52.2)	75.0 (16.4,97.9)	28.2 (17.4,42.2)	0.0 (0.0,*)	33.8 (22.0,48.0)	25.0 (2.1,83.6)
N	78.3 (60.8,89.3)	50.0 (23.5,76.5)	6.5 (1.7,22.2)	43.8 (19.1,71.9)	15.2 (6.4,32.1)	6.2 (0.6,43.3)
S	61.5 (38.2,80.6)	-	34.6 (16.7,58.3)	-	3.8 (0.4,30.7)	-

* technically hard to estimate; - No Nymphs present.

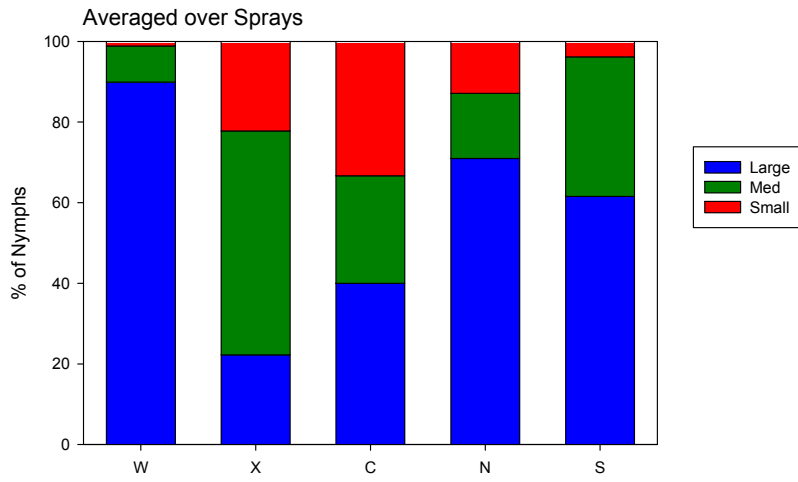


Figure 14: Percentage of nymphs that were of each size, averaged over sprays. Note: there were no nymphs for J, and no nymphs for S with 2 Sprays.

4 Discussion & conclusions

Based on the 15 min behaviour bioassay, Sap Sucker Plus and JMS Stylet Oil[®] produced the strongest repellent effect on adult female TPP, followed by Excel Oil[®] and Eco Oil[®], with 88%, 77%, 60% and 53% of the time spent off the leaf respectively. However, on Eco-Oil[®] a relatively large amount of the time was spent feeding/probing (28%) compared with Sap Sucker Plus (0%), JMS Stylet Oil[®] (7%) and Excel Oil[®] (10%). An initial repellent and probing/feeding deterrent effect is important when considering the potential risk of adult TPP settling in a potato crop and transmitting disease. Buchman et al. (2011) reported that a single adult TPP could transmit *Ca. L. solanacearum* to a potato plant in as little as 6 h, resulting in the development of zebra chip symptoms. Neem 600 WP did not induce a difference in behaviour when compared with water. Oviposition was even observed on one occasion on this product. This result differs from that found by Walker et al (2011) who showed significant repellence to female adult TPP after 1 h. However, a different Neem formulation was used in these trials.

In the TPP mortality study, there was no obvious adult mortality or oviposition-deterrent effect for any of the soft chemicals over a 3-day period after the spray application date. However, 13 days after the first spray (14 May); nymph numbers were lower for all soft chemicals when compared with water. The lowest number of nymphs was found on Organic JMS Stylet Oil[®] followed by Neem 600 WP, Sap Sucker Plus, Excel Oil[®], and Eco Oil[®], respectively. Results were not significant for Eco-Oil[®]. The reduction in nymph numbers could suggest that the products have some residual effect on egg hatching rates and/or young instar mortality. Organic JMS Stylet Oil[®] and Neem 600 WP showed good potential for early control of TPP.

Twenty-three days after the first spray (24 May), Eco Oil[®] and Neem 600 WP seemed to have lost their effect, as these treatments had a larger number of nymphs compared with the other soft chemicals. However, the number of emerged adults was only slightly higher than for the other soft chemicals. Ten days after the second spray (24 May), nymph numbers were lower for all soft chemicals compared with water. However, the reduction in total nymphs compared with water was only significant for Organic JMS Stylet Oil[®] and Excel Oil[®]. Walker et al. (2010) reported 48% TPP nymphal mortality with Excel Oil[®] in a potted plant bioassay on capsicum and even higher mortality for Eco-Oil[®] (58%). For all soft chemicals, significantly fewer adults had emerged compared with the water control for both 1 and 2 sprays. Numbers of large nymphs were reduced by more than half with the application of the second spray, and numbers of small nymphs by almost 90%. This is not surprising as many of the soft chemicals kill by direct contact. No nymphs or emerging adults were found on Organic JMS Stylet Oil[®] for either 1 or 2 sprays. John Trumble (University of California, Riverside, USA) reported very good repellence of up to 4 weeks with Organic JMS Stylet Oil[®] (Brian Smith, pers. comm.).

Although soft chemicals have the potential to control TPP through repellency and mortality, there is also a need to consider potential adverse effects of using these products in the cropping system. One potential risk with soft chemicals is phytotoxicity. In this experiment we noticed some phytotoxicity to leaves sprayed with Neem 600 WP, Excel Oil[®] and Eco-Oil[®]. The phytotoxicity appeared most severe on leaves sprayed with Neem 600 WP. Phytotoxicity from other Neem products, Excel Oil[®] and Eco-Oil[®] has also been reported in the industry (Stuart Attwood, pers. comm.). The use of soft chemicals also creates the potential risk of adversely affecting beneficial insects in the cropping system. Soft chemical oils could be defined as broad spectrum insecticides, as they are not systemic in the plant, but work via direct contact, e.g. by inhibiting insect respiration (Berry & Bourhill, 2012). The detrimental effects of soft chemicals (or organic pesticides) have been reported before (Johnson & Krugner 2004; Bahlai et al. 2010).

5 Overall recommendations

Given the efficacy of JMS Stylet Oil® and Excel Oil® at reducing TPP numbers and their probing/feeding deterrent qualities, these two products could warrant further testing in field trials. Sap Sucker Plus was also notable for its high repellence effect in the 15 min behavioural studies of adult female TPP, but left noticeable residue on the leaves. The impact of the tested soft chemicals on beneficial insects should also be assessed in future trials.

6 Acknowledgements

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7 References

- Al-Jabr AM 1999. Integrated pest management of tomato/potato psyllid, *Paratrioza cockerelli* (Sulc) (Homoptera: Psyllidae) with emphasis on its importance in greenhouse grown tomatoes Unpublished Dissertation thesis, Colorado State University.
- Bahlai CA, Xue Y, McCreary CM, Schaafsma AW, Hallett RH 2010. Choosing Organic Pesticides over Synthetic Pesticides May Not Effectively Mitigate Environmental Risk in Soybeans. *Plos One* 5(6).
- Berry NA, Bourhill A 2012. Review of soft chemical options and research for insect pest control. Plant & Food Research Report No. 6065.
- Berry NA, Walker MK, Butler RC 2009. Laboratory studies to determine the efficacy of selected insecticides on tomato/potato psyllid. *New Zealand Plant Protection* 62: 145–151.
- Buchman JL, Sengoda VG, Munyaneza JE 2011. Vector Transmission Efficiency of *Liberibacter* by *Bactericera cockerelli* (Hemiptera: Triozidae) in Zebra Chip Potato Disease: Effects of Psyllid Life Stage and Inoculation Access Period. *Journal of Economic Entomology* 104(5): 1486–1495.
- CycSoftware 2009. CycDesigN 4.0 A package for the computer generation of experimental designs. Version 4.0, CycSoftware Ltd, Hamilton, New Zealand.
- GenStat Committee 2011. The Guide to GenStat Release 14 - Parts 1-3. Oxford, VSN International.
- Johnson MW, Krugner R 2004. Impact of legally compliant organic pesticides on natural enemies.
- Kale A 2011. Report on the Economic and Business Impacts of Potato Psyllid on the Potato Industry. Survey conducted on behalf of ELAK Consultants Ltd for Potatoes New Zealand (PNZ).
- Lee Y, Nelder JA, Pawitan Y 2006. Generalized Linear Models with Random Effects: Unified Analysis via H-likelihood. London, Chapman & Hall/CRC Press.
- Liefting LW, Sutherland PW, Ward LI, Paice KL, Weir BS, Clover GRG 2009. A New 'Candidatus *Liberibacter*' Species Associated with Diseases of Solanaceous Crops. *Plant Disease* 93(3): 208-214.
- Liu DG, Trumble JT 2004. Tomato psyllid behavioral responses to tomato plant lines and interactions of plant lines with insecticides. *Journal of Economic Entomology* 97(3): 1078–1085.
- Marcic D, Peric P, Prijovic M, Ogurlic I 2009. Field and greenhouse evaluation of rapeseed spray oil against spider mites, green peach aphid and pear psylla in Serbia. *Bulletin of Insectology* 62(2): 159–167.
- McCullagh P, Nelder JA 1989. Generalized Linear Models. 2nd ed. London, Chapman & Hall.
- Munyaneza JE, Crosslin JM, Upton JE 2007. Association of *Bactericera cockerelli* (Homoptera : Psyllidae) with "zebra chip," a new potato disease in southwestern United States and Mexico. *Journal of Economic Entomology* 100(3): 656–663.

Teulon DAJ, Workman PJ, Thomas KL, Nielsen MC 2009. *Bactericera cockerelli*: incursion, dispersal and current distribution on vegetable crops in New Zealand. *New Zealand Plant Protection* 62: 136–144.

Walker MK, Butler RC, Berry NA 2010. Evaluation of selected soft chemicals as potential control options for tomato/potato psyllid. *Plant & Food Research Report No. 3937*.

Walker MK, Butler RC, Berry NA 2011. Evaluation of selected essential oils as potential repellents for tomato/potato psyllid control. *Plant & Food Research Report No. 5617*.

Yang XB, Zhang YM, Hua L, Peng LN, Munyaneza JE, Trumble JT, Liu TX 2010. Repellency of selected biorational insecticides to potato psyllid, *Bactericera cockerelli* (Hemiptera: Psyllidae). *Crop Protection* 29(11): 1320–1324.