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Effect of selected oils and insecticides on beneficial insect species: 2013/14 results

Gardner-Gee R, Puketapu A, MacDonald F, Walker, G and Connolly P

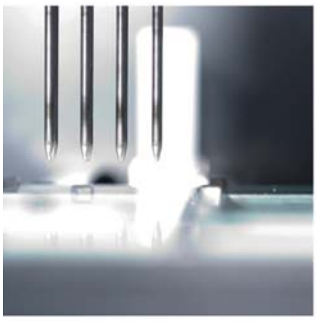
June 2014





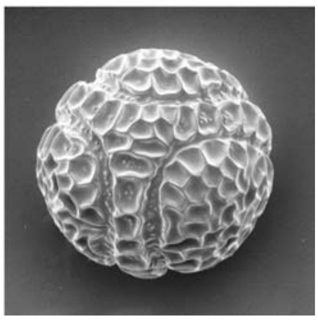










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Executive summary

Effect of selected oils and insecticides on beneficial insect species: 2013/14 results

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Plant & Food Research, Auckland

June 2014

The current SFF project (SFF 11-058: Developing IPM tools for TPP management in potato) aims to reduce the number of insecticide applications being used within the potato industry for the control of the Tomato Potato Psyllid (TPP; *Bactericera cockerelli*). Previous work by The New Zealand Institute for Plant & Food Research Limited has already shown that in the north of New Zealand (Pukekohe), early potato crops that are harvested before Christmas can be successfully grown without insecticide applications for TPP, due largely to predation by beneficial species and the low TPP numbers that occur in the spring and early summer. The current project has therefore focused on “main crop” potatoes (i.e. potato crops for table use and processing that are grown through the summer and harvested in autumn) as these crops can be exposed to high TPP pressure in the late summer and early autumn.

Research work in the first 2 years of SFF 11-058 has focused on three lines of enquiry: 1) the potential use of oils to provide non-insecticide protection for crops, 2) the residual activity of newer insecticides and 3) potential practical applications of TPP monitoring and modelling. Laboratory trials in this research programme have shown that a number of oil-based products (Sapsucker, Excel® Oil, Organic JMS Stylet Oil®) are repellent to TPP. SFF work has also shown that a number of relatively new insecticides have potential to disrupt TPP behaviour (especially egg-laying) for at least 14 days after application.
The disruptive effects of these oils and insecticides may be sufficient to protect the crop for extended periods, enabling longer spray intervals and fewer total insecticide applications across the growing season. However, impacts on beneficial insects need to be understood before these control options can be utilised within integrated pest management (IPM) systems. Some information on beneficial insect impacts is already available for the insecticides but there is less information available for oils and further trials using key New Zealand beneficial insects were considered necessary. In particular, the impact of insecticides on hoverflies is poorly understood.

To address these knowledge gaps, a series of laboratory-based assays was conducted to investigate the effects of a selection of oil-based products and insecticides on representative psyllid predators.
The impacts of oils on beneficial insects were addressed within the SFF 11-058 project in 2012/13.
The present report focuses on the effects of four selected insecticides: Avid®, Movento®, Sparta™ and Benevia®. All insecticides were used at maximum recommended field rates (with adjuvant or wetter if recommended). Two beneficial insect species were examined in these trials: Tasmanian lacewing (*Micromus tasmaniae*) and the small hoverfly (*Melanostoma fasciatum*). Two types of bioassay were conducted: direct spray bioassays and residue bioassays. In the direct spray bioassays, insects were sprayed with product mixtures using a Potter Spray Tower. In the residue bioassays, 40 mm potato leaf discs were dipped for 5 s in product mixtures. Twenty-four hours after dipping, a single insect was added to the centre of each leaf disc. In both types of assay, mortality was assessed at 72 h. There were at least 30 individual insects tested for each insecticide/beneficial species combination.

All of the four insecticide/adjuvant combinations tested (Avid/Eco-Oil®, Benevia/Actiwett®, Sparta/Bond® Xtra and Movento®) caused significantly less mortality than Tamaron®, the broad-spectrum insecticide used as a “high control” (i.e. a treatment that was expected to cause high mortality). Only one of the

insecticide/adjuvant combinations (Sparta plus Bond Xtra) caused mortality that would place it in the highest IOBC (International Organisation for Biological and Integrated Control of Noxious Animals and Plants) side effect category (i.e. Sparta plus Bond Xtra residues caused average mortality >79% in lacewing larvae). Movento had the lowest impact, never causing more than 8% average mortality. Lacewings were the more tolerant of the two beneficial species tested, surviving well in most assays.

When considered together with the results from the 2012/13 assays of oil-based products, it is clear that a range of selective products are now available in New Zealand for TPP control that are potentially compatible with key beneficial insects. Two products consistently caused little mortality on the species tested: Sapsucker /Thunderbolt (a monoterpene mixture plus neem oil tested against small hoverfly larvae, Tasmanian lacewing larvae and adults and 11 spotted ladybird beetle adults) and Movento (tested against small hoverfly larvae and Tasmanian lacewing larvae only). Four other products caused little mortality to at least one of the species tested: Benevia (with Actiwett) and Avid (with Eco-Oil) caused less than 20% average mortality to lacewing larvae, while the two paraffinic oils tested (Organic JMS Stylet Oil and Excel Oil) caused less than 20% average mortality to hoverfly larvae. The results are encouraging and suggest that some selective insecticides and oils could be used in TPP management programmes without jeopardising biological control although further work is needed to examine the effects of field applications of these products.

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1 Introduction

A range of relatively new agrichemicals is now available to potato growers for the control of the Tomato Potato Psyllid (TPP; Bactericera cockerelli) and other pests, including abamectin (e.g. Avid®), spirotetramat (e.g. Movento®), spinetoram (e.g. SpartaTM), and cyantraniliprole (e.g. Benevia®). Previous work within SFF 11-058 has shown that a number of these active ingredients (especially abamectin, cyantaniliprole and spinetoram) have significant residual activity against TPP and may therefore provide extended crop protection (Gardner-Gee et al. 2012). However, non-target impacts on beneficial insects need to be understood before these insecticides can be utilised within integrated pest management (IPM) systems, especially as research carried out by The New Zealand Institute for Plant & Food Research Limited (PFR) suggests that beneficial insects (notably the Tasmanian lacewing, *Micromus tasmaniae* and the small hoverfly *Melanostoma fasciatum*) can contribute to TPP control in New Zealand in the early to mid-growing season (Walker et al. 2012).

Extensive research on non-target impacts has been published for some active ingredients. For example, Williams et al. (2003) reviewed the non-target effects of spinosad; their review covered 228 observations on natural enemies, including 27 predatory species and 25 parasitoid species. Most studies found that spinosad was harmless to predators, but hymenopteran parasitoids were significantly more susceptible to spinosad, with 86% of field trials showing moderately harmful or harmful results for parasitoids. The review concluded that spinosad was likely to be a biorational option for conservation of predators, but also noted that different predatory species can differ markedly in their response to spinosad, even within the same genus. For example, two species of predatory bugs in the *Podsius* genus show very different levels tolerance to spinosad. Williams et al. (2003) caution that generalisations based on toxicity tests for one species may not be reliable for another species. In this context, it is worth noting that prior to this study there was very little non-target impact information available that was specific to the natural enemy species that occur in New Zealand potato crops (see Table 5).

To address these knowledge gaps, a series of laboratory-based assays was conducted to investigate the effects of a selection of both oil-based products and insecticides on representative psyllid predators. The impacts of oils on beneficial insects was addressed within SFF 11-058 in 2012/13 (Gardner-Gee et al. 2013). The present report focuses on the effects of four selected insecticides (Avid, Movento, Sparta and Benevia) and aims to provide equivalent information for agrichemicals that may assist growers in their spray application decisions, particularly during times in the growing season when beneficial numbers are high within these crops.

1.1 Aim

To investigate the acute direct and residual effects of four agrichemicals (Avid, Movento, Sparta and Benevia) on two psyllid predators commonly found in potato crops in New Zealand, namely the Tasmanian lacewing (*Micromus tasmaniae*) and the small hoverfly (*Melanostoma fasciatum).*

2 Methods

Colonies of Tasmanian lacewing were established in September 2013 and held at PFR's Mt Albert Research Centre. The small hoverfly cannot currently be maintained in captivity so the trials used field-collected hoverflies. Hoverfly eggs were collected as opportunity arose from potato crops in Matamata, and hatched hoverfly larvae were maintained on a diet of green peach aphids. Hoverfly and lacewing larvae (5–7 days old) were used in the bioassays.

Laboratory bioassays were used to determine acute effects of four products on the selected beneficial insect species. Products were used at maximum rates recommended for field use, with recommended adjuvant or wetter (Table 1). The effects of both direct spraying and residues were investigated. Protocols followed Gardner-Gee et al. (2013) and were similar to those used by Cole et al. (2010). In the direct bioassays, insects were sprayed directly with the products and then transferred to ventilated containers with potato leaf discs and prey as a food source for the predatory larvae. Mortality was assessed at 72 hours. Direct spray assays were carried out in three separate runs (10 replicates of each treatment per run). All runs included both positive and negative controls. Tamaron®, a broad-spectrum insecticide, was used as a "high control" (i.e. a treatment that was expected to cause high mortality) and water was used as the "low control" (i.e. a treatment expected to cause low or nil mortality). In the residue bioassays potato leaf discs were dipped in solutions, air-dried and mounted on agar in Petri dishes. Prey species (TPP nymphs) were added to the Petri dish set-ups as a food source. After 24 hours individual lacewing or hoverfly larvae were placed onto each leaf disc. Assessment was at 72 h. Three residue runs were undertaken (10 replicates of each treatment in each run) and high and low controls were included in all runs. See Gardner-Gee et al. (2013) for further details of methods.

One insecticide (Avid) was tested with and without an adjuvant (Eco-Oil®), in order to investigate whether the use of an adjuvant altered the impacts of the insecticide. Avid and Avid plus Eco-Oil combinations were tested on hoverfly larvae in 2012/13 (reported in Gardner-Gee et al. 2013) and on lacewing in 2013/14. Results from both years of testing are reported here for completeness.

Table 1: Insecticides used in bioassays. International Resistance Action Committee (IRAC) insecticide groups are given, along with active ingredients, mode of action and application rates. Application rates were calculated with 500 L/ha water.

Trade name	Active ingredient (IRAC group)	Mode of action	Recommended field rates	Application rate used in assays (product/200ml)
Tamaron®	methamidophos (1B)	Contact and stomach poison. Penetrates plant tissue and enters sap, killing sucking insects.	800 ml (aphids) – 1 L (potato tuber moth)/ha in 500–1000 L water	400 µl
Avid®	abamectin (6)	Paralyses insect, eventually causing death (may take 7 days to reach maximum effectiveness). Moves into leaves and remains there for several weeks.	600 ml/ha (tested alone and with Eco-Oil® at 1 ml/L)	240 µl (tested alone and with 200 µl Eco-Oil)
Benevia®	cyantraniliprole (28)	Contact and ingestion poison. Translaminar and local systemic movement in the plant	500 ml/ha plus non-ionic surfactant (Actiwett® at 25 ml/100 L)	200 ul plus 50 µl Actiwett
Movento® (OD)	spirotetramat	Systemic (xylem and phloem mobile)	560 ml/ha	224 µl
Sparta™	spinetoram (5)	Spinosyn: Contact and ingestion poison. Exposed larvae stop feeding but may take 3 days to die.	375–500 ml /ha with suitable spreader/ wetter (Bond® Xtra at 200 ml/ha)	200 µl plus 80 µl Bond Xtra

2.1 Data analysis

Generalized Linear Models (GLMs) were used in R (R Core Team 2013) to estimate mean mortality (and confidence intervals) of the predators in the presence of the various products. A quasi-binomial model was used to compensate for the high degree of underdispersion. Fisher's Exact tests were used to make comparisons with water and with Tamaron (as low and high controls respectively). Data from each trial were graphed separately to provide a visual indication of inter-trial variability. Horizontal lines were added to all graphs to indicate side-effect thresholds, as determined by the International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) (Table 2).

Table 2: International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) classification of side-effects of pesticides (mortality and/or reduction in beneficial capacity) (Boller et al. 2005).

	IOBC classification		
	N (harmless or slightly harmful)	M (moderately harmful)	T (harmful)
Laboratory test results	<30% mortality	30–79% mortality	>79% mortality
Field/semi-field test results	0–50% reduction	51–75% reduction	>75% reduction

3 Results

All of the four insecticides tested (Avid, Benevia, Sparta and Movento) caused significantly less mortality than Tamaron, the broad-spectrum insecticide used as a “high control” (i.e. a treatment that was expected to cause severe mortality). Only one of the insecticide/adjuvant combinations (Sparta plus Bond Extra) caused mortality that would place it in the highest IOBC side effect category (Table 3). Movento had the lowest impact, never causing more than 8% average mortality (Table 3).

Table 3: Mean percent mortality (95% confidence intervals) of Tasmanian lacewing (*Micromus tasmaniae*) and the small hoverfly (*Melanostoma fasciatum)* exposed to four insecticides (plus suitable adjuvant if recommended). Means that differ significantly (*P* < 0.05) from the water control in that column are marked with an asterisk (*).

	Tasmanian lacewing larvae		Small hoverfly larvae	
	Direct	**Residues**	**Direct**	**Residues**
Water (low control)	13 (5–30)	8 (3–21)	2 (0–15)	4 (1–14)
Tamaron® (high control)	88* (75–96)	94* (84–99)	97* (88–100)	99* (93–100)
Movento®	7 (1–37)	8 (1–37)	3 (0–27)	7 (1–28)
Benevia® +Actiwett®	13 (3–42)	16 (5–45)	14* (5–37)	20* (9–42)
Avid® + Eco-Oil®	15 (4–44)	12 (3–40)	14* (5–37)	63* (45-–82)
Sparta™ + Bond® Xtra	25 (10–54)	82* (64–94)	63* (44–82)	63* (45–82)

3.1 Tasmanian lacewing

Tasmanian lacewing larvae were the more tolerant of the two beneficial species tested, surviving well in most assays (Figure 1, Table 3). However, residues of Sparta plus Bond Xtra were harmful to the lacewing larvae (Figure 1, Table 3).

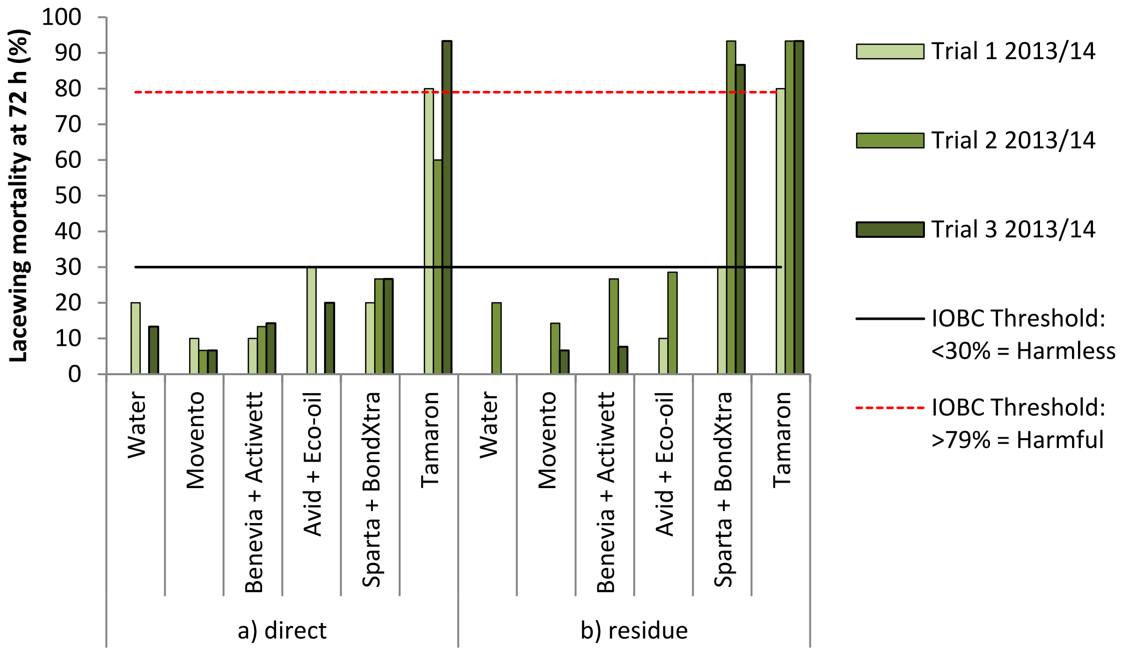

Figure 1. Mortality of Tasmanian lacewing larvae following a) direct spray application of insecticides and b) exposure to residues on potato leaf surfaces. Assessments were carried out after 72 hours.

3.2 Small hoverfly

Direct sprays and residues of Movento were not harmful to the larvae of the small hoverfly whereas the combination of Sparta plus Bond Xtra was moderately harmful both as a direct spray and as a residue (Figure 2, Table 3). The insecticide plus adjuvant combinations of Avid plus Eco-Oil and Benevia plus Actiwett caused little mortality as direct sprays, but Avid plus Eco-Oil residues were moderately harmful and some larvae exposed to Benevia plus Actiwett residues were alive but moribund at 72 h and were unlikely to complete development (Figure 3).

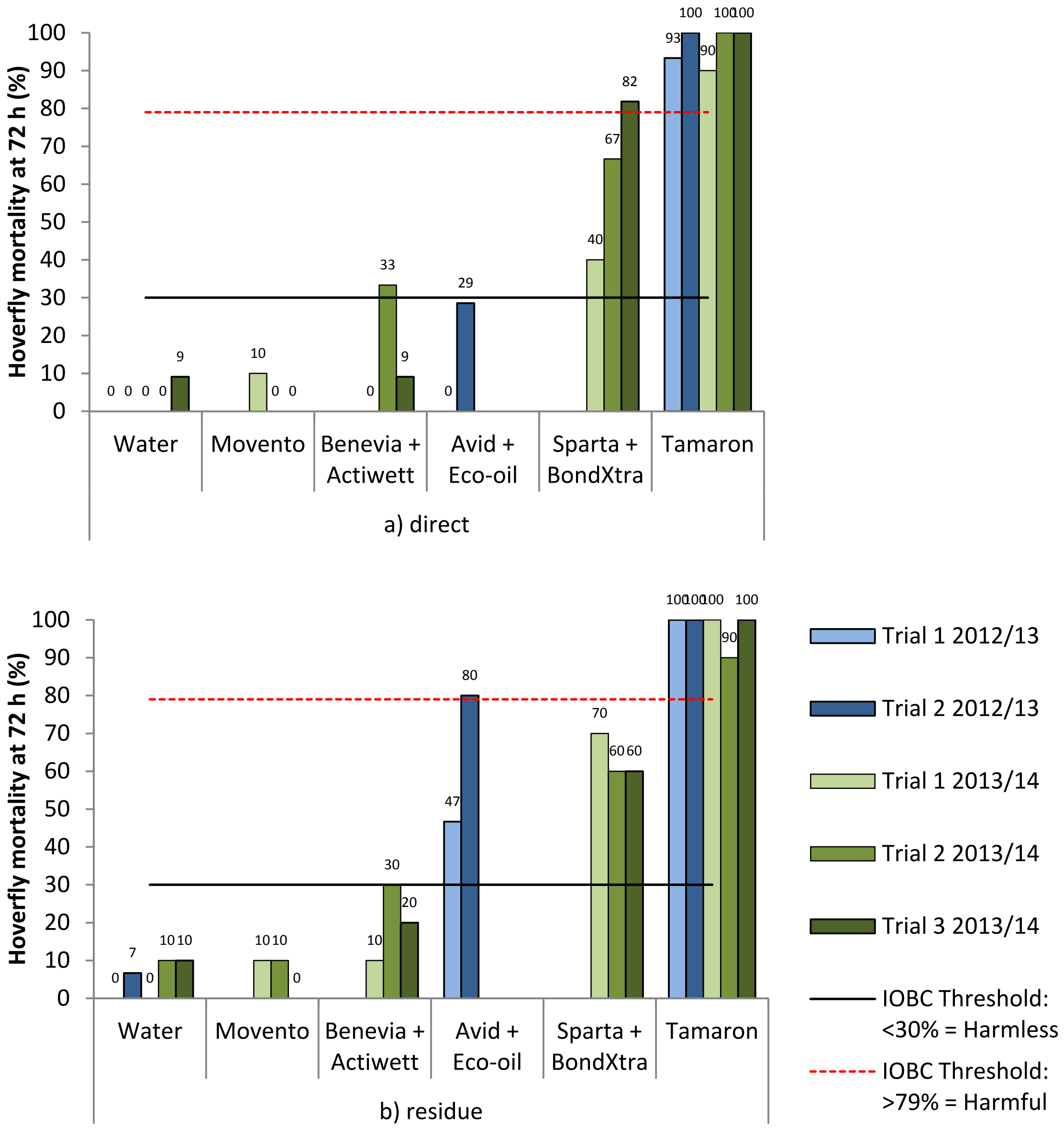

Figure 2. Mortality of small hoverfly larvae following a) direct spray application of insecticides and b) exposure to residues on potato leaf surfaces. Assessments were carried out after 72 hours.

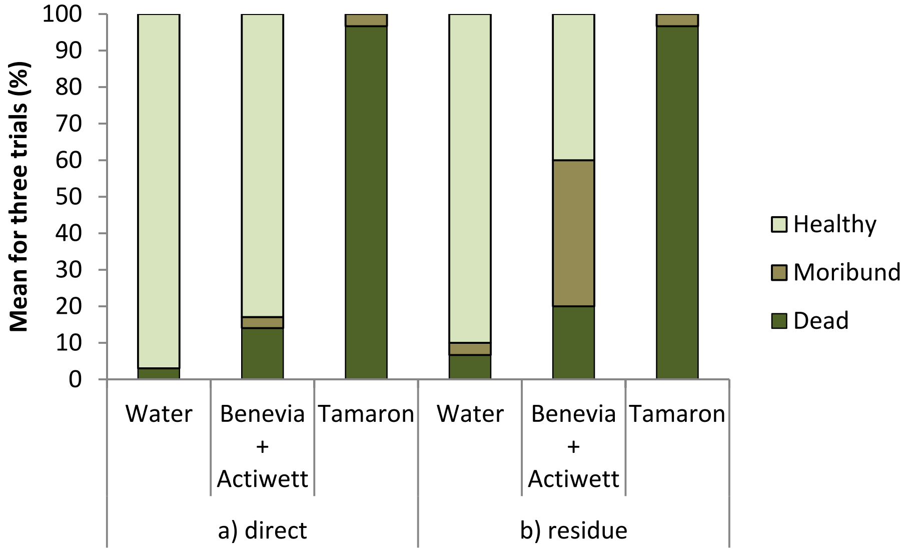

Figure 3. The mean percentage of healthy, moribund and dead small hoverfly larvae, following a) direct spray application of Benevia® plus Actiwett® and b) exposure to Benevia plus Actiwett residues on potato leaf surfaces. Assessments were carried out after 72 hours.

3.3 Comparison of product impacts with and without adjuvant.

One product (Avid) was tested with and without an adjuvant (Eco-Oil). Although mortality was typically higher when the adjuvant was added, the differences were not statistically significant (Table 4).

Table 4: Mean percent mortality (95% confidence intervals) for 2012/13 and 2013/14 trials with Avid® and Avid plus Eco-Oil®. Means that differ significantly (P < 0.05) within a column are marked with an asterisk (*).

	Tasmanian lacewing larvae		Small hoverfly larvae	
	Direct	Residues	Direct	Residues
Avid	5 (1–37)	12 (3–40)	7 (1–28)	44 (30-62)
Avid + Eco-Oil	15 (4–44)	12 (3–40)	14 (5–37)	63 (45–82)

3.4 Comparison with 2012/13 results for oil-based products

Figure 4 presents data from all trials conducted from 2012 to 2014. Two products consistently caused little mortality on the species tested: Sapsucker/Thunderbolt (a monoterpene mixture plus neem oil tested against small hoverfly larvae, Tasmanian lacewing larvae and adults and 11 spotted ladybird beetle adults) and Movento (tested against small hoverfly larvae and Tasmanian lacewing larvae only). Four other products caused low mortality to at least one of the species tested: Benevia plus Actiwett, and Avid plus Eco-Oil caused less than 20% average mortality to lacewing larvae, while the two paraffinic oils tested (Organic JMS Stylet Oil and Excel Oil) caused little less than 20% average mortality to hoverfly larvae.

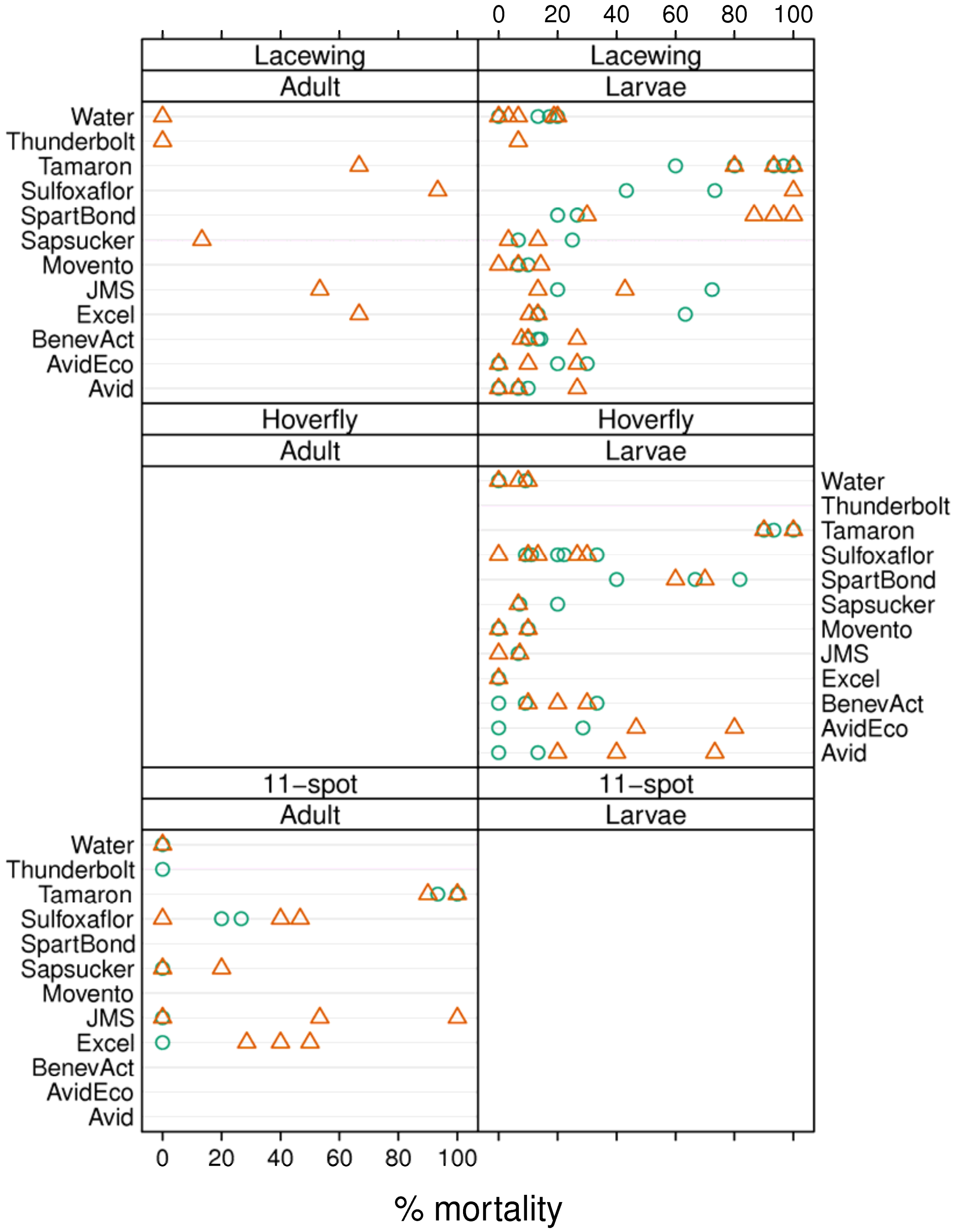

Figure 4. Trellis plot for all trials conducted in 2012–14. Each symbol represents the mortality observed in one assay run (typically 10 insects tested in each treatment in each run). Circles indicate direct spray assays, triangles indicate residue assays. SpartBond = Sparta™ plus Bond® Xtra, BenevAct = Benevia® plus Actiwett®, AvidEco = Avid® plus Eco-Oil®. Note that Thunderbolt is a reformulation of the product Sapsucker. See Gardner-Gee et al. (2013) for details of oil-based products used.

4 Discussion

In this study we investigated the effects of four insecticides (Sparta, Avid, Benevia and Movento) on beneficial insects, as non-target effects need to be well understood before these products are incorporated into IPM programmes. The results of the 2013/14 assays are summarized in Table 5 and each of the four insecticides is discussed in more detail below.

Two of the products (Sparta and Avid) are derived from microbial fermentation processes. The first of these, Sparta, is related to the better-known active ingredient (a.i.) spinosad. Aerobic fermentation of *Saccharopolspora spinosa* produces a mixture with two dominating forms (known as spinosyn A and D) and spinosad is a defined combination of these two forms (hence its name, spinosAD). Since the commercial release of spinosad, a number of semi-synthetic spinosyn analogues have been designed in an attempt to increase activity against selected pests and minimize non-target impacts. The active ingredient of Sparta and other such products is spinetoram, a semi-synthetic second generation derivative composed mainly of two new spinosyns, J and L (Biondi et al. 2012). Compared with spinosad, spinetoram has greater efficacy against a wider range of insect species while retaining environmental and toxicological properties that are similar to its parent compound (Lumaret et al. 2012). Non-target effects of spinosad have been comprehensively reviewed by Williams et al. (2003) and more recently by Lumarat et al. (2012) and Biondi et al. (2012). Biondi et al. (2012) note that the effects of spinetoram have not been extensively examined yet but that existing studies suggest it can have different effects than spinosad. For example, spinetoram is safer to use with bumblebees than spinosad (Besard et al. 2011).

Our results indicate that 1-day-old residues of Sparta (plus Bond Xtra) are harmful to Tasmanian lacewing larvae (causing 82% mortality on average). Amaraseke and Shearer (2013) observed lower larval mortality (7–20% 2 days after exposure to spinetoram) in two species of *Chrysoperla* lacewings, but found that surviving larvae had significantly reduced adult lifespans. These results are in contrast to previous studies with spinosad by Cole et al. (2010) who found that spinosad residues caused only 39% adjusted mortality in Tasmanian lacewing larvae and that surviving larvae showed no long term negative impacts. Williams et al. (2003) also found that spinosad was generally harmless to lacewing in the *Chrysoperla* genus. This difference may be due to differences between chemistries (spinetoram plus adjuvant versus spinosad) or differences between genera (*Micromus* v. *Chrysoperla*) and highlights again the need for information on the specific chemistries and beneficial insect species relevant to the crop of interest. Our laboratory assays also indicate that Sparta plus Bond Xtra is moderately harmful as both a direct spray and as a residue to small hoverfly larvae. The present results suggest that spinetoram (+/- adjuvants) does need to be used with care in situations where maintaining Tasmanian lacewing and small hoverfly populations is desirable.

The second product derived from microbial fermentation is the insecticide Avid (a.i. abamectin). Abamectin (or avermectin B_1) is one of eight naturally occurring avermectin compounds produced by *Steptomyces avermilitis*. The avermectins are active against a number of pest helminths and arthropods and are widely used to control parasites in livestock and insect pests in crops. Studies have also shown that abamectin is able to kill TPP adults rapidly and also has anti-feeding effects (Butler et al. 2011). As a result, the abamectin-based product Avid is used for TPP control in New Zealand and elsewhere. However, Gentz et al. (2010) note that the avermectins are relatively broad-spectrum with activity observed against 84 species in 10 orders and that severe non-target impacts have been recorded. Avermectins have short environmental persistence which can act to limit their non-target effects but Gentz et al. (2010) suggest avermectins should be used with considerable care within IPM programmes where beneficial insects are central. In the present study, 1-day-old Avid residues were found to be moderately harmful to small hoverfly larvae, causing mortality of 44–63% (with and without the adjuvant Eco-Oil respectively). However, direct sprays of Avid (with or without Eco-Oil) caused little mortality in the small hoverfly larvae. Tasmanian lacewing larvae also appear to tolerate to Avid, as there was relatively little mortality in either the direct spray or residue assays in our study. Similarly Cole et al. (2010) found that an abamectin derivative (emamectin benzoate) caused less that 25% mortality to Tasmanian lacewing larvae in acute tests and had no long-term effects. Hence, despite the broad activity of the avermectins in general, Avid appears to be tolerated reasonably well (in short-term laboratory assays) by two of the key predatory species in New Zealand potato crops.

Benevia (a.i. cyantraniliprole, DuPont Code: DPX-HGW86) is a very recent addition to the insecticides registered for use in New Zealand against TPP in potatoes. Benevia is an anthranilic diamide, a new type of diamide developed by DuPont. The first anthranilic diamide, chlorantraniliprole, was discovered in 2001, while cyantraniliprole was discovered in 2003 after a research effort targeted at broadening the pest spectrum: although the two compounds have very similar chemical structures, chlorantraniliprole is active primarily against Lepidoptera (caterpillars) while cyantraniliprole is active against a range of piercing, sucking and chewing pests including whiteflies, leaf-feeding beetles, leafminers, psyllids, and fruit flies as well as caterpillars (Lahm et al. 2012). Importantly, unpublished studies also suggest cyantraniliprole stops targeted pests from feeding within minutes (Cornwell 2012) and may therefore prevent the transmission of pathogens. Despite this cross-spectrum activity, it has been reported that cyantraniliprole has minimal impacts on many beneficial insect species such as hymenopteran parasitoids (e.g. *Aphelinus*), predatory mites (e.g. *Amblyseius*) and predatory insects (e.g. *Chrysoperla* lacewings) (Lahm et al. 2012). This selectivity is thought to be due to predators and parasitoids having reduced contact with the treated foliage (compared with herbivorous pests) (Lahm et al. 2012). In our short-term assays Benevia plus Actiwett caused low mortality in Tasmanian lacewing larvae, which accords with results from Amarasekare and Shearer (2013) who examined cyantraniliprole impacts on larvae of two species of *Chrysoperla* lacewings. Dinter et al (2012) concluded that negative population effects on *Chrysoperla carnea* were unlikely. It should be noted though that despite the low larval mortality observed in their study, Amarasekare and Shearer (2013) found that cyantraniliprole caused 100% mortality in *Chrysoperla* adults (mortality recorded 10 days after treatment) and that *Chrysoperla* larvae exposed to cyantraniliprole had severely reduced adult lifespans (adult longevity: 1–2 days) compared with control insects (adult longevity: 43–48 days). In our assays Benevia plus Actiwett sprays caused low mortality in small hoverfly larvae as well, but residues caused sub-lethal effects. Our results suggest further longer-term testing of this product would be warranted for the small hoverfly.

Movento (a.i. spirotetramat) is a second generation tetronic acid-based insecticide developed by Bayer. The first two tetronic acid-based insecticides, spirodiclofen (e.g. Envidor®) and spiromesifen (e.g. Oberon®), were primarily contact insecticides whereas spirotetramat is taken up by the plant then translocated into both roots and newly-forming shoots (Brueck et al. 2009). Spirotetramat is most effective when ingested as it has limited contact activity, a feature which is likely to reduce its impacts on non-target predators and parasitoids (Brueck et al. 2009). Indeed, a summary of Bayer's non-target testing indicates that Movento is harmless or slightly harmful to most beneficial species tested (Schnorbach et al. 2008; Brueck et al. 2009). In our short-term assays, Movento had the least impact of the four insecticides we tested, never causing significantly more mortality than that observed in the water controls. In addition, Movento has good efficacy against TPP, making it a useful tool in psyllid management, especially in late spring and early summer when beneficial insect numbers are high in potato crops in northern New Zealand (Walker et al. 2012).

Table 5. Summary of SFF 11-058 trials and key published studies on the impacts of selected agrichemicals on key New Zealand beneficial insect species and hymenopteran parasitoids. Information on related species provided (in gray) if little information is available on New Zealand species.

Active ingredient (a.i.) (example of product)	IRAC group (sub group or exemplifying a.i.)	New Zealand beneficial insect species			Hymenopteran parasitoids
		Tasmanian lacewing (*Micromus tasmaniae*)	Small hoverfly (*Melanstoma fasciatum*)	11-spotted ladybird beetle (*Coccinella undecimpunctata*)	
spinetoram (e.g. Sparta™)	5 (spinosyn)	Sparta (and Bond® Xtra) direct sprays caused 25% larval mortality, residues caused 82% larval mortality in short term assays (this report). Spinetoram caused high adult mortality in two *Chrysoperla* species and larvae exposed to spinetoram had <1/10 the control adult lifespan (Amarasekare & Shearer 2013)	Sparta (and Bond Xtra) direct sprays and residues caused moderate larval mortality (63%) in short term assays (this report).		Residues caused 100% mortality to *Tamarixia triozae* (Liu et al. 2012).
abamectin (e.g. Avid®)	6 (abamectin)	Avid direct sprays and residues harmless to larvae in short term assays, with or without Eco-Oil® (this report).	Avid direct sprays harmless to larvae in short term assays, 1 d.o. Avid residues caused 44% and 63% mortality to larvae with and without the adjuvant Eco-Oil (Gardner-Gee et al. 2013).		Residues caused 100% mortality to *Tamarixia triozae* (Liu et al. 2012).
spirotetramat (e.g. Movento®)	23 (tetronic and tetramic acid derivatives)	Movento direct sprays and residues harmless to larvae in short-term assays (this report). Harmless to *Chrysoperla* spp. (Schnorbach et al. 2008).	Movento direct sprays and residues harmless to larvae in short-term assays (this report). Harmless to larvae of *Episyrphus balteatus*, fertility of adults treated as larvae not negatively affected (Moens et al. 2011).	Harmless to moderately harmful to *Coccinella* spp. and *Chilocorus nigritus* (Schnorbach et al. 2008). Low toxicity in lab trials on *Coccinella septempunctata* (Maus 2008).	Harmless to parasitoid wasps (Schnorbach et al. 2008). Residues did not cause significant mortality to *Tamarixia triozae* (Liu et al. 2012).
cyantraniliprole (alternative name for a.i. is Cyazypyr™) (e.g. Benevia®)	28 (diamide)	Benevia (and Actiwett®) direct sprays and residues harmless to larvae in short term assays (this report). Negative population effects on *Chrysoperla carnea* considered unlikely (Dinter et al. 2012) but cyantraniliprole caused high adult mortality in two *Chrysoperla* species and larvae exposed to cyantraniliprole had <1/10 the control adult lifespan (Amarasekare & Shearer 2013).	Benevia (and Actiwett) direct sprays harmless to larvae in short-term assays (this report). 1 d.o. residues caused moderate mortality and harm (>30% larvae moribund at 72 hr assessment) (this report).	Negative population effects on *Coccinella septempunctata* considered unlikely (Dinter et al. 2012). Field trials indicate little impact on *Coccinella septempunctata* numbers (Misra & Mukherjee 2012).	*Aphidius rhopalosiphi* sensitive to cyantraniliprole (Dinter et al. 2012). Cyantraniliprole residues did not cause significant mortality to *Tamarixia triozae* (Liu et al. 2012).

Overall, results from the present study are encouraging, as they suggest that some selective insecticides could be used in New Zealand TPP management programmes without jeopardising biological control. When considered together with the results from the 2012/13 assays of oil-based products, it is clear that a range of selective products that are potentially compatible with key beneficial insects is now available in New Zealand (Table 6). Further work is needed to examine the effects of field applications of these products. The results of this and previous studies also highlight the need for knowledge about the beneficial species present in a given crop, as effects of both oils and insecticides varied considerably among species.

Table 6. Summary of non-target impacts on key New Zealand beneficial insects for selected insecticides and oil-based products, based on short-term assays conducted for SFF 11-058 (2012–14). Assay results are indicated by two triangles, the first summarising direct spray assays, the second summarising residue assays. Symbols follow the IOBC non-target impacts classification for laboratory trials: ▲ = <30% mortality (harmless or slightly harmful), ▶ = 30–79% mortality (moderately harmful), ▼ = >79% mortality (harmful). NA indicates that a species/product combination was not tested.

Active ingredient (product and adjuvant actually tested)	IRAC group (sub-group or exemplifying active ingredient)	HSNO environmental hazard classifications:	New Zealand beneficial insect species		
			Tasmanian lacewing larvae (*Micromus tasmaniae*)	Small hoverfly larvae (*Melanstoma fasciatum*)	11-spotted ladybird adults (*Coccinella undecimpunctata*)
methamidophos (Tamaron®)	1 (organo-phosphates)	Tamaron: 9.1A = Very ecotoxic in the aquatic environment 9.2B = Ecotoxic in the soil environment 9.3A = Very ecotoxic to terrestrial vertebrates 9.4A = Very ecotoxic to terrestrial invertebrates	▼ ▼	▼ ▼	▼ ▼
spinetoram (Sparta™ plus Bond®Xtra)	5 (spinosyns)	Sparta: 9.1A = Very ecotoxic in the aquatic environment 9.4A = Very ecotoxic to terrestrial invertebrates	▲ ▼	▶ ▶	NA
abamectin (Avid® plus Eco-Oil®)	6 (avermectins)	Avid: 9.1A = Very ecotoxic in the aquatic environment 9.2C = Harmful in the soil environment 9.3B = Ecotoxic to terrestrial vertebrates 9.4A = Very ecotoxic to terrestrial invertebrates	▲ ▲	▲ ▶	NA
spirotetramat (Movento®)	23 (tetronic & tetramic acid derivatives)	Movento: 9.1B = Ecotoxic in the aquatic environment	▲ ▲	▲ ▲	NA
cyantraniliprole (Benevia® plus Actiwett®)	28 (diamides)	Benevia: 9.1A = Very ecotoxic in the aquatic environment 9.4B = Ecotoxic to terrestrial invertebrates	▲ ▲	▲ ▶	NA
paraffinic mineral oil (JMS Organic Stylet Oil®)	-	OrganicJMS Stylet Oil: 9.1B = Ecotoxic in the aquatic environment	▶ ▲	▲ ▲	▲ ▶
paraffinic mineral oil (Excel® Oil)	-	Excel Oil: 9.1D = Slightly harmful to the aquatic environment	▶ ▲	▲ ▲	▲ ▶
Monoterpene mixture plus neem oil (Sapsucker/Thunderbolt)	-	Sapsucker: Not registered for use in New Zealand	▲ ▲	▲ ▲	▲ ▲

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