Insect Management in Organic Blueberries

Final Project Report to:

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By:

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Executive Summary

Three important insect pests of blueberries are aphids, leafrollers and weevils. In other cropping systems organic methods for management of these pests have been developed. The objective of this study was to determine if the tools currently available and acceptable for use in organic production of other crops could also be effective in blueberries. For the most part trials were conducted in potted blueberry plants with artificial infestations of pests (leafroller and weevil). For aphid trials, however, we switched to a field trial as aphids failed to establish on research plants. For leafrollers, Entrust provided effective control in both experiments. Dipel worked well in the first experiment but not the second, most likely because older larvae were used for the second study. Both products thus could be used, in conjunction with a monitoring program to effectively time sprays, for leafroller control. Entrust is not currently registered for blueberries, but our data has been provided to the Minor Use Program for possible label expansion. Caution should be taken when using Entrust however as it is toxic to pollinators. For aphids, we found that two soap sprays, spaced a week apart, were needed to cause a significant reduction in aphid populations. The neem-based product AzaDirect performed similarly, but is no longer being considered for registration. Adding alyssum and coriander to the base of blueberry plants, as a way to attract natural enemies, did not result in an increase in natural enemies or a reduction in aphids. This is most likely because we did not have the alyssum and coriander in the field long-enough to see an effect. Finally, for black vine weevil significantly more mortality was obtained by drenching the root zone with the nematode *Steinernema carpocapsae* than with the entomopathogenic fungus *Metarhizium anisopliae*. The poor efficacy of the fungus was most likely due to the application method and the challenge of getting fungal spores to the blueberry root zone. Our report concludes with a summary of recommendations for future trials and of management practices that could be implemented immediately with the tools currently available – Dipel, soap and nematodes.

Introduction

Blueberry (*Vaccinium corymbosum*) production in British Columbia has expanded rapidly over the last 5 years. Although blueberries are native to North America and tolerant to many insect pests, pest levels often exceed threshold levels in blueberry fields grown in monocultures. Insect pests can affect blueberry production in two ways. They can feed directly on the fruit, causing cosmetic damage to the berries, or they can affect the long-term vigour and yield of a blueberry planting. Because blueberries are a perennial crop kept in production for over 20 years, both short-term and long-term pest issues must be addressed.

One recurring pest that directly feeds on the fruit is the oblique banded leafroller, *Choristoneura roseceana.* The first generation of leafrollers hatch in May and feed in the flower and green berry clusters. Because the emergence of this pest coincides with blossom and bee activity in the fields, both organic and conventional growers require tools to manage leafrollers without harming pollinators. The microbial insecticide Dipel (*Bacillus thuringiensis kurstaki)* is registered for blueberries and not toxic to bees, but cool spring temperatures are thought to affect its efficacy in the field. The microbial insecticide Entrust (spinosad) is registered in Canada on apple for control of oblique banded leafrollers and in the US on blueberries for leafrollers, fruitworms and but is not yet registered on blueberries in Canada. Entrust is an OMRI-listed insecticide that has potential for a label expansion to blueberries; however it is also toxic to bees (Riedl et al. 2006).

A second pest, the blueberry aphid, *Ericaphis fimbriata,* transmits the Scorch Virus, a virus that causes flower and leaf dieback and from which the bushes cannot recover. The blueberry aphid has become a priority pest for all blueberry growers in the Fraser Valley. The population growth rate of the blueberry aphid is highest in the spring (Raworth and Schade 2006), with aphid densities peaking in late June or early July (Raworth 2004). The Scorch Virus is transmitted primarily by winged aphids, which emerge in May (Raworth 2004). Thus, to reduce aphid population growth and the rate of virus spread, aphids should be managed in May and June. Soap sprays have been promoted for aphid control but field efficacy is unknown. In the US, Agroneem Plus (azadirachtin) is an organic insecticide registered for control aphids on blueberries. In early 2009, registration for a similar neem-based product, Azadirect (azadirachtin) was being pursued for Canada.

Biological control of blueberry aphids by native predators and parasitoids is highest in July and August (Raworth *et al.* 2008) as these beneficial populations build up after the pest population. One method of enhancing biological control of aphids is by introducing flowering companion plants earlier in the season, i.e. conservation biological control. Flowering companion plants provide alternate sources of food (pollen and nectar) and shelter to beneficial insects. McGregor (2006) found that parasitoids can be attracted by sweet alyssum (*Lobularia maritime*) and yarrow (*Achillea millefolium)* in plantings of cabbage. In broccoli, companion plants of coriander the most attractive to syrphid flies (Ambrosino *et al*. 2006). By attracting beneficial insects to a combination of sweet alyssum and coriander in May and June, the population of blueberry aphids and the rate of scorch virus transmission may be reduced.

A complex of weevil species, including black vine weevil, *Otiorhynchus sulcatus*, strawberry root weevil, *O. ovatus*, clay colored weevil, *O. singularis*, and obscure root weevil, *Sciopithes obscurus* are a threat to the long-term vigour of blueberry plantings. Weevils attack the roots of blueberry bushes, reducing their ability to take up water or nutrients, and increasing their susceptibility to root rot. The most susceptible weevil life stage is the larval stage which is present in the soil from September to May. Neither organic nor conventional blueberry growers have field-tested tools that target the larval stage. One potential product for weevil control is the entomopathogenic fungus Met 52 (*Metarhizium anisopliae),* which has been successful in controlling black vine weevil larvae in nursery ornamentals (Bruck and Donahue 2006). A second biological control agent is the entomopathogenic nematode, *Steinernema carpocapsae.* This nematode has shown some efficacy against weevil larvae in the roots of strawberries in Washington State (Booth *et al.* 2002).

While organic growers have historically relied upon cultural controls to manage insect pests, both organic and conventional growers would benefit from more tools to deal with short and long-term recurring insect pests. In recent years, numerous organic-certified products, including microbial insecticides, have come onto the market for other organic crops. We propose to test these organic products alongside conventional insecticides and cultural and biological techniques for control of leafrollers, aphids and weevils.

Objective

To evaluate the efficacy and develop use protocols for organic methods of controlling leafrollers, aphids and weevils in blueberries in British Columbia

Methodology

Leafrollers

These trials were conducted on three-year old blueberry plants cv. Reka growing in gallon containers. The trial was run at the E.S. Cropconsult Ltd. Abbotsford field site. A single plant was a replicated, plants were spaced 1 metre apart and treatments were randomly assigned to each plant prior to infestation with pest.

Experiment 1
Five hundred early instar leafroller larvae were collected in rolled leaves from a farm in Delta on May 4th. The leafrollers were transferred in the rolled leaves onto the research plants. Each plant received 10 leafrollers. Assessment of leafroller numbers on the research plants on May 18th indicated that leafrollers had failed to establish. On May 20th an additional 200 early instar leafrollers were collected and transferred onto the research plants (5 leafrollers/plant). The second infestation was successful and treatments were applied on May 25th. There were five treatments (Table 1), each replicated eight times (N=40). Leafroller numbers per plant were assessed immediately prior to treatment, five and seven days after treatment (5DAT, 7DAT). Each treatment was applied with a 4-L hand pump sprayer. Plants were kept in the shade following application of treatments to prevent breakdown of microbial products. Application rates were calibrated based on a planting density of 3658 blueberry plants per hectare, which is the mean planting density suggested in the BC Production Guide.

Table 1. Trade name, active ingredient, and application rate of treatments for leafrollers based on a standard planting density of 3658 plants per hectare.

Treatment	Active Ingredient	Registrant	Rate	Amount of product per plant
Dipel 2X DF	*Bacillus thuringiensis kurstaki*	Valent BioSciences Corp	1680g/300 litres water per hectare	0.46g
Entrust	Spinosad	Dow AgroSciences Canada Inc	109g/1000 litres water per hectare	0.03g
Decis	Deltamethrin	Bayer CropScience Inc	125ml/1200 litres water per hectare	0.03ml

Delegate	Spinetoram	Dow AgroSciences Canada Inc	100g/1000 litres water per hectare	0.03g
Untreated Control				

Experiment 2
Four hundred mid-instar leafroller larvae were collected in rolled leaves from a Delta farm on June 4th. Leafrollers were transferred onto the research plants by paintbrush. Each plant received six leafrollers. Treatments were applied on June 11th and were the same as those used for Experiment 1 (Table 1), with the addition of a water control (1000 litres/Ha). Each treatment was replicated five times (N = 30). Leafroller counts were carried out immediately prior to treatment and five, seven and 12 days after treatment. Experiment 2 was run on clean plants (i.e. not the same ones used for Experiment 1).

Aphids

These trials were run on three-year old potted blueberry plants cv. Duke. A single replicate for this study consisted of a pair of blueberry plants. Potted blueberry plants were tied together with flagging tape. Pairs of plants were spaced 50 cm apart and treatments randomly assigned. For the Beneficial Plant treatment pots containing alyssum and coriander were placed near replicates assigned to this treatment.

Aphids were collected on infested shoot tips from a Surrey blueberry farm on June 3rd. Two aphid-infested shoot tips were clipped to branch tips for each replicate. Branch tips were searched for natural enemies prior to adding aphids, and infested tips were covered with a fine mesh bag to prevent aphid escape or natural enemy attack. Despite these steps aphids failed to establish. Plants were re-infested with additional aphids, following the same protocol on July 6th and July 24th. Aphids failed to establish following each of these infestations.

On July 30, the potted-plant trial was abandoned and the experiment was moved to an established planting of highbush blueberries, cv. Duke in Port Coquitlam. A single row of mature blueberry bushes was used for this experiment. Every fifth bush was flagged for treatment. There were four aphid treatments (Table 2), each replicated eight times (N=32). All treatments were applied on July 30th. The Insecticidal soap and Azadirect treatments were applied with a 10 litre backpack sprayer on July 30th and repeated with a second application on August 7th. Application rates were calibrated based on a planting density of 3658 blueberry plants per hectare, which is the mean planting density suggested in the BC Production Guide. Beneficial plants (alyssum and coriander) were grown in a one gallon pot and placed at the base of the blueberry bush. The beneficial plants were watered every 5 days. Aphid infestations were assessed immediately prior to treatment on July 30th and 5, 8 and 12 days following initial treatment by randomly selecting ten young shoot tips and recording the number of shoot tips with aphids. Beneficial levels were also assessed by tagging three shoot tips with aphid infestations and recording the number of beneficials on each shoot tip prior to treatment and 5 days after treatment.

Table 2. Trade name, active ingredient, and application rate of treatments for aphids based on a standard planting density of 3658 plants per hectare.

Treatment	Active Ingredient	Registrant	Rate	Amount of product per plant
Insecticidal Soap	soap	Safers	30.6 litres/ 1500 litres water per hectare	8.38 ml
Azadirect	azadirachtin	Gowan	4.1 litres/1500 litres	1.12 ml

	(neem)		water per hectare	
Beneficial plants – alyssum and coriander				
Water Control				

Weevils

For this trial twenty-four, three-year old potted blueberry plants cv. Reka, were used. Plants used for this trial were those used for the Control treatments in the two leafroller experiments (above). A single plant was a replicate and the trial was conducted at the Institute for Sustainable Horticulture (Langley, BC). Plants were maintained at 20±2°C, with natural light.

Weevil eggs were acquired from Agriculture and Agri-Food Canada (Kentville, NS) and mixed into the soil of the blueberry plants at a rate of 50 eggs per plant on September 9, 2009. Additionally, three early instar weevil larvae, collected from cranberry fields in Richmond, BC, were inserted to a 2-cm depth in the root zone of each blueberry pot on November 30th and December 2nd. There were three treatments (Table 3), each replicated eight times (N=24). Nematodes were applied with a watering can mixed with 100 mL of water. Met 52 granules were sprinkled on to the surface of the soil and then lightly incorporated into the top layers of the soil and then watered (100mL/pot). Weevil survival was assessed on January 18, 2010 by manually sifting through the roots and soil of each blueberry pot. All live and dead weevils were removed from the soil and counted.

Table 3. Trade name, active ingredient, and application rate of treatments for weevils based on a standard planting density of 3658 plants per hectare.

Treatment	Active Ingredient	Registrant	Rate	Amount of product per pot
Met 52	*Metarhizium anisopliae*	Novozymes	60kg/ha	16g 100 ml of water applied post treatment
Nematodes	*Steinernema carpocapsae*	Becker Underwood	3 billion/acre	2,000,000 in 100ml of water
Water Control				100 ml water

Statistical Analysis

Data were analyzed statistically, using JMP-IN Version 5 software. Leafroller counts, the number of aphid-infested shoot tips and number of natural enemies (aphid study) were analyzed with repeated measures MANOVA. In the event of a significant Treatment X Time interaction in the MANOVA analyses, a profile analysis – one way ANOVA for each date – was conducted. Weevil mortality data was acrsine-transformed prior to analysis with one way ANOVA. All *post-hoc* analyses were conducted using Tukey-Kramer HSD (α = 0.05).

Results and Discussion

Leafrollers – For both trials there was significant interaction of Treatment X Time (Table 4), indicating that caterpillar numbers responded in different ways to each treatment, over the course of each experiment. In Experiment 1, all four insecticides caused a significant and immediate reduction in caterpillar numbers compared to pre-treatment counts. In the untreated Control caterpillar numbers stayed the same (Fig. 1a). In Experiment 2, caterpillar numbers declined in all treatments 5 days after treatments (5DAT), including the Water and untreated Control. However, 5DAT caterpillar numbers were significantly lower in the Entrust, Delegate and Decis treatments than either control. By 12DAT, caterpillar counts were essentially zero in all treatments. Dipel did not provide significantly better control than either Control treatment in Experiment 2.

The difference in the outcome for the Control (water and untreated) treatments between Experiment 1 and 2 is most likely due to the use of older larvae for Experiment 2 (which are more mobile). Consistent between the two trials is the performance of Entrust, which was as effective as the conventional standards Decis and Delegate (Fig. 1 a, b). Dipel performed as well as Decis and Delegate in Experiment 1 (Fig. 1a) but not in Experiment 2 (Fig. 1b). This is probably because Dipel efficacy is known to decline as caterpillar size increases; higher rates are recommended on the product label for older larvae. Our findings support the use of both Entrust and Dipel for caterpillar control for organic blueberries. Caution should be taken, however, when using Entrust during bloom as it is toxic to bees; Riedl *et al.* (2006) recommend using Entrust in the late evenings or night when bees are not foraging.

Table 4. Statistical results for effect of caterpillar control treatments on leafrollers on blueberry.

Experiment 1	F	df	P-value	Means comparison for Profile Analysis
Repeated-measures MANOVA				
Treatment	10.78	4, 35	<0.0001	
Time	79.14	2, 34	<0.0001	
Time X Treatment	3.61	8, 68	0.002	
Profile Analysis				
Pre-spray	4.06	4,35	0.008	Entrust ≠ Decis, Delegate, Control
5DAT	13.57	4,35	<0.0001	Control ≠ Decis, Delegate, Dipel, Entrust
7DAT	6.76	4,35	0.0004	Control ≠ Decis, Delegate, Dipel, Entrust
Experiment 2				
Repeated-measures MANOVA				
Treatment	3.71	5, 24	0.013	
Time	63.73	3, 22	<0.0001	
Time X Treatment	3.71	15, 61	0.0001	
Profile Analysis				
Pre-spray	0.56	5,24	0.73	N/A
5DAT	7.17	5,24	0.0003	Control ≠ Decis, Delegate, Entrust Water ≠ Delegate, Entrust
7DAT	6.86	5,24	0.0004	Control ≠ Water, Dipel Decis, Delegate, Entrust Water = Dipel Decis, Delegate, Entrust
12DAT	1.00	5,24	0.44	N/A

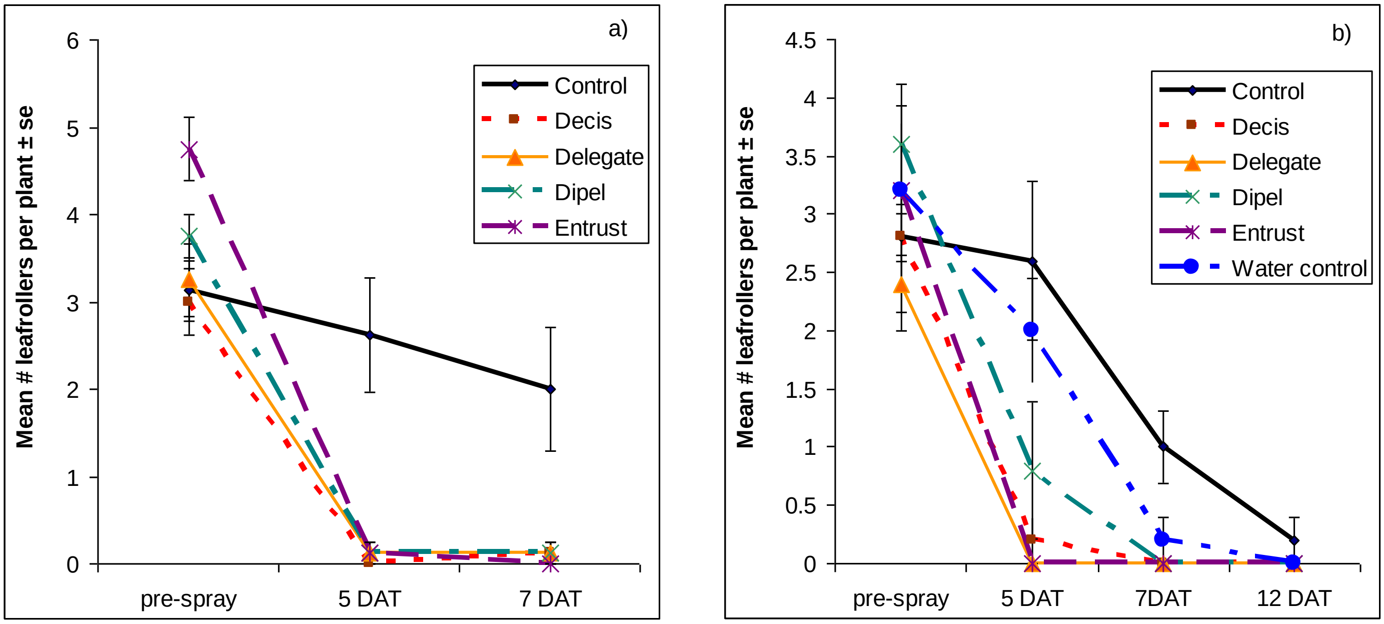

Figure 1. Mean number of leafrollers (± s.e.) alive on blueberry plants 5 and 7 days after treatment in Experiment 1 (a) and 5, 7 and 12 days after treatment in Experiment 2 (b)

Aphids – Our repeated attempts to establish aphids on potted blueberry plants through June and July were unsuccessful and by the end of July we abandoned these attempts and ran the trial in an established blueberry field, that had been unsprayed and had high aphid populations during most of June through early July. Unfortunately, by the time we ran our trial however aphid populations were declining on their own which is typical as plant quality declines and aphids prepare to overwinter. For production purposes aphid control in blueberries should be done in May and June. Despite running the trial later than intended we did see a significant reduction in aphids as a result of some of our treatments (Table 5).

Aphid levels were not significantly different prior to the application of treatments (Pre-treatment: F = 2.02, df = 3,28, p = 0.13). Following the first application of soap or neem we did not see a significant reduction in aphids (Fig. 2). Following the second spray however aphid infestation was significantly lower in the soap and neem treatments compared to the Control (Fig. 2). These findings are consistent with label recommendations for both soap and Azadirect that indicate repeat applications may be needed in order to observe efficacy. Our findings for the Beneficial Plant treatment, where aphid levels did not decline compared to the Control, are not surprising. In order for conservation biocontrol to be effective the alyssum and coriander should have been out for several weeks prior to the start of the trial in order to attract natural enemies to the adjacent bushes. At the same time, we did not see any impact of the Beneficial Plant, or any other, treatment on natural enemy levels in the trial (Fig. 3; Table 5). Again, not surprising given that the plants were not in the field long enough to attract enemies and support egg laying. It is encouraging however, to note that natural enemy numbers did not decline following the soap or Azadirect treatments (Fig. 3). These results indicate that following the use of either treatment natural enemies would still be active and able to provide additional aphid control.

Table 5. Statistical results for effect of control treatments on aphids and natural enemies on blueberry.

Aphid counts	F	df	P-value
Repeated-measures MANOVA			
Treatment	3.45	3,28	0.03
Time	30.86	3,26	<0.0001
Time X Treatment	1.89	9,63.43	0.07

Beneficial insects			
Repeated-measures MANOVA			
Treatment	1.17	3,28	0.34
Time	0.80	3,26	0.50
Time X Treatment	1.15	9,63.43	0.34

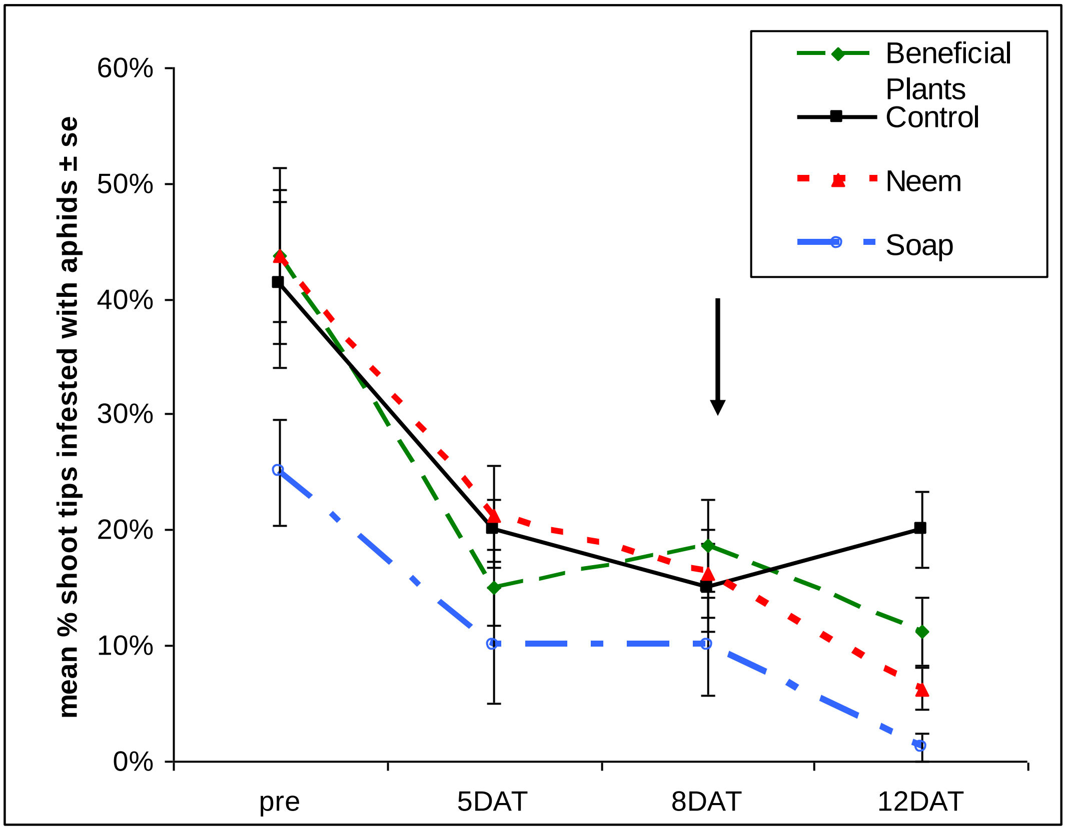

Figure 2. Percentage (mean ± s.e.) of shoot tips infested with aphids prior to treatment and 5, 8 and 12 days after treatment. The arrow indicates the timing of the second application of Azadirect (neem) and soap treatments.

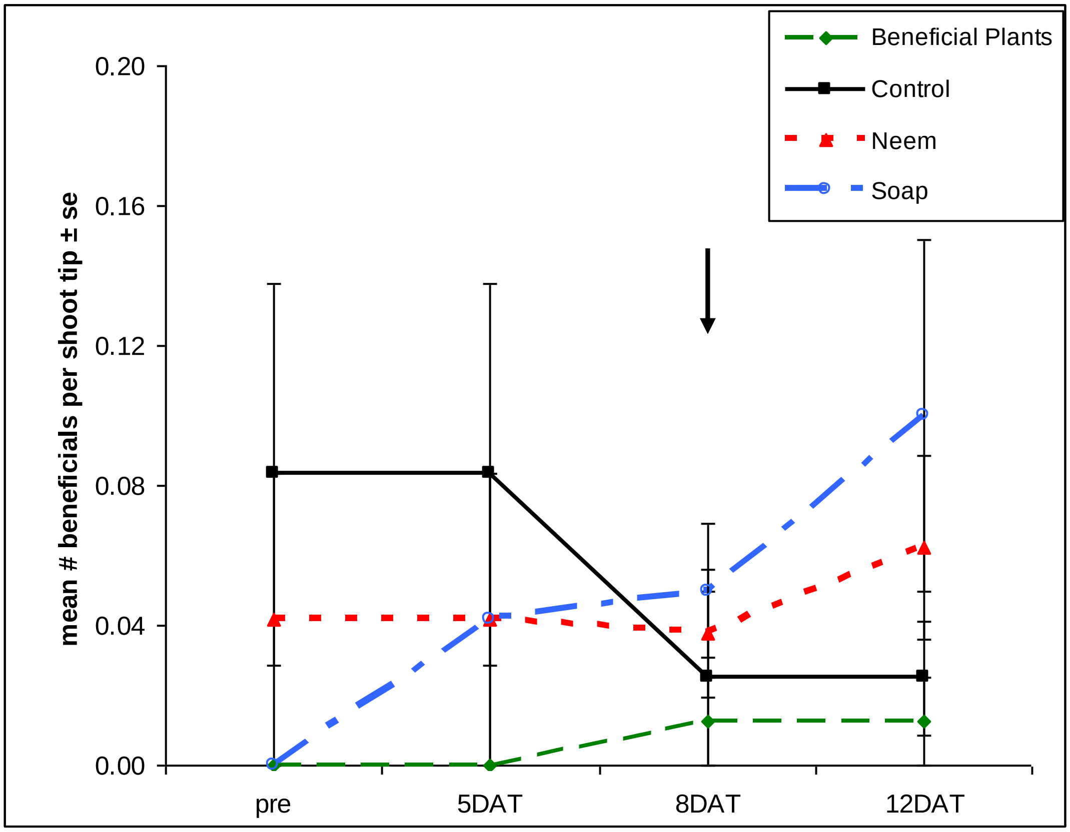

Figure 3. Impact of aphid control treatments on the number (mean ± s.e.) of beneficials/shoot tip prior to treatment and 5, 8 and 12 days after treatment. The arrow indicates the timing of the second application of Azadirect (neem) and soap treatments.

<u>Weevils</u>

Weevil mortality was significantly higher in potted blueberry plants treated with the nematode *S. carpocapsae* than in pots treated with the fungus *M. anisopliae* or Control plants (Fig 4, *F*=25.16, *df*= 2,21, $p < 0.0001$). Weevil mortality was 88% in *M. anisopliae*-treated plants, and 92% in untreated control plants, compared to 100% mortality observed in plants treated with *S. carpocapsae*. High levels of mortality are not unusual for studies with black vine weevils – eggs are vulnerable to dessication and larvae do not tolerate handling very well. The lack of efficacy of *M. anisopliae* against black vine weevil is surprising given that in previous work with black vine weevils by ourselves (E.S. Cropconsult Ltd., 2008) and others (Bruck and Donahue 2006) has shown that this biofungicide causes significant mortality. Both of these studies were conducted in containerized nursery stock and *M. anisopliae* granules were pre-incorporated into potting mix prior to weevil infestation. Similarly, Ansari *et al.* (2008, 2010) found that applications of *M. anisopliae* added to potting media prior to weevil infestation combined with the nematode *Steinernema kraussei* had an additive effect in controlling black vine weevils in strawberries grown in grow-bags.

For the current trial, we applied *M. anisopliae* following weevil infestation – to mimic the growers practice in the field. Thus the difference between our previous work by Ansari *et al*. (2008, 2010), Bruck and Donahue (2006) and the current study in blueberry seems to be due to the timing of application. Application and incorporation of *M. anisopliae* granules to the upper surface of the soil (5 cm deep incorporation), may not have been sufficient for the fungal spores to reach larvae. Our water regime also may not have been sufficient to wash spores down to where weevil larvae were feeding. In cranberries, Booth et al. (2000) found that *M. anisopliae* granules sprinkled on to the surface of cranberry fields resulted in a trend toward reduced survival of weevil larvae, however the differences observed were not significant between Control and *M. anisopliae* treatments . In their study, Booth et al. (2000) also irrigated for 1 hour following application of *M. anisopliae*, which may have helped to wash spores down to the root zone.

Our results do show however that nematodes can be effective for black vine weevil control in blueberries. We recommend that growers do test patches in their fields before investing heavily in a whole field nematode application. Nematode efficacy is impacted by a number of factors including soil type, soil moisture and exposure to sunlight. As with *M. anisopliae* it is important to use a sufficient volume of water to get nematodes into the root zone where larvae feed. One effective way to use nematodes for black vine weevil control in blueberries, maybe spot applications with a backpack sprayer in areas where weevil feeding has been confirmed or is suspected.

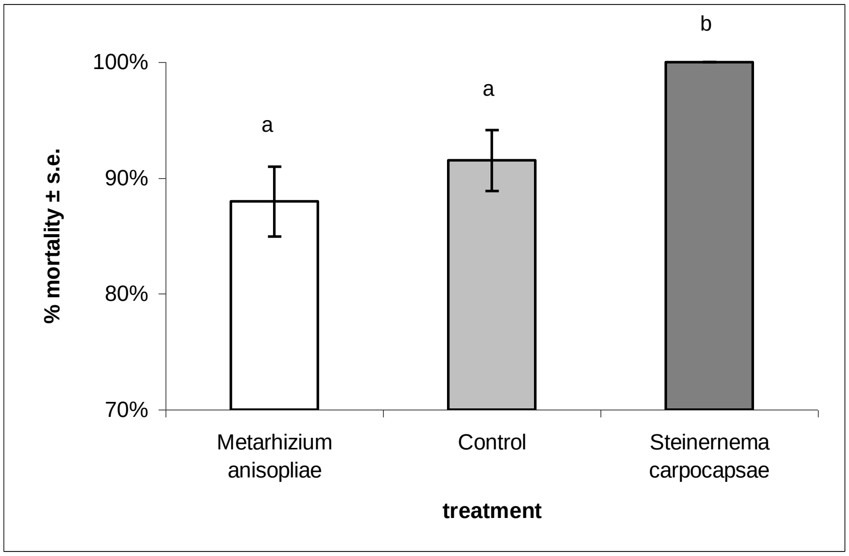

Figure 4. Mortality (mean ± s.e.) of weevils by treatment. Bars with the same letter are not significantly different based on Tukey Kramer HSD (α = 0.05).

Summary

Based on our potted-plant trials the following recommendations are made for either further testing of unregistered products or field use of registered products

- Leafrollers – Dipel is currently registered for blueberries and was effective when used against early instar larvae, not as effective when used against older larvae; ensure thorough coverage. Entrust should be field tested further and efficacy data collected to support a label expansion to include leafrollers on high bush blueberry. Caution should be used however as Entrust is highly toxic to bees.
- Aphids – Soap sprays were effective with repeat applications and in general soap treatments should start in May when aphid populations are still low. Although Azadirect showed promising results, registration for this product is no longer being pursued in Canada. In order for conservation biological control – using flowering plants like alyssum and coriander– to be effective plantings should be done early in the season to attract enemies to the field as soon as aphids migrate in. Further testing should be done to establish an effective protocol for attracting natural enemies of blueberry aphid into organic fields.

- Weevils – *Steinernema carpocapsae* is currently available, however further field testing should be conducted to confirm potted plant results. Growers should be aware that soil temperature and composition can dramatically impact nematode performance. We recommend small hotspot applications with a backpack sprayer, rather than whole field treatment. Further testing is needed to determine an application protocol (rate, incorporation depth, water volume for irrigation after treatment) to effectively deliver *M. anisopliae* spores to weevil larvae feeding on blueberry roots.

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