Project Title: Exploring Tools to Address Priority Insect and Weed Pests of British Columbia Cranberries

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Commission Research Priority

1. Perennial Weeds (High Priority)
2. Cranberry Tipworm (High Priority)

Objectives

1. Explore field performance of newly registered, soon-to-be-registered, and experimental herbicides on priority weeds in British Columbia growing conditions.
2. Continue efficacy trials of Compound X to support future potential registration for cranberry tipworm control.

Project Summary

Screening and evaluating effective crop protection tools to assist in the management of difficult weeds and insect pests is a high priority for British Columbia cranberry producers. Historically, herbicides have been the most difficult pesticide tool for which to gain registration for cranberry growers, due in part to regulatory hurdles, but also the inherent challenges of managing weeds in a broadleaf perennial groundcover crop. Coupled with high weed pressure in cranberry beds and the Fraser Valley's relatively mild winter climate that allows for an extended season of weed growth, this dearth of herbicides has meant labourious and expensive weed control efforts for growers. This project generated efficacy and crop tolerance data for an array of herbicides that both support novel product registrations as well as guide recommendations for newly registered and pipeline products. In addition to herbicide product trials, this work further explored a promising insecticide tool for the control of cranberry tipworm. With the recent discoveries on this pest's overwintering behaviour, a laboratory-based protocol was adapted to capture product efficacy data more accurately for this small gall-inducing midge pest. The data from this project supports both local growers as well as the cranberry industry at large as the scientific and extension community seek to understand best practices of currently available and potential tools.

Project Duration

March 2022 to November 2022

Location

British Columbia Cranberry Research Farm (BCCRF)

Research Objective 1: Explore field performance of newly registered, soon-to-be-registered, and experimental herbicides on priority weeds in British Columbia growing conditions.

Herbicide Summary

Product	2022 Field Activities	Key Takeaways
Compound A	Crop tolerance (yield) in established Mullica Queen plots, efficacy and crop tolerance (visual) on establishing Vasanna vines. All applications done in 200 L/ha water volume with irrigation incorporation on April 1st (tight bud stage).	No statistical yield impacts on established Mullica Queen vines when applied at tight bud stage (April 1st) with subsequent water incorporation via sprinklers (but trended to lower yield). Moderate to severe crop injury observed on establishing Vasanna vines when applied at tight bud stage (April 1st). Product provided good control of hardhack, variable control of sheep sorrel, and no control of clover in 2021 trials; moderate to poor control of sheep sorrel and silvery sedge in 2022. Key management recommendations are to apply early to avoid plant injury (prior to bud break) and incorporate with irrigation water immediately following application. This product has a significant risk for plant injury, with apparent higher risk on new plantings. Growers should use with caution.
Authority (Sulfentrazone)	Crop tolerance (yield) in established Mullica Queen plots, efficacy and crop tolerance (visual) on establishing Vasanna vines. All applications done in 200 L/ha water volume with irrigation incorporation on April 1st (tight bud stage).	No statistical yield impacts on established Mullica Queen vines when applied at the tight bud stage (April 1st) with subsequent water incorporation via sprinklers. No visual injury on establishing Vasanna vines when applied at tight bud stage (April 1st). Product provided good control of hardhack, poor control of sheep sorrel (reported to provide good control at US rates), and no control of clover in 2021 trials; moderate to good control of sheep sorrel in 2022, particularly when paired with a post-emergent application of Callisto, moderate control of spirea and silvery sedge. Key management recommendations are to apply early to avoid plant injury (prior to bud break) and incorporate with irrigation water immediately following application. This product has some plant injury risk potential and has been reported to have strong synergistic effects when mixed with other herbicides (growers should not tank mix before establishing site-specific crop safety).
Compound B	Crop tolerance (yield) in established Mullica Queen plots at 1x and 2x rates, efficacy and crop tolerance (visual) on establishing Vasanna vines at 1x rate. All applications done in 200 L/ha water volume with irrigation incorporation on April 1st (tight bud stage).	No statistical yield impacts on established Mullica Queen vines when applied at the tight bud stage (April 1st) with subsequent water incorporation via sprinklers at 1x and 2x rates. No visual injury on establishing Vasanna vines when applied at tight bud stage (April 1st) at 1x rate. Moderate to good control of sheep sorrel in 2022 with or without a post-emergent application of Callisto. Key management recommendations are to apply early to avoid plant injury (prior to bud break) and incorporate with irrigation water immediately following application. This product has some plant injury risk potential but no indication that the second active increases risk over Authority (sulfentrazone) alone.
Compound C	Efficacy trial in establishing Vasanna vines applied on June 8th at hook stage. Efficacy trial on morning glory applied on May 19th in established Mullica Queen vines at late roughneck stage. Applications in 200 L/ha water volume.	Crop safety well-established for this product. Provided good control of silvery sedge on establishing Vasanna vines in 2021 and 2022; moderate control of sheep sorrel and spirea in 2022. Good control of morning glory in established Mullica Queen vines. No visual signs of phytotoxicity in any plots. Other research suggests activity on additional sedge species, as well as goldenrod, buttercup, loosestrife, and grasses. Good candidate for Callisto tank-mix. Product was selected as the 2021 Canadian PMC minor-use project for cranberries (AAFC22-018).

Compound D	Efficacy trial in establishing Vasanna vines applied on June 8th at hook stage. Applications in 200 L/ha water volume.	Crop safety well-established for this product. Provided good control of silvery sedge on establishing 'Vasanna' vines in 2021 and 2022 with no visual signs of phytotoxicity. Other research suggests activity on buttercup, goldenrod, morning glory, and nutsedge. Good candidate for Callisto tank-mix. Product was selected as the 2020 Canadian PMC minor-use project for cranberries (AAFC21-008).
Compound E	Crop tolerance assessment in established Mullica Queen vines and clover efficacy trial in establishing 98-11 vines, applied on April 22nd and August 8th (white bud and fruit set stages). Applications in 200 L/ha water volume.	Based on current and past years' work, appears to be safe if sprayed at fruit set at a rate of 290.5 – 387.3 mL/ha with 0.25 – 0.5 % Gateway® adjuvant, or prior to bud break for spot sprays of common rush (avoid contact with cranberry vine to minimize injury risk). Lower rate recommended at the white bud stage, and no applications should be made to tender new cranberry growth. Can provide good control of clover, vetch, some activity on birdsfoot trefoil and horsetail. Could be used as a dormant spot spray for common rush.
Compound F	Crop tolerance assessment in established Mullica Queen vines and clover efficacy trial in establishing 98-11 vines, applied on April 22nd and August 8th (white bud and fruit set stages). Applications in 200 L/ha water volume.	Based on current and past years' work, appears to be safe if sprayed at fruit set at a rate of 27.4 – 36.5 mL/ha with 0.25 – 0.5 % Gateway® adjuvant. Lower rate recommended at the white bud stage, and no applications should be made to tender new cranberry growth. Can provide good control of clover, some activity on birdsfoot trefoil, possible candidate for control of other legume weeds.
Compound G	Efficacy assessment in establishing Vasanna vines and established Mullica Queen vines (on morning glory). Applications in 200 L/ha water volume.	Crop tolerance is now well established for this product through field trials and US registration (under third party label). No notable efficacy was seen in 2022 field trials at BCCRF on the spectrum of weeds assessed (eg. sheep sorrel, spirea). High organic matter content at BCCRF may have affected efficacy. High rates at second Delta site offered suppression to moderate control of morning glory. Registration will continue to be pursued with BASF at the proposed highest label rate of 0.69 L/ha.

Summary of Treatments

Pre-emergent herbicides Authority (sulfentrazone), Compound B, and Compound A

<table>
<tr><th>Product Name</th><th>Active Ingredient</th><th>Site</th><th>Spray Timing</th><th>Date of Application</th><th>Rate</th><th>Water Volume</th><th>Adjuvant</th><th>Notes</th></tr>
<tr><td>Authority</td><td>Sulfentrazone</td><td rowspan="4">BCCRF (Mullica Queen Field 3 and Vasanna Field 5)</td><td rowspan="4">Tight Bud</td><td rowspan="4">April 1st</td><td>292 mL/ha</td><td rowspan="4">200 L/ha</td><td rowspan="4">N/A</td><td rowspan="4">Immediate incorporation with sprinklers</td></tr>
<tr><td rowspan="2">Compound B</td><td rowspan="2"></td><td>600 mL/ha (1x)</td></tr>
<tr><td>1200 mL/ha (2x)</td></tr>
<tr><td>Compound A</td><td></td><td>425.24 g/ha</td></tr>
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Post-emergent herbicides Compound F and Compound E

<table>
<tr><th>Product Name</th><th>Active Ingredient</th><th>Site</th><th>Spray Timing</th><th>Date of Application</th><th>Rate</th><th>Water Volume</th><th>Adjuvant</th></tr>
<tr><td rowspan="4">Compound F</td><td rowspan="4"></td><td rowspan="8">BCCRF (Mullica Queen Field 3 and Vasanna Field 5)</td><td>White Bud</td><td>April 22nd</td><td rowspan="4">27.4 mL/ha</td><td rowspan="4">200 L/ha</td><td rowspan="2">0.25% Gateway</td></tr>
<tr><td>Fruit Set</td><td>August 8th</td></tr>
<tr><td>White Bud</td><td>April 22nd</td><td rowspan="2">N/A</td></tr>
<tr><td>Fruit Set</td><td>August 8th</td></tr>
<tr><td rowspan="4">Compound E</td><td rowspan="4"></td><td>White Bud</td><td>April 22nd</td><td rowspan="4">290.5 mL/ha</td><td rowspan="4">200 L/ha</td><td rowspan="2">0.25% Gateway</td></tr>
<tr><td>Fruit Set</td><td>August 8th</td></tr>
<tr><td>White Bud</td><td>April 22nd</td><td rowspan="2">N/A</td></tr>
<tr><td>Fruit Set</td><td>August 8th</td></tr>
</table>

Post-emergent herbicides Compound C, Compound D, Compound G, and Callisto (mesotrione)

<table>
<tr><th>Product Name</th><th>Active Ingredient</th><th>Site</th><th>Spray Timing</th><th>Date of Application</th><th>Rate</th><th>Water Volume</th><th>Adjuvant</th></tr>
<tr><td>Compound C</td><td></td><td rowspan="2">BCCRF (Vasanna Field 5)</td><td>Hook</td><td>June 8th</td><td>60 g/ha</td><td>200 L/ha</td><td>0.2 % Agral 90</td></tr>
<tr><td>Compound D</td><td></td><td>Hook</td><td>June 8th</td><td>36 g/ha</td><td>200 L/ha</td><td>0.2 % Agral 90</td></tr>
</table>

Compound G			Hook	June 8th	0.69 L/ha	200 L/ha	0.5% Merge
Callisto tank-mixed with above treatments	Mesotrione		Hook	June 8th	0.21 L/ha	200 L/ha	N/A

Post-emergent herbicides Compound C, Compound G, and Callisto (mesotrione)

Product Name(s)	Active Ingredient	Site	Spray Timing	Date of Application	Rate	Water Volume	Adjuvant
Compound G + Compound C		Second Delta Farm (Mullica Queen)	Roughneck (some scattered hook)	May 19th	0.69 L/ha + 60 g/ha	200 L/ha	0.5% Merge
Compound G					0.69 L/ha		0.5% Merge
					1.38 L/ha		
Compound G + Callisto					0.69 L/ha + 0.21 L/ha		0.5% Merge

Summary of Field Activities

Pre-emergent herbicides Authority (sulfentrazone), Compound B, and Compound A

Crop tolerance was assessed in establishing Vasanna vines (visually) and in established Mullica Queen vines (yield). Applications were completed on April 1st, 2022 (tight bud stage) with a CO_2 backpack sprayer using a 200 L/ha water volume, followed immediately by an irrigation incorporation (~2 cm water). The field trials were randomized complete block design with four replicates. Square-foot samples were hand-harvested in each plot for yield assessments in the Mullica Queen vines and visual phytotoxicity ratings were completed on the Vasanna vines.

There were no statistically significant yield impacts of any of the pre-emergent herbicides (table 1). Compound A plots in establishing Vasanna vines showed moderate to severe plant injury. Yields did trend lower for Compound A plots in the Mullica Queen vines, although no visual injury was evident. Past years' work has shown yield impacts on Stevens vines, demonstrating this product's potential for plant injury and yield loss, and variable injury depending on the variety and spray timing. Once registered, growers should proceed with extreme caution when getting to know how this product behaves on their farms and minimize risk by using reduced rates, applying well before bud break, and incorporating with irrigation immediately following application. While crop injury risk is evident with this product, growers should be able to expect control of moss, some control of hardhack and sheep sorrel, and suppression of some sedges.

Authority and Compound B applications had no effect on yield in Mullica Queen vines and showed no visual signs of injury in establishing Vasanna vines. Past years' work with Authority has shown that this product can be relatively safe when applied early (well before bud break) and incorporated immediately with irrigation to get product off foliage and into the top layer of soil. It has been observed in other regions that Authority can have strong synergistic effects when tank-mixed with other herbicides, which may improve weed control, but increases the likelihood of crop injury. Growers can expect some degree of control of hardhack, sheep sorrel (very good control reported at higher US rates), spirea, and silvery sedge (no control of clover). The second active in Compound B did not appear to increase plant injury risk. No additional weed control beyond single active Authority was noted in these trials, but this active's efficacy should continue to be explored now that crop safety is somewhat established. Most notably, Authority is showing promise as a control/suppressor of horsetail when paired with post-emergent applications of Callisto. Dr. Jichul Bae's work on herbicide layering demonstrates this and shows the importance of using both pre and post-emergent products throughout a weed's lifecycle.

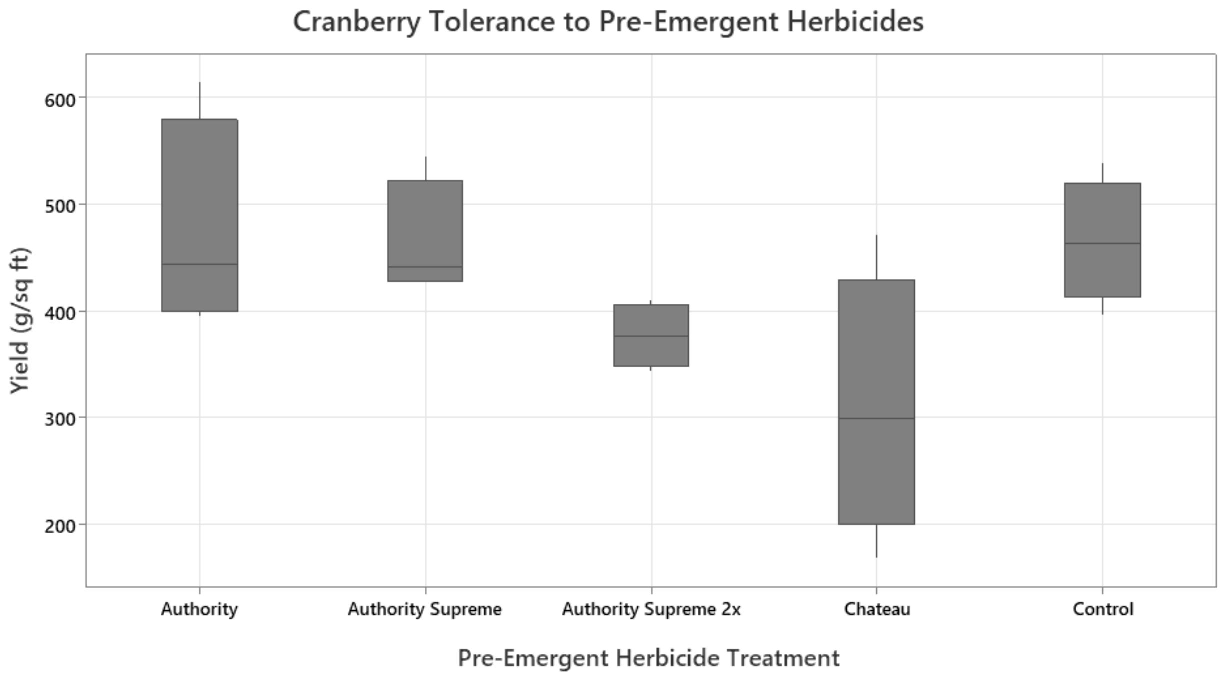

Table 1: Yield impacts of Authority (sulfentrazone), Compound B, and Compound A applications on Mullica Queen vines ($p = 0.044$).

Grouping Information Using the Tukey Method and 95% Confidence

Pre-Emergent Treatment	N	Yield (g/ft^2)	Grouping
Authority	4	473.6	A
Control	4	464.8	A
Compound B	4	463.0	A
Compound B 2x	4	376.0	A
Compound A	4	308.9	A

Means that do not share a letter are significantly different.

Table 2: Statistical analysis for yield impacts of Authority (sulfentrazone), Compound B, and Compound A applications on Mullica Queen vines ($p = 0.044$).

Figure 1: Control (right) versus Authority application (left). Hardhack control was evident in Authority-treated areas in establishing Vasanna vines in 2021.

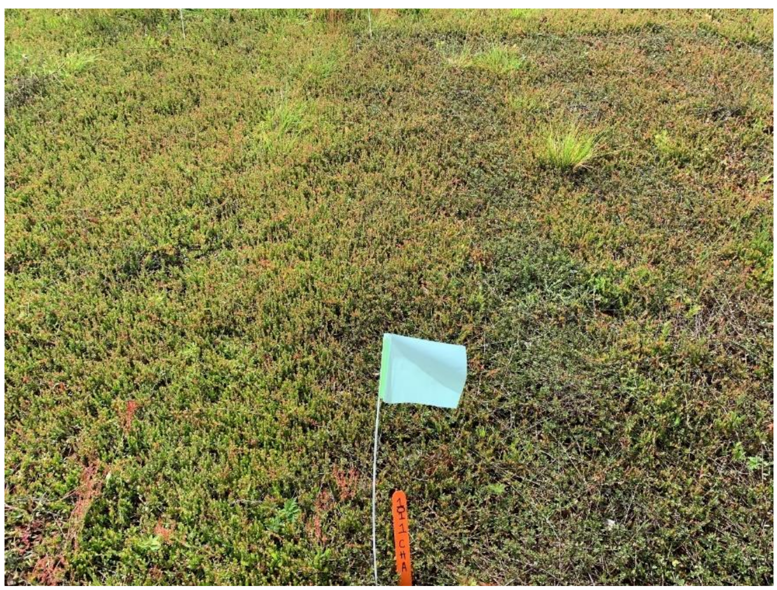

Figure 2: Control (left) versus Compound A application (right). Crop injury was evident in treated areas in establishing Vasanna vines in 2022.

Post-emergent herbicides Compound F and Compound E

Crop tolerance was assessed in established Mullica Queen vines (yield). Clover efficacy was assessed in an unreleased variety (98-11) with heavy weed pressure. Applications were completed on April 22nd and August 8th, 2022 (white bud and fruit set stage) with a CO_2 backpack sprayer using a 200 L/ha water volume. The field trials were randomized complete block design with four replicates. Square-foot samples were hand-harvested in each plot for yield assessments in the Mullica Queen vines and visual phytotoxicity ratings and weed efficacy ratings were completed in the 98-11 vines. Previous years' work has shown that there is potential for injury with these products when applied to actively growing cranberry tissue, so early and late plant stages were chosen for 2022 plot work. Surfactant treatment effects were also included in the treatment list to try to pinpoint cause of potential injury.

There were no statistically significant yield impacts of any of the Compound F or Compound E herbicide treatments, with or without surfactant and regardless of spray timing (table 3). This suggests that the surfactant recommended with the products (Gateway®) was not the cause of injury in previous seasons' applications. Higher herbicide rates and non-ideal spray timing were likely the cause of injury. Very slight injury was noted in the establishing 98-11 vines from Compound E applications, but the vines seemed to grow out of the injury and set buds successfully. Both products showed promise for clover control or suppression, control of vetch, with some activity also noted on birdsfoot trefoil. Compound E also showed suppression on common rush in 2021.

Both products have a place in weed control for cranberry growers, with some caution being given to rates and spray timing. Compound F appears to be safe if sprayed at fruit set at a rate of 27.4 – 36.5 mL/ha with 0.25 – 0.5 % Gateway® adjuvant. Lower rate recommended at the white bud stage, and no applications should be made to tender new cranberry growth. Compound E appears to be safe if sprayed at fruit set at a rate of 290.5 – 387.3 mL/ha with 0.25 – 0.5 % Gateway® adjuvant, or prior to bud break for spot sprays of common rush (avoid contact with cranberry vine to minimize injury risk). Lower rate recommended at the white bud stage, and no applications should be made to tender new cranberry growth.

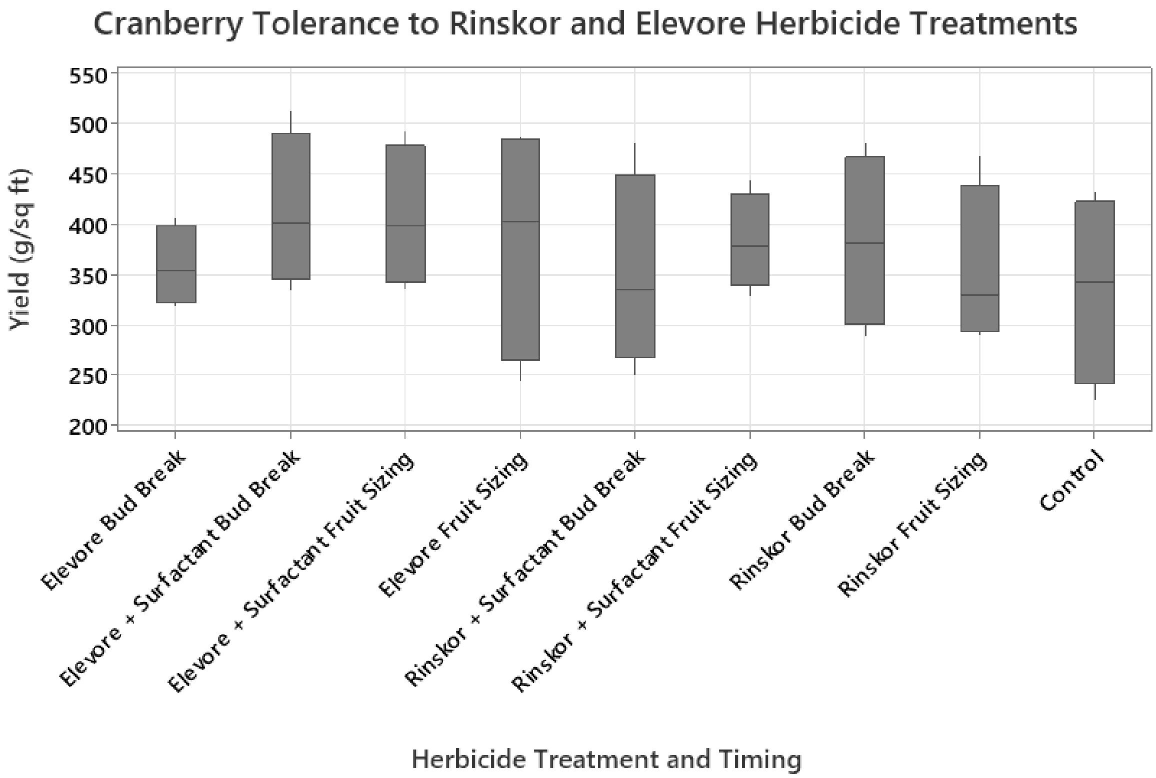

Table 3: Yield impacts of Compound F and Compound E at white bud and fruit set timing, with and without surfactant on Mullica Queen vines (p = 0.912).

Grouping Information Using the Tukey Method and 95% Confidence

Treatment	N	Yield (g/ft^2)	Grouping
Compound F + Surfactant Bud Break	4	412.4	A
Compound F + Surfactant Fruit Siz	4	406.6	A
Compound F Fruit Siz	4	384.0	A
Compound E Bud Break	4	383.1	A
Compound E + surf Fruit Siz	4	382.7	A
Compound F Bud Break	4	358.6	A
Compound E Fruit Size	4	354.6	A
Compound E + surf Bud Break	4	350.9	A
Control	4	335.9	A

Means that do not share a letter are significantly different.

Table 4: Statistical analysis for yield impacts of Compound F and Compound E at white bud and fruit set timing, with and without surfactant on Mullica Queen vines (p = 0.912).

Figure 3: Control (top) versus Compound E + surfactant application (bottom) on establishing 98-11 vines. Clover control was observed in all Compound E and Compound F treatments in 2022.

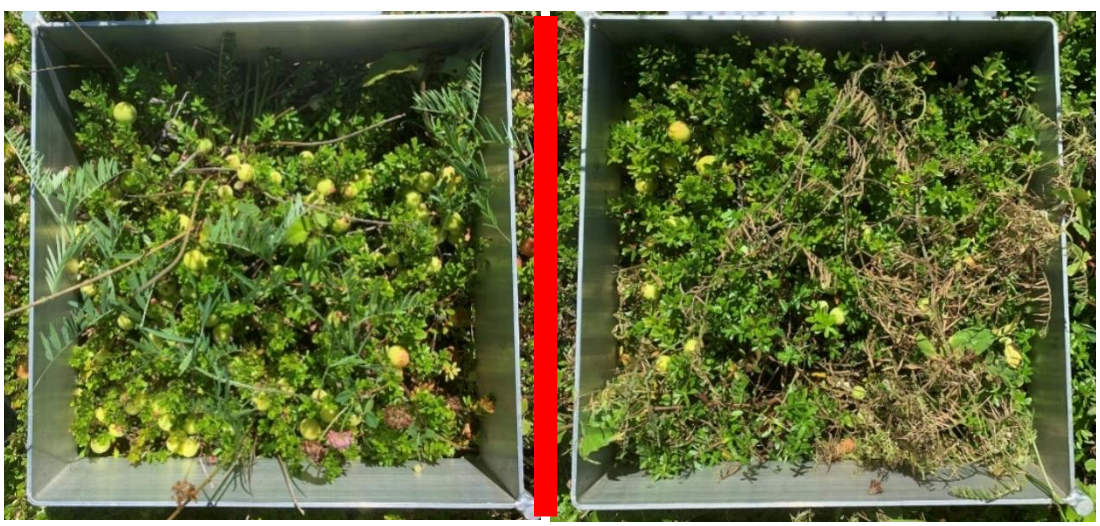

Figure 4: Control (left) versus Compound E + surfactant application (right) on vetch in establishing 98-11 vines. Good control of vetch was observed in 2022.

Post-emergent herbicides Compound C, Compound D, and Compound G ()

With crop tolerance well-established for these three compounds in previous studies and through US registrations, efficacy work was the focus of 2022 trials for these products. Efficacy was assessed in establishing Vasanna vines and a subset of treatment combinations was applied at a neighbouring Delta farm with heavy morning glory pressure (established Mullica Queen field). Applications were completed on June 8th, 2022 at BCCRF on the Vasanna vines (hook stage) targeting 3-5 leaf stage of as many weed species as possible (post-emergent but before large plants were established). Applications were made with a CO_2 backpack sprayer using a 200 L/ha water volume. The field trials were randomized complete block design with four replicates at BCCRF and two replicates at the second Delta site. Visual phytotoxicity ratings and weed efficacy ratings were completed at both sites.

Compound Cand Compound D both showed suppression or control of silvery sedge (excellent control in 2021 plots under heavy pressure). Suppression of sheep sorrel was evident in some plots but was not consistent (sheep sorrel is difficult to assess as it appears in satellite patches). Spirea control was noted for all treatments, including Compound G (suppression to good control). A tank mix of Compound Cand Compound G at the second Delta site showed promising suppression of morning glory, a very challenging and aggressive weed in BC cranberry fields. Solo Compound G plots did not perform as well as the tank mix, suggesting synergy with Compound Cor Compound Chaving the primary activity on morning glory.

No visual injury was observed on any plot with any treatment in 2022 trials or in past years' field work. Tank mixes of these products with Callisto did not yield additional weed control (no crop injury), but Callisto mixes should continue to be explored by growers as they have promise for control of problematic weeds (eg. buttercup, morning glory). When registered in Canada, growers should be able to use these products with low risk for crop injury.

Figure 5: Control (right) versus Compound D application in establishing Vasanna vines in 2021. Good control of silvery sedge was observed in both Compound Cand Compound D plots in 2021 and 2022.

Figure 6: Compound C + Compound G tank-mix treated morning glory plot in established Mullica Queen

Figure 7: Compound G 2x (left) treated morning glory plot in established Mullica Queen vines compared to untreated area (right).

Figure 8: Field trial setups in (top left) establishing Vasanna vines; (top right) establishing 98-11 vines; and (bottom) established Mullic Queen vines.

Relevant Literature

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Graham, G. L. (2011). Evaluation of herbicide options within newly established cranberry production. Report for the New Brunswick Department of Agriculture and Aquaculture, Crop Development Branch.

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Special Local Needs Stinger Label (Washington-030006). Supplemental Stinger Label (Wisconsin). Special Local Needs Stinger Label (Oregon-030009). EPA Reg No. 62719-73.

Research Objective 2: Continue efficacy trials of Compound X to support future potential registration for cranberry tipworm control.

Abstract

Cranberry tipworm (*Dasineura oxycoccana*) is a major pest in commercial cranberry production. The insect can severely impact yields by feeding on the tender meristematic tissue of the cranberry shoot tip and reduce the plant's ability to set a fruit bud for the following year's crop. Late season feeding damage tends to be the most economically significant, as the plant has less time to produce a compensatory shoot and set a reproductive bud before the onset of dormancy. This project assessed the efficacy of the insecticide Compound X at a rate of 150 g ai/ha (750 mL/ha) for control of cranberry tipworm compared to the industry standard, Movento® (spirotetramat) at a rate of 104.4 g ai/ha (435 mL/ha). A higher rate of Compound X was tested in 2021 (200 g ai/ha). Product efficacy was assessed by treating cranberry shoots in a laboratory setting and monitoring for adult tipworm emergence for 21 days post-treatment. Cranberry shoots were also dissected after the 21 days of adult emergence to quantify dead larvae in each treatment. In both 2021 and 2022, A significantly higher number of adult tipworms emerged from the untreated shoot tips than the Movento® or Compound X treatments and significantly more dead larvae were recovered from the Movento® and Compound X treatments than the untreated control. These results indicate that Compound is a strong candidate for cranberry tipworm control, with similar performance to the current industry standard Movento®. The product manufacturer (Bayer) indicated support for registration up until February 2022, but has since withdrawn support; however, as industry has experienced with past compounds, registration may be supported in the future.

Background

Cranberry tipworm can significantly reduce yields in commercial cranberry crops. The insect reduces the number of floral/fruit-bearing shoots in the field by feeding on and killing shoot tips (Figure 1). Cranberry tipworm is consistently ranked as a priority pest by the Canadian provinces during the Minor Use Priority Setting Workshops and solutions are actively sought. Growers and researchers in the United States growing regions also deal with this insect pest and prioritize efficacy trials addressing its control. Currently, there are only three insecticides registered for control in Canada: Movento®, Delegate™ (suppression), and Rimon® (suppression). The most effective insecticide, Movento® (spirotetremat), is limited to post-bloom applications. While Movento® has been highly effective in reducing cranberry tipworm populations in the field with its systemic activity, it remains important to explore alternative control options that allow growers to achieve population reductions throughout the entire season and prevent insecticide resistance development. Delegate™ and Rimon® are both labelled for suppression only and have not been shown to be particularly good controls in a commercial setting, hence growers' reliance on Movento®.

Compound X represents a novel insecticide resistance class (4D – butenolide) in the cranberry spray rotation. It is labelled in several other berry crops including strawberry and both lowbush and highbush blueberry. The blueberry gall midge, a morphologically identical (but cryptic species) to cranberry tipworm, has been shown to have some success with Compound X applications (Collins, 2016 and Liburd, 2019). The product's pre-bloom label potential also makes it a strong fit for this integrated pest management gap, as the post-bloom Movento® label leaves cranberry tipworm populations uncontrolled early in the season. Compound X has been trialled in cranberries previously with varying results (Mauza, 2014 and Patten, 2016); however, these trials were field-based, which can be a difficult environment in which to elicit cranberry tipworm efficacy data given the insect's unique overwintering behaviour.

It was recently found (Fitzpatrick *et al.* 2018) that cranberry tipworm adults can emerge from overwintering sites in the soil all season long, ensuring continuous infestation in the field. Unless dead larvae are recovered from treated shoots, it is difficult to elucidate the true effects of systemic products in field-based trials, as newly emerged tipworm adults can enter the trial area and deposit new eggs on shoots. For this reason, this trial was done in a controlled laboratory setting with isolated shoots and dead larval quantification to show true treatment effects.

Study Methods

A commercial cranberry farm was identified as having a moderate to severe cranberry tipworm infestation with the assistance of a local crop consultant. This farm is located in the Fraser Valley of British Columbia and has several well-established cranberry fields (15+ years old). Cranberry shoots were collected from this farm and brought back to the laboratory in a cooler. A subset of shoots (50) were dissected to determine a baseline rate of infestation which was found to be 8% in 2022 and 28% in 2021. The cultivar used in this experiment was 'Ben Lear'.

Shoots were then grouped into sets of ten and placed into "micro greenhouses" (Figure 4). Micro greenhouses were made using two clear plastic cups. The bottom cup was filled with plain chlorinated tap water and covered with cling film. Holes were poked in the cling film and the ten shoots were placed in the holes, ensuring the bottoms of the shoots reached the water. Each of the three treatments had thirty replicates, for a total of three hundred treated shoots per treatment.

Shoots were then treated with a micropipette. A droplet of the insecticide solution (0.3 microlitres) was placed directly on the cranberry shoot near the tip, without disturbing the tip. Insecticide solutions were mixed in a rate equivalent to 200 L/ha water volume and 750 mL/ha and 435 mL/ha of product for Compound X and Movento®, respectively (1000 mL/ha for Compound X in 2021). It is key to leave the shoot tip microenvironment intact during treatment so as not to injure developing larvae. This method of micro pipetting was used successfully in a 2014 study assessing neem pesticides on cranberry insect pests (Henderson *et al.* 2014). A droplet of plain water was applied to the control shoots. After treatments were applied, the top cup was placed over the shoots and parafilm was used to secure the two cups together.

Cranberry shoots were exposed to a 16-hour daylight cycle. Adult tipworm emergence was checked every few days for 21 days with adult tipworms being removed and placed in a 97% alcohol solution. Parasitoids were also removed upon their occasional emergence (Figures 11 and 12). After 21 days, adult emergence had sufficiently declined, so all shoots were removed from the micro greenhouses and were dissected. Signs of infestation were recorded to confirm an equal baseline infestation in each treatment group. Dead larvae were also recorded (Figures 3, 9, and 10).

Shoots were dissected at 16x magnification using a standard dissecting microscope. Data were analyzed using an analysis of variance (Minitab 17 Statistical Software, State College, PA).

Study Limitations

Ideally, only infested shoots would have been placed in the treatments during experimental setup with pre-treatment infestation quantified, but the process of opening shoot tips to check for infestation is too disruptive to the tiny fragile eggs and larvae. For this reason, the experiment included a high number of replicates per treatment (300 shoots) to account for any non-infested shoots in the micro greenhouses.

Field use of these products in British Columbia would be in chemigation water volumes.

Summary of Results

1. Significantly fewer tipworm adults emerged from the Movento® and Compound X-treated replicates than the untreated replicates in both 2021 and 2022 (Figures 7 and 8).
2. Post-emergence shoot dissections confirmed that baseline (pre-treatment) infestations were equal for all treatments.
3. Significantly more dead larvae were recovered from the Movento® and Compound X-treated shoots than the untreated shoots in both 2021 and 2022 (Figures 9 and 10).
4. The lower rate of Compound X appears slightly less effective than the higher rate tested in 2022 (as compared to Movento), but still offers significant control at the lower rate (as compared to untreated shoots).
5. The cranberry tipworm parasitoids *Aprostocetus* sp. and *Ceraphron* sp. emerged from both treated and untreated shoots (Figures 11 and 12).

Conclusion

Compound X offers good control of cranberry tipworm at rates of 750 – 1000 mL/ha with comparable results to the industry standard, Movento®. This product offers an exciting new mode of action for the cranberry industry and could play an important role in resistance management for the long-term control of cranberry tipworm. It is particularly promising as a targeted systemic product with chemigation delivery, pre-bloom. This product should be pursued for registration as a potential solution for the industry’s cranberry tipworm integrated pest management gaps, registrant support allowing.

Figures Section

  

Figures 1, 2, and 3 (left to right): Tipworm feeding damage with subsequent lateral branching; healthy larvae feeding on meristematic shoot tissue; dead desiccated larva observed during post-emergence dissections in a necrotic cranberry shoot tip.

 

Figures 4, 5, and 6 (left to right): “Micro greenhouse” containing 10 cranberry shoots; emerged tipworm adult amidst cranberry shoots in micro greenhouse; close-up of emerged cranberry tipworm adult.

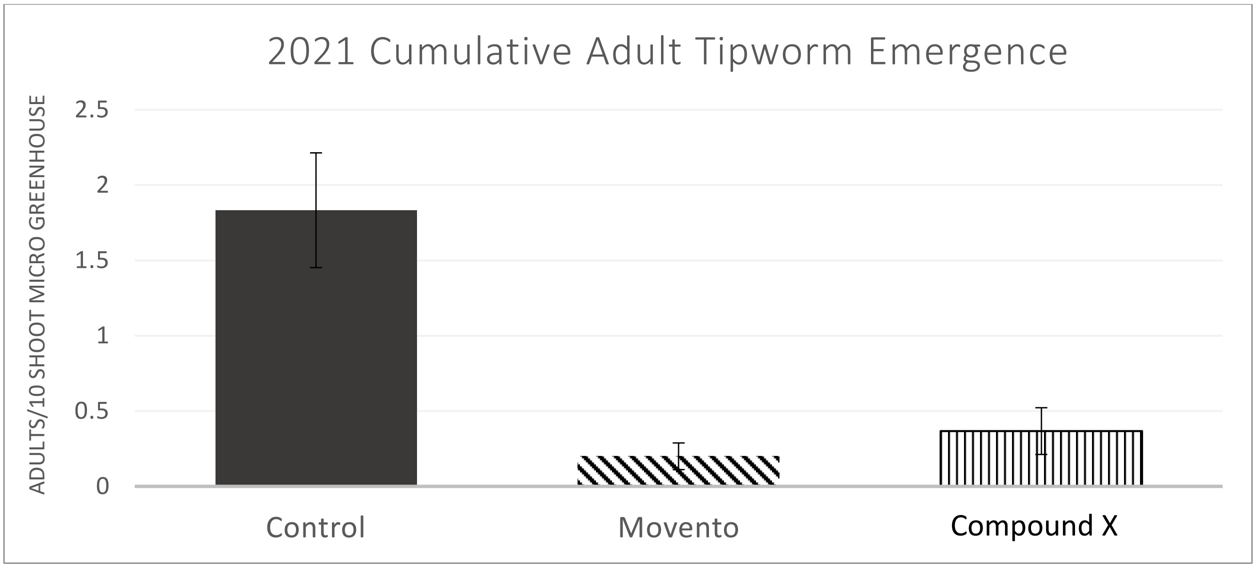

Figure 7: Emerged tipworm adults per 10 shoot micro greenhouse replicate over the course of the 21-day experiment in 2021. Untreated shoots had significantly higher levels of adult emergence than the Movento® and Compound X treated shoots (p=0.000).

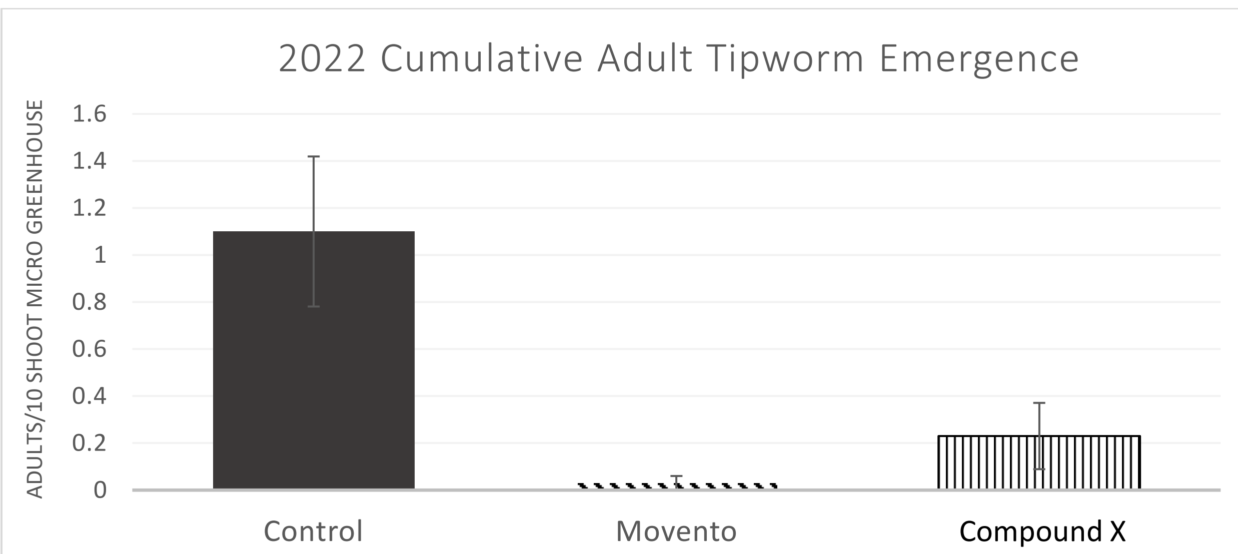

Figure 8: Emerged tipworm adults per 10 shoot micro greenhouse replicate over the course of the 21-day experiment in 2022. Untreated shoots had significantly higher levels of adult emergence than the Movento® and Compound X treated shoots (p=0.001).

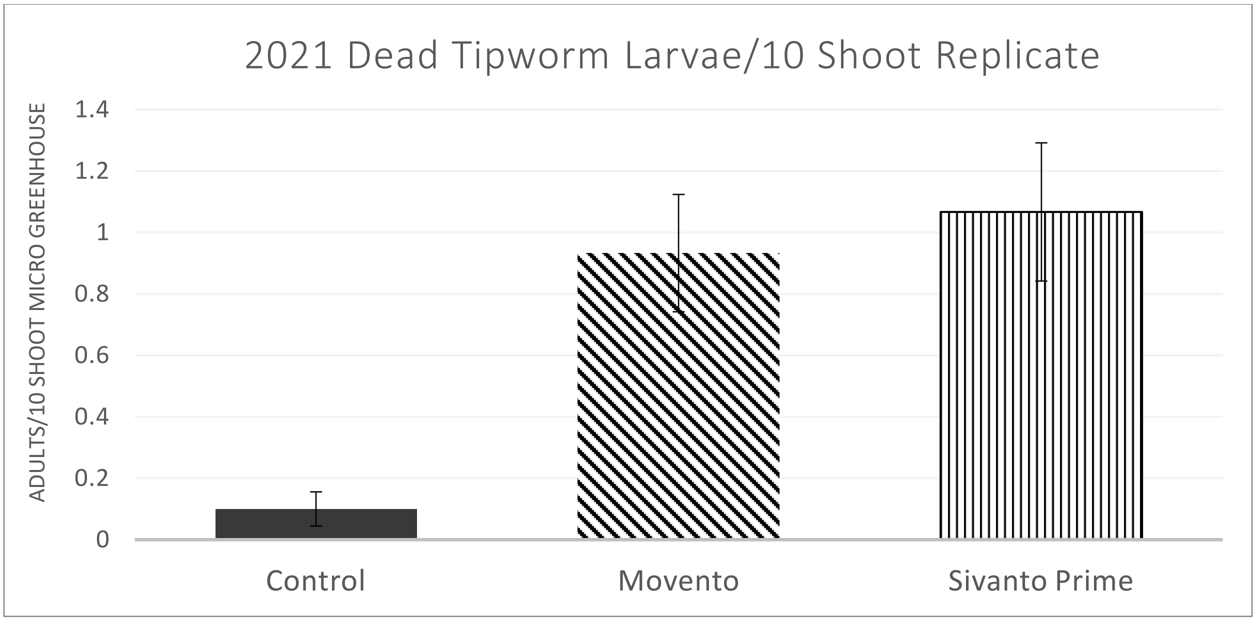

Figure 9: Cranberry shoot dissections post 21-day experiment recovering dead larvae to demonstrate treatment differences in 2021. Both Movento® and Compound X had significantly higher levels of dead larvae than the untreated shoots (p=0.000).

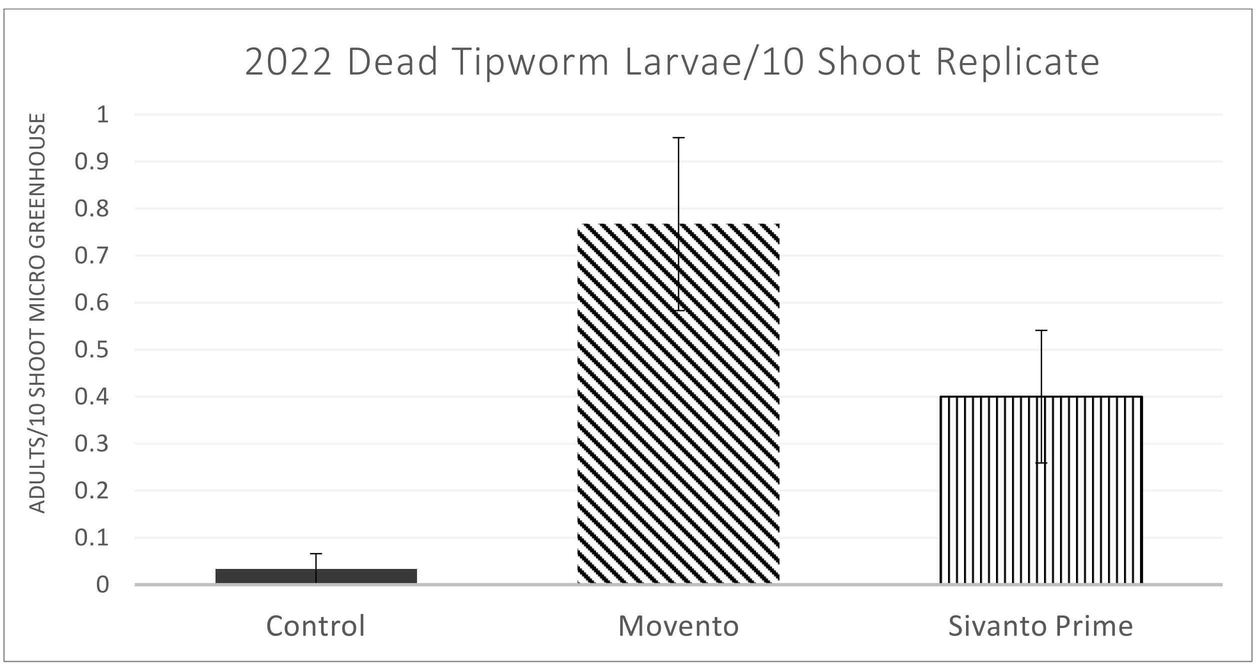

Figure 10: Cranberry shoot dissections post 21-day experiment recovering dead larvae to demonstrate treatment differences in 2022. Both Movento® and Compound X had significantly higher levels of dead larvae than the untreated shoots (p=0.000).

Figures 11 and 12: *Aprostocetus* sp. and Ceraphron sp. parasitic wasps, known parasitoids of cranberry tipworm (Fitzpatrick et al. 2018) emerged from infested shoots in both treated and untreated replicates.

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