# Best Management Practices for Cranberry Tipworm in Western Canada

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Photos by Miranda Elsby

**Table of Contents**

**Executive Summary**

Best Management Practices (BMPs) for cranberry tipworm in western Canada are described. BMP's are developed from previous research on tipworm populations and from 2015 data, which showed that cranberry tipworm adults emerge throughout the growing season from sites in the soil where they overwintered as late instar larvae.

More female than male cranberry tipworms emerged in 2015 from overwintering sites in the soil, and females tended to begin emerging earlier in the season than males.

Four species of parasitoids attack and feed on tipworm larvae. Parasitoids that overwintered in the soil began emerging later in the 2015 growing season than did cranberry tipworm adults.

Progress on the second edition of **"Integrated Pest Management for Cranberries in Western Canada"** is well underway. The full-colour second edition should be available early in 2016.

One oral and two poster presentations reporting this research were presented at the North American Cranberry Research and Extension Workers Conference (NACREW) in Bandon, Oregon, in August 2015.

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## Introduction

Recent research in British Columbia has generated knowledge and developed techniques for science-based management of cranberry tipworm[1]. These science-based principles are used to guide Best Management Practices (BMPs).

Detection and monitoring of cranberry tipworm is best done by collecting cranberry shoot tips regularly and examining them under magnification to count the numbers of immature tipworms (the eggs, larvae and pupae) (Fitzpatrick 2012, 2013). Two methods of monitoring adult tipworms have been tested but are presently cost-prohibitive (synthetic pheromone) or ineffective (white sticky traps) (Fitzpatrick 2012, 2013).

The decision to apply insecticide against cranberry tipworm is based on detection of immature tipworms in 30% of collected shoots and the concurrent absence of pollinators from the field (Fitzpatrick 2013). The 30% threshold is referred to as a working threshold or an action threshold rather than an economic threshold, because it is based on experience of growers and pest management consultants in British Columbia, not on a mathematical relationship between numbers of tipworms and subsequent crop loss. The 30% threshold is usually reached and exceeded during the bloom period when pollinators are in the field and insecticide should not be applied. Therefore, an operational compromise must be made, such that insecticide is applied after bloom when more than 30% of collected shoots contain immature tipworms (Fitzpatrick 2013).

Of the insecticides registered in Canada for management of cranberry tipworm, only Movento® (active ingredient spirotetramat; Bayer CropScience US) penetrates through the leaf cuticle and is translocated to growing shoots (Brück et al. 2009) where immature tipworms reside and feed. When applied by chemigation, Movento killed the majority of feeding instars (Fitzpatrick 2013). Prepupae and pupae, which do not feed, were not killed (Fitzpatrick 2013). Applications of Movento in 2013 apparently reduced the overwintering population of cranberry tipworms and the number of egg-laying females in spring 2014 (Fitzpatrick 2014).

Movento is a very effective management tool for cranberry tipworm, but sometimes eggs and first instars are detected in shoots even after a Movento application (e.g., Fitzpatrick 2013, Fig. 26, page 34). The female tipworms that laid such eggs were probably in the pupal stage, either in the shoot tip or in the soil, during the Movento application. The pupae could have developed from larvae that fed during the current season's bloom period. Alternatively, the pupae could have developed from larvae that fed during the previous season, then overwintered.

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[1] *Dasineura oxycoccana* (Johnson) (Diptera: Cecidomyiidae)

There have been no studies of emergence by overwintered cranberry tipworms. Cranberry tipworm prepupae spend the winter in the soil (Tewari et al. 2013), in a state of suspended development called diapause. It is assumed that adult tipworms emerge in spring from pupation sites in the soil. However, if emergence of overwintered tipworms continues through the summer, then adults could emerge after insecticide applications have killed larvae hatched from eggs laid by females that emerged in spring.

To ensure that management of cranberry tipworm is as accurate as possible, it is important to track the seasonal timing of adult emergence from overwintering sites. The first objective of the present study is, therefore, **to determine if cranberry tipworm population increases are due to reproduction by successive generations and to emergence from overwintered pupae**. To meet this objective, the emergence trap designed in 2014 (Fitzpatrick 2014) was used to detect adult tipworms emerging from overwintering sites in the soil.

The second objective of the present study is **to write the second edition of "Integrated Pest Management for Cranberries in Western Canada"** (Maurice et al. 2000). Progress is well underway. The full-colour second edition should be available early in 2016.

## Methods

**Objective 1: To determine if cranberry tipworm population increases are due to reproduction by successive generations and to emergence from overwintered pupae.**

Six farms with a history of cranberry tipworm infestation were chosen as study sites. Three of the farms were in the Glen Valley area of Langley and Abbotsford. The other three farms were in Pitt Meadows.

In early May, 2015, 10 cylindrical emergence traps (Fitzpatrick 2014) were placed on each farm. Each trap consisted of two 2-litre, 16-cm tall, white plastic buckets, placed one inside the other (Figure 1). The bottom of each bucket was cut off so that tipworms emerging from the soil could enter and be contained by the walls of the buckets and the lid of the topmost bucket. The height of the topmost bucket was reduced to about 10 cm, and the lid was fitted with no-see-um mesh. A length of dowel, positioned within the topmost bucket, was fitted with a foldback clip from which a yellow sticky card was suspended. To seat the trap into the cranberry bed, we gently parted the cranberry vines to expose an area of bare soil over which the trap was installed. Anchoring wire pegs penetrated the soil, then the groundcloth skirt at the base of the trap was spread over the vines and held in place with five wire staples. The wire pegs seated the trap firmly without harming the cranberry roots or vines. The stapled skirting formed a dark seal that prevented emerged tipworms from escaping from the trap and helped guide them up toward daylight. The skirting also prevented tipworms outside the trap from entering it. Adult tipworms that emerged from pupae in the soil under the trap were guided upward to encounter the double-sided yellow sticky card.

On each farm, traps were placed 10 to 20 metres apart along the edge of one field. Where possible, the edge chosen was the one that warmed earliest in spring. Traps were placed over areas that showed evidence of tipworm damage in the previous year. The effective area of the trap was approximately circular, measuring about 200 square cm.

Traps were checked weekly by removing the topmost bucket, unclipping the yellow sticky card and inserting a fresh one (Figure 1). Used yellow sticky cards were examined under magnification (20 X) in the laboratory to count adult tipworms and parasitoids of tipworms that had emerged during the week.

**Figure 1.** (Clockwise from top left). **Exploded view of cylindrical emergence trap**, showing top bucket and suspended yellow sticky card that slide into bottom bucket with its dark ground cloth skirting and wire pegs. The yellow sticky card is covered in protective paper that is removed as the trap is installed in the field. **View of trap anchored into cranberry field**, showing top bucket with mesh lid sliding into bottom bucket. The end of the dowel is visible on the lip of the lid of the top bucket. The foldback clip on the dowel can be seen through the mesh on the lid. **Miranda Elsby** removing double-sided yellow sticky card from top bucket and preparing to install a new yellow sticky card.

*Photos by Warren Wong*

**Results**

The first detection of newly emerged cranberry tipworm adults on four of the six farms (A, B, E, F) was in early May during the week following trap installation (Table 1). On farms C and D, emergence began in early June (Table 1). Following first detection, emergence continued during most weeks until mid July (Farm F), late July (Farm E), early August (Farms C, D) and mid August (Farms A, B) (Table 1).

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farm A | | in | ● | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | | ● | | out |
| Farm B | | in | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | | | out |
| Farm C | | | in | | ● | ● | | ● | ● | ● | | ● | ● | | | | | out |
| Farm D | in | | | | ● | ● | nc | ● | | ● | ● | | ● | | | | | out |
| Farm E | in | ● | ● | | | ● | ● | ● | | ● | ● | ● | | | | | | out |
| Farm F | in | ● | | ● | ● | ● | | ● | | | ● | | | | | | | out |
| *WEEK* | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* |
| | MAY | | | | JUNE | | | | JULY | | | | AUGUST | | | | | SEPT |

**Table 1**. Weeks when cranberry tipworm adults emerged (●) from overwintering sites in the soil under the traps. Traps were installed during the week indicated by "**in**", and removed during the week indicated by "**out**". "**nc**" indicates that the traps were not checked that week.

Week 0 = May 4 – 10
Week 1 = May 11 – 17
Week 2 = May 18 – 24
Week 3 = May 25 – 31
Week 4 = June 1 – 7
Week 5 = June 8 – 14
Week 6 = June 15 – 21
Week 7 = June 22 – 28
Week 8 = June 29 – July 5
Week 9 = July 6 – 12
Week 10 = July 13 – 19
Week 11 = July 20 – 26
Week 12 = July 27 – August 2
Week 13 = August 3 – 9
Week 14 = August 10 – 16
Week 15 = August 17 – 23
Week 16 = August 24 – 30
Week 17 = August 31 – September 6

The number of cranberry tipworms that emerged from overwintering sites in the soil under each trap ranged from 1 to 7, depending on the farm and the week. The average number of emerged tipworms per trap per week was approximately 0.2 in May through early June, 0.3 through 0.4 in June and July, and less than 0.1 in August (Figure 2). There was a decrease in emergence in the first week of July (Figure 2).

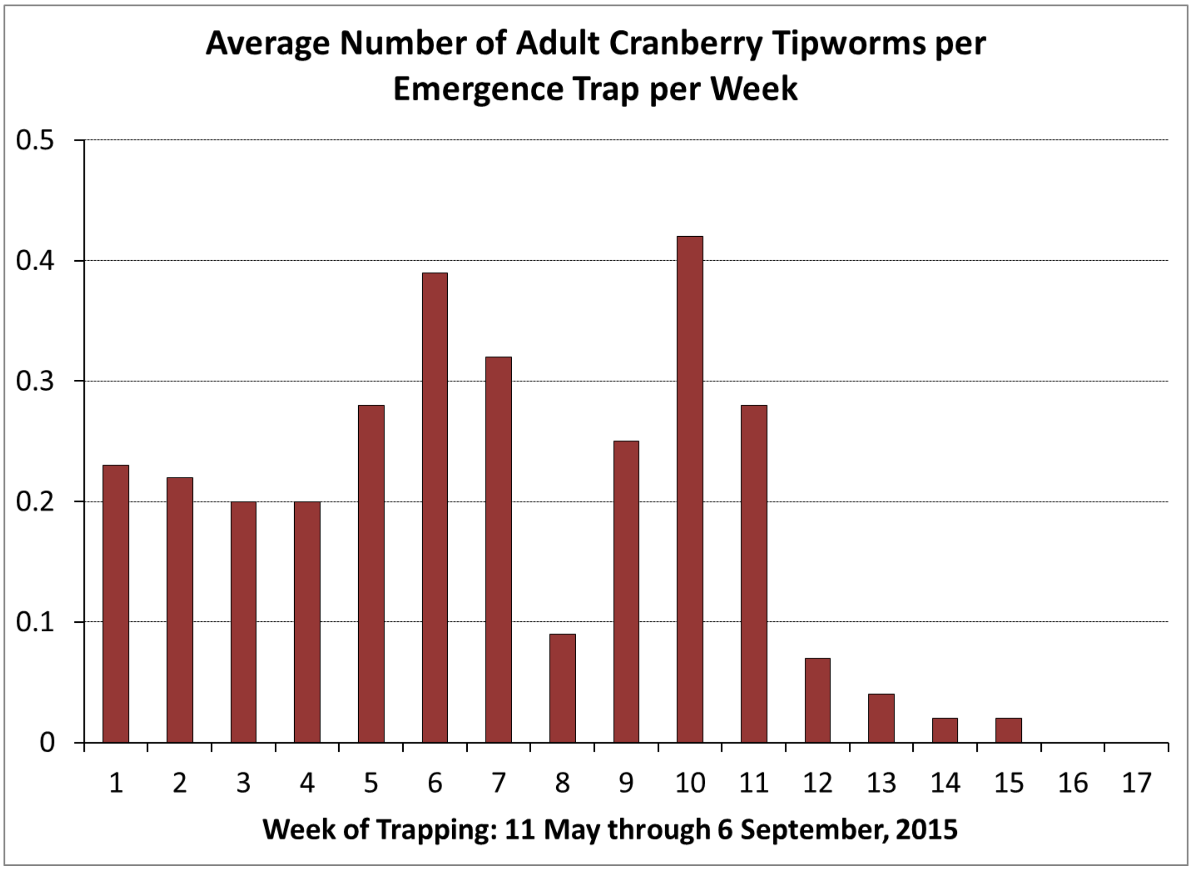


**Figure 2**. Average number of cranberry tipworms that emerged from overwintering sites in the soil under each trap. The number of traps per week was 30, 50, 59, 60, 60, 46, 56, 57, 57, 57, 57, 57, 57, 57, 57, 51, 51 for weeks 1 through 17, respectively. The bloom period in 2015 began in late May, around week 3, and continued until early July, around week 8.

During the 17-week trapping period, a total of 101 females and 61 males emerged from overwintering sites in the soil under the traps. The greater number of females is statistically significant (SYSTAT 13; Pearson chi-square = 9.9, df = 1, P = 0.002).

Females tended to begin emerging earlier in the season than males (Figure 3). Nonparametric Mann-Whitney U test confirmed that the average number of females was greater than males (SYSTAT 13; test statistic = 432,422.5, chi-square = 4.2, df = 1, P = 0.04). It was not possible to apply parametric statistical tests to the distributions of female and male, because the distribution of data was extremely non-normal.

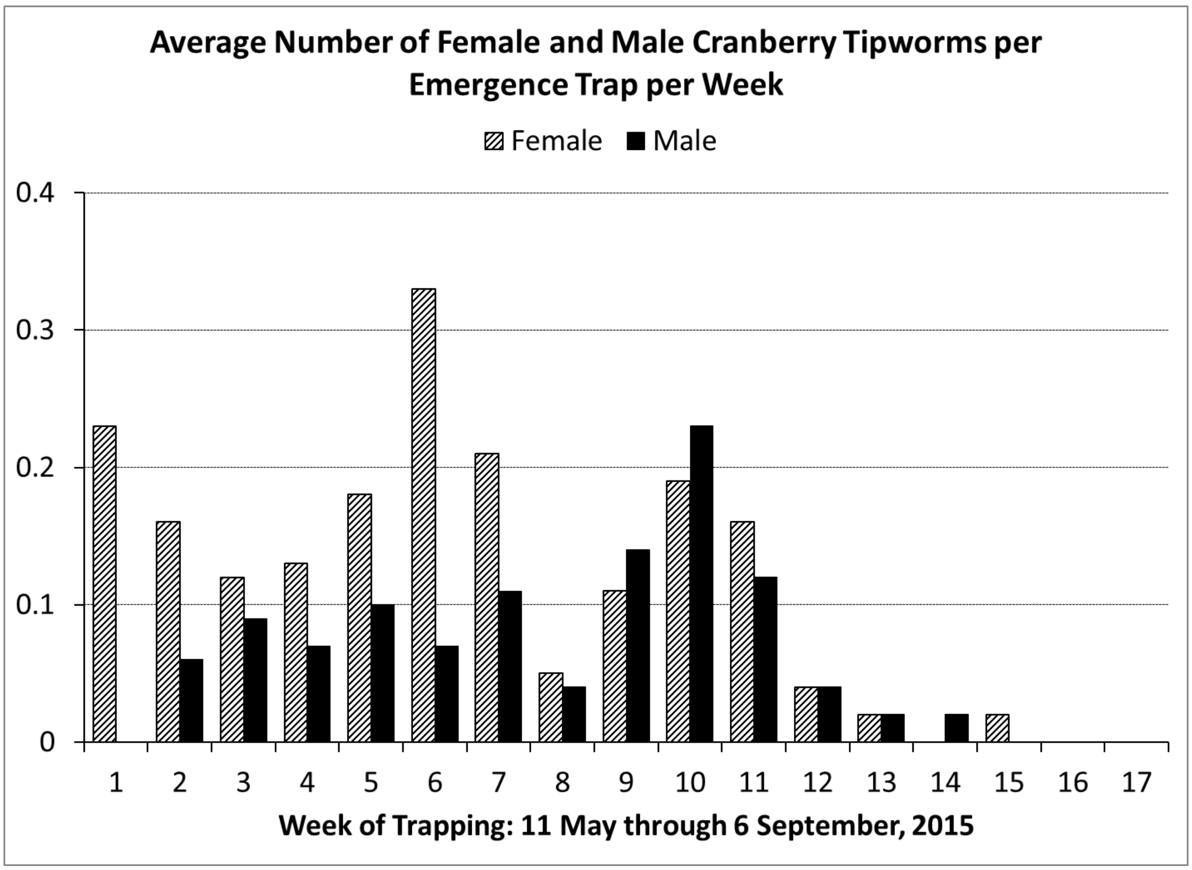


**Figure 3**. Average number of female and male cranberry tipworms that emerged from overwintering sites in the soil under each trap. The number of traps per week was 30, 50, 59, 60, 60, 46, 56, 57, 57, 57, 57, 57, 57, 57, 57, 51, 51 for weeks 1 through 17, respectively. The bloom period in 2015 began in late May, around week 3, and continued until early July, around week 8.

Four species of parasitoids were trapped in the cylindrical emergence traps (Figure 4). Three species (*Aprostocetus* nr *marylandensis*; *Playtgaster* sp.; *Inostemma* sp.) are known to parasitize cranberry tipworms in British Columbia (Peach et al. 2012, Fitzpatrick 2014). The fourth species (*Ceraphron* sp.) has in previous years been trapped on yellow sticky traps in BC but was not identified as a parasitoid of cranberry tipworm. In 2015, we observed *Ceraphron* individuals emerging from field collected cranberry tipworm larvae. Franklin (1919, 1950) identified *Ceraphron*, specifically *Ceraphron pallidiventris* Ashm., as a parasitoid of cranberry tipworm in Massachusetts.

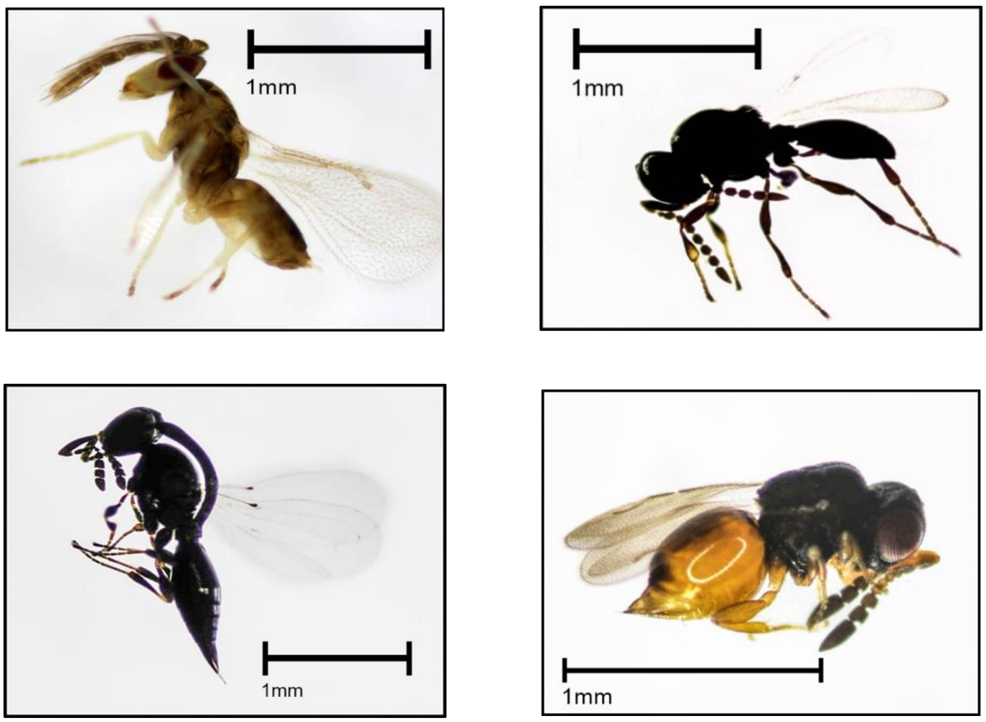


**Figure 4**. Clockwise from top left: male *Aprosocetus* nr *marylandensis*, male *Platygaster* sp., female *Ceraphron* sp., female *Inostemma* sp. Photos by Warren Wong.

It is most likely that all the parasitoids trapped in the emergence traps emerged from cranberry tipworm hosts that overwintered in the soil. There is a possibility that the smallest parasitoids, *Ceraphron* sp., entered the traps from outside by passing through the mesh lids. Further study is needed to determine if the parasitoids pass through no see um mesh.

On all farms, emergence of parasitoids began later (mid June) and ended later (late August) than emergence of tipworms (compare Table 2 with Table 1).

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Farm A | | in | | | | | | | Ⓟ | Ⓟ | | Ⓟ | Ⓟ | Ⓟ | Ⓟ | | Ⓟ | out |
| Farm B | | in | | | | | Ⓟ | | | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | out |
| Farm C | | | in | | | | | | | Ⓟ | Ⓟ | | | | | | | out |
| Farm D | in | | | | | Ⓟ | nc | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | | | out |
| Farm E | in | | | | | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | out |
| Farm F | in | | | | | | Ⓟ | Ⓟ | Ⓟ | Ⓟ | Ⓟ | | Ⓟ | Ⓟ | Ⓟ | Ⓟ | | out |
| *WEEK* | *0* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* |
| | MAY | | | | JUNE | | | | JULY | | | | AUGUST | | | | | SEPT |

**Table 2**. Weeks when parasitoids of cranberry tipworm emerged (Ⓟ) from overwintering sites in the soil under the traps. Traps were installed during the week indicated by "**in**", and removed during the week indicated by "**out**". "**nc**" indicates that the traps were not checked that week.

| | |
|---|---|
| Week 0 = May 4 – 10 | Week 9 = July 6 – 12 |
| Week 1 = May 11 – 17 | Week 10 = July 13 – 19 |
| Week 2 = May 18 – 24 | Week 11 = July 20 – 26 |
| Week 3 = May 25 – 31 | Week 12 = July 27 – August 2 |
| Week 4 = June 1 – 7 | Week 13 = August 3 – 9 |
| Week 5 = June 8 – 14 | Week 14 = August 10 – 16 |
| Week 6 = June 15 – 21 | Week 15 = August 17 – 23 |
| Week 7 = June 22 – 28 | Week 16 = August 24 – 30 |
| Week 8 = June 29 – July 5 | Week 17 = August 31 – September 6 |

Most of the parasitoids trapped in the emergence traps belonged to the species *Ceraphron* (Figure 5). Parasitoids of the species *Aprostocetus* and *Playtgaster* occurred infrequently in the traps, in contrast to previous field studies where they were frequently reared from field collected larvae (Peach et al. 2012). Parasitoids of the species *Inostemma* occurred infrequently, as reported in Fitzpatrick (2014).

The greatest number of parasitoids emerged during weeks 8 and 9 (late June and early July) and week 13 (early August). During those weeks, the average number of parasitoids per trap ranged from about 1.0 to about 1.6, which is 2.5 to 4 times greater than the greatest weekly numbers of cranberry tipworm (compare Figure 5 with Figure 2, and see Figure 6).

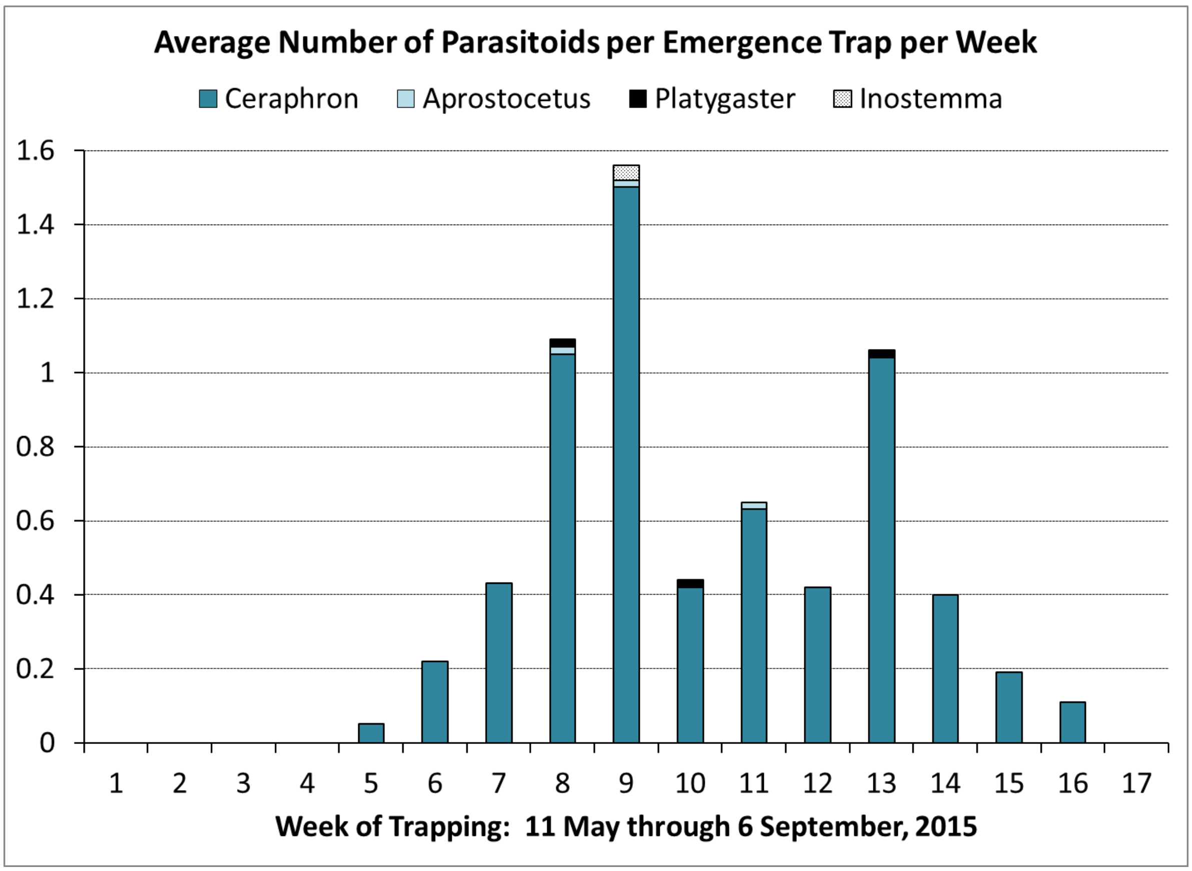


**Figure 5**. Average number of four species of parasitoids of cranberry tipworm that emerged from overwintering sites in the soil under each trap. The number of traps per week was 30, 50, 59, 60, 60, 46, 56, 57, 57, 57, 57, 57, 57, 57, 57, 51, 51 for weeks 1 through 17, respectively. The bloom period in 2015 began in late May, around week 3, and continued until early July, around week 8.

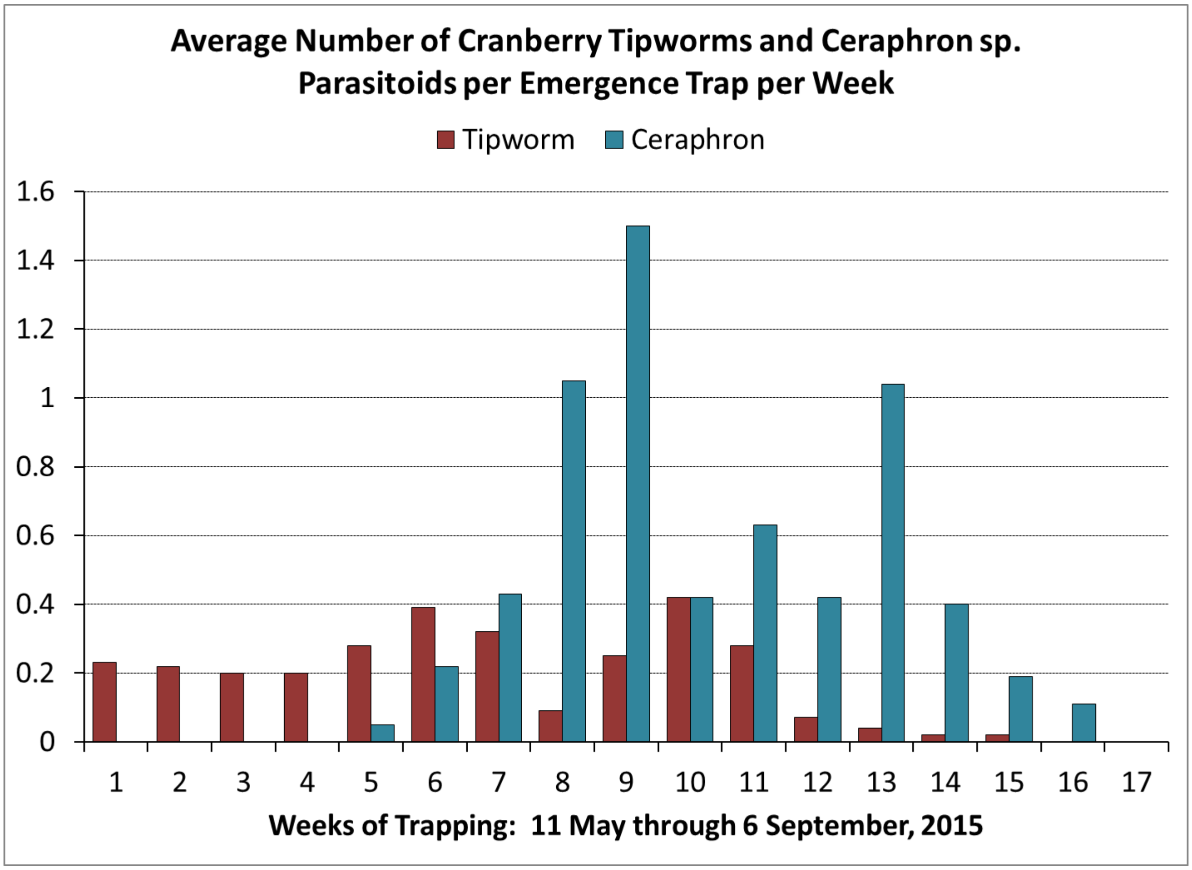


**Figure 6**. Average number of cranberry tipworms and parasitoids of the species *Ceraphron* that emerged from overwintering sites in the soil under each trap. The number of traps per week was 30, 50, 59, 60, 60, 46, 56, 57, 57, 57, 57, 57, 57, 57, 57, 51, 51 for weeks 1 through 17, respectively. The bloom period in 2015 began in late May, around week 3, and continued until early July, around week 8.

## Discussion

After spending the winter as cocooned immatures in the soil, cranberry tipworm adults emerge during the growing season, from spring through mid to late summer. In 2015, emergence traps placed on farms in early to mid May detected tipworm adults in the week following trap placement. Earlier placement of emergence traps, in April, would have facilitated detection of the very beginning of tipworm emergence in spring.

Thus the first objective of this study has been met. Cranberry tipworm population increases are due to reproduction by successive generations and to emergence from overwintered pupae.

For example, cranberry tipworm adults that emerge in early May will mate and lay eggs, from which larvae will emerge. These larvae will feed until they reach the pupal stage in late May or early June. Following pupation, the descendant adults of those that emerged in early May will produce another generation – eggs to larvae to pupae to adults – that will probably produce a subsequent generation. So, early emerging tipworm adults will give rise to two or three generations.

Cranberry tipworm adults that emerge in late July from overwintering sites in the soil will give rise to one generation, and probably no more, before plant growth slows and temperatures cool in late summer/early fall.

**Insecticide such as Movento, applied after bloom, kills feeding stages of larvae in the cranberry shoot tips (Fitzpatrick 2013, 2014). When eggs and early instar larvae are found in shoot tips after the insecticide application, the effectiveness of the insecticide comes into question (e.g., Fitzpatrick 2013, p. 34). Results from the present study help to understand how eggs appear after insecticide kills most larvae in the shoot tips. Eggs would be laid by females that emerged from pupae in the shoot tips or in the soil. Pupae in the shoot tips would be progeny of females that emerged earlier in the growing season. Most pupae in the soil would be progeny from the previous year, and would have overwintered.**

More female than male cranberry tipworms emerged from overwintering sites in the soil, and females tended to begin emerging earlier in the season than males. It is likely that one male can inseminate more than one female. The female-biased sex ratio of overwintered tipworms might be a result of mortality factors, such as microorganisms or parasitism, that reduce survival of male pupae.

Parasitoids began emerging later in the growing season than cranberry tipworm adults. Later emergence of parasitoids has been reported by Fitzpatrick (2013, 2014), Peach et al. (2012), and Franklin (1950). The two species – *Aprostocetus* nr. *marylandensis* and *Platygaster* sp. – that have been frequently reared from tipworm larvae in BC and frequently trapped on yellow sticky cards on BC cranberry farms were extremely infrequent in the emergence traps. *Inostemma* sp., which is infrequently trapped on yellow sticky cards (Fitzpatrick 2014) was similarly infrequent in the emergence traps. By far the most prevalent parasitoid in the emergence traps was *Ceraphron* sp., which emerged later than most cranberry tipworms and often outnumbered them by a factor of 2.5 to 4. *Ceraphron* sp. was observed on yellow sticky cards in BC in 2013 and 2014, but not recognized as a parasitoid of cranberry tipworm until 2015. However, the Massachusetts entomologist Henry Franklin reported *Ceraphron* sp. as the most important species of parasitoid in 1916 and 1917 (Franklin 1919), and later had it identified as *Ceraphron pallidiventris* Ashm. (Franklin 1950).

Parasitoids of these four species attack and feed on tipworm larvae. Those parasitoids that emerged into the traps in 2015 were progeny of parasitoids that laid their eggs in tipworm larvae in 2014. The parasitoid eggs hatched into parasitoid larvae that fed on the body tissues of their tipworm host. The parasitoid pupae overwintered in the soil, and emerged when the tipworm population was well established in 2015.

Clearly there is a complex and cyclical ecological relationship among cranberry tipworms and their parasitoids, which is overshadowed or interrupted by insecticide applications.

**Deliverables:**

The following three submissions were presented at the North American Cranberry Research and Extension Workers Conference (NACREW) in Bandon, Oregon, in August 2015.

**Systemic Insecticide [Movento (spirotetramat)] Applied After Bloom Reduces Populations of Cranberry Tipworm, *Dasineura oxycoccana*, in British Columbia, Canada**
Sheila Fitzpatrick, Miranda Elsby, Kaitlyn Schurmann, Warren Wong, Kieryn Matthews, Snehlata Mathur. (Oral)

**An Efficient Trap for Detecting Overwintered Cranberry Tipworm, *Dasineura oxycoccana*, and its Parasitoids**
Miranda Elsby, Warren Wong, Kieryn Matthews, Kaitlyn Schurmann, Snehlata Mathur, Sheila Fitzpatrick. (Poster)

**Production of "Integrated Pest Management for Cranberries in Western Canada – 2nd Edition"**
Warren Wong, Miranda Elsby, Renee Prasad, Heidi van Dokkumburg, Snehlata Mathur, Sheila Fitzpatrick. (Poster)

**Best Management Practices for Cranberry Tipworm in Western Canada:**

Early in the growing season, at or before the time that cranberry shoots reach "roughneck" stage (per Workmaster et al. 1997), begin weekly collections of cranberry shoots. Clip the most advanced shoots from the edges and interior of the field. Using a stereomicroscope at magnification of 10X to 20X, open the shoot tips and count eggs, larvae and pupae. Plot or summarize the information to show the progression of infested shoots and tipworm stages in the field.

The decision to apply insecticide will be based on: the presence of tipworm immatures in greater than or equal to 30% of collected shoots; and the absence of pollinators from the field. The working threshold of 30% shoots infested will probably be exceeded by the time pollinators are out of the field.

The most effective insecticide currently registered is Movento. Minimize the number of applications of Movento in order to reduce the likelihood of resistance to the active ingredient developing in later years. Closely follow the directions on the insecticide label. Plant symptoms such as leaf cupping can occur after Movento application. Growers observe that the cranberry shoot grows out of the symptoms, and that cranberry yield is not affected.

During or soon after roughneck stage, place yellow sticky traps to monitor flying parasitoids. If traps are not placed, assume that at least one species of parasitoid is present. Overwintered parasitoids will lay eggs in immature tipworms. Parasitoid larvae that are not killed by insecticide will either emerge as adult parasitoids and seek immature tipworms, or drop to the ground, overwinter and emerge the following year. The combined effects of Movento and the naturally occurring beneficial parasitoids should reduce tipworm populations to low and sustainable levels.

When designing a fertilizer program for cranberry fields, try to minimize the amount of nitrogen applied, in order to minimize vegetative shoot growth that provides sites for cranberry tipworm development.

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We thank Heidi van Dokkumburg of ES Cropconsult for recommending sites for the 2015 study, and all participating growers for their willingness to host the trials and discuss their pest management practices. We acknowledge the BC Cranberry Marketing Commission and the BC Cranberry Growers Association for agreeing to fund this research in partnership with Agriculture and Agri-Food Canada under the Agri-Science Project (ASP). Thanks to the Lower Mainland Horticultural Improvement Association (LMHIA) for including the cranberry association in the LMHIA-ASP grant.

Agriculture and Agri-Food Canada provided the following in-kind contributions: use of fleet vehicle; technical support; growth chambers and growth rooms; cameras, microscopes, vials and other supplies; computer, software, network access and computer support.

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