Biology and lifecycle of the cranberry tipworm in BC cranberry beds and the relationship to cranberry plant phenology and growing degree days

Shannon Buckshaw
Deborah Henderson
E.S. Cropconsult Ltd

January 2008

Funding provided by:

Canada
Investment Agriculture Foundation of British Columbia
British Columbia The Best Place on Earth

Introduction

Cranberry tipworm, *Dasineura oxycoccana*, is a tiny insect pest found in all cranberry growing regions. This pest first appeared in B.C. in 1998 (BCMAL, 2007) and has become an increasing problem in the last few years. The female tipworm lays eggs in the tip of cranberry uprights and when the eggs hatch larvae feed on the tip by rasping the tissue. This rasping causes the tip to cup and then blacken and die. The damage affects the bud that will develop into next year's crop.

Tipworm adults are tiny midge-like flies, 1/10 the size of a mosquito (Mahr, 2005). Eggs are small, oblong and transparent. There are 3 stages of larvae each with a distinct appearance: first instars are clear, second instars are milky-white and 3rd instars are orange. The pupae are orange to brown and stay in the upright tip, except the last generation of pupae, which overwinter in the litter layer.

Cranberry tipworm are a difficult pest to monitor and to control. To monitor for tipworm eggs and young larvae, cranberry uprights need to be examined under a dissecting microscope. Controlling tipworm is a challenge because there are usually at least 2 generations and the generations will overlap in the field. Also, because tipworm damage causes cranberry tips to cup, the larvae are protected from contact pesticide applications.

The purpose of this research project was to monitor tipworm populations in the field and use the data to develop some practical techniques for more effective monitoring and management. Studying the phenology of the tipworm over several years can give general calendar dates for emergence and timing. However, calendar based timing is often inaccurate due to weather and other environmental factors. In order to develop a predictive tool to effectively time monitoring and control we explored three different methods for predicting tipworm phenology.

1. Predicting tipworm oviposition based on cranberry phenology - Using plant phenology to predict insect activity can be a useful tool for integrated pest management. Cockfield (1994) investigated the relationship between timing of cranberry tipworm oviposition and timing of cranberry plant stages. This study found that in Wisconsin the majority of tipworm oviposition began within a week of the first shoots elongating and ended after most flowers had opened. Recommendations were made to concentrate monitoring during this period to improve efficiency.

2. Predicting tipworm oviposition based on cranberry growing degree-days - Although a fixed development threshold for the cranberry plant has not been determined, thresholds between 40°F and 50°F have been used to predict cranberry plant events like vegetative growth, fruit development and high stress periods (Hawker and Stang, 1985). In B.C., Ocean Spray uses a formula with development thresholds of 40°F and 85°F to compare cranberry development from year to year. The development thresholds are based on research by J. Vanden Heuval at the University of Massachusetts Cranberry Station (unpublished data). Because the cranberry tipworm and its host, the cranberry plant, are

both dependant on temperature for development we can look at the cranberry development model and see if it relates to tipworm phenology.

3. Predicting tipworm development (50% oviposition) based on *Dasineura tetensi* development model- A development threshold model for *D. oxycoccana* has not been developed. However, threshold temperatures have been developed for related midge species in Europe. Degree day modeling has been investigated for the blackcurrant leaf midge, *D. tetensi* (Cross and Crook, 1999; Hellqvist, 2001) and the pod gall midge, *Dasineura brassicae* (Axelsen, 1992). Both of these insects have a similar lower development threshold of 7° C and 6.7° C respectively. We have used the model from the Hellqvist paper, and the development threshold of 7°C to predict *D. oxycoccana* emergence and compare it to actual field results.

Materials and Methods

This study was conducted in three cranberry fields, two of which were at one farm and the third at another; both farms were in Pitt Meadows, BC. Monitoring for cranberry tipworm involved collecting ten uprights from five randomly chosen sites in each field, for a total of 50 uprights. Uprights were collected twice/week for a total of 100 uprights/week/field. Uprights were examined under a dissecting microscope and the number of eggs, larvae and pupae on each was recorded. A similar study was conducted in 2006, with the same number of fields and uprights collected. However, in 2006 we only sampled once per week for a total of 50 uprights/week/field. To account for the difference in total number of uprights sampled per week, all data are presented as number of tipworm (eggs, larvae, pupae) per upright per week. In both years, fields were treated with insecticides for fireworm management (see Appendix A).

Predicting tipworm development based on cranberry phenology:

For assessing cranberry plant development 30 uprights were collected from each field, 10 uprights from three random sites within the field, once per week. Cranberry upright development was classified into 8 bud growth stages that are known and used in the industry: 1. Tight bud, 2. Bud swell, 3. Cabbagehead, 4. Bud break, 5. Bud elongation, 6. Roughneck, 7. Hook, and 8. Bloom (Workmaster et al. 1991). This categorization is for spring development so we also added a category for fruit set and new bud development. Cranberry phenology from all 3 fields was averaged and charted in Excel.

Predicting tipworm development based on cranberry growing degree-days:

Cranberry growing degree-days were calculated using an online degree day calculator (IPPC, 2004). The thresholds used for cranberry development were 40°F and 85°F, a start date of March 1st and single sine curve calculation method (B. Mauza, Ocean Spray, personal communication). Temperature data was obtained from the Pitt Meadows Coastal Stn. BC and was available online at the IPPC site (http://ippc2.orst.edu/cgi-bin/ddmodel.pl).

Predicting tipworm development based on *D. tetensi* development model:

This same program was used to obtain daily maximum and minimum temperatures from Pitt Meadows Coastal Stn. Mean temperature data was then calculated and used in the following model developed by Stenseth (1966) for *D. tetensi*:

$$r=0.18(1-1/1+e(^{T-20.22/5.58}))$$

This equation was used to predict 50% oviposition (when the cumulative r = 1) by Hellqvist (2001). These authors found that the dates predicted by the above model were more closely matched to actual dates of 50% oviposition observed during their sampling for *D. tetensi*, than Cross & Crook's (1999) model.

Results and Discussion

Tipworm Life Cycle (phenology): Summary of Observations

General observations:

In 2007 the earliest date that eggs were found in a field was April 27th. However we did not start to see eggs in all fields on a regular basis until May 15th (Fig. 1). Eggs were observed in low levels in May and June with a couple of small peaks but we did not see a large peak in oviposition until the beginning of July. There was another ovipositional peak in early August and levels fluctuated at lower levels for the remainder of August into September. Tipworm larvae were first observed in the fields on May 15th and after this date larvae were present in the field every week (Fig. 1). In 2006 there were higher levels of tipworm present in the spring and five ovipositional peaks were observed (Fig. 2a). As in 2007, once larvae were found in the field they were present for the remainder of the monitoring season (Fig. 2b).

Comparison between fields:

Distinct generations are difficult to identify because there are several small peaks in egg occurrence and larva are present for most of the season. Further, combining data from different fields may obscure any seasonal patterns in the pests' occurrence, as field-to-field differences in terms of management and microclimate can be significant. Figure 3 demonstrates the differences between fields. Field 1 and Field 2 are at the same farm, and Field 3 is at a nearby farm. The fields vary in terms of population size and population build-up over time. However, all fields have a spring hatch that is spread out over several weeks, 2 larger larval peaks about one month apart in July and August, with a small population continuing through September.

Based on these data it is difficult to say whether there is a separate generation in the spring or whether the peak seen at the end of June is still the first generation. Studies on other midge species have similarly found that spring emergence is not uniform and is difficult to predict with models because of delayed emergence of some of the population likely due to factors of diapause (Cross and Cook, 1999). It is also possible that insecticidal sprays for fireworm in May have disrupted the normal phenology of the first

Also, eggs are very small and clear so they may be missed, even with the use of a microscope, especially if there is any moisture in the tip. Collecting a larger sample of uprights and or collecting uprights when fields are dry may result in more consistent egg counts.

Impact of management:

Arrows in Figure 3 show dates when insecticide treatments were applied**.** In fields 1 & 2, several applications were made in the spring**,** however, even with weekly sprays from mid-May to mid-June, the tipworm population increased in July and August. In 2006 one field (3f) had higher levels of tipworm oviposition in mid May and June, insecticides were applied and population was lower for the remainder of the season. In general, our observations suggest that monitoring and treatment in May, might not be very effective if the population is low and the egg hatch is spread out over several weeks.

There are no economic thresholds developed for cranberry tipworm but action thresholds are suggested in Maine and Wisconsin. In Maine, the action threshold is 60% uprights infested or 60% of uprights already damaged (Cranberry tipworm [updated 2007]). In Wisconsin the action threshold is 40% infestation (Dittl, 2006). Figure 4 shows percentage of uprights infested with tipworm in 2006 and 2007 in our monitored fields. The lower threshold of 40% infestation is not reached until mid June to early July. This corresponds with our observations that it may not be efficient to treat tipworm early in the season when populations are low.

Predicting Tipworm Oviposition: Cranberry Plant Phenology

Tipworm prefer to lay their eggs in actively growing tissue (Eck, 1990) and this is reflected in tipworm phenology. The majority of oviposition did not start until new growth emerged from the buds and there were enough actively growing uprights suitable for larvae. Oviposition started as cranberry buds began to swell and break, however we do not see any significant numbers of eggs laid until cranberry plants reached elongation-roughneck phase (Figure 5a & 5b.). A peak hatch occurred at the end of June to beginning of July in all fields monitored in 2007. This corresponds to the time when most uprights have bloomed and are beginning to set fruit. Another ovipositional peak occurred just after all uprights had set fruit and had begun bud-set for next year began. Table 1 shows the corresponding ovipositional peaks, dates and cranberry development stage for the average of the fields; Appendix B shows a breakdown for all fields. Oviposition continues through the end of August and into September at low levels. Tipworm injury causes uprights to produce new growth but if the damage is done later in the season this new growth will likely be vegetative (Eck, 1990). In our studies we observed that in fields with higher levels of tipworm, many cranberry uprights produced vegetative growth later in the season which may have helped the tipworm populations survive late into summer.

Observations from 2007 monitoring show that the most important oviposition peaks are at the beginning of July and the beginning of August (3rd and 4th peak Table 1). These are the most concentrated peaks and damage done at this stage is more likely to have a negative impact on next years' yield and therefore these peaks should be targeted for control. In 2007 the timing of the 3rd peak corresponded to 50% Fruit-set and for 4th peak, the corresponding plant stage was the week after 100% of the uprights had set fruit. These measurable crop stages could be used to time scouting and or insecticidal sprays. In order to determine if cranberry development stage can accurately predict peak tipworm egg hatch more years of study will have to be done to verify our data.

Table 1. Correspondence between peak oviposition dates and cranberry phenology

Tipworm Phenology	**Date (2007)**	**Cranberry Phenology**
Start of oviposition	April 27	Bud swell-bud break
1st peak	May 15	49% Roughneck - 16% Hook
2nd peak	June 1	61% Roughneck - 36% Hook
3rd peak	July 3	43% Bloom - 50% Fruitset
4th peak	August 3	58% End of fruitset - 42% bud development

Predicting Tipworm Oviposition: Cranberry Growing Degree Days

We examined the accumulation of degree days based on cranberry plant development to determine if the degree day accumulation could be used to predict tipworm ovipositional peaks. When using the cranberry plant development phenology the differences ranged from 14 degree days to 144 degree days between 2006 and 2007 (Table 2). Although using degree days could give a rough idea of when to scout for tipworm, i.e. start scouting when 600 degree days have accumulated, the accuracy of this method does not appear sufficient for predicting tipworm oviposition from year to year.

Table 2. Accumulation of degree-days based on cranberry plant development

Tipworm Phenology	Date 2006	Date 2007	GDD 2006	GDD 2007	Difference in (GDD)
Start of oviposition	May 12*	April 27	550.2*	405.9	144.3
1st peak	May 19	May 15	601.0	657.7	56.7
2nd peak	June 2	June 1	952.5	966.4	13.9
3rd peak	June 28	July 3	1519.4	1584.7	65.3
4th peak	July 21	August 3	2091.5	2413.9	47.8
5th peak	August 11**		2640.7		

*In 2006 sampling did not begin until May, so it is unknown whether any eggs were present in April.
**In 2006 there were two ovipositional peaks in late summer

Predicting Tipworm Oviposition: D. tetensi development threshold

Models developed for management of other *Dasineura* spp. have used 50% oviposition, (when 50% of the eggs have been laid), as a developmental marker. However, as our data has shown, it is difficult to identify the date of 50% oviposition by the first generation because the first generation peak is not distinct. For the purposes of the present study we chose the week when we saw the first peak in oviposition (Table 3a. Column B). The date of 50% oviposition by first generation cranberry tipworm predicted by Stenseth's model was close to the actual sampling date in 2006 but later than the actual sampling date in 2007(Table 3a.). Thus it appears that this model would not be able to predict cranberry tipworm first generation oviposition accurately every year. A model based on actual development thresholds for cranberry tipworm would likely be more accurate. However, it is unclear if 50% oviposition of the 1st tipworm generation is the most appropriate phenological event to consider for a degree-day model. Timing of oviposition of later generations, those occurring in July and August, may be more important for mitigating yield loss.

Table 3b. lists the degree day accumulations (based on 7˚ C development threshold for *D. tetensi*) for all ovipositional peaks and compares the numbers from 2006 and 2007. This data shows that using this threshold to calculate degree-day accumulations may predict midseason peaks but that early and late season peaks are not accurately predicted using degree-day accumulations. To confirm that accumulated degree-days could be used to predict these midseason peaks another year or two of data comparison would be needed. It would also be important to compare this information in different fields in different regions. The temperature data used here was from a regional air temperature station and the temperature at bog level could be quite different and affect the accuracy of predictions. Because the timing of the tipworm lifecycle is quite short and the time that the tipworm is susceptible to insecticides is quite limited, a prediction method will need to be highly accurate.

Table 3a Dates for 50% oviposition by first generation cranberry tipworm, based on estimates from field sampling, and predicted based on the developmental equation for *D. tetensi* (Stenseth 1966). Accumulated degree days to reach each of the dates are also presented.

Year	Estimated date based on sampling (See Fig. 2A)	Predicted date based on Stenseth 1966	Day-degrees
2006	May 12-19	May 15	180.7-246.9
2007	May11-15	May 28	190.5-217.7

Table 3b. degree days based on threshold value of 7˚C (*Dasineura tetensi*)

Tipworm Phenology	Date 2006	Date 2007	GDD 2006	GDD 2007	Difference in GDD
Start of oviposition	May 12*	April 27	180.7	120.7	60
1st peak	May 19	May 15	246.9	217.7	29.2
2nd peak	June 2	June 1	352.0	346.6	5.4
3rd peak	June 28	July 3	600.8	608.4	7.6
4th peak	July 21	August 3	860.1	990.1	130
5th peak	August 11**	-	1112.1	-	-

*In 2006 sampling did not begin until May, so it is unknown whether any eggs were present in April.
**In 2006 there were two ovipositional peaks in late summer

Conclusions and Recommendations

Due to uneven spring emergence it is difficult to tell when the peak oviposition period for the first generation of tipworm occurs. If spring generations are consistently low and sporadic it may not be necessary to treat for tipworm until later in the season (mid June-mid August). If these later populations are large it would be important to control them as they can impact the following years' crop. More data collection will help to clarify patterns. It would also be good to monitor fields with tipworm infestation in other areas to see if the population patterns are similar.

Currently, the most accurate way to monitor for tipworm populations is to look at a minimum of 50 uprights per field under a dissecting microscope. In order to make monitoring more efficient it would be helpful to have a method to predict tipworm phenology. This method would have to be accurate enough to predict peak egg hatch and be less time consuming than examining uprights under a microscope. This report has shown that using degree-day accumulations, based on cranberry development thresholds and *Dasineura tetensi* thresholds, may not be accurate in all years. Our one year of data indicates that oviposition of later generations corresponds to specific stages of cranberry development, i.e. 50% and 100% fruit set. If cranberry plant development can be used to predict tipworm emergence and peak oviposition events, it would be an efficient way to improve the timing of monitoring and control. Another year of data should be collected to verify that cranberry plant development can be used as an accurate way to time both monitoring and management of cranberry tipworm.

Figures

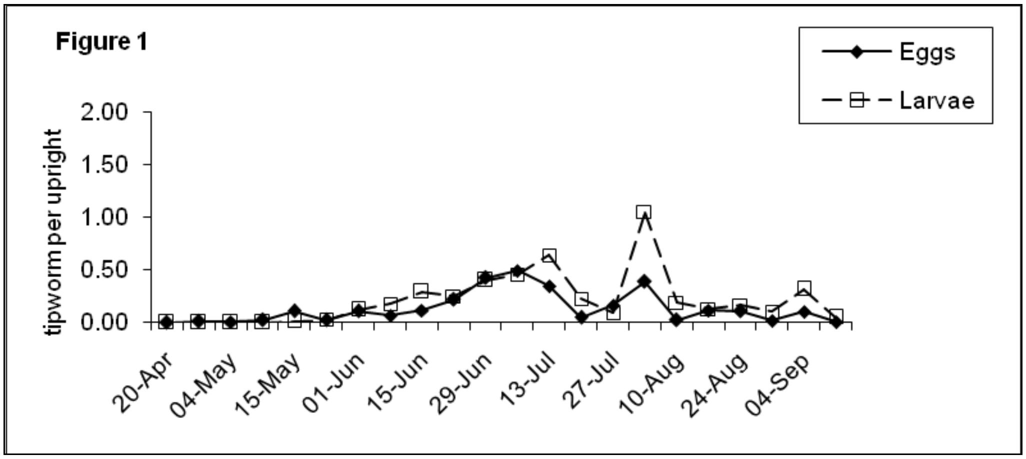
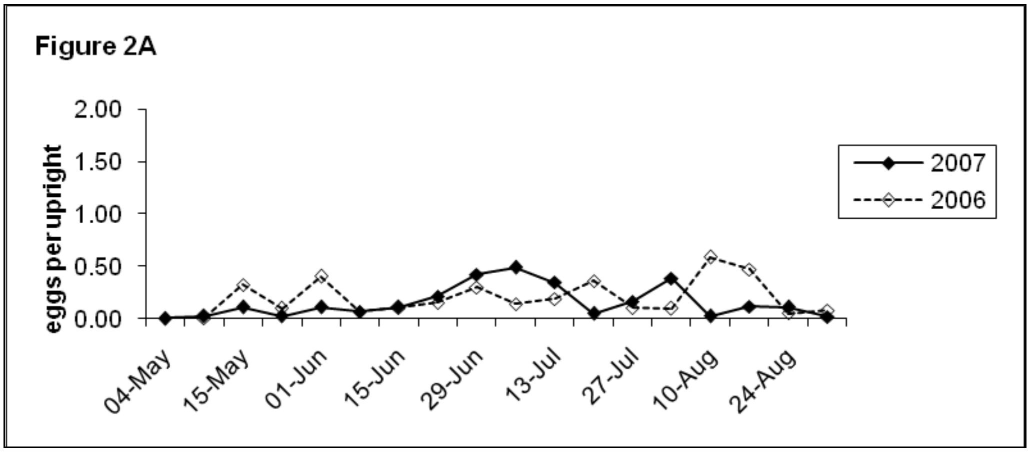


Figure 1. Tipworm monitoring data from 2007. Weekly average of the number of tipworm eggs and larvae per upright per field.



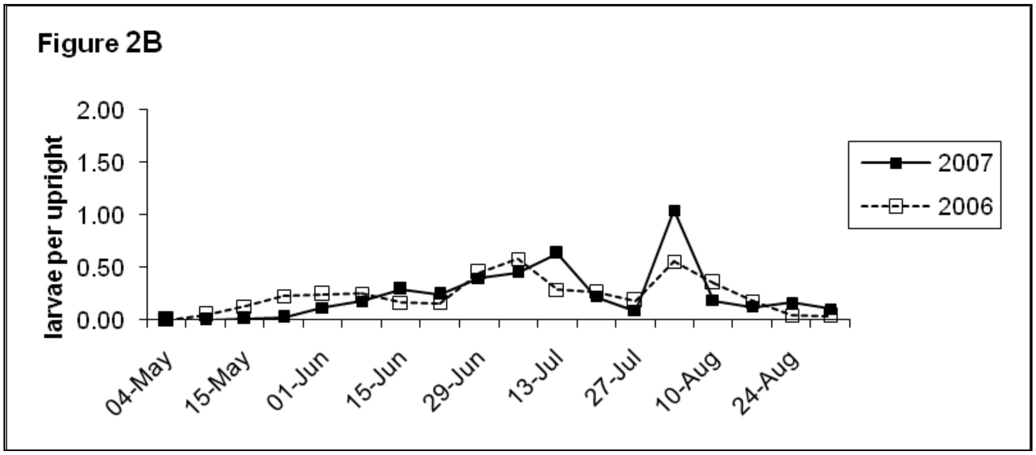


Figure 2a. Average number of tipworm eggs per upright in 2006 and 2007.
Figure 2b. Average number of tipworm larvae per upright in 2006 and 2007.

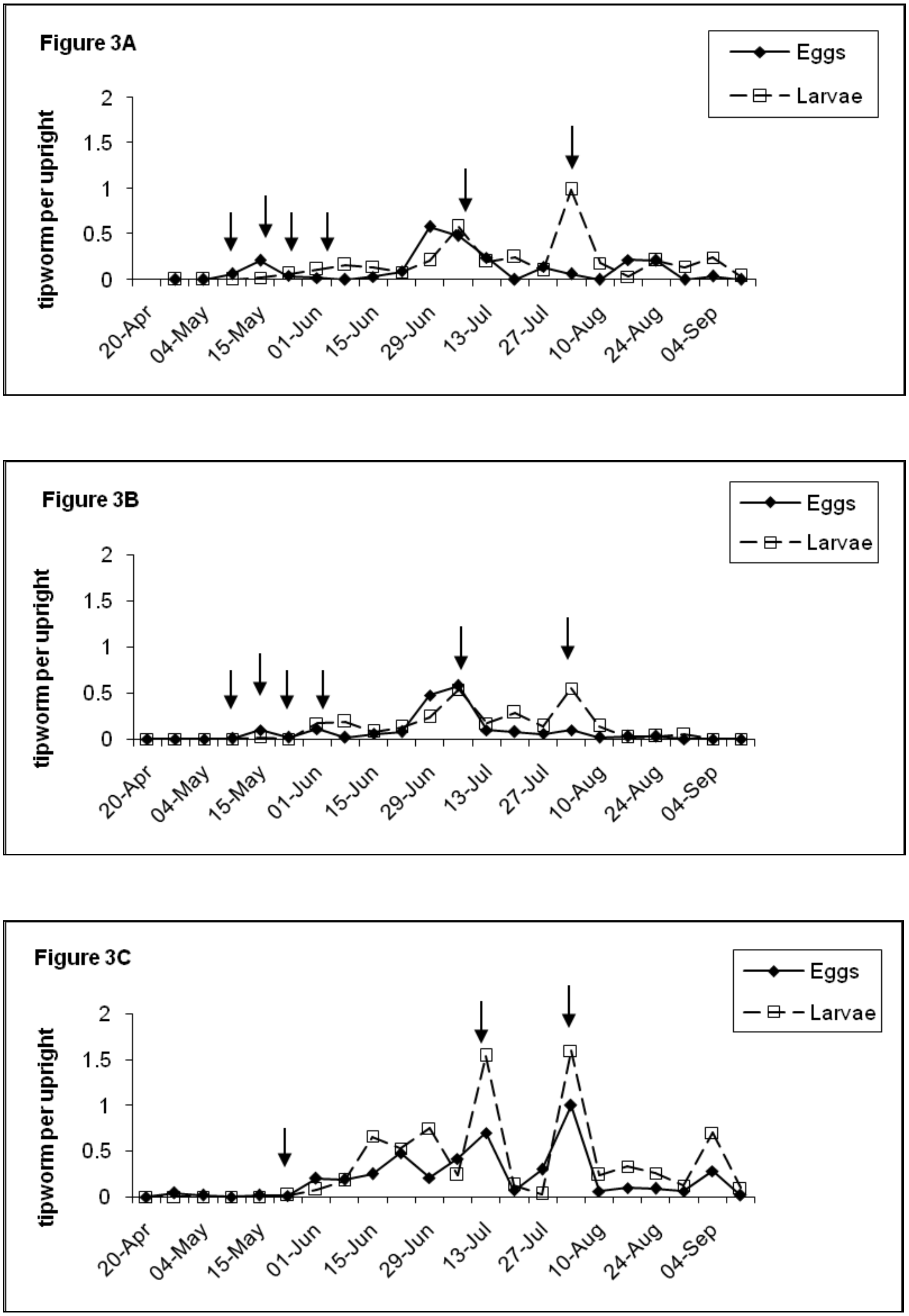


Figure 3a-c 2007 Fields: Average number of tipworm eggs and larvae per upright in Field 1 (3a), Field 2 (3b) and Field 3 (3c). Arrows indicate Diazinon sprays.

Figure 3D

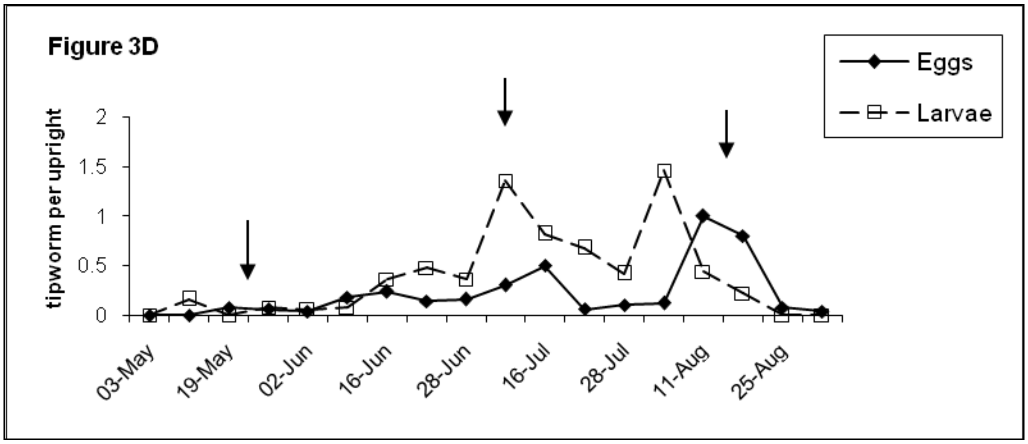


Figure 3E

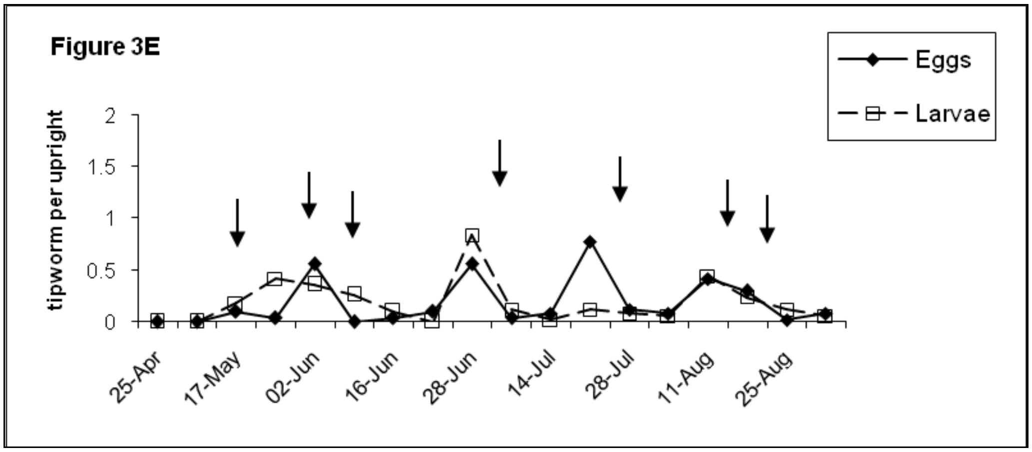


Figure 3F

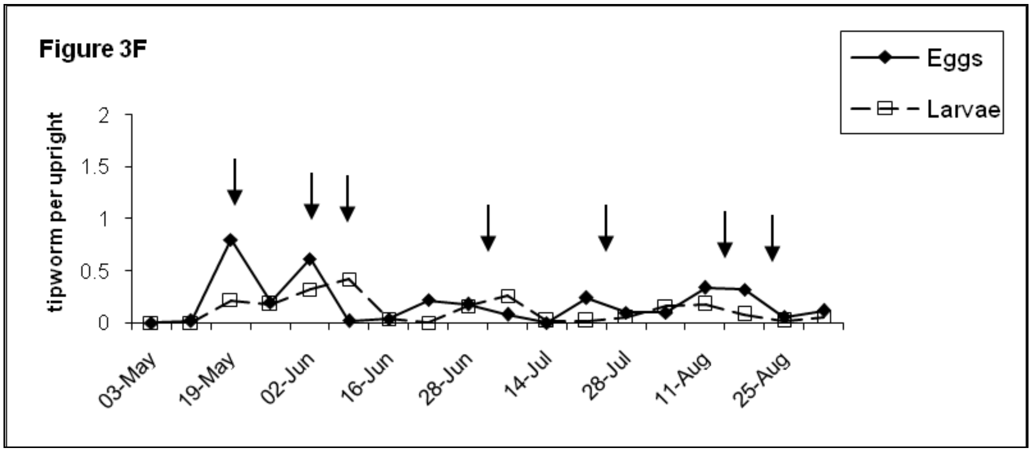


Figure 3a-c 2006 Fields: Average number of tipworm eggs and larvae per upright in Control 1 (3a), Control 2 (3b) and Sanded 2 (3c). Arrows indicate Diazinon sprays.

Figure 4

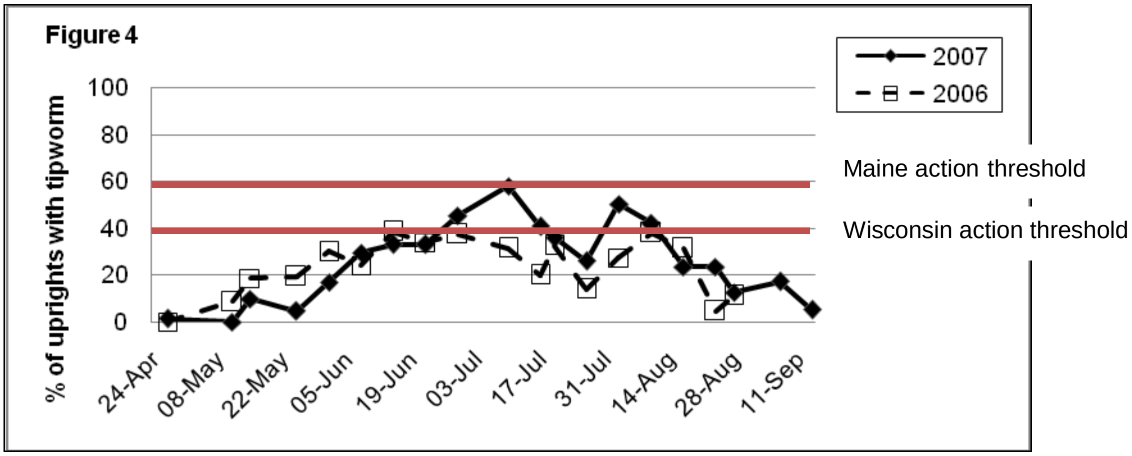


Figure 5A

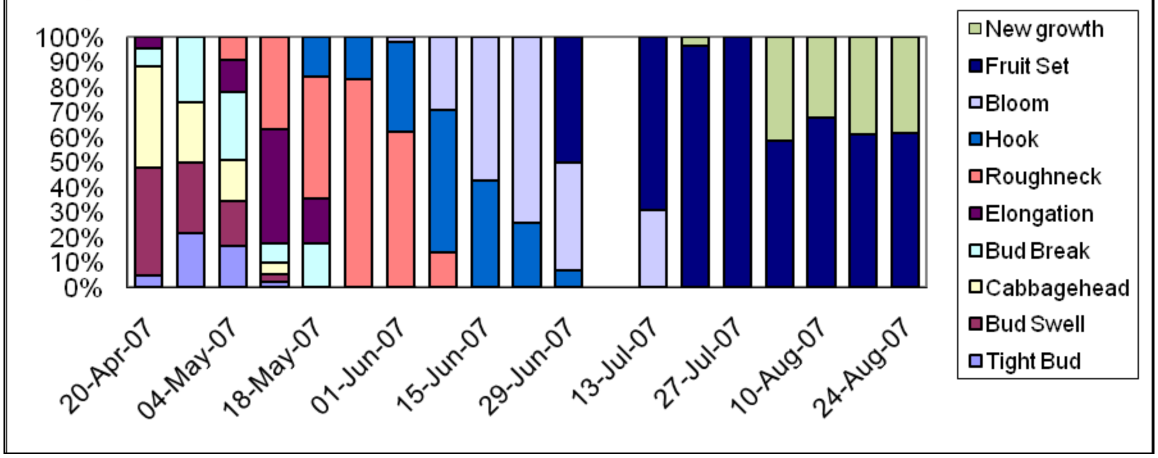


Figure 5B

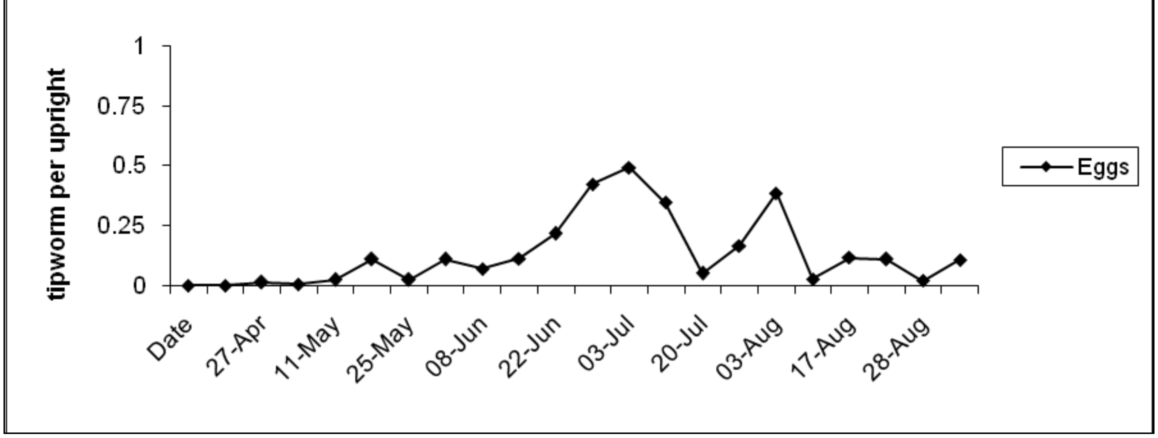


Figure 4a. Cranberry development stages recorded weekly (Average of 3 fields).
Figure 4b. Average number of cranberry tipworm eggs per upright.

References

Axelsen, J. 1992. The developmental time of the pod gall midge, *Dasyneura brassicae* Winn. (Dipt., Cecidomyiidae). Journal of Applied Entomology 114: 263-267.

British Columbia Ministry of Agriculture and Lands (BCMAL). 2007. Berry Production Guide for Commercial Growers 2007-2008 Edition.

Buckshaw, S. 2006. Assessment of tipworm damage on cranberries throughout the season and how sanding affects tipworm populations and tipworm damage. Report to B.C. Cranberry Growers Association.

Cockfield, S.D. and D.L. Mahr. 1994. Phenology of oviposition of dasyneura oxycoccana (dipteral: cecidomyiidae) in relation to cranberry plant growth and flowering. The Great Lakes Entomologist 27(4): 185-188.

Cranberry Tipworm [internet]. [updated 2007 May 16]. The University of Maine, Cooperative Extension; [cited 2008 January 30]. Available from: http://www.umaine.edu/umext/cranberries/tipworm.htm

Cross, J.V. and D.J. Crook. 1999. Predicting spring emergence of blackcurrant leaf midge (*Dasineura tetensi*) from air temperature. Entomologia Experimentalis et Applicata 91: 421-430.

Dittl, T. 2007.Cranberry tipworm – monitoring and management. In: Proceedings of the 1st annual Cranberry Congress; 2007 February 8; British Columbia. The BC Cranberry Marketing Commission and BC Cranberry Growers' Association.

Eck, P. 1990. The American cranberry. Rutgers, New Brunswick. 420 pp.

Hawker, G.M. and E.J. Stang. 1985. Characterizing vegetative growth and fruit development in cranberry (*Vaccinium macrocarpon* ait.) by thermal summation. Acta Horticulturae 165: 311-315.

Hellqvist, Sven. 2001. Phenology of the blackcurrant leaf midge (Dasineura tetensi) in Northern Sweden. Acta Agriculturae Scandinavia, Section B, Soil and Plant Science 51: 84-90.

Mahr, D. L. Cranberry Tipworm. November 2005. University of Wisconsin Cranberry Crop Management software (CCM). http://www.hort.wisc.edu/cran/mgt_articles/articles_pest_mgt/insects/profiles_insects/TIPWORM.pdf

Workmaster, B.A. et al. 1997. Terminology for cranberry bud development and growth. Cranberries February 1997: 11-14.

Appendix A Spray records for 3 fields monitored for 2007 trial.

Field	Date	Product Used
Field 1 & Field 2	May 11 May 12 May 17 May 25 June 3 July 7 July8 July 31 Aug 4	Diazinon Diazinon Diazinon Diazinon Diazinon Diazinon Sevin Sevin Diazinon
Field 3	May 24 July 11 Aug 2	Guthion Diazinon Diazinon

Appendix B. Phenology Table

Tipworm Phenology	**Date A1**	**A4**	**M2**	**Cranberry Phenology A1**	**A4**	**M2**
Start of oviposition	May 8	May 11	April 28	43% elongation	34% elongation-59% roughneck	43% budbreak
1st peak	May 15	May 15/Jun 1	June 1	-	59% roughneck/ 70% roughneck	43% roughneck-50% bloom
2nd peak	June 29	July 3	June 22	50% bloom – 40% fruitset	33% bloom-56% fruitset	16% hook - 63% bloom
3rd peak	July 27	Aug 3	July 13	100% fruitset	63% fruitset-37% new growth	90% fruitset
4th peak	Aug 17	-	Aug 3	66% fruitset – 34% new growth	-	100% fruitset