Improving Cutworm Risk Forecasting in the Fraser Valley (Year 3 of 3)

Final Report to:
Lower Mainland Horticultural Improvement Association
BC Potato and Vegetable Growers Association

Prepared by:
Megan Gray, E.S. Cropconsult Ltd.

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Executive Summary

Cutworm moth trapping has the potential to augment in-field scouting for larvae and provide regional-level pest pressure information to growers in the Fraser Valley. However, multiple years of data are required to determine the possibility of outbreak years, as no current local thresholds exist. In addition, the effects of cutworm damage to belowground crops such as table beets and potatoes are not well described. In this three-year project, the objectives were to continue the trapping and monitoring work performed in 2017 and 2018 for local Noctuid species of concern and improve local understanding of the relationship between cutworm species and feeding damage. The third year of the study determined the species of cutworm and armyworm larvae present in the field.

Trapping and monitoring project

Moth specimens were collected weekly from pheromone traps in 14 fields located throughout the Fraser Valley (Delta, Surrey, and Abbotsford/Sumas) for three species: variegated cutworm (*Peridroma saucia*), black cutworm (*Agrotis ipsilon*), and bertha armyworm (*Mamestra configurata*). Pest hotspots were noted from data collected from in-field monitoring, and the data were linked using growing degree day (GDD) models based on local weather data.

Supported by previous years' data, pheromone accuracy was highest for variegated cutworm and black cutworm, and lowest for bertha armyworm, with the highest number of non-target specimens caught in the bertha armyworm traps. Lure accuracy decreased for variegated and black cutworm, but increased for bertha armyworm as the season progressed. Numbers of variegated cutworm moths were highest in 2019, bertha armyworm numbers were highest in 2020, and black cutworm numbers were highest in 2021, indicating potential outbreak years. In 2019, 26 spray recommendations in commercial potato and beet fields were made for cutworms across the three regions, this number decreasing to nine recommendations in 2020, and only two spray recommendations made in 2021. In 2021, 172 potato and seven beet fields were monitored, which is similar to the number of fields monitored in 2019 and 2020.

Larval spray recommendations for variegated cutworm occurred six to seven weeks after peak mean moth trap catch in 2020 and only four to five weeks in 2019. No spray recommendations were made for variegated cutworm in 2021. Spray recommendations in 2021 were only made for black cutworm, ocurring six to nine weeks after the highest peak mean moth trap catch. Two spray recommendations were made for green larvae, both occurring during the 2020 season. The larvae were unable to be confirmed as bertha armyworm and the spray recommendations occurred seven weeks apart from each other, not appearing to relate to moth flights that season.

The GDD models varied in their accuracy from year to year and for each species. It predicted fairly accurate life stages for variegated cutworm in 2019, especially in Sumas. However in 2020, the models generally predicted key lifestages later than what was seen in the field for variegated cutworm and bertha armyworm in Sumas and matched up within one week of what was seen in the traps in Surrey and Delta. The GDD model for black cutworm may be accurate, but further work would need to be performed, as the only black cutworm larvae spray recommendations occurred in 2021.

Larval species identification

Across the three years of the study, several larvae from each of the species studied were able to be reared into adult moths to confirm species identity. Bertha armyworm, especially small instars, are unable to be confirmed based solely on the larvae due to other similar green cutworms (e.g.,

Spodoptera spp.). However, variegated cutworm and black cutworm can be identified at any instar and confirmed by rearing into adult moths.

The feeding habits of the three species studied differed in that variegated cutworm and bertha armyworm larvae were not seen to readily feed belowground, while black cutworm larvae preferentially fed on potato tubers, beetroots, and stems of small plants.

Introduction

Field monitoring for cutworms and armyworms (Family: Noctuidae) in the Fraser Valley has historically been reliant on scouting for foliar feeding damage and presence of larvae. Damage to root crops pre-harvest is difficult to see, which increases the difficulty of monitoring for larvae. Targeting the adult moths can assist in predictions of larvae present in the fields and determine if the species could pose a region-wide outbreak risk. Multiple years of data need to be collected to determine if a cutworm forecasting network is feasible for the Fraser Valley, and results from previous years of data provided a baseline for the moth trapping performed in this three-year project (Yates *et al*. 2018; Yates 2019).

Noctuid development is dependent on temperature, so climate data within each trapping region in the Fraser Valley can be combined with trap catch data through growing degree day (GDD) models. GDD models are a commonly used tool in pest management for various species and can help in understanding the moth catch peaks and when larvae may be expected in the field.

Belowground damage to potatoes and beets has not been well-described. There is a local knowledge gap regarding the effect of cutworm species and their feeding habits, timing of belowground damage, and how early-season damage appears at harvest. Underground larval damage may not be an issue until the foliage on the plants is removed, but it is also possible that the larvae cause damage when they move below ground to pupate. Damage to potatoes by black cutworm has been shown to occur throughout the growing season, on both foliage and tubers (Das and Ram 1988). However, understanding of variegated cutworm and bertha armyworm damage is not as well known. A lab study performed by Shields *et al.* (1985) assessed the foliar feeding damage by variegated cutworm larvae on potatoes, however the relationship between foliar and tuber damage in cutworm field 'hotspots' is unclear.

Vegetable growers in the Fraser Valley can benefit from an improved understanding of cutworm population dynamics and visual examples of belowground cutworm damage – especially potato, beet, and carrot growers who have been affected by cutworm and armyworm damage in recent years. Continuing the trapping network and refining techniques will provide more information on cutworm and armyworm outbreak years and broaden understanding of local pest pressure in potato and beet fields.

The objectives of Year 3 of this three-year project were:

1. To continue work done in 2017 and 2018 for a cutworm outbreak forecasting system within the Fraser Valley, based on moth counts in traps and larvae hotspot detection in beet and potato fields.
2. To keep local growers informed of flight numbers and expected cutworm pest pressures during the growing season to allow for effective management.
3. To improve local understanding of how to use moth trapping to improve monitoring for cutworms of concern to potatoes and table beets in the Fraser Valley.

4. To identify the species of economically damaging cutworm and amyworm species present in the Fraser Valley.

Methods

Moth trapping

During the 2021 growing season, green bucket traps for catching cutworm moths were placed in 14 field locations throughout three vegetable growing regions of the Fraser Valley, British Columbia (BC): Delta, Surrey, and Abbotsford/Sumas (Fig. 1). Similar to Years 1 and 2, fields were selected based on availability due to planting date, accessibility, and surrounding crops(Gray and Yates 2020; Gray and McFarlane 2021). To optimize spatial representation within each region, traps were placed in distinct subregions wherever possible. In addition, priority was given to placing traps on a field margin bordering both a potato and a beet field. Two fields in Sumas were harvested prior to the end of the trapping period, requiring the traps to be moved to the nearest unharvested potato field.

Figure 1. Map of the Fraser Valley showing the 14 field locations containing cutworm moth traps during the 2021 growing season. The five Delta region fields are highlighted in blue, four Surrey region fields are highlighted in yellow, and five Sumas region fields are highlighted in red.

Consistent with the past two years of data collection, trapping in each field consisted of three bucket traps containing individual pheromone lures (Alpha Scents Inc., West Linn, Oregon) for variegated cutworm (*Peridroma saucia*), black cutworm (*Agrotis ipsilon*), and bertha armyworm (*Mamestra configurata*) (Gray and Yates 2020; Gray and McFarlane 2021). In total, 42 bucket traps were set up across all three regions. The traps were placed evenly along the field edge, spaced 50 m apart to minimize pheromone lure interference. The bucket traps were secured to wooden stakes with wire and were approximatey 1 m above ground. An insecticide strip (active ingredient: dichlorvos 19.2%) was placed in the bucket to ensure quick moth death and prevent damage to moth wings. Lures and insecticide strips were replaced every four to five weeks.

Traps were in place for a total of 19 weeks. They were set up between April 26-30, 2021 and taken down between August 30-September 3, 2021. Traps were placed regardless of crop stage (i.e., some fields were recently planted while others had emerged plants) and were checked every seven days. If a field could not be entered on the scheduled trap checking day due to a pesticide application, the trap would be checked once it was safe to re-enter the field. If this was not possible and the field was not entered for another seven days, that field's trap data was excluded from calculations for that two-week period.

Moth trap counts were separated into target (species in trap matches pheromone) and non-target (species in trap does not match pheromone) moths. Target moths were identified to species based on morphotype (Fig. 2), informed by previous local morphotyping and identification work (Yates *et al.* 2018; Yates 2019). Where possible, recurring non-target moths were identified based on morphotype (Powell and Opler 2009; Peterson 2012; Yates *et al.* 2018; Yates 2019). However, non-target moths were determined to not be of economic importance and much less emphasis was placed on identification this year.

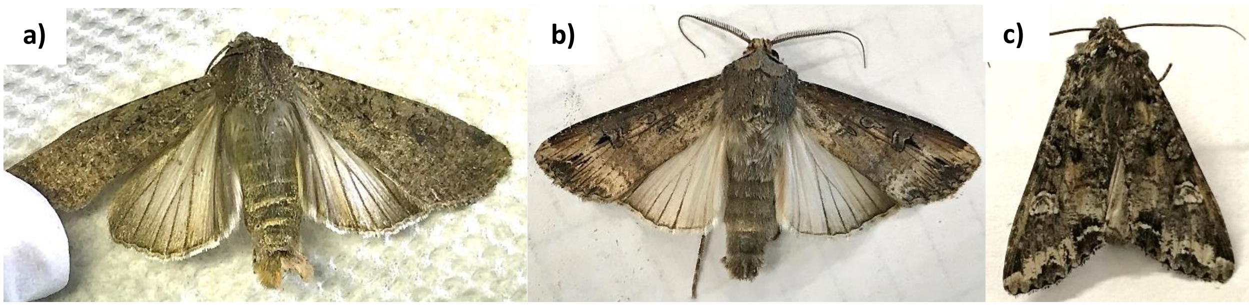

Figure 2. Photo examples of variegated cutworm moth (a), black cutworm moth (b), and bertha armyworm moth (c), collected during the 2020 trapping season. The same morphotypes were present during the 2019 and 2021 seasons.

Larvae field observations

Integrated pest management (IPM) monitoring data and reports were provided by E.S. Cropconsult Ltd. for all field study locations. Monitoring data were available from 168 potato fields and six beet fields. Weekly monitoring data for cutworm larvae in potato and beet fields were counted throughout the season to identify trends in larvae numbers compared to moth trap counts. Patches of cutworm damage ('hotspots') were recorded, noting the larvae number and size, feeding damage to foliage and tubers/roots (Table 1), the plant stage, variety, growing degree day (GDD), and whether or not a spray recommendation was made.

Table 1. Tuber feeding damage scale based on CFIA standards for potato tuber damage (CFIA 2015)

Damage rating	Description of damage
0	No damage
1	Feeding damage is present, but does not exceed an aggregate area of more than 10% of the surface
2	Feeding damage is present, exceeds an aggregate area of more than 10% or two or more eyes of the tuber are affected

Larval species indentification

At the start of the growing season, the intended lab to receive the larval samples was closed due to the COVID-19 pandemic. Thus, higher emphasis was placed on rearing larvae into adult moths to then identify morphologically. Whenever possible, large-sized larvae collected from the field were placed into clear plastic containers with mesh lids to allow for sufficient airflow while also preventing the larvae from escaping. Foliage from the crop they were collected from was placed inside the container and was changed several times a week. Adult moths were identified solely based on key identifying features for each species in the same way as moths caught in the traps.

Due to higher levels of belowground feeding damage present in August and September this season compared to the 2019 and 2020 seasons, several local potato and beet growers were contacted to see if belowground cutworm damage had been noted on their farms. In addition, one potato field with significant cutworm feeding damage on the tubers was visited during harvest and two pupae were collected from the field to rear into adult moths.

Larvae collected and reared during the 2019 and 2020 field seasons are also included in this report.

Growing degree day models

The most regionally relevant and available GDD models for the three target species were accessed from the Oregon State University (OSU) Online Phenology and Degree Day Models (OSU n.d.). Local weather data (Environment Canada 2021) from the closest and/or most central weather station available within each of the three regions were used in the models: Delta station CW2194, Surrey station AR283, and Abbotsford station C8841. Moth trapping data for 2021 was also used as model input as needed for the black cutworm and bertha armyworm GDD models, but was not necessary for the variegated cutworm model. The variegated cutworm model start date is set to be on May 1 for all regions, independent of trap catch data as a model input, and this model predicts key dates for both moth and larval life stages. The black cutworm model start date is dependent on the peak capture in pheromone traps which was May 18 for Sumas and Surrey. Delta had two peaks; the first peak ocurred May 27, which was used for the GDD model, but it should be noted that there was a second, larger peak during the week of July 12-16, 2021. Finally, for bertha armyworm the GDD model start date is dependent on the first catch in pheromone traps which was May 18 for Sumas, June 3 for Surrey, and May 3, 2021 for Delta.

Region-wide communication

During the growing season, trap count data and other relevant information (i.e., cutworm larvae spray recommendations) were shared with growers via the BC Potato and Vegetable Growers' Association's bi-weekly potato newsletter to a mailing list of over 100 recipients. A total of nine newsletters with cutworm trap updates and management tips were issued throughout 2021 (Fig. A1).

Results and Discussion

Moth trapping

<u>Variegated cutworm (*Peridroma saucia*)</u>

Variegated cutworm consistently showed the highest overall moth numbers compared to black cutworm and bertha armyworm across the three-year study (Fig. B1; Gray and Yates 2020; Gray and McFarlane 2021). During the 2021 trapping period, a total of 2,276 variegated cutworm moths were caught as on-target species in the variegated cutworm baited pheromone traps. These numbers are similar to 2020, where 2,610 target moths were captured (Gray and McFarlane 2021). However, 2019 appears to have been an outbreak year for variegated cutworm in the Fraser Valley, as 6,037 total moths were seen in the variegated cutworm traps all season and many were also captured as off-type catches in the black cutworm and bertha armyworm traps (Gray and Yates 2020). This increased pest pressure and effectiveness of pheromone trapping has proven to be consistent with local data collected in 2017 and 2018 (Yates *et al.* 2018; Yates 2019).

The 2021 trap counts did not have a clear peak in Sumas or Surrey (Fig. 3; Table C1). There was a peak in Delta during the week of June 20 to June 26, 2021, capturing a mean of 16.4 variegated cutworm moths per trap. The highest mean number of variegated cutworm moths per trap in Sumas also occurred during the week of June 20 to June 26, 2021 at 15.6 moths per trap. The first trapping week caught the highest number of moths in Surrey, with a mean of 19.5 moths per trap that week (Fig. 3). The 2020 trapping period had one clear peak in trap counts for each region, between May 18 to May 24, 2020 in Sumas at 47.4 mean variegated cutworm moths per trap, and May 25 to May 31, 2020 in Surrey and Delta at 41.8 and 32 mean moths per trap, respectively (Gray and McFarlane 2021). Conversely, the 2019 season showed very clear peaks of high variegated cutworm moth activity in all regions (Gray and Yates 2020). These peaks in 2019 occurred from May 20 to June 2, June 24 to June 30, and then a smaller peak between August 21 to August 18. The highest numbers were seen in Sumas, reaching a mean of 189 moths per trap on May 21, 2019.

The life cycle of variegated cutworm is difficult to asses, as there is evidence of overwintering larvae and pupae, but also migration of adults into cooler areas in the spring (Heppner *et al.* 2008). They are not suspected to overwinter in Canada, except for regions that remain relatively warm throughout the winter (Heppner *et al.* 2008). This potential overlapping of generations, along with their wide host range, can make assessment of outbreak years difficult to predict until high moth trap counts are seen.

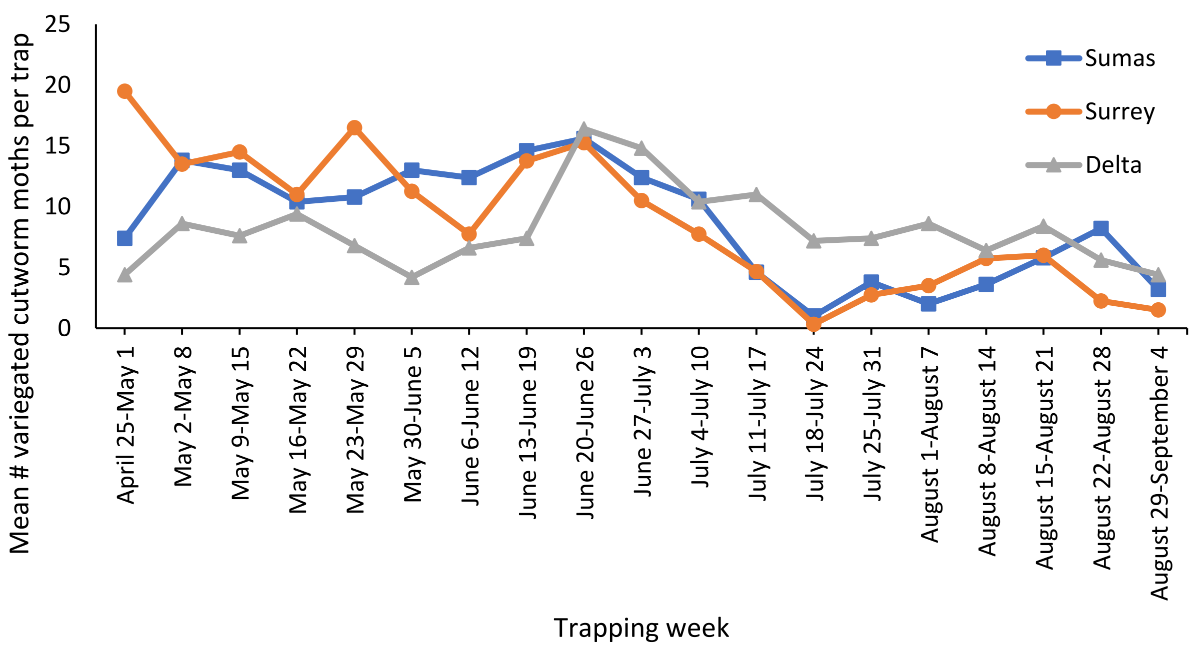

Figure 3. Target moth catches for variegated cutworm pheromone traps per region at 19 weekly intervals during the 2021 growing season. Trap counts are the mean value of all traps placed in each region: Sumas (n=5), Surrey (n=4), and Delta (n=5). In Surrey, trapping data was unavailable between July 11-17 and July 18-24, so n=3 for these weeks.

<u>Black cutworm (*Agrotis ipsilon*)</u>

Black cutworm moth trap catches were lowest in 2019 and highest in 2021, with the 2020 data generally following the same trends seen for variegated cutworm moth trapping but with lower numbers (Fig. B2; Gray and Yates 2020; Gray and McFarlane 2021). In 2021, 783 black cutworm moths were caught as on-target captures in the black cutworm traps, much higher than the 203 seen in 2020 and only 44 in 2019. This year is suspected to have been an outbreak year due to the higher numbers and clearer trends in moth flights compared to the previous two years of data collection. Trapping in previous years has seen low to moderate numbers of moths caught and no clear trends in the data.

In 2021, the trapping for black cutworm showed moth numbers increasing in all regions in mid May to then plateau until mid-June with no clear single peak during this time period (Fig. 4). However, there was a large peak in Delta between July 11 to July 17, 2021 with a mean of 16.4 moths per trap. The 2020 moth trap counts had a peak in Surrey on May 27 with a mean of 11.5 moths per trap, but the numbers in Sumas and Delta were negligible (Gray and Yates 2021). Black cutworm was present in lower numbers compared to variegated cutworm, but the potential for outbreak years is present if the conditions are conducive to their development.

Black cutworm moths prefer hot and dry years, migrating to the Pacific Northwest from the southern states and Mexico (CABI 2020, PNW Moths n.d.). They are not known to overwinter locally, and this migratory nature makes outbreaks sporadic and highly localized (OMAFRA 2009, PNW Moths n.d.). Caution should be taken for black cutworm outbreaks especially when weather conditions are warm and dry, using moth trapping as a predictor for larval outbreaks.

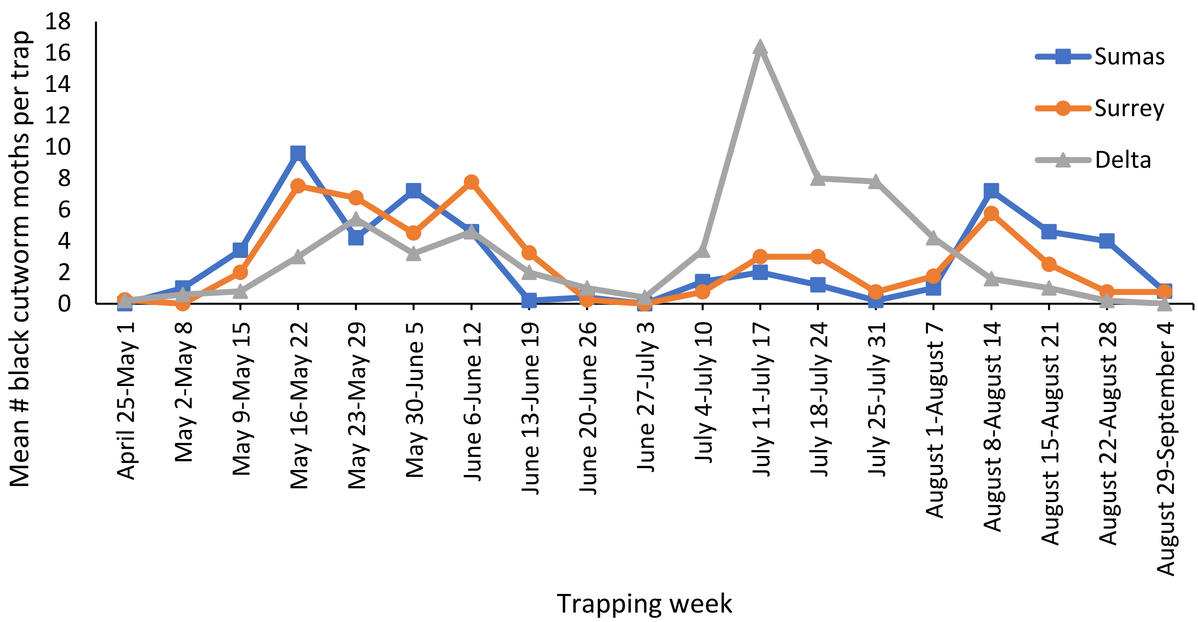

Figure 4. Target moth catches for black cutworm pheromone traps per region at 19 weekly intervals during the 2021 growing season. Trap counts are the mean value of all traps placed in each region: Sumas (n=5), Surrey (n=4), and Delta (n=5). In Surrey, trapping data was unavailable between July 11-17 and July 18-24, so n=3 for these weeks.

<u>Bertha armyworm (*Mamestra configurata*)</u>

Bertha armyworm appears to be a late-season pest, consistently showing increasing numbers in mid- to late-August, based on the three years of this study (Fig. B3; Gray and Yates 2020; Gray and McFarlane 2021). The highest numbers of bertha armyworm moths were in 2020 in all regions, with comparatively low numbers caught during the 2019 and 2021 trapping periods. A total of 137 bertha armyworm moths were caught in the bertha armyworm pheromone traps in 2021, 420 moths caught in 2020, and only 73 moths caught in 2019 (Gray and Yates 2020; Gray and McFarlane 2021). This information, in addition to the consistency of bertha armyworm moths captured as off-types in the variegated cutworm and black cutworm traps in 2020, indicates that 2020 was a possible outbreak year for bertha armyworm.

The 2021 trap catches show a peak in Sumas between August 15 to August 21 with a mean of 3.6 moths per trap, and in Surrey there was a peak the following week with a mean of 4.25 moths per trap (Fig. 5). This is similar to the results from 2019, where the peak mean moth catches were between June 10 and June 16, and August 12 to August 18, 2019 in Sumas and Surrey. For both 2019 and 2021, numbers in Delta remained low all season. In 2020, the peak mean moth catch in Sumas was on August 18 with a mean of 19.6, largely driven by 77 moths caught in one trap that day (Gray and McFarlane 2021). In Surrey, the peak mean moth catch was the last week of trapping, with a mean of 10.5 moths per trap on August 26, 2020 (Gray and McFarlane 2021). The peak mean moth catch in Delta was between August 10 to August 16, 2020 at a mean of 10 moths per trap.

Information on bertha armyworm in potatoes and table beets is limited, but they don't appear to have the same population dynamics as either variegated or black cutworm in the Fraser Valley. Their consistent increases late in the season raise the risk of tuber damage when foliage is unavailable to feed on, but currently no tuber damage has been noted from bertha armyworm.

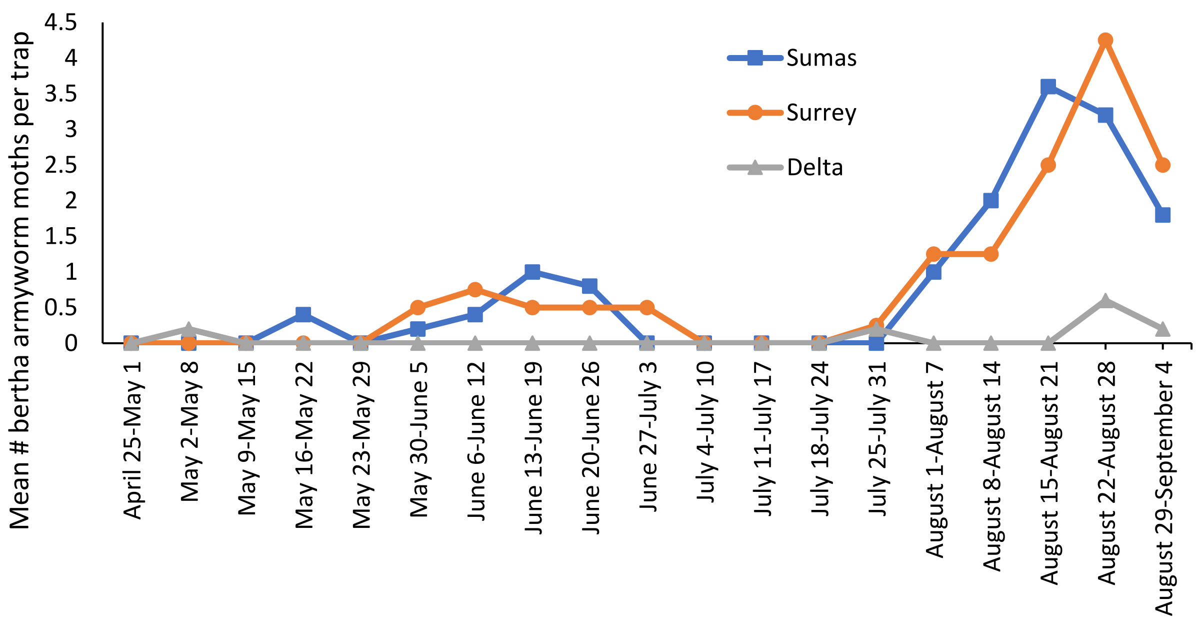

Figure 5. Target moth catches for bertha armyworm pheromone traps per region at 19 weekly intervals during the 2021 growing season. Trap counts are the mean value of all traps placed in each region: Sumas (n=5), Surrey (n=4), and Delta (n=5). In Surrey, trapping data was unavailable between July 11-17 and July 18-24, so n=3 for these weeks.

Trap specificity

Variegated cutworm (*Peridroma saucia*)

A total of 2,441 moths of various species were caught in the variegated cutworm traps throughout the 19-week trapping period, with 93% identified as on-target variegated cutworm moths (Table 2). The high level of species accuracy is supported by 95%, 98%, 88%, and 95% target accuracy in the 2020, 2019, 2018, and 2017 seasons, respectively (Yates *et al.* 2018; Yates 2019; Gray and Yates 2020, Gray and McFarlane 2021).

During the three years of moth trapping from 2019-2021, non-target catches were low throughout the season, only increasing in August of their respective years. Common off-types caught were bertha armyworm (*Mamestra configurata*), common yellow underwing (*Noctua pronuba*), rosy dart (*Diarsia rosaria*), and *Eurois* spp.

Black cutworm (*Agrotis ipsilon*)

A total of 1,106 moths of various species were caught in the black cutworm traps during the 2021 trapping period across all regions. Of these, 71% were identified as black cutworm moths and considered on-target catches for the pheromone trap (Table 2). This is similar to 2020 and 2018, where lure accuracy was 78% and 70%, respectively (Yates 2019; Gray and McFarlane 2021). Interestingly, in 2017 and 2019, the lure accuracy was much lower, at 14% and 12% respectively (Yates *et al.* 2018; Gray and Yates 2020).

The total number of non-target moths are generally consistent from year to year, so when black cutworm numbers are lower, the lure accuracy appears to be lower. Thus, it is more difficult to assess lure accuracy during years of low black cutworm numbers or during periods of high non-target moth activity.

Similarly to the trend seen for variegated cutworm, non-target species tended to increase in August until the end of trapping. In 2019, there was a peak of non-target moths in Sumas primarily consisting of cabbage loopers (*Trichoplusia ni*) on May 21 (Gray and Yates 2020). Smith's dart moth (*Xestia smithii*) were the most common non-target catches for all three years of data collection. However a few other catches included bertha armyworm (*Mamestra configurata*), cabbage loopers (*Trichoplusia ni*), thoughtful apamea (*Apamea cogitata*), yellowstriped armyworm (*Spodoptera praefica*) and common yellow underwing (*Noctua pronuba*).

Bertha armyworm (*Mamestra configurata*)

Similarly to previous years of data, the bertha armyworm traps caught the highest percentage of non-target catches than either black or variegated cutworm. A total of 559 moths of various species were caught in the bertha armyworm traps, of which only 25% were identified as on-target bertha armyworm moths. In 2020, many more bertha armyworm moths were seen in all traps and 81% of total moths caught in the bertha armyworm baited traps were identified as on-target catches (Gray and McFarlane 2021). This is much higher than only 5% species accuracy in 2019, potentially due to the high number of variegated moth counts that year and thus many getting caught as off-types in bertha armyworm traps (Gray and Yates 2020).

Numbers of non-target moths were often higher than target moths, and this trend was consistent throughout the three-year study. In 2019, the off-type catch seen in highest numbers in the bertha armyworm traps by a large margin was variegated cutworm (*Peridroma saucia*) compared to other off-types (Gray and Yates 2020). Other consistent trap catches throughout the three year study included rosy dart (*Diarsia rosaria*), thoughtful apamea (*Apamea cogitata*), and nutmeg (*Anarta trifolii*).

*Table 2. The percentage of target moth catches per month for variegated cutworm, black cutworm, and bertha armyworm pheromone traps in 2021. Trap catches in Sumas, Surrey, and Delta were combined due to trap specificity being similar across the three regions. There were five traps in Sumas, four in Surrey, and five in Delta. * indicates trapping data missing due to spray out or fallen trap(s). Note that there were only five trapping dates in April and three trapping dates in September.*

	Percentage (%) of target species in traps		
Month	**Variegated cutworm**	**Black cutworm**	**Bertha armyworm**
April	99.3	100	0
May	99.2	98.1	4.1*
June	99.6	91.3	22.8
July	98.3*	91.2*	65.6*
August	74.6	38.8	41
September	14.3	14.3	35.5

Due to lack of molecular analysis for larvae (and therefore moth analysis), collected moths of unknown species have been discarded. Off-types of unknown species did not appear in any considerable amount that would be cause of concern for economic damage to potato or beet crops.

Larval species identification

In 2020 and 2021, cutworm larvae hotspots within the field were assessed for foliar damage and tuber damage, as well as counting, sizing, and identifying the larvae present. There were only two spray recommendations for cutworm larvae during the 2021 growing season in the integrated pest management (IPM) reports provided by E.S. Cropconsult Ltd. (Table 3). In 2019, larvae hotspots were recorded but some information is missing due to limited knowledge of larval species and high numbers of hotspots likely due to variegated cutworm presence. Many more spray recommendations were made in 2019 compared to 2020 and 2021 as more information was gathered throughout the course of the study that allowed for more targeted cutworm spray recommendations (Table D1).

Table 3. Information for fields that received cutworm larvae spray recommendations during the 2021 trapping season (from E.S. Cropconsult Ltd. monitoring data). Additional details in Table D1.

Region	**Number of spray recommendations**	**Number of fields monitored**	**Number of fields with spray recommendations within 1 km of moth trapping site**	**Larval species present**
Delta	1	126	0	Black cutworm Bertha armyworm
Surrey	1	14	1	Black cutworm
Sumas	0	38	N/A	N/A

Throughout the three-year study, more was learned about the larvae species present and their damage risk to potato and beet crops. No official cutworm larvae threshold exists for either potatoes or beets in the Fraser Valley (BCMA 2017), but spray recommendations for variegated cutworm and bertha armyworm became more conservative over the three years. Spray recommendation frequency was adjusted based not only on larvae and foliar damage presence, but also placed a much higher emphasis on species identification as well as plant stage. This is because over the course of this project, levels of foliar damage did not appear to be related to tuber damage. In hotspots with variegated cutworm and bertha armyworm, foliar damage ratings ranged from low to high but no tuber damage was seen in-field. Black cutworm feeding habits appear to be the opposite, with little to no aboveground feeding damage but with damage to small stems, tubers, or beetroots.

Based on results from the beet and potato damage demonstrations performed in Years 1 and 2 of the project, variegated cutworm and bertha armyworm appear to prefer feeding on foliage (Gray and Yates 2020; Gray and McFarlane 2021). Of the test pots, only one potato tuber had feeding damage from a late instar variegated cutworm (Gray and McFarlane 2021). However, the wide host range of variegated cutworm makes them a pest for many crops, clipping seedlings and defoliating larger plants (Heppner *et al.* 2008). Therefore, they still have the ability to cause economic damage on smaller plants and/or when their numbers are high enough.

Data collected this year about black cutworm confirms what was seen in one beet field in 2020, in which a suspected black cutworm larva had been found feeding on the beetroot but no foliar feeding damage was present in the area (Gray and McFarlane 2021). Cutworm damage to belowground crops appears as a “gouged out cavity” (UC IPM 2008). On small plants, low numbers of black cutworm larvae can cause unproportionally high amounts of feeding damage, as they can clip small plants without feeding (Floate 2017). The first sign of black cutworm damage seen during the 2021 season was in Surrey beet fields, where small beet plants were clipped at the base of the stem and large beet plants had belowground feeding damage (Fig. 6ab). A spray recommendation was made for the small beet plants on August 11, 2021. Feeding damage to one potato tuber was seen in-field on August 27, 2021 in Delta (Fig. 7) and a spray recommendation was made due to recently seen damage in the beet fields. Cutworm damage was seen at harvest in another Delta potato field with damage ratings from 1-2 on many tubers (Fig. 8a; CFIA 2015). Unfortunately black cutworm larvae were not seen in time to make a spray recommendation.

In Years 1 and 2, larvae collected were reared into moths to confirm variegated cutworm and bertha armyworm identification (Gray and Yates 2020, Gray and McFarlane 2021). This year, collected larvae and pupae from hotspots of belowground feeding damage were reared and confirmed to be black cutworm (Figs. 6, 7, 8). A goal from the 2021 season was to determine the difference between green larvae present in beet fields, as the larvae of beet armyworm (*Spodoptera exigua*), bertha armyworm, and other species with green larvae appear very similar. All green larvae collected and reared in 2021 were bertha armyworm, and no beet armyworm larvae were seen.

Figure 6. Black cutworm larva collected from a beet field with dark grey to black colouring and greasy appearance (a) and (b). The adult moth was reared and confirmed to be black cutworm by morphological wing patterning, with dark dagger-shaped marking on either forewing (c) – circled.

Figure 7. Black cutworm larva found feeding belowground on an Agata tuber.

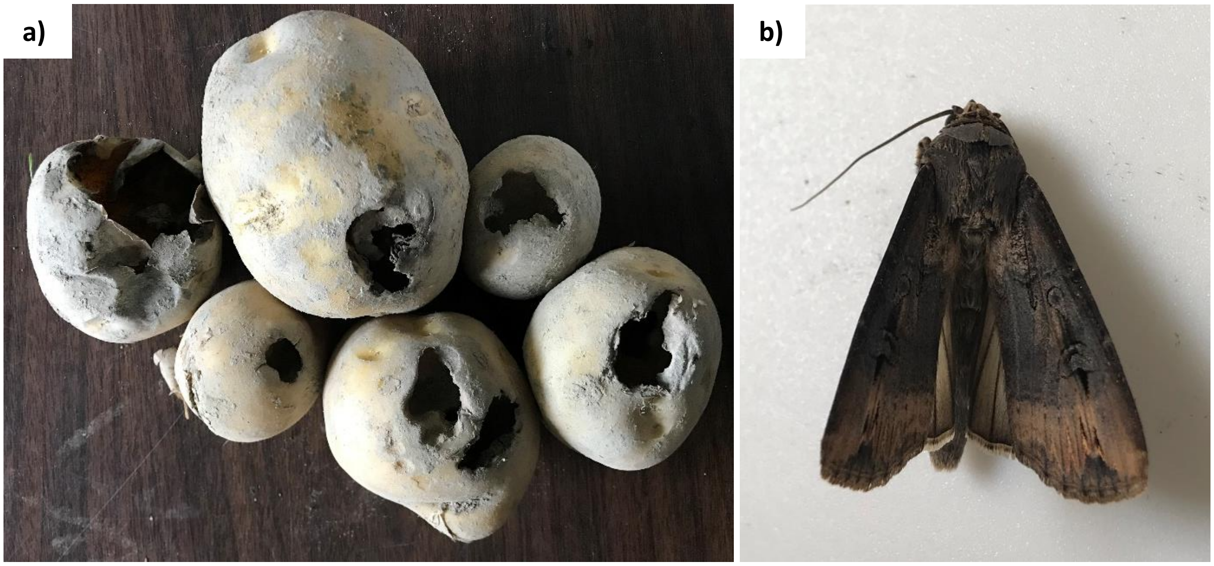

Figure 8. Damaged Agata tubers collected during harvest (a) and one of two black cutworm moths (b) that were reared from pupae collected from the same field and identified morphologically.

The development of many insects, including cutworm and armyworm, are dependent on temperature (Shields *et al.* 1985; Heppner *et al.* 2008). The timing of variegated cutworm larval spray recommendations after peak moth trap catch was four to five weeks in 2019 (Gray and Yates 2020). In 2020, this time period was six to seven weeks between peak moth trap catches and the timing of larvae being observed in the field (Gray and McFarlane 2021). After egg-laying (i.e., peak moth flight of variegated cutworm), larvae at third instar and larger can be seen in the field in three to six weeks at 15°C (Heppner *et al.* 2008). At 25°C, development occurs faster and the first third instar larvae can be found as soon as one to two weeks after egg-laying. Smaller larvae are observationally difficult to find with in-field scouting, as foliar feeding damage is minimal.

The timing of black cutworm spray recommendations in 2021 occurred six to nine weeks after peak moth trap catch. In Surrey, the spray recommendation was made nine weeks after the largest peak in black cutworm moth trap catches, and in Delta, the recommendation was made six weeks after the highest peak. The only spray recommendations made for green cutworms were made in Surrey in 2020, but the larvae were unable to be reared to adults and so it was unclear whether these larvae were bertha armyworm.

Growing degree day models

Variegated cutworm (*Peridroma saucia*)

The growing degree day (GDD) model start date for variegated cutworm is set at May 1, independent of trap catch, and was developed for peppermint by Coop (1987), so it has limitations when looking at variegated cutworm in potatoes and beets. The predicted dates of major developmental milestones are very similar from year to year and between each of the regions, despite very different weather conditions, numbers of moths caught in traps, and regional temperature differences (Table 4). It is difficult to predict the accuracy of the model in 2021 due to lack of larval hotspots in the field and lack of a clear peak in moth flights.

In 2020, the model predicted that the peak overwintering generation occurred on May 29, 2020 in all three regions, which is within the timeframe of the actual moth trapping peak in Surrey and Delta between May 25 to May 31 (Gray and McFarlane 2021). The actual peak moth flight in Sumas was five to 11 days earlier, between May 18 to May 24, 2020. Larvae were present in the field earlier than predicted by the GDD model in 2020. The first spray recommendation for variegated cutworm was made on June 23, 2020 (Table D1; Gray and MacFarlane 2021) while the model predicted peak third instar larvae for all three regions between July 15 to 16 of that year, over three weeks after the first spray recommendation. The 2019 trapping period had highest and most clear moth peaks with many larval hotspots in the field (Gray and Yates 2020). The model predicted peak overwintering generation to be around May 27 to May 28, 2019, which lined up fairly close to the actual moth trapping peak between May 20 to May 26 in Sumas. The actual peak moth flight in Surrey was the following week, from May 27 to June 2, 2021. Delta had a small increase between May 20 to June 2, 2019 but the numbers of moths caught were lower than the other two regions. The predicted peak first instar larvae for all three regions was expected at the end of June from the GDD model, and Sumas larval spray recommendations lined up closest to the prediction, where recommendations were made for small and medium larvae (second to third instar) at the end of June and beginning of July (Table D1; Gray and Yates 2020). The GDD model is most effective on outbreak years, and the effectiveness is decreased during years of lower trap catches.

Table 4. Dates corresponding with variegated cutworm development predicted by the variegated cutworm degree day model (OSU Online Phenology and Degree Day Models) and temperatures from 2019 to 2021 (Environment Canada). DDs stands for number of degree days (in Celsius) following May 1 of calendar year.

Region	**Year**	**Peak overwintering generation (278 DDs)**	**Peak egg laying* (500 DDs)**	**Peak 1st instar larvae (639 DDs)**	**End of moth flight overwintering generation (722 DDs)**	**Peak 3rd instar larvae (806 DDs)**	**Peak 5th instar larvae (1,056 DDs)**
Sumas	2019	May 27	June 16	June 27	July 4	July 10	July 28
	2020	May 29	June 20	July 1	July 9	July 15	July 31
	2021	June 2	June 21	June 28	July 3	July 9	July 26
Surrey	2019	May 28	June 15	June 26	July 3	July 10	July 27
	2020	May 29	June 20	July 2	July 9	July 16	August 1
	2021	June 1	June 21	June 28	July 2	July 8	July 25
Delta	2019	May 28	June 16	June 28	July 5	July 12	July 29
	2020	May 29	June 20	July 2	July 9	July 16	August 2
	2021	June 1	June 21	June 29	July 4	July 10	July 28

* In peppermint

Black cutworm (*Agrotis ipsilon*)

The GDD model for black cutworm predicts major life cycle milestones for the larvae, therefore it is difficult to make conclusions for the 2019 and 2020 trapping periods due to lack of larval presence in the field (Gray and Yates 2020; Gray and McFarlane 2021). During the 2021 growing season, two cutworm spray recommendations were made, both for medium to large sized black cutworm larvae seen in August (Table D1). The model predicted the presence of large larvae in July, several weeks earlier than they were seen in the field (Table 5). However, due to their nocturnal nature and propensity for feeding belowground, it is possible that larvae were present earlier and the damage had not been seen.

Table 5. Dates corresponding with black cutworm development predicted by the black cutworm degree day model (OSU Online Phenology and Degree Day Models) and temperatures from 2019 to 2021 (Environment Canada). DDs stands for number of degree days (in Celsius) following peak captures in pheromone traps each year for each region. The GDD model for black cutworm was not used in 2020, so it is denoted as N/A.

Region	**Year**	**First egg laying (44 DDs)**	**First egg hatch (100 DDs)**	**Small larvae (222 DDs)**	**First 4th instar larvae (278 DDs)**	**Large larvae (389 DDs)**	**First pupae (456 DDs)**	**Last large larvae (556 DDs)**
Sumas	2019	May 28	June 6	June 23	July 1	July 14	July 22	August 1
	2020	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2021	May 28	June 3	June 21	June 25	July 2	July 8	July 17
Surrey	2019	May 22	May 31	June 17	June 25	July 9	July 16	July 27
	2020	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2021	May 29	June 5	June 23	June 27	July 5	July 12	July 23
Delta	2019	June 5	June 13	July 1	July 9	July 22	July 29	August 7
	2020	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2021	June 2	June 14	June 27	July 1	July 12	July 20	July 30

<u>Bertha armyworm (*Mamestra configurata*)</u>

Similar to the GDD model for black cutworm, the bertha armyworm model is more effective at predicting key larval stages rather than moth catches (Bailey 1976). In 2021, no spray recommendations were made for bertha armyworm but two hotspots of bertha armyworm larvae were seen; one in Surrey on June 30 and another in Delta on July 2, 2021. This is supported by the model predicting the fourth instar on June 29 in Surrey, but differs by about two weeks for Delta (Table 6). In 2020, the first fourth instar larvae predicted by the model was July 7 in Sumas and Surrey, and July 22, 2020 in Delta. Based on larval observations in the field, spray recommendations for high numbers of bertha armyworm larvae were made in Sumas on June 30 and in Delta on July 17, 2020 (Gray and McFarlane 2021). The model prediction for larval presence in Sumas and Delta lines up within one week of what was seen in the field. There was a spray recommendation for a hotspot of green larvae in beets made on July 8, 2020 in Surrey but it was unclear whether or not those larvae were bertha armyworm or another species, such as *Spodoptera* spp. (Table D1). Assuming these larvae were bertha armyworm, the spray recommendation made lines up with the GDD model within one day. The 2019 season had low bertha armyworm pressure overall, and only one hotspot of suspected bertha armyworm larvae was identified (Table D1; Gray and Yates 2020). Similarly to what was seen for variegated and black cutworm, the GDD model for bertha armyworm seems to be most effective during outbreak years.

Table 6. Dates corresponding with bertha armyworm development predicted by the bertha armyworm degree day model (OSU Online Phenology and Degree Day Models) and temperatures from 2019 to 2021 (Environment Canada). DDs stands for number of degree days (in Celsius) following first catch in pheromone traps each year for each region.

Region	Year	First egg laying (97 DDs)	First egg hatch (181 DDs)	First 4th instar larvae (311 DDs)	First 5th instar larvae (350 DDs)	First 6th instar larvae (403 DDs)	First pupae (536 DDs)
Sumas	2019	May 26	June 3	June 17	June 21	June 27	July 10
	2020	June 14	June 23	July 7	July 11	July 16	July 26
	2021	June 1	June 11	June 23	June 26	June 28	July 7
Surrey	2019	May 26	June 4	June 16	June 20	June 26	July 9
	2020	June 14	June 23	July 7	July 11	July 16	July 27
	2021	June 15	June 22	June 29	July 2	July 6	July 16
Delta	2019	July 16	July 23	August 2	August 5	August 10	August 21
	2020	July 1	July 10	July 22	July 26	July 29	August 10
	2021	May 18	May 31	June 15	June 19	June 23	July 1

Conclusion and Recommendations

The objectives of this project were to determine the effectiveness of a cutworm outbreak forecasting system within the Fraser Valley using moth trapping as well as larval hotspots within potato and beet fields. Improving the knowledge about damage to belowground crops by cutworm, as well as determining the species of highest risk will allow for effective management decisions. The final objective was to communicate the results with growers in a timely manner in-season and also through the final deliverables.

Cutworm moth trapping networks across a region provides information to make more effective management decisions, but in-field scouting for cutworm larvae is still necessary to determine risks for damage (Floate 2017; Yates *et al.* 2018; Yates 2019; Gray and Yates 2020). Due to the migratory nature of many Noctuids, moth numbers have been seen to fluctuate between each of the growing seasons. In 2019, the Fraser Valley likely saw an outbreak year of variegated cutworm, but belowground damage was not seen in-field and only present in the potato damage demonstration in 2020. Bertha armyworm numbers were highest in 2020, although tuber damage was not seen in-field. Black cutworm appears to have the highest risk for damaging crops belowground, as they readily fed on beets and potatoes in-field. Black cutworm moth numbers were highest in 2021, and the belowground damage and larval presence is reflected by this. These observations highlight the importance of multi-year studies when assessing moth flights for forecasting.

The consistent accuracy of pheromone trapping for variegated cutworm saves time since species in these traps were most likely to be variegated cutworm, reducing the need for manual identification. Black cutworm pheromones show a higher species accuracy during years of increased moth flights, but high numbers are needed to counteract the non-target catches present. Bertha armyworm pheromone trapping is the least effective of the three species studied, as they had the highest percentage of non-target catches and were also seen as non-target catches themselves in the variegated and black cutworm traps. When an outbreak year occurs for any of these species, predictions can be made for the timing of larvae in the field using GDD models, although, these predictions may be more difficult to determine during non-outbreak years.

Identifying larvae to species can be challenging, especially with green larvae such as bertha armyworm because the instars appear different from each other and similar to other green larvae. However, larvae can be reared to moths wherever possible to confirm identification. Variegated cutworm and black cutworm larvae are easily identified in the Fraser Valley, as no other species seen locally so far are similar in appearance.

Future studies should focus on the relationship between moth trapping and larval damage for black cutworm in potato and beet fields, as significant damage was seen in 2021 but the moth numbers were much lower compared to the variegated cutworm outbreak year in 2020. Another route of study could look at developing regional thresholds for this potentially economically damaging species.

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References

Bailey, C.G. 1976. Temperature effects on non-diapause development in *Mamestra configurata*. Canadian Entomologist, **108:** 1319-1326.

(BCMA) British Columbia Ministry of Agriculture. 2017. BC vegetable production guide. Available from https://www2.gov.bc.ca/gov/content/industry/agriservice-bc/production-guides/vegetables

(CABI) Centre for Agriculture and Bioscience International: Invasive Species Compendium – *Agrotis ipsilon*. 2020. Available from https://www.cabi.org/isc/datasheet/3801

(CFIA) Canadian Food Inspection Agency. 2015. Vegetable inspection manual – potatoes. Available from http://www.inspection.gc.ca/food/fresh-fruits-and-vegetables/quality-inspection/vegetable-inspectionmanuals/potatoes/eng/1387374793841/1387374861996?chap=8#s41c8

Coop, L.B. 1987. Management of variegated cutworm in peppermint – PhD thesis, Department of Entomology, Oregon State University, Corvallis, Oregon.

Das, B.B. and Ram, G. 1988. Incidence, damage and carry-over of cutworm (*Agrotis ypsilon*) attacking potato (*Solanum tuberosum*) crop in Bihar. Indian Journal of Agricultural Sciences, **58(8):** 650-651.

Environment Canada. 2021. Historical climate data. Available from http://climate.weather.gc.ca/

Floate, K.D. 2017. Cutworm pests on the Canadian Prairies: Identification and management field guide. Agriculture and Agri-Food Canada, Lethbridge, Alberta.

Gray, M. and McFarlane, J. 2021. Improving cutworm risk forecasting in the Fraser Valley (Year 2). Interim report prepared for the Investment Agriculture Foundation, the Lower Mainland Horticultural Improvement Association, and the BC Potato and Vegetable Growers Association.

Gray, M. and Yates, D. 2020. Improving cutworm risk forecasting in the Fraser Valley (Year 1). Interim report prepared for the Investment Agriculture Foundation, the Lower Mainland Horticultural Improvement Association, and the BC Potato and Vegetable Growers Association.

Heppner, J.B., Capinera, J.L., Ellis, J., Alekseev, A.N., Weintraub, P.G., … Shirk, P.fig. bD. 2008. Variegated cutworm, *Peridroma saucia* (Hübner) (Lepidoptera: Noctuidae). Encyclopedia of Entomology, 4038–4041.

(OMAFRA) Ontario Ministry of Agriculture, Food, and Rural Affairs. 2009. Available from http://www.omafra.gov.on.ca/IPM/english/potatoes/insects/blackworm.html#advanced

(OSU) Oregon State University. n.d. Online phenology and degree day models for agricultural and pest management decision making in the US. Available from http://uspest.org/cgi-bin/ddmodel.us

(PNW Moths) Pacific northwest moths – *Agrotis ipsilon*. n.d. Available from http://www.pnwmoths.biol.wwu.edu/browse/family-noctuidae/subfamily-noctuinae/tribe-noctuini/agrotis/agrotis-ipsilon/

Peterson, M. 2012. Pacific northwest moths – photographic plates. Available from http://pnwmoths.biol.wwu.edu/photographic-plates/

Powell, J.A. and Opler, P.A. 2009. Moths of western North America. University of California Press, Berkeley and Los Angeles, CA.

Shields, E.J., Rouse, D.I., and Wyman, J.A. 1985. Variegated cutworm (Lepidoptera: Noctuidae): Leaf-area consumption, feeding site preference, and economic injury level calculation for potatoes. Journal of Economic Entomology, **78:** 1095-1099.

(UC IPM) University of California Statewide Integrated Pest Management Program. 2008. Agriculture: potato pest management guidelines – Cutworms. Available from http://ipm.ucanr.edu/PMG/r607300511.html

Yates, D. 2019. Cutworm monitoring and forecasting network in the Fraser Valley. Final report prepared for the Investment Agriculture Foundation, the Lower Mainland Horticultural Improvement Association, and the BC Potato and Vegetable Growers Association.

Yates, D., Ma, K., Benn, A., and Dessureault, M. 2018. Evaluation of methods to improve cutworm monitoring in potatoes and table beets in the Fraser Valley. Final Report prepared for the Investment Agriculture Foundation, the Lower Mainland Horticultural Improvement Association, and the BC Potato and Vegetable Growers Association.

Appendix A – Sample of cutworm trapping update

Cutworm Monitoring Project Update:

Observed: Moth trap counts are decreasing for all species monitored (black cutworm, variegated cutworm, and bertha armyworm) in all regions. Low numbers of larvae have been seen in the field and no larval spray recommendations have been made so far.

Recommendation: Continue to scout for cutworm larvae this week. They may be found on the foliage in hotspots of feeding damage or in the top two inches of soil. It is suspected that larvae preferentially feed on foliage, but they have the potential to feed on potato tubers underground. It is recommended to scout for cutworm larvae even if the field is close to top-kill.

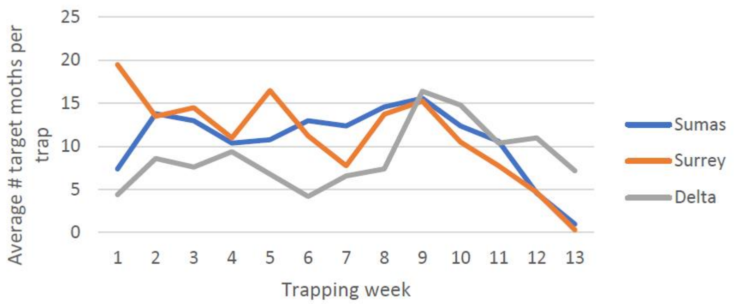

Figure 1. The average number of variegated cutworm target moths caught in traps for each region: Sumas n=5 traps, Surrey n=4 traps, Delta n=5 traps.

You may find cutworms on the foliage early in the morning or on an overcast day

Figure A1. Excerpt from Potato Newsletter July 30, 2021.

Appendix B – Graphs of moth trap counts for all regions and years for each species

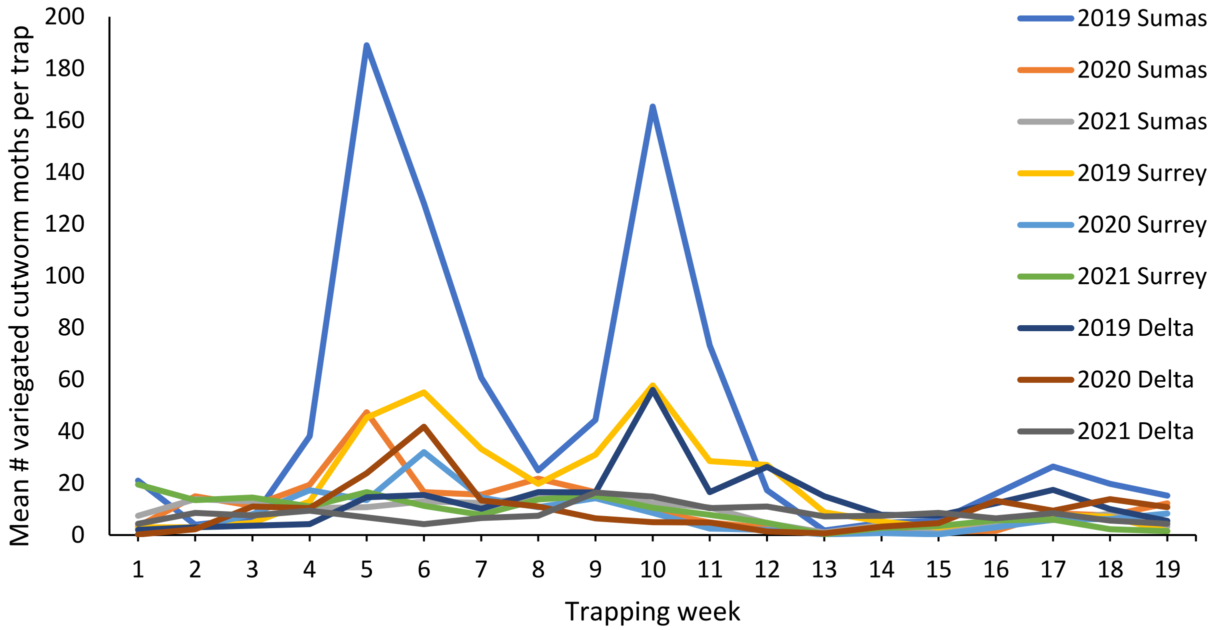

Figure B1. Target moth catches for variegated cutworm pheromone traps at 19 weekly intervals in Sumas, Surrey, and Delta from 2019 to 2021. Trap counts are the mean value of all traps placed in each region: Sumas (n=5), Surrey (n=4), and Delta (n=5). Note that some trapping dates are missing and start and end dates differed from year to year.

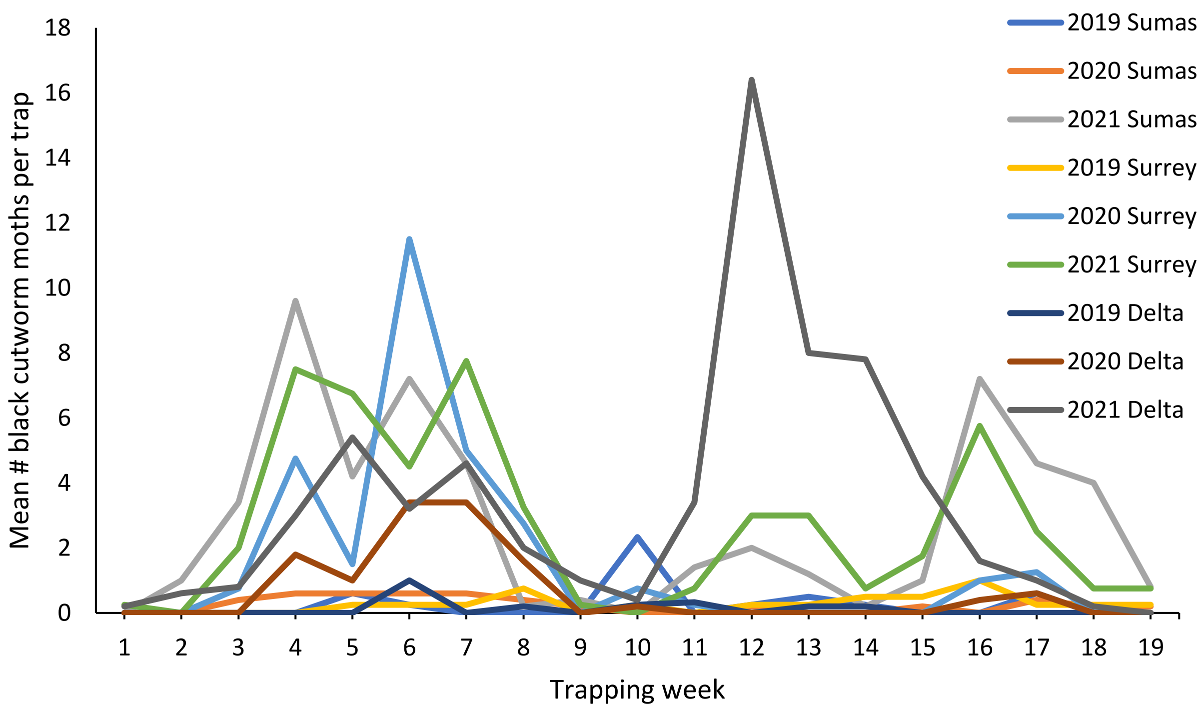

Figure B2. Target moth catches for black cutworm pheromone traps at 19 weekly intervals in Sumas, Surrey, and Delta from 2019 to 2021. Trap counts are the mean value of all traps placed in each region: Sumas (n=5), Surrey (n=4), and Delta (n=5). Note that some trapping dates are missing and start and end dates differed from year to year.

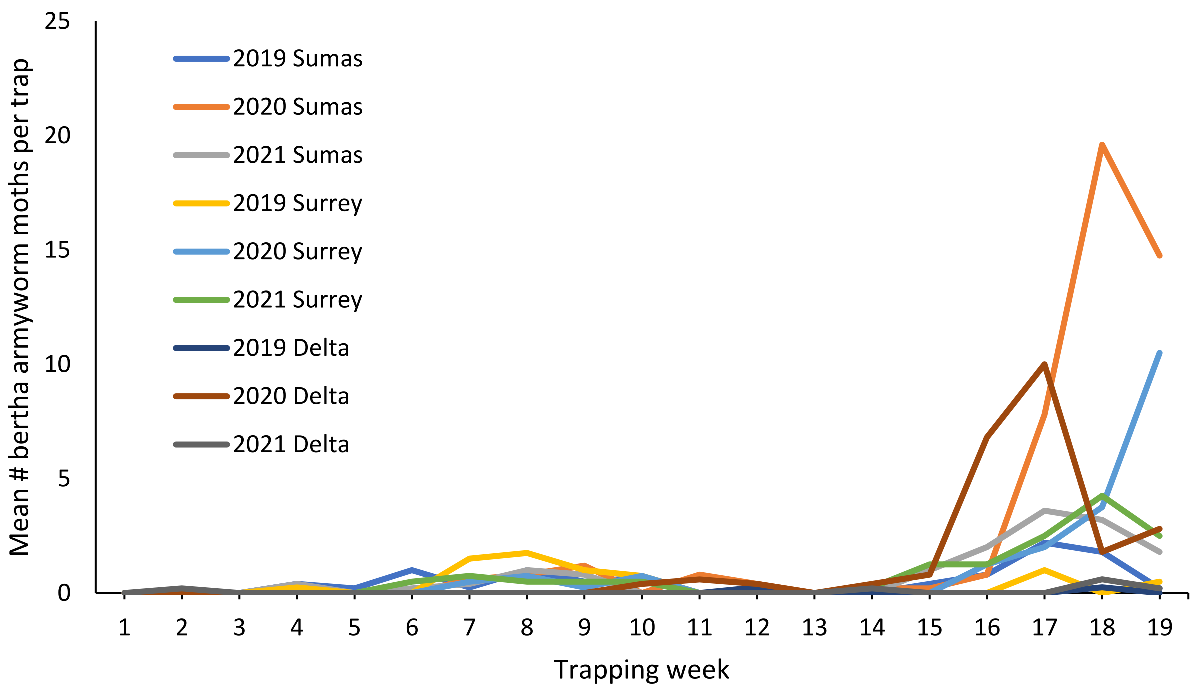

Figure B3. Target moth catches for bertha armyworm pheromone traps at 19 weekly intervals in Sumas, Surrey, and Delta from 2019 to 2021. Trap counts are the mean value of all traps placed in each region: Sumas (n=5), Surrey (n=4), and Delta (n=5). Note that some trapping dates are missing and start and end dates differed from year to year.

Appendix C – Table of variations from standard moth trap numbers for each region

*Table C1. The mean number of target moths caught in traps for each species and region: Sumas n=5, Surrey n=4, and Delta n=5. Minimum and maximum numbers of target moths per trap that week are noted in parentheses. * indicates trapping data missing due to spray out or fallen trap(s) and n=1 for these weeks.*

		Variegated cutworm			Black cutworm			Bertha armyworm		
Week	**Date**	**Sumas**	**Surrey**	**Delta**	**Sumas**	**Surrey**	**Delta**	**Sumas**	**Surrey**	**Delta**
1	April 25- May 1	**7.4** (2-10)	**19.5** (0-42)	**4.4** (3-8)	**0**	**0.25** (0-1)	**0.2** (0-1)	**0**	**0**	**0**
2	May 2- May 8	**13.8** (2-20)	**13.5** (0-29)	**8.6** (4-14)	**1** (0-3)	**0**	**0.6** (0-3)	**0**	**0**	**0.2** (0-1)
3	May 9- May 15	**13** (2-24)	**14.5** (0-26)	**7.6** (4-13)	**3.4** (2-8)	**2** (0-7)	**0.8** (0-2)	**0**	**0**	**0**
4	May 16- May 22	**10.4** (1-25)	**11** (1-17)	**9.4** (6-13)	**9.6** (3-20)	**7.5** (0-27)	**3** (0-8)	**0.4** (0-1)	**0**	**0**
5	May 23- May 29	**10.8** (1-17)	**16.5** (1-27)	**6.8** (4-10)	**4.2** (1-9)	**6.75** (1-17)	**5.4** (0-17)	**0**	**0**	**0**
6	May 30- June 5	**13** (0-18)	**11.25** (0-21)	**4.2** (0-15)	**7.2** (0-19)	**4.5** (0-10)	**3.2** (0-12)	**0.2** (0-1)	**0.5** (0-1)	**0**
7	June 6- June 12	**12.4** (0-25)	**7.75** (0-13)	**6.6** (2-21)	**4.6** (2-9)	**7.75** (0-24)	**4.6** (1-15)	**0.4** (0-1)	**0.75** (0-2)	**0**
8	June 13- June 19	**14.6** (0-34)	**13.75** (0-22)	**7.4** (1-19)	**0.2** (0-1)	**3.25** (0-9)	**2** (1-4)	**1** (0-3)	**0.5** (0-1)	**0**
9	June 20- June 26	**15.6** (0-32)	**15.25** (0-21)	**16.4** (2-40)	**0.4** (0-1)	**0.25** (0-1)	**1** (1-2)	**0.8** (0-1)	**0.5** (0-1)	**0**
10	June 27- July 3	**12.4** (0-22)	**10.5** (2-21)	**14.8** (0-56)	**0**	**0**	**0.4** (0-1)	**0**	**0.5** (0-2)	**0**
11	July 4- July 10	**10.6** (0-23)	**7.75** (0-11)	**10.4** (0-21)	**1.4** (0-3)	**0.75** (0-3)	**3.4** (0-7)	**0**	**0**	**0**
12	July 11- July 17	**4.6** (0-14)	**4.67*** (0-10)	**11** (3-19)	**2** (0-5)	**3*** (0-9)	**16.4** (4-33)	**0**	**0***	**0**
13	July 18- July 24	**1** (0-4)	**0.33*** (0-1)	**7.2** (4-10)	**1.2** (0-3)	**3*** (0-7)	**8** (0-21)	**0**	**0***	**0**
14	July 25- July 31	**3.8** (0-6)	**2.75** (0-6)	**7.4** (2-12)	**0.2** (0-1)	**0.75** (0-3)	**7.8** (0-21)	**0**	**0.25** (0-1)	**0.2** (0-1)
15	August 1- August 7	**2** (0-5)	**3.5** (1-5)	**8.6** (2-18)	**1** (0-3)	**1.75** (0-4)	**4.2** (1-15)	**1** (0-3)	**1.25** (0-3)	**0**
16	August 8- August 14	**3.6** (0-7)	**5.75** (2-12)	**6.4** (1-14)	**7.2** (0-22)	**5.75** (0-17)	**1.6** (0-4)	**2** (0-3)	**1.25** (0-3)	**0**
17	August 15- August 21	**5.8** (0-16)	**6** (0-12)	**8.4** (4-17)	**4.6** (1-13)	**2.5** (0-8)	**1** (0-2)	**3.6** (0-12)	**2.5** (0-5)	**0**
18	August 22- August 28	**8.2** (1-17)	**2.25** (0-7)	**5.6** (0-15)	**4** (2-6)	**0.75** (0-2)	**0.2** (0-1)	**3.2** (1-8)	**4.25** (0-9)	**0.6** (0-2)
19	August 29- September 4	**3.2** (1-5)	**1.5** (0-4)	**4.4** (1-6)	**0.8** (0-2)	**0.75** (0-2)	**0**	**1.8** (1-6)	**2.5** (0-4)	**0.2** (0-1)

Appendix D – Table of cutworm spray recommendations and associated information

Table D1. Potato and beet fields that received cutworm larvae spray recommendations from the 2019-2021 growing seasons (from E.S. Cropconsult Ltd. monitoring data). Larvae species identification is based on visual morphology and rearing collected larvae into adults to compare to known species. Numbers of larvae seen throughout the field varied from five to 78 larvae present across all hotspots. Tuber or root damage is underlined.

Year	Region	Crop	Plant stage	Date of spray recommendation	Distance to closest trapping site (km)	Larval morphology	Field notes
2019	Sumas	Potatoes	Unknown	June 25	0.8	Unknown	Two patches of foliar damage throughout North side of field.
2019	Sumas	Potatoes	Unknown	June 25	0	Unknown	Several patches of low damage throughout field but higher damage on North side.
2019	Sumas	Potatoes	Unknown	June 25	1.3	Unknown	One patch of low foliar damage in South side near East row ends.
2019	Sumas	Potatoes	Unknown	July 9	0.5	Unknown	One patch of low foliar damage in South variety near West row ends.
2019	Sumas	Potatoes	Unknown	July 16	0.6	Unknown	Low to high foliar damage throughout field.
2019	Sumas	Potatoes	Unknown	July 16	0.5	Unknown	Several patches of low foliar damage throughout North side.
2019	Sumas	Potatoes	Unknown	July 23	1	Unknown	Several patches of low to moderate foliar damage throughout field.
2019	Sumas	Potatoes	Unknown	July 30	1.7	Unknown	Low to high foliar damage throughout field, one out of ten tubers with underground damage.
2019	Surrey	Potatoes	Unknown	June 19	0.3	Unknown	One patch of moderate foliar damage on North side near West row ends.
2019	Surrey	Beets	Unknown	June 26	0	Suspect bertha armyworm or beet armyworm	Moderate foliar damage throughout, higher feeding damage in South half of field.
2019	Surrey	Potatoes	Unknown	July 3	0	Unknown	Few patches of low to high foliar damage throughout South side.
2019	Surrey	Potatoes	Unknown	July 3	0.3	Unknown	Several patches of moderate to high feeding damage throughout South side.
2019	Delta	Potatoes	Unknown	July 8	0	Unknown	One patch of moderate foliar damage on East row ends of North variety.
2019	Delta	Potatoes	Unknown	July 11	1	Unknown	One patch of low foliar damage in West variety near North side.

Year	Region	Crop	Plant stage	Date of spray recommendation	Distance to closest trapping site (km)	Larval morphology	Field notes
2019	Delta	Potatoes	Unknown	July 11	3	Unknown	One patch of moderate to high foliar damage on West side of headland.
2019	Delta	Potatoes	Unknown	July 18	1.9	Unknown	One patch of low foliar damage on South edge.
2019	Delta	Potatoes	Unknown	July 19	1	Unknown	Two patches of moderate foliar damage on South side in middle of field and one patch of moderate damage near West row ends.
2019	Delta	Potatoes	Unknown	July 22	0.8	Unknown	One patch of low to moderate foliar damage on North side of field by East row ends.
2019	Delta	Potatoes	Unknown	July 22	2.7	Unknown	One patch of low to moderate foliar damage on East side near North row ends.
2019	Delta	Potatoes	Unknown	July 22	1.1	Unknown	One patch of low feeding damage in Southwest section.
2019	Delta	Potatoes	Unknown	July 24	1.5	Unknown	Several patches of low to moderate foliar damage throughout, with patches of high foliar damage present in the Yukon Gold variety.
2019	Delta	Potatoes	Unknown	July 25	1	Unknown	Several patches of moderate to high feeding damage.
2019	Delta	Potatoes	Unknown	August 1	1.8	Unknown	Patches of moderate to high foliar damage throughout East side of field, damaged fruits but no underground damage. Expected higher larvae numbers (high frass).
2019	Delta	Potatoes	Unknown	August 5	0.5	Unknown	Few patches of low foliar damage throughout Northwest section of field.
2019	Delta	Potatoes	Unknown	August 26	3.8	Suspect bertha armyworm	Few patches of moderate foliar damage on Northeast side.
2019	Delta	Potatoes	Unknown	September 6	N/A - traps removed	Unknown	Few patches of high foliar damage in mid to North half of field on East side. Present in Imola variety.
2020	Sumas	Potatoes	III	June 23	1	Variegated cutworm	Several patches of larvae with low foliar feeding damage on the west side.
2020	Sumas	Potatoes	V	June 30	1.2	Bertha armyworm	Several patches of larvae with low foliar feeding damage on the east side.

Year	Region	Crop	Plant stage	Date of spray recommendation	Distance to closest trapping site (km)	Larval morphology	Field notes
2020	Sumas	Potatoes	V	June 30	1.2	Variegated cutworm and bertha armyworm	Many patches of larvae with low to moderate foliar feeding damage throughout field, but especially on the north side.
2020	Sumas	Potatoes	IV	July 7	1	Variegated cutworm	Several patches of low to moderate foliar feeding damage on the south side.
2020	Sumas	Potatoes	V	July 14	0.5	Unknown	Many patches of low to moderate foliar feeding damage throughout field.
2020	Surrey	Beets	8-10 leaf	August 26	0.5	Suspect bertha armyworm	Many patches of low to moderate foliar feeding damage throughout field.
2020	Surrey	Beets	6-8 leaf	July 8	0	Suspect beet armyworm or bertha armyworm	Few patches of low foliar feeding damage throughout field.
2020	Delta	Potatoes	IV-V	July 9	2.3	Variegated cutworm	Few patches of low to moderate foliar feeding damage on northeast side.
2020	Delta	Potatoes	IV-V	July 17	3.9	Variegated cutworm and suspected bertha armyworm	Many patches of low to moderate foliar feeding damage throughout field.
2021	Surrey	Beets	4-6 leaf	August 11	0.5	Black cutworm	Significant damage throughout field; small beet plants clipped at the base and foliar damage to leaves.
2021	Delta	Potatoes	V	August 27	3	Black cutworm and bertha armyworm	One tuber damaged with black cutworm present belowground. Damage rating 1 (CFIA 2015) Bertha armyworm present only on foliage.

Plant stage for beets is determined by the number of leaves present on the foliage, and so the number of leaves generally increases relative to the size of the beetroot. Tuber initiation of potatoes starts at growth stage III, tubers begin to bulk at IV, and foliage senesces at V as the tuber skin sets.