FINAL PROJECT REPORT
Canola Agronomic Research Program (CARP)

Project Title: Detection, Identification and control strategies for management of cutworms (Noctuidae) on the prairie provinces

Research Team Information

Lead Researchers:		
Name	***Institution***	***Expertise Added***
Kevin Floate	Agriculture and Agri-Food Canada (Lethbridge, AB)	project coordinator, biocontrol of pest insects, graduate student supervisor
Research Team Members		
Name	***Institution***	***Expertise Added***
Jeremy Hummel	Lethbridge College (Lethbridge, AB)	Insect monitoring and pest management - southern AB
Jim Broatch	Alberta Agriculture and Rural Development (Lacombe, AB)	Insect monitoring and pest management - central AB
Jennifer Otani	Agriculture and Agri-Food Canada (Beaverlodge, AB)	Insect monitoring and pest management - northern AB
Maya Evenden	University of Alberta (Edmonton, AB)	pheromone traps for cutworm surveys; cutworm feeding behaviour, graduate student supervisor
Martin Erlandson	Agriculture and Agri-Food Canada (Saskatoon, SK)	molecular tools for rapid species identification of cutworm larvae
Rob Laird	University of Lethbridge, Lethbridge, AB	insect-plant interactions, insect biology, graduate student supervisor

Other individuals who contributed to this project include provincial entomologists Scott Meers and Shelley Barkley (Alberta Agriculture and Rural Development, Brooks AB), Scott Hartley (Saskatchewan Ministry of Agriculture, Regina, SK) and John Gavloski (Manitoba Agriculture, Food & Rural Initiatives, Carmen, MB). They were instrumental in the collection of cutworm samples and in spreading word of this project at numerous events that are not included in the list of tech-transfer events in Section 3. Dr. Bob Byers (Emeritus Research Scientist, AAFC, Lethbridge) helped collect adult moths and provided valuable guidance on the rearing of larvae. Gary Anweiler (retired) provided training on the identification of adult moths. Charley Bird (retired) and Patty Reid (Agriculture and Agri-Food Canada, Lacombe, AB) provided critical research support to Broatch. Chaminda Weeradana (PhD) and Ronald Battalas (MSc) are graduate students being supervised by Evenden. Vincent Hervet (PhD) is a graduate student being co-supervised by Floate and Laird. Other students and staff that assisted with field collections and rearing include Mark Cutts, Lorne Howey, Kayleigh Loberg, Shelby Dufton, Amanda Jorgensen, Jadin Chahade, Kaitlin Freeman, Graham Fonseca, Sara Stagg, Arlan Benn, Miko Micovic, Paul Coghlin and Holly Spence. We gratefully acknowledge the contributions of numerous

agronomists and producers.

Project Start Date: **April 1, 2012** **Project Completion Date:** **December 31, 2016**

Reporting Period: **April 1, 2012** **to** **December 31, 2016**

CARP Project Number: 2012.1

1. Forecasted Date of Completion:

December 31, 2015 (original); December 31, 2016 (revised)

2. Status of Activity: (please check one)

_____ Ahead of Schedule _____ On Schedule _____Behind Schedule __X___ Completed

Comment:

3. Completed actions, deliverables and results; any major issues or variance between planned and actual activities.

Executive Summary

Four main objectives were identified in the original proposal. All four objectives were met as follows:

Objective 1 (DNA multiplex – PCR): A multiplex PCR protocol was developed that permits rapid and accurate identification of key cutworm pest species. Results are reported in a peer-reviewed manuscript that is currently '*in press*' in a scientific journal. Publication of the manuscript releases information on the protocol into the public domain, which will allow for its commercialization by service labs.

Objective 2 (Natural enemies):

a) *Cotesia vanessae* is a European species of wasp parasitic on cutworms. During the current project, this wasp was discovered for the first time in North America. This finding has been published in a scientific journal.

b) *Cotesia vanessae* was tested for its ability to develop on different species of Lepidoptera. Results identified 33 new host species, including many of the key cutworm pest species affecting crops in Canada. This finding identifies the potential for *C. vanessae* to be distributed to regions where it does not already occur, to increase parasitism of cutworms and delay/reduce the severity of future outbreaks. A scientific paper is being prepared that reports on these findings.

c) Thirty-nine species of cutworms and other moths were reared on an artificial diet. This finding identifies the diet as an inexpensive and practical method to maintain diverse species of Lepidoptera in laboratory culture. Use of the diet will accelerate research on lepidopteran pest species. Results have been published in a scientific journal.

d) Collections of cutworm larvae were made in 2012, 2013 and 2014 in north, central and southern Alberta. Parasitoids reared from these larvae included at least three species of flies and at least 13 species of wasps. Parasitism averaged about 20% during the three years, but occasionally was much high depending upon year and site of collection. These results confirm the importance of parasitoids as natural mortality factors helping to reduce the severity and duration of cutworm outbreaks.

Objective 3 (Cutworm biology): Experiments were performed during the period 2012-2015 to develop tools and information for application to improve monitoring and control of cutworm species. Pheromone traps were shown to be more effective that food bait traps to monitor adult cutworm populations. Use of fertilizer was associated with increased oviposition by bertha armyworm on canola. In tests on true armyworm, spring wheat was found to be less suitable for development than winter wheat, feed barley or malt barley. Use of fertilizer increased larval developmental time and weight. Larval weight of pale western cutworm was greatest when reared on wheat, and then canola and peas. Redbacked cutworm larvae developed more rapidly and attained greater pupal weights when reared on canola than on wheat. Larval development of redbacked and pale western cutworms was greatest when reared on fertilized versus non-fertilized plants (canola, wheat). For a clubroot resistant variety of canola, oviposition by bertha armyworm was greater on infected plants. For a clubroot susceptible variety of canola, oviposition by bertha armyworm was greater on uninfected plants.

Objective 4 (Technology Transfer): Information arising from this project has been presented in at least 19 field tours, 66 meetings and workshops, and 19 interviews (radio, magazines, newspapers). Results have been published in two book chapters, four peer-reviewed scientific papers, and in a series of weekly web documents disseminated by the Prairie Pest Monitoring Network. Other scientific papers are being prepared for publication. A book targeting farmers and producer groups reporting on the identification and control of 21 cutworm pest species has been completed and is currently being formatted. It will be available for electronic distribution before the 2017 growing season. Samples of live cutworms and of parasitic wasps emerging from cutworms were provided for use at several CanoLAB and FarmTech workshops in recent years. Time-lapse videos of parasitoids emerging from cutworms were produced and made available for use at producer workshops

Funding provided research support for two MSc students, two PhD students and about 20 undergraduate students. The expertise gained by these individuals will benefit the canola industry in future years.

Full details

Objective 1 (DNA multiplex – PCR): This objective resulted in a molecular identification 'kit' that allows for rapid and accurate identification of key cutworm pest species.

Accurate and rapid methods of identification are required to maximize control methods during cutworm outbreaks. Some species of cutworm feed below ground, which negates the use of contact insecticides. Other species are nocturnal foliage feeders, such that contact insecticides are best applied in the evening. Identifying the species of cutworm by visual examination can be difficult, even for the experts. Molecular methods allow for accurate species identification of the cutworm, whether it is an egg, larva, pupa, or moth.

Each cutworm species has unique genetic markers. Associating these markers with a species name is a 4-step process: i) DNA is extracted from the cutworm, ii) the extracted DNA is amplified to isolate the genetic marker, iii) the genetic marker is sequenced, and iv) the sequence is compared with a library of sequences to identify the cutworm species. The genetic marker is normally sent to a commercial facility for sequencing, such that this 4-step process may take a week or more to obtain a species identification. During this time, the crop continues to be damaged by cutworm feeding.

To accelerate species identification, a multiplex PCR molecular tool was developed to detect and identify five key cutworm species. These species are the redbacked cutworm (*Euxoa ochrogaster*), army cutworm (*Euxoa auxiliaris*), pale western cutworm (*Agrotis orthogonia*), dingy cutworm (*Feltia jaculifera*), and bristly cutworm (*Lacinipolia renigera*). These species were selected after discussions with provincial entomologists, and based on their prevalence in previous cutworm outbreak cycles in the historical record.

The multiplex PCR method does not use sequencing to identify species, but instead uses the length of the

genetic marker. This eliminates Steps iii and iv to provide species identification in one or two days. The method uses of a universal moth forward primer that targets the rRNA internal transcribed region 2 (ITS2) and species-specific reverse primers within the ITS2. These primers generate genetic markers of different lengths. Preliminary results determined that the genetic marker for redbacked cutworm was comparable in length to that for a common non-pest cutworm species, the divergent dart (*Euxoa divergens*). The genetic markers for dingy cutworm and pale western cutworm also were of comparable length. Thus, the method was modified such that two genetic markers are amplified for the divergent dart and the pale western cutworm, whereas one genetic marker is amplified for the other species. The length of these genetic markers is: dingy (540 bp), pale western (560 + 160 bp), redbacked (439 bp), divergent dart (440 + 143 bp), bristly (353 bp), and army (250 bp) cutworms. When the DNA is amplified is Step ii, differences in length and number of genetic markers is used to identify the unknown sample (Fig. 1). A sample may contain a species of cutworm that is not one of the five for which the multiplex PCR has been designed. In such cases, no genetic marker is amplified.

The method was validated by comparing the number and length of genetic markers obtained from cutworms of known species against those obtained from a large number of cutworms collected in fields near Lethbridge, Lacombe and Peace River, Alberta. Results confirm the accuracy of the method, with only a low level of error. In samples collected near Lethbridge and Lacombe, army cutworms were the dominant species followed by redbacked cutworm. Near Peace River, the species complex on forage crops (red clover) was much more diverse. In canola, the redbacked cutworm was the dominant species although sample sizes were limited. The diversity of cutworm species in the Peace River collections was confirmed by CO1 bar code sequencing (Steps iii and iv).

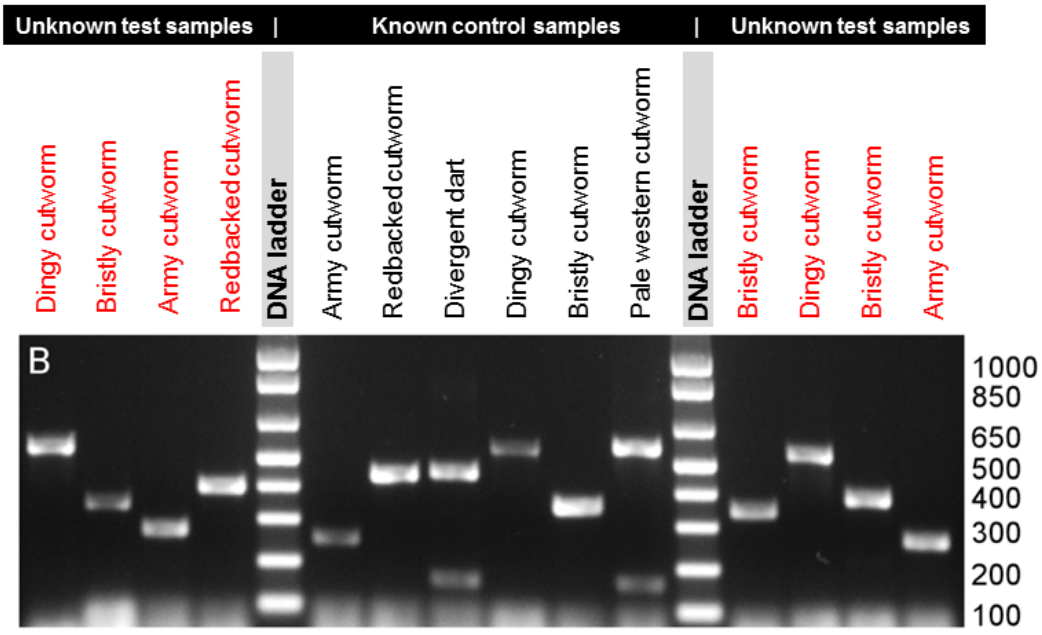

Figure 1. Known control samples show the number and size of genetic markers associated with six species of cutworms (black font). The identity of unknown test samples (red font) is determined by comparing the number and length of genetic markers with those of the known control samples. DNA ladders contain DNA that forms genetic markers of known length. They are used to 'measure' the length of the genetic markers obtained from the cutworm samples.

Objective 2 (Natural enemies):

a) In Year 1 of the project, a colony of a parasitic wasp identified as *Cotesia plathypenae* (Hymenoptera: Braconidae) was obtained from a colleague in Ontario. They had established the colony with parasitoids reared from cabbage loopers, which were collected in greenhouses in southern Ontario. This colony is

maintained at the Lethbridge Research and Development Centre (LRDC). A combination of morphological and reproductive characters led us to question the identification of this wasp. We subsequently did DNA barcoding that confirmed that the wasp was *Cotesia vanessae*, a European species of wasp not previously reported in North America. This finding, a detailed description of the wasp, and details of its reproductive biology were published in a scientific journal (Hervet *et al.* 2014).

b) European populations of *C. vanessae* may contain males and females, or only females. The colony at LRCD only contains females. In addition, *C. vanessae* reproduces continuously with a new generation about every five weeks. In contrast, other species of parasitoids only have one generation per year. Further, more than 100 *C. vanessae* may emerge from one host caterpillar, whereas other species of parasitoids may produce only one parasitoid per host. Because of its ease of lab-rearing and high reproductive capacity, we assessed *C. vanessae* as a potential biocontrol agent of cutworms affecting crops in Canada.

We exposed an average of 24 (range of 2 to 35) caterpillars for each of 45 different lepidopteran species (29 pest, 16 non-pest) to parasitism by *C. vanessae* (Table 1). The identity of these species was confirmed using DNA barcoding. Caterpillars were obtained from commercial insectaries, collected in the field, or reared from eggs laid by adult moths recovered in light traps. After parasitism was observed, the caterpillars were reared on an artificial diet and observed for the emergence of parasitoids, or until the caterpillars had died or had completed development. Data was recorded for the percentage of exposed caterpillars that produced parasitoids, and the number and average weight of the parasitoids that emerged from these caterpillars. Female weight provides an indirect measure of the number of eggs that she can potentially lay. Data also was recorded for the number of days required for development of wasp larval and pupal stages.

Results identified 33 new host species for this parasitoid and show that it can develop in many of the key cutworm pest species affecting crops in Canada. For example, *C. vanessae* emerged from 100% of the redbacked cutworm larva exposed to parasitism. High levels of parasitism also were observed for army cutworm, clover cutworm, dingy cutworm, early cutworm, glass cutworm, and darksided cutworm. Intermediate levels of parasitism (7 to 52%) were observed for nine species, with no parasitism observed for a further 12 species. For some non-host species (e.g., fall armyworm), parasitism prevented caterpillars from digesting food, killing both the caterpillar and the parasitoids developing within. Other non-host species completed development, due to the ability of their immune system to encapsulate and kill parasitoid eggs. Future research could be undertaken to study the immune responses of caterpillars to determine why some parasitoids, but not others, can develop in a given species of pest cutworm. A scientific paper is being prepared that reports on these findings.

Although more species need to be tested for confirmation, these results allow for some general conclusions. Species of Plusiinae (loopers) are good hosts for *C. vanessae*. Most of the exposed caterpillars will produce parasitoids and, relative to other species of caterpillars, these parasitoids will be greater in number and weight, and develop more quickly. Species of *Abagrotis*, *Apamea* and *Euxoa* also are good hosts for *C. vanessae*. Species of *Agrotis* support development of this parasitoid, but are not good hosts; i.e., parasitism is low. Species of *Lacinipolia* and *Spodoptera* do not support development of *C. vanessae*.

These findings suggest that *C. vanessae* potentially could be distributed to regions of the prairies where it does not already occur, to increase levels of cutworm mortality. However, consideration is needed with regards to the risks that redistribution might pose to non-pest species of Lepidoptera. Future research could be undertaken to determine the current distribution of *C. vanessae* in Canada to identify regions for potential introduction.

Species host of *Cotesia vanessae*		Status	Parasitism	Number tested
Scientific name	Common name			
Anarta trifolii	clover cutworm	pest	100%	32
Apamea sordens	Rustic shoulder-knot	pest	100%	2
Chrysodeixis includens	soybean looper	pest	100%	34
Euxoa ochrogaster	redbacked cutworm	pest	100%	29
Euxoa tristicula	early cutworm	pest	100%	13
Heliothis virescens	tobacco budworm	pest	100%	15
Spaelotis clandestina	w-marked cutworm	pest	100%	2
Trichoplusia ni	cabbage looper	pest	100%	27
Anagrapha falcifera	celery looper	pest	97%	35
Anaplectoides prasina	green arches moth	not a pest	97 %	32
Abagrotis baueri	-	pest	96%	24
Cryptocala acadiensis	catocaline dart	not a pest	96%	27
Euxoa auxiliaris	army cutworm	pest	96%	26
Noctua pronuba	winter cutworm	pest	96%	28
Feltia jaculifera	dingy cutworm	pest	92%	26
Caradrina morpheus	mottled rustic	not a pest	90%	31
Actebia balanitis	-	not a pest	88%	24
Apamea lignicolora	wood-coloured quaker	not a pest	88%	25
Euxoa messoria	darksided cutworm	pest	87%	30
Euxoa satis	-	not a pest	87%	30
Autographa californica	alfalfa looper	pest	86%	29
Apamea devastator	glassy cutworm	pest	83%	6
Abagrotis reedi	-	pest	82%	22
Aglais milberti	Milbert's tortoiseshell	not a pest	72%	25
Agrotis vancouverensis	Vancouver dart	not a pest	52%	23
Eurois occulta	great brocade	pest	35%	23
Agrotis ipsilon	black cutworm	pest	27%	15
Mythinma unipuncta	true armyworm	pest	22%	28
Dargida diffusa	wheat head armyworm	pest	20%	15
Feltia herilis	master's dart	pest	17%	30
Mamestra configurata	Bertha armyworm	pest	9%	22
Helicoverpa zea	corn earworm	pest	8%	39
Lacanobia grandis	grand arches moth	not a pest	7%	28
Anticarsia gemmatalis	velvetbean caterpillar	pest	0%	39
Habrosine scripta	scribe moth	not a pest	0%	27
Hyles euphorbiae	spurge hawk-moth	not a pest	0%	12
Lacinipolia renigera	bristly cutworm	pest	0%	22
Lacinipolia sareta	-	not a pest	0%	31
Pieris rapae	introduced cabbage white	pest	0%	12
Sideridis rosea	rosewing moth	not a pest	0%	26
Spilosoma virginica	yellow woolly bear	not a pest	0%	30
Spodoptera eridania	southern armyworm	pest	0%	19
Spodoptera exigua	beet armyworm	pest	0%	27
Trichordestra lilacina	aster cutworm	not a pest	0%	19
Xestia c-nigrum	spotted cutworm	pest	0%	17

Table 1. Species of Lepidoptera exposed to parasitism by *Cotesia vanessae*.

We also completed studies to examine the effect of host quality on *C. vanessae*. We reared cabbage looper (a good host) on an artificial diet with different levels of protein. Some of these loopers were exposed to parasitism, whereas others were allowed to complete development to assess the effect of diet quality. Loopers were unable to complete development of low quality diet, had delayed development on diet of intermediate quality, and were able to quickly complete development on high quality diet. We found that this relationship extended to parasitoids; i.e., the number and weight of *C. vanessae* was greatest on loopers reared on a high

quality diet. Thus, although the species of caterpillar is the key factor determining its suitability as a host for C. vanessae, the diet of the host also can play a role. A scientific paper is being prepared that reports on these findings.

c) During the course of studies on *C. vanessae*, we reared 39 species of cutworms and other moths on an artificial diet (McMorran diet). This doubles the number of insects previously reported to be reared on the diet. The diet is inexpensive, easily prepared, and can be stored in dry form until needed. To increase awareness of the diet, we published our findings in a scientific paper that lists the 39 species of Lepidoptera from our study, plus additional insect species that have reportedly been reared on McMorran diet. Identifying this diet as an inexpensive and practical method to maintain diverse species of Lepidoptera in laboratory culture accelerates experimental studies on lepidopteran pest species.

d) To obtain information on species' biology and parasitoids, field collections of cutworm larvae were made in 2012, 1013 and 2014. Collections were made mainly by research team members, provincial entomologists and industry cooperators, and primarily were from north, central and southern Alberta with additional collections from Saskatchewan. Larvae were held indoors and reared on McMorran diet until either parasitoids (flies, wasps) emerged, the cutworms died, or the cutworms completed development to adult moths. When wasps emerged, the wasps and the cutworm were sent to Dr. Barb Sharanowski (University of Manitoba) for identification. When a fly emerged, the fly and cutworm were barcoded in Lethbridge. Cutworms that were not parasitized were barcoded in Saskatoon.

Field collections (2012):

- In northern Alberta, a collaborator sent ~50 cutworms from a garden near Manning; but only four surveyed shipment. Two calls were received from agronomists reporting cutworm outbreaks, but producers sprayed the fields almost immediately such that no larvae were recovered. Of 14 specimens held for rearing, 50% died, 36% pupated, and 21% were parasitized.
- In central Alberta, 88 larvae were received of which 13 were crane fly larvae (Diptera: Tipulidae). Confusing crane fly larvae for cutworms is an easy mistake (Fig. 2) and may result in unnecessary insecticide applications. However, cutworms have legs whereas crane fly larvae do not. Getting this type of information out to producers is part of the rationale for the book publication reported under Objective 4. Of the 65 cutworm larvae held for rearing, 46% developed into adult moths, 37% were parasitized, and the remainder either died or pupated without further development. Adult moths were mainly the non-pest species *Euxoa campestris* and *Lacinipolia olivacea*. Lesser numbers of dusky cutworm and redbacked cutworm were recovered.

Figure 2. Mistaking cutworm larvae (left) for crane fly larvae (right) is common.

- in southern Alberta and Saskatchewan, respectively, 225 and 32 cutworm larvae were recovered and held for rearing. Of these, 47% developed into adult moths, 20% were parasitized and the remainder either died or pupated without further development. Adult moths were mainly redbacked cutworm (from across southern Alberta), glassy cutworm (Lethbridge area) and bristly cutworm (mostly from Saskatchewan). Collections from all regions identify parasitoids as major cutworm mortality factors.

Field collections (2013):

- In northern Alberta, 233 cutworms from 10 fields were collected and reared. These were mainly black army cutworm, dingy cutworm, redbacked cutworm, glassy cutworm and yellow headed cutworm. Parasitoids

emerged from about 25% of individuals.

- In central Alberta, 246 cutworms were collected and held for rearing. The most common species was the army cutworm, which confirmed an observed fall flight in 2012 of army cutworm adults and their successful overwintering in fall-seeded cereals. Redbacked cutworm was the next most common species. Of the cutworms collected, 29 died as pupae, 18 emerged as adults but did not completely emerge/eclose (full wings), and 38 larvae died before pupation. A further 78 cutworms (11 species) developed into adults with fully expanded wings. The parasitoids that emerged from the remaining cutworms included tachinid flies (9 cases), ichneumonid wasps, braconid wasps, and encyrtid wasps.
- In southern Alberta, 405 cutworms from 15 fields were collected and reared. About half of these were from an outbreak of army cutworm near and east of Lethbridge. The remaining individuals included red-backed cutworm, pale western cutworm, glassy cutworm, and two other unidentified species. Immature and adult parasitoids emerged from 22% (90) of individuals. Of the 81 cutworms producing adult parasitoids, 46 cutworms produced the parasitic wasp *Copidosoma* sp. Other species of parasitoids included wasps in Families Ichneumonidae and Braconidae, plus flies in Family Tachinidae.

Field collections (2014):

- In northern Alberta, 284 cutworms from 10 fields were collected and reared. In descending order of abundance, species were identified as dingy, redbacked, bristly, glassy and pale western cutworms. Parasitism averaged 9% versus 24% (*n* = 185) in 2013. In both years, cutworm parasitism was higher in forage seed fields than in canola.
- In central Alberta, 166 cutworms were collected from different crops; i.e., canola (56), faba bean (20), horticultural (73), winter wheat (10) and oats (7). Of these samples, 49% emerged as adults, 22% were parasitized, and 29% failed to develop. Emerged moths were identified as redbacked, army, bristly and dusky cutworms, plus the non-pest cutworm, the clear dart (*Spaelotis clandestine*).
- In southern Alberta, 198 cutworms from collected from different crops; i.e., canola (130), wheat (28), peas (14), sugar beets (6), horticultural (5) and other (15). About 20% emerged as adults, 64% were parasitized, and 16% failed to develop. In descending order of abundance, samples were identified as redbacked, dingy, pale western, army and glassy cutworms.

Combined across the three years, parasitism averaged about 20%, but occasionally was much higher depending upon the year and field of collection. Species of flies that were recovered as parasitoids were identified as *Tachina algens, Euexorista rebaptizata* and *Linnaemya tessellata*. Species of wasps that were recovered as parasitoids are listed in Table 2 (see next page). *Copidosoma bakeri* was the most common parasitoid recovered and previously has been reported to be among the main parasitoids affecting cutworms on the Prairies. These results confirm the importance of parasitoids as natural mortality factors helping to reduce the severity and duration of cutworm outbreaks.

Other natural enemies of cutworms that were not considered in the current project include pathogenic fungus, viruses, nematodes and predaceous insects. The photograph to the right shows a species of ground beetle feeding on a cutworm larva. Ground beetles are among the most important cutworm predators in agro-ecosystems, with about 400 species on the Canadian Prairies and upwards of 80 species present in any field.

Table 2. Species of hymenopteran parasitoids reared from cutworms collected in Alberta. Identifications by U. Wanigasekara and B. Sharanowski (University of Manitoba).

Scientific name	Host species	Adult emergence time	Biological Remarks
Encyrtidae			
Copidosoma bakeri	redbacked cutworm, darksided cutworm, army cutworm, dingy cutworm	June to July	Polyembryonic[1]
Copidosoma cuproviridis	Army cutworm	mid-June	Polyembryonic
Braconidae			
Cotesia spp.	army cutworm	May to June	Gregarious[2]
Meteorus sp. 1		July	Gregarious
Meteorus sp. 2		June	Gregarious
Parotapanteles neomexicanus			Gregarious
Ichneumonidae			
Diphyus euxoae	army cutworm	early June to mid-July	Solitary[3]
Ichneumon sp. 1	army cutworm	early June	Solitary
Spilichneumon superba	army cutworm	early June to early July	Solitary
Ichneumon sp. 2 *Campoplex* sp. 1	army cutworm	early July June	Solitary Solitary
Exetastes syriacus		early August	Solitary
Erigorgus sp.	army cutworm		Solitary

[1] one egg produces many parasitoids; [2] many eggs laid in one host; [3] one egg laid per host

Objective 3 (Cutworm biology): Experiments were performed during the period 2012-2015 to develop tools and information to improve monitoring of cutworm species and their control using agronomic methods.

In 2012, three experiments were performed to examine the use of pheromone traps and food bait traps to monitor species of cutworms in different regions of the province. Eleven sites (2 near Lethbridge, 7 in central Alberta, 2 in the Peace River region) were monitored at 1-2 week intervals from June to September.

- Experiment 1 compared the attractiveness of two types of traps to bertha armyworm (*Mamestra configurata*), dusky cutworm, pale western cutworm and red-backed cutworm. The first type of trap was baited with sex pheromones specific for the target species. The second type of trap used food bait (glacial acetic acid and 3-methyl-1-butanol) attractive to adult cutworms. In contrast to pheromone traps, food bait traps attract both male and female moths, and are more likely to attract moths from short distances (at the field scale) rather than from long distances.

  Far fewer moths were captured in food bait versus pheromone traps. Redbacked cutworm was most common in samples combined across regions. The species most common in different regions were: pale western cutworm (Lethbridge), bertha armyworm (central AB, esp. nr. Wainwright), and redbacked cutworm (Peace River region, central AB). Traps baited with pheromone for redbacked cutworm captured large numbers early in the season of the noctuid moth *Plusia putnami* (Putnam's Looper Moth).

- Experiment 2 tested four different pheromone blends as attractants for adult male dingy cutworm and compared the attractiveness of different pheromones to food bait traps. The same 11 trap sites were used as for Experiment 1. Each pheromone blend targeted a different 'pheromone race' of dingy cutworm, for which four (Race A to D) have been reported by previous researchers. Recoveries of dingy cutworm were

highest in Lethbridge and in the Peace River region. There also was a geographic variation in response to the pheromones tested; e.g., Race C pheromone more commonly attracted species of *Agrotis* cutworms. (A replication of this experiment in 2013 confirmed this finding.)

- Experiment 3 tested to the response of true armyworm (*Pseudaletia unipuncta*) to food bait traps using laboratory wind tunnel studies. Male and female moths were flown in the wind tunnel with food bait traps (glacial acetic acid and 3-methyl-1-butanol) and with unbaited control traps. More moths were captured in baited versus control traps, with no difference in the response of males and females. Starved moths were more attracted than were moths previously fed on sugar water.

In 2013, experiments were performed on redbacked cutworm, bertha armyworm, and true armyworm.

- Redbacked cutworm: Larvae of red-backed cutworm were monitored in seven fields in central Alberta planted to canola in 2012 and wheat in 2013. Larvae were monitored using Modified Missouri Cutworm Traps (MMCT) placed at different distances from the field edge and baited with seedlings of different species; i.e., canola, wheat, barley, no seedlings (control). Low recovery of larvae, possibly due to predation by ground beetles, did not allow for any conclusions.

  Adults were monitored in fields of canola, wheat and barley at each of seven sites using Green Uni traps (1.5 m above ground). One set of traps baited with sex pheromone lures recovered large numbers of males. Results identified the start of male activity on the third week of July, with peak flight from late-August to Mid-September. There was no difference in the number of red-backed cutworm males captured among crop types. A second set of traps was baited with a feeding attractant (i.e., 10 ml of (50:50 mixture) glacial plus acetic acid and 3-methyl-1-butanol. Only five redbacked cutworm moths were recovered. Other pest cutworm species were infrequently captured, and included dingy cutworm, bertha armyworm, true armyworm, glassy cutworm, and army cutworm. Recovered non-pest cutworm species included the smoked sallow moth (*Enargia infumata*), olive green cutworm (*Dargida procinctus*), gray swordgrass moth (*Xylena cineritia*), american ear moth (*Amphipoea americana*), *Apamea* spp. and *Leucania* spp. Preliminary results indicated that both sexes were equally attracted to the feeding lures.

  To test the effect of host plant on larval survival, newly-hatched larvae were fed on canola, wheat, barley or on an artificial diet. Plants and diet were replaced upon depletion or desiccation. Individuals reared on canola seedlings and artificial diet developed to adults; all individuals reared on barley and wheat died as larvae. [In a subsequent experiment in 2014, redbacked cutworm did develop on wheat, but had more rapid growth and greater pupal weights when reared on canola.]

- Bertha armyworm: The effect of canola variety and insecticide treatment was assessed on larvae. Treatments comprised two canola varieties (6060RR, 5535CL) with and without insecticide seed treatments; an untreated Q2 variety was used as a control. When fed plants aged 5 and 6 wks, treatment did not affect weight gain, plant damage or plant biomass. When the experiment was repeated using plants aged 2½ wks, insecticide treatments reduced plant damage. The difference between the two experiments may reflect a higher concentration of insecticides in younger plants.

  The effect of canola variety (Clearfield hybrid 5535 CL, Roundup Ready hybrid 6060RR, Q2) and fertilizer regime (20-20-20; 0, 1.0, 3.0, 5.0 g/L) was assessed on ovipositing females. For the Roundup Ready and Clearfield varieties, females laid more eggs on plants grown with increasingly higher levels of fertilizer. The Q2 variety had an increased number of eggs with fertilizer treatment only until the 3 g/L treatment after which egg number decreased.

  The effect of adult nutrition was assessed for adult female fecundity. Individual pairs of moths were provided with one of five diets; i.e., 10% (w/v) in distilled water of glucose, fructose, sucrose or honey, or 100% distilled water (control). No effect of diet on total number of eggs laid by females was detected.

- True armyworm: Larvae were reared on spring wheat (CDC go), winter wheat (Buteo), feed barley (Xena) or malt barley (Copeland) grown under identical conditions. Results indicated that spring wheat was least

suitable for larval development. In a related experiment, mated pairs of adults were introduced into cages with the two wheat and two barley varieties. Data collected one week later did not detect a difference in the number of eggs laid on the four varieties.

Larval growth was measured on spring wheat (CDC go) and feed barley (Xena) grown with no, half, or the full rate of recommended nutrients. Fertilized plants (half, full) had greater dry mass than unfertilized plants for both wheat and barley. Based on changes in head capsule width, larvae generally developed faster on fertilized versus unfertilized plants (wheat, barley). Time to pupation was significantly faster for armyworm larvae reared on fertilized versus unfertilized barley. Pupation time was unaffected by use of fertilizer on wheat plants. Larvae were significantly heavier when reared on fertilized versus unfertilized plants (wheat, barley). Larvae reared on fertilized versus non-fertilized barley tended to form heavier pupae, but the difference was not significant. Too few larvae pupated on wheat for statistical analyses.

In 2014 and 2015, lab experiments were performed to test the effect of host plant species and plant nutrition on the larval performance on pale western cutworm. Results of this study, in combination with those previously obtained for redbacked cutworm, establish a hierarchical host preference for both species to develop management strategies using crop rotation.

- The larval performance of pale western cutworm was evaluated on canola, peas, spring wheat, and on an artificial diet. Seedlings were grown for 21 days, watered every other day and received no fertilizer application. The experiment was conducted in a growth chamber under controlled conditions (21°C; photoperiod 16h light: 8h darkness; 80% RH). Newly-hatched larvae were reared on artificial diet until they became third-instar larvae. Individual third-instar larvae were placed in a petri dish (140 mm diam. × 25 mm height) with randomly assigned seedlings or artificial diet (32 larvae per treatment) and held until pupation. Seedlings and artificial diet were replaced upon depletion or desiccation. Data was recorded for head capsule width and weight at each instar stage, total and per instar development time, and pupal weight.

  Host species did not affect head capsule width for any instar stage. For larval weight, weight gains were greatest for individuals reared on artificial diet, followed by wheat, and then canola and peas. Larvae reared on artificial diet (48.3 ± 1.3 d) and wheat (50.1 ± 1.2 d) developed more quickly than larvae reared on canola (66.8 ± 3.8 d) and peas (57.8 ± 4.3 d). The weight of pupae also was affected by host species and diet (Fig. 3). Overall, development of pale western cutworm was greater on wheat than on canola or peas.

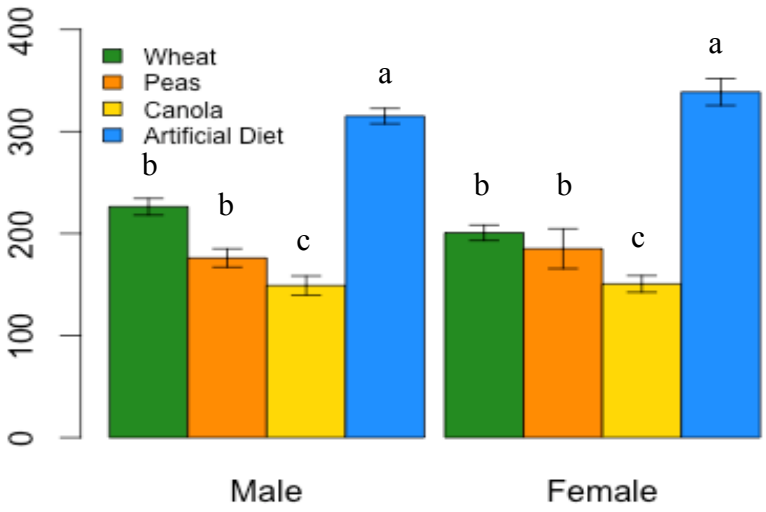

Figure 3. Pupal weight of male and female pale western cutworm reared on different diets. Bars marked with different letters are significantly different within sex.

- Laboratory studies were performed to evaluate the larval performance of redbacked and pale western cutworms reared on canola and spring wheat grown with (20-20-20, 1 g/L every seven days) and without applications of fertilizer. Seedlings were grown for 21 days, watered every other day. The experiment was conducted in a growth chamber under controlled conditions (21°C; photoperiod 16h light: 8h darkness; 80% RH). Newly-hatched larvae were reared on artificial diet until they became third-instar larvae. Individual third-instar larvae were placed in a petri dish (140 mm diam. × 25 mm height) with randomly assigned seedlings or artificial diet (32 larvae per treatment) and held until pupation. Seedlings and artificial diet were replaced upon depletion or desiccation. Data was recorded for head capsule width and weight at each instar stage, total and per instar development time, pupal weight, and adult longevity.

  Development of both cutworm species was quicker on fertilized versus non-fertilized plants regardless of the host species. For non-fertilized plants, redbacked cutworm had a shorter development time and greater pupal weight on canola versus wheat. Conversely, pale western cutworm had a shorter development time and greater pupal weight on wheat versus canola (Fig. 4).

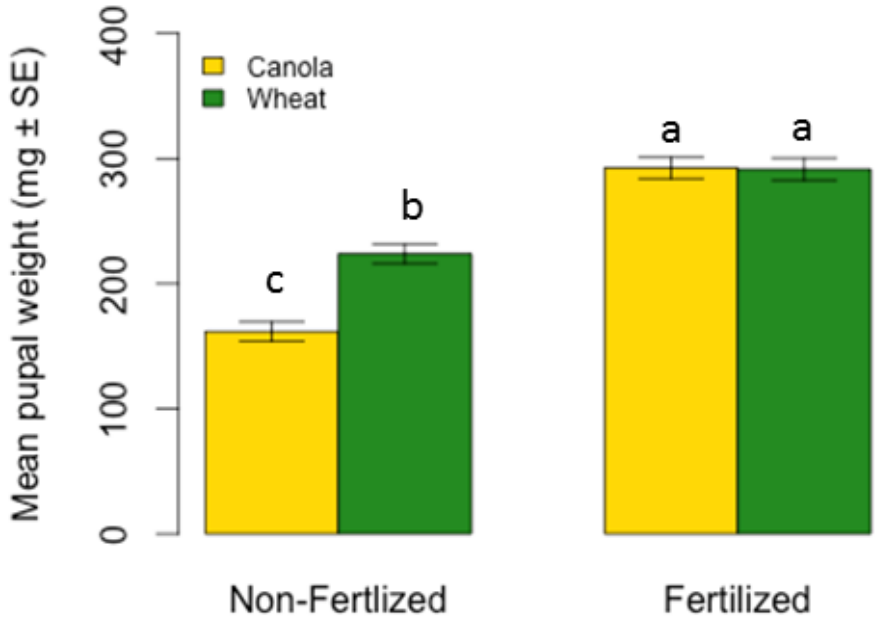

Figure 4. Pupal weight (mg) of pale western cutworm by host species and fertilizer treatment. Bars marked with different letters are significantly different.

- Laboratory studies were performed to examine the effect of clubroot disease (*Plasmodiophora brassicae*) on oviposition preference by Bertha armyworm. Both pathogen and insect are major pests of canola, such that knowledge of interactions (if any) may help to properly manage both threats. Clubroot resistant cultivars of canola currently are being used to manage the disease.

  A no-choice experiment was performed using four treatments. The treatments included infected and uninfected plants of a resistant cultivar (Pioneer 45H29), and infected and uninfected plants of a susceptible cultivar (Pioneer 45H26). Three pairs of moths were allowed to lay eggs for four consecutive days. Data were recorded for plant height, total number of leaves, fresh weight, dry weight, severity disease index (SDX), and the number of eggs laid. Preliminary results show that moths laid more eggs on infected,

clubroot-resistant plants than on healthy, clubroot-resistant canola (Fig. 5). Moths laid fewer eggs on infected, clubroot-susceptible plants than on uninfected, clubroot-susceptible plants.

Using the same treatments in a choice experiment, moths laid more eggs on healthy plants than on infected, clubroot-susceptible plants. In this same experiment, moths showed no oviposition preference for healthy or infected clubroot-resistant plants.

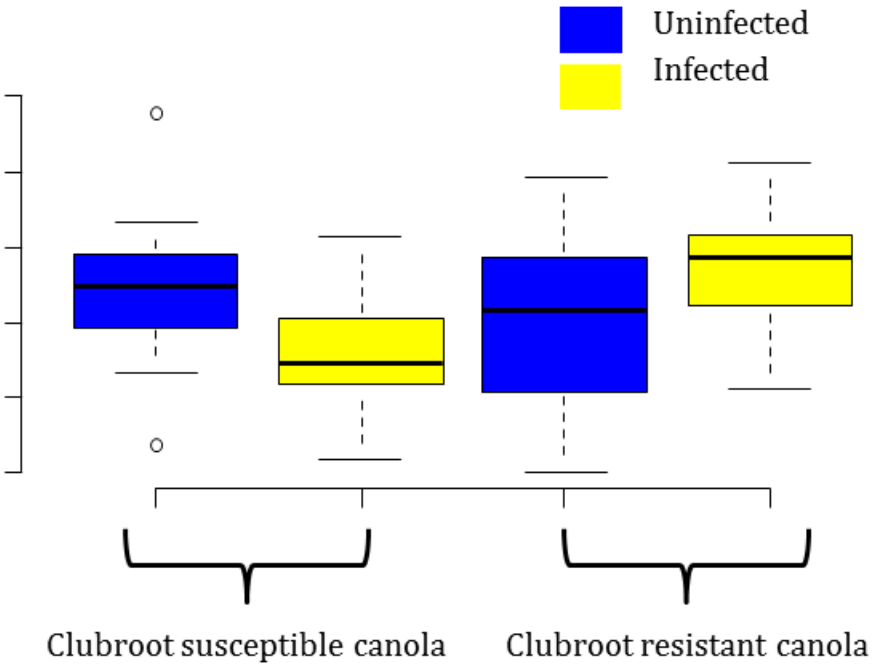

Figure 5. Mean number of eggs laid by female Bertha armyworm in a non-choice experiment. Canola variety*clubroot infection status $P < 0.01$

Objective 4 (Technology Transfer): This objective ensured that information arising from the project was disseminated in a timely manner to farmers, agronomists, provincial entomologists and other interested parties.

Field tours:

Batallas, R. and M.L. Evenden. 2013. Control of redbacked cutworm (Lepidoptera: Noctuidae): Development of a life cycle model and assessment of feeding behaviour. CanolaLab, St. Albert, AB, February 20-22.

Broatch, J., P. Reid. 2014. Olds College Summer IPM training for Fruit and Vegetable producers July 27-28

Hervet, V. 2013. Farming Smarter field school workshop on beneficial insects in canola. Crop Diversification Centre South, Brooks, AB, August 1. Invited speaker (~ 45 participants).

Hervet, V. 2014. Canola Galla field workshop for producers (20 minute talk), Brooks AB, August 1

Hervet, V. 2014. Canola Galla field workshop for producers (20 minute talk), Lethbridge AB, July 31

Hervet, V. 2014. Farming Smarter Crop Walk (15 minute talk), Lethbridge AB. August 7

Hummel, J. 2013. What's bugging you and your crops? Presentation at Nobleford-area McRae Holdings producers meeting and BBQ. Monarch, Alberta, June 30. Invited speaker.

Hummel, J. 2013. You got worms? Farming Smarter field school workshop on cutworm and wireworm identification, damage, and monitoring. Lethbridge, Alberta, June 25-27. Invited speaker.

Hummel, J.D. 2014. Cutworm update. Farming Smarter Crop Walk, Lethbridge, AB. June 12

Otani, J. 2012. Pest update. Peace Region Forage Seed Association Annual Field Tour, Fort St. John BC, July 4, 2012.

Otani, J. 2013. Crop Walk #1. Smoky Applied Research and Demonstration Association Crop Walk, May 28, 2013, at Falher AB (~25 participants).

Otani, J. 2013. Insect pest update and BC Peace monitoring. BC Grain Producers Association Annual Field Tour, July 16, 2013, at Dawson Creek BC (~100 participants).

Otani, J. 2013. Insect pest update for Peace River region. All Crops Tour, July 4, 2013, at Beaverlodge Research Farm (~150 participants).

Otani, J. 2014. IPM Program research update for canola-related projects. Alberta Canola Producers Commission Director and Staff Tour of AAFC-Beaverlodge Research, Beaverloge AB, July 15, 2014. (Organized by J. Otani and G. Semach; 11 ACPC Directors, 5 ACPC Staff, 1 CCC agronomist, CCC's VP Research).

Otani, J. 2014. IPM research and pest update. Richardson Pioneer Field Tour of AAFC-Beaverlodge Research, Beaverlodge AB, July 8, 2014. (Organized by J. Otani and G. Semach; ~60 regional outlet staff, ~5 in-house agronomists).

Otani, J. 2015. "Insects and monitoring in agricultural field crops.", 2015 Provincial ASB Tour, Beaverlodge, AB, July 15-16, ~130 people + ~120 people from across the province including elected officials and employees from each County or Municipal District of Alberta + their respective family members. Coordinator for site.

Otani, J. 2015. "Insect update and ongoing research.", Peace Region Forage Seed Association's Annual Field Tour, Beaverlodge, AB, July 7 (~45 attendees including ~25 growers).

Weeraddana, C.D.S. and M.L. Evenden. 2013. Oviposition behaviour of bertha armyworm, *Mamestra configurata*. CanolaLab, St. Albert, AB, Feb. 20-22.

Yoder, C., R. Azooz, and J. Otani. 2012. Forage Seed Program Update. Peace Region Forage Seed Association Annual Field Tour, Beaverlodge AB, July 19, 2012.

Presentations:

Batallas, R. and M.L. Evenden, 2014. Effects of host species on larval development and fitness of the redbacked cutworm (*Euxoa ochrogaster*) (Lepidoptera: Noctuidae). 62nd Annual Meeting of the Entomological Society of Alberta, Lethbridge AB, October 17-18

Batallas, R. and M.L. Evenden. 2013. Activity and abundance of redbacked cutworm, *Euxoa ochrogaster* (Lepidoptera: Noctuidae), on multiple crops in Central Alberta. Entomological Society of Alberta, Olds, AB, October 11.

Batallas, R. and M.L. Evenden. 2015. Influence of host plant species and plant nutrition of larval development of cutworms (Lepidoptera: Noctuidae). Entomological Society of America, Minneapolis, MN, November 15-18.

Batallas, R., J. Kwon, J. Rossato, C. Weeraddana and M. Evenden. 2014. Cutworms: Effects of crop management on larval development and adult flight monitoring on multiple crops. PPMN, Saskatoon, SK, March 2014.

Batallas, R., J. Rossato, C. Weeraddana, J. Kwon and M. Evenden. 2014. Cutworms: adult flight monitoring on multiple crops and effects of crop management on larval development. Prairie Pest Monitoring Network Meeting, Saskatoon, SK, March 25.

Broatch, J. S. 2014. Alberta Farm Fresh School, Olds, Alberta. On-Farm Pest Monitoring in Alberta. February 27, 2014.

Broatch, J., M. Erlandsen, M. Evenden, K. Floate, V. Hervet and J. Otani. Each author presenting individual research updates at a cutworm workshop co-organized by J. Otani and K. Floate, Joint Annual Meeting of the Entomological Society of Canada and the Entomological Society of Alberta, Edmonton, AB, November 4, 2012. [6 presentations]

Broatch, J., P. Reid. 2014. Olds College IPM workshop for Fruit and Berry School, February.

De Silva Weeraddana, C., M.L. Evenden, S. Strelkov, and V. Manolii. 2015. The effect of clubroot disease infection on oviposition preference of bertha armyworm, *Mamestra configurata* Walker (Lepidoptera: Noctuidae). Entomological Society of America, Minneapolis, MN, November 15-18.

Dufton, S., A. Benn, M. Erlandson, K. Floate, J. Otani. 2014. 2014 CARP cutworm rearing project summary: Peace River region. Alberta Canola Producers Commission's Regional Meetings, Rycroft, Alberta, November 26, 2014 (~60 attendees).

Dufton, S., A. Benn, M. Erlandson, K. Floate, J. Otani. 2014. 2014 CARP cutworm rearing project summary: Peace River region. Alberta Canola Producers Commission's Regional Meetings, Falher, Alberta, November 27, 2014 (~45 attendees).

Erlandson, M. 2012. Research update presented at the Saskatchewan Insect Advisory Council Meeting in Saskatoon, SK., November 21, 2012. [written report]

Erlandson, M. 2014. Developing molecular markers as tools for species identification and population genetics assessment of noctuid pest species on the Canadian prairies. Prairie Pest Monitoring Network Meeting, Saskatoon, SK, March 25.

Erlandson, M. 2015. CARP Cutworm and BAW genomics project updates. Prairie Pest Monitoring Network, Saskatoon, SK. March 24.

Erlandson, M.A., Floate, K.D., and Otani, J. 2015. DNA markers help identify cutworm species. AAFC's Weekly Science Story – April 1, 2015.

Erlandson, M., M. Evenden, K. Floate and J. Otani. 2013. Each author presenting individual research updates at the Prairie Pest Monitoring Network meeting, Saskatoon, SK, March 19, 2013. [4 presentations]

Evenden et al. 2013. Two posters reporting on research at the University of Alberta (Objectives 2 and 3) were presented at CanoLAB, St. Albert, AB, February 20-22, 2013.

Evenden, M.L. 2013. CARP/ACIDF-funded cutworm project-Evenden lab. Prairie Pest Monitoring Network, Saskatoon, SK, March 19-20.

Evenden, M.L. 2013. Challenges monitoring lepidopterous pests of canola on the Canadian Prairie Provinces. Entomological Society of America, Austin, TX, November 10-13.

Evenden, M.L., J.J. Kwon, J. Rossato, and BA Mori. 2014. Effect of crop cultivar and fertilization regime on preference and performance of the true armyworm, *Mythimna unipuncta* Haworth (Lepidoptera: Noctuidae). Joint Annual Meeting of Entomological Societies of Canada and Saskatchewan, Saskatoon SK, September 28-October 1.

Evenden, M.L., R. Batallas, C. Weeraddana, J. Rossato. 2015. Cutworm-crop interactions. Prairie Pest Monitoring Network, Saskatoon, SK. March 24.

Floate, K., J. Broatch, M. Erlandson, M. Evenden, J. Gavloski, S. Hartley, J. Hummel, R. Laird, S. Meers, C. Olivier, J. Otani, Jennifer and B. Sharanowski. 2012. New projects for control of cutworms (Lepidoptera: Noctuidae) affecting canola crops on the prairies. Joint Annual Meeting of the Entomological Society of Canada and the Entomological Society of Alberta, Edmonton, AB, November 4-7, 2012. [poster presentation]

Floate, K.D. 2013. Alberta Agriculture Insect Program Advisory Committee Meeting, Calgary, AB, November 13.

Floate, K.D. 2015. Update on CARP Cutworm project. Prairie Pest Monitoring Network, Saskatoon, SK. March 24.

Hervet V.A.D., Laird R., Floate K. 2014. Effect of diet protein concentration on the development of caterpillars (Noctuidae) and their parasitoids (Braconidae). Joint Annual Meeting of the Entomological Societies of Canada and Saskatchewan, Saskatoon SK, September 28 – October 1.

Hervet V.A.D., Laird R., Floate K. 2014. Study of the host range of a hymenopteran parasitoid found in the Nearctic but endemic to the Palearctic. Canadian Society for Ecology and Evolution meeting, Montreal QC, May 25-29.

Hervet V.A.D., Laird R., Floate K. 2014. Tri-trophic influence of nitrogen on the development of a parasitoid wasp. 62nd Annual Meeting of the Entomological Society of Alberta, Lethbridge AB, October 17-18.

Hervet, V.A.D. 2013. Presentation on parasitoids of loopers and cutworms given to 50 Grade 8 students in French immersion, Lethbridge Research Centre, Lethbridge, AB, March 28, 2013.

Hervet, V.A.D. 2013. Six presentations, each with 60 attendees (ca. 350 persons total) on topics of cutworm identification, types of crop damage, scouting techniques and the natural enemies of cutworms with an emphasis on parasitic wasps. Presentations included live displays of cutworms of different species (larvae, pupae, adults), adult parasitoids of cutworms, and parasitoid larvae emerging from cutworms; CanoLAB workshop, St. Albert, AB February 20-22, 2013.

Hervet, V.A.D. 2013. Two posters reporting on 1) natural enemies of cutworms in North America, and 2) taxonomic and host-range investigations of the cutworm parasitoid, *Cotesia vanessae*. CanoLAB workshop, St. Albert, AB February 20-22, 2013.

Hervet, V.A.D. 2014. 2014 CanoLab event, Olds, AB, February 19-21 (co-presenter of a 50-minute talk on natural enemies of cutworms; given 12 times during the 2-day event).

Hervet, V.A.D. 2014. FarmTech conference, Edmonton AB, January 28-29 (presenter of a 60-minute talk on natural enemies of cutworms; given each day of the conference).

Hervet, V.A.D. 2014. Update on cutworm and parasitoids presented at the Annual Meeting of the Prairie Pest Monitoring Network, Saskatoon, SK, March 25.

Hervet, V.A.D., K.D. Floate and R. Laird. 2013. Assessment of a hymenopteran parasitoid's potential as biocontrol agent of cutworms. 61st Annual meeting of the Entomological Society of Alberta, Olds College, Olds, AB, October 11.

Hervet, V.A.D., K.D. Floate and R. Laird. 2013. Assessment of the potential for the parasitic wasp, *Cotesia vanessae* (Braconidae), as a biological control agent of cutworms (Lepidoptera: Noctuidae). Annual Meeting of the Western Committee on Crop Pests, Winnipeg, MB, October 8.

Hervet, V.A.D., K.D. Floate and R. Laird. 2013. *Cotesia vanessae* (Hymenoptera: Braconidae): a potential biological control agent of crop pest caterpillars. Annual meeting of the Canadian Society for Ecology and Evolution. University of British Columbia, Kelowna, BC, May 12-16.

Hervet, V.A.D., K.D. Floate and R. Laird. 2014. Research update on parasitoids attacking cutworms. Prairie Pest Monitoring Network Meeting, Saskatoon, SK, March 25.

Hervet, V.A.D, R.A. Laird, and K.D. Floate. 2012. *Cotesia 'vanessae'* (Hymenoptera: Braconidae): a potential biological control agent of cutworms (Lepidoptera: Noctuidae). Joint Annual Meeting of the Entomological Society of Canada and the Entomological Society of Alberta, Edmonton, AB, November 4-7, 2012. [poster presentation]

Hervet, V.A.D., R.A. Laird and K.D. Floate. 2015. Multitrophic interactions influencing parasitism success and larval development of the parasitoid wasp *Cotesia vanessae*. Joint Annual Meeting of the Entomological Societies of Canada

and Quebec. Montreal, QC, November 7-11.

Hervet, V.A.D., R.A. Laird and K.D. Floate. 2015. Evaluation of the fitness of a parasitoid wasp on a range of caterpillar hosts. 4th Annual Biology Graduate Research Symposium University of Lethbridge, Lethbridge, AB, January 30.

Hervet, V.A.D. and J. Gavloski. 2012. Natural enemies of army cutworm, redbacked cutworm and darksided cutworm (Lepidoptera: Noctuidae) in North America. Joint Annual Meeting of the Entomological Society of Canada and the Entomological Society of Alberta, Edmonton, AB, November 4-7, 2012. [poster presentation]

Hervet, V.A.D., R.A. Laird and K.D. Floate. 2016. Ecology of a hymenopteran parasitoid, *Cotesia vanessae* (Braconidae). XXV International Congress of Entomology. Orlando, FL, September 25-30. [oral presentation]

Holowachuk J, Sieminska E, Otani J, Erlandson MA. 2014. Development of DNA marker technology for identification of common cutworm species in the cutworm complex attacking canola in western Canada. Joint Annual Meeting of Entomological Societies of Canada and Saskatchewan, Saskatoon SK, September 28-October 1.

Hummel, J. 2013. Beneficial insects. Rosemary Ag Society 3rd Annual Spring Meeting, Rosemary, AB, March 25, 2013.

Hummel, J. 2013. Beneficial insects: Obscure superheroes? FarmTech 2013, Edmonton, AB, January 29-31, 2013. Online version at http://farmtechconference.com/wp-content/uploads/2013/02/Jeremy-Hummel-FarmTech2013.pdf

Hummel, J. 2013. Cutworms, wireworms, and their management. Agronomy Update and Conference 2013, Lethbridge, AB, January 15-16, 2013.

Hummel, J. and V. Hervet. 2012. "Farming Smarter" workshop organized by the Southern Alberta Research Association. Cutworm research update, identification and control of pest species. Lethbridge, Alberta, June 7, 2012. Invited speakers.

Hummel, J. and V. Hervet. 2012. Display on cutworms featured at part of 'Insect Discovery Day' at the Coaldale Bird of Prey Centre. Highlighted on Global News Lethbridge (August 13) and in the Lethbridge Herald (August 26). Coaldale, AB, August 25, 2012.

Hummel, J.D., J. Otani, J. Broatch, P. Reid, M. Erlandson, A. Benn, K. Loberg, S. Dufton, K. Floate. 2014. Cutworm outbreaks in Alberta. Joint Annual Meeting of Entomological Societies of Canada and Saskatchewan, Saskatoon SK, September 28-October 1.

Hummel, J.D., J. Otani, J. Broatch, P. Reid, M. Erlandson, A. Benn, K. Loberg, S. Dufton and K.D. Floate. 2014. Where the cutworms are: Three years of cutworm reports and collections in Alberta. 62nd Annual meeting of the Entomological Society of Alberta, Lethbridge, AB, October 16-18.

Hummel, J.D., J.S. Broatch, J. Otani. 2014. *Apamea*, *Euxoa*, *Nephelodes*…huh? Centre of Applied Arts and Sciences Annual Meeting, Lethbridge College, 27 August. Lethbridge, AB.

Otani J. 2014. Wheat midge and 2013-14 pest monitoring updates. Ag-Service Board Meeting, March 5, 2014, Bonanza AB (~25 people).

Otani, J. 2012. An 2012 insect update for the Peace River region. Alberta Canola Producers Commission's Regional Meetings, LaCrete, AB, November 21, 2012. Invited speaker.

Otani, J. 2012. An 2012 insect update for the Peace River region. Alberta Canola Producers Commission's Regional Meetings, Falher, AB, November 28, 2012. Invited speaker.

Otani, J. 2012. An 2012 insect update for the Peace River region. Alberta Canola Producers Commission's Regional Meetings, Sexsmith, AB, November 29, 2012. Invited speaker.

Otani, J. 2013. IPM Program and Activities. BC Climate Change Action Initiative workshops (#3), Taylor, BC, February 6, 2013. Invited speaker.

Otani, J. 2013. IPM Program and pest update for 2013. BC Grain Producers Association AGM, Dawson Creek, BC, February 12, 2013.

Otani, J. 2013. Pests and predators – avoiding friendly fire. Peace Pest Update, MD of Smoky River Producer Meeting, Falher, AB, March 28, 2013.

Otani, J. 2014. Interesting Insect Issues: A research and pest update for the Peace River region. Alberta Canola Producers Commission's Regional Meetings, Rycroft, Alberta, November 26, 2014 (Invited speaker; ~60 attendees).

Otani, J. 2014. Interesting Insect Issues: A research and pest update for the Peace River region. Alberta Canola Producers Commission's Regional Meetings, Falher, Alberta, November 27, 2014 (Invited speaker; ~45 attendees).

Otani, J. 2015. "Insect pest monitoring updates.", Agricultural Research and Extension Council of Alberta (ARECA) Meetings, Spirit River, AB, Invited speaker (~30 attendees).

Otani, J. et al. 2014. Cutworm update. Agronomy Update, January 12, 2014, at Red Deer AB. Invited speaker.

Otani, J., and C. Yoder. 2012. Curious cutworm incidence in the Peace. Peace Region Forage Seed Association AGM, Fairview AB, March 15, 2012.

Otani, J., K. Floate, J. Broatch, J. Hummel, M. Evenden, S. Hartley, J. Gavloski, S. Meers. 2012. Cutworm research project update. Western Committee on Crop Pests, Regina SK, October 17, 2012.

Wanigasekara, U., J. Otani, J. Broatch, J. Hummel, B. Sharanowski. 2014. The parasitoid community associated with economically important cutworms in Canada. Entomological Society of Canada−Entomological Society of Saskatchewan Joint Annual Meeting, 28 September – 1 October. Saskatoon, SK.

Weeraddana, C. and M.L. Evenden. Effect of crop cultivar and soil fertility on larval performance and oviposition behavior of Bertha armyworm, *Mamestra configurata*. Joint Annual Meeting of Entomological Societies of Canada and Saskatchewan, Saskatoon SK, September 28-October 1.

Weeraddana, C.D.S., V. Pearson, and M.L. Evenden. 2013. The effects of insecticide-coated canola seeds on larval development of bertha armyworm, *Mamestra configurata*. Entomological Society of Alberta, Olds, AB, October 11.

Interviews:

Erlandson, M. 2014. Interviewed for an article titled 'Identifying cutworm species key to effective control', which appeared in The Western Producer, November 13

Evenden, M. 2015. Interviewed on January 9, 2015 for article: "Tracking insect movement a productive challenge" by Julienne Isaacs, Top Crop Manager, Western Edition, September 2015.

Floate, K. 2012. Interview on new cutworm project aired on CBC French Radio, Edmonton, AB. June 20, 2012.

Floate, K., V. Hervet and B. Byers. 2012. Interview on new cutworm project published as full page article in the Western Producer; online version at http://www.producer.com/2012/06/scientists-study-crop-killing-cutworms%E2%80%A9/. June 7.

Floate, K.D. 2014. Interviewed for an article titled 'Cutworms take a slice out of Sask. canola yields', which appeared in The Western Producer, November 6

Floate, K.D. 2014. Live radio interview with Dan Kerslake, CBC News, Saskatoon (306-956-7416). Discussed cutworm project and its objectives. May 29

Floate, K.D. 2016. Interviewed for an article titled 'Getting to Know Cutworms', which appeared in Top Crop Manager (June 2016 issue). (http://www.mydigitalpublication.com/publication/?m=1031&l=1#{"issue_id":302669,"page":8})

Hervet, V. 2013. Interview on cutworm research published as "*The power of parasitoids: gruesome bugs employ their natural wiles to keep crop pests in check*", in the St Albert Gazette, February 27th, 2013, p. 2 (http://edition.pagesuite-professional.co.uk/launch.aspx?eid=f92be3d6-cc31-4803-b1fc-94a23bbb06e4)

Hervet, V. 2013. Interviewed by a reporter on natural enemies of cutworms. Interview will be broadcast as one of a series of online videos in "CanolaSchool", hosted by the Alberta Canola Producers Commission (http://canola.ab.ca/canola_school.aspx).

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Hummel, J. 2013. Video interview on beneficial insects published by realagriculture.com: at www.realagriculture.com/2013/02/the-danger-of-overlooking-beneficial-insects/. February 21.

Otani, J. 2015. Radio Interview for the "Canola Show", a syndicated radio program to be broadcasted on April 10, 2015, on CJVRFM/CK750AM in Melfort, SK, and XM105FM Whitecourt, AB. Topic was the Prairie Pest Monitoring Network.

Extension tools/publications:

Erlandson, M. 2012. Written progress report presented at Saskatchewan Insect Advisory Council Meeting in Saskatoon, SK, November 21, 2012.

Erlandson, M.A., J. Holowachuk, E.A. Sieminska, J. Hummel, J. Otani and K.D. Floate (*in press*). Development of a mulitplex PCR assay for the identification of common species in the cutworm complex infesting canola in western

Canada. The Canadian Entomologist.

Floate, K.D. and V.A. Hervet (*in press*). Noctuid (Lepidoptera: Noctuidae) pests of canola in North America. In: Integrated management of insect pests on canola and other Brassica oilseed crops. Reddy, G.V.P. (ed.), CABI Publishing, Wallingford, Oxon, UK.

Floate, K.D. (*in press*). Cutworm pests of crops on the Canadian Prairies: identification and management guide. AAFC No. 12345Z, Agriculture and Agri-Food Canada, Lethbridge, Alberta. 102 pp.

Gavloski, J. and V. Hervet. 2013. *Euxoa ochrogaster* (Guenée), redbacked cutworm, *Euxoa messoria* (Harris), darksided cutworm, and *Euxoa auxiliaris* (Grote), army cutworm (Lepidoptera: Noctuidae). *In* Biological Control Programmes in Canada 2001-2010 (Eds. P. Mason and D. Gillespie), CABI Publishing U.K. [book chapter] (reported as '*in press*' in previous report).

Hervet, V. 2013. Provided live specimens of cutworms, adult cutworm parasitoids and parasitized cutworms for use in presentations at CanoLAB in Saskatoon, SK, March 27-28, 2013.

Hervet, V.A.D., R.A. Laird and K.D. Floate. 2016. A review of the McMorran diet for rearing Lepidoptera species with addition of a further 39 species. Journal of Insect Science (http://dx.doi.org/10.1093/jisesa/iev151)

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Kaye, T., Otani, J., Giffen, D.W., Svendsen, E., and Olfert, O.O. 2015. Prairie Pest Monitoring Network e-Bulletin – June 24, 2015 edition.

Martinsen, M. 2013. Information package developed for CanoLAB presentation in Saskatoon, SK, March 27-28, 2013.

Otani, J. 2012. QR Insect Cheat Sheet. To be posted to the web on the Prairie Pest Monitoring Network website December 2012.

Otani, J., J. Gavloski, K. Floate, S. Hartley, S. Meers, V. Hervet. 2012. Cutworms (Noctuidae) larval collecting protocol. Prairie Pest Monitoring Network website located at: http://www.westernforum.org/Documents/IPMN%20Protocols/2012_Cutworm%20Protocol.pdf

Otani, J., Giffen, D.W., Svendsen, E., and Olfert, O.O. 2015. Prairie Pest Monitoring Network e-Bulletin (14 weekly issues; May through September)

Other:

- A 'Team Cutworm' workshop was held September 29, 2014 during the Joint Annual Meeting of Entomological Societies of Canada and Saskatchewan in Saskatoon. Attendees disseminated research results arising from CARP-funded cutworm projects led by Floate and by Sharanowski.
- Reports of cutworm outbreaks identified by members of the research team are provided to Alberta Agriculture Food & Rural Development. These reports appear on AAFRD's 'Cutworm Survey Results' map for use by farmers to assess the risk of cutworm outbreaks in their region (http://www.agric.gov.ab.ca/app68/listings/cutworm/cutworm_map.jsp).

MAJOR VARIANCES:

- At the start of the project, Drs. Olivier and Erlandson had joint responsibility for research under Objective 1. Due to new time commitments required for other projects Dr. Olivier excused herself from the current project. This has not affected research progress.
- In August of 2015, Dr. Hummel accepted a new position in the United States. Because Dr. Hummel's contribution largely was completed in 2014, his move has not affected research progress.

4. Significant Progress/Accomplishments

Objectives have been completed as identified in the previous section.

5. Research and Action Plans/Next Steps

The research funded by this grant is complete. Where this has not already been done, data are being analyzed and summarized for publication as scientific papers and book chapters.

Objective 4 included production of a book; i.e., *Cutworm pests of crops on the Canadian Prairies: identification and management guide*. This book has been written and currently is being formatted. It will be available for electronic distribution to producers and the agricultural sector before the 2017 growing season.

6. Budget impacts in the event major issues or variance between planned and actual is noted:

In December of 2015, the week before the original end-date of this project, an accounting error was identified that revealed approximately $20,000 in unspent funds. We subsequently requested and received permission from the Canola Council of Canada to extend the project deadline to December 31, 2016. Doing so allowed these funds to be used to support further research on cutworms.

Please forward an electronic copy of this completed document to:

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