PROJECT DETAILS

- **Title**: Detection, surveillance and management of weed, insect and disease pests that threaten the economic viability of crop production and the environmental health of Prairie agro-ecosystems
- **Funders:** Agriculture and Agri-Food Canada
- **Research program:** Growing Forward
- **Principal investigator:** Owen Olfert, Agriculture and Agri-Food Canada (AAFC), Saskatoon
- **Collaborators/additional investigators:** Bob Elliott, Héctor Cárcamo, Julia Leeson, Debra McLaren, Jennifer Otani, Gary Peng, Julie Soroka, and Kelly Turkington
- **Year completed:** 2013

Final report

Abstract: Knowledge, tools and practices were developed and implemented to detect, monitor and manage crop pests (weeds, insects, plant diseases) and used to assist the agriculture industry in the mitigation of threats against the economic viability of crop production and the environmental health of prairie agro-ecosystems. Dynamic forecasts, risk assessments and decision-support systems contributed both to the extension aspects of the management system as well as to the decision-making process at the agro-industry and farm level. Weed, insect and plant pathogen population distribution and abundance were correlated with climate, weather, agronomic practices and natural enemies and were utilized to predict risks to field crop production in western Canada. Knowledge of biology, ecology and population dynamics of the organisms under study enhanced the potential for successful integrated management of cyclical native pest species and the increasing number of invasive species. This included the development of new alternative, integrated control and mitigation tactics to manage pests in crop production systems. The potential impacts of climate change, new agronomic practices and new crops on pest populations and diversity of beneficial arthropods were documented.

Knowledge and information on pest status, occurrence, forecasting tools, risk assessment analyses, and other outputs arising from the project were made available through a number of vehicles, including databases, models, software, technology transfer reports and publications such as oral and written reports to agri-business communities, and scientific publications such as scientific papers, proceedings, research reports, invited/volunteer talks and posters to research partners and the scientific community. Using the data collected, timely risk warnings, provided as risk map formats (prairie-wide, provincial and regional) and accompanied with interpretive text, were produced in a format useful to the industry (electronically, field days, producer meetings). The project complemented the technology transfer efforts already in place through the

respective provincial networks
Publications include 61 scientific papers, review articles and proceedings derived from this study. There were also several awards for best papers and best posters at international conferences. In addition, the group was very active with over 3000 technology transfer articles / events / media interviews.

Executive Summary
Cárcamo: In southern Alberta cabbage seedpod weevils are chronic pests of canola and lygus bugs, once considered an intermittent pest, are now becoming also a chronic pest in some regions. Our spring surveys in brassicaceous weeds at flower showed that potential weevil pest problems in canola in the summer (mid to late June) can be identified early by sweeping these plants in the spring in May (primarily flixweed, stinkweed and hoary cres). For lygus bugs abundance in spring weeds could not be used as an indication of potential problems in canola in the summer. This lack of correspondence may be related to the fact that these are separate cohorts that belong to different generations and climatic conditions (hot and dry) during the summer are likely more important determinants of lygus outbreaks. Future research on lygus pest forecasting should focus on development of a sampling method that quantifies adults and young nymphs at flower as an indication of pest problems at the pod stage. Shaking plants to dislodge bugs onto sticky cards seems to be a promising method.

Biological control of lygus bugs using *Peristenus* wasps is an attractive prospect throughout North America after the success story in North East USA with the European species *P. digoneutis*. This species successfully controls lygus in alfalfa and other crops. The Insect Pest Management (crop pests) lab at LRC has continued to make progress during the last three years as part of a long term study. We have determined that older weedy alfalfa sites are sources of higher populations of native *Peristenus* parasitoids compared to seed alfalfa fields; uncultivated sites with hedge mustard have the highest levels of parasitism, yet, canola fields are not invaded by the parasitoid. Controlled choice studies using an olfactometer support these field observations. Furthermore, using laboratory assays, we have determined that the cold hardiness (super-cooling points) of native *Peristenus* are in the same range as the exotic species; therefore, the exotic species is sufficiently cold-hardy to survive Prairie winters. In collaboration with entomologists in Ontario, we have begun ecological studies with the exotic species. We have determined that our common lygus pests are attacked by the exotic and also preliminary studies suggests that in Ontario this species will follow lygus onto canola fields. Environmental risk assessment studies are planned before a decision is made on releasing the exotic species in the Prairies.

Elliott: Flea beetles are the most serious insect pest of canola and mustard in western Canada. Biological

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agents and cultural practices have little effect on flea beetle populations so producers are reliant on neonicotinoid seed treatments. However, recent concerns regarding efficacy and potential impact on insect pollinators have prompted the Pesticides Directorate to issue a "re-review" of neonicotinoid insecticides. Field trials were conducted annually to investigate the effect of neonicotinoid seed treatments and seeding date on flea beetle damage and agronomic performance of six canola and mustard cultivars. Tests also focused on developing accurate methods of forecasting emergence of the summer generation of crucifer and striped flea beetles.

Emergence of the summer generation of crucifer, striped and hop flea beetles from early- and late-seeded plots of canola and mustard varied yearly at AAFC-Saskatoon. Between 2004 and 2009, crucifer flea beetles were the most abundant species, comprising 92-100% of the total flea beetle population in early- and late-seeded plots. However, since 2009, populations of crucifer flea beetles have declined whereas populations of striped and hop flea beetles have increased. The shift in species was greater in early-seeded plots than in late-seeded plots. The shift is troublesome because laboratory bioassays have shown that neonicotinoid seed treatments provide poor control of striped flea beetles. If their abundance and geographic range is increasing in western Canada, then producers should monitor canola and mustard crops to determine what species are present.

Emergence of the summer generation of crucifer and striped flea beetles from early- and late-seeded plots of canola and mustard was assessed in relation to calendar dates. In early-seeded plots, dates for 10%, 50% and 90% emergence of striped flea beetles (July 24, Aug. 9 and Aug. 26, respectively) were 2-3 weeks earlier than the corresponding dates for emergence of crucifer flea beetles (Aug. 16, Aug. 26 and Sept. 10). In late-seeded plots, dates for 10%, 50% and 90% emergence of striped flea beetles (July 25, Aug. 12 and Sept. 4) were also 2-3 weeks earlier than those of crucifer flea beetles (Aug. 21, Sept. 1 and Sept 4). Emergence from year to year varied by 3-19 days depending on the species. The variation in emergence related to air temperatures. Adults of each species emerged earlier than expected in years with above-average temperatures and later than expected in years with below-average temperatures. Emergence of each species was assessed in relation to accumulated degree-days (DD) above 0, 5 and 11°C. Accumulated DD above 5°C starting 18 days after seeding provided the most accurate estimates of emergence in early-seeded plots whereas accumulated DD above 5°C starting 8 days after seeding provided the most accurate estimates of emergence in late-seeded plots. Forecast maps depicting DD accumulations above 5°C would assist canola and mustard producers in assessing the relative abundance of crucifer and striped flea beetles in July and August.

Field tests were conducted annually to investigate the effect of seeding date on flea beetle damage, beetle

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emergence and agronomic performance of six canola and mustard cultivars. Seed lots of each cultivar were seeded relatively early (May 13-21) and late (May 27-June 7). Flea beetle damage to the cotyledons varied significantly depending on the year, seeding date and cultivar. Over three test years, damage was lower in early-seeded plots (14.6%) than in late-seeded plots (21.4%). Damage was lowest in yellow mustard and highest in canola mustard. Emergence of the summer population of striped flea beetles was higher in early-seeded plots than in late-seeded plots. In contrast, emergence of crucifer flea beetles was higher in late-seeded plots than in early-seeded plots. More crucifer and striped flea beetles emerged from oriental mustard and canola mustard than from yellow mustard. Stand establishment, shoot weight, biomass and seed yield varied depending on the year, seeding date and cultivar. Over three years, establishment averaged 69.5% in early-seeded plots and 76.3% in late-seeded plots. Establishment was lowest in canola mustard and highest in hybrid canola. Shoot weights and biomass were 2.1-2.3 times higher in late-seeded plots than in early-seeded plots. Shoot weights and biomass were usually lowest in op canola and highest in yellow mustard. Seed yields were 12% higher in early-seeded plots than in late-seeded plots. Seeding early rather than late improved seed yield by 5-20% depending on the cultivar.

Previous investigations at AAFC-Saskatoon have shown that neonicotinoid seed treatments provide excellent protection against flea beetle damage when warm dry conditions occur during germination and stand establishment. Field trials were conducted annually to evaluate the effect of the seed treatments on flea beetle damage and agronomic performance of open-pollinated (op) canola in summer fallow and wheat stubble. Unlike previous years, precipitation was above-average in 2010-2012. Conversely, air and soil temperatures were below-average. With cool wet conditions, neonicotinoid seed treatments had no effect on flea beetle damage after 20-22 days in all tests on summer fallow and wheat stubble. Despite poor protection, Gaucho, Prosper FX, Helix and Helix XTra improved the establishment of op canola in summer fallow by 6-20%. Neonicotinoid seed treatments had no effect on the shoot weight, biomass and seed yield of op canola in most tests on wheat stubble. Over three test years, Prosper FX, Helix and Helix XTra improved biomass and yield in summer fallow by 28-39% and 6-7%, respectively. Results in 2010-2012 indicate that cool wet conditions during seedling emergence reduced the efficacy of neonicotinoid seed treatments against flea beetles. The results also indicate that more efficacious seed treatments are needed to protect canola seedlings from flea beetles when cool wet conditions occur during stand establishment. Also see Appendix.

Leeson: The 2012 Weed Survey is part of series of surveys of annual crops (including canola) conducted in Saskatchewan starting in the 1970s. The use of similar methodology in the surveys allows for an assessment of changes. Wet conditions in 2012 led to weedier fields due to difficulties with timing of in-crop herbicide applications. Median weed densities were the second highest recorded; higher only in the 1970s. Weed

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species richness was higher than ever previously recorded. Several species are increasing since 1970s including: wild buckwheat, spiny annual sow-thistle, cleavers, barnyard grass, biennial wormwood, foxtail barley, round-leaved mallow and kochia. Species that are decreasing include: lamb's-quarters, stinkweed, annual smartweed species, field horsetail, wild mustard, Russian thistle, flixweed, bluebur and cow cockle.

McLaren: The distribution and abundance of plant pathogen population can be correlated with climate, weather and agronomic practices to predict risks to field crop production in western Canada. A number of diseases were present in each of the four regions of Manitoba, but clubroot symptoms were not observed in any of the crops surveyed throughout the project. No clubroot spores were detected in soil samples from 60 and 79 Manitoba canola fields targeted for DNA analysis (S. Strelkov, University of Alberta) in 2009 and 2010, respectively. Analysis of 69 soil samples collected from canola fields in 2011 indicated that two were positive for DNA of *P. brassicae.* However, bioassays performed on these soils were negative for clubroot symptoms. In the 2012 canola disease survey, no clubroot disease symptoms were seen in any of the canola fields surveyed across Manitoba. However, soil samples from six unrelated fields were confirmed through PCR analysis to contain clubroot DNA. Further testing under greenhouse conditions indicated that two of the six soil samples produced weak clubroot gall symptoms on highly susceptible plants. These test results are considered positive cases of clubroot. Additional soil samples from all of these fields will be tested in 2013.

Aster yellows, blackleg and sclerotinia stem rot were the most prevalent diseases throughout the province. In 2012, Aster yellows was observed in 95% of canola fields in Manitoba with a mean disease incidence of 9.9% in diseased crops. The mean prevalence of aster yellows in crops surveyed in 2011 and 2010 was much lower at 18% and 14%, respectively. Drought in the midwestern United States, the early arrival of aster leafhoppers and the higher than normal percentage of infected leafhoppers in the population may have been contributing factors to the record high level of aster yellows in all regions of Manitoba in 2012.

Olfert: Long-term surveys of insect populations provide a general overview of pest and natural enemy population trends over time. Annual surveys are a snapshot in time and depending on a large number of factors, will reflect the future to varying degrees. As a result, survey results are often translated into qualitative terms such as "light/moderate/heavy" infestation. Project team members, together with provincial and industry collaborators, annually monitored approximately 3500 sites for grasshoppers, 700 for wheat midge, 600 for cabbage seedpod weevil, 500 for bertha armyworm, 100 for pea leaf weevil and wheat stem sawfly (see Appendix). In addition, sentinel sites were monitored annually for flea beetles, cutworms, swede midge and cereal leaf beetle. The potential for migratory pest species, such as diamondback moth, leafhoppers, cereal rusts and clubroot, was assessed using wind trajectory data (in collaboration with Environment Canada). Back

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trajectory data from 60 sites in Canada and forward trajectory data from 20 sites in USA and Mexico were assessed on a daily basis during each growing season (12,000 maps at three wind altitudes).

For researchers, these data are essential in order to identify environmental and agronomic factors that influence pest population increase and decrease. In turn, these data were used to understand the dynamics of pest populations within farming systems. Risk warnings/forecasts consisted of bringing forward annual survey data from the previous year and providing an update with more current information on factors that affect crop risk in the current growing season. Risk warnings employed models that have been developed to predict insect and crop response to environmental factors. The long-term impact of field surveys will be to provide a quantitative database of insect population trends over time and will provide the necessary baseline to quantify potential impacts of climate change, new agronomic practices and new crops on pest populations and diversity of beneficial arthropods.

Climate is the principal factor governing the distribution and abundance of most insects. Given that the magnitude of the predicted temperature changes associated with climate change is outside our current agricultural experiences, is unlikely that we can use historical data as analogues to predict the impact of a warming climate on crop pests such as wheat midge. As a result, general circulation models have proven useful in assessing the impact and related system vulnerability due to climate and produce relatively detailed modelling of important ecological processes. General circulation model scenarios were applied to bioclimate simulation models of 10 insect species (including two beneficial species), two plant pathogens and one weed species to assess the potential impact of a warming climate on its distribution and relative abundance. In general, results indicated that all crop pests would have increased range and relative abundance in more northern regions of North America, compared to predicted range and distribution under current climate conditions. Conversely, model output predicted that climate conditions became limiting for these species in some southern regions of North America and could cause a decrease in the distribution range, seasonal development or relative abundance.

Otani: Issues for the Peace: Insect pest monitoring in the northern Peace River region continues to be of vital importance; the region is vast, the growing conditions are unique compared to other regions of the prairies, pest and natural enemy diversity within field crops needs to be described, plus traditional and introduced insect pest species continues to increase. While monitoring sites generally increased in the Alberta side of the Peace River region, no insect pest monitoring data from agricultural field crops has been collected in the BC Peace since 2005 other than the annual canola survey performed by the IPM Program at Beaverlodge through Cluster support from this project.

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The IPM Program at Beaverlodge has performed an annual canola survey at flowering throughout the Peace River region since 2003. Each year, the program surveys, processes, summarizes and communicates results by early pod stage. Since 2003, annual results included (i) zero cabbage seedpod weevils (Ceutorhynchus obstrictus) were present in survey samples, (ii) Lygus distribution maps and text summaries reporting the occurrences of economically significant insect species (e.g., DBM, grasshoppers) observed in the 115-167 fields surveyed annually.

Weekly monitoring of flea beetle species near Beaverlodge AB since 2001 confirmed the species dominance of Phyllotreta striolata each year in commercial fields. Since 2010, Beaverlodge collections in commercial fields documented that Phyl. striolata proportions ranged from 0.94 (N=4579 beetles from three sites), 0.91 (N=3066 beetles from nine sites), to 0.82 (N=1715 beetles from 10 sites).

A laboratory study conducted in 2010 and 2011examining the impact of native, general predators on lygus nymphs demonstrated that damselbugs, lacewing larvae, crab spiders, ladybird adults and larvae will prey upon lygus nymphs and it suggests these predators have feeding niches when it comes to lygus instar stages. No-Choice study results revealed that (i) damselbugs and lacewing larvae preyed upon the most lygus nymphs whereas (ii) C7 ladybird beetles consumed the fewest lygus nymphs, and (iii) a maximum of seven 5th instar lygus nymphs were consumed by these foliar, general predators during a 24-hr test period. Results from the Choice study indicated that most test predators demonstrated preferences for 3rd, 4th or 5th instar nymphs. More specifically, (i) lacewing larvae preferred 5th instar compared to 4th or 3rd instar lygus nymphs while damselbugs preferred 4th and 5th instar nymphs over the smaller 3rd instar prey whereas (ii) lacewings, damselbugs and crab spiders preferred larger 4th or 5th instar nymphs compared to eating more 3rd instars and finally (iii) ladybird beetles showed no preference when provided with 3rd , 4th or 5th instar lygus nymphs in a petri dish.

Wheat midge was confirmed at low densities within Albertan fields growing near Fort Vermilion and Manning AB in 2011. The IPM Program at Beaverlodge supported AARD's midge monitoring by surveying 12-25 fields the fall of 2011 and 2012 to determine densities of wheat midge and its parasitoids; low densities of midge were confirmed near Manning, Eaglesham, High Prairie, Grande Prairie and Spirit River and zero parasitism was observed when midge cocoons were retrieved from soil cores. Wheat midge monitoring has been proposed for the BC Peace in 2013 to confirm a new northwestern distribution for this introduced pest and its parasitoids.

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Peng: The study on *Leptosphaeria maculans* (blackleg) race structure was continued using basal stem-canker samples collected from commercial canola fields across the prairies during canola disease surveys in 2010. A total of 299 *L. maculans* isolates from Manitoba and Saskatchewan were analyzed using a set of Brassica host differentials with 11 known resistance genes (*Rlm1-Rlm4, Rlm5, Rlm6, Rlm7, Rlm9*, and *LepR1-3*) to profile avirulence genes (*Av*) in the pathogen population. Overall, the *L. maculans* races with *Av1, Av3, Av9, AvLep1* and *AvLep2* avirulence genes showed low frequencies (0-8%), indicating that canola cultivars with the corresponding resistance genes *Rlm1, Rlm3, Rlm9, LepR1* and *LepR2* are ineffective against blackleg in both provinces. The pathogen races with the *Av2, Av4, Av5, Av6,* and *Av7* avirulence genes showed >80%, and those with *AvLep3* showed >50% frequencies in the pathogen population, indicating a value for blackleg resistance with any of the corresponding R genes. One noticeable change from the previous data (test of 850 isolates collected in 2007) is the further reduction of *Av1* and *Av3* avirulence genes in the pathogen population. Almost all *L. maculans* isolates carried multiple *Av* alleles, ranging from as few as two to as many as eight. The majority of the isolates carried 4-6 *Av* alleles. The fewer the number of *Av* genes carried by an isolate, the more likely it is able to affect more canola cultivars due to limited number of specific R genes revealed from commercial cultivars (collaboration with Dr. Fernando at U of M). By determining the *Av* alleles in the *L. maculans* population and specific R genes in canola, cultivar recommendation can be better guided. The analysis of Alberta *L. maculans* isolates will be finished in a couple of months.

The majority of the isolates carried 4-6 *Av* alleles. The fewer the number of *Av* genes carried by an isolate, the more likely it is able to infect canola due to limited number of specific R genes used in commercial cultivars. By determining the *Av* alleles in the *L. maculans* population and specific R genes in canola (in collaboration with Dr. Fernando at U of M), cultivar recommendation can be better guided. The testing of 2010 Alberta *L. maculans* isolates has just been completed and data are being analyzed. Due to the bottle of growth cabinet space, testing of 2011 isolates is still in progress and will be completed in next few months. A new PCR-based protocol is being validated to detect 4 of the *Av* genes in the pathogen population and resolve the bottle-neck issue with the growth cabinet space.
Turkington: CLIMEX and preliminary DYMEX model projections for sclerotinia stem rot severity broadly reflect known at risk areas in the prairie region. Sensitivity analysis suggested that moisture is the key limiting factor for stem rot development and that economic levels of stem rot are projected to occur over large areas of the prairie region with 20% or more increase in summer precipitation, while reductions in summer precipitation of at least 20% limit the projected development of stem rot, even in areas prone to this disease.

Clubroot resting spores are <10 um in diameter, while soil particles of <0.005 mm can enter the upper atmosphere and move significant distances. Thus, long-distance transport of clubroot inoculum via wind-

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mediated soil erosion is a possibility although the risk of spread and establishment is likely limited given the relatively small amount of inoculum that may be transported and any corresponding dilution effect in the air or soil. Wind events that passed over the Edmonton region (source of clubroot inoculum) have ended up primarily in the Edmonton region, but also into eastern AB and a few single events into Saskatchewan and Manitoba. Regional movement of clubroot resting spores (within tens of kilometres) via wind-mediated soil erosion is more of a significant concern and could move significant amounts of soil and clubroot resting spores. Soil particles of 0.05-0.1 or greater can become airborne, but would sediment out within a couple of kilometres of the source field. Thus, field-to-field movement or regional movement within a few kilometres of clubroot resting spores via wind erosion of soil particles is likely to occur and represent a significant risk of an area introduction of the pathogen. Limiting the risk associated with wind erosion and transport of airborne infested soil particles or resting spores will depend on producers utilizing conservation tillage, while avoiding any significant soil disturbance during the spring and fall, which tend to be key periods for wind erosion events to occur.

Introduction:

Knowledge, tools & practices to detect, monitor and manage crop pests assist the agriculture industry in the mitigation of threats against the economic viability of crop production & the environmental health of prairie agro-ecosystems. Dynamic forecasts, risk assessments and decision-support systems contribute both to the extension aspects of the management system as well as to the decision-making process at the agro-industry and farm level. Weed, insect and plant pathogen population distribution and abundance are correlated with climate, weather, agronomic practices & natural enemies and can be utilized to predict risks. Knowledge of biology, ecology and population dynamics of the organisms under study enhance the potential for successful management of the increasing number of invasive species. Climate change, new agronomic practices and new crops affect pest populations and diversity of beneficial arthropods.

Objectives:

The objectives are to develop novel assessment technologies and crop management tools for control of insects, weeds and diseases in field crops by: 1. Developing & implementing field surveillance technologies and laboratory assays; 2. Developing novel forecast & risk assessment technologies; 3. Determining ecological, biological, climatological & crop management relationships that influence pest status; 4. Developing new alternative integrated control & mitigation tactics.

Approach and Methodology:

Objective 1: Use established techniques such as quadrats, sweep sampling, trapping or other appropriate tools

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as part of statistically robust sampling procedures to monitor crop pests from field to landscape to regional scale; Use real-time PCR and image analysis to develop novel tools for early detection of pests in field, seed/seedling stocks, and other agricultural environments. **Objective 2:** Use multi-variate and spatial analyses to develop and validate mathematical, mechanistic and real-time weather models to forecast outbreaks, economic risk & crop losses due to insects, weeds and pathogens; Use long-term climate data sets and biological records to develop and validate bio-climate models to forecast development, reproduction, population dynamics & life history of pests and their natural enemies; Use molecular markers and bioassay-driven selection procedures in greenhouse or field to screen for pest resistance. **Objective 3**: Use plant-pest-weather analyses (laboratory & field) to determine and quantify risks and benefits associated with implementing components or a combination of mitigation strategies**;** Use questionnaires surveys in conjunction with weed surveys to obtain information on farm management practices to determine IPM adoption rates and to identify practices that are important determinants of pest communities; Use laboratory and field assessments to develop methods for monitoring emergence of flea beetles from canola and mustard during pod-fill; and validate tests to identify mustard seed lots with superior establishment, growth and yield potential in conventional and reduced tillage; Use laboratory/field protocols and appropriate statistical analyses to identify seeding practices that reduce insect damage and build up of pest populations in oilseed crops; Use specialized thermo-gradient plate equipment to determine rates of plant, insect and pathogen growth, seed germination, insect diapause, etc., over a range of temperatures. **Objective 4:** Use multivariate analyses to evaluate the effects of seed quality, seeding date and seeding rate on flea beetle damage, seedling establishment, shoot growth, biomass accumulation and seed yield of oilseed crops under different growing conditions and tillage systems; Use controlled growth cabinets and statistical analyses to evaluate the effect of neo-nicotinoid seed treatments on germination, emergence, root elongation and shoot growth of canola at different temperatures; Use laboratory/field protocols and appropriate statistical analyses to evaluate the effect of the treatments on flea beetle damage, establishment, dry matter, biomass and seed yield of canola under different growing conditions and tillage practices; Use field surveys for collections and controlled growth cabinets for bioassays to determine the races of *L. maculans* that occur at various locations across western Canada.

Results and Discussion:

Objective 1: *Developing & implementing field surveillance technologies and laboratory assays. Anticipated output is fundamental knowledge of severity, distribution & impact of biotic stresses.*

Carcamo: Lygus bugs and cabbage seedpod weevils were sampled by sweeping early spring flowering cruciferous weeds (stinkweed, flixweed, hoary cress) and alfalfa in May and June and in canola later in July and

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August. High aggregations of cabbage seedpod weevils of more than 10 per sweep were collected at some weed sites in 2010 but much lower numbers in 2011 and up to 8 per sweep in 2012. These abundances were reflected in the relative abundances observed in canola at early flower in late June and early July in these years. In 2010, about half of 20 fields throughout the area had 2 or more weevils per sweep, approaching the nominal economic threshold of 3-4/sweep. In 2011 and 2012 only about 25% of canola fields had 2 or more weevils per sweep at early flower. For lygus bugs, we did not notice any pattern of correspondence between lygus per sweep in weeds and lygus in canola at the pod stage. At the weed sites, lygus were generally between 0.1 to 1 per sweep but could reach, though rarely, up to 3 per sweep in alfalfa at some sites. From these and other study years, it appears that lygus in canola were not related to relative abundances in the spring in weeds, though a quantitative long time series analysis remains to be done. Lygus nymphs of the second generation are likely severely underestimated by sweeping at the pod stage. This contrasts with weevils that are sampled as adults of the same generation in canola at flower; this crop stage is much easier to sample and the method is likely more efficient. We hypothesize that lygus populations that reach pest levels in canola at the pod stage result from local recruitment and are not related to spring populations in weeds. Therefore, a method such as shaking plants onto sticky cards or vaccuming an area needs to be developed to relate lygus at early flower to populations at the pod stage.

Leeson: Completed survey of 464 canola fields in Saskatchewan. Gave four invited presentations and three media interviews discussing the 2012 results in relation to previous weed surveys in canola crops. Two book chapters utilizing Prairie Weed Survey data were published. Survey of Manitoba was delayed.

McLaren Survey of Manitoba canola fields (142) for the prevalence and incidence of plant diseases was completed. A number of diseases were present in each of the four regions of Manitoba, but clubroot symptoms were not observed in any of the crops surveyed in 2012. No clubroot spores were detected in soil samples from 60 and 79 Manitoba canola fields targeted for DNA analysis (S. Strelkov, University of Alberta) in 2009 and 2010, respectively. Analysis of 69 soil samples collected from canola fields in 2011 indicated that two were positive for DNA of *P. brassicae.* However, bioassays performed on these soils were negative for clubroot symptoms. In the 2012 canola disease survey, no clubroot disease symptoms were seen in any of the canola fields surveyed across Manitoba. However, soil samples from six unrelated fields were confirmed through PCR analysis to contain clubroot DNA. Further testing under greenhouse conditions indicated that two of the six soil samples produced weak clubroot gall symptoms on highly susceptible plants. These test results are considered positive cases of clubroot. Additional soil samples from all of these fields will be tested in 2013.
Aster yellows, blackleg and sclerotinia stem rot were the most prevalent diseases throughout the province in 2012. Aster yellows was observed in 95% of canola fields in Manitoba with a mean disease incidence of 9.9% in

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diseased crops. The mean prevalence of aster yellows in crops surveyed in 2011 and 2010 was much lower at 18% and 14%, respectively. Drought in the midwestern United States, the early arrival of aster leafhoppers and the higher than normal percentage of infected leafhoppers in the population may have been contributing factors to the record high level of aster yellows in all regions of Manitoba in 2012.

The prevalence of sclerotinia-infested crops ranged from a high of 75% in the northwest region to 51% in the central region with a provincial mean of 65%. Mean disease incidence averaged across all crops was 8.6% and ranged from 10.3% in the northwest region to 6.9% in the central region. For infested crops only, mean disease incidence was 13.2%. Throughout the province, mean severity of sclerotinia stem rot was low at <2.0. In 2012, both the prevalence and incidence of sclerotinia stem rot were higher than in 2011.

Blackleg basal cankers occurred in 77% of the crops surveyed in 2012, with the prevalence ranging from 90% in the central region to 61% in the eastern/interlake region. The mean disease incidence of basal cankers averaged across all crops was 12%, while the incidence in infested crops was 15.7%. In 2011, basal cankers were found in 69% of crops surveyed with a mean disease incidence of 9%. The severity of blackleg basal cankers was similar in both years, with average ratings of 2 or less. A value of 2 indicates diseased tissue occupies 26-50% of the basal stem cross section.

Canola stem samples were collected for isolation of *L. maculans* and type to race (Kutcher/Peng). The survey data has been submitted for publication in the Canadian Plant Disease Survey. Technology transfer includes invitations to speak to industry and canola growers, and presentation of a webinar (training).

Olfert: Continued to develop, coordinate and implement surveys to determine insect pest population distribution and abundance (cabbage seedpod weevil- sweep sampling; grasshoppers - visual counts; bertha armyworm – pheromone traps; diamondback moth – pheromone trap; wheat midge – visual counts). Insect survey protocols were developed and standardized; (ii) surveys for the major insect pests were coordinated & implemented across 71 million acres of cropland in western Canada to determine insect pest and natural enemy distribution and abundance. Project team members, together with provincial and industry collaborators, annually monitored approximately 3500 sites for grasshoppers, 700 for wheat midge, 600 for cabbage seedpod weevil, 500 for bertha armyworm, 100 for pea leaf weevil and wheat stem sawfly (see Appendix). In addition, sentinel sites were monitored annually for flea beetles, cutworms, swede midge and cereal leaf beetle. The potential for migratory pest species, such as diamondback moth, leafhoppers, cereal rusts and clubroot, was assessed using wind trajectory data (in collaboration with Environment Canada). Back trajectory data from 60 sites in Canada and forward trajectory data from 20 sites in USA and Mexico were

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assessed on a daily basis during each growing season (12,000 maps at three wind altitudes).

Otani: Coordinated and implemented annual Peace River region canola survey (2003-present); surveyed 167 fields at mid-flower throughout AB and BC Peace River regions in 2012. Sweep-net samples were processed to generate abundance maps and pest incidence was reported for prominent pests including Lygus and diamondback moth in 2012. Leafhopper specimens were retrieved from survey samples and forwarded in July for processing (Olivier at AAFC-Saskatoon). Results, in the form of 2012 distribution maps accompanied by a text summaries were circulated by early pod stage to provincial, applied research association, and industry members plus ACPC generously posted the 2012 survey summary to their website.

Performed weekly diamondback moth pheromone monitoring from mid-April to mid-August at 11 producer-cooperator sites near Beaverlodge in 2012 with 3024 moths intercepted and identified. The weekly DBM counts were forwarded to Alberta Agriculture for inclusion in their real-time growing season distribution map, data was forwarded to O. Olfert (AAFC-Sask) for inclusion in the prairie-wide long-term database, and data was included in prairie-wide distribution maps generated for the 2012 growing season.

Performed weekly bertha armyworm moth pheromone trap monitoring from May 31 until August 8 at six producer-cooperator sites near Beaverlodge in 2012 with 119 moths intercepted plus 225 native bees. Of the 199 moths trapped, a total of 25 moths were identified as bertha armyworm moths then forwarded to M. Erlandson (AAFC-Sask) for genetic processing as part of an A-Base genomics project. The weekly bertha armyworm moth trap counts were forwarded to (i) Alberta Agriculture for inclusion in their real-time growing season distribution map, (ii) to O. Olfert (AAFC-Sask) for inclusion in the prairie-wide long-term database, and (iii) was used to generate the 2012 prairie-wide distribution maps. All intercepted bees were pinned and shipped to A. Melathopoulos (AAFC-Kentville) for species identifications (pending as of April 10, 2013).

Soroka: Developed, co-ordinated, evaluated, summarized and publicized an insect survey of alfalfa fields in the province over a three year period 2010-2012. Alfalfa weevil, found throughout the province in low numbers in 2010, reached economic levels in several fields in the south eastern quadrant of the province in 2011, and outbreak levels in the same area in 2012. The weevil parasitoid *Bathyplectes curculionis* was found generally distributed, although in low numbers, wherever alfalfa weevil was found, suggesting it has moved to new areas along with the pest. In 2012 some of the most heavily weevil-infested fields of the survey had noticeable numbers of weevil larvae infected with an *Entomophthorales*-like fungus, which may contribute to decline in weevil numbers in future years. The distribution of the alfalfa blotch leaf miner *Agromyza frontella* was mapped for the province. From the first occurrence record in the southeastern corner of the province in 2001,

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the pest has spread throughout the province by 2012. However, alfalfa forage yield loss from this pest is negligible, at least to date. Clover casebearer *Coleophora trifolii* was collected and identified from two or three locations in north eastern Saskatchewan from 2010-2012. Survey indicates numbers of the pest are slowly increasing in the province, but at much lower levels than in northern Alberta. In 2012 noticeable damage to canola crops by swede midge, *Contarinia nasturtii*, was discovered in 11 of 44 fields surveyed for the pest, the first incidence of field damage to canola by the pest in the province.

OBJECTIVE 2: *Characterize risk to crop yield, quality & food safety caused by pests through the development of novel forecast & risk assessment technologies. Anticipated output is information regarding extent and nature of production and food safety risks caused by crop pests.*

Elliott: A manuscript describing the calendar and degree-day requirements for emergence of the fall generation of crucifer and striped flea beetles will be submitted for publication within the next six months. Emergence of crucifer, striped and hop flea beetles was evaluated in early- and late-seeded plots of canola and mustard at AAFC-Saskatoon in 2004-2012. In each year of testing, two canola types (open-pollinated and hybrid) and three mustard types (oriental, brown and yellow) were seeded early (May 10-16) and late (May 25-June 7). Each test was replicated four times using a randomized complete block design. In mid-July, individual plants were pruned to 8-10 cm and covered with emergence cages containing a sticky strip below the lid (n = 3 cages/plot). Numbers of flea beetles on the sticky strips were assessed weekly until early October.

Emergence of striped flea beetles (n = 4 years) and crucifer flea beetles (n = 9 years) from early- and late-seeded plots was assessed in relation to calendar date and days after seeding (Tables 1 and 2). In early-seeded plots, dates for 10%, 50% and 90% emergence of striped flea beetles (July 24, Aug. 9 and Aug. 26, respectively) were 2-3 weeks earlier than the corresponding dates for emergence of crucifer flea beetles (Aug. 16, Aug. 26 and Sept. 10, respectively). In late-seeded plots, dates for 10%, 50% and 90% emergence of striped flea beetles (July 25, Aug. 12 and Sept. 4, respectively) were also 2-3 weeks earlier than those of crucifer flea beetles (Aug. 21, Sept. 1 and Sept. 14, respectively). Emergence from year to year varied by 2.9-19.0 days in striped flea beetles and by 7.5-13.2 days in crucifer flea beetles. The year-to-year variation in emergence related to air temperatures. Adults of each species emerged earlier than expected in years with above-average temperatures and later than expected in years with below-average temperatures. Higher temperatures also advanced the emergence of each species in late-seeded plots compared to early-seeded plots. In terms of days after seeding (DAS), 10%, 50% and 90% emergence of striped flea beetles occurred 7-13 days sooner in late-seeded plots (58, 76 and 98 DAS, respectively) than in early-seeded plots (71, 88 and 105 DAS, respectively). Similarly, 10%, 50% and 90% emergence of crucifer flea beetles occurred 9-12 days sooner in late-seeded plots

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(84, 95 and 108 DAS, respectively) than in early-seeded plots (95, 104 and 120 DAS, respectively). From year to year, emergence based on days after seeding varied by 1.5-17.1 days in striped flea beetles and by 7.6-13.5 days in crucifer flea beetles.

Emergence of striped and crucifer flea beetles from early- and late-seeded plots was assessed in relation to accumulated degree-days above 0, 5 and 11°C (APPENDIX Elliott Tables 1 and 2). These base temperatures have been used in other studies to describe the development of canola (0 and 5°C) and emergence of crucifer flea beetles in eastern Canada (11°C). In early-seeded plots, accumulated degree-days above 5°C starting 18 DAS provided the most accurate estimates of 10%, 50% and 90% emergence of striped flea beetles (676 DD, 901 DD and 1089 DD, respectively) and crucifer flea beetles (913 DD, 1016 DD and 1157 DD, respectively). Degree-day accumulations for 10%, 50% and 90% emergence varied by 3.2, 11.9 and 12.8 days, respectively, in striped flea beetles (n = 4 years) and by 2.9, 4.0 and 7.1 days, respectively, in crucifer flea beetles (n = 9 years). In late-seeded plots, accumulated degree-days above 5°C starting 8 DAS provided the most accurate estimates of 10%, 50% and 90% emergence of striped flea beetles (647 DD, 875 DD and 1121 DD, respectively) and crucifer flea beetles (916 DD, 1026 DD and 1136 DD, respectively). Degree-day accumulations for 10%, 50% and 90% emergence varied by 2.0, 14.1 and 15.5 days, respectively, in striped flea beetles (n = 4 years) and by 4.2, 6.4 and 8.0 days, respectively, in crucifer flea beetles (n = 9 years). The results indicate that forecast maps based on degree-day accumulation above 5°C provide the most accurate method of predicting emergence of crucifer and striped flea beetles from early- and late-seeded canola or mustard. Forecast maps providing degree-day accumulations above 5°C would assist canola and mustard producers in monitoring fields for the presence of crucifer and striped flea beetles during pod-fill.

Olfert: Spatial analysis systems (Arc-GIS®, SPANS®) were used to summarize the distribution and density of insect pests (bertha armyworm, cabbage seedpod weevil, grasshoppers, pea leaf weevil, wheat midge) into risk forecasts. Techniques included summarization of the economic risks associated with insect pest populations. GIS models were developed for major crop pest species using weather data and pest biology to estimate the risk of these invasive insect pests in field crops; The results were provided to the industry in timely updates throughout the growing season. Key monitoring sites were identified by R. Weiss for 2011 DBM pheromone trap deployment by provincial cooperators and will be done to improve and/or optimize monitoring efforts by (i) optimizing the geographic area surveyed with available cooperators, and ensuring (ii) pheromone traps are situated near reliable weather data sites.

Otani: Surveyed flea beetle populations at 10 sites in the south AB Peace in 2012 using yellow sticky cards (N=5 per field, each trap positioned 20 m apart along edge of commercial field). A total of 1715 flea beetles

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were collected in 2012 near Beaverlodge AB with the dominant species again being *Phyllotreta striolata* (proportion=0.82) but then followed by *Crepidodera nana* (proportion=0.12), *Chaetocnema irregularis* (proportion=0.04), *Psylliodes punctulata* (proportion=0.01), *Chaetocnema protensa* (proportion=0.00), and the least common *Phyllotreta.*

cruciferae (proportion=0.00) (APPENDIX Otani Figure 1). Sticky cards were forwarded to J. Soroka (AAFC-Sask) on April 15, 2013, for identification of parasitoid wasps attacking flea beetles at Beaverlodge sites in 2012.

Initiated a one-year field plot trial at Beaverlodge AB in 2012 to assess new seed insecticide treatments for canola seedling and yield protection. Nine seed treatments were applied to *B. napus cv.* 1012RR then seeded on May 15, 2012, using a Fabro double-disk seeder set to 22.9cm-row spacing. Treatments were organized in a RCBD with four replicates. Flea beetle damage assessments (APPENDIX Otani Figure 2) stand densities (APPENDIX Otani Figure 3) and growth ratings (APPENDIX Otani Figure 4) were recorded in all plots. Overall, Treatments 5, 6, 7, 8, and 9 suffered less flea beetle feeding damage at 17, 20 and by 27 days after seeding (DAS) compared to plants in the remaining Treatments (APPENDIX Otani Figure 2). Plant densities were comparatively higher by 27 DAS in Treatments 6, 7, and 8 compared to the other Treatments (APPENDIX Otani Figure 3). Additionally, canola plants started to flower earliest in plots of Treatments 3 and 7 at 58 DAS but, by 63 DAS, more plants were flowering (i.e., growth stage >4.0) in Treatments 5, 6, 7, and 9 (APPENDIX Otani Figure 4) compared to plants in the remaining treatments which were still at the late bolting stage (i.e., growth ratings <4.0) on that same assessment day. Hand-harvested plant samples collected on August 27, 2012, were processed to record above-ground dry biomass (APPENDIX Otani Figure 5) and yield data (APPENDIX Otani Figure 6). The highest yields were observed in plots of Treatment 5 (mean=300.83 g/m^2), followed by plots of Treatment 7 (mean=298.28 g/m^2), Treatment 6 (mean= 280.65 g/m^2), Treatment 9 (mean=276.90 g/m^2), Treatment 4 (mean=272.55 g/m^2), Treatment 2 (mean=270.38 g/m^2), Treatment 3 (mean=267.55 g/m^2), Treatment 1 (mean=264.65 g/m^2), with the lowest yields observed in plots of Treatment 8 (mean=259.08 g/m^2)

Initiated a new field plot trial with PMC support to investigate the impact of high densities of Lygus feeding introduced at the bolting stage of canola development. Field plots of three canola varieties (cv. Westar, L150, RR7345) were seeded into a RCBD with four replicates on May 14, 2012, at AAFC-Beaverlodge. At late rosette stage, cages (1m x 1m x 1.5m tall) were erected in plots. Densities of 20 Lygus adults per cage (compared to a paired, untreated density of zero Lygus per cage) were introduced to cages at bolting stages and left to feed and reproduce until harvest. At maturity, the arthropods contained within each field cage were vacuumed out and caged canola plants were hand-harvested at ground level and placed inside in cotton sacks. Plant samples were allowed to cure outdoors, placed on a standing-leg dryer then above-ground dry biomass data was

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recorded. Plant samples were then threshed and yield was recorded (APPENDIX Otani Figure 7).

Soroka: Presented a module on insect pests of alfalfa forage at CFIA-sponsored training sessions for producers and inspectors of hay destined for export to China.

Turkington: **(i) S**clerotinia: A DYMEX model to simulate the development of sclerotinia stem rot has been developed and is coupled with a model for canola growth. Some preliminary runs have been performed, but further development has been limited due to issues related to AAFC's travel restrictions for the past three years. Travel has been difficult is not impossible as completion of this component of the project relied on Dr. Turkington visiting staff at AAFC Lacombe for at least 1-2 weeks per year. A CLIMEX model for potential distribution and severity sclerotinia stem rot has been developed. The model generally reflects previous survey information whereby more severe stem rot would be expected in the black soil zone region of the Prairies, where more rainfall is received during the summer. Sclerotinia distribution and severity was projected to increase with 20% higher summer rainfall, while projected distribution of severe levels of stem rot was greatly restricted with a 20% reduction in summer rainfall. AAFC travel restrictions precluded further progress in relation to model refinement. **(ii)** Wind trajectories and club root dispersal risk: Continued analysis of wind trajectory data from Environment Canada has been performed for the period from 2007 to 2012. Air parcel movement (< 250 m above ground level [AGL]) from an area centred on Edmonton has been evaluated for specific locations in the prairie region. Given the size or clubroot resting spores their dispersal with soil particles within a field or between adjacent fields can likely readily occur. It is unclear whether significant long distance transport of clubroot resting spores occurs via wind erosion. However, given the size of clubroot resting spores and the occurrence of wind trajectories that pass over the Edmonton region there may be the potential for movement over tens to hundreds of kilometers. Of greater concern is there is likely a greater potential for regional and field-to-field spread of clubroot via wind-mediated erosion of soil particles and clubroot resting spores. Companion research as part of a clubroot AAFC A-base project (PI G. Peng) indicates the presence of significant numbers of clubroot resting spores in wind-eroded soil particles trapped in BSNE dust collectors. Localized regional movement of clubroot resting spores via soil erosion is likely of greater concern versus movement of soil via farm or oil and gas field equipment. Movement of equipment represents a point introduction of potential clubroot infested soil and there maybe potential to mitigate the risk by treating the smaller entry area of the field with soil treatments. In contrast, wind-mediated soil erosion represents an area source of inoculum that can introduce the pathogen into adjacent or regional fields at multiple points of introduction. Encouraging conservation tillage and the avoidance of excessive soil disturbance will be key to limit potential wind-mediated erosion in the early spring and fall periods which are critical periods for soil erosion events.

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OBJECTIVE 3: *Determine the ecological, biological, climatological & crop management relationships that influence pest status. Anticipated output is recommendations for best management practices to reduce or avoid crop losses.*

Elliott: Field tests were conducted annually in 2010-2012 to investigate the influence of seeding date on flea beetle damage, flea beetle emergence and agronomic performance of six canola and mustard cultivars. Seed lots of oriental mustard, brown mustard, yellow mustard, canola mustard, open-pollinated canola and hybrid canola were treated with Helix® and seeded in summer fallow relatively early (May 13-21) and late (May 26-June 7). Each test was replicated four times using a randomized complete block design. Flea beetle evaluations focused on assessing flea beetle damage to the cotyledons (n = 20 cotyledons/plot) 14, 18 and 21 DAS and quantifying numbers of crucifer, striped and hop flea beetles that emerged from caged plants (n = 3 cages/plot) from mid-July until early October. Agronomic assessments focused on stand establishment, shoot growth and seed yield.

Emergence of the summer generation of crucifer, striped and hop flea beetles from early- and late-seeded plots at AAFC-Saskatoon varied greatly from year to year since 2004 (APPENDIX Elliott Figure 1). Flea beetle emergence, particularly in late-seeded plots, was higher in 2004-2008 than in subsequent years. Crucifer flea beetles were the most abundant species in early- and late-seeded plots in 2004-2009 (Fig. 2). Crucifer flea beetles comprised 92-99% of the total beetle population in early-seeded plots and 97-100% of the total population in late-seeded plots. The relative abundance of crucifer flea beetles in early-and late-seeded plots declined to 89% and 86%, respectively, in 2010; 37% and 61%, respectively, in 2011 and 59% and 65%, respectively, in 2012. The decline in relative abundance of crucifer flea beetles was associated with an increase in striped and hop flea beetles. In 2010, 2011 and 2012, striped flea beetles accounted for 7%, 62% and 29% of the total beetles in early-seeded plots and 5%, 36% and 24% of the total beetles in late-seeded plots. In 2004-2009, hop flea beetles accounted for less than 1% of the total flea beetle population. However, in 2012, hop flea beetles accounted for 11-13% of the total beetle population in early- and late-seeded plots. The results indicate that there has been a shift in flea beetle species that attack canola and mustard at AAFC-Saskatoon. Since 2009, populations of crucifer flea beetles have declined whereas populations of striped and hop flea beetles have increased. The shift in species was greater in early-seeded plots than in late-seeded plots.

Flea beetle damage to the cotyledons 20-21 DAS varied significantly depending on the year, seeding date and cultivar (APPENDIX Elliott Table 3). In 2010, 2011 and 2012, damage in the six cultivars averaged 2.3, 11.0 and 30.6%, respectively, in early-seeded plots and 21.2, 26.2 and 16.8%, respectively, in late-seeded plots. Over

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three test years, damage was lower in early-seeded plots (14.6%) than in late-seeded plots (21.4%). In 2010-2012, flea beetle damage in early-seeded plots ranged from 8.3% in the yellow mustard cultivar to 20.8% in the canola mustard cultivar. Damage in late-seeded plots ranged from 16.0% in the yellow mustard cultivar to 24.0% in the oriental mustard cultivar.

In 2010-2012, emergence of the summer generation of crucifer flea beetles was higher in late-seeded plots (3.0 beetles per plant) than in early-seeded plots (2.0 beetles per plant) (APPENDIX Elliott Table 4). In early- and late-seeded plots, more crucifer flea beetles emerged from oriental mustard (3.0 and 4.9 beetles per plant, respectively) than from yellow mustard (1.4 and 2.3 beetles per plant, respectively) and hybrid canola (1.3 and 1.9 beetles per plant, respectively). In contrast, emergence of striped flea beetles in 2010-2012 was higher in early-seeded plots (1.8 beetles per plant) than in late-seeded plots (0.8 beetles per plant) (APPENDIX Elliott Table 5). Emergence of striped flea beetles in early-seeded plots ranged from 1.2 beetles per plant in the canola cultivars to 3.2 beetles per plant in the yellow mustard cultivar. Emergence of striped flea beetles in late-seeded plots ranged from 0.6 beetles per plant in the brown mustard and hybrid canola cultivars to 1.1 beetles per plant in the canola mustard cultivar.

Stand establishment, shoot fresh weight, biomass and seed yield varied significantly depending on the year, seeding date and cultivar. In 2010, 2011 and 2012, stand establishment in the six cultivars after 20-21 days averaged 81.2, 67.9 and 59.4%, respectively, in early-seeded plots and 83.2, 74.1 and 71.6%, respectively in late-seeded plots (APPENDIX Elliott Table 6). Over three test years, establishment averaged 69.5% in early-seeded plots and 76.3% in late-seeded plots. Establishment in early-seeded plots in 2010-2012 ranged from 53% in the canola mustard cultivar to 75% in the yellow mustard and hybrid canola cultivars. Establishment in late-seeded plots ranged from 69% in the canola mustard cultivar to 81% in the hybrid canola cultivar. In 2010, 2011 and 2012, shoot fresh weights of the cultivars after 27-30 days averaged 1029, 4035 and 987 mg/plant, respectively, in early-seeded plots and 4079, 6604 and 2147 mg/plant, respectively, in late-seeded plots (APPENDIX Elliott Table 7). Over three test years, shoot weights were 2.1 times higher in late-seeded plots (4277 mg/plant) than in early-seeded plots (2017 mg/plant). Shoot weights in early-seeded plots in 2010-2012 ranged from 1550 mg/plant in the open-pollinated canola cultivar to 3013 mg/plant in the yellow mustard cultivar. Shoot weights in late-seeded plots ranged from 3078 mg/plant in the open-pollinated canola cultivar to 6116 mg/plant in the yellow mustard cultivar. Shoot biomass of the cultivars after 27-30 days in 2010, 2011 and 2012 averaged 27.4, 89.5 and 21.0 g/m-row, respectively, in early-seeded plots and 111.3, 163.0 and 49.3 g/m-row, respectively, in late-seeded plots (APPENDIX Elliott Table 8). Shoot biomass over three test years was 2.3 times higher in late-seeded plots (107.9 g/m-row) than in early-seeded plots (45.9 g/m-row). Shoot biomass in early-seeded plots in 2010-2012 ranged from 33.2 g/m-row in the canola mustard cultivar to 67.8

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g/m-row in the yellow mustard cultivar. Biomass in late-seeded plots ranged from 76.1 g/m-row in the open-pollinated canola cultivar to 156.3 g/m-row in the yellow mustard cultivar. Seed yields of the cultivars in 2010, 2011 and 2012 averaged 256, 375 and 228 g/m^2, respectively, in early-seeded plots and 228, 306 and 238 g/m^2, respectively, in late-seeded plots (APPENDIX Elliott Table 9). Seed yields over three test years were 12% higher in early-seeded plots (286 g/m^2) than in late-seeded plots (257 g/m^2). Yields in early-seeded plots in 2010-2012 ranged from 252 g/m^2 in the open-pollinated canola cultivar to 337 g/m^2 in the oriental mustard cultivar. Yields in late-seeded plots ranged from 219 g/m^2 in the open-pollinated canola cultivar to 291 g/m^2 in the hybrid canola cultivar. Seeding early rather than late improved the seed yield of all cultivars. Early seeding improved yields of yellow mustard and canola mustard by 5%, yields of hybrid canola and brown mustard by 9-12% and yields of open-pollinated canola and oriental mustard by 15-20%. The benefits of seeding early to reduce crucifer flea beetle damage and improve seed yield were described in presentations to the Prairie Pest Monitoring Group and will be submitted for publication by December.

Leeson: Draft of report summarizing management information from the questionnaires completed by Alberta producers who participated in the weed survey is complete. Management information from the questionnaires completed by Saskatchewan producers who participated in the weed survey is being processed. Management data collected in conjunction with weed surveys was subject of book chapter in Integrated Weed Management currently in press.

Olfert: Spatial data for a tri-tropihc system, namely wheat host crop – invasive pest species (wheat midge) - biological control agents (*Macroglenes penetrans*) - climate , were obtained from European and North American sources to develop a wheat host crop – pest species biological control agent - climate model. Datasets of the pest species (*Sitodiplosis mosellana*) and the biological control agent (*Macroglenes penetrans*) have been compiled from across Europe and North America; Bioclimate models were developed, using weather data and pest biology, to predict ecological and economic impact of invasive insect pests and the natural enemies in field crops in Western Canada.

Soroka: A three year field investigation was conducted into wheat stubble heights and soil preparation practices in canola production that could deter feeding by flea beetles and root maggots. Infestations of both pests were low for the duration of the three year study; trends towards decreased feeding with increased stubble height.

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OBJECTIVE 4: *Development of new alternative, integrated control & mitigation tactics to manage pests in crop production systems, including low input and organic production systems. Anticipated output is technologies to reduce losses in yield, quality & food safety caused by pests.*

Cárcamo: 2010-2012. Lygus nymphs were collected annually from alfalfa crops in southern Alberta, and an uncultivated site with hedge mustard at a city park in Lethbridge. Parasitism rates by *Peristenus* were highly variable. The highest at any sampling time was near 80% (hedge mustard); in alfalfa a weedy old site had around 40% of the nymphs parasitized at its peak of the first generation in June. Our studies confirmed results observed in Saskatchewan by Braun et al. (1998) that native *Peristenus* do not attack lygus in canola. A number of laboratory studies were conducted during this period to improve ecological knowledge of Peristenus wasps in support of lygus biocontrol. The supercooling points of native *Peristenus* wasps was determined in 2010 for a sample of adults (likely *P. brunae*, *P. carcamoi*, *P. broadbenti*) and ranged from -19 to -25ºC. This was similar to the exotic *P. digoneutis* (-22ºC). This suggests that this exotic species should withstand the southern Alberta winter conditions if introduced. In 2011 and 2012 we obtained *P. digoneutis* from the London area in southern Ontario (courtesy of B. Broadbent and T. Gariepy). Using lab assays, we showed that it attacks and survives on *L. keltoni, L. elisus and L. lineolaris* (APPENDIX Cárcamo - Figure 1). Data from southern Ontario (Broadbent and Gualtieri) suggests that *P. digoneutis*, unlike the native *Peristenus* of western Canada, can attack lygus nymphs in canola. In related studies with native *Peristenus*, we used an olfactometer to investigate the influence of host plant (alfalfa or canola) on *Peristenus* choices but very few wasps made a choice initially. Carolyn Herle at Lethbridge discovered that by covering the apparatus with an opaque film (mylar paper) the wasps were more likely to make a choice after 20 minutes. Using this method, it appears that the wasps do respond to plant odour (APPENDIX Carcamo - Figure 2). More wasps chose to enter the chamber containing canola or alfalfa when the option was one of these crops or a blank chamber. When the choice was between the crops, a few more chose alfalfa over canola but the data is preliminary. This research is the focus of an Abase project proposal under review.

Elliott: Field tests were conducted annually in 2010-2012 to determine the effect of neonicotinoid seed treatments on flea beetle damage and agronomic performance of open-pollinated (op) canola in summer fallow and wheat stubble. Each test was replicated four times using a randomized complete block design. Untreated seeds and seeds treated with Tribune (fungicides only), Cruiser (200 g and 400 g thiamethoxam), Gaucho CS FL (400 g imidacloprid), Prosper FX (400 g clothianidin), Helix (200 g thiamethoxam) and Helix XTra (400 g thiamethoxam) were planted in summer fallow May 16-18 and wheat stubble May 17-26. Cruiser contained a neonicotinoid insecticide whereas the last four seed treatments contained a neonicotinoid insecticide and several fungicides.

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Precipitation before planting (Oct-April) was above-average in 2010 (126 mm) and 2012 (114 mm) and below-average in 2011 (50 mm). Mean air and soil temperatures during the first 21 days after seeding were higher in 2011 (12.3°C and 15.5°C, respectively) than in 2010 (11.6°C and 14.5°C, respectively) and 2012 (12.0°C and 13.6°C, respectively). Soil temperatures during germination and stand establishment ranged from 2.9-37.2°C in 2010, from 6.4-26.7°C in 2011 and from 4.2-28.2°C in 2012. Rainfall during this period was higher in 2010 (130 mm) than in 2011 (24 mm) and 2012 (53 mm).

With relatively cool moist conditions, flea beetle damage to the cotyledons after 16-17 days was below the economic threshold in most tests (APPENDIX Elliott Table 10). Damage varied depending on the year and seed treatment. In 2010, 2011 and 2012, damage in all treatments averaged 2.9, 10.8 and 18.9%, respectively, in summer fallow and 6.6, 1.4 and 24.2%, respectively, in wheat stubble. Damage over three test years averaged 10.9% in summer fallow and 10.7% in wheat stubble. In summer fallow, neonicotinoid seed treatments reduced damage in 2010 and 2011 but not in 2012. Prosper FX and Helix XTra provided the best protection in 2010. The high rate of Cruiser and Helix XTra provided the best protection in 2011. Compared to untreated seed, the treatments reduced damage by 2-3% in 2010 and by 4-6% in 2011. Helix XTra and Gaucho CS FL reduced damage in 2010-2012 by 3-4%. In wheat stubble, neonicotinoid seed treatments reduced flea beetle damage in 2010 and 2011 but not in 2012. Prosper FX and low or high rate of Cruiser provided the best protection in 2010. Helix XTra, Prosper FX and low or high rate of Cruiser provided the best protection in 2011. Compared to untreated seed, the treatments reduced damage by 4-5% in 2010 and by 1-2% in 2011. Neonicotinoid seed treatments had no effect on flea beetle damage over three test years in wheat stubble.

Neonicotinoid seed treatments had little effect on flea beetle damage after 20-22 days in summer fallow and wheat stubble (APPENDIX Elliott Table 11). In 2010, 2011 and 2012, damage in all treatments averaged 10.9, 15.2 and 26.8%, respectively, in summer fallow and 9.4, 7.6 and 27.9%, respectively, in wheat stubble. Damage over three test years averaged 17.7% in summer fallow and 15.0% in wheat stubble. Neonicotinoid seed treatments had no effect on flea beetle damage to op canola in summer fallow and wheat stubble in 2010, 2011 and 2012. Damage exceeded the economic threshold in most treatments in summer fallow and wheat stubble in 2012.

Despite limited protection against flea beetle damage, neonicotinoid seed treatments had a significant effect on the establishment of op canola in most tests (APPENDIX Elliott Table 12). Stand establishment after 20-22 days in 2010, 2011 and 2012 averaged 83, 76 and 72%, respectively, in summer fallow and 63, 42 and 43%, respectively, in wheat stubble. Stand establishment over three test years was 27% higher in summer fallow (77%) than in wheat stubble (50%). Compared to untreated seed, Gaucho CS FL, Prosper FX, Helix and Helix XTra improved the establishment of op canola in summer fallow by 6-9% in 2010, by 10-20% in 2011 and by 6-11% in 2012. Prosper FX and Helix XTra provided the best establishment over three years. Compared to untreated seed, the treatments improved the establishment of op canola in summer fallow by 11-13%. The

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high rate of Cruiser, Prosper FX, Helix and Helix XTra improved the establishment of op canola in wheat stubble by 15-25% in 2010. Neonicotinoid seed treatments had no effect on stand establishment in 2011 and 2012. Over three years, the high rate of Cruiser, Gaucho CS FL, Prosper FX and Helix improved the establishment of op canola in wheat stubble by 7-13%.

Neonicotinoid seed treatments had little effect on the shoot fresh weight of op canola after 20-22 days in most tests (APPENDIX Elliott Table 13). In 2010, 2011 and 2012, shoot weights in all treatments averaged 164, 362 and 181 mg/plant, respectively, in summer fallow and 105, 223 and 128 mg/plant, respectively, in wheat stubble. Shoot weights over three test years averaged 235 mg/plant in summer fallow and 152 mg/plant in wheat stubble. Compared to untreated seed, the high rate of Cruiser, Helix and Helix XTra improved the shoot weight of op canola in summer fallow by 40-50% in 2010. Helix improved the shoot weight of op canola in summer fallow by 20% in 2011 and by 18% in 2010-2012. Neonicotinoid seed treatments had no effect on the shoot weight of op canola in all tests in wheat stubble.

Neonicotinoid seed treatments had limited effect on the shoot biomass of op canola after 20-22 days in most tests (APPENDIX Elliott Table 14). Shoot biomass in 2010, 2011 and 2012 averaged 4.5, 9.1 and 4.3 g/m-row, respectively, in summer fallow and 2.2, 3.1 and 1.8 g/m-row in wheat stubble. Shoot biomass over three test years was 2.4 times higher in summer fallow (5.9 g/m-row) than in wheat stubble (2.4 g/m-row). Compared to untreated seed, the high rate of Cruiser, Prosper FX, Helix and Helix XTra improved the biomass of op canola in summer fallow by 40-55% in 2010 and by 28-39% in 2010-2012. The high rate of Cruiser, Prosper FX and Helix XTra improved the biomass of op canola in wheat stubble by 37-75% in 2010. Neonicotinoid seed treatments had no effect on the biomass of op canola in wheat stubble in 2011, 2012 and 2010-2012.

Neonicotinoid seed treatments had little effect on the seed yield of op canola in summer fallow and wheat stubble (APPENDIX Elliott Table 15). In 2010, 2011 and 2012, yields of op canola averaged 172, 339 and 204 g/m^2, respectively, in summer fallow and 236, 234 and 210 g/m^2, respectively, in wheat stubble. Yields over three test years were 5% higher in summer fallow (238.1 g/m^2) than in wheat stubble (227 g/m^2). Compared to untreated seed, the low rate of Cruiser and Helix improved the yield of op canola in summer fallow by 15-20% in 2010. The high rate of Cruiser, Helix and Helix XTra improved the yield of op canola in summer fallow by 6-7% in 2010-2012. Neonicotinoid seed treatments had no effect on the yield of op canola in wheat stubble in 2010, 2011 and 2012.

Field tests in 2010-2012 suggest that cool moist conditions during germination, emergence and establishment reduced the efficacy of neonicotinoid seed treatments against flea beetles. The treatments provided limited protection against flea beetle damage after 20-22 days in summer fallow and wheat stubble. Although neonicotinoid seed treatments improved seedling establishment in most tests, the treatments had little effect on shoot growth, biomass accumulation and seed yield in most tests. In contrast, field tests in 2003-2008 indicated that neonicotinoid seed treatments provide excellent protection against flea beetle damage in warm

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dry soil. With better protection, neonicotinoid seed treatments improved stand establishment, shoot growth, biomass accumulation and yield. Consequently, field trials in 2010-2012 suggest that more effective seed treatments are needed for flea beetle control when cool moist conditions prevail after seeding. The results were described at an ISTA Workshop in Edmonton and will be submitted for publication within the next 6-8 months.

McLaren: Submit manuscript on integrated control of pea root rot. Data compilation and manuscript preparation were delayed due to the addition of another dataset to the document. It is anticipated that the manuscript will be submitted for publication in the 2013-2014 fiscal year.

Olfert: General Circulation Models were applied to bioclimatic models for a number of significant crop pest species, including grasshoppers, cereal leaf beetle, kochia and fusarium headblight, using weather data and pest biology to estimate the risk of these invasive insect pests in cereal and oilseed crops. Results indicated that all four crop pests would have increased range and relative abundance in more northern regions of North America, compared to predicted range and distribution under current climate conditions. The next phase of this activity was to apply these tools to the canola host crop – *Lygus* species – *Peristenus digoneutis* - climate ecosystem model to examine the potential of further releases of *Persitenus* spp. to manage lygus bug populations in Canada. Results showed that the southern distribution of *P. digoneutis* is expected to be limited by hot summer temperatures, whereas its northern range is limited by the number of *Lygus* host generations rather than cold stress. *Peristenus digoneutis* has the potential to occur in the southern parts of the prairie ecozone of western Canada; however, Ecoclimatic Index values in the prairies indicate mainly marginal or unfavourable conditions, which may explain why earlier releases of *P. digoneutis* for biocontrol of lygus bugs in Western Canada failed.

Soroka: New lines of crucifers were evaluated for resistance/susceptibility to flea beetle feeding. Laboratory bioassays were conducted to determine feeding levels of striped flea beetles on lines of canola with increased numbers of trichomes in order to detect differences in the feeding habits of striped *vs* crucifer flea beetles. There did not appear to be any differences in choice of preferred host; that is, hairy canola was as unpalatable to striped flea beetles as to crucifer flea beetles. Results from laboratory and field bioassays on sources of resistance/ susceptibility to flea beetles in brassicaceous lines, cultivars and species were summarized and submitted for scientific publication.

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