FINAL PROJECT REPORT
Canola Agronomic Research Program (CARP)

The Final Report should fully describe the work completed for the year and note the personnel involved. It should also note any deviations from the original plan and next and/or corrective steps as may be required if deviations are noted. The report should also provide an update on the status of the Project including forecasted date of completion. A complete statement of expenses should be included. In the event major changes are anticipated within the budget supporting notes along with a proposed budget should also be included. The report should also capture a complete summary of activity for the year.

Project Title: Validation of lygus and other insect pest thresholds in commercial farms throughout the Prairie Provinces

Research Team Information

Lead Researchers:		
Name	**Institution**	**Expertise Added**
Hector Carcamo	AAFC – Lethbridge	Insect Pest Management
Research Team Members		
Name	**Institution**	**Expertise Added**
Jennifer Otani (2016)	AAFC-Beaverlodge	Lygus biology and management
Neil Harker (2016-17)	AAFC-Lacombe	Integrated Crop Management
Breanne Tidemann	AAFC-Lacombe	Agronomy & Weed Science
Patty Reid	AAFC-Lacombe	Applied Entomology and Agronomy
Tyler Wist	AAFC-Saskatoon	Dynamic Action Thresholds
Meghan Vankosky (2018-19)	AAFC-Saskatoon	Applied Insect Ecology
Alejandro Costamagna (2016-17)	University of Manitoba	Landscape Insect Ecology & Statistics
Tharshi Nagalingam (2016-17)	University of Manitoba	Crop Entomology
John Gavloski (2016-17)	Manitoba Agriculture	Extension Entomology
Piratheepa Jegatheeswaran (2019-2020)	University of Lethbridge	Landscape Ecology
Daniel Johnson (2019-2020)	University of Lethbridge	Insect Biogeography

Project Start Date: **April 1, 2016** **Project Completion Date:** **December 31, 2020**

Reporting Period: **April 1, 2016** **to December 31, 2020**

CARP Project Number: 2016-27

Instructions: This Final Project Report shall be completed and submitted on or about March 31st of the fiscal year that the agreement is in effect (upon completion of the project). The Lead Researcher of the project in question shall complete and submit the report on behalf of his/her complete research team.

This Report is a means by which to provide a detailed account upon completion of the project.. Final project financial reporting should be provided at this time.

The following template is provided to assist you in completing this task. Please forward the completed document electronically to the CCC contact listed below.

In addition to the Final Project Report, a one page Research Abstract including rationale, objective, methodology, summary and conclusions (with a summary graph/table or supporting image for the project), acknowledgement and references is due upon completion. The Research Abstract is intended for use in publications such as the *Canola Digest* and the CCC Research Hub and is intended to support messaging to all audiences.

Acknowledgements:

This study was funded through the Canola Agronomic Research Program of the Canola Council of Canada with funds from the Alberta Canola Producers Commission and SaskCanola. Project CARP #2016.27. We are deeply grateful to the numerous canola producers that collaborated with this study and the dozens of students that collected the data. Keith Gabert of the Canola Council of Canada was a key catalyst to initiate this work and implementing the research in south central Alberta. The work could not have been possible without the excellent technical support from numerous staff at AAFC and the collaborating institutions, in particular Sheree Daniels and Randall Brandt at AAFC-Lethbridge Research and Development Centre.

1. Date of Completion:

February 10, 2021

2. Status of Activity: (please check one)

_____ Ahead of Schedule _____ On Schedule _____ Behind Schedule __X__ Completed

Comment: Agreement was amended to obtain an extension until December 2020; data analysis for the report was completed in January 2021.

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

Background:

Lygus bugs are a sporadic pest of canola at the pod stage from south western to north central Alberta (along highway 2). In the Peace Region of Northern Alberta, some growers are concerned that they pose a risk even at earlier bud and early flower stages. In Saskatchewan they are sometimes a concern in the Meadow Lake area in the northwest and also in southern Manitoba where the thresholds were originally developed. Insecticide spraying during late flower or early pod is becoming a common practice in some regions but there is no agreement on economic thresholds and limited data for the benefit of spraying at the mid pod stage. Past and current studies in Alberta support the traditional threshold of 1-2 per sweep. However in west central Alberta this threshold is considered too low; in recent years, most fields in this region exceed 2 lygus per sweep. Therefore, applying the current low threshold would result in excessive, potentially unnecessary insecticide sprays with added costs and detrimental environmental impacts on beneficial insects or spiders and pollinators like bees. In addition to lygus, other insects such as flea beetles at the seedling stage in humid sites and cabbage seedpod weevil in southern Alberta require monitoring and potential control actions. Diamondback moth and other Lepidoptera pests may become abundant in some sites and also need monitoring and potential control. All these variables need to be taken into account to explain yield differences between sprayed and unsprayed treatments in field studies.

Objectives:

1) Validate lygus economic thresholds in commercial canola fields
2) Determine the impact of spraying for other pest insects that may reach nominal economic thresholds (e.g. flea beetles in central/northern areas, and cabbage seedpod weevils in the south.

3) Document landscape features that can influence risk of lygus damage
4) Survey lygus bugs in canola in Saskatchewan and validate thresholds

Overview of work done by year and activity.

PART 1:Threshold validation

Experimental design and methodology

The design for the study to validate lygus thresholds consisted of a randomized complete block design using large plots in farmers' fields (Fig. 1). It was not feasible to include other insect pests in the validation, thus, a simpler design was adopted. The treatments allocated were unsprayed and sprayed with insecticide (Matador@34 ml/ac), which was done by the farmer using his ground sprayer (25-35 m wide). Each experimental unit (a plot) was the width of the farmer's sprayer (25-35 m wide) and 100 m long or more and the plots and replicate blocks were separated by 20-40 m.

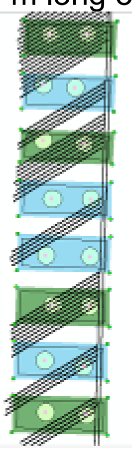


Fig. 1: Example of a field plot layout used to validate lygus threshold in a farmer's field. Lines indicate combine harvest swaths. Circles are 10 m radius where yields were extracted to relate to lygus sampled near the centre of the circle.

Sampling for lygus bugs was carried out at two points within each plot, about 25 m away from the ends of the plot and near the centre line of each plot. A sample consisted of 10 sweeps taken while walking and swinging the net along an arc of about 90-180 degrees at the early pod stage before spraying insecticide and at the mid-maturity pod stage a week after the plots were sprayed. Lygus were counted in the laboratory according to each nymphal instar and adults were sexed and identified to species. Other key pests and natural enemies were also counted to the level of order or family or species if known.

Yield was measured using the farmers' yield combine monitor or a weighing wagon and for most sites, also from manual harvesting of small quadrat samples (0.7 m x 2 rows) that could fit into a harvest sac. Arc-GIS software was used to extract yield data from the combine monitor files to coincide with a 10-20 m radius near the spot where insects were collected and quadrat yield samples were taken (Fig. 1). Dry weights with zero moisture were taken or calculated whenever possible.

Analysis of lygus abundance after spraying insecticide and average yield from quadrats, wagons or combine monitors was done using a mixed anova with treatment as a fixed factor and site, year and replicate block as random factors. Where necessary a non-parametric test had to be used if data was not normal or had heterogeneous variances. To validate the thresholds two approaches were used. First the samples were divided into categories that correspond to varying levels of lygus abundance that were considered below or above threshold, all expressed as a sample of 10 sweeps: 1) 1-10, 2)

10-20, 3) 20-30, 4) +30. For these categories yield was compared for the sprayed and unsprayed treatments (check) and the relationship between lygus abundance and yield was tested with linear regression for the samples within each category.

Summary of activities and results by year.

Threshold validation work completed in 2016.

Six canola fields were monitored for lygus bugs and flea beetles using sticky cards in southern Alberta and other regions of the Prairies as required for a related landscape study. A protocol was developed (see Appendix 1) and an experiment was attempted unsuccessfully, in Manitoba to integrate flea beetle and lygus threshold validation as described below. Survey fields were swept for lygus bugs during the flower to pod stage. Similar numbers of fields were monitored in Lacombe, Beaverlodge, Saskatoon and southern Manitoba. Through the action of collaborating agronomists and our own sampling, we monitored dozens of other fields. Lygus bugs were not abundant in all areas with the exception of two fields near Chlaresholm where the study was done and one field in Manitoba where the grower agreed to do a spray study for flea beetles although damage was modest. Near Lacombe, one field had lygus numbers near threshold and the farmer agreed to do the study but the sprayer broke and was not able to complete it.

<u>Lygus validation study in southern Alberta in 2016.</u>

Site one was dryland Invigor L252 canola seeded (on winter wheat stubble) with a 10 inch row spacing John Deer Drill on 4 May 2016 at 5.2 lb/ac in a full section farmed by the Clear Lake Hutterite Colony north east of Claresholm. This field was part of the flea beetle landscape study and was monitored regularly with a sweep net from early flower to the pod stage. At late flower, lygus averaged around to 3 per sweep (up to 6 in some places) and the farmer decided to spray the field. Therefore we delineated 4 large blocks in a relatively uniform (flat or gently rolling) area on the north side of the field. Each block had two big plots, each of 80 m wide by 200 m wide so that the grower could do two passes with his sprayer. The plots and the replicate blocks were separated by a 40 m buffer area. One of the two big plots in each replicate block was designated randomly as a control to be left unsprayed. The field was sprayed on 9 August at 9 am with Matador at 34 ml/ac with 10L water per acre. No other insecticide was applied before for weevils or other insects but the seed was treated with a neonicotinoid as a standard practice.

Site 2 was located less than 10 km south west of site one. It was irrigated RR canola planted at similar rates and in mid-May using a 10 in Josh Deer row drill on wheat stubble. Three replicate blocks were set up using the same dimensions as those in site one. Block (replicate) 1 was on the south west corner with the 200 m long side parallel to the south edge of the field but reps 2 and 3 were at a right angle near the centre of the field along the south edge. The fourth replicate block was only 100 m long and 40 m wide and located at an angle near the north west corner of the pivot area. This was necessary because of low wet spots in other regions that prevented a complete block of two plots to be accommodated. This layout caused problems both to spray and to extract the data using our records of GPS points and should be avoided in the future.

<u>Flea beetle farm level study in 2016</u>.

One site in southern Manitoba was set up and labelled the “Edgar” site. Four plots were used in the canola field soon after planting as per the protocol in appendix A (in the end only half the plots were used because lygus were low). The plots were 36.5 m wide by 100 m long. The plots identified for flea beetle spray treatments were sprayed on 24 May with Matador at the recommended label rate of 34 ml/ac. A sticky yellow card was placed in the middle of each plot and replaced weekly. Foliage damage was assessed from 40 seedlings by selecting two transects of 20 plants per plot at the front and back end of each plot. Also, seedling survivorship from the first to the second leaf stage was determined in a fixed quadrat (0.25 square meter) in each plot. Lygus bugs were swept (10, 180 degree sweeps per plot) at the flower stage and the pod stage (5.2). Lygus were too low to spray. At harvest time a 0.25 m.s. quadrat was taken from both ends of each plot and yields were also collected from the whole plot by the grower using a weigh wagon.

<u>Results, recommendations and preliminary conclusions from the 2016 data</u>.

At the southern Alberta sites, Lygus bugs were just over the new threshold of 3 per sweep at site one (Clear Lake, 3.1 per sweep) and just under threshold at site 2 (Lamb farms, 2.6 per sweep). After spraying there were zero or near zero lygus in the sprayed plots as expected at both sites.

Yields were not statistically significant, but the trends (Figure 2) are in line with the lygus abundance. At site one where lygus were over threshold, sprayed plots had an average of 1.7 more bushels per acre than the control plots not sprayed. At site two there was a similar pattern, but the difference was only 0.7 bushels per acre.

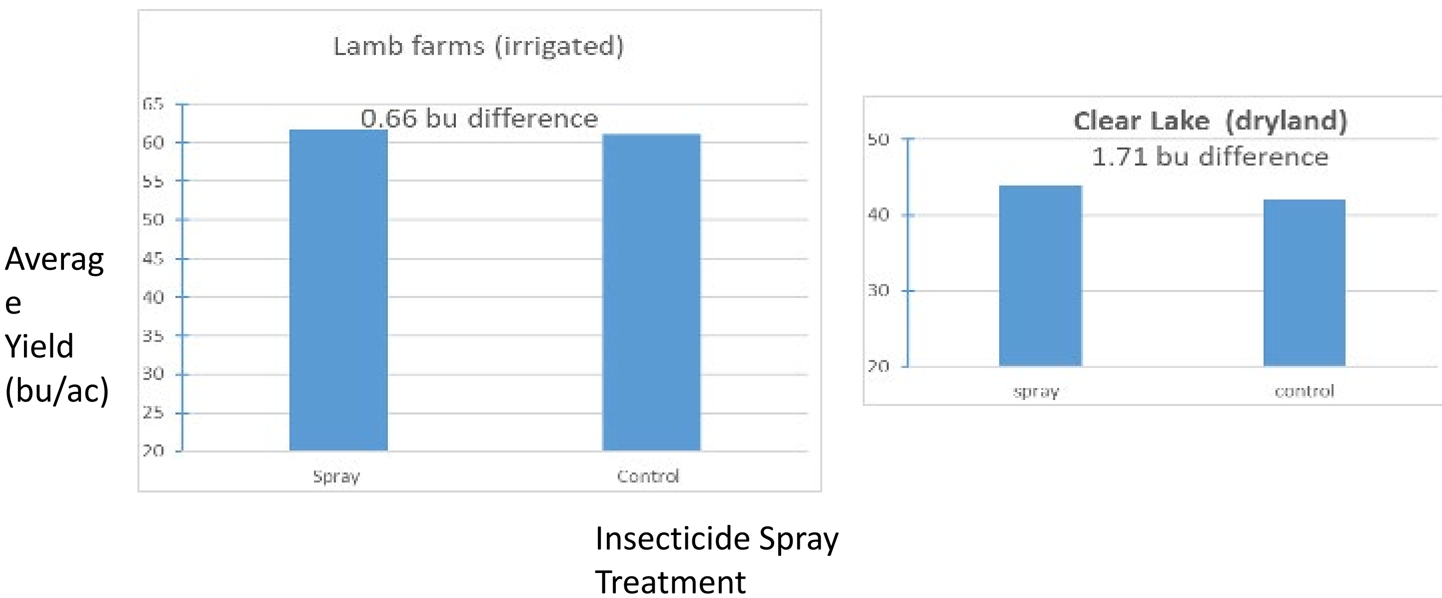


Figure 2: Canola yield at two farms near Chlaresholm in 2016

For the flea beetle study in southern Manitoba, foliage damage was well below the 25% nominal threshold (Figure 3).

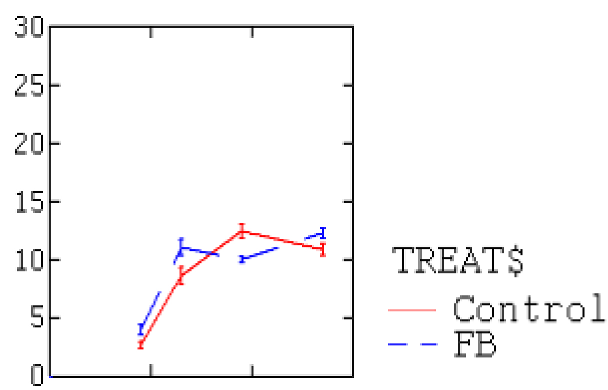
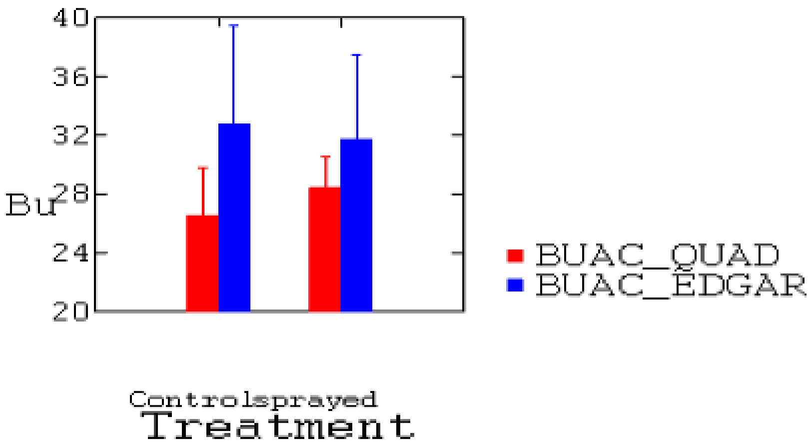


Fig. 3: Flea beetle damage on cotyledons at Edgar's field, 2016 in southern Manitoba from 20 May to 6 June 2016

Yields estimated from quadrats or provided by the grower were not different in the control and sprayed plots (Figure 4).



The conclusion from these preliminary results for lygus is that the farm scale data from these two fields is consistent with the economic thresholds developed from cages and plots so far. It appears that 3 per sweep is the correct value at this point for the conditions in this region of Alberta and consistent with a cage study also funded by CARP and the Pest Management Centre of AAFC from 2012 to 2015 (**2013F060R Final Report submitted 12.Dec.16)**. For flea beetles no yield losses were expected given the low levels of damage and that was confirmed despite the low level of replication.

1.2 Threshold work completed in 2017

The farm studies were conducted at 3 fields in southern Alberta and 3 fields in central Alberta in the Lacombe region. Yields were obtained from the combine yield monitor in southern Alberta or with a weigh-wagon in central Alberta. Quadrat samples were also collected at each field.
In Saskatchewan, seven canola fields that spanned the majority of the soil zones in Saskatchewan were monitored weekly with sweep net and yellow sticky card sampling for development of Lygus populations. This was similar to the work done in 2016 when lygus also had low abundance. Agronomists serving these growers and several growers near Saskatoon were asked to participate in the Lygus spray study in the growing season of 2017 if Lygus numbers in fields reached the economic threshold of 2 Lygus bugs per sweep. Lygus bugs were scarce in the weekly surveyed fields and populations levels were never in danger of reaching the economic thresholds.
In Manitoba, 4 larger plot experiments were set up in growers' fields for the farm level study but unfortunately, the lygus numbers were low so that none of them got treated. Researchers monitored the lygus bug numbers in all these fields using sweep nets in the flower, early and mid-pod stage. Also, the lygus bug numbers were monitored in another 3 fields in which they set up sticky cards for flea beetle related studies. Altogether, 7 fields were monitored for lygus bugs during the season. Further, we also monitored for diamond back moth late in the season but we found very few numbers.

Details of experiments completed in 2017:

Study sites and lygus abundance
The six study sites where the lygus threshold validation study was completed are described in Table 1

(appended xl file). In the south, the sites were located around 60-80 km north west of Lethbridge in the Carmangay and Chlaresholm area. The fields were planted between the 6-12 of May to either a Liberty Link or a Round Up Ready cultivar. The abundance of lygus bugs was variable within the fields. The species in the south were mainly *L. keltoni* (red color) with *L. elisus* less common (Fig. 5).

Fig. 5: Photo of *Lygus keltoni* (top) and *L. elisus* on a canola plant near Lethbridge. By Dan Johnson.

In central Alberta. *L. lineolaris* was dominant at one of the sites, but at the other two, *L. keltoni* was dominant or co-dominant. At one field in the south (Clear Lake), lygus were around 22 per 10 sweeps (a sample=10 sweeps) at the early pod stage. At the other two fields, lygus averaged 15-18 per 10 sweeps per field during the pod stage. These numbers are considered moderate, but some growers may have sprayed them if they followed the old threshold of 10-15 per 10 sweeps or the new threshold of 20 per 10 sweeps at Clear Lake. At the sites in Central Alberta, the averages in the 3 fields were around 15 (Bowden), 40 (Rimbey) and 80 (Airdrie) per 10 sweeps.

Yield results

Of the six sites, only two (Clear Lake and Airdrie) had numerically higher yields in the sprayed plots than in the unsprayed and the differences were not statistically significant (Figures 5 and 6). In four of the fields the unsprayed plots had around 200 kg/ha more yield than those unsprayed, but the differences were significant only at the site near Carmangay and only for the combine monitor yield data. At this site the plots not sprayed with insecticide had 262 kg/ha more seed yield than those sprayed at the pod stage.

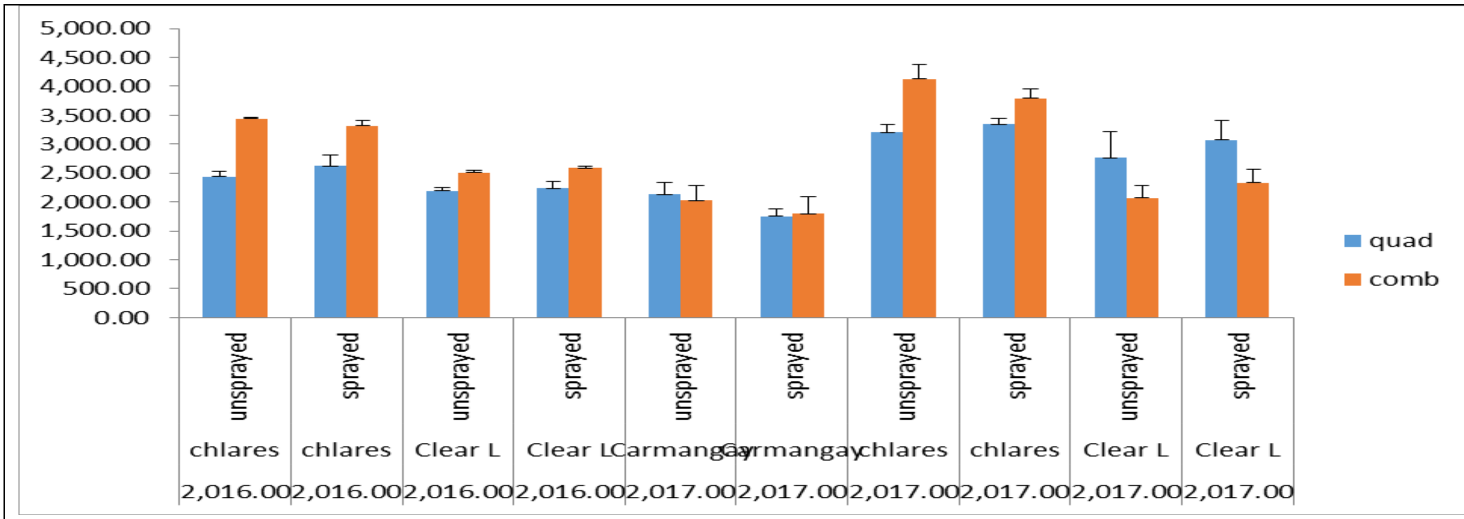


Fig. 6: Yield(kg/ha) for 2016 and 2017 at all study sites in southern Alberta from quadrats or combine. Yields estimated for each strip from the combine yield monitor or using a weigh wagon were regressed against the yield estimates obtained from 4 small quadrat (0.36 m2) samples cut from two spots in each strip (big plot). Interestingly, although the predictive power was modest (0.3-0.4 R square values), the regression was significant ($p<0.05$) for the two regions when all the sites were combined per region. In general, based on statistically significant differences, the same conclusions would be reached regarding lygus effects on yield using either method. In central Alberta, there were no significant yield differences between sprayed or unsprayed treatments.At Bowden, the farmer sprayed plots early for flea beetles and late for lygus, but there were no significant differences in yield (Fig. 7).

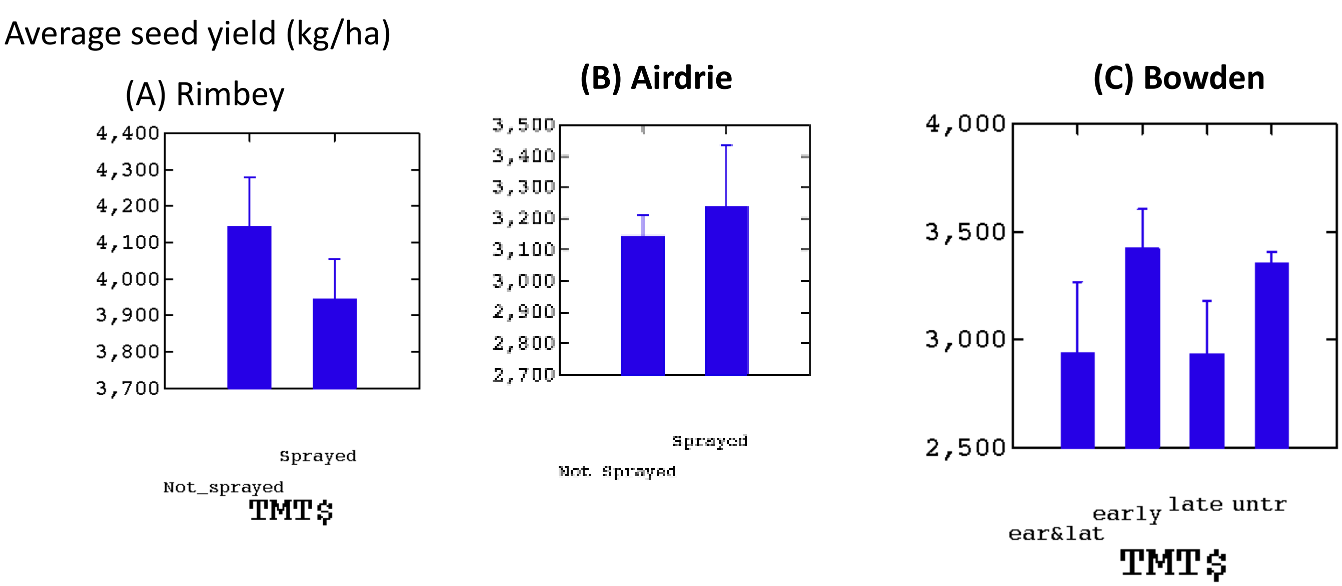


Fig.7: Yields at canola sites in south central Alberta in 2017

1.3 Threshold work completed in 2018

Fort Vermillion (Mackenzie Applied Research Association)

MARA staff conducted the study at three sites designated B, G, and K in the Fort Vermillion area. Eight long strips, 9 m wide and 500 m to 3,000 m long, were established in each field at full flower.

They sampled lygus bugs by collecting 2 samples of 10 sweeps near the middle of each strip. Half the strips were sprayed with Decis one day after sampling (July 9 or 10) and re-swept within one week. The strips were swathed and combined with the farmers' equipment; yield weights were collected with a weigh wagon. Lygus were sampled too early to determine thresholds and were generally low as it is often the case at full flower (average of 5-7 per 10 sweeps). After spraying, lygus abundances were only slightly lower in the sprayed strips than in those not sprayed, which may result from spraying too early. The lygus stages need to be determined to help explain this pattern. It is possible that on the day of sampling the population was represented by old adults and most of the new summer generation were still at the egg stage; a week later new nymphs may have been in the samples collected post spray. Also the strips were too narrow, only 9 meters in these fields and lygus from the adjacent unsprayed areas migrated to the sprayed narrow strips. Other explanations are also possible but less likely. For example the spraying was done incorrectly (low rates), or if it rained immediately after (need to get weather data), or the insects have developed resistance to insecticides. The last hypothesis is unlikely because there is no history of intensive insecticide spraying against insects in the area. There were no significant differences in yields between the two treatments at any field (Figure 8), but two of the fields had an average around 2 and 4 bushels higher in the sprayed than in the untreated areas. There were no other potential insect pests reported in the sweep samples to explain these trends; for example diamond back moth larvae were extremely low (around 2-3 per 10 sweeps). One would expect 10 times these numbers to be concerned about this pest.

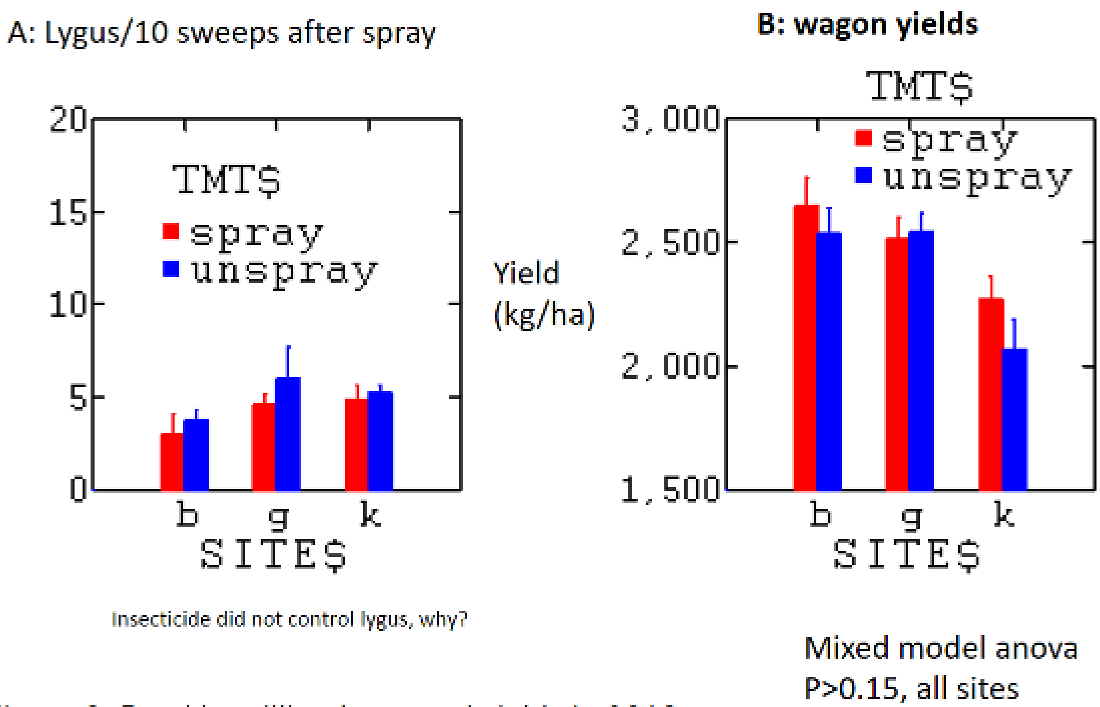


Figure 8: Fort Vermillion lygus and yields in 2018

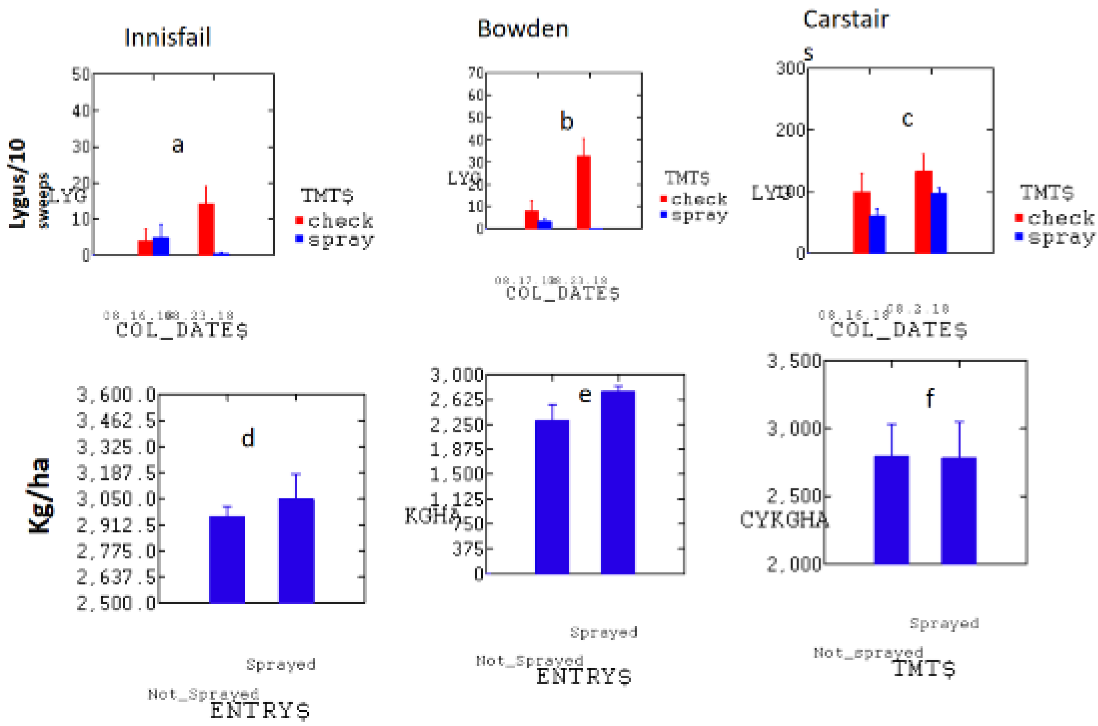


Figure 9: Lacombe 2018 lygus and yield

Lacombe region (Patty Reid and Keith Gabert)

Our team in south central Alberta conducted the study at three fields near Innisfail, Carstairs and Bowden. These three fields had an ideal gradient of lygus abundances: just below the old threshold around 1 per sweep at Innisfail, just over 3 per sweep at Bowden, and extremely high abundance around over 5 per sweep near Carstairs (Figs 9a-c). After spraying Matador by air on 8 August, the Carstair site still had very large number of lygus around 7 per sweep (over twice the new threshold of 2 per sweep). The reason for the failure of the application to provide better control is unknown, but it is worth checking for resistance because this area has had history of lygus problems and the populations may have been exposed to repeated insecticide spraying. At the other two sites, lygus were reduced to near zero as expected by the insecticide spraying and yields were numerically higher in the sprayed plots (Figures 9 d and e) although not significantly different. At the Carstairs site, yields were very similar between the sprayed and unsprayed treatments (Figure 9f).

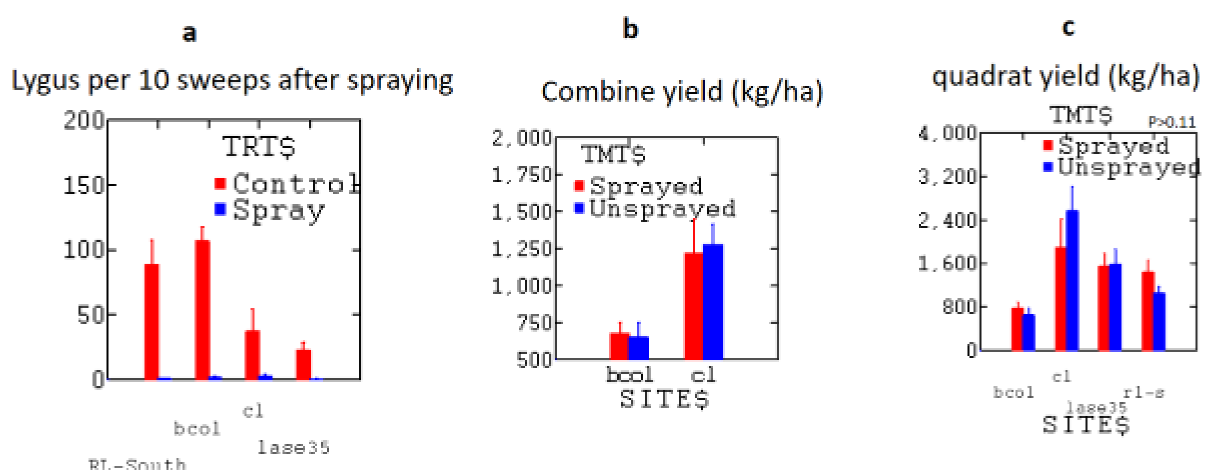


Figure 10: 2018 Lethbridge sites – lygus (a) and combine (b) and quadrat (c) yields

Lethbridge region (Carcamo, Daniels and Brandt)

After surveying around 20 fields in southern Alberta at the end of flower (from Stirling, to Lomont and Chlaresholm areas), we set up 4 canola fields where lygus were around or over the threshold of 2 per sweep. Two fields were located ca. 20 km east of Chlaresholm and about 2 km from each other in a very long field. Despite the proximity, the southern location in this long field had around 100 lygus per 10 sweeps and the northern around 10-20 per 10 sweeps (Fields RL-south and lase35, Figure 10). The third field was part of the Clear Lake Hutterite Colony about 20 km north of the previous sites and had lygus abundances around 30 per 10 sweeps (around or just over the new threshold for the region). The fourth field was volunteered just before the farmer sprayed at the Brant Hutterite Colony south of High River and around 60 km north of Chlaresholm. This field had the highest numbers, but it was very patchy due to drought stress; the dry stunted patches had 100-200 lygus per 10 sweeps and the thick healthy patches only around 50 lygus per 10 sweeps (Figure 10a). The insecticide spray with Decis successfully controlled lygus to near zero at the early pod stage in all fields. Despite abundances around or past thresholds, the yields were not significantly different between the sprayed and unsprayed strips in any of the fields (Figure 10b and 10c). Combine yield monitor data was only used from the Clear Lake and Brandt sites because the readings were too sparse from the fields east of Chlaresholm. This may be related to the age of the equipment. Quadrat yield samples appear to agree with combine yields for the two sites. The numerical patterns, though not significant are worth discussing with caution. The two sites where lygus were 2-3 per sweep had very similar yields or the yield was higher in the untreated strips than those sprayed with insecticide. Despite very high counts over 10 per sweep at the Brandt site, the yields based on the combine monitor were only about half a bushel higher in the sprayed than in the treated strips. The estimates from the quadrats are expected to be less accurate and according to these, the difference was around 2 bushels higher in the sprayed vs unsprayed plots. For the RL-south site near Chlaresholm only quadrat data was used and it suggested a very large numerical difference in favour of the sprayed strips over the unsprayed strips of around 7 bushels. This value seems too high. At the Clear Lake site, for the second year in a row, yield was numerically higher by about 1 bu/ac in the unsprayed strips than those unsprayed.

Updated summary for 2018:
A total of 18 farm site-years have been completed from 2016 to 2018. The results so far, support the idea that the previous threshold of 1 lygus per sweep was too low. In 2018 one site near Brandt (about 30 km SE of High River) had almost 10 lygus per sweep and there was less than half a bushel increase in the strips that were sprayed with Decis over those left unsprayed. These differences were not statistically different as the error bars overlapped. Severe drought at some sites such as Brandt may have masked insect pest effects on yield. As observed in past years, in some fields there was a slight yield depression when the strips were sprayed. This may result from trampling at the pod stage and other unknown biological or abiotic costs of spraying. We do not have data to explain these unexpected results (for example activity of natural enemies

1.4 Threshold validation work completed in 2019.

Lethbridge region (Cárcamo, Daniels and Brandt)

Twelve fields were selected in southern Alberta to monitor lygus and other insects. At these fields we also set up weather stations to measure rainfall and temperature. Two fields were located near Magrath, about 50 km southwest of Lethbridge and the other 10 were located near Carmangay (5), Chlaresholm (1) and Brandt (4), about 40 to 130 km northwest of Lethbridge. These fields were sampled from early flower to pod maturity (mid-June to mid-August). From these fields, only one field in the Brandt area and another near Carmangay had lygus bugs near or above economic thresholds to complete a meaningful test. However, through our network of growers and agronomists, we found two other fields (Nanton and Brandt) where the growers had decided to spray against lygus and they were willing to leave check strips. At 3 of these fields (br31[east and west], Nanton [naNW, naSe], and Carmangay [CarE, CarW]) we set up 2 tests at opposite sides or corners of each field, so that 7 tests were completed (Fig. 11)

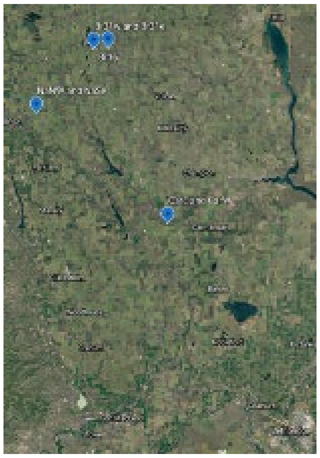


Figure 11: Location of the 4 fields where 7 tests were set up in 2019.

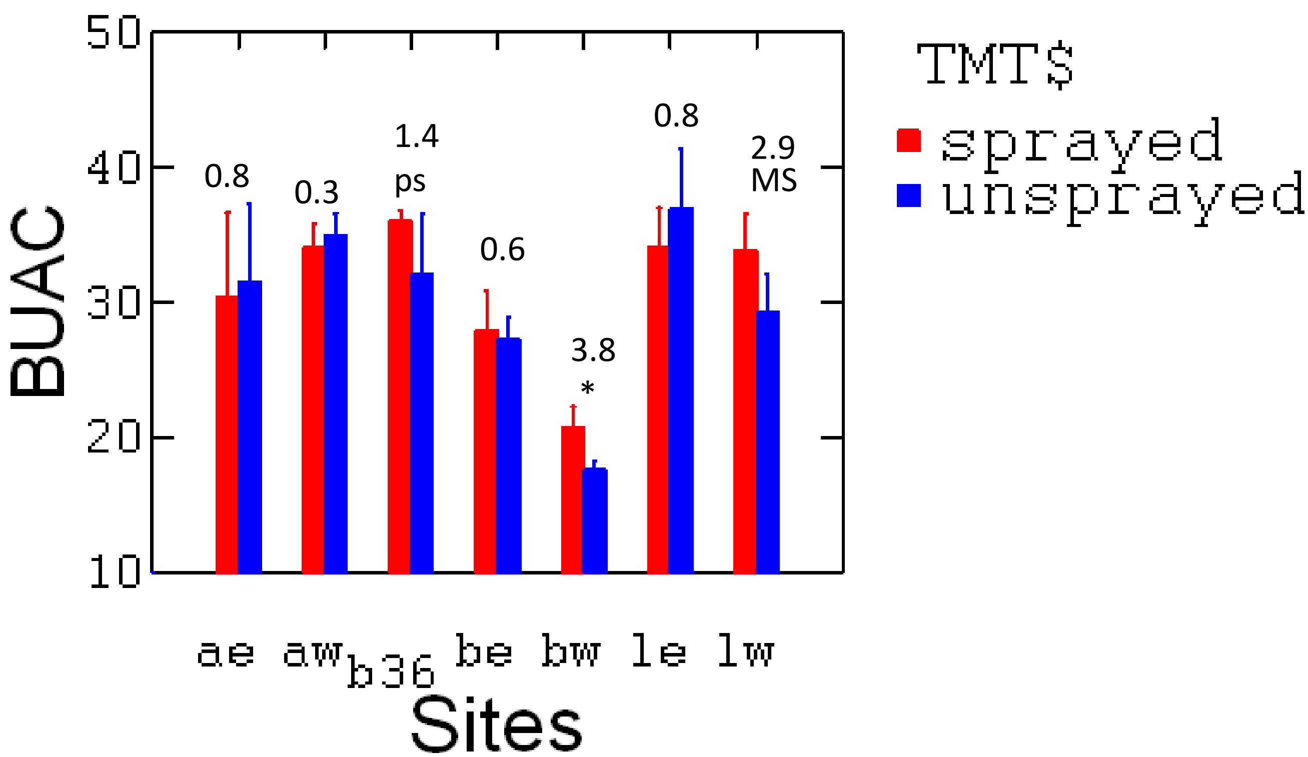


Figure 12: Canola yield (bushels per acre) at the 7 insecticide spray sites (4 farms, 2 sites in 3 of the farms) where lygus approached or surpassed abundance of 0.5, 1, 2 or 3 per sweep. * and MS denote differences that were statistically different at p = 0.03 and p = 0.10, respectively. Numbers on top of the bars denote the average number of lygus caught per sweep from 16, 10-sweep samples (2 per plot) before spraying, unless otherwise noted. “ps” denotes sweep sampling about 1 week after insecticide was sprayed (post-spray).

The number of lygus per sweep at early pod were variable within each farm and also varied with sampling day. Some had a few spots where lygus were close to the old threshold of 1 lygus per sweep when the fields were scouted at late flower and selected for the study. However, after the 8 plots were set up and each plot was sampled at two spots, the average number of lygus was closer to 0.5 lygus per sweep in two fields and just under 1 per sweep in two other fields. One of the fields near Brandt had almost 4 lygus per sweep on the west corner, but only 0.6 lygus per sweep on the east side of the same field. The field near Nanton had 2.9 lygus per sweep at the NW corner of the field. There was one field near Brandt where lygus were close to the old threshold at 1.4 per sweep. Only the field near Brandt that had almost 4 lygus per sweep had significantly more yield (3 bushels) in the sprayed plots than those unsprayed (Fig 12, p = 0.03). The field with almost 3 lygus per sweep also had marginally significant differences: there were about 4 more bushels in the sprayed than unsprayed plots (p = 0.10 Mixed model ANOVA). For the sites where lygus were 1 or less per sweep, the yields were similar or slightly higher in the unsprayed than in the sprayed plots and the differences were not statistically different.

Lacombe region (Reid, Gabert and Tidemann)

Several fields were scouted in the Lacombe area (by K. Gabert), but only two fields had enough lygus bugs at the early pod stage: near Carstairs (4.7/sweep) and Crossfield (1.5/sweep). The yields at the Crossfield site were very similar between the two treatments for the manual quadrat samples or the combine harvest using a weigh wagon (71.1 and 71.5 bu/ac in the unsprayed and sprayed plots, respectively, Figure 13). At the site near Carstairs where lygus were over threshold (almost 5 per sweep, Figure 4), combine yields were not significantly different, but there were about 2 bu/ac more in the unsprayed than in the sprayed plots (Fig 4b, 77 vs 75 bu/ac). The yield difference was much higher for the manual quadrat samples: 80 bu/ac in the sprayed vs 95 bu/ac in the unsprayed (Fig 13a, p = 0.06).

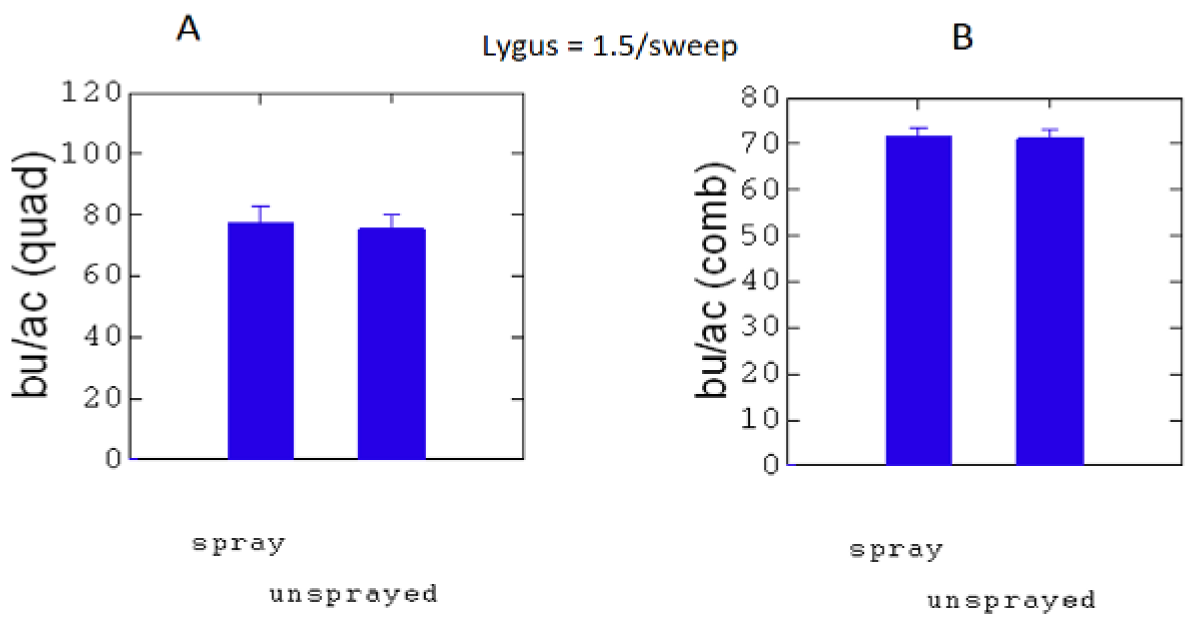


Figure 13. Yields from quadrat samples (3A) and combine (3B) with weigh wagon from a canola field near Crossfield. Yields were not significantly different, Mixed model anova P > 0.05.

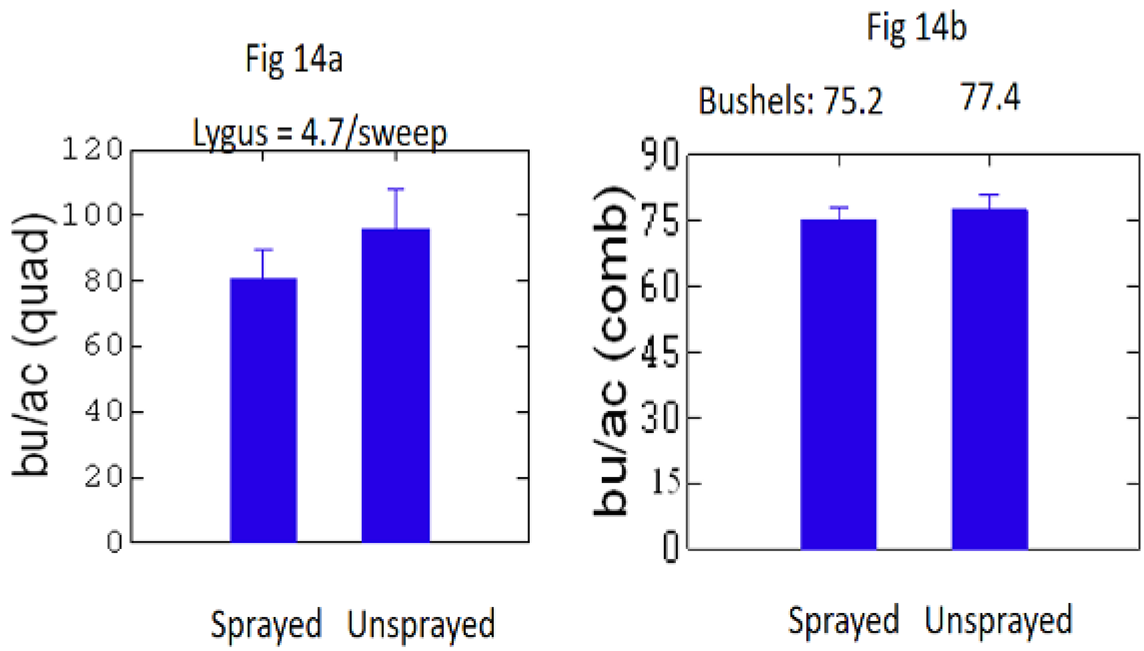


Figure 14. Yields from a canola field near Carstairs estimated from quadrat samples (4A) and combine (4B) were not significantly different, but were numerically higher in the unsprayed than sprayed plots at Carstairs. Lygus were over threshold (4.7 per sweep). For quadrat yields, $p = 0.06$ Mixed model anova.

Fort Vermillion region (Mackenzie Applied Research Association MARA, Samuel Peprah)

Three grower fields (Figure 15), in collaboration with MARA, were sprayed in the Peace River area near Fort Vermillion around 6-11 August when the crop was at early pod. They scouted 5 fields and selected these 3. Lygus were very low at these fields: only 1-2 in 10 sweeps (0.2/sweep) before and after spraying them with the insecticide and yields were not affected by the treatment. These fields also received an insecticide application for bertha armyworm earlier (19-21 July at flower) which would have confounded the study. Preselection of canola fields is not suitable for insect studies because the insects may not reach the required abundance in the few selected fields. This was explained to the collaborators (Fort Vermillion and Saskatchewan) and the need for scouting several fields, up to 20.

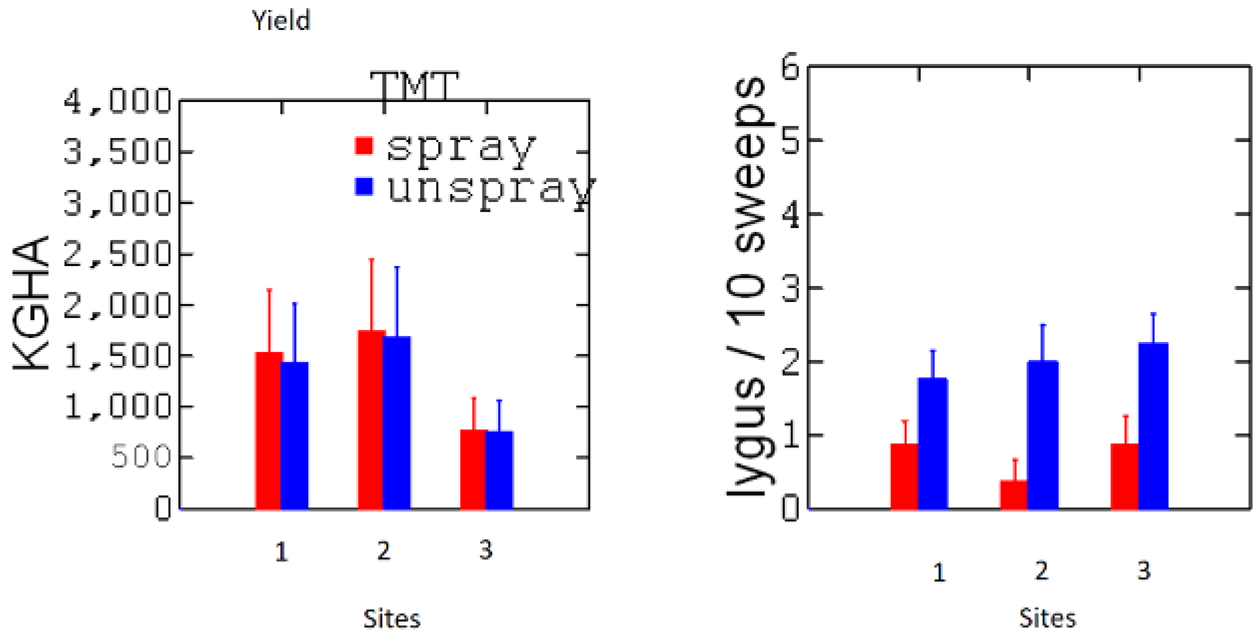


Figure 15. Canola yield and lygus at the Fort Vermillion sites, MARA in 2019, sprayed at early pod (6 to 11 August)

Saskatoon region (Tyler Wist and Meghan Vankosky)

The study could not be completed due to lack of canola fields with enough lygus. Data on their scouting efforts with lygus abundance and landscape documentation is included in a separate section below.

Updated summary as of 2019:
A total of 28 farm site-years have been completed from 2016 to 2019. The results so far despite large variability, support the idea that the previous threshold of 1 lygus per sweep was too low. In 2018 one site near Brandt (about 30 km SE of High River) had almost 10 lygus per sweep and there was less than half a bushel increase in the strips that were sprayed with Decis over those left unsprayed. Unfortunately the field also had a major drought problem. In 2019 at Lacombe a site with 5 lygus per sweep had more yield in the unsprayed than sprayed areas. The cultivar in this case was a very high yielding shatter resistant line. The differences generally are not statistically different because of high variability and the low replication possible (N=4). Severe drought at some sites such as Brandt and the Peace region as well as bertha armyworm issues may have masked lygus pest effects on yield. As observed in past years, in some fields there was a non-statistically significant yield depression when the strips were sprayed. This may result from trampling at the pod stage and other unknown biological or abiotic costs of spraying. We do not have data to explain these unexpected results (for example activity of natural enemies or other beneficials)

1.5 Combined results over years (2016 – 2019) and analysis of a related data set from 2010-2013

In this section we analyze all the data for all the years for the “new study” (2016 – 2019) and revisit data from a previous field study (“old study”, 2010-2013) designed to determine the effect of spraying insecticide to manage cabbage seedpod weevil at early flower on lygus abundance at the pod stage. For the latter Old study, there were far more sites studied and many had very high numbers of lygus bugs at the pod stage despite having been sprayed for weevils at early flower.

Summary of the methodology for the Old study.

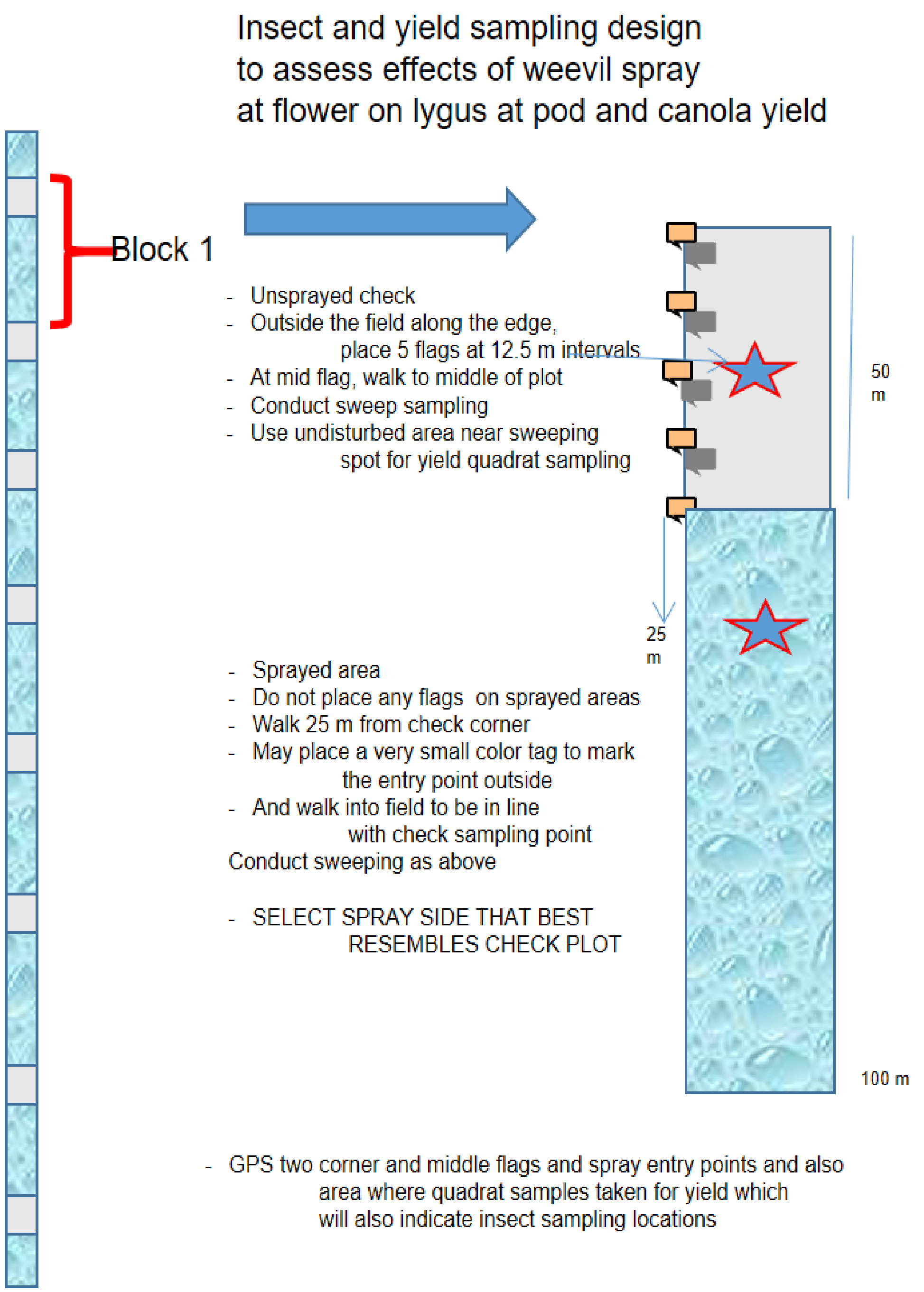


Fig. 16: Field layout for the "old study" 2010-2013 (N =73 sites)

The field layout most commonly used in the old study is shown on figure 16. Entire fields or a border as wide as the sprayer were treated with insecticide at early flower to manage cabbage seedpod weevil, except for 4 to 8 check plots that were flagged to remind the sprayer operator to turn off the nozzles. The check plots were 50 to 100 m long and also the width of the sprayer (25-35 m). Ten sweeps were taken in the middle of the 50 m plots or 2 samples of 10 sweeps if they were 100 m in both the check and sprayed areas. Yields were estimated from four quadrat samples (each 0.25 m.s.) from each position where a sweep sample was taken. Statistical analysis was similar to the new study described above and more details can be found in Carcamo et al 2018. The majority of these fields were planted early (late April) or at normal times (early to mid May), but enough were planted late after the second week of May, which increases the risk to lygus damage. To investigate lygus effects on yield and its relationship to validate a threshold, we divided the fields into various categories of lygus abundance. Lygus bugs can be highly mobile, plus populations can explode within a field depending on local weather or landscape conditions. Thus, it is reasonable to consider lygus impacts on canola yield even when the fields have been sprayed for earlier pests, such as the cabbage seedpod weevil or flea beetles.

Results and discussion.

Spraying for lygus at the pod stage did not result in overall significant yield differences in either study (Fig. 17) when the entire sample of data including all ranges of lygus abundances are included. For the New study where yields were estimated from the combine yield monitors within a 10-20m radius at two spots near the middle of each plot, there was only a numerical difference of 29 kg/ha higher in the sprayed than the unsprayed plot. For the Old study where quadrats were used to estimate yields, the difference was much higher (263 kg/ha) but the variability was also extremely high because there were fewer fields sprayed at the pod stage. For the old study done from 2010 to 2013, only the flower insecticide spraying resulted in a significant increase in yields relative to the control, which suggests that the weevil is a more serious pest than the lygus as discussed by Carcamo et al (2018).

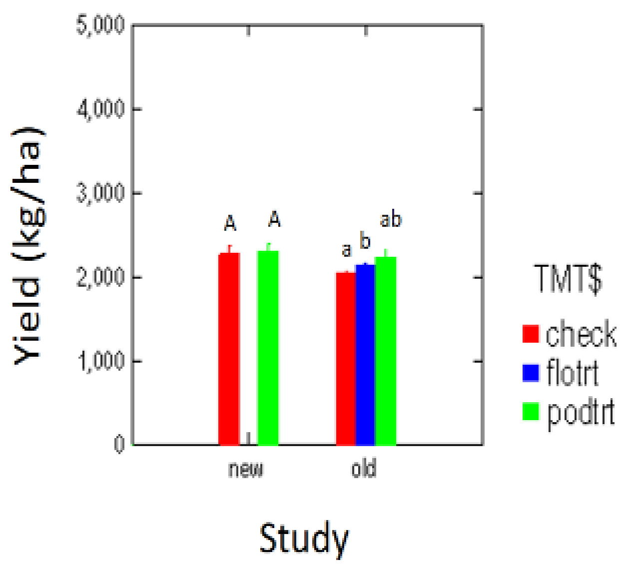


Fig. 17: Average yields (kg/ha) per subsample in two commercial canola studies sprayed for insects at flower for seedpod weevils or for lyugs at the pod stage in Alberta. Old study: 2010-2013, New: 2016-2019. Differences were statistically different only for Old Study, non parametric Kruskal Wallis test Conover-Inman pairwise comparison, p = 0.04 for checks vs flower treated plots.

A more detailed analysis of yields was conducted by selecting subsamples of plots that had various densities of lygus bugs. The four ranges of abundance per 10 sweeps tested were: 1-10, 10-20, 20-30 and +30. The only significant difference occurred in the New study (Fig. 18) at the lowest abundance (1-10 lygus per 10 sweeps) where yields were higher in the unsprayed plots than in those sprayed. At higher lygus abundance of greater than 1 or 3 per sweep, yields were numerically higher in the sprayed plots but the differences were not statistically significant in either study (Fig 18). This type of analysis is important because insect plant interactions may not be linear throughout the range of pest densities as plants may compensate or even overcompensate for herbivory (Carcamo 2012). In a cage study of individual canola plants, Jones et al (unpublished data) reported a trend of higher plant vigor at low lygus feeding pressures during early flower compared to higher densities. Our studies appear to support the concept of plant overcompensation at low lygus abundances. Interestingly, given high canola prices in early 2021 and linear regression analysis presented next, the thresholds could deep well below 1 per sweep, but farmers may be reducing yields by spraying at such low levels of lygus abundance.

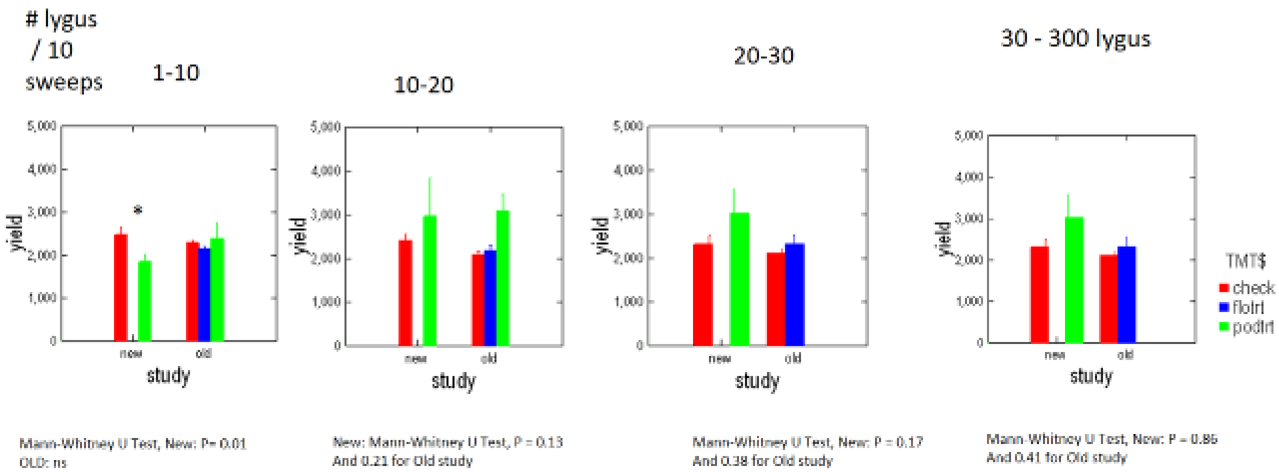
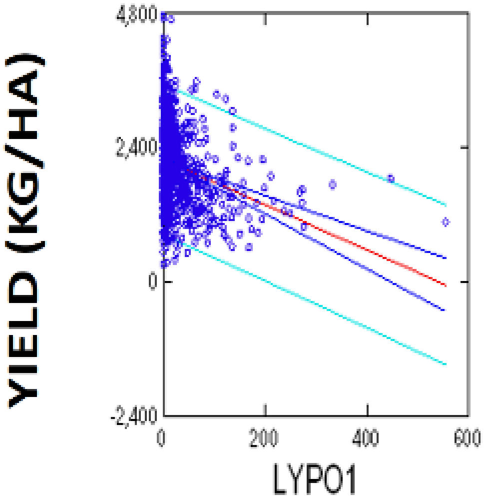


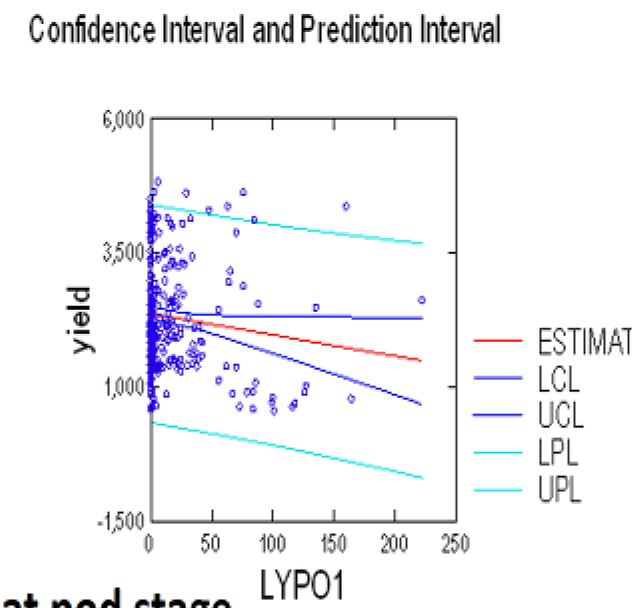
Fig. 18: Validation of lygus thresholds through yield comparisons using a stepwise approach with varying lygus pressure

Regression analysis followed a similar strategy to the one used above to compare yield differences. First, all the sites were included in the Old and New studies separately and both suggested a very weak relationship between lygus bugs at the early pod stage and canola yield (Fig 19); this implies that other factors are far more important for canola yield than lygus bugs. Nevertheless, the relationship was significant because of the large sample size and an Economic Injury Level could be calculated with the significant slope coefficients (-b). Using recent average canola prices for 2020 of $617.44 per ton, the EIL's would be 8.9 and 9.1 lygus per 10 sweeps for the old and new studies respectively, which is essentially the same ET as the one suggested about 10 years ago by entomologists and agronomists. Based on results from a cage study completed in 2015 at 3 sites in Alberta (Beaverlodge, Lacombe and Lethbridge), we suggested that the ET should be 2-3 lygus per sweep. According to some (at least one) agronomists this ET is still too low because in some regions in South Central Alberta (Red Deer area) some growers do not spray until they have over 5 lygus per sweep. Thus, to further refine the validation of an economic threshold, we conducted a more detailed analysis dividing the numerous samples into ranges of lygus abundances.

Old study, EIL: 8.9/10 sweeps



New study, EIL: 9.1/10 sweeps



Lygus / 10 sweeps at pod stage

```
▼OLS Regression

Results for STUDYS = old

84 case(s) are deleted due to missing data.

Dependent Variable          : BESTYLD
N                           : 1,154
Multiple R                  : 0.25
Squared Multiple R          : 0.06
Adjusted Squared Multiple R : 0.06
Standard Error of Estimate  : 689.29

Regression Coefficients B = (X'X)^-1X'Y

         |                                    Std.
Effect   | Coefficient   Standard Error   Coefficient   Tolerance        t   p-Value
---------+--------------------------------------------------------------------------
CONSTANT |    2,187.76            22.78          0.00           .    96.05      0.00
LYPO1    |       -4.04             0.46         -0.25        1.00    -8.81      0.00

Analysis of Variance

Source     |        SS      df   Mean Squares   F-Ratio   p-Value
-----------+------------------------------------------------------
Regression | 3.69E+007       1      3.69E+007     77.66      0.00
Residual   | 5.47E+008   1,152     475,118.42
```

```
Results for study = new

1,114 case(s) are deleted due to missing data.

Dependent Variable          : yield
N                           : 278
Multiple R                  : 0.12
Squared Multiple R          : 0.01
Adjusted Squared Multiple R : 0.01
Standard Error of Estimate  : 1,031.04

Regression Coefficients B = (X'X)^-1X'Y

         |                                    Std.
Effect   | Coefficient   Standard Error   Coefficient   Tolerance        t   p-Value
---------+--------------------------------------------------------------------------
CONSTANT |    2,371.29            70.16          0.00           .    33.80      0.00
LYPO1    |       -3.96             1.98         -0.12        1.00    -2.01      0.05

Analysis of Variance

Source     |           SS    df   Mean Squares   F-Ratio   p-Value
-----------+-------------------------------------------------------
Regression | 4,278,929.28     1   4,278,929.28      4.03      0.05
Residual   |    2.93E+008   276   1,063,031.52
```

Fig. 19 Regression of yield on lygus abundance at early pod for the old and new studies (using 2020 canola prices)

Figure 20 shows the results from regression analysis for the same four ranges of lygus abundance per 10 sweeps used above to compare yield means: 1-10, 10-20, 20-30 and +30 lygus. For the sites in the New Study, lygus bugs did not have a negative relationship with yield, even at the highest abundance over 30 lygus per 10 sweeps. For the Old Study, there was a significant negative relationship only at the highest abundance (3 lygus per sweep) although, the R^2 was only 0.06. Based on these results (N = 246, b = -2.28, p=0.00) and 2020 mean canola prices, the EIL (=ET) would be 15.8 (=16) lygus per 10 sweeps at the early pod stage. This value is comparable to the ET of 2/sweep estimated in the cage study reported by Carcamo et al (2015); if the same canola prices from that study were used (gain threshold of 50.03 vs 36.02) the threshold would be 21.9 lygus per 10 sweeps.

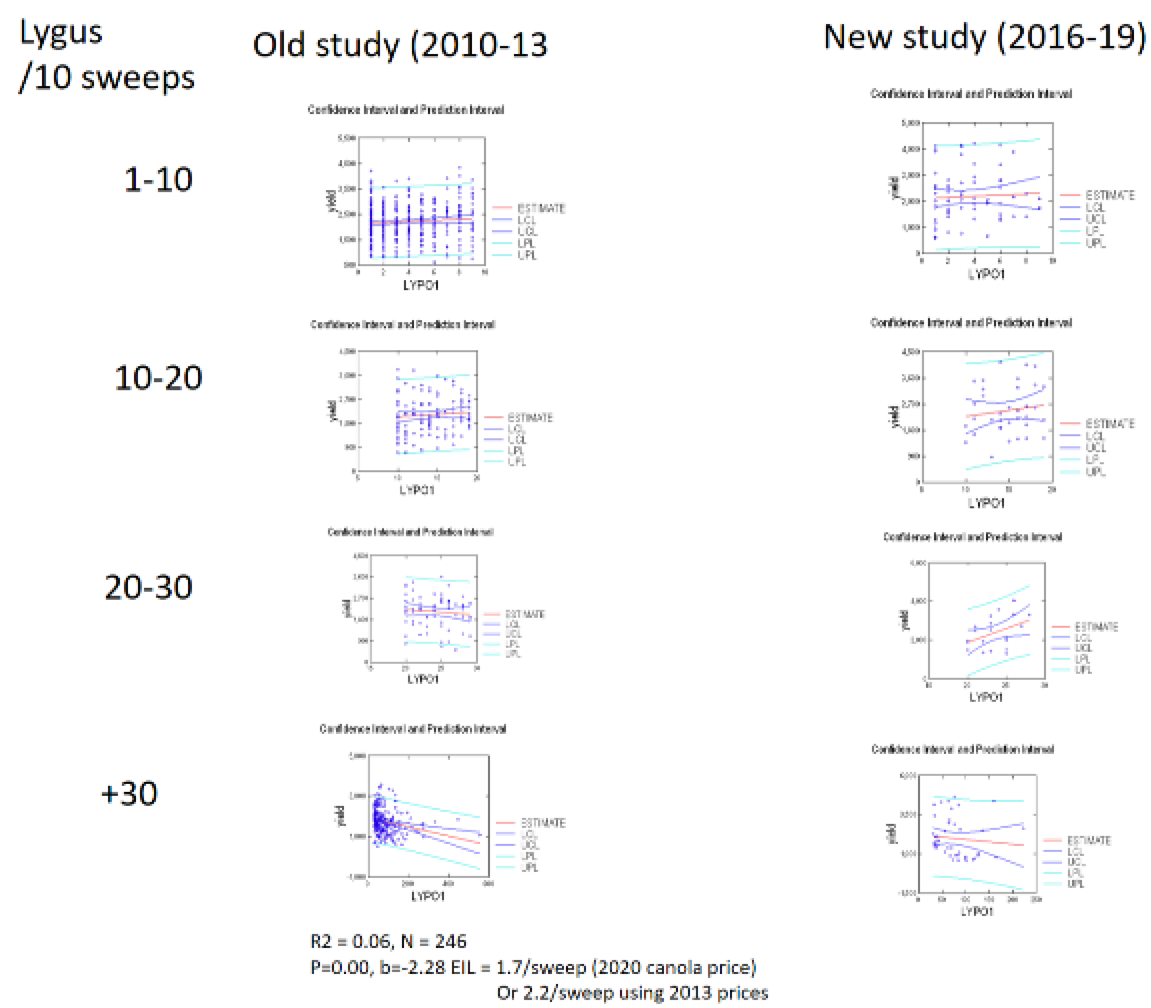


Figure 20: Regression of yield on lygus using 4 levels of lygus abundance per 10 sweeps for the Old and New studies. Only the figure for the Old study with +30 lygus/10 sweeps had a significant negative relationship but weak predictive power.

The lack of significant lygus effects on yield in the New Study compared to the Old Study is difficult to explain, but the studies differed considerable in some respects. First, in the Old Study, the main focus was finding sites that would require spraying insecticide at early flower, therefore, earlier planted sites prevailed because these tend to accumulate more weevils and fewer lygus. Still, there were enough sites planted in May that had very high numbers of lygus bugs at the end of the flower stage and pod stage. For the New Study, our focus was finding sites with risk of lygus damage so these tended to be fields planted late. One important factor that may have confounded lygus damage was drought. During 2017 and 2018 of the New Study there was severe drought with only 50 to 60 mm of total growing season rain at the study sites, which was about half of the rain that fell during 2016 and 2019. Another difference between the two studies was plant cultivars. The cultivars planted were different between the two studies and newer cultivars that may have better shatter resistant traits might be less vulnerable to lygus feeding damage. This is an area that could be researched further.

Providing a firm suggestion on a lygus threshold remains a challenge given the large variability and lack of significant relationship between lygus abundance and yield in most cases. The best evidence of effects was observed in the older data set which agreed with the previous cage study that set an ET of 2 lygus per sweep rather than the current lower threshold of 1 per sweep. In most cases it seems that even up to 3 lygus per sweep may not affect yield. Thus, similar to the suggestion made for cabbage seepod weevils, a range of 2-3 lygus per sweep can be recommended so that growers who are risk-aversed can take action at the lower range and those willing to take some risk and also increase protection of natural enemies by spraying less, can take action only when lygus are over 3 per sweep. Reducing the threshold because of increasing prices is not recommended for lygus or most pests because there is not a close strong linear relationship with most insect pests and yield throughout the range of pest abundance. For lygus, abundance below 1 per sweep may in fact stimulate yield.

Part 2: Interactions with other insects, particularly flea beetles (or diamond back moth, cabbage seedpod weevil)

Flea beetles did not damage any of the selected canola study sites in southern Alberta during the period of this study to the point of requiring foliar spraying. This is likely because the dominant species is the crucifer flea beetle and it is managed well with the seed treatments that all farmers use. The interaction with cabbage seedpod weevil was reported in another extensive study already published (Carcamo et al 2018).

Potential interactions between flea beetle damage and lygus was studied at one site in southern Manitoba. Four plots were used in the canola field soon after planting as per the protocol in appendix A. The plots were 36.5 m wide by 100 m long. The plots identified for flea beetle spray treatments were sprayed on 24 May with Matador at the recommended label rate of 34 ml/ac. A sticky yellow card was placed in the middle of each plot and replaced weekly. Foliage damage was assessed from 40 seedlings by selecting two transects of 20 plants per plot at the front and back end of each plot. Also, seedling survivorship from the first to the second leaf stage was determined in a fixed quadrat (0.25 square meter) in each plot. Lygus bugs were swept (10, 180 degree sweeps per plot) at the flower stage and the pod stage (5.2). At harvest time a 0.25 m.s. quadrat was taken from both ends of each plot and yields were also collected from the whole plot by the grower using a weigh wagon.

Interactions between lygus bugs and flea beetles may be elucidated in part from a small plot study in southern Alberta conducted between 1915 to 2020. Those studies were designed to validate flea beetle thresholds and management practices, but we have also monitored abundance of cabbage seedpod weevil and lygus bugs at the later growth stages. Another team is currently analyzing that data and results are not available at the time of writing this report.

PART 3: LANDSCAPE EFFECTS ON LYGUS BUGS

A power point presentation given at the 2020 Entomological Society of Alberta Conference is attached.

Title: Do lygus bugs response to landscape and cropping history?
Authors: Piratheepa Jegatheeswaran, Hector Carcamo, Dan Johnson, Scott Meers, James Byrne and Evan Kruiper

Introduction:
Lygus bugs are intermittent pest of many crops including canola, which are native to North America. Both nymphs and adult bugs infest canola crops when the crop produces buds, flower and pod which can lead to flower and pod abscission, and shrunken seeds (Butts and Lamb 1990; Turnock *et al*. 1995). These bugs population vary greatly and difficult to predict because of their multiple generations, species complexity, high mobility and wide host range (Wise and Lamb 1998; Carcamo *et al*. 2002). Adult bugs overwinter in tree shelters or field margins in late summer and emerge in early spring to find out suitable host plants like stink weed or flixweed. They invade into canola field when they are at bolting to early flowering stage (Wise and Lamb 1998). These bugs are mainly managed by chemical insecticides. Several natural enemies are reported against these bugs. Among those, *Peristenus* wasp was observed as causing higher nymphal mortality (Braun *et*

al. 2001). Biological control is considered as potential strategy to manage these bugs.
However, previous studies reported that pest and natural enemies abundance, and biocontrol could be affected by surrounding landscape (Chaplin-Kramer *et al*. 2011; Rusch *et al*. 2016). Lygus population was observed varying with crop components (Dorman *et al*. 2020). Higher parasitism of *Lygus lineolaris* by *P. digoneutis* was observed in fields with more open natural habitats (Grab *et al*. 2018). Further, agriculture landscape patterns are changed greatly due to crop rotation practice. Therefore, carryover effects of previous crops could influence the current insect pest population (Kheirodin *et al*. 2020). But these effects vary greatly with different pests and different landscapes. There is a need to understand the effect of landscape factors and cropping history to improve sustainable management of lygus bugs in canola.

Objectives: This study aimed to investigate the effect of surrounding landscape on the abundance of lygus bugs in canola. Further we are going to evaluate the impact of previous cropping history on the abundance of lygus in canola.

Methods:
Independent canola fields (N =49) were selected from simple (crop land with low percentage of non-crop habitats) to complex (crop land with higher percentage of non-crop habitats) from a large sample of fields that were surveyed from 2015 to 2019 as part of the field monitoring needed to find canola fields for insecticide spraying tests. In each canola field, landscape structure was estimated by conducting detail ground surveys in 4 circular sectors with a radius of 0.5km, 1km, 1.5km, and 2km. From the survey, land cover types were identified and categorized. Crop history data were obtained from an annual crop inventory of Agriculture and Agri-Food Canada in the online site: http://www.agr.gc.ca/atlas/aci. Digital maps were constructed using ARC GIS Pro to quantify the different habitats occupied in each landscape. By using these digital maps, proportion of different land covers were calculated.
Abundance of Lygus bugs was determined by sweeping with a standard sweep net (38 cm diameter with a 92 cm handle) at the mature pod stage (5.1-5.2) in each canola field. Four samples of 10 sweeps (180^0 degrees) were taken 2-5m from edge of each field and each of four samples was spaced 20m apart along the field edge. Entire sweep contents from each sample were emptied into a labelled plastic bag and stored at -20^0C in the laboratory. Later, samples were processed and number of Lygus bugs recorded.

Results and discussion

Data were analyzed by using JMP 14.1. Correlations between different land cover and lygus abundance were found. Among those, canola land cover showed a negative correlation with lygus abundance at all four scale levels. A positive linear relationship was observed with cereal cover at 500m and 1000m scales. This is consistent with the negative correlation between canola land coverand lygus. Higher land cover of cereal crops means that there is fewer acres of canola so that lygus would be concentrated at higher densities in those fewer canola fields. Lygus bug abundance was not influenced by pasture cover. Previous canola crop distance did not show any impact on current canola lygus population. The same result was obtained for previous canola cover within 5km radius. Lygus bugs are considered strong flyers and may be able to reach canola fields from long distances of several km regardless of where they developed the previous year or where they overwinter. Also, the high frequency of canola in agricultural landscapes in the prairies means that they never have to fly too far to find a canola host field.

In conclusion, lygus bugs abundance was associated negatively with surrounding canola, and suggests a dilution effect. In years with fewer canola fields, these insects which are strong flyers, can disperse a long distance to aggregate in the fewer fields. So the more canola in a region, the fewer lygus that will occur locally. There was no carry over effects of previous canola on lygus population.

PART 4: SURVEYS OF LYGUS BUGS IN SASKATCHEWAN

Validation of thresholds through insecticide spray field trials was not completed in Saskatchewan due to low lygus numbers.

In Saskatchewan, seven sites (9 canola fields, 2016) and five sites (5 canola fields, 2017) that spanned the majority of the soil zones in Saskatchewan were monitored weekly with sweep net and yellow sticky card sampling for development of Lygus populations. Agronomists serving these growers and several growers near Saskatoon were asked to participate in the Lygus spray study in the growing seasons of 2016 and 2017 if Lygus numbers in fields reached the economic threshold of two Lygus bugs per sweep. In 2016, nine Canola fields from seven sites were monitored weekly with sweep nets and the number of Lygus was enumerated by combining late-instar nymphs, and adults of *L. lineolaris, L. borealis and L. elisus.* The numbers of Lygus by date (2016) are combined by sample week and the average shown in Figure 1 with bars representing the average amount of Lygus from each of the sample days across all sites. Most of the sites had no Lygus and the average number of Lygus during the podding stage (Weeks six and seven) were 0.05 Lygus per sweep (Fig. 1). The cabbage seedpod weevil survey collects sweep data from across Saskatchewan and the Lygus bycatch was used to create Figure 2 that shows that only one RM in Saskatchewan approached the economic threshold of two Lygus per sweep.

Lygus bugs were scarce in the weekly surveyed fields and populations levels did not approach the economic thresholds in 2017. Canola fields in Rural Municipalities across Saskatchewan were surveyed when the canola was in full bloom as part of the cabbage seedpod weevil survey administered by the Prairie Pest Monitoring Network. Across Saskatchewan, no appreciable populations of Lygus bugs (close to 2 per sweep) developed in any of the surveyed canola fields except for RM 51 which did approach the economic threshold at full bloom (Fig. 3) but no growers were know in that area.

Using data on Lygus abundance from the cabbage seedpod weevil survey might not be ideal based on the different canola crop staging targets of the insects however (flowering vs. podding). In 2018 and 2019, the number of sentinel fields in Saskatchewan was expanded and the podding stages of canola were targeted for sample timing. Collaborations were in place with the growers in the event that Lygus populations approached the economic thresholds and sentinel canola fields at AAFC research farm that could be treated at near-farm scale were included for monitoring populations of Lygus weekly.

Lygus population buildup was monitored in canola (and other crops) on the AAFC SRDC research farms at Melfort, Outlook and Saskatoon (Lowe Rd. and Llewellyn Rd. farms). Lygus numbers were negligible in canola at all sites at full bloom and podding. Fields of alfalfa that were being monitored for pea aphids however, had the highest numbers of *Lygus lineolaris* compared to other crops at the same locations. The population of Lygus in alfalfa however, did not "spill over" into the canola.

We worked with two producers, one in Meadowlake and one in Blaine Lake as potential collaborators in the Lygus threshold spray experiment. None of these sampled canola fields had appreciable levels of Lygus bugs. Blaine Lake data for three fields at full bloom are shown. Meadowlake data not shown.

The three fields identified by the producer were sampled on July 19, 2018 at full bloom. At each field 4 sets of 10 180 ^{o} sweeps were taken and the number of *Lygus* were assessed. Counts were made for both the adult and nymph stages.

Table 1. Number of *Lygus* collected per 10 sweeps

Location	Lat/Long	Sample	Lygus Adult	Lygus 1-3rd Instar	Lygus 4-5th Instar
Pterofka Grid	**52.6385 -106.9325**	**1**	0	0	0
		2	0	0	0
		3	0	0	0
		4	0	0	0
Blaine Lake	**52.7507**	**1**	1	0	0

Hwy 12	**-106.8751**	**2** **3** **4**	0 0 0	0 0 0	3 0 0
Blaine Lake Range Rd 3054	**52.8562** **-106.6816**	**1** **2** **3** **4**	0 1 0 0	0 0 0 0	0 1 0 0

The Lygus population in was also assessed during the Pollen Beetle survey in 2018. The survey protocol was to sample 1 field, selected at random, from every RM along 2 transects in southern Saskatchewan. The transects were sampled from the Alberta to the Manitoba border. One sample of 25 sweeps was taken at each of the sites (n=36). Samples were frozen and processed later in the lab. The number of Lygus collected was low; 14 sites had no Lygus collected in 25 sweeps; 21 sites had a range of 1-8 Lygus collected and 1 site had 24 Lygus in 25 sweeps (Fig. 4). The site with 24 Lygus was west of Orkney along highway 18 (N 49.15528, W -107.863) (Fig. 4).

1) Landscape Mapping

Landscape mapping was carried out August 29th 2018. At each of the 3 sites a 3km radius was mapped. Crop type was recorded on a printout of the Google Satellite map and this time landscape feature such as farm yards were confirmed. Non-crop landscape features such as trees & water were determined from the satellite photo. Economic populations of Lygus were not found in any of the fields however and no spray experiment was initiated. In 2019, the number of fields observed for Lygus population build up was increased, and no economic thresholds were approached so no landscape maps were made.

In 2019, 14 grower's fields and four AAFC research farm fields were sampled at several time periods for the presence of Lygus bugs and diamondback moth larvae. The 14 grower's fields were swept at two time points representing the early-pod (1st week of August) and full-pod stage (14 days late, mid-August) of canola (Table 2). Eight transects of ten sweeps each per field were conducted at both time points. None of the Saskatchewan sentinel canola fields had Lygus populations that approached the Lygus per sweep target, so landscape analysis was not done on the 14 fields in 2019.

The four AAFC Research farm canola fields (Lowe and Llewellyn Road of the Saskatoon Farm, Melfort and Outlook) were sampled on a weekly basis over the course of the growing season in 2019 with one transect of 50 sweeps each week.

In 2019 and in 2020, two fields of Roundup-Ready, Hybrid canola were planted, one at the Lowe Road Farm and one at the Llewellyn Road farm, to survey and potentially spray for, diamondback moth and flea beetle infestations. No significant populations of Lygus or diamond back moth occurred in the AAFC fields and damage from Lygus to this neonicotinoid seed-treated field was below the action threshold of 25% damage. In these AAFC sentinel sites in 2019, four adult Lygus in total were found in 50 sweeps per sample date in canola across the four farms (Llewellyn: *Lygus lineolaris*, July 24 2019, *L. borealis*, Aug 14 2019, Melfort *L. elisus*, July 3 2019, *L. lineolaris*, July 24 2019). No diamondback moth larvae were found in these four fields in 2019.

In the growing season of 2020, the majority of work on this project was put on hold at AAFC Saskatoon due to the Covid pandemic, besides the trap cropping and population monitoring in two canola fields at the AAFC Saskatoon Research farms. In 2020, Saskatchewan AAFC projects had to meet a number of criteria for approval under the Covid19 protocols. This project was heavily based on travel, and with project travel very limited, the Lygus survey did not meet the criteria for approval at the AAFC Saskatoon Research and Development Centre (SRDC). Sentinel site monitoring in two canola fields at the two AAFC Saskatoon farm sites (within a 16 km radius of the SRDC) did occur in 2020 and weekly sweep samples are nearly complete. The numbers of Lygus and DBM were not significant in either field in 2020 (Table 3).

Table 2: The average number (±se) of Lygus late-stage nymphs and adults (all species) and diamondback moth larvae (DBML) per field from right transects of ten sweeps per field at two stages of canola development from three grower sites in Saskatchewan 2019.

Site	**Field**	**Crop stage and field**	**Mean Lygus/10 sweeps ± se**	**Mean DBML/10 sweeps ± se**
Blaine Lake	1	Early pod	0.25±0.16	7.5±1.1
	2		0.375±0.26	0.75±0.32
	3		0±0	3.75±0.99
	4		0.25±0.25	1.75±0.45
	1	Full pod	0±0	1.625±0.63
	2		0±0	0.625±0.32
	3		0±0	0.875±0.13
	4		0±0	0.5±0.19
Guernsey	1	Early pod	0.25±0.16	0.5±0.33
	2		0.375±0.26	0.125±0.13
	3		0.5±0.27	0.375±0.26
	4		0.25±0.16	0.125±0.13
	5		0.5±0.27	0.375±0.26
	1	Late pod	0±0	0.5±0.27
	2		0±0	0.25±0.16
	3		0.25±0.16	1.25±0.37
	4		0.375±0.26	2.375±0.94
	5		0±0	0.375±0.26
Alvena	1	Early pod	0.875±0.58	1±0.73
	2		0.625±0.38	0.75±0.31
	3		0.25±0.18	8.5±1.21
	4		0.5±0.35	2.25±0.34
	5		not sampled	not sampled
	1	Late pod	0.375±0.26	2.125±0.48
	2		0.125±0.13	1.125±0.48
	3		0.375±0.26	1.375±0.65
	4		0.25±1.16	0.875±0.61
	5		0±0	1.625±0.59

Table 3. The total number of Lygus adults nymphs and Diamondback moth (DBM) larvae in 50 sweeps from canola fields at the AAFC SRDC Llewelyn (Llew) and Lowe Rd farms in July 2020.

Date	**Location**	**Lygus - Adult**	**Lygus - Nymph**	**DBM-Larvae**
3-Jul-20	Llew	0	0	0
7-Jul-20	Llew	0	0	0
7-Jul-20	Lowe	0	0	0
15-Jul-20	Llew	3	0	0
15-Jul-20	Lowe	1	0	0
21-Jul-20	Llew	0	0	0
21-Jul-20	Lowe	13	0	0
28-Jul-20	Llew	4	0	3
28-Jul-20	Lowe	17	1	2

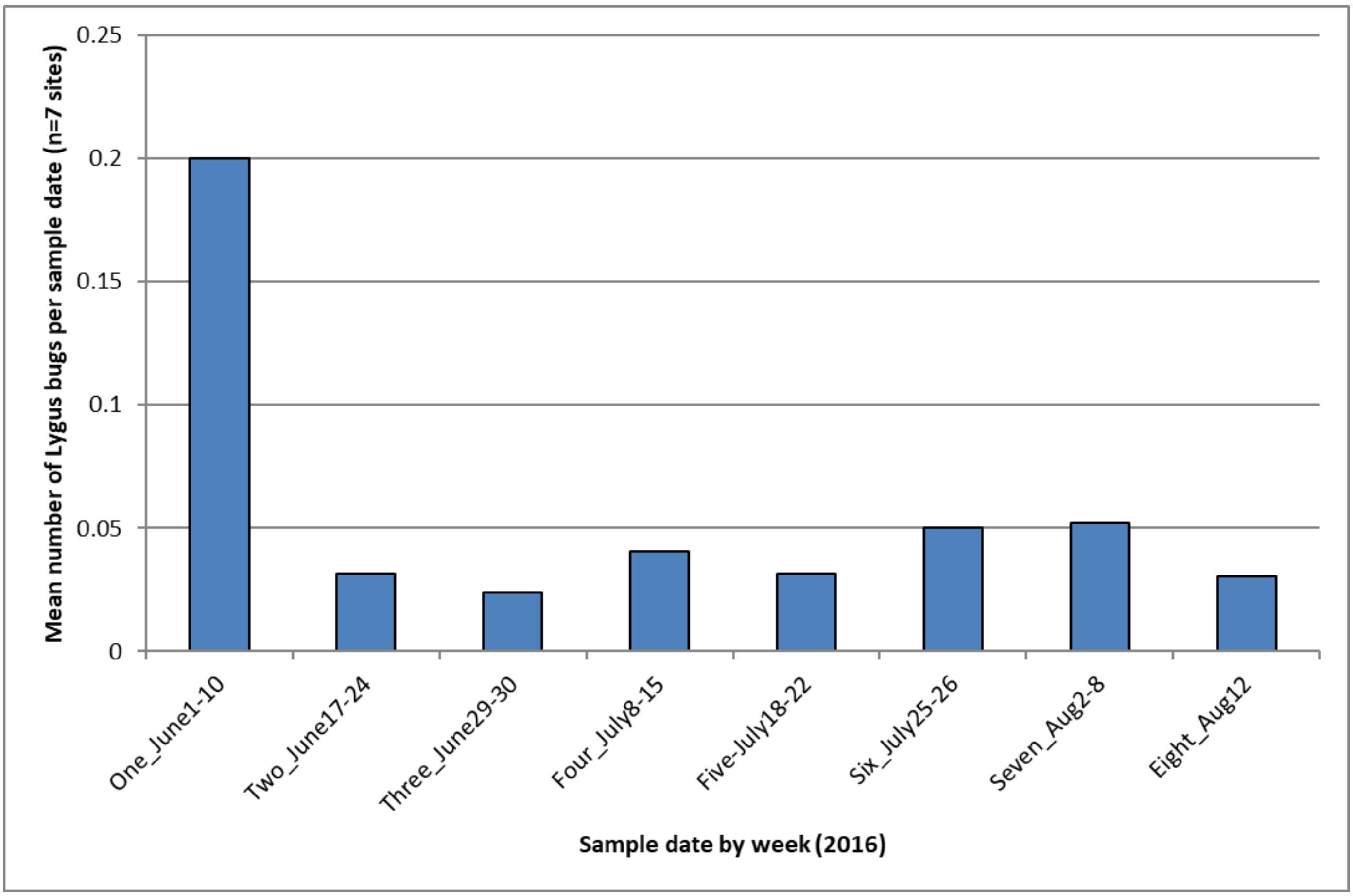


Figure 1. Average number of *Lygus* bugs (nymphs and *L. lineaolaris*, *elisa* and *borealis* combined) per sample date from seven sites in Saskatchewan (2016).

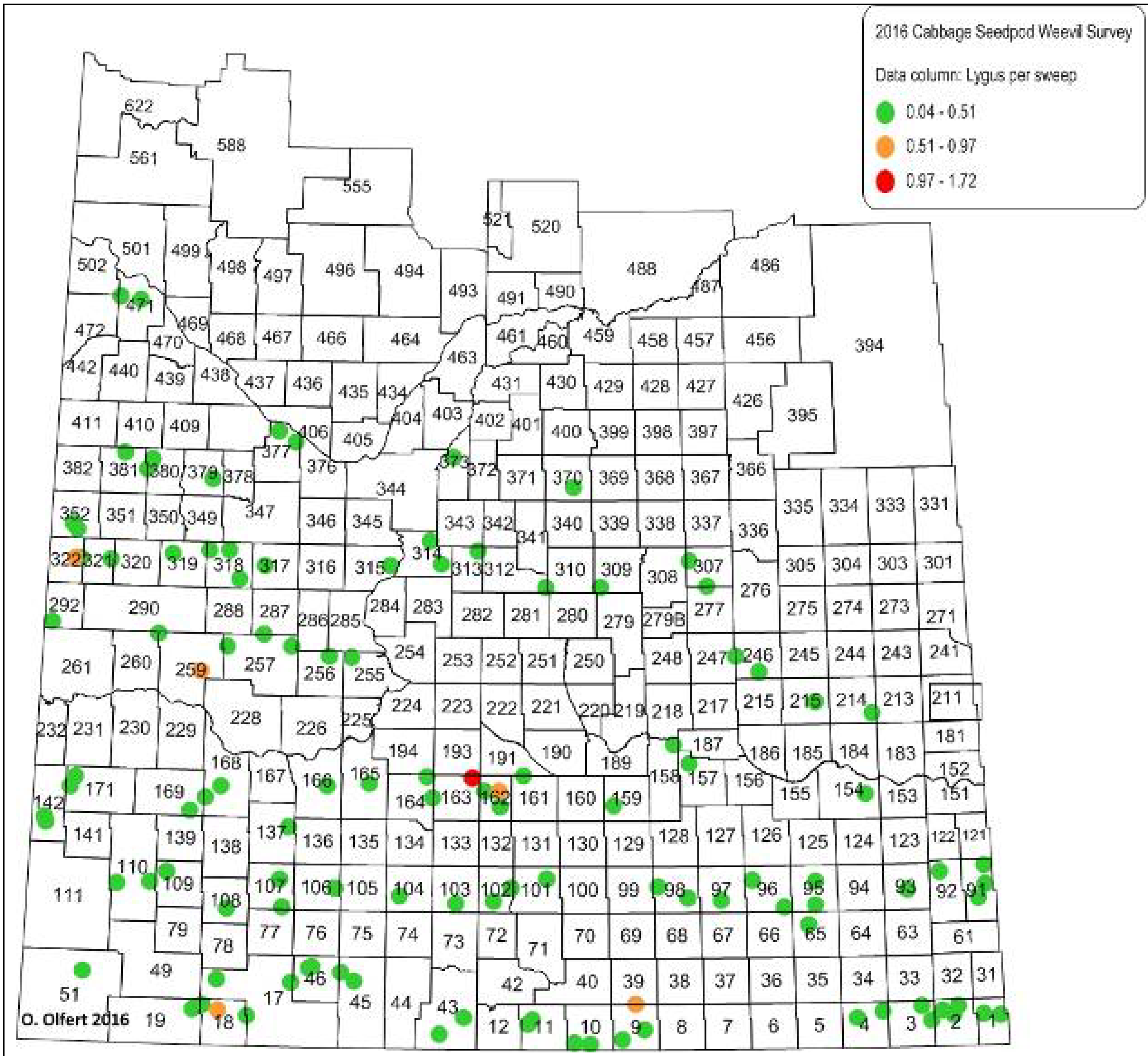


Figure 2. Number of Lygus bugs per sweep in Canola at the flowering stage recorded on the Cabbage Seedpod Weevil Survey across Saskatchewan, 2016.

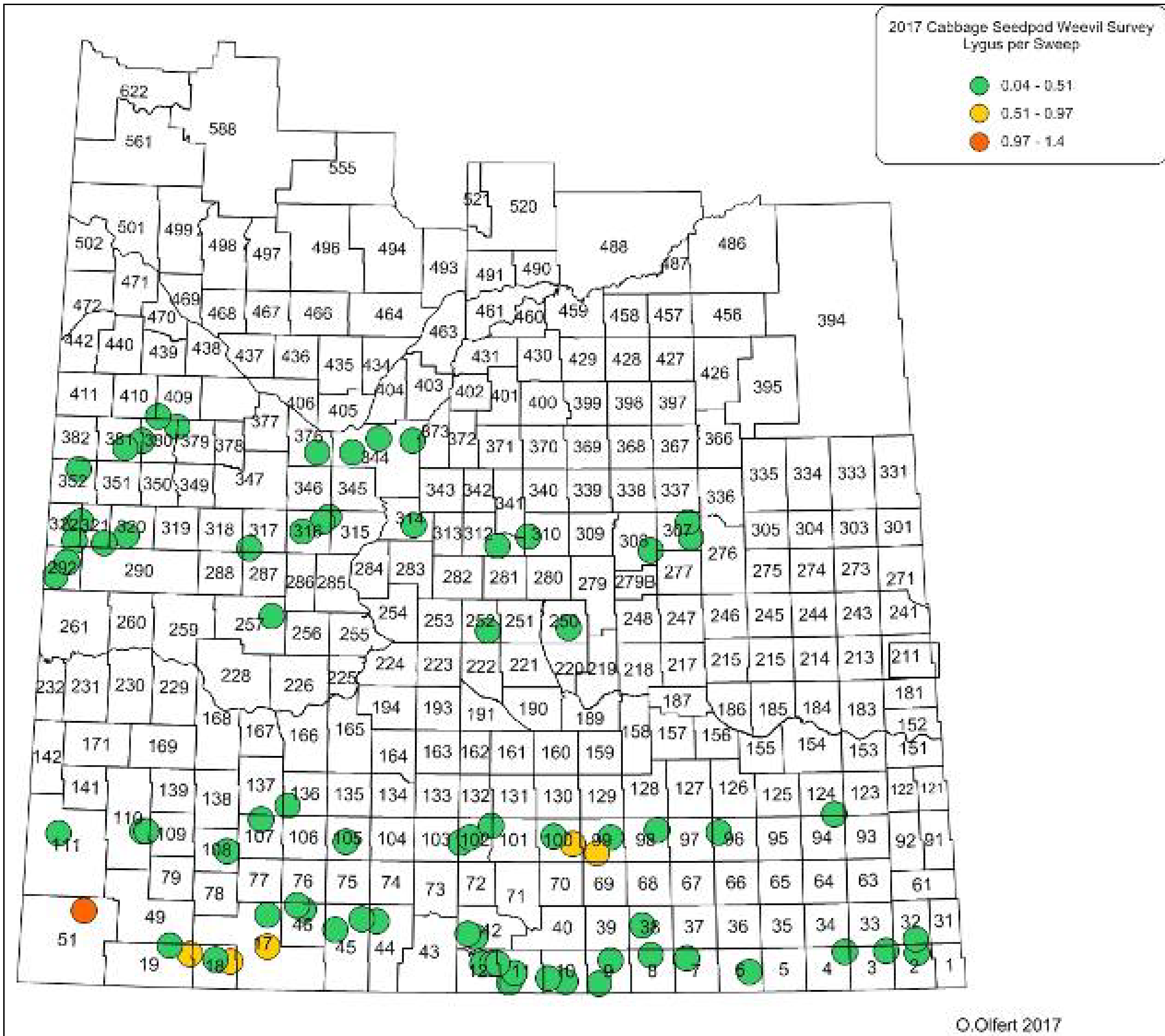


Figure 3. Number of Lygus bugs per sweep in Canola at the flowering stage recorded on the Cabbage Seedpod Weevil Survey across Saskatchewan, 2017.

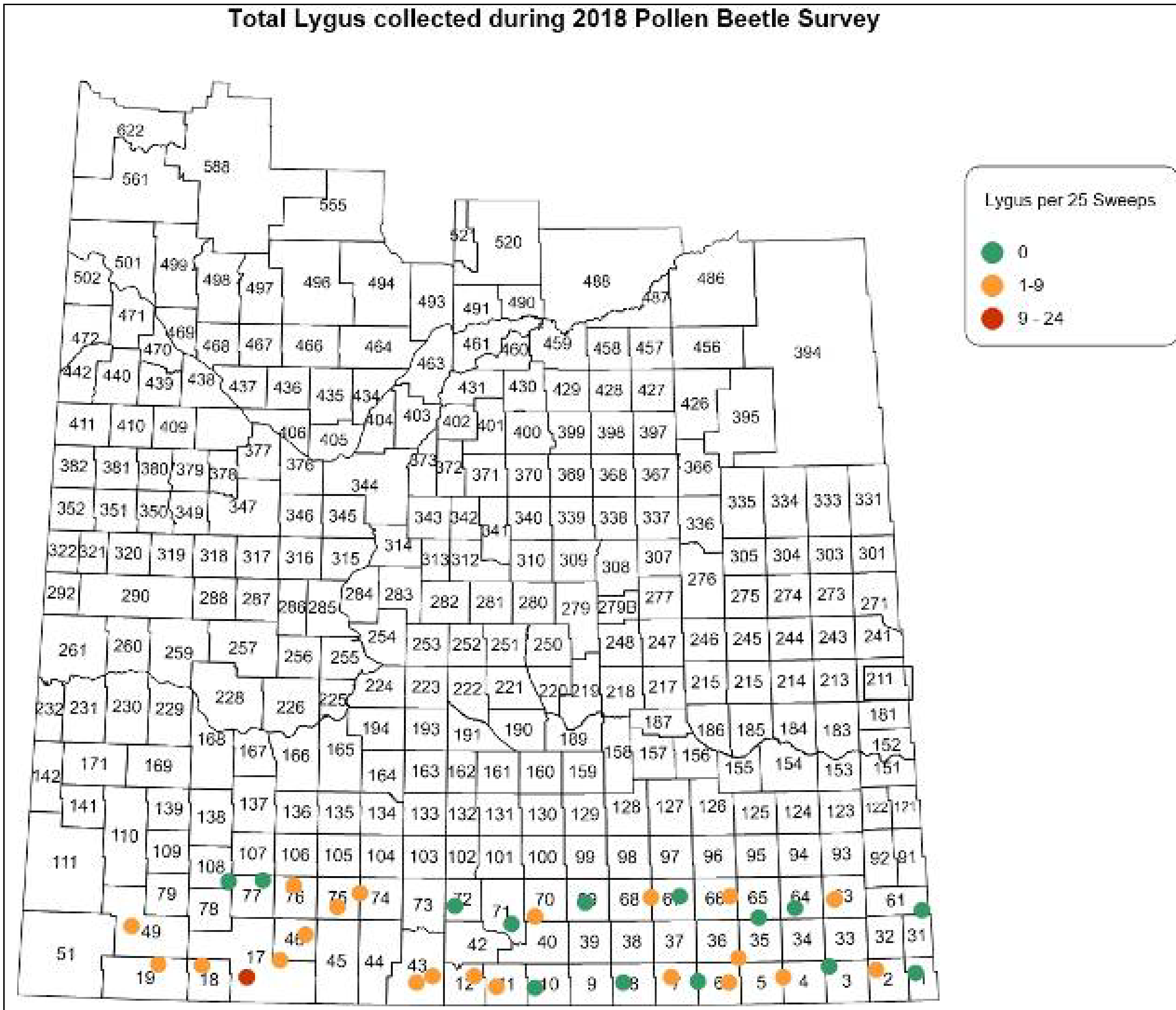


Figure 4. Number of Lygus bugs per 25 180 degrees sweeps with a standard sweep net in Canola at the flowering stage recorded on the pollen beetle survey (CARP funded) across Saskatchewan, 2018.

4. Significant Accomplishments

The main accomplishment of this study is the validation of a new threshold for lygus in canola. Despite large variability at many levels (within a field, between fields and years), there was a general pattern that abundances below 2 lygus per sweep do not reduce yield. In fact at low abundances below 1 per sweep yields were on average higher in fields left unsprayed compared to those sprayed at the late flower/early pod stage. This may result from damage caused by ground spraying at the late flower stage or early pod stage or from indirect impacts of the insecticide on beneficial insects like predators. Thus, the threshold derived from a previous cage study of 2-3 lygus per sweep is recommended. Because current canola cultivars appear to tolerate lygus damage better than older cultivars, reducing this threshold as prices of canola increase is not recommended.

A second important finding from this study is that lygus bugs no longer reach pest status in most regions of the Prairies: Manitoba, Saskatchewan and northern Alberta. It appears that pest risk from lygus occurs mainly in a narrow

corridor between Edmonton and Lethbridge towards the foothills. The main pest species of lygus are *Lygus keltoni* with *L. lineolaris* becoming as prevalent in the more northern portion of this corridor. Furthermore, in the southern portion of this corridor it appears that new cultivars may be less susceptible to lygus damage than older cultivars. Significant yield losses were not observed in the new study (2016-2019) in contrast to a related study done from 2010-2013 where older hybrid cultivars were planted.

Landscape factors affect lygus abundance in southern Alberta. We determined that regions with fewer canola fields could result in higher lygus pest abundance because they concentrate in the fewer fields. This may explain why lygus are less of a problem in the Peace Region area if they are diluted in the vast canola acreages of neighboring fields. Previous cropping history in a landscape had no effect on lygus abundance, which is not surprising given the high dispersal ability of these bugs.

An important lesson, perhaps not an accomplishment, is that studying interactions between pests is nearly impossible due to logistics. Finding sites where a given pest will damage a crop is already difficult enough and finding one where two pests will be high enough and a proper experiment can be executed is nearly impossible for a researcher (of course farmers see it all the time!). Nevertheless, it would be of interest to keep track of lygus bugs in fields where flea beetles, seedpod weevils or diamondback moth, delay crop maturity.

5. Research and Action Plans

The field data collection and analysis for this report is completed. However, the senior author (Carcamo) has access to a large number of related plot and older cage studies of lygus bugs done with other researchers. Thus, in the long term (within the next two years) I plan to do a meta analysis of all the lygus-canola data and attempt a synthesis to better understand the insect plant relationship between lygus and canola that may further support our efforts to reduce potential yield losses from this insect and also help to design better methods of management that rely less on insecticides. Also, I have involved a statistician from our research centre to help me explore novel or more complex statistical methods to study lygus bug spatial distribution within canola fields and also non-linear methods to better quantify the impact of lygus bugs on canola yield. Once all that work is completed and published, I plan to translate it into a fact sheet to make it available to the industry.

6. Final Project Budget and Financial Reporting

To be submitted separate by our Financial Officer.

Please forward an electronic copy of this completed document to:

Gail M. Hoskins
Crop Production Administrator and CARP Coordinator
Canola Council of Canada
400 – 167 Lombard Ave.
Winnipeg, MB R3B 0T6
Phone: (204) 982-2102
Fax: (204) 942-1841
E-Mail: hoskinsg@canolacouncil.org

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Appendix A : protocol to validate thresholds for lygus bugs and flea beetles in commercial fields

PROTOCOL 1
Validation of lygus and flea beetle threshold in commercial farms throughout the Prairie Provinces.

Funded by the Canola Agronomic Research Program (April 2016 to March 2019)

Objective:

Validate lygus and flea beetle economic thresholds in commercial canola fields throughout the Prairies

Design:

Treatments to be randomly assigned to each of 4 strips (25 x 100 m) in each of 4 blocks:

1) Control strip never sprayed
2) Early sprayed “strip” for flea beetles
3) Late sprayed strip for lygus.

4) Early and late sprayed strip.

Site selection and staking:

- Select dryland fields (any cultivar of Argentine canola) planted within a normal range of seeding dates for the region
- Fields need to be large enough to accommodate 4 replicate blocks (100 m x 100 m, 25m wide strips); blocks 50-100 m apart (minimum field size: 200m x 600 m)
- Select 6 - 10 fields at the early cotyledon stage where lygus damage expected (history in the area) or if there is evidence of moderate flea beetle feeding. (expect that half the fields will not have the necessary pest pressure or will not work out for x reason)
- Procedure to mark fields during the cotyledon stage
    - Get verbal approval from grower to scout and mark the field (should understand that an agreement will be forthcoming if field selected and payment will only take place when yield data is received)
    - Find out the width of his sprayer (will determine distance from edge, usually ca. 120 ft or 36.5 m) and the width of each strip
    - Drive around the field to identify uniform side to set up study strips and best access (4 blocks will be perpendicular to the access road)
    - Park the truck along road or in approach in a safe area without trampling any crops
    - wear protective booties or rubber boots disinfected to prevent pathogen spread
    - set up the first block at least 1 sprayer width (e.g. 120 ft) away from the access road and the perpendicular edge; place two flags 480 ft apart or as determined by sprayer width to have 4 strips
    - Next, place 4 short stakes (1 ft) outside the field along the margin of the access road where it is outside the path of the machinery. This stakes should be near the center of each of the strip. Label them as follows with a permanent marker: site name, strip number and treatment (Smith_203-T4), where Smith is the field's name, 203 refers to the strip number 3 in replicate (block) number 2 and tmt_4 refers to the strip sprayed for flea beetles and for lygus
    - Now, fence the two strips that will not be sprayed for flea beetles (1 sprayer width from edge)
        - First, place 1 flag in line with the short stake near the middle of each strip, then mark the corners and place one in between to end up with 5 tall flexible flags along each of the short sides
        - Next, place 3 tall flags along each of the long sides (every 25 m; the corralled area will have a total of 16 flags around its perimeter
        - Repeat for the other check plot in the first replicate block
    - Place a sticky card (received from Tharshi) near the middle of control strip (tmt_1) in line with the first tall flag that marks the long edge of the strip. Repeat this procedure for the early spray strip (tmt_2) using the small stake from the outside as a guide and one of the tall flags from tmt_2 (both sticky cards will be in line). See related protocol for flea beetle work appended.

- Walk about 2-3 sprayer widths (50-100 m) to set up the next block and repeat to complete 4 blocks. If space is limited reduce the intervals between blocks to 50 m or only do 3 replicate blocks.

- Set up a hobo and rain gauge in the corner near the first block outside the field.

Need 3-4 fields with data on flea beetles.
Data collection:

- Place Hobo probe at 1.2m on headland to record ambient hourly temperature and a rain gauge in a spot out of the way in a corner
- Use GPS to record coordinates for each of the 4 corners of each strip and the weather station
- Mark probe with stake
- Sampling for lygus (and seedpod weevils in the south) will be done at one spot within the middle of each strip (about 25 m into the strip) using a sweep net at key growth stages (early flower, early pod and mid pod).
- Flea beetle abundance will be determined using sticky cards from control strips (trt 1) and in flea beetle early spray strip (trt 2). In control strips the sticky card will be placed from the emergence of the crop and continued for 12 weeks period. In flea beetle early spray treatment strips, the sticky card will be placed from the emergence of the crop to 2-3 leaf stage (4 weeks) only.

  <u>Installation of sticky cards in the sampling stations</u>

  We suggest you to install the sticky cards as shown in the figure 1 and at about 1 inch above the ground level at the early growth stages (when the plants are small). The wire holder is placed in the middle of the sticky card and secured with a twist tie. Note that the sticky card has its "top" end in the holder to avoid covering up a section of the sticky trap (Fig. 1). This is the same place where you will write your trap data (location, date etc.) so be careful after a rain when the card will be more delicate not to rip that section of the card when changing the traps each week. Please also remember to take off the paper that covers the sticky trap before deployment and save it to cover the trap back up in a week. You could also use transparent nylon film or food wrap to cover the card.