PROJECT DETAILS

- **Title:** Management of lygus bugs and seedpod weevil in canola at the farm level
- **Funders:** Alberta Canola, Manitoba Canola Growers Association, and SaskCanola
- **Research program:** Canola Agronomic Research Program (CARP)
- **Principal investigator:** Hector Carcamo, Agriculture and Agri-Food Canada (AAFC) Lethbridge
- **Collaborators/additional investigators:** Scott Meers, Lloyd Dosdall and Owen Olfert
- **Year completed:** 2014

Final report

Executive Summary

Cabbage seedpod weevils and lygus bugs were studied in 75 sites over the four years and yield was collected from all these sites using quadrat samples and from farmer's combine monitors from 20 fields. Also, damage to pods by seedpod weevil was determined from sub-samples from the main racemes of selected fields. Spraying weevils at the early flower stage reduced abundance of lygus at the pod stage in most fields. Seeding period clearly influenced abundance of weevils and lygus and in opposite ways. Early seeding in April increased the risk of having high weevil pests but decreased the risk of lygus. Sites planted latest, during the last two weeks of May, had the most lygus and the fewest weevils and those planted at a normal period (first 2 weeks of May) had intermediate numbers of both pests. Quadrat and combine yield estimates for all subsamples pooled across years and regions suggested that spraying insecticide at early flower resulted in a yield increase over the untreated (check) strips of 2.1 (combine monitors) to 1.8 (quadrats) bushels per acre. However, there was very high variability from site to site and year to year even for those sites close to each other within a region. In about half of the fields yields were higher in the sprayed strips than in the checks and in the other half it was either higher in the check strips than the controls or there was no difference. Correlation analysis was conducted between insect abundances or weevil damage with yield from quadrat samples. Most correlations were weak suggesting that in many cases canola tolerated or compensated for insect feeding; this is in agreement with the low yield response to insecticide spraying. Weevils at early flower had the most significant correlations, followed by lygus at the pod stage. Lygus at early flower were not related to yield nor to lygus numbers at later crop stages. From these results it can be recommended that growers do not extrapolate economic thresholds for lygus below one per sweep even at high canola prices or reduce the nominal threshold for weevils below 2-3 per sweep as recommended now. Ongoing cage studies will be used with these field results to provide more accurate thresholds. Local rainfall during the growing season measured with rain gauges on site were better correlated with lygus abundance than annual precipitation or rainfall two weeks before the pod stage obtained from regional nearby weather stations. The only major issue encountered

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during this study was the difficulty in obtaining yield data from the combine monitors from most growers, only 20 sites out of 75 were obtained. Although 80 sites were targeted for study over the 4 years a few sites were lost due to hail or weather problems preventing the sprayer operator from leaving check strips or low insect numbers and the farmers not willing to spray only the experimental borders.

Background

Cabbage seedpod weevil is a chronic exotic pest of Canola in southern Alberta and Saskatchewan where it continues to expand eastward toward Manitoba. Weevils arrive in canola fields starting at the bud stage and into flowering to feed on buds, flowers and young pods. The main damage is caused by larval feeding on seeds. The timing of insecticide spray is at early flower to target adults. Upon hatching, the larvae are protected inside the pod and cannot be controlled. Fields planted early are at greatest risk of weevil damage by the larvae. However, fields planted late that mature slowly in a cold year may be damaged by adults of the new generation that feed on immature seeds before over-wintering.

Lygus bugs are native pests that attack many crops including canola throughout Canada. The dominant species in humid regions such as the Parkland Eco-Region is the tarnished plant bug (*Lygus lineolaris*) while in the drier Short Grassland Eco-Regions of the southern prairies, the dominant species are *L. elisus* and *L. borealis* and *L. keltoni* with the latter occurring closer to the foothills in western Alberta (Carcamo et al. 2002). Lygus bugs, like the seedpod weevil, arrive to canola fields at bud and early flower but they peak later at the early or mature pod stage; their numbers can increase rapidly under dry hot weather through production of young and dispersal from other sites as plants senesce. Populations of young nymphs may also crash rapidly under conditions of excessive rainfall (Day 2006) but this requires further research locally. Economic thresholds have been developed for lygus bugs (Wise and Lamb 1998, Otani and Carcamo 2011) and nominal thresholds are available for seedpod weevils (Dosdall et al 2001 Agdex). Also a cage study using both pests suggested that around two of each pest per plant added at flower can reduce seed yield (Carcamo et al 2002 CARP Final Report). These data from plots and cages need to be validated at the field level where insects are not concentrated in a small area and movement from control to treated plots is less likely. Furthermore, important considerations when managing these two pests are seeding date and the effect of weather on the insect-plant interactions.

Results from this study have several potential benefits to the canola industry. Firstly, managing insect pests in a timely manner before they damage the crop can increase crop yields. Each of these pests can reduce yields by 10-20 % on their own if they surpass thresholds; therefore, growers can increase canola seed production on the same acreage of land. Second, validating economic thresholds will allow farmers to avoid unnecessary crop spraying and thereby, reduce input costs and prevent harming beneficial insects. Finally, this

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research will provide basic information on the role of seeding date and the effects of local rainfall and temperature on weevil and lygus dynamics. An important component will be to improve our ability to forecast potential lygus bug problems in relation to their numbers at flower stage and the role of weather parameters such as rainfall and temperature. One of the major advantages of a farm scale study is that it adds greater realism to the results by validating thresholds using real farms and testing how plot or cage results apply to commercial scale farming.

Objectives:

1) Determine impact of spraying insecticide for cabbage seedpod weevil at early flower on abundance of lygus bugs at early pod in commercial farms
2) Develop recommendations for managing combinations of seedpod weevil and lygus bug as a pest complex, including joint thresholds at the early flower stage from farm studies
3) Determine effect of seeding date on the management of this pest complex
4) Determine effect of local weather, rainfall and temperature, on abundance of weevils and lygus bugs
5) Develop a predictive tool for lygus abundance at early pod

Detailed results by year

2010

Field work for all years was coordinated by staff of Alberta Agriculture located at CDC south in Brooks (Scott Meers and Shelley Barkley) and at the Lethbridge Research Centre in Lethbridge (Hector Carcamo and Carolyn Herle). Site selection was done based on farmer contacts by the study co-ordinators (Carcamo and Meers) and through referrals from a number of agronomists, extension and industry personnel (see acknowledgements).

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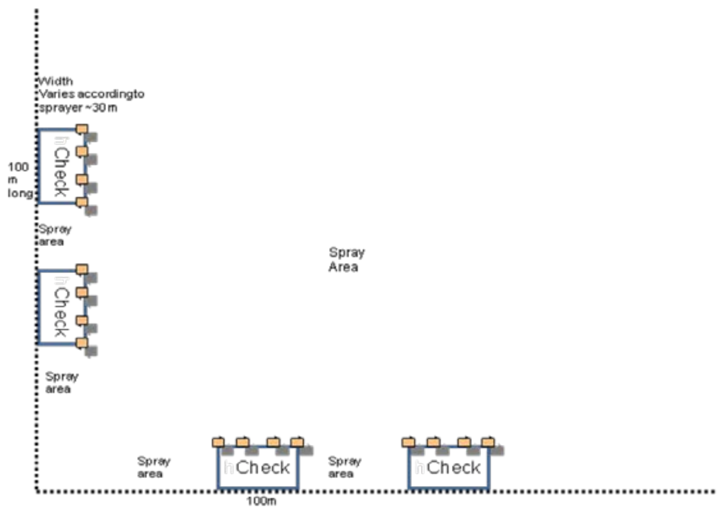

Figure 1: Diagram illustrating generalized layout of check strips along the border in the canola farm study and areas sprayed with insecticide available to assess effects of spray treatments on insects and yield. Layout along the border will vary with each farm; in some cases all 4 occur along edge.

In 2010, 4 check strips and 4 sprayed strips each 100 m were set up in each field (Fig 1) but for the remaining 3 years 50 m strips were used (up to 8 per field, Fig. 2) to avoid the large spatial variability in yield observed in the larger strips in year 1 of the study.

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Fig. 2: Revised design to test effect of flower spray for weevils on lygus and canola yield using commercial farms

-smaller "blocks" needed because of large Inherent yield variation (at 100 m apart, sprayed and check differ naturally because of soil or other factor)

- A "block" consists of a flagged check and an adjacent unmarked sprayed area selected to sample insects at 25 m from the check – see diagram on next slide

- If possible, place 8 checks along west border of field; may need to use two or more borders in smaller fields
- Checks should be 50 m long and at least 100 apart from each other
- Width should equal sprayer width or minimum of 20 m

- Check plots, at least 50 m away from corner
- and 100 m away from other check

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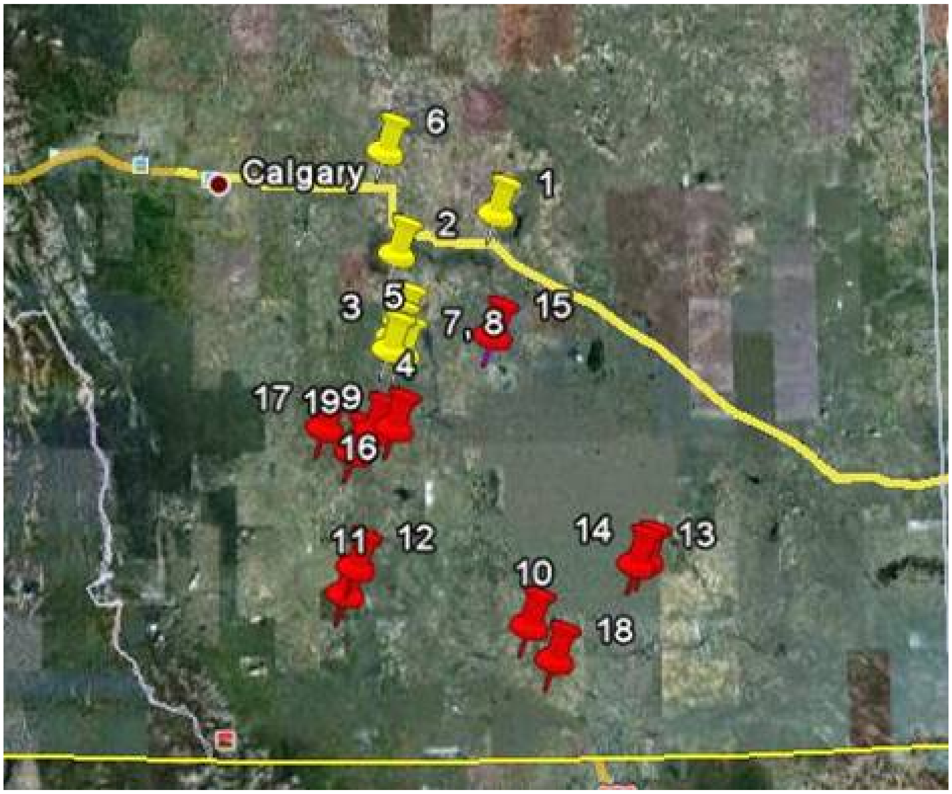

Figure 3: Location of the 19 sites selected to survey insects and to determine effect of insecticide spray at flower or weevils on lygus bug abundance at the pod stage.

The location of the farms included the main regions where the cabbage seedpod weevil and lygus bugs are known to coincide (Fig. 3) south of highway 1 to the US border. Eight study sites were established in the more northern portion between Vulcan and Strathmore. All of these sites were planted to Argentine canola in early to mid-May using seed coated with an insecticide to protect plants from flea beetle feeding. Eleven sites were set up in the more southern region including southern Vulcan county, north and south Willow Creek, south of Taber, and Warner. The two sites south of Taber were planted to Polish canola and all others to Argentine canola.

Growing conditions were characterized by unusually high levels of rainfall and cooler than normal temperatures which delayed the traditional early seeding and growth that normally occurs south of Lethbridge. Seeding dates ranged from 20 April to 25 May, but cold conditions delayed plant growth and also insect activity

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so that seeding date effects were likely confounded. Flea beetles were not a concern in any of the 19 study sites that were monitored. An early survey of cabbage seedpod weevils and lygus bugs conducted in weedy areas (e.g. flix weed, stinkweed) around some of the potential study sites revealed high numbers of weevils but low or average numbers of lygus bugs. A rainfall and temperature mini weather station (HOBO) was set up at each site in the more southern zone. The Hobos (Onset Corp.) recorded soil temp at a 2.5cm depth. The rainfall was collected in a plastic rain gauge (Canadian Tire) and manually recorded and emptied at each site visit.

In general sites planted in mid-May or later had numbers of cabbage seedpod weevils below 4 per sweep. The highest abundances of weevils were 10 per sweep in two fields north of Vulcan and in the more southern region, a polish canola field south of Taber had the highest abundance around 5 per sweep (Figure 4).

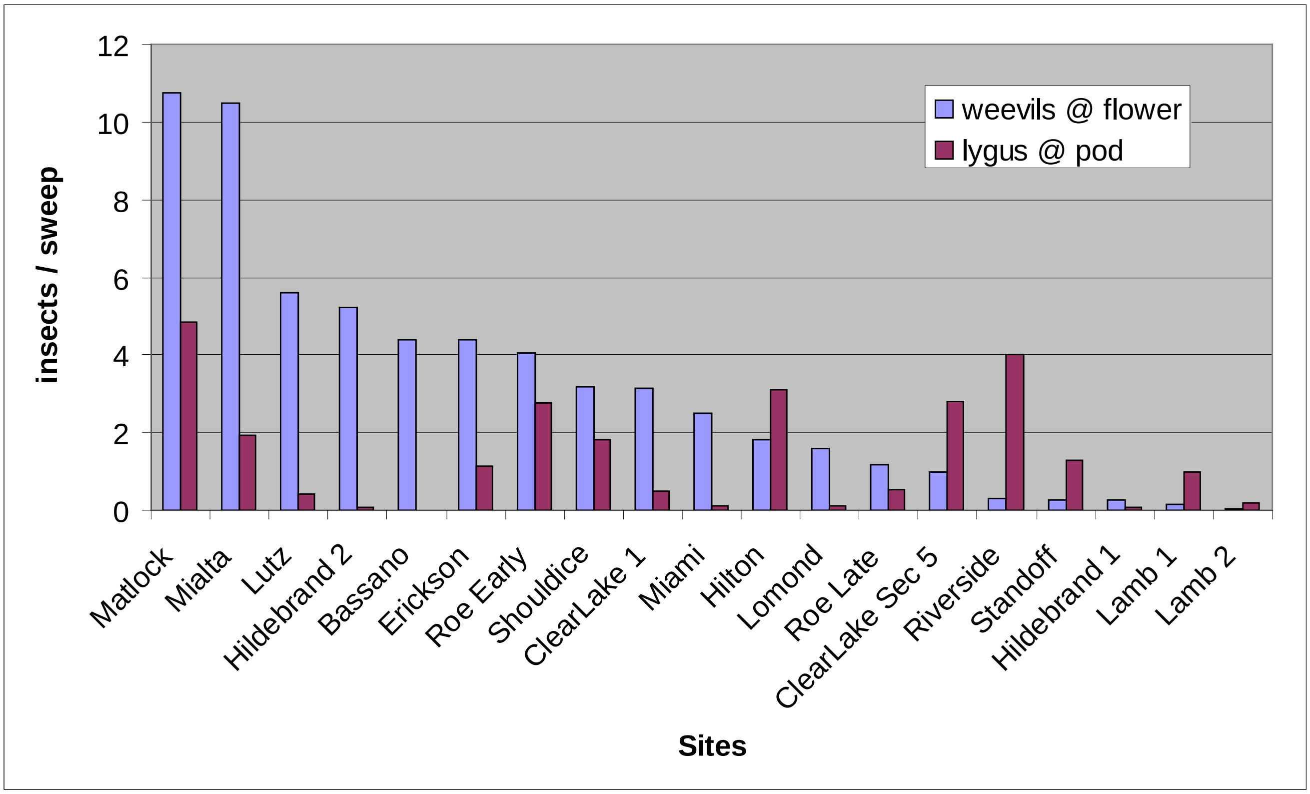

Figure 4: Abundance of cabbage seedpod weevils per sweep at early flower before spraying insecticide and lygus in check plots at early pod.

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Damage by cabbage seedpod weevils in the form of exit holes on canola pods was quantified (Fig. 5) for 10 sites that had the highest weevil abundance. Only 2 of these sites reached damaging levels considered economical (>25 holes/100 pods) but there were significant reductions in exit holes in 5 of the sites. These preliminary results suggest that weevil damage despite high weevil abundance may be lower than anticipated and this is supported by the lack of consistent effects on yield.

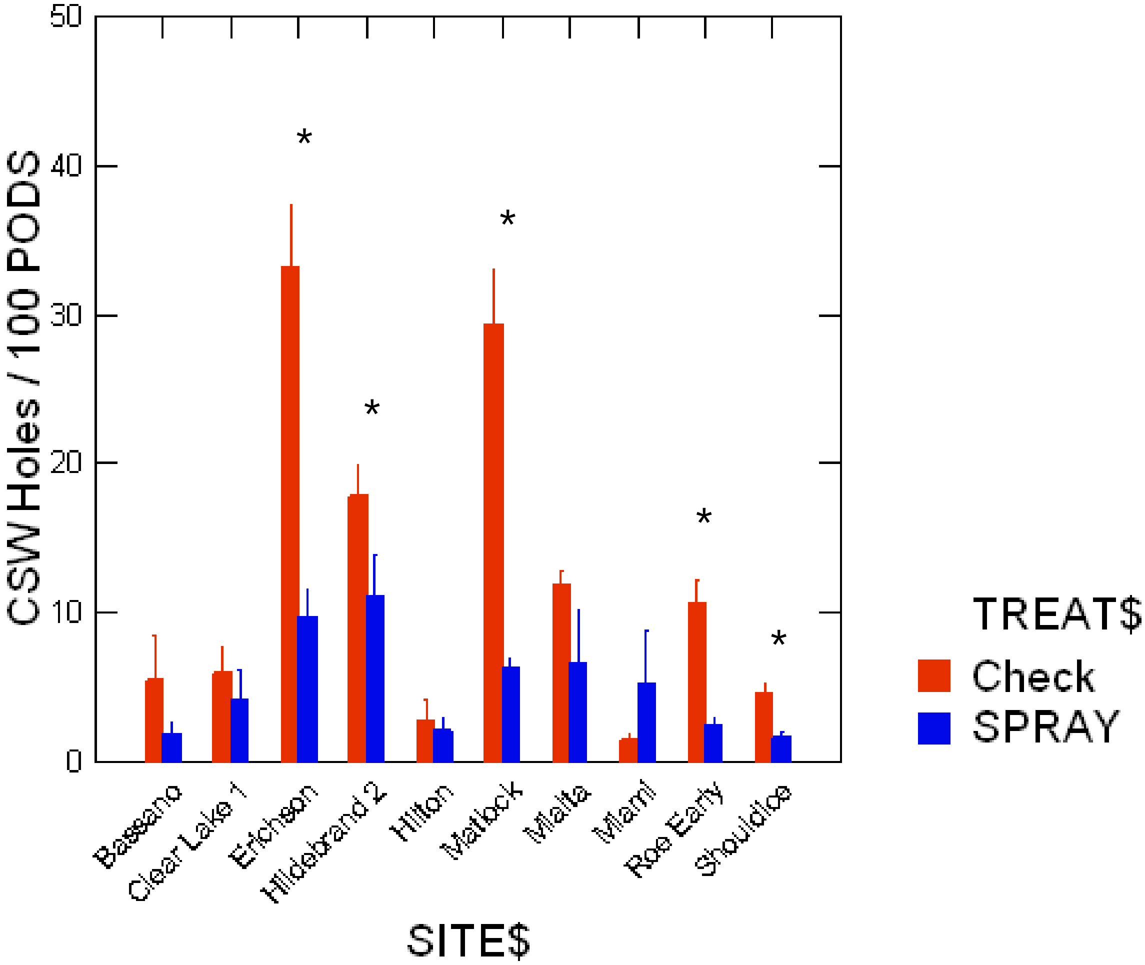

Figure 5: Damage to canola pods (exit holes/100 pods) by cabbage seedpod weevil larvae in the insecticide study in 10 farms with highest weevil abundance.

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The highest lygus abundance was near 5 per sweep at the same site with high weevil numbers north of Vulcan. In the south a similar number of lygus was observed at the pod stage in a field near Standoff. Only two of the sites selected by the Lethbridge staff were not sprayed, one near Lomond and another south of Vulcan. Some of the sites were sprayed even though insect numbers were below threshold because it was either the standard farming practice followed by the grower or it was done to assist with the research to determine potential effects of early spray at flower on lygus bugs at the later pod stage. Insecticide was sprayed using ground equipment in most cases or in at least three cases by contracted aerial applicators. A summary of the sites studied suggests that in 2010, at 13 of the sites that were sprayed, the average number of total lygus collected over the season was significantly lower in areas sprayed at early flower relative to the check plots (Figure 6).

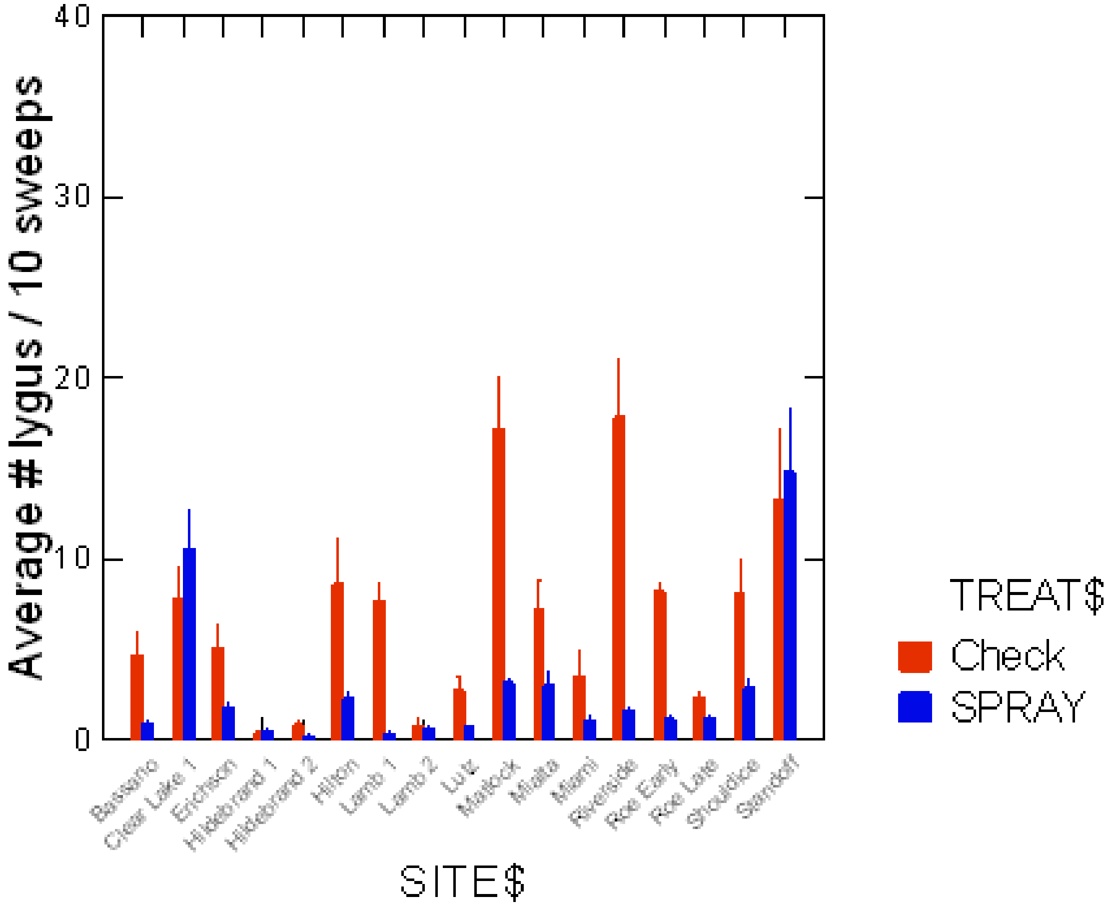

Figure 6: Average number of cumulative lygus bug catches in insecticide-sprayed and check areas of commercial canola fields in 2010.

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At all 17 farm sites that were sprayed during flower 4, 0.25 square meter samples were collected at each sampling spot and pooled into a harvest sac (2 sub-samples in each of 8 blocks, i.e. 16 sacs per farm) at the late pod stage (5.3-5.4) to estimate impact of insecticide spray on crop yield. Samples were dried indoors in a bulk plant drier and threshed using a stationary thresher. Seeds were cleaned using a Cyclone bench top seed cleaner. Total seed weight, plant biomass weight, 1000 seed wt and test volume wts were obtained.

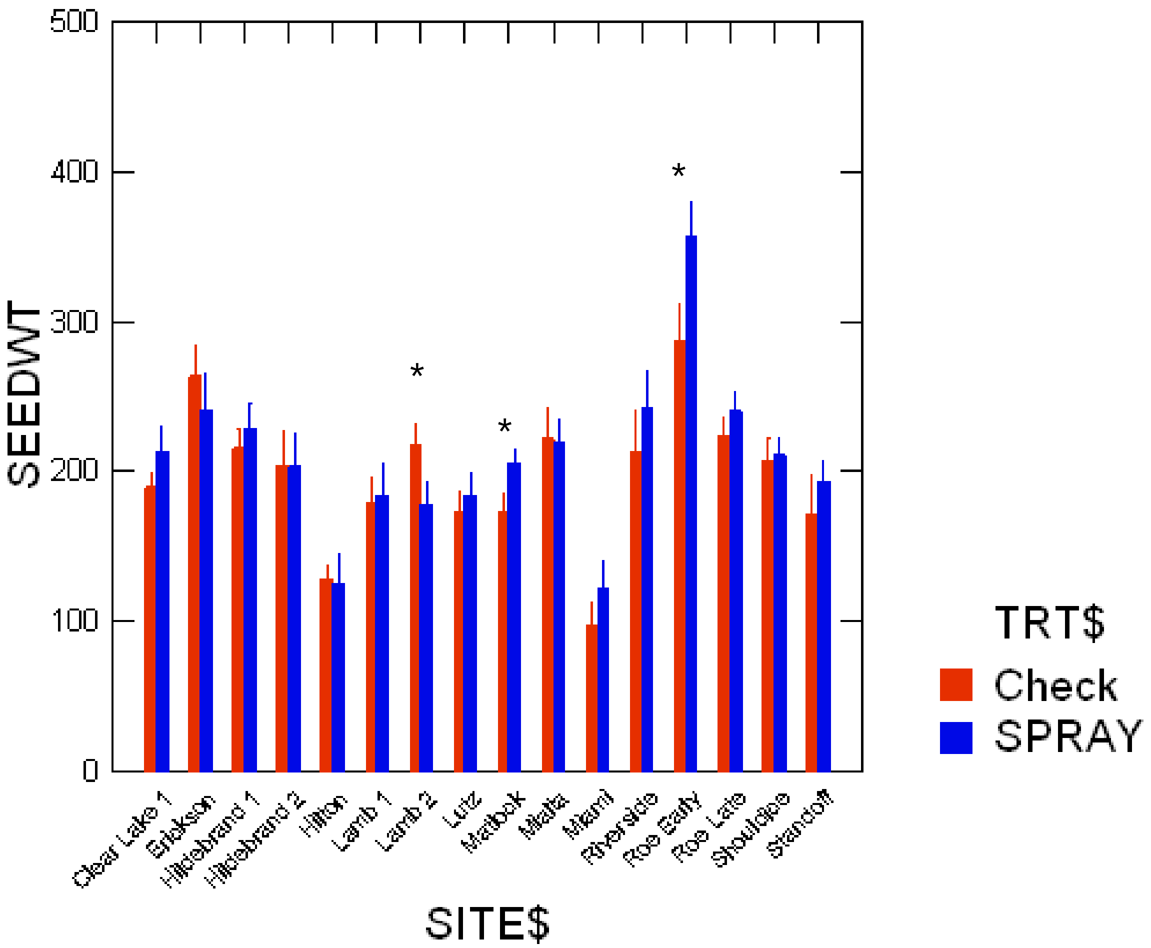

Figure 7: Average canola seed weight per quadrat sample from canola areas sprayed with insecticide or checks. Asterisks denote significant differences (Proc Mix, Systat, P < 0.05, FPLSD).

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Canola seed weights were significantly higher in sprayed areas compared to checks, only in two sites and the reverse was observed in one site (Figure 7). Similar inconsistent results were observed from the four farms that provided yield estimates from the combine monitors as discussed later.

2011

Ten study sites were set up between Vulcan and Strathmore and fourteen study sites in the more southern region. Four of the southern sites were not sprayed with insecticide due to the low numbers of cabbage seedpod weevils and dropped from the study. Figure 8 shows the 20 sites selected for complete insect sampling. One southern site was planted to Polish canola and the remaining sites were all Argentine canola. Seeding dates varied widely from the end of April until early June.

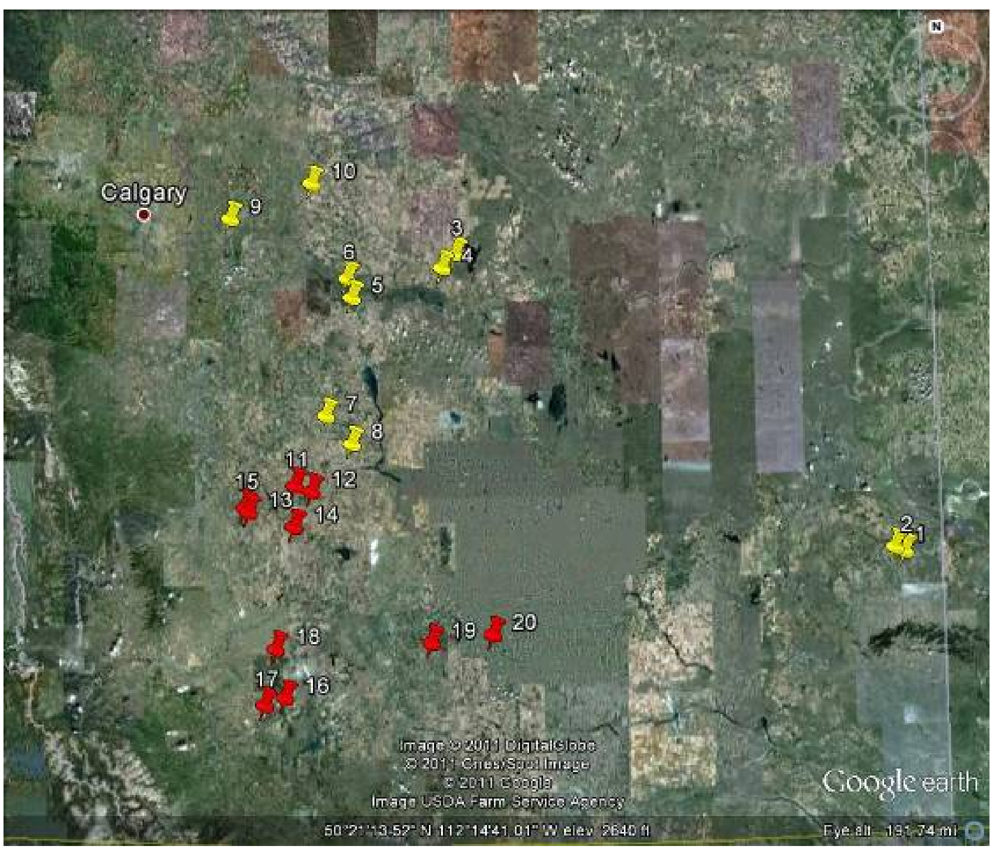

Figure 8: Map showing study sites in canola farms in southern Alberta to assess early flower insecticide spraying on lygus abundance at pod stage in 2011. Red flags are Lethbridge (sites 1-10 in table) and yellow represent those in the more northern area managed by Scott Meers and Shelley Barkley.

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At flowering (GS 4.1) one site from the Elkwater Colony near Irvine AB had CSW numbers over the threshold of 4 per sweep and another south east of Coaldale was border-line at 3 per sweep (Fig. 9). The remaining sites had lower numbers of csw but growers sprayed at least the border to comply with experimental protocols.

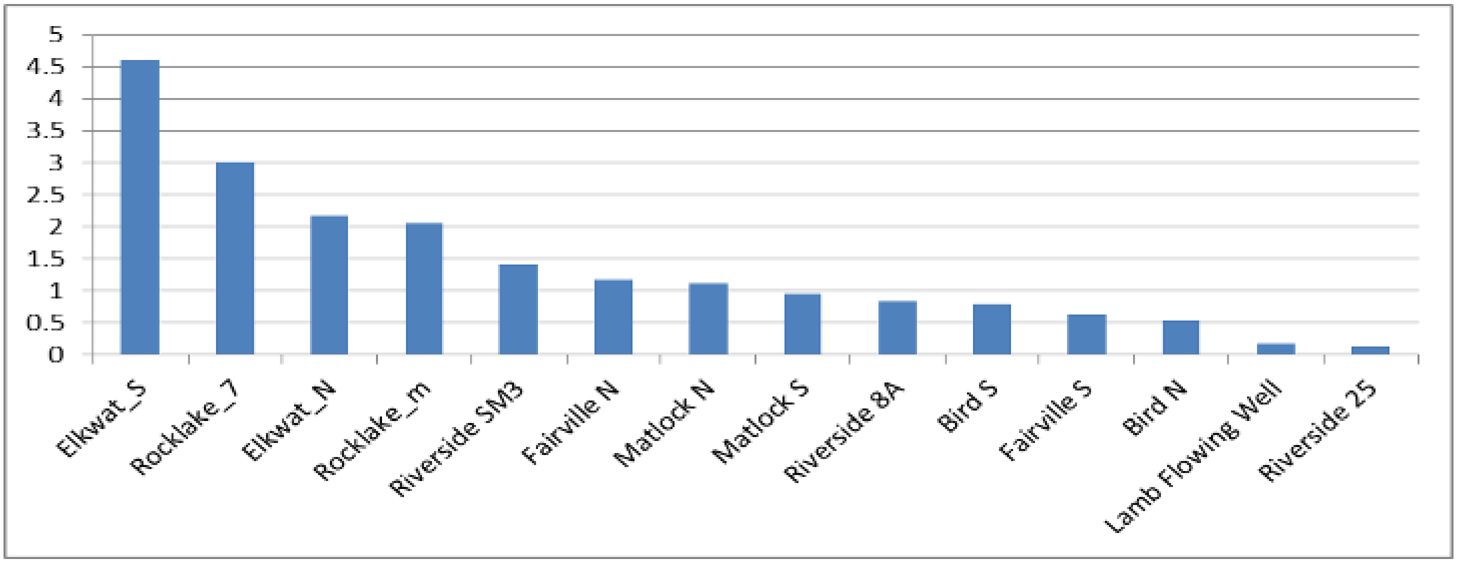

Figure 9: Abundance of cabbage seedpod weevils (per sweep) during the early flowering stage of canola at selected study sites in 2011. Others had less than 0.1/sweep.

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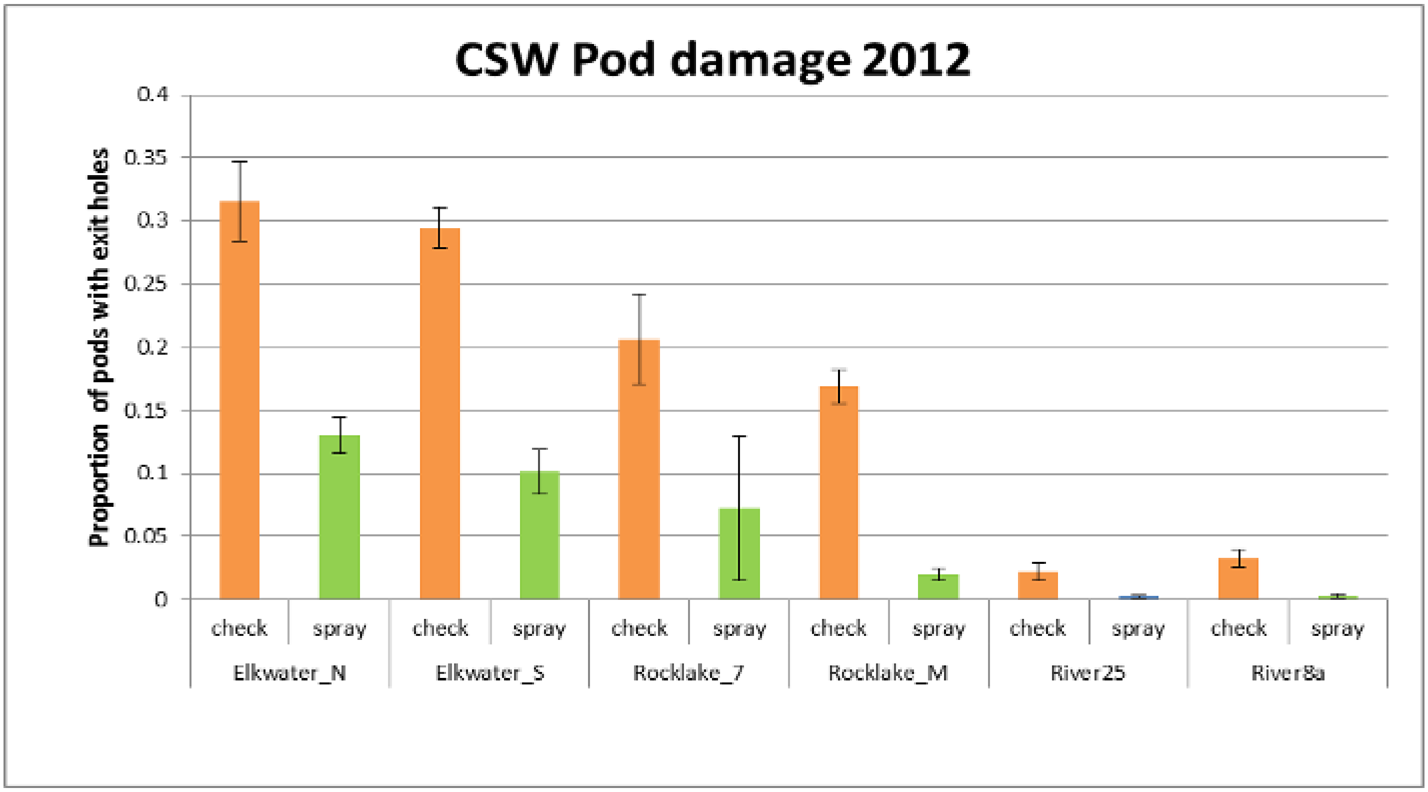

Figure 10: Proportion of canola pods with seedpod weevil exit holes at farms throughout southern Alberta that had the highest weevil abundance at flower in 2011. Fields with damage over 0.25 are expected to suffer yield losses. * Denote significant differences based on preliminary analysis, Systat, ANOVA, $p < 0.05$.

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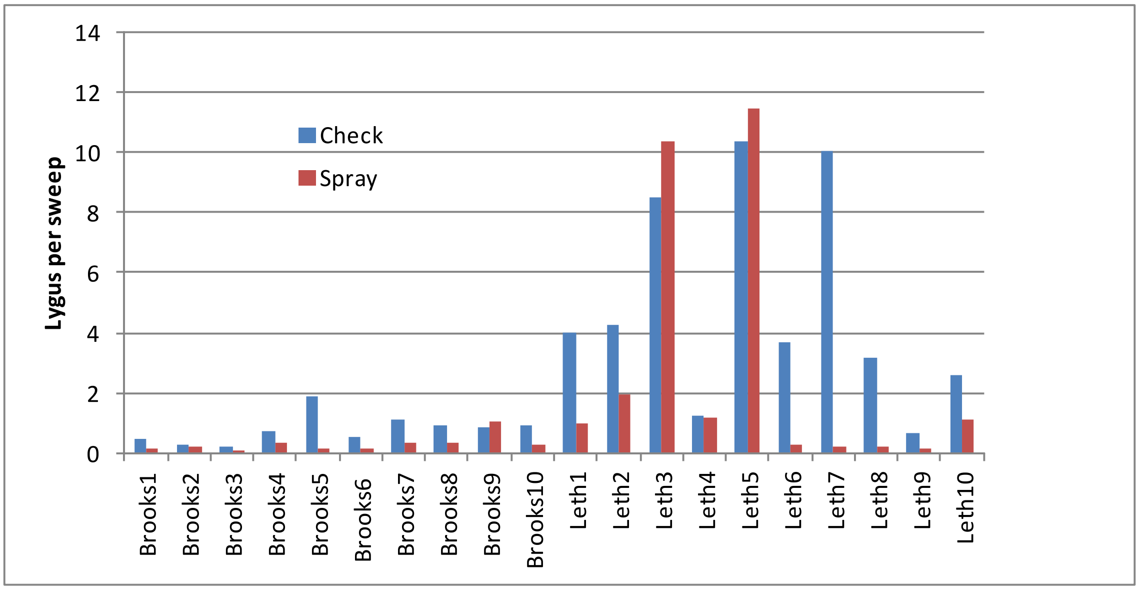

Figure 11: Abundance of lygus bugs (per sweep) during early or mid pod stage of canola at the study sites in 2011.

Lethbridge 3 and 5 received hailed on the same day as the insecticide was applied (July 19th) which delayed the plant maturity and negatively impacted the efficacy of the insecticide. With the exception of Lethbridge 3 and 5, the sprayed plots had far fewer Lygus bugs than the check plots (Figure 11).

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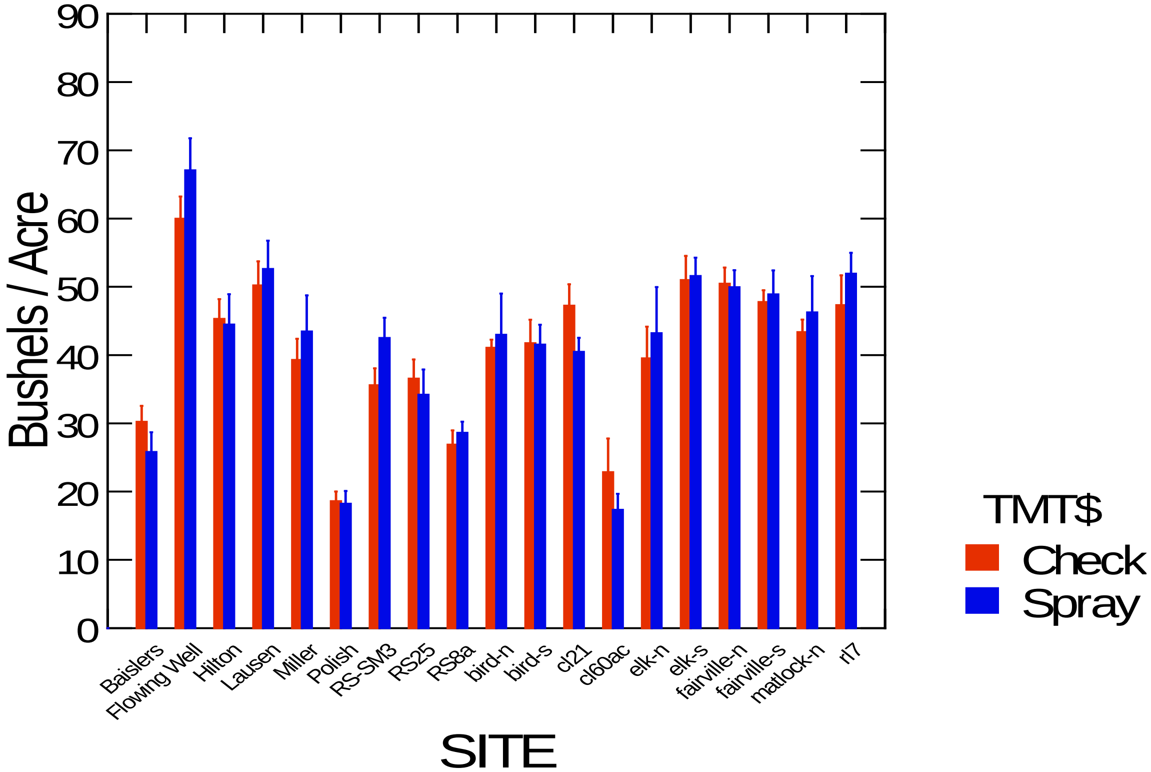

Figure 12: Average yield estimates from 4 quadrats collected at two positions in each of the sprayed or unsprayed large plots used to study effects of spraying for weevils at flower on lygus bugs. None of the treatment pairs differed statistically, $p < 0.05$.

At crop maturity, four 0.25m^2 quadrats were collected at each sweep net sampling point for each site. Quadrat samples were threshed with a stationary thresher, seeds cleaned, weight, 1000-seed wt and test volume wt obtained. Yields did not differ significantly in any of the farms, and in 9 of the 20 fields the yields were the same or numerically higher in the check plots than the sprayed plots (Figure 12). However, in the four fields that had the highest levels of weevil damage the yields were numerically lower in the check than in the sprayed plots. Differences in lygus abundances did not seem to relate to yield differences. For example at the field labelled Lethbridge 7 (Riverside 8a), lygus reached 10 per sweep at late pod in the check and less than 0.5/sweep in the sprayed but the yield difference was about a bushel or less which would not justify the economic (and environmental) cost of spraying.

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2012

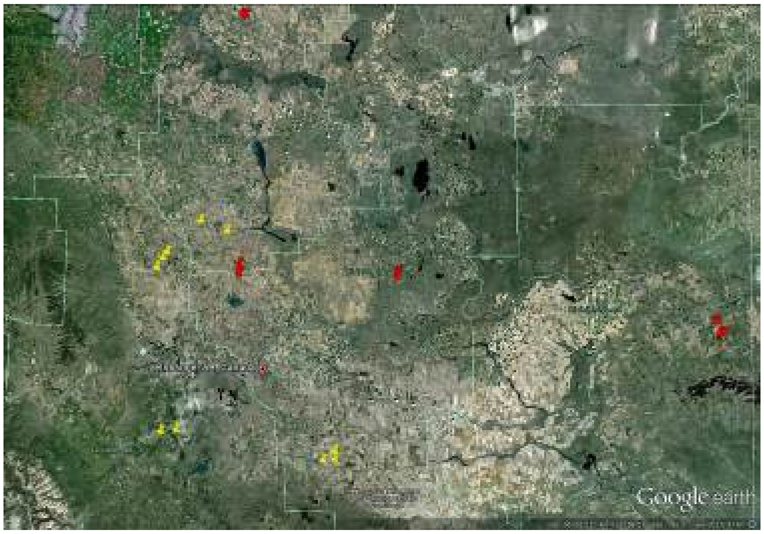

Figure.13. Google Earth image of the Canola study sites 2012. Yellow pins designate sites sampled from the Lethbridge Research Centre and red pins designate sites sampled from the Crop Diversification Centre South at Brooks AB.

Ten study sites were set up between Strathmore and Medicine Hat (referred to as “Brook sites”) and eleven study sites in the more southern region (“Lethbridge sites” see Fig 13 below.). The study sites were Argentine canola and seeding was from April 22 through May 15.

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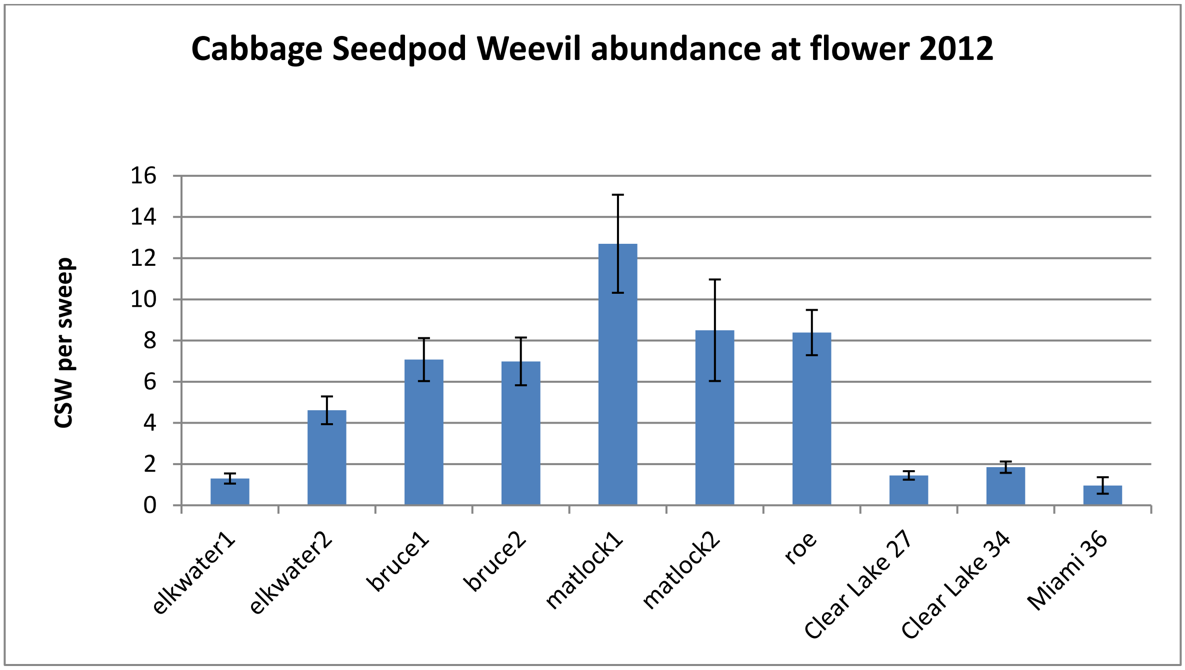

Figure. 14. Cabbage Seedpod weevil abundance at canola flowering stage. Only sites with 1 or more csw per sweep are shown.

Cabbage seedpod weevils were more prevalent in the Vulcan area (see Fig 14) with 7 sites near or above economic threshold of 2-12 weevils/sweep. One site near Irvine also reached ET. Two other sites had weevil abundances of 1-2 per sweep and the remaining 11 sites (8 of the Lethbridge sites) had less than 1 weevil per sweep at the flower stage but growers sprayed at least the border to comply with experimental protocols. The highest weevil damage in 2012 (18-23%, Fig. 15) was in the two fields in the Brooks area that had over 8 weevils per sweep.

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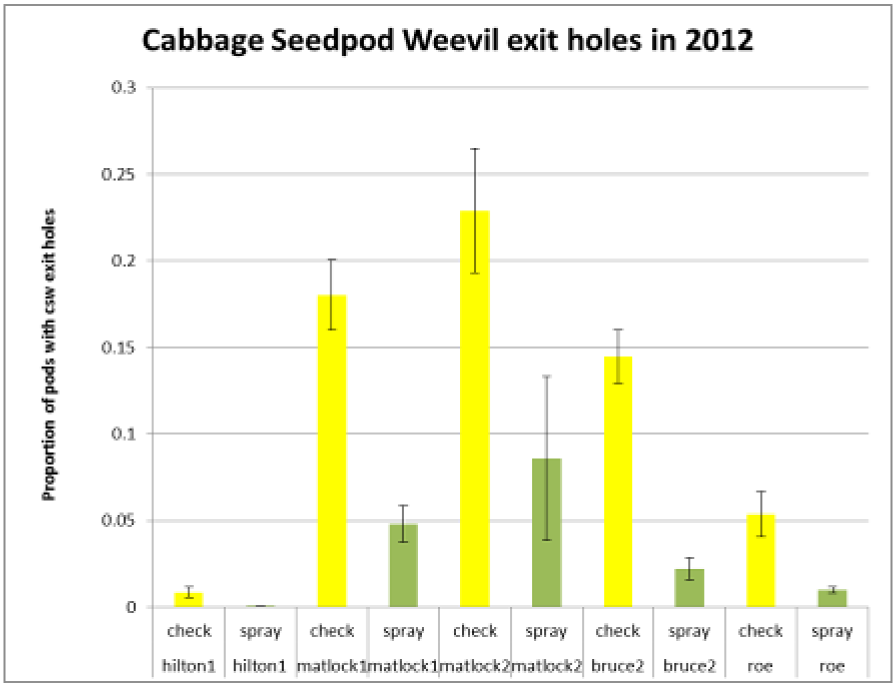

Figure. 15. Damage to canola pods by cabbage seedpod weevils (proportion with holes) in 2012 sites that had more than 1 weevil per sweep.

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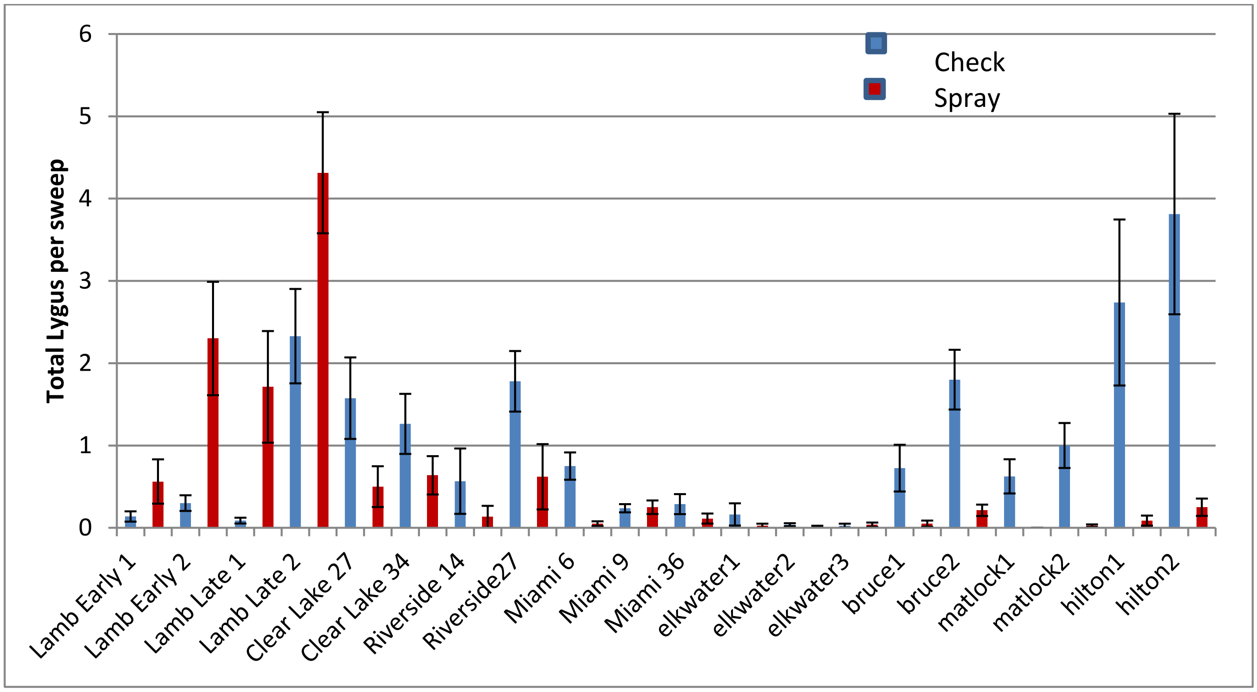

Figure 16. Total Lygus abundance at Canola pod stage.

Lygus reached potentially damaging abundances in 10 sites (1-4 per sweep), but were only around 0.5 per sweep in 5 sites and negligible in 6 sites (Fig 16). With the exception of the Lamb Farms sites, the early-flower-sprayed plots had fewer Lygus bugs than the check plots.

At crop maturity, four 0.25 m^2 quadrats were collected at each sweep net sampling point for each site. Quadrat samples were threshed with a stationary thresher, seeds cleaned, and 1000seed weight and test volume weights were obtained (see Figs 17 and 18). Yields were numerically higher in the sprayed plots than in the checks in 9 of the 21 fields but the opposite trend was observed, though at smaller differences, in 5 of the fields. Seven fields had negligible differences in yield between sprayed and unsprayed.

Yields from the combine monitor were analyzed for the two fields at the Riverside colony. Both of these fields had less than 1 weevil per sweep but lygus were 2/sweep in field 27 and around 0.5/sweep in field 14. Yields were higher in the sprayed plots of field 27 but the opposite result was observed in field 14. These results suggest that there is no need to spray for lygus when they are at low abundances even though the current table to economic thresholds would suggest that at current high canola prices the ET should be 0.5 lygus per sweep. It will of interest to see from more fields if the trend of higher yields in check plots with few lygus

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relative to sprayed plots, is held. If it does, it will support the hypothesis that canola yields are stimulated by low levels of lygus herbivory. Figures for yields from all combine monitors are presented in the synthesis section below (Fig. 26)

Seed quality parameters (oil, protein and chlorophyll (green seed) content) were analyzed using a Near Infrared Spectrophotometer. Oil and protein content were similar for check and sprayed plots. Green seed content was higher in the check than in the sprayed plots in 10 of the fields, lower in the checks than sprayed in 4 fields and similar in 7 fields. A statistical correlation analysis with insect abundance of damage remains to be done but it appears that high lygus abundance caused and increase in green seed. This phenomenon may be time dependent. If lygus exploded at the very late pod stage when the crop is about to be swathed, they may feed preferentially on the small pods at the top of the racemes and potentially could reduce the level of green seed. If they reach high numbers during the early or mid-pod stage, their feeding likely results in an increase in green seed. Greenhouse controlled studies confining various canola crop stages with various densities of lygus at varying developmental stages are required to test this hypothesis experimentally.

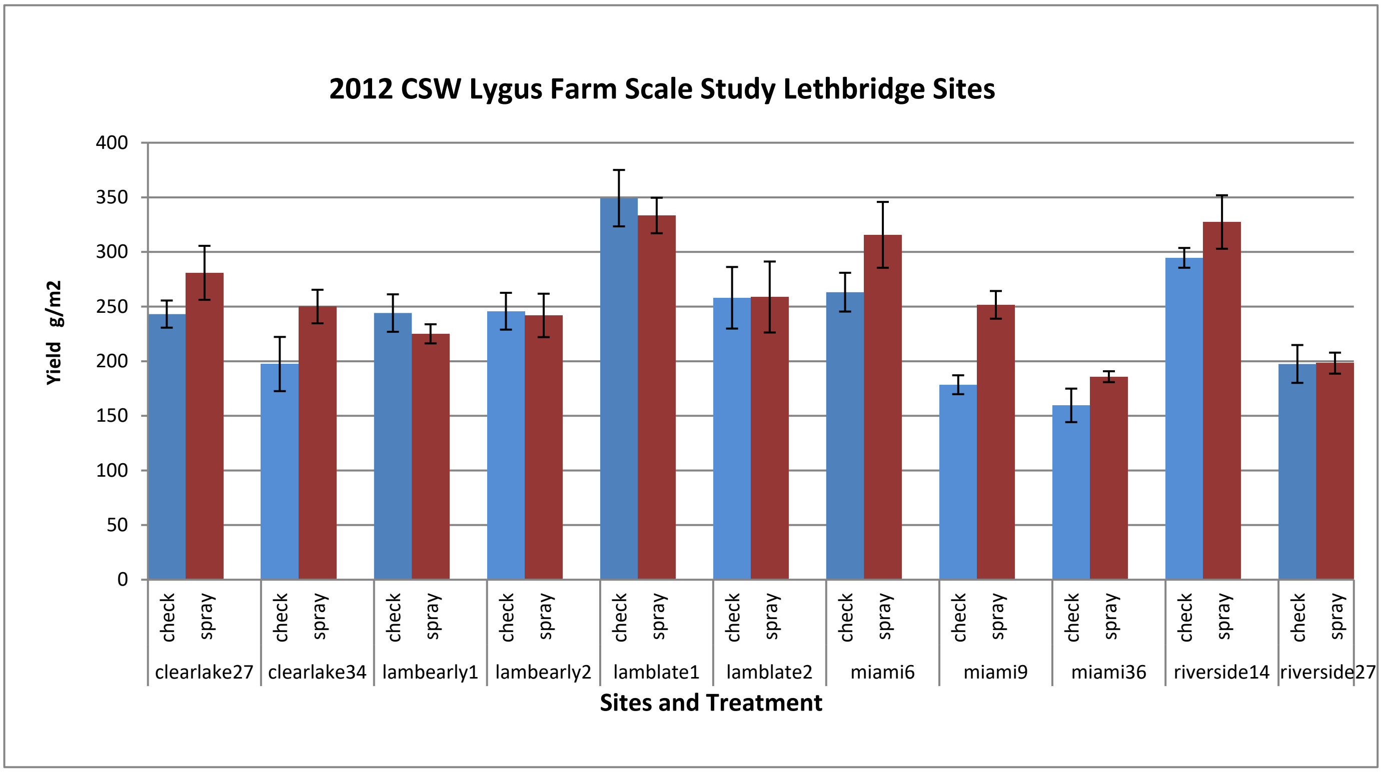

Figure 17. Quadrat yields from sites sampled by LRC.

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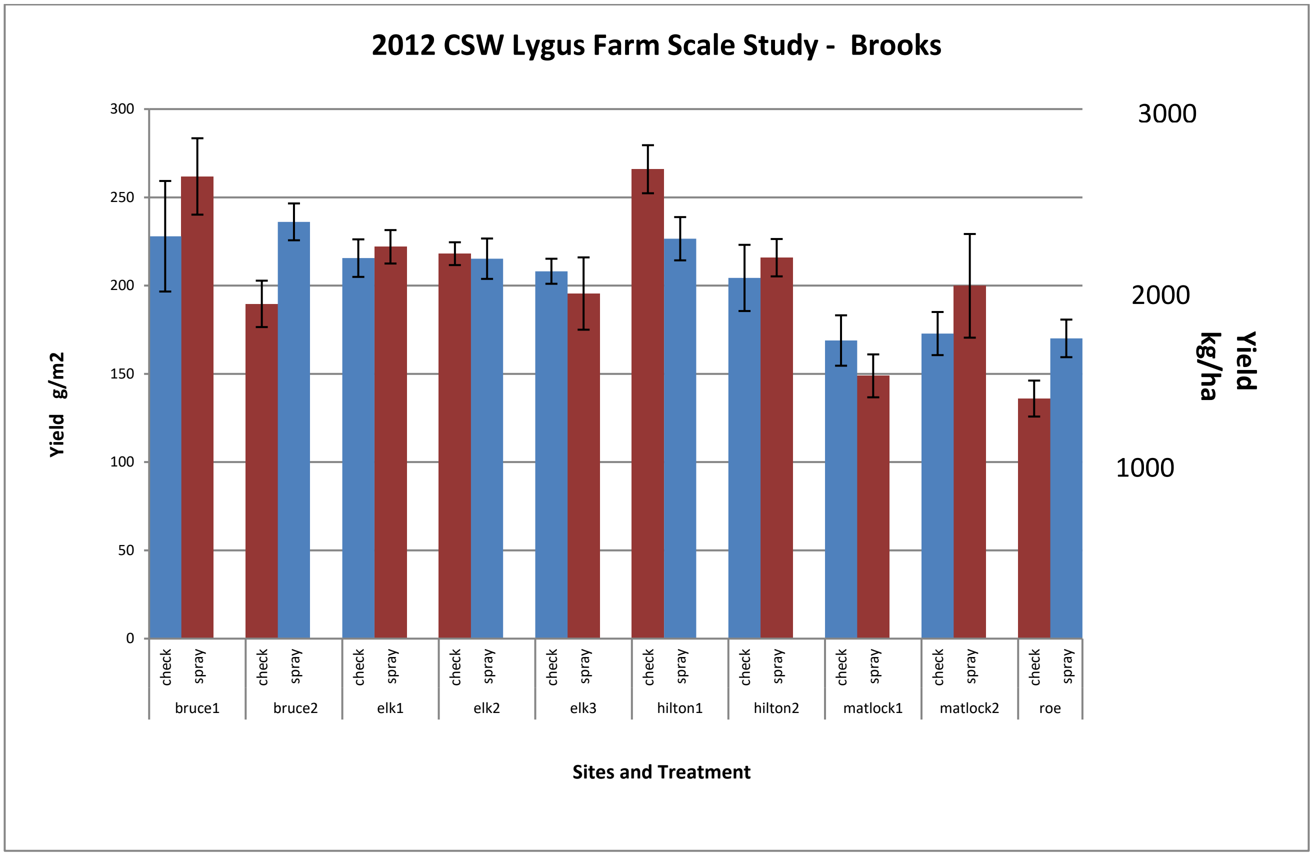

Figure 18. Quadrat Yields from sites sampled by Crop Diversification Centre South.

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2013

Six study sites were included in the region between Strathmore and Medicine Hat (referred to as “Brook sites”) and nine study sites in the more southern region (“Lethbridge sites”, Fig. 19). The study sites were Argentine canola and seeding was from April 22 through May 22.

Figure 19. Google Earth image of the Canola study sites in 2013.

Cabbage seedpod weevils (CSW) were more prevalent in the Vulcan area at flowering (Fig 20) with 4 sites above economic threshold of 4csw/sweep. Only one of the sites near Claresholm had CSW greater than 1 per sweep and the study sites in the Lethbridge area had low levels of CSW but growers still sprayed the strips within the borders to complete the experiment. Damage to pods was less than the critical level of 25% except in 3 fields in the more northern region (Fig 21).

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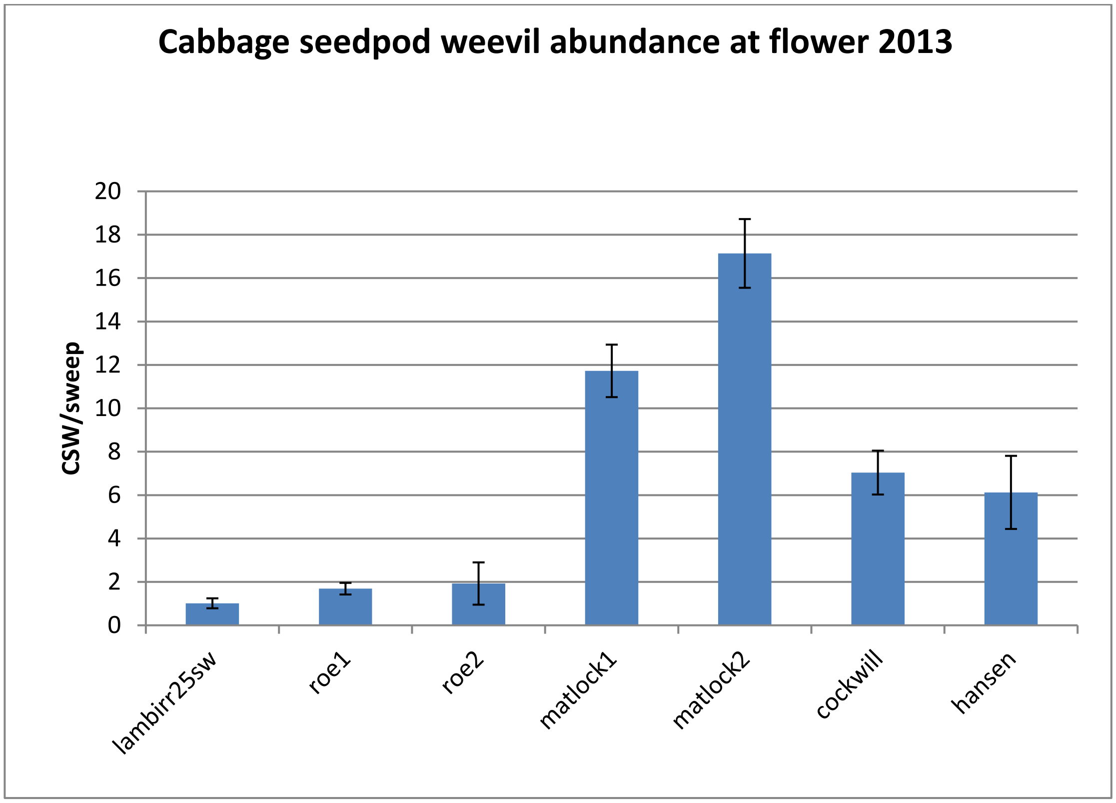

Figure 20. Cabbage Seedpod weevil abundance at canola flowering stage. Only sites with 1 or more csw per sweep are shown.

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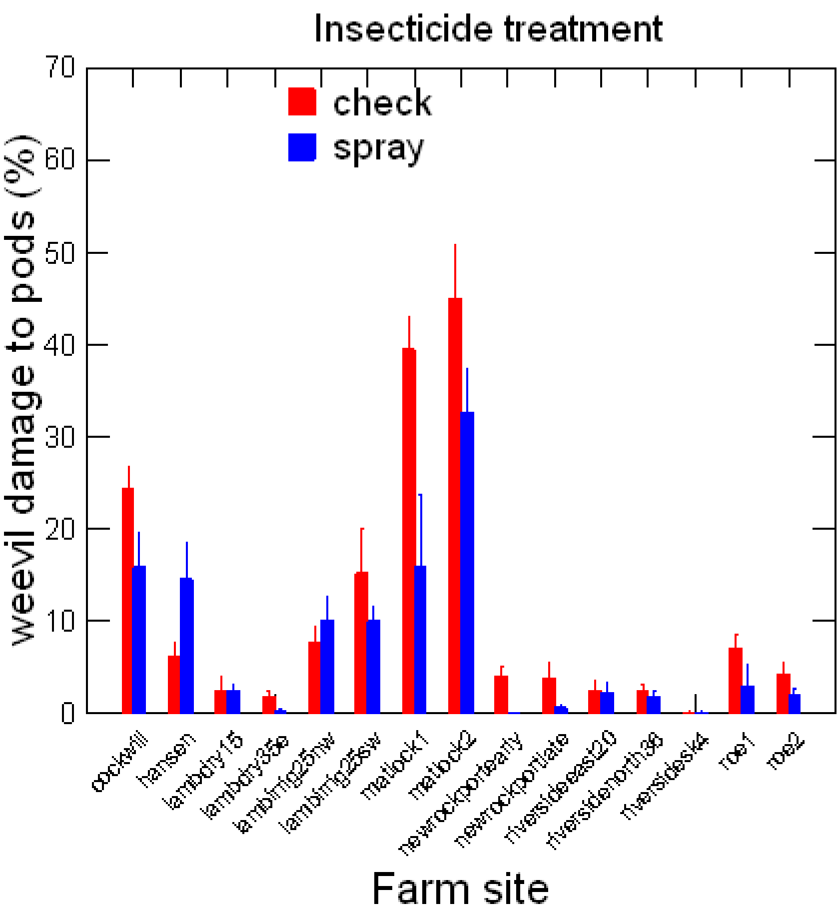

Figure 21. Percentage of canola pods damaged by seedpod weevil in 2013.

The sprayed plots had fewer Lygus bugs at the pod stage than the check plots in 12 out of the 15 sites (Fig. 22). One site, Hansen had the opposite results; similar patterns though rare were observed in previous years in some sites.

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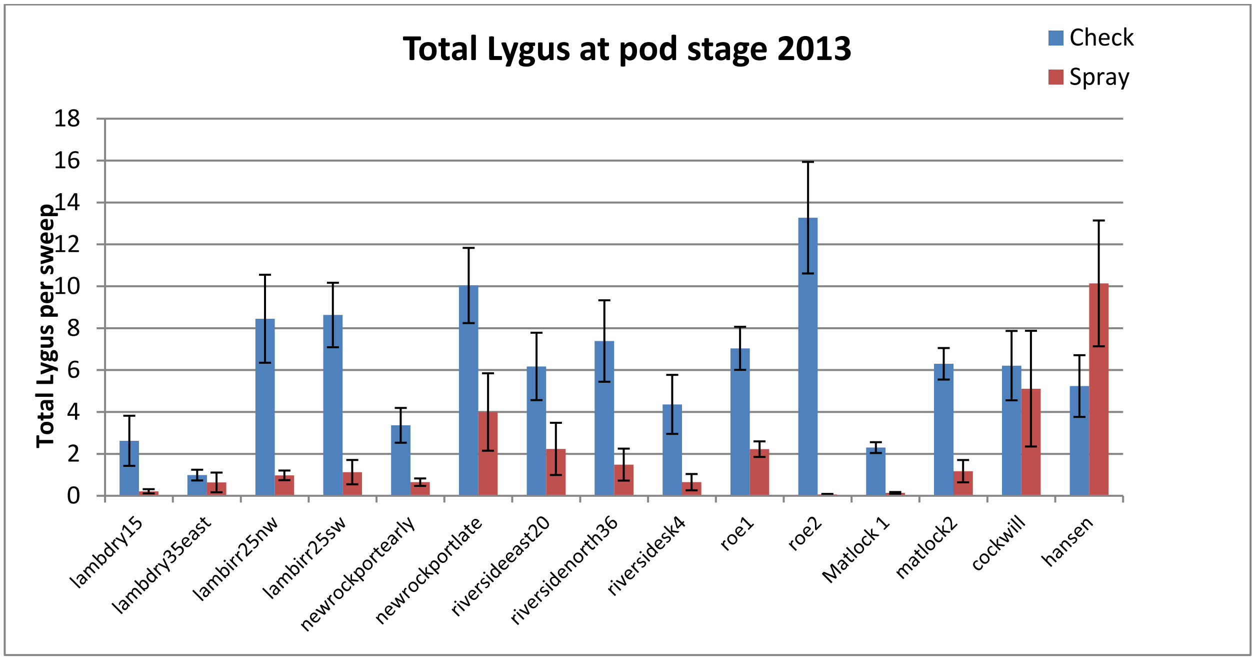

Figure 22. Total Lygus abundance at Canola pod stage.

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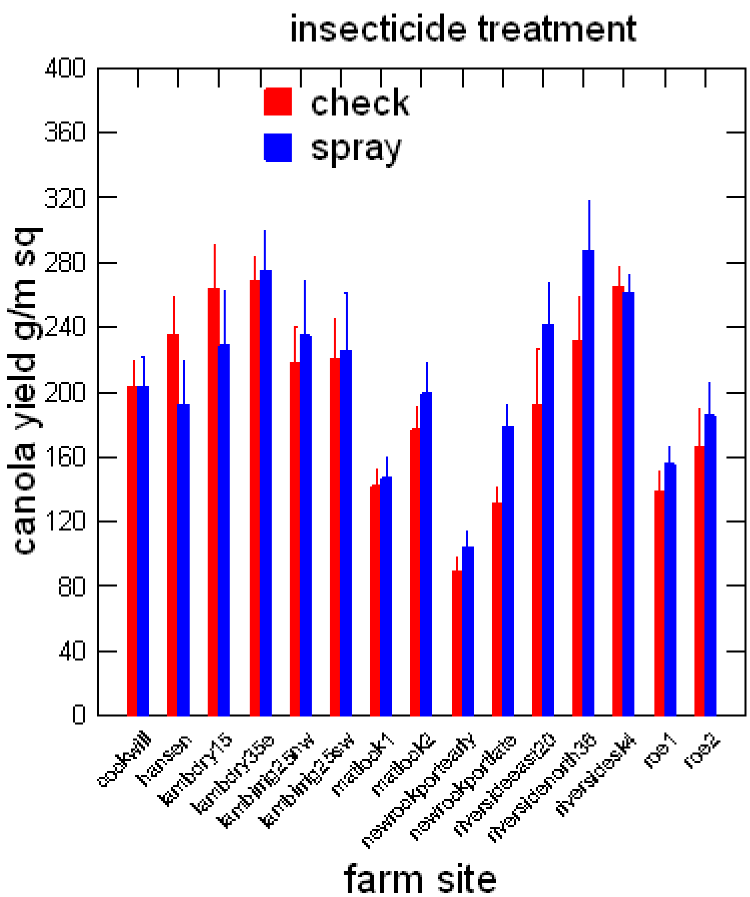

Figure 23. Total seed weights of quadrat samples in 2013.

At crop maturity, four 0.25m2 quadrats were collected at each sweep net sampling point for each site. Quadrat samples were threshed with a Wintersteiger plot combine, seeds cleaned, weight, 1000seed wt and test volume wt obtained. Yields differed significantly among sites but not consistently by treatment (Fig. 23). In 8 of the 15 sites, yields were at least 10 g/m2 (~1.8 bushels/ac) higher in the sprayed than in the untreated strips. In the other 7 sites, yields were similar or the check strip had higher yield than the sprayed strips as observed in two fields.

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Synthesis and discussion of 2010-2013 data including yields from combine monitors.

Yields from quadrats and combine monitors from all sites and years

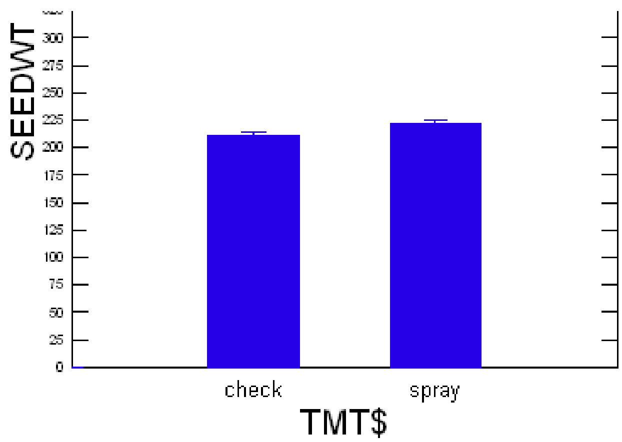

Figure 24. Overall average yields from all quadrats from 2010-2013 with all sites pooled (212 vs 222 g).

Overall yields from quadrats from all years and sites were about 10 g/m^2 (1.8 bu/ac) higher in the sprayed strips than in those unsprayed (Fig. 24). A similar analysis using yield data from the combine monitors from 17 sites (Fig. 25) showed a similar difference of 1.5 bu/ac between the two spray treatments.As with the quadrat data, combine monitors yield data was quite variable each year (Fig. 26). In a related study with fewer sites targeting insecticide spray for lygus at the pod stage using a weigh wagon also suggested yield increases in the order of 1-2 bushels per acre. These results suggest that the relationship between yield lossess and the abundances of these two pests are not linear. An important consideration that needs more research is the effect of trampling the plants during spraying on yield losses, particularly at the pod stage.

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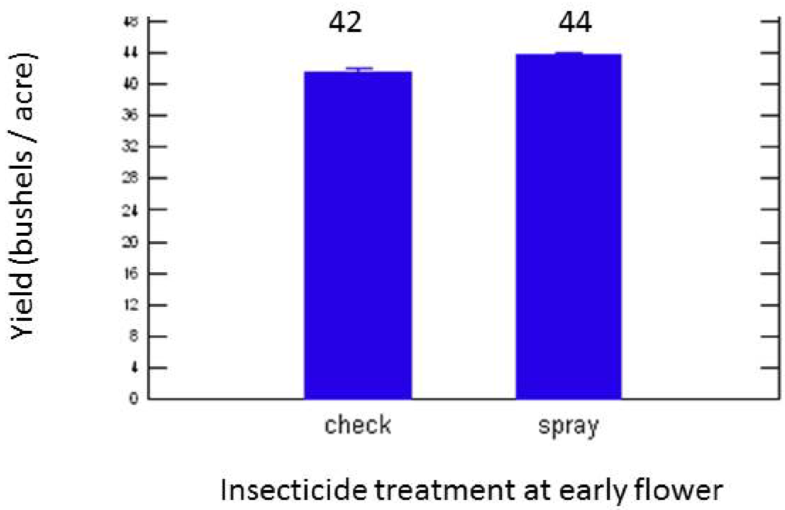

Figure 25. Overall average yields from all combine monitors from 2010-2013 with all 20 sites pooled (41.53 vs 43.66 bu/ac).

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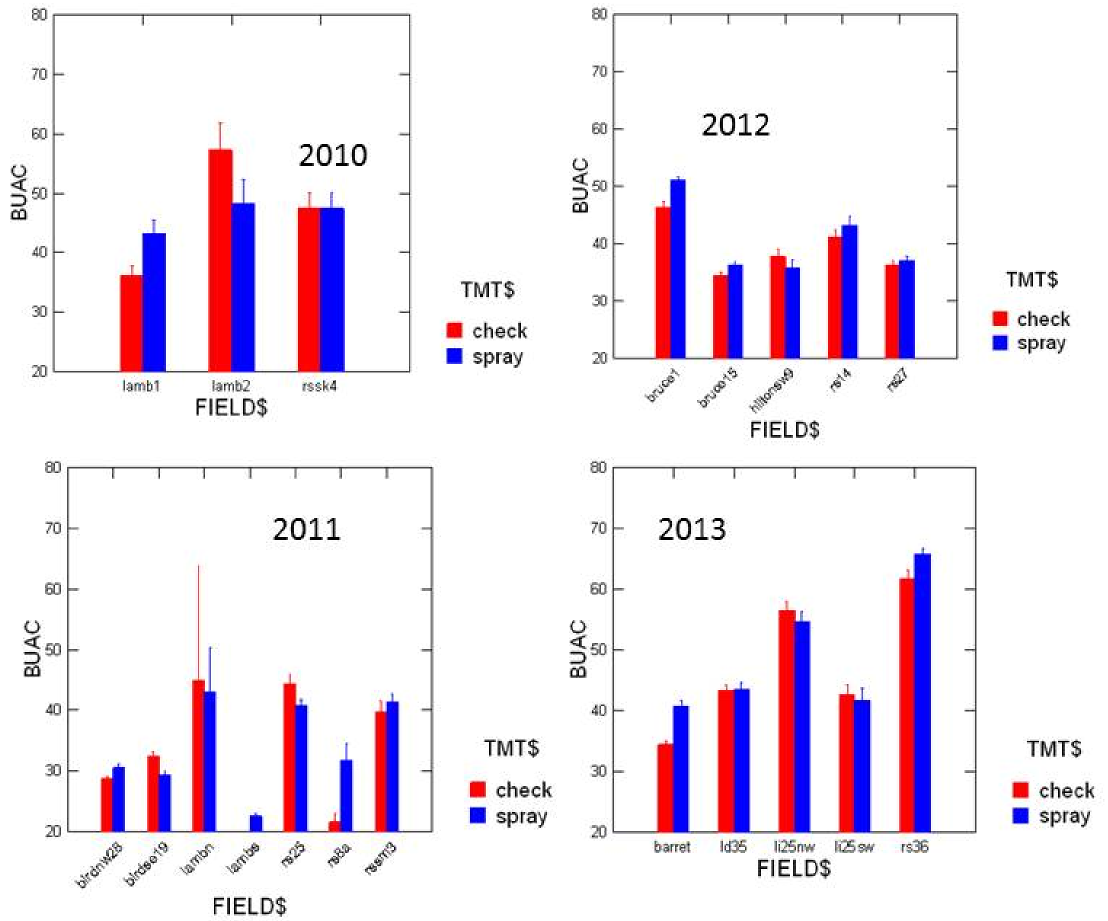

Figure 26. Yields from combine monitors for each year from 2010-2013.

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Effects of seeding date on insects

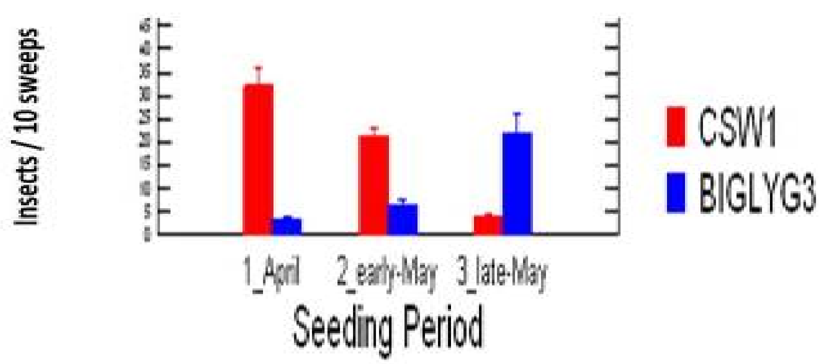

Figure 27: Effect of seeding period on lygus (BIGLYG3= adults and juveniles at least 3rd instar) and weevils (CSW1= cabbage seedpod weevils in first collection). Period 1 = April; 2= first two weeks in May; 3 = last two weeks of May.

Seeding period is suspected to affect these two insects in opposite ways but actual data to demonstrate this field observation has been lacking from commercial fields so far. Here, our data showed very clearly that seeding early during the month of April or in early May will result in a much higher accumulation of cabbage seedpod weevils (20-40 per sample of 10 sweeps) compared to fields planted during the last two weeks of May (less than 5 per 10 sweeps). The effect of seeding period on lygus bugs was opposite to that of seedpod weevils. Fields planted in the last two weeks of May had around 20 lygus or bigger juveniles per 10 sweeps during the pod stage whereas those planted earlier had only 3-6 per 10 sweeps. Canola is planted as early as possible and those fields may require weevil management but lygus risk is minimal. Therefore, only fields planted late, which would escape weevil damage, are at risk of lygus damage.

Insects and seed yield and quality correlations

Average yields and seed quality parameters (100 seed weights, green seed in the form of chlorophyl content and test volumes) from quadrat samples and insect abundance or damage (pods with weevil exit holes) collected at each strip was analyzed using Pearson Correlations to determine any possible relationships with insects (Table 1 in attached power point). Correlations between seed weight (g/m^2) and insects were negative but generally weak. Both insects had a similar negative association and as expected the highest coefficient (-0.19 for weevils and -0.18 for lygus) occurred at different crop stages: early flower for weevils and pod stage

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for lygus. These patterns are in agreement with current recommendations to apply management strategies at these two stages for these insects. The correlation of seed yield with the percentage of pods damaged by weevils was also negative and weak (-0.13); the low value suggests that plants were able to compensate or tolerate weevil feeding. As expected there was a stronger correlation between pod damage and weevil abundance, especially with the first two collections at early flower (0.53 and 0.51). Weevil activity (adult catches) and their damage appeared negatively associated with green seed content in contrast with lygus bugs that appear to increase it, but again correlations were weak. Further research is needed to determine if weevil feeding, especially later in the season when pods are maturing, may cause earlier senescence and a reduction in green seed, and weather lygus feeding do increase it as suggested by this data and from preliminary related ongoing cage studies.

An interesting pattern observed from Table 1 is the lack of correlations among the abundances of lygus bugs at various collections, which are in contrast to weevils. Correlations between weevil catches in sweepnets were reasonably well correlated (0.50 for CSW1 and CSW2) for the first two sampling weeks during flower. In contrast the correlation coefficient for lygus during the first two weeks was only 0.09 and generally remained low except for the late sampling periods when pods were maturing. This pattern can be explained by the very low catches of lygus during the flower stage and the difficulty in catching or counting small juvenile lygus at the full flower or late flower stage.

Rainfall interactions with insects

Total 12 month precipitation preceding the collections of insects during the pod stage was obtained for some sites from regional weather stations maintained by Alberta Agriculture. This value was used to test for correlations with insect abundance (Table 1). Also, the rainfall preceding the two weeks of the collection of insects during the pod stage was selected to determine impacts on lygus juveniles (Table 2). None of these measures from the regional weather stations were correlated with lygus or weevil abundances. On the other hand, rainfall measurements from local onsite rain gauges were negatively and significantly correlated with lygus numbers at the early pod stage (Table 3). This data suggests that localised rainfall may influence lygus populations and that regional weather stations have limited value to predict their populations.

Conclusions:

1) Spraying insecticide at the early flower stage for cabbage seedpod weevils reduced the abundance of lygus bugs at the pod stage in most cases
2) Overall fields and years, spraying at early flower for weevils resulted in an average yield increase of around 1.5 bushels per acre compared to unsprayed fields; this is likely primarily due to weevil feeding in excess of 20 per 10 sweeps but also includes lygus in some cases. Local results were highly variable for yield response

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to insecticide spraying and in several cases unsprayed strips had similar or higher yields than those sprayed. Seeding in April increased the risk of weevil damage but reduced that of lygus; the opposite occurred in fields seeded in late May and those seeded in early May had intermediate pest abundances.

3) Correlations among insects and yield or seed quality parameters were weak but more significant for weevils during early flower and big lygus (bigger than 3rd instar juveniles) during the pod stage compared to other stages. This is consistent with the small and variable yield response to insecticides. There was no indication that having the two pests at moderate numbers increased the risk of higher yield losses compared to fields with only high numbers of seedpod weevils.
4) Percent of pods with weevil damage was well correlated with abundance of weevils at flower; however, pod damage was only weakly correlated with yield.
5) Lygus abundance at early flower was not correlated with subsequent abundance at later crop stages even a week later; this was in contrast to the case of seedpod weevils and related to the more complex life cycle of lygus bugs.
6) Local growing season rainfall using rain gauges should be used to estimate lygus populations rather than regional weather stations. This was supported by significant negative correlations of lygus abundance with local rainfall but not with average regional values.
7) This information is useful for the improved management of lygus bugs and some of it has been transferred via Canola Digest and other means, but some of the new results remain to be dispersed; for example the yield and seeding date results need to be transferred.

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Suggestions for future research

1) Further research is still required on the need to manage lygus bugs that outbreak at the late pod stage, when the crop stays at 5.2 more than a week away from swathing. Some data was collected as part of a related study but results were too variable to make conclusions. Such a study is very difficult to accomplish because of the unpredictable nature of lygus outbreaks at the late pod stage and the practice to spray by airplane at that stage.
2) Effect of localized rainfall on insect damage, such as lygus and weevils, is a key factor that should be documented better to help growers reduce insecticide use.
3) Effect of lygus and weevils on canola seed quality needs further study but an ongoing cage study may provide insight into this question.
4) A perennial challenge with field studies is collecting proper yield measurements. This will require some innovative methods such as collecting data remotely directly from combine monitors and/or using weigh wagons to determine canola seed weights in relations to insects and insect pest management strategies such as insecticide spray.
5) Ultimately, alternative, long term sustainable strategies such as biological control to reduce insect pest populations should be researched.

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