SaskCanola Project Final Report Format

1. Project title and file number.

Monitoring of swede midge populations in Saskatchewan and determining the impact of swede midge on different growth stages of canola.

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2. Name of the Principal Investigator(s) and contact information.

Dr. Julie Soroka
Agriculture and Agri-Food Canada
107 Science Place
Saskatoon, SK, S7N 0X2
Email: Julie.Soroka@agr.gc.ca
Phone: (306) 385-9352

Dr. Owen Olfert
Agriculture and Agri-Food Canada
107 Science Place
Saskatoon, SK, S7N 0X2
Email: Owen.Olfert@agr.gc.ca
Phone: (306) 385-9355

3. Name of the collaborators and contact information.

Larry Grenkow
Agriculture and Agri-Food Canada
107 Science Place
Saskatoon, SK, S7N 0X2
Email: Larry.Grenkow@agr.gc.ca
Phone: (306) 385-9263

Dr. Lars Andreassen
Email: AndreassenLars@hotmail.com

Dr. Boyd Mori*
Agriculture and Agri-Food Canada
107 Science Place
Saskatoon, SK, S7N 0X2
Email: Boyd.Mori@canada.ca
Phone: (306) 385-9398
* Compiled Report

4. Abstract/ Summary:

The swede midge, *Contarinia nasturtii*, is a significant pest of brassica vegetable crops and canola in eastern Canada. It was first discovered in Saskatchewan in 2007 where it now threatens the canola industry. Here, we investigate the susceptibility of canola at different growth stages to infestation by swede midge, and the influence of seeding date and insecticide seed treatments on levels of infestation. Furthermore, we assess the effectiveness of swede midge adult sampling techniques (emergence and pheromone traps) throughout the summer to determine the phenology of swede midge populations. Over the course of our investigations we identified a second *Contarinia* midge species infesting canola that previously was unknown. We could not differentiate the damage caused by both species; therefore, we consider the assessed damage caused by the *Contarinia* midge complex (which includes swede midge and the new *Contarinia* midge species). We found that seeding date influences midge damage levels. Generally, early seeded plots had higher midge damage levels

than late seeded plots. The agronomic benefits of early seeding most likely outweigh the effects of the midge damage observed; therefore, it is still imperative that producers plant when conditions are most agronomically suitable. Additionally, insecticide seed treatment did not influence midge damage levels, which may indicate that midge attack after the insecticide loses effectiveness or that the midge damage levels were so low that no differences could be observed between the seed treatments. Two parasitoid species were found to attack midge infested flowers. If these parasitoids are attacking swede midge, this is the first report of parasitism in North America.

5. Introduction:

An invasive alien species, the swede midge, *Contarinia nasturtii* (Diptera: Cecidomyiidae) is a serious pest of brassica vegetable and canola crops that was first identified in North America from Ontario in 2000 (Hallett and Heal 2001). Swede midge winter as larvae in cocoons, which they exit in spring in response to moisture and heat accumulation. Larvae move towards the soil surface to pupate in a second cocoon. Adults emerge from the pupal cocoons and mate soon after (Readshaw 1961). In Ontario, emergence is protracted, and there are multiple emergence phenotypes (Hallett et al. 2009). Mated swede midge females lay eggs in a suitable host plant, which include most *Brassica* spp., including canola and a number of cruciferous weed species (Hallett 2007; Chen et al. 2009). Eggs are deposited in tight crevices among incipient buds and leaves. Larval feeding distorts plant growth and can destroy meristematic tissue. Larvae develop through three instars, then drop to the soil, and create larval cocoons that overwinter, or pupal cocoons from which adults will emerge in the same season, depending on environmental factors including photoperiod and soil moisture levels (Des Marteaux et al. 2015). In Ontario, there are usually four generations annually (Hallett et al. 2007); the number of generations on the Prairies is not known. The midge was first found in pheromone traps in northeastern Saskatchewan in 2007, and noticeable injury to canola was observed in fields in the area in 2012.

Several agronomic practices including planting date and insecticide seed treatment may affect the ability of swede midge to damage canola crops. Insecticide seed treatments are used to protect young canola plants from injury from flea beetles. These are principally neonicotinoids like thiamethoxam, a component of Syngenta's Helix Xtra and Helix Vibrance; however, the relatively new diamide, cyantraniliprole, a component of DuPont's Lumiderm, may be more effective than neonicotinoids against the striped flea beetle. Seed treatments are used in eastern Canada for early-season protection against swede midge in *Brassica* vegetable crops, and may protect canola in the same way. Furthermore, experiments with canola in Ontario have indicated that early seeded crops are less injured than later seeded crops. Whether this applies also on the Prairies has not been determined.

This research will aid in determining the phenology of swede midge populations in Saskatchewan, and will help identify canola growth stages most vulnerable to swede midge damage and the impact of common insecticide treatments.

6. Methodology: *Include approaches, experimental design, methodology, materials, sites, etc.*

In all study years (2014-2016) plots were established in four commercial canola fields in northeastern Saskatchewan: west of Ridgedale; southeast of Codette ("Codette 1"); halfway between Codette and Carrot River ("Codette 2"); and southeast of Carrot River.

To determine the susceptibility of canola at different growth stages to infestation by swede midge, and the influence of seeding date and insecticide seed treatments on levels of infestation, a split-plot experimental design was set up at each location, with early and late seeding date applied to whole plots, and four different seed treatments applied to the subplots. Subplots were four rows wide, with 30 cm between rows, and 6.1 m long, with 200 seeds planted per row. All seed for the experiment was treated with the fungicides penthiopyrad

(20 g a.i./100kg seed) and mefenoxam (6.67 g). The four experimental seed treatments were fungicide alone, Helix Vibrance (439 g), Lumiderm (400 g), and Helix Vibrance plus Lumiderm (439 g and 400 g, respectively). The varieties used depended on the site, and were the same as the producer seeded in the rest of the field (Table 1). Seedling emergence and flea beetle injury were rated for early and late seeded plots. Starting in late June, 10 randomly selected plants in the center two rows of each plot were assessed for growth stage using the Harper and Bergenkamp (1975) system, and for swede midge injury on a scale from 0-3, adapted slightly from that developed by R. Hallett (University of Guelph) for swede midge in Ontario (See Appendices). Damage was rated weekly thereafter to the pod-fill stage. Plots were swathed, harvested, and seed yield per subplot was measured.

To assess the effectiveness of swede midge adult sampling techniques (emergence and pheromone traps) throughout the summer to determine the phenology of swede midge populations, pheromone traps and emergence cages were used. Four white Jackson traps baited with a swede midge pheromone lure (Distributions Solida, Saint-Ferreol-les-Neiges, Quebec) were placed on 1.5 m tall stakes in early May, in a line on one edge of each field, 50 m apart and 20 cm above the soil surface. The sticky boards were changed weekly, and the pheromone lures were replaced every four weeks. Four emergence cages (BugDorm Co., Taichung, Taiwan), 60 by 60 cm at the base, were placed over canola stubble near each site in early May. Insects that emerged from the soil were captured in a container at the top of the cage, and the contents of the container were removed weekly for processing in the laboratory. Two of the cages had a pheromone trap inside, 20 cm above the soil surface. A second set of four cages, including two with pheromone traps, were put over soil within a solid stand of canola in late July. These were removed with the pheromone traps at the time of swathing.

7. **Research accomplishments**:

Flea beetle damage was low across all three study years. In 2014, seed treatment had no effect on flea beetle damage, but there was a significant site by date seeded interaction ($F_{3, 78.5} = 8.83$, $p < 0.001$). Flea beetle damage was lower for the early seeded treatments at all sites except Ridgedale (Table 2). In 2015, there was a significant date seeded by site interaction ($F_{3, 90} = 5.42$, $p = 0.002$) and a significant date seeded by seed treatment interaction ($F_{3, 90} = 2.77$, $p = 0.05$). All sites but Codette 2 had higher flea beetle damage on early seeded plots compared to late seeded plots and the combined seed treatment of Vibrance and Lumiderm had the lowest flea beetle damage on early seeded plots, but Vibrance alone had the lowest flea beetle damage in late seeded plots (Table 2). In 2016, seed treatment was the only variable that had a significant effect on flea beetle damage ($F_{3, 27} = 7.46$, $p < 0.001$). Fungicide alone had the highest incidence of flea beetle damage, and the combined seed treatment of Vibrance and Lumiderm had the lowest flea beetle damage (Table 2). Across all sites and years only the fungicide alone treatment in the late seeded plots at Ridgedale in 2015 exceeded the 25% economic threshold. The low incidence of flea beetle damage indicates that flea beetles did not significantly influence canola yield across the three years of this study.

During our investigations over the course of this study, we identified a second species of midge attacking canola. The midge is new to science and lacks a formal scientific name, but is in the same genus as swede midge, *Contarinia*. At the present time it is not possible to differentiate the damage caused by swede midge and this new species; therefore, all results in this study will refer to the *Contarinia* midge complex, *Contarinia* spp. Work is currently proceeding to formally describe the new species of midge and in the future the biology of the midge will be investigated.

Because the swede midge damage rating system used is qualitative instead of quantitative, in order to compare midge injury levels among sampling dates we utilized multinomial cumulative logit analysis and present the results as probability of occurrence of injury. Across all years, site, seeding date and injury rating date all affected the predicted probability of damage levels, but seed treatment had only a marginally significant effect on midge injury rating, and only in 2014. In 2014, there was a significant interaction between date of midge injury rating and site ($F_{3, 5682} = 11.581$, $p < 0.001$). Codette 1 had lower overall injury compared to Codette 2 and Carrot River (Fig. 1). There was also a significant injury rating date by date seeded interaction ($F_{1, 5682} = 8.25$, $p < 0.01$). Early in the growing season the probability of injury was higher on the early seeded plots, but as the season progressed the damage increased to a greater extent on late seeded plots compared to early (Fig. 1). Additionally, there was a site by date seeded interaction ($F_{3, 5682} = 4.08$, $p < 0.01$). Early seeded plots had a lower probability of midge injury during the first three weeks of ratings, but at the fourth week (August 5) injury was higher in the Codette 2 and Ridgedale early seeded plots compared to the late seeded (Fig. 1). Finally, seed treatment appeared to have a marginal effect on the probability of midge injury ($F_{3, 5682} = 2.74$, $p = 0.04$). Interestingly, the fungicide only treatment had the lowest probability of midge injury early in the season and late in the season (Fig. 2), and the probability of midge injury appears to be the highest on the plants with the combined Vibrance and Lumiderm seed treatment.

In 2015, at the first rating period (July 9), the probability of plants with midge injury was higher in early seeded plots compared to late seeded plots (Fig. 3). Injury was the lowest at the Ridgedale site for both early and late seeded plots compared to the other three sites and a lower probability of injury was observed on the final rating date compared to the previous week (Fig. 3). This was indicated by a significant three-way interaction between day of injury rating, site and date of seeding ($F_{3, 4711} = 8.61$, $p < 0.0001$). In 2016, the only significant variable was a date of injury rating by site interaction ($F_{3, 3079} = 17.03$, $p < 0.001$). Early seeded plots had a higher probability of midge injury, and Codette 2 had the lowest overall injury levels across the season (Fig. 4).

Seed treatment had no effect on seed yield across all three field seasons ($p > 0.05$). Seed yields were affected by a site by seeding date interaction in 2014 ($F_{3, 74.7} = 23.44$, $p < 0.0001$). Carrot River, Codette 1 and Ridgedale had higher seed yields in early seeded plots compared to late seeded plots, whereas seed yield was higher in late seeded plots at Codette 2 compared to early seeded plots (Table 3). Neither site nor seeding date effected seed yield in 2015 ($p > 0.05$). However, in 2016 site significantly affected seed yield ($F_{2, 8.2} = 45.80$, $p < 0.0001$), with Carrot River and Codette 2 yielding higher seed quantities than Ridgedale (Table 3). Unfortunately, due to extreme weather conditions in 2016 early seeded plots at Codette 1 could not be seeded, and due to late ripening and early snowfall seed could not be harvested from late seeded plots at Carrot River or Codette 1.

Across all years pheromone traps captured very few swede midges. In 2014 pheromone traps at the Ridgedale site caught two males in the week of 7 July, and one in the week of 28 July. The Codette 1 site had seven in the week of 30 June and one in the week of 18 August. The Carrot River site had one, the week of 4 August. No midges were found at the Codette 2 site. In 2015 the first swede midge captured on pheromone traps was one male from a trap at Ridgedale on 15 July. The Codette 1 traps caught one midge on 4 August, and 17 more on 14 August. Likewise, the Carrot River pheromone traps caught 36 male midges on 4 August, while no midges were found on pheromone traps at Codette 2. These captures are suspect as it wasn't until 2016 that the second midge species was identified and unfortunately the midge captured in 2014 and 2015 could not be compared to the new midge species. In 2016 we can confirm no swede midge were captured on pheromone traps at any of the four sites, nor were the newly identified *Contarinia* sp.

Examination of emergence trap specimens determined that only the newly identified *Contarinia* sp. was collected across all three years. In 2014, the four emergence cages at Ridgedale set up in May had no midges, likely because the soil was under water for about a week. Among the others, cages with the pheromone traps inside caught the same number of males as cages without the pheromone, in both the cages set up in May, and in those set up in late July. Given a peak in midge emergence in cages placed out in May (spring cages) and a second peak in cages placed out in July (summer cages) there was indication of two possible generations (Fig. 5

a, b). In 2015, midges first emerged from emergence cages set on canola stubble at the Carrot River, Codette 1, and Ridgedale locations in the week of 8 July (Fig. 5c), one week earlier than the first midges to emerge at Codette 2. As in 2014, there was evidence of a second generation of midge adults from emergence traps set on our plots later in the summer, which seemed consistently to begin emerging around 3–4 August, peak around 10–11 August, and largely to have ceased emerging a week later (Fig. 5d). Midge numbers in the summer generation were considerably larger than in the overwintering generation; the greatest number occurred at the Codette 1 site, averaging 109.5 midges per cage or 304 midges per m^2 of soil surface on 14 August. In 2016, midge emergence began in late June, earlier than both 2014 and 2015 and peaked in early July (Fig. 5e). Emergence from the Codette 1 site was the highest across all three years and corresponds with the large overwintering generation noted in 2015. In the cages placed out in late July (summer cages), it appears the second generation peak was missed at Codette 1, but occurred in the second or third week of August at Carrot River, Codette 2 and Ridgedale (Fig. 5f). Collections from all three years indicated that the newly identified *Contarinia* sp. has at least 2 generations per year, with at least one occurring when the crop is susceptible to midge injury.

In 2014, it was noted that galled flowers were attacked by a parasitoid wasp. This prompted further study, and two undescribed wasp species were discovered: *Inostemma* sp. (Platygastridae), which attacks midge eggs, or young larvae; and *Gastrancistrus* sp. (Pteromalidae) which attacks older midge larvae. The level of parasitism at Carrot River was estimated to be 16% at the end of July, and 36 % in early September. At Codette 2, 21% of the midge larvae collected in early September were parasitized. Collections of midge larvae were made at Codette and at Ridgedale in early September, but no parasitoids were present. It remains to be determined whether the parasitoids were parasitizing swede midge or the newly identified *Contarinia* sp.

Objectives	Progress
1) To determine the susceptibility of canola at different growth stages to infestation by swede midge, and the influence of seeding date and insecticide seed treatments on levels of infestation.	Complete – 2014-2016
2) To assess the effectiveness of swede midge adult sampling techniques (emergence and pheromone traps) throughout the summer to determine the phenology of swede midge populations.	Complete – 2014-2016

Discussion:

The most important discovery to come from this project is the identification of a new *Contarinia* sp. infesting canola. We plan to formally describe this new species and determine its biology and whether or not it causes economic damage in Saskatchewan. The newly identified species can be easily confused with swede midge and may have led to false reports of swede midge presence on the Prairies in previous years. The lack of male swede midge captured on pheromone traps indicates that swede midge populations were either extremely low or not present at our study sites. Emergence traps indicate that the main midge species present is the newly identified *Contarinia* sp. At the present time we are unable to separate injury caused by swede midge and the newly identified midge species; thus, results obtained on seeding date and seed treatment must be examined in the context of a *Contarinia* midge complex.

Across all years midge injury was extremely low. Site was a prominent variable in our study which indicates that midge levels varied significantly between locations, even if these are within a region. Seed treatment only marginally affected midge injury ratings in 2014; however, these results weren't as expected as injury ratings were higher on the combined Vibrance and Lumiderm seed treatment (Fig. 2). It is likely that midge attack Prairie canola after the insecticide in seed treatments is no longer effective, resulting in no consistent differences among seed treatments. In most study years, late seeded plots had a lower probability of midge injury compared to early seeded plots; however, the reduced agronomic benefits of late seeding make the practice impractical given such low midge damage. Finally, seed yield was not affected by seed treatment, and only in 2014 did planting date influence yield; however, the influence of planting date was not consistent and varied by site (Table 3).

Another significant discovery to come from this project was the identification of two parasitoid wasps attacking galled flowers. It is not known which midge species the parasitoid is attacking, swede midge or the newly identified *Contarinia* sp., but if the parasitoid is attacking swede midge this is the first report of parasitism in North America.

Emergence trap samples provided an initial perspective on the lifecycle of the newly identified *Contarinia* sp. The new midge species has at least two generations on the Prairies with the first generation occurring in the canola crop. In 2015 the large summer generation was reflected in the large spring generation of 2016, and indicates many midges successfully overwintered. Surprisingly, the large spring generation of 2016 did not carry over into a large summer generation. However, these trends indicate that when climatic conditions are favourable there is tremendous potential for population build up. Additional observations in the field have found larvae of this new species present on volunteer canola later in the season after the main crop has finished flowering, which would indicate a possible third generation. We plan to follow up this study and have submitted two grant proposals to fund this work starting in 2017.

Conclusions and Recommendations:

The damage caused by the *Contarinia* midge complex was extremely low for the duration of this project. Generally, early seeded plots had higher injury ratings than late seeded plots, however, seed yield was not impacted. Seed treatment had no effect on midge damage and indicates either that insecticides are no longer effective when midge attack or midge damage is so low that no differences could be observed between all the seed treatments. This study should be repeated in areas with high swede midge population levels such as those observed in Ontario.

Pheromone traps captured very few midges across all study years which indicates swede midge is either present in extremely low population levels or not present at our study sites. The newly identified *Contarinia* midge is not attracted to swede midge pheromone; therefore if any were captured in swede midge pheromone traps it was most likely by happenstance. In the future we hope to identify the pheromone from the new *Contarinia* midge in order to more accurately monitor population levels.

Emergence traps provided some initial data on the lifecycle of the new *Contarinia* midge species which has at least two generations on the Prairies, with only one appearing at the time of canola susceptibility in the course of our study. Emergence traps also indicate that swede midge were not emerging from the soil at our four particular sites. Future work is needed to elucidate where swede midge is present on the Canadian Prairies.

8. Success stories/ practical implications for producers or industry:

Although swede midge levels were too low to reliably determine the influence of seeding date and seed treatment on swede midge damage levels, two significant findings occurred from this work.

1) The identification of a new *Contarinia* midge species infesting canola. The origin, lifecycle, and ability to cause economic damage is currently unknown, but the initial identification allows us to be proactive and determine the potential damage this species may cause on canola.

2) The identification of two parasitoid wasps attacking galled canola flowers is the first report of parasitism of swede midge or the *Contarinia* sp. in North America. If these parasitoids are attacking swede midge, they may have a substantial impact on swede midge population levels and may keep them below economic damaging levels.

9. Patents/ IP generated/ commercialized products:

NA

10. List technology transfer activities:

1. Soroka, J. and Andreassen, L. (2014) Swede midge biology, symptoms, and outlook in Saskatchewan? Presentation at Agri-Trend Field Day, Shellbrook, SK, 17 Jul. 2014

2. Soroka, J. (2014) Swede midge in Saskatchewan canola. Presentation at Saskatchewan Ministry of Agriculture Crop Diagnostic School, Scott Research Station, Unity, SK, 21 & 22 Jul. 2014

3. Andreassen, L. (2014) Swede midge research update. Presentation at Melfort Research Station Field Day, Melfort, SK, 23 Jul. 2014

4. Soroka, J. and Andreassen, L. (2014) Swede midge in Saskatchewan canola. Presentation at Saskatchewan Ministry of Agriculture Crop Diagnostic School, Melfort Research Station, Melfort, SK, 28 & 29 Jul. 2014

5. Soroka, J. and Andreassen, L. (2014) Distribution of swede midge on the prairies. Presentation at the Annual Meeting of the Entomological Society of Canada, Saskatoon, SK, 30 Sept. 2014

6. Andreassen, L. and Soroka, J. (2014) Swede midge injury as influenced by crucifer species, and canola planting date and cultivar. Presentation at the Annual Meeting of the Entomological Society of Canada, Saskatoon, SK, 30 Sept. 2014

7. Andreassen, L. and Soroka, J. (2014) Swede midge status on the prairies. Presentation at the Western Committee on Crop Pests meeting, Canmore, AB, 30 Oct. 2014

8. Soroka, J., Andreassen, L., and Hartley, S. (2014) Saskatchewan insect outlook 2014-2015. Presentation to Canola Industry Days, Saskatoon, SK, 3 Dec. 2014

9. Andreassen, L. and Soroka, J. (2014) Swede midge on the prairies 2014. Presentation at the Saskatchewan Ministry of Agriculture Agronomy Update, Saskatoon, SK, 11 Dec., 2014

10. Andreassen, L. and Soroka, J. (2014) Everything you wanted to know about swede midge. Presentation at Ag-Days, Brandon, MB, 22 Jan. 2015

11. Soroka, J., Andreassen, L., and Wist, T. (2105) Insect research at Saskatoon Research Centre. Four talks given at four field tours to attendees of the 14th International Rapeseed Congress, Saskatoon, SK, 9 Jul. 2015

12. Soroka, J. and Andreassen, L. (2105) Research on swede midge at the Melfort Research Farm. Invited oral presentation at Melfort Research Farm Field Day, Melfort, SK, 22 Jul. 2015

13. Soroka, J., Andreassen, L., and Olfert, O. 2015. Swede midge –canola nemesis or flash in the pan – an update. Invited oral presentation to 2015 Regional SaskCanola Workshop, North Battleford, SK., 18 Nov. 2015

14. Soroka, J., Andreassen, L., and Olfert, O. (2016) Swede midge – new canola scourge or flash in the pan. Oral presentation to 2016 Agronomy Update. Alberta Agriculture Food and Rural Development, Red Deer, AB, 20 Jan. 2016

15. Andreassen, L., Soroka, J., and Olfert, O. (2106) Swede midge update 2016. Invited oral presentation at Prairie Pest Monitoring Network Annual Meeting, Saskatoon, SK, 22 Mar. 2016

16. Mori, B.A., Soroka, J., and Andreassen, L. (2016) Swede midge monitoring and biology on the Prairies. Western Committee on Crop Pests – Saskatchewan Entomology Research Summary

17. Mori, B.A. (2016) Swede midge research in Saskatchewan. Crop Protection Services – Western Canada Agronomy Meeting, Saskatoon, SK. 2 Nov. 2016

11. List any industry contributions or support received.

Dupont (Sagir Alam) treated the seed for each year of our study.

12. Is there a need to conduct follow up research?

Further work is in development to explore the distribution of swede midge and the new *Contarinia* sp. across the Prairies to determine their range extent and their overlap. Furthermore, the biology and parasitoids of both species will be investigated including the identification of the pheromone of the new *Contarinia* sp.

13. Acknowledgements.

We are greatful to SaskCanola for their support of this project. Wade Annand (Ag-Grow Consulting) was instrumental in getting this project off the ground and we thank Wade, Tim Perkins, Lyle Cowell and Mark Gordon for their help locating field sites and damage rating. We also thank Jamie Freedman, Ian Rushmer, Kent Baxter and Norm Ens for allowing us the use of their land. We thank Bayer CropScience and Pioneer Seeds for supplying seed for the project and DuPont for applying the seed treatments.

14. Literature Cited

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Readshaw JL (1961) The biology and ecology of the swede midge, *Contarinia nasturtii* (Kieffer) (Diptera: Cecidomyiidae). Ph.D. thesis, University of Durham, Durham, UK.

15. Appendices

Swede midge damage rating system:

The swede midge injury scale used depended on canola growth stage (Harper and Bergenkamp 1975). Up to bud stage 3.2:

0 = no damage

1 = mild twisting of foliage or slight crumpling of leaves, or up to 1/3 of buds on primary raceme misshaped, small, not developing normally

2 = severe twisting and/or crumpling of leaves, or more than 1/3 of buds on primary raceme misshaped, small, not developing normally

3 = death of meristem; including bud clusters that were initiated, but did not develop; may see swelling of buds, rot of bud cluster, bouquet of leaves, but no elongation of stem, no signs of flowers opening, no pod formation

For reproductive stages 4 and 5:

0 = no damage; includes racemes where stem is elongated with flower stalks, even if no flowers left and no pods have formed.

1 = stem of raceme may be slightly twisted, but still elongated; up to 1/3 of flowers fused; or, up to 1/3 of buds swollen and closed

2 = **either** i) stem of raceme may be slightly twisted, but still elongated; more than 1/3 of flowers fused; or, more than 1/3 of buds swollen and closed; **or**, ii) distorted pod bunches **-** ie.s tem not elongated, pods in a bunch on a short length of stem (umbrella or bouquet effect);

3 = death of meristem; including bud clusters that were initiated, but did not develop; may see swelling of buds, rot of bud cluster, bouquet of leaves, but no elongation of stem, no signs of flowers opening, no pod formation

Table 1: Site name, variety of canola and date early and late plots were seeded, swathed and harvested.

			Date					
			Seeded		Swathed		Harvested	
Site	Year	Variety	Early	Late	Early	Late	Early	Late
Carrot River	2014	45H31	24-May	03-Jun	27-Aug	03-Sep	10-Sep	16-Sep
	2015	45H29	20-May	04-Jun	01-Sep	11-Sep	24-Sep	29-Sep
	2016	L130	25-May	07-Jun	06-Sep	22-Sep	13-Sep	NA
Codette 1	2014	L130	23-May	03-Jun	27-Aug	03-Sep	10-Sep	16-Sep
	2015	45H29	20-May	04-Jun	01-Sep	11-Sep	24-Sep	29-Sep
	2016	45H31	NA	07-Jun	NA	22-Sep	NA	NA
Codette 2	2014	45H29	23-May	03-Jun	03-Sep	03-Sep	16-Sep	16-Sep
	2015	L130	21-May	04-Jun	01-Sep	11-Sep	24-Sep	29-Sep
	2016	45H31	25-May	07-Jun	06-Sep	15-Sep	13-Sep	28-Sep
Ridgedale	2014	45H29	23-May	03-Jun	27-Aug	03-Sep	10-Sep	18-Sep
	2015	L252	21-May	04-Jun	01-Sep	11-Sep	24-Sep	29-Sep
	2016	L252	26-May	07-Jun	06-Sep	15-Sep	13-Sep	28-Sep

Table 2: Mean flea beetle damage (% defoliation on the first 4 leaves) per plot by insecticide seed treatment, year and seeding date (Early and Late seeded date corresponds to Table 1).

		Year					
		2014 Mean Damage (%)		2015 Mean Damage (%)		2016 Mean Damage (%)	
Site	Treatment	Early Seeded	Late Seeded	Early Seeded	Late Seeded	Early Seeded	Late Seeded
Carrot River	Fungicide	18.75	20.48	15.19	8.83	17.00	18.03
	Fung. + Lumiderm	13.25	18.25	11.56	9.87	10.92	15.20
	Fung. + Vibrance	17.71	20.13	8.33	8.92	7.26	12.39
	Fung. + Vib. + Lum.	9.31	16.02	9.85	14.27	7.31	10.80
Codette 1	Fungicide	10.78	9.31	23.71	19.96	NA	8.26
	Fung. + Lumiderm	13.40	7.29	17.38	12.21	NA	5.69
	Fung. + Vibrance	10.69	6.48	10.67	8.75	NA	5.53
	Fung. + Vib. + Lum.	10.17	3.88	8.88	6.04	NA	4.75
Codette 2	Fungicide	15.71	9.15	8.77	12.63	21.51	12.73
	Fung. + Lumiderm	19.27	8.06	3.02	16.17	14.57	9.28
	Fung. + Vibrance	14.08	8.06	3.56	7.65	20.27	7.81
	Fung. + Vib. + Lum.	11.83	9.08	1.75	11.64	7.56	8.08
Ridgedale	Fungicide	19.00	14.54	25.17	17.79	6.63	13.34
	Fung. + Lumiderm	13.29	15.35	14.08	18.61	5.82	4.94
	Fung. + Vibrance	9.63	17.10	10.06	14.08	1.33	8.41
	Fung. + Vib. + Lum.	11.17	12.85	9.63	16.50	2.25	4.74

Table 3: Mean canola seed yield per treatment by site and year (Early and Late seeded date corresponds to Table 1).

		Year								
		2014			2015			2016		
		Mean Seed Yield (kg/ha)			Mean Seed Yield (kg/ha)			Mean Seed Yield (kg/ha)		
Site	Treatment	Early Seeded	Late Seeded	Mean	Early Seeded	Late Seeded	Mean	Early Seeded	Late Seeded	Mean
Carrot River	Fungicide	3563	2556	3059	2331	2348	2340	2805	NA	
	Fung. + Lumiderm	4106	2591	3349	2104	1805	1955	2970	NA	
	Fung. + Vibrance	4089	2472	3281	2441	2274	2357	3032	NA	
	Fung. + Vib. + Lum.	4002	2450	3226	2601	2100	2350	3049	NA	
	Mean Seed Yield (kg/ha)	3940	2517		2369	2132		2964		
Codette 1	Fungicide	559	432	496	2330	2436	1970	NA	NA	
	Fung. + Lumiderm	839	655	747	2985	2351	2062	NA	NA	
	Fung. + Vibrance	597	453	525	2542	2660	2233	NA	NA	
	Fung. + Vib. + Lum.	1023	724	874	2770	2519	2156	NA	NA	
	Mean Seed Yield (kg/ha)	754	566		1995	2216				
Codette 2	Fungicide	2044	2788	2415	1862	2078	2383	3313	3184	2656
	Fung. + Lumiderm	2505	2833	2669	1979	2145	2668	3240	3287	2668
	Fung. + Vibrance	2054	2654	2354	2035	2430	2601	3311	3236	2676
	Fung. + Vib. + Lum.	2766	3003	2885	2102	2209	2645	3354	3221	2688
	Mean Seed Yield (kg/ha)	2343	2819		2657	2492		3305	3232	
Ridgedale	Fungicide	2413	2118	2266	2099	2503	2301	1414	799	905
	Fung. + Lumiderm	2634	2041	2337	1994	2421	2208	1738	1217	1208
	Fung. + Vibrance	2662	2276	2469	2209	2517	2363	1584	1510	1265
	Fung. + Vib. + Lum.	2449	2339	2394	2133	2320	2227	1791	859	1083
	Mean Seed Yield (kg/ha)	2540	2193		2109	2440		1632	1096	

Figure 1: Mean predicted probability of a midge damage rating of 1 at four locations in Saskatchewan, 2014. Solid lines – early seeding; Dashed lines – late seeding.

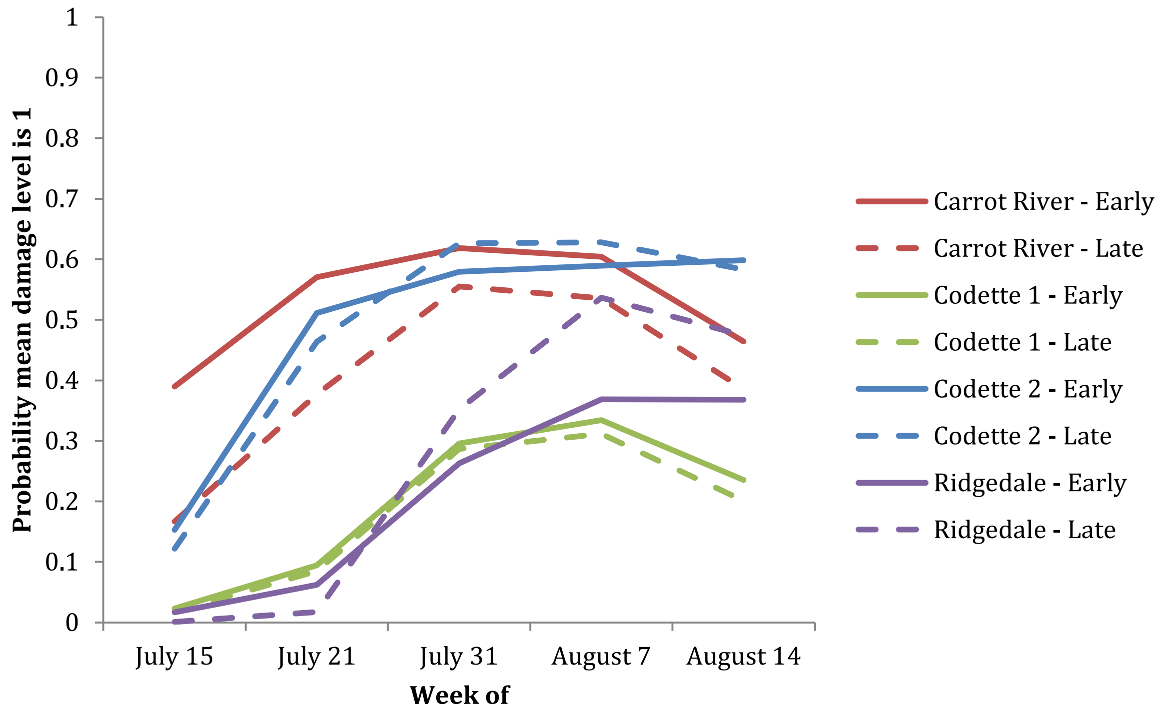


Figure 2: Mean predicted probability of a midge damage rating of 1 by seed treatment in 2014.

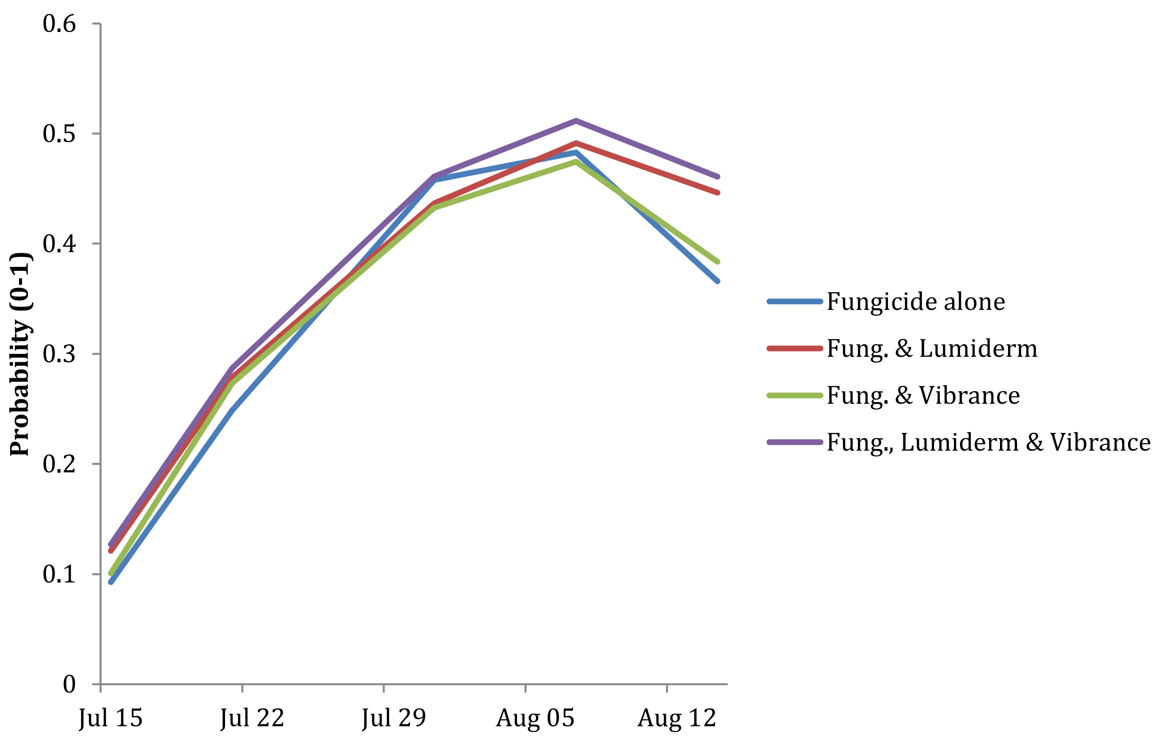


Figure 3: Mean predicted probability of a midge damage rating of 1 at four locations in Saskatchewan, 2015. Solid lines – early seeding; Dashed lines – late seeding.

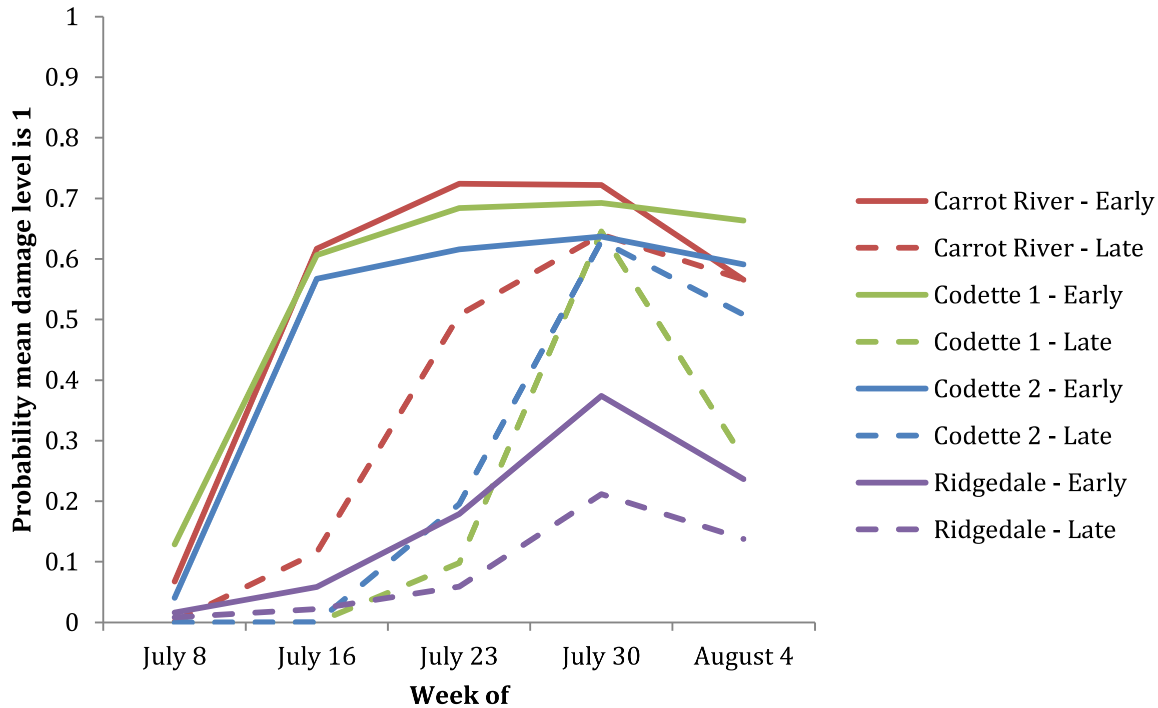


Figure 4: Mean predicted probability of a midge damage rating of 1 at four locations in Saskatchewan, 2016. Solid lines – early seeding; Dashed lines – late seeding.

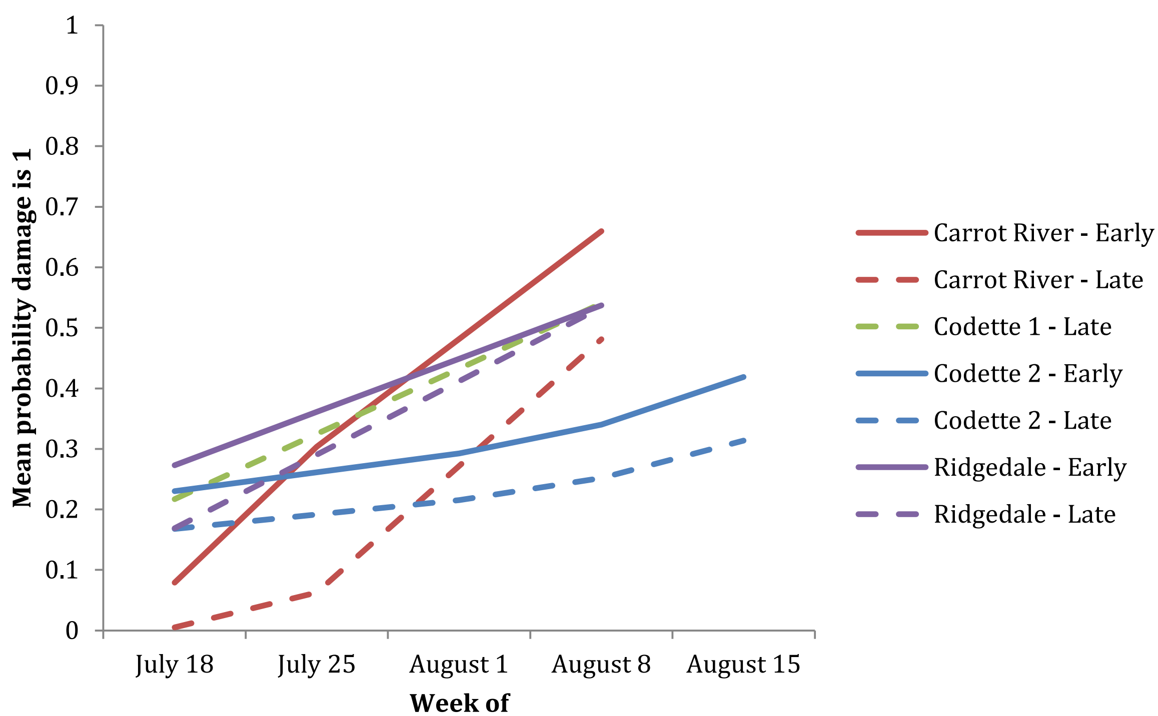
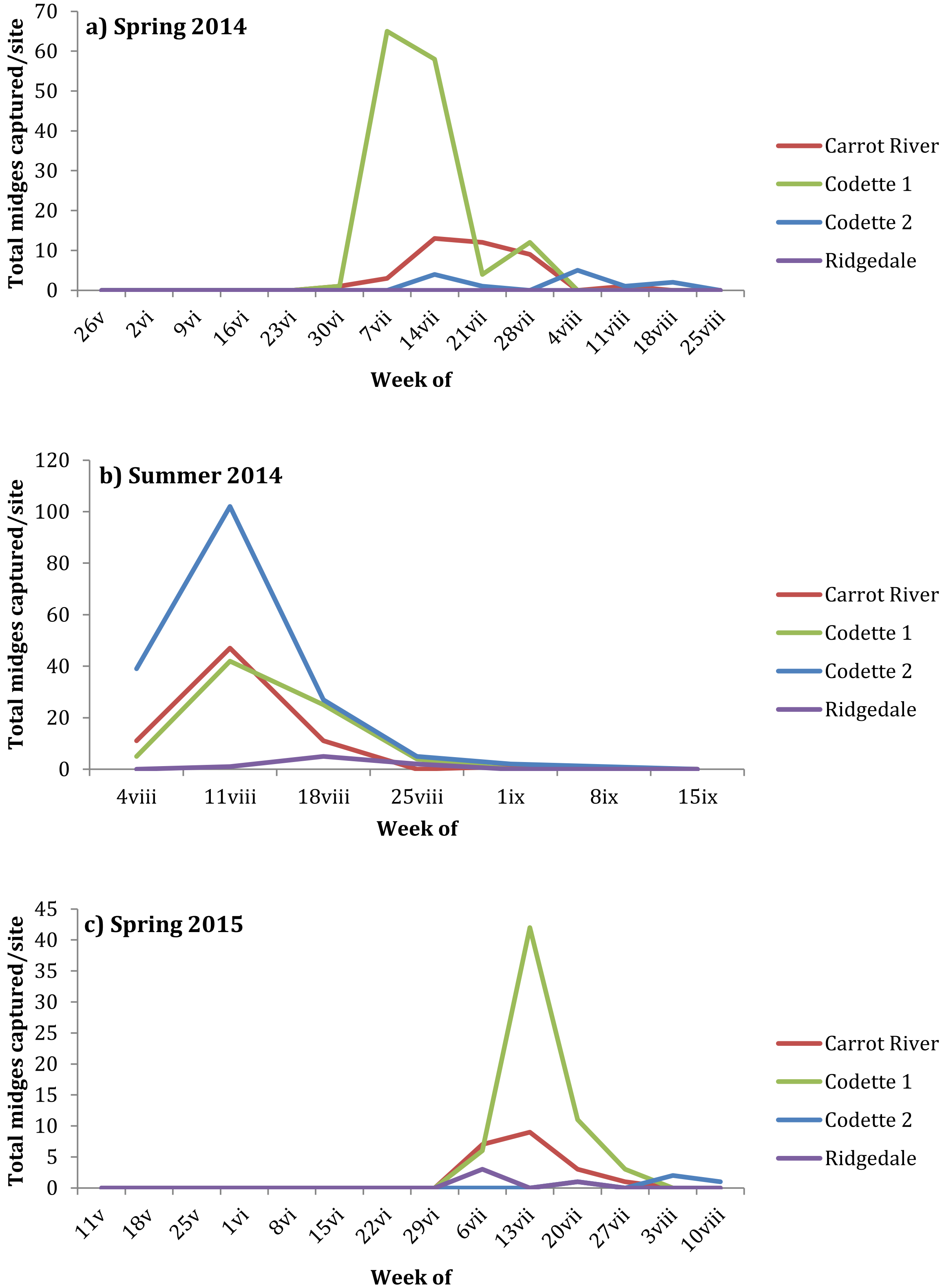
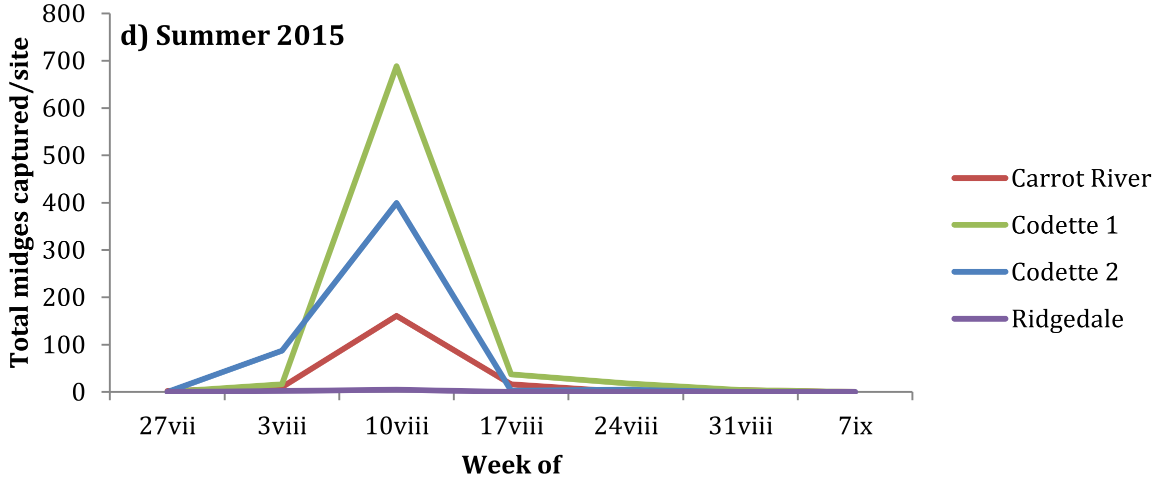
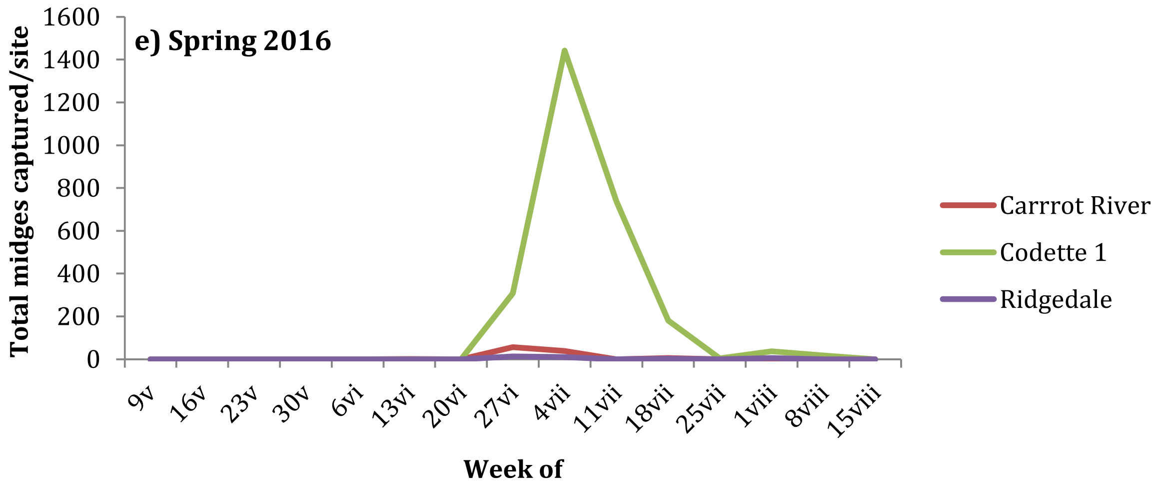
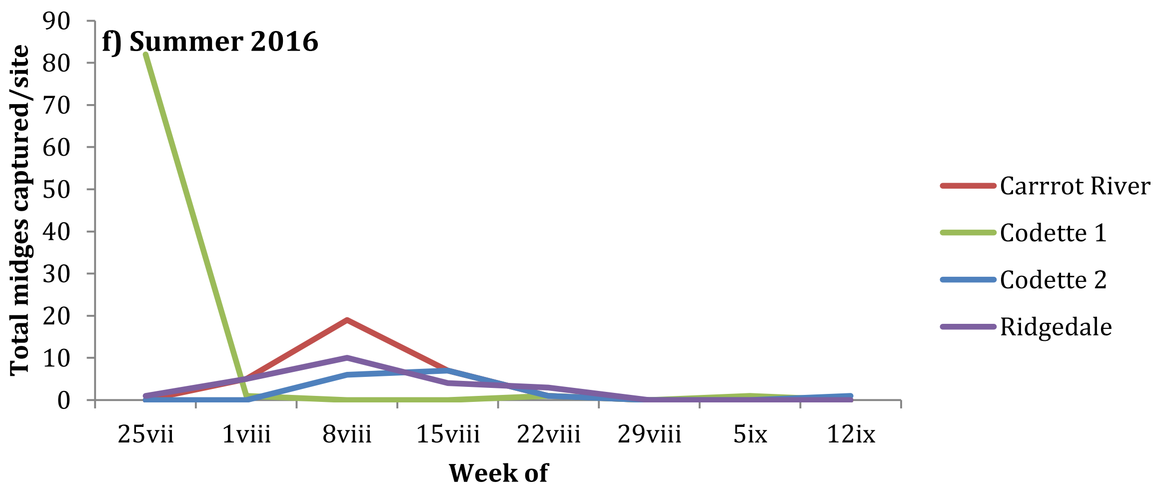


Figure 5: Total weekly number of midge captured in spring and summer emergence traps by site, year, and trapping period (Summer vs. Spring). a) Spring cages 2014; b) Summer cages 2014; c) Spring cages 2015; d) Summer cages 2015; e) Spring cages 2016; f) Summer cages 2016. NOTE: the scale of the y-axis changes by year and season.




d) Summer 2015
Total midges captured/site
800
700
600
500
400
300
200
100
0
27vii
3viii
10viii
17viii
24viii
31viii
7ix
Week of
Carrot River
Codette 1
Codette 2
Ridgedale


e) Spring 2016
Total midges captured/site
1600
1400
1200
1000
800
600
400
200
0
9v
16v
23v
30v
6vi
13vi
20vi
27vi
4vii
11vii
18vii
25vii
1viii
8viii
15viii
Week of
Carrrot River
Codette 1
Ridgedale


f) Summer 2016
Total midges captured/site
90
80
70
60
50
40
30
20
10
0
25vii
1viii
8viii
15viii
22viii
29viii
5ix
12ix
Week of
Carrrot River
Codette 1
Codette 2
Ridgedale