Comparative efficacy of insecticidal seed treatments for flea beetle control in canola and evaluation of a novel mitigation strategy to reduce neonicotinoid use

James A Tansey, John Ippolito and Lyndon Hicks

Abstract

Flea beetles in the genus *Phyllotreta* are the most damaging pests of seedling canola in Western Canada. Prophylactic use of insecticidal seed treatments, primarily the neonicotinoids thiamethoxam and clothianidin, are used by the vast majority of canola growers to protect crops from these insects. Recently, the Pest Management Regulatory Agency (PMRA) of Health Canada has proposed deregistration of the neonicotinoids thiamethoxam and clothianidin for use as seed treatments due to concerns over their potential impacts on aquatic ecosystems. There is a very limited suite of alternatives to these substances. These alternatives include: the diamide, cyantraniliprole and the sulfoxamine, sulfoxaflor. Although the efficacy of these alternatives is reported, direct comparisons of these substance to the registered neonicotinoid products is lacking. The PMRA has also proposed the importance of alternate strategies to reduce the inputs of neonicotinoids into aquatic systems. Here, we present the results of a study to compare the relative efficacies of several commercial seed treatment products for canola and another study to evaluate the effects of administering seed treatments as border strips.

Introduction

Flea beetles in the genus *Phyllotreta* (Coleoptera: Chrysomelidae) are the most serious pests of seedling canola in western Canada (Lamb and Turnock 1982). Two Brassicaceae-feeding species dominate this region: *Phyllotreta cruciferae* (Goeze) and *P. striolata* (Fab.). Each is regionally prevalent with parkland regions dominated by *P. striolata* and southern regions of the Prairies dominated by *P. cruciferae* (Elliot et al. 2011, Soroka et al 2018). Each species differs in its response to insecticides: *P. striolata* is more tolerant of neonicotinoids and diamides (Tansey et al. 2008, 2009; Elliot et al. 2011). Differential susceptibility to class 4 insecticides is thought to be contributing to a shift in the species composition from *P. cruciferae* to *P. striolata* in increasingly southern Prairie canola producing regions, historically dominated by *P. cruciferae*. Additionally, *P. striolata* emerges ca. two weeks earlier (Soroka and Elliot 2011, Elliot et al 2011, Soroka et al 2018), increasing the need for prophylactic use of seed treatments for canola.

In 2016, a special review of the neonicotinoid, imidacloprid, was released by the Pest Management Regulatory Agency (PMRA) of Health Canada (PMRA 2016). The results of this review indicated that the effects of seed treatments that incorporate this neonicotinoid should not present unacceptable risks to pollinators. Because of the similarities in toxicological profile of imidacloprid to thiamethoxam and clothianidin, special reviews of these two other neonicotinoid chemistries were triggered. Results of these special reviews also indicated pollinator safety for the seed treatment use-pattern but illustrated some new concerns associated with the heath of aquatic invertebrate populations (PMRA 2018 a, b). Importantly, neither cyantraniliprole nor sulfoxaflor are subject to special reviews by PMRA.

In response to the imidacloprid special review, Agriculture and Agri-Food Canada (AAFC) initiated the Multi-Stakeholder Environmental Working Group to examine actual concentrations of imidacloprid, thiamethoxam, and clothianidin in aquatic systems throughout Canada. Specialists from the

Saskatchewan Ministry of Agriculture sit on this committee and contribute to data collection and report preparation. These data were submitted for the 2017-2019 period to PMRA and will contribute to anticipated final decisions associated with the effects of thiamethoxam and clothianidin on aquatic invertebrates. Discussion with the PMRA under the auspices of this group have addressed strategies such as mitigation of neonicotinoid runoff. Specifically, the installation of vegetative buffer strips and reduced insecticide application techniques have been addressed as necessary by the working group and PMRA.

Insecticidal seed treatments are the primary means of reducing flea beetle damage in seedling canola. Growing canola on the Prairies is very challenging without their prophylactic use. Most of the commercially-available products currently contain the active ingredients clothianidin or thiamethoxam (Government of Saskatchewan 2019). Recently, formulations with the anthranilic diamide cyantraniliprole have also been made available as have products containing the sulfoxamine, sulfoxaflor. All of these products have reputed efficacy for reducing flea beetle damage. What is needed is evaluations and demonstrations of the relative efficacies of these products, particularly those that will gain market share in the event of thiamethoxam and clothianidin deregistration.

We have conducted comparative evaluations of the efficacies of commercially-available insecticidal seed treatments for flea beetle control. We have also assessed the efficacies of reduced insecticide application techniques: reduced input of treated seed by applying treated seed to the borders of plots rather than to the entire plot. The former involved the use of small-plot demonstration trials, the latter incorporated near-farm-scale trials of reduced seed treatment usage. The results of both trials can contribute to the interactions of Ministry of Agriculture specialists and the PMRA and inform grower and regulator decisions and recommendations made by Ministry extension personnel.

Methods

Helix Vibrance-, Helix JumpStart- and Helix + Lumiderm-treated seed was obtained from Nutrien Ag Solutions. Untreated seed and Lumiderm and fungicide seed treatments were provided by Corteva. Prosper seed treatment was provided by Bayer. Seed was 45H33 (Corteva)/ Proven PV 540 G (Nutrien). All seed was Roundup Ready.

Small plots

This study was conducted at three contractor sites: East Central Research Foundation (Yorkton), Western Applied Research Corporation (Scott), and Irrigation Crop Diversification Corporation (Outlook). Plots were established at each site with treatments arranged in a four-replicate, randomized complete block design (RCB). Treatments included: 1) an untreated control, 2) fungicidal seed treatment (difenoconazole), 3) the thiamethoxam products, Helix Vibrance, and 4) Helix JumpStart, 5) the cyantraniliprole (diamide) seed treatment, Lumiderm, 6) the sulfoxaflor product, Visivio (mixed with thiamethoxam), a mixture of Lumidem and thiamethoxam, and the clothianidin product, Prosper. Pre-seed burn-off was conducted with a glyphosate product ca. one week prior to seeding. Plots at all sites were seeded the last week of May to the first Week of June. Each plot was ca. 10 m by 3.5 m and seeded at 12-inch row spacing and ca. 6 pounds per acre. At the Yorkton ECDF site, plots were fertilized at 59 lb/ac MAP (in seed row), 62.5 lb/ac Ammonium Sulphate (side banded at seeding), 217 lb/ac Urea (side banded at seeding). Fungicide (Acapela 350 ml/ac) was applied late July. Plots were desiccated with

Reglone (diquat) late September and middle rows harvested early-October with small plot research harvesters. At the Outlook ICDC site, plots were swathed September 6 and combined September 19. At the Scott (WARC) site, a fertilizer blend (0-75-33-0 @ 100 lb/ac) was side-banded and 80-0-20 @ 100 lbs/ac was applied mid row. An in-crop Roundup 540 application @ 0.67L/ac @ 10gpa was made July 3. Plots were harvested 17 October.

Flea beetle damage was evaluated weekly from cotyledon stage for four weeks by visual inspections of 20 seedlings at four randomly chosen 30 cm by 30 cm quadrats randomly placed in each plot. At the Scott (WARC) site, plots were monitored bi-weekly for the first two weeks. The first three monitoring period are included in the analysis. To reduce subjectivity of evaluators, photographs were taken from 40 cm above each sampling site, so that the quadrat filled the field of view of camera(s); all damage was evaluated from photographs by Tansey. Flea beetle species composition was also evaluated from photographs. Because flea beetle damage accumulated primarily in the first two weeks, these data were subject to analysis.

Large plot reduced rate-neonicotinoid seeding trail

Trials were conducted on the AAFC Saskatoon and Llewelyn research farm sites. We evaluated targeted use of a neonicotinoid seed treatments by comparing flea beetle damage and harvest data among three treatments: 1) 60 m by 60 m plots seeded completely to commercial neonicotinoid-treated seed, 2) Plots of these dimensions seeded with a 9.45 m strip around the plot's inner periphery seeded to neonicotinoid-treated seed, the remainder was seeded with untreated seed, 3) as treatment 2 except that the border strip was 18.33 m. Seed were Helix Vibrance-treated (thiamethoxam) for the Saskatoon site. Llewelyn site insecticide treatment plots were seeded with Prosper-treated (clothianidin) seed. Prior to seeding, a soil test analysis indicated the required level of fertilization for growth of Canola on both 8 acre fields. According to the soil test, a fertilizer regime of 50N: 30P:25S was applied. Both large plots were seeded in 9.5m swaths with a conventional seed drill on Friday May 31st 2019. Seeds were sown at 12-inch row spacing and at approximately 6 pounds per acre according to the recommended seeding density (Canola Council of Canada). Within 48hrs the plots were irrigated (29mm) to counteract the extremely dry conditions of the spring and stimulate germination. Emergence of seedlings began of the 6th of June 2019.

Each of the large plots in the Latin Square at the Saskatoon research farm was straight cut and subsampled 4x in 1.2 x 60m plot widths with a Wintersteiger Quantum plot combine outfitted with a Harvest Master Classic GrainGage which calculated total weight of all the seeds from each subsample, as well as seed moisture content and yield from the subsamples. This field was sampled on September 24th 2019 with the remainder of the standing canola straight cut on the 25th of September 2019 by a standard sized combine. The randomized complete block at the Llewellyn Research Farm was swathed on 25th September 2019 and each whole plot was harvested by standard combine on Oct 18 2019, and whole plot wet and dry weights and moisture taken from the combine sensors and the entire seed yield from each plot weighed on a calibrated weigh wagon and seed weight adjusted for moisture. Flea beetle damage evaluations were conducted three times at each sites from the cotyledon to the four leaf stage using 30 cm by 30 cm quadrats at ca. 8 m intervals along diagonal transects that ran from the top left to bottom right of each plot. In each quadrat a picture was also taken for confirmation of each damage assessment. Photos were taken using the cameras on Apple iPads and Samsung A series tablets with pictures lined up with meter stick ruler at the bottom for consistent scale Evaluations and harvest were conducted by AAFC staff. Treatments were arranged as a Latin square at the Saskatoon site and in a completely randomized array at the Llewelyn site.

Data analysis

All data were evaluated with the R statistical package. Small plot flea beetle ratings, yields and moisture values were analyzed as RCB analysis of variance (ANOVA), specifying 'block' as a random factor. Latin square data were analyzed by ANOVA, specifying 'row' and 'column' as random factors. When significant main factors were detected, pairwise comparison was accomplished with Tukey's Honestly Significant Difference (HSD) test.

Results

Flea Beetle Damage Ratings (small plots)

Photographs indicated the prevalence of *P. striolata* at all sites. The Yorkton region has historically been dominated by *P. cruciferae.* At the Outlook ICDC site, a significant effect of treatment was detected ($F_{7, 42} = 56.64$; $P < 0.001$). Greater flea beetle feeding damage to seedlings was found in control and fungicide-treated plots than in any insecticide-treated plots (Table 1). Significant ($P < 0.05$) increases in damage occurring between 10 June (mean: 1.60%) and 13 June (mean: 2.03%).

Treatment effects were also seen at the Yorkton ECDF site ($F_{7, 47} = 12.53$; $P < 0.001$). Greatest damage was to the control and fungicide plots; significantly less damage was not seen on the lumiderm-treated plots (Table 1). Plants grown from seed treated with all other insecticidal seed treatments suffered significantly less damage than the controls ($P < 0.05$); the best control was seen with the Helix + Lumiderm treatment (Table 1). A significant effect of monitoring period was also seen with a significant increase in damage between 17 June and 20 June ($F_{1, 47} = 13.60$; $P < 0.001$).

At the Scott site, a treatment effect was also apparent ($F_{7, 71} = 90.80$; $P < 0.001$), as was date effect ($F_{2, 71} = 151.48$; $P < 0.001$). Control and 'fungicide' treatments suffered the greatest damage; of the insecticide treatment, plant grown from Lumiderm-treated seed were the most heavily damaged (Table 1).

Table 1. Differences in mean flea beetle feeding damage among treatments at three Agri-ARM sites. Like-lettered treatments are not significantly different according to Tukey's Honestly Significant Difference (HSD) test (α = 0.05)

Site	**Treatment**	**Mean feeding damage rating (% defoliation)**	**HSD designation (within-site)**
Yorkton (ECRF)	Control	28.8	A
	Fungicide	25.9	AB
	Lumiderm	23.4	ABC
	Prosper	17.1	BCD
	Helix Vibrance	14.4	CDE
	Visivio	10.9	DE
	Helix JumpStart	7.2	DE
	Helix + Lumiderm	5.0	E
Outlook (ICDC)	Control	42.1	A
	Fungicide	33.6	B

	Lumiderm	14.5	C
	Visivio	13.1	C
	Prosper	12.8	C
	Helix JumpStart	10.3	C
	Helix Vibrance	9.9	C
	Helix + Lumiderm	8.6	C
Scott (WARC)	Control	24.0	A
	Fungicide	22.7	A
	Lumiderm	13.8	B
	Prosper	9.8	C
	Visivio	9.2	CD
	Helix + Lumiderm	7.3	CD
	Helix JumpStart	6.3	D
	Helix Vibrance	6.3	D

Flea Beetle Damage Ratings (large plots)

At the Saskatoon site, significant differences among treatments were also apparent ($F_{2, 14} = 6.53$; P = 0.010). Greater damage was recorded for plots with increasing amounts of untreated seed (Table 3). A significant effect of date was also apparent ($F_{2, 14} = 24.72$; $P < 0.001$) with a significant ($P < 0.05$) increase in damage from 14 June (mean: 6.09%) to 18 June, 2019 (mean: 13.09%). Damage did not increase significantly ($P > 0.05$) from 18 June to 27 June (mean: 14.77). A treatment effect was not apparent when only treated plants were assessed ($F_{2, 14} = 0.851$; $P = 0.448$), although damage increased with monitoring time ($F_{2, 14} = 25.49$; $P < 0.001$). Significantly ($P < 0.05$) increasing damage to treated plants was seen from 14 June (mean: 4.81%) to 18 June, 2019 (mean: 12.20%). Damage was numerically higher to untreated plants in the 30-ft strip plots (mean: 17.01%) than in the 60-ft strip plots (mean: 14.07). No effect of date was detected ($F_{2, 8} = 2.58$; $P = 0.136$), indicating early feeding damage.

Table 2. Differences in mean flea beetle feeding damage among treatments at the AAFC Saskatoon site. Like-lettered treatments are not significantly different according to Tukey's Honestly Significant Difference (HSD) test (α = 0.05)

Treatment	**Mean feeding damage rating (% defoliation)**	**HSD designation**
30-ft strip	13.90	A
60-ft strip	10.82	AB
Complete use of seed treatment	9.24	B

At the Llewelyn site, significant differences among treatments were apparent ($F_{2, 18} = 7.24$; $P = 0.005$). The greatest flea beetle feeding was seen in plots with 30-ft strips of treated seed, followed by plots with 60-ft strips, and complete treatment plots. (Table 2). Damage to all plants is roughly proportional to the numbers of untreated plants per treatment. A significant effect of date was also apparent with significant increases in damage ratings to all plots between 18 June and 27 June, 2019 ($F_{2, 18} = 6.61$; P = 0.007). A significant treatment effect was not seen when damage to plants grown from treated seed in each plot was evaluated ($F_{2, 18} = 0.182$; $P = 0.835$, indicating that the treatment effect seen was a product of the proportion of treated seed per treatment. No significant date effect ($F_{2, 18}$ = 2.81; P = 0.086) indicated no significant accumulation of damage to treated plants after the first monitoring period. A significant treatment effect on damage to untreated plants was not detected ($F_{2, 12}$ = 0.39; P = 0.543) but an effect of date was seen ($F_{2, 12}$ = 7.07; P = 0.009). Damage increased significantly (P < 0.05) from 18 June (mean: 3.2) to 27 June (mean: 8.95).

Table 3. Differences in mean flea beetle feeding damage to plants grown from treated seed among treatments at the Llewelyn site. Like-lettered treatments are not significantly different according to Tukey's Honestly Significant Difference test (α =0.05).

Treatment	**Mean feeding damage rating (% defoliation)**	**HSD designation**
30-ft strip	4.68	A
60-ft strip	3.73	AB
Complete use of seed treatment	2.35	B

Harvest Data (small plots)

At the Scott (WARC) site, differences in days to maturity (DTM) among treatments were too small to be detected by pairwise comparison with Tukey's Honestly Significant Difference (HSD) test. No differences in yield were detected among treatments at this site ($F_{7,21}$ = 0.583; P = 0.762). No differences in DTM or yield were apparent at the Outlook (ICDC) site ($F_{7,21}$ = 0.745; P = 0.637, $F_{7,21}$ = 0.680; P = 0.687, respectively). Plant height was not effected by treatment ($F_{7,21}$ = 0.695; P = 0.676). No effect of treatments on yield were apparent at the Yorkton (ECRF) site ($F_{7,21}$ = 0.483; P = 0.572). Maturity data were not reported for this site.

Harvest Data (large plots)

At the Saskatoon site, yields did not differ significantly among treatments ($F_{2,2}$ = 10.04; P = 0.091). However, a significant row effect was seen ($F_{2,2}$ = 48.82; P = 0.020). Moisture level differences approached significance ($F_{2,2}$ = 16.70; P = 0.057) with numerically higher values seen in mixed-treatment plots (60-ft strip = 9.60%; 30-ft strip = 9.10%) than in plots with complete use of seed treatments (7.28%). At the Llewelyn site, treatment did not influence yields ($F_{2,7}$ = 0.431; P = 0.666) or moisture content ($F_{2,7}$ = 0.025; P = 0.976).

Discussion

Flea beetle pressures were relatively low when these trials were conducted. These beetles overwinter as adults and can emerge in April if degree day accumulation supports their activity; typically, *P. striolata* emergence precedes that of *P. cruciferae* by about two weeks (Soroka and Elliot 2011, Elliot et al 2011). Adults typically mate and lay eggs in developing canola fields by late spring; populations wane as oviposition is completed (Feeny et al. 1970, Burgess 1977). Populations of *P. striolata* typically wane earlier than those of *P. cruciferae* which can be sustained though June. A great deal of overspraying with pyrethroid insecticides occurred in SK in 2019. It is likely that this practice reduced populations that might otherwise have invaded test plots.

The relatively late seeding date for these trials (early June) likely reduced the amount of flea beetles pressure exerted on seedlings. However, this observation suggests a major lesson from this work. Current recommendations for SK include early seeding to allow plants to develop to a point where they are tolerant of flea beetle damage. Once *B. napus* canola is at the four leaf stage, it is relatively tolerant of *Phyllotreta* spp. feeding (Dosdall and Stevenson 2005). Late seeding may contribute to asynchrony of flea beetle populations and sensitive crops stage. Late seeding may also reduce the risk of spring frost damage to seedlings, as was widespread in central SK in 2019, but may also contribute to late-season frost damage and incomplete maturity at harvest.

Despite relatively low population densities, damage to plants in small plots and fungicide treatments was about the action threshold (25% damage) and significant reductions in feeding damage were seen with all insecticidal treatments. The most effective of these were generally the combination of thiamethoxam and cyantraniliprole. Differences among insecticidal treatments were apparent at two sites: cyantraniliprole used alone was generally, if only numerically less effective than the neonicotinoids. Differences in the performance of thiamethoxam and clothianidin products were rarely significant. The addition of sulfoxaflor to thiamethoxam (Visivio) apparently had little benefit to damage control. Elliot et al (2011) reported that both *P. striolata* and *P. cruciferae* were less-effected by cyantraniliprole than thiamethoxam or clothianidin.

One of the more interesting results of this work was the lack of significant differences in harvest weights among treatments in either small or large plots. Canola is a plastic crop and is capable of great compensation to foliar damage. Kirkegaard et al (2012) reported that recovery of spring canola after defoliation was rapid and included recovery in the absolute growth of leaves and negligible effect on pod biomass. Nominal thresholds for flea beetle control in spring canola are based on rapid accumulation of damage with active flea beetle populations; immediate attention is required once damage reaches the action threshold. Since damage did not accumulate beyond the current action threshold (25% defoliation to cotyledons and first true leaves), this work supports this value and the economic injury level of 50% defoliation. Despite significant differences in damage to seedlings by flea beetles, large plot yields also did not differ among treatments. This result also suggests the tolerance of spring canola to foliar damage and supports the current nominal thresholds.

Large plot feeding damage was roughly proportional to the amount of untreated seed. However, greater damage to untreated plants was seen in the 30-ft strip plot than in the 60-ft strip plots. It is currently assumed that *Phyllotreta* spp. invade crops from field edges and at least initially concentrate their feeding on these plants. These insects are capable flyers (e.g. Tansey et al 2012, 2015) and apparently bypassed treated plants to reach the inner, untreated sections of plots, suggesting that the depth of the protective border can be influential. As indicated earlier, any differences in feeding did not influence yields. One point of difference between treatments was in harvest moisture content seen at the Saskatoon site. These approached significances and may be attributed, in part, to delays in maturity between plants grown from treated and untreated seed.

Conclusions

The main points taken from this work were: 1) all of the commercial seed treatments substantially reduce flea beetle feeding, 2) There are, however, differences in the performance of seed treatments and cyantraniliprole as a standalone should not be recommended, 3) the combined use of sulfoxaflor and thiamethoxam does little to improve performance over thiamethoxam alone, 4) the current action and economic thresholds have merit, 5) similarities in harvest data among treatments in both trials indicate the plasticity of response of spring *B. napus* canola to moderate levels of flea beetle damage. Further work is required to determine the relative performance of these seed treatments under heavy pressure from *Phyllotreta* spp. flea beetles and assess the effects of border strips. The current study supports, given similarities in yields among strip treatments despite differences in feeding damage among treated and untreated plants, recommendations for reduced use of neonicotinoid seed treatments.

Acknowledgements

This work was funded through the Saskatchewan Ministry of Agriculture's Strategic Field Plan. Many thanks to the contractors: Dr. Tyler Wist, AAFC; Jessica Weber, WARC; Garry Hnatowich, ICDC, and Mike Hall, ECRF for their invaluable help with this project. Thanks too to Corteva, Bayer, and Nutrien Ag Solutions for their material support.

References

Dosdall, L.M. and Stevenson, F.C., 2005. Managing flea beetles (Phyllotreta spp.) (Coleoptera: Chrysomelidae) in canola with seeding date, plant density, and seed treatment. *Agronomy Journal*, *97*(6), pp.1570-1578.

Elliot, B., L. Mann, J. Soroka, and S. Hartley. 2017. Evaluation of seed treatments for control of crucifer and striped flea beetles in canola. https://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/crop15631

Kirkegaard, J.A., Sprague, S.J., Lilley, J.M., McCormick, J.I., Virgona, J.M. and Morrison, M.J., 2012. Physiological response of spring canola (Brassica napus) to defoliation in diverse environments. *Field Crops Research*, *125*, pp.61-68.

Lamb, R.J. and Turnock, W.J., 1982. Economics of insecticidal control of flea beetles (Coleoptera: Chrysomelidae) attacking rape in Canada. *The Canadian Entomologist*, *114*(9), pp.827-840.

PMRA 2016. Pest management Regulatory Agency Proposed Re-evaluation Decision PRVD2016-20, Imidacloprid.

PMRA 2018 a. Pest management Regulatory Agency PSRD2018-01, Special Review of Clothianidin Risk to Aquatic Invertebrates: Proposed Decision for Consultation.

PMRA. 2018 b. Pest management Regulatory Agency Proposed Special Review Decision PSRD2018-02, Special Review of Thiamethoxam Risk to Aquatic Invertebrates: Proposed Decision for Consultation.

Soroka, J., Grenkow, L., Otani, J., Gavloski, J. and Olfert, O., 2018. Flea beetle (Coleoptera: Chrysomelidae) species in canola (Brassicaceae) on the northern Great Plains of North America. *The Canadian Entomologist*, *150*(1), pp.100-115.

Soroka, J.J. and Elliott, B., 2011. Innovative methods for managing flea beetles in canola. *Prairie Soils and Crops*, *4*, pp.1-7.

Tansey, J.A., Dosdall, L.M. and Keddie, B.A., 2009. Phyllotreta cruciferae and Phyllotreta striolata responses to insecticidal seed treatments with different modes of action. *Journal of Applied Entomology*, *133*(3), pp.201-209.

Tansey, J.A., Dosdall, L.M., Keddie, A. and Blake, A.J., 2012. A novel trapping system for monitoring insect flight heights. *The Canadian Entomologist*, *144*(4), pp.617-620.

Tansey, J.A., Dosdall, L.M., Keddie, B.A. and Sarfraz, R.M., 2008. Differences in Phyllotreta cruciferae and Phyllotreta striolata (Coleoptera: Chrysomelidae) responses to neonicotinoid seed treatments. *Journal of economic entomology*, *101*(1), pp.159-167.

Tansey, J.A., Dosdall, L.M., Soroka, J.J. and Keddie, B.A., 2015. The influence of weather parameters on crucifer flea beetle (Coleoptera: Chrysomelidae) capture heights. *The Canadian Entomologist*, *147*(1), pp.89-96.

Turnock, W.J., Lamb, R.J. and Bilodeau, R.J., 1987. Abundance, winter survival, and spring emergence of flea beetles (Coleoptera: Chrysomelidae) in a Manitoba grove. *The Canadian Entomologist*, *119*(5), pp.419-426.