

Emergence of overwintered and new generation adults of the crucifer flea beetle, *Phyllotreta cruciferae* (Goeze) (Coleoptera: Chrysomelidae)

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Received 21 December 2004; received in revised form 11 February 2005; accepted 3 March 2005

Abstract

Spring emergence of the crucifer flea beetle, *Phyllotreta cruciferae* (Goeze), was investigated in 2003 and 2004 in relation to habitat type, vegetative cover, and soil temperature in the Mixed Grassland Ecoregion of western Canada. Although total emergence extended over 10–12 weeks, emergence patterns were quite similar in both years with limited emergence for several weeks before and after a large emergence peak of comparatively short duration. In each year, peak emergence occurred near the end of May as mean ground temperature reached 15 °C. Approximately 45,000 flea beetles were collected with the greatest number of flea beetles recorded from a single 1 m² emergence cage being 3736. Significantly more flea beetles emerged from sheltered locations than from open habitats; sheltered areas were predominantly shelterbelts and yard sites of Caragana and poplar trees. In each year, highest numbers of flea beetles emerged in cages placed in Caragana while the fewest emerged from cages in grassy areas. Consistently more females than males emerged throughout the spring with a sex ratio of approximately 1.5 females: 1 male. Emergence of new generation adults occurred from the middle of August until the end of September; this emergence was delayed and extended in late-seeded canola. Seeding date and rate did not significantly affect the abundance of new generation flea beetles. The sex ratio of new generation adults was approximately 1.2 females: 1 male. Emergence cages could be a useful tool for researchers monitoring year-to-year populations of *P. cruciferae* but the narrow time frame between spring emergence and crop infestation may restrict the usefulness of this tool for producers.

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Keywords: *Phyllotreta cruciferae*; Emergence; Canola; Sex ratio; Habitat selection

1. Introduction

The crucifer flea beetle *Phyllotreta cruciferae* (Goeze) is oligophagous on Brassicaceae and a significant economic pest of brassicaceous oilseed crops, including canola (*Brassica napus* (L.) and *Brassica rapa* (L.)) and mustard (*Brassica juncea* (L.) Czern.) in North America. Both *P. cruciferae* and its congener *Phyllotreta striolata* (F.) attack canola, but *P. cruciferae* is the dominant species in the semi-arid agroclimatic region of the

southern prairies of western Canada, with a range extending through the parkland and into the boreal forest (Burgess, 1982). Flea beetles are chronic pests of canola production across the prairies and it has been estimated that these pests cause annual yield losses of approximately 10% (Lamb and Turnock, 1982).

Adult crucifer flea beetles overwinter in leaf litter and turf beneath shelterbelts, native trees, fence rows, and grassy areas (Burgess, 1977, 1981). Upon emergence in the spring, flea beetles may disperse directly into early seeded crops but generally seek out weeds or volunteer crop plants before moving into canola crops as seedlings emerge. The most severe crop damage occurs in spring when overwintered adults feed on the cotyledons and

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stems of seedlings and can cause significant seedling mortality (Westdal and Romanow, 1972). The adult beetles continue to cause some plant damage into the growing season; however, once plants are beyond the seedling stage they are much less vulnerable to feeding damage. Eggs are laid predominantly throughout June and early July but oviposition may start as early as mid-May (Westdal and Romanow, 1972). Flea beetle larvae feed on root material of the host plant and further crop damage can be inflicted late in the season, generally at the pod stage, by new generation adults which start emerging in early August. When infestations of new generation adults are significant, pod feeding can result in reduced seed production and quality (Knodel and Olson, 2002).

The objective of this study was to better understand the spring emergence biology of the crucifer flea beetle as a key to improved monitoring and forecasting of outbreaks. Previous studies (Wylie, 1979; Burgess, 1981; Lamb, 1983; Burgess and Spurr, 1984) have investigated *P. cruciferae* overwintering and spring migration habits; however, the relationship between emergence and soil temperature has not been investigated previously, and the pattern of emergence over time has not been documented. We examined emergence patterns from different habitats and in relation to sex ratio. The proximity of canola stubble to overwintering sites and usefulness of spring emergence cages as a means of monitoring or forecasting flea beetle populations were also considered. Emergence of new generation *P. cruciferae* adults has not previously been studied. This aspect of *P. cruciferae* life history was examined in 2004 in canola seeded at different rates and on different dates.

2. Methods and materials

In 2003 and 2004, spring emergence biology of *P. cruciferae* was investigated with emergence cages placed in noncultivated sites near Lethbridge, Alberta (49°27'N, 112°39'W). In 2003, 49 cages were placed at nine different sites within a 20-km-radius of Lethbridge; in 2004, 57 cages were placed at six different sites within a 15-km radius of Lethbridge. Emergence cages were set out on 9 April in both 2003 and 2004. The first flea beetle collections were made on 15 April both years and weekly thereafter (weather permitting) until flea beetle emergence ended (mid-July). The emergence cages were pyramidal, 1 m² at the base, and followed the design of Dossall et al. (1996).

Emergence cages at each site were placed in either open, intermediately sheltered, or fully sheltered habitat. Cages in open habitats were not shaded from any direction and were in an exposed grassy area, consisting of one or both of smooth brome (*Bromus inermis* Leyss.) (Poaceae) and crested wheat grass (*Agropyron cristatum* L.) (Poaceae). Cages in sheltered habitats were in

natural bluffs, shelterbelts or trees surrounding yard sites and were shaded on at least three sides and from above by trees higher than the cages. The predominant tree species were Caragana (*Caragana arborescens* Lam.) (Fabaceae) and poplar (*Populus* spp.) (Salicaceae), but American elm (*Ulmus americana* L.) (Ulmaceae), Siberian elm (*Ulmus pulmila* L.) (Ulmaceae), ash (*Fraxinus americana* L.) (Oleaceae), and willow (*Salix* spp.) (Salicaceae) were also present at some sites. Those cages which were slightly shaded or sheltered on only one or two sides were categorized as intermediate. For each cage, the proximity to the nearest canola field during the preceding growing season was recorded.

On each collection date, all insects were collected from each emergence cage with a battery-powered aspirator (Hausherr's Machine Works, Toms River, NJ) inserted through an opening in the side of the cage (openings were sealed except during sampling). Insect collections from each cage were frozen and flea beetles were later counted, and in 2004 dissected to determine sex. All undamaged flea beetles were sexed for collection periods early and late in the spring when relatively low numbers of flea beetles were emerging. During the weeks of peak emergence, a sub-sample of 20 flea beetles was sexed from those cages that contained more than 20 flea beetles; however, the total number of flea beetles sub-sampled and sexed during the weeks of peak emergence was still substantially higher than the total number of flea beetles that were sexed during the other collection periods (Fig. 3).

Temperature data within cages were recorded in 2004 by Onset temperature probes (Onset Optic Stowaways (WTA32), Bourne, MA, temperature range = -39 to +75 °C) placed in individual cages from each of the three habitat types. Mean temperatures for each sampling date were based on recordings made every 20 min between each sampling period. Temperature probes were not set up until the first sampling date, so no weekly mean was obtained for that date. Regional ground temperature data were recorded by the Agriculture and Agri-Food Canada Lethbridge Research Centre weather station. Mean temperatures for each sampling period were calculated from hourly recordings between each sampling period and for 1 week preceding the first sampling period each year. The ground cover at the weather station was grass mowed to 10 cm and the surrounding area was dryland crops. Most overwintering flea beetles are found in the top 6 cm of leaf litter, soil and debris (Burgess, 1981); thus, temperature probes in individual cages were placed 2–4 cm deep in the leaf litter and ground temperature data at the 5 cm depth were used from the Agriculture Canada weather station.

In May 2004, research plots were established in a randomized complete block experimental design with four replications to assess the effect of canola plant stand manipulation on new generation flea beetle

emergence. Treatments comprised factorial combinations of seeding rate (1.0, 3.0, and 5.0 kg ha⁻¹) and seeding date (“early” and “normal”). Plots were seeded on two dates in spring: 7 and 14 May; these correspond to “early” and “normal” planting dates, respectively, according to accepted agronomic practices for this agricultural region and local environmental conditions. Plots measured 100 × 9 m, and were seeded into wheat stubble. Seeding with *B. napus* cv. InVigor 2153 was performed with a John Deere 9450 Hoe Press Drill using 18 cm row spacing. To replicate conditions similar to those in commercial production, all seeds were treated with Helix[®] (containing 10.3% thiamethoxam, 1.2% difenoconazole, 0.4% metalaxyl-m, and 0.1% fludioxonil) to reduce seedling mortality from phytopathogens and herbivory by overwintered *P. cruciferae*. In early August, canola plants over two 1 m² areas of each plot were cut off at the base, and an emergence cage (as above) was placed over the stubble. All flea beetles within each cage were aspirated, counted, and recorded weekly using battery-powered aspirators (as above) until

all flea beetles had emerged. All flea beetles from the early and normal-seeded canola at the 3 kg ha⁻¹ rate were dissected to determine the sex ratio of new generation flea beetles at the time of emergence.

To analyze habitat type, degree of vegetative cover and effect of adjacent canola stubble, as well as detect significant differences between the means ($P < 0.05$), data were subjected to a Kruskal–Wallis ANOVA. A sign test (Snedecor and Cochran, 1980), which included every cage in which one or more flea beetles emerged each sampling period, was used to analyze the sex ratio data. To determine seeding date and rate effects on emergence of new generation adults, data were subjected to a Factorial Design ANOVA (Statistix[®] 8 Analytical Software, 2003).

3. Results

P. cruciferae began emerging on 23 April in 2003 when 197 adults were collected. A total of 576, 2387,

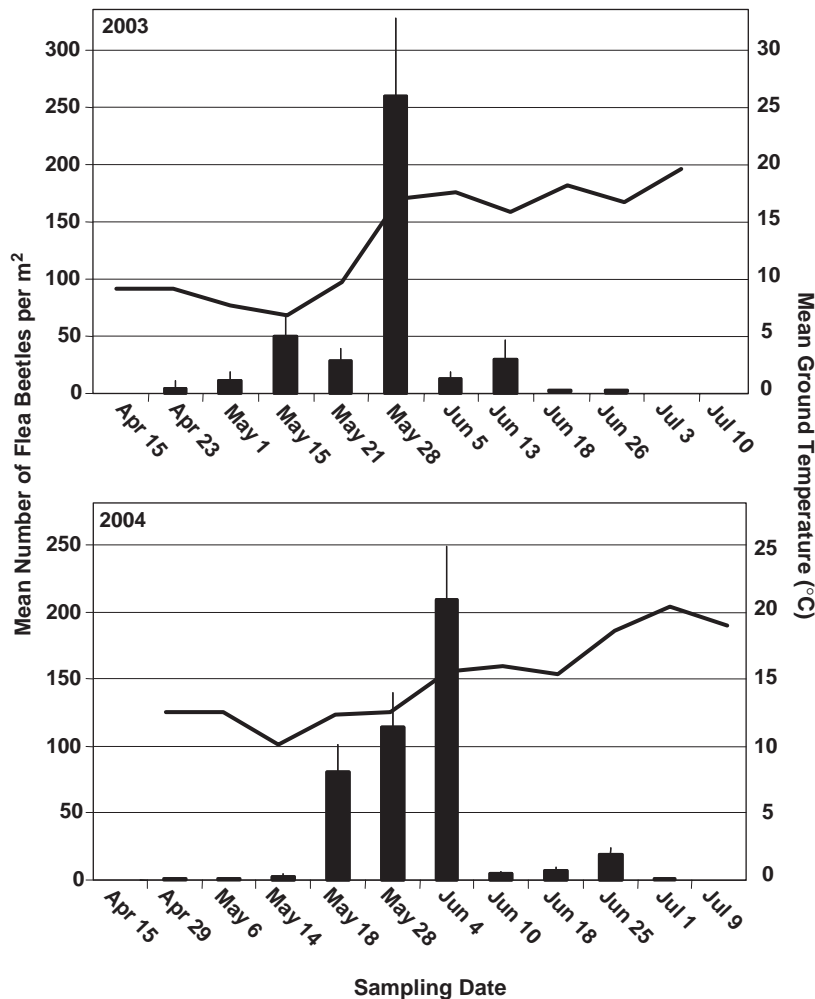


Fig. 1. Mean number of *Phyllotreta cruciferae* (\pm SE) emerging per emergence cage (vertical bars) for each sampling date and mean ground temperature (horizontal line) of each sampling period in 2003 and 2004.

1384, 12,488, 589, 1434, 28, and 61 adults were collected, respectively, on subsequent collection dates (Fig. 1) until the week of 28 June when the last flea beetle emerged. Peak spring emergence occurred during the week preceding the 28 May collection when 65.2% of all crucifer flea beetles emerged.

P. cruciferae began emerging on 29 April in 2004 when 50 adults were collected. A total of 4, 139, 4616, 6489, 11,893, 306, 379, 1110, 81, 16 and 1 adults were collected, respectively, on subsequent collection dates (Fig. 1) until the week of 13 July when the last *P. cruciferae* emerged. Peak spring emergence occurred during the week of the 4 June collection period when 47.4% of all crucifer flea beetles emerged. During the 3-week period from the week preceding the 18 May collection until the 4 June collection, 91.7% of *P. cruciferae* emerged.

Overall (Table 1), and at each site (data not shown), significantly more flea beetles emerged from sheltered locations than from open habitats in 2003 and 2004 (2003: $F_{2,522} = 11.7, P < 0.001$; 2004: $F_{2,680} = 13.5, P < 0.001$) (Table 1). In 2003, significantly more flea beetles emerged in intermediately sheltered cages than in open cages; however, in 2004 there was no significant difference between intermediately sheltered and open cages. The greatest total number of flea beetles recorded from a single 1 m² emergence cage was 3736 in 2003; this cage was protected within a shelterbelt (Caragana) and the site was adjacent to canola stubble from the previous year. In 2004 the greatest number of crucifer flea beetles collected from a single emergence cage was 3330; this cage was within a shelterbelt of mature poplar trees adjacent to canola stubble. At least one flea beetle emerged from each of the 106 cages over the 2 years of study. There were 11 emergence cages at five different sites in which 10 or fewer flea beetles emerged; eight of these were cages in open habitat, two were intermediately sheltered, and one was sheltered.

Table 1
Mean weekly number (\pm SE) of *Phyllotreta cruciferae* collected per m² over the entire spring emergence period in open, intermediate, and sheltered habitats in 2003 and 2004

Habitat	Weekly mean flea beetles per m ² (\pm SE)	Total mean flea beetles per m ²	# of cages
2003			
Open	8.43 (12.26)a	90	18
Sheltered	57.48 (11.90)b	614	19
Intermediate	44.74 (14.81)ab	488	12
2004			
Open	11.72 (9.06)a	141	19
Sheltered	87.51 (10.55)b	1050	14
Intermediate	26.82 (8.07)a	321	24

Means in the columns followed by the same letter within each year indicate no significant difference using Kruskal–Wallis one-way-ANOVA ($P = 0.05$).

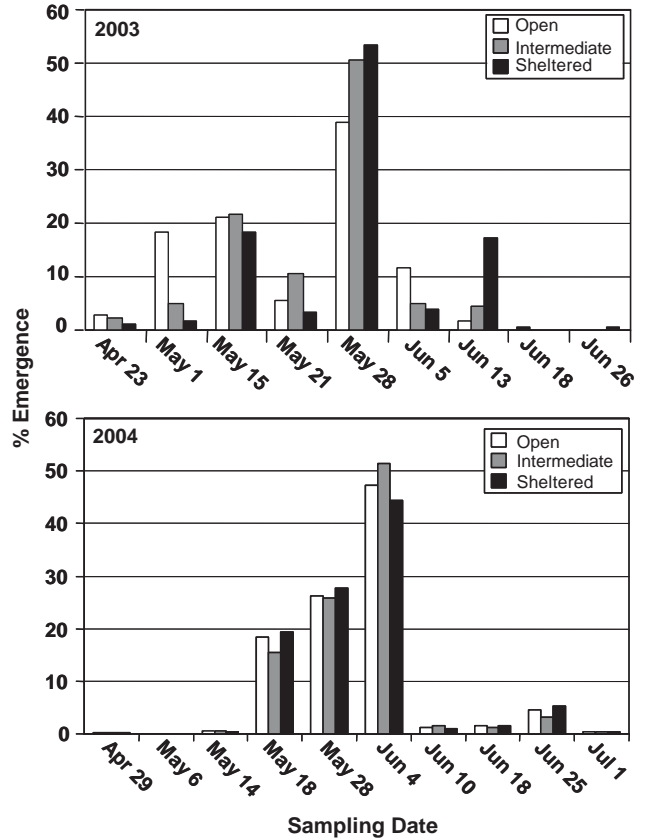


Fig. 2. Percent *Phyllotreta cruciferae* emergence in each sampling period from each of the three habitat types in 2003 and 2004.

Although a slightly higher proportion flea beetles emerged from open habitats earlier in the season and from sheltered habitats late in the season, the pattern of flea beetle emergence was similar in the three habitat types (Fig. 2). In 2004, temperature probes within the leaf litter of cages from each habitat recorded the highest mean temperature in each week from cages in grassy habitat. Cages in grassy habitats also recorded the highest maximum and lowest minimum temperatures for each sampling period (Table 2).

Vegetation type significantly affected flea beetle emergence from the various habitats in both years. In 2003, significantly more flea beetles emerged (weekly mean number per cage) in the seven cages placed within Caragana shelterbelts (77.11 ± 19.29) and the 15 cages placed within stands of other tree species such as elm, ash, or willow (67.30 ± 13.09) than in the nine cages within poplar stands (6.19 ± 17.16) or the 18 cages in open grassy areas (8.43 ± 12.26) ($F_{2,521} = 30.7, P < 0.001$). In 2004, significantly more flea beetles emerged (weekly mean number per cage) in the 19 cages placed within poplar stands (49.22 ± 9.22) and the 19 cages placed in Caragana (49.24 ± 9.20) than in the 19 cages placed in open grassy areas (11.72 ± 9.20) ($F_{2,680} = 8.08, P < 0.001$).

Table 2

Mean, maximum and minimum leaf litter temperatures (°C) within cages during each sampling period for each habitat type during peak *Phyllotreta cruciferae* emergence in 2004

Date	Habitat	Mean	Maximum	Minimum
May 14	Sheltered	7.5	24.3	-1.3
	Intermediate	7.2	23.2	-0.2
	Open	8.2	30.7	-3.0
May 18	Sheltered	11.7	26.4	3.1
	Intermediate	10.6	20.7	2.6
	Open	12.9	28.3	1.7
May 28	Sheltered	10.6	24.6	1.2
	Intermediate	10.1	23.9	2.5
	Open	11.3	29.4	0.4
June 4	Sheltered	13.5	29.6	6.3
	Intermediate	13.1	25.9	6.7
	Open	14.8	38.2	2.5
June 10	Sheltered	13.5	29.1	4.5
	Intermediate	13.6	28.1	5.0
	Open	15.2	38.2	2.2

No cages were placed in shelterbelts comprised of other species in 2004.

Significantly more females than males were collected over the entire spring emergence period ($P < 0.001$, Sign Test, 83 Negative differences, 276 positive differences) and on each sampling date through the month of peak emergence (May 18–June 18) when sample sizes included 150 or more flea beetles ($P < 0.05$, Sign Test) (Fig. 3). The sex ratio over the entire 2004 emergence period was very near 1.5 female: 1 male with 64.1% females ($n = 2505$ females, 1402 males).

Overall, more flea beetles emerged per m² from sites directly adjacent to canola stubble from the preceding growing season (495.2 ± 99.6) than from sites not bordered by canola stubble (318.4 ± 93.7); however, this difference was marginally nonsignificant over the 2-year study ($F_{1,103} = 3.22, P = 0.07$).

More *P. cruciferae* were collected per cage in 2004 than in 2003 in the open and sheltered habitat types, while fewer were collected in intermediately sheltered cages (Table 1). A total of 19,144 crucifer flea beetles were collected in 2003; 25,084 crucifer flea beetles were collected in 2004.

In 2004, new generation flea beetles began emerging from early seeded canola during the week preceding 12 August (Fig. 4). Emergence peaked 20 August and no flea beetles emerged after 8 September. In canola seeded later, emergence of the new generation began in the week preceding 20 August, peaked on 27 August, and continued until 25 September (Fig. 4).

There were no significant differences in the numbers of flea beetles emerging per m² from plots seeded at rates of 1, 3, and 5 kg ha⁻¹ ($F_{2,41} = 0.30, P = 0.74$). Mean

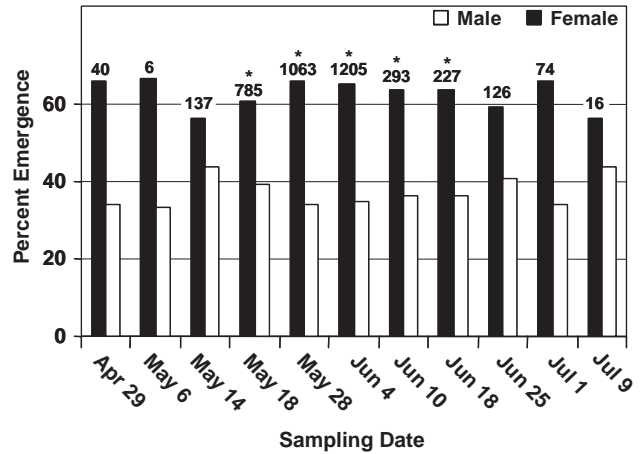


Fig. 3. Percent emergence of male (open bars) and female (solid bars) *Phyllotreta cruciferae* in each sampling period, 2004. Numbers above the bars are the total number of flea beetles sexed for that sampling period. Asterisks above the bars indicate a significant difference between the number of males and females emerging for that sampling period ($P < 0.05$, Sign Test).

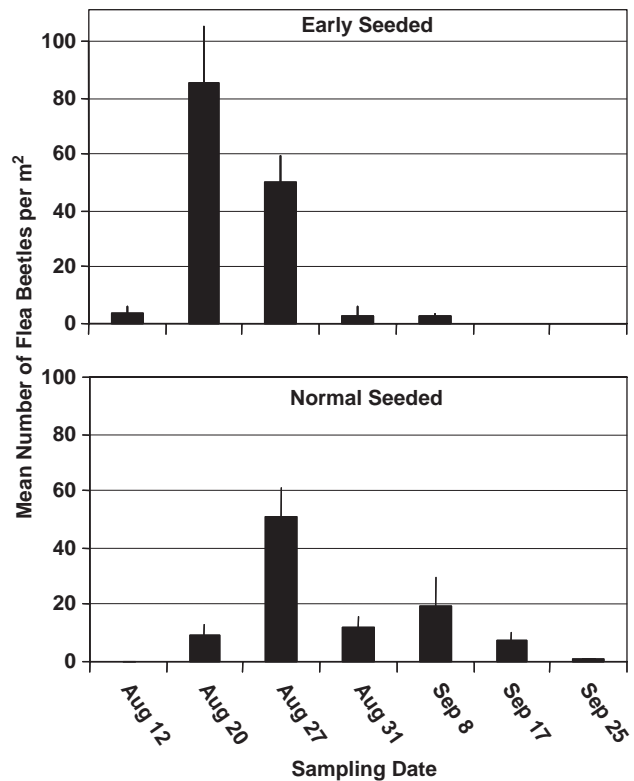


Fig. 4. Mean number of new generation adults of *Phyllotreta cruciferae* (\pm SE) emerging per m² from stubble of canola seeded early (May 7) and later (May 14).

numbers of flea beetles (\pm SE) emerging from the plots (seeding dates combined) were 134.4 (26.5), 128.2 (34.8), and 104.4 (22.1) for the 1, 3, and 5 kg ha⁻¹ seeding rates, respectively. A total of 3452 flea beetles emerged from

the 24 cages in the early seeded canola and 2419 flea beetles emerged from the 24 cages in canola seeded later. However, there were no significant seeding date effects on flea beetle emergence ($F_{1,41} = 1.66, P = 0.20$).

There was no significant difference in the number of females and males collected over the entire fall emergence period ($P = 0.16$, Sign Test, 21 Negative differences, 29 positive differences). More females than males were collected on each sampling date in August during peak emergence, but slightly more males than females were collected each week in September as emergence waned. The sex ratio over the entire 2004 fall emergence period was very near 1.2 female: 1 male with 54.3% females ($n = 1159$ females, 977 males).

4. Discussion

Temperature is an important determinant of spring emergence for *P. cruciferae*. In both years, *P. cruciferae* emergence began in late April when soil temperatures at the 5-cm depth reached 10–12°C and peaked when mean soil temperatures reached 14–15°C. In 2003, a rapid temperature increase near the end of May was accompanied by a spike in emergence during a 1 week period. In 2004, however, soil temperatures increased more gradually to 15°C in May and June and emergence was also more gradual, resulting in a 3 week period of peak emergence. Our study determined that spring emergence of *P. cruciferae* peaked from mid-May to early June when soil temperature warmed to a sufficient level, a time frame consistent with spring field collections of adults in other parts of western Canada and Ontario (Burgess, 1977; Kinoshita et al., 1979; Wylie, 1979; Lamb, 1983). Mean soil temperature at the 5-cm depth was approximately 2°C higher than temperatures recorded in leaf litter within the cages; minimum and maximum temperatures were more extreme in the leaf litter. This study took place in southern Alberta where spring temperatures increase earlier than regions further north, so spring emergence in other canola-producing areas should be delayed as latitude increases.

Our data have not resolved whether a critical threshold temperature exists for emergence, or whether there is a thermal accumulation above a developmental threshold that initiates emergence of *P. cruciferae* from its overwintering sites. To accurately predict the time of emergence in spring, it is important to know the threshold temperature or “developmental zero” for crucifer flea beetle. The usual way of determining the threshold developmental temperature is to record the rate of insect development over a large series of temperatures, generally every 2°C over a range of 20°C (Baker, 1980), so that a regression model can be

fitted to the linear part of the insect developmental curve (Sharpe and DeMichele, 1977; Baker, 1980; Van Kirk and Aliniaee, 1981). Research to develop this threshold temperature, followed by determination of the accumulated day–degrees required for 50% emergence, would provide extremely useful information for improving monitoring strategies for *P. cruciferae*, and would also help facilitate the timing of insecticidal spray applications.

Shelter appears to be an important factor in the selection of overwintering sites for *P. cruciferae* in western Canada. In both 2003 and 2004, significantly more flea beetles (6.5 times) emerged from sites sheltered within groves of trees and shrubs than from open grassy areas. This is consistent with previous studies examining overwintering sites (Burgess, 1981), in which approximately 5.5 times as many *P. cruciferae* adults were found in soil and leaf litter from hedges and shelterbelts than from grassy areas. The preference for sheltered overwintering sites may be related to temperature fluctuation as temperature probes within cages from each habitat type showed that temperatures were much more stable in cages fully and intermediately sheltered than in cages placed in open habitat. Cages in open habitat had higher maximum and lower minimum temperatures in each sampling period than cages with some degree of shelter; open cages also had higher mean temperatures throughout the spring. Lamb (1983) found that minimum daily temperature was a factor in flea beetle spring activity which suggests that a more stable environment may be favorable during spring emergence. Overwintering success was not investigated in the present study. Thus, it is possible that greater overwintering success of *P. cruciferae* occurred under more sheltered conditions. In addition to more stable spring temperatures, increased snow cover in sheltered areas would reduce exposure to extreme temperatures during the winter, perhaps leading to greater survival within sheltered sites. Regardless, most *P. cruciferae* emergence in the spring occurred from shelterbelts and other protected areas.

In each year, there were significant differences in emergence among different types of cover. In 2003, emerging flea beetles were most abundant in Caragana and hedges of other trees such as ash and elm. In 2004, flea beetles were abundant in both rows of poplar and Caragana. It is apparent that *P. cruciferae* emergence was highest from sheltered areas but the importance of specific types of vegetative cover is not clear. An earlier study (Burgess, 1981) showed that more *P. cruciferae* overwintered in hedges and shelterbelts than in groves of native trees. Thus, the structure of the cover and the proximity to open agricultural areas may have greater importance than the species composition of the habitat. Cages positioned in habitats that appeared very similar at the same site often showed great differences in the

number of *P. cruciferae* emerging indicating an aggregated overwintering habit consistent with previous findings (Burgess, 1981; Burgess and Spurr, 1984; Peng and Weiss, 1992).

The sex ratio of emerging *P. cruciferae* was approximately 1.5 female: 1 male throughout the spring emergence period in southern Alberta. The predominance of emerging females is consistent with previous work conducted in North Dakota where upward of 75% of flea beetles collected in the spring were female (Weiss et al., 1994). However, sampling from early May until the end of June, Wylie (1981) found from 39% to 62% females at different sites in Manitoba. In the present study, 54% of new generation adults were female; Wylie (1981) found from 30% to 56% females in collections made after 1 August in Manitoba. The relatively higher proportion of females in the spring appears to be a result of improved overwintering success among females, but further study is required to establish a causal relationship.

Though there was a trend toward higher numbers of flea beetles emerging from overwintering sites that were adjacent to canola stubble from the previous year, this difference was not significant. The capacity of *P. cruciferae* to move away from canola crops may be a result of new generation dispersal from canola fields to green brassicaceous host plants in late summer and fall while feeding and building fat reserves. *P. cruciferae* adults are also relatively strong fliers which would allow them to migrate some distance from fall emergence sites before choosing an overwintering site. Lamb (1983) showed that considerable inter-field dispersal was likely as adult flea beetles were collected > 100 m from canola crops and it is logical that they could travel similar distances to locate overwintering sites. Burgess and Spurr (1984) also found that though the proximity of canola fields may influence the number of overwintering flea beetles in an area, the direction and location of the nearest canola field does not affect their distribution. We did not examine overwintering sites that were more than 1 km from canola stubble.

The majority of *P. cruciferae* emergence occurred over a relatively short period in spring. However, small numbers of flea beetles emerged over an extended period before and after the peak emergence. This emergence pattern may benefit the population as a whole by reducing the risks associated with catastrophic environmental events. An extended emergence period would also enable adults to exploit a larger range of host plant resources than would be possible with a narrow emergence period. The extended emergence pattern of the crucifer flea beetle also has implications for producers who often use insecticide-treated seed for protection against flea beetle damage. Such seed treatments generally protect seedlings for a 2–3 week

period which may leave crops vulnerable to a considerable portion of the flea beetle population if crop development is slow and crop emergence is not synchronized with peak emergence and invasion of flea beetles in the spring.

New generation adults emerged from mid-August through September. As would be expected, the onset and peak of late-season emergence occurred a week earlier in early seeded canola than in canola seeded later. However, emergence phenologies differed by more than the timing of emergence maxima: in later-seeded canola, new generation adults emerged over a longer period, and with a less-pronounced emergence peak. The number of emerging flea beetles was highest at the lowest seeding rate and lowest at the highest seeding rate but these differences were not statistically significant. Dossall et al. (1999) suggested that flea beetles may respond positively to visual contrasts between vegetation and soil background which may lead to reduced damage with wider row spacings, and a similar situation may exist at low seeding rates. It is also possible that flea beetles are attracted to the higher soil surface temperatures associated with increased bare soil at lower seeding rates. Although 30% more flea beetles emerged from early seeded canola than from canola seeded later, this difference was not significant statistically. It is possible, however, that our sampling regime late in the season was not able to detect seeding date differences because of high variability between cages, and increasing cage number may have been more effective for detecting those differences.

Emergence cages appear to be a valid method of assessing spring and fall flea beetle populations. The cages are relatively inexpensive, simple to establish and maintain, and insects can be readily collected and processed. However, the time period between spring emergence and crop infestation is short to nonexistent which would not give producers the opportunity to assess spring flea beetle populations in time to make decisions about control before damage has occurred. It is therefore unlikely that emergence cages would be useful to producers for making management decisions unless those decisions can be based on new generation emergence in the fall; a great deal more study is required to link fall populations to damage in the following spring. The issue is also complicated by the variation in the numbers of *P. cruciferae* sampled in individual cages and different habitat types. Emergence cages can provide valuable information to researchers concerning year-to-year changes in *P. cruciferae* abundance. Several sites within a canola-producing area should be sampled with a minimum of five cages at each site. The maximum number of *P. cruciferae* can be expected beneath shelterbelts but one must be consistent between sites and years when choosing the habitat and degree of shelter in which the cages are placed.

Acknowledgments

We are grateful to R. Weiss and H. McLean for assistance with temperature data and D. Spaner for statistical guidance. We also thank J. Soroka for helpful advice on sexing flea beetles. Special thanks are extended to K. Peake and B. Peake for technical assistance, and J. Broatch for helpful advice on degree-day analysis. This research was funded by the Alberta Agricultural Research Institute, the Canola Council of Canada, the Alberta Canola Producers Commission, the Saskatchewan Canola Development Commission, the Manitoba Canola Growers Association and Alberta Agriculture, Food and Rural Development.

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