Phytoprotection

Damage potential and phenology of the Colorado potato beetle [Coleoptera: Chrysomelidae] on potato in southern Alberta

Potentiel d'endommagement et phénologie du doryphore de la pomme de terre [Coleoptera : Chrysomelidae] sur la pomme de terre dans le Sud de l'Alberta

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Volume 83, Number 2, 2002

URI: https://id.erudit.org/iderudit/706231ar
DOI: https://doi.org/10.7202/706231ar

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Publisher(s)

Société de protection des plantes du Québec (SPPQ)l

ISSN

0031-9511 (print)
1710-1603 (digital)

Explore this journal

Cite this article

Noronha, C., Duke, G. & Goettel, M. (2002). Damage potential and phenology of the Colorado potato beetle [Coleoptera: Chrysomelidae] on potato in southern Alberta. *Phytoprotection*, *83*(2), 89–98. https://doi.org/10.7202/706231ar

Article abstract

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Damage potential and phenology of the Colorado potato beetle [Coleoptera: Chrysomelidae] on potato in southern Alberta

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Received 2001-12-28; accepted 2002-07-19

PHYTOPROTECTION 83 : 89-98

The phenology and damage potential of the Colorado potato beetle (*Leptinotarsa decemlineata*) were studied in the potato producing area in southern Alberta. Experimental plots were established at Lethbridge in 1998, 1999 and 2000, and at Vauxhall in 1998 and 1999. At each site, one plot was protected against the beetle by application of insecticides while the other was "unprotected." Natural potato beetle populations quickly colonized unprotected plots each year. Overwintered adults appeared in plots by mid June with mean densities reaching between 0.3 and 0.6 per plant. Eggs were laid on young plants with mean densities reaching two egg masses per plant by late June. Maximum larval densities reached 9.5 per plant for each of 1st, 2nd and 3rd instars and 14 per plant for 4th instars. Maximum density for newly emerged adults was 57 per plant in mid-July at the 2000 Lethbridge unprotected plot. Defoliation was very low at the beginning of the season but increased sharply when 3rd and 4th instar populations peaked and continued to rise as new adults emerged. Maximum defoliation occurred at the Lethbridge plot in 2000 with 100% defoliation by 10 August. Total yields in all unprotected plots ranged from 10 to 40% lower than in the protected plots. Mean density of overwintering adults within potato plots was 76 beetles m^{-2} with a maximum of 232 m^{-2}. Mean overwintering mortality was 22% and mean depth of overwintering adults was 12 cm, with 63% of the beetles collected at depths $\leq$ 10 cm. Our results indicate that the phenology of the beetle is similar to that reported in areas where population buildups were rapid and devastating soon after insecticide resistant populations appeared. Consequently the beetle must be considered as a serious threat to potato production in southern Alberta.

[Potentiel d'endommagement et phénologie du doryphore de la pomme de terre [Coleoptera : Chrysomelidae] sur la pomme de terre dans le Sud de l'Alberta]

La phénologie et le potentiel d'endommagement du doryphore de la pomme de terre (*Leptinotarsa decemlineata*) ont été étudiés dans la zone productrice de pommes de terre du Sud de l'Alberta. Des parcelles expérimentales ont été installées à Lethbridge en 1998, 1999 et 2000, et à Vauxhall

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en 1998 et 1999. À chaque site, une parcelle était protégée du doryphore par l'application d'insecticides alors qu'une autre était laissée « sans protection ». À chaque année, les populations naturelles du doryphore ont rapidement colonisé les parcelles non protégées. Les adultes hivernants sont apparus dans les parcelles à la mi-juin avec des densités moyennes atteignant de 0,3 à 0,6 par plante. Les œufs ont été pondus sur les jeunes plantes avec des densités moyennes qui ont atteint deux masses d'œufs par plante à la fin de juin. Les densités maximales de larves ont atteint 9,5 par plante pour chacun des 1^{er}, 2^{e} et 3^{e} stades larvaires, et de 14 par plante pour le 4^{e} stade. La densité maximale des adultes nouvellement émergés a été de 57 par plante à la mi-juillet de 2000 dans la parcelle non protégée de Lethbridge. La défoliation a été très faible en début de saison, mais a augmenté abruptement lorsque les populations larvaires des 3^{e} et 4^{e} stades sont arrivées à leur optimum, elle a continué à augmenter avec l'émergence des adultes. La défoliation maximale s'est produite à la parcelle de Lethbridge en 2000 avec 100 % de défoliation au 10 août. Les rendements totaux de toutes les parcelles non protégées ont été de 10 à 40 % inférieurs à ceux des parcelles protégées. La densité moyenne des adultes hivernants dans les parcelles de pommes de terre a été de 76 doryphores m^{-2} avec un maximum de 232 m^{-2}. La mortalité moyenne au cours de l'hiver a été de 22 % et la profondeur moyenne des adultes hivernants a été de 12 cm, avec 63 % des doryphores trouvés à une profondeur de $\leq$ 10 cm. Nos résultats montrent que la phénologie du doryphore est similaire à celle rapportée pour des régions où les accroissements de population ont été rapides et dévastateurs dès que des populations résistantes aux insecticides sont apparues. En conséquence, le doryphore doit être considéré comme une menace sérieuse pour la production de la pomme de terre dans le Sud de l'Alberta.

INTRODUCTION

The Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say) [Coleoptera: Chrysomelidae], is the most destructive foliage feeding pest of potatoes in North America (Hare 1990). In Canada and the northern part of the United States, overwintered adults emerge from the soil in the spring and either walk or fly in search of food plants and oviposition sites. Eggs are deposited on foliage of newly emerged plants in late spring. Larvae emerge and pass through four instars that feed voraciously on potato foliage. Mature larvae burrow into the soil around the base of the host plant and pupate. Approximately 10-15 d later, adults of the new generation emerge and begin feeding on the maturing potato plants. In areas where the beetle is univoltine, the new adults do not lay eggs, but feed heavily mainly to store reserves in preparation for diapause (Dortland and Kort 1978). When ready to diapause, beetles either enter the soil within potato fields, or move out by walking or flying in search of peripheral overwintering sites such as forest borders and drainage ditches potentially offering more protection (Noronha and Cloutier 1998, 1999; Voss and Ferro 1990; Weber and Ferro 1993).

CPB can cause heavy economic loss if left uncontrolled (Cranshaw and Radcliffe 1980; Ferro *et al.* 1983; Hare 1980). Severe defoliation by CPB can, not only result in total yield loss, but may also decrease the quality of harvested potatoes (Senanayake and Holliday 1990; Shields and Wyman 1984). Insecticides have been used extensively to control the CPB, but their long term efficacy is threatened by multiple resistance (Roush *et al.* 1990). Widespread economic losses become apparent only when insecticide control measures begin to fail. In eastern Canada, loss of control efficacy due to resistance to all four chemical classes of insecticides resulted in the emergency registration of imidacloprid (Admire™ 240F), an insecticide with a new mode of action. In western Canada, there have been recent reports of insecticide resistance from Manitoba (Gavloski 1997; Noronha *et al.* 2001). In Alberta, tested CPB populations remain susceptible to cheaper conventional insecticides (Noronha *et al.* 2001), making the cost of CPB control more economical relative to areas that must apply more expensive, newer chemical insecticides. However, little is known about the phenology and damage potential of CPB in Alberta.

Potato agroecosystems and production practices differ among regions. Factors, such as the crops used in a rotation, distance of rotation, irrigation and cultivation may influence the colonization and successful development of the beetle (Hough-Goldstein and Whalen 1996). There is also growing evidence that differences exist among beetle populations from different regions (Senanayake *et al.* 2000). Potatoes in southern Alberta are grown under irrigation on sandy loam soil principally for french fry production or chipping. Rotations are typically with cereals and sugar beets with potatoes grown every fourth yr. The purpose of this study was to gain a better understanding of the phenology and damage potential of CPB in the heart of the potato producing area in southern Alberta.

MATERIALS AND METHODS

Experimental plots were established at two different locations in southern Alberta: the Lethbridge Research Centre (49°42' N, 112°47' W), approximately 50 km from major potato producers, and the Lethbridge Research Centre's Vauxhall substation (50°03' N, 112°08' W), which is in the heart of the potato growing region of southern Alberta. The soil at the Lethbridge site is a dark brown chernozem and at Vauxhall a brown chernozem. At each site, Russet Burbank potatoes were planted in two 10 m x 10 m plots with 10 rows of 30 plants per row, with a 5 m buffer zone between plots. At each site, one plot was designated as the "protected" plot and the other as an "unprotected" plot. In the protected plots, the seed was treated at planting with phorate (Thimet 15G™), a systemic organophosphorus insecticide, at the recommended rate of 45.6 kg a.i. ha^{-1}. When beetles reappeared within these protected plots, infestations were subsequently controlled with foliar applications of an organophosphorous insecticide, methamidophos (Monitor 480E™) and a pyrethroid, permethrin (Ambush 500E™) at the recommended rates of 3 L a.i. ha^{-1} and 172 mL a.i. ha^{-1} respectively. Unprotected plots received no insecticide treatment.

At both sites, plots were established and monitored in 1998 and 1999; the Lethbridge plots were established and monitored for a third yr in 2000. In 1998, two unprotected plots were established in Lethbridge: plot A was planted on 24 April, and plot B and all other plots at both sites were planted on 7 May. In 1999, all plots were planted on 7 May, and in 2000, the plots at Lethbridge were planted on 27 April. In all yr, natural beetle populations were allowed to colonize the unprotected plots.

Sampling Procedure

Each plot was divided into three blocks consisting of 10 plants per row x 10 rows. Sampling for beetles began as soon as the plants emerged and adults were first observed. Twice weekly, two randomly selected plants per row per block were examined to estimate CPB population density and defoliation. From mid June to mid August, the number of eggs, first, second, third and fourth instar larvae and adults were counted and the extent of defoliation noted for each sample plant. A defoliation index (**1.** < 10%; **2.** 11-25%; **3.** 26-39%; **4.** 40-50%; **5.** 50%; **6.** 51-74%; **7.** > 75%; **8.** 100%) was employed to classify the extent of damage per plant over the summer (modified from Boiteau 1994).

Yield and Quality

At the end of August, potatoes from two plants per row from each block were harvested (total of 60 plants per plot per location). The total weight of all potato tubers from each block was determined. Tubers were then divided into unmarketable (< 48 mm diam), marketable (48-88 mm) and large (< 88 mm) sizes. All the marketable tubers harvested from a block were weighed again to determine marketable yield. A *t* test was used to determine significant differences between yields in protected and unprotected plots for each yr and site.

Traps
In 1998 and 1999, two 1 m long pitfall traps (Hunt and Vernon 2001) were each placed approximately 2 m from each edge of the plot, along all four borders of each plot at both sites. At the Lethbridge site, two flight interception traps per border were also set up. Each flight trap was 3 m high and 1.2 m wide and was placed 1 m above the surface of the soil, at approximately the canopy level. The edges of the trap were bordered with a strip of Tangle Trap™ and a trough was placed at the bottom of each side of the trap to catch any beetles that hit the trap and fell while flying either into or out of the plot (Noronha and Cloutier 1998). The intercept traps on each side were 3 m apart. Both pitfall and flight traps were monitored twice weekly throughout the summer. All adults caught in traps were returned to the laboratory to determine if they were ready for diapause. Adults were placed in containers with soil and potato foliage in a greenhouse with only natural day length. Adults that failed to feed (i.e., were satiated) or that entered the soil within 24-48 h were considered ready to enter diapause.

Overwintering
Overwintering beetle densities were monitored in the 2000 Lethbridge plots. Between 11 and 17 May 2001, the numbers of live and dead beetles within the soil were counted. Ten quadrats (37 cm x 49 cm) were excavated within each plot. Soil was carefully removed layer by layer until hard sub top soil clay was encountered (at approximately 40 cm). Each cm of soil was separately sieved and presence and numbers of beetles was noted at each depth.

RESULTS

Protected plots
Less than two adult beetles per plant were recorded in all protected plots for all sites and yr. In late summer of 2000, beetles began moving from the unprotected plot to the protected plot as defoliation of the unprotected plot reached 100%.

General phenology
Natural CPB populations quickly colonized all unprotected plots in all yr with the exception of Lethbridge plot B in 1998 (Fig. 1B). The phenology remained essentially the same in all plots and yr with only minor shifts in time between plots and sites. While overwintered adults began to colonize the plots by mid June with maximum mean densities reaching between 0.3 and 0.6 per plant, no beetles were found in traps at this time. Eggs were laid on young plants with mean densities reaching two egg masses per plant by late June. Hatch began within the first wk following oviposition. First and 2nd instar larvae were present in the field from late June to early July, 3rd instar larvae from late June to mid July, and 4th instar from early July to the third wk of July. Maximum larval densities were as follows: 1st and 2nd instar, 9.5 per plant, 3rd instar, 9.5 per plant and 4th instar, 13.6 per plant. A considerable overlap in larval instars was observed from late June to mid July; at times all four larval instars were observed within a plot. In plot B at Lethbridge in 1998, there was a delay in colonization and in emergence of 3rd and 4th instars and new adults compared to plot A (Figs. 1A and B).

New adults started emerging from the end of July to early August. A maximum density of 57 adults per plant was recorded at the 2000 Lethbridge plot and 20 adults per plant at the 1999 Vauxhall plot. Emerging adults began to feed on the potato foliage. Very few eggs were laid by the females. By mid-August, the adults began to leave the plants and were found in pitfall and flight interception traps. In 1998, a total of 104 beetles were found in traps in

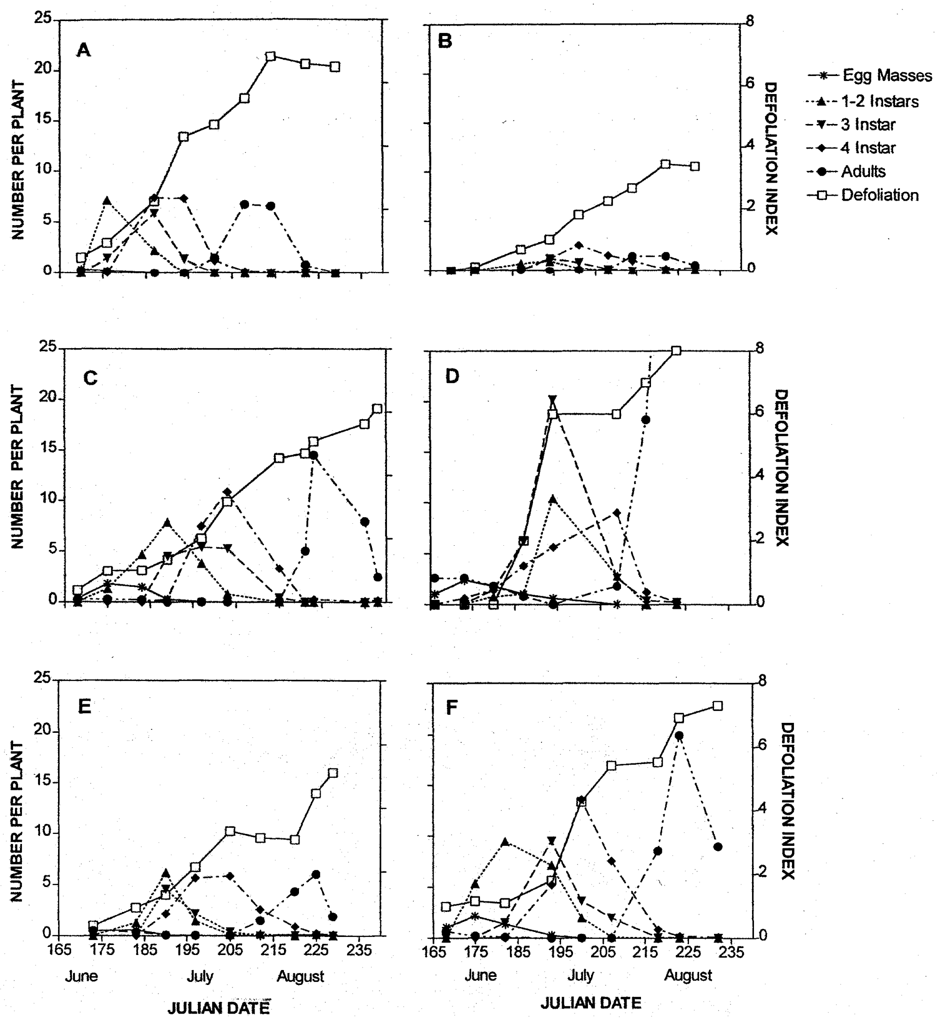

Figure 1. Mean Colorado potato beetle densities and defoliation index in unprotected potato plots. A) Lethbridge plot A in 1998; B) Lethbridge plot B in 1998; C) Lethbridge plot in 1999; D) Lethbridge plot in 2000; E) Vauxhall plot in 1998; F) Vauxhall plot in 1999. Defoliation index: **1.** < 10%; **2.** 11-25%; **3.** 26-39%; **4.** 40-50%; **5.** 50%; **6.** 51-74%; **7.** > 75%; **8.** 100% (modified from Boiteau 1994).

plot A at the Lethbridge site; 73% of these beetles were satiated and ready for diapause. At Vauxhall, 91% of 51 beetles found in the traps were satiated. In 1999, 34 beetles were collected from the traps at the Lethbridge site and 303 at the Vauxhall site. Of these beetles, 9% were found to be satiated at the Lethbridge site and 46% at the Vauxhall site. Flight was not very extensive in 1998 and 1999, only 11 and 5 beetles were respectively trapped. All beetles from flight traps were satiated and were moving out of the plots. Although traps were not established in 2000, adults were seen moving from the unprotected plot into the protected plot in early August.

Defoliation

Overall, defoliation was very low at the beginning of the season, increased sharply when the third and fourth instar populations peaked and continued to rise as new adults emerged from pupation (Fig. 1). In 1998, defoliation was slower in Lethbridge plot B reaching only 30% by the end of the summer compared to 75% in plot A. Maximum defoliation occurred at Lethbridge in 2000 with 100% defoliation by 10 August. Defoliation did not exceed 10% in protected plots. It was restricted mainly to outer rows later in the season when new adults were moving into these plots.

Yield and Quality

While average total yields in all unprotected plots ranged from 10 to 49% lower than in the protected plots (Table 1), only the Vauxhall yields were significantly lower in unprotected than protected plots ($P < 0.05$). At Vauxhall, marketable yield was reduced by 38 and 24% in 1998 and 1999 respectively. At Lethbridge, decreases in marketable yield of 13% in 1999 and 17% in 2000 were not statistically significant.

Overwintering

A total of 141 beetles were collected from the soil in the protected plot and 25 from the unprotected plot. All beetles were found within cells, indicating that they had not yet started to move upwards. Mean density of overwintering adults was 76 beetles (± 21.5 SEM) m^{-2} with a maximum of 232 m^{-2} in the protected plot, and 13 beetles (± 3.4 SE) m^{-2} with a maximum of 27 m^{-2} in the unprotected plot. Mortality in both plots averaged 22%; only a single beetle (3%) was diagnosed as infected by the fungus *Beauveria bassiana* (Balsamo) Vuillemin. Mean depth of live and dead beetles was similar with a mean of 12.3 (± 0.95 SE) cm for living beetles and 11.9 (± 2.13 SE) for dead beetles, and ranges of 0 to 39 cm for both groups. Distribution of beetles at different depths is summarized in Table 2. Minimum temperatures recorded at a turf

Table 1. Yield of potatoes from protected and unprotected plots at Lethbridge and Vauxhall, Alberta, 1998-2000

	Total Yield			Marketable Yield		
Year/Site	Protected ($kg\ plot^{-1}$)	Unprotected ($kg\ plot^{-1}$)	Change (%)	Protected ($kg\ plot^{-1}$)	Unprotected ($kg\ plot^{-1}$)	Change (%)
Lethbridge						
1998						
Plot A		204			120	
Plot B	277	249	-10	124	128	+3
1999	398	306	-23	207	180	-13
2000	782	399	-49	225	187	-17
Vauxhall						
1998	318	180	-43*	198	123	-38*
1999	280	186	-34*	182	138	-24*

* *t* test: $P<0.05$.

Tableau 2. Overwintering depths of adult Colorado potato beetles, Lethbridge, Alberta, 2000

		% adult beetles at indicated depth (cm)			
Status	n	≤ 10	> 10-20	> 20-30	> 30-39
Live	131	63	10	11	12
Dead	36	67	8	14	11

field at the Lethbridge Research Centre were as follows: -31.4°C at the soil surface on 11 December 2000; -8.8 and -7.2°C at 5 cm, -7.6 and -6.7°C at 10 cm, and -5.3 and -5.5°C at 20 cm respectively on 16 December 2000 and 27 February 2001. There was no appreciable precipitation during the winter and the plots remained essentially dry and without snow cover throughout the winter period.

DISCUSSION

Although the Lethbridge site was far from major potato production areas, while the Vauxhall site was in the heart of the potato growing area in southern Alberta, we observed no difference between these two sites in the timing of adult colonization in the spring; each yr, overwintered adults were found at both sites by early to mid June. We suspect that home gardens and smaller potato plots around Lethbridge may have contributed colonizing beetles at this site.

The timing of plant emergence, however, played a role in beetle colonization. In 1998, plot B in Lethbridge, which was planted two wk later than plot A, had delayed colonization and reduced defoliation. Mean larval densities reached seven 4th instars per plant in plot A and two per plant in plot B; defoliation in these plots reached 60% and only 30% respectively by the end of the summer (Figs. 1A and B). The lower beetle pressure in plot B may explain the smaller difference in total yield between the protected plot and unprotected plot B during this yr.

In all three yr we found an overlap of larval instars in the field, with overwintered adults, eggs, and all four instars present at the same time at the end of June and early July. Early in the season, when 1st and 2nd instar larvae were present in the field, defoliation was generally low. However, as was previously reported in other areas (e.g., Boiteau 1994), after larvae molted to 3rd and 4th instars, defoliation rapidly increased. Populations in our plots were high with numbers of 3rd and 4th instars exceeding 6 larvae per plant.

Beetle infestations in all yr reduced total potato yield. This decrease in yield was smaller in the plot with lower beetle populations (plot B, 1998, Lethbridge). With the exception of Lethbridge in 1998 (< 5%), marketable yields were decreased from 13 to 38%. The phenological age and defoliation of the plant influences yield reduction. Defoliation during the bloom period has the greatest impact on yield reduction (Boiteau 1988; Hare 1980; Shields and Wyman 1984). The difference in timing of major defoliation by 4th instar larvae may account for the greater yield loss at Vauxhall relative to Lethbridge in 1998 (Table 1; Figs.1B and E).

Our overwintering survival data indicated that fewer beetles overwintered directly in a defoliated plot (13 adults m^{-2}) than in an adjacent protected plot (76 adults m^{-2}). Similarly, Hunt and Tan (2000) presented evidence that beetles would remain in a tomato field if a food source was available. Noronha and Cloutier (1999) also demonstrated that protected potato plots may act as a sink for diapausing adults emigrating from defoliated plots. In contrast, Milner *et al.* (1992) found that, in central Wisconsin, adults attracted to trap potatoes in the fall, did not overwinter in those plots.

All adults intercepted in flight traps and the majority of adults intercepted in the pitfall traps were satiated indicating that movement in late summer was mainly in search of overwintering sites. In eastern North America, large numbers of pre-diapause beetles walk or fly from potato or tomato fields to surrounding forested or wooded edges to overwinter, resulting in higher densities of overwintering adults along these edges than in the host fields (Hunt and Tan 2000; Noronha and Cloutier 1999; Weber and Ferro 1993). Densities of overwintering beetles in our plots were much higher than reported elsewhere in tomato fields in Ontario (2 - 5 m^{-2}; Hunt and Tan 2000) or in potato fields in Massachusetts (5 - 20 m^{-2}; Voss and Ferro 1992; Weber and Ferro 1993). Beetles on the prairies may overwinter in the fields rather than emigrate to edges of wooded areas, which are scarce on the prairies. This hypothesis warrants further investigation.

Mean depth of overwintering beetles in our study was 12 cm with 63% being found at depths of ≤ 10 cm. Similar mean depths were reported for beetles overwintering in New Jersey (8-13 cm; Lashomb *et al.* 1984) and in central Wisconsin (80% in top 15 cm; Milner *et al.* 1992). Hunt and Tan (2000), however, reported that 74-78% of beetles overwintered at depths between 10 and 25 cm in Ontario while Weber and Ferro (1993) found 68% of the overwintering beetles at 10 to 20 cm depth with only 12% in the top 10 cm. Body size and soil temperature, density and moisture affect digging behavior and depth of prediapausing Colorado potato beetles (Noronha and Cloutier 1998). The exceptionally mild and dry winter of 2000/2001 in southern Alberta may thus account for this shallower overwintering depth.

Mean overwintering survival of beetles in this study was 78%. Survival rates can vary tremendously with survivorship of 14 to 75% recorded in New Jersey (Lashomb *et al.* 1984), 55 to 91% in Massachusetts (Weber and Ferro 1993), 17 to 29% in central Wisconsin (Milner *et al.* 1992) and 0 to 100% in Ontario (Hunt and Tan 2000). In those studies, the direct relationship between decreasing mortality with increasing depth is generally attributed to thermal shock (Kung *et al.* 1992; Milner *et al.* 1992). While a depth-mortality relationship was not apparent in this study, the sample size was relatively low. Kung *et al.* (1992) reported < 50% survival after exposure of diapausing beetles to six cold-shock exposures of ≤ -4°C, but much higher survival after a single thermal shock. In this study, only two thermal shocks were experienced; temperature differences between the 5 and 20 cm depths differed by less than 4°C and temperatures never dropped below -8.8°C. The 78% survival compares favorably with the survival of 71% after a single shock of -8°C reported by Kung *et al.* (1992). In Massachusetts, Weber and Ferro (1993) reported that over 70% of the dead beetles were infected by *B. bassiana*. In this study, only one infected cadaver was identified which represented less than 3% of the dead beetles.

In Alberta, beetle populations have been historically low. With the presently expanding potato industry, an increase in the CPB population could result in the need for increased insecticide applications and the possible rapid development of resistance. The large numbers of beetles already demonstrating lower susceptibility to insecticides in southern Alberta are an indication that resistant populations are being selected (Noronha *et al.* 2001). Our results indicate that the phenology of CPB is similar to that reported in areas where population buildups were rapid and devastating, soon after insecticide resistant populations appeared. Beetle populations rapidly increase following colonization by relatively few beetles. Overwintering survival during the winter of 2000/2001 was estimated to 78%. Although our results are based on small plot sizes and cannot be directly extrapolated to beetle densities and yield reductions in commercial fields, they demonstrate that beetles can overwinter in large numbers and have the potential to cause severe economic damage. Thus, caution must be exercised and a resistance management program should be implemented immediately in southern Alberta to prevent, or at least delay, further selection of insecticide resistant populations.

ACKNOWLEDGEMENTS

We thank Pualele Atoa, Loa Barendregt, Jason Chinn, Kelly Holowka, Don Howard and Alicia Valgardson for technical assistance. Bob Vernon, Pacific Agri-Food Research Centre, Agassiz, B.C. provided pitfall traps and Sean McGinn, Lethbridge Research Centre, provided temperature data. Drs. Conrad Cloutier, Dave Hunt and 2 anonymous reviewers provided useful comments on the manuscript. The Potato Growers of Alberta provided financial assistance. This is LRC publication number 387 01054.

REFERENCES

Boiteau, G. 1988. Timing of insecticide applications for the control of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), on potatoes in New Brunswick. Can. Entomol. 120 : 587-591.

Boiteau, G. 1994. Visual index for the estimation of defoliation in the potato crop. Research Summary Bulletin, Vol 3, Agriculture and Agri-Food Canada, Fredericton, New Brunswick, Canada.

Cranshaw, W.S., and E.B. Radcliffe. 1980. Effect of defoliation on yield of potatoes. J. Econ. Entomol. 73 : 131-134.

Dortland, J.F., and C.A.D. de Kort. 1978. Protein synthesis and storage in the fat body of the Colorado potato beetle. Insect Biochem. 8 : 93-98.

Ferro, D.N. , B.J. Morzuch, and D. Margolies. 1983. Crop loss assessment of the Colorado potato beetle (Coleoptera: Chrysomelidae) on potatoes in western Massachusetts. J. Econ. Entomol. 76 : 349-356.

Gavloski, J. 1997. Rotation, rotation, rotation. Potato Perspectives 16 : 2.

Hare, D.J. 1980. Impact of defoliation by the Colorado potato beetle on potato yields. J. Econ. Entomol. 73 : 369-373.

Hare, D.J. 1990. Ecology and management of the Colorado potato beetle. Annu. Rev. Entomol. 35 : 81-100.

Hough-Goldstein, J.A., and J.M. Whalen. 1996. Relationship between crop rotation distance from previous potatoes and colonization and population density of Colorado potato beetle. J. Agric. Entomol. 13 : 293-300.

Hunt, D.W.A., and C.S. Tan. 2000. Overwintering densities and survival of the Colorado potato beetle (Coleoptera: Chrysomelidae) in and around tomato (Solanaceae) fields. Can. Entomol. 132 : 103-105.

Hunt, D.W.A., and R.S. Vernon. 2001. Portable trench barrier for protecting edges of tomato fields from Colorado potato beetle (Coleoptera: Chrysomelidae). J. Econ. Entomol. 94 : 204-207.

Kung, K.-J.S., M. Milner, J.A. Wyman, J. Feldman, and E. Nordheim 1992. Survival of Colorado potato beetle (Coleoptera: Chrysomelidae) after exposure to subzero thermal shocks during diapause. J. Econ. Entomol. 85 : 1695-1700.

Lashomb, J.H., Y.-S. Ng, G. Ghidiu, and E. Green. 1984. Description of spring emergence by the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae), in New Jersey. Environ. Entomol. 13 : 907-910.

Milner, M., K.-J.S. Kung, J.A. Wyman, J. Feldman, and E. Nordheim. 1992. Enhancing overwintering mortality of Colorado potato beetle (Coleoptera: Chrysomelidae) by manipulating the temperature of its diapause habitat. J. Econ. Entomol. 85 : 1701-1708.

Noronha, C., and C. Cloutier. 1998. Effects of soil conditions and body size on digging by prediapausing Colorado potato beetles (Coleoptera: Chrysomelidae). Can. J. Zool. 76 : 1705-1713.

Noronha, C., and C. Cloutier. 1999. Ground and aerial movement of adult Colorado potato beetle (Coleoptera: Chrysomelidae) in a univoltine population. Can. Entomol. 131 : 521-538

Noronha, C., G.M. Duke, J.M. Chinn, and M.S. Goettel. 2001. Differential susceptibility to insecticides by *Leptinotarsa decemlineata* [Coleoptera: Chrysomelidae] populations from western Canada. Phytoprotection 82 : 113-121.

Roush, R.T., C.W. Hoy, D.N. Ferro, and W.M. Tingey. 1990. Insecticide resistance in the Colorado potato beetle (Coleoptera: Chrysomelidae): Influence of crop rotation and insecticide use. J. Econ. Entomol. 83 : 315-319.

Senanayake D.G, and N.J. Holliday. 1990. Economic injury levels for Colorado potato beetle (Coleoptera: Chrysomelidae) on Norland potatoes in Manitoba. J. Econ. Entomol. 83 : 2058-2064.

Senanayake D.G, E.G. Radcliffe, and N.J. Holliday. 2000. Oviposition and diapause behaviour in Colorado potato beetle (Coleoptera: Chrysomelidae) populations from east central Minnesota and the valley of the Red river of the north. Environ. Entomol. 29 : 1123-1132.

Shields, E.J., and J.A. Wyman. 1984. Effects of defoliation on specific growth stages on potato yields. J. Econ. Entomol. 77 : 1194-1199.

Voss, R.H., and D.N. Ferro. 1990. Ecology of migrating Colorado potato beetles (Coleoptera: Chrysomelidae) in western Massachusetts. Ecol. Entomol. 19 : 123-129.

Voss, R.H., and D.N. Ferro. 1992. Population dynamics of the Colorado potato beetle (Coleoptera: Chrysomelidae) in western Massachusetts. Am. Potato J. 69 : 473-482.

Weber, D.C., and D.N. Ferro. 1993. Distribution of overwintering Colorado potato beetles in and near Massachusetts potato fields. Entomol. Exp. Appl. 66 : 191-196.