EFFECT OF HARVEST ON EUPHORINE (HYMENOPTERA: BRACONIDAE) PARASITISM OF *LYGUS LINEOLARIS* AND *ADELPHOCORIS LINEOLATUS* (HEMIPTERA: MIRIDAE) IN ALFALFA

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Effective biological control of *Lygus lineolaris* and *Adelphocoris lineolatus* depends on the availability of appropriate host stages to sustain populations of euphorine parasitoids which are important in reducing pest populations. In Quebec alfalfa, crops are cut 2–4 times during the summer season, yet how this affects the host and parasitoid populations is poorly understood. A 3-year study conducted from 2000–2002 in southern Quebec demonstrated that overall, abundance of susceptible host stages (N2+N3) in cut alfalfa were less than half of those collected in uncut alfalfa, even after 4–5 weeks when the cut crop reached the same height as the uncut crop. Parasitism levels of N4+N5 nymphs in the cut crop were usually less than those in the uncut crop, although on several sampling dates the reverse was observed. Numbers of adult *L. lineolaris* and *A. lineolatus* were always lower immediately after harvest in the cut crop but numbers increased in the following weeks to equal those collected in the uncut crop. These results suggest that periodic harvest of alfalfa reduces available host stages for parasitism and subsequent levels of parasitism but does not cause elimination of parasitoid populations. Furthermore, dispersing adults likely contributed to an increase in abundance of susceptible host stages after habitat modification, thereby sustaining parasitoid populations.

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Introduction

Effective biological control of *Lygus lineolaris* (Palisot) and *Adelphocoris lineolatus* (Goeze) (Hemiptera: Miridae) depends on the availability of appropriate

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host stages to sustain populations of euphorine parasitoids such as native species of the *Peristenus mellipes* complex and the introduced *Peristenus digoneutis* Loan (Hymenoptera: Braconidae) (Day 2005). Alfalfa, *Medicago sativa* L. (Fabaceae), is an important reservoir for *Lygus* spp. and its euphorine parasitoids (Mueller et al. 2005; Seymour et al. 2005; Pickett et al. 2009), and management of alfalfa, as a main crop or as a trap crop, influences pest numbers in adjacent crops such as cotton and strawberries (Godfrey and Leigh 1994; Pansa and Tavella 2009; Pickett et al. 2007, 2009). In alfalfa, crops are typically cut 2–4 times during the summer season. Although cutting may or may not result in mass migration of *Lygus* to adjacent crops (Poston and Pedigo 1975; Stolz and McNeal 1982; Cárcamo et al. 2003; Demirel and Cranshaw 2006), how cutting affects the natural enemy populations is poorly understood. The effects of cutting alfalfa on host and predator populations have been studied (Rakickas and Watson 1974; Schaber et al. 1990; Godfrey and Leigh 1994) but no study was found that documents the effects of cutting on parasitoid populations. This study compared populations of *L. lineolaris* and *A. lineolatus* in cut and uncut alfalfa to determine the effect of harvest on the availability of susceptible host stages for parasitism and levels of parasitism in a managed crop system.

Materials and Methods

A 3-year study was conducted from 2000–2002 in southern Quebec at the Agriculture and Agri-Food Canada Research Farm near Sainte-Clotilde-de-Châteauguay (45.15°N 73.67°W). In each year, weekly samples consisting of 200 180°-arc sweeps were taken from a 2-ha field beginning in early May (2001 and 2002) or mid June (2000) until first frost in late September. At first harvest, the first or second week of June, half of the field was cut and the other half was left as uncut. Samples were taken from cut and uncut parts until the next harvest at which time the previously uncut portion was cut and the treatments reversed. Each half of the field was cut twice during the season. Each sample was aspirated into plastic vials using a Hausherr's Machine Works® power aspirator, labeled, and placed in a cooler. In the laboratory, for each sample, species and nymphal instars (N1−N5) were documented and parasitism levels determined by dissecting individuals of each instar. Due to manpower limitations, rearing of sub-samples of parasitized hosts were not done, however, a parallel study (Goulet and Mason 2006) conducted during the same years provided information on the euphorine parasitoid species present.

Analysis of variance using PROC GLM and LSD means comparisons were performed using the SAS statistical package (SAS 2008). Comparisons were made within each year and among years of mean weekly counts and mean parasitism of *L. lineolaris* and *A. lineolatus* populations in cut and uncut portions of the field. Data were normalized by using the log (x+1) transformation for plant bug counts and the square root of percent parasitism values.

Results and Discussion

For *L. lineolaris*, mean numbers per week did not differ between cut and uncut alfalfa in 2000, although values in cut alfalfa were lower, but did differ in 2001 and 2002

TABLE 1. Mean number per week (±SE) of N2+N3, N4+N5, and adult *Lygus lineolaris* and *Adelphocoris lineolatus*, and mean % parasitism (±SE) of N4+N5 in cut and uncut alfalfa near Sainte-Clotilde-de-Châteauguay, QC in 2000, 2001, and 2002.

	2000		**2001**		**2002**	
	uncut	**cut**	**uncut**	**cut**	**uncut**	**cut**
Lygus lineolaris						
N2+N3	27.4 (11.0)	3.6 (1.4)	51.1 (24.7)	4.5 (3.2)	20.5 (6.6)	1.4 (0.8)
N4+N5	48.4 (11.6)	22.9 (6.1)	91.3 (36.7)	23.7 (13.5)	87.1 (36.3)	9.8 (3.3)
Adult	72.7 (24.5)	29.6 (8.7)	83.9 (19.0)	34.7 (17.1)	49.4 (16.0)	22.8 (8.3)
% parasitism of N4+N5	22.7 (5.7)	15.5 (5.7)	22.5 (5.2)	20.2 (9.1)	22.4 (8.4)	29.3 (19.2)
Adelphocoris lineolatus						
N2+N3	4.4 (1.9)	1.7 (1.1)	2.0 (0.9)	0.8 (0.4)	7.2 (1.9)	4.3 (2.5)
N4+N5	8.6 (3.2)	17.9 (11.2)	16.2 (5.4)	13.7 (7.7)	21.2 (7.8)	16.1 (7.7)
Adult	11.9 (3.6)	5.1 (2.4)	33.1 (8.4)	11.5 (5.5)	28.4 (9.1)	9.6 (3.8)
% parasitism of N4+N5	3.6 (2.3)	1.7 (1.4)	10.5 (6.6)	1.2 (0.8)	6.9 (2.0)	10.5 (9.0)

(Table 1). In both 2001 and 2002 significantly more N2+N3 (2001—$F_{(1,28)}$=5.88, P=0.0223; 2002—$F_{(1,34)}$=12.16, P=0.0014) and adults (2001—$F_{(1,28)}$=8.54, P=0.0069; 2002—$F_{(1,34)}$=4.50, P=0.0415) occurred in the uncut alfalfa compared to the cut alfalfa. Overall, mean numbers of N2+N3, N4+N5, and adults did not differ significantly among years in the uncut and cut alfalfa, except numbers of N4+N5 were significantly higher ($F_{(2,41)}$=3.51, P=0.0396) in the cut alfalfa in 2000 compared to 2002 (Table 1). There were no significant differences (P>0.05) in parasitism (N4+N5) of *L. lineolaris* between cut and uncut alfalfa in each year and among years for either cut or uncut alfalfa (Table 1).

For A. *lineolatus*, mean numbers per week did not differ significantly between cut and uncut alfalfa in 2000 but did differ in 2001 and 2002 (Table 1). In 2001 mean numbers of adults were significantly higher in the cut alfalfa compared to the uncut alfalfa ($F_{(1,37)}$=5.85, P=0.0207) and in 2002 numbers of N2+N3 were significantly higher in the uncut than cut alfalfa ($F_{(1,28)}$=5.88, P=0.0223). Mean numbers of nymphs and adults were not significantly different among years, except N2+N3 numbers which were significantly lower in the uncut alfalfa ($F_{(2,51)}$=4.69, P=0.0136) in 2001 compared to 2002 (Table 1). There were no significant differences (P>0.05) in parasitism of N4+N5 between cut and uncut alfalfa in each year and among years for either cut or uncut alfalfa (Table 1).

In all three years, for both *L. lineolaris* and *A. lineolatus*, numbers of susceptible host stages (N2+N3) collected weekly in cut alfalfa were less than half of those collected in uncut alfalfa, even after 4–5 weeks when the cut crop reached the same height as the uncut crop (Figures 1 and 2). This was anticipated since cutting destroys eggs and reduces the food source for nymphs, many of which die, and adults, which migrate out of the crop (Lim and Stewart 1976) leading to time delays as adults re-colonize and rebuild these cohorts. Numbers of adults were always lower immediately after harvest in the cut crop but numbers increased in the following weeks, in some cases to levels similar to (e.g., for *L. lineolaris*, weeks 10 and 19 in 2000, week 11 in 2001 and week 19 in 2002; for *A. lineolatus*, week 19 in 2000, and week 11 in 2001) or higher (e.g., for *L. lineolaris*, week 15 in 2000, week 15 in 2001, and week 14 in 2002; for *A. lineolatus*, week 10 in 2000, week 15 in 2001, and week 14 in 2002) than those in the uncut crop (Figures 1 and 2). Several studies have shown that

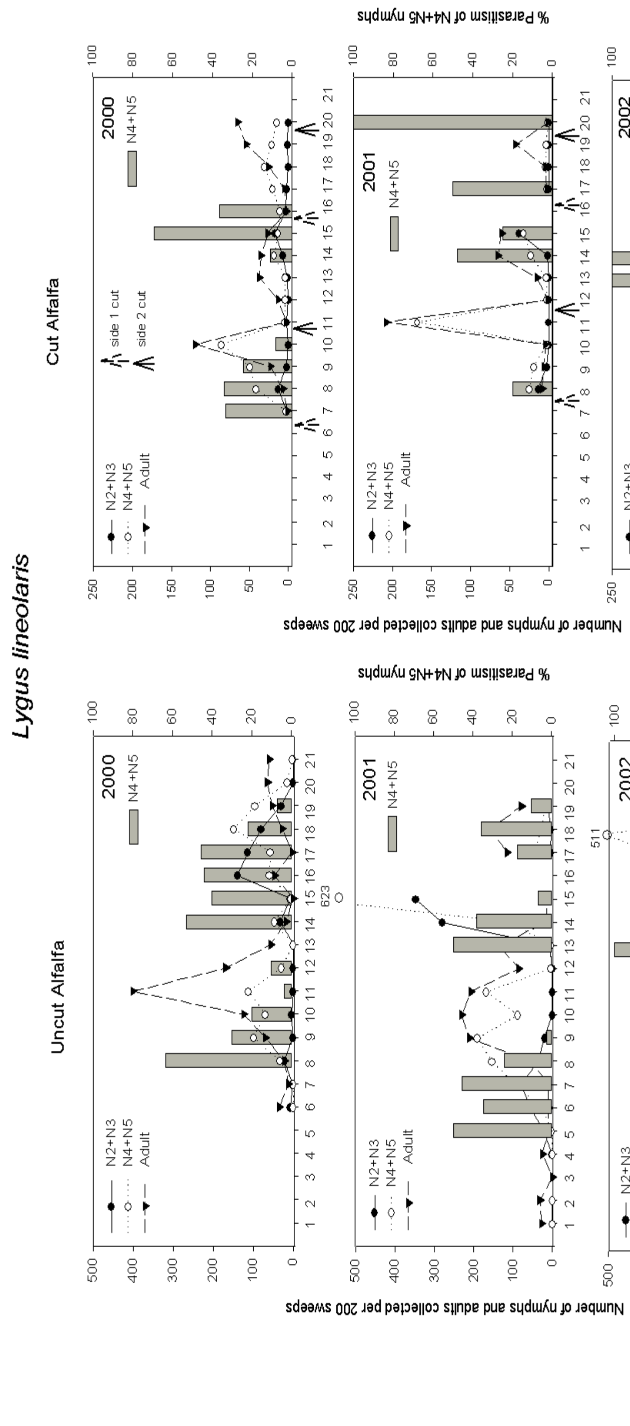

FIGURE 1. Number of *Lygus lineolaris* (Palisot) nymphs (N2+N3 and N4+N5) and adults collected (lines) and parasitism (%) of N4+N5 nymphs in uncut and cut alfalfa (bars) in 2000–2002.

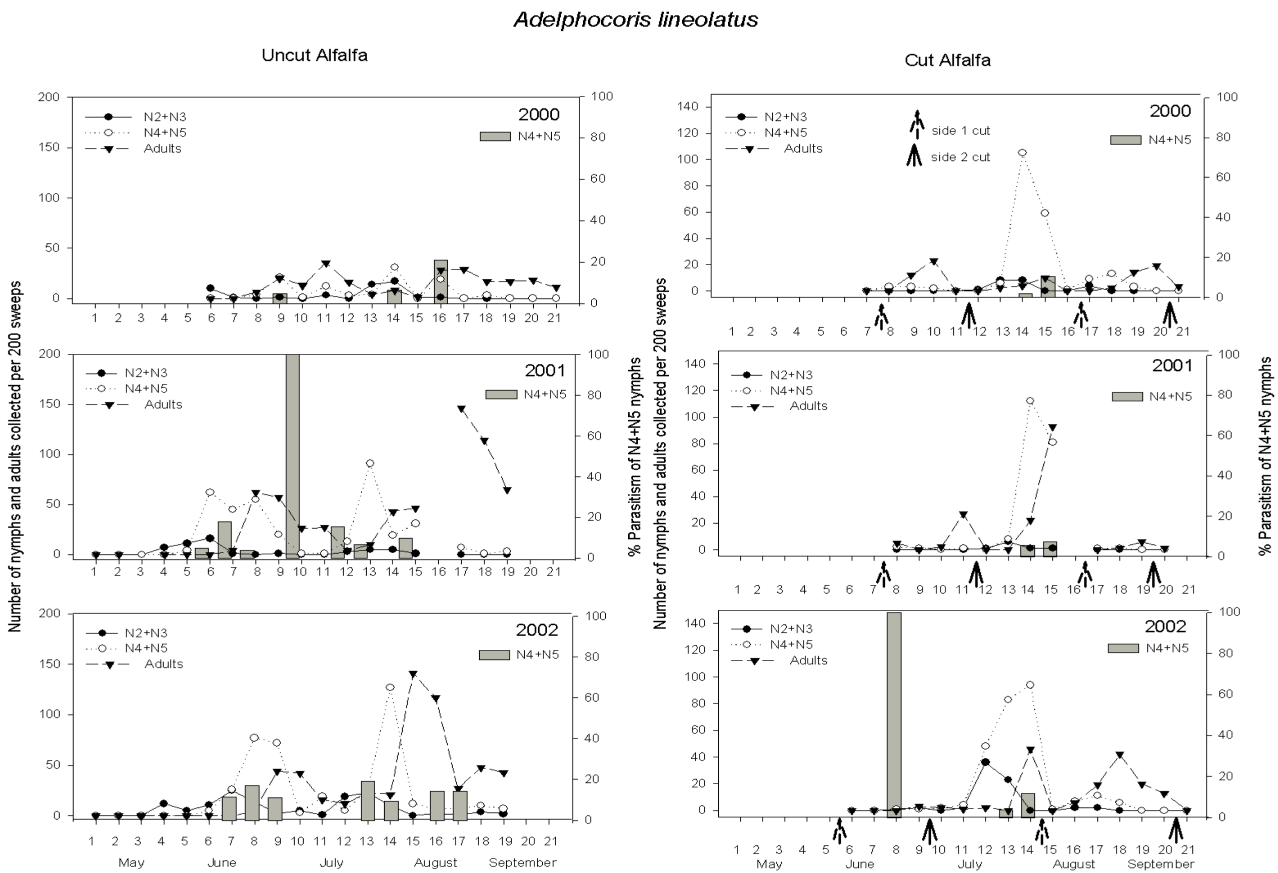

FIGURE 2. Number of *Adelphocoris lineolatus* (Goeze) nymphs (N2+N3 and N4+N5) and adults collected (lines) and parasitism (%) of N4+N5 nymphs in uncut and cut alfalfa (bars) in 2000–2002.

alfalfa is more attractive to pest species (*L. hesperus* Knight, *L. lineolaris*, *L. rugulipennis* Poppius) than are other crops and wildflower species in and around agro-ecosystems (Jackson 2003; Demirel et al. 2005; Mueller et al. 2005; Demirel and Cranshaw 2006; Pansa and Tavella 2009), so immigration from surrounding areas is expected. In contrast, parasitism of *L. lineolaris* in traditionally managed alfalfa was lower than in weedy habitat (Lim and Stewart 1976). Thus, nearby weedy habitats may serve as refuges for parasitoids and generalist species such as *L. lineolaris*, from which plant bug and parasitoid individuals re-invade the alfalfa crop.

Although Day (2007) argued that the most accurate measure of parasitism is achieved by assessing the N4 stage (earlier stages can still be attacked and parasitoid larvae egress from the N5 stage), we assessed the N4+N5 cohort because we concluded this better represented parasitism levels in our study. We consistently found parasitoid larvae in N5 hosts and believe that N5 hosts from which parasitoids had egressed would still be alive and show evidence of parasitoids (holes) allowing us to determine that they had been parasitized. In our study, parasitism levels of N4+N5 nymphs in the cut crop were usually less than in the uncut crop, although on a very few sampling dates the reverse was observed (Figures 1 and 2). Collection of parasitized N4+N5 nymphs in the cut crop suggests that harvest does not eliminate all individuals and more of this cohort survives than of the younger cohort (N2+N3). This may be due to the larger size of the N4+N5 individuals or behavioural changes induced by the parasitoids. In other systems it has been shown that parasitized hosts move down the plant to avoid hyperparasitism or to seek pupation sites (see Brodeur and McNeil 1989, 1992; Pivnick 1993). Whatever the mechanism, the occurrence of parasitized nymphs in the cut alfalfa provides for a continuum of parasitoids.

Our results are similar to the findings for plant bug predators. Godfrey and Leigh (1994) looked at the effects of cutting on populations of the predators *Orius tristicolor* (White), *Geocoris pallens* Stål, *G. punctipes* (Say), *Nabis alternatus* Parshley and *N. americoferus* (Carayon) (Hemiptera: Miridae) and found that all of these highly mobile species persisted in significantly higher numbers, as did those of the pest *L. hesperus*, in alfalfa strip-cut every 28 days compared to alfalfa entirely cut every 28 days. The significantly higher numbers of *L. hesperus* in the strip-cut alfalfa compared to the entire-cut crop suggests that strip-cut alfalfa will retain pest individuals whereas complete cutting will result in adult migration to other crops.

The importance of parasitism, particularly by *P. digoneutis*, in reducing pest populations of *L. lineolaris* has been documented by Day (2005). Goulet and Mason (2006) reported six euphorine parasitoids associated with *L. lineolaris* and *A. lineolatus* from the study area. Among those associated with *L. lineolaris* are the introduced bivoltine *P. digoneutis*, the native univoltine *P. mellipes* (Cresson) and *P. pseudopallipes* Loan, and the native bivoltine *Leiophron lygivorus* (Loan). Two species, *P. dayi* Goulet and *P. rubricollis* (Thomson), both of which are univoltine, are rarely associated with *L. lineolaris*, their main host being *A. lineolatus*. The proportion of *P. digoneutis* relative to *L. lygivorus, P. mellipes*, *P. pseudopallipes,* and *P. dayi* increased from <1% in 1998 to 62% in 2002 (Goulet and Mason 2006). Thus, management strategies that conserve hosts for parasitism will facilitate regulation of pest species populations and spread of biological control agents such as *P. digoneutis*, first released in northern New Jersey (Day et al. 1990) and now established in southern Quebec (Broadbent et al. 1999) and still dispersing.

Conclusions

These results suggest that periodic cutting of alfalfa reduces available host stages for parasitism and reduces levels of parasitism but does not eliminate parasitoid populations. Furthermore, dispersing adults likely speed up the increase in abundance of susceptible host stages after habitat modification, thereby sustaining parasitoid populations.

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