Seasonal occurrence, species composition, and parasitism of *Lygus* spp. in alfalfa, canola, and mustard

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Abstract—Field collections of over-wintering and summer adults and nymphs of *Lygus lineolaris* (Palisot de Beauvois) (Hemiptera: Miridae), *Lygus borealis* (Kelton), and *Lygus elisus* Van Duzee were made weekly in five fields in Saskatchewan in 1998 and 1999. The crops sampled were alfalfa, *Medicago sativa* L. (Leguminosae), canola, *Brassica napus* L. (Cruciferae), and mustard, *Sinapis alba* L. (Cruciferae), at Vonda, and alfalfa and canola at Saskatoon. In alfalfa, the most abundant *Lygus* spp. found in May and June were over-wintering adult *L. lineolaris* and (or) *L. borealis*; the predominant species in mid-June to early July was *L. borealis*; and the population from mid-July to late August was dominated by *L. lineolaris*. In canola, adult populations of *Lygus* spp. were not found until mid-June. The predominant species, *L. lineolaris*, probably over-wintering adults, was first detected in canola at the early bud stage in late June to early July; high numbers of *L. lineolaris* adults occurred in canola in mid-August. Populations of *Lygus* spp. in organic mustard were negligible. Dissections of field-collected *Lygus* spp. nymphs revealed parasitism in up to 70% of the midsummer population in alfalfa. In contrast, less than 1% of the late-season *Lygus* spp. population, primarily *L. lineolaris* in canola and *L. lineolaris* and *L. borealis* in alfalfa, was parasitized.

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Résumé—Nous avons procédé à des échantillonnages hebdomadaires de larves et d'adultes d'hiver et d'été de *Lygus lineolaris* (Palisot de Beauvois) (Hemiptera : Miridae), de *Lygus borealis* (Kelton) et de *Lygus elisus* Van Duzee dans cinq champs en Saskatchewan, en 1998 et 1999. Les champs échantillonnés contenaient de la luzerne, *Medicago sativa* L. (Leguminosae), du colza, *Brassica napus* L. (Cruciferae), et de la moutarde, *Sinapis alba* L. (Cruciferae) à Vonda et de la luzerne et du colza à Saskatoon. Dans la luzerne, les punaises les plus abondantes en mai et juin étaient des adultes de *L. lineolaris* et (ou) de *L. borealis* ayant survécu à l'hiver; *L. borealis* a été l'espèce prédominante de la mi-juin au début de juillet et, de la mi-juillet à la fin d'août, c'est *L. lineolaris* qui prédominait. Dans les cultures de colza, les

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populations d'adultes de *Lygus* spp. ont été absentes jusqu'à la mi-juin. La présence d'adultes de l'espèce prédominante, *L. lineolaris*, probablement des adultes qui ont survécu à l'hiver, a été détectée pour la première fois dans le colza au stade de bourgeonnement de la plante, à la fin de juin et au début de juillet. Les adultes étaient très nombreux dans les cultures de colza au milieu d'août. Les populations de *Lygus* spp. dans les champs de moutarde organique étaient négligeables. La dissection de larves de *Lygus* spp. récoltées en nature a révélé que jusqu'à 70 % de la population de larves dans la luzerne étaient parasitées à la mi-été. Cependant, le parasitisme affectait moins de 1 % de la population de *Lygus* spp. de fin de saison, surtout *L. lineolaris* dans le colza, *L. lineolaris* et *L. borealis* dans la luzerne.

[Traduit par la Rédaction]

Introduction

Several of the 31 North American species of *Lygus* (Hemiptera: Miridae) occur on the Canadian Prairies (Craig 1983; Schwartz and Foottit 1992*a*, 1998; Timlick *et al.* 1993). Long considered a pest of alfalfa, *Medicago sativa* L. (Leguminosae), grown for seed production (Carlson 1940), *Lygus* spp. have only recently been identified as a pest of oilseed rape or canola, *Brassica napus* L. and *Brassica rapa* L. (Cruciferae) (Lamb 1989). Overwintering as adults, female *Lygus* spp. seek preferred oviposition sites such as alfalfa and winter annual weeds (Kelton 1955; Domek and Scott 1985; Sohati *et al.* 1992), with host preference correlated with time of flowering (Butts and Lamb 1990, 1991*a*). Only one generation of *Lygus* spp. occurs in canola in Manitoba and Alberta (Gerber and Wise 1995; Gerber 1996; Butts and Lamb 1991*a*; Otani 2000). Sexually mature *Lygus* spp. females move into canola at bud and oviposit into the plant. Feeding by nymphs and adults on canola buds, flowers, and pods can cause economic seed yield losses (Butts and Lamb 1991*b*; Turnock *et al.* 1995).

Recent outbreaks of *Lygus* spp. in southern Alberta led to insecticide application to over 400 000 ha of canola in 1998 (M Dolinski, personal communication). One alternative to insecticide application is the use of biological control agents to control nymphal populations of *Lygus* spp. In western Canada the univoltine *Peristenus pallipes* (Curtis)[2] (Hymenoptera: Braconidae, Euphorinae) attacks and kills *Lygus* spp. nymphs in alfalfa (Craig and Loan 1987). Adults of the genus *Peristenus* Foerster oviposit in first- to third-instar *Lygus* spp. nymphs, and final instar larval parasitoids emerge from fifth-instar or teneral adults to spin cocoons in soil debris (Brindley 1939). Loan and Craig (1976) recovered only *P. pallipes* from *Lygus borealis* (Kelton), *Lygus lineolaris* (Palisot de Beauvois), and *Lygus elisus* Van Duzee (= *desertinus*) in western Canada. Reported parasitism levels in *Lygus* spp. from alfalfa in western Canada have ranged up to 83% (Loan and Craig 1976; Moline 1983, cited in Craig and Loan 1987); in contrast, parasitism of *Lygus* spp. in canola can range from 0 to 5% (P Mason and J Soroka, unpublished data).

In an effort to determine the nature of the recent *Lygus* spp. infestation in canola, season-long sampling of *Lygus* spp. in alfalfa, canola, and mustard fields was undertaken at two Saskatchewan locations for 2 years. We identified the predominant *Lygus* species in each crop, the insect's phenology, and the occurrence of nymphal parasitism. Further, we investigated the tri-trophic relationships between crop, *Lygus* species, and parasitoid.

[2] *Peristenus pallipes* is a complex of species, at least one of which occurs in the prairies (H Goulet, personal communication).

Materials and methods

Field collections of over-wintering and summer adults and nymphs of *Lygus* spp. were made weekly at two locations in Saskatchewan from mid-April to late August in 1998 and 1999. Five sites were sampled, including commercial fields of alfalfa, canola, and mustard, *Sinapis alba* L. (Cruciferae), near Vonda, and research plots of alfalfa and canola at Saskatoon at the Agriculture and Agri-Food Canada Research Centre farm (Table 1). Insecticides were not applied to any fields.

Seasonal occurrence and species composition of *Lygus* spp. were assessed for each site by making 10 sweeps (180° arc) at each of 10 locations per site through the top third of the foliage using a standard 38 cm diameter insect sweep net. Samples were collected between 10:00 and 12:00 noon. Sweeps were initiated at approximately the same location in the field every week, fanning out from the field edge, with 10 m between samples.

Captured *Lygus* spp. were sorted into groups: nymphal instars L1–L3 and L4–L5 and adults, the latter identified to species according to Schwartz and Foottit (1992*b*). There is no key for *Lygus* spp. nymphs. Nymphs were randomly selected proportionately (L1–L3 or L4–L5) from each sample for dissection (to a maximum of 50 per sample) to estimate rates of parasitism. Each nymph selected for dissection was teased apart and examined under a microscope for the presence of a parasitoid. Plant development in canola and mustard was assessed according to the scale of Harper and Berkenkamp (1975): stage 1, seedling; stage 2, rosette; stage 3, bud; stage 4, flower; and stage 5, ripening. A growth-stage score was assigned for each field on the basis of the predominant growth stage within the field.

Results and discussion

The total number of *Lygus* spp. adults and nymphs collected at all locations throughout the sampling periods, the ratios of parasitized nymphs per number of dissected nymphs, and the resulting estimated rate of parasitism for L1–L3 and L4–L5 nymphs are summarized in Table 1. Seasonal occurrence and distribution of *Lygus* spp. nymphs and adults and estimated rates of nymphal parasitism are depicted graphically in Figs. 1–5. Weather-station data from Saskatoon were used to calculate accumulated degree-day units (base 10°C) at Saskatoon in 1998 and 1999 (Fig. 6).

Lygus species composition and seasonal occurrence in alfalfa

Three main species of *Lygus* were found in samples collected in alfalfa in 1998 and 1999 (Table 1). In both years at Vonda, the adult population of the early, middle, and late season was composed predominately of *L. lineolaris*, *L. borealis*, and *L. lineolaris*, respectively (Fig. 1). In contrast to the warm spring conditions of 1998, the cool spring of 1999 (Fig. 6) delayed and extended the emergence of adult *Lygus* spp. from their over-wintering sites.

Lygus species composition in alfalfa at Saskatoon was similar to that at Vonda. The seasonal occurrence differed slightly from that at Vonda: in 1998, early-season populations of *L. borealis* were more numerous than *L. lineolaris* (Figs. 1A, 2A). The main difference in population phenology between the 2 years at Saskatoon was the absence of a second adult population peak of *L. borealis* in 1999 (Fig. 2B), suggesting that the first generation of *L. borealis* adults entered reproductive diapause. This can be explained by the delayed occurrence of the first-generation population peak of *L. borealis* in 1999 (30 June 1998 *versus* 13 July 1999). Craig (1983) reports that one to two

TABLE 1. Total numbers of nymph and adult *Lygus* spp. and estimated percent parasitism of

			Adults			
Crop	Year	Site	*L. lineolaris*	*L. borealis*	*L. elisus*	Other spp.
Alfalfa						
'Beaver'	1998	Vonda; 52°18′N, 106°8′W	966	924	3	2
'Beaver'	1999	Vonda; 52°18′N, 106°8′W	1491	561	6	0
'AC Graceland'	1998	Saskatoon; 52°9′N, 106°34′W	246	528	8	0
'Beaver'	1999	Saskatoon; 52°9′N, 106°35′W	871	559	69	0
Canola						
'46A73'	1998	Vonda; 52°19′N, 106°8′W	46	8	2	0
'46A73'	1999	Vonda; 52°18′N, 106°8′W	345	23	1	0
'AC Excel'	1998	Saskatoon; 52°9′N, 106°34′W	73	122	65	1
'AC Excel'	1999	Saskatoon; 52°9′N, 106°34′W	62	20	2	0
Mustard						
'AC Pennant'	1998	Vonda; 52°18′N, 106°3′W	10	8	0	0
'AC Pennant'	1999	Vonda; 52°18′N, 106°4′W	34	8	2	0

generations of adult *Lygus* spp. can occur annually in Saskatchewan depending on location.

Without characterization of egg development in adult females it was impossible to differentiate between over-wintering and first-generation adult populations (*e.g.*, Gerber 1996); however, the two peaks of *L. borealis* in alfalfa in Vonda in 1998 and Saskatoon in both years are consistent with the occurrence of two generations of *L. borealis* (Figs. 1A, 2A, 2B). In both years at Saskatoon and in 1998 at Vonda, two peaks of *Lygus* spp. nymphs occurred, supporting the observation of Gerber and Wise (1995) that nymphal populations in alfalfa do not overlap (Figs. 1A, 2A, 2B). Two smaller peaks of *Lygus* spp. nymphs in Vonda alfalfa in 1999 also suggest the presence of two generations (Fig. 1B). The reduced second adult peak of *L. borealis* in alfalfa at Vonda in 1999 (Fig. 1B) is likely due to the high nymphal parasitism rate in late June (Table 1).

Results for *L. lineolaris* are not as easily interpreted. Timlick *et al.* (1993) and Gerber and Wise (1995) found two non-overlapping generations of *L. lineolaris* on alfalfa at Winnipeg. Gerber and Wise found that over-wintering adults were present from early May until the last 2 weeks of July, when they were rapidly replaced by first-generation adults; second-generation adults were present from the first half of August until mid-October. In eastern Ontario, the egg-laying period for first-generation *L. lineolaris* females was 6–7 weeks, from early July until late August (Painter 1929). Craig (1983) found that at Saskatoon, about 50% of first-generation adults become reproductively active without diapause and produce a second generation. In our study, the lack of a mid-season adult *L. lineolaris* peak in alfalfa in 1998 and 1999 implies only one generation; Stewart and Gaylor (1991, 1994) and Gerber and Wise both noted that young parous *L. lineolaris* females readily disperse and are inclined to colonize new host plants. We were unable to determine if *L. lineolaris* completed only one generation, if adults left the alfalfa field, or if adults died; however, our findings suggest that in 1998 and 1999 *L. lineolaris* was univoltine in alfalfa in and near Saskatoon.

***Lygus* spp. nymphs collected by sweep netting three crops in Saskatchewan in 1998 and 1999.**

Nymphs						
L1–L3			L4–L5			
Collected (*n*)	Dissected (*n*)	Parasitism (%)	Collected (*n*)	Dissected (*n*)	Parasitism (%)	Total parasitism (%)
277	57	9	1068	377	12	12
301	160	38	863	430	24	28
100	39	10	395	246	15	14
466	182	7	1124	443	10	9
18	17	0	69	69	0	0
64	53	0	268	179	1	1
46	36	0	227	124	0	0
66	55	0	87	77	0	0
26	26	0	48	47	0	0
22	22	0	23	23	0	0

There was no evidence to suggest that cutting the alfalfa stand resulted in emigration of *Lygus* from the field. Indeed, in 1998 at Vonda adult numbers increased after the second cut.

Lygus species composition and seasonal occurrence in canola

Lygus species found in canola were similar to those in the corresponding alfalfa fields in both years (Table 1); however, the abundance of adults and nymphs was considerably lower than that in alfalfa from each location for each year. *Lygus lineolaris* was the predominant species at Vonda in both years and at Saskatoon in 1999 (Figs. 3, 4B). Populations at Saskatoon in 1998 were anomalous: *L. borealis* predominated, with lower, equal numbers of *L. lineolaris* and *L. elisus* (Fig. 4A).

Only one generation of *Lygus* spp. occurred in canola in our study (Figs. 3, 4). An initial peak of immigrant adults was detected in late June or early July, coinciding with bud formation, the canola plant stage known to be preferred by *Lygus* spp. (Butts and Lamb 1990, 1991*a*). *Lygus* spp. females arriving in canola have fully developed eggs and oviposit immediately upon arrival (Gerber and Wise 1995; Otani 2000). The canola field at Vonda in 1998 was adjacent to our alfalfa sampling site. A decrease in adults in alfalfa between 30 June and 7 July (Fig. 1A) coincided with an increase in adults in canola for the same period; however, the species composition of adults collected was markedly different: at Vonda in both years and at Saskatoon in 1999 the predominant species in canola was *L. lineolaris* (Figs. 3A, 3B, 4B), whereas the adult population in alfalfa was *L. borealis*. Butts and Lamb (1991*a*) suggested that the most likely source of *L. lineolaris* populations invading canola is cruciferous weeds.

Lygus species composition and seasonal occurrence in mustard

Two species of *Lygus* were found in mustard fields sampled in 1998; *L. elisus* was also found in 1999 (Table 1). Only one generation of *Lygus* occurred in mustard at the sites sampled in Saskatchewan in 1998 and 1999, and numbers of both nymphs and

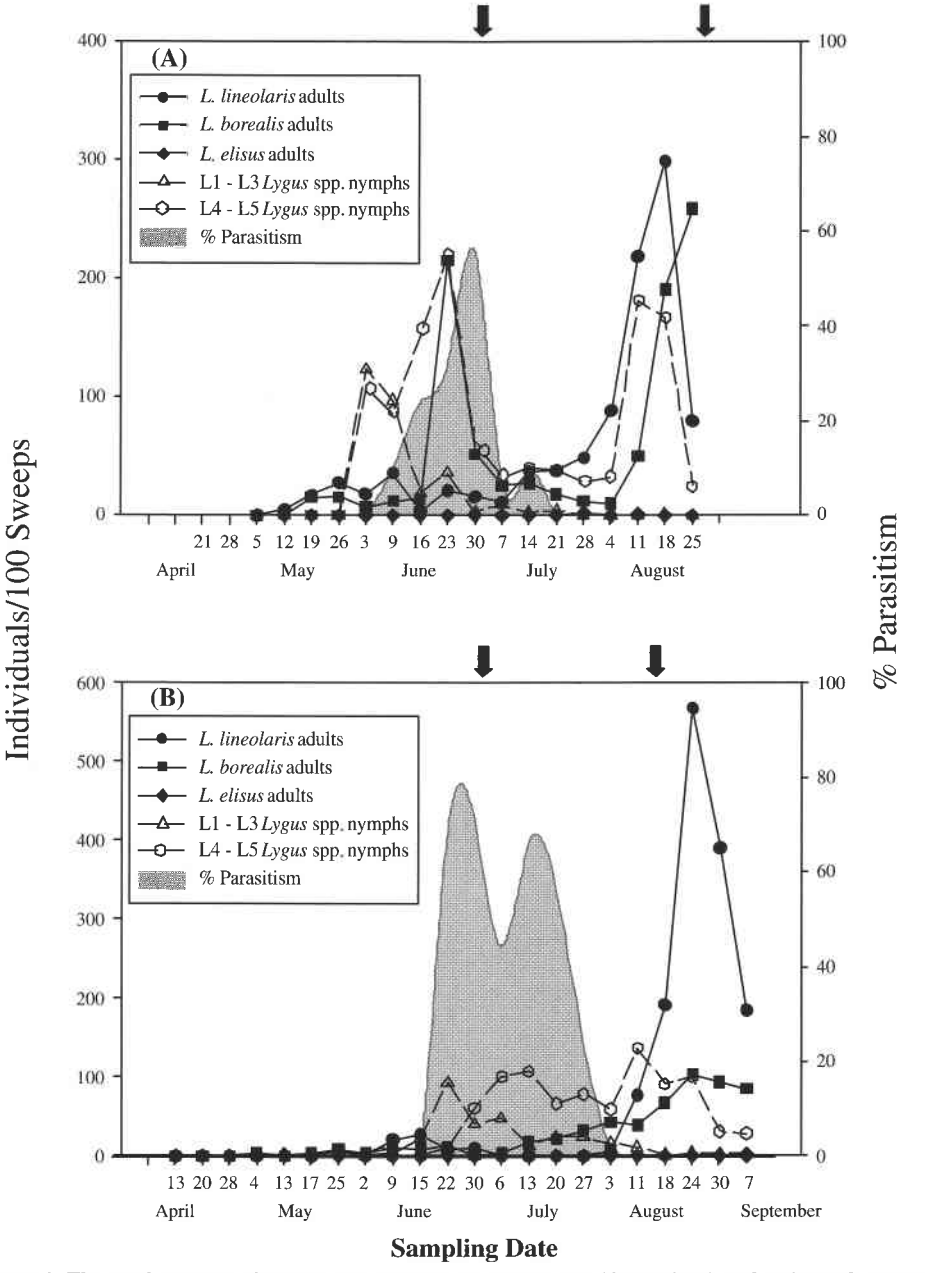

FIGURE 1. The total number of adults and nymphs (10 sweeps per 10 locations) and estimated percent parasitism of *Lygus* spp. collected in *Medicago sativa* at Vonda, Saskatchewan, in 1998 (A) and 1999 (B). Arrows indicate dates crop was harvested. Note the use of different scales on the left-hand *y* axes.

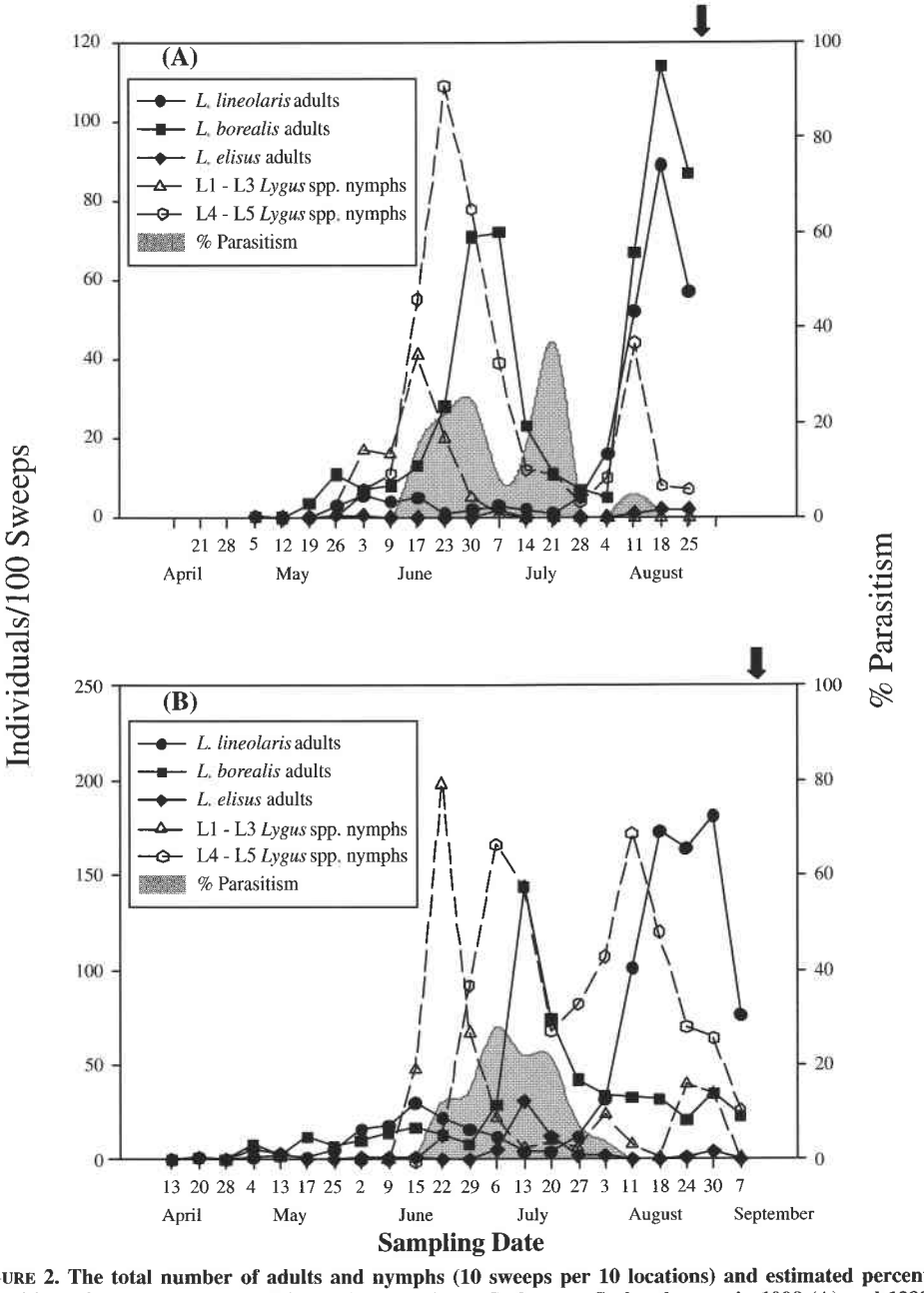

FIGURE 2. The total number of adults and nymphs (10 sweeps per 10 locations) and estimated percent parasitism of *Lygus* spp. collected in *Medicago sativa* at Saskatoon, Saskatchewan, in 1998 (A) and 1999 (B). Arrows indicate dates crop was harvested. Note the use of different scales on the left-hand *y* axes.

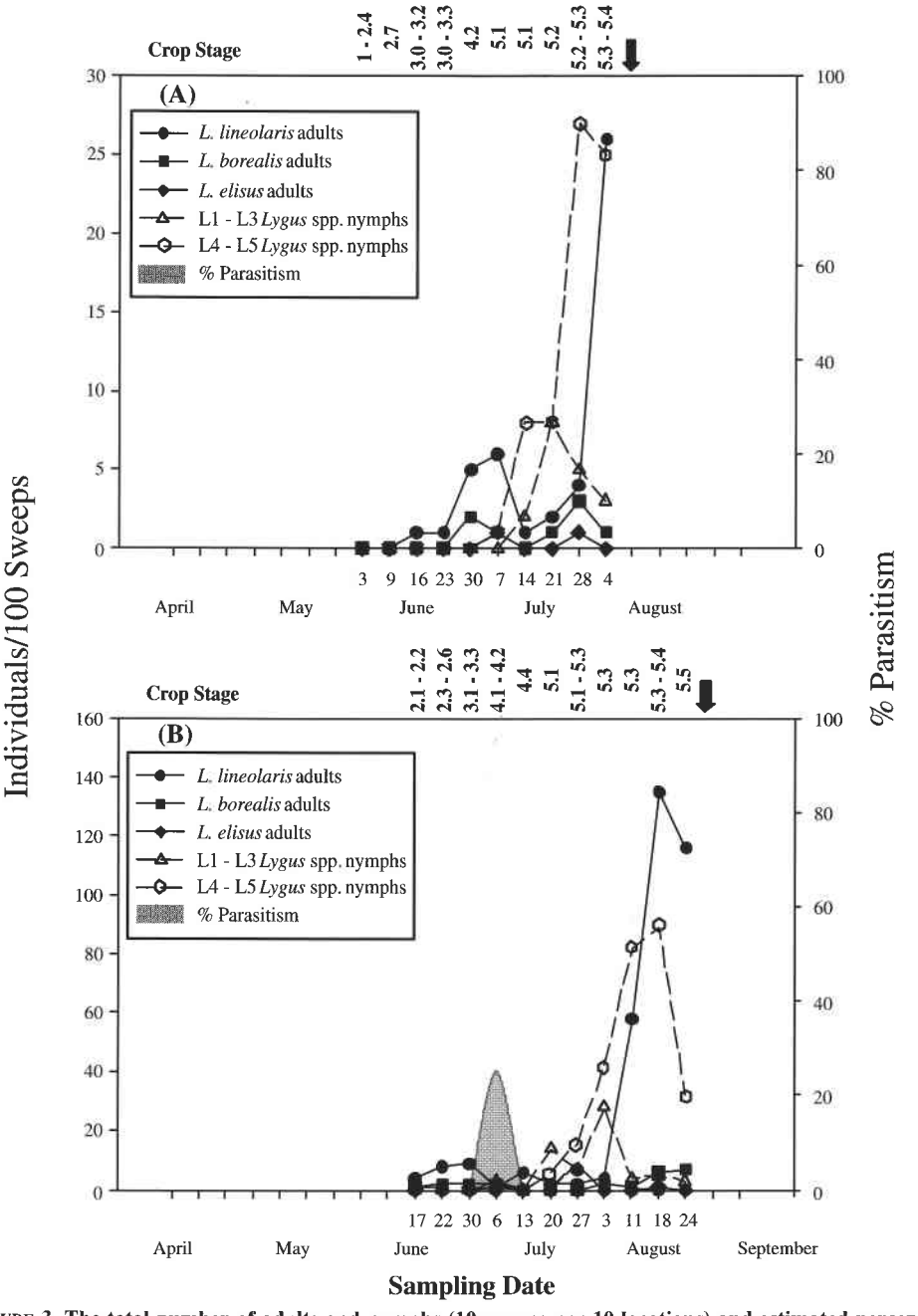

FIGURE 3. The total number of adults and nymphs (10 sweeps per 10 locations) and estimated percent parasitism of *Lygus* spp. collected in *Brassica napus* at Vonda, Saskatchewan, in 1998 (A) and 1999 (B). Arrows indicate dates crop was harvested. Crop stage on top axis according to Harper and Berkenkamp (1975). Note the use of different scales on the left-hand *y* axes.

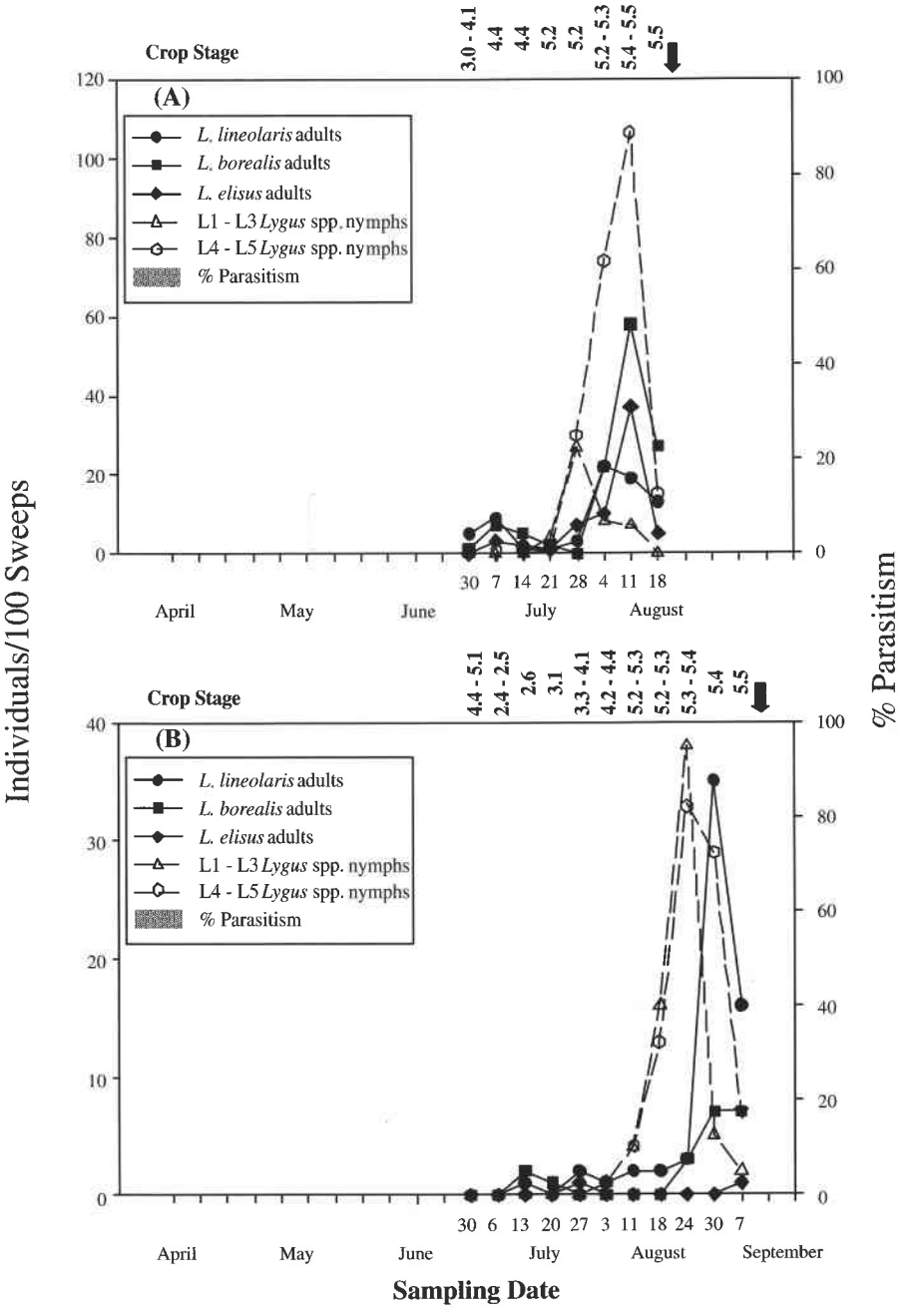

FIGURE 4. The total number of adults and nymphs (10 sweeps per 10 locations) and estimated percent parasitism of *Lygus* spp. collected in *Brassica napus* at Saskatoon, Saskatchewan, in 1998 (A) and 1999 (B). Arrows indicate dates crop was harvested. Crop stage on top axis according to Harper and Berkenkamp (1975). Note the use of different scales on the left-hand *y* axes.

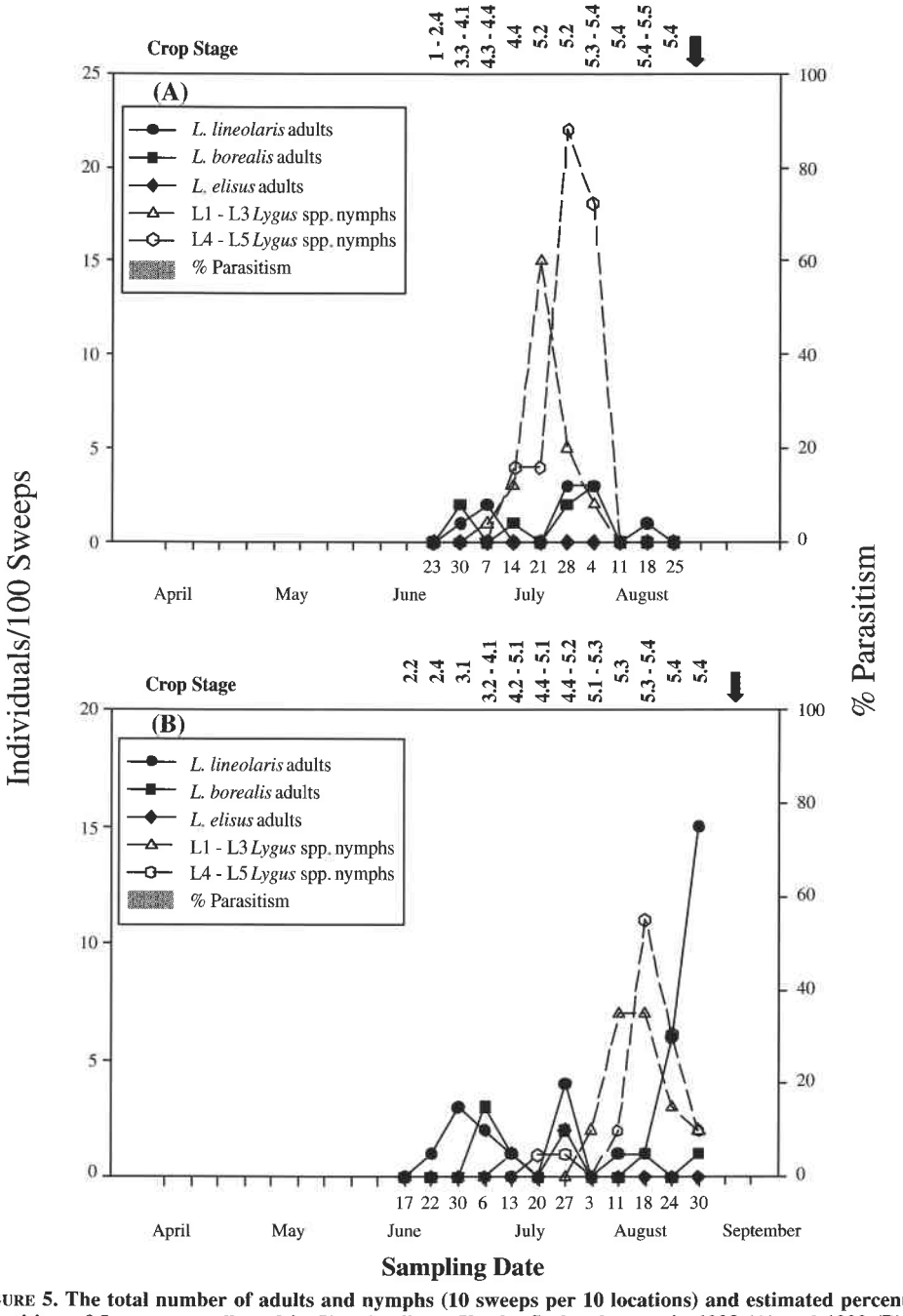

FIGURE 5. The total number of adults and nymphs (10 sweeps per 10 locations) and estimated percent parasitism of *Lygus* spp. collected in *Sinapis alba* at Vonda, Saskatchewan, in 1998 (A) and 1999 (B). Arrows indicate dates crop was harvested. Crop stage on top axis according to Harper and Berkenkamp (1975). Note the use of different scales on the left-hand *y* axes.

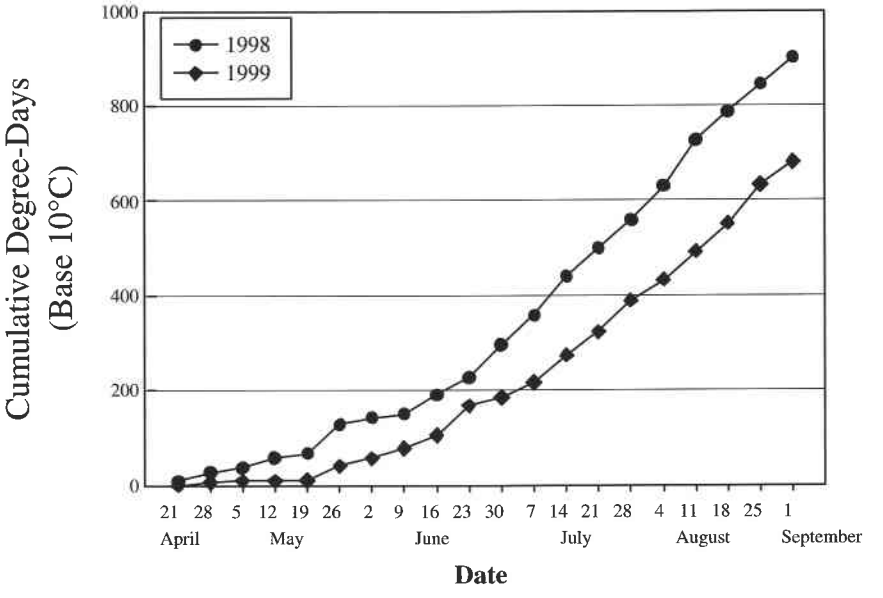

FIGURE 6. Accumulation of degree-day units (base 10°C) at Saskatoon in 1998 and 1999.

adults collected were considerably lower than those in alfalfa. As in canola, there was no indication of an over-wintering population of *Lygus* spp., but rather incoming *Lygus* spp. adults entered the crop when it was at four-leaf to bud stage (Fig. 5). There was one generation of nymphs indicated by nymphal peaks for L1–L3 and L4–L5 in mid-July (1998) and early August (1999) (Fig. 5).

Parasitism of *Lygus* nymphs in alfalfa

In 1998, parasites were first found in nymphs collected 1 week (in Vonda) to 2 weeks (in Saskatoon) after the appearance of *Lygus* spp. nymphs (Figs. 1A, 2A). At Vonda, parasitized nymphs were found only in samples collected until 14 July 1998, despite the presence of a second nymphal population beginning in early August (Fig. 1A). Parasites were recovered from *Lygus* spp. nymphs collected in Saskatoon from 17 June to 11 August, with peak collections on 30 June and 21 July (24 and 36% parasitized, respectively) (Fig. 2A).

In 1999, parasitized nymphs were collected from alfalfa fields at both Vonda and Saskatoon from 22 June until 3 August. Parasitism reached a maximum of 70% at Vonda on 30 June (Fig. 1B) and in Saskatoon was similar to that in 1998 (28% on 6 July) (Fig. 2B).

Parasitism of *Lygus* nymphs in canola and mustard

The low rate of parasitism in nymphs collected in the canola and mustard fields is conspicuous (Table 1), especially in fields immediately adjacent to alfalfa, where parasitism was high. It appears that adult female parasitoids are present only in early summer (late May to early June) and are thus available to parasitize early-instar nymphs that are present in high numbers in alfalfa (Figs. 1, 2) but have not yet appeared in canola and mustard (Figs. 3–5). This timing is consistent with the presence of a univoltine parasitoid such as *P. pallipes* as previously reported by Loan and Craig (1976). Because

the parasitoid is univoltine, estimated parasitism expressed as a total over the season (last column in Table 1) critically underestimates the actual impact of the parasitoid.

Because the majority of first-generation adults collected in alfalfa are *L. borealis*, it is likely that the majority of nymphs parasitized are *L. borealis*. Further, because our results suggest that a single generation of *L. lineolaris* occurred in 1998–1999, overwintered *Lygus* spp. oviposit over a prolonged time period (Kelton 1975), and parous *L. lineolaris* females readily disperse to new host plants (Stewart and Gaylor 1991, 1994; Gerber and Wise 1995), over-wintering adult *L. lineolaris* probably moved into budding canola in late June to complete oviposition. Thus, adult *P. pallipes* are not present when suitable nymphs (L1–L3) of *L. lineolaris* are available in canola. The introduction of a bivoltine parasitoid (*e.g.*, the European *Peristenus digoneutis* Loan) or a late-season (summer) species (*e.g.*, the eastern *Peristenus pseudopallipes* Loan) to parasitize second-generation nymphs could possibly increase overall parasitism of *Lygus* spp. nymphs in canola.

Conclusions

Our results indicate that the species of *Lygus* most likely to be responsible for economically damaging populations in canola in Saskatchewan is *L. lineolaris*. Parasitism of *Lygus* spp. nymphs in alfalfa ranged up to 70%, whereas parasitism in canola and mustard fields was negligible. In addition, parasitism in alfalfa is associated with the mid-June nymphal population only, indicating that a univoltine nymphal parasitoid was responsible for the observed parasitism. Currently it is not possible to accurately identify early-instar *Lygus* nymphs to species. Development of precise methods to differentiate *Lygus* spp. nymphs would assist in elucidating whether low parasitism rates in canola are the result of host–parasitoid temporal asynchrony or are caused by specific host–parasitoid incompatibility.

Acknowledgments

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