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Biology and management of *Lygus* in canola

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Summary

Lygus (Hemiptera: Miridae) are unpredictable pests in canola. This stems from their ability to produce multiple generations, having up to six species forming a "complex", and a wide host plant range combined with highly variable canola growing regions in Canada. The number of generations and synchrony of *Lygus* adults and nymphs with canola varies across the growing regions of the Canadian prairies. The economic threshold for *Lygus* in conventional canola is well established for southern Manitoba. Other areas of the prairies, particularly the northern growing regions, have inherently different growing conditions that are likely to lead to different economic injury levels. This, combined with the advent and widespread adoption of new hybrid canola varieties, suggests that this unpredictable pest deserves new research efforts designed to examine the relationship between *Lygus* and current canola production systems. Further, a closer investigation of the natural enemies and unique growing conditions that contribute to the "unpredictable" nature of *Lygus* outbreaks in canola is needed.

Introduction

Plant bugs belonging to the genus *Lygus* (Hahn) are important pests of canola with both adult and juvenile (nymph) stages causing economic damage by feeding on buds, new pods and seeds[1,2,3,4]. The taxonomic revision of the genus by Schwartz and Foottit[5] (1998) and subsequent field experiments performed in Canada[6,7] revealed that up to six species can be present in agricultural areas of the northern prairies: *L. keltoni* Schwartz, *L. lineolaris* (Palisot de Beauvois), *L. elisus* Van Dusee, *L. borealis* (Kelton), *L. rufidorsus* (Kelton), *L. solidaginis* (Kelton). All these species tend to follow a univoltine lifecycle in the northern prairies[8]. In agricultural areas of the southern prairies, the species common in canola include *L. keltoni*, *L. lineolaris*, *L. elisus*, and *L. borealis* which follow a bivoltine[9] or occasionally trivoltine lifecycle[10]. *Lygus lineolaris* is very rare in the short grassland prairies of southern Alberta[9]. All *Lygus* collected in canola grown in Canada are Nearctic species (native to North America).

Seasonal biology

The seasonal biology of *Lygus* varies by geographic region, seasonal growing conditions, and host plant availability. *Lygus* overwinter as adults (Fig. 1). In late summer or early fall, *Lygus* leave late season feeding hosts to find tree shelters or field margins to spend the winter under leaf litter where they experience low mortality. Field experiments conducted in southern and northern Alberta showed that in these insulated habitats, *Lygus* experience temperatures above -5˚C although air temperatures can dip below -30˚C[11]. The supercooling points of species common in Alberta remains below -10˚C (Cárcamo and Herle unpublished data) which explains their overwintering success.

Fig. 1. *Lygus lineolaris* adult (left; body length of 6-7 mm) and fifth instar nymph (right; body length of 3-4 mm) each resting on an alfalfa shoot (photos: AAFC-Nemecz).

The variation in number of generations, host plants utilized and economic injury is related to several factors: *Lygus* have no obligatory diapause and voltinism for the species commonly occurring in canola depends on the growing region of Canada[8]. In northern Alberta, overwintered adults emerge in the early spring (e.g., early May) to seek out early growing vegetation such as willows breaking bud, and then move onto rapidly growing stinkweed (*Thlaspi arvense* L.) or flixweed (*Descurainia sophie* (L.) Webb) which are both winter annual weeds (Fig. 2). Eggs and nymphs (first to fifth instars) can emerge and develop on these earlier season weed hosts, but usually adults relocate to or even emerge from overwintering in alfalfa (*Medicago sativa* L.) and clovers (*Trifolium* spp.) in mid-spring (Fig. 2). Once canola (*Brassica napus* L., *B. rapa* L.) is at bolting to early flowering stages, *Lygus* adults start to arrive and, by mid-flowering, high numbers of *Lygus* adults and nymphs can be present and peak generally at the pod stage (Fig. 2). Late flower to early pod stages are the most critical canola stages for *Lygus* damage to affect yield[12]. Years or growing regions where spring commences earlier in the calendar, as in southern Alberta (Fig. 3), or when spring is unusually warm and dry, can result in overwintered *Lygus* emerging in mid-April and completing a generation in the spring on flixweed, hoary cress, stinkweed or alfalfa. In such cases, newly molted adults relocate from senescing weedy hosts or swathed alfalfa hay crops to canola at early to mid-flower stages, where they mate and lay eggs. This results in *Lygus* adults and nymphs occurring in canola from late-flower to early pod stages in southern Alberta (Fig. 3). In southern Manitoba an additional generation of *Lygus* can arise in buckwheat into mid-September[10]. Thus, in southern Alberta *Lygus* are generally bivoltine whereas *Lygus* in southern Manitoba can be trivoltine[3,10].

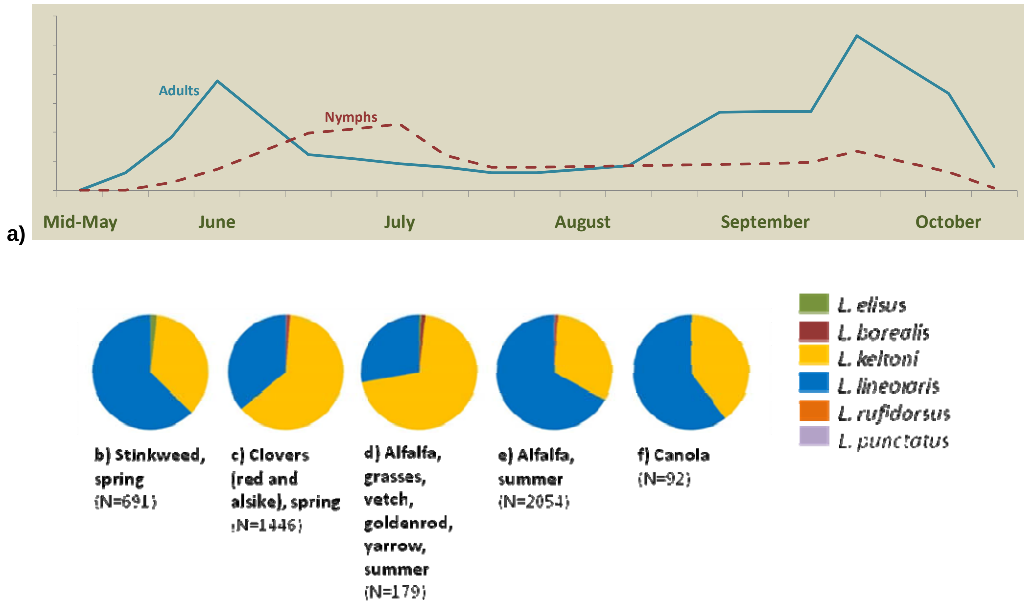

Fig. 2. Relative seasonal abundance of *Lygus* adults and nymphs in stinkweed, red and alsike clovers, alfalfa and canola (a), plus species composition of adult *Lygus* occurring in sweep-net samples performed in spring stinkweed (b), spring red and alsike clovers (c), summer mixed vegetation (d), summer alfalfa (e), and canola (e) sampled near Beaverlodge, Alberta, in 2005 (Otani et al. unpublished).

Lygus are unpredictable pests. They have a wide host range[12] and various species can compose a varying "complex" that appears to change by host plant, by region, or even seasonally[9,13,6,14]. In northern Alberta, the *Lygus* "complex" is dominated by *L. keltoni* and *L. lineolaris* (Fig. 2). For example, early in the spring of 2005, *L. lineolaris*, *L. keltoni*, and *L. elisus* were present on budding stinkweed but within two weeks *L. keltoni*, *L. lineolaris* and *L. borealis* were present on budding alsike and red clover at bud stage in hay fields (Fig. 2). By mid-summer, relatively undisturbed vegetation mixes composed mainly of alfalfa yet containing other flowering plants such as grasses, vetches, and yarrow, typically hosted large numbers of *L. keltoni* with *L. lineolaris* and small numbers of *L. borealis*, and *L. elisus* (Fig. 2). Extremely low numbers of *L. rufidorsus* and *L. punctatus* (e.g., one adult per 100 sweeps) were also collected on this same undisturbed vegetation mix during mid-summer. Hay fields in full flower in mid-summer were dominated by *L. keltoni* with some *L. lineolaris* and small numbers of *L. borealis* and *L. elisus* (Fig. 2). By mid- to late flowering, *L. lineolaris* and *L. keltoni* were present in canola (Fig. 2). In southern Alberta, pan trap catches from 1999 to 2004 (Fig. 3) from fall and spring in tree shelters indicated that the *Lygus* complex is dominated by *L. elisus,* but *L. keltoni* and *L. borealis* were also present. Later in the spring, sweep-net sampling indicated that species composition in weedy habitats resembles that found in tree shelter. However, by late summer the newly molted generation was dominated by *L. borealis* in alfalfa and *L. keltoni* in canola (Fig. 3). There is a common belief that *Lygus* can reach pest status in canola after alfalfa hay is harvested nearby. However, a study over several site years in the parkland region (dominated by *L. lineolaris* in canola and *L. borealis* in alfalfa) including the three prairie provinces, found no such evidence[14], though none of the sites experienced outbreak levels in the years of the study. *Lygus lineolaris* was very rare throughout the season in southern drier Prairie sites (Fig 3).

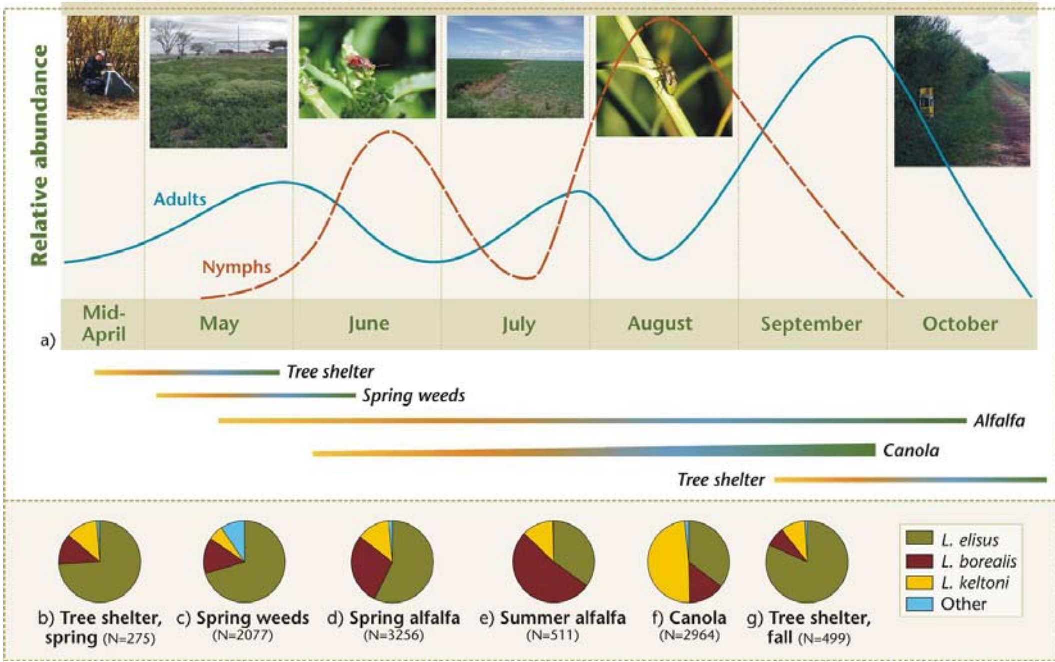

Fig. 3. Relative seasonal abundance of *Lygus* adults and nymphs (a) plus species composition of adult *Lygus* collected using pan traps deployed in tree shelters in the spring (b), in spring weeds (c), in spring alfalfa (d), summer alfalfa (e), canola (f) and tree shelters in the fall (g) near Lethbridge, Alberta between 1999 and 2004 (Note: "Other" category includes *L. lineolaris* and *L. solidaginis*) (Cárcamo et al. unpublished).

Hosts and damage

Lygus are generalist herbivores attacking hundreds of plant species globally[14] ranging from conifer tree seedlings, strawberries, fruiting trees and shrubs[13] to major field crops such as canola, alfalfa, flax[16], wheat[17], cotton[18,19,20], and a wide range of weed species[21]. *Lygus* prefer to feed upon meristematic tissues of a host plant[22]. Adults and nymphs feed by sucking on reproductive structures using a proboscis. Once a suitable plant structure is encountered, the proboscis is inserted into the tissue and various digestive enzymes are injected then sucked back along with pre-digested plant nutrients[22]. In canola, buds, flowers, young pods, and newly developing seeds within pods are preferred feeding structures resulting in pod abscission or shrunken seeds[1]. Collectively, abscission plus shrunken canola seed is referred to as "blasting" and can result in economic yield losses[1,2,8,4] when serious infestations occur.

Field plot, cage and laboratory studies have shown that *Lygus* fare better on some hosts compared to others, yet outbreaks can occur in less "preferred" hosts shown to adversely affect *Lygus* survivorship. Butts and Lamb[23] reported economically significant losses due to *L. borealis* and *L. elisus* feeding on *B. napus* (cultivars Andor and Westar) and *B. campestris* cv. Tobin. Data examining naturally occurring populations of *Lygus* in field plots of *B. napus* or *B. campestris* in northern Alberta revealed significantly higher numbers of *Lygus* in *B. campestris* compared to *B. napus* at the early bud stage but similar populations of nymphs in these same plots later in the growing season at the early pod stage[23]. Adult *L. elisus* and *L. borealis* caged on plant racemes preferred to feed upon and survived better on alfalfa compared to *B. napus* [23]. Controlled environment studies revealed that seven-day-old *L. lineolaris* adults fed five to 10 times more frequently upon canola pods (*B. napus* cv. Westar) compared to white mustard pods (*Sinapis alba* cv. Gisilba) in no-choice studies[24]. That study concluded that hairy pods and relatively high concentrations of the glucosinolate, sinalbin, in *S. alba* deterred *L. lineolaris* feeding[24] (Bodnaryk 1996). The caging studies revealed that *L. lineolaris* fed less frequently upon seeds within hairy *S. alba* pods compared to shaved pods and that four times less feeding occurred on seeds contained within pods of a high sinalbin cultivar of white mustard (*S. alba* cv. Gisilba) compared to a near-isogenic low-glucosinolate line[24]. These results resemble that observed for Bertha armyworm and flea beetles which determined the glucosinolate sinalbin deterred feeding[25]. In another glucosinolate manipulation study, Gerber[26] collected *L. lineolaris* adults then placed them in field cages stocked with a choice of potted *Sinapis alba* cv. Gisilba (high glucosinolate), *S. alba* (experimental line of low glucosinolate), wild *S. arvensis*, *B. carinata* cv. Dodolla, *B. juncea* cv. Cutlass, *B. napus* cv. AC Excel and *B. rapa* cv. AC Parkland . In contrast to feeding responses, at least 80% of *L. lineolaris* eggs were oviposited on *Sinapis* rather than *Brassica* plants and the eggs were oviposited within the initial six days of caging[26]. So, where glucosinolates and hairy pods deterred *Lygus* feeding, these plant characteristics failed to deter oviposition. Secondarily, when Gerber[26] compared oviposition on *Brassica* species, significantly more *L. lineolaris* eggs were laid on *B. carinata* and *B. napus* than on *B. juncea*. When provided with *Sinapis* species, significantly more eggs were laid on *S. alba* (high glucosinolates) than on *S. arvensis* [26]. Thus, *Lygus* survivorship is lower in alfalfa compared to canola and they prefer to feed on canola compared to hairy, high glucosinolate mustard, yet they will still oviposit on the latter even though fewer nymphs will survive on that host. Even so, *Lygus* infestations still occur in mustard[27] and *Lygus* populations in canola can exceed that observed in adjacent alfalfa fields[15]. These varied results for feeding, oviposition, and nymph survival have continued to make it difficult to predict what species or varieties will suffer *Lygus* infestations. Additionally, the available field studies examining *Lygus* in older varieties of canola or closely related *Brassica* species do not fully explain the sporadic nature of *Lygus* outbreaks, nor do they offer clear insight into which growing region, crop or variety is at the greatest risk for *Lygus* damage. Because of the continued complexity of *Lygus*-plant interactions, degree-day studies and area-wide management data may provide insight into host crop utilization by *Lygus* in canola production areas as it has been studied in cotton production systems[28,29,19,21].

Lygus are always present in canola fields because they are native, yet high populations causing economic levels of damage occur infrequently (e.g., 1998-1999, 2010 in the Peace River region, isolated fields in south central Alberta in 2010). Cage and research plot studies have shown the relationship between *Lygus* and canola damage and yield losses. Field plot trials with *B. napus* (cv. Westar) and *B. campestris* (cv. Tobin) seeded on three different dates in 1985 at Fairview, Alberta, and 1986 at Vegreville, Alberta, showed *Lygus* (i.e., *L. elisus*, *L. borealis*, *L. lineolaris*) were absent at the seedling stage in plots at any seeding date but increased at the bud stage, regardless of seeding date or canola species[8]. This same study observed that *Lygus* peak densities were significantly higher in early- (mid-May) compared to late-seeded plots (June) of *B. napus* and *B. campestris* in 1985, and that this trend also occurred in 1986[8]. In addition, there were significantly more summer generation *Lygus* in *B. campestris* compared to *B. napus* plots that were seeded on the same date (late-May or early-June in 1985 or 1986), but this was concluded to be a product of earlier budding in the *B. campestris* plots compared to *B. napus.* Plots that budded earlier appeared to retain and produce the highest peak densities of summer generation *Lygus* [8]. Wise and Lamb[7] confined *Lygus* (mainly *L. lineolaris*) between flowering to pod maturity on *B. napus* plants and found that yields were reduced by approximately 20% in southern Manitoba. A similar cage plot study assessing combinations of *Lygus* plus cabbage seedpod weevils (*Ceutorhynchus obstrictus* Marsham) on canola near Lethbridge, Alberta (Cárcamo, unpublished data) found no effects on yield or plant architecture at a density of either 20 *Lygus* (mixed population of *L. elisus* and *L. keltoni*) per cage or 10 *Lygus* plus 10 weevils per cage. Yield reductions were observed at a density of 40 *Lygus* plus 40 weevils per cage. Jones et al.[30] confined individual plants (*B. napus* cv. Q2) seeded within field plots from bud to early flower stages and manipulated the densities of local *Lygus* species occurring in southern, central and northern Alberta. Rather than causing damage, Jones et al.[30] observed that *Lygus* herbivory occurring from bud to early flower induced greater branching and thicker stems compared to plants caged without *Lygus* adults. Additionally, their central Alberta results at Ellerslie showed increased seed yield in response to *Lygus* feeding compared to plants caged without *Lygus* adults. Although individually caged plants may compensate for insect herbivory more so than those caged in natural stands, the results from Jones et al.[30] are in agreement with other plot studies (discussed below) that revealed no yield responses to insecticide sprays applied at growth stages earlier than late flower in canola.

Monitoring and thresholds

The use and application of economic thresholds as a tool in integrated pest management relies on positive identification, uniform insect monitoring methods, current crop value estimates, and costs of implementing a control strategy to accurately determine when insect control is necessary and profitable. More specifically, economic thresholds are based on the cost of spraying, the value of canola and the amount of crop loss likely to be caused by the insects, keeping in mind that insect damage varies with the crop stage and weather conditions. Most importantly, accurate monitoring and application of an economic threshold for *Lygus* in canola will delay insecticide resistance. Some *Lygus* in cotton in the mid-south of the United States are resistant to pyrethroids and/or some carbamates (e.g., acephate, dicrotophos, malathion, and oxamyl)[31](Zhu et al. 2004), cyclodiene and organophosphates[32,33]. Insecticide resistance has also been detected for the neonicotinoid imidacloprid[34].

Canola fields should be monitored for *Lygus* starting at the bolting stage through to the mid-pod stages. A minimum of 100 sweeps should be taken in each field by selecting 10 spots and doing 10 walking sweeps (180° arc) at each spot. Sweeping should be done with a standard insect sweep-net (38 cm diameter). Sampling spots should be sufficiently spread throughout the field to provide accurate estimates for the entire field. Samples can be collected near the edges since Wise and Lamb[12] observed no significant differences in *Lygus* abundance in the edge versus the middle of a canola field.

The only control strategy available for *Lygus* at present is the application of foliar, contact insecticides. Products registered in western Canada for *Lygus* control in canola in 2010 were Decis 5 EC (deltamethrin at 24.3 mL/ha), Matador 120 EC (cyhalothrin lambda at 13.8 mL/ha), and Lorsban 4E (chlorpyrifos at 163.9 mL/ha). The economic threshold or number of *Lygus* per 10 sweeps at which the cost of controlling the pest equals the economic damage for *Lygus* are provided in Tables 1 and 2 and are based on the work performed in Manitoba by Wise and Lamb[7]. Insecticide applications should be done in the early morning or late afternoon when beneficial insects (e.g., pollinators and natural enemies) are less active and therefore less likely to come into direct contact with the insecticide.

Table 1. Economic thresholds for *Lygus* in canola at late flowering and early pod stages[7].

Control costs		Late flower to early pod (Canola crop stages 4.4-5.1[1])						
$/ac	$/ha	Economic Injury Level[2]						
$8.00	$19.77	8	6	5	4	4	3	3
$10.00	$24.71	10	8	7	6	5	4	4
$12.00	$29.65	12	9	8	7	6	5	5
$14.00	$34.59	14	11	9	8	7	6	5
$16.00	$39.54	16	13	10	9	8	7	6
$18.00	$44.48	18	14	12	10	9	8	7
$20.00	$49.42	20	16	13	11	10	9	8
Canola value	**$/bu**	$8.00	$10.00	$12.00	$14.00	$16.00	$18.00	$20.00
	$/tonne	$352.42	$440.53	$528.63	$616.74	$704.85	$792.95	$881.06

[1] Canola crop stage estimated using Harper and Berkenkamp[35].
[2] Economic thresholds are based on an assumed loss of 0.715 g / m^2 or 0.1275 bu/ac per *Lygus* caught in 10 sweeps[7].

Table 2. Economic thresholds for *Lygus* in canola at pod stage[7].

Control costs		Late pod (Canola crop stages 5.2[1])						
$/ac	$/ha	Economic Injury Level[2]						
$8.00	$19.77	11	9	7	6	5	5	4
$10.00	$24.71	14	11	9	8	7	6	5
$12.00	$29.65	16	13	11	9	8	7	7
$14.00	$34.59	19	15	13	11	10	9	8
$16.00	$39.54	22	18	15	13	11	10	9
$18.00	$44.48	25	20	16	14	12	11	10
$20.00	$49.42	27	22	18	16	14	12	11
Canola value	**$/bu**	$8.00	$10.00	$12.00	$14.00	$16.00	$18.00	$20.00
	$/tonne	$352.42	$440.53	$528.63	$616.74	$704.85	$792.95	$881.06

1 Canola crop stage estimated using Harper and Berkenkamp[35].

2 Economic thresholds are based on an assumed loss of 0.512 g/m^2 or 0.0913 bu/ac per *Lygus* caught in 10 sweeps[7].

An important factor to consider prior to spraying is the amount of rainfall during the growing season. During years when moisture conditions are ideal for canola growth, plants may be able to compensate and spraying may not be necessary even when *Lygus* numbers are near or above the economic threshold.

Chemical management

Timing and frequency of insecticide applications for *Lygus* control in canola has been the subject of past and current research in Manitoba, British Columbia and Alberta (Table 3). With the exception of two very dry site years in Lethbridge (2000 and 2001), research to date has been conducted during non-outbreak years and showed that a single application at the early pod stage (5.1) produces the highest financial returns. These results are similar to those observed by Butts and Lamb[2] and by Wise and Lamb[7]. A study of chemical spraying for *Lygus* near Lethbridge (Cárcamo et al. unpublished) in 1999, 2000 and 2001 showed that numbers of *Lygus* in plots sprayed during the bolting stage surpassed the economic thresholds of 15 per 10 sweeps during the early pod stage (Table 3). In 1999 and 2000 applications at flowering reduced *Lygus* abundance at the pod stage to levels below threshold but not in 2001 when *Lygus* reached 256 per 10 sweeps in unsprayed plots under drought conditions. In the Lethbridge trials, there were no yield advantages of multiple sprays at bolting, flower and pod stages or single sprays at bolting and flower, compared to a single spray at the early pod stage. Yields of plots sprayed once at the bolting stage were always lower than those from plots sprayed once at the early pod stage (Table 3). Large numbers of cabbage seedpod weevils in 2000 and flea beetles in 2001 likely increased the yield response to the insecticide application at the bolting stage at the Lethbridge site and require further research to develop thresholds that account for species combinations.

Similarly, results from the Peace River region from experiments conducted between 1999 and 2001 with natural infestations of *Lygus* (Table 4) indicated that applying a single insecticide spray at the early pod stage resulted in consistently higher yields that were comparable or exceeded yields in plots sprayed multiple times throughout the season (Table 3) (Otani et al. unpublished). Additionally, in 2001, *B. napus* cv. Q2 yields in both Beaverlodge and Dawson Creek from plots treated with a single insecticide spray at bud stage were similar to yields observed in plots sprayed multiple times or singly at the early pod stage (Table 3). It should be emphasized that the results observed by applying insecticide at the bud stage may be restricted to canola production in the Peace River region which typically experiences a shorter growing season, a univoltine *Lygus* population, and greater *Lygus* pressure at the bud stage compared to other areas of the prairies. Still, in 1999 and 2001, yield was consistently better in plots treated at the early pod stage compared to all other single or multiple insecticide treatments in the Peace River region (Table 3). As a cautionary note, plots in the Peace River region were affected by drought in 1999 and were moisture-stressed in 2001. However, in spite of moisture stress, the Peace River region results indicated that a producer, even under extreme growing conditions, would have protected yield and reduced the costs of applying insecticide by coordinating a single control effort at the early pod stage.

When the relationship between *Lygus* and yield was calculated as described in Wise and Lamb[7] using *B. napus* cv. Q2 data pooled for Beaverlodge and Dawson Creek between 1999 to 2001, a significant yield loss of -0.311 kg/ha per *Lygus* (adults + nymphs) per 10 sweeps (38 cm dia. sweep-net) was observed in canola (SE=0.079, P=0.001, r^2=0.46, N=20) at the early pod stage (5.1) (Otani et al. unpublished). Similarly, there was a significant yield loss of -0.387 kg/ha for every *Lygus* (adults + nymphs) per 10 sweeps (38 cm dia. sweep-net), SE=0.129, P=0.01, r^2=0.39, N=16) at the late pod stage (5.3). Although, the highest yields were still obtained in plots sprayed at early pod (5.1), the significant yield loss at late pod stage (5.3) is important because this stage can last for up to three weeks in the Peace River region when growing conditions turn cool during pod ripening.

In the case of *Lygus* bugs in canola, the Economic Injury Level (EIL) is the same as the Economic Threshold (E_T). Thus, applying the EIL to *Lygus* populations (adults and older nymphs per 10 sweeps) in canola in the Peace River region, it is clear that controlling *Lygus* at the early or late pod stages when their densities reach critical levels, can produce economic benefits to producers. It should be noted that the E_T values for the early pod stage (Table 5) are almost double the populations Wise and Lamb[7] observed in plots of *B. napus* cv. Westar grown in southern Manitoba (canola yield loss of 0.715 g / m^2 or 0.1275 bu/ac per *Lygus* caught in 10 sweeps). While it might be argued the low r^2-values in the Peace River region data (Table 5) could explain the discrepancy in yield loss values, the differences between the two geographic regions in terms of shorter versus longer growing season, the presence of a univoltine versus bivoltine *Lygus* complex, the presence of longer days accumulating comparable heat units over a shorter period are all suspected to contribute to the difference in the relationship between *Lygus* and canola in the northern versus southern canola growing regions of Canada.

Table 3. *Lygus* populations occurring in research plots examining an economic threshold for *Lygus* in canola (*B. napus*).

Year	Site	Growth stage when *Lygus* peak occurred[1]	Calendar date	Peak *Lygus* (adults + nymphs) in 10 sweeps Mean ± SE	Yield from untreated plots (gm/m^2) Mean ± SE	% of yield compared to sprayed check[2]	Accumulated precipitation during growing season[3]
1989	Glenlea MB[4]	5.1	~28 July 1989	26.2 ± 2.3	110.8 ± 8.5	§	67
1990	Glenlea MB[4]	5.2	~23 July 1990	5.8 ± 0.7	83.3 ± 3.5	§	54
1991	Glenlea MB[4]	5.2	~29 July 1991	64.6 ± 4.8	188.9 ± 4.0	§	111
1992	Glenlea MB[4]	5.2	~10 Aug 1992	22.2 ± 0.9	238.4 ± 9.5	§	122
1990	Portage la Prairie MB[4]	5.2	~31 July 1990	16.6 ± 3.7	139.7 ± 11.0	§	62
1999	Beaverlodge AB[5]	4.3	27-Aug-1999	81.8 ± 19.2	81.0 ± 9.7	94.0	79
2000	Beaverlodge AB[5]	5.2	22-Aug-2000	80.5 ± 25.4	104.0 ± 18.6	76.7	279
2001	Beaverlodge AB[5]	5.2	15-Aug-2001	23.5 ± 6.6	135.7 ± 20.0	120.5	138
1999	Dawson Creek BC[5]	5.1	19-Aug-1999	59.8 ± 9.7	149.5 ± 4.7	85.1	73
2001	Dawson Creek BC[5]	5.2	15-Aug-2001	9.8 ± 3.4	343.2 ± 21.5	82.2	254
1999	Lethbridge AB[6]	5.1	20-Aug-1999	17.2 ± 1.7	140.3 ± 5.9	87.0	149
2000	Lethbridge AB[7]	5.1	26-Aug-2000	23.8 ± 3.9	75.4 ± 4.3	66.0	64
2001	Lethbridge AB[7]	5.1	8-Aug-2001	124.3 ± 16.1	10.6 ± 2.6	30.0	55

[1] Growth stages estimated using Harper and Berkenkamp[35] who described flowering stages as values 4.0-4.4, early pod as values 5.1-5.2 and late pod stages as values 5.3-5.4.

[2] Matador™ (Cyhalothrin lambda at 10 g A.I./ha) was applied to plots at bud (3.1), and late flower (4.3) to keep insect-free at Beaverlodge in 1999 but in 2000 and 2001 Matador™ (Cyhalothrin lambda at 10 g A.I./ha) was applied to plots at bud (3.1), late flower (4.3) and early pod (5.1) stages to keep insect-free at Beaverlodge and Dawson Creek.

[3] Precipitation from Wise and Lamb estimated from bud (3.1) to late flower (4.4). Precipitation from Otani et al. estimated from May to mid-September. Precipitation from Carcamo et al. estimated from precipitation data including June, July, plus mid-August.

[4] Source is Wise and Lamb (1998) from *B. napus* cv. Westar plots.

[5] Source is Otani et al. unpubl. data from *B. napus* cv. Q2 plots.

[6] Source is Cárcamo et al. unpubl. data from *B. napus* cv. Q2 plots.

[7] Source is Cárcamo et al. (2002) from *B. napus* cv. Q2 plots.

§ Data not available.

Table 4. *Lygus* populations observed in field plots† grown in the Peace River region between 1999 and 2001 (Otani et al. unpublished).

Year	Site	Plant Stage	Growth Stage	*Lygus* (adults + nymphs) in 10 sweeps Mean ± SE
1999	Beaverlodge AB	Bud	3.2	5.4 ± 0.8
		Early pod	5.2	107.1 ± 5.5
2000	Beaverlodge AB	Bud	3.2	24.9 ± 2.0
		Early pod	5.2	59.4 ± 5.6
2001	Beaverlodge AB	Bud	3.1	3.9 ± 0.7
		Early pod	5.2	17.2 ± 1.5
1999	Dawson Creek BC	Bud	3.1	2.3 ± 0.4
		Early pod	5.1	58.0 ± 4.7
2001	Dawson Creek BC	Bud	3.2	4.1 ± 0.3
		Early pod	5.2	3.6 ± 0.5

† Research plots seeded at 9 kg/ha using 23 cm row spacing at Beaverlodge AB, in 1999, 2000, 2001 (plots each 4 m x 15 m) and at Dawson Creek BC, in 1999 and 2001 (plots each 5m x 20 m).

Table 5. Peace River region† economic threshold estimates for *Lygus* (adults + nymphs) per 10 sweeps in canola at early pod (stage 5.1).

Control costs		Late flower to early pod (Canola crop stages 5.1[1])						
$/ac	$/ha	Economic Injury Level[2]						
$8.00	$19.77	18	14	12	10	9	8	7
$10.00	$24.71	23	18	15	13	11	10	9
$12.00	$29.65	27	22	18	15	14	12	11
$14.00	$34.59	32	25	21	18	16	14	13
$16.00	$39.54	36	29	24	21	18	16	14
$18.00	$44.48	41	32	27	23	20	18	16
$20.00	$49.42	45	36	30	26	23	20	18
Canola	**$/bu**	$8.00	$10.00	$12.00	$14.00	$16.00	$18.00	$20.00
value	**$/tonne**	$352.42	$440.53	$528.63	$616.74	$704.85	$792.95	$881.06

[1] Canola crop stage estimated using Harper and Berkenkamp[35].

[2] Economic thresholds are baseddata from Beaverlodge AB and Dawson Creek BC 1999-2001 calculating an assumed loss of -0.311 kg.ha for every *Lygus* (adult + nymph) per 10 sweeps (38 cm dia. Sweep-net), SE=0.079, P=0.001, r^2=0.46, N=20).

Natural enemies of *Lygus* and biological control

Lygus, like other insects, have a suite of natural enemies that in most years help to keep populations from reaching pest levels. Egg parasitoids have been poorly studied, but a survey using sentinel plants near Lethbridge (2005-2006) in uncultivated and weedy alfalfa habitats reported four species of parasitoid wasps (Hymenoptera: Mymaridae): *Anaphes iole, Telenomus sp*. and *Polynema* (2 species)[36]. The average rate of *Lygus* egg attack due to all of these parasitoids was 9%. Nymphal mortality caused by parasitoids of the genus *Peristenus* (Hymenoptera: Braconidae) is much higher and can reach 70% at peak times in some alfalfa sites as reported for *P. braunae* near Saskatoon[27] (Fig. 4). In southern Alberta, the dominant species attacking the spring and early summer first generation of *Lygus* nymphs is *P. carcamoi,* whereas the second generation is attacked mainly by *P. broadbenti* [37]. In northern Alberta, *P. braunae* and the more common *P. otaniae* attack the first and only generation of *Lygus* nymphs occurring in alfalfa and clover hay mixes[37]. Sweep-net collections targeting third to fifth instar *Lygus* in an alfalfa hay field in late June near Beaverlodge, Alberta (N55º 13.172' by W119 º 17.129'), revealed parasitism rates estimated from healthy *Peristenus* puparia ranging from 38.3% in 1999 (N=400 *Lygus* nymphs) to 9.8% in 2000

(N=135 *Lygus* nymphs) (Otani, unpublished data). In all regions, parasitism of *Lygus* is common in older weedy alfalfa stands or uncultivated weedy sites but virtually absent in canola sites[27,38]. Current research is in progress to evaluate the exotic *P. digoneutis* as a potential neoclassical biocontrol agent to assess the impact of this European species on *Lygus* nymphs occurring in canola and to evaluate its impact on native communities of natural enemies and other naturally occurring arthropods.

Tachinid flies have been reported to attack *Lygus* adults in the Peace River region of Canada, although no specimens have been obtained to confirm the species (Otani, unpublished data). Collections of *L. pratensis* and *L. rugulipennis* in oilseed rape in Sweden revealed parasitism rates by the tachinid *Phasia obesa* of up to 12% for *L. pratensis* and up to 10% for *L. rugulipennis* [39]. Day[40] observed lower parasitism rates of 0.58% by the tachinid *P. robertsonii* collected and reared from *L. lineolaris* in alfalfa in the northwest of New Jersey, USA.

General predators exist in canola grown on the prairies and the impact of these species has not been studied . Several species of ladybird beetles, damselbugs, lacewings, ambush bugs, and spiders are regularly collected in sweep-net, pan and pitfall traps deployed to monitor arthropods in canola or specifically for *Lygus* monitoring . Together, the assemblage of specialist parasitoid and generalist predators is expected to significantly reduce the abundance of *Lygus*. When *Lygus* are near threshold levels and plants are growing vigorously, it is important to consider beneficial insects when making insecticide application decisions.

Fig. 4. *Peristenus digoneutis* attacking a *Lygus* nymph (photo: USDA-Agricultural Research Service, S. Bauer).

Summary

Lygus are an intermittent and still somewhat unpredictable pest in many field crops of the Prairies including canola. Depending on the region, up to six species can be found, but the more common ones include *L. lineolaris*, *L. elisus*, *L. borealis* and *L. keltoni*. The species complex, seasonal activity, number of generations and impact on canola yield will vary depending on the site, available hosts, natural enemies and local climate. Despite this biological complexity, *Lygus* management in canola during most years is possible with a single spray application during the pod stage if the numbers per 10 sweeps exceed recommended economic thresholds. Some exceptions to this recommendation may take place in the most northern range of the canola growing region, such as the Peace River region, where, during exceptionally early, warm and dry springs, unusually high densities of *Lygus* may affect plants adversely at the bud stage.

However, past research has not indicated a strong effect of *Lygus* on canola during early growth stages; further validation at the field level is required. As with many other field crop pests, biological control options have been poorly studied and should receive increased emphasis for sustainable long term management.

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