



What do *Lygus* like? Looking for potential trap crops to reduce faba bean damage

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Abstract

Grain legumes, such as faba bean (*Vicia faba* L.), are crucial for protein supply and soil fertility enhancement through nitrogen fixation. However, faba bean cultivation is challenged by *Lygus* plant bugs (Hemiptera: Miridae), which cause significant crop damage and seed quality loss. This study aimed to evaluate *Lygus* preferences between faba bean and alternative crops to develop effective management strategies. We conducted choice bioassay experiments under laboratory conditions and field plot experiments. Laboratory results indicated sex-based host preferences, with males favoring faba beans and females preferring canola. Field studies showed that faba beans adjacent to canola had higher *Lygus* abundance and damage compared to those next to peas, flax, and safflower. Safflower and sunflower demonstrated potential as trap crops to reduce *Lygus* damage to faba beans. Our findings provide insights into *Lygus* behavior and suggest that a combination of trap cropping, and targeted insecticide use could mitigate the impact of *Lygus* infestations on faba bean cultivation.

Keywords Trap crops · *Lygus* · Miridae · Canadian Prairies · Faba beans

Introduction

Globally, grain legumes represent a vital source of protein for human and animal nutrition and play a crucial role in crop rotations where they enhance soil fertility (Mwanamwenge et al. 1998). Among these legumes, faba bean (*Vicia faba* L.) stands out as an exceptional nitrogen fixer, forming a symbiotic relationship with *Rhizobium* bacteria (Singh & Upadhyaya 2013). Faba bean flourishes in humid agricultural regions and thrives under cooler growing conditions. Thus, it is well suited for the Parkland Ecoregion of the Canadian Prairies and particularly in Saskatchewan (Government of Saskatchewan 2023). According to Mhlanga and Pierre (2022), in 2021, faba beans covered 24,808 ha of farmland in Saskatchewan, accounting for 50% of Canada's total faba bean cultivation. However, this crop faces challenges due to a number of arthropod pests, in particular, species in the genus *Lygus* (Hemiptera: Miridae) (Kaur et al. 2019).

The *Lygus* pest complex in the Canadian Prairies is dominated by *L. lineolaris* (Palisot de Beauvois), *L. keltoni* (Schwartz & Footitt), *L. elisus* (Van Duzee), and to a lesser extent, *L. borealis* (Kelton) (Schwartz and Footitt 1998; Cárcamo et al. 2002). *Lygus* inject salivary enzymes as they feed (Williams et al. 2005), which inflicts mechanical damage on plant tissues. Their feeding range encompasses a broad niche of at least 328 host plant species (Snodgrass 2003; George et al. 2021). Andow (2023) notes that *Lygus* migration between different plants correlates with the ongoing growing season in Tompkins County, New York; similar migration patterns could occur in Saskatchewan. Faba bean, being a late crop in western Canada, becomes an attractive host option for *Lygus*, especially as it enters its flowering stage which coincides with the harvest or maturity of early crops like canola and mustard.

Faba beans are particularly susceptible to damage from *Lygus* feeding during the pod stage. This feeding damage can include hull perforations, seed coat discoloration, pitting, and tissue wilting (Kaur et al. 2019; Smith et al. 2019) and results in quality downgrades since faba for human consumption has a very low tolerance to such damage (< 1% for Grade No. 1) (Canadian Grain Commission 2021). The economic implications of *Lygus* damage are substantial. Faba bean under ideal growing conditions yield around 6.7 tonnes

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per ha (100 bu/acre) (Saskatchewan Pulse Growers 2024). Currently, prices range from \$10 to \$10.50/bushel for feed grade and \$13.50 to \$14.00/bushel for export, with less than 1% of perforated damage. (Boersch 2023). In a scenario with less than 1% damage, a quarter of section in Saskatchewan (64.75 ha) yields a crop valued at \$224,000 CA, while in a scenario with more than 1% damage, the same 64.75 ha yields a crop valued only at \$168,000 CA, a difference of \$56,000 CAD. This stark difference underscores the necessity for comprehensive research to address the complex challenges posed by *Lygus* infestations in faba beans. Despite these challenges, applying insecticide during the flowering stage is not recommended as it interferes with the pollination process important for faba bean development. Considering this, we are exploring alternative methods to manage this pest, recognizing the importance of mitigating its impact on faba bean cultivation. The primary objective of this study was to evaluate *Lygus* preferences between faba bean and alternative crops. To achieve this goal, we conducted choice bioassay experiments under laboratory conditions to assess the impact of four potential plants on *Lygus* behavior. Furthermore, we investigated the effects of seven potential crops on *Lygus* infestation in field conditions. Specifically, our choice bioassays aimed to quantify the percentage of faba bean seed damage in the presence of alternative crops, while our field experiments evaluated the efficacy of seven potential crops as trap crops alongside faba beans in field plots. By understanding the influence of alternative crop presence, we aim to lay the foundations to develop trap crop strategies as another tool for an Integrated Pest Managing strategy to reduce *Lygus* infestations in faba bean.

Materials and methods

Plants

Choice bioassay

Five plant species were used as treatments in the choice bioassay, Faba bean (*Vicia faba*, 1310–5) as the susceptible, and canola (*Brassica napus*, AC Excel), pea (*Pisum sativum*, CDC Meadow), alfalfa (*Medicago sativa*, CV Bridgeview), and flax (*Linum usitatissimum* L., CDC Glas), as the alternative crop. All of the plants were cultivated for 4 months in Conviron controlled growth chambers located at the University of Saskatchewan Controlled Growth Facility (Phytotron). The growth chambers maintained an 18-h light and 6-h dark photoperiod using LED lights. Day-time temperatures were consistently maintained at 21 °C, with night-time temperatures at 18 °C. Additionally, humidity levels were regulated at 30%. Seeds were sown in two-gallon pots filled with Pro Mix HP with Mycorise

soil. Seeding times for each crop were adjusted to grow the plants to the required pod stage for conducting the insect preference assay at the following BBCH stages: faba at 72, Canola at 74, Flax at 69, Pea at 77, and alfalfa at 65. To prevent insect infestation, the pots were placed within insect tents measuring 75 × 75 × 115 cm (Bugdorm, Taiwan). Biocontrol agents *Orius laevigatus* and *Hypoaspis miles*, supplied by Biobest (Ontario, Canada), were introduced into the tents to manage thrips. For faba bean and pea, watering occurred every four days from seeding until the vegetative stage. During this period, a weekly application of 20:20:20 water-soluble fertilizer (Plant-Prod MJ) was administered. Subsequently, from flowering until seed maturity, watering frequency increased to every 2 days, with a weekly application of 15:30:15 water-soluble fertilizer (Plant-Prod MJ). Canola, flax, and safflower were watered every three days using 20:20:20 water-soluble fertilizer throughout their growth stages.

Field study

In 2022, four plant species were used as potential trap crops, canola (*Brassica napus*, L233P), flax (*Linum usitatissimum* L., CDC Rowland), safflower (*Carthamus tinctorius*, AAC Saffire), and pea (*Pisum sativum*, AAC Chrome). In 2023, mustard (*Sinapis alba*, Andante), hemp (*Cannabis sativa*, Finola) and sunflower (*Helianthus annuus* L., ExpressSun) were added to the original four.

Insects

Laboratory assays were performed with *Lygus lineolaris* from colonies maintained at the University of Saskatchewan and originally sourced from colonies at AAFC Lethbridge. Colonies were maintained in Phytotron growth chambers with a 14-h light and 8-h dark photoperiod. Day-time temperatures were maintained at 24 °C and night-time temperatures were 21 °C. Humidity levels were regulated at 60%. All colonies were maintained on potato (*Solanum tuberosum*, cultivar Ranger Russet) to facilitate insect egg laying. Potatoes were grown from seed pieces in 8-inch pots filled with Pro Mix HP soil enriched with Mycorise. Colonies were kept inside 60 × 60 × 60 cm insect cages (Bugdorm, Taiwan). Organic romaine lettuce leaves, serving as a food source for the insects, were added to the cage and the plants were watered every four days.

For the field study, *Lygus elisus*, *L. borealis*, *L. keltoni*, and *L. lineolaris* were found in Alberta and Saskatchewan. In Saskatchewan, the species composition varied with both geography and time. However, *Lygus lineolaris* was consistently among the most common species collected from faba in Saskatchewan (Aguiar-Cordero, Unpublished Data). In Alberta, *Lygus keltoni* was the dominant species, with some

occurrences of *Lygus elisus* also being common. In contrast, *Lygus borealis* was rare, and *Lygus lineolaris* was extremely rare as expected for the dry areas in southern Alberta given its dominance in more humid ecoregions in this province (Carcamo et al. 2002).

Choice bioassay

To evaluate host plant preferences and degree of damage when faba bean is grown in the presence of a potential alternate host plant species, choice bioassay experiments were conducted pairing faba bean with one of four alternative crops (faba, canola, flax, safflower, or pea). The flowering and seed maturation stages of these crops were synchronized to the early pod stage of faba bean and the percentage of perforated faba bean seeds was analyzed. Once faba bean plants reached the BBCH 72 growth stage, they were caged in a 75 × 75 × 115 cm insect tent (Bugdorm, Taiwan) along with one of the alternative crops (faba, canola, flax, alfalfa, or pea). Faba bean was positioned near one corner of the cage, while the alternative crop was placed in the opposite corner. The positions of the crops were rotated between replications. At the start of the assay, one adult *Lygus* insect was released at the center of the cage, the insect was allowed free range within the cage and was removed after 24 h. A total of 10 replications for each of females and males were conducted for each crop (total 20 individuals per crop). After the feeding period, the insects were removed, and the faba bean pods were examined for black dots representing feeding damage (Fig. 1). Since only damage to faba bean was of interest to this study, only faba bean plants were allowed to mature, and the percentage of perforated seeds was analyzed using both the percentage of perforated seed damage and the weight of perforated seeds.



Fig. 1 *Lygus lineolaris* damage to faba bean seeds from a laboratory study shown at the immature (left) and dry (right) stages

Seed samples

To determine the percentage of perforated seed damage in faba bean, the total sample was weighed and a visual evaluation of each seed was conducted to separate those without perforation damage from those with clear perforation damage. Subsequently, the weights of the seeds without perforation and those with clear perforation were recorded to calculate the damaged percentage.

Field study

The study site for the field plot experiment was located 6 km east of Lethbridge on land operated by Agriculture and Agri-Food Canada (49.703826, -112.696364). The site is within the Mixed Moist Grassland Ecoregion, with dark brown chernozemic soils and long-term average annual precipitations of less than 450 mm (Ecological Stratification Working Group 1995). The study was conducted in 2022 and 2023 and each year crops were planted during the first 2 weeks in May. Crop husbandry practices in terms of seeding depths, rates, fertility, and weed management, followed recommendations from soil testing completed pre-planting and local guidelines for the province of Alberta (Douglas et al. 2013).

Experimental design and sampling

Each year the study consisted of 4 blocks with plot pairs of a “trap” crop and an adjacent faba bean plot less than 1 m apart. In 2022 the trap crops were canola, flax, safflower, and peas. In 2023 mustard, hemp and sunflowers were added. Plot dimensions were 9 m x 10 m for the trap crops and faba in both years with a 2 m gap between plot pairs and 8 m between blocks to allow operation of equipment. Weed management with herbicides was insufficient, so manual roguing was performed at least once in all plots during the crop vegetative stage. Half of each trap and faba plots were sprayed with an insecticide (Flonicamid (Beleaf) @ 200 g/ha and lambda-cyhalothrin (Matador)-at 84 ml/ha in 2023) at the early pod stage (BBCH 75). Both years, a fungicide (trifloxystrobin/prothioconazole) was applied at the pod stage in 2022 (BBCH 80) and flower stage in 2023 (BBCH 65). Faba bean plants were desiccated with Glyphosate (2.5L/ha) in September (BBCH 95) before harvesting a strip of 1.5 m with a Wintersteiger plot combined in an area of the plot left relatively undisturbed during the growing season. The seed was cleaned and dried to around 16% humidity before the weights were taken to express them as tons per hectare.

Necrotic damage of faba bean seed, attributed to *Lygus* feeding, was expressed in two ways. First, the incidence of damage represented by the proportion of seeds exhibiting any level of damage from the total number of seeds

counted in a petri dish (9 cm diameter). The second measure of necrotic damage was severity. The exposed side of each damaged seed in each of the two petri dishes was classified to one of five damage categories based on a visual estimate of the total surface with necrotic spots: 0% damage, 1–25%, 26–50%, 51–75%, and 76–100%. Next, an average proportion of damage per seed was estimated by multiplying the number of seeds in each category by the median damage level, for example, 12.5 for the second category of 1–25% damage.

Data Analysis

All analyses were conducted using R version 4.3.1 (2023–06–16 ucrt, © 2023 The R Foundation for Statistical Computing). In the choice bioassay, the alternative crops were considered a fixed factor and the damage in the seeds the response variable. Two analyses were conducted. The first involved a one-way ANOVA to determine if there were any significant differences in the number of perforated seeds among the treatments at each time interval. A QQ plot was generated to confirm the normality of the data distribution. Following this, a Tukey test was performed to identify which means were significantly different.

In the field study, the trap crops planted next to faba bean plots were considered a fixed factor. The insecticide sprayed to half of each faba bean plot was also treated as a fixed factor nested within the plot. The block and its potential interaction with the trap crop were considered random factors. Prior to selecting generalized linear mixed models for fitting the data, the distributions of the response variables were assessed. Yield data were normally distributed, whereas *Lygus* counts, and damage estimates followed Poisson or negative binomial distributions. The packages “lme4” (“glmer” function) and “MASS” (“glm.nb” function) were used to explore the best regression models for the response variables. Model selection was based on the Akaike Information Criterion (AIC), with the lowest AIC values indicating the best models. After determining significant group effects with the modeling, pairwise comparisons between group means were conducted using the Tukey test, available in the “agricolae” package. Model results with significant effects ($P < 0.05$)

were further analyzed using the Tukey test or the non-parametric Dunnett test (dunnett.test package in R). Finally, the potential association between *Lygus* abundance and the incidence of damage and the associations between *Lygus* in the trap crops and *Lygus* in the faba bean plots were explored using the Pearson correlation function (cor.test in base R).

Results

Choice bioassay

Lygus lineolaris choices were evaluated by analyzing two different metrics of feeding-related damage. Since damage is associated with feeding, more damage would suggest more time spent feeding on a plant. The metrics used were the percentage of faba bean seed damage (SD) and the percentage of faba bean seed weight damage (WD) (Table 1). This distinction is important because the percentage of seed damage does not correspond proportionally to the percentage of seed weight damage. This discrepancy arises from our observation that in some cases, feeding occurs in seeds that are not fully mature, producing distinct perforations. The weight difference between a fully mature seed and a developing seed is substantial, leading to different proportions in the percentages of damage.

According to the control (faba beans vs. faba beans), the percentage of perforated seeds was 0.98% SD and 0.98% WD for females and 0.62% SD and 1.529% WD for males (Table 1). The difference in percentages between the number of seeds and the weight of the seeds indicates that males tend to feed on fully developed seeds. In contrast, the similar percentages for females suggest they prefer feeding on pods with immature seeds. This assumption is corroborated by the choice plants, where the difference between SD and WD is not significant for males.

In alfalfa, canola, and flax, the percentages of seed damage (SD) and seed weight damage (WD) were similar for both females and males (Fig. 1). Faba next to canola exhibited the greatest damage, with an SD mean ($\pm$ SE) of 3.72 ± 2.55 and a WD mean ($\pm$ SE) of 4.35 ± 3.08 , caused exclusively by *Lygus* males. Faba seeds in plants next to canola had zero damage from *Lygus* females. The flax

Table 1 Mean ($\pm$ SE) relative percent of Seed Damage (SD) and Weight Damage (WD) produced by *Lygus lineolaris* during the choice experiment per plant choice by sex

	Females		Males	
Choice	Mean ($\pm$ SE) SD	Mean ($\pm$ SE) WD	Mean ($\pm$ SE) SD	Mean ($\pm$ SE) WD
Faba vs. faba	$0.66 \pm (0.44)$	$0.64 \pm (0.45)$	$0.62 \pm (0.62)$	$1.22 \pm (1.22)$
Canola vs. faba	0	0	$3.72 \pm (2.55)$	$4.35 \pm (3.08)$
Pea vs. faba	$1.80 \pm (1.05)$	$1.30 \pm (0.81)$	$0.52 \pm (0.52)$	$0.31 \pm (0.31)$
Alfalfa vs. faba	$0.62 \pm (0.62)$	$0.70 \pm (0.70)$	0	0
Flax vs. Faba	$1.15 \pm (1.15)$	$0.82 \pm (0.82)$	$2.5 \pm (2.5)$	$3.52 \pm (3.52)$

treatment followed, with males causing an SD mean ($\pm$ SE) of 2.5 ± 2.5 and a WD mean ($\pm$ SE) of 3.52 ± 3.52 , while females caused an SD mean ($\pm$ SE) of 1.15 ± 1.15 and a WD mean ($\pm$ SE) of 0.82 ± 0.82 . In peas, only females caused more than 1% of damage, with an SD mean ($\pm$ SE) of 1.80 ± 1.05 and a WD mean ($\pm$ SE) of 1.30 ± 0.81 . *Lygus* females in canola, males in peas, and both males and females in alfalfa presented less than 1% of perforated damage for both metrics, SD and WD (Fig. 1).

There were no statistically significant differences in the percentage of damage weight ($P=0.47$) and percentage of seeds damaged ($P=0.29$) between the choice plants for both male and female sexes. However, during the modeling, canola presented a P of 0.0834 for the interaction of male sex with damage weight. Additionally, the percentage of seed damage presented a nearly significant P (0.0578) for the interaction with male sex.

Field study

Lygus abundance differed significantly among the trap crops during the flower and pod stages of faba beans (Fig. 2). In 2022, canola had more *Lygus* than peas at both crop stages. Flax also had significantly more *Lygus* than peas (Dunn test, $p < 0.05$), but only at the pod stage, not earlier when faba bean was at the flowering stage. In 2023, during the flowering stage of faba bean, both Brassicaceae crops, mustard and canola had more *Lygus* than peas. Although the same numeric trend observed during flowering persisted at the pod stage of faba bean, the differences were no longer

statistically significant. Only sunflower had a clear and significantly larger population of *Lygus* than peas at the pod stage of faba beans.

Lygus abundance in faba bean was affected by adjacent trap crops, but not by the Beleaf insecticide spray treatment in 2022 in contrast to 2023 when only insecticide (Matador) affected *Lygus* abundance (Fig. 3). In 2022, there were more *Lygus* (median of 30/sample) in faba bean next to canola compared to faba plots next to peas, flax, or safflower (Fig. 3, Tukey test, $p < 0.05$). In 2023, none of the 7 crops tested affected *Lygus* abundance, but application of the pyrethroid insecticide reduced them to very low numbers (Fig. 3).

In 2022, the necrotic damage on faba bean seeds followed the same pattern as *Lygus* abundance: incidence (proportion of all seeds with any damage) and the severity of damage (amount of damage per seed) was highest in plots next to canola (Fig. 4). However, only damage severity differed significantly with faba next to canola having higher damage than faba bean next to safflower (Fig. 4, Tukey test, $p < 0.05$). *Lygus* abundance during the flower stage was not significantly correlated with incidence of necrotic damage (Table 2). On the other hand, the correlation between *Lygus* abundance at the pod stage and damage incidence approached significance ($p = 0.056$). Damage severity also was not correlated with *Lygus* abundance at the flower stage ($R = 0.16$, $p = 0.56$), only with *Lygus* abundance at the pod stage ($R = 0.41$, $P = 0.022$) (Table 2). The magnitude and significance of the latter correlation was similar before the insecticide was sprayed ($R = 0.39$, $P = 0.028$). Yields ranged

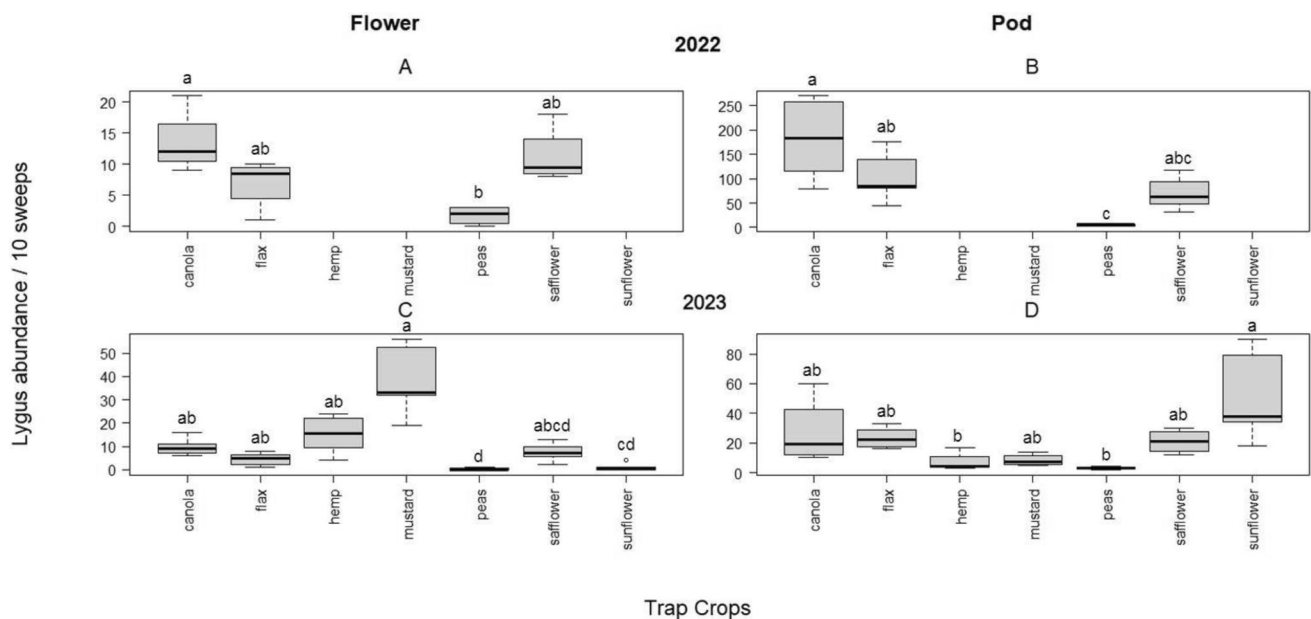


Fig. 2 *Lygus* abundance (per 10 sweeps) in potential trap crop plots adjacent to faba bean at the flower (left panels) or early pod (right panels) stage, near Lethbridge in 2022 (top) and 2023 (bottom)

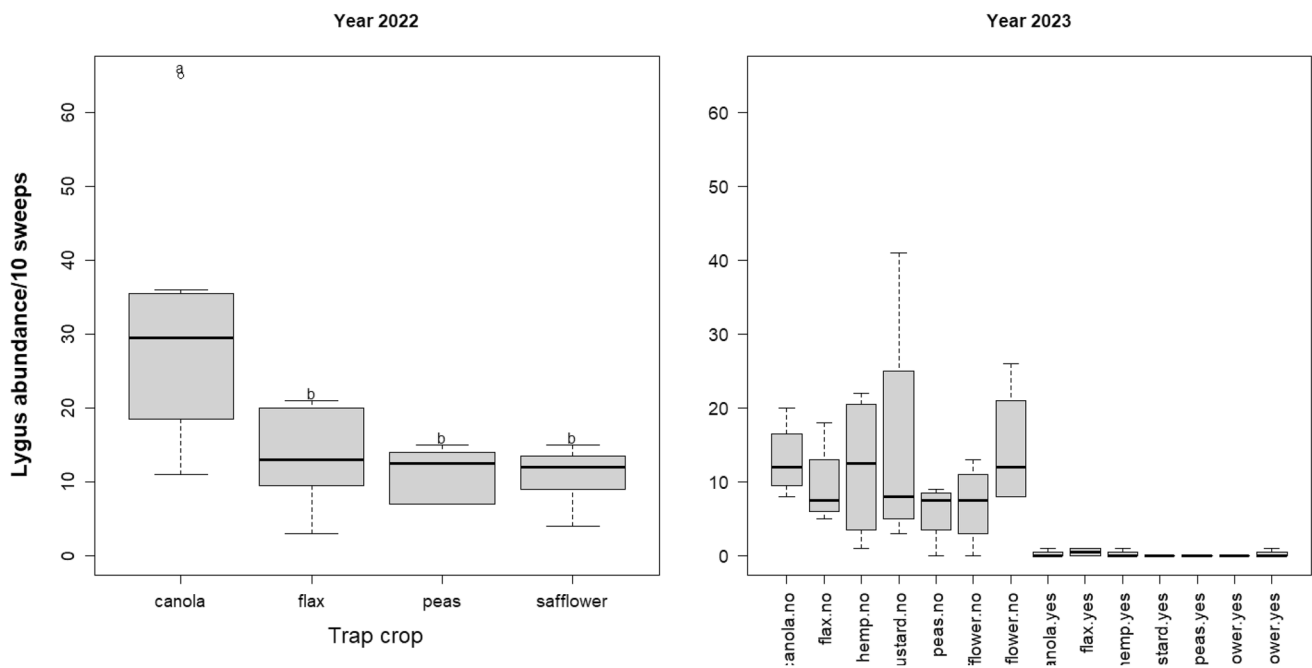


Fig. 3 Abundance of *Lygus* (per 10 sweeps) in faba bean plots adjacent to various potential trap crops in 2022 (left) and 2023 (right). Insecticide had no effects in 2022 and trap crops had no effects on the number of *Lygus* in the adjacent faba bean plots in 2023

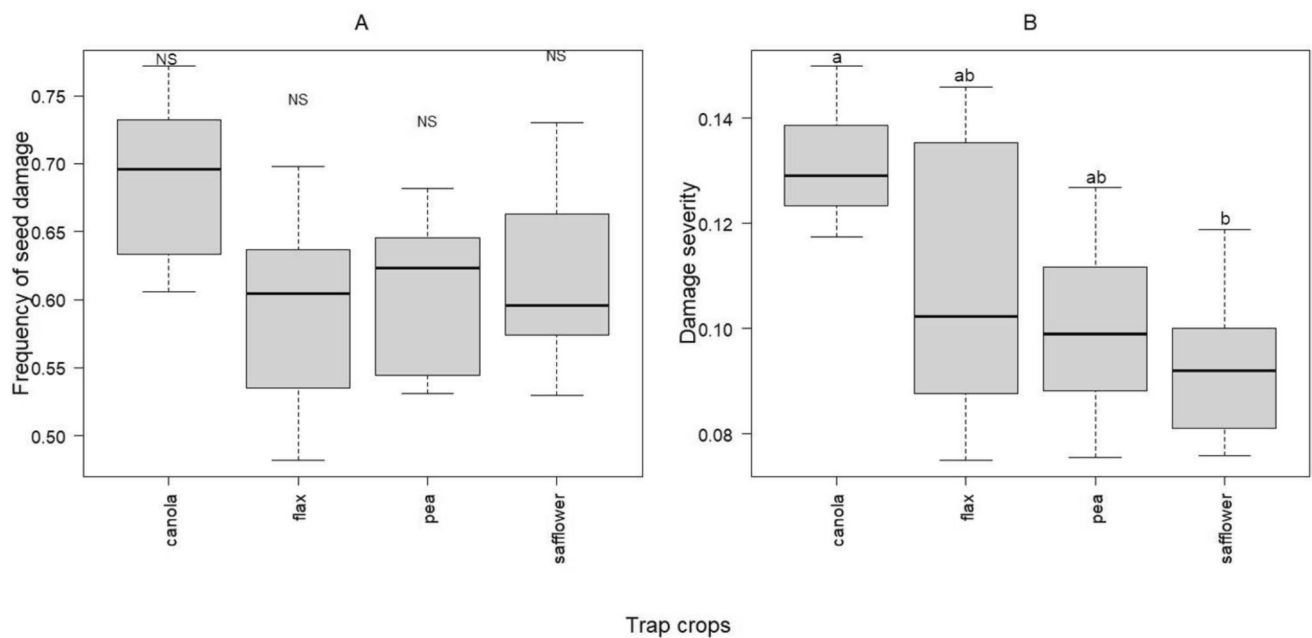


Fig. 4 Faba bean seed damage incidence (frequency, **A**) and severity (**B**) from *Lygus* feeding in 2022 plots adjacent to various trap crops in a field study near Lethbridge, Alberta Canada

from about 3 to 4 ton/ha and were not affected by trap crop or insecticide spraying (data not shown).

In 2023, necrotic damage was similar in all plots, regardless of trap crop but was much lower in the sprayed than in the unsprayed plots (Fig. 5). *Lygus* abundance during

the flower stage of faba beans was not correlated with incidence of necrotic damage (Table 2). At the pod stage, however, there was a significant positive association between damage incidence and *Lygus* abundance (Table 2). Yields in 2023 also were not affected by any of the trap crops or the

Table 2 Correlations (Pearson) of *Lygus* abundance with faba bean damage (incidence and severity) and yield in the field plot study near Lethbridge in 2022 and 2023. (* denotes significant R values $p < 0.05$)

Period	2022			2023		
	Incidence	Severity	Yield	Incidence	Severity	Yield
Flowering stage	0.3	0.16	− 0.32	0.06	0.14	0.08
Pod, pre-spray	0.22	0.38*	− 0.15	0.35*	0.32*	0.10
Pod, post-spray	0.41*	0.38*	− 0.13	0.44*	0.30*	− 0.14

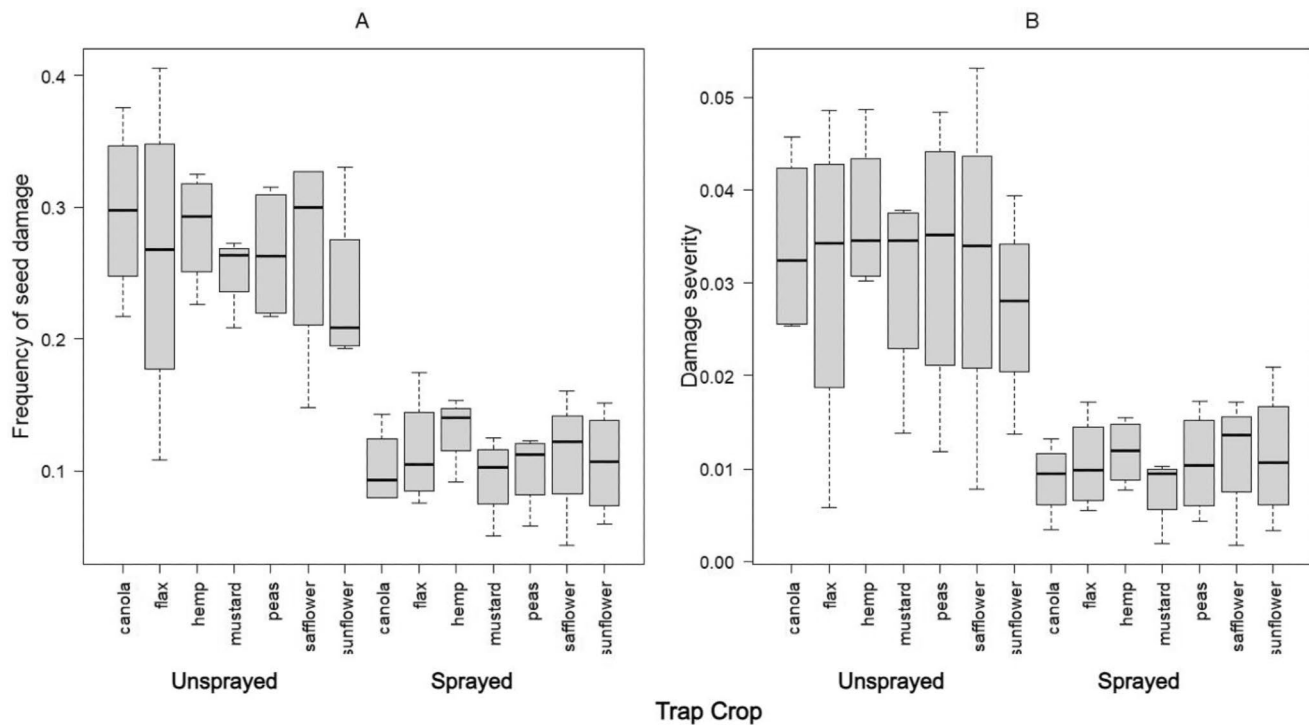


Fig. 5 Faba bean seed damage incidence (frequency, **A**) and severity (**B**) from *Lygus* feeding in 2023 plots adjacent to various trap crops in a field study near Lethbridge, Alberta Canada

spray treatment and averaged around 3.5 tons per ha (Tukey contrasts, $P > 0.5$, after lmer test). Necrotic damage severity, incidence, or individual seed weights were not associated with faba bean yield (Pearson correlations, $P > 0.68$).

Discussion

Lygus utilize a wide array of plant species, including cultivated crops, weeds, and native plants, including alfalfa, canola, flax, safflower, pea, mustard, hemp, sunflower, and faba bean (Young 1986; Snodgrass 2003; George et al. 2021). However, despite being reported on many host plants, *Lygus* exhibit some preferences for certain plant species and stages (Andow 2023). For example, in Alberta, *L. borealis* is more common in alfalfa than in canola (Butts and Lamb 1991; Cárcamo et al. 2003) and *Brassica* field crops are dominated by other species (*L. keltoni*, *L. elisus*, or *L. lineolaris*) depending on the location and the year (Braun

et al 2001; Cárcamo et al 2002). According to Fleischer and Gaylor (1987), *Lygus lineolaris* prefers plants at their reproductive stage with flowers and Andow (2023) showed that *Lygus* feed on apical buds, meristematic tissue, flowers, and young seeds and he noted that they have preferred food sources for oviposition to ensure availability of good-quality resources (e.g., nitrogen content in meristematic tissue) for their progeny to feed. A comprehensive review of the diversity of factors that influence *Lygus* host choices and their ability to recognize them is provided by Holopainen and Hokkanen (2024).

Our study aimed to investigate plant preferences through laboratory choice bioassays and field experiments. In our laboratory experiments, we replicated the plant growth stages commonly found occurring in fields during the same period, focusing on the reproductive stages that are crucial for *Lygus* host selection (Dong et al. 2013; Andow 2023). All the host plants presented flowers, but canola had fewer flowers at BBCH 74. Our results confirmed that *Lygus* can

distinguish between different host plants for feeding. It is well established that insects have variable developmental rates depending on the nutritional content of their food sources (Pedigo et al. 2021), and these preferences may represent differences in quality among the plant varieties. *Lygus* can actively choose between high-quality and low-quality host plants (Shrestha and Rondon 2024). Interestingly, flax did not elicit a significant difference in preference between sexes, with both males and females feeding on both developed and undeveloped seeds.

We observed as Cooper and Spurgeon (2010), significant variation between males and females. For example, males preferred faba beans over canola, whereas females showed a preference for canola, supporting the hypothesis that host plant preference may be linked to sex (Jaenike 1986) and may reflect differences in the nutritional needs of males and females. In our control assay, we observed that *Lygus* females tend to feed on young faba bean seeds, as confirmed by the differences in weight damage, while males prefer fully developed seeds. This difference in resource choice has been observed in other insects and it is influenced by future fitness gains for the next generation (Jaenike 1986). Young seeds likely have higher concentrations of essential amino acids, vitamins, and minerals that are critical for the development of eggs and the health of the females and may signal immature hosts with appropriate resources for the progeny to complete development. Cooper and Spurgeon (2011) noted that females exhibited more test probes and fewer ingestion probes, likely to confirm host quality, which can more easily damage young seeds than fully developed seeds. Males, on the other hand, may increase ingestion probes to facilitate the replenishment of the accessory glands (Cooper and Spurgeon 2011). Fully developed seeds might provide more immediate energy reserves necessary for sustaining activities, such as searching for mates.

Canola and pea elicited clear host plant responses between males and females. *Lygus* males preferred faba beans over canola, while in the choice bioassay between peas and faba beans, males preferred peas and females preferred faba beans. The difference between the percentage of seed number and seed weight, along with our observations of the seeds in peas, indicated that females preferred feeding on seeds that were not fully developed. The bioassay between alfalfa and faba bean was the only one that presented less than 1% seed damage and seed weight damage. This confirms the results of Barman et al. (2010), who mentioned that alfalfa at the flowering stage is very attractive to *Lygus* spp. Compared to other economic crops like cotton or strawberries, alfalfa is the most suitable and attractive host plant for *Lygus* (Swezey et al. 2013). In agreement with our results, Williams et al. (2010) showed that *Lygus hesperus* females preferred alfalfa because it contains high amounts of terpenoid compounds released primarily during the flowering

stage. Among the 5 choice plants used in the choice bioassay, alfalfa could be considered the preferable host compared to faba bean. Spatial scale may influence the populations of *Lygus* in commercial fields of alfalfa and canola. Cárcamo et al. (2003) and Meers and Sim (unpub. data) reported similar *Lygus* numbers in canola and alfalfa fields growing side by side in the Canadian Prairies, even when alfalfa was cut for hay, which resulted in drastic changes to the developmental stage of alfalfa. The potential to manipulate landscapes to improve *Lygus* management through alfalfa trap crop strips deserves more attention from researchers.

Our field studies in southern Alberta aimed to further explore *Lygus* preferences and the potential for managing their impact on crops through trap cropping and insecticide applications. Field observations aligned with laboratory findings, showing that *Lygus* abundance and corresponding necrotic damage in faba beans were influenced by the adjacent crops. Butts and Lamb (1991) noted in commercial fields that *L. lineolaris* had a preference for canola over alfalfa and Cárcamo et al. (2003) also in field studies noted that *L. borealis* tended to be more common in alfalfa than in canola. The objective of our field study was to investigate if the *Lygus* pest complex (dominated by *L. keltoni*) in southern Alberta had relative preferences for a number of crops compared to faba beans and reduce necrotic damage of the seeds. Faba beans planted next to canola had higher *Lygus* abundance and corresponding necrotic damage than in faba bean adjacent to peas, flax, and safflower only in 2022. In 2023, faba next to canola and sunflowers had numerically more *Lygus* and damage than other crops, but the results were not statistically different. The abundance of *Lygus* in the faba bean plots followed the same pattern as the abundance of *Lygus* in the adjacent crops. For example, peas tended to have the lowest numbers and canola the highest, and this was mimicked in the adjacent faba bean plots. This suggests that the attractive alternative crops like canola and sunflowers cannot retain the *Lygus* and prevent them from migrating to faba bean at the small scale of the plots used in our study. Given the very mobile nature of *Lygus*, it is likely that even in commercial fields, *Lygus* will disperse from senescing canola to faba bean as observed in other studies with crops around cotton (Carrière et al. 2012).

In 2022 safflower had a clear impact in reducing *Lygus* necrotic damage to faba bean seed compared to canola. This result is promising and in agreement with the recent findings by Wang et al. (2021) who reported a reduction in damage to cotton by *L. pratensis* in fields with border or inner strips of safflower in China. In our study, we planted the alternative crops at the same time as faba beans, but for a more effective trap crop, the planting dates should be researched to determine the most efficacious planting date to deliver the most attractive crop stage. It will likely depend on the region: for central Alberta, an early planting of faba bean

is recommended to escape *Lygus* in time (Dosdall 2003); thus, a late planted safflower crop next to faba bean may ensure the trap crop stays young and attractive to retain the *Lygus* pest, while the faba bean is maturing and at the most susceptible stage. This may vary depending on the number of *Lygus* generations. Choosing a late maturing cultivar of safflower and an early maturing cultivar of faba bean would be crucial regardless of the region.

Sunflowers are attractive crops to *Lygus* because of their combination of height, flower color, and potential plant volatile mix (Holopainen and Hokkanen 2024). We included this crop in 2023 and noted high abundance of *Lygus* in adjacent faba bean plots and similar to the pattern of abundance for faba bean plots adjacent to canola. Our collection of *Lygus* bugs by shaking the sunflower heads onto a tray suggested that this crop had a large population of *Lygus*. In a study conducted in China, sunflower strips along field borders of cotton combined with periodic insecticide applications on the trap borders were used successfully to reduce *L. pratensis* damage to cotton bolls (Zhang et al. 2020). In our study, the lowest median necrotic damage severity for faba beans was observed in plots next to sunflower (less than 3% mean surface damage) and around 20% for incidence, but the differences were not statistically different relative to other crops. Dissection of a sample of *Lygus* nymphs from the sunflower plots suggested that this crop attracts a high number of *Peristenus* parasitoids of *Lygus* (sunflower and flax had around 37% parasitism in this plot study, Cárcamo unpublished data), thus making it a candidate for continued research as a potential trap crop. Pest management practices or selective insecticides that would preserve pollinator hymenopterans would likely have the added benefit of maintaining populations of natural enemies, such as *Peristenus* wasps, thus having multiple benefits for ecosystem services.

Insecticides were applied to half of all the trap crops and faba bean plots in both years. In 2022, a “soft on Hymenoptera” insecticide, Beleaf did not affect *Lygus* abundance or necrotic damage. We speculate that this insecticide, due to its repellent mode of action, may not be ingested in sufficient quantities to kill *Lygus*. In 2023, we switched to a pyrethroid, lambda-cyhalothrin and it reduced *Lygus* and damage to very low levels. Our correlation analysis clearly showed that *Lygus* abundance during the pod stage, not the flower, was associated with necrotic damage, but yield was not correlated with *Lygus* either year and consistent with Dosdall’s unpublished data from central Alberta. In our design, we did not include a treatment where only the trap crop was sprayed. Thus, it remains to be tested if at moderate *Lygus* abundance, the trap crop retention of *Lygus* might be sufficient to avoid *Lygus* necrotic damage and maintain the quality of the seeds at the class 1 levels needed to get growers the top market price. We speculate that given the fact that the nominal threshold for *Lygus* in faba bean to prevent

damage is very low, only 0.5 *Lygus* per sweep (Cárcamo unpub data; Bogdan 2023), it is unlikely that a trap crop alone will protect the crop. Thus, a more likely scenario is that the most attractive crop such as sunflower or safflower will require spraying of both the trap crop and the faba bean to maintain damage under 3% of necrotic severity. In years when *Lygus* are only around 1 per sweep, spraying just the trap crop might be sufficient. Increasing mortality of *Lygus* through a biologic control agent such as a European *Peristenus* species as demonstrated in parts of the USA (Day 1996) would contribute toward a more integrated approach to reduce insecticide dependency. But considerably more research in commercial fields is needed before trap crop recommendations can be made.

Overall, our integrated approach combining laboratory choice bioassays and field experiments provides a comprehensive understanding of *Lygus* host preferences and the potential for trap cropping to manage their populations. Further research is needed to optimize planting dates, crop combinations, insecticide use, and biologic control agents to develop sustainable *Lygus* management strategies. Our finding that crop stages can differentially affect *Lygus* species based on their sex, points to the need to manipulate seeding dates or cultivars with various maturity rates to ensure a steady supply of immature reproductive plants to retain females in a trap crop.

Conclusion

This study highlights the complex interplay between *Lygus* and their host plants, such as faba beans, in the Canadian Prairies. Laboratory choice bioassays demonstrated distinct host preferences between male and female *Lygus*. Field experiments further illustrated the complex dynamics of *Lygus* infestations, showing that adjacent crops significantly influence *Lygus* abundance and may reduce damage in faba bean plots.

Our findings suggest that safflower and sunflower could have potential as trap crops to reduce *Lygus* damage to faba beans, although the effectiveness of trap cropping is contingent on appropriate timing and management practices. Specifically, planting dates and the selection of cultivars with differing maturation times are critical factors that warrant further investigation. Insecticide applications, ideally selective to kill pests and spare beneficial insects, are required to reduce *Lygus* populations and associated damage, underscoring the need for integrated pest management (IPM) approaches that combine chemical and biological controls.

Overall, our research provides a foundation for developing sustainable *Lygus* management strategies in faba bean cultivation. Future studies should focus on optimizing trap crop configurations, investigating the role of biological

control agents, and conducting large-scale field trials to validate the efficacy of these approaches in commercial settings. By advancing our understanding of *Lygus*–host interactions and refining IPM techniques, we can mitigate the economic impact of *Lygus* infestations and enhance the productivity and profitability of faba bean cultivation in the Canadian Prairies.

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Data availability Data from these studies is available upon request to the authors.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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