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Research article

Field and Forage Crops

Increased Risk of Insect Injury to Corn Following Rye Cover Crop

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Abstract

Decreased pest pressure is sometimes associated with more diverse agroecosystems, including the addition of a rye cover crop (*Secale cereale* L.). However, not all pests respond similarly to greater vegetational diversity. Polyphagous pests, such as true armyworm (*Mythimna unipuncta* Haworth), black cutworm (*Agrotis ipsilon* Hufnagel), and common stalk borer (*Papaipema nebris* Guenee), whose host range includes rye have the potential to cause injury to crops following a rye cover crop. The objectives of this study were to compare the abundance of early-season insect pests and injury to corn (*Zea mays* L.) from fields with and without a rye cover crop on commercial farms. Fields were sampled weekly to quantify adult and larval pests and feeding injury to corn plants from mid-April until corn reached V8 stage, during 2014 and 2015. Measurements within fields were collected along transects that extended perpendicularly from field edges into the interior of cornfields. Adult true armyworm and adult black cutworm were captured around all cornfields, but most lepidopteran larvae captured within cornfields were true armyworm and common stalk borer. Cornfields with a rye cover crop had significantly greater abundance of true armyworm and greater proportion of injured corn. Both true armyworm abundance and feeding injury were significantly greater in the interior of cornfields with rye. Common stalk borer abundance did not differ between cornfields with or without rye cover. Farmers planting corn following a rye cover crop should be aware of the potential for increased presence of true armyworm and for greater injury to corn.

Key words: Black cutworm, common stalk borer, true armyworm

Decreased pest abundance is associated with more diverse agroecosystems (Root 1973, Andow 1991a, Landis et al. 2000). Diversity in agroecosystems can be measured by the number of species present, the spatial arrangement of species, the temporal relationship among species, or combinations of these factors (Andow 1991a). The scale at which cropping diversity is measured also can vary from the landscape level, to fields, or to individual plants. Greater landscape heterogeneity can increase habitat quality for natural enemies, especially when the area planted to annual monoculture decreases (Landis et al. 2000). Furthermore, increasing the connectivity of suitable habitat within landscapes may enable natural enemies to move and colonize new areas (Frampton et al. 1995). For example, parasitism rates were significantly higher for *Mythimna unipuncta* Haworth (Lepidoptera: Noctuidae), true armyworm, larvae released and recaptured from complex landscapes containing small agricultural fields, hedgerows, and woodlots compared with larvae released and recaptured in simple landscapes dominated by agricultural fields (Marion and Landis 1996). The addition of a second crop or noncrop species increases diversity within fields, and farming practices that promote intra-field diversity include intercropping, weedy culture, and the addition of cover crops (Andow 1991b). Recent literature reviews suggest that greater vegetational diversity within fields generally has a positive effect on natural enemy abundance and a negative effect on the abundance of insect pests (Sunderland and Samu 2000, Symondson et al. 2002, Langellotto and Denno 2004, Letourneau et al. 2011).

The addition of cover crops to agroecosystems can reduce soil erosion and water runoff from fields (Kasper et al. 2001, Hartwig and Ammon 2002) and limit nitrate leaching (Owens et al. 2000). Furthermore, planting a cover crop also increases vegetational diversity within fields (Andow 1991b). Cover crops can positively affect predator abundance within fields (Prasifka et al. 2006, Schmidt et al. 2007) and negatively affect the abundance of insect pests (Tillman et al. 2004, Koch et al. 2012). Rye (*Secale cereale* L.) is planted as a cover crop in the U.S. Corn Belt because of its cold hardiness and early regrowth during the spring (Bollero and Bullock 1994, Dinnes et al. 2002). In the Corn Belt, a rye cover crop is most commonly planted during the fall and terminated in spring before the cash crop is planted (Clark 2007, USDA, NRCS 2013a).

A rye cover crop can reduce insect pest pressure, though the mechanisms for this are not always discernible. The enemies hypothesis predicts that pests should be less abundant in polycultures because natural enemies are more abundant in polycultures compared with monocultures (Root 1973). However, there are observations in which the addition of a rye cover crop resulted in lower pest abundance without a concurrent significant increase in natural enemy abundance (Bottenberg et al. 1997, Koch et al. 2012). Not all pests respond similarly to agroecosystem diversification, and host range is one factor that can alter a pest's response to polyculture. The abundance of monophagous pests is predicted to be lower in more diverse cropping systems compared with monocultures (Root 1973, Risch et al. 1983, Andow 1991). The resource concentration hypothesis predicts that monophagous pests would be more successful in monocultures than in a more diverse agroecosystem based on their capacity to find their host plant (Root 1973). The response of polyphagous pests to greater vegetational diversity in agroecosystems is complex (Andow 1991a) and varies widely among pest species (Risch 1980, Andow 1990, 1991a).

Polyphagous pests associated with rye have the potential to injure a cash crop when rye is added as a cover crop. There are several species of noctuid moths with host ranges that include rye: true armyworm (*M. unipuncta*), black cutworm (*Agrotis ipsilon* Hufnagel; Lepidoptera: Noctuidae), and common stalk borer (*Papaipema nebris* Guenee; Lepidoptera: Noctuidae). In addition to their ability to feed on rye, all are early-season pests of corn (Willson and Eisley 1992, Showers 1997, Rice and Davis 2010). Black cutworm and common stalk borer are highly polyphagous and can complete development on hosts from several plant families (Highland and Roberts 1987, Showers 1997, Rice and Davis 2010). True armyworm is associated primarily with grasses (Poaceae), though its host range also includes other families (Capinera 2008). True armyworm and black cutworm do not overwinter in the Corn Belt, and both migrate northward from southern states each year during early spring (Hendrix III and Showers 1992). Oviposition by true armyworm and black cutworm occurs on grasses and weeds before corn is planted (Showers 1997, Capinera 2008), and black cutworm also will lay eggs on plant debris (Showers 1997). Common stalk borer successfully overwinter in the Corn Belt, diapausing as eggs that have been oviposited on dead vegetation during the fall (Levine 1985, Rice and Davis 2010). Larvae of each species can defoliate young, vegetative corn. In addition, black cutworm and common stalk borer larvae injure corn by cutting stalks and tunneling into plants.

Each of these pests is affected by agronomic practices that alter host-plant diversity within fields, such as the destruction of weed populations, tillage, and planting of cover crops (Rice and Pedigo 1997, Showers 1997, Capinera 2008). Cultural practices that allow for weeds to exist within fields can increase the risk of injury to corn from black cutworm and common stalk borer (Shower 1997, Rice and Davis 2010), as removal of weeds may force black cutworm and common stalk borer larvae migration to corn plants (Showers et al. 1985, Rice and Davis 2010). True armyworm injury to corn is more frequent in fields without tillage that were previously planted to a grassy crop (Harrison et al. 1980, Willson and Eisley 1992). The current recommendations for the use of rye as a cover crop are to terminate the rye 2 wk before corn is planted (MCCC 2012, USDA, NRCS 2013a) to prevent the likelihood of overlap between rye and corn, which could reduce corn yield due to competition (Tollenaar et al. 1993). Whether this recommendation will decrease the risk of injury to corn from these pests is not clear, especially given the challenges that farmers can face in timely removal of a cover crop and planting of the primary crop. In this study, we conducted on-farm research to compare the abundance of early-season insect pests and injury to corn between cornfields with and without a rye cover crop.

Table 1. Number of cornfields sampled and crop phenology during 2014 and 2015

		2014	2015
Cornfields sampled		16	11
Rye cover crop		10	6
Termination method	Herbicide	5	5
	Tillage	5	1
No cover crop		6	5
# Weeks sampled		11	9
Start week		14 April	13 April
End week		30 June	15 June
50% Rye termination[a]		12 May	20 April
50% Corn emergence			
Rye cover crop fields		26 May	11 May
No cover crop fields		19 May	11 May

[a]The date at which the rye cover crop is terminated in >50% of the fields sampled.

We hypothesized that the addition of a rye cover crop to cornfields would increase the abundance of lepidopteran pest species. Furthermore, we hypothesized that injury to corn in fields including a rye cover crop would be greater compared with cornfields without a cover crop.

Materials and Methods

Data Collection

Cornfields were sampled for early-season insect pests and injury to corn on commercial farms in Iowa during 2014 and 2015. There are no genetically modified corn hybrids expressing *Bacillus thuringiensis* (Bt) toxins that are labeled for management of true armyworm, although there are corn hybrids expressing Bt toxins that are labeled for management of common stalk borer and black cutworm (Cullen et al. 2013). Therefore, all cornfields sampled were planted to non-Bt corn hybrids. Corn was either planted following a rye cover crop or into a field without a cover crop. The timing and method of termination for the rye are reported in Table 1. Although fields did not receive insecticide applications in 2014, insecticide was applied to foliage in three of the six cornfields with a rye cover crop in 2015 to manage true armyworm populations that exceeded economic thresholds. In each of these three cornfields, insecticides were applied once between 18 May and 1 June. For these fields, data on larval abundance recorded after application of insecticide were excluded from all analyses.

Cornfields were sampled weekly each year beginning in mid-April until corn reached the V8 developmental stage (Abendroth et al. 2011), which occurred in late June and early July. This stage was selected because corn exceeding the V6 to V8 stage is considered large enough to tolerate injury from true armyworm, black cutworm, and common stalk borer (Showers et al. 1983, Mulder and Showers 1986, Davis and Pedigo 1991).

Data were collected on farming practices within fields, including tillage, application of pesticides, planting date of corn, and emergence of corn plants. Data also were collected weekly on percentage of ground cover, presence of adult and larval pests, insect injury to corn plants, status of the rye cover crop (live or dead), and corn developmental stage. These weekly measurements were taken along a single transect that ran from the edge of each field to the interior. Transects began at an arbitrarily selected location at the border of each field and extended perpendicularly 80 m into the interior of a field, with samples taken every 20 m (0 m [field edge], 20 m, 40 m, 60 m, and 80 m). At each sampling interval, a quadrat (i.e., PVC pipe frame; 0.6 by 1.5 m) was placed on the ground and data collected on the area inside the quadrat (Laub and Luna 1991). When corn emerged within fields, the quadrat was centered over a single row of corn and contained 5.4 ± 0.1 corn plants (mean ± SEM; $N = 779$ samples).

Measurements of percent ground cover included total ground cover and rye ground cover. Total ground cover included everything that covered the soil surface, including plant debris, weeds, corn, and rye. Rye ground cover was defined as the percentage of the ground covered by the rye cover crop, and including both live and dead rye plants. Both total ground cover and rye ground cover were visually estimated to the nearest 5%. The soil surface and all plant material within quadrats were searched for lepidopteran larvae. All larvae were captured, stored in 85% ethanol, and identified to species. Data were collected on feeding injury to each corn plant within a quadrat, including the incidence of feeding injury (the number of plants that displayed feeding injury) and the severity of feeding injury (the percentage of leaf area consumed on each injured plant). The severity of feeding injury was estimated to the nearest 5% based on visual inspection.

Species-specific sex pheromone wing traps (Trece Inc., Adair, OK) were used to sample true armyworm and black cutworm adults to estimate the potential for true armyworm and black cutworm larvae to be found within cornfields. Two wing traps per species were placed around the border of each cornfield. Traps were changed weekly and pheromone lures within traps were changed every fourth week.

Data Analysis

All analyses were performed in SAS statistical software version 9.3 (SAS Institute, Cary, NC). Total ground cover within cornfields, adult true armyworm abundance, and adult black cutworm abundance were each analyzed separately by year with repeated-measures analysis of variance (ANOVA; PROC MIXED). Fixed effects in the model were cover treatment (rye cover crop vs. no cover crop), sampling week, and their interaction. Sampling week was used as a repeated measure with compound symmetry covariance structure. Random factors in the analysis included location nested within cover treatment and the interaction of sampling week and location nested in cover treatment. Data were transformed by the Log $(x + 0.5)$ function to ensure normality of the residuals. When significant effects were present, pairwise comparisons were made using the PDIFF option in PROC MIXED. Alpha levels were adjusted for multiple comparisons using the Bonferroni correction. For cornfields with a rye cover crop, the percentage of rye ground cover within fields was analyzed with repeated-measures ANOVA (PROC MIXED). Model effects were identical to the analysis of total ground cover, but excluded the effect of cover treatment. Data on percent rye ground cover were also transformed by the Log $(x + 0.5)$ function to ensure normality of the residuals. The LSMEANS statement was used to test if rye cover during each sampling week was significantly different from zero.

Variances for larval abundance and feeding injury to corn were heterogeneous even after data were transformed; therefore, analyses were performed with nonparametric Mann–Whitney–Wilcoxon test (PROC NPAR1WAY). Mann–Whitney–Wilcoxon tests were used to compare the effect of cover treatment on the overall abundance of larvae, larval abundance by sampling week, and larval abundance by distance measured along transects. Data were analyzed separately

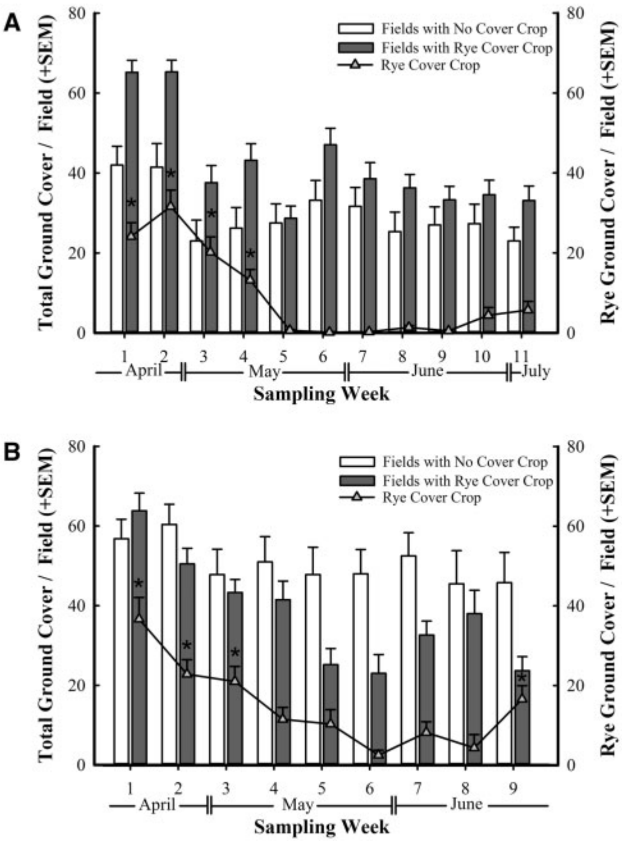

Fig. 1. Total ground cover and rye ground cover in cornfields from 2014 (**A**) and 2015 (**B**). Bar heights and points represent sample means and error bars are the standard error of the means. Stars represent sampling weeks when the percentage of rye ground cover was significantly greater than 0%.

for each species. Furthermore, analyses also were conducted to test the effect of cover treatment on the incidence and severity of feeding injury. Data from 2014 and 2015 were analyzed separately for larval abundance by sampling week, but years were combined for all other analyses. To conserve statistical power, tests of larval abundance by sampling week were only performed for weeks when both corn and larvae were present within fields. Alpha levels were adjusted for multiple comparisons using the Bonferroni correction based on the number of comparisons.

Results

Ground Cover

In 2014, total ground cover did not significantly differ between cornfields that had a rye cover crop and those that did not ($F = 2.09$; df = 1, 14; $P = 0.17$), but did change significantly among sampling weeks ($F = 4.91$; df = 10, 140; $P < 0.0001$; Fig. 1A). The percentage of rye ground cover in fields with a rye cover crop changed significantly over time in 2014 ($F = 17.5$; df = 10, 90; $P < 0.0001$; Fig. 1A). The majority of rye cover crops within fields were terminated by the fourth week of sampling (12 May; Table 1), and after the fourth week of sampling, the percentage of rye ground cover did not differ significantly from zero. In 2015, total ground cover again did not significantly differ between cornfields with and without a rye cover crop ($F = 0.8$; df = 1, 9; $P = 0.40$), but varied significantly over time ($F = 4.08$; df = 8, 64; $P = 0.0006$; Fig. 1B). Rye ground cover in 2015 also differed significantly over time ($F = 3.98$; df = 8,

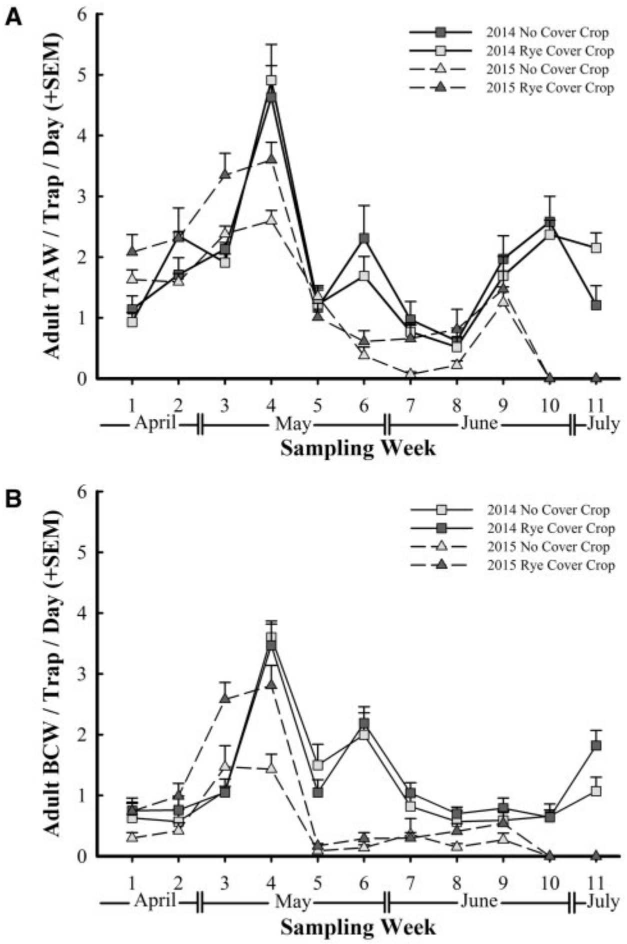

Fig. 2. Adult true armyworm (TAW) (**A**) and black cutworm (BCW) (**B**) captured by pheromone traps during 2014 and 2015. Bar heights represent sample means and error bars are the standard error of the means.

36; $P = 0.0019$; Fig. 1B). The rye cover crops were terminated earlier than in 2014 (Table 1), though rye ground cover was significantly greater than zero within cornfields 2 wk after termination and during the final week of sampling.

Lepidopteran Community

During both 2014 and 2015, adult true armyworm and black cutworm were captured at all cornfields sampled regardless of the presence or absence of a rye cover crop. There was no significant difference in the abundance of adult true armyworm ($F = 0.01$; df = 1, 14; $P = 0.92$) or black cutworm ($F = 0.86$; df = 1, 14; $P = 0.37$) captured between cornfields with or without a rye cover crop in 2014 (Fig. 2A and B, respectively). By contrast, in 2015, the number of true armyworm ($F = 5.88$; df = 1, 8; $P = 0.042$; Fig. 2A) and black cutworm ($F = 8.86$; df = 1, 8; $P = 0.018$; Fig. 2B) captured was significantly greater for cornfields with a rye cover crop.

Larvae of six lepidopteran species were collected in cornfields. The majority of larvae captured during the study, 82%, were captured from fields that had a rye cover crop (Table 2). In 2014, the majority of larvae captured were true armyworm (42%) and common stalk borer (42%), while only one black cutworm larvae was found. Three other species were collected in 2014: *Hypena scabra* Fabricius (Lepidoptera: Erebidae), green cloverworm; *Feltia jaculifera* Guenee (Lepidoptera: Noctuidae), dingy cutworm; and *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae), fall armyworm. Three species of larvae were collected from cornfields in 2015, of which true armyworm represented 80% of larvae captured. Common stalk borer represented 19% of larvae captured. Again, there was only a single black cutworm larva collected.

Larval Distribution Within Fields

True armyworm larvae were significantly more abundant in cornfields that had a rye cover crop ($Z = 4.28$; $P < 0.0001$). Ninety-six of the 102 true armyworm larvae were collected from fields that had a rye cover crop (Table 2). Furthermore, there were significantly more true armyworm larvae captured in the interior of cornfields with a rye cover crop than cornfields without a cover crop (Fig. 3A). True armyworm larvae were significantly more abundant at 60 m ($Z = 2.61$; $P = 0.028$) and 80 m ($Z = 2.60$; $P = 0.028$) into the interior of fields that had a rye cover crop. In cornfields without a rye cover crop, true armyworm was captured only at field edges. Differences in true armyworm abundance were significant only once when compared between field types over time, with significantly more larvae found in fields with a rye cover crop during the ninth week of sampling in 2014 (Table 3).

Common stalk borer larval abundance did not differ between cornfields with or without a rye cover crop ($Z = 0.01$; $P = 0.99$). These larvae were almost exclusively found at the edges of cornfields, and abundance of larvae did not differ between fields with and without a rye cover at any distance along transects (Fig. 3B). In addition, there were no differences in abundance of common stalk borer larvae between field types over time (Table 3). Black cutworm larvae were rare (Table 2); therefore, no statistical analyses were performed for black cutworm larvae.

Feeding Injury

There was a significantly greater incidence of defoliated corn plants in fields that had a rye cover crop (8.5% ± 0.9; mean ± SEM) compared with fields without a cover crop (2.3% ± 0.5; $Z = 5.89$; $P < 0.0001$). The incidence of feeding injury was also significantly greater in fields with a rye cover crop when sampled at 40 m ($Z = 3.11$; $P = 0.011$), 60 m ($Z = 3.97$; $P < 0.0001$), and 80 m ($Z = 3.35$; $P = 0.005$) from field edges (Fig. 4). For corn plants that were defoliated by insect larvae, the severity of feeding injury did not differ between fields with a rye cover crop (27.6% ± 1.9) and without a cover crop (22.3% ± 2.6; $Z = 0.02$; $P = 0.92$).

Discussion

From 2 yr of sampling commercial cornfields, we observed a significant increase in the occurrence of an early-season lepidopteran pest and defoliation of corn in cornfields that followed a rye cover crop. These results support the hypothesis that rye as a cover crop in cornfields increases the abundance of an early-season pest. However, true armyworm was the only early-season pest to respond significantly to the presence of a rye cover crop within fields (Fig. 3A). Common stalk borer abundance was not affected by the presence of the rye cover crop (Fig. 3B) and other lepidopteran larvae were rare (Table 2). These data also support the hypotheses that the use of rye as a cover crop in cornfields would increase the incidence of feeding injury to corn, as there were significantly more defoliated corn plants present in fields that included a rye cover crop (Fig. 4).

Table 2. Larvae captured by year from cornfields with and without a rye cover crop

Year	Family	Species		No cover	Rye cover
2014	Erebidae	*Hypena scabra*	Green cloverworm	0	1
	Noctuidae	*Agrotis ipsilon*	Black cutworm	0	1
		Feltia jaculifera	Dingy cutworm	0	1
		Mythimna unipuncta	True armyworm	1	19
		Papaipema nebris	Common stalk borer	6	14
		Spodoptera frugiperda	Fall armyworm	0	4
2015	Noctuidae	*Agrotis ipsilon*	Black cutworm	1	0
		Mythimna unipuncta	True armyworm	5	77
		Papaipema nebris	Common stalk borer	13	6

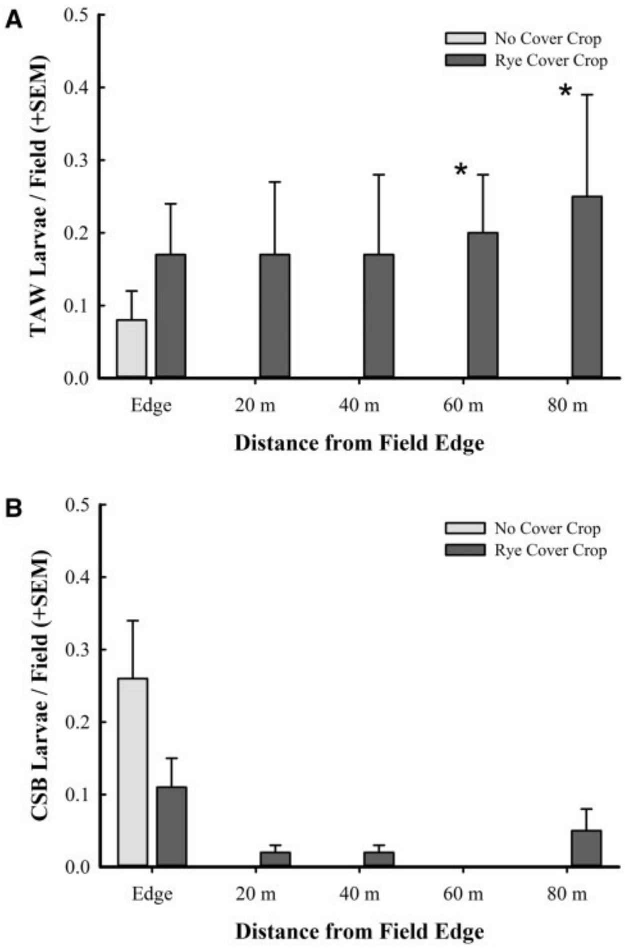

Fig. 3. True armyworm (TAW) (**A**) and common stalk borer (CSB) (**B**) larvae captured along transects. Data were combined from 2014 and 2015. Bar heights represent sample means and error bars are the standard error of the means. Stars represent a significant difference in larval abundance between cornfields with and without a rye cover crop at a specific distance along transects.

There was no significant difference in common stalk borer abundance between cornfields with or without a rye cover crop (Fig. 3B). Female common stalk borer preferentially oviposit on thin-stemmed, perennial grasses compared with annual, wide-leaved grasses (such as rye) or broad-leaved plants (Levine 1985, Highland and Roberts 1989, Rice and Davis 2010). The majority of common stalk borer eggs are deposited throughout the fall between curled leaves and stems, most frequently on dead vegetation (Levine 1985). Common stalk borer oviposition appears unlikely to occur within fields with a rye cover crop, given that common stalk borer larvae were rarely observed in the interior of cornfields (Fig. 3B). Injury to corn by common stalk borer is typically limited to field margins where corn is found adjacent to grass waterways, ditches, or terraces (Davis and Pedigo 1990, Meyer and Peterson 1998). Destruction of weedy host plants by herbicides can facilitate common stalk borer movement into cornfields (Levine 1993), and studies have shown that common stalk borer larvae readily consume and tunnel into rye plants (Highland and Roberts 1987). However, the abundance of common stalk borer larvae at field edges (Fig. 3B) and the incidence of defoliated corn plants at field edges (Fig. 4) both did not differ between cornfields with or without a rye cover crop. Therefore, the use of a rye cover crop did not facilitate injury to corn by common stalk borer.

When corn is planted following a rye cover crop, timing of rye termination is considered critical to preventing negative impacts on corn development (Raimbault et al. 1990, Tollenaar et al. 1993, MCCC 2012). Early termination of a rye cover crop is thought to reduce the risk of injury to corn by true armyworm because eggs oviposited prior to the rye's termination hatch without sufficient food and may starve before corn emerges (MCCC 2012). However, our data indicate that early termination of a rye cover crop did not ameliorate the risk of true armyworm injury to corn (Table 1; Fig. 3A). Defoliation of corn plants was significantly greater throughout cornfields that contained a rye cover crop (Fig. 4). As common stalk borer was predominately found at field edges (Fig. 3B) and the presence of other lepidopteran larvae was rare (Table 2), defoliation injury to corn in the interior of fields can be attributed primarily to true armyworm (Figs. 3A and 4).

There are limited preventative management tactics available to farmers for true armyworm and some of the other lepidopteran larvae that we observed. At present, there are no seed treatments labeled for either true armyworm or common stalk borer management, though most seed treatments offer at least some suppression of black cutworm (Smith and Proost 2011). Furthermore, there are no genetically modified corn hybrids expressing Bt toxins that are labeled for true armyworm management (Cullen et al. 2013). Greenhouse and field trials have demonstrated that Bt corn hybrids expressing Cry1Ab (events Mon810 and Bt176) and Cry1F (event TC1507) each experienced less true armyworm injury compared with their respective non-Bt isolines (Schaafsma et al. 2007). Field trials have shown that insecticides including organophosphate (chlorpyrifos and acephate) applied at planting can provide protection from true armyworm injury to corn following a rye cover crop (Harrison et al. 1980).

Table 3. Mean larval abundance (± standard error of the mean) by sampling week from cornfields with and without a rye cover crop during 2014 and 2015

Week sampled	True armyworm			Common stalk borer		
	No cover	Rye cover		No cover	Rye cover	
2014						
(June)[a] Wk 7	0.0 (±0.0)	0.0 (±0.0)		0.0 (±0.0)	0.0 (±0.0)	
Wk 8	0.0 (±0.0)	0.02 (±0.1)	$Z = 0.8$; $P = 1.0$[b]	0.0 (±0.0)	0.0 (±0.0)	
Wk 9	0.03 (±0.1)	0.3 (±0.1)	$Z = 2.8$; $P = 0.04$	0.0 (±0.0)	0.02 (±0.1)	$Z = 0.8$; $P = 1.0$
Wk 10	0.0 (±0.0)	0.04 (±0.1)	$Z = 1.1$; $P = 1.0$	0.0 (±0.0)	0.08 (±0.1)	$Z = 1.1$; $P = 1.0$
(July) Wk 11	0.0 (±0.0)	0.0 (±0.0)	.	0.07 (±0.1)	0.10 (±0.1)	$Z = 0.5$; $P = 1.0$
Wk 12	0.0 (±0.0)	0.02 (±0.1)	$Z = 0.8$; $P = 1.0$	0.13 (±0.1)	0.08 (±0.1)	$Z = 0.5$; $P = 1.0$
2015						
(May) Wk 4	0.0 (±0.0)	0.0 (±0.0)		0.0 (±0.0)	0.0 (±0.0)	
Wk 5	0.0 (±0.0)	0.0 (±0.0)		0.0 (±0.0)	0.0 (±0.0)	
Wk 6	0.0 (±0.0)	0.6 (±0.2)	$Z = 2.3$; $P = 0.08$	0.08 (±0.1)	0.07 (±0.1)	$Z = 0.1$; $P = 1.0$
(June) Wk 7	0.04 (±0.1)	0.4 (±0.2)	$Z = 1.7$; $P = 0.3$	0.08 (±0.1)	0.04 (±0.1)	$Z = 0.01$; $P = 1.0$
Wk 8	0.02 (±0.1)	3.3 (±1.2)	$Z = 2.2$; $P = 0.12$	0.0 (±0.0)	0.13 (±0.1)	$Z = 0.7$; $P = 1.0$
Wk 9	0.01 (±0.1)	0.01 (±0.1)	$Z = 0.4$; $P = 1.0$	0.20 (±0.1)	0.10 (±0.1)	$Z = 0.04$; $P = 1.0$
Wk 10	0.0 (±0.0)	0.0 (±0.0)	.	0.20 (±0.1)	0.0 (±0.0)	$Z = 1.1$; $P = 1.0$

[a]Denotes the month in which sampling weeks occurred.

[b]Mann–Whitney–Wilcoxon test results comparing differences between larval abundance from cornfields with and without a rye cover crop. Tests were only performed during sampling weeks when both corn and larvae were present within fields.

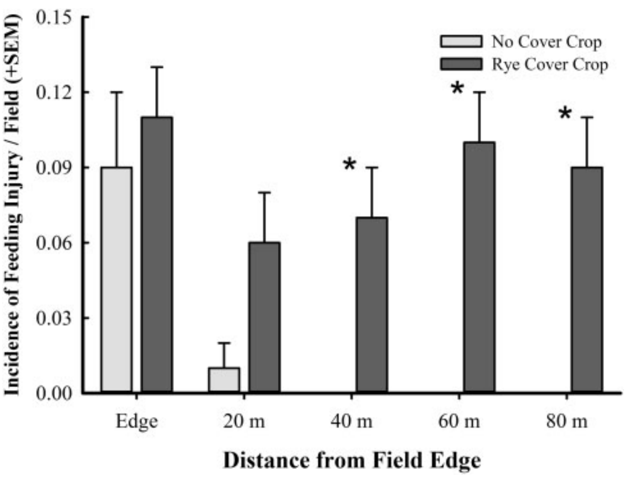

Fig. 4. Incidence of feeding injury by distance along transects. Data were combined from 2014 and 2015. Bar heights represent sample means and error bars are the standard error of the means. Stars represent a significant difference in injury between cornfields with and without a rye cover crop at a specific distance along transects.

As true armyworm sporadically reach high densities, in irregular intervals anywhere between 5 and 20 yr apart (Guppy 1961, Capinera 2008), the prophylactic use of insecticides is likely not cost-effective. An alternative approach could include integrative pest management strategies, such as scouting for true armyworm larvae and injury, economic thresholds for treatment decisions (Varenhorst et al. 2015), and farm management practices that conserve beneficial arthropods (Marion and Landis 1996, Landis et al. 2000). The three farmers who experienced higher true armyworm larval abundance and corn defoliation in 2015, of which all three had planted corn following a rye cover crop, used a foliar-applied, pyrethroid insecticide (lambda-cyhalothrin or zeta-cypermethrin), and true armyworm populations were suppressed successfully in each case (M.W.D., personal observation). However, farmers planting corn following a rye cover crop should be aware of the potential effect of rye cover crop on injury to corn from true armyworm.

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