Winter Cereal Cover Crops Have Limited Impact on Invertebrate Activity in Corn and Soybean Field Experiments in East Central Illinois[1]

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Abstract Illinois corn and soybean farmers have increased their use of cover crops, particularly winter cereals such as cereal rye (*Secale cereale* L.) and winter wheat (*Triticum aestivum* L.), as a conservation practice in recent years. Use of a winter cereal cover crop could impact the invertebrate fauna present within a field, including potentially both pest and beneficial species. We assessed insect and slug activity density and injury to the crop in field experiments planted to corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merrill) that had been established to study the impact of cover crops on agronomic management and nutrient loss reduction. A cereal rye cover crop resulted in marginal increases in ground beetle (Coleoptera: Carabidae) and spider (Araneae) activity and a slight decrease in early-season injury to soybean. Increased cover crop biomass associated with later termination timings resulted in higher spider activity densities. Slight increases in slug activity were associated with the latest termination of cover crops, but the effect was not consistent at the other termination timings. Neither cover crop presence nor termination timing affected injury to corn; however, in most cases the cover crop was terminated well before corn planting (≥3–4 weeks). Plant stand was not affected by cover crop treatment at any of our sites. Although care should be taken in drawing broad conclusions, cover crops had a relatively minor impact on economically important insects and other invertebrates in this experiment and reduced injury in one instance.

Key Words conservation cropping, ground beetle, slug, spider

Farmers in the United States expanded their use of cover crops in recent years, resulting in a roughly 50% increase in acreage across the country from 2012 to 2017 (Wallander et al. 2021). Cover crops are used to provide ground cover during periods when it would otherwise be left bare in the fall–spring after corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merrill) grown in the midwestern United States. Cover crops can provide a variety of environmental and crop management benefits, while sometimes limiting yield and posing other challenges to the crop production system.

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As an in-field management practice that can mitigate soil erosion and nutrient runoff, cover crop adoption was made a central part of the Illinois Nutrient Loss Reduction Strategy (Illinois Environmental Protection Agency et al. 2015). State and federal programs have been created to incentivize cover crop adoption, providing stipends ranging from approximately US$5 to $37 per hectare (Wallander et al. 2021). Winter cereals (Poales: Poaceae), including varieties of rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.), and several other fall-seeded overwintering grasses, have been the most frequently used cover crops in the midwestern United States, either alone or in combination with a species blend (Wallander et al. 2021). Despite this expansion in acreage, cover cropped acres make up a relatively small proportion of the agricultural landscape, particularly in flat, tile-drained areas such as east central Illinois.

The addition of a cover species into a cropping system could alter the insect community present and ultimately affect pest management. Cover crops have resulted in both positive and negative pest management outcomes in corn and soybean (reviewed by Inveninato Carmona et al. [2021]). In some cases, incorporating a cover crop reduced pest injury or incidence. A winter rye cover crop resulted in lower densities of soybean aphid (*Aphis glycines* Matsumura) and potato leafhopper (*Empoasca fabae* (Harris)) in soybean in Minnesota (Koch et al. 2012). Reduced western corn rootworm (*Diabrotica virgifera* LeConte) densities when slender wheatgrass (*Elymus trachycaulus* (Link) Gould ex Shinners) was used as a winter cover were attributed to increased rates of predation in South Dakota cornfields (Lundgren and Fergen 2010). Cover crops often increased beneficial insect abundance and/or activity density (particularly ground beetles [Coleoptera: Carabidae]; Adhikari and Menalled 2020, Dunbar et al. 2017, Inveninato Carmona et al. 2022, Lundgren and Fergen 2010). However, greater pest abundance and injury have also been linked to cover crop use in some cases. A rye cover crop was associated with a greater risk of insect injury to seedling corn in Iowa, with the armyworm *Mythimna unipuncta* Haworth (Lepidoptera: Noctuidae) identified as the most frequent culprit (Dunbar et al. 2016). Either alfalfa or rye cover crops increased seedcorn maggot (*Delia platura* (Meigen)) injury to soybean dramatically in Ohio, but only when they were incorporated using tillage before planting (Hammond 1990). Occasionally, cover crop use has led to atypical pest infestations; for example, grass cover crop use was associated with injury from wheat stem maggot (*Meromyza americana* Fitch) in some Nebraska cornfields (Inveninato Carmona et al. 2019).

Although the tendency for cover crops to increase predatory insect activity represents an additional potential benefit, the potential for increased injury to the crop could dissuade farmers from adopting cover crops as a management tool. Farmers must know the nature and frequency of pest and beneficial incursions into cover-cropped fields to make an informed assessment of their impact on pest management. We evaluated insect and slug activity and crop injury at field experiments that had been established to assess nutrient management and crop performance when winter cereal cover crops were used in corn and soybean production systems on land drained by tile. Our objective was to determine the impact of winter cereal cover crops on pest management in these crops in east central Illinois, an area where cover-cropped land currently makes up a small portion (<5%) of the overall agroecosystem.

Materials and Methods

Experimental sites and design. We monitored insect population densities and injury at the sites of 2 field experiments established to study the effects of winter cereal cover crops on nutrient management and runoff. Our assessments represented a baseline evaluation during the early stages of cover crop introduction onto the flat, tile-drained prairie soils that make up much of the agricultural landscape in east central Illinois. Before planting, seed at both sites was treated with up to 0.15 mg of thiamethoxam per seed (soybean) or with up to 1.25 mg of clothianidin per seed (corn); however, precise seed treatment details for any particular site-year were not available. Both sites were strip tilled in the spring with the cash crop planted into the tilled strip, resulting in minimal disturbance to cover crops. The first field experiment in Douglas Co., IL (39.720114, −88.239728), evaluated corn and soybean grown in an annual rotation with 6 replicate blocks (3 planted to corn and 3 planted to soybean in any given year; agronomic information including cultivar provided in Table 1). Cover crops were planted on 2.3% of farmland in Douglas Co. in 2022, up from 1.1% in 2017 (U.S. Department of Agriculture National Agricultural Statistics Service [USDA NASS] 2022). Plots were 24–25 m wide (each plot was centered over one of a series of parallel tile lines that varied slightly in their spacing) and from 475 to 660 m long, depending on the length of the field, resulting in a plot area of 1.14–1.65 ha. The 6 experimental treatments were different N management (in the corn blocks) and cover crop regimes; the design and rotation history (through 2019) at this site are described in more detail in Gentry et al. (2024). Our monitoring focused on only 2 of these treatments: one that had no cover crop and one in which a winter cereal cover crop was used each year (i.e., before both corn and soybean). In years in which soybean was to be planted in the spring, cereal rye was used as the cover crop; in years in which corn was to be planted in the spring, annual ryegrass (2019 growing season) or winter wheat (2020 and 2021) was used as the cover crop. All plots we sampled were treated with the same N-management regime during seasons in which corn was planted: 89.7 kg/ha of N applied as anhydrous ammonia (NH_3) during early spring followed by 89.7 kg/ha of N applied as side-dressed 32% urea–ammonium nitrate solution at growth stage V4/V5 (Ritchie et al. 1986). The corn blocks were not sampled in 2019 due to a harsh winter that killed the planned annual ryegrass cover crop stand. Thus, we sampled soybean plots in 2019, corn and soybean plots in 2020, and corn and soybean plots in 2021.

The second field experiment in Champaign Co., IL (40.025680, −88.275657), evaluated the impacts of termination timing of cereal rye and N application timing on continuous corn (since 2017) in 2019 and 2020. Cover crops were planted on 3.9% of farmland in Champaign Co. in 2022, up from 1.7% in 2017 (USDA NASS 2022). Plots were 12 m wide and 402 m long, resulting in a plot area of 0.48 ha; agronomic information, including cultivar, is provided in Table 1. The experimental design was a randomized complete block split-plot design with 3 replicate blocks. The whole plot factor was cover crop treatment (4 levels): no cover (control), cereal rye–early termination, cereal rye–middle termination, and cereal rye–late

Table 1. Agronomic characteristics of field experiments evaluating the effects of presence or absence (Douglas Co.) or timing of termination with a herbicide (Champaign Co.) of winter cereal cover crops on invertebrate activity and injury to corn or soybean.

Douglas Co. Site

Year	Cover Crop (Planting Date–Termination Date), Biomass	Cash Crop Planting Date (Variety, Seeding Rate)
2018–2019	Cereal rye* (5 Sept. 2018–6 May 2019), 2.9 Mg/ha	Soybean 8 June 2019 (AG32X8**), 72,870 seeds/ha
2019–2020	Cereal rye* (6 Nov. 2019–13 May 2020), 2.2 Mg/ha	Soybean 2 June 2020 (3110†), 56,680 seeds/ha
	Winter wheat‡ (10 Oct. 2019–14 Apr. 2020), 0.46 Mg/ha	Corn 2 June 2020 (6368SX†), 13,970 seeds/ha
2020–2021	Cereal rye* (3 Nov. 2020–5 May 2021), 0.5 Mg/ha	Soybean 6 June 2021 (3110†), 56,680 seeds/ha
	Winter wheat§ (14 Oct. 2020–5 May 2021), 1.19 Mg/ha	Corn 6 June 2021 (5829A4†), 13,970 seeds/ha

Champaign Co. Site

Year	Cereal Rye* Planting Date–Termination Date, Biomass	Corn Planting Date (Variety, Seeding Rate)
2018–2019	15 Oct. 2018–9 Apr. 2019, 1.06 Mg/ha	Corn planted 6 June 2019 (FS 63ZX1 RIB§§), 13,970 seeds/ha
	15 Oct. 2018–23 Apr. 2019, 1.50 Mg/ha	
	15 Oct. 2018–7 May 2019, 3.20 Mg/ha	
2019–2020	10 Nov. 2019–7 Apr. 2020, 0.13 Mg/ha	Corn planted 13 May 2019 (FS 63ZX1 RIB§§), 13,970 seeds/ha
	10 Nov. 2019–21 Apr. 2020, 0.22 Mg/ha	
	10 Nov. 2019–12 May 2020, 0.84 Mg/ha	

* Variety not stated (Kitchen Seed Company, Arthur, IL).
** Asgrow, Bayer Crop Science (St. Louis, MO).
† Beck's Hybrids (Atlanta, IN).
‡ Variety not stated, bin-run winter wheat seed.
§ Variety not stated, landscape cover wheat (Kitchen Seed Company).
§§ FS 63ZX1 RIB, Growmark Inc. (Bloomington, IL).

termination. The split-plot factor was 3 different combinations of N-fertilizer type (NH_3 and/or 32% urea–ammonium nitrate solution) and application timing that each resulted in 224.0 kg/ha of total N. Because we did not expect N-fertilizer timing or form to have an impact on insect populations and to avoid damage to our traps from the side-dress applications, our insect monitoring was conducted only within split-plots that received N fertilizer as a single application of NH_3 applied in the spring. This made the experimental design for the insect response variables we assessed effectively a randomized complete block design with 3 replicate-blocks based on field location and 4 treatments: the 3 cereal rye termination timings plus a no-cover crop control.

Invertebrate sampling. We sampled each plot to assess pest and beneficial insect/invertebrate population densities as well as the injury to corn or soybean seedlings, during the early growing season. Our intent was to sample each plot for a 6-week period centered around cash crop planting date (i.e., 3 weeks before planting and 3 weeks after planting). However, because planting date was variable due to weather and soil conditions, our sampling window also varied among site-years. We sampled 2 points from each plot by using the following methods, described individually in subsequent paragraphs: pitfall traps (a measure of activity density of ground beetles and other ground-dwelling invertebrates), shingle traps (a time point sample to assess slug density), cash crop stand, and insect injury to cash crop. The locations of the 2 sampling points per plot where we performed these assessments remained consistent throughout each sampling season, but no effort was made to use identical locations in subsequent years.

Pitfall traps were composed of 473.2-ml (16-fl oz) plastic deli cups (ULINE, Pleasant Prairie, WI) that were buried in the soil such that the 10.5-cm-diameter opening of the cup was at ground level. Approximately 100 ml of a 50:50 propylene glycol:water mixture was used in each trap to arrest and preserve small invertebrates that fell in during their natural movement behaviors (i.e., this was a passive trap that did not use an attractant). In 2019, each deli cup was nested within an identical cup that maintained a cavity in the ground, allowing for easy removal of the contents of the pitfall trap. Spring 2019 was unusually wet, and the swelling of saturated soils pushed these traps out of the ground, resulting in frequent loss of data due to lost trap contents, ineffective traps, or both. In 2020, the outer cup was replaced by a polyvinyl chloride (PVC) pipe socket coupler designed for 10.16-cm (4-in.) outer diameter PVC sewer and drain pipe. The deli cups fit snugly into these couplers, leaving a 5-mm "lip" of the deli cup exposed that could be easily grasped to remove and replace the deli cups during trap servicing without disturbing the surrounding soil. This more rigid structure with an open bottom resisted soil swelling, and no traps were lost for this reason following this design change. A disposable plastic dinner plate (30.5 cm in diameter) was elevated on steel duplex nails over each trap in 2019 to form a cover to prevent rain from entering the traps; in 2020 and 2021, this was replaced by a 30.5 $\times$ 30.5-cm square polypropylene fluted plastic board elevated by steel wire threaded through the interior corrugation. In all years, the elevation of the trap cover created a gap of 2.5 cm between the cover and the ground through which invertebrates could pass. Pitfall traps were emptied each time plots were sampled (approximately once per week); therefore, each sample represented the total number of insects collected during the sampling interval. Collected invertebrates were placed in a labeled resealable plastic bag and stored at −4° C until they could be processed. Slugs (Stylommatophora: Agriolimacidae; primarily the grey garden slug, *Deroceras reticulatum* Müller), ground beetles, spiders (Araneae), and millipedes (Diplopoda) were identified to the taxonomic level indicated and counted. Slugs were counted from 2019 to 2021, whereas other invertebrates were only counted from 2020 to 2021.

Shingle traps were used to estimate slug density at a point in time; when placed on the ground, the shingles create a dark, moist, slug-attractive shelter (Douglas and Tooker 2012). White rolled roofing material was cut into 30.5 × 30.5-cm squares to construct the traps. At each sampling point, crop residue was brushed away by hand and an individual shingle trap was placed directly on the soil surface. A wire flag was placed through the center of each trap to mark its location and hold it in place. Each time plots were sampled, the shingle trap was lifted, and all slugs on the surface of the ground or attached to the underside of the shingle trap were counted and recorded in the field (i.e., specimens were not collected).

Once the cash crop (corn or soybean) had emerged, stands were estimated at each sample location by counting all plants in a 0.000405-ha sample. Because the cash crop at all locations was planted using a 0.762-m row spacing, each sample was 5.3 m of a single row. In addition to the total number of live plants, the total number of plants showing insect or slug injury was recorded. Stands were recorded from all plots from 2019 to 2020, but not in 2021.

Data analysis. Pitfall captures were totaled by plot and year before analysis for both the Douglas Co. and Champaign Co. sites. All analyses were performed using SAS 9.4 (SAS Institute, Inc., Cary, NC). All analyses for the Douglas Co. site were performed separately for each cash crop (corn and soybean). Total slugs, ground beetles, spiders, and millipedes collected per plot were analyzed separately for each site by using a generalized linear mixed model (PROC GLIMMIX) where cover crop treatment (Douglas Co.: 2 levels, cover crop or no cover crop; Champaign Co.: 4 levels, no cover or first, second, or third termination timing) was the lone fixed effect, whereas year and replicate block (nested within year) were considered random effects. Plant stand and proportion of plants injured by invertebrates were analyzed using similar models; 1 sampling date was chosen per site per year where the proportion of plants injured by invertebrates reached its seasonal peak (Douglas Co.: 3 July 2019 and 22 June 2020; Champaign Co.: 8 July 2019 and 15 June 2020). Because injury to soybean was much higher in 2019 than in 2020 at Douglas Co., proportion injury to soybean at that site was subjected to additional, separate analyses by year, where cover crop treatment was the lone fixed effect and replicate block was the lone random effect.

Results

Douglas Co. site. The effect of cover crop treatment on the activity density of invertebrates was not significant ($\alpha = 0.05$) in most cases (Table 2). Ground beetles (Fig. 1) and spiders (Fig. 2) had greater mean activity densities in soybean plots following a cereal rye cover crop than in the no-cover soybean plots. The proportion of soybean plants injured by invertebrates was slightly greater in the no-cover plots than in the plots that followed cereal rye (Table 2); this effect was pronounced in 2019 (Fig. 3) when the overall proportion of plants injured was 0.584 ± 0.042 (mean ± SE), but was not significant in 2020 when the overall proportion of soybean plants injured

Table 2. Generalized linear mixed model statistics for data collected from the Douglas Co. field experiment evaluating the presence or absence of a winter cereal cover crop (cereal rye ahead of soybean or winter wheat ahead of corn).

Dependent Variable	Distribution	df Numerator	df Denominator	*F*	*P*
Carabids - pitfall traps - corn	Poisson	1	5	1.42	0.287
Carabids - pitfall traps - soybean	Poisson	1	5	6.79	0.048*
Slugs - pitfall traps - corn	Poisson	1	5	5.43	0.067
Slugs - pitfall traps - soybean	Poisson	1	16	0.03	0.868
Slugs - shingle traps - soybean	Poisson	1	16	3.98	0.063
Spiders - pitfall traps - corn	Poisson	1	5	1.15	0.333
Spiders - pitfall traps - soybean	Poisson	1	5	11.56	0.019*
Millipedes - pitfall traps - corn	Poisson	1	5	1.11	0.340
Millipedes - pitfall traps - soybean	Poisson	1	5	4.65	0.084
Plant stand - corn	Lognormal	1	2	1.33	0.368
Plant stand - soybean	Lognormal	1	5	3.73	0.111
Proportion injured plants - corn	Normal	1	2	1.00	0.423
Proportion injured plants - soybean (2019–2020)	Beta	1	5	14.00	0.013*
Proportion injured plants - soybean - 2019	Beta	1	2	67.39	0.015*
Proportion injured plants - soybean - 2020	Beta	1	2	1.26	0.379

* Effect is significant at $\alpha = 0.05$.

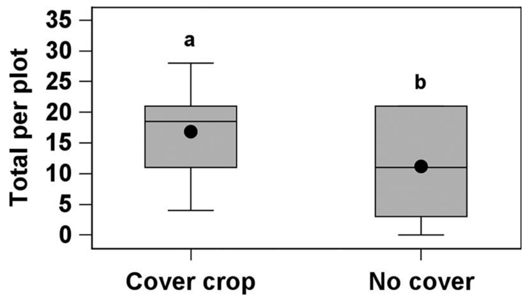

Fig. 1. Total ground beetles (Coleoptera: Carabidae) captured in pitfall traps (2 per plot) in plots of soybean that were either preceded by cereal rye (cover crop) or fallow ground (no cover) during fall–spring.

was much lower (0.020 ± 0.004). Plant stand was not affected by cover crop treatment in either corn or soybean (Table 2).

Champaign Co. site. The effect of cover crop termination timing ahead of corn planting on the activity density of invertebrates was not significant ($\alpha = 0.05$) in most cases (Table 3). Slugs (Fig. 4) were highest in plots where the rye cover crop was terminated last; however, variability was high and there was not a consistent pattern of increased slugs with delayed termination/increasing cover crop biomass (Table 1). By contrast, spiders (Fig. 5) did follow a consistent pattern, with lowest activity densities in the no-cover plots and increasing activity densities as cover crop termination was delayed. Corn stand and injury to corn due to invertebrate feeding were not affected by cover crop termination timing (Table 3); the overall proportion of corn plants injured by invertebrates was consistently low in this field experiment (0.027 ± 0.007 in 2019, 0.130 ± 0.017 in 2020).

Discussion

Cover crops resulted in only minor differences in injury to soybean and no differences in injury to corn in this study. In soybean, the cereal rye cover crop resulted in a

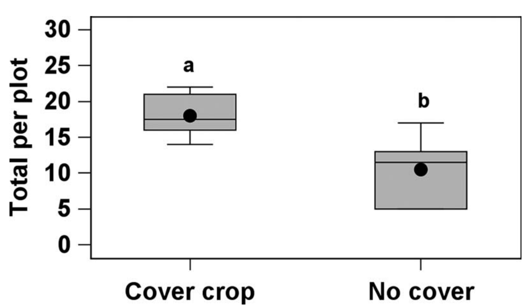

Fig. 2. Total spiders (Araneae) captured in pitfall traps (2 per plot) in plots of soybean that were either preceded by cereal rye (cover crop) or fallow ground (no cover) during fall–spring.

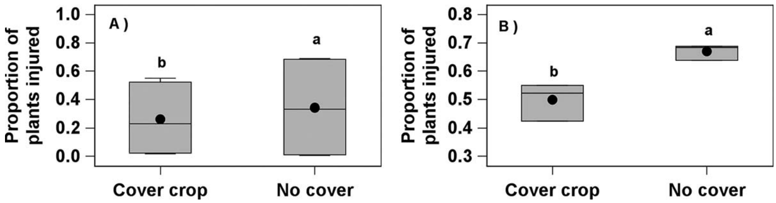

Fig. 3. Proportion of soybean plants injured by invertebrates (insects or slugs) over both years (A) and on 3 July 2019 (soybean growth stage V2) (B) in plots that were either preceded by cereal rye (cover crop) or fallow ground (no cover) during fall–spring. Overall injury was negligible in 2020 (data not shown).

minor overall reduction in injury, due primarily to a clear effect at one site-year. Similar reductions in insect injury to soybean have been observed for bean leaf beetle (*Cerotoma trifucata* (Forster)), potato leafhopper, and soybean aphid in the midwestern United States (Koch et al. 2012). Use of a cereal rye cover crop resulted in an increase in injury to corn due to armyworm feeding in a previous study that used a range of cover crop termination timings, with a median termination timing of approximately 2 weeks before corn emergence (Dunbar et al. 2016). At most of our site-years, the winter cereal cover crop was terminated well before the cash crop was planted. The cereal rye cover crop was terminated 2–4 weeks before planting in each soybean experiment and 4–6 weeks before planting corn at the Douglas Co. site

Table 3. Generalized linear mixed model statistics for data collected from the Champaign Co. field experiment evaluating the effect of termination timing of a winter cereal cover crop (cereal rye) ahead of corn.

Dependent Variable	Distribution	df Numerator	df Denominator	*F*	*P*
Carabids - pitfall traps	Poisson	3	6	0.56	0.662
Slugs - pitfall traps	Poisson	3	15	5.95	0.007*
Slugs - shingle traps	Poisson	3	15	1.61	0.229
Spiders - pitfall traps	Poisson	3	6	5.07	0.044*
Millipedes - pitfall traps	Poisson	3	6	3.22	0.104
Plant stand	Lognormal	3	15	0.81	0.508
Proportion injured plants	Normal	3	15	0.29	0.831
Proportion injured plants - 2019	Normal	3	6	0.61	0.631
Proportion injured plants - 2020	Normal	3	6	0.60	0.634

* Effect is significant at $\alpha = 0.05$.

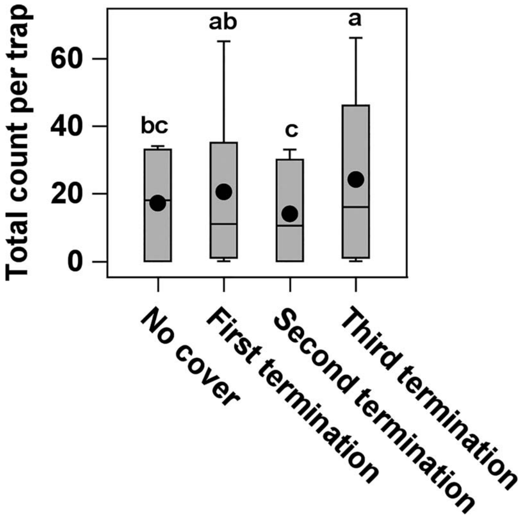

Fig. 4. Total slugs (Stylommatophora: Agriolimacidae) captured in pitfall traps (2 per plot) in plots of corn following either fallow ground (no cover) or a cereal rye cover crop terminated with glyphosate herbicide at 1 of 3 timings before corn planting.

(where presence or absence of a cover crop was the experimental treatment). At the Champaign Co. site (where termination timing was the experimental treatment), the interval between cereal rye termination and corn planting ranged from 8 weeks to 1 d depending on treatment and year; however, most termination intervals were at least 3 or 4 weeks—plenty of time to allow the cover crop to fully die before corn emergence. These intervals were likely sufficiently long to facilitate the dispersal of any invertebrate pests that were feeding on the winter cereal cover crop.

The effects of cover crops on ground beetles were minimal, with a slight increase in ground beetle activity density observed in soybean plots at the Douglas Co. site following a cover crop. Ground beetles are among the most frequently cited beneficial insects that are potentially favored by use of a winter cover crop (Inveninato Carmona et al. 2022). As in the current study, Dunbar et al. (2017) found an increase in ground beetle activity density in soybean plots that followed cereal rye, but not in corn plots. They suggested later termination timing in soybean as one potential reason for this discrepancy; the cereal rye cover crop planted ahead of soybean was indeed terminated later than in corn in 1 of the 2 site years where we made observations on both crops.

Of the invertebrates that we examined, spiders were the most responsive to the presence and/or termination timing of a winter cereal cover crop in terms of activity density. Increased spider activity was associated with increased grass cover crop biomass in Nebraska (Inveninato Carmona et al. 2022) and with use of Italian ryegrass (*Lolium multiflorum*) in Maryland (Hooks et al. 2011), consistent with our observations that spider activity densities increased as cover crop termination was delayed. Interestingly, spider abundance as measured using sweep nets was

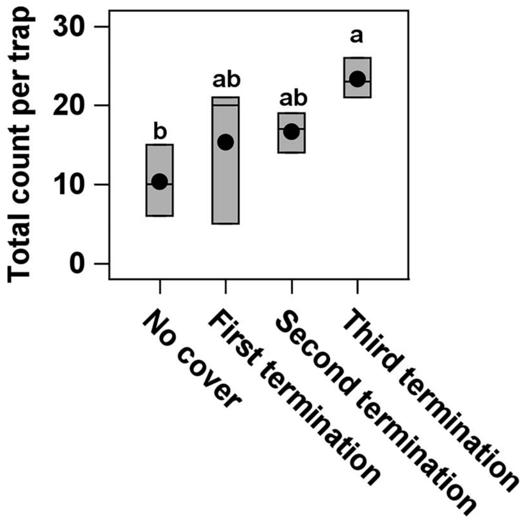

Fig. 5. Total spiders (Araneae) captured in pitfall traps (2 per plot) in plots of corn following either fallow ground (no cover) or a cereal rye cover crop terminated with glyphosate herbicide at 1 of 3 timings before to corn planting.

highest in a bare ground treatment in a separate study in Maryland (Leslie et al. 2017); however, like many similar studies (including the current study), the effect of cover treatment was variable among site-years, reflecting a high degree of ecological variability inherent to these relationships.

Cover crop treatment did not have a consistent impact on slugs. Although economic thresholds for slugs in corn and soybean are not well established (Douglas and Tooker 2012), slug activity and injury to plants in our study were much lower than in previous studies that reported yield impacts to corn or soybean from slug feeding (Douglas et al. 2014, Reed et al. 2019). Although we did not attempt to determine the taxa responsible for feeding injury to plants based on appearance, we only rarely observed injury that resembled published descriptions of slug injury to corn or soybean (e.g., Byers and Calvin 1994, Douglas and Tooker 2012). Slugs do not often impact corn or soybean production in east central Illinois where these field experiments were conducted, although they can be a major pest where no-till production is more common (e.g., in the southern third of Illinois). Although cereal rye termination timing affected slug activity density at the Champaign Co. site, the effect did not follow a consistent pattern of increasing slug activity with increasing biomass or decreasing interval between cover crop termination and corn planting. Variability among traps was high and the second termination resulted in lower slug activity than the no-cover control, although the third termination (which accumulated the greatest cover crop biomass in both years) had the highest slug activity. A study in Pennsylvania examining the impacts of cover crop termination timing on slug injury also showed inconsistent results in corn, with later termination either reducing or increasing slug injury depending on the year (Reed et al. 2019). As the authors of that study noted, slugs can readily move from plot to plot and are responsive to changes in temperature, moisture, and availability of food resources over time. Furthermore, the relatively low activity densities of slugs observed at our sites limited our ability to make strong conclusions about their activity.

Cover crop adoption is currently relatively low in the area where this research was conducted, representing $<5\%$ of the surrounding landscape (USDA NASS 2022); our results should be interpreted in that context, representing the "early" stages of adoption of this production practice in a particular area. Increased cover crop adoption could alter the situation that we observed, either by providing additional habitat for pest and/or beneficial organisms or by "diluting" the concentration of immigrating pests (e.g., armyworm moths) over a larger area. Further assessment in areas with higher rates of cover crop adoption would be useful to determine whether the relatively small impacts that we observed on pest management hold true where cover crops make up a larger proportion of the surrounding environment. In addition, we examined corn and soybean plots that had been treated with commercial rates of insecticide seed treatments; future work assessing the risk of insect injury to corn and soybean without an insecticide seed treatment in the midwestern United States would be valuable.

In conclusion, we observed a modest reduction in injury to soybean following a winter cereal cover crop that was most pronounced in a single site year and a small increase in ground beetle and spider activity densities where a cover crop was used in some cases. The effects we observed were subtle, reflecting the ecological variability involved in the interactions between cover crops and insect/invertebrate activity levels. The broader effects of winter cereal cover crops on pest management will likely vary depending on year, geographic location, weather conditions, and other factors.

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References Cited

Adhikari, S. and F.D. Menalled. 2020. Supporting beneficial insects for agricultural sustainability: The role of livestock-integrated organic and cover cropping to enhance ground beetle (Carabidae) communities. Agronomy 10(8): 1210. doi: 10.3390/agronomy10081210.

Byers, R.A. and D.D. Calvin. 1994. Economic injury levels to field corn from slug (Stylommatophora: Agrolimacidae) feeding. J. Econ. Entomol. 87(5): 1345–1350. doi: 10.1093/jee/87.5.1345.

Douglas, M.R., J.R. Rohr and J.F. Tooker. 2014. Neonicotinoid insecticide travels through a soil food chain, disrupting biological control of non-target pests and decreasing soya bean yield. J. Appl. Ecol. 52(1): 250–260. doi: 10.1111/1365-2664.12372.

Douglas, M.R. and J.F. Tooker. 2012. Slug (Mollusca: Agriolimacidae, Arionidae) ecology and management in no-till field crops, with an emphasis on the mid-Atlantic region. J. Integr. Pest Manag. 3(1): C1–C9. doi: 10.1603/IPM11023.

Dunbar, M. W., A.J. Gassmann and M.E. O'Neal. 2017. Limited impact of a fall-seeded, spring-terminated rye cover crop on beneficial arthropods. Environ. Entomol. 46(2): 284–290. doi: 10.1093/ee/nvw177.

Dunbar, M.W., M.E. O'Neal and A.J. Gassmann. 2016. Increased risk of insect injury to corn following rye cover crop. J. Econ. Entomol. 109(4): 1691–1697. doi: 10.1093/jee/tow101.

Gentry, L.E., J.M. Green, C.A. Mitchell, L.F. Andino, M.K. Rolf, D. Schaefer and E.D. Nafziger. 2024. Split fertilizer nitrogen application with a cereal rye cover crop reduces tile nitrate loads in a corn-soybean rotation. J. Environ. Qual. 53: 90–100. doi: 10.1002/jeq2/20530.

Hammond, R.B. 1990. Influence of cover crops and tillage on seedcorn maggot (Diptera: Anthomyiidae) populations in soybeans. Environ. Entomol. 19(3): 510–514. doi: 10.1093/ee/19.3.510.

Hooks, C.R.R., K.H. Wang, S.L.F. Meyer, M. Lekveishvili, J. Hinds, E. Zobel, A. Rosario-Lebron and M. Lee-Bullock. 2011. Impact of no-till cover cropping of Italian ryegrass on above and below ground faunal communities inhabiting a soybean field with emphasis on soybean cyst nematodes. J. Nematol. 43: 172–181.

Illinois Environmental Protection Agency, Illinois Department of Agriculture, and University of Illinois Extension. 2015. Illinois nutrient loss reduction strategy. https://epa.illinois.gov/content/dam/soi/en/web/epa/documents/water-quality/watershed-management/nlrs/nlrs-final-revised-083115.pdf. (Last accessed 2 September 2025).

Inveninato Carmona, G., L.M. Delserone, J.N. Duarte Campos, T. Ferreira de Almeida, D.V. Branco Ozório, J.D. Betancurt Cardona, R. Wright and A.J. McMechan. 2021. Does cover crop management affect arthropods in the subsequent corn and soybean crops in the United States? A systematic review. Ann. Entomol. Soc. Am. 114(2): 151–162. doi: 10.1093/aesa/saaa049.

Inveninato Carmona, G., J. Rees, R. Seymour, R. Wright and A.J. McMechan. 2019. Wheat stem maggot (Diptera: Chloropidae): An emerging pest of cover crop to corn transition systems. Plant Health Prog. 20(3): 147–154. doi: 10.1094/PHP-01-19-0009-S.

Inveninato Carmona, G., E. Robinson, A. Tonon Rosa, C.A. Proctor and A.J. McMechan. 2022. Impact of cover crop planting and termination dates on arthropod activity in the following corn. J. Econ. Entomol. 115(4): 1177–1190. doi: 10.1093/jee/toac090.

Koch, R.L., P.M. Porter, M.M. Harbur, M.D. Abrahamson, K.A.G. Wyckhuys, D.W. Ragsdale, K. Buckman, Z. Sezen and G. E. Heimpel. 2012. Response of soybean insects to an autumn-seeded rye cover crop. Environ. Entomol. 41(4): 750–760. doi: 10.1603/EN11168.

Leslie, A.W., K.-H. Wang, S.L.F. Meyer, S. Marahatta and C.R.R. Hooks. 2017. Influence of cover crops on arthropods, free-living nematodes, and yield in a succeeding no-till soybean crop. Appl. Soil Ecol. 117–118: 21–31. doi: 10.1016/j.apsoil.2017.04.003.

Lundgren, J.G. and J.K. Fergen. 2010. The effects of a winter cover crop on *Diabrotica virgifera* (Coleoptera: Chrysomelidae) populations and beneficial arthropod communities in no-till maize. Environ. Entomol. 39(6): 1816–1828. doi: 10.1603/EN10041.

Reed, H.K., H.D. Karsten, W.S. Curran, J.F. Tooker and S.W. Duiker. 2019. Planting green effects on corn and soybean production. Agron. J. 111(5): 2314–2325. doi: 10.2134/agronj2018.11.0711.

Ritchie, S.W., J.J. Hanway and G.O. Benson. 1986. How a corn plant develops. Iowa State Univ. of Science and Technology Coop. Ext., Ames, IA. Special Report No. 48.

[USDA NASS] U.S. Department of Agriculture National Agricultural Statistics Service. 2022. 2022 Census of agriculture. https://www.nass.usda.gov/Publications/AgCensus/2022 (Last accessed 2 September 2025).

Wallander, S., D. Smith, M. Bowman and R. Claassen. 2021. Cover crop trends, programs, and practices in the United States. U.S. Dept. Agric. Econ. Res. Serv. Econ. Info. Bull. Report No. 222.