

Project Title: Harnessing farm wildlife for weed management: Measuring suppression by rodents and insects

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Project Summary:

There are many ecological tools for managing weeds on organic farms, but a significant percentage are killed naturally every year by animals that feed on weed seeds. Crickets, ground beetles and small mammals are common, permanent residents of crop environments, and all contribute to weed seedbank reductions. To measure the ecosystem services that these weed seed predators provide, we built small fences with two gauge sizes and quantified seedbank reductions attributable to vertebrates and invertebrates separately by counting weeds germinated the following growing season. We tracked growth of common lambsquarters in fenced plots with natural seedbanks, and plots where we simulated a heavy seed rain the previous fall.

In plots with seed subsidies, lambsquarters counts were twice as high behind fences that excluded all seed predators as they were when insects or rodents had access. Seedling counts were lowest in unsubsidized plots where only insects had access- even lower than in completely open plots. We also compared the effects of seed predators and seed subsidies in plots planted with a rye/vetch cover crop the previous fall, but found very few weeds across all treatments. Our results suggest that that seed predators contribute significantly to weed suppression, but negative interactions between rodents and insects may slightly diminish their biological control services. Cover crops were far more important for weed suppression than seed predators, and because rodents and granivorous insects both use vegetative cover as overwintering habitat and refuge from predation, the use of cover crops and living mulches may synergize with the weed control services provided by wildlife.

Problem Addressed:

Rising demand for organic crops challenges us to consider weed management alternatives to herbicides, and conservation biocontrol of weed seeds is an ecosystem service that may be developed and enhanced to address this challenge. Crickets, ground beetles and small rodents are ubiquitous residents of crop environments, and all contribute to weed seedbank reductions. Combined with other weed management tools, weed seed predation by insects and rodents may decrease weed pressure in organic crop environments, although the magnitude of suppression and farm-scale relevance are yet unclear.

Summer annual weeds are extremely prolific, e.g., a single common lambsquarters plant can produce as many as 170,000 seeds. Given this intense propagule pressure, it is possible that weeds are not seed-limited in agricultural systems. If that were the case, foraging activity by seed predators would not overcome any site limitation for weed germination, and granivore impact on weed recruitment would be negligible. To investigate seed limitation and measure the ecosystem services that weed seed predators provide, we built seed predator exclusion fences in fallow and fall cover crop plots, and monitored seedling emergence over the following growing season. We tracked growth of common lambsquarters in plots with natural seedbanks, and also in plots where we simulated a heavy seed rain the previous fall.

Project Objectives:

- **Identify the weed reductions in cover crops specifically due to seed predation by vertebrates and invertebrates.**

My main objective was to quantify the ecosystem services that granivores provide under ambient seedbank conditions and also under high propagule pressure. I used fences that allowed differential

access to vertebrates and invertebrates to examine their seed predation services separately and combined.

- **Compare seed predator activity among spring and fall-killed cover crop treatments.**

Seed predators utilize available vegetative resources like cover crops and field margins, and research shows that cover may facilitate weed seed destruction (Gallandt et al. 2005, Pullaro et al. 2006, Meiss et al. 2010). My second objective was to compare seed predator activity in fallow, killed cover crop, and living mulch systems, and evaluate how granivore activity relates with subsequent weed growth.

Methodology:

STUDY SYSTEM

The experiment was conducted at the Purdue University Meigs Horticulture Research Farm near Lafayette, IN. Three fall cover crop treatments (Rye/vetch, red clover living mulch, and fallow) were planted in 8 replicated 40x30ft plots (24 plots total) in the fall of 2012 with 15ft margins between them. In spring 2013, rye/vetch cover crops were killed by flail mowing and left as mulch on the soil surface. Red clover germination was poor in the fall, but established by spring 2013.

The variables tested included cover crop type, seed predator enclosure, and weed seed additions. To quantify the specific contributions from vertebrate and invertebrate granivores to weed population reductions, we constructed 0.5m² enclosures from aluminum flashing and bird netting to exclude all seed predators in half the plots. To evaluate the effects of seed predators at high and ambient seedbank densities, we added 10 grams of lambsquarters seeds (about 15,000 seeds total) to half the 0.5m² plots four weeks after the cover crops were sown. Seed additions were made to approximate the timing and density of weed seed rain in the fall (Gallandt 2009).

DATA COLLECTION

The variables we measured were spring weed germination (given as stem counts per subplot), harvested weed biomass, and well as cover crop biomass. Beginning in May 2013 we counted lambsquarters seedlings every 6 weeks until the end of September, when biomass was harvested, dried and weighed. To identify the invertebrate seed predators in the system, we sampled the ground-dwelling insect community in the fallow and rye/vetch treatments using standard pitfall trapping techniques every two weeks from May-August 2013.

Results and Discussion:

Invertebrate seed predator activity was not positively correlated with cover crop biomass (data not shown), but strongly associated with weed biomass (Fig 1). These data are consistent with other work we have done evaluating granivore activity in response to plant community composition (Blubaugh et al 2011), and suggest that seed predators distinguish between mulched plant cover and living plant cover and aggregate around seed sources. More than twice as many beetles were captured in fallow plots compared to the rye/vetch plots (Fig 2), thus, killed cover crop mulch may not provide preferable micro-habitat compared with un-mulched space (Ward et al 2011).

At separate sites in 2012 (data not shown) and 2013, **I found that seed predators overcame intense propagule pressure and substantially reduced germination rates following seed rain, demonstrating that granivores perform relevant services that improve weed control.** In plots with seed subsidies, lambsquarters emergence rates were almost twice as high behind fences that excluded all seed predators as they were when insects or rodents had access (Fig 3). There was no difference in weed emergence between the two types of seed predator exclosures, suggesting that small mammals contribute little to weed suppression in this system, consistent with other work performed in midwestern field crop environments (Menalled et al 2000, Westerman et al 2008).

Reductions in weed emergence attributable to seed predators were not significant under ambient seedbank conditions, although seedling counts were lowest in unsubsidized plots where rodents were excluded (accessible only by insects)- even lower than in completely open plots (Fig 4). These results are interesting because while rodents forage on weed seeds during the winter (Williams et al 2009), they are opportunistically insectivorous when prey resources are available (Flick 2013). Although seed predators contribute significantly to weed suppression, predator-prey interactions between rodents and insects may diminish the biological control services they provide. Weed seeds are only accessible by invertebrate seed-feeders while they remain on the soil surface, thus their ecosystem services are critical following seed rain (consistent with our results; Fig 3), but negligible once seeds are incorporated in the soil (Westerman et al 2006). If weed senescence occurs in crop fields, delaying tillage will increase the amount of time seeds are vulnerable to predation services.

We compared the effects of seed predators and seed subsidies in plots planted with a rye/vetch cover crop the previous fall, but found very few weeds across all rye/vetch treatments, even after we removed all the cover crop mulch from the soil surface (these data are not presented). Cover crops are critical ecological tools for organic weed suppression, and because rodents and granivorous insects both use vegetative cover as overwintering habitat and refuge from predation (Moorman et al 2013, Gallandt et al 2005), the use of cover crops and living mulches may synergize with the weed control services provided by wildlife.

Conclusion:

This work clarifies the roles of different seed predator groups in weed population dynamics, documenting weed seed biocontrol in a comprehensive, agriculturally relevant framework. My results validate the utility of beneficial seed-feeding insects by demonstrating a 50 percent reduction in weed germination over multiple field seasons in plots with seed predator access (compared to plots where seed predators were excluded). This new knowledge of the magnitude of weed seed biocontrol services will inform a holistic approach to weed management by growers. We hope that management strategies that reduce insecticide use and minimize tillage will be adopted to limit mortality of weed biological control agents. These strategies can be combined with the use of cover crops to synergize the benefits of weed competition and biocontrol. Here are a few synthesized “take home messages” from this project that I will communicate with growers.

- For three consecutive seasons, seed feeding beetles strongly associated with early spring weed cover, but not cover crop biomass.

- **Implication:** Granivores can identify living weed seed sources at the soil surface, and may feed preferentially in weed patches, making them excellent biological control agents.
- **Recommendation:** Including live plant cover between crop rows may enhance seed predator activity. This can be accomplished with living mulches, or merely by tolerating benign weed growth until it threatens yield or senescence.
- Seed predators reduced weed germination by 50% in fallow plots after being subsidized with almost 15,000 weed seeds.
 - **Implication:** Granivores are efficient biocontrol agents. In order to have an agriculturally meaningful effect on weed growth, seed destruction must reduce germinable seedbank densities beyond the number of possible germination sites (as high as 400/meter²). That requires more than 98% efficiency!
 - **Recommendation:** Include perennial overwintering sites (like grassy un-tilled margins) on-farm for resident seed predators. While they can disperse over long distances, few granivores overwinter successfully in seasonally-tilled crop areas, and are often limited by overwintering site availability. Minimize tillage and insecticide use as possible, to reduce risk to beneficial insects.
- Seed predators did not reduce weed emergence in plots where artificial seed rain did not occur the previous fall.
 - **Implication:** Seed predators' ecosystem services are most critical immediately following seed rain, and minimal once seed burial occurs over the winter.
 - **Recommendation:** Delay fall tillage if weed senescence occurs to maximize the amount of time seeds may be consumed on the soil surface.

Outreach:

Presentations:

Tippecanoe Co. Master Gardener's Assoc. Lafayette, IN (5/6/2014)

"Love your bugs: insectary plantings to attract predators and pollinators" ~ 100 participants

Indiana Small Farm Conference Danville, IN (2/2014)

"Harnessing farm wildlife for weed management: Measuring suppression by rodents and insects"

MOSES Organic Farming Conference LaCrosse, WI (2/2014)

"Harnessing farm wildlife for weed management: Measuring suppression by rodents and insects"

Indiana Small Farm Conference. Danville, IN (2/20/2014)

Growing Organic workshop: Insect pest management ~ 50 participants

Publications:

Submitted:

Blubaugh, C.K. and I. Kaplan. 2014. Mechanical weed management tactics compromise recruitment of weed seed predators across developmental stages. *Biological Control*

In preparation:

Blubaugh, C.K. and I. Kaplan. 2014. Undercover predators: impacts of structural refuge on invertebrate and vertebrate weed seed predation.

Extension:

Blubaugh, C.K. 2014. Putting the weed seed predators to the test. International Organization for Biological Control Nearctic Regional Section Newsletter. 36:1-3.

Blubaugh, C.K. 2013. Organic Insect Pest Management. Purdue University College of Agriculture.
<<https://ag.purdue.edu/extension/smallfarms/Pages/Insects.aspx>>

We are currently collecting data for the final season of this experiment, and will submit a manuscript to Weed Science in 2015. I will prepare eOrganic articles for use by growers once peer-reviewed manuscripts are complete.

References:

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- Williams, C., M. Liebman, P. Westerman, J. Borza, D. Sundberg, and B. Danielson. 2009. Over-winter predation of *Abutilon theophrasti* and *Setaria faberi* seeds in arable land. *Weed Res*. 49:439-447.

Figures:

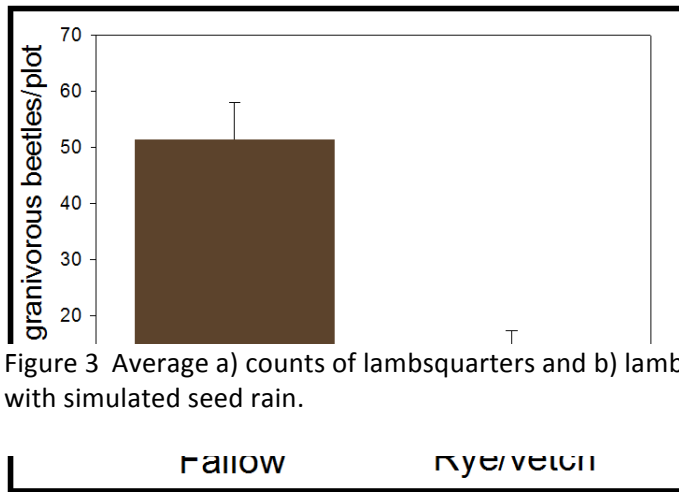
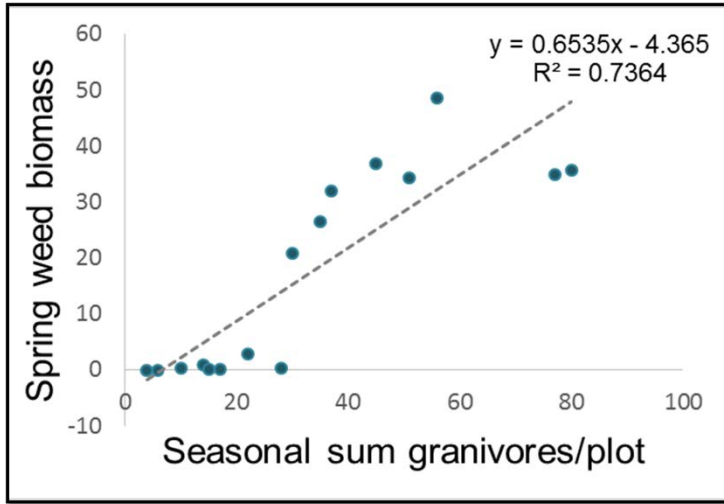


Figure 3 Average a) counts of lambsquarters and b) lambsquarters biomass per subplot for each enclosure type with simulated seed rain.

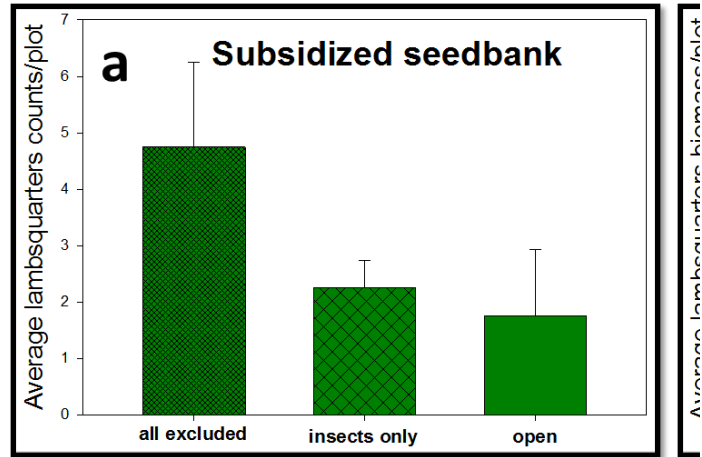


Figure 2. More than twice as many seed-feeding beetles were caught in the weedy fallow plots compared to the rye/vetch cover

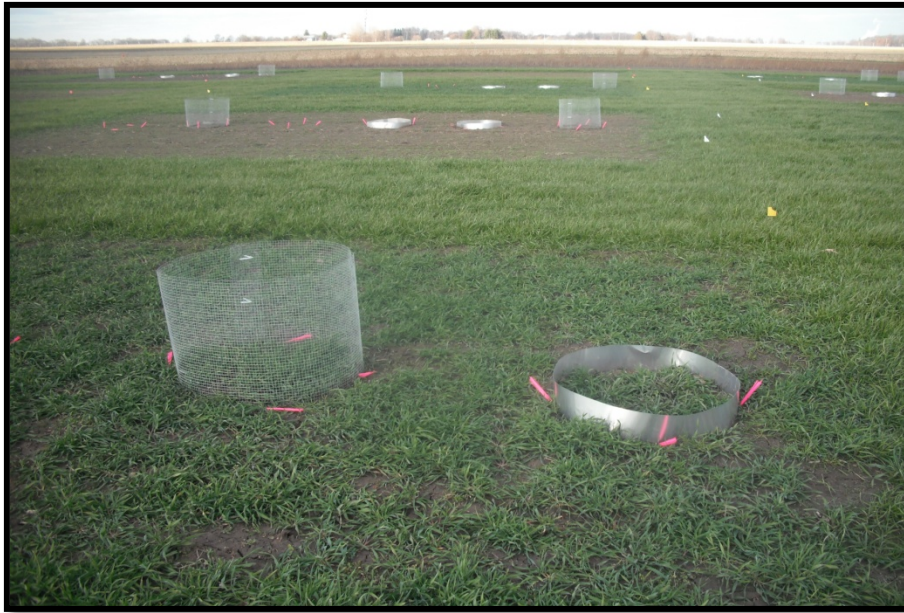
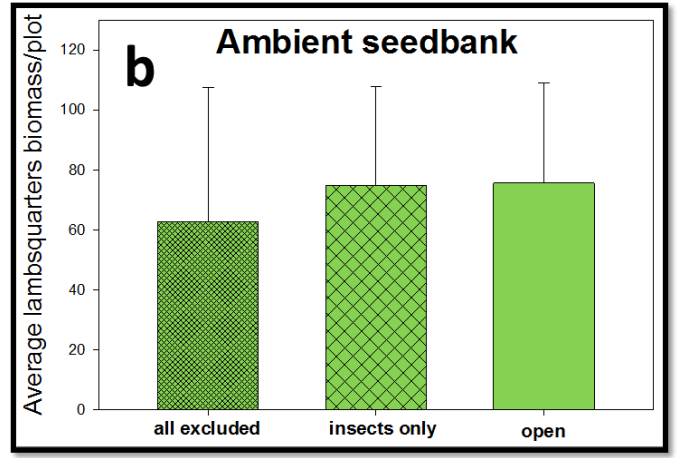
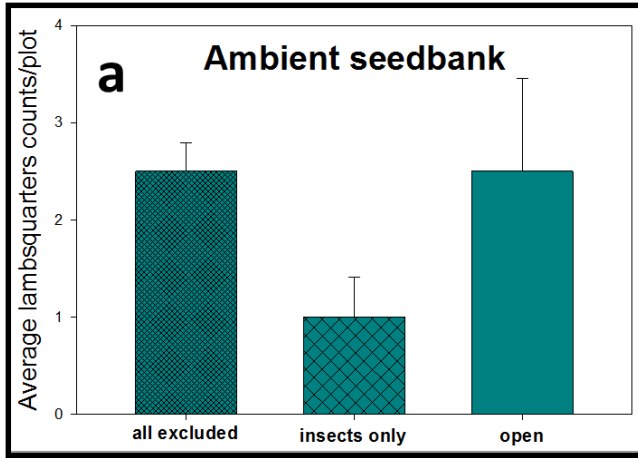


Figure 5. Photo of field site when seed predator enclosures were installed in Fall 2012



Figure 6. Photos of field site in summer 2013: examples of Rye/vetch (left) and fallow (right) plots.