Threshold-based Cover Cropping Strategies for Weed Management

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Report of Progress for the Period of July 1, 2004 through June 30, 2005

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Project Overview

Integrating tillage system and cover cropping practices, this project aims to develop management strategies that will lower the equilibrium density of the weed seed bank. This systems approach promises an effective means for managing weed seed banks while maintaining or improving soil health. Field experiments and case studies of innovative growers in Maine and Pennsylvania will address three objectives described below.

Progress by Objective

Objective 1. Evaluate the impact of increasing cover cropping system intensity on weed seed bank dynamics.

Field experiments were established in the fall of 2003 and 2004 at the University of Maine Rogers Farm in Stillwater, Maine (ME) and the Russell E. Larson Agricultural Research Center near University Park, Pennsylvania (PA). The experiments are a split-plot, randomized complete block design with four replications; main plot treatments are a factorial cross of four (ME) or six (PA) cover crop systems representing different levels of intensity and a fallow control (Figure 1).

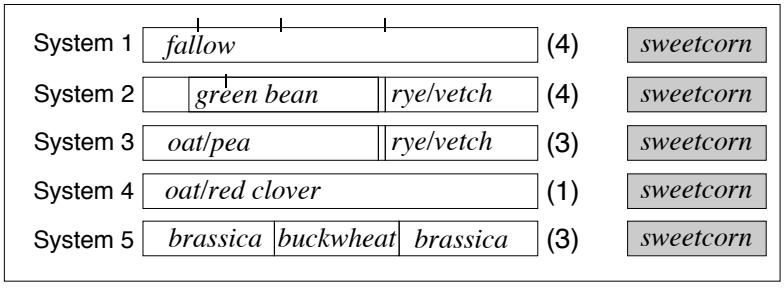


Figure 1. Cover cropping systems established in 2004 and repeated in 2005 the Maine and Pennsylvania Experiment Station research sites. Numbers in parentheses indicate major disturbance events that would preempt weed growth. Residues were either incorporated or killed and left on the soil surface prior to planting the uniform test crop of sweet corn.

Plots (13.4 by 13.4 m) were flagged and, within each tillage system split-plot, synthetic weed seed banks (1.5 by 2.7 m), comprised of a mixture of common lambsquarters (*Chenopodium album*), yellow foxtail (*Seteria lutesens*) and velvetleaf (*Abutilon theophrasti*), were established at four densities (0, 60, 450, and 2100 seeds m^{-2}) (Figure 2). Each synthetic seed bank also included ceramic beads, sized to match the diameter and density of common lambsquarters, sown at 2100 beads m^{-2}. The beads will serve as an internal standard to quantify our efficiency of seed recovery.

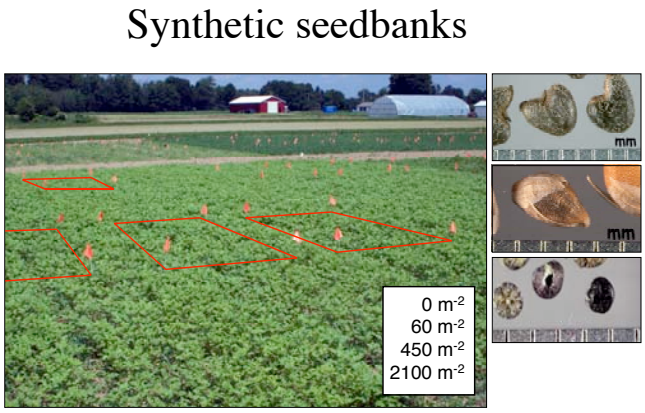


Figure 2. Synthetic weed seedbanks were established in the fall (Pennsylvania) or early spring (Maine) prior to the cover crop phase of the field experiments. Velvetleaf, yellow foxtail and common lambsquarters were sown at four densities within permanently marked areas in each plot.

To establish the baseline values for the germinable portion of the synthetic seed banks ten soil cores (9 cm diam. by 10 cm deep) were taken from each synthetic seed bank location in the spring of 2004 and 2005, preceding the initial and repeated cover crop phase of the experiment. These samples were subjected to several cycles of germination, seedling identification and removal, drying mixing and re-watering will exhaust the germinable portion of the seed bank. An additional five soil cores were taken from each synthetic seed bank location, mixed, and the velvetleaf seeds and synthetic beads were directly extracted using a hydropneumatic elutriation device (Gillison's Variety Fabrication, Inc., Benzonia, MI); viability was estimated by applying pressure to seeds with forceps ('firm' seeds are assumed to be viable) (Ball and Miller 1989).

To quantify seed bank losses due to establishment, densities of the synthetic seed bank species, and the most abundant resident species, measured in the spring of 2004 and 2005. Subsequently, primary and secondary tillage were performed to initiate the fallow treatment, and the cover cropping systems were planted.

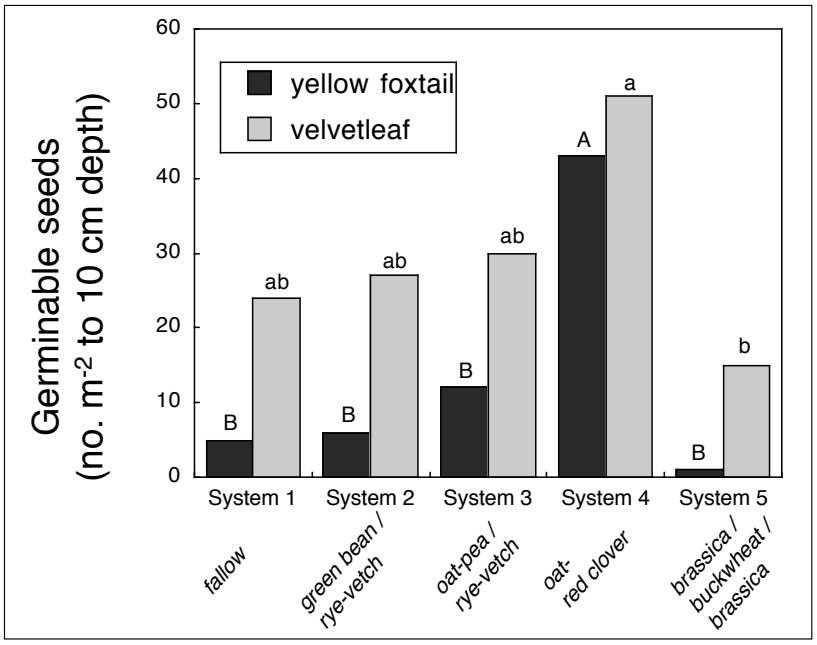
System 1, *fallow*, was periodically disturbed, based on weed emergence timing, to maximally encourage the "stale-seedbed" approach to reducing the weed seed bank. System 2, "cash crop," followed by winter rye/hairy vetch, was planted to green bean (ME) or spring oat for grain (PA). System 3 included pea/oat followed by winter rye/hairy vetch; System 4 included oat/red clover; and System 5 included brassica/buckwheat/brassica (Figure 3). The brassicas were 'Idagold' condiment mustard and 'dwarf Essex,' respectively. System 6, present only in PA, was organic soybean for grain, grown in rows and managed using cultivation. Prior to each disturbance event, weed densities were measured in the synthetic seed bank areas to quantify seed bank losses due to establishment.

Figure 3. Selected examples of cover crop treatments established in Maine and Pennsylvania in 2004 and 2005 System 2, "cash crop," followed by winter rye/hairy vetch, was planted to green bean (ME), upper left, or spring oat for grain (PA), not shown. System 3 included pea/oat, lower left, followed by winter rye/hairy vetch; System 4 included oat/red clover, upper right; and System 5 included brassica/ buckwheat/brassica, lower right. System 1, fallow, is not shown.

Weed Seedbank Deline

In Maine we have completed a preliminary analysis of the year two germinable weed seedbank, following the 2004 cover cropping systems, which indicated that yellow foxtail seed density was greatest in System 4, oat/red clover, which included only a single disturbance event. Yellow foxtail density was lower, and equivalent, in the remaining systems (Figure 4). Density of germinable velvetleaf seeds was likewise greatest in the oat/red clover system, and least in the highly disturbed brassica/buckwheat/brassica system, with intermediate density in the remaining treatments (Figure 4).

Figure 4. Effect of 2004 cover cropping systems on the density of germinable yellow foxtail and velvetleaf seeds, averaged over density, in spring 2005 samples.



At the Pennsylvania site, background populations of common lambsquarters and giant foxtail have prohibited us from distinguishing the density relationships targeted in the field. However, the 2005 cover cropping systems were established on a new field in PA, and greenhouse emergence data showed significantly lower initial weed seed populations.

Weed Seedling Recruitment

There was a strong relationship between initial weed seed bank densities and the recruitment data in 2005 at both locations. Weed seed recruitment was measured by counting weed seedling densities within the six cover cropping systems prior to each field disturbance from May through August of 2004 and 2005. Increasing frequency of disturbance and species selection resulted in higher weed recruitment in 2004 ranging from 10-22% of the total weed seed bank. Velvetleaf recruitment data in 2004 and foxtail spp., common lambsquarters and velvetleaf recruitment data in 2005 shows a strong relationship between seedling numbers and initial seed bank density.

Seed Predator Research

Harpalus pensylvanicus' activity density was monitored July through October 2004 and June through September of 2005 with year, date, cover type and position of the traps being significant. The 2004 year had significantly lower beetle activity density (0.7 beetles/pitfall) than in 2005 (4.9 beetles/pitfall). Peak activity density could not be determined for the 2004 sampling season, however; peak activity density occurred during the beginning of August for 2005 (14.9 beetles/pitfall). A drastic increase in activity density was seen twelve days before peak activity density (11.4 beetles/pitfall) and a drastic decrease occurred (7.1 beetles/pitfall) one month later. The cropping rotation with soybean had the lowest activity density (2.3 beetles/pitfalls), while the oat-pea followed by rye-hairy vetch rotation had the highest (4.2 beetles/pitfall). Soil disturbance was greatest in the soybean plot and the fallow treatments which may have reduced

beetle activity density. Block was also significant and we speculate that grassway borders next to some plots may have influenced beetle populations.

Giant foxtail *(Setaria faberi)* seed rain was monitored at two locations in 2005 in an effort to determine if *Harpalus* activity density has an association with foxtail. Giant foxtail seed rain occurred between August and October. Results showed that peak seed rain occurs in central Pennsylvania during the period of October (5688 seeds/plot). There was also a rapid increase in seed rain of 2139 seeds/plot one week before peak seed rain and a rapid decrease of 4673 seeds/plot one week after. A significant difference in seed rain was also seen within the two giant foxtail fields. The seed rain from a natural giant foxtail infestation (1813 seeds/plot) was greater than the established giant foxtail plots (1225 seeds/plot), although the timing of seed shed was similar. The potential association between giant foxtail seed rain and beetle activity density is still being determined.

Finally, weed seed feeding preference and weed seed removal experiments were conducted in 2005. The data collected from these trials are still being analyzed.

Objective 2. Determine the effect of varying germinable seed bank densities on the efficacy of weed control and yield loss in a subsequent test crop.

The first sweet corn test crop was planted in May and July of 2005 in Pennsylvania and Maine, respectively. However, do to cool spring temperatures and high populations of Seedcorn maggots (*Delia platura*) in Pennsylvania, and record-breaking rainfall forcing late planting in Maine, the initial sweet corn plantings failed. The experiment was repeated and ensuing weed seed densities were recorded in each plot. Crop stand densities as well as crop yield were recorded in Pennsylvania, but it was too late for a second planting in Maine. While weed density data were collected for both tillage treatments, additional challenges and significant crop failure in the incorporated split resulted in yield data collected for the no-till split only.

Objective 3. Assemble innovative cover cropping systems concepts or techniques into case studies and conduct on-farm research that demonstrates key pest and soil management benefits.

An evaluation of regionally-available descriptions of innovative cover cropping strategies used by growers indicated that case studies are available, or are being published, that feature some of the farms participating in this research project. Thus, instead of farm-centered case studies we have focused our outreach efforts on field days and grower talks featuring the theoretical basis for our field experiments with cover crops, preliminary results from these experiments, and focused educational materials on weed seed predators.

In 2005, educational field days were held on June 13 at the PSU Russell E. Larson Agricultural Research and Education Center near Rock Springs, PA and on October 7 at the Charlestown Cooperative Farm in Chester County, PA. Both field days were co-hosted by the Pennsylvania Association of Sustainable Agriculture (PASA). Approximately 60 people attended the field day at Rock Springs and about 30 individuals attended the Chester County

field day. Preliminary results from the threshold-based cover crop project were presented and attendees had an opportunity to view some of the research and demonstration experiments. Of particular interest to the group were the seed predation work and the potential impact of ground beetles. Evaluations were conducted at both locations and participants responded very positively about the educational activities. Additional field days are planned in 2006 both with farmer-cooperators and at the Penn State Experiment Station Research Farm and an extension publication is in the works.

In Maine, two field day activities featured this project. The first was an educational program for eighteen urban high school students from Maine and New York City. This three-hour program featured a presentation on ecological weed management (Shearin, A. and E.R. Gallandt) and field exercises in which the students recovered invertebrate pitfall traps and weed seed feeding stations that had been previously placed in the field. The second event, a more traditional grower field day held on July 27, 2005, included presentations on the preliminary seed bank results from the project, a tour of the plots, and a second presentation on invertebrate seed predators by John Shearin, a University of Maryland undergraduate who developed our "Seed Predator Test Kits." Approximately 85 growers and agricultural professionals attended these presentations. In 2006 field days will be held again at the University of Maine Rogers Farm, and at the Peacemeal Farm in Dixmont, Maine.

Seed Predator Test Kits

Twenty Test Kits were constructed for distribution to extension personnel interested in incorporating weed seed predation into their programming on ecological weed management. The kits contain the following materials:

- 15 pitfall traps, incl. 15 specimen cups with lids
- 1 box of beetle specimen cards
- 5 beetle ID cards
- 1 Bulletin
- 1 Lesson Plan
- Seed predation testing supplies
    - 15 small (15 x 100 mm) petri dishes covered with double-sided mounting film
    - 30 extra pieces of double-sided mounting film
    - packet of seeds— ~1200 common lambsquarters seeds
      ~1200 redroot pigweed seeds

Set of exclosures

- 5 vertebrate with petri dish (15 x 150 mm) covers
- 5 vertebrate/invertebrate with petri dish (15 x 100 mm) covers
- 5 open (15 x 100 mm petri dishes with legs)

- 30 marking flags

We are presently editing the bulletin which will be color printed and distributed in the Test Kits and as a pdf file via the web. This will be completed in time for distribution of the Test Kits in the spring of 2006.

Additional Presentations

Gallandt, E.R. Soil-improving practices for ecological weed management. Biology Department, Colby College, Waterville, ME. *Invited presentation*. November 19, 2004 (55 attending).

Gallandt, E.R. How can we target the weed seedbank? North Central Weed Science Society Annual Meeting. *Invited presentation*. December 15, 2004 (40 attending).

Gallandt, E.R. Managing the weed seedbank. Northeast Organic Farming Association. *Invited presentation*. August 13, 2005 (40 attending).

Ball, D. A., and S. D. Miller. 1989. A comparison of techniques for estimation of arable soil seedbanks and their relationship to weed flora. Weed Res. 29:365-373.