Managing weed seed rain: A new paradigm for organic and low-input farmers

Final Report for LNE06-237

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Project Information

Summary:

The seedbank ensures that annual weeds persist in agroecosystems. A high density of weed seeds leads to a corresponding high density of seedlings, and thus a need for increased weeding efforts to minimize interference with cash crops. On organic and low-external-input farms, weed seedlings are typically controlled by cultivation. Because cultivation controls a proportion of the seedlings present, the density of surviving weeds increases proportionally with increasing density of the seedbank, often requiring multiple cultivation events and supplemental hand weeding.

The aim of this project was to shift the focus of weed management from weed seedlings to the weed seedbank. Inspired by impressive rates of weed seed predation estimated in our own research and documented in the literature, we reasoned that post-seed rain management that maintained weed seeds on the soil surface would lead to enhanced fall and over winter seed losses and a reduction in weed seedling density the following spring. On-farm and research station experiments compared flail mowing weeds, with and without a no-till rye cover crop, to a tilled cover crop, and a “No Weeds,” zero seed rain control. Wire mesh cages excluding weed seed predators were used to estimate predation rates.

Over the course of this project, through consistent outreach efforts, the “seedbank” has become something that growers now routinely refer to when discussing weed management. We demonstrated that weed seed predation can cause major reductions in the seedbank (42% fewer germinable seeds in the presence of predators compared to within exclosure controls). This effect was also observed at our on-farm in 207-2008 where, at the Goranson Farm, there were 40% fewer germinable seeds outside the predation exclosures. However, predation effects were inconsistent, detected in only one of the four years of this project. As censuses of seed predator communities was beyond the scope of this project, we have no explanation for the lack of significant predation losses in three of the four years.

Zero seed rain, included originally as a control treatment in this project, emerged as the single consistent and major effect on the weed seedbank. The “No Weeds”
treatment reduced the subsequent year’s germinable seedbank by 45%, 93%, 88%, and 69% compared to the other fall management treatments, over the four field seasons of this project, respectively. These reductions in the seedbank were manifest in lower in-field weed seedling densities of 23 to 90%, although at some sampling points weed seedling densities were similar among the fall weed management treatments. Such reduction in initial seedling densities would result in fewer seedlings surviving cultivation events.

Compared to fall tillage, no-till cover cropping treatments were expected to maintain weed seeds at the soil surface and thereby maximize losses due to predators. Contrary to this hypothesis, however, germinable weed seedbanks were generally similar when sampled in the spring following tillage-based and no-till cover cropping.

Complete prevention of weed seed inputs, our “zero seed rain” control, provided consistent and impressive reductions in the weed seedbank. A single year in which seed rain is prevented can present measurable benefits to weed management in the succeeding crop. Thus, farmers who have discounted “seedbank management” as a waste of time because years of progress are thought to wiped out by a single seed rain event may reconsider this philosophy.

Introduction:

Modern weed management strategies continue to be focused on controlling weed seedlings, most often using herbicides or cultivation. This focus on early season weed control effectively minimizes yield loss due to weeds, but weed seed rain from individuals that survive may be extraordinary, resulting in a recurring weed problem. Furthermore, growers are frequently encouraged to plant fall cover crops, an operation that usually involves tillage and, consequently, burial of the new seed rain. Burial effectively places the weed seed in “cold storage,” offering protection from predators, and fewer environmental cues to encourage germination, a fatal process when it occurs late in the year.

This project used our current knowledge of weed seedbank ecology to evaluate the efficacy and economics of fall weed management tactics designed to maximize weed seed mortality. Specifically, we engaged Maine farmers in related on-farm trials focused on fall weed management strategies including: preemption of seed rain by hand hoeing/pulling; managing seed rain by flail mowing for maximal presentation to post-dispersal seed predators (exclosures will demonstrate the contribution of various weed seed predator guilds); and no-till seeding of fall cover crops to maintain weed seed on the soil surface where they are exposed to weed seed predators. A replicated comparison of these treatments was conducted each year at the University of Maine Rogers Farm. Presentations detailing the on-farm fall weed management trials have demonstrated to farmers the large but unpredictable contribution that predators can have in reducing the seedbank, and the short-term benefits of preempting weed seed rain.

Performance Target:

Through field days, meeting presentations, and published case studies, 150 New England vegetable and organic dairy farmers will learn about the Fall Weed Management Project; direct-mail and follow up telephone surveys will demonstrate that one third of this target audience implemented a new strategy focused on fall weed management, with 10% of the group adopting multiple tactics to preempt seed rain and maximize weed seed predation and mortality.

Evidence Performance Targets Have Been Reached
1. Attendance at on-farm site field days and grower meetings will reach an audience of over 300 mixed vegetable growers. There has been an increasing interest in the topic of weed seedbank management at local and regional grower meetings. The new datasets from Managing Weed Seed Rain were featured at invited presentations during the 2008-09 calendar year and a symposium at the Northeast regional weed science meeting in early 2010. Overall, presentations featuring this project reached an audience of 580, approximately 2/3 of whom were farmers.

2. Surveys of growers in cooperation with the Maine Organic Farmers and Gardeners Association (MOFGA) and the Northeast Organic Farming Association (NOFA) will indicate the number of growers implementing strategies for weed seed rain management, and the source of their information. Formal surveys were not conducted as part of this study. While this seemed to be a good idea at the inception of the project, our primary means of engaging growers beyond the project participants, was through presentations at meeting. These talks included results from this project as well as others, so providing sole credit to this study would have been inaccurate. We are presently conducting a new project that aims to understand grower’s practices and decision-making regarding weed management.

3. Requests for information and on-farm visits will be used as an indicator that performance targets are being met. In the past two falls the PI has received telephone inquiries from growers not participating in this project, specifically wanting advice on late-season management of their weedy fields. We need to produce some educational materials to help growers who are working to reduce seed rain identify mature seeds. Very practical questions such as: “Can I pull them and leave them in the field, or do I need to remove them?” “How can you tell whether lambsquarters seeds are viable or not?” To address this need, we are presently producing a short video to demonstrate some quick ways to look for viable seed in several weeds common to vegetable systems.

4. We will anonymously review MOFGA applications for organic certification (for growers who agree to participate in the survey) from a one- to three-year period prior to implementation of our project, and applications submitted in the fall and winter of 2008, recording the proportion of applicants implementing weed seed rain management practices. As an independent source of information that would indicate grower adoption, we reviewed the “Weed Management” field (without any information identifying the farm) from the database of 2010 MOFGA Certified Organic Growers. Fifty of the 440 records included reference to preventing weed seed production. Most were generally referring to the practice of preventing weed seed rain; ten references mowing specifically. Only one record stated specifically: “No fall tillage to reduce seed bank potential.” By this measure, despite a considerable outreach effort, this project failed to affect significant adoption. However, it is possible that individuals in the group of fifty are indeed now managing to prevent seed production due to the impact of this project.

Cooperators
Research

Materials and methods:
Germinable seedbank
On-farm trials

2006: Treatment establishment: In the late summer of 2006, four treatments were established at three organic diversified vegetable farms (Peacemeal Farm, Freedom Farm, Goranson Farm) and three dairy farms (Clovercrest Farm, Rainbow Valley Farm, and Third Street Farm). Each treatment consisted of a 10x10 foot plot, with the following treatments:

1. Control: No seed addition
2. Seed addition of 100 seeds per plot
3. Seed addition of 500 seeds per plot
4. Seed addition of 1000 seeds per plot

Each treatment was replicated three times, for a total of 12 plots per farm. The experiments were conducted over a 2-year period, with yearly evaluations for germination and yield.
Farm, and Bull Ridge Farm) located in Maine. The treatments included three large, single-block treatments, a zero seed rain area, a flail mowed no tillage area, and a flail mowed tilled area. The zero seed rain treatments were established at four sites, Peacemeal Farm, Clovercrest Farm, Bull Ridge Farm and Rainbow Valley Farm. Where possible, fall cover crops were planted at the sites using a no-till drill. Also, two exclosure cages were also placed in the no-till treatments (only one was placed at Peacemeal Farm).

2007: Data collection: All of the on-farm sites were visited in the spring, before primary tillage, to collect soil cores for weed seed bank work. Ten soil cores were collected from each of the large treatment blocks. The cores were taken to a 10 cm depth using the bulb planters (6.5 cm. dia.). The exclosures were sampled separately with ten cores also collected from within the caged area and a corresponding 10 cores collected immediately outside the caged area. The soils were sieved and placed in greenhouse flats lined with vermiculite. Germinating weeds were identified and counted over the course of the summer. There was concern that not all the growers implemented the treatments as requested.

Treatment establishment: In the fall of 2007, three farms were revisited including Peacemeal Farm, Rainbow Valley Farm, and Goranson Farm. A zero seed rain control treatment was established at Peacemeal Farm. At the Rainbow Valley Farm, no till + zero seed rain, flail tillage, and no till treatments were established. At the Goranson Farm, tilled and no till treatments were established. The number of seed predator exclosure cages was increased based on results from the 2007 seedbank. Ten seed predator exclosure cages were placed in no till treatment fields at Rainbow Valley Farm and Goranson Farm.

2008: Data collection: Spring soil sampling methods were identical from 2007 methods.

2009: Data collection: To prepare case studies of growers with a range of weed seedbank management philosophies we resampled two farms that were originally sampled as part of a 2001 NESARE project, the Peacemeal Farm and the New Leaf Farm. This is an exciting opportunity to resample fields and examine changes in the weed community and relative abundance of problem species over eight years of management. We also sampled the Beech Grove Farm of Eric and Anne Nordell who are well known for their intensive rotation and cover cropping strategies, and a weed management philosophy that focuses on the seedbank. These farms were sampled in the spring using methods identical to 2007 methods, except that silver bucket auger coring devices were used (8 cm diam.). This was the last year of analyzing on-farm weed seed rain.

Replicated research farm trials: Rogers Farm
For the replicated trials at Rogers Farm Research Station, methods were improved and adapted over the four years of the project. In 2006, four treatments were established at the Rogers Farm Research Station; zero seed rain control via hand pulling and hoeing, standard fall tillage with cover crop (tilled/cover crop), no-till planting with cover crop (no till/cover crop), and flail mow with no tillage and no cover crop (flail). The zero seed rain control treatment was established before the fall seed rain event. In September of each year, the other treatments were established by first flail mowing all the plots. The tillage treatments were then rototilled twice with each pass going in opposite directions. Winter rye (var. unnamed) was planted in the cover crop treatments using a Great Plains no-till drill at 125 lb per acre. In 2008, 22 lbs. of fish meal were added to each plot before sweet corn planting. The test crop planted in the spring was sweet corn for 2007-08 and silage corn for 2009-10.

The plot sizes ranged by year from 20-22’ x 30-35’ and were replicated four or five
times. In 2006, the flail treatment included one seed predator exclosure cage, which prevented access by vertebrates and invertebrates. In 2007-08, four exclosure cages were added to each flail treatment plot. In 2009, plot sizes were increased to 30’ x 40’; an additional moldboard plow treatment was added; and five cages were added to both the flail and till/cover crop treatment plots. This moldboard plow treatment was added based on questions from growers who have considered deep plowing to bury seed rain of relatively non-persistent species, including many annual grass species.

In May of 2007-08, soil was collected with bulb planters (6.5 cm diameter) to a depth of 10 cm. In May of 2009-10, silver bucket augers (8 cm diameter) were used to collect soil to a 10 cm depth. Ten soil cores from each plot were taken, mixed, and spread on greenhouse flats. For the exclosure cages in 2007, ten cores were taken from within the cage perimeter and ten were taken nearby and outside the exclosure. In 2008-09, five cores were taken from inside the cages with a corresponding five taken from nearby and outside the cages. Flats were watered daily in the greenhouse and weeds were counted and pulled soon after emergence. Flats were dried down, crumbled, and re-watered approximately every five weeks.

In-field weed counts

On-farm trials
In the spring and early summer of 2007, each site was sampled to quantify the treatment effects on spring weed emergence. Quadrats of various size and number were used to sample the in-field weeds.

Research farm trials
In 2007-10, in-field counts of weed seedlings were taken with various quadrat sizes and numbers. In 2007, each treatment plot was sampled three times throughout the summer and always before a tillage event. For each sampling date, two x 1/8 square meter quadrats were used to sample the main plot area and one x 1/8 square meter quadrat was used to sample the within/without cage area. In 2008, each treatment plot was sampled five times throughout the summer. Quadrats of various sizes were used for the plot counts. A within and without cage census also occurred in the no-till treatments in May. In 2009, one in-field census was taken with four x ¼ square meter quadrats. In 2010, an in-field census count of crabgrass was taken for each plot, as this was the predominant weed present. Two x 1/16 square meter quadrats were used in each plot.

Weed biomass collection

On-farm trials
In 2006, weed biomass was collected at each on-farm site before the final harvest or tillage to predict weed pressure at the end of the season. Quadrats of various sizes were used at different farms. Weed samples were separated, dried, and weighed.

Research farm trials
For most project years, weed biomass samples were taken in the fall prior to flail mowing and tillage. This sampling helped illuminate the weed pressure found at each plot prior to treatment establishment. The zero seed rain treatment was usually already established by the time of biomass sampling. In 2007, an additional final weed biomass sample taken at the end of the summer growing season. Weeds were separated by species (except for final weed biomass taken in the fall of 2007), dried, and weighed. Quadrats of various sizes and numbers were used in sampling.

Depth sampling

Research farm trials
In 2009, during the May soil sampling, an additional depth sampling occurred in plots that were tilled with a cover crop and no-till cover crop planting. This was
attempted to identify weed seed position in the soil stratum in tilled vs. no-till treatments. For each plot, ten cores at two depths (total of 20 cores) were taken. The first depth layer consisted of the topsoil to a 10 cm depth. The second layer was the deeper 10 cm layer of soil below the first sample. Each depth layer was kept separate, mixed and spread on a greenhouse flat lined with vermiculite. All flats were watered in the greenhouse and dried down twice throughout the summer. All weeds were counted and pulled shortly after emergence.

Vacuumed soil samples

Research farm trials

In 2009, soil was vacuumed in attempt to assess weed seeds present in the soil. Plots were sampled for weed seed on 23 September 2009. Two one-quarter square meter quadrats of weeds were cut from each plot and the weed seeds on the surface were collected using a canister vacuum cleaner. The seeds and associated soil was later dried and sieved through a box-framed screen. For each plot, 250 g of soil from the vacuumed soil sample were run through a hydropneumatic root washer (Gillison’s Variety manufacturer). The washed soil sample was flushed onto a piece of bridal veil to catch seeds but allow water to flow through. These samples were then dried and hand picked for weed seeds. Viable seeds were counted and the data recorded. Due to the large volume of seeds in the 250 g sample, a sub-sample of 20%-33% of total weight was apportioned, weighed, and counted. Eleven out of twenty samples were counted before termination. The process proved too costly to continue.

- Hand weeding at Peacemeal Farm, Dixmont, Maine, to establish zero seed rain treatment.
- Estimating the germinable weed seedbank by exhaustive germination in the greenhouse.
- Wire mesh cages were used to exclude weed seed predators. Seedbank density within cages was compared to outside cages to estimate predation losses.
- Participating farmer Mark Guzzi (and Camilla) from Peacemeal Farm examine seedbank flats from their farm in Dixmont, Maine.
- Fall weed biomass sampling.
- Participating farmer Rob Johanson no-till seeding a fall rye cover crop; predator exclosures were installed to estimate predation losses.
- “No Weeds” subplot in melons at Peacemeal Farm, Dixmont, Maine.

Research results and discussion:

We have successfully demonstrated the potential short-term benefits of fall weed management that focus on the weed seedbank to farmers throughout the region through case studies and presentations to nearly 600 people, approximately 400 farmers. While predation caused a large reduction in the weed seedbank in one of four years, the zero seed rain treatment proved to cause a consistent and dramatic reduction in the weed seedbank.

Outcomes

Field experiments examined effects of management for zero seed rain and practices that maintain weed seed rain at or near the soil surface to encourage losses due to predation and germination.

Germinable seedbank
On-farm trials
In 2007, the data in this trial and preliminary results indicated a variable response to the treatments. As to be expected, each site varied considerably in the weed species present, their overall densities and the timing of establishment of the treatments. When comparing tillage treatments, which bury weed seeds, and flail treatments, which leave the seeds on the soil surface, three of the six on-farm sites did see a reduction in the germinable portion of the seedbank with the flail treatments. However, only one site had a reduction that was dramatic enough to be somewhat conclusive. Two sites ended up having a higher seedbank in the tilled treatment. At one site, the two treatments were very similar. The samples collected from within and near to the seed predator exclosures also varied considerably between sites. Two sites did have dramatically lower seedbank numbers outside of the caged areas, perhaps indicating seed predator activity. However, at two other sites, more seeds were found outside the cages.

In 2008, the number of exclosure cages was increased from two to ten per plot. One site saw no change in spring germinable seedbank (an average of 5,000 germinable seeds within predation exclosures, and 5,000 germinable seeds outside the exclosure). However, at two other farm sites, the predator exclosures resulted in more weed seeds. For example, at the Goranson Farm, the germinable weed seedbank averaged 10,000 seeds within exclosures, but 6,000 seeds outside the exclosures (see Appendix).

In 2009, on-farm weed communities were comprised of an average 8 to 10 species on each farm. The three most abundant species at the Peacemeal Farm, redroot pigweed, common lambsquarters and hairy galinsoga, are a widespread problem among northeastern vegetable growers. At the New Leaf Farm, smooth crabgrass was the top-ranked species, primarily because of a large infestation in a field where pigs had been pastured. The number two- and three-ranked species, low cudweed and corn spurry, while a problem in salad mix, are not particularly troublesome in most other vegetable crops. At the Beech Grove Farm, typically pernicious summer annual weeds were rare and not among the top ranked species which included marsh yellowcress, mouseear chickweed, and Virginia strawberry. Mean seedbank density at the Beech Grove Farm was 550 germinable seeds per square meter (10 cm depth); this compares to 5,000 and 12,500 germinable seeds per square meter at the New Leaf and Peacemeal Farms, respectively. The focus on managing the weed seedbank at Beech Grove is clearly reflected in this small dataset which represents the low, medium and high seedbank conditions that are found on diversified organic vegetable farms (see Appendix).

Research farm trials
According to data collected in 2007, hairy galinsoga, Galinsoga ciliata, and smooth crabgrass, Digitaria ischaemum, dominated the germinable portion of the seedbank, comprising 41 and 43 percent of the total number of germinable seeds respectively. Common lambsquarters, Chenopodium album, was the third most common weed found but when averaged over all of the treatments it comprised only 5 percent of the seedbank. Contrary to expectations, there were no detectable differences found between the four treatments for the germinable portion of the seedbank (Table 1).

In 2008, the number of exclosure cages was increased to overcome within-field heterogeneity which may have obscured detection of the effects of weed seed predators. In both on-farm and research farm trials, the effects of weed seed predators on the subsequent year germinable seedbank was dramatic, averaging nearly a 40% reduction over the fall, winter, and early spring period of predation. The germinable weed seedbank averaged 62,000 seeds within exclosures, but 36,000 outside the exclosures (Table 2). The fall seedbank management practices,
however, generally resulted in similar levels of predation, despite our expectation that no-till/cover cropping would result in greater levels of predation and thus a lower spring germinable seedbank. For example, common lambsquarters measured in the spring following either no-till or till/cover crop treatment resulted in 11,000 and 13,000 germinable seeds per square meter, respectively. The “zero-seed” treatment consistently resulted in the lowest seedbank levels, as expected. Notable, however, is the fact that a single season of seed rain prevention resulted in large reductions in the germinable seedbank of both long-lived (e.g., common lambsquarters) and short-lived seeds (e.g., hairy galinsoga and annual grasses), suggesting that the benefits of such a practice may be realized within a shorter time frame than is generally expected. The impact of the zero seed rain treatment was dramatic: 600 germinable common lambsquarters seeds per square meter. While it may not be surprising that eliminating weed seed rain causes a reduction in the germinable seedbank, the magnitude of this single-season effect is noteworthy. It demonstrates that, even for a species with complex seed dormancy such as common lambsquarters, benefits of seedbank management practices may be realized within a short time frame (Table 5).

In 2009, barnyard grass response was consistent with our hypotheses regarding greater seed loss with no-tillage (860 seeds per square meter) compared to a tilled cover crop (2,800 seeds per square meter) (Table 6). However, these treatments had similar effects on the other dominant weed species including redroot pigweed, Amaranthus retroflexus, common lambsquarters, Chenopodium album, low cudweed, Gnanaphalium uliginosum, and marsh yellowcress, Rorippa islandica. It appears that, inexplicably, predation levels were very low in the fall/over-winter period of 2008-09; for all species, spring seedbank density was similar in samples collected within and outside seed predator exclosures. After the dramatic exclosure effects documented in the 2007-08 field season, this was unexpected, but demonstrates the potentially large variability in predation effects. Management to enhance predation losses has consistently been equal to tillage-based treatments, but only in 2008 did it contribute to significant seed losses.

In 2010, crabgrasses, Digitaria spp., and barnyard grass, Echinochloa crus-galli, were the most abundant weed species (Table 7). Treatment differences were not as clearly delineated in this year’s trial. The zero seed rain treatments had the lowest abundance of annual grasses and total weeds present, while the flail treatment had the highest. Likewise, the lowest perennial broadleaves abundance was in the zero seed rain treatment and highest in the moldboard plow treatment. Though no significant differences were found between exclosure treatments (within/without), on average, there were fewer redroot pigweed, lambsquarters, and barnyard grass found outside the cages.

In-field counts

In 2007, sampling of weed densities in the field before primary tillage demonstrated that the till/cover crop treatment had significantly more weed seedlings compared to the other three treatments. Annual grasses (most likely smooth crabgrass) and common chickweed, Stellaria media, were the most abundant weeds at this sampling date and were also found in significantly higher numbers in the till/cover crop treatment. At the sampling before the first weed control cultivation event, when the corn was in the 2 to 3 leaf stage, the zero seed rain control treatment had significantly fewer weed seedlings then the other three treatments. Hairy galinsoga was found in significantly higher numbers in the till/cover crop treatment. Annual grasses were the second most common weed at this sampling and were found at similar levels in all of the treatments. At the second weed control cultivation event, when the corn was in the 6 to 8 leaf stage, the zero seed rain control treatment had
significantly fewer weeds than the other three treatments. The most abundant weed species were, again, hairy galinsoga and annual grasses combined. Hairy galinsoga was more abundant in the till/cover crop and the flail treatments. Annual grasses were lower in the zero seed rain control treatment.

In 2008, the no till/cover crop treatment averaged more seedlings in field than any other treatment. Surprisingly, the till/cover crop treatment averaged fewer seedlings than the zero seed rain treatment. In 2009, the zero seed rain treatment had the lowest number of weed seedlings, while the till/cover crop had the highest. In 2010, the lowest abundance of crabgrass seedlings was in the zero seed rain treatment, with the highest abundance found in no till/cover crop treatment.

Weed biomass

After the 2007 final weed biomass sampling, the no till/cover crop treatment had the greatest biomass of weeds when compared to the other three treatments. As expected, the zero seed rain treatment had the lowest weed biomass. After the final weed biomass sampling in 2008, the flail and till/cover crop treatments had the greatest amount of weed biomass (717 g and 670 g per square meter), followed closely by the no till/cover crop (570 g per square meter). The zero seed rain treatment averaged the lowest amount of weed biomass (7 g per square meter). In 2009, the pre-over wintering, fall biomass sampling averaged the lowest amount of weed biomass for the zero seed rain treatment (7.3 g per square meter) compared to the other four treatments (plow 205 g per square meter, till/cover crop 230 g per square meter, no till/cover crop 250 g per square meter, and flail 303 g per square meter).

Depth sampling

There were significantly more total weed seedlings found in the top 10 cm layer of soil in both till/cover crop and no-till/cover crop treatments (42,000 seeds vs. 20,000 seed in no-till/cover crop, top layer to bottom layer respectively; 63,000 seeds vs. 18,000 seeds in till/cover crop). This lends credence to the idea that most germinable seeds will be found in the top 10 cm of soil.

Vacuumed samples

While not all vacuumed soil samples were examined, the zero seed rain samples averaged significantly fewer viable crabgrass and barnyard grass seeds than the other treatments (360 crabgrass and 170 barnyard in zero seed rain treatments vs. 3,900 crabgrass and 170 barnyard in the flail treatments).

- Data Tables 1 through 6.

Participation Summary

Education

Educational approach:

There has been an increasing interest in the topic of weed seedbank management at local and regional grower meetings. The new datasets from Managing Weed Seed Rain were featured at invited presentations during the 2008-09 calendar year and a symposium at the Northeast regional weed science meeting in early 2010:

• Managing Weeds with Crop Rotation. New England Vegetable and Berry Conference, Manchester, NH (16 December 2009; attendance 250).
• Managing weed seed rain to enhance physical weed control efforts. 8th European Weed Research Society Workshop on Physical and Cultural Weed Control, Zaragoza, Spain (9 March 2009; attendance 90).
• Seed Rain Project — Weed Master. Maine Agricultural Trades Show, Augusta, ME (13 January 2009; 75 attending).
• Managing the weed seedbank with many little hammers. Growing Organic Grains, University of Vermont Cooperative Extension Spring Grain Growers’ Meeting, Berlin, VT (April 3, 2008; 45 attending).

The on-farm seedbank sampling has been of great interest to growers, used as a handout by Eric and Anne Nordell during their recent presentations (see attachment), and posted to the University of Maine Weed Ecology Group Blog (gallandt.wordpress.com). As of 10 December 2010, the posts related to this project, “Weed Seedbanks: 2009 On-farm Sampling,” and “Managing Weeds with Crop Rotation,” have had 51 and 141 views, respectively.

• On-farm seedbank sampling including Beech Grove Farm of Eric and Anne Nordell.
• Poster presented at the European Weed Research Society Physical and Cultural Weed Control Working Group Meeting.

No milestones

Additional Project Outcomes

Project outcomes:

Impacts of Results/Outcomes

Over the course of this project, through consistent outreach efforts, the “seedbank” has become something that growers now routinely refer to when discussing weed management. We demonstrated that weed seed predation can cause major reductions in the seedbank (42% fewer germinable seeds in the presence of predators compared to within exclosure controls). This effect was also observed at our on-farm in 2007-2008 where, at the Goranson Farm, there were 40% fewer germinable seeds outside the predation exclosures. However, predation effects were inconsistent, detected in only one of the four years of this project. As censuses of seed predator communities was beyond the scope of this project, we have no explanation for the lack of significant predation losses in three of the four years.

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sampling points weed seedling densities were similar among the fall weed management treatments. Such reduction in initial seedling densities would result in fewer seedlings surviving cultivation events.

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Farmer Adoption

Two organic vegetable growers, both leaders in the community, were most engaged by the project and have made significant changes in weed management on their farms. Rob Johanson, Goranson Farm in Dresden, Maine, noted that he “stopped disking his weed seed into the soil,” which used to be standard practice on his 70 acre diversified organic vegetable farm, and “If I had a no-till drill I would no-till all my fall cover crops.” Mark Guzzi, Peacemeal Farm, Dixmont, Maine, bought a flail mower to permit mowing weeds and residues without risk of damage to neighboring crops. According to Mark, “If I have a weedy patch, I’ll flail mow it to give the beetles a chance to eat the seeds.”

The strong attendance at grower meetings focused on managing the weed seedbank, and the frequent inclusion of reference to the seedbank when growers discuss weeds suggests that this project has contributed importantly to their expanded view of weed management. Overall, while this project failed to identify practices and engage growers in radical change in their farming practices, we succeeded in contributing to a more incremental change in weed management, with realization that progress over time will require efforts to reduce the weed seedbank.

- **Rob Johanson, Goranson Farm, Dresden, Maine**, pleased to have abundant weed germination in the early spring, encouraged by avoiding fall tillage thereby leaving weed seeds at the soil surface.

Assessment of Project Approach and Areas of Further Study:

Areas needing additional study

Promising predation rates, but inconsistent predation, will require more fundamental research regarding this phenomenon. Despite the lack of consistency, it is unlikely that fall weed management to keep weed seed at the soil surface has any downside. Rather, there is opportunity for predation, as well as unfortunate germination that will contribute to seedbank debits greater than conventional fall tillage and cover cropping practices.