

# **Organic Weed Management: Balancing Pest Management and Soil Quality in a Transitional System**

**Russell E. Larson Agricultural Research Center  
Rock Springs, PA**

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## Project Summary

Weed management is one of the primary IPM challenges for organic producers. This project, funded under USDA IREECGP - IPM - ORG - 112.E in September, 2003, focuses on weed management during the transition to an organic feed grain rotation through specific research, education and outreach, and strategic objectives. Field research focuses on the efficacy of multiple tactics for reducing initial weed populations: reduction of the seedbank through tillage-stimulated germination, suppression of germination through cover cropping and minimizing tillage. The effect of these tactics on soil quality, pest and beneficial invertebrates, and economic indicators is being measured. This report provides a brief summary of the data collected and the preliminary results from this field experiment and documents related teaching and technology transfer activities over the first 18 months of this project. Education and outreach programs and materials are being developed and delivered to a broad audience including students, technology transfer agents and the general public. The effectiveness of the outreach programs in changing technology transfer agents' behaviors and attitudes will be evaluated over the course of this project as research activities in the field experiment continue.

### Introduction

This project focuses on crops that support transition to organic production in segments of agriculture appropriate to Pennsylvania and the northeastern U.S., and illustrates underlying principles broadly relevant to organic production nationwide.

*Organic Production Trends:* Nationally, the number of certified organic milk cows increased by 469% between 1992-1997, and organic dairy sales in mainstream supermarkets were up 200 % or more in major markets between December 1997 and 1998 (Greene, 2000). Dairy and poultry are major segments of the agricultural economy in PA. In 2000, Pennsylvania ranked 4<sup>th</sup> in the U.S. with over 5000 certified organic dairy cows, and ranked 3<sup>rd</sup> after California and New York with over 66,000 certified organic layers and broilers. The growing demands for organic milk and eggs is increasing the need for certified organic pasture and organic feed grains (Dimitri & Greene, 2002). In most organic livestock operations it is desirable to raise animals on a mix of organic pasture and supplemental feed, such as grain or hay. Producers can grow supplemental feed for use on-farm or gain additional income through the production of organic feed for sales. According to the 1997 Organic Farming Research Foundation (OFRF) survey, 59% of respondents who produce livestock conventionally on their farms indicated that the price and/or availability of organic feed is a barrier to producing livestock organically (OFRF, 1998).

*Stakeholder IPM Needs and Input:* Weed management in reduced pesticide and organic cropping systems is a priority for a large number of growers nationally and is consistently listed near the top of organic and reduced-input grower's pest management concerns (Smith and Henderson 1998; OFRF 1998; Francis 2002). In the 1997 National Organic Farmers' Survey, which included Northeast Organic Farming Association members, 28% of respondents ranked weeds as the greatest barrier to organic transition. Weed management was the highest ranked research priority by the 1,192 nationwide respondents (OFRF, 1998). This need was followed closely by research on insect pest management, soil fertility, best organic cultural practices, and soil biology. The Northeast IPM Needs Assessment which resulted from grower input, cited alternative management practices for weeds and weed seed production as a major research need. In a survey conducted on membership research needs by the Pennsylvania Association for Sustainable Agriculture (PASA) in Spring 2002, cropping systems, tillage techniques and pest

management were recognized as priority areas (Francis, 2002). About 40% of the cropping system priority topics identified in the PASA survey focused on cover crops and reduced tillage and about half of the identified pest management needs focused on weeds in organic and reduced pesticide use systems.

*Current Research and Background:* A growing body of scientific literature emphasizes the importance of weed seedbank size to successful weed management and crop productivity (Liebman et al., 2000; Mortensen et al., 2000). Although alternative systems may successfully limit crop yield loss to comparable levels attained with herbicides, weed control efficacy may be lower and more variable than in conventional systems, resulting in larger annual inputs into the weed seedbank in and on the soil (Roberts, 1981; Forcella et al., 1993; Gallandt et al., 1998). Biological and cultural weed management methods that focus on reduction of weed seedbanks and their maintenance at low levels may be highly effective (Jordan et al., 1995; Jordan 1996). Somewhat higher weed densities and weed seed inputs associated with non-chemical management strategies may not have negative long-term economic consequences if seedbank densities can be maintained at low levels (Mortensen et al., 1993).

A critical first step in the successful transition to organic production is the reduction of the weed seedbank. Weed management efforts usually focus on achieving a critical weed-free period early in the growth of the cash crop (Wyse, 1992). The focus on limiting crop yield loss instead of weed seed production, however, may result in a recurring weed problem if seed production by early surviving weed cohorts is very high and later emerging weeds produce viable seed. When numbers of viable seeds in the seedbank are high, mortality factors such as allelopathic effects of residues, enhanced crop competition, and seed predation will not be sufficient to maintain low weed density and biomass (Liebman & Gallandt, 1997, Mortensen et al., 2000). The density of weeds surviving cultivation and early crop competition is directly proportional to the density of viable weed seeds in the seedbank (Dieleman et al., 1999), and at lower weed densities less intensive weed management is needed to achieve acceptable weed suppression (Hartzler & Roth, 1993; Dieleman et al., 1999).

The most common tactic for managing weeds in organic systems is tillage (Bowman, 1997; Smith & Henderson, 1998; Mohler, 2001). Seventy-five percent of the respondents of the OFRF survey used mechanical tillage, weeding by hand or with hand implements, and crop rotations to manage their weed problems (OFRF, 1998). The reliance of organic growers on tillage as a weed management tactic can be in conflict with goals of soil conservation and promotion of soil quality. Systems of crop management focusing on soil quality hold great promise for sustainable and organic agricultural production. A common assumption is that soil on organic farms has a higher abundance and diversity of beneficial soil organisms, and therefore, greater soil quality, compared to conventional farms. Soil organic matter is the base of the soil food web and soil organisms can play a major role in providing beneficial ecosystem services, e.g., decomposition and nutrient cycling and biological control of pests (Coleman & Crossley 1996; Wolters, 2001). Disturbance from intensive tillage used to control weeds and incorporate green manures and compost can rapidly degrade organic matter and suppress soil organisms (Stinner & House, 1990; Hummel et al., 2002; Barbercheck, unpubl. data). To enhance soil quality and function, alternatives to tillage for management of weeds and cover crops should be considered. It is also critical to know what effects these management practices will have on other parts of the system.

## **Project Objectives**

The overarching goal of our work is to identify weed management approaches that balance the goals of pest management, soil fertility, crop productivity, and soil quality. We are approaching the project through specific research, education and outreach, and strategic objectives.

### Research Objectives

- 1) Compare weed management approaches based on weed seedbank depletion through stimulation and/or suppression of weed seed germination.
- 2) Compare the effects of these management approaches on soil quality indicators, pest and beneficial organism populations, crop productivity, and economic indicators.

### Education and Outreach Objectives

- 1) Gather and synthesize existing information from multiple sources that illustrate production and ecological principles critical to transition to organic production systems
- 2) Incorporate information on transition to certified organic production into educational materials to support resident education
- 3) Make information on transition to organic production available to extension agents and other trainers, producers, and organizations that represent agricultural interests by developing and delivering outreach materials and programs.

### Strategic Objectives

- 1) Help build and strengthen collaborative relationships within and among Penn State faculty, the organic farming community, producers considering transition, and organizations that represent organic and sustainable agriculture interests in Pennsylvania and the northeastern U. S.
- 2) Establish certified organic land at the Russell E. Larson Agricultural Research Center that will serve as a resource for interdisciplinary research, education and outreach activities
- 3) Increase the level of awareness of Penn State University faculty, staff and students, and the general public about organic production.

## **Research Methods**

### **Field Plots**

The field experiment is being conducted at the Russell E. Larson Agricultural Research Center near Rock Springs, PA. The dominant soil type at this location is a Hagerstown silt loam. There are two consecutive phases in the experiment: Phase I.) a preparatory phase designed specifically to reduce the weed seedbank and to address research Objective 1 above, followed in the same plots by Phase II.) a crop production phase to measure the weed reduction effects of the preparatory phase and to address research Objective 2 above. Field and laboratory activities/operations are summarized in Appendix 1. Plot maps are located in Appendix 2.

The field experiment has been established twice, in the falls of 2003 and 2004, in a split-plot, randomized complete block design with four replications. The approximate total combined area of the field experiments is 4 hectares and is surrounded by a minimum of 7 m of routinely mown grassy border on all sides. There are 16 main plots (4 treatments x 4 blocks) in each start year which are each 0.125 ha in size. Plots were laid out in the field so that plot length and width are as close to equal as allowed by field equipment operational needs. The second start was

managed with organic methods for the year before its inclusion as a temporal replicate in the over all transition experiment. In the fall of 2003, two cover cropping strategies were initiated and intensively managed over the spring and summer of 2004. The two cover crop treatments were rye (*Secale cereale*) (managed for grain production) and a mixture of red clover/timothy (*Trifolium pratense* / *Phleum pratense*) (managed for forage production that was established with an oat [*Avena sativa*] nurse crop that winterkilled and was subsequently replanted in the spring of 2004). These two cover cropping systems were split over two tillage systems which were conventional (moldboard plow-based) and a reduced tillage system (chisel plow + field cultivator based). Feed-grade soybean (late Group III maturity) will be planted in all cover crop/tillage treatments in the spring of 2005 at a row spacing of 76 cm.

The following tables are a timeline for the crop rotation in the first start year. The second start will be managed in a similar fashion, but will be delayed by one year.

<b>Phase I: Weed seedbank reduction</b>						
2003	2003	2004	2004	2004	2004	2005
Fall	Winter	Spr	Sum	Fall	Win	Spr
Treatments 1 & 3: rye			Rye Stubble- Hairy Vetch			
Treatments. 2 & 4: Timothy/Oats			Timothy /Red Clover			

<b>Phase II: Crop production</b>					
2005	2005	2005	2006	2006	2006
Sum	Fall	Win	Spr	Sum	Fall
Soybeans		rye		corn	forage
Soybeans		rye		corn	forage

## Soil Measures

Three composite soil samples, comprised of 15 cores (2.54 cm X 15.25 cm )were collected from three random locations within each treatment plot. This sampling depth represents the most biologically active zone in the soil profile. Each composite soil sample was placed in a large bucket lined with plastic garbage bags and thoroughly mixed. This composite sample was then divided in the laboratory into three portions of approximately 500 g each. Therefore, the same soil sample was used for both chemical and biological analyses. The sub sample for soil borne insect pathogen analysis and Tullgren funnel analysis was placed in plastic containers (Reynolds 473 mL deli containers) and stored in an incubator (11.5 – 14 C) until the baiting procedure and extraction procedures which are described in detail below. The two sub-samples used for characterizing soil physical properties (active carbon, soil fertility, pH, EC, gravimetric soil water content and matric potential) were placed in plastic bags and stored in a cold room (4.5 C). Dates that soil samples were collected on are listed in Appendix 1.



### Active Carbon

Permanganate oxidizable C levels (POC) were determined for the soil samples taken from each plot as described above using the lab method proposed by Weil et al. (2003). Soil samples were air-dried and then ground to pass through a 2-mm sieve. Soil (5 g) was reacted with 20.0 ml of 0.02 M permanganate solution in 47.5-ml screw top polycarbonate centrifuge tubes. The soil was added first followed by sequential aliquots of DI water (18.0 ml) and permanganate reagent (2.00 ml) using a mechanical pipette. The permanganate reagent contained 0.2 M  $\text{KMnO}_4$ , 1 M  $\text{CaCl}_2$  and was adjusted to a pH of 7.2 using NaOH. The  $\text{CaCl}_2$  was included to promote rapid flocculation of soil colloids. Weil et al. (2003) recommended raising the pH to 7.2 to increase reagent stability. Tubes were prepared in sets of 10, with each set including 8 experimental samples and 1 tube containing a standard soil and 1 tube containing a solution standard. Tubes were capped and shaken end to end (240 oscillations per minute) for 2 min and then allowed to settle an additional 10 minutes. Two hundred  $\mu\text{l}$  was collected from the supernatant after centrifuging and added to 9.8 ml of DI water and then vortexed to mix thoroughly. A mechanical pipette was used to transfer one 3.6 ml aliquot of supernatant to clean cuvette (4 ml) and the absorbance was measured at 550 nm using a spectrophotometer (Spectronic 21 D, Milton Roy).

The following equation was used to calculate POC as a function of the quantity of permanganate reduced ( $\text{Mn}^{+7} \rightarrow \text{Mn}^{+4}$ ) in each tube:

$$\text{POC (g/kg)} = [0.02 - (a + b \times \text{absorbance})] \times 9 \times 0.02 / \text{sm}$$

where 0.02 is the initial  $\text{MnO}_4^-$  concentration (mol/liter) in each tube, a and b are the intercept and slope of a standard curve, 9 is the mass (g) of C oxidized by 1 mol of  $\text{MnO}_4^-$ , 0.02 is the volume (l) of solution in each tube and sm is the mass (g) of soil added to each tube (Weil et al., 2003).

### Electrical Conductivity

Soil samples were air-dried and then ground to pass through a 2-mm sieve. Thirty ml of DI water was added to 15 g of soil. This mixture was shaken on a platform shaker for 1 minute and then allowed to settle for 15 min. The mixture was then centrifuged (IEC HN-SII) at 2000 rpm for 5 minutes. The EC electrode was then inserted into the centrifuge tube and EC ( $\mu\text{S/cm}$ ) was immediately read with a standardized EC meter (Thermo Orion 555A).

### Bulk Density

To determine the soil physical properties at the start of the trial, intact soil core samples were taken in August of 2004 in the treatment plots that had been harvested for rye in July. In December of 2004, the timothy/red clover treatment plots were sampled. Samples were taken to approximate 3 depths, i.e., 0-10 cm, 10-20 cm, and 20-30 cm. Two sampling locations were chosen in each plot for the August sampling, but due to shortage of sampling rings only one sampling location was taken in the center of each timothy /red clover plot in December. A hammer driven core sampler (Blake and Hartge, 1986) was used to obtain the intact soil cores

(7.6-cm in diameter by 7.6-cm in length) at each depth. The bulk density was calculated after coarse fragment (>2 mm) correction and is the oven-dry mass (105 C) of the sample divided by the sample volume.

### Soil Fertility

Soil samples from each of the three composite samples per treatment plot were analyzed by the Penn State Soil Analytical Laboratory for the following characteristics: soil pH, Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), CEC, % saturation of the CEC (K, Mg, Ca), Organic Matter, Trace Elements (Zinc, Copper and Sulfur).

### Hydraulic Conductivity

Hydraulic conductivity was determined for three soil depths (0-10 cm, 10-20 cm, and 20-30 cm) from intact soil cores (sample procedure as described in above Bulk Density section) using the constant head method (Klute and Dirksen 1986). Water retention was determined on these undisturbed cores at saturation, 33 kPa, 100kPa, and 300 kPa, and on disturbed samples at 1500 kPa using porous plates as described in Klute (1986).

### pH

Soil samples were air-dried and then ground to pass through a 2-mm sieve. Soil pH was determined using a 1:1 soil to water ratio (Smith and Doran, 1996). Five ml of DI water were added to 5 g of soil. The mixture was stirred for 1 minute and then allowed to settle for 10 minutes. The electrode was then inserted into the container and is swirled again with the electrode. The pH was then read on the pH meter (Thermo Orion 555A). The electrode was rinsed in distilled water between samples.

### Soil Matric Potential

Soil matric potential for each of the three samples per plot was determined using the filter paper method (Hamblin 1981). Briefly, oven-dried filter paper (Whatman No. 42, 55mm dia.) of known weight was placed in plastic bags containing 125 g of soil. The bags were sealed and stored in a sealed box and the filter paper allowed to equilibrate with the water in the soil for 48 hrs. The moisture-equilibrated filter paper was removed and brushed to remove attached soil particles and reweighed to obtain a wet weight. The percentage moisture of the filter paper was calculated as  $[(\text{wet weight} - \text{dry weight}) / \text{dry weight}] \times 100 = \% \text{ moisture of filter paper}$ . The water potential (-kPa) for each percentage was determined from a graph relating percentage moisture of the filter paper to soil matric potential in Hamblin (1981).

### Soil Gravimetric Moisture

Gravimetric soil moisture was determined for each of the three samples per plot by placing 30 g of wet weight soil in 10 cm X 6.25 cm tin soil cans (Gardner, 1986). The cans containing the weighed moist soil were dried in a bench-top oven (VWR 1324, Sheldon Manufacturing) at 45 C for 72 hrs. The dried samples were then weighed to obtain the dry

weight of soil. Percentage soil moisture was calculated as  $[(\text{wet weight soil} - \text{dry weight soil}) / \text{dry weight soil}] \times 100 = \% \text{ soil moisture}$ .

## **Arthropods**

### Epigeal Arthropods

Pitfall sampling methods (see photograph below) were used to assess the soil surface dwelling arthropod populations in the field experiment (Morrill, 1975). The pitfall traps consisted of 32 oz. plastic containers (~114mm mouth diameter, 129 mm deep) manufactured by Container and Packaging Supply with Dart Styrofoam cups (~87mm mouth diameter, ~60mm deep) and lids. Three traps per plot were placed randomly and buried to the rim of the container in each of the main plots in the field experiment so that the tops of the traps were flush with the soil surface. Once these larger containers were placed in the plot, the smaller Styrofoam cup were filled with ethylene glycol (40 mL) and placed in the bottom of the larger container. Funnels made of the tops of polyethylene 2 L bottles were placed in the top of the trap to exclude larger organisms from falling into the trap. The traps were opened for 72 hours, the contents collected and processed in the lab. The organisms were removed from the ethylene glycol with larger specimens pinned, and smaller specimens (< 2mm diameter) mounted on slides for identification.



### Soil Arthropods

Collembolans, mites, and a variety of small arthropods collectively known as microarthropods can be sampled in soil cores and extracted by a heat gradient apparatus such as Tullgren or Berlese funnels (Coleman and Crossley, 1996). Soil samples (65 g) collected as described above were placed in a Tullgren funnel (Crossley and Blair, 1991) constructed of 5 cm X 5 cm PVC pipe with one end screened with plastic window screen. The PVC with screen covering the lower edge was placed inside a 355 mL aluminum can that had the ends removed and a plastic funnel glued to one end. Ten mL vials filled with 80% ethanol were fixed to the

spout of the funnel, and prepared funnels placed on a frame that was fitted with indoor/outdoor transparent lights. Approximately 65 g of soil of soil was placed in each funnel for one week. Mites and collembolans were sorted from the microarthropods that collected in the vials and will be identified under a dissecting stereoscope (Nikon SMZ1500). Mites and Collembola will be identified to family (Evans 1992, Krantz 1970). A category called “Other” will be used for all of the unidentifiable (male and immature) mites. The category “Total” combined the counts of all mites, collembolans, and other arthropods and served as a general indicator of the abundance of soil microarthropods in samples. The larger organisms were retained in scintillation vials filled with 80% ethanol plus glycerol and microarthropods (< 2 mm) were mounted on microscope slides in Berlese’s Fluid for identification.

### Soilborne Insect Pathogens

A baiting bioassay method using *Galleria mellonella* as a host insect was used to detect entomopathogenic nematodes and fungi in soil samples (Goettel and Inglis 1997; Kaya and Stock, 1997). Soil samples were collected as described above. Soil (125 g) was placed in 710 mL deli container (Reynolds) along with 5 last-instar wax moth larvae (*Galleria mellonella*). The baited soil samples were stored at room temperature in the dark for up to 10 days. The cadavers were removed and placed in 59 mL lidded cups (Solo) cups for symptoms and signs of infection to develop. The bags of soil were then re-baited with five new larvae and incubated for an additional 10 days.

Cause of death was identified as fungal (*Metarhizium antisopliae*) or (*Beauveria bassiana*), entomopathogenic nematode or other. The nematode family was determined by the color of the cadaver. An ocher color indicated the presence of *Xenorhabdus nematophila*, the bacterium associated with *Steinernema*, whereas a red color indicated the presence of *Photorhabdus luminescens*, the bacterium associated with *Heterorhabditis* (Kaya and Stock, 1997). If there was uncertainty as to the infecting nematode species, the cadavers were dissected. Cadavers exhibiting symptoms of fungal infection were held individually in humid chambers (59 mL Solo cups) until sporulation. Sporulating cadavers were then classified as being infected with *Beauveria* (white spores) or *Metarhizium* (green spores) (Goettel and Inglis, 1997).

### **Weed Populations**

Seedbanks consisting of a mixture of weed species, foxtail (*Setaria* spp.), common lambsquarters (*Chenopodium album*) and velvetleaf (*Abutilon theophrasti*), were established at three densities in permanently marked individual 2 m<sup>2</sup> subplots within each treatment plot. The seeded weed densities were low, medium and high (60, 450, 2100 seeds/m<sup>2</sup>). These species and seed densities were chosen with the goal of establishing a range of plant densities in the study that could be used to quantify thresholds of plant densities above which the success of a given transitional weed management practice would be limited. The weed seed was mixed with 250 g of sand and applied by hand to ensure even distribution of the weed seed within the subplot. Location of the subplots was permanently marked with flags and through the use of a backpack GPS unit. Plot maps in Appendix 2 show the location of the weed subplots within the main plots of both start years. Seedling density and mature plant densities were quantified in both the weed sub-plots and within the larger main plots throughout the growing season in 2004.

## **Environmental Data**

Data loggers (HOBO Micro Station System, Onset Computer Corporation) equipped with soil temperature and soil moisture content sensors were placed in one replicate of each cover crop/tillage treatments (Rye/ConventionalTillage, Rye/ReducedTillage, Timothy Clover/Conventional Tillage, Timothy Clover /Reduced Tillage). Sensors were placed at a depth of 10 cm and data recording was started on May 14<sup>th</sup> and continued through September 27<sup>th</sup> at 1 hr intervals. All downloading was done with the loggers left ON to prevent data loss during downloading.

## **Economic Analyses**

Since the inception of the project, all related input costs and crop yields have been recorded. Detailed spreadsheets have been developed for each of the two start years of the field experiment. These spreadsheets provide details of actual costs and yields on the experimental plots (example in Appendix 4). The results will be used for two purposes. First, they will provide an accounting for the actual costs and returns accruing to the work under the project. These results may prove useful to future researchers converting other plots of land on experimental farms. Second, they will be used to adjust existing enterprise budgets to reflect the transition period to certified organic production. This information will be useful to commercial farmers exploring a transition to organic production methods. The enterprise budgets developed under this project will ultimately be used within a partial budgeting framework to compare the net returns during the transition period to net returns under alternative scenarios, such as if the transition had not occurred.

## Results

### Crop Yield

Yields for the rye (grain) and the timothy/clover (forage) crops in 2004 are presented in Tables 1 and 2 below.

**Table 1.** Mean crop and forage yields in 2004 in rye and timothy/red clover cover crop treatments.

Date	Treatment	Yield (kg/ha)
7/29/04	Rye (grain)	2669 <sup>1</sup>
8/2/04	Timothy/Red Clover (forage)	6781 <sup>2</sup>
8/3/04	Rye (straw)	4383 <sup>3</sup>
10/14/04	Timothy/Red Clover (forage)	1258 <sup>4</sup>

<sup>1</sup> Rye harvested at 12.9% moisture, 22.9 kg/bushel

<sup>2</sup> Forage harvested as high moisture hay round bales (63 % moisture) due to poor drying conditions.

<sup>3</sup> Rye straw was mown to ground level with a flail mower and removed from plots in round bales (24 % moisture).

<sup>4</sup> Forage yield at 23% moisture.

**Table 2.** Forage yields in 2004 in the 2<sup>nd</sup> start year timothy/red clover crop.

Date	Treatment	Yield (kg/ha)
6/30/04	Timothy/Red Clover (forage)	3562 <sup>1</sup>
8/2/04	Timothy/Red Clover (forage)	4844 <sup>2</sup>
10/14/04	Timothy/Red Clover (forage)	533 <sup>3</sup>

<sup>1</sup> Forage harvested as round bales (25 % moisture)

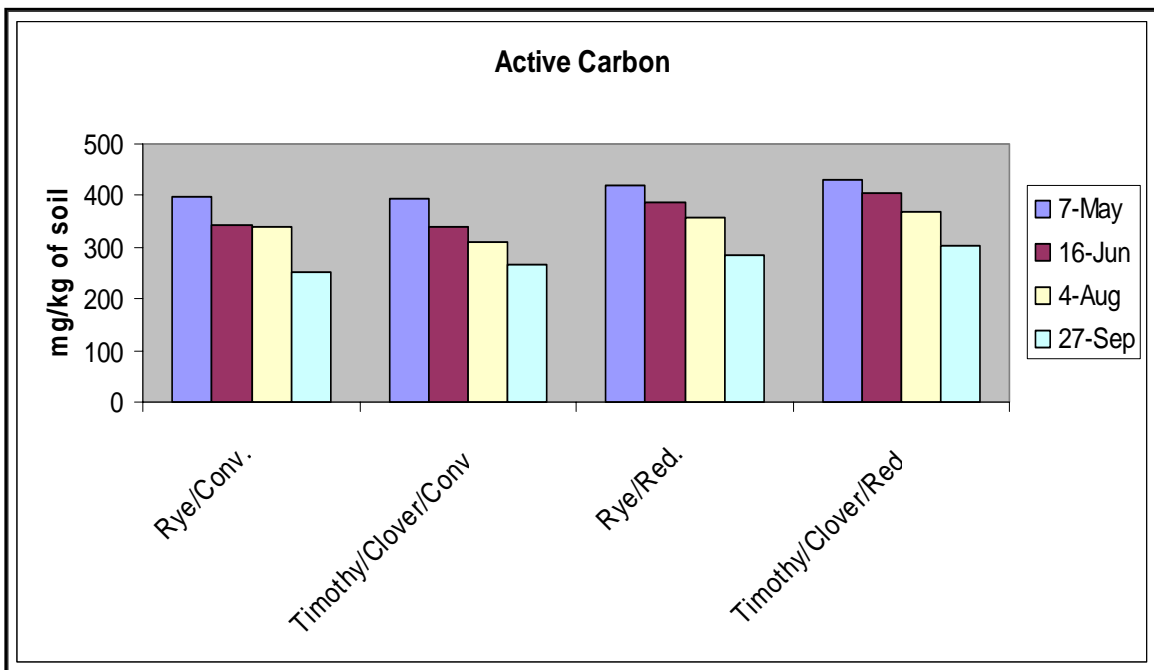
<sup>2</sup> Forage harvested as high moisture hay round bales (63 % moisture) due to poor drying conditions.

<sup>3</sup> Forage yield at 23% moisture.

## Soil Measures

### Active Carbon

Initial permanganate oxidizable C levels (POC) were influenced by both tillage system and sampling date (Figure 1). Cover crop type did not affect POC levels. The mean values averaged over tillage systems for the two cover crop systems were 347.7 mg/kg soil of POC in the rye crop and 352.9 mg/kg soil in the timothy clover crop, respectively. When separated by tillage type, the reduced tillage system (370.2 mg/kg) had significantly higher values of POC compared to the conventional system (330.4 mg/kg). POC values decreased over the duration of the sampling period with the highest values quantified early in the growing season (Julian date 128) compared to the end of the growing season (Julian date 271).



**Figure 1.** Values of permanganate oxidizable C (mg/kg of soil) in 2004 shown by sampling date for each cover crop/tillage treatment.

### Electrical Conductivity

EC measurements were completed for all the soil samples in the lab on March 3, 2005. Data are currently being summarized.

### Bulk Density

Bulk density measurements on soil cores collected in 2004 are ongoing as of May 1, 2005.

### Soil Fertility

Initial soil fertility testing at the site indicated that a liming rate of 3800 kg/ha and liquid dairy manure application rate of 38,000 L/ha would be needed to bring soil pH and soil nutrient levels into the optimum ranges for crop production (data are summarized in Appendix 3). Those applications were made on October 10<sup>th</sup> and 7<sup>th</sup>, 2003, respectively. Soil fertility tests in May 2004 indicated that all fertility levels were in the optimum to above optimum range so no further fertility applications were made. One application of compost was made (7257 kg/ha, purchased from Penn State Farm Services, Contact Person-Nadine Davitt, [njh103@psu.edu](mailto:njh103@psu.edu), (814) 865-6606) to stimulate biological activity in the soil profile.

### Hydraulic Conductivity

Hydraulic conductivity measurements were completed for all depths of all the soil cores in late March 2005. Data are currently being summarized.

## **Arthropods**

### Epigeal Arthropods

The number of mites collected/pitfall trap was unaffected by crop type and tillage system. However, sample date significantly affected numbers of mites collected. Similar results were found with the number of collembolans/pitfall trap, however, the trend was the opposite of the mite data with the highest number of individual quantified later in the growing season. The reasons for the opposite temporal dynamic exhibited in the collembolan data are unclear. It may be related to specific management practices employed on the research plots. Crop type, tillage system, and sampling date significantly influenced the number of microarthropods/pitfall trap (data not shown). Densities for each of the groups for the three sampling dates are summarized in the table below.

**Table 3.** Mean number of arthropods per pitfall trap over a 72 hr period averaged over crop type and tillage system from the pitfall sampling method.

Julian Date	Calendar Date	Mites	Collembolan	Microarthropods	Total
128	May 8th	15.8	28.4	21.0	65.3
168	June 7th	1.5	12.5	8.5	22.6
217	August 5th	3.6	147.7	15.0	166.4

Beetles collected by the pitfall sampling method were identified by Tim Leslie, Dept. of Entomology, PSU. Data and species lists are included in Appendix 5.



### Soil Arthropods

The abundance of microarthropods collected using the Tullgren funnel method was extremely low. This may be an indication that the soils in the transition field experiment have low levels of biological activity in general or that this sampling method is not sufficiently robust to detect these organisms under the current sampling regimen. Similar to the pitfall trap data, sampling date appears to be the major factor influencing the abundance of mites, collembolan, and microarthropods. Sampling date was a significant factor in both mite and collembolan numbers for the Tullgren funnel method. Crop type and sampling date both influenced the microarthropod counts using this method.

**Table 4.** Mean number of arthropods per soil sample averaged over crop type and tillage system using the Tullgren funnel method.

<u>Julian Date</u>	<u>Calendar Date</u>	<u>Mites</u>	<u>Collembolan</u>	<u>Microarthropods</u>	<u>Macroarthropods</u>
128	May 8th	0.5	0.1	0.1	0.6
168	June 7th	0.5	0.4	0.1	0.2
217	August 5th	0.4	0.4	0	0.1
271	Sept. 28th	0	0	0.25	0.4

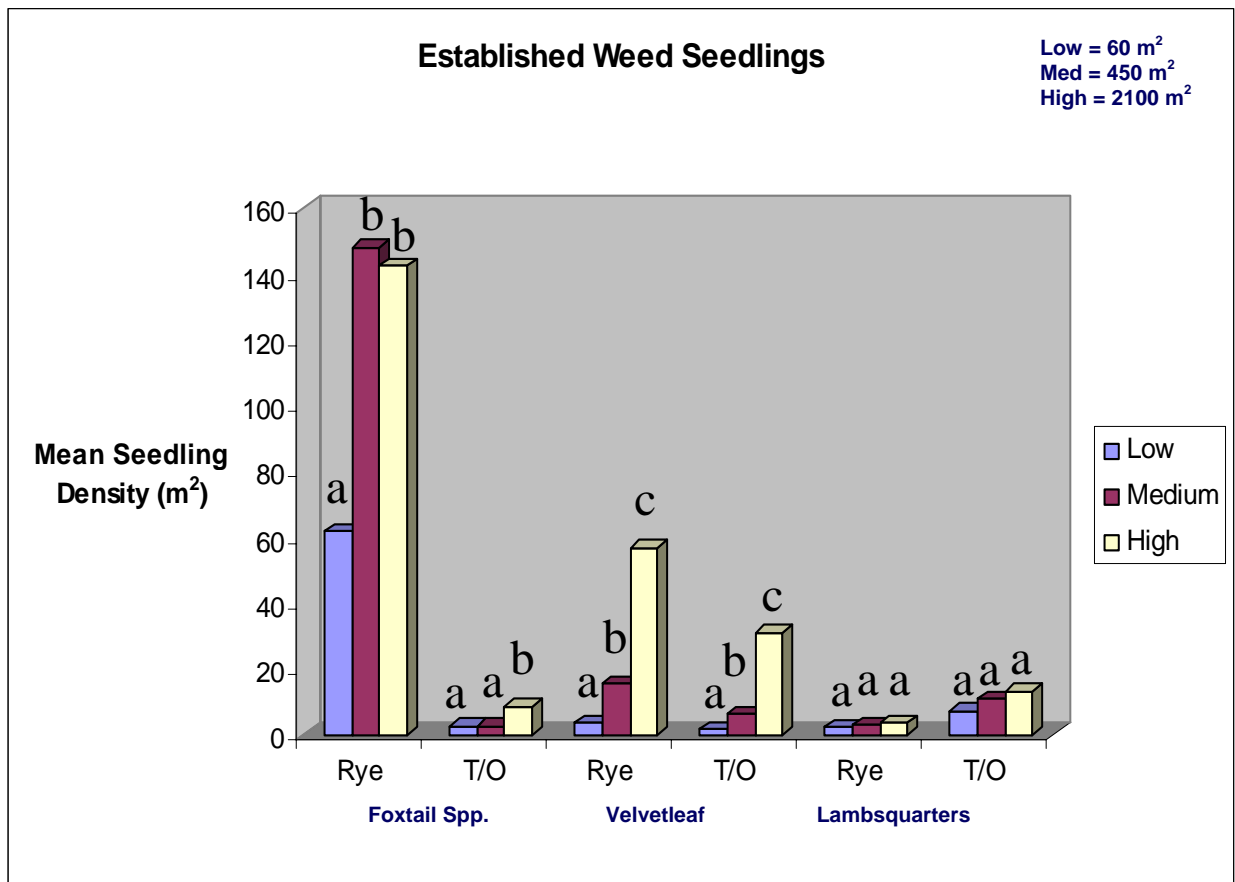
### Soilborne Insect Pathogens

Infection rates of *Galleria mellonella* were highly variable. Actual infection rates ranged from 0-80 %, but were usually very low. Infection rate was highest in the soil collected on September 28<sup>th</sup>, 2004. Cover crop type did not influence infection rate. Only the entomopathogenic fungus *Metarhizium*, was detected using the *Galleria* bait method and therefore has been documented at the field location. No EPN infection was documented in this baiting procedure. In general, the potential for biological control of pest insect species by soil dwelling insect pathogens appears to be limited at the field location at this point in the transition period.

### **Weed Populations**

Weed seedling densities were quantified in May and June in both the seed bank subplots as well as in the larger plots to quantify background weed densities. The three seeded weed species established in different proportions across the three seed densities and two cover crop treatments. In the rye cover crop treatment, foxtail establishment was higher than both velvetleaf and common lambsquarters. Foxtail seedling densities ranged from 60 seedlings/m<sup>2</sup> in the low subplot to near 150 seedlings/m<sup>2</sup> in both the medium and high subplots. Velvetleaf and common lambsquarters establishment was low in the rye treatment and averaged less than 10 seedlings/m<sup>2</sup> across all subplot densities for both species (except for the high velvetleaf density which was 60

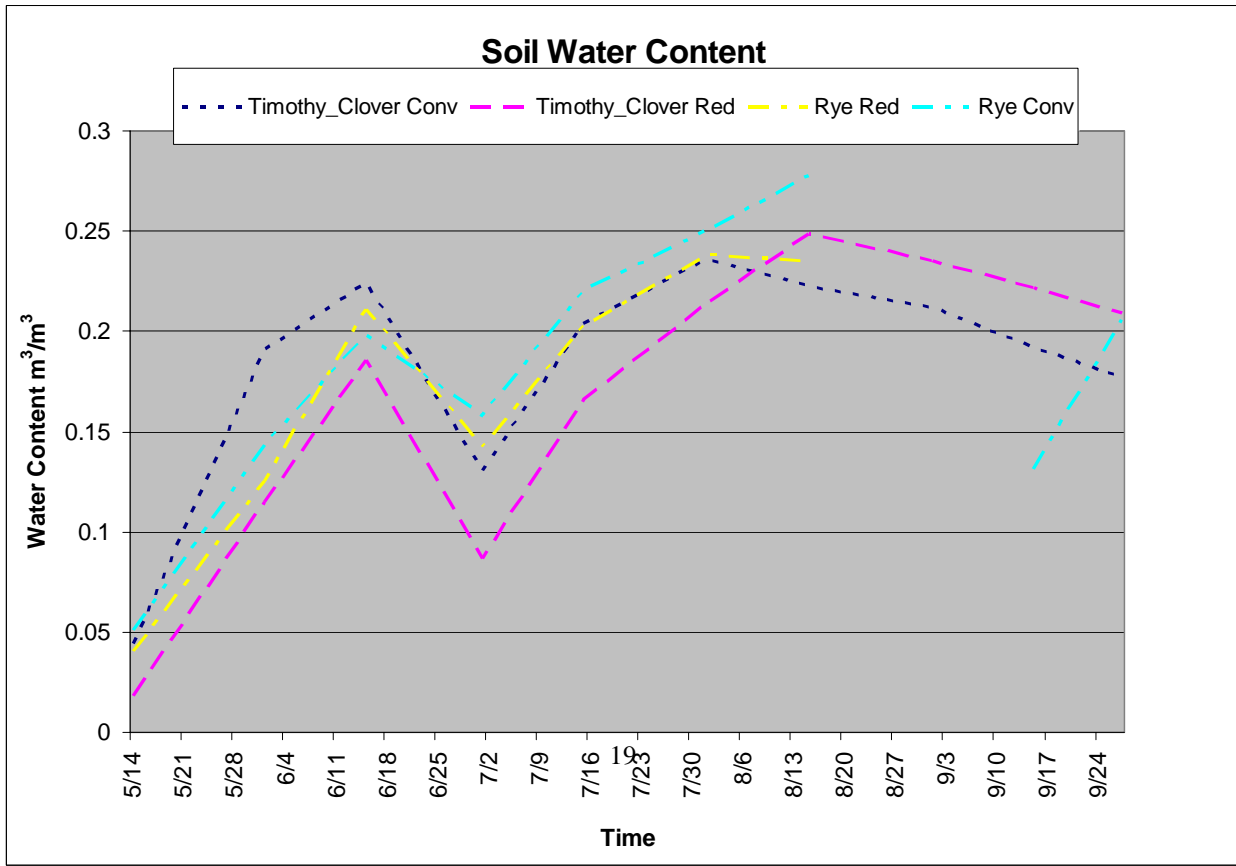
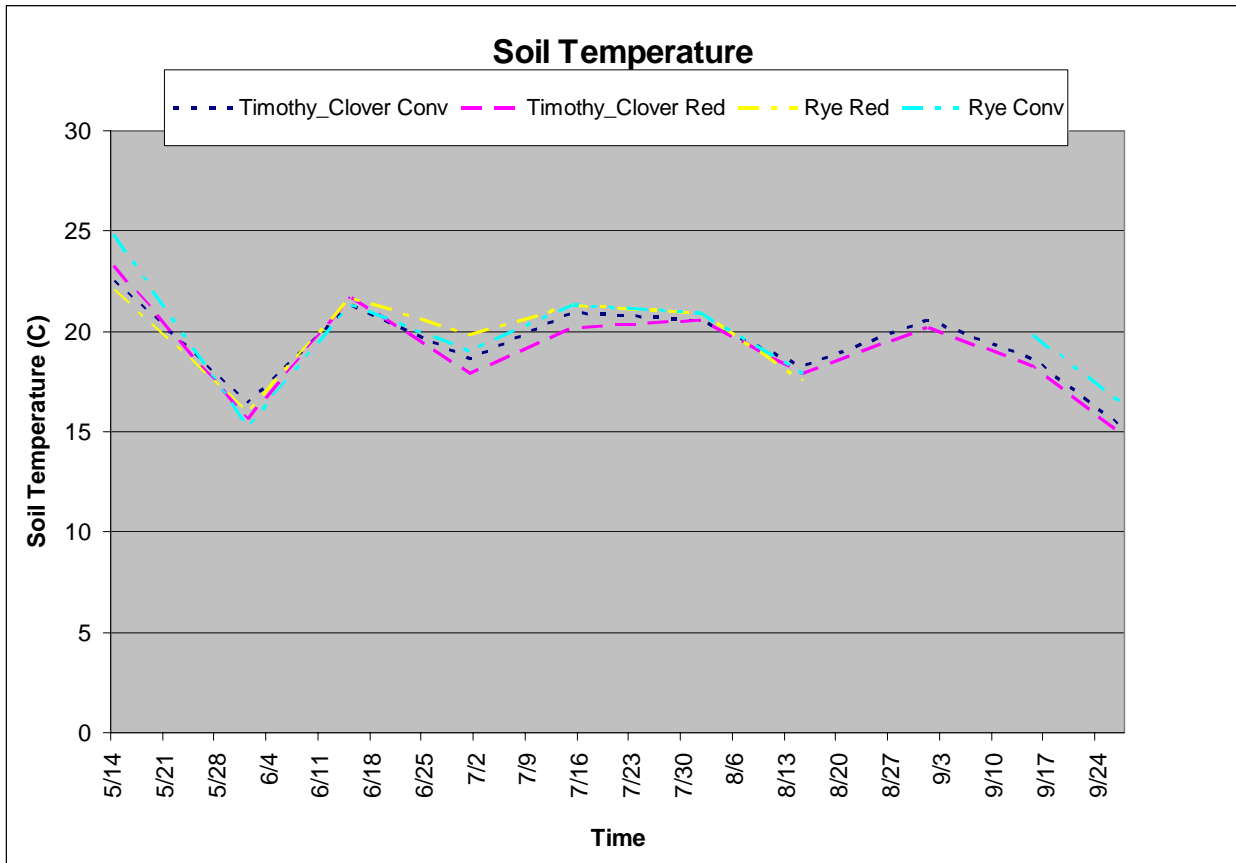
seedlings/m<sup>2</sup>). Conversely, foxtail establishment in the red clover/timothy treatment was very limited with less than 10 seedlings/m<sup>2</sup> establishing across all the subplot densities. Common lambsquarters established more than both foxtail and velvetleaf in the red clover/timothy treatment with a range of 12-18 seedlings/m<sup>2</sup> quantified across the subplot densities. These established densities (Figure 2) will be monitored over time to gauge the success of mechanical and cultural weed management practices (tillage induced germination, delayed seeding) on the dynamics of the weed populations in this organic system. As the crop rotation moves forward into soybean production it is apparent that perennial weed species such as Canada thistle (*Cirsium arvense*) and hedge bindweed (*Calystegia sepium*), which had patchy population distributions in this study, will need to be addressed.



**Figure 2.** Weed seedling densities in the rye and timothy/red clover (T/O) cover crop treatments across the three weed subplot densities (low, medium and high). Significantly different values of seedling densities for a given weed species within a crop type are signified by different lower case letters.

### Environmental Data

Soil water content and soil temperature curves are summarized in Figures 3 and 4 below. Sampling was conducted from mid May through late September.



## **Research/Teaching/Extension Activities**

### Education and Outreach Objectives

- 1) Gather and synthesize existing information from multiple sources that illustrate production and ecological principles critical to transition to organic production systems
- 2) Incorporate information on transition to certified organic production into educational materials to support resident education
- 3) Make information on transition to organic production available to extension agents and other trainers, producers, and organizations that represent agricultural interests by developing and delivering outreach materials and programs.

### Strategic Objectives

- 1) Help build and strengthen collaborative relationships within and among Penn State faculty, the organic farming community, producers considering transition, and organizations that represent organic and sustainable agriculture interests in Pennsylvania and the northeastern U. S.
- 2) Establish certified organic land at the Russell E. Larson Agricultural Research Center that will serve as a resource for interdisciplinary research, education and outreach activities
- 3) Increase the level of awareness of Penn State University faculty, staff and students, and the general public about organic production

Activities related to the above objectives are summarized below.

### **Teaching Activities**

Karsten, H. (Instructor)

[Agroecosystems Science 134, Political Science 134](#)

Sustainable Agriculture and Policy-new teaching materials on organic agricultural management

[Agroecosystems Science 461](#) - Integrated Crop Management

[Agroecosystems Science 490](#) - Producer Speaker Series

[Agronomy 597B](#) - Ecology of Agricultural Systems

Mortensen, D.A., (Instructor) Crop and Soil Science 497A-Principles of Management, Cropping Systems Lab Tour, 31 students. (Presenter) Hulting, A. Oct. 14, 2004.

Mortensen, D.A., and Dennis Calvin (Instructors) Entomology 457 Introduction to Integrated Pest Management, Development of 2 Case Studies, 15 students. Spring 2005

Uhl, C. (Instructor) Bio 297, Special Topics, Transition Project Field Tour, 15 students. (Presenter) Hulting, A. Sept., 30, 2004.

## Extension Presentations

Barbercheck, M. Organic Crop Production: the Basics. PSU cooperative Extension Inservice. March 17, 2005. State College, PA (w/ Andy Hulting, Linda Moist), 10 attendees.

Barbercheck, M. Penn State Transition to Organic Cropping Study. Dec. 8, 2004, Lititz, PA. PCO Annual Meeting and Banquet. Presented for Dr. A. Hulting (author), 100 attendees.

Barbercheck, M. Oct 29, 2004. Organic Basics: What do Organic Farmers Need? 2004 Fall CCA Continuing Education Seminar. Grantville, PA. 15 attendees.

Barbercheck, M. Farm Twilight Tour on Soil Biology, October 7, 2004, 5:30-7:30 pm, Eagle Point Farm, Kutztown, PA, Gail and Steve Ganser. 30 attendees, 6 women, 1 male teen.

Barbercheck, M. The soil food web and soil quality: Letting the soil work for you. Northeast Organic Farming Association Annual Meeting, Amherst, MA, Aug. 13, 2004, 75 attendees.

Barbercheck, M. Soil Health, Soil Quality, Impacts on Residual Effects of Pesticide in No-Till. Centre Region Crops Day. Pleasant Gap, PA. Feb. 11, 2004, 50 attendees (2 women).

Barbercheck, M. Soil Quality: Making the Soil Work for You. Southeast Pennsylvania Crops Conferences, Bucks Co. Feb. 5, 2004, 80 attendees.

Barbercheck, M. Soil Quality: Making the Soil Work for You. Southeast Pennsylvania Crops Conferences, Montgomery Co. Feb. 3, 2004, 200 attendees (10 women).

Barbercheck, M. The role of soil organisms in pest management. March 4, 2003. PSU Grounds staff in-service, University Park, PA., 75 attendees.

Barbercheck, M. Conserving Beneficial Organisms in Soil, PSU Technical Service Pesticide Training, January 6, 2004, PSU, 75 attendees.

Barbercheck, M. Insect Pest Management in Organic Systems. Lackawanna Co., Scranton, PA, Dec. 11, 2003. 15 attendees (4 women, 1 man and 1 woman of Asian descent)

Barbercheck, M. Organic Research at PSU. Pennsylvania Certified Organic 2003 Annual Meeting, Dec 10, 2003. Millerstown, Perry Co., 75 attendees.

Barbercheck, M. Agronomy Extension In-Service, Beneficial organisms in agricultural soil, November 20-21, 2003, PSU. 20 attendees.

Curran, W., D. Mortensen, D. Lingenfelter, and A. Hulting. July 15 2004. PSU Weed Science Group Field Day, Transition Project Presentation to Industry Representatives, 60 attendees.

Curran, W., D. Mortensen, D. Lingenfelter and A. Hulting. July 23, 2004. PSU Weed Science Group Field Day, Transition Project Presentation to PSU Extension Agents, 25 attendees.

Hulting, A. and C. Nardozzo. July 21, 2004. Governor's School Field Day Presentation, Transition To Organic. 100 students/attendees.

Nardozzo, C., Jabbour, R. August 17-19, 2004. Ag Progress Days Bus Tour of Transition Plots August 2004. 120 attendees.

Nardozzo, C. Delta School Field Activities August 15, 2004  
Two class sessions-Collected and Processed Soil Samples from Transition Field Plots, 16 attendees.

Nardozzo, C., Jabbour, R., and Klinestiver, B. (presented for Barbercheck, M.)  
Introduction to Organic Agriculture. Nov. 19, 2004. Agronomy Extension Agent In-Service. University Park, PA. 40 attendees.

### **Extension Bulletins**

Barbercheck, M.E. Insect Parasitic Nematodes for the Management of Soil Dwelling Insects, Entomopathogenic Nematodes in Biological Control. PSU Entomology Extension Bulletin. 2004

Barbercheck, M. 2004. Organic Crop Production, pp. 199-120 in: The Agronomy Guide. PSU COAS.

Barbercheck, M. and D. Calvin. 2004. Pest Management in Organic systems: Insects, pp. 158-160 in: The Agronomy Guide. PSU COAS.

Curran, W. 2004. Agronomy Facts 64, Weed Management in Organic Cropping Systems, PSU College of Agriculture Extension Bulletin.

### **Newsletter Articles**

Barbercheck, M. (editor) PSU Sustainable Ag Newsletter. Regular news and articles on organic. <http://www.ento.psu.edu/extension/sustainableAg/default.html>

Barbercheck, M. 2004. Penn State Studies Transition to Organic Agriculture  
Field Crop News 4 (12): 4-5

Barbercheck, M. 2004. Organic Corn and Soybeans for Exceptional Organic Milk Field Crop News 4 (12): 5-6

Sanchez, E. 2004-2005. Editor-The Vegetable & Small Fruit Gazette, Department of Horticulture, PSU. Regular Column "The Organic Way".

### **Seminar Presentations**

Barbercheck, M. Building Pest Suppressive Soils: Research at Multiple Spatial Scales (w/ D. Mortensen), USDA Sustainable Ag Lab, Beltsville, MD February 26, 2004

Barbercheck, M. Ten reasons why you should buy locally grown food. Penn State Earth Day, April 13, 2003. Invited. (w/ L. Garling and S. Seeley)

Barbercheck, M. The Impact of Agricultural Practices on Soil Organisms. Ohio State University, Wooster, Entomology Departmental Seminar, January 28, 2003 invited.

Barbercheck, M. Soil Ecology Research. Rodale Institute, January 24, 2003 invited.

Hulting A. Department of Crop and Soil Science Departmental Seminar, November 19, 2004, Update on Transition to Organic at Rock Springs.

Hulting A. Department of Entomology Departmental Seminar, April 22, 2005, Update on Transition to Organic at Rock Springs-Initial Measures of Soil and Arthropod Diversity and Abundance.

Mortensen, D.A. Weed Ecology Research. Rodale Institute, January 24, 2003. invited.

### **Meeting Abstracts**

Hulting, A., C. Nardozzo, B.P. Jones, M. Barbercheck, D. Mortensen. 2005. Fate of seedbank pools during the transition to an organic feed grain rotation in PA. NEWSS Proceedings, Washington D.C.

Koenning, S.R., M.E. Barbercheck 2002. Influence of diverse agricultural systems on the population dynamics of free living, plant-parasitic, and entomopathogenic nematodes. Nematology 34:254.

Leslie, T., A. Hulting, J. Kozak, S. Fleischer, D. Mortensen. 2005. Agriculture and forest mosaic effects on epigeal coleopteran species assemblages. NEWSS Proceedings, Washington D.C.

### **Related Funded Projects**

NE SARE PDP Grant. 2004-2008 Advanced Organic Training for Agricultural Professionals. Anusuya Rangarajan, Vern Grubinger, Eric Sideman, Marianne

Sarrantonio, Ruth Hazzard, Mary Barbercheck, Abby Seaman, Kim Stoner, Brian Caldwell, Emily Brown Rosen. Will hold Session 2 on organic IPM in State College, PA. June 27 - 30, 2005.

USDA NE IPM Grant 2003-2005 Threshold-based Cover Cropping Strategies for Weed Management. E. Gallandt, C. Reberg-Horton, W. Curran, D. Mortensen, M. Barbercheck, and R. Hoover.

NE SARE Research and Education Grant. 2005-2007 Using cover crops and crop diversity to optimize ecologically-based weed management. W.S. Curran, D.A. Mortensen, M.E. Barbercheck, T.S. Hoover, A.G. Hulting, R.J. Hoover, S.C. Reberg-Horton, E.R. Gallandt.

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**Appendix 1.** Timeline of project activities from Fall 2003 -2004.

<b><u>Date</u></b>	<b><u>Operation</u></b>	<b><u>People Involved</u></b>
7 Oct 03	Rocks picked from field	Mortensen lab group, Barbercheck lab group
7 Oct 03	37,825 L/ha of manure was applied	Farm Crew
10 Oct 03	3810 kg/ha of lime was applied	
13 Oct 03	Fields plowed with Cultimulcher and S tine	Mortensen lab Barbercheck lab
14 Oct 03	Planted 8 .06 ha Rye plots Planted at a rate of 34 kg/ha. 8 .06 ha Timothy/Oat plots planted at a rate of 153 kg/ha.	Mortensen lab Barbercheck lab
19 April 04	Re-seeded 'Jay' Oats at a rate of 108.85 kg/ha and incorporated Certified Organic 'Mammouth' Red Clover at a rate of 17 kg/ha into the Timothy cover crop	Mortensen lab Barbercheck lab Farm Crew
7 May 04	Took soil samples from Transition plots	Mortensen lab Barbercheck lab
14 May 04	Data Loggers were placed in plots 1, 2 (Rye), 11, 12(Timothy/Oat/Clover)	Mortensen lab Barbercheck lab
24 May 04	Data logger readouts	Mortensen lab Barbercheck lab
26 May 04	Mowed volunteer Rye in Timothy/Oat plots to control seed production	Mortensen lab
28 May 04	Finished weeding out volunteer Rye/Wheat out of Timothy/Oat/Clover plots	Mortensen lab Barbercheck lab
2 June 04	Data logger readouts	Mortensen lab Barbercheck lab
2 June 04	Weed seedling counts	Mortensen lab Barbercheck lab
3 June 04	Weed seedling counts	Mortensen lab

4 June 04	Weed seedling counts	Barbercheck lab Mortensen lab Barbercheck lab
16 June 04	Data logger readouts	Mortensen lab Barbercheck lab
16 June 04	Took soil samples from Transition plots	Mortensen lab Barbercheck lab
18 June 04	Opened pitfall traps for collection	Leslie lab Mortensen lab Barbercheck lab
21 June 04	Collected pitfalls	Mortensen lab Barbercheck lab
28 June 04	Took Biomass samples from Timothy/Oat plots	Sjoerd Duiker Barbercheck lab Mortensen lab
1 July 04	Sampled Rye biomass	Barbercheck lab Mortensen lab
21 July 04	Data logger readouts	Mortensen lab Barbercheck lab
26 July 04	Data logger readouts	Mortensen lab Barbercheck lab
29 July 04	Rye was combined, straw mowed	Farm Crew
2 Aug 04	Data logger readouts	Mortensen lab Barbercheck lab
2 Aug 04	Timothy/Clover harvested, taken as high moisture hay	Farm Crew
3 Aug 04	Opened pitfalls	Mortensen lab Barbercheck lab
4 Aug 04	Took soil samples from Transition plots	Mortensen lab Barbercheck lab
6 Aug 04	Collected pitfalls	Mortensen lab Barbercheck lab
9 Aug 04	Data logger readouts	Mortensen lab Barbercheck lab
15 Aug 04	Mature plant weed counts	Mortensen lab Barbercheck lab
16 Aug 04	Mature plant weed counts	Mortensen lab Barbercheck lab

17 Aug 04	Data logger readouts	Mortensen lab Barbercheck lab
17 Aug 04	Mature plant weed counts	Mortensen lab Barbercheck lab
25 Aug 04	Compost was applied at 7,257 kg/ha to 1 <sup>st</sup> year	Mortensen lab Barbercheck lab Farm Crew
26 Aug 04	Rye plots were tilled (Min/Full Till)	Mortensen lab Barbercheck lab
27 Sept 04	Took soil samples from Transition plots	Mortensen lab Barbercheck lab
4 Oct 04	Opened pitfalls Data logger readout	Mortensen lab Barbercheck lab
5 Oct 04	Sweep Netted	Barbercheck lab
7 Oct 04	Collected pitfalls	Mortensen lab Barbercheck lab
14 Oct 04	Timothy/Clover was again harvested	Farm Crew
3 Oct 04	Hairy Vetch was planted at a rate of 34 kg/ha in tilled Rye plots	Farm Crew
27 Oct 04	Removed data loggers for winter	Mortensen lab Barbercheck lab
16 Nov 04	Planted weed seed sub- plots in 2 <sup>nd</sup> year start	Mortensen lab Barbercheck lab
3 Dec 04	Collected core samples	Mortensen lab Barbercheck lab Sjoerd Duiker

### **Principal Investigator Meetings**

March 8, 2004  
 March 18, 2004  
 April 14, 2004  
 April 28, 2004  
 May 19, 2004  
 June 22, 2004

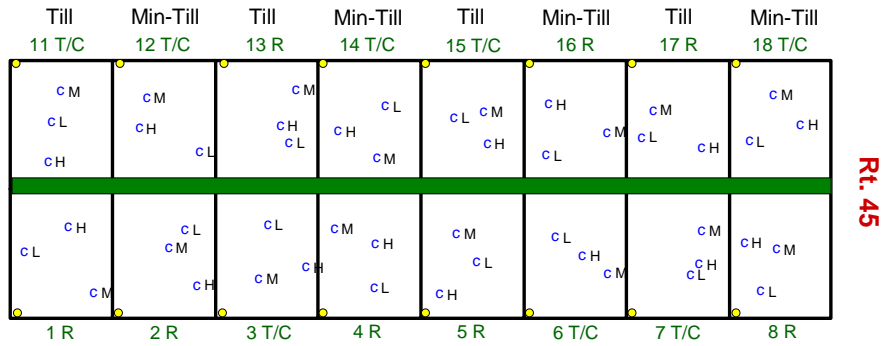
### **Advisory Board Meetings**

September 12, 2003  
 March 15, 2004  
 August 31, 2004

## Appendix 2. Field experiment plot maps at Rock Springs site.

### Transition to Organic 2004 Experimental Plan

#### First Year Transition



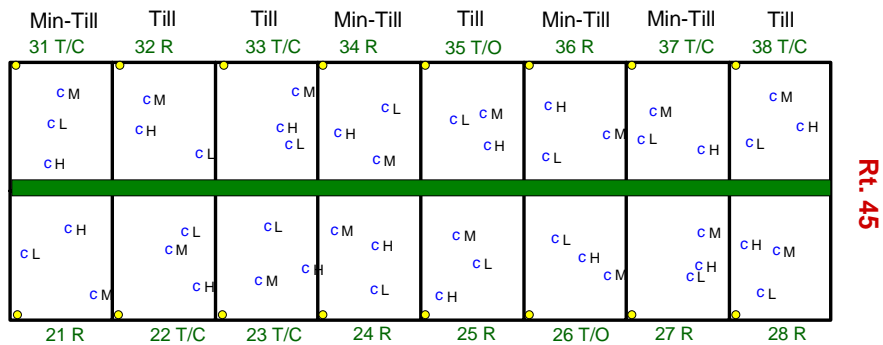
Where: T/C = Timothy / Clover  
 R = Rye  
 L = Low weed density  
 M = Medium weed density  
 H = High weed density

■ = field traffic  
 (Please keep foot traffic on this path)

● = flags indicating plot numbers

### Transition to Organic 2004 Experimental Plan

#### 2<sup>nd</sup> Year Start Transition



Where: T/C = Timothy / Clover  
 R = Rye  
 L = Low weed density  
 M = Medium weed density  
 H = High weed density

■ = field traffic  
 (Please keep foot traffic on this path)

● = flags indicating plot numbers