

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

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

2005 Annual Report



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Project Summary

Weed management is one of the primary pest management challenges for organic producers. This project focuses on weed management during the transition to an organic feed grain rotation to support the growing organic dairy industry in the northeastern US 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 soil weed seedbank through tillage-stimulated germination and suppression of germination through cover cropping and minimizing tillage. The effect of these tactics on soil quality parameters, pest and beneficial invertebrates, and economic indicators is being measured. This report provides a brief summary of data collection methods and generalized results from this field experiment as well as documents related teaching and technology transfer activities over the first 2 yr of this project. Education and outreach programs and materials are continuously being developed and delivered to a broad audience including resident undergraduate and graduate students at Penn State University, county technology transfer agents and the general public. The effectiveness of the outreach programs in informing or changing technology transfer agents' behaviors and attitudes towards organic agriculture will continue to be evaluated through the use of surveys over the course of this project as research activities in the field experiment continue through the fall of 2007.

Project Objectives

The overall goal of this project is to identify weed management strategies 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 county educators 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.

Field Research Methods

Field Research

The field experiment is being conducted at the Russell E. Larson Agricultural Research Center near Rock Springs, PA (40° 43'N, 77° 55'W, 350 m elevation). This research center is located in Centre County, PA, about 10 miles from The Pennsylvania State University Park campus. The climate of central PA is continental with 975 mm mean annual precipitation and mean monthly temperatures ranging from 3°C (January) to 21.6°C (July). Soils at the site are shallow, well drained Lithic Hapludalfs formed from limestone residuum (Braker 1981). The dominant soil type at this location is Hagerstown silt loam (Fine, mixed, semiactive, mesic, Typic Hapludalf). Soil texture in the experimental fields is predominantly clay loam with spatial variability in silt (range of 39.9-54.7 %) and sand (14.0-26.5 %) content across the experimental site.

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 experimental units 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 presented in Appendix 2.



The field experiment has been established twice, in the fall of 2003 and again in 2004, in a split-plot, randomized complete block design with four replications. The approximate total combined area of the field experiment 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 year of the experiment 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 (*Glycine max*) (late Group III maturity) was planted in all cover crop/tillage treatments in the spring of 2005 at a row spacing of 76 cm. The second start is managed in a similar fashion, but treatments are delayed in time by one year.

Crop Rotations to Date (Fall 2003-Fall 2005)

1. Rye (Grain)-Hairy Vetch-Soybean
-Reduced Till (Chisel Plow Based)
2. Rye (Grain)-Hairy Vetch-Soybean
-Conventional Till (Moldboard Plow Based)
3. Timothy/Red Clover (Forage)-Soybean
-Reduced Till (Chisel Plow)
4. Timothy/Red Clover (Forage)-Soybean
-Conventional Till (Moldboard Plow)



Soil Measures

Soil Chemical and Biological Properties

Three composite soil samples comprised of 15 cores each (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 soil core sample was placed in a large bucket lined with plastic garbage bags and thoroughly mixed to form the composite sample. This composite sample was then divided in the laboratory into three portions of approximately 500 g each. These triplicate sub-samples were used for both chemical and biological analyses. The sub-samples for soilborne insect pathogen analysis and microarthropod analysis were placed in plastic containers (Reynolds 473 mL deli containers) and stored in an incubator (11.5 – 14 C) until the baiting 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). Sampling dates that soil samples were taken on are listed in Appendix 1.

Active Carbon

Permanganate oxidizable carbon 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). Briefly, soil samples were air-dried and then ground to pass through a 2-mm sieve. This 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 to the tube 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 KMnO_4 , 1 M CaCl_2 and was adjusted to a pH of 7.2 using NaOH. The 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 one tube containing a soil standard and one 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 μl 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 3.8 ml aliquot of supernatant to a 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 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 MnO_4^- , 0.02 is the volume (μl) 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. 20 ml of DI water was added to 10 g of soil. This mixture was shaken on a platform shaker for 1 minute and then allowed to settle for 15 minutes. The mixture was then centrifuged (International Equipment Company 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).

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 Physical Properties-Baseline Measures

To determine baseline soil physical properties at the beginning of the experiment, intact soil core samples were taken in August of 2004 in the plots that had been recently harvested for rye grain in late July. In December of 2004, the timothy/red clover treatment plots were sampled. Samples were taken to approximately 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 at each depth using aluminum rings (7.62 cm length x 7.62 cm inner diameter). After the cores were hammered into the soil, the soil-filled core was carefully excavated from the soil profile with a spade. The amount of soil sampled per core was approximately 10-cm (the length of the metal core plus approximately 2.5 cm of excess soil at the lower end of the core). The excess soil was gently pushed upward until there were equal lengths of soil extending past both ends of the metal core. The soil cores were then wrapped in plastic wrap, placed in plastic coolers, and stored in a cold room (4.5 C). Soil collected through this process was tested for its bulk density, water retention, and hydraulic conductivity.

Intact soil core samples for baseline soil property analysis in the second year start experimental plots were collected in April 2006 from rye and timothy/clover plots. Samples were taken to 3 depths (0-10 cm, 10-20 cm, and 20-30 cm) in one sampling location per plot and laboratory procedures with this group of samples were similar to procedures stated below.

Bulk Density

The bulk density calculation for each sample was achieved by cutting off the excess soil at both ends of the metal cores and placing a representative sample of this soil in a pre-weighed metal can. The weight of the moist soil and can is determined before placing the samples in a bench-top oven (VWR 1324, Sheldon Manufacturing) at 105 C until the soil was oven dry (approximately 24 hours). The soil cans were removed and reweighed. Moisture retention was determined by using the equation:

$$[(\text{weight of moist sample} + \text{can weight}) - (\text{weight of dry sample} + \text{can weight})] / (\text{weight of dry sample} + \text{can weight})$$

Bulk density was determined by the equation (Lal and Shukla 2004) :

$$\{[(\text{weight of moist soil} + \text{ring}) - \text{ring}] / (\text{volume of soil in ring})\} / (\text{moisture content} + 1)$$

Water Retention Curves

Water retention was determined on the undisturbed cores at saturation when exposed to pressures of 100kPa and 300 kPa; and on disturbed samples at 1500 kPa using porous plates as described in Klute (1986). Soil was saturated for 24 to 48 hours before being placed into the pressure chamber. Samples were exposed to the previously stated pressures for 24 hours and then weighed. The volumetric water content, θ , is determined by the equation:

$$\theta = (\text{wet weight} - \text{dry weight}) / (\text{density of water} * \text{core volume})$$

Hydraulic Conductivity

Before grinding soil from the intact core samples for coarse fragment correction, the intact soil core samples were tested for their hydraulic conductivity. Hydraulic conductivity was determined for three sampling depths from intact soil cores using the constant head method (Klute and Dirksen 1986).

Aggregate Stability

After all other measurements had been completed on the intact soil cores, the soil was removed from the metal sampling rings and was air dried, ground, and passed through a 2-mm sieve. The soil that passed through the sieve was collected and used in both the last step (15 bar) in the moisture retention curve as described above and in aggregate stability measurements. Four grams of 1-mm to 2-mm air-dried aggregates were placed in a 0.25 mesh/cm basket and placed in a wet sieving instrument (Five Star Cablegation and Scientific Supply). Aggregates were dunked (1.3 cm, 35 times/min) in a can of distilled water for 3 minutes. The mesh basket was then removed from the wet sieving instrument and placed in another can containing distilled water. An ultrasonic probe (Sonifier® Cell Distributor Model W185, Heat Systems-Ultrasonics, Inc.) was placed in the water for 30 s at medium frequency. Both soil cans were placed in a drying oven at 105 C until the water evaporated. The soil cans were then weighed and the stability was determined by dividing the particles collected through ultrasonic dispersion by the sum of the weights in the two cans (Kemper and Rosenau 1986)

Routine Soil Property Measurements

Soil Matric Potential

For each soil sampling date, soil matric potential 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 was allowed to equilibrate with the water in the soil for 48 hrs. The moisture-equilibrated filter paper was removed, 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 figure relating percentage moisture of the filter paper to soil matric potential (Hamblin 1981).

Soil Gravimetric Moisture

For each soil sampling date, gravimetric soil moisture was determined by placing ~50 g of wet weight soil in pre-weighed 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 $[(\text{wet weight soil} - \text{dry weight soil}) / \text{dry weight soil}] \times 100 = \% \text{ soil moisture}$.

Soil Fertility

Soil samples from May 16, 2005, sampling date 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 and trace elements (Zinc, Copper and Sulfur).

Soil Biological Measures

Epigeal Arthropods

Pitfall sampling methods 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 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, classified as either macro (>2mm diameter) or micro (< 2mm diameter) arthropods, and placed in corresponding (macro or micro) scintillation vials (20 mL volume) filled with ~19 mL of 80% ethanol plus glycerol. All organisms are stored in the scintillation vials until they can be prepared for identification. The larger arthropods were pinned and microarthropods were mounted on microscope slides in Berlese's Fluid.

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 covered by plastic window screen. The PVC container was placed screened side down inside a 355 mL aluminum can that had the ends removed and a plastic funnel glued to one end. Twenty mL vials filled with 80% ethanol were fixed to the spout of the funnel, and these prepared funnels were placed on a frame that was fitted with indoor/outdoor transparent lights. Approximately 65 g of soil was placed in each funnel for one week to collect arthropods moving out of the drying soil. Mites and collembolans were 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 and other microarthropods. The category "Total" combined the counts of all mites, collembolans, and other microarthropods and served as a general indicator of the abundance of soil microarthropods in samples. The larger organisms were retained in scintillation vials filled with approximately 19 mL 80% ethanol and 1 mL glycerol. 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 then removed and placed in 59 mL cups (Solo) with lids for symptoms and signs of infection to develop. The containers 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 anisopliae* 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 m² subplots within each treatment plot. The seeded weed densities were low, medium and high (60, 450, 2100 seeds/m²). 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. Cumulative seedling density and mature plant densities were quantified in both the weed sub-plots and within the larger main plots prior to and after management disturbances throughout the growing seasons of 2004 and 2005.

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 treatment and soybean treatment in 2004 and 2005. Sensors were placed at a depth of 10 cm and data recording was started in late April and continued through October at 1 hr intervals (except when sensors were removed from the soil to accommodate tillage treatments). All downloading (approximately once/week) was done with the loggers left ON so data were not lost in the downloading process.

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. Data has also been applied to generalized enterprise budget worksheets in the Penn State University Agronomy Guide. 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 management scenarios.

Results

Crop Yield

Yields for the rye (grain), timothy/clover (forage) and soybean crops in 2005 are presented in Tables 1 and 2 below. Table 1 represents crop yield from the 2nd replicate in time of the field experiment and Table 2 represents soybean yield data from the initial start year.

Table 1. Mean crop and forage yields in 2005 in rye and timothy/red clover cover crop treatments.

Harvest Date	Treatment	Yield (kg/ha)
7/21/05	Rye (grain)	3261 ¹
7/14/05	Timothy/Red Clover (forage)	2024 ²
7/30/05	Rye (straw)	3528 ³

¹ Rye harvested at 16.4% moisture, 22.9 kg/bushel

² Forage was harvested as high moisture round bales at 64.2% moisture and is reported at a 12% moisture equivalent.

³ Rye straw was mown to ground level with a flail mower and bailed as small square bales.

Table 2. Mean soybean yields in 2005 following rye/hairy vetch and timothy/red clover cover crop treatments in 2004.

Harvest Date	Treatment (cover crop previous year)	Yield (kg/ha)
10/27/05	Rye (grain)/Minimum Till	2956
10/27/05	Rye (grain)/Conventional Till	2284
10/27/05	Timothy/Red Clover (forage)/Minimum Till	1881 ¹
10/27/05	Timothy/Red Clover (forage)/Conventional Till	2083 ¹

¹ Soybeans in these treatments were replanted due to poor germination and emergence following timothy/red clover cover termination in the spring of 2005.

Soil Measures

Soil Chemical and Biological Properties

Active Carbon

Permanganate oxidizable carbon levels (POC) in the initial start year planted with soybeans in 2005 appear to be influenced by tillage system but not by cover crop or sampling date (Fig. 1). The mean values averaged over cover crop for the two tillage systems were 394.47 ± 7.01 mg/kg POC in the reduced tillage system and 334.26 ± 7.19 mg/kg POC in the conventional tillage system, respectively. When separated by cover crop, POC levels were 363.16 ± 7.69 mg/kg POC in the rye and 365.57 ± 7.79 mg/kg POC in the timothy/clover crop for the first year start.

Permanganate oxidizable carbon levels (POC) in the second year start planted with either rye or timothy/cover are similar when averaged by tillage system, cover crop type or sampling date (Fig. 2). The mean values averaged over cover crops for the two tillage systems were 374.85 ± 8.02 mg/kg POC in the reduced tillage and 382.08 ± 6.73 mg/kg POC in the conventional tillage system, respectively. When separated by cover crop, mean POC levels were 380.22 ± 7.70 mg/kg POC in the rye crop and 376.70 ± 7.10 mg/kg POC in the timothy/clover crop.

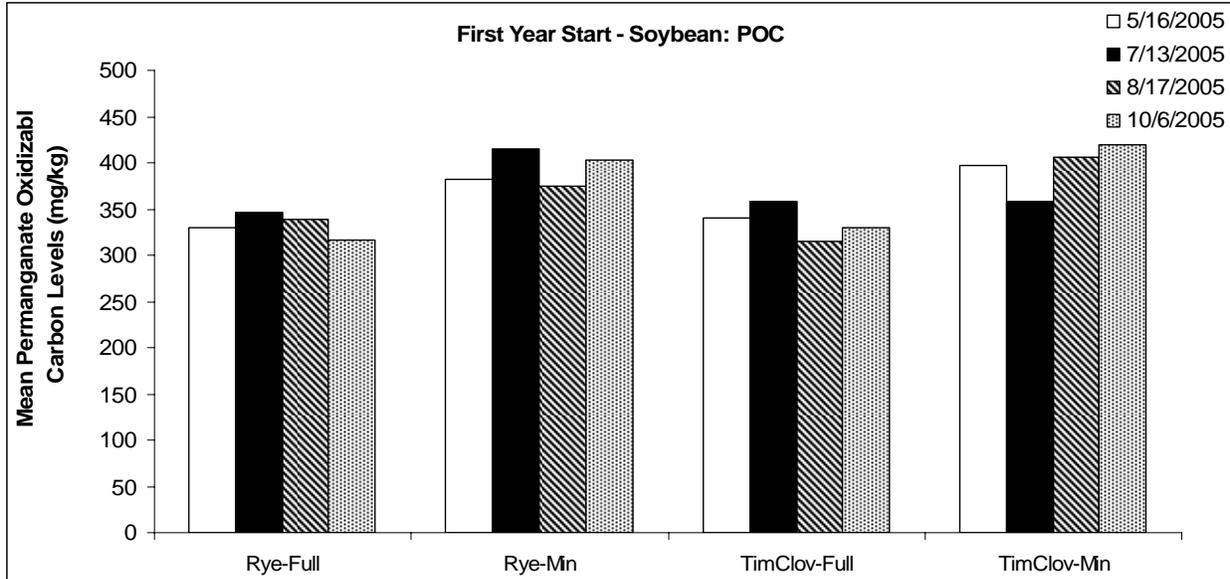


Figure 1. Values of permanganate oxidizable C (mg/kg of soil) in 2005 shown by sampling date for each cover crop/tillage treatment for the first year start.

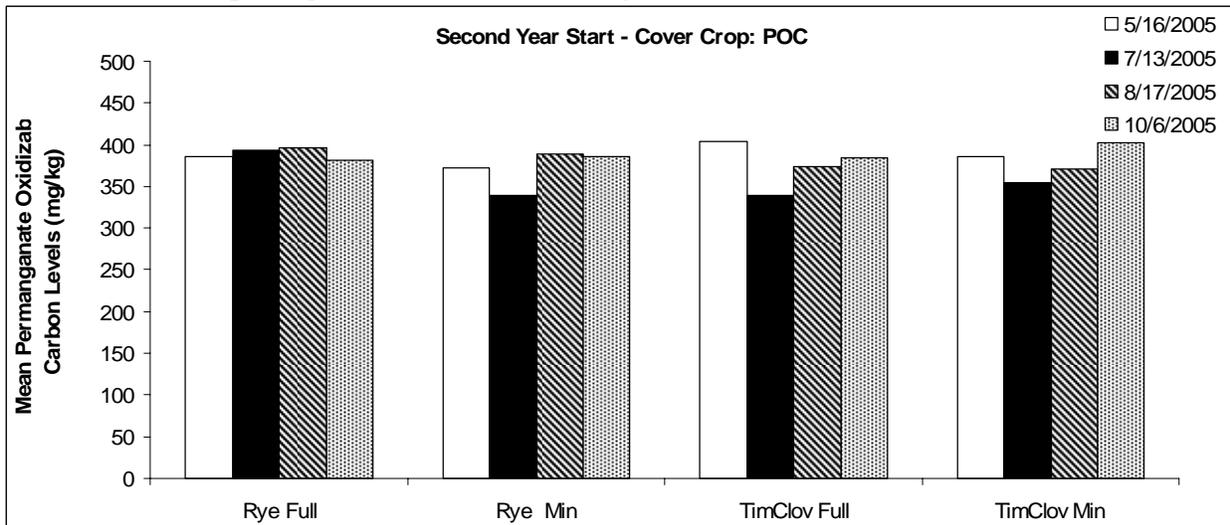


Figure 2. Values of permanganate oxidizable C (mg/kg of soil) in 2005 shown by sampling date for each cover crop/tillage treatment for the second year start.

Electrical Conductivity

2004 Results

Electrical conductivity (EC) analysis was completed on soil collected September 27th (Figure 3). The mean EC averaged over both tillage systems was $225.78 \pm 9.47 \mu\text{S}/\text{cm}$ in the rye treatments and $229.41 \pm 9.79 \mu\text{S}/\text{cm}$ in the timothy/clover treatments. When compared by tillage systems, the mean EC was $218.83 \pm 10.09 \mu\text{S}/\text{cm}$ in the conventional tillage and $236.36 \pm 8.80 \mu\text{S}/\text{cm}$ in the reduced tillage treatments.

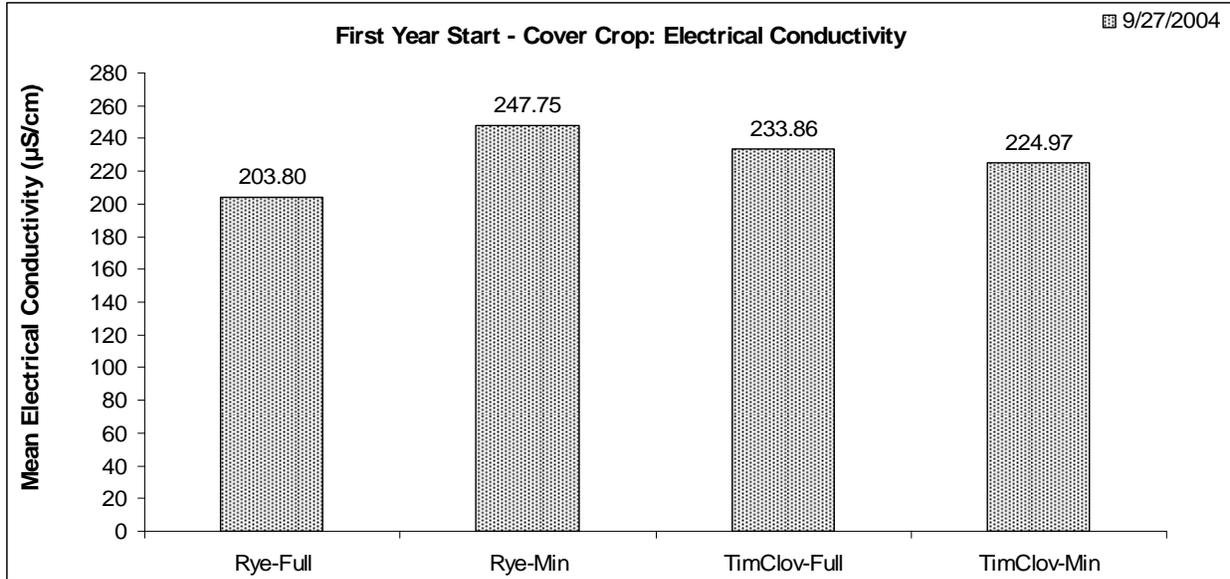


Figure 3. Mean electrical conductivity (EC) ($\mu\text{S}/\text{cm}$) in 2004 shown for September 27th sampling date for each cover crop/tillage treatment for the first year start (cover crop year).

2005 Results

EC in the first year start (soybean production year) were within acceptable agronomic limits (average $69.23 \pm 3.02 \mu\text{S}/\text{cm}$) in all treatment plots on the first sampling date (May 16th). However, average EC increased to $157.71 \pm 6.51 \mu\text{S}/\text{cm}$ by the next sampling date (July 13th) and remained near this level for the remainder of the sampling dates and growing season (Figure 4). Cover crop type and tillage treatment history appear to not have affected EC. The mean EC values averaged over cover crop treatment for the two tillage systems were $133.89 \pm 4.98 \mu\text{S}/\text{cm}$ in the reduced tillage system and $139.10 \pm 5.93 \mu\text{S}/\text{cm}$ in the conventional tillage system, respectively. When separated by cover crop, the EC was $140.96 \pm 5.81 \mu\text{S}/\text{cm}$ in the rye and $132.03 \pm 5.09 \mu\text{S}/\text{cm}$ in the timothy/clover crop treatments.

EC in the second year start (cover crop year) increased over the growing season with the highest values observed in the October 6th samples (Figure 5). The mean EC values averaged over cover crop was $98.04 \pm 6.74 \mu\text{S}/\text{cm}$ in the reduced tillage and $99.13 \pm 6.48 \mu\text{S}/\text{cm}$ in the conventional tillage treatments. When separated by cover crop, mean EC was $104.39 \pm 7.14 \mu\text{S}/\text{cm}$ in the rye crop and $92.79 \pm 5.98 \mu\text{S}/\text{cm}$ in the timothy/clover treatments.

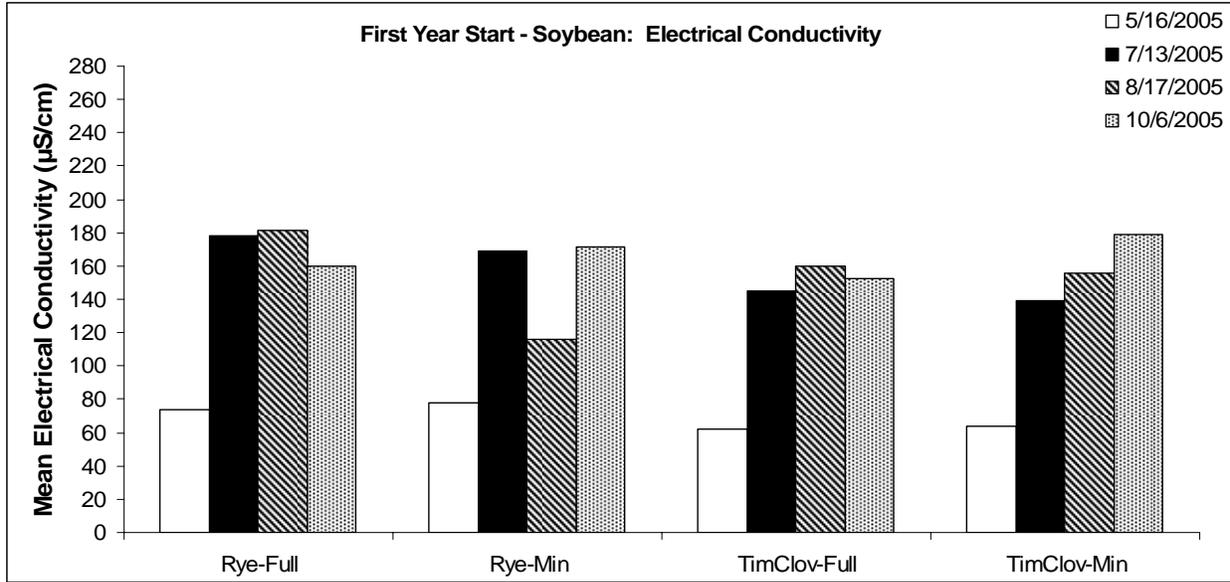


Figure 4. Mean electrical conductivity ($\mu\text{S}/\text{cm}$) in 2005 shown by sampling date for each cover crop/tillage treatment for the first year start (soybean year).

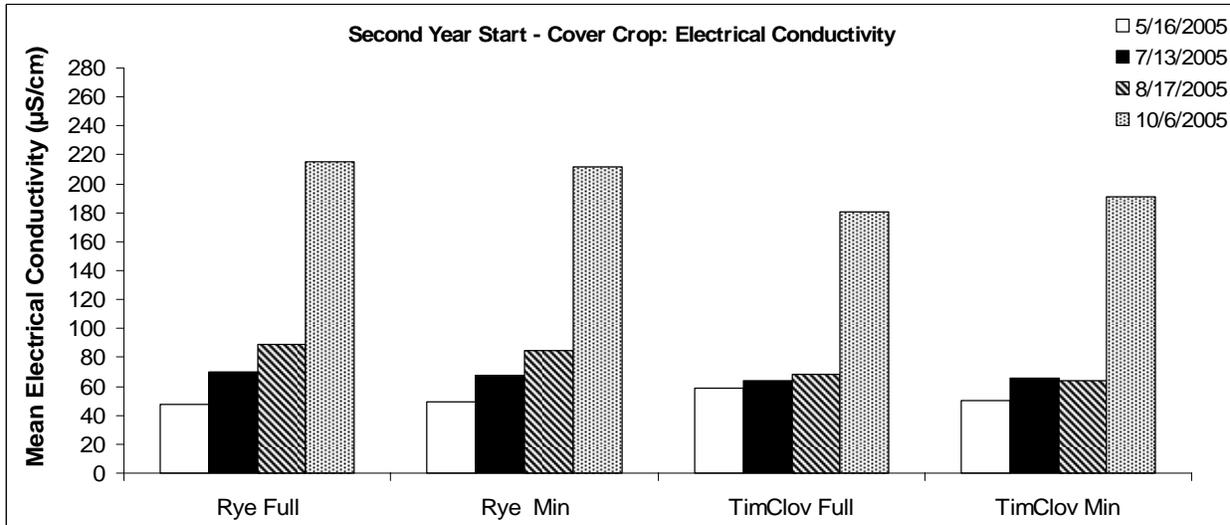


Figure 5. Mean electrical conductivity ($\mu\text{S}/\text{cm}$) in 2005 shown by sampling date for each cover crop/tillage treatment for the second year start (cover crop year).

pH

2004 Results

pH analysis was measured on soil collected on the last collection date on September 27th, 2004 (Figure 6). The mean soil pH was 6.65 ± 0.08 in rye cover crop treatment and 6.68 ± 0.09 in timothy clover cover crop treatment. When separated by tillage system, the mean pH level in the conventional tillage was 6.72 ± 0.09 and 6.62 ± 0.08 in reduced tillage treatments.

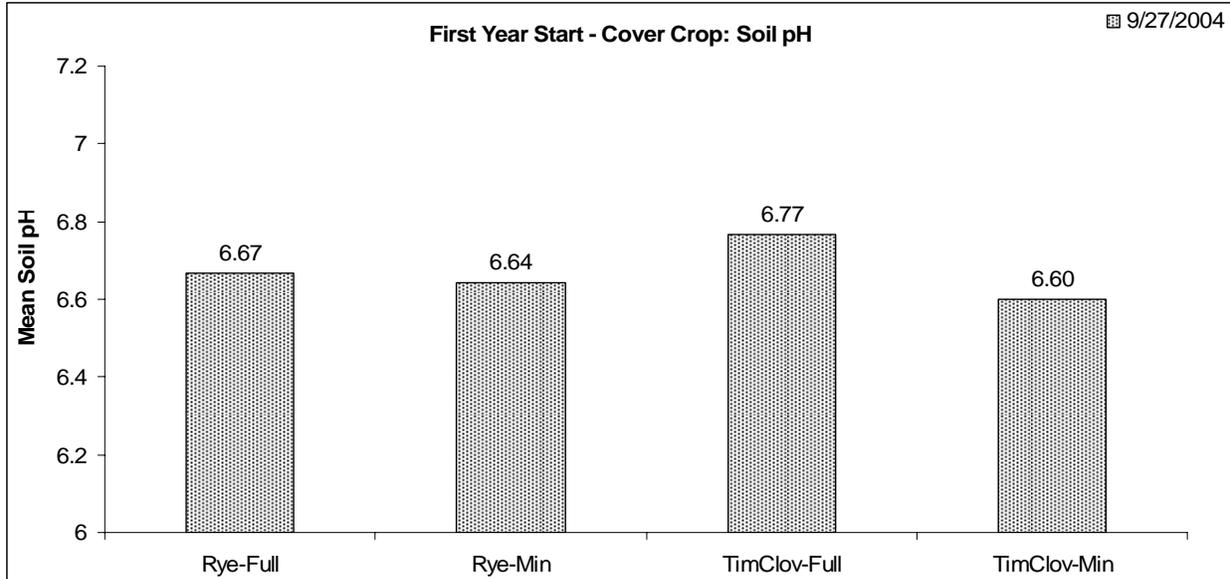


Figure 6. Soil pH for soil collected 27 September, 2004, for each cover crop/tillage treatment for the first year start (cover crop year).

2005 Results

pH levels varied in both starts by sampling date (Figures 7 and 8). Mean soil pH levels in the first start year were 6.72 ± 0.04 in the rye and 6.73 ± 0.04 in the timothy/clover treatments. Mean soil pH in the reduced tillage treatment was 6.76 ± 0.04 and 6.69 ± 0.04 in the conventional tillage treatment. In the second year start (cover crop year) mean soil pH averaged over cover crop for the two tillage treatments were 6.68 ± 0.03 in the reduced tillage and 6.70 ± 0.03 in the conventional tillage treatments. Mean soil pH in the second year start (cover crop year) were 6.72 ± 0.03 in the rye crop and 6.66 ± 0.03 in the timothy/clover treatments.

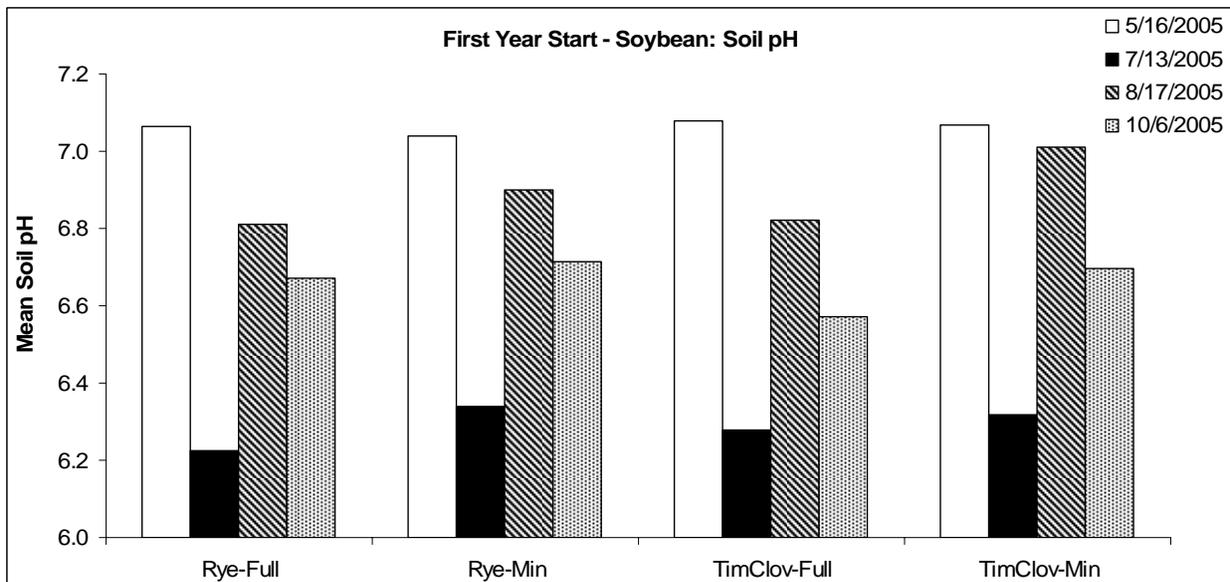


Figure 7. Mean soil pH in 2005 shown by sampling date for each cover crop/tillage treatment for the first year start (soybean year).

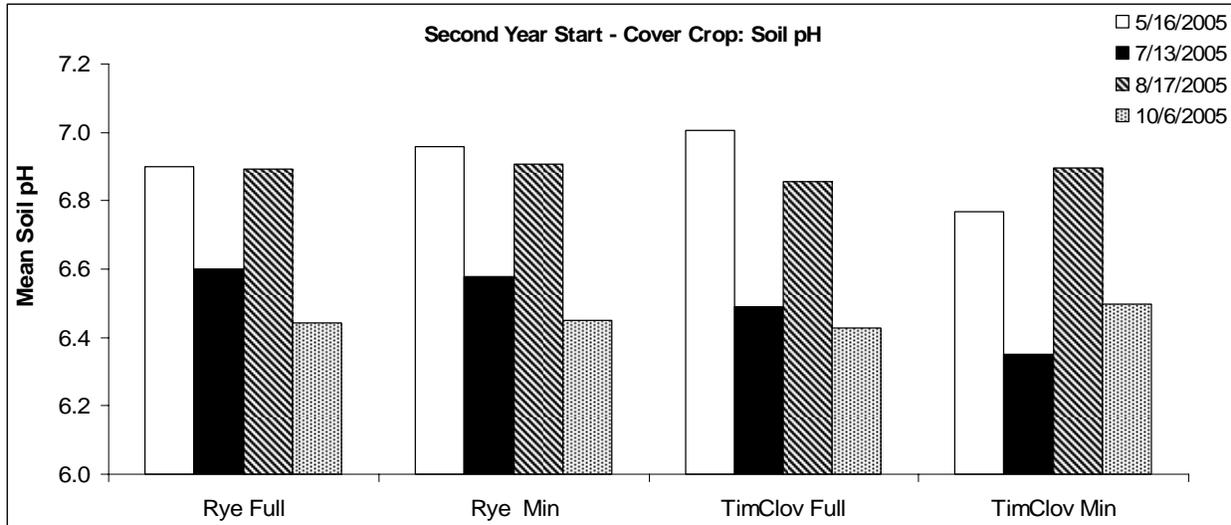


Figure 8. Mean soil pH in 2005 shown by sampling date for each cover crop/tillage treatment for the second year start (cover crop year).

Soil Physical Properties-Baseline Measures

Bulk Density

2004 Results

Bulk density over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 1.54 ± 0.11 g/cm³, 1.57 ± 0.09 g/cm³ and 1.53 ± 0.08 g/cm³ respectively, following the rye cover crop grown for grain. Bulk density over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 1.38 ± 0.08 g/cm³, 1.47 ± 0.06 g/cm³ and 1.48 ± 0.06 g/cm³ respectively, for the timothy/red clover system.

Calculation of bulk density on soil from the soil cores collected from the second start year in April of 2006 will be completed using the same methodology. These data will be compared to bulk density calculations of soil sampled from each treatment in the fall of 2006 and the fall of 2007 at the conclusion of the transition period.

Water Retention Curves

2004 Results

Percentage plant available water over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 20.5 ± 2.60 , 21.3 ± 2.70 and 14.53 ± 4.20 respectively, following the rye cover crop grown for grain. Percentage plant available water over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 20.64 ± 1.82 , 19.91 ± 2.40 and 17.02 ± 1.91 respectively, for the timothy/red clover system.

Calculation of water retention curves on soil from the soil cores collected from the second start year in April of 2006 will be completed using the same methodology. These data will be compared to moisture retention calculations of soil sampled from each treatment in the fall of 2006 and the fall of 2007 at the conclusion of the transition period.

Hydraulic Conductivity

2004 Results

Hydraulic conductivity over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 3.71 ± 6.66 cm/hr, 1.60 ± 1.95 cm/hr and 0.97 ± 1.49 cm/hr respectively, following the rye cover crop grown for grain. Hydraulic conductivity over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 4.02 ± 2.78 cm/hr, 2.21 ± 1.09 cm/hr and 1.71 ± 1.01 cm/hr respectively, for the timothy/red clover system.

Calculation of hydraulic conductivity of the soil cores collected from the second start year in April of 2006 will be completed using the same methodology. These data will be compared to hydraulic conductivity calculations of soil sampled from each treatment in the fall of 2006 and the fall of 2007 at the conclusion of the transition period.

Aggregate Stability

2004 Results

After all other measurements had been completed on the intact soil cores, aggregate stability of the soil from the three depth classes was measured using an ultrasonic dispersion method (Kemper and Rosenau 1986). Percentage aggregate stability over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 23.1 ± 1.89 , 23.1 ± 1.75 and 27.7 ± 3.17 respectively, following the rye cover crop grown for grain. The percentage aggregate stability of the soil from the cores collected from the timothy/red clover cover crop treatment was higher at each depth class, but was more variable than the percentages calculated in the rye system at the two shallower profile depths. Percentage aggregate stability over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 36.1 ± 2.75 , 27.8 ± 2.56 and 35.6 ± 2.53 respectively, for the timothy/red clover system.

Calculation of percentage aggregate stability on soil from the soil cores collected from the second start year in April of 2006 will be completed using the same methodology.

Routine Soil Property Measurements

Soil Matric Potential

2004 Results

Soil matric potential varied by sampling date and cover crop, and less so by tillage system (Figure 9). Matric potentials averaged over crop type and tillage systems indicated that the soil matric potential was the highest on May 7th, 2004, (188.63 ± 22.66 –kPa) and then decreased one month later. Mean matric potential was lower in rye (52.38 ± 7.07 –kPa) than in timothy/clover treatments (97.69 ± 13.36 –kPa). When averaged over cover crops, there was little difference between conventional (77.16 ± 11.76 –kPa) and reduced (72.91 ± 10.04 –kPa) tillage treatments.

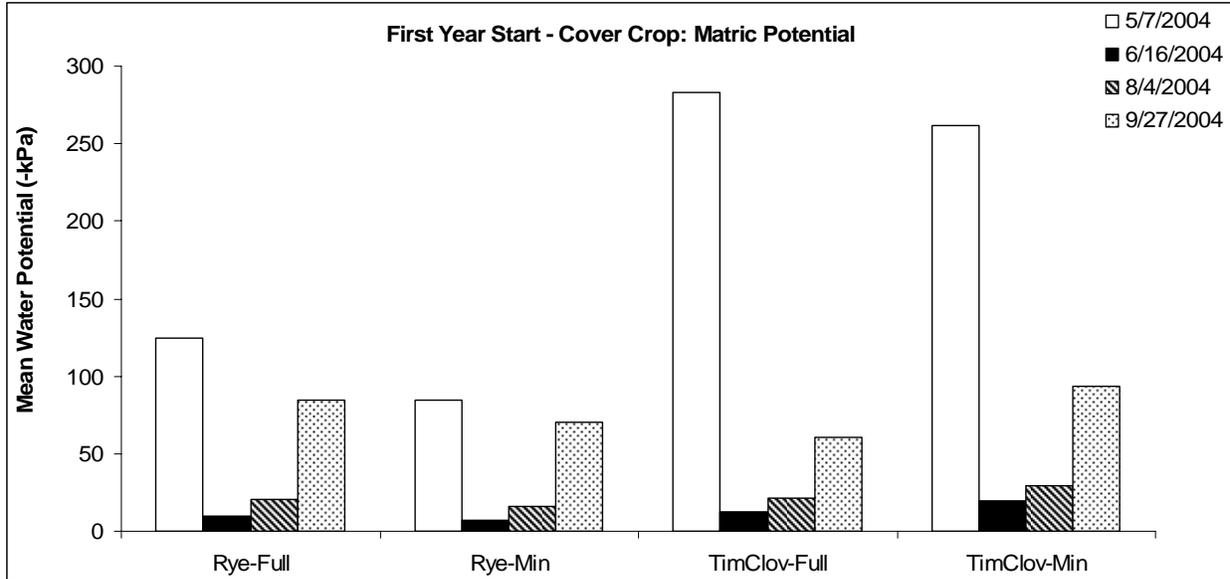


Figure 9. Mean soil matric potential (-kPa) in 2004 shown by sampling date for each cover crop/tillage treatment for the first year start (cover crop year).

2005 Results

Soil matric potential in both starts varied by sampling date, cover crop, and tillage treatments. Soil matric potential was greater on the October 6th sample date in all crop and tillage systems in both starts (Figures 10 and 11). The mean values for the two tillage systems in the first year start (soybean year) were 2764.00 ± 488.63 -kPa in the reduced tillage system and 2231.92 -kPa ± 461.69 in the conventional tillage system. When separated by cover crop, soil matric potential in the first year start was 2873.03 ± 547.27 -kPa in the timothy clover treatment and 2122.89 ± 388.52 -kPa in the rye treatment. Means for the two tillage treatments in second year start (cover crop year) were 3515.56 ± 799.85 -kPa in the conventional tillage and 2585.29 ± 461.22 -kPa in the reduced tillage treatment. When separated by cover crop, soil matric potential in the second year start (cover crop year) was 4603.66 ± 860.64 -kPa in the timothy/clover treatment and 1479.20 ± 256.03 -kPa in the rye treatment.

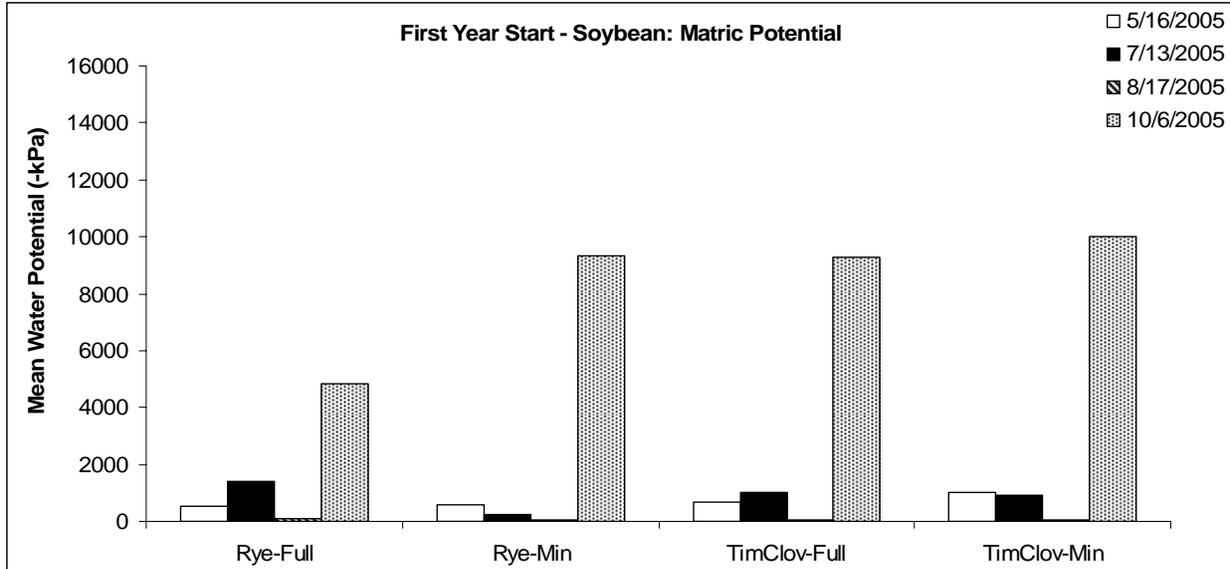


Figure 10. Mean soil matric potential (-kPa) in 2005 shown by sampling date for each cover crop/tillage treatment for the first year start (soybean year).

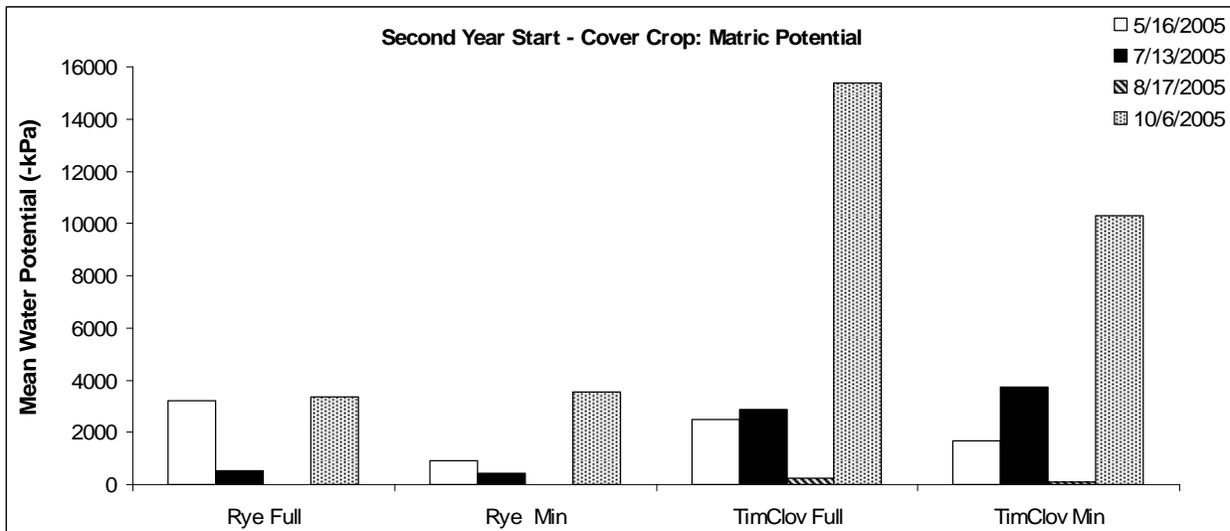


Figure 11. Mean soil matric potential (-kPa) in 2005 shown by sampling date for each cover crop/tillage treatment for the second year start (cover crop year).

Soil Gravimetric Moisture

2004 Results

Soil gravimetric moisture varied by sampling date (Figure 12). Gravimetric moisture averaged over tillage system was 19% in rye and 18% in timothy/clover treatments. When averaged over cover crops, the mean gravimetric moisture for both conventional and reduced tillage was 18%.

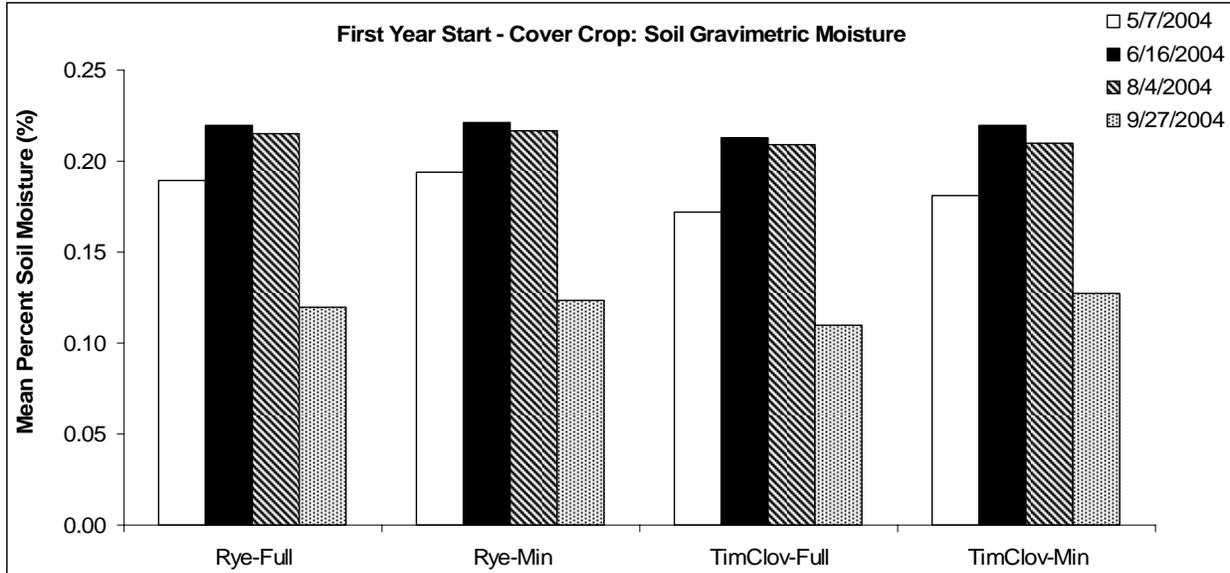


Figure 12. Soil gravimetric moisture (% soil moisture) in 2004 shown by sampling date for each cover crop/tillage treatment for the first year start (cover crop year).

2005 Results

Soil gravimetric moisture for 2005 sample dates is shown in Figures 13 and 14. Mean gravimetric moisture values over both cover crop and tillage treatment were 10% in the first year start (soybean year) and 10% for both tillage treatments in the second year start (cover crop year). When separated by cover crop, mean gravimetric moisture in the second year start was 11% in the rye and 9% in the timothy clover treatments.

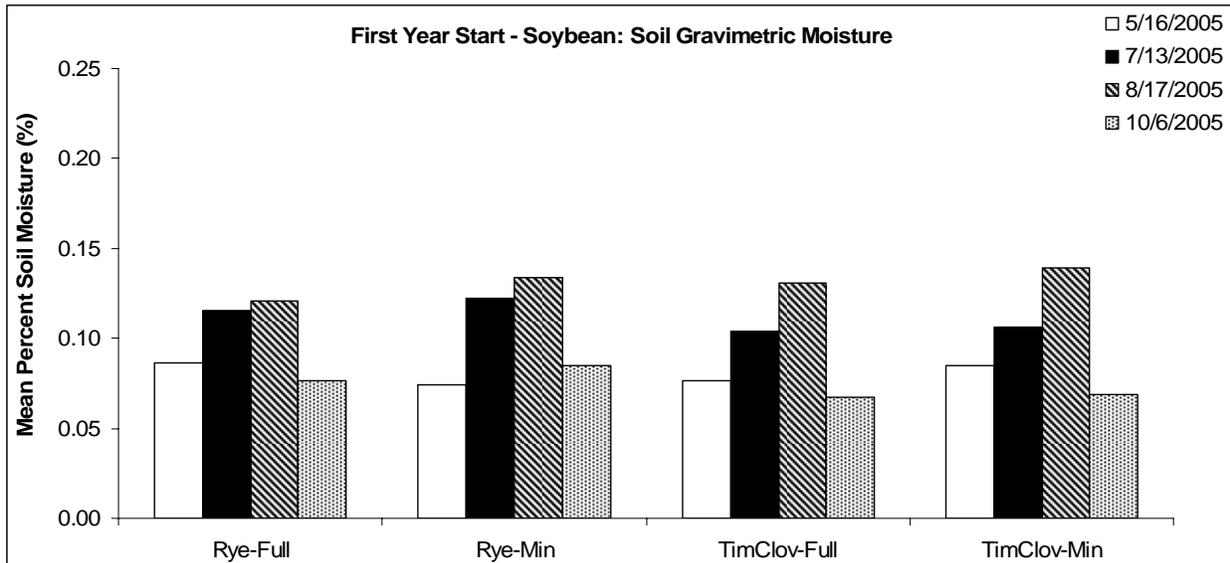


Figure 13. Mean soil gravimetric moisture (% moisture) in 2005 shown by sampling date for each cover crop/tillage treatment for the first year start (soybean year).

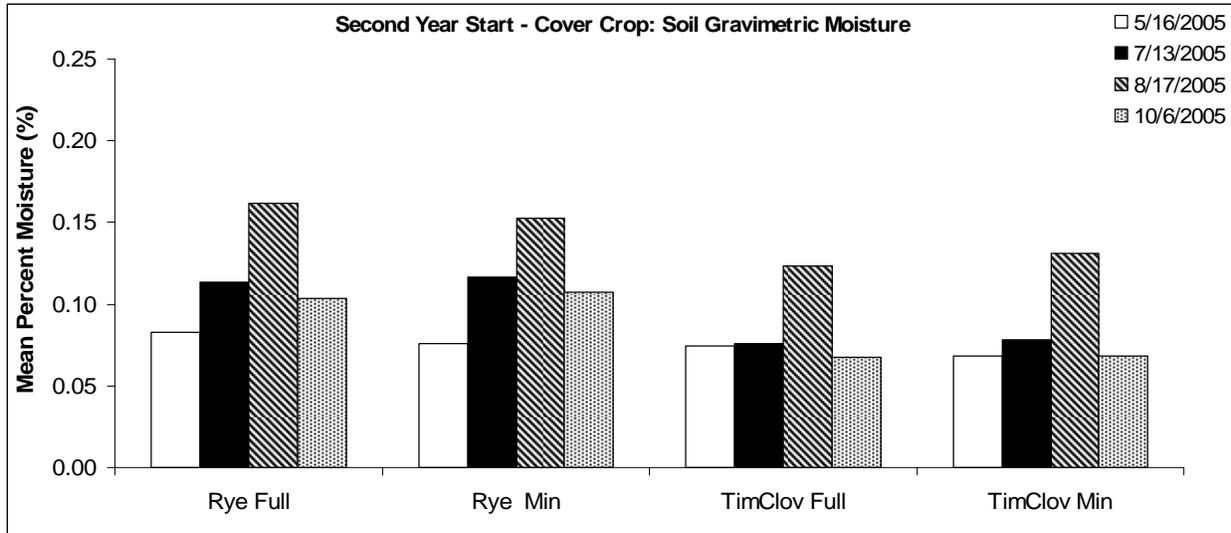


Figure 14. Mean soil gravimetric moisture (% moisture) in 2005 shown by sampling date for each cover crop/tillage treatment for the second year start (cover crop year).

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 agronomic crop production. Those applications were made on 7 and 10 October, 2003, respectively. Soil fertility tests in May 2004 indicated that all fertility levels were in the optimum to above optimum range and no further fertility applications were made in 2004. Specific results can be found in the 2004 Annual Report-Appendix 3.

An application of compost was made in the first start year (8/25/04) at a rate of 17,920 kg/ha and in the second start year (9/2/05) at a rate of 16,800 kg/ha to stimulate biological activity in the soil profile (compost purchased from Penn State Farm Services, Nadine Davitt, njh103@psu.edu, (814) 865-6606).

Soil Biological Measures

Epigeal Arthropods

Numbers of microarthropods collected through the pitfall trapping method varied with sampling date (Table 3). In general, activity density of microarthropods detected from the soil surface in June and October tended to be higher than numbers detected in August. This bimodal detection of detection is common and is usually attributed to conditions associated with climate.

Collembolans were the most frequently detected arthropods in pitfall samples. Mean collembolan numbers (activity density) over tillage treatments were 85.18 (\pm 14.58 SE) in the rye and 40.67 (\pm 4.58 SE) in the timothy/cover treatments. Community analysis may reveal differences in treatments that are not detectable in abundance data for arthropods identified into coarse taxonomic groups.

Table 3. Mean numbers (activity density) of micro- and macroarthropods collected per pitfall trap over a 72 hr period averaged over crop type and tillage system from the pitfall sampling method completed in 2004 in the first year start plots.

Date	<u>Mean Numbers of Microarthropods</u>			
	Mites	Collembolans	Other Micros	Total Micros
21-Jun-04	15.81 ± 2.73	28.48 ± 3.65	21.04 ± 4.27	65.33 ± 6.56
23-Aug-04	1.58 ± 0.48	12.58 ± 1.76	8.46 ± 1.06	22.26 ± 2.51
4-Oct-04	3.60 ± 0.74	147.71 ± 17.68	15.08 ± 1.26	166.40 ± 18.07

Date	<u>Mean Numbers of Macroarthropods</u>				Total Macros
	Other Macros	Ants	Spiders	Opiliones	
21-Jun-04	17.79 ± 1.25	2.51 ± 0.28	7.50 ± 0.65	2.69 ± 0.43	30.44 ± 1.55
23-Aug-04	8.27 ± 0.78	4.33 ± 1.49	5.02 ± 1.01	0.08 ± 0.05	17.50 ± 2.01
4-Oct-04	14.81 ± 1.22	4.08 ± 0.41	0.48 ± 0.09	0.71 ± 0.14	20.08 ± 1.34

Table 4. Mean numbers (activity density) of micro- and macroarthropods collected per pitfall trap over a 72 hr period averaged over tillage system in 2004 on the first year start plots planted with either rye or timothy/clover cover crops.

Crop	<u>Mean Numbers of Microarthropods</u>			
	Mites	Collembolans	Other Micros	Total Micros
Rye	6.36 ± 1.08	85.18 ± 14.58	10.56 ± 1.05	102.10 ± 15.10
Timothy/Clover	7.64 ± 1.89	40.67 ± 4.58	19.17 ± 2.89	67.47 ± 5.64

Crop	<u>Mean Numbers of Macroarthropods</u>				Total Macros
	Other Macros	Ants	Spiders	Opiliones	
Rye	13.18 ± 1.10	2.93 ± 0.29	3.15 ± 0.43	0.64 ± 0.12	19.86 ± 1.41
Timothy/Clover	14.07 ± 0.91	4.38 ± 1.02	5.49 ± 0.80	1.68 ± 0.32	25.49 ± 1.51

Table 5. Mean numbers (activity density) of micro- and macroarthropods collected per pitfall trap over a 72 hr period averaged over cover crop in 2004 on the first year start plots planted with either rye or timothy/clover cover crops.

Tillage	<u>Mean Numbers of Microarthropods</u>			
	Mites	Collembolans	Other Micros	Total Micros
Conventional	7.31 ± 1.63	64.39 ± 11.94	11.79 ± 1.22	83.49 ± 12.21
Reduced	6.69 ± 1.45	61.46 ± 10.25	17.93 ± 2.87	86.08 ± 10.92

Tillage	<u>Mean Numbers of Macroarthropods</u>				Total Macros
	Other Macros	Ants	Spiders	Opiliones	
Conventional	15.31 ± 0.94	3.77 ± 0.52	4.87 ± 0.77	1.24 ± 0.30	25.07 ± 1.34
Reduced	11.94 ± 1.05	3.53 ± 0.92	3.77 ± 0.52	1.08 ± 0.19	20.28 ± 1.60

Soil Arthropods

As in 2004, the abundance of microarthropods collected using the Tullgren funnel method was extremely low in 2005. Crop type and tillage system both influenced the numbers of microarthropod detected using this method. In the first year start, mean mite and collembolan numbers were higher in the rye treatment than in timothy clover treatment (Table 6). Conversely, the mean number of other microarthropods was lower in rye than in timothy/clover treatment. When comparing tillage systems, mean mite numbers were higher in the conventional tillage system (1.25 ± 0.26) than in the reduced tillage system (0.54 ± 0.20). However, mean collembolan and microarthropod numbers were higher in the reduced tillage than the conventional tillage system (Table 7).

In the second year start, mean mite and other microarthropod numbers were higher in the timothy/clover treatment than in the rye treatment (Table 6). Mean number of mites, collembolans, and other microarthropods were higher in fields under reduced tillage than fields under conventional tillage (Table 7).

Table 6. Mean numbers of arthropods collected per soil sample averaged over tillage system using the Tullgren funnel method in 2005.

2005 Crop Comparison				
Start	Crop	Mite	Collembolans	Other Micros
First	Rye	0.92 ± 0.24	0.50 ± 0.25	0.08 ± 0.06
First	Timothy/Clover	0.88 ± 0.25	0.25 ± 0.11	0.21 ± 0.13
Start	Crop	Mite	Collembolans	Other Micros
Second	Rye	0.42 ± 0.19	0.13 ± 0.07	0.08 ± 0.06
Second	Timothy/Clover	0.79 ± 0.22	0.13 ± 0.07	0.29 ± 0.11

Table 7. Mean numbers of arthropods collected per soil sample averaged over crop type using the Tullgren funnel method in 2005.

2005 Tillage Comparison				
Start	Tillage	Mite	Collembolans	Other Micros
First	Full	1.25 ± 0.26	0.33 ± 0.22	0.08 ± 0.05
First	Min	0.54 ± 0.20	0.42 ± 0.16	0.21 ± 0.13
Start	Tillage	Mite	Collembolans	Other Micros
Second	Full	0.50 ± 0.20	0.04 ± 0.04	0.12 ± 0.09
Second	Min	0.71 ± 0.21	0.21 ± 0.08	0.25 ± 0.09

Soilborne Insect Pathogens

2004 Results

Infection rates of sentinel *Galleria mellonella* larvae placed in the soil samples were highly variable. Actual infection rates ranged from 0-90 % (0 to 9 insects infected per sample), with a mean infection rate of 20.5% (mean 2.05 ± 0.12 insects per sample) for *Metarhizium anisopliae* and 0.2% (mean 0.02 ± 0.01 insects per sample) for *Beauveria bassiana*. Infection rate for *M. anisopliae* was lowest in the soil collected on September 27th. *B. bassiana* infections only occurred on September 27th. Cover crop type did not significantly affect infection rate from

B. bassiana Mean detection of *M. anisopliae* in rye (2.34 ± 0.18) was greater than the detection in timothy/clover (1.76 ± 0.16). When comparing tillage treatments, there was a greater detection of both *M. anisopliae* and *B. bassiana* in conventional tillage compared to reduced tillage treatments. No entomopathogenic nematode (EPN) infection was documented by this baiting procedure.

2005 Results

Similar to results in 2004, detection rates using the *G. mellonella* baiting method were highly variable (Figures 15-18). Mean infection ranged from 0-100 %, with a mean infection rate of 16.6% (mean 1.66 ± 0.16 *Galleria* infected per sample) for *M. anisopliae* and 1.5% (mean 0.15 ± 0.08 *Galleria* infected per sample) for *B. bassiana* collected from the first year start (soybean). Infection rates in the second year start (cover crop) were comparable to the first year start with a mean infection rate of 20.6% (2.06 ± 0.18 *Galleria* infected per sample) for *M. anisopliae* and 1% (0.10 ± 0.03 *Galleria* infected) for *B. bassiana*. Infection rate for both pathogens was highest in the soil collected on 6 October from both experimental starts.

When averaging the infection rate over tillage system in the first year start (soybean), the mean detection of *M. anisopliae* in rye (1.39 ± 0.22 individuals/sample) was less than in timothy/clover (1.93 ± 0.24 infected *Galleria* per sample) treatments. Conversely, the mean infection rate for *B. bassiana* was 0.25 ± 0.15 *Galleria*/sample in rye and 0.05 ± 0.03 *Galleria*/sample in timothy/clover treatments. When comparing tillage treatments, the mean infection rate of *M. anisopliae* was 1.91 ± 0.25 *Galleria*/sample in conventional tillage and 1.41 ± 0.21 *Galleria*/sample in reduced tillage treatments. The mean infection rate by *B. bassiana* was 0.24 ± 0.15 *Galleria*/sample in reduced tillage and 0.06 ± 0.04 *Galleria*/sample in conventional tillage treatments.

In the second year start (cover crop), the mean infection rate of *M. anisopliae* in the rye treatment was 1.93 ± 0.23 *Galleria*/sample and 2.20 ± 0.27 *Galleria*/sample in timothy/clover treatments. Mean infection of *B. bassiana* was 0.13 ± 0.05 *Galleria*/sample in timothy/clover and 0.07 ± 0.03 *Galleria*/sample in rye treatments. Infection by *M. anisopliae* under reduced tillage was 2.53 ± 0.28 *Galleria*/sample and 1.59 ± 0.22 *Galleria*/sample in conventional tillage treatments. Infection by *B. bassiana* under conventional tillage was 0.10 ± 0.04 *Galleria*/sample and 0.09 ± 0.03 *Galleria*/sample in the reduced tillage treatment.

EPN were not detected in either experimental start in the second year of the experiment.

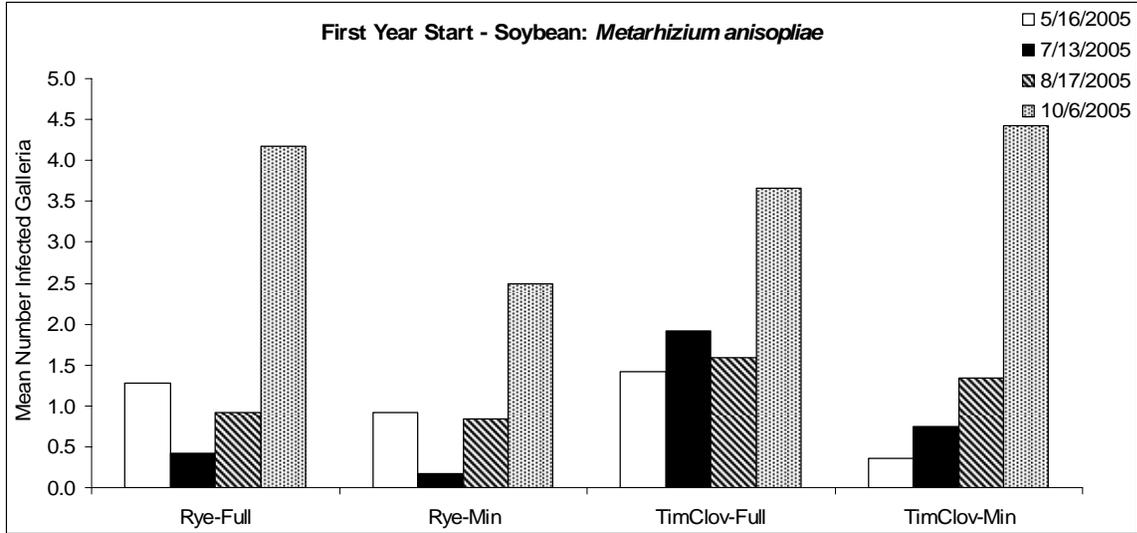


Figure 15. Mean infection rates of *Galleria mellonella* by *Metarhizium anisopliae* in soil samples collected in 2005, shown by sampling date for each cover crop/tillage treatment for the first year start (soybean).

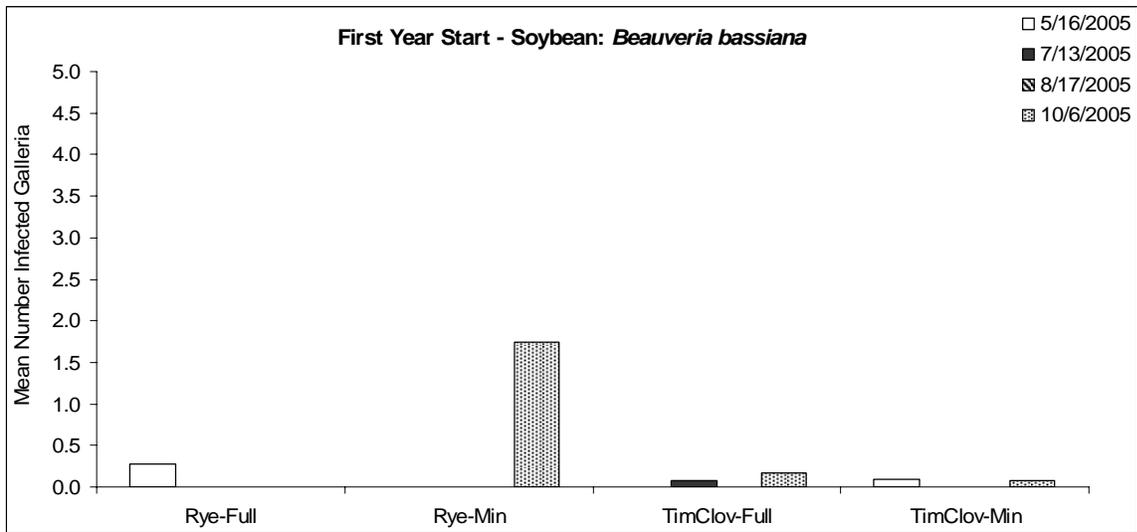


Figure 16. Mean infection rates of *Galleria mellonella* by *Beauveria bassiana* in soil samples collected in 2005, shown by sampling date for each cover crop/tillage treatment for the first year start (soybean).

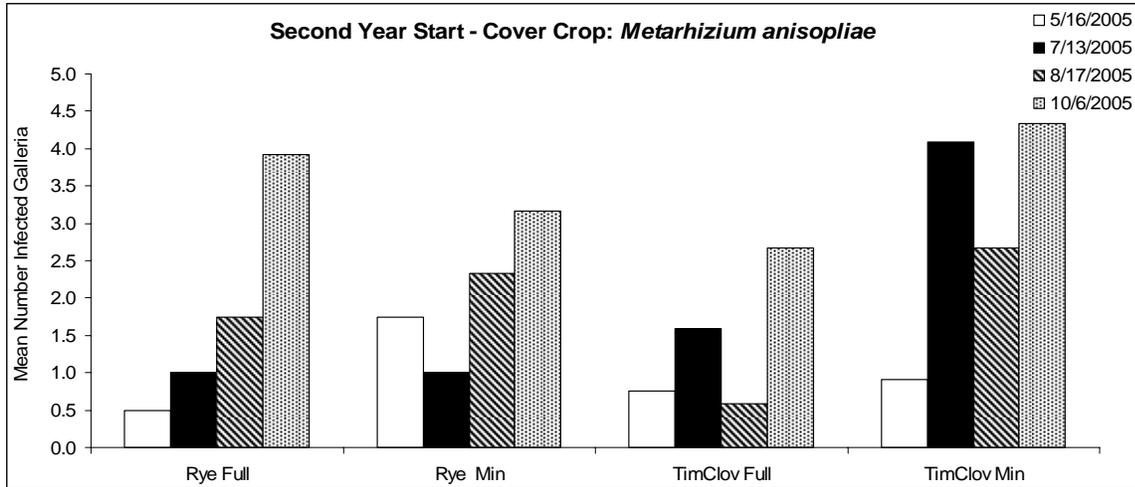


Figure 17. Mean infection rates of *Galleria mellonella* by *Metarhizium anisopliae* in soil samples collected in 2005, shown by sampling date for each cover crop/tillage treatment for the second year start (cover crop).

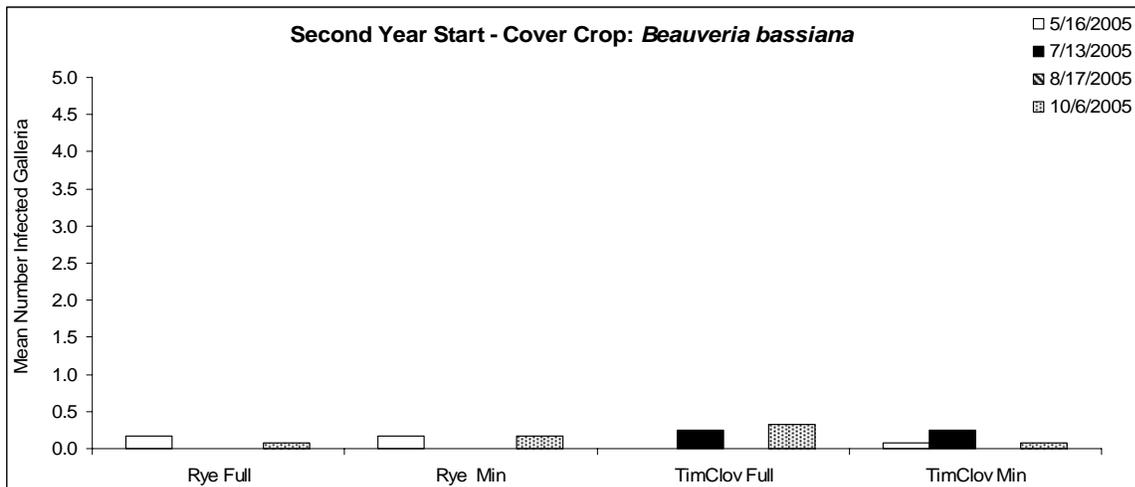


Figure 18. Mean infection rates of *Galleria mellonella* by *Beauveria bassiana* in soil samples collected in 2005, shown by sampling date for each cover crop/tillage treatment for the second year start (cover crop).

Weed Populations

Cumulative weed seedling densities were quantified throughout May and June in both the weed seed bank subplots as well as in the larger plots to quantify background weed densities in 2004 and 2005. The three seeded weed species established in different proportions across the three seeding 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/m² in the low subplot to near 150 seedlings/m² in both the medium and high subplots. Velvetleaf and common lambsquarters establishment was low in the rye treatment and averaged less than 10 seedlings/m² across all subplot densities for both species (except for the high velvetleaf density which was 60 seedlings/m²). Conversely, foxtail

establishment in the red clover/timothy treatment was very limited with less than 10 seedlings/m² 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/m² quantified across the subplot densities. There was likely limited broadleaf weed seed production in timothy/clover because of frequent mowing of forage. Similar results were quantified in the second start year (Figure 19.)

The established densities in the first start year were monitored over time (Figure 20) 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 moved forward into soybean production it is apparent that density dependent effect of initial seedbank size is specific to both weed species and crop type. For the grass species (foxtails) the impact of the initial seedbank size is swamped out in the soybean following both the rye/ vetch and timothy/clover cover crops. The impact of initial seedbank size is still apparent for the two broadleaf species in the soybean year following both cover crop types. Therefore we may be quantifying a lag in the seedbank dynamics of lambsquarters and to a lesser extent with velvetleaf. A potential mechanism for this lag is that weed seeds of these two species have remained viable in the soil profile and have responded to increased soil disturbance during the soybean production year to germinate and emerge. Perennial weed species such as Canada thistle (*Cirsium arvense*) and hedge bindweed (*Calystegia sepium*), which have patchy population distributions in this study, will need to be continually addressed likely through the use of spatially targeted tillage operations or by manipulating the crop rotation to include a competitive perennial forage crop like alfalfa, for example.

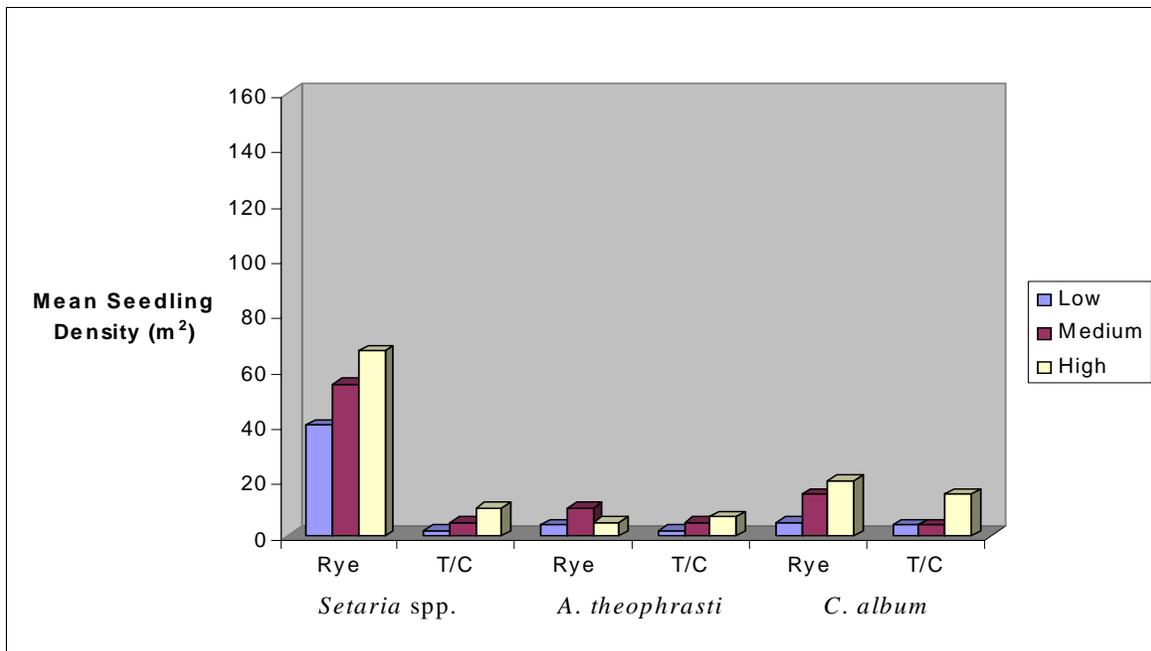


Figure 19. Cumulative weed seedling densities in the rye and timothy/red clover (T/C) cover crop treatments across the three weed subplot densities (low, medium and high) in second start year in 2005.

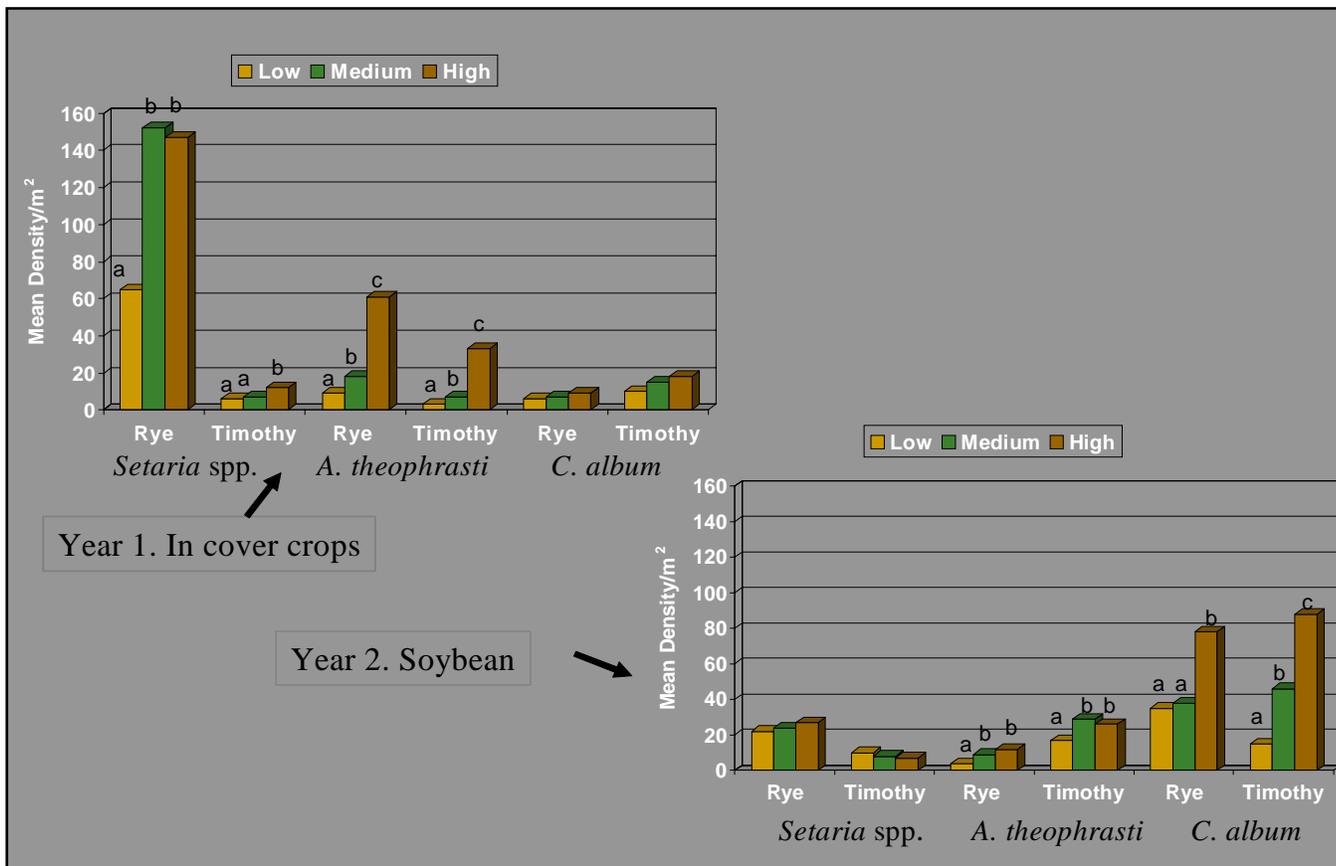


Figure 20. Cumulative weed seedling densities in the rye and timothy/red clover cover crop treatments across the three weed subplot densities (low, medium and high) in cover crops in year 1 of the study and in the following year (2005) in soybean production.

Environmental Data

Data from the soil temperature and soil moisture sensors equipped with data loggers are currently being summarized. Figures 21 and 22 below exemplify the raw data for the soil water content and soil temperature curves in the timothy/red clover cover cropping treatment for the 2004 and 2005 growing seasons. These data indicate that in general 2004 was a much cooler and wetter year (specific to this set of experimental treatments) than 2005. Data from the other experimental treatments indicate similar results. These data will be used as covariates to supplement field sample data sets. Sampling was conducted from late April through October.

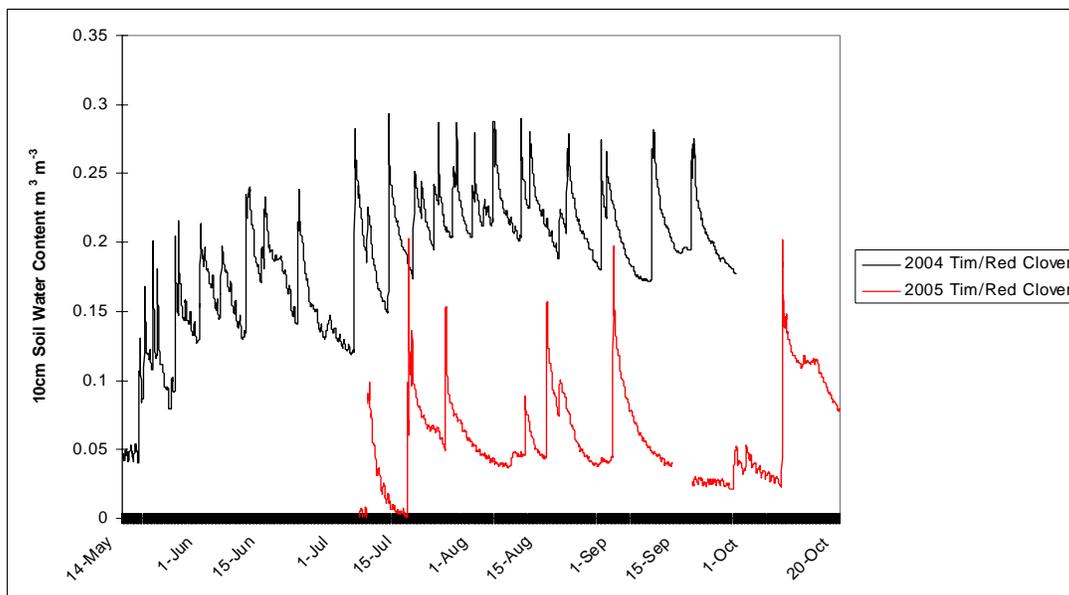


Figure 21. Soil water content in 2004 and 2005 in timothy/red clover cover crop treatment.

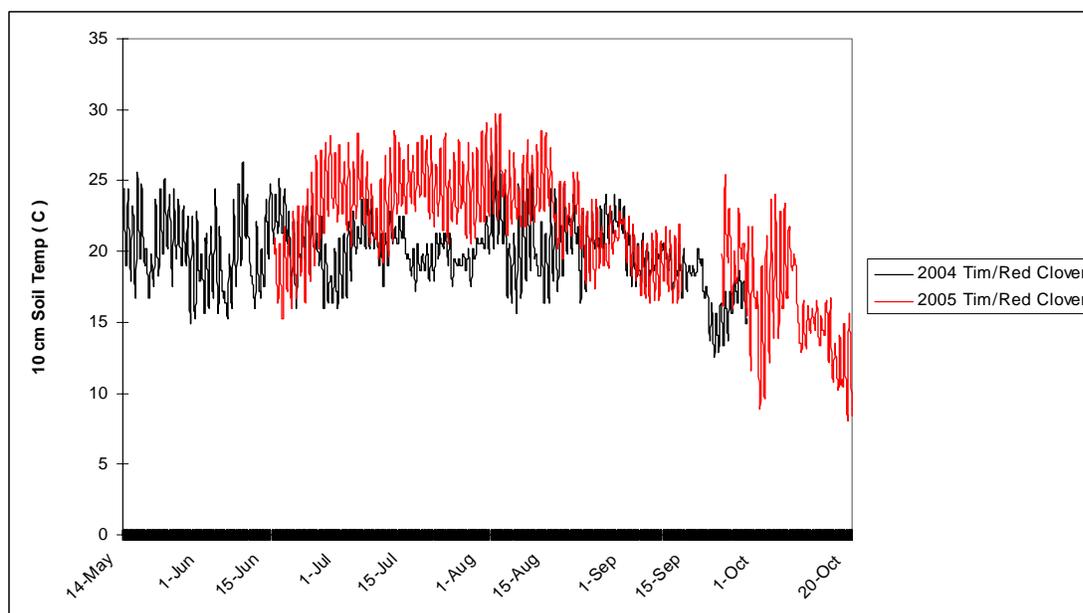


Figure 22. Soil temperature in 2004 and 2005 in timothy/red clover cover crop treatment.

Economic Analyses

Since the inception of the project, all input costs (fixed and variable) and crop yields have been recorded. These types of data were applied to generalized enterprise budget worksheets in the Penn State University Agronomy Guide (<http://agguide.agronomy.psu.edu/>). Example completed budgets typical of this project are presented in Appendix 4 of this report. This information may be useful to commercial farmers exploring a transition to organic production methods and we encourage growers to use their own production costs and returns in this type of budget framework. 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 management scenarios.

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 county educators 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 during 2005 related to the above objectives are summarized below.

Teaching Activities

Barbercheck, M. and R Jabbour (Instructors)

Stephen Pietruska and Creighton Knopsnider -Pennsylvania Governor School students (high school) who worked on individual projects related to the field experiments described above. Summer 2005.

Karsten, H. (Instructor) Fall 2005 and Spring 2006 Semesters

Agroecosystems Science 134, Political Science 134 - Sustainable Agriculture and Policy- Included new teaching materials on organic agricultural management.

Agroecosystems Science 461 - Integrated Crop Management

Agroecosystems Science 490 - Producer Speaker Series

Agroecosystems Science 510- Ecology of Agricultural Systems.

Agronomy 597B - Ecology of Agricultural Systems

Extension Presentations

Barbercheck, M. Biorational Decisions to Replace Synthetic Chemicals in Landscape Maintenance. Using Bioproducts in Vehicle and Landscape Maintenance Workshop, Oct. 13, 2005, Lancaster, PA.

Barbercheck, M. Insect-Parasitic Nematodes. Greenhouse IPM Workshop, Oct. 12, 2005. Black Creek Greenhouse, East Earl, PA. 65 attendees (35 women, 60 Mennonite)

Barbercheck, M. Advanced Training in Organic Agriculture. NE SARE Extension Professional Development workshop, Sept. 19-22, 2005. Auburn, ME. 30 attendees. (15 women)

Barbercheck, M. Soil: The Hidden World Beneath our Feet. Using Soil Biology to Increase Farm Productivity Field Day. Rodale Institute, Kutztown, PA, Friday, July 22, 2005. (130 attendees, ~ half women)

Barbercheck, M. Advanced Training in Organic Agriculture. NE SARE Extension Professional Development workshop, June 27 - 30, 2005. State College, PA. 20 attendees. (10 women)

Barbercheck, M. PSU/PASA/PCO Ecological Weed Management Field Day (Transition to Organic Plots), Rock Springs, Centre County, 13 June 2005. 60 attendees (30 women).

Barbercheck, M. Organic Basics. 17 March 2005. Cooperative Extension In-Service. University Park, PA. 6 attendees (0 women)

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. Advanced Training in Organic Agriculture. NE SARE Extension Professional Development workshop, Feb. 28 - April 3, 2005. Albany, NY. 20 attendees. (10 women)

Hulting, A.G. and D. A. Mortensen. February 28, 2006. Organic Feed and Forage Production: Where Do We Start? Virginia Cooperative Extension Producer Meeting. Dayton, VA.

Hulting, A.G. Organic Crop Production: The Basics. October 27, 2005. PSU Cooperative Extension, Crop Management and Extension Group Inservice Training. State College, PA (w/ W. Curran)

Sánchez, E. Blueberry Nutrition in Organic Farming. February 1, 2006. Hershey, PA, 150 attendees.

Sánchez, E. Organic Blueberries. January 19, 2006. Mifflinburg, PA, 30 attendees.

Sánchez, E. Transitioning to Organic Small Fruit Production. January 19, 2006. Mifflinburg, PA, 30 attendees.

Sánchez, E. Using Cover Crops as Part of a Rotational Scheme for Vegetable Crops, January 13, 2006. Martinsburg, PA, 25 attendees.

Sánchez, E. Transitioning to Organic Production in High Tunnels. August 22, 2005. Rock Springs, PA, 10 attendees.

Sánchez, E. Organic Gardening. August 17, 2005. Rock Springs, PA, 30 attendees.

Sánchez, E. Current Organic Efforts. June 28, 2005. Rock Springs, PA, 22 attendees.

Sánchez, E. Organic Production in High Tunnels. June 21, 2005. Rock Springs, PA, 10 attendees.

Sánchez, E. Introduction to Organic Production. March 1, 2005. Mill Hall, PA, 15 attendees.

Sánchez, E. Green Manures to Proceed Blueberries. February 3, 2005. Hershey, PA, 75 attendees.

Sánchez, E. Use of Specialized Green Manures in Small Fruit Production. January 20, 2005. Mifflinburg, PA, 25 attendees.

Sánchez, E. Organic Weed Control in Small Fruit. January 20, 2005. Mifflinburg, PA, 40 attendees.

Newsletter Articles

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

Sánchez, E. 2006. The Organic Way – Resource Guide for Organic Insect and Disease Management. The Vegetable & Small Fruit Gazette, Volume 10(2).

Sánchez, E. 2006. The Organic Way – Weeds as Indicators of Soil Health. The Vegetable & Small Fruit Gazette, Volume 10(1).

Sánchez, E. and B. Scirappa. 2005. The Organic Way – Coming Attractions. The Vegetable & Small Fruit Gazette, Volume 9(12).

- Sánchez, E. 2005. The Organic Way – Gray Mold on Raspberries and Cultural Management. *The Vegetable & Small Fruit Gazette*, Volume 9(11).
- Sánchez, E. 2005. The Organic Way – OMRI Lists. *The Vegetable & Small Fruit Gazette*, Volume 9(10).
- Sánchez, E. 2005. The Organic Way – The National Organic Standards Board Wants Your Comments. *The Vegetable & Small Fruit Gazette*, Volume 9(8).
- Sánchez, E. and P. Ferretti. 2005. The Organic Way – Diagnosing Cultural Problems in the Field. *The Vegetable & Small Fruit Gazette*, Volume 9(7).
- Sánchez, E., K. Demchak and G. Sanders. 2005. The Organic Way – In Search of Sustainable Botrytis Management. *The Vegetable & Small Fruit Gazette*, Volume 9(6).
- Sánchez, E. 2005. The Organic Way – Plant Families. *The Vegetable & Small Fruit Gazette*, Volume 9(5).
- Sánchez, E. 2005. The Organic Way – Organic Methods for Blueberry Nutrition. *The Vegetable & Small Fruit Gazette*, Volume 9(4).
- Sánchez, E. and M. Orzolek. 2005. The Organic Way – Different Colored Plastic Mulches for Tomato Production. *The Vegetable & Small Fruit Gazette*, Volume 9(3).
- Sánchez, E., P. Ferretti, T. Elkner and A. Montri. 2005. The Organic Way – Fresh Market Tomato Cultivars. *The Vegetable & Small Fruit Gazette*, Volume 9(2).
- Sánchez, E. 2005. The Organic Way – Organic News. *The Vegetable & Small Fruit Gazette*, Volume 9(1).

Seminar Presentations

- Barbercheck, M. Organic Weed Management: Balancing Pest Management and Soil Quality in a Transitional System. November 5, 2005, CSREES, USDA Awardees Workshop on Biologically-based Pest Management at the Entomological Society of America Annual Meeting Fort Lauderdale, Florida
- Barbercheck, M. and R. Jabbour. Biotic factors and farming systems affecting persistence and recycling. Symposium on Ecology of Entomopathogenic Nematodes. 38th annual meeting of the Society for Invertebrate Pathology will be held at the University of Alaska, Anchorage, Alaska. Aug. 7-11, 2005. (Invited symposium speaker)
- 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.

Meeting Abstracts

Hulting, A. G., D. A. Mortensen and M. Barbercheck. 2006. Managing weed seed bank pools during the transition to an organic feed grain rotation in Pennsylvania. WSSA Abstracts (in press).

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.

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.

Sánchez, E. 2006. Blueberry Nutrition in Organic Systems. 2006 Mid-Atlantic Fruit and Vegetable Convention Proceedings.

Sánchez, E. 2005. Organic Methods for Blueberry Nutrition. New England Vegetable & Fruit Conference Proceedings.

Related Funded Projects

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

USDA NE SARE 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.

Principal Investigator Meeting Dates

March 8, 2004

March 18, 2004
April 14, 2004
April 28, 2004
May 19, 2004
June 22, 2004
January 11, 2005
May 6, 2005
January 9, 2006

Advisory Board Meeting Dates

September 12, 2003
March 15, 2004
August 31, 2004
March 16, 2005
March 16, 2006

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Appendix 1. Timeline of project activities from Spring to Fall 2005.

<u>Date</u>	<u>Operation</u>	<u>People Involved</u>
10 May 2005	Flagged and staked 1 st and 2 nd year. Plot size 80'x 90'. 1 st year Aisle size 23' Second year aisle size 20'.	Barbercheck and Mortensen labs.
10 May 2005	1 st year plots measured the Hairy Vetch. Measured 70cm. Rye measured 91-100cm. Timothy 15-20cm, Clover 20-25cm. 2 nd year rye 62cm, Timothy 15-20cm, Clover 20-25cm.	Barbercheck and Mortensen labs.
16 May 2005	Data Loggers placed in plots 3,4 & 13,14. Each logger has 4 sensors. 1 Temp, 1 moisture sensor per plot. The logger sits between 2 plots and the sensors are extended into each plot 5-6'.	Barbercheck and Mortensen labs.
16 May 2005	Took soil samples from each start year. 3 samples were taken per plot.	Barbercheck and Mortensen labs.
18 May 2005	Downloaded info from loggers	Barbercheck lab
18 May 2005	Took biomass samples in Timothy/Clover	Mortensen lab
19 May 2005	Took biomass samples in Hairy Vetch	Barbercheck and Mortensen labs
24 May 2005	Downloaded info from loggers	Barbercheck lab
26 May 2005	Downloaded info from loggers and removed from fields in order to till and maintain the fields	Barbercheck and Mortensen labs
26 May 05	Bush hogged the Hairy Vetch in the till plots. Proceeded to till with moldboard plow. The timothy/clover plots were chisel plowed. ** All equipment has been cleaned prior to use if it had been used in other fields.	Barbercheck Lab Mortensen Lab

	Implements used: Ford 6600 tractor, Bush hog 32100, International Muldboard plow with a John Deere, John Deere tractor with chisel plow.	
27 May 05	All plots except for Min-Till vetch were disked.	Barbercheck Lab
1 June 2005	Min-till Hairy Vetch plots were rolled with mechanical roller. John Deere tractor was used.	Barbercheck and Mortensen labs.
1 June 2005	Plots were disked again and cultimulched.	Entomology Farm
6 June 05	Soybeans were planted with the New Idea planter. This planter is used only for the organic project. All new parts and totally clean.	Mortensen Lab Entomology Farm
8 June 05	Ford 6600 tractor and flail mower were used in order to mow the min-till Hairy Vetch plots in 1 st year plots. John Deere tractor and John Deere 926 haybine were used to mow prior to flail mowing	Barbercheck Lab Mortensen Lab Entomology Farm
8 June 05	Pitfalls were placed in both starts. Pitfalls are not in Hairy Vetch plots (min-till). The beans are not yet planted in these plots. Stakes are placed in aisle ways. All are labeled field # then either A,B,C.	Barbercheck Lab
9 June 05	Put stakes in 1 st year plots. Placed PVC pipe to mark Data logger plots.	Barbercheck lab
9 June 05	Farm crew tried to plant the soybeans in min-till Hairy Vetch plots, but were unsuccessful. The rows weren't cleaned out enough and seed was either not going into the ground or was being planted too	Entomology Farm

	deep.	
10 June 05	Soybeans were planted in min-till Hairy Vetch plots in 1 st year. Ford tractor 3930 and 2 row John Deere with a yetter tool bar no-till coultter set to run 3" deep. Most seeds were ending up an 1" deep because of the vetch left on the surface.	Barbercheck Lab Mortensen Lab Entomology Farm
13 June 05	Put sign on stakes in plots 1-2, 11-12, 21-22, 31-32 for field day. Replaced stakes in vetch plots. Put data loggers back in plots 3-4 and 13-14. Loggers were stopped to put in new batteries.	Barbercheck Lab
13 June 05	Had PASA Field day at the Transition Plots along with Bill Currans plots.	
14 June 05	Checked the data loggers to make sure they were working.	Barbercheck lab
14 June 05	Pitfalls placed in Hairy Vetch/ Rye plots.	Barbercheck Lab
15 June 05	Ford 6600 tractor, rotary hoe from Horticulture farm. 4 row 10' wide went in about 2" to loosen up the soil for the soybeans to come up. Ran at 8-9 mi. an hour.	Mortensen Lab
16 June 05	Re-place pitfalls and stakes that were taken out for rotary how.	Barbercheck Lab
17 June 05	Opened pitfalls and put in antifreeze in both starts. Used 8oz. cups in 1 st year and 6oz. in 2 nd year.	Barbercheck Lab
20 June 05	Collected pitfalls	Barbercheck Lab
20 June 05	Data collected from all loggers except 31-32. 31-32 didn't collect data and needs a silicone pack.	Barbercheck Lab
27 June 05	Downloaded data from all	Barbercheck Lab

	loggers. Loggers in plot 31-32 did not collect.	Mortensen Lab
28 June 05	Logger was re-launched. Weed counts were done in Timothy/Clover and Rye plots in the 2 nd year start	Mortensen Lab
30 June 05	Downloaded data from all loggers. Re-launch on 6/27 was successful.	Barbercheck Lab
11 July 05	Did management in soybean plots with Ford 6600 tractor and S-tine. Took out pitfalls in Tim/Clover 1 st year plots (now in soybeans).	Mortensen Lab Entomology Farm Crew
12 July 05	Soybeans replanted in Timothy/Clover plots	
12 July 05	Collected data from loggers. Took out the sensors from field 3 & 14 for field maintenance	Barbercheck Lab
12 July 05	Did weed counts [5 random and the 3 weed density (low medium, and high) sub-plots] in 8 plots in the 1 st year. (Timothy/Clover till, min-till) GPS was not working so Andy flagged what he thought to be the weed plots indicated by the maps. Timothy/Clover till plots were replanted with certified organic soybeans.	Barbercheck Lab Mortensen Lab Entomology Farm Crew
13 July 05	Took out pitfalls so that the Timothy/Clover plots could be harvested in the 2 nd year.	Barbercheck Lab
13 July 05	Took soil samples from both 1 st and 2 nd year starts. Soybean planting was completed in the Timothy/Clover till, min-till plots in the 1 st year.	Barbercheck Lab Mortensen Lab Entomology Farm Crew
14 July 05	Mowed and bailed	Entomology Farm

	Timothy/Clover in 2 nd year start. Took out pitfalls in Tim/Oats fields in the second year start.	Crew
20 July 05	Cultivated half of the soybeans.	Farm Crew
21 July 05	Collected data from loggers	Barbercheck Lab
21 July 05	Harvested the Rye. Took out all pitfalls in order to harvest rye.	Entomology Farm Crew Barbercheck Lab
24,25 July 05	We had ¾ inch of rain	
25 July 05	Put pitfalls back in and opened them.	Barbercheck Lab
27 July 05	Cultivated all the beans Major weeds: Pigweed Lambs quarter Canada Thistle Field Bindweed Soil moisture excellent. Cultivator worked well. Used Ford 6600 tractor.	Barbercheck Lab Mortensen Lab Entomology Farm Crew
28 July 05	Picked up pitfalls. Took pitfalls out of Rye. Collected data from loggers.	Barbercheck Lab
28 July 05	Cultivated all the beans. 1 st time in the vetch treatment and 2 nd time in the vetch ploughed and Rye straw bailed resulting in 105 30 lbs. bails. 1 st time in Timothy/ Clover plot.	Mortensen Lab Entomology Farm Crew
29 July 05	Put data loggers back in except for plot 4	Barbercheck Lab
10 Aug 05	Downloaded information from data logger for field #3. Tried to fix data logger for field #4 but the new water content probe would not register in the system. Computer froze and was unable to re-launch data	Barbercheck Lab

11 Aug 05	logger for field #3. Re-launched data logger I field #3.	Barbercheck Lab
17 Aug 05	Downloaded information from the other data loggers. Downloaded information from all four data loggers.	Barbercheck Lab
17 Aug 05	Took soil samples from both starts.	Barbercheck Lab
23 Aug 05	Downloaded information from all four data loggers	Barbercheck Lab
31 Aug 05	Downloaded information from all four data loggers	Barbercheck Lab
2 Sept 05	Applied compost to the second year start at a rate of 7.5 tons/A for a total of 22.5 tons. Compost was dryer this year compared to last year	Entomology Farm Crew
8 Sept 05	Bulk density sampling in the rye plantings for the second year start. Sampled the first 3 blocks (fields 21, 24, 25, 32, 34, and 36) at three depths and two locations in each field.	Barbercheck Lab Sjoerd Duiker
9 Sept 05	Bulk density sampling in the 4 th block's (fields 27 and 28) rye plantings.	Barbercheck Lab
15 Sept 05	Downloaded data loggers. Moisture sensor for Rye plot #24 broke prior to tillage.	Barbercheck Lab
15 Sept 05	Hairy Vetch planted at ~ 30 lbs/A. Chisel and moldboard plowed rye plots prior to planting hairy vetch seed.	Farm Crew
22 Sept 05	Downloaded data loggers. Moisture sensor for Rye plot #24 will not be replaced until next year.	Barbercheck Lab
30 Sept 05	Downloaded data loggers.	Barbercheck Lab
6 Oct 05	Soil sampled first and second year starts at 12	Barbercheck Lab Andy Hulting

	cores per location, three locations per plot.	
17 Oct 05	Put in pitfalls for both years. Three pitfalls per field. (Pitfalls <u>in</u> the soybean rows.)	Barbercheck Lab Andy Hulting
18 Oct 05	Opened pitfalls and put in antifreeze. Soybeans that were replanted still need to dry down while those that were planted on the original planting date are already dried down. There is concern about Canadian Thistle management. Should we cultivate them after soybean harvest or wait until spring? There are concerns about tilling in the weed seeds.	Barbercheck Lab Andy Hulting
20 Oct 05	Collected data logger info. Brought in data loggers before it frosted. Sensors for field 23 were in field 24. Field 24 had a total of 4 sensors in it. This was probably a result of moving them before a tillage event.	Christy Mullen Andy Hulting
21 Oct 05	Collected pitfalls	Christy Mullen, Andy Hulting, Randa Jabbour, Matt Ryan, Steve K., Dan
27 Oct 05	Collected representative soybean plants for soybean seed count. (10ft of a row, 3 random rows per field). Bagged the plants (3 bags/field, 48 samples total) and took them back to campus. Air drying them in one of the Agronomy greenhouses.	Christy Mullen Andy Hulting

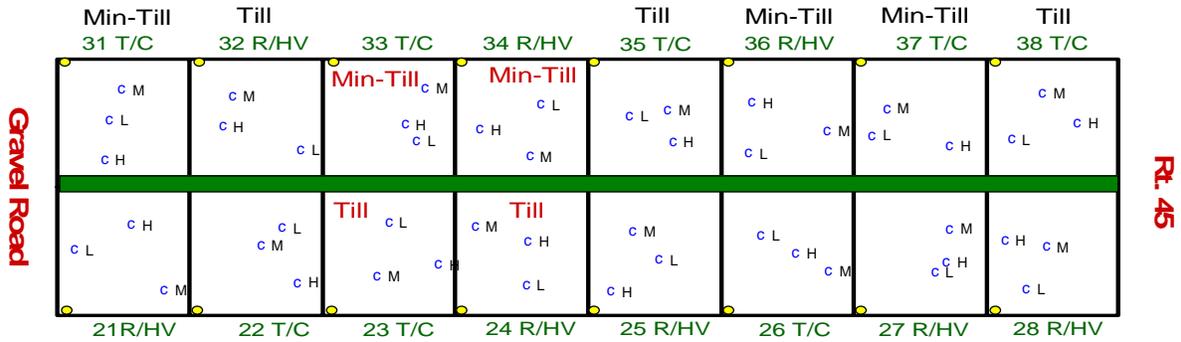
Harvested soybeans.

Farm Crew

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

Transition to Organic 2005 Experimental Plan

2nd Year Start Transition (nearest the high tunnels)



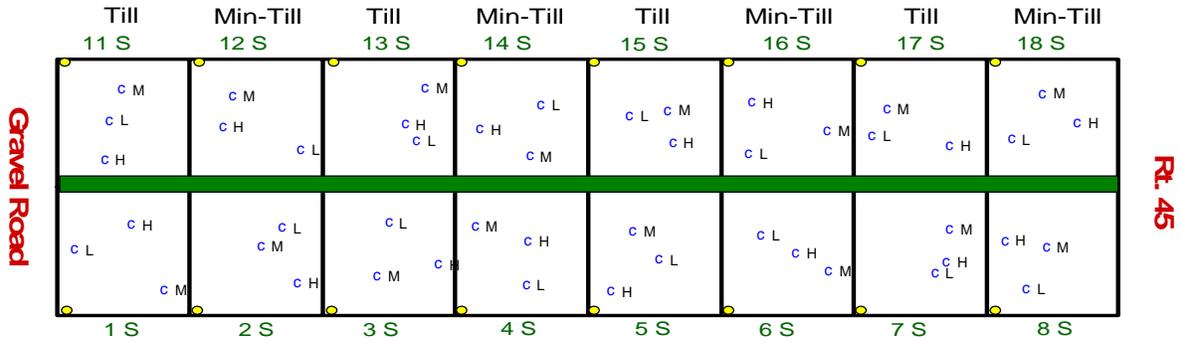
Where: T/C = Timothy / Clover
 R/HV = Rye/Hairy vetch
 L = Low weed density
 M = Medium weed density
 H = High weed density

= field traffic

= flags indicating plot numbers

Transition to Organic 2005 Experimental Plan

First Year Transition



Where: S = Soybean
 L = Low weed density
 M = Medium weed density
 H = High weed density

= field traffic

= flags indicating plot numbers

Appendix 3. Economic Analyses

Rye Production

■ Total Receipts	
□ Grain (47.7 bu X \$3.10)	147.00
□ Straw (1.97 tons X \$100.00)	197.00
■ Total Variable Costs	
□ Seed	21.00
□ Lime	34.00
□ Manure	18.00
□ Labor (\$9.00/hr)	21.00
□ Fuel (\$ 2.00/gal)	20.00
□ Grain Drying	4.00
□ Repairs and Maintenance	8.00
□ Custom Harvesting Rate	24.00
■ Fixed Costs	
□ Tractors	6.00
□ Tillage and other Equipment	11.00
□ Land-Cash Rent	70.00
■ Net Returns	109.00

<http://agguide.agronomy.psu.edu/cm/sec12/sec12toc.cfm>

Prepared by Andy Hulting

Timothy/Red Clover Hay Production

■ Total Receipts	
□ 2 Mixed Hay Harvests (Large Round Bale System)	458.00
■ (3.0 tons X \$129.00 + 0.5 tons X \$121.00)	
■ Total Variable Costs	
□ Seed	56.00
□ Lime	34.00
□ Manure	18.00
□ Labor (\$9.00/hr)	40.00
□ Fuel (\$ 2.00/gal)	22.00
□ Repairs and Maintenance	26.00
□ Custom Harvesting Rate	24.00
■ Fixed Costs	
□ Tractors	13.00
□ Tillage and Hay Equipment	20.00
□ Land-Cash Rent	70.00
■ Net Returns	177.00

<http://agguide.agronomy.psu.edu/cm/sec12/sec12toc.cfm>

Prepared by Andy Hulting