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

Russell E. Larson Agricultural Research Center
Rock Springs, PA

2006 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 to teaching and technology transfer activities over the first 3 years 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, agricultural professionals, producers 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 2008.

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-based extension 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.

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 Penn 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 experiment 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. Field management since the beginning of the experiment for each cover crop and tillage treatment for the first replicate ("Start 1") is detailed in Appendix 3 and in Appendix 4 for the second replicate ("Start 2").

The field experiment has been established twice, in the fall of 2003 (Start 1) and again in 2004 (Start 2), 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 replicate, which are each 0.067 ha (80' x 90') 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. Start 2 of the experiment was managed with organic methods for the year before its inclusion as a temporal replicate in the 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). The red clover/timothy treatment 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: conventional (moldboard plow-based) and a reduced tillage (chisel plow + field cultivator-based). In the third year (final transition year) of Start 1(Spring 2006), untreated feed–grade corn (*Zea mays* cv. Pioneer 36B08) in all cover crop/tillage treatments at a row spacing of 76 cm. Start 2 was managed in a similar fashion, but treatments were delayed in time by one year. In 2006, the second year of Start 2, untreated feed-grade soybean (*Glycine max* cv. 93B87) (late Group III maturity) was planted in all cover crop/tillage treatments at a row spacing of 76 cm.

Transition Treatments

1. Rye (Grain)-Hairy Vetch-Soybean-Corn
   -Reduced Till (Chisel Plow Based)

2. Rye (Grain)-Hairy Vetch-Soybean-Corn
   -Conventional Till (Moldboard Plow Based)

3. Timothy/Red Clover (Forage)-Soybean-Corn
   -Reduced Till (Chisel Plow)

4. Timothy/Red Clover (Forage)-Soybean-Corn
   -Conventional Till (Moldboard Plow)

Crop Yield Measures

Three sub-samples of corn and soybeans were hand harvested randomly throughout each plot. Corn ears were removed from 11.6 ft of randomly selected crop row, bagged, and air-dried in the Agronomy greenhouse. The dried corn kernels were removed from the cob by hand and placed into labeled paper bags. Ten row-feet of soybean plants were clipped at ground level, bagged and air-dried in the Agronomy greenhouse. Once dry, the plants were passed through a Gravity® plot combine located at the Entomology farm to collect seeds. Seeds of both the corn and soybeans were weighed and their moisture assessed using a Dickey-John® grain moisture meter (GSF Inc.) Yield was calculated based on kilograms per hectare for each treatment.

Soil Measures

<u>Soil Chemical and Biological Properties</u>

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 divided in the laboratory into three portions of approximately 250 mL 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 subsamples used for characterizing soil chemical and 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). Soil sampling dates are listed in Appendix 1.

Soilborne Insect Pathogens

A baiting bioassay method using *Galleria mellonella* as a sentinel 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 (~250 mL) was placed in 473 mL deli container (Reynolds) along with 5 last-instar wax moth larvae (*G. 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 cups (Solo) with lids for symptoms and signs of infection to develop. The containers of soil were re-baited with five new larvae and incubated for an additional 10 days.

Cause of death was identified as fungal (*Metarhizium antisopliae*, *Beauveria bassiana*, or *Paecilomyces fumosoroseus*), 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 classified as being infected with *Beauveria* (white spores), *Metarhizium* (green spores), or *Paecilemyces* (pink spores) (Goettel and Inglis 1997).

Active Carbon

Concentrations of permanganate oxidizable carbon (POC) were determined from the soil samples taken from each plot (Weil et al.,2003). Briefly, soil samples were air-dried and 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 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, 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 centrifugation and added to 9.8 ml of DI water and vortexed to mix thoroughly. A mechanical pipette was used to transfer one 3.8 ml aliquot of supernatant to a clean cuvette (4 ml). 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 (Mn+7 -> Mn+4) in each tube:

POC (g/kg) = [0.02 - (a + b x absorbance)] x 9 x 0.02 / 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 ground to pass through a 2-mm sieve. A 2:1 ratio of 20 ml of DI water was added to 10 g of soil in a 47.5-ml screw top polycarbonate centrifuge tube. Tubes were capped and shaken end to end (240 oscillations per minute) for 2 min and then allowed to settle an additional 15 minutes. The mixture was then centrifuged (International Equipment Company HN-SII) at 2000 rpm for 5 minutes. The EC (µS/cm) was immediately read in the centrifuge tube with a standardized EC meter (Thermo Orion 555A).

pH

Soil samples were air-dried and 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 shaken for about 30 seconds and then allowed to settle for 10 minutes. The electrode was inserted into the container and swirled again with the electrode and pH recorded (Thermo Orion 555A). The electrode was rinsed in distilled water between samples.

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 sandwiched between two pieces of filter paper and buried in ~250 mL of soil contained in Ziploc plastic bags. 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 [(wet weight - dry weight) / dry weight] x 100 = % 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 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 weighed to obtain the dry weight of soil. Percentage soil moisture was calculated as [(wet weight soil - dry weight soil) / dry weight soil] x 100 = % soil moisture.

Soil Fertility

Soil samples collected on May 22, 2006, 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 Physical Properties

To determine baseline soil physical properties at the beginning of the experiment, intact soil core samples were taken in Start 2 in April of 2006. Secondary soil core samples were taken in December of 2006 in Start 1plots to determine the effect of tillage intensity and/or cover crop treatment on soil physical properties. These results will be compared to baseline samples collected in 2004.

Samples were collected from 3 depths: 0-10 cm, 10-20 cm, and 20-30 cm. Due to shortage of sampling rings, one sampling location was chosen in each plot for the April sampling. Two sampling locations were chosen in each plot for the December sampling. A hammer driven core sampler (Blake and Hartge 1986) was used to obtain 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 bulk density, water retention, hydraulic conductivity, and aggregate stability.

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 was 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:

[(weight of moist sample + can weight) – (weight of dry sample + can weight)] / (weight of dry sample + can weight)

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

[{(weight of moist soil + ring) – ring] / (volume of soil in ring)} / (moisture content + 1)

Hydraulic Conductivity

Hydraulic conductivity was determined for three sampling depths from intact soil cores using the constant head method (Klute and Dirksen 1986). The volume of water that passed through the soil was recorded hourly for five hours. This volume (ml) of water was converted to cm of water and averaged over the five hours to determine the amount of water (cm) that passed through the undisturbed soil cores.

Water Retention Curves

Baseline samples

Water retention was determined on the undisturbed cores at saturation when exposed to pressures of 33 kPa, 100 kPa and 300 kPa. Cores were then dried, ground, and passed through a 2 mm sieve. A sub-sample of the disturbed soil was saturated and exposed to 1500kPa 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 plant available water, PAW, is determined by the equations:

% water volume = 100* (wet soil weight - ring weight – dry soil weight)/ ring volume

PAW = 33 kPa % water volume – 1500kPa % water volume

Secondary Samples

Water retention was determined on the undisturbed cores at saturation using both a tension table and pressure plates as described in Klute (1986). Soil was saturated for 24 to 48 hours before being placed on a tension table and allowed to equilibrate when a graduated cylinder was placed 10 cm, 30 cm, 50 cm, 70 cm, and 90 cm (0.01kPA, 0.03 kPA, 0.05 kPA, 0.07 kPA, and 0.09 kPA, respectively) below the center of the core. Samples were weighed at saturation and after cores had equilibrated at each height. Undisturbed soil cores were then transferred to pressure plates and exposed to pressures of 33k PA, 100 kPa, and 300 kPa. A sub-sample of the disturbed soil was saturated and exposed to 1500kPa using porous plates as described in Klute (1986). Samples were exposed to the previously stated pressures for 24 hours and then weighed. The plant available water was determined as stated above.

Aggregate Stability

After all other measurements had been completed on the intact soil cores, the soil was removed from the metal sampling rings, 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 (1500 kPa) 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 distilled water for 3 minutes. The mesh basket was then removed from the wet sieving instrument and placed in a container of 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 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)

Aggregate stability = (dispersed soil weight / (dispersed soil weight + dunked soil weight)) * 100

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 deli containers (~114mm mouth diameter, 129 mm deep) manufactured by Container and Packaging Supply, Dart Styrofoam cups (~87mm mouth diameter, ~60mm deep) and lids. Three traps per plot were placed randomly and buried to the rim of the deli 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 1 mL glycerol, and stored until prepared for identification. The larger arthropods were identified and stored in 80% ethanol plus glycerol. Microarthropods were mounted on microscope slides in Berlese's Fluid. Insects are being identified to family or genus, as necessary to place in a trophic group (e.g., chewing herbivore, sucking herbivore, omnivore, predator) for analysis.

Soil Arthropods

Collembolans, mites, and a variety of small arthropods collectively known as microarthropods were sampled in soil cores and extracted in Tullgren funnels (Coleman and Crossley 1996). A sub-sample of soil collected for soil and biological measures was 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 scintillation vials filled with 80% ethanol were fixed to the spout of the funnel, and prepared funnels were placed on a frame fitted with indoor/outdoor transparent lights. Approximately 100 mL of soil was placed in each funnel for approximately one week to collect arthropods moving out of the drying soil. Mites and collembolans were collected in the vials for identification using a dissecting stereoscope (Nikon SMZ1500). Mites and collembolans are being identified to family (Evans 1992, Krantz 1970). A category called "Other" will be used for other microarthropods. The category "Total" combines the counts of all mites, collembolans, and other microarthropods and serves 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.

Weed Populations

Cumulative seedling densities were quantified in both the weed subplots and within the larger main plots prior to and after management disturbances in early May through late June (Appendix 1). 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^2 subplots within each treatment plot. The seeded weed densities were low, medium and high (60, 450, 2100 seeds/m^2). 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 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 Starts. Weed density counts were performed using a 0.25 m^2 quadrate in each seeded weed density. Five randomized locations were sampled throughout each plot to determine the background weed seedling densities. Each replicate was a 0.25 m^2 section of the plot that was not part of the seeded weed density area.

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 in both Starts. Sensors were placed at a depth of approximately 10 cm and 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 Starts 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

Soybean (2005) and soybean and corn (2006) yields are presented in Tables 1, 2, and 3. Table 1 represents the corrected soybean yields from the Start 1. Table 2 represents the corn yield from Start 1 and Table 3 represents the soybean yield from Start 2 of the field experiment. Yields were determined by both hand sampling and harvest by combine from the center six rows of each treatment plot. Tables 2 and 3 compare the yields based on hand sampling and combine harvest.

Table 1. Mean soybean yields in 2005 in Start 1.

Harvest Date	Treatment	Soybean Yield (kg/ha)
10/27/05	Rye/Minimum Till	2,940.09
10/27/05	Rye/Conventional Till	2,308.44
10/27/05	Timothy/Red Clover /Minimum Till	1,911.07
10/27/05	Timothy/Red Clover/Conventional Till	2,070.18

Table 2. Mean corn yields in 2006 in Start 1.

Harvest Date	Treatment (cover crop in 2004)	Hand Harvest Yield (kg/ha)	Combine Yield (kg/ha)
10/27/06	Rye/Minimum Till	7,656.09	5,859.92
10/27/06	Rye/Conventional Till	10,602.16	9,411.38
10/27/06	Timothy/Red Clover/Minimum Till	6,333.97	5,948.70
10/27/06	Timothy/Red Clover/Conventional Till	10,872.15	9,322.60

Table 3. Mean soybean yields in 2006 in Start 2.

Harvest Date	Treatment (cover crop previous year)	Hand Harvest Yield (kg/ha)	Combine Yield (kg/ha)
10/27/06	Rye/Minimum Till	2,538.21	2,063.44
10/27/06	Rye/Conventional Till	3,590.76	3,490.75
10/27/06	Timothy/Red Clover/Minimum Till	3,497.40	3,458.15
10/27/06	Timothy/Red Clover/Conventional Till	3,944.74	3,704.43

Soil Measures

<u>Soil Chemical and Biological Properties</u>

Active Carbon

Permanganate oxidizable carbon levels (POC) in Start 1 planted with corn in 2006 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 416.67 ± 52.49 mg/kg POC in the reduced tillage system and 342.52 ± 46.76 mg/kg POC in the conventional tillage system, respectively. When separated by cover crop, POC levels were 378.86 ± 49.46 mg/kg POC in the rye/hairy vetch and 380.34 ± 72.60 mg/kg POC in the timothy/clover crop for Start 1.

Permanganate oxidizable carbon levels (POC) in Start 2 planted with soybean are similar when averaged by tillage system, cover crop type or sampling date (Fig. 2). The mean concentrations (± s.d.) averaged over cover crops for the two tillage systems were 401.93 ± 65.09 mg/kg POC in the reduced tillage and 394.97 ± 52.09 mg/kg POC in the conventional tillage system, respectively. When separated by cover crop treatment, mean POC concentrations (± s.d.) were 400.75 ± 58.59 mg/kg POC in the rye/hairy vetch treatment and 396.16 ± 59.42 mg/kg POC in the timothy/clover treatment.

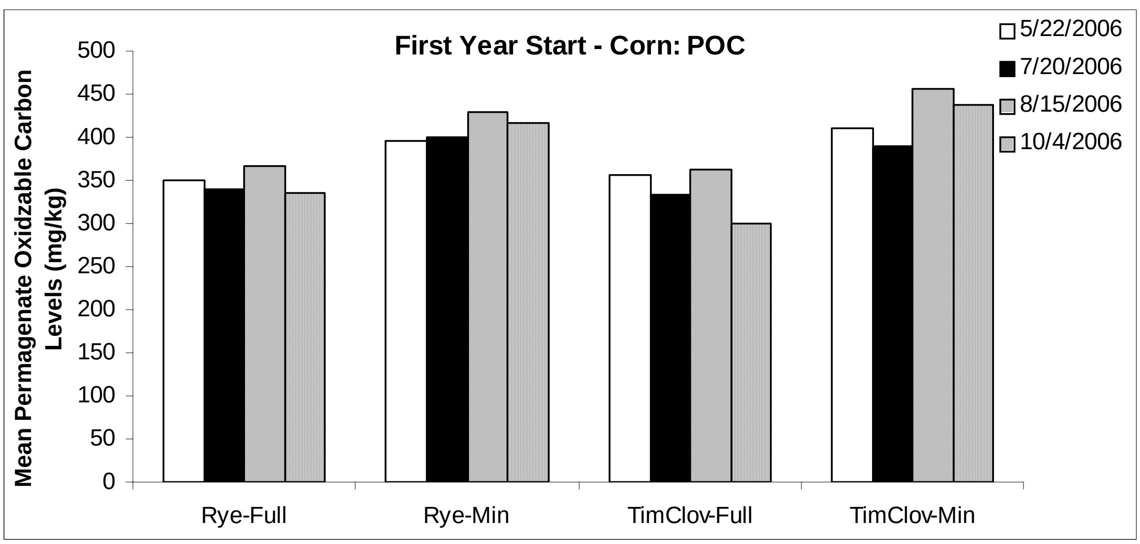

Figure 1. Concentrations of permanganate oxidizable C (mg/kg of soil) in 2006 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

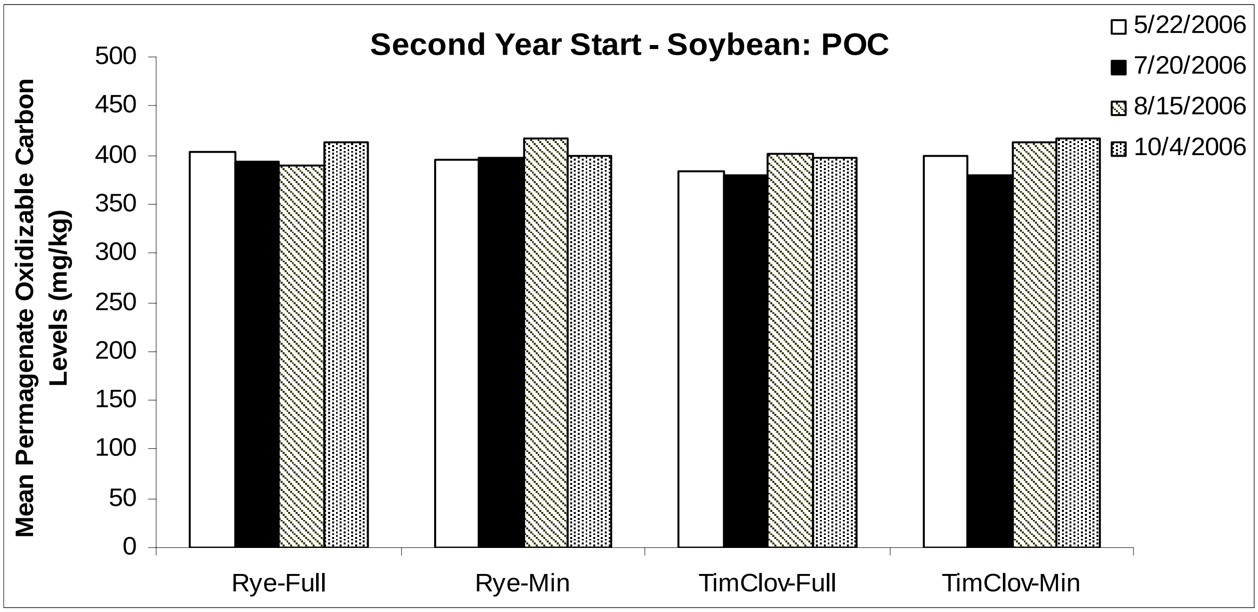

Figure 2. Concentrations of permanganate oxidizable C (mg/kg of soil) in 2006 in soybean shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

Electrical Conductivity

EC in Stat 1 (corn production year) were within acceptable agronomic limits (average ± s.d., 172.46 ± 55.05 µS/cm) in all treatment plots on the first sampling date (22 May). However, average ± s.d., EC decreased to 88.41 ± 25.24 µS/cm by the next sampling date (20 July) and increased to 102.16 ± 32.19 µS/cm by the next sampling date (15 August) (Figure 3). EC levels increased slightly to 115.36 ± 31.67 by the last sampling date (October 4^{th}). Cover crop type did not appear affect EC. Mean EC values (average ± s.d.), were 122.95 ± 54.34 µS/cm in the rye/hairy vetch and 116.25 ± 43.75 µS/cm in the timothy/clover crop treatments. Mean EC values (± s.d.), averaged over cover crop treatment for the two tillage systems were 136.95 ± 48.43 µS/cm in the reduced tillage system and 102.25 ± 44.00 µS/cm in the conventional tillage system, respectively.

EC levels in the Start 2 (soybean production year) varied over the growing season (Figure 4). Mean (± s.d.) EC values averaged over cover crop was 101.42 ± 24.66 µS/cm in the reduced tillage and 92.55 ± 23.85 µS/cm in the conventional tillage treatments. When separated by cover crop, mean EC (± s.d.) was 101.36 ± 29.73 µS/cm in the rye/hairy vetch and 92.61 ± 17.14 µS/cm in the timothy/clover treatments.

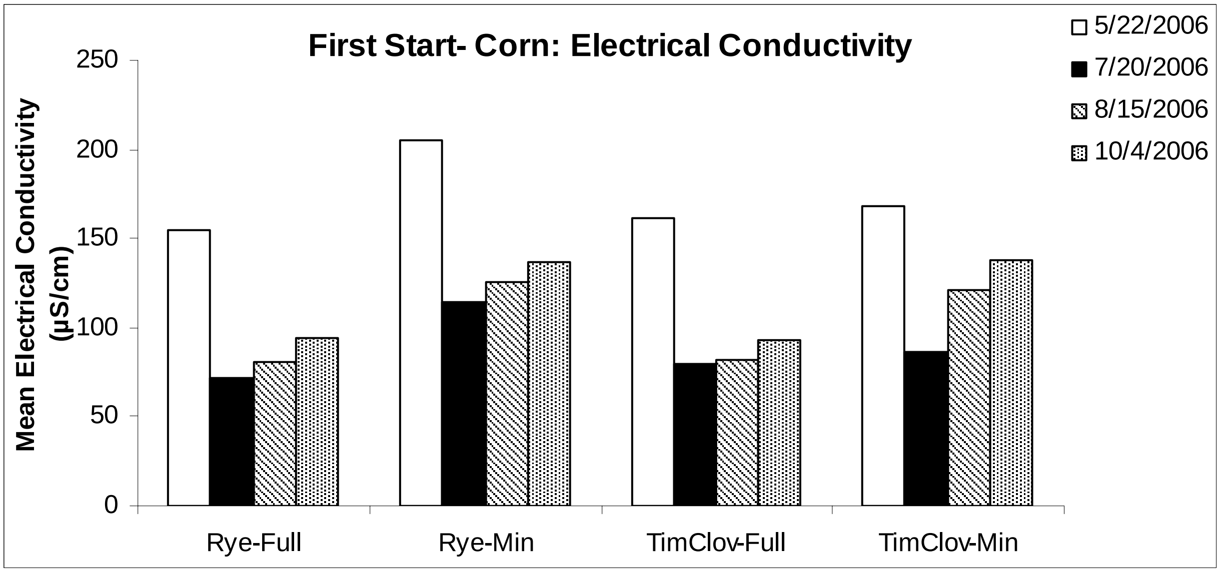

Figure 3. Mean electrical conductivity (µS/cm) in 2006 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

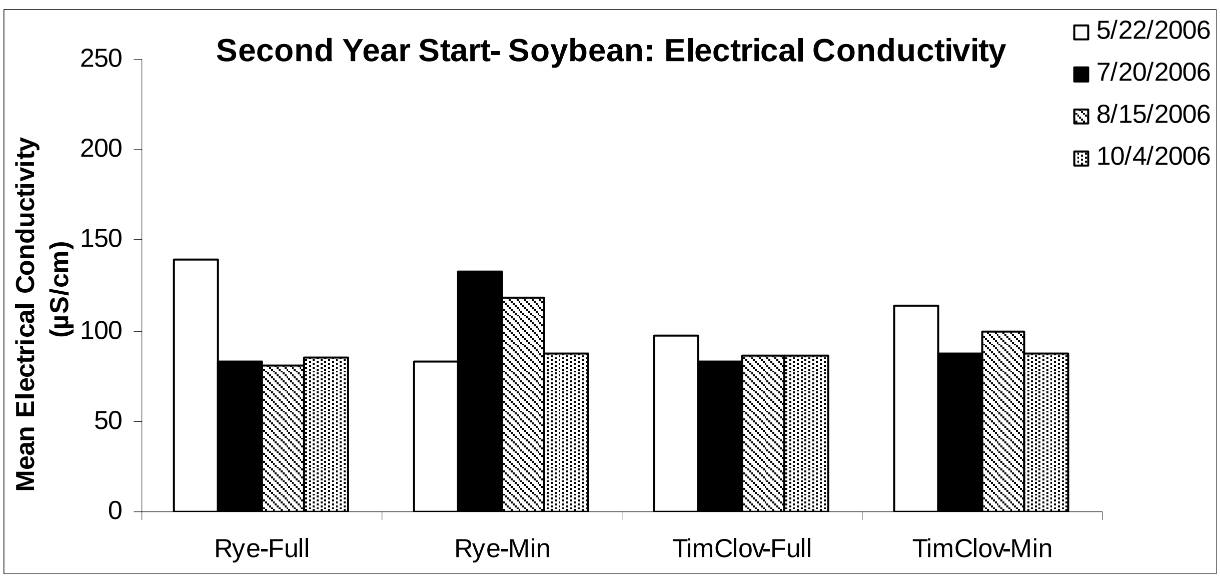

Figure 4. Mean electrical conductivity (µS/cm) in 2006 in soybean shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

pH

pH varied in both Starts by sampling date (Figures 5 and 6). Mean (± s.d.) soil pH levels in Start 1 (corn production year) were 6.88 ± 0.32 in the rye/hairy vetch and 6.95 ± 0.33 in the timothy/clover treatments. Mean (± s.d.) soil pH in the reduced tillage was 7.01 ± 0.31 and 6.82

± 0.32 in the conventional tillage treatments. In Start 2 (soybean production year) mean (± s.d.) soil pH averaged over cover crop for the two tillage treatments were 6.87 ± 0.39 in the reduced tillage and 6.80 ± 0.38 in the conventional tillage treatments. Mean (± s.d.) soil pH in Start 2 (soybean production year) was 6.90 ± 0.36 in the rye/hairy vetch and 6.77 ± 0.39 in the timothy/clover treatments.

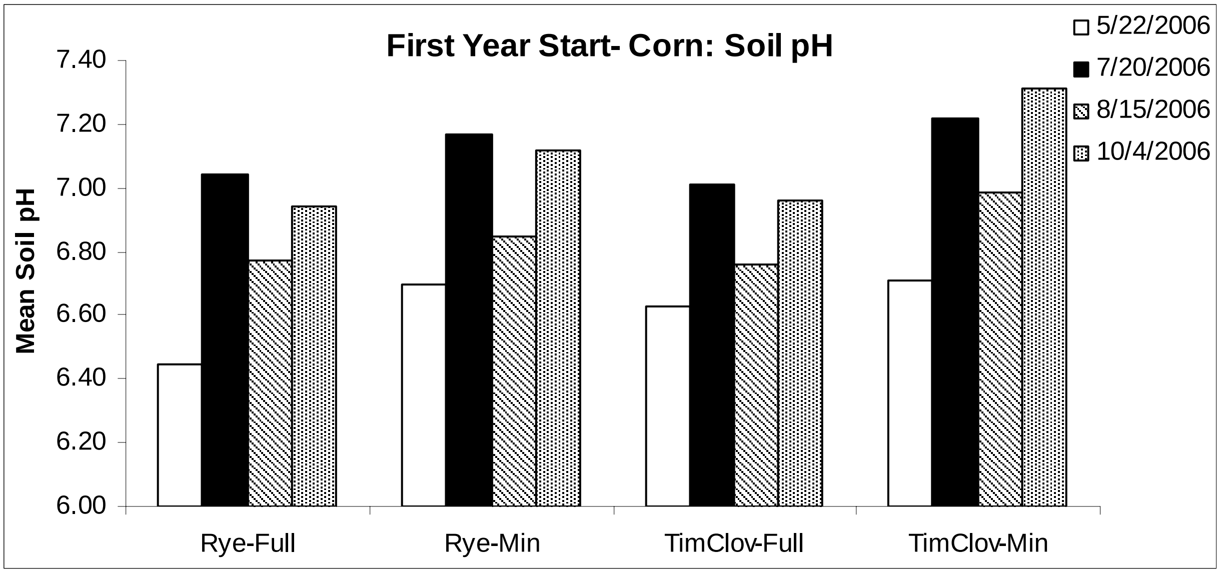

Figure 5. Mean soil pH in 2006 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

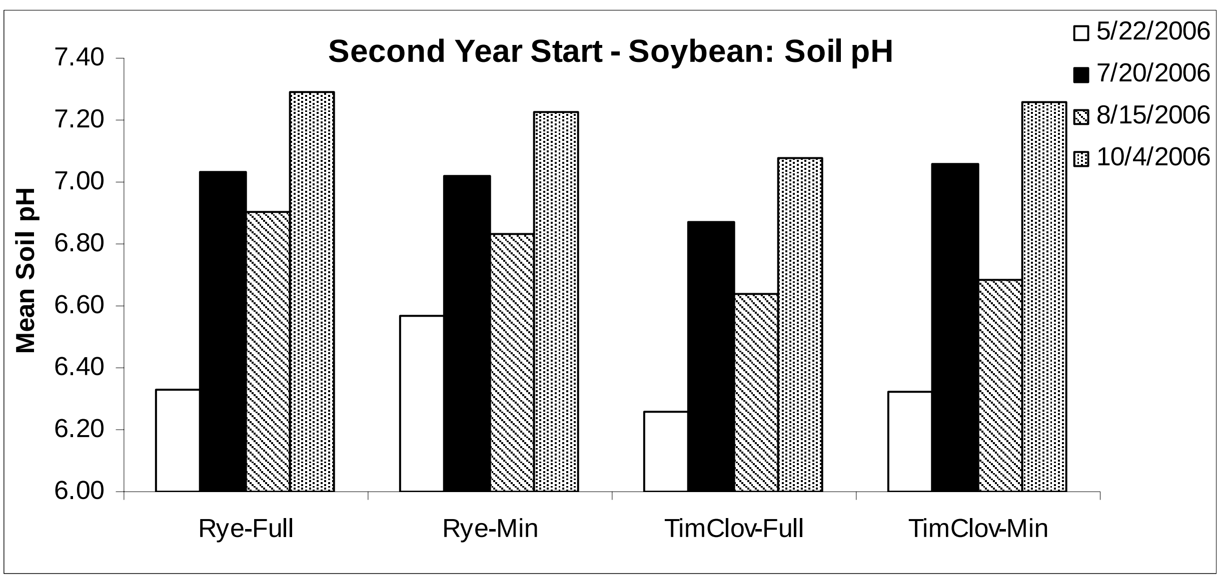

Figure 6. Mean soil pH in 2006 in soybean shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

Soil Physical Properties

Bulk Density

Start 2, Baseline Results

Mean (± s.d.) bulk density over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 1.30 ± 0.03 g/cm^3, 1.33 ± 0.07 g/cm^3 and 1.46 ± 0.11 g/cm^3 , respectively, following the rye/hairy vetch cover crop grown for grain. Mean (± s.d.) bulk density over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 1.34 ± 0.07 g/cm^3, 1.45 ± 0.06 g/cm^3 and 1.49 ± 0.07 g/cm^3, respectively, for the timothy/red clover treatments.

Start 1, End Results

Mean (± s.d.) bulk density based on cover cropping system was 1.44 ± 0.08 g/cm^3, 1.55 ± 0.07 g/cm^3 and 1.58 ± 0.06 g/cm^3 in the rye/hairy vetch plots (corn production year) at depths of 0-10 cm, 10-20 cm, and 20-30 cm, respectively. Mean (± s.d.) bulk density over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 1.44 ± 0.07 g/cm^3, 1.37 ± 0.86 g/cm^3 and 1.58 ± 0.05 g/cm^3, respectively, for the timothy/red clover system (corn production year). When comparing tillage treatments, mean (± s.d.) bulk density over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 1.45 ± 0.08 g/cm^3, 1.56 ± 0.07 g/cm^3 and 1.58 ± 0.06 g/cm^3, respectively, in the conventional tillage treatments and 1.43 ± 0.06 g/cm^3, 1.36 ± 0.86 g/cm^3 and 1.58 ± 0.05 g/cm^3, respectively, in the reduced tillage treatments.

Water Retention Curves

Start 2, Baseline Results

Mean (± s.d.) percentage plant available water over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 7.62 ± 4.72%, 8.92 ± 6.15% and 8.79 ± 5.83%, respectively. Mean (± s.d.) percentage plant available water over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 14.65 ± 3.21%, 9.87 ± 7.50% and 3.55 ± 12.23%, respectively, for the timothy/red clover system.

Calculation of water retention curves on soil from the soil cores collected from Start 1 (corn production year) in December of 2006 was completed using the same methodology.

Hydraulic Conductivity

Start 2, Baseline Results

Mean (± s.d.) hydraulic conductivity over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 0.31 ± 0.08 cm/hr, 0.43 ± 0.51 cm/hr and 0.13 ± 0.10 cm/h,r respectively, following the rye/hairy vetch cover crop grown for grain. Mean (± s.d.) hydraulic conductivity over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 0.31 ± 0.18 cm/hr, 0.55 ± 0.77 cm/hr and 0.26 ± 0.32 cm/hr, respectively, for the timothy/red clover system.

Start1, End Results

Mean (± s.d.) hydraulic conductivity based on cover cropping system was 1.40 ± 3.17 cm/hr, 1.21 ± 3.10 cm/hr and 1.07 ± 2.49 cm/hr in the rye/hairy vetch plots (corn production year) at depths of 0-10 cm, 10-20 cm, and 20-30 cm, respectively. Mean (± s.d.) hydraulic conductivity over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 0.79 ± 1.22 cm/hr, 0.71 ± 2.50 cm/hr and 1.28 ± 3.28 cm/hr, respectively, for the timothy/red clover system (corn production year). When comparing tillage treatments, mean (± s.d.) hydraulic conductivity over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 1.22 ± 3.16 cm/hr, 1.58 ± 3.84 cm/hr and 1.07 ± 2.64 cm/hr, respectively, in the conventional tillage treatments and 0.97 ± 1.30 cm/hr, 0.34 ± 0.69 cm/hr and 1.28 ± 3.16 cm/hr, respectively, in the reduced tillage treatments.

Aggregate Stability

Start 2, Baseline Results

After all other measurements had been completed on the intact soil cores, mean (± s.d.) aggregate stability of the soil from the three depth classes was measured using an ultrasonic dispersion method (Kemper and Rosenau 1986). Mean (± s.d.) percentage aggregate stability over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 37.14 ± 10.32, 34.84 ± 11.32 and 29.24 ± 8.91, respectively, following the rye/hairy vetch cover crop grown for grain. Mean (± s.d.) percentage aggregate stability of the soil from the cores collected from the timothy/red clover cover crop treatment was higher at each depth class than the percentages calculated in the rye/hairy vetch system at the two shallower profile depths. Mean (± s.d.) percentage aggregate stability over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 38.54 ± 8.92, 40.57 ± 14.73 and 34.25 ± 13.62 respectively, for the timothy/red clover system.

Calculation of percentage aggregate stability on soil from the soil cores collected from Start 1 (corn production year) will be completed using the same methodology.

Routine Soil Property Measurements

Soil Matric Potential

Soil matric potential in both Starts varied by sampling date, cover crop, and tillage treatments. The mean (± s.d.) soil matric potential for the two tillage systems in Start 1 (corn production year) was 145.74 ± 187.93 –kPa in the reduced tillage system and 116.80 ± 194.34 –kPa in the conventional tillage system (Figure 7). When separated by cover crop, mean (± s.d.) soil matric potential in Start 1 was 110.47 ± 162.98 –kPa in the timothy clover treatment and 152.07 ± 214.65 –kPa in the rye/hairy vetch treatment. Mean (± s.d.) soil matric potential for the two tillage treatments in Start 2 (cover crop year) were 218.86 ± 325.39 –kPa in the conventional tillage and 177.38 ± 198.75 –kPa in the reduced tillage treatments (Figure 8). When separated by cover crop, mean (± s.d.) soil matric potential in the Start 2 (cover crop year) was 230.28 ± 273.19 –kPa in the timothy/clover treatment and 165.96 ± 263.68 –kPa in the rye/hairy vetch treatment.

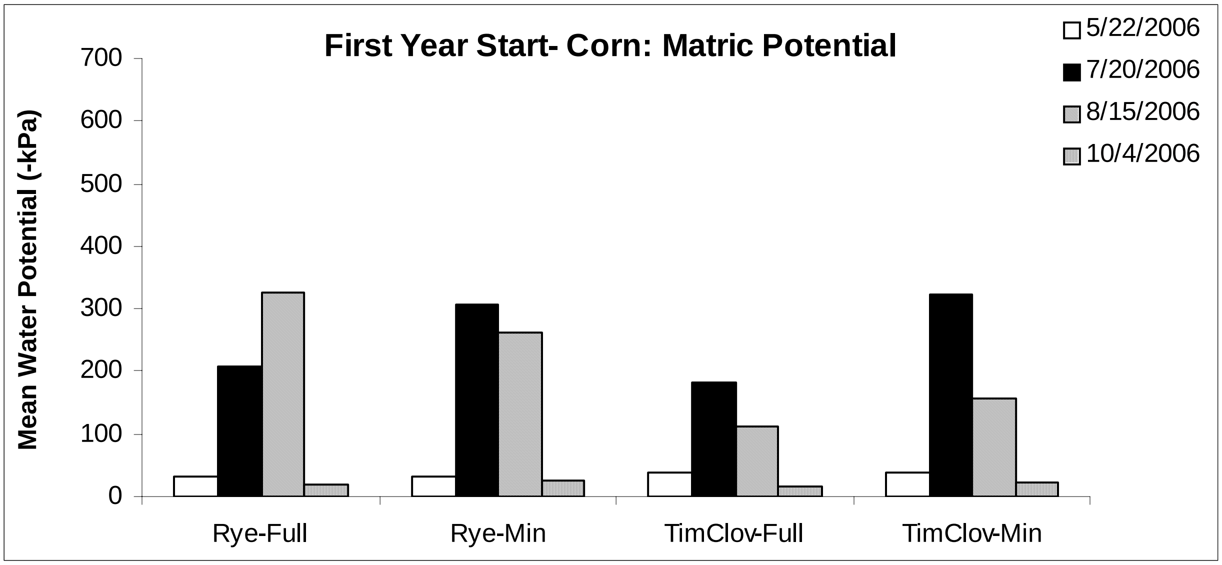

Figure 7. Mean soil matric potential (-kPa) in 2006 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

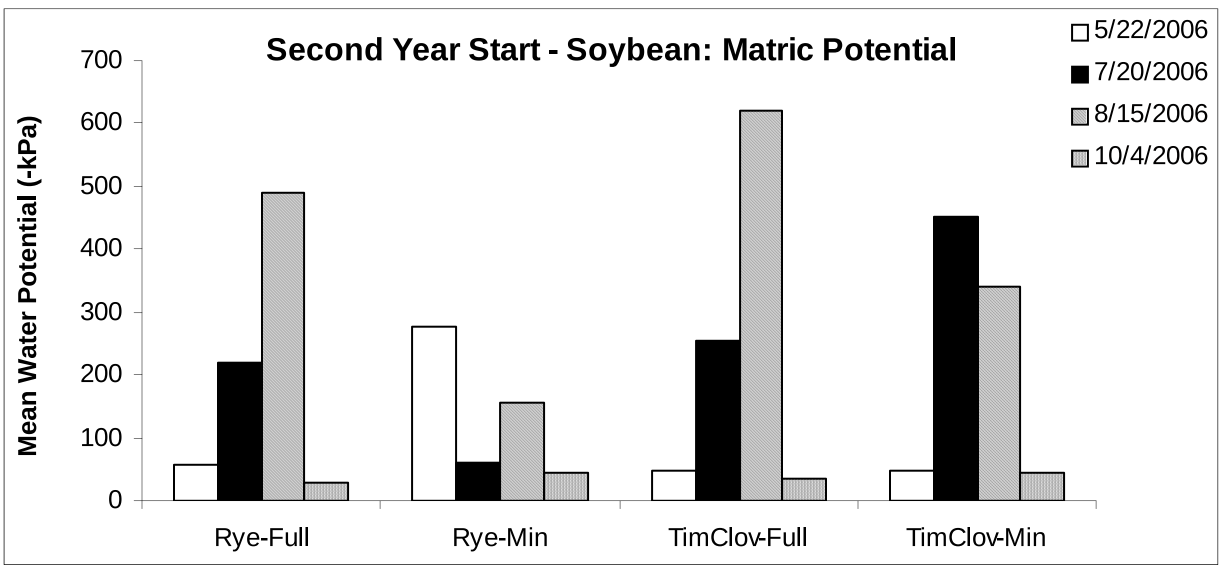

Figure 8. Mean soil matric potential (-kPa) in 2006 in soybean shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

Soil Gravimetric Moisture

Mean (± s.d.) gravimetric moisture values for soil sampled in both Starts were higher on the October 4th compared with the other sampling dates (Figures 9 and 10). Mean (± s.d.) gravimetric moisture values for soil collected from Start 1 (corn production year) were 19% in rye/hairy vetch and 20% in timothy clover treatments. When separated by tillage treatment, mean gravimetric moisture values were 19% in conventional tillage and 20% in reduced tillage treatments.

Mean gravimetric moisture values for soil sampled from Start 2 (soybean production year) were similar to gravimetric moisture values in Start 1. Gravimetric moisture values over cover cropping treatments were 19% in rye/hairy vetch and 18% in timothy clover. When separated by tillage treatment, mean gravimetric moisture values were 18% for both conventional and reduced tillage treatments.

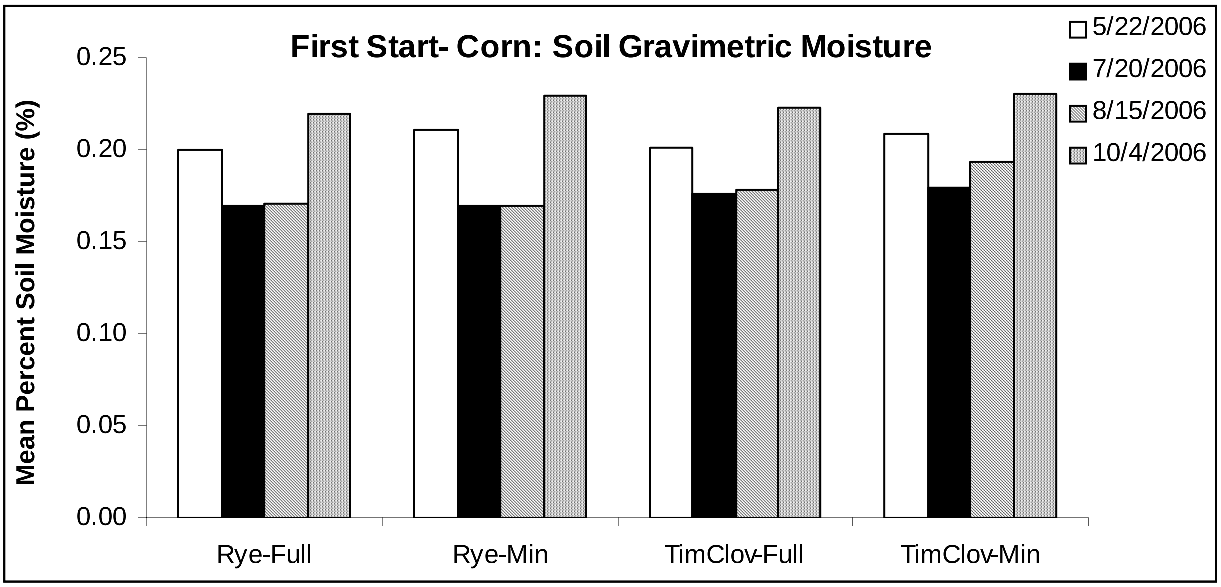

Figure 9. Mean soil gravimetric moisture (% moisture) in 2006 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

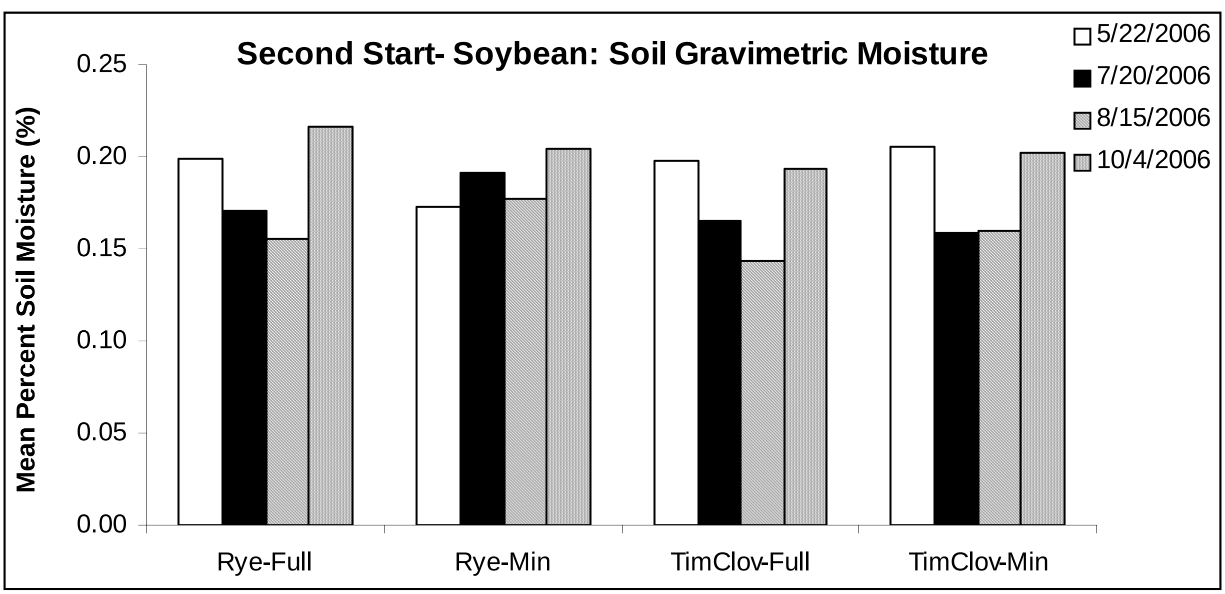

Figure 10. Mean soil gravimetric moisture (% moisture) in 2006 in soybean shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

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. Soil tests made in the spring of both 2005 and 2006 have indicated that the soil is in the optimum range for pH and soil fertility.

An application of bullpen manure was made in Start 1 (February and March 2006) at a rate of 46,119.96 kg/ha to add fertility and organic matter to the soil profile (manure purchased from the Pennsylvania Department of Agriculture Samuel E. Hayes, Jr. Livestock Evaluation Center, (814) 238-1785).

Soil Biological Measures

Epigeal Arthropods

Start 1 (Soybean Year)

The number of microarthropods collected through the pitfall trapping method varied with sampling date (Table 4). Collembolans were the most frequently detected arthropods in pitfall samples. Mean collembolan numbers (activity density) (± s.d.) over tillage treatments were 193.61 ± 278.92 in the rye/hairy vetch and 204.75 ± 224.79 in the timothy/clover treatments (Table 5). Microarthropod activity density tended to be higher in the conventional tillage treatments than the reduced tillage treatments (Table 6). Collembolan activity density (± s.d.) averaged 227.31 ± 290.16 in conventional tillage plots and 171.06 ± 202.31 in the reduced tillage plots.

Start 2 (Cover Crop Year)

Similar to Start 1, the activity density of microarthropods varied among sampling dates with collembolans being the most frequently detected arthropod (Tables 4 and 5). The mean (± s.d.) activity density of collembolan over tillage treatments were 90.78 ± 44.73 in the rye/hairy vetch and 133.56 ± 129.32 for the timothy/clover treatments. Microarthropod activity density tended to be higher in the reduced tillage treatments than the conventional tillage treatments (Table 6). Collembolan activity density (± s.d.) averaged 98.22 ± 58.58 in conventional tillage plots and 126.11 ± 125.81 in the reduced tillage plots.

Calculation of the activity density of arthropods sampled in June, July, and October of 2006 for both starts will be completed using the same methodology. Community analysis may reveal differences in treatments that are not detectable in abundance data for arthropods identified into coarse taxonomic groups.

Table 4. Mean numbers (activity density) (± s.d.) of micro- and macro-arthropods collected per pitfall trap over a 72 hr period averaged over crop type and tillage system from the pitfall sampling method completed in 2005 for both starts.

2005 Sampling Date Comparison

Start 1 (Soybean)

Date	Mites	Collembolans	Micros	Total Micros	Total Macros
6/17/2005	51.48 ± 78.14	137.06 ± 81.68	11.71 ± 7.79	200.25 ± 138.36	25.88 ± 18.50
7/25/2005	27.56 ± 25.83	436.54 ± 302.71	24.35 ± 12.65	488.46 ± 305.59	38.23 ± 18.92
10/21/2005	8.00 ± 7.79	23.94 ± 16.94	7.15 ± 4.36	39.08 ± 20.33	17.79 ± 10.27

Start 2 (Cover Crop)

Date	Mites	Collembolans	Micros	Total Micros	Total Macros
6/17/2005	16.60 ± 13.96	88.58 ± 51.15	27.56 ± 15.42	132.75 ± 55.78	27.98 ± 11.21
7/25/2005	10.56 ± 16.38	156.56 ± 148.79	18.11 ± 8.88	185.24 ± 160.42	39.10 ± 17.19
10/21/2005	55.19 ± 52.27	91.35 ± 43.71	11.08 ± 6.28	157.63 ± 75.06	25.08 ± 15.11

Table 5. Mean (± s.d.) numbers (activity density) of micro- and macro-arthropods collected per pitfall trap over a 72 hr period averaged over tillage system in 2005 for both starts where plots were rye/hairy vetch or timothy/clover cover crops.

2005 Cover Crop Comparison

Start 1 (Soybean)

Crop	Mites	Collembolans	Micros	Total Micros	Total Macros
Rye/HV	26.75 ± 36.06	193.61 ± 275.92	13.78 ± 12.35	234.14 ± 286.67	32.24 ± 20.31
Tim/Clov	31.28 ± 62.08	204.75 ± 224.79	15.03 ± 10.62	251.06 ± 250.03	22.36 ± 14.65

Start 2 (Cover Crop)

Crop	Mites	Collembolans	Micros	Total Micros	Total Macros
Rye/HV	26.50 ± 43.50	90.78 ± 44.73	16.08 ± 13.84	133.36 ± 67.61	23.64 ± 11.57
Tim/Clov	28.40 ± 31.83	133.56 ± 129.32	21.76 ± 10.97	183.72 ± 133.79	37.81 ± 16.39

Table 6. Mean (± s.d.) numbers (activity density) of micro- and macro-arthropods collected per pitfall trap over a 72 hr period averaged over cover crop in 2005 for both starts where full= conventional tillage and min= reduced tillage.

2005 Tillage Comparison

Start 1 (Soybean)

Tillage	Mites	Collembolans	Micros	Total Micros	Total Macros
Full	39.42 ± 67.06	227.31 ± 290.16	15.00 ± 11.34	281.72 ± 312.07	26.17 ± 18.27
Min	18.62 ± 21.16	171.06 ± 202.31	13.81 ± 11.69	203.47 ± 210.59	28.43 ± 18.45

Start 2 (Cover Crop)

Tillage	Mites	Collembolans	Micros	Total Micros	Total Macros
Full	25.03 ± 29.91	98.22 ± 58.58	19.94 ± 11.06	143.19 ± 66.51	31.60 ± 16.48
Min	29.88 ± 44.74	126.11 ± 125.81	17.90 ± 14.27	173.89 ± 137.31	29.85 ± 15.21

Soil Arthropods

Start 1

As in 2004, the abundance of microarthropods collected using the Tullgren funnel method was extremely low in 2005 and 2006. Crop type and tillage system both influenced the numbers of microarthropod detected using this method. In 2005, the Start 1 mean mite and collembolan numbers were higher in the rye/hairy vetch treatment than in timothy clover treatment (Table 7). Conversely, the mean number of other microarthropods was lower in rye/hairy vetch than in timothy/clover treatment. When comparing tillage systems in 2005, mean (± s.d.) 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 (± s.d.) collembolan and microarthropod numbers were higher in the reduced tillage than the conventional tillage system (Table 8).

In 2006, the Start 1 mean collembolan and microarthropod numbers were higher in the rye/hairy vetch treatment than in the timothy/clover treatment (Table 9). Mean (± s.d.) mite numbers were higher in the timothy/clover treatments than in the rye/hairy vetch treatments. When comparing the tillage systems in 2006, mean (± s.d.) arthropod numbers were higher in the reduced tillage treatments in Start 1 than in conventional tillage (Table 10).

Start 2

In 2005, the Start 2 mean (± s.d.) mite and other microarthropod numbers were higher in the timothy/clover treatment than in the rye/hairy vetch treatment (Table 7). Mean (± s.d.) number of mites, collembolans, and other microarthropods were higher in fields under reduced tillage than fields under conventional tillage (Table 8).

In 2006, Start 2 followed a similar trend as the 2005 Start 1 mean arthropod numbers. Collembolan and mites tended to be found in higher numbers in the rye/hairy vetch fields and the miscellaneous microarthropods were more prevalent in the timothy/clover fields (Table 9). Mean arthropod numbers were higher in the conventionally tilled fields than in fields with reduced tillage (Table 10).

Table 7. Mean (± s.d.) numbers of arthropods collected per soil sample averaged over tillage system using the Tullgren funnel method in 2005 for both starts.

2005 Cover Crop Comparison

Start	Crop	Mite	Collembolans	Other Micros
First	Rye	0.92 ± 0.24	0.50 ± 0.25	0.08 ± 0.06
First	Tim/Clov	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	Tim/Clov	0.79 ± 0.22	0.13 ± 0.07	0.29 ± 0.11

Table 8. Mean (± s.d.) numbers of arthropods collected per soil sample averaged over crop type using the Tullgren funnel method in 2005 for both starts where full= conventional tillage and min= reduced tillage.

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

Table 9. Mean (± s.d.) numbers of arthropods collected per soil sample averaged over tillage system using the Tullgren funnel method in 2006 for both starts.

2006 Cover Crop Comparison

Start	Crop	Mites	Collembolans	Other Micros	Nematodes
First	Rye/HV	1.79 ± 1.67	1.21 ± 1.77	1.79 ± 2.36	0.33 ± 0.70
First	Tim/Clov	1.96 ± 1.94	0.88 ± 1.19	1.00 ± 1.38	0.33 ± 1.09

Start	Crop	Mites	Collembolans	Other Micros	Nematodes
Second	Rye/HV	0.50 ± 0.72	0.13 ± 0.34	1.17 ± 2.26	0
Second	Tim/Clov	0.75 ± 1.19	0.54 ± 1.44	0.75 ± 1.85	0.17 ± 0.48

Table 10. Mean (± s.d.) numbers of arthropods collected per soil sample averaged over crop type using the Tullgren funnel method in 2006 for both starts where full= conventional and min= reduced tillage.

2006 Tillage Comparison

Start	Crop	Mites	Collembolans	Other Micros	Nematodes
First	Full	1.38 ± 1.50	0.71 ± 1.04	1.21 ± 2.30	0.21 ± 0.59
First	Min	2.38 ± 1.95	1.38 ± 1.81	1.58 ± 1.56	0.46 ± 1.14

Start	Crop	Mites	Collembolans	Other Micros	Nematodes
Second	Full	0.71 ± 1.16	0.46 ± 1.25	0.92 ± 2.12	0.13 ± 0.45
Second	Min	0.54 ± 0.78	0.21 ± 0.83	1.00 ± 2.02	0.04 ± 0.20

Soilborne Insect Pathogens

Detection rates using the *G. mellonella* baiting method were highly variable (Figures 11-14). Mean infection ranged from 0-100 %, with a mean (± s.d.) infection rate of 14.4% (0.44 ± 2.13 *Galleria*/sample) for *M. anisopliae* and 1.3% (0.13 ± 0.84 *Galleria*/sample) for *B. bassiana* collected from Start 1 (corn). Infection rates in Start 2 (soybean) were comparable to Start 1 with a mean (± s.d.) infection rate of 9.3% (0.93 ± 1.52 *Galleria*/sample) for *M. anisopliae* and 1.2% (0.12 ± 0.89 *Galleria*/sample) for *B. bassiana.* Infection rate for both pathogens was highest in the soil collected on 16 August 2006 from both experimental starts.

When averaging the infection rate over tillage system in Start 1 (corn), the mean (± s.d.) detection of *M. anisopliae* in rye/hairy vetch (0.63 ± 2.27 *Galleria*/sample) was less than in timothy/clover (1.25 ± 1.98 *Galleria*/sample) treatments. Conversely, the mean infection rate (±

s.d.) for *B. bassiana* was 0.18 ± 1.10 *Galleria* per sample in rye/hairy vetch and 0.07 ± 0.44 *Galleria* per sample in timothy/clover treatments. When comparing tillage treatments, the mean (± s.d.) infection rate of *M. anisopliae* was 1.74 ± 2.11 *Galleria* per sample in conventional tillage and 1.14 ± 2.12 *Galleria* per sample in reduced tillage treatments. The mean (± s.d.) infection rate by *B. bassiana* was 0.13 ± 0.74 *Galleria* per sample in reduced tillage and 0.13 ± 0.93 *Galleria* per sample in conventional tillage treatments.

In Start 2 (soybean), the mean infection rate (± s.d.) of *M. anisopliae* in the rye/hairy vetch treatment was 0.70 ± 1.38 *Galleria* per sample and 1.17 ± 1.63 *Galleria* per sample in timothy/clover treatments. Mean infection (± s.d.) of *B. bassiana* was 0.11 ± 1.02 *Galleria* per sample in timothy/clover and 0.13 ± 0.74 *Galleria* per sample in rye/hairy vetch treatments. Infection (± s.d.) by M. *anisopliae* under reduced tillage was 0.93 ± 1.36 *Galleria* per sample and 0.94 ± 1.68 *Galleria* per sample in conventional tillage treatments. Infection (± s.d.) by *B. bassiana* under conventional tillage was 0.04 ± 0.20 *Galleria* per sample and 0.20 ± 1.24 *Galleria* per sample in the reduced tillage treatment.

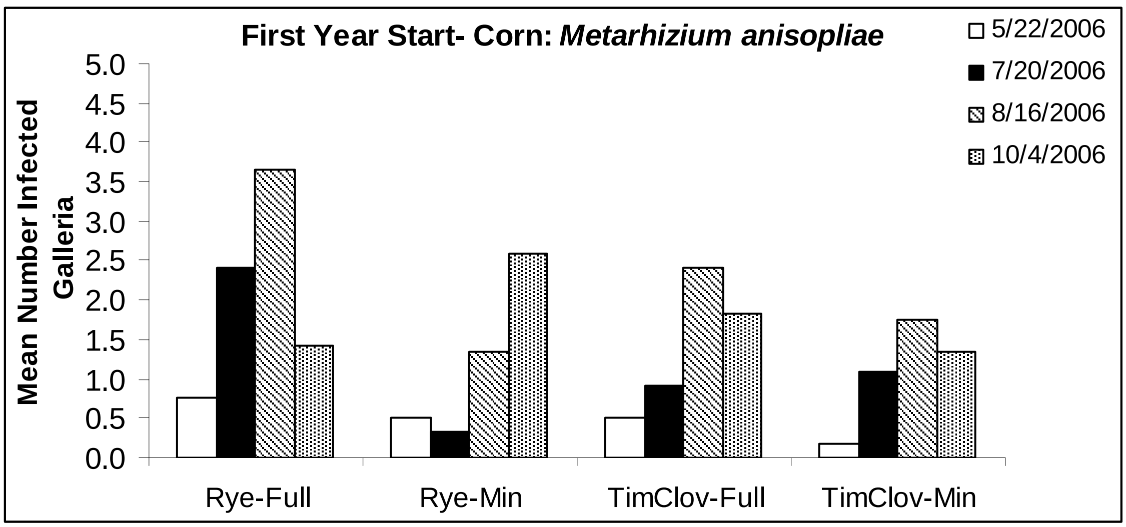

Figure 11. Mean infection rates of *Galleria mellonella* by *Metarhizium anisopliae* in soil samples collected in 2006, shown by sampling date for each cover crop/tillage treatment for Start 1 (corn) where full= conventional tillage and min= reduced tillage.

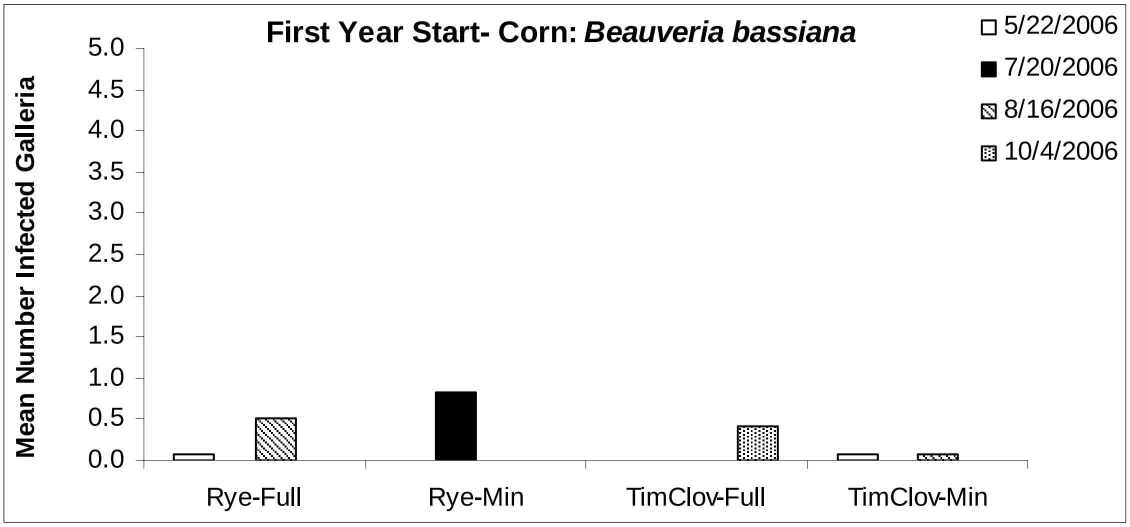

Figure 12. Mean infection rates of *Galleria mellonella* by *Beauveria bassiana* in soil samples collected in 2006, shown by sampling date for each cover crop/tillage treatment for Start 1 (corn) where full= conventional tillage and min= reduced tillage.

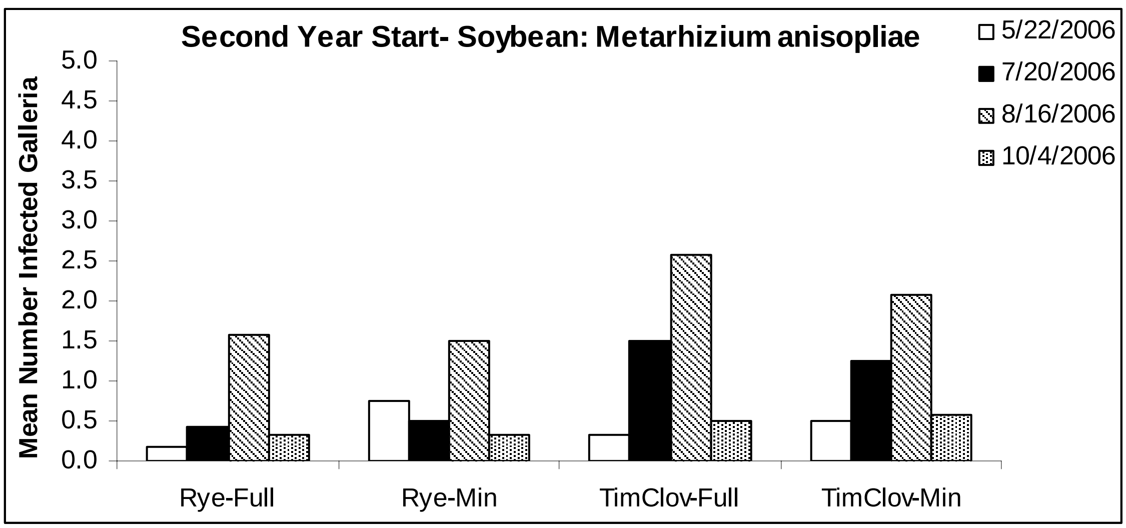

Figure 13. Mean infection rates of *Galleria mellonella* by *Metarhizium anisopliae* in soil samples collected in 2006, shown by sampling date for each cover crop/tillage treatment for Start 2 (soybean) where full= conventional tillage and min= reduced tillage.

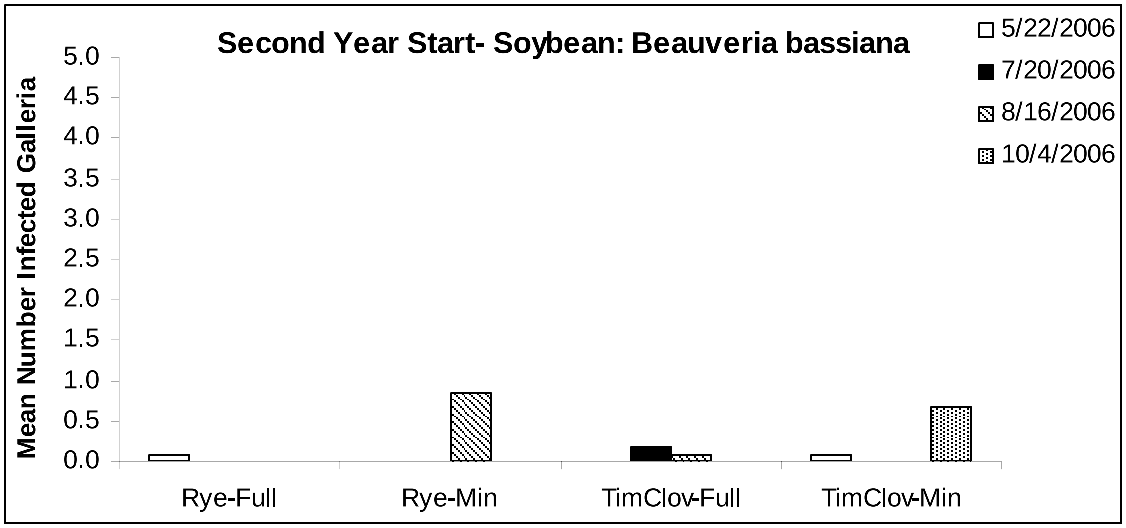

Figure 14. Mean infection rates of *Galleria mellonella* by *Beauveria bassiana* in soil samples collected in 2006, shown by sampling date for each cover crop/tillage treatment for Start 2 (soybean) where full= conventional tillage and min= reduced tillage.

Weed Populations

Cumulative weed seedling densities were quantified three times at the beginning of the growing season (early May to late June) in both the weed seed bank subplots as well as in the larger plots in 2006. The three seeded weed species in Start 1 (corn production year) established in different proportions across the three seeding densities and two cover crop treatments. In the rye/hairy vetch cover crop treatment, foxtail establishment was higher than both velvetleaf and common lambsquarters (Fig. 15). Foxtail seedling densities ranged from 25 seedlings/m^2 in the low subplot to 53 and 55 seedlings/m^2 in the medium and high subplots, respectively. Velvetleaf and common lambsquarters establishment was low in the rye/hairy vetch treatment and averaged less than 10 seedlings/m^2 across all subplot densities for both species (except for the high velvetleaf density which was 22 seedlings/m^2). Conversely, establishment of foxtail, velvetleaf, and lambsquarters in the red clover/timothy treatment was very limited with less than 10 seedlings/m^2 establishing across all the subplot densities (except for the high foxtail density which was 11 seedlings/m^2).

The density of seeded weeds in Start 2 (soybean production year) exhibited the same trend as in Start 1 with foxtail densities much higher than the lambsquarter and velvetleaf (Fig. 20). However, seeded weed densities were much lower in Start 2 than seeded weed densities in Start 1 (Figs. 15 and 16). Foxtail, velvetleaf, and lambsquarters seedling densities in the rye/hairy vetch and timothy/red clover treatment were less than 10 seedlings/m^2 across all subplot densities (except for foxtail in the high seeded density plot which was 11 seedlings/m^2).

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. Canada thistle numbers in Start 1 have increased drastically over the last three years in fields that experienced reduced tillage (Table 11). The conventional tillage treatments exhibited similar Canada thistle numbers over the three year period. This trend has also been seen in Start 2.

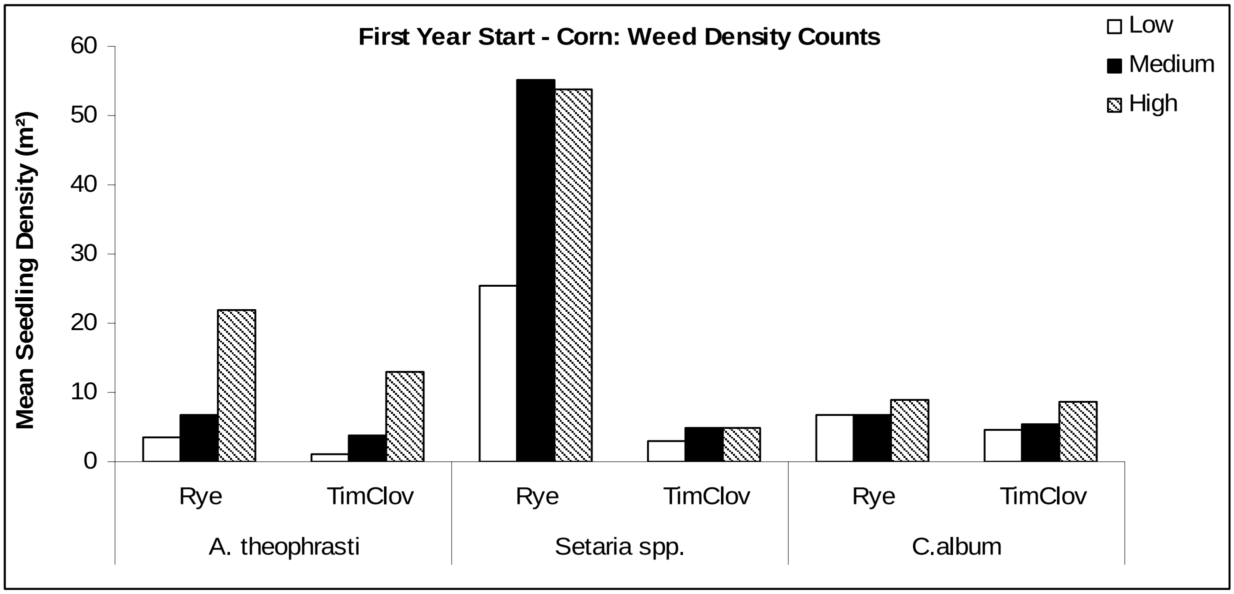

Figure 15. Cumulative weed seedling densities in the rye/hairy vetch and timothy/red clover (T/C) cover crop treatments across the three weed subplot densities (low, medium and high) in Start 1, corn production, in 2006.

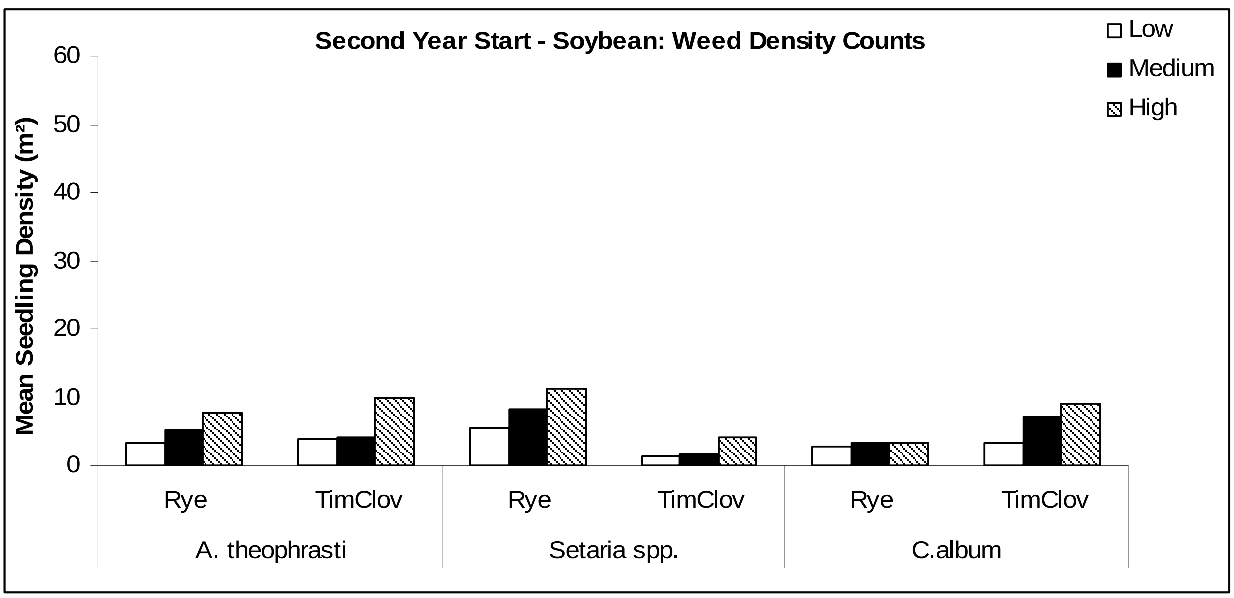

Figure 16. Cumulative weed seedling densities in the rye/hairy vetch and timothy/red clover (T/C) cover crop treatments across the three weed subplot densities (low, medium and high) in Start 2, soybean production, in 2006.

Table 11. Response of Canada thistle in an organic transition soybean (2005) and maize (2006) sequence to initial cover crop (2004) and soil management (full = conventional tillage and min = reduced tillage).

Treatment	Cover Crop	Crop Soybean	Corn
Rye/HV-Full	3.5	5.6	3
Rye/HV-Min	3.5	8.4	10.5
Tim/Clov-Full	3.5	4.3	2.8
Tim/Clov-Min	3.5	9.2	11.3

Environmental Data

Figures 17 through 24 below exemplify the average, daily soil temperature and moisture content for both starts and cover crop histories. These data will be used as covariates to supplement field sample data sets. Sampling was conducted from early May through October.

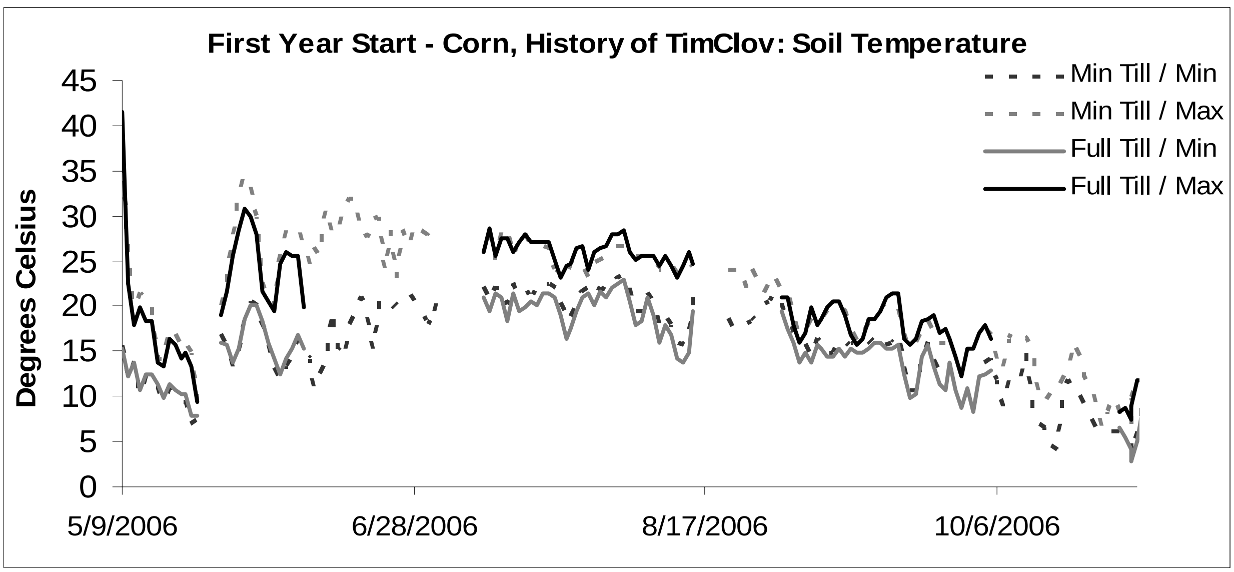

Figure 17. Soil temperature (°C) in 2006 in corn with a history of timothy/clover planted in 2004 where Min Till= reduced tillage and Full Till= conventional tillage.

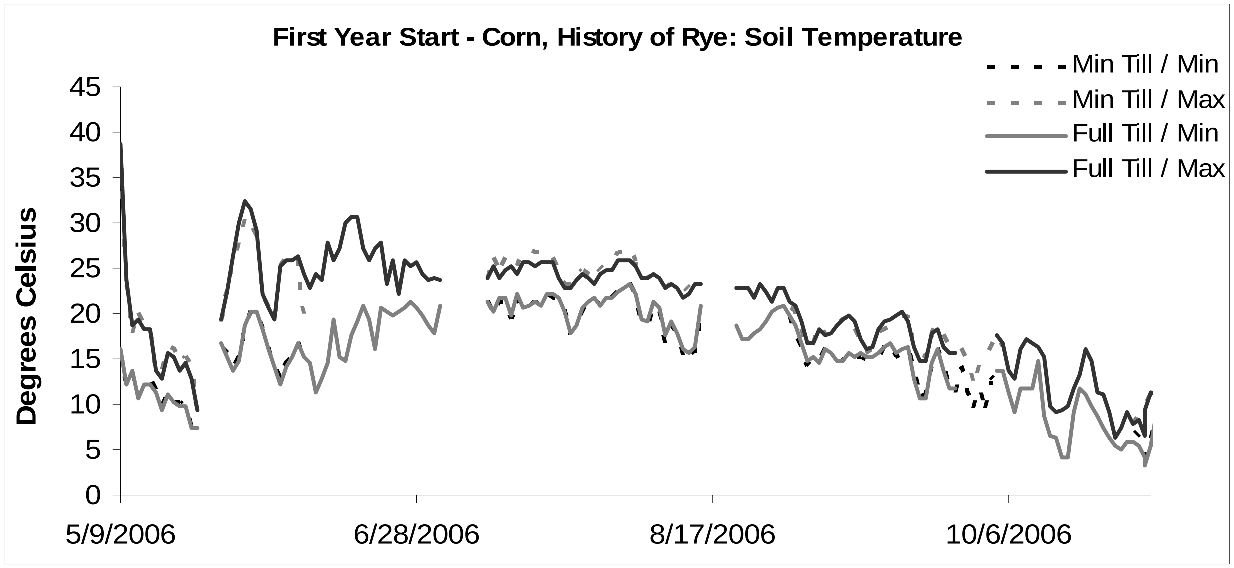

Figure 18. Soil temperature (°C) in 2006 in corn with a history of rye/hairy vetch planted in 2004 where Min Till= reduced tillage and Full Till= conventional tillage.

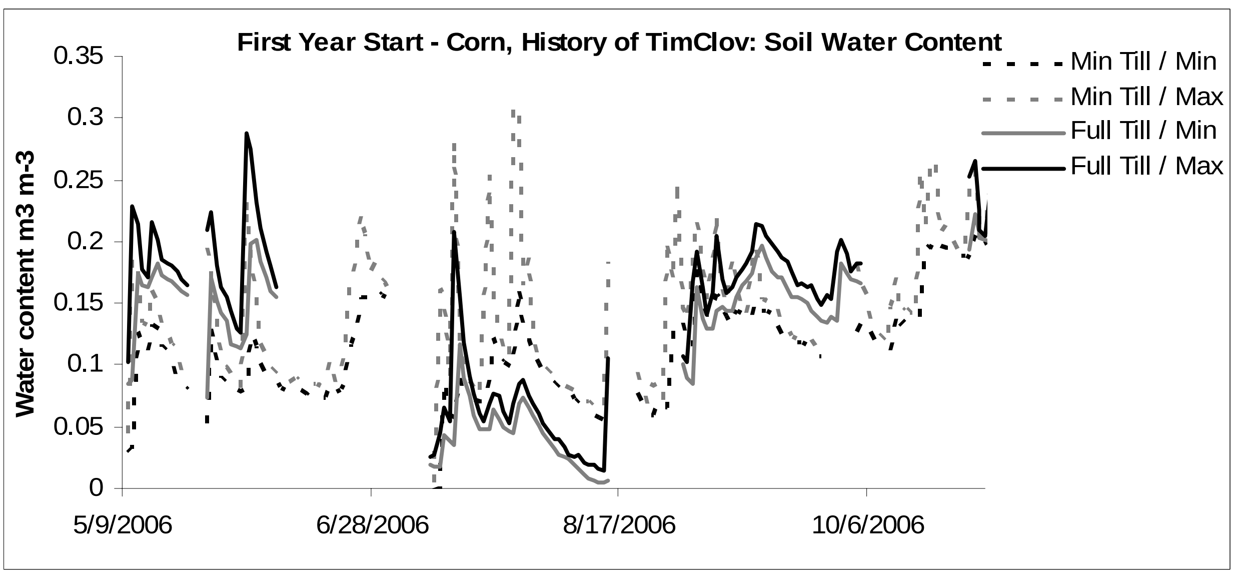

Figure 19. Soil water content (m^3/m^3) in 2006 in corn with a history of timothy/clover planted in 2004 where Min Till= reduced tillage and Full Till= conventional tillage.

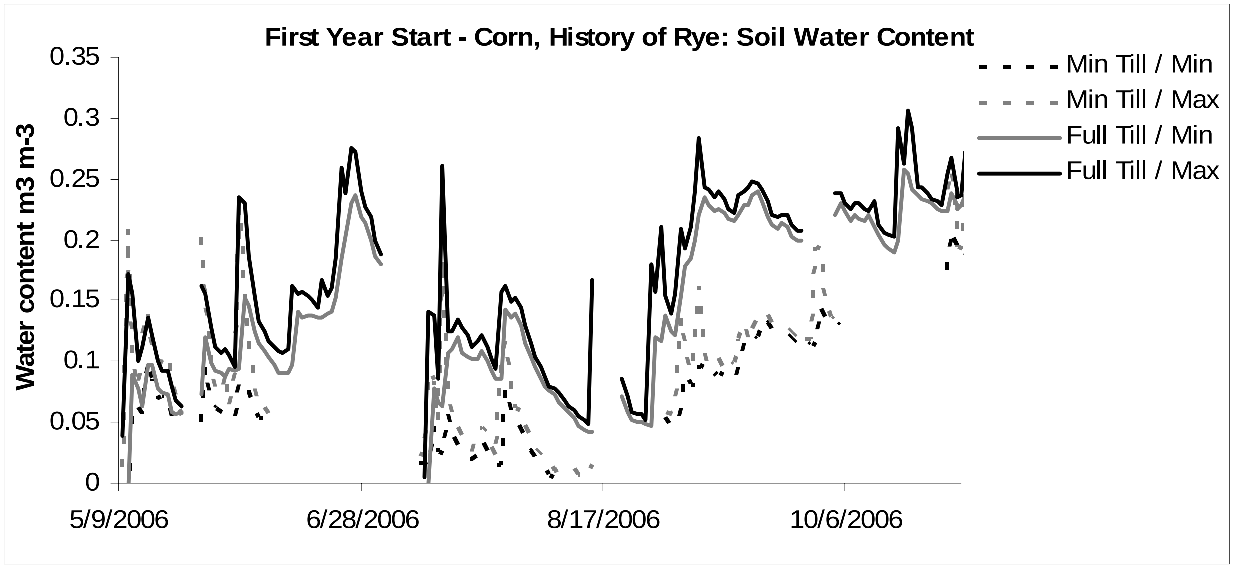

Figure 20. Soil water content (m³/m³) in 2006 in corn with a history of rye/hairy vetch planted in 2004 where Min Till= reduced tillage and Full Till= conventional tillage.

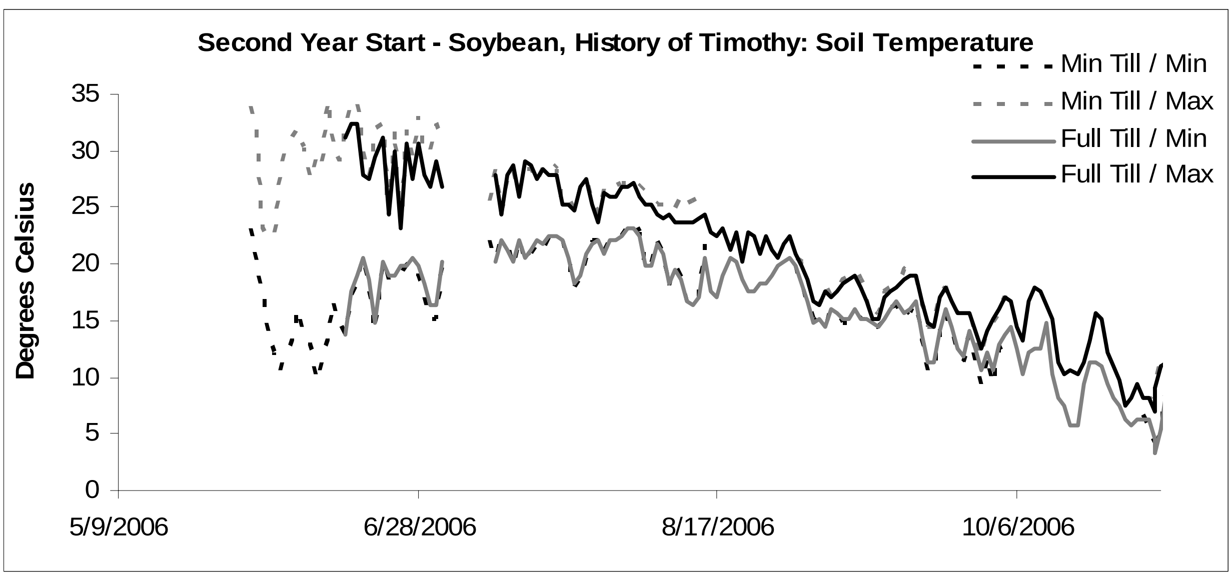

Figure 21. Soil temperature (°C) in 2006 in soybean with a history of timothy/clover planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

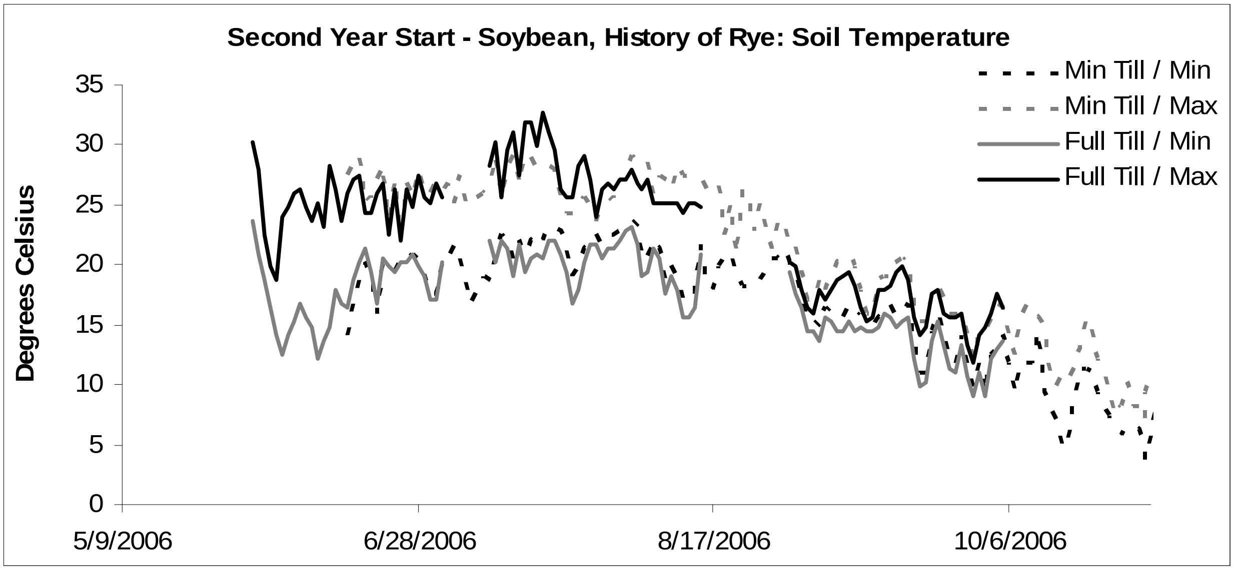

Figure 22. Soil temperature (°C) in 2006 in soybean with a history of rye/hairy vetch planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

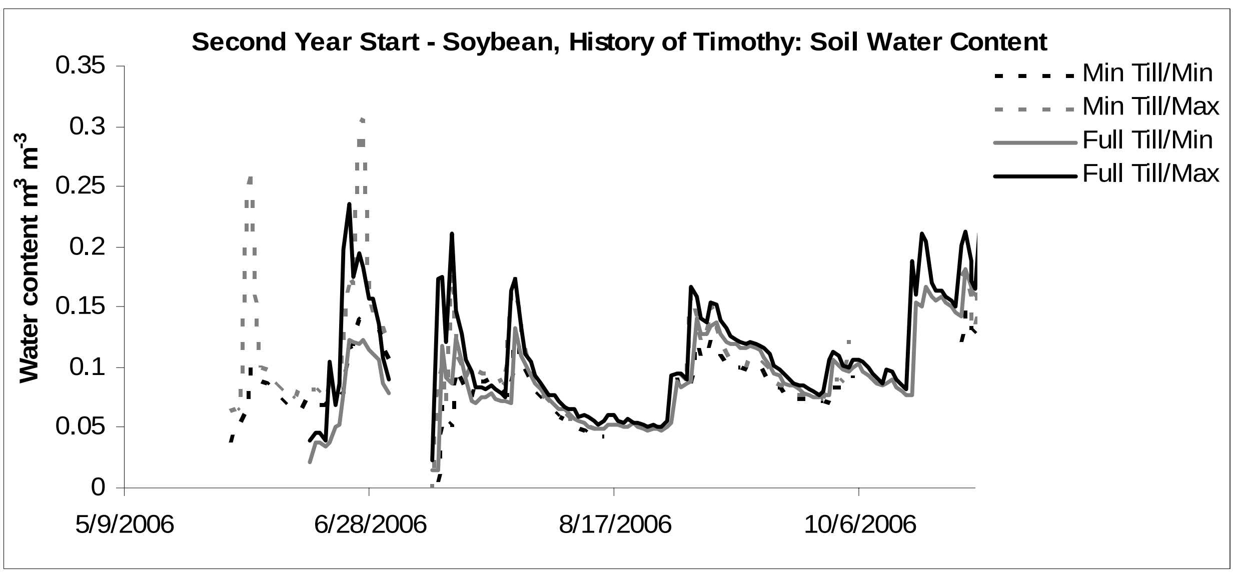

Figure 23. Soil water content (m^3/m^3) in 2006 in soybean with a history of timothy/clover planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

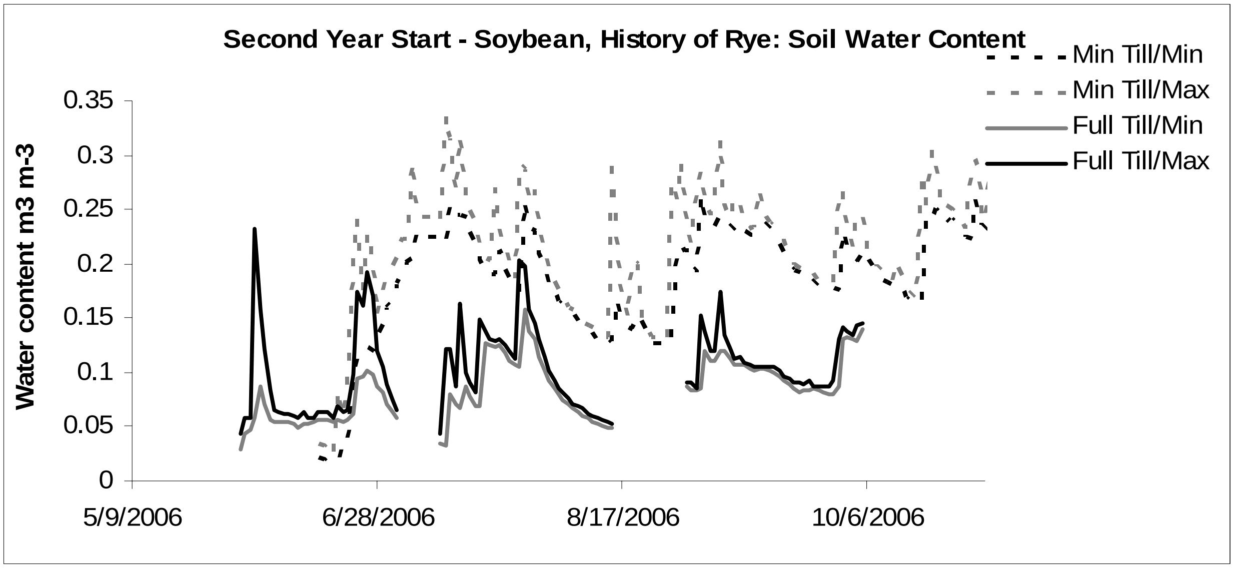

Figure 24. Soil water content (m³/m³) in 2006 in soybean with a history of rye/hairy vetch planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

Economic Analyses

Since the inception of the project, all input costs (fixed and variable) and crop yields have been recorded. A partial budget analysis was preformed for all crop years and treatments. The final analysis was to compare the relative costs and returns across the four sets of transitional systems. Comparing the average partial budget reports across both starts provides a more thorough picture of the economic implications of transitioning using different cover crop methods or tillage methods. Table 14 shows that reduced tillage systems led to lower profitability in the experiments. At this point, we do not have the corn results from Start 2. So no conclusions can yet be drawn about that crop. Soybeans, on the other hand, showed average returns being almost $8.00 lower when following timothy and nearly $10.00 lower when following rye.

Similarly, soybean returns were lower when following rye/hairy vetch compared to soybean returns when following timothy in both tillage systems. In the conventional tillage treatments, average returns were nearly $46.00 lower and about $47.50 lower in the reduced tillage treatments.

This takes into account the costs and returns associated with the cover crops prior to the cash crops of soybeans and corn; providing the most thorough analysis of the profitability across each system. The results clearly indicate that the timothy treatments provided the greatest economic returns in the experiments (Table 15). Additionally, the conventionally tilled sequence showed greater returns compared to the reduced tillage systems. It is very important to note that two costs, land and management, have been excluded from all analyses. For purposes of the partial budget analysis, this is not at all problematic. Including them would simply shift the returns for all crops downward. In relative terms, however, the returns remain as shown throughout this report.

Table 14. Average Results of Partial Budget Analyses across both starts.

Comparison	Start 1	Start 2	Average
Reduced tillage vs. conventional tillage systems in soybeans following timothy/clover/oats	- $3.81	- $12.02	- $7.92
Reduced tillage vs. conventional tillage systems in corn following timothy/clover/oats	- $85.02	NA	- $85.02
Reduced tillage vs. conventional tillage systems in soybeans following rye/hairy vetch	$67.25	- $86.41	- $9.58
Reduced tillage vs. conventional tillage systems in corn following rye/hairy vetch	- $87.98	NA	- $87.98
Soybeans following rye/hairy vetch vs. soybeans following timothy/clover/oats; conventional tillage	$16.35	- $32.00	- $7.83
Corn following rye/hairy vetch vs. corn following timothy/clover/oats; conventional tillage	$4.22	NA	$4.22
Soybeans following rye/hairy vetch vs. soybeans following timothy/clover/oats; reduced tillage	$87.41	- $106.39	- $9.49
Corn following rye/hairy vetch vs. corn following timothy/clover/oats; reduced tillage	$1.26	NA	$1.26

Table 15. Average Cumulative Returns of Four Alternative Transitional Strategies across Both Starts

Strategy					
Tillage	**Cover Crop**	**Year 1 (Cover Crop)**	**Year 2 (Soybeans)**	**Year 3 (Corn)[a]**	**Total**
Conventional	Timothy/clover/oats	$100.57	- $96.94	$140.36	$143.99
Conventional	Rye/hairy vetch	- $19.33	- $142.80	$144.58	- $17.55
Reduced	Timothy/clover/oats	$100.57	- $104.85	$55.34	$51.06
Reduced	Rye/hairy vetch	- $19.33	- $152.31	$56.60	- $115.04

[a] Start 2 data will be included after harvest in fall of 2007.

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 2006 related to the above objectives are summarized below.

Teaching Activities

Barbercheck, M. (Instructor) PSU Altoona, 2 April 2007, 25 students
Agriculture 160 - Ethics and Issues in Agriculture. Organic and sustainable farming.

Barbercheck, M., R Jabbour, and C. Mullen (Instructors)
Sheryl Hosler and Victoria Piccone -Pennsylvania Governor School students (high school) who worked on individual projects related to the field experiments described above. Summer 2006.

Karsten, H. (Instructor) Fall 2006 and Spring 2007 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

Karsten, H, E. Sánchez, and M. Barbercheck (Instructors)
Agroecology/Hort 497A – Principles and Practices of Organic Agriculture (In development for spring 2008)

Sánchez, E., M. Barbercheck, and H. Karsten. (Instructors)
Horticulture 232 – Organic Vegetable and Berry Production. (In development for fall 2008)

Extension Presentations

Barbercheck, M. Community of Practice Organic Entomology Team Leader for eOrganic. eXtenstion Project. Alexandra Stone, Oregon State University, is lead PI.

Barbercheck, M. Soil Quality and Arthropods in Pasture Systems. Sept. 21, 2006. Pasture Walk, John G, Esh Farm, Quarryville, Lancaster Co., PA (45 attendees, 35 Anabaptist, 5 women, 1 African-American)

Barbercheck, M. Manage Insects on Your Farm - Eco-strategies. September 16, 2006. Small Farms Conference. Rutgers University, NJ (50 attendees, 5 Asian, 20 women)

Barbercheck, M. What to Eat: Organic, Local, Sustainable? Cafe Scientifique at Penn Brewery, Pittsburgh, PA. Sept. 11, 2006. (60 attendees, 40 women)

Barbercheck, M. Soil Biology. Penn State Agronomic Field Diagnostic Clinic. July 20, 2006. Agronomy Research Farm, Rock Springs, Centre Co. (80 attendees, 2 women)

Barbercheck, M. Soil Biology. Penn State Agronomic Field Diagnostic Clinic. July 18, 2006. Agronomy Research Farm, Rock Springs, Centre Co. (60 attendees, 2 women)

Barbercheck, M., D. Mortensen, A. Hulting. Ecological Weed Day for Teachers, July 17, 2006, Rock Springs Agronomy Farm Pavilion, Centre County. (50 attendees, 2 women)

Barbercheck, M. and R. Jabbour. Soil Biology. Integrating No-Till Practices and Cover Crop Use to Build Soil Quality and Manage Pests. July 14, 2006. Cedar Meadow Farms Field Day. Holtwood, Lancaster Co. 250+ attendees.

Barbercheck, M. Insect IPM in Organic Systems. Advanced Organic Training for Agricultural Professionals. July 12 - 14, 2006. Ithaca, NY. (25 participants, 20 women, 1 African-American, 1 Hispanic).

Barbercheck, M. and S. Duiker. Soil Quality Workshop: Concepts, Practice, Methods and Program Development. July 5 - 7, 2006. The Rodale Institute, Kutztown, PA. (45 attendees, 20 women, 1 Hispanic male)

Barbercheck, M., D. Mortensen, A. Hulting. Soil Biology. Integrating Cover Crops and Tillage to Manage Weeds and Build Soil Quality. June 28, 2006. Village Acres Farm, Mifflintown, Juniata Co. 75 attendees (@ 30 women).

Barbercheck, M., D. Mortensen, A. Hulting. Ecological Weed Management Field Day. June 13, Rock Springs Agronomy Farm, Centre Co. 50 attendees (@ 25 women)

Barbercheck, M. Biorational Decisions: Bio-based IPM in Christmas Trees. March 15, 2006. Schuykill Co. Extension Center. (25 attendees, 4 women)

Barbercheck, M. Beneficial Insects: Know Your Allies. 15th Annual PASA Conference. February 3, 2006. University Park, PA. (100 attendees, about 35 women).

Barbercheck, M. Organic Insect Management: Letting the Environment Work for You. Pennsylvania Vegetable Grower's Association. January 31, 2006. Harrisburg, PA (90 attendees, @ 30 women)

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. The Organic Way. Monthly Column in the PSU Vegetable and Small Fruit Gazette. http://hortweb.cas.psu.edu/extension/vegcrops/newsletterlist.html

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.

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

Related Funded Projects

USDA/ARS Pasture Systems and Watershed Management Research. Organic Dairy Production Systems In Pennsylvania: A Case Study Evaluation. C.A. Rotz, G.H. Kamphuis, H. D. Karsten, and R. D. Weaver.

NE SARE. WAgN: Sustainable Ag Network by and for Women Producers. C. Sachs, M. Barbercheck, K. Brazier, N.E. Kiernan

NE SARE. Whole Farm Nutrient Planning for Organic Farms. E. Sánchez, T. Richard, H. Karsten, and R. Stehouwer.

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 Integrated Organic Program and eXtenstion. eOrganic: Resource for Organic Agriculture Information. Lead PI: Alexandra Stone, Dept. of Horticulture, Oregon State University. Local contact: Mary Barbercheck.

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.

USDA NRI. Ecologically Based Weed Management. Penn State, Rodale, and the USDA Small Farms Group in Beltsville, MD. PSU contact: D. Mortensen.

USDA NRI. Sustaining Small Farms and Rural Communities: The Role of Women Farmers. Project Leaders: C. Sachs, M. Barbercheck, J. Findeis, N.E. Kiernan, A Trauger. Project Extension Associate: L. Moist.

The Pennsylvania Vegetable Growers Marketing and Research Board. Various Composts for Nutrient Management of Organic Bell Peppers. E. Sánchez, E. Cook, and H. Karsten.

Effect of Landscape Complexity on Beneficial Soil Organisms in Agroecosystems. R Jabbour and M. Barbercheck.

Mulches for Suppressing Weeds in a High Tunnel Cucumber Crop Under Organic Management. E. Sánchez, W. Lamont, and M. Orzolek.

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
July 27, 2006
April 9, 2007

Advisory Board Meeting Dates

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

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Weil R.W., Islam K.R., Stine, M., Gruver J.B. and S.E. Samson-Liebig. 2003. Estimating active carbon for soil quality assessment: a simplified method for laboratory and field use. American J. Alt. Ag. 18: 3 -17.

Appendix 1. Timeline of project activities from Spring to Fall 2006.

Date	Operation	People Involved
Feb/March	Bull pen manure applied (15 loads; 7,260lbs per load) to last years soybean stubble. Used PDA tractor/spreader	Farm Crew
5-Apr	Flagged Starts 1 and 2 plots.	Randa and Christy
9-Apr	Measured out and flagged Start 2 plots. Fields are 80' x 90' Adjusted flags to represent the field dimensions (1 red flag/field plot corner)	Christy
12-Apr	Measured out and flagged Start 1 plots. Fields are 80' x 90' Picked up debris from damaged high tunnels Andy flagged fields for tillage treatments (yellow- till; orange- min-till) Tillage indicators IN field about 10' to avoid confusion with boundary indicators that are at each corner of each field plot	Randa, Andy, and Christy
19-Apr	Miller disked (JD 7700/ Miller-offset disk) soybean stubble in Start 1 fields (both tillage treatments)	Farm Crew
20-Apr	Tilled in manure and soybean stubble in Start 1fields. Full-till- Moldboard Plow; Min-Till: Chisel Plow (Both plows were pulled with a Ford 6600)	Farm Crew
26-Apr	Bulk Density sampling in Start 2 fields. One location per field, three depths. Both T/C and Rye/HV fields were sampled.	Andy, Sjoerd, and Christy
26-Apr	Cover crop biomass sampling using orange quadrat (20cm x 50cm). Three locations per field. HV and Rye separated. Timothy and Clover separated.	Andy and Christy
26-Apr	Half of full-till fields moldboard plowed (Ford 6600/Ford-roll-over plow) in the Start 2. About 1/4 of a min-till rye/HV field accidentally plowed. (Field 34)	Farm Crew
27-Apr	Finished full-till fields with moldboard plows in the Start 2	Farm Crew
27-Apr	Chisel plowed (Ford 5600/Ford chisel plow) tim/clov, min-till plots in the Start 2	Farm Crew
28-Apr	Disked (Ford 6600/McConnal disk) both soybean and corn plots (all treatments)	Farm Crew
2-May	Ran cultipacker (Ford 4610/cultipacker) in Start 1 fields (all treatments) and Start 2 field (excluding HV/Rye fields that are in min-till)	Farm Crew
3-May	Picked up trash in Start 1	Andy and Christy
3-May	Ran S-tine (Ford 6600/S-tine) through Start 1fields (all treatments)	Farm Crew
3-May	Planted corn (Ford 3930/New Idea planter) in Start 1 fields (all treatments)	Farm Crew
9-May	Reflagged corn field. Placed flags with corn rows.	Andy and Christy
9-May	Setup and launched data loggers in fields 3/4 and 13/14. Placed a flag at the end of the moisture sensor. Crossed 2 rows of corn @ a 45° angle from plot border	Andy and Christy
22-May	Soil sampled. 15 cores/location	Barbercheck Lab
22-May	Stopped and pulled data loggers for tillage	Barbercheck Lab
22-May	Put up Do Not Spray Signs	Barbercheck Lab
22-May	Ran S-tine (Ford 6600/ S-tine) in soybean plots (all but vetch, min-till plots)	Farm Crew
22-May	Rotary hoed corn (Ford 3600/ Rotarty hoe) (all treatments)	Farm Crew

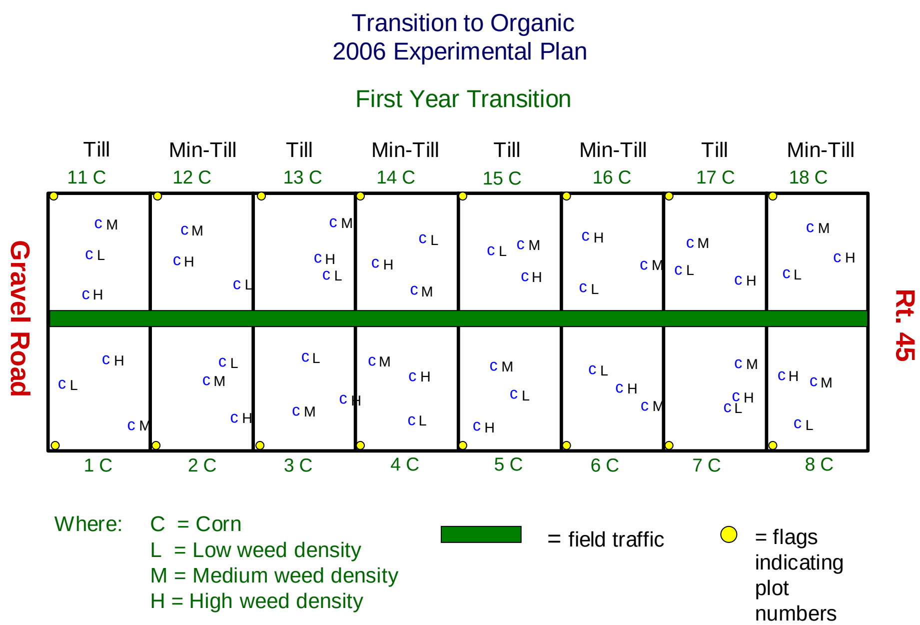
23-May	Planted soybeans (Ford 3930/New Idea planter) in Start 2 fields (all but vetch, min-till plots)	Farm Crew
	Ran Pittsburgh disk (Ford 5600) in Timothy, min-till blocks	
26-May	Reburried and relaunched data loggers in fields 3/4, 13/14	Christy and Alyssa
31-May	Rotary hoed corn (Ford 3600, all treatments)	Farm Crew
	Setup data loggers in soybean fields 31 and 32. Placed a flag at the end of the sensor. Crossed 2 rows of soybeans @ a 45° angle from plot border.	Christy and Alyssa
	Added extra flags where sensors are buried in corn to prevent damage when farm crew rotary hoes the corn today.	
5-Jun	Dug 5 pitfalls in triangle plot (in soybean) for the agronomy field day	Alyssa and Christy
6-Jun	Biomass sampling in the min-till HV/Rye plots (#21, 34, 26, 27) at three random locations/plot, 20cm x 50cm area using 2 meter sticks due to HV cover and lack of a quadrat, separated rye and HV, counted # of rye stalks	Christy, Alyssa, Randa
	Put up Do Not Spray Signs in the 2 back corners of the plots	Christy, Alyssa, Randa
7-Jun	Picked up trash in both starts (about 3 trash bags)	Christy and Alyssa
	Rolled (John Deere 7700/roller) HV/Rye, min-till plots	Farm Crew
8-Jun	Randomized weed counts in **corn** plots. 5 random locations/plot. No till had a lot more weeds. Common weeds found were: pigweed, buckwheat, thistle, foxtail, and lambwsquarter. Other weeds found were: woodsorrel, nightshade, henbit, dandelion, soybean, and bindweed.	Christy, Alyssa, Randa, Andy
	Rolled HV death at till rows, the rest is a carpet of purple	
	Rye is dying in rolled plots	
9-Jun	Dug up old irrigation pipes in Start 2	Alyssa and Christy
	Downloaded loggers for 3/4, 13/14. and 31/32	
	Vetch still alive	
13-Jun	Soybeans planted (Ford 3930/New Idea planter) in rolled vetch, min-till blocks	Christy, Alyssa, Randa
14-Jun	Flagged soybean plots (80' x 90') within soybean rows. Plowed fields are more like 100' wide. Flagged ~5' in the soybean row on each side to maintain lanes. This was done more in the 20's than in the 30's.	Christy, Alyssa, Randa
	Buried data loggers in fields 21/22. Crossed 2 rows and flagged the end of the moisture sensor. Temperature sensor crossed 1 row.	
	Rotary hoed (Ford 3600) the soybeans (all blocks excluding vetch, min-till)	Farm Crew
15-Jun	Re-buried sensors in fields 21/22 due to rotary hoe pulling them out yesterday	Christy, Alyssa, Randa, Andy, and Brosi
	Downloaded data loggers	
	Did density weed counts in corn plots. GPS file corrupted so Andy flagged areas based on the map (orange: low, yellow: medium, and green: high weed seed density plot). Plots were tilled yesterday so we had to count dead and alive weeds. Placed the white pvc quadrate over a corn row. Most of quadrat was on the side facing Rt. 45.	

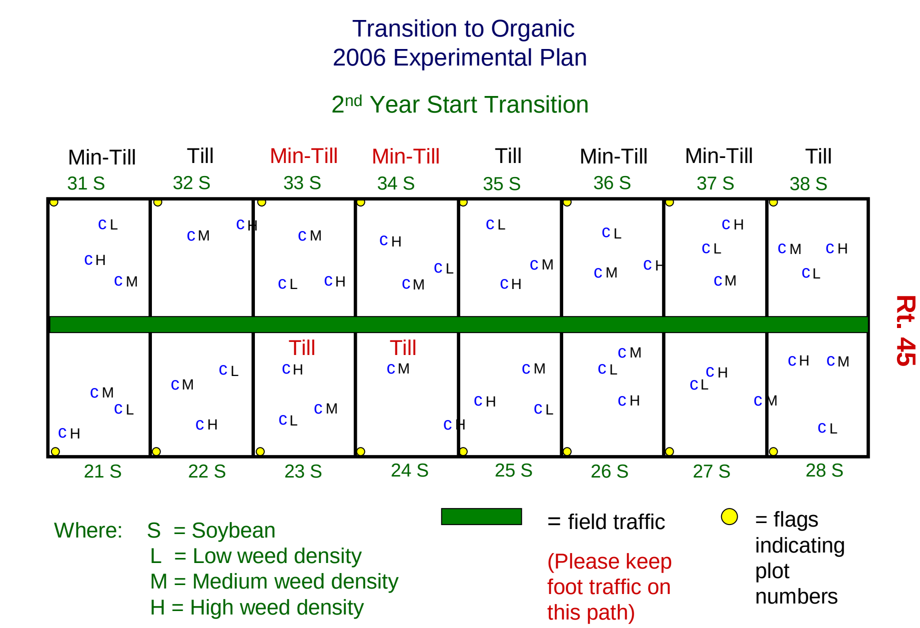
	Common weeds found were: Foxtail, Pigweed, Lambsquarter, and Thistle. Other weeds found included: volunteer soybeans, velvet leaf, smartweed, ragweed, dandelion, woodsorrel, nightshade, penny cress, buckwheat, bind weed, and henbit.	
15 & 16-Jun	Cultivated corn plots (Ford 3930, all treatments)	Farm Crew
16-Jun	Rolled (John Deere 7700/Roller) HV/Rye min-till plots again	Farm Crew
20-Jun	Put in pitfalls. 3 pitfalls/ plot located close to the crop row but not in the row or in the center of the between row the spacing. Lids were left on.	Mary, Andy, Alyssa, Brosi, and Christy
	HV almost completely dead. Appears that the second rolling was successful.	
	Soybeans are beginning to emerge in the rolled HV/Rye plots	
30-Jun	Opened pitfalls	Andy, Randa, Brosie, Alyssa
	Did random weed counts in the soybeans (Start 2). 5 random locations per plot.	
3-Jul	Collected pitfalls	Alyssa, Dan, Andy
	Downloaded loggers and dug up loggers for cultivation.	
6 & 7-Jul	Soybeans cultivated (Ford 3930, all treatments except vetch, min-till). Couldn't cultivate corn (too big)	Farm Crew
10-Jul	Re-buried and re-launched data loggers.	Alyssa and Christy
	Plot 3 temperature probe had to be replaced.	
20-Jul	Soil sampled. 15 cores/location	Andy, Alyssa, Brosie, Dan, Randa, and Steve
	Most of the soybeans plots were cultivated yesterday (Ford 3930). Plots 28 and 38 were cultivated this morning (all treatments but vetch/min-till).	
	Corn beginning to tassle (most of it)	
24-Jul	Downloaded data loggers	Alyssa
31-Jul	Downloaded data loggers	Alyssa and Christy
	Ran N-Coulter/attachment (Ford 3930) from potato project in vetch/min-till blocks	Farm Crew
1-Aug	Placed two cores per plot to gather baseline information on greenhouse gas fluxes. Cores placed in the following corn plots: 1, 2, 7, 8, 11, 12, 17, and 18. Core is a large PVC pipe ring. Marked with orange flags and yellow tape. Total of 16 rings.	Barbara Fricks, Jaosn Kaye, and Andy Hulting
3-Aug	Cultivated soybeans (Ford 3930) in vetch/min-till plots	Farm Crew
10-Aug	Downloaded data loggers	Alyssa and Christy
16-Aug	Soil sampled both starts. 12 cores per replicate.	Mary, Alyssa, Randa, and Christy
17-Aug	Dug holes for pitfalls in both starts. Placed the hole close to the crop row but not in it. Used an orange flag near the pitfall and another at the end of the row (in between the 2 crop rows).	Alyssa, Randa, Brosi, and Christy
	Accidentally pulled out some orange flags associated with the greenhouse gas cores.	
	Pulled red plot marker flags out of the soybeans and corn rows and placed them at the edge of the rows to help determine plot perimeter. Originally they were about 5 ft. in from the edge of the rows because the fields are wider than 90 ft.	
	Insect damage on corn was more prevalent in weedier, min-till plots.	

	Took pics of the fields.	
18-Aug	Opened pitfalls in soybean fields	Alyssa, Randa, Brosi, and Christy
21-Aug	Collected pitfalls.	Alyssa, Randa, Brosi, and Christy
	Covered deli containers and left them in the field.	
	Plots 35B and 26A cups were pulled out of deli container and chewed. Pulled the deli containers to filter antifreeze in the deli container.	
	Plots 34C and 25A had cups overflown with water and antifreeze. Lost antifreeze into ground as a result of holes in the bottom of the deli container.	
	Rainfall occurred over the collection days. Insects that died on the bottom of the deli container have begun to rot.	
	There were a lot of larger beetles that were alive and located on the bottom of the deli container. When placed in the antifreeze, some remained alive until they were placed in alcohol during the filtration process back in the lab. A few began to chew the styrofoam cups.	
	Pitfall 24A had a grasshopper that chewed a hole into the side of the cup. Lost some antifreeze due to the holes in the bottom of the deli container.	
	Downloaded data loggers. Restarted 13/14.	
30-Aug	Downloaded data loggers. Restarted 3/4 and 31/32. 21/22 was the only weather station that didn't stop logging after 8/15.	Alyssa and Christy
12-Sep	Downloaded data loggers	Randa and Christy
4-Oct	Soil sampled both starts. 12 cores per replicate; three replicates per plot	Randa, Christy, Jess, and Mary
	Downloaded data loggers. 13/14 stopped on 9/21, restarted	
	Some pitfalls in both crops are out of their holes	
	Soil was moist and relatively easy to sample	
	Corn is yellowing	
	Soybeans in till (both cover crops) and min till T/C are almost completely dried down and most of their leaves have dropped	
	Soybeans min-till HV are just starting to yellow	
26-Oct	Checked pitfalls and re-dug ones that popped out of the holes	Randa, Jess, and Christy
	Flagged 6 rows in the center of each corn plot for Scott to harvest the corn with combine (2 passes, 3 rows per pass)	
	Hand harvested corn plot 1-1, 3 replicates, 11.6' per replicate. Placed harvested corn in large paper grocery bags	
	Soil moist and easy to dig	
	All soybeans and corn are brown	
27-Oct	Harvested soybeans 3 replicates per field, 10' per replicate. Soybean plants appear to be larger than last year; most of the fields required 2 grocery bags/ replicate	Randa, Jess, Mary, and Christy
	Downloaded data loggers. 3/4 and 31/32 stopped recording 10/4 (restarted) 13/14 and 21/22 appears to be working fine	
30-Oct	Harvested corn; 3 replicates per field, 11.6' per replicate.	Randa, Jess, Mary, and

	Field 6 had highest weed (thistle) population, resulted in a reduced corn production, plants took longer to mature, and a major percentage of the sampled rows didn't have mature corn	Christy
	Opened pitfalls (same holes as 8/21/06)	
	Did weed rating (high, medium, low) for soybeans and corn. Mostly based on between row areas	
	Took representative photos for soybean and corn to document weed densities in the fields	
2-Nov	Picked up pitfalls. It rained 11/1 so some pitfalls were really full and there were a lot of earthworms and slugs.	Christy and Jess
	Soybeans had no real problems except for 22 A's cup breaking	
	Corn pitfalls had some animal damage in the first strip of fields. Some funnels were pulled out and cups damaged and pulled out of the pitfall	
	In total, there were 3 pitfalls where the styrofoam cup and funnel were pulled out of the ground	
	2 of them (4c and 6c) had the antifreeze poured into a deli container that didn't have drainage holes	
	Pitfall 3C's antifreeze was poured into a container that did have drainage holes in the bottom, collected as much anitfreeze as possible out of hole using a small plastic vial	
	Pitfall 2b had the funnel pulled out, styrofoam cup damamaged but not removed from hole; there was some antifreeze on the bottom of the deli container	
	Pitfall 3B and 5C had their funnels removed but no cup damage	
	Pitfalls 11b and 18b were overflown with rain water	
3-Nov	Downloaded and removed data loggers. 31/32 sensors in wrong field after last tillage event (wires were wrapped around the post)	Christy
	31 (sensed field 32) was slightly damaged but appeared to log the data	
	32 (sensed field 31) was severed from the logging station, appears to be some sort of animal damage	
10-Nov	Soybean harvest with a Massey Fergeson 300 (Ford 6600/Gravity) plot combine (2 row, 1 pass)	Farm Crew
5-Dec	Soybean harvest, whole field	Farm Crew
5 and 6-Dec	Corn harvest with Massey Fergeson 300 (Ford 6600/Gravity) plot combine (6 rows, 3 rows per pass)	Farm Crew
	Corn harvest, whole field	
19 and 20-Dec	Soil core sampling- corn plots (Start 1), 2 locations per field, three depths per location	Alyssa, Jessie, Mary, Christy

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





Appendix 3. Field work in Start 1 fields, 2003-2006, for all four treatments.

Start 1: Timothy/Oats/Clover - Conventional Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Plowed fields: Cultimulcher and S-tine
10/14/2003	Planted Timothy/Jay Oats
4/19/2004	Re-seeded Jay Oats
4/19/2004	Planted Red Clover
5/14/2004	Mowed volunteer Rye
5/25/2004	Mowed volunteer Rye
5/26/2004	Hand weeded volunteer Rye and Wheat
5/28/2004	Hand weeded volunteer Rye and Wheat
8/2/2004	Baled Timothy as high moisture hay
8/25/2004	Compost application
10/14/2004	Timothy/Clover harvest
5/26/2005	Moldboard plowed
5/27/2005	Disked
6/1/2009	Disked
6/1/2009	Cultimulched
6/6/2005	Planted soybean seeds
6/15/2005	Rotary hoed
7/11/2005	S-tined
7/12/2005	Replanted Soybeans
7/13/2005	Replanted Soybeans
7/27/2005	Cultivated
7/28/2005	Cultivated
10/27/2005	Harvested soybeans
Feb/Mar 2006	Bull pen manure application
4/19/2006	Miller disked
4/20/2006	Moldboard plowed
4/28/2006	Disked
5/3/2006	S-tined
5/3/2006	Planted corn
5/22/2006	Rotary hoed
5/31/2006	Rotary hoed
6/15/2006	Cultivated
6/16/2006	Cultivated
12/5/2006	Harvested corn
12/6/2006	Harvested corn

Start 1: Timothy/Oats/Clover - Minimum Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Plowed fields: Cultimulcher and S-tine
10/14/2003	Planted Timothy/Jay Oats
4/19/2004	Re-seeded Jay Oats
4/19/2004	Planted Red Clover
5/14/2004	Mowed volunteer Rye
5/25/2004	Mowed volunteer Rye
5/26/2004	Hand weeded volunteer Rye and Wheat
5/28/2004	Hand weeded volunteer Rye and Wheat
8/2/2004	Baled Timothy as high moisture hay
8/25/2004	Compost application
10/14/2004	Timothy/Clover harvest
5/26/2005	Chisel plowed
5/27/2005	Disked
6/1/2005	Disked
6/1/2005	Cultimulched
6/6/2005	Planted soybean seeds
6/15/2005	Rotary hoed
7/11/2005	S-tined
7/12/2005	Replanted Soybeans
7/13/2005	Replanted Soybeans
7/27/2005	Cultivated
7/28/2005	Cultivated
10/27/2005	Harvested soybeans
Feb/Mar 2006	Bull pen manure application
4/19/2006	Miller disked
4/20/2006	Disked
4/28/2006	Disked
5/3/2006	S-tined
5/3/2006	Planted corn
5/22/2006	Rotary hoed
5/31/2006	Rotary hoed
6/15/2006	Cultivated
6/16/2006	Cultivated
12/5/2006	Harvested corn
12/6/2006	Harvested corn

Start 1: Rye/Hairy Vetch - Conventional Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Cultimulched
10/13/2003	S-tined
10/14/2003	Planted Rye
7/29/2004	Rye combined
8/2/2004	Straw mowed
8/3/2004	Straw baled
8/25/2004	Compost application
8/26/2004	Moldboard plowed
10/3/2004	Hairy Vetch planted
5/26/2005	Bush hogged Hairy Vetch
5/26/2005	Moldboard plowed
5/27/2005	Disked
6/1/2009	Disked
6/1/2009	Cultimulched
6/6/2005	Planted soybean seeds
6/15/2005	Rotary hoed
7/20/2005	Cultivated (half of plots)
7/27/2005	Cultivated
7/28/2005	Cultivated
10/27/2005	Harvested soybeans
Feb/Mar 2006	Bull pen manure application
4/19/2006	Miller disked
4/20/2006	Moldboard plowed
4/28/2006	Disked
5/3/2006	S-tined
5/3/2006	Planted corn
5/22/2006	Rotary hoed
5/31/2006	Rotary hoed
5/15/2006	Cultivated
5/16/2006	Cultivated
12/5/2006	Harvested corn
12/6/2006	Harvested corn

Start 1: Rye/Hairy Vetch - Minimum Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Cultimulched
10/13/2003	S-tined
10/14/2003	Planted Rye
7/29/2004	Rye combined
8/2/2004	Straw mowed
8/3/2004	Straw baled
8/25/2004	Compost application
8/26/2004	Chisel plowed
10/3/2004	Hairy Vetch planted
6/1/2005	Rolled Hairy Vetch
6/8/2005	Flail mowed
6/8/2005	Haybine vetch
6/9/2005	Planted Soybeans
6/10/2005	Yetter tool bar no-till coulter set
6/10/2005	Planted Soybeans
7/20/2005	Cultivated (half the plots)
7/27/2005	Cultivated
7/28/2005	Cultivated
10/27/2005	Harvested soybeans
Feb/Mar 2006	Bull pen manure application
4/19/2006	Miller disked
4/20/2006	Disked
4/28/2006	Disked
5/3/2006	S-tined
5/3/2006	Planted corn
5/22/2006	Rotary hoed
5/31/2006	Rotary hoed
5/15/2006	Cultivated
5/16/2006	Cultivated
12/5/2006	Harvested corn
12/6/2006	Harvested corn

Appendix 4. Field work in Start 2 fields, 2003 – 2006, for all four treatments.

Start 2: Timothy/Oats/Clover - Conventional Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Plowed fields: Cultimulcher and S-tine
10/14/2003	Planted Timothy/Jay Oats
4/19/2004	Re-seeded Jay Oats
4/19/2004	Planted Red Clover
5/28/2004	Hand weeded volunteer Rye and Wheat
6/30/2004	Baled Timothy as high moisture hay
8/2/2004	Baled Timothy as high moisture hay
10/14/2004	Timothy/Clover harvest
7/14/2005	Mowed for hay
8/28/2005	Mowed for hay
9/2/2005	Compost
4/26/2006	Moldboard plow
4/27/2006	Moldboard plow
5/2/2006	Cultipacked
5/22/2006	S-tine
5/23/2006	Planted Soybeans
6/15/2006	Rotary hoed
7/7/2006	Cultivated soybeans
7/6/2006	Cultivated soybeans
7/18/2006	Cultivated soybeans
7/19/2006	Cultivated soybeans
11/10/2006	Harvested soybeans

Start 2: Timothy/Oats/Clover - Minimum Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Plowed fields: Cultimulcher and S-tine
10/14/2003	Planted Timothy/Jay Oats
4/19/2004	Re-seeded Jay Oats
4/19/2004	Planted Red Clover
6/30/2004	Baled Timothy as high moisture hay
8/2/2004	Baled Timothy as high moisture hay
10/14/2004	Timothy/Clover harvest
7/14/2005	Mowed for hay
8/28/2005	Mowed for hay
9/2/2005	Compost
4/27/2006	Chisel plowed
5/2/2006	Cultipacked
5/22/2006	S-tine
5/23/2006	Pittsburgh disked
5/23/2006	Planted Soybeans
6/15/2006	Rotary hoed
7/7/2006	Cultivated soybeans
7/6/2006	Cultivated soybeans
7/18/2006	Cultivated soybeans
7/19/2006	Cultivated soybeans
11/10/2006	Harvested soybeans

Start 2: Rye/Hairy Vetch - Conventional Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Cultimulched
10/13/2003	S-tined
10/14/2003	Planted Timothy/Jay Oats
4/19/2004	Re-seeded Jay Oats
4/19/2004	Planted Red Clover
6/30/2004	Baled Timothy as high moisture hay
8/2/2004	Baled Timothy as high moisture hay
9/22/2004	Moldboard plowed
9/22/2004	Rye planted
7/2/2005	Harvested Rye
7/28/2005	Baled Rye
9/2/2005	Applied Compost
9/15/2005	Moldboard Plowed
9/15/2005	Planted Hairy Vetch
4/26/2006	Moldboard plow
4/27/2006	Moldboard plow
5/2/2006	Cultipacked
5/22/2006	S-tine
5/23/2006	Planted Soybeans
6/15/2006	Rotary hoed
6/7/2006	Cultivated soybeans
6/6/2006	Cultivated soybeans
6/18/2006	Cultivated soybeans
6/19/2006	Cultivated soybeans
11/10/2006	Harvested soybeans

Start 2: Rye/Hairy Vetch – Minimum Tillage

Date	Field Work
10/7/2003	Manure application
10/10/2003	Lime application
10/13/2003	Cultimulched
10/13/2003	S-tined
10/14/2003	Planted Timothy/Jay Oats
4/19/2004	Re-seeded Jay Oats
4/19/2004	Planted Red Clover
6/30/2004	Baled Timothy as high moisture hay
8/2/2004	Baled Timothy as high moisture hay
9/22/2004	Moldboard plowed
9/22/2004	Rye planted
7/2/2005	Harvested Rye
7/28/2005	Baled Rye
9/2/2005	Applied Compost
9/15/2005	Chisel Plowed
9/15/2005	Planted Hairy Vetch
6/9/2006	Rolled vetch
6/13/2006	Planted soybeans
6/16/2006	Rolled vetch
7/31/2006	Ran N-Coulter/attachment
8/3/2006	Cultivated Soybeans
11/10/2006	Harvested Soybeans