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

Russell E. Larson Agricultural Research Center
Rock Springs, PA

2007 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 and documents related teaching and technology transfer activities over the first 4 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, county technology transfer agents and the general public.

Project Objectives

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

Research Objectives

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

Education and Outreach Objectives

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

Strategic Objectives

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

Field Research Methods

Field Research

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

There are two consecutive phases in the experiment: Phase I.) a preparatory phase designed specifically to reduce the weed seedbank and to address Research Objective 1 above, followed in the same experimental units by Phase II.) a crop production phase to measure the weed reduction effects of the preparatory phase and to address Research Objective 2 above. Field and laboratory activities/ operations are summarized in Appendix 1. Plot maps are presented in Appendix 2. Field management over the past four years for each cover crop and tillage treatment for starts one and two is detailed in Appendices 3 and 4, respectively. Field management diagrams representing the planting, primary and secondary cultivation, row closure, and crop harvest for each cover crop/tillage treatment and start are shown in Appendix 5.

The field experiment has been established twice, in the fall of 2003 and again in 2004, in a split-plot, randomized complete block design with four replications. The approximate total combined area of the field experiment is 4 hectares and is surrounded by a minimum of 7 m of routinely mown grassy border on all sides. There are 16 main plots (4 treatments x 4 blocks) in each start year, which are each 0.067 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. The second start year of the experiment was managed with organic methods for the year before its inclusion as a temporal replicate in the over all transition experiment. In the fall of 2003, two cover cropping strategies were initiated and intensively managed over the spring and summer of 2004. The two cover crop treatments were rye (*Secale cereale*) (managed for grain production) and a mixture of red clover/timothy (*Trifolium pratense* / *Phleum pratense*) (managed for forage production that was established with an oat (*Avena sativa*) nurse crop that winterkilled and was subsequently replanted in the spring of 2004). These two cover-cropping systems were split over two tillage systems which were conventional (moldboard plow-based) and a reduced tillage system (chisel plow + field cultivator-based). In the spring of 2007 the first start was planted with a 50/50 mix of organic field pea (*Pisum sativum* L. cv. Arivika.) and spring triticale (*Triticale hexaploide* Lart.) in all cover crop/tillage treatments. The second start was planted with feed-grade corn (*Zea mays* cv. Pioneer 36B08) in all cover crop/tillage treatments in the spring of 2007 at a row spacing of 76 cm.

Crop Rotations to Date (Fall 2003-Fall 2007)

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 were hand harvested randomly throughout each plot. Corn ears were removed from 11.6 ft of randomly selected crop row, bagged, and dried in the Entomology/Plant Pathology head house. The dried corn kernels were then removed from the cob using a mechanical corn sheller (R.R. Brownfield D/B/A, Swanson Machine Co.) and placed into labeled paper bags. The corn seeds were then 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

Soil Chemical and Biological Properties

Three composite soil samples comprised of 15 cores each (2.54 cm X 15.25 cm) were collected from three random locations within each treatment plot. This sampling depth represents the most biologically active zone in the soil profile. Each soil core sample was placed in a large bucket lined with plastic garbage bags and thoroughly mixed to form the composite sample. This composite sample was then divided in the laboratory into three portions of approximately 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 at room temperature until the baiting and extraction procedures, which are described in detail below. The two sub samples 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). Sampling dates that soil samples were taken on are listed in Appendix 1.

Active Carbon

Permanganate oxidizable carbon levels (POC) were determined for the soil samples taken from each plot as described above using the lab method proposed by Weil et al. (2003). Briefly, soil samples were air-dried and then ground to pass through a 2-mm sieve. This soil (5 g) was reacted with 20.0 ml of 0.02 M permanganate solution in 47.5-ml screw top polycarbonate centrifuge tubes. The permanganate reagent contained 0.2 M $KMnO_4$, 1 M $CaCl_2$ and was adjusted to a pH of 7.2 using NaOH. The $CaCl_2$ was included to promote rapid flocculation of soil colloids. Weil et al. (2003) recommended raising the pH to 7.2 to increase reagent stability. Tubes were prepared in sets of 10, with each set including 8 experimental samples and one tube containing a soil standard and one tube containing a solution standard. Tubes were capped and shaken end to end (240 oscillations per minute) for 2 min and then allowed to settle an additional 10 minutes. Two hundred µl was collected from the supernatant after centrifuging and added to 9.8 ml of DI water and then vortexed to mix thoroughly. A mechanical pipette was used to transfer one 3.8 ml aliquot of supernatant to a clean cuvette (4 ml) and the absorbance was measured at 550 nm using a spectrophotometer (Spectronic 21 D, Milton Roy).

The following equation was used to calculate POC as a function of the quantity of permanganate reduced (Mn+7 -> Mn+4) in each tube:

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

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 then 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 electrode was then inserted into the centrifuge tube and EC (µS/cm) was immediately read with a standardized EC meter (Thermo Orion 555A).

pH

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

Soil Matric Potential

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 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 tin soil cans (Gardner 1986). The cans containing the weighed moist soil were dried in a bench-top oven (VWR 1324, Sheldon Manufacturing) at 45 C for 72 hrs. The dried samples were then weighed to obtain the dry weight of soil. Percentage soil moisture was calculated as [(wet weight soil - dry weight soil) / dry weight soil] x 100 = % soil moisture.

Soil Fertility

Soil samples from May 23, 2007, sampling date were analyzed by the Penn State Soil Analytical Laboratory for the following characteristics: soil pH, Phosphorus (P), Potassium (K), Magnesium (Mg), Calcium (Ca), CEC, % saturation of the CEC (K, Mg, Ca), % organic matter and trace elements (Zinc, Copper and Sulfur).

Soil Physical Properties

To determine baseline soil physical properties at the beginning of the experiment, intact soil core samples were taken in the second start in April of 2006 prior to tillage implementation. Secondary soil core samples were taken in December of 2006 in the first start fields to determine if tillage intensity and/or cover crop treatment affected soil physical properties. These results will be compared to baseline samples for the first start fields that were collected in 2004. Secondary samples will be taken early spring (March or April) of 2008 for the second start fields.

Samples were taken to approximately 3 depths, i.e., 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 2006 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 the intact soil cores at each depth using aluminum rings (7.62 cm length x 7.62 cm inner diameter). After the cores were hammered into the soil, the soil-filled core was carefully excavated from the soil profile with a spade. The amount of soil sampled per core was approximately 10-cm (the length of the metal core plus approximately 2.5 cm of excess soil at the lower end of the core). The excess soil was gently pushed upward until there were equal lengths of soil extending past both ends of the metal core. The soil cores were then wrapped in plastic wrap, placed in plastic coolers, and stored in a cold room (4.5 C). Soil collected through this process was tested for its bulk density, water retention, hydraulic conductivity, and aggregate stability.

Bulk Density

The bulk density (g/cm^3) 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 after the soil cores were processed for hydraulic conductivity and moisture retention. The cores were dried in a bench top oven at 55ºC. The dried soil was then weighed prior to the soil being removed from the core and ground with a mechanical soil grinder (Model F257, Nasco-Asplin, Fort Atkinson, WI). The ground soil was then sieved through a 2-mm sieve. The fragments that didn't pass through the sieve were labeled as aggregates and what did pass through the sieve was labeled <2-mm soil. The aggregates were washed over a 2-mm sieve to remove any loose soil that may be on the rock fragments before being placed in a plastic container. Water was added to the container to a level just above the rock fragments. An ultrasonic probe (Sonifier® Cell Distributor Model W185, Heat Systems-Ultrasonics, Inc.) was used for about 30 seconds to remove any particles of soil remaining on the rock fragments. The water was decanted off the fragments, fresh water added, and sonified again until there were no longer soil particles being released from the fragments. The fragments were placed in soil cans, dried, and weighed. The bulk density (g/cm^3) was determined by using the equation (Lal and Shukla, 2004):

(total oven dry mass of sample in ring – oven dry mass of rock fragments) / (total core volume - rock fragment volume*)

*Rock fragment volume is estimated as Mr/ρs; ρs = particle density of rock fragments (in g cm^3, assumed to be 2.65 g cm^3).

The oven dry weight of the second start, baseline cores was not measured before the soil cores were ground. The dry weight of the soil cores was determined by using the equation (Fritton, 2002):

$$Ms = Mt/(1+\theta dm)$$

or

Estimated dry weight = moist mass of sample in ring (g) / (1+ water content (g/g))

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. The 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 <2-mm 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 33 kPA, 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 dried, ground, and passed through a 2-mm sieve. The soil that passed through the sieve was collected and used in both the last step (15 bars) in the moisture retention curve as described above and in aggregate stability measurements. Four grams of <2-mm air-dried aggregates were placed in a 0.25 mesh/cm basket and placed in a wet sieving instrument (Five Star Cablegation and Scientific Supply). Aggregates were dunked (1.3 cm, 35 times/min) in a can of distilled water for 3 minutes. The mesh basket was then removed from the wet sieving instrument and placed in another can containing distilled water. An ultrasonic probe (Sonifier® Cell Distributor Model W185, Heat Systems-Ultrasonics, Inc.) was placed in the water for 30 s at medium frequency. Both soil cans were placed in a drying oven at 105ºC until the water evaporated. The soil cans were then weighed and the stability was determined by dividing the particles collected through ultrasonic dispersion by the sum of the weights in the two cans (Kemper and Rosenau 1986)

% 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 with Dart Styrofoam cups (~87mm mouth diameter, ~60mm deep) and lids. Three traps per plot were placed randomly and buried to the rim of the 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. All organisms are stored in the scintillation vials until they can be prepared for identification. The larger arthropods were identified and stored in 80% ethanol plus glycerol and microarthropods were mounted on microscope slides in Berlese's Fluid. Insects with be 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 can be sampled in soil cores and extracted by a heat gradient apparatus such as Tullgren or Berlese funnels (Coleman and Crossley 1996). A sub-sample of soil collected for chemical 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 these prepared funnels were placed on a frame that was 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 and will be identified under a dissecting stereoscope (Nikon SMZ1500). Mites and collembolans will be identified to family (Evans 1992, Krantz 1970). A category called "Other" will be used for all of the unidentifiable (male and immature) mites and other microarthropods. The category "Total" combined the counts of all mites, collembolans, and other microarthropods and served as a general indicator of the abundance of soil microarthropods in samples. The larger organisms were retained in scintillation vials filled with approximately 19 mL 80% ethanol and 1 mL glycerol. Microarthropods (< 2 mm) were mounted on microscope slides in Berlese's Fluid for identification.

Soiborne Insect Pathogens

A baiting bioassay method using *Galleria mellonella* as a host insect was used to detect entomopathogenic nematodes and fungi in soil samples (Goettel and Inglis 1997; Kaya and

Stock 1997). Soil samples were collected as described above. Soil (~250 mL) was placed in 473 mL deli container (Reynolds) along with 5 last-instar wax moth larvae (*Galleria mellonella*). The baited soil samples were stored at room temperature in the dark for up to 10 days. The cadavers were then removed and placed in 59 mL cups (Solo) with lids for symptoms and signs of infection to develop. The containers of soil were then re-baited with five new larvae and incubated for an additional 10 days.

Cause of death was identified as fungal (*Metarhizium antisopliae, Beauveria bassiana*, or *Isaria* (*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 then classified as being infected with *Beauveria* (white spores) or *Metarhizium* (green spores) (Goettel and Inglis 1997). Few sporulating cadavers were identified as *Isaria* (*Paecilomyces)* (pink spores).

Weed Populations

Cumulative seedling densities were quantified in both the weed sub-plots 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 start years. 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 the corn plots. Sensors were placed at a depth of approximately 10 cm and data recording was started in mid May and continued through 1 Nov 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 was not lost in the downloading process.

Economic Analyses

Since the inception of the project, all related input costs and crop yields have been recorded. Detailed spreadsheets have been developed for each of the two start years of the field experiment. These spreadsheets provide details of actual costs and yields on the experimental plots. Data has also been applied to generalized enterprise budget worksheets in the Penn State University Agronomy Guide. The results will be used for two purposes. First, they will provide an accounting for the actual costs and returns accruing to the work under the project. These results may prove useful to future researchers converting other plots of land on experimental farms. Second, they will be used to adjust existing enterprise budgets to reflect the transition period to certified organic production. This information will be useful to commercial farmers exploring a transition to organic production methods. The enterprise budgets developed under this project will ultimately be used within a partial budgeting framework to compare the net returns during the transition period to net returns under alternative management scenarios.

Data Analysis

Data was summarized using pivot tables in excel to determine the mean and standard deviation for each tillage and cover crop treatment.

Results

Crop Yield

Yields for the corn crop in 2007 are presented in Table 1. Yields were determined by both hand sampling and harvest by combine down the center six rows of the plots.

Table 1. Mean corn yields in 2007 following rye/hairy vetch and timothy/red clover cover crop treatments in 2005.

Harvest Date	Treatment (cover crop in 2005)	Hand Harvest Yield (kg/ha)	Combine Yield (kg/ha)
10/30/07	Rye (grain)/Minimum Till	9292.04	9778.26
10/30/07	Rye (grain)/Conventional Till	10483.37	9531.74
10/30/07	Timothy/Red Clover (forage)/Minimum Till	9526.42	8588.34
10/30/07	Timothy/Red Clover (forage)/Conventional Till	11189.65	10199.27

Soil Measures

Soil Chemical and Biological Properties

Active Carbon

Permanganate oxidizable carbon levels (POC) in the second year start planted with corn were similar when averaged by tillage system and cover crop type (Fig. 1). The mean (± s.d.) values averaged over cover crops for the two tillage systems were 386.77 ± 48.52 mg/kg POC in the reduced tillage and 368.00 ± 46.59 mg/kg POC in the conventional tillage system, respectively. When separated by cover crop, mean (± s.d.) POC levels were 379.33 ± 52.51 mg/kg POC in the rye/hairy vetch crop and 375.44 ± 44.02 mg/kg POC in the timothy/clover crop.

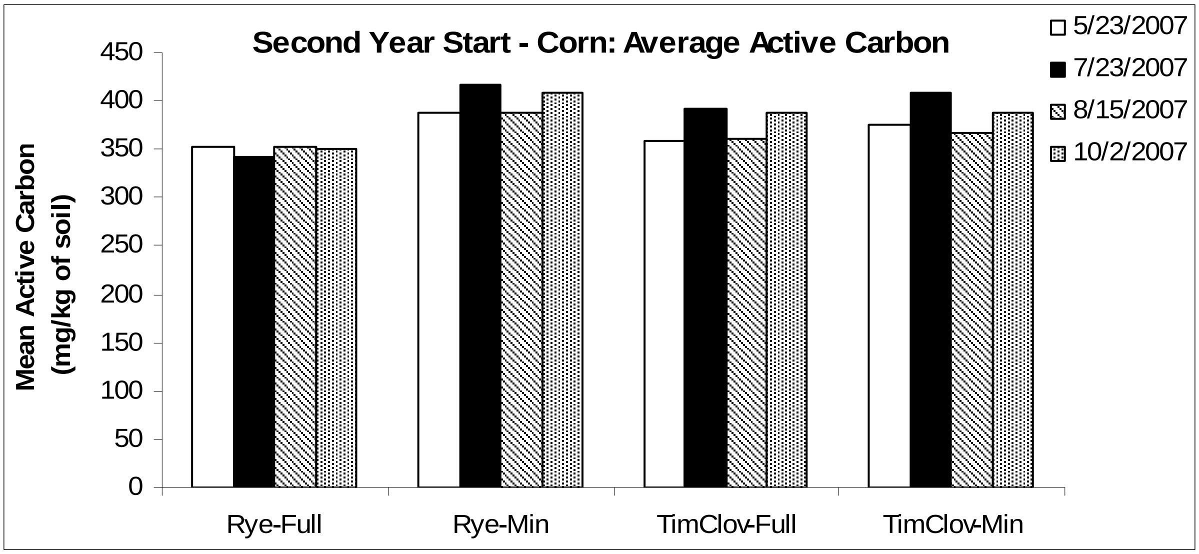

Figure 1. Mean permanganate oxidizable carbon (mg/kg of soil) in 2007 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

Electrical Conductivity

EC levels in the second year start (corn production year) varied over the growing season (Figure 2). Mean (± s.d.) EC values averaged over cover crop was 92.94 ± 26.01 µS/cm in the reduced tillage and 86.21 ± 36.79 µS/cm in the conventional tillage treatments. When separated by cover crop, mean (± s.d.) EC was 89.61 ± 27.25 µS/cm in the rye/hairy vetch crop and 89.54 ± 36.20 µS/cm in the timothy/clover treatments.

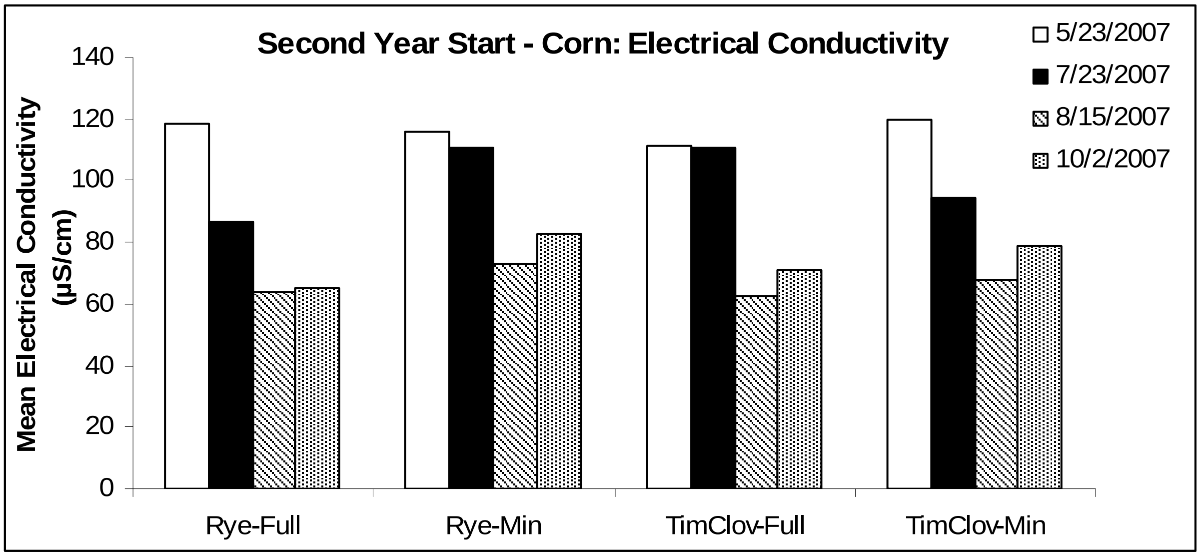

Figure 2. Mean electrical conductivity (µS/cm) in 2007 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

pH

pH levels were relatively similar over the sampling dates (Figure 3). Mean (± s.d.) soil pH levels in the second start (corn production year) were 7.16 ± 0.26 in the rye/hairy vetch and 7.10 ± 0.28 in the timothy/clover treatments. Mean (± s.d.) soil pH in the reduced tillage treatment was 7.15 ± 0.31 and 7.11 ± 0.23 in the conventional tillage treatment.

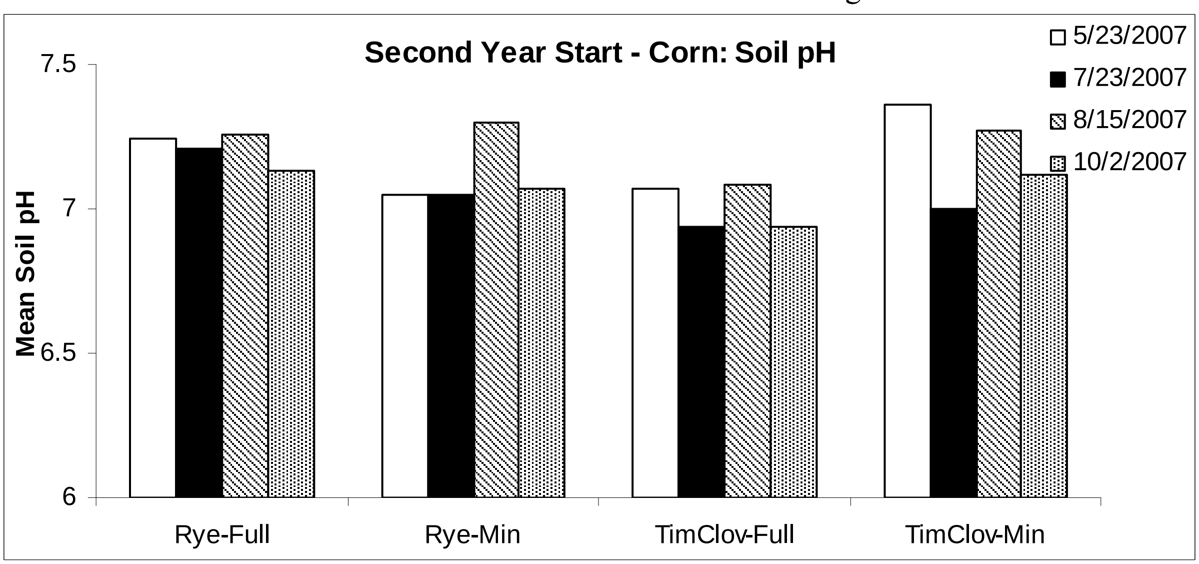

Figure 3. Mean soil pH in 2007 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

Soil Matric Potential

Soil matric potential in the second start (corn production year) varied by sampling date, cover crop, and tillage treatments (Figure 4). The mean (± s.d.) soil matric potential for the two tillage systems were 758.40 ± 479.49 –kPa in the reduced tillage system and 851.13 ± 543.33 –kPa in the conventional tillage system. When separated by cover crop, mean (± s.d.) soil matric potential in the first year start was 773.36 ± 512.41 –kPa in the timothy clover treatment and 836.16 ± 514.69 –kPa in the rye/hairy vetch treatment.

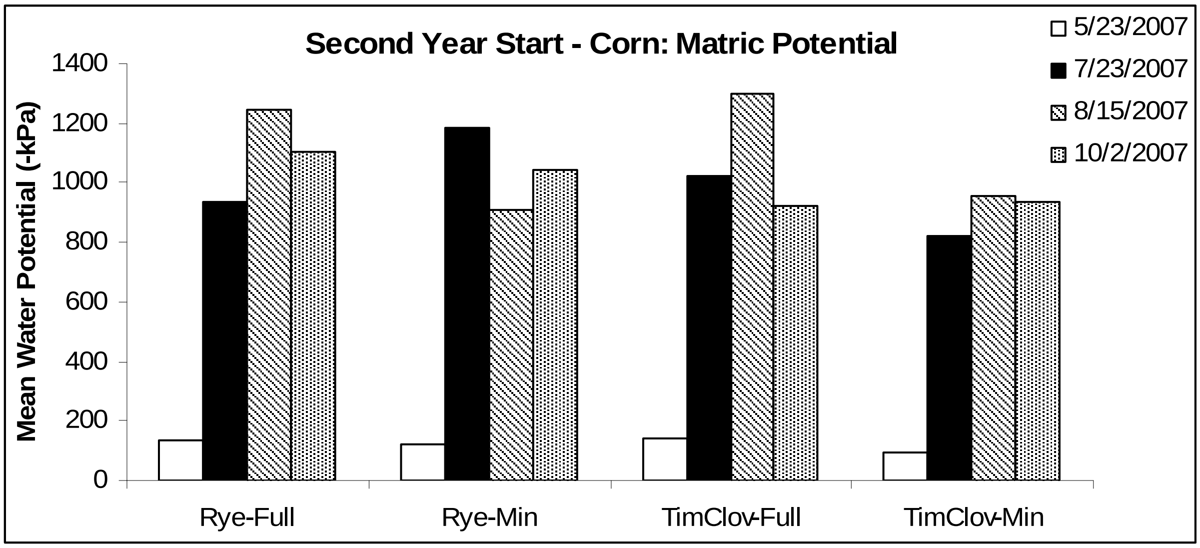

Figure 4. Mean soil matric potential (-kPa) in 2007 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

Soil Gravimetric Moisture

Mean gravimetric moisture values for soil sampled from the second year start (corn production year) were highest in May with a mean (± s.d.) of 18 ± 1% moisture (Figure 5). Gravimetric moisture values over cover cropping treatments was 15 ± 2% for both rye/hairy vetch and timothy clover fields. When separated by tillage treatment, mean (± s.d.) gravimetric moisture values were 15 ± 2% for both conventional and reduced tillage treatments.

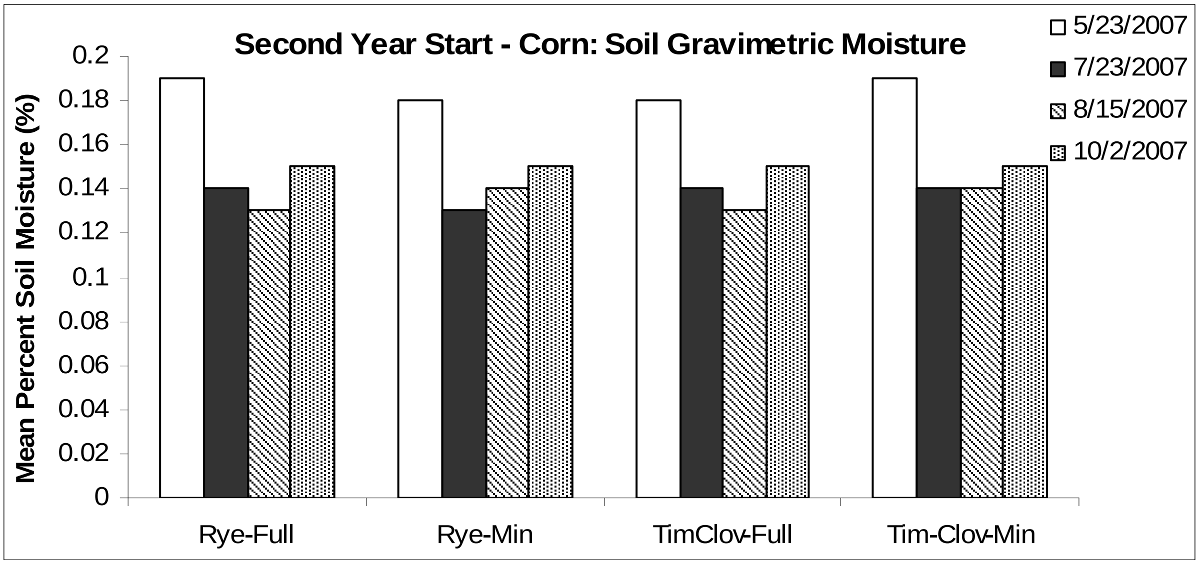

Figure 5. Mean soil gravimetric moisture (% moisture) in 2007 in corn shown by sampling date with a history or either rye/hairy vetch (Rye) or timothy/clover (TimClov) where full= conventional tillage and min= reduced tillage.

Soil Fertility

An application of bullpen manure was made in the second start year (February and March 2007) at a rate of 32,124.74 kg/ha (14.33 tons/A) 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 tests made in the spring of 2007 indicated that the soil is in the optimum range for pH and soil fertility.

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 1.29 ± 0.03 g/cm^3, 1.32 ± 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, 1.44 ± 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 1.38 ± 0.07 g/cm^3, 1.49 ± 0.08 g/cm^3 and 1.52 ± 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 1.39 ± 0.06 g/cm^3, 1.52 ± 0.04 g/cm^3 and 1.53 ± 0.06 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 1.40 ± 0.08 g/cm^3, 1.49 ± 0.08 g/cm^3 and 1.53 ± 0.07 g/cm^3, respectively, in the conventional tillage treatments and 1.37 ± 0.05 g/cm^3, 1.52 ± 0.04 g/cm^3 and 1.52 ± 0.05 g/cm^3, respectively, in the reduced tillage treatments.

Second Start, End Results

Bulk density will be determined on soil cores collected in early spring 2008, prior to any tillage events.

<u>*Water Retention Curves*</u>

First Start, End Results

Calculation of water retention curves on soil from the soil cores collected from the first start (corn production year) in December of 2006 was determined through exposing the soil cores to pressures of 0.01 kPA to 1500 kPA. Mean (± s.d.) percentage of plant available water based on the cover cropping system was 34.63 ± 11.33%, 29.67 ± 14.86%, and 30.51 ± 11.99% in the rye/hairy vetch plots (corn production year) at the depths of 0-10 cm, 10-20 cm, and 20-30 cm, respectively. Mean (± s.d.) percentage of plant available water in the timothy/clover plots (corn production year) was 33.86 ± 10.68%, 32.42 ± 10.52%, and 26.13 ± 12.69% at the depths of 0-10 cm, 10-20 cm, and 20-30 cm, respectively.

When comparing tillage treatments, mean (± s.d.) plant available water over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 33.61 ± 12.13, 29.76 ± 13.28, and 28.31 ± 11.46 respectively, in plots managed with conventional tillage practices. Mean (± s.d.) plant available water in plots managed under reduced tillage practices was 34.89 ± 9.73, 32.33 ± 12.48, and 28.33 ± 13.55 at the depths of 0-10 cm, 10-20 cm, and 20-30 cm, respectively.

Second Start, End Results

The water retention curve will be determined on soil cores collected in early Spring of 2008, prior to any tillage events.

<u>*Hydraulic Conductivity*</u>

Second Start, End Results

Hydraulic conductivity will be determined on soil cores collected in early spring of 2008, prior to any tillage events.

<u>*Aggregate Stability*</u>

First Start, End Results

After all other measurements had been completed on the intact soil cores; aggregate stability of the soil from the three depth classes was measured using an ultrasonic dispersion method (Kemper and Rosenau 1986). Mean (± s.d.) aggregate stability based on cover cropping system was 23.71 ± 6.04%, 25.09 ± 5.25% and 30.91 ± 30.29% in the rye/hairy vetch plots (corn production year) at the depths of 0-10 cm, 10-20 cm, and 20-30 cm, respectively. Mean (± s.d.)

aggregate stability over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) was 24.96 ± 7.89%, 25.26 ± 4.48% and 23.76 ± 4.30% respectively, for the timothy/red clover system.

When comparing tillage treatments, mean (± s.d.) aggregate stability over the three depths (0-10 cm, 10-20 cm, and 20-30 cm) in plots tilled conventionally was 22.12 ± 6.62%, 23.62 ± 4.88%, and 22.52 ± 4.22%, respectively. Plots managed under reduced tillage practices exhibited a mean (± s.d.) aggregate stability of 26.55 ± 6.73%, 26.74 ± 4.31%, and 32.15 ± 29.91% over the depths of 0-10 cm, 10-20 cm, and 20-30 cm, respectively.

Second Start, End Results

Aggregate Stability will be determined on soil cores collected in early spring of 2008, prior to any tillage events.

Soil Biological Measures

<u>*Epigeal Arthropods*</u>

First Year Start (Corn Year)

The number of microarthropods collected through the pitfall trapping method varied with sampling date (Table 2). Arthropods numbers were higher in July compared to the November sampling date. Collembolans were the most frequently detected arthropods in pitfall samples. Mean (± s.d.) collembolan numbers (activity density) over tillage treatments were 523.04 ± 704.66 in the rye/hairy vetch and 588.94 ± 826.64 in the timothy/clover treatments (Table 3). Microarthropod activity density tended to be higher in the conventional tillage treatments than the reduced tillage treatments (Table 4). Collembolan activity density averaged (± s.d.) 685.81 ± 895.78 in conventional tillage plots and 426.17 ± 587.58 in the reduced tillage plots.

Second Year Start (Soybean Year)

Similar to the first year start, the activity density of microarthropods varied among sampling dates with collembolans being the most frequently detected arthropod (Table 2). The activity density of collembolan over tillage treatments averaged (± s.d.) 69.14 ± 52.83 in the rye/hairy vetch and 60.80 ± 44.37 for the timothy/clover treatments (Table 3). Microarthropod activity density tended to be higher in the reduced tillage treatments than the conventional tillage treatments (Table 4). Collembolan activity density averaged (± s.d.) 57.97 ± 37.37 in conventional tillage plots and 71.93 ± 57.37 in the reduced tillage plots.

Second Year Start (Corn Year)

Similar to 2006, the number of microarthropods collected through the pitfall trapping method varied with sampling date (Table 5). Arthropod numbers (activity density) were higher in the July sampling than in the November sampling. Mites were the most frequently detected arthropods in pitfall samples (Table 6). Mean mites numbers (± s.d) over tillage treatments were 76.15 ± 80.55 in the rye/hairy vetch treatment and 106.10 ± 104.19 in the timothy/clover treatment. Mean collembolan numbers (± s.d) over tillage treatments were 73.44 ± 67.25 in the rye/hairy vetch and 70.04 ± 33.82 in the timothy/clover treatments (Table 6). Microarthropod activity density tended to be higher in the conventional tillage treatments than the reduced tillage treatments for mites but lower for collembolans (Table 7). Mite activity density averaged (± s.d.)

106.48 ± 106.24 in conventional tillage plots and 75.77 ± 77.67 in reduced tillage plots. Collembolan activity density averaged (± s.d) 60.69 ± 31.62 in conventional tillage plots and 82.79 ± 66.50 in the reduced tillage plots.

Table 2. Mean numbers (± s.d.) (activity density) 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 2006 for both starts.

2006 Sampling Date Comparison

Start 1 (Corn)

Date	Mites	Collembolans	Micros	Total Micros	Total Macros
6/30/2006	60.19 ± 86.96	1064.27 ± 808.61	27.79 ± 19.02	1152.25 ± 809.52	69.19 ± 27.96
11/2/2006	5.10 ± 6.25	47.71 ± 23.25	1.27 ± 1.70	54.08 ± 25.17	69.19 ± 27.96

Start 2 (Soybean)

Date	Mites	Collembolans	Micros	Total Micros	Total Macros
6/30/2006	17.98 ± 18.72	94.02 ± 50.38	10.63 ± 8.92	122.63 ± 60.78	75.63 ± 26.44
8/21/2006	17.30 ± 15.85	54.96 ± 52.75	7.98 ± 8.01	78.56 ± 54.64	59.92 ± 30.15
11/2/2006	11.77 ± 17.41	45.81 ± 24.52	0.77 ± 1.12	58.35 ± 34.17	75.63 ± 26.44

Table 3. 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 2006 for both starts where plots were either initially planted with rye/hairy vetch or timothy/clover cover crops.

2006 Cover Crop Comparison

Fist Year Start (Corn)

Crop	Mites	Collembolans	Micros	Total Micros	Total Macros
Rye/HV	22.50 ± 28.54	523.04 ± 704.66	13.17 ± 14.47	558.71 ± 724.41	69.13 ± 20.88
Tim/Clov	42.79 ± 90.15	588.94 ± 826.64	15.90 ± 22.60	647.63 ± 861.96	69.25 ± 33.59

Second Year Start (Soybean)

Crop	Mites	Collembolans	Micros	Total Micros	Total Macros
Rye/HV	16.79 ± 18.11	69.14 ± 52.83	6.51 ± 7.89	92.44 ± 62.40	69.96 ± 29.05
Tim/Clov	14.54 ± 16.88	60.80 ± 44.37	6.38 ± 8.31	80.58 ± 51.86	70.82 ± 28.18

Table 4. 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 2006 for both starts where full= conventional tillage and min= reduced tillage.

2006 Tillage Comparison

Fist Year Start (Corn)

Tillage	Mites	Collembolans	Micros	Total Micros	Total Macros
Full	35.33 ± 63.73	685.81 ± 895.78	16.08 ± 23.16	737.23 ± 930.46	64.67 ± 20.58
Min	29.96 ± 71.24	426.17 ± 587.58	12.98 ± 13.52	469.10 ± 607.71	73.71 ± 33.15

Second Year Start (Soybean)

Tillage	Mites	Collembolans	Micros	Total Micros	Total Macros
Full	16.76 ± 20.33	57.97 ± 37.37	6.63 ± 8.62	80.24 ± 45.17	64.72 ± 26.85
Min	14.60 ± 14.19	71.93 ± 57.37	6.26 ± 7.55	92.79 ± 67.34	76.06 ± 29.19

Table 5. Mean (± s.d.) numbers (activity density) 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 2007.

2007 Sampling Date Comparison
Second Year Start (Corn)

Date	Mites	Collembolans	Micros	Total Micros	Total Macros
7/2/2007	144.58 ± 104.57	95.71 ± 61.25	10.67 ± 13.63	250.96 ± 130.94	54.52 ± 20.10
11/1/2007	37.67 ± 32.09	47.77 ± 27.34	2.25 ± 2.85	87.69 ± 52.79	38.69 ± 48.53

Table 6. 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 2007 where plots were either planted with rye/hairy vetch or timothy/clover cover crops in 2005.

2007 Cover Crop Comparison
Second Year Start (Corn)

Crop	Mites	Collembolans	Micros	Total Micros	Total Macros
Rye/HV	76.15 ± 80.55	73.44 ± 67.25	4.35 ± 9.19	153.94 ± 131.73	50.92 ± 44.01
Tim/Clov	106.10 ± 104.19	70.04 ± 33.82	8.56 ± 11.69	184.71 ± 125.33	42.29 ± 30.20

Table 7. 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 2007 where full= conventional tillage and min= reduced tillage.

2007 Tillage Comparison
Second Year Start (Corn)

Tillage	Mites	Collembolans	Micros	Total Micros	Total Macros
Full	106.48 ± 106.24	60.69 ± 31.62	7.69 ± 11.62	174.85 ± 128.85	46.50 ± 35.05
Min	75.77 ± 77.67	82.79 ± 66.50	5.23 ± 9.59	163.79 ± 129.92	46.71 ± 40.72

Soil Arthropods

Mean mite and miscellaneous microarthropod numbers were higher in the rye/hairy vetch treatment than in timothy/clover treatment (Table 8). Mean number (± s.d.) of collembolans were higher in the timothy/clover treatment. Mean (± s.d.) number of collembolans, other microarthropods, and nematodes were higher in fields tilled conventionally (Table 9).

Table 8. Mean numbers (± s.d.) of arthropods collected per soil sample averaged over tillage system using the Tullgren funnel method in 2007 in plots that were planted with either rye/hairy vetch or timothy/clover in 2005.

2007 Cover Crop Comparison

Start	Crop	Mites	Collembolans	Other Micros	Nematodes
Second	Rye/HV	5.54 ± 6.97	0.67 ± 0.96	1.08 ± 1.86	1.04 ± 1.30
Second	Tim/Clov	3.00 ± 3.23	0.58 ± 0.83	0.96 ± 1.12	1.75 ± 3.34

Table 9. Mean numbers (± s.d.) of arthropods collected per soil sample averaged over crop type using the Tullgren funnel method in 2007 where full= conventional and min= reduced tillage.

2007 Tillage Comparison

Start	Crop	Mites	Collembolans	Other Micros	Nematodes
Second	Full	2.67 ± 2.24	0.75 ± 0.85	1.08 ± 1.47	1.92 ± 3.30
Second	Min	5.88 ± 7.21	0.50 ± 0.93	0.96 ± 1.60	0.88 ± 1.30

<u>*Soilborne Insect Pathogens*</u>

Detection rates using the *G. mellonella* baiting method were highly variable (Figures 6 and 7). Mean infection ranged from 0-100 %, with a mean (± s.d.) infection rate of 29.0% (2.90 ± 2.55 *Galleria*/sample) for *M. anisopliae* and 0.2% (0.02 ± 0.18 *Galleria*/sample) for *B. bassiana* collected from the second year start (corn production year). When averaging the infection rate over tillage system, the mean (± s.d.) detection of *M. anisoplia* in the rye/hairy vetch was 25.8% (2.58 ± 2.42 *Galleria*/sample) and 32.1% (3.21 ± 2.64 *Galleria*/sample) in the timothy/clover treatment. Conversely, the mean (± s.d.) infection rate for *B. bassiana* was 0.2% (0.02 ± 0.14 *Galleria*/sample) in rye/hairy vetch and 0.2% (0.02 ± 0.20 *Galleria*/sample) in timothy/clover treatments. When comparing tillage treatments, the mean (± s.d.) infection rate of *M. anisopliae* was 26.5% (2.65 ± 2.41 *Galleria*/sample) in the conventional tillage and 31.5% (3.15 ± 2.66 *Galleria/*sample) in the reduced tillage treatment. The mean (± s.d.) infection rate by *B. bassiana* was 0.2% (0.02 ± 0.14 *Galleria*/sample) in reduced tillage and 0.2% (0.02 ± 0.20 *Galleria*/sample) in conventional tillage treatments.

EPN was detected in field 23 in the second start during the 23 July sampling and in field 36 during the 2 October sampling.

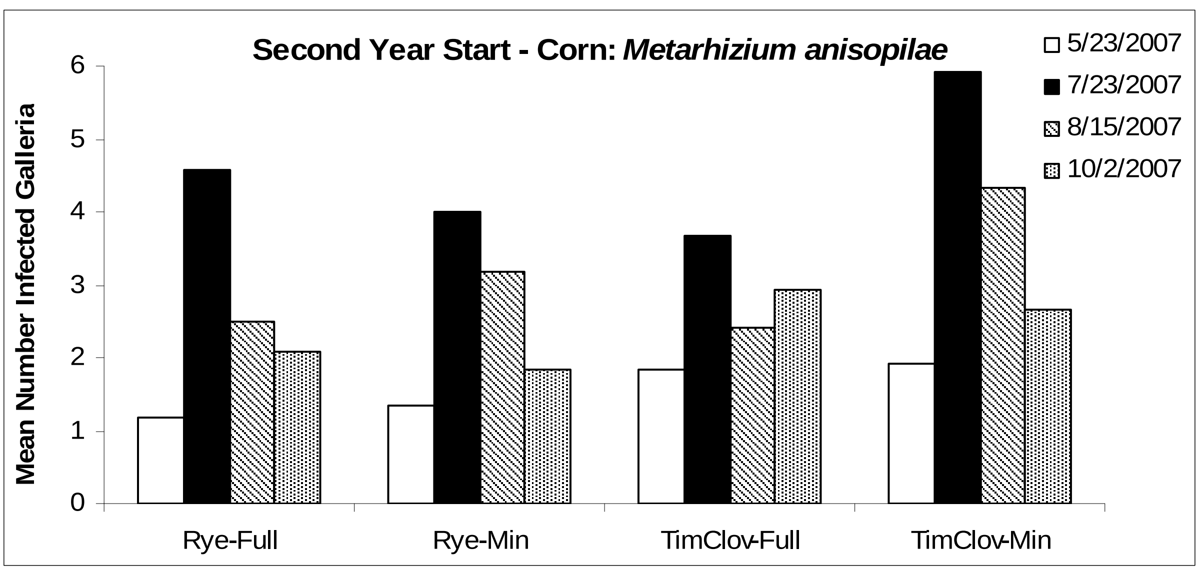

Figure 6. Mean infection rates of *Galleria mellonella* by *Metarhizium anisopliae* in soil samples collected in 2007, shown by sampling date for each cover crop/tillage treatment for the second year start (corn) where full= conventional tillage and min= reduced tillage.

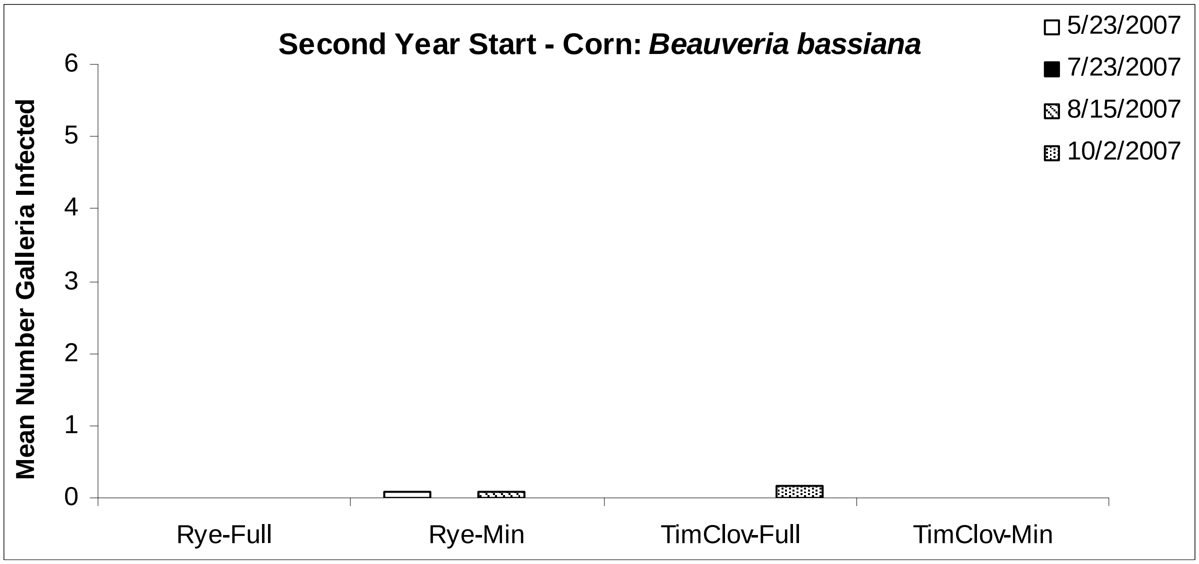

Figure 7. Mean infection rates of *Galleria mellonella* by *Beauveria bassiana* in soil samples collected in 2007, shown by sampling date for each cover crop/tillage treatment for the second year start (corn) where full= conventional tillage and min= reduced tillage.

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 2007. The three seeded weed species in the second year start (corn production year) were 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 during the cover cropping years for both starts (Table 10). Foxtail numbers in both cover cropping treatments reduced dramatically in the soybean year and were comparable to lambsquarters (Table 11). Lambsquarters and foxtail numbers remained similar in the rye/hairy vetch plots under reduced tillage in the corn year (Table 12). Conversely, lambsquarters numbers were much higher than the foxtail in the rye/hairy vetch conventional tillage and timothy/clover plots under either tillage treatment.

Weed numbers outside of the weed density subplots were high in pigweed, thistle, bindweed, and lambsquarters in 2007 (Table 13). Reduced till plots had a proportionality higher number of these weeds compared to conventionally tilled plots.

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 the first start have increased drastically over the last three years in fields that experienced reduced tillage (Table 14). The conventional tillage treatments exhibited similar Canada thistle numbers over the three year period. Canada thistle numbers in the second start are lower than in the first start plots (Table 15). The reduced tillage treatments exhibited higher Thistle density in than the conventional tillage treatments.

Table 10. Mean (±s.e.) weed seedling densities/ 0.25m² in the first and second year starts (cover cropping year) according to cover crop treatment (rye/hairy vetch and timothy/red clover (T/C)) and tillage treatments (conventional = full and reduced = min) across the three weed subplot densities (low, medium and high) for lambsquarters (lambsq) (*Chenopodium album* L.), velvetleaf (*Abutilon theophrasti* Medicus), and foxtail (*Setaria spp.*). Weed counts corrected for background population.

		Start 1: Cover Crop Year (2004)			**Start 2: Cover Crop Year (2005)**		
Treatment	**Weed Spp**	**H**	**M**	**L**	**H**	**M**	**L**
Rye-Full	Foxtail	169.40 ± 55.20	22.85 ± 22.85	24.10 ± 24.10	18.25 ± 2.56	14.50 ± 2.50	6.00 ± 3.67
	Lambsq.	1.30 ± 0.93	1.85 ± 0.90	0.30 ± 0.24	0.10 ± 0.10	0 ± 0	0 ± 0
	Velvetleaf	56.95 ± 8.10	15.45 ± 3.68	0.75 ± 0.48	4.00 ± 0.82	0.50 ± 0.50	0.50 ± 0.50
Rye-Min	Foxtail	10.80 ± 10.80	99.70 ± 62.50	4.05 ± 4.05	15.25 ± 5.19	7.00 ± 2.48	3.50 ± 3.50
	Lambsq.	2.60 ± 1.20	0 ± 0	0.75 ± 0.68	0 ± 0	0.15 ± 0.15	0.15 ± 0.15
	Velvetleaf	56.00 ± 8.39	14.50 ± 3.59	5.75 ± 0.93	3.00 ± 1.08	3.50 ± 2.87	0 ± 0
T/C-Full	Foxtail	10.15 ± 4.04	0 ± 0	0 ± 0	4.50 ± 1.50	0 ± 0	1.50 ± 0.87
	Lambsq.	12.75 ± 10.54	2.00 ± 1.62	5.00 ± 2.89	1.35 ± 1.35	0 ± 0	0 ± 0
	Velvetleaf	37.15 ± 17.30	1.90 ± 1.10	0.50 ± 0.50	0.25 ± 0.25	1.00 ± 0.71	1.00 ± 0.58
T/C-Min	Foxtail	1.80 ± 1.41	1.60 ± 1.60	2.35 ± 2.03	5.25 ± 3.04	0.75 ± 0.75	0.75 ± 0.75
	Lambsq.	2.25 ± 1.87	9.50 ± 5.48	2.70 ± 2.44	1.00 ± 1.00	0 ± 0	3.20 ± 2.09
	Velvetleaf	25.20 ± 17.56	10.25 ± 5.95	2.95 ± 2.36	2.00 ± 1.41	0 ± 0	1.25 ± 0.75

Table 11. Mean (±s.e.) weed seedling densities/ 0.25m² in the first and second year starts (soybean year) according to cover crop treatment (rye/hairy vetch and timothy/red clover (T/C)) and tillage treatments (conventional = full and reduced = min) across the three weed subplot densities (low, medium and high) for lambsquarters (lambsq) (*Chenopodium album* L.), velvetleaf (*Abutilon theophrasti* Medicus), and foxtail (*Setaria spp.*). Weed counts corrected for background population.

		Start 1: Soybean Year (2005)			**Start 2: Soybean Year (2006)**		
Treatment	**Weed Spp**	**H**	**M**	**L**	**H**	**M**	**L**
Rye-Full	Foxtail	12.10 ± 1.75	6.55 ± 2.56	1.05 ± 1.05	4.45 ± 2.60	3.35 ± 1.51	11.10 ± 2.88
	Lambsq.	14.75 ± 1.51	7.00 ± 2.43	12.40 ± 4.70	4.45 ± 1.55	3.35 ± 1.51	2.95 ± 1.73
	Velvetleaf	6.75 ± 1.44	3.75 ± 0.48	8.25 ± 2.56	14.50 ± 1.26	8.25 ± 0.48	5.50 ± 1.04
Rye-Min	Foxtail	9.70 ± 2.53	10.90 ± 3.80	10.20 ± 3.65	4.75 ± 2.08	5.65 ± 2.57	1.25 ± 1.25
	Lambsq.	9.30 ± 1.86	5.80 ± 2.09	12.80 ± 0.83	3.10 ± 1.77	2.90 ± 2.34	0.45 ± 0.45
	Velvetleaf	7.75 ± 0.75	6.00 ± 1.08	5.00 ± 0.71	9.25 ± 5.65	8.55 ± 3.42	6.80 ± 0.58
T/C-Full	Foxtail	2.00 ± 2.00	2.20 ± 1.43	1.50 ± 0.61	1.20 ± 1.20	0.95 ± 0.95	1.20 ± 0.71
	Lambsq.	5.70 ± 3.15	1.55 ± 0.90	4.45 ± 2.40	14.85 ± 0.57	13.10 ± 0.97	3.85 ± 0.87
	Velvetleaf	5.20 ± 2.03	3.95 ± 1.81	2.25 ± 1.93	17.00 ± 7.36	5.70 ± 3.57	6.45 ± 1.47
T/C-Min	Foxtail	4.75 ± 0.95	1.75 ± 1.03	1.25 ± 0.75	3.20 ± 2.44	3.20 ± 2.12	0.45 ± 0.33
	Lambsq.	2.15 ± 1.56	0.75 ± 0.75	1.60 ± 0.93	16.05 ± 3.14	13.30 ± 0.90	3.95 ± 1.45
	Velvetleaf	6.75 ± 0.25	2.25 ± 0.25	1.00 ± 0.41	20.00 ± 1.91	9.25 ± 3.20	6.25 ± 2.10

Table 12. Mean (±s.e.) weed seedling densities/ 0.25m² in the first and second year starts (corn year) according to cover crop treatment (rye/hairy vetch and timothy/red clover (T/C)) and tillage treatments (conventional = full and reduced = min) across the three weed subplot densities (low, medium and high) for lambsquarters (lambsq) (*Chenopodium album* L.), velvetleaf (*Abutilon theophrasti* Medicus), and foxtail (*Setaria spp.*). Weed counts corrected for background population.

		Start 1: Corn Year (2006)			Start 2: Corn Year (2007)		
Treatment	**Weed Spp**	**H**	**M**	**L**	**H**	**M**	**L**
Rye-Full	Foxtail	0.50 ± 0.50	2.25 ± 1.65	2.35 ± 1.75	6.60 ± 4.57	0.20 ± 0.20	0.20 ± 0.20
	Lambsq.	7.60 ± 5.38	7.35 ± 4.85	0.35 ± 0.35	12.00 ± 11.73	0.20 ± 0.20	0 ± 0
	Velvetleaf	1.90 ± 1.38	0.15 ± 0.15	0.50 ± 0.50	2.75 ± 1.03	0 ± 0	0 ± 0
Rye-Min	Foxtail	3.75 ± 2.17	8.75 ± 8.75	2.35 ± 1.52	4.25 ± 1.33	2.95 ± 1.68	0.60 ± 0.60
	Lambsq.	9.25 ± 3.42	9.00 ± 2.74	4.50 ± 1.04	4.25 ± 2.28	0 ± 0	1.60 ± 1.29
	Velvetleaf	1.75 ± 1.03	0 ± 0	0 ± 0	1.00 ± 0.41	0.25 ± 0.25	0 ± 0
T/C-Full	Foxtail	1.10 ± 0.53	2.60 ± 1.65	0.85 ± 0.72	1.20 ± 1.20	0.65 ± 0.65	0.25 ± 0.15
	Lambsq.	3.40 ± 2.40	1.50 ± 1.19	0.40 ± 0.24	40.65 ± 37.84	0.15 ± 0.15	45.50 ± 34.36
	Velvetleaf	2.00 ± 1.22	0.75 ± 0.48	0 ± 0	0.25 ± 0.25	0 ± 0	0.25 ± 0.25
T/C-Min	Foxtail	3.40 ± 1.48	14.75 ± 8.41	6.25 ± 2.51	13.70 ± 4.96	3.50 ± 1.85	0 ± 0
	Lambsq.	11.05 ± 7.48	5.05 ± 2.53	2.80 ± 1.36	13.95 ± 13.95	0 ± 0	0 ± 0
	Velvetleaf	1.25 ± 1.25	1.75 ± 1.18	0 ± 0	1.25 ± 1.25	2.00 ± 1.41	0.50 ± 0.50

Table 13. Mean (± s.d) Foxtail spp. (*Setaria spp.*), Hedge bindweed (*Calystegia sepium*), Lambsquarters (*Chenopodium album* L.), and Pigweed spp. (*Amaranthus spp.)* in Start 2 of an organic maize (2007) sequence in response to initial cover crop (2004) and soil management (full = conventional tillage and min = reduced tillage) per 0.25m². Weed data is from random sampling and not from weed density subplots.

	Weed spp			
Treatment	Foxtail spp	Hedge Bindweed	Lambsquarters	Pigweed spp
Rye-Min	1.10 ± 1.55	3.05 ± 5.01	3.00 ± 2.15	98.50 ± 96.78
Rye-Full	0.35 ± 0.59	0.60 ± 1.64	9.20 ± 15.64	17.70 ± 12.67
Tim/Clov-Min	2.25 ± 4.64	0.50 ± 1.15	39.55 ± 29.81	75.05 ± 44.19
Tim/Clov-Full	0.65 ± 0.99	0.55 ± 0.76	14.50 ± 25.25	16.65 ± 11.60

Table 14. Mean (± s.d) Canada thistle (*Cirsium arvense* (L.) Scop.) per 0.25m² in Start 1 of an organic transition soybean (2005) and maize (2006) sequence to initial cover crop (2004) and soil management (full = conventional tillage and min = reduced tillage).

		Crop	
Treatment	Cover Crop	Soybean	Corn
Rye-Min	0.35 ± 1.57	0.40 ± 1.23	2.20 ± 4.31
Rye-Full	1.35 ± 3.25	0.40 ± 1.27	0.40 ± 0.82
Tim/Clov-Min	0.50 ± 1.24	2.45 ± 2.89	5.40 ± 5.32
Tim/Clov-Full	0.25 ± 0.72	1.25 ± 1.74	0.15 ± 0.49

Table 15. Mean (± s.d) Canada thistle (*Cirsium arvense* (L.) Scop.) per 0.25m² in Start 2 of an organic transition soybean (2006) and maize (2007) sequence to initial cover crop (2005) and soil management (full = conventional tillage and min = reduced tillage.

		Crop	
Treatment	Cover Crop	Soybean	Corn
Rye-Min	5.00 ± 4.77	1.40 ± 2.91	1.40 ± 2.70
Rye-Full	2.15 ± 3.41	0.20 ± 0.70	0.40 ± 1.35
Tim/Clov-Min	3.60 ± 3.38	0.70 ± 1.98	0.50 ± 1.05
Tim/Clov-Full	0.90 ± 1.29	0 ± 0	0.15 ± 0.49

Environmental Data

Figures 9 through 12 below exemplify the minimum and maximum, daily soil temperature and moisture content for both cover crop histories in the second year start (corn year). These data will be used as covariates to supplement field sample data sets. Sampling was conducted from mid May through 1 November.

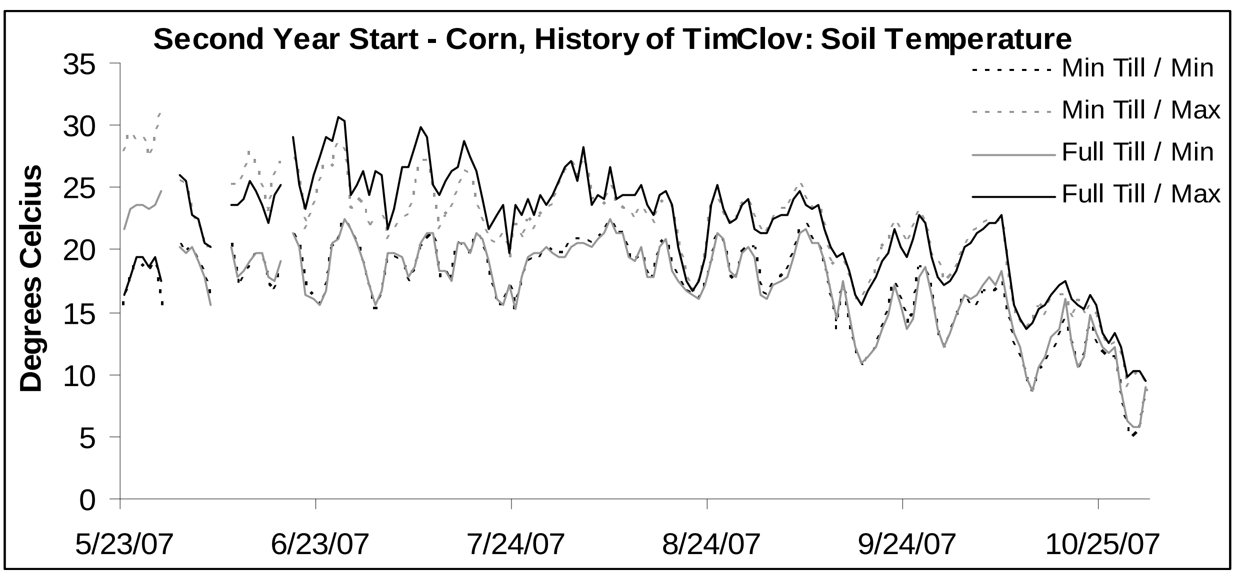

Figure 9. Soil temperature (°C) in 2007 in corn with a history of timothy/clover planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

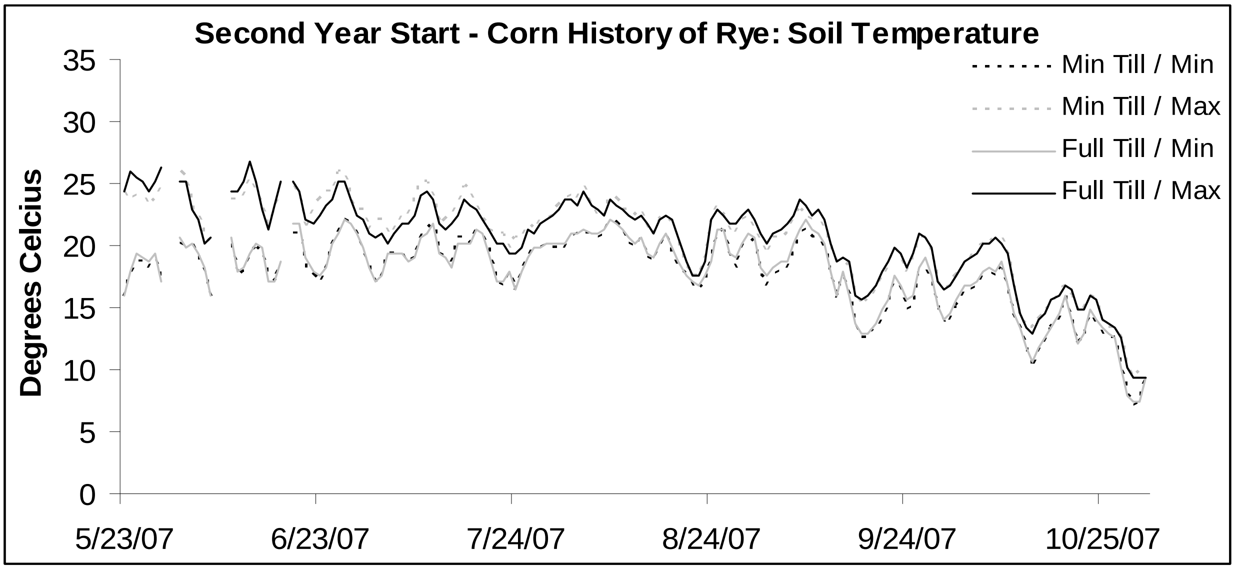

Figure 10. Soil temperature (°C) in 2007 in corn with a history of rye/hairy vetch planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

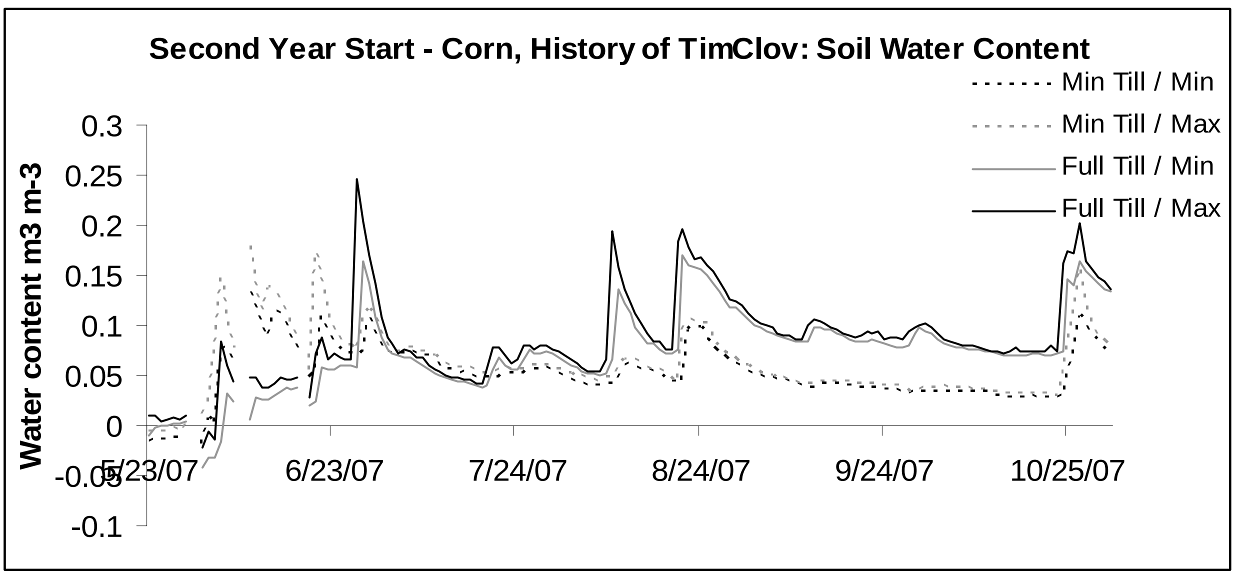

Figure 11. Soil water content (m³/m³) in 2007 in corn with a history of timothy/clover planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

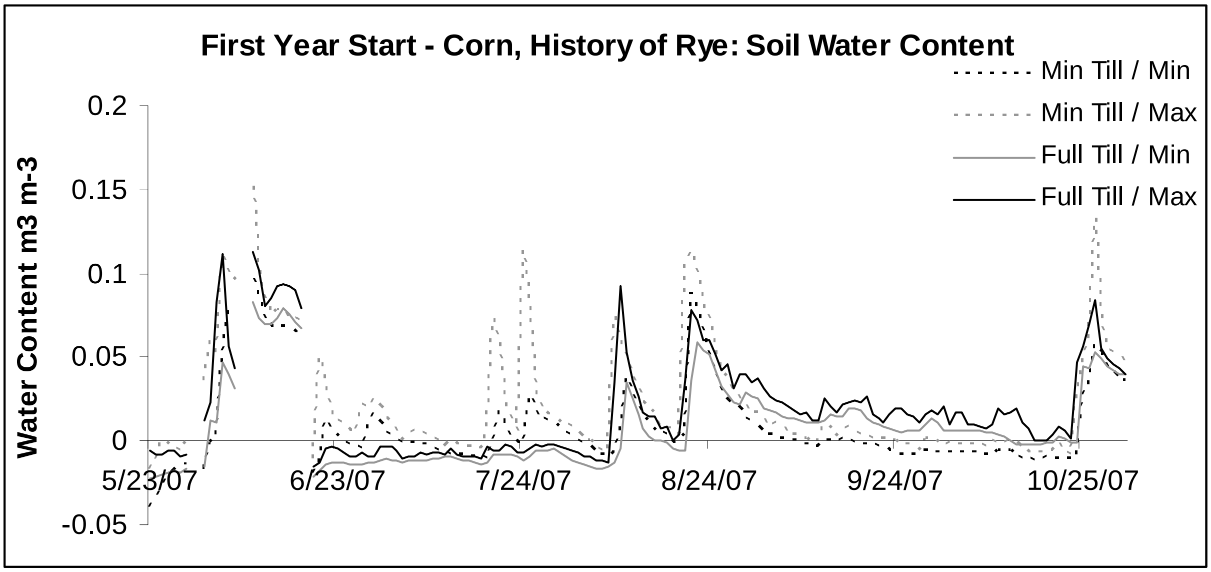

Figure 12. Soil water content (m^3/m^3) in 2007 in corn with a history of rye/hairy vetch planted in 2005 where Min Till= reduced tillage and Full Till= conventional tillage.

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 start years provides a more thorough picture of the economic implications of transitioning using different cover crop methods or tillage methods. Table 11 shows that reduced tillage systems led to lower profitability in the experiments. Soybeans showed average returns being almost $8.00 lower when following timothy and nearly $10.00 lower when following rye. Corn production was sharply lower in the reduced tillage treatment, leading to average returns that were lower than the conventionally tilled treatment by over $50.00 per acre.

Similarly, soybean returns were lower when following rye 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. By comparison, the profitability of corn in the rye treatments was less than $10.00 per acre below that of the timothy treatment.

The final analysis compared the relative costs and returns across the four unique transitional systems. 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 12). 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 11. Average Results of Partial Budget Analyses across Project Start-Years

Comparison	First-Year Start	Second-Year Start	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	- $32.22	- $58.62
Reduced tillage vs. conventional tillage systems in soybeans following rye/hairy vetch	$67.25	- $86.62	- $9.69
Reduced tillage vs. conventional tillage systems in corn following rye/hairy vetch	- $87.98	- $16.34	- $52.16
Soybeans following rye/hairy vetch vs. soybeans following timothy/clover/oats; conventional tillage	- $21.35	- $70.04	- $45.70
Corn following rye/hairy vetch vs. corn following timothy/clover/oats; conventional tillage	$4.22	- $23.74	- $9.76
Soybeans following rye/hairy vetch vs. soybeans following timothy/clover/oats; reduced tillage	$49.78	- $144.07	- $47.15
Corn following rye/hairy vetch vs. corn following timothy/clover/oats; reduced tillage	$1.26	- $7.86	- $3.30

Table 12. Average Cumulative Returns of Four Alternative Transitional Strategies across Both Start Years

Strategy					
Tillage	**Cover Crop**	**Year 1 (Cover Crop)**	**Year 2 (Soybeans)**	**Year 3 (Corn)**	**Total**
Conventional	Timothy/clover/oats	$69.29	- $89.61	$179.30	$158.98
Conventional	Rye/hairy vetch	- $8.21	- $128.74	$169.54	$32.59
Reduced	Timothy/clover/oats	$69.29	- $97.52	$120.68	$92.45
Reduced	Rye/hairy vetch	- $8.21	- $138.35	$117.38	- $29.18

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 2007 related to the above objectives are summarized below.

Teaching Activities

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

Barbercheck, M., R Jabbour, and C. Mullen (Instructors)
Stephen Bond and Suzanne Yocom -Pennsylvania Governor School students (high school) who worked on individual projects related to the field experiments described above. Summer 2007.

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 497A – Principles and Practices of Organic Agriculture (In development for spring 2008)

Sánchez, E., M. Barbercheck, and H. Karsten. (Instructors)
Agroeclology/Horticulture – Organic Horticultural Production. (In development for Fall 2008.

Extension Presentations

Barbercheck, M. Beneficial Insects. PA Crops and Soil Conference, PA Crops and Soils Conference, Oct. 24, 2007, Grantville, PA. (40 attendees, 3 women)

Barbercheck, M. Biological Soil Quality. PA Project Grass Rotational Grazing Field Day, Sept. 12, 2007, Blue Mountain View Farm, Annville, PA. (100 attendees, 10 women)

Barbercheck, M. Soil Quality Workshop. WAgN Field Day, Aug. 1, 2007, Ron Gargasz Organic Farm, Lawrence County, PA. (50 attendees, 20 men, 30 women)

Barbercheck, M. Sustainable and Organic Agriculture. Ag in the Classroom, July 15, 2007. Centre Co., PA. (65 attendees, 50 women, 15 men)

Barbercheck, M. and D. Mortensen. Organic Ag Field Day, June 13, 2007, Rock Springs Agronomy Farm. (60 attendees, 30 men, 30 women)

Barbercheck, M. Cover Crops and Life in the Soil. Cover Crop Research and Management Summit, June 5, 2007, Rock Springs Agronomy Farm. (100 attendees, 75 men, 25 women)

Barbercheck, M. Transition to Organic Production. PA IPM Advisor Board, June 1, 2007. (20 attendees, 15 men, 5 women)

Extension Publications

Barbercheck, M. and E. Sánchez. 2007. Japanese beetle Management for Organic Fruit Farms. Vegetable & Small Fruit Gazette. (September 2007)

Barbercheck, M. and E. Sánchez. 2007. Japanese Beetle Management for Organic Fruit Farms. New York Berry News. (September 2007)

Barbercheck, M. White Grubs in Pastures. Feb 13, 2007. Field Crop News. http://fcn.agronomy.psu.edu/2007/white_grubs_in_pasture.pdf

Barbercheck, M. 2007 Managing Weeds and Soil Quality Organically. PSU-SAWG Sustainable Ag Newsletter. July 2007. p 1-5.

Barbercheck, M., D. Calvin, B. Curran. 2007. Organic Crop Production, in: The Agronomy Guide. PSU COAS.

Kiernen, N.E. Are You Reaching New Agricultural Audiences? Program Evaluation Tipsheet #78, University Park, OA: Penn State Cooperative Extension. http://www.extension.psu.edu/evaluation/pdf/TS78.pdf

Newsletter Articles

Barbercheck, M. (editor) PSU Sustainable Ag Newsletter. Bi-monthly 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

Journal Publications

Rotz, C. A., H. D. Karsten, and R. D. Weaver. 2008. Grass-based dairy production provides a viable option for producing organic milk in Pennsylvania. Forage and Grazinglands. 19.1094/FG-2008-0212-01-RS.

Rotz, C. A., G. H. Kamphuis, H. D. Karsten, and R. D. Weaver. 2007. Organic Dairy Production Systems in Pennsylvania: A Case Study Evaluation. J. Dairy Sci. 90:3961-3979.

Seminar Presentations

Meeting Abstracts

Jabbour, R., A.G., Hulting, M.E., Barbercheck, and C.A. Mullen. 2008. Soil management effects on entomopathogenic fungi during the transition to organic agriculture. Presentation at 78th Annual Entomopathogenic Society of America Eastern Branch Meeting, Syracuse, NY.

Barbercheck, M., D. Mortensen, A. Hulting, R. Jabbour, H. Karsten, E. Sánchez., S. Duiker, J. Hyde, and N.E. Kiernan. 2007. Balancing pest management and soil quality in a transitional system. Entomological Society of America 55th Annual Meeting: Making Connections, San Diego, CA. (abstract)

Jabbour, R., M.E., Barbercheck, A. Gendron, B. Bradley. Habitat complexity effects on entomopathogenic nematode dispersal. Entomological Society of America 55th Annual Meeting: Making Connections, San Diego, CA. (abstract)

Jabbour, R., M.E., Barbercheck, and C.A., Mullen. 2007. Effect of soil management on naturally occurring entomopathogenic fungi during the transition to an organic farming system. Poster presentation at 40^{th} Annual Society of Invertebrate Pathology Meeting, Quebec City, Quebec.

Jabbour, R., A.G., Hulting, M.E., Barbercheck, and C.A. Mullen. 2007. Effect of the method of transition to organic agriculture on naturally occurring soil-dwelling entomopathogenic fungi. Oral presentation at 92nd Annual Ecological Society of America Meeting, San Jose, CA.

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 2006-2007. 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.

Related Unfunded Projects

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.

Interviews with Principle Investigators on the Transition to Organic Project. N.E. Kiernen. (Synthesis is forthcoming).

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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Appendix 1. Timeline of project activities from Spring to Fall 2007.

Date	Operation	People Involved
22-Feb	Corn seed ordered: 2 bags of untreated 36B08 from Marlin Sauers	Christy
Feb/Mar	Manure application: 15 loads over entire 2nd start	Farm Crew
1-Mar	Set up data loggers in the lab to make sure that they were working properly.	Christy
	Process — Original Setting — New Setting	
	Log time — 30 second — 2 minutes	
	Sample time — 4 minutes — 2 minutes	
	Duration — 35 days — 143 days	
	Labeled wires with their corresponding field numbers	
	Replaced severed sensors (plot 32 temp and moisture)	
3-Apr	Tilled 1st start and triangle plot with John Deere 7700 and mulch tiller	Farm Crew
10-Apr	Flagged 2nd strip of 1st start (plots 11-18) and checked with GPS. Used the flagged plots in the 1st start as a reference for the second start. This is because we couldn't find a GPS file for the plot corners of the second start. Tillage differences were somewhat noticeable (min HV vs. Conv.) but exact borders were hard to determine. Flagged 21 - 28 with measuring tape and checked with first start. Eyed 31-38 to line up with 21-28. Placed flags on the outer edge of the tilled areas because they need to till the plots some more. We will go back at a later time to move the flags so that the plots are 90' wide. The widths of some of the fields are between 95 and 100'.	Dave, Jess, Christy
	Scott came out and checked the moisture of the 1st start fields. Soil is still too wet to disk and there is a chance of rain for the next few days.	
21-Apr	Washed out the inside seed boxes of the Brillon seeder according to organic standards	Dave S.
23-Apr	Picked up 2 bags of untreated 36B08 corn from State College and delivered to the Entomology Farm cooler. Marlin won't charge us because it took so long to get the seed. The seed would have cost us $117.00 per bag	Dave S.
	S-tined (Ford 6600) and cultimulched (John Deere 6310) first start and triangle field	Farm Crew
	Planted pea/tricale mix in the first start with international grain drill and Ford 3930	
	Chisel plowed min till plots in the second start with the Ford 6600.	
24-Apr	Washed out the Brillon seeder and John Deere 955 tractor according to organic standards. Seeded the 12 beds of demo cover crops at the base the triangle plot. The Brillon seeder and John Deere 955 were borrowed from Agronomy. Each bed measures 10' wide and runs parallel to the gravel road. Cover crop beds consisted of: Pea/oats/vetch mix, field pea/spring oats mix, spring oats/tricale mix, spring oats, alfalfa/spring oats mix, buckwheat/jap millet mix, buckwheat, jap millet, red clover, rapeseed, red clover/rapeseed, red clover/rapeseed/jap millet mix.	Dave S.
	Planted tricale in triangle plot with international seed drill and Ford 3930	Farm Crew
	Moldboard plowed full till plots in the second start with Ford 6600	

27-Apr	Planted giant foxtail seed in the cover crop demo plots (2 g of seed per 10' plot). Seed was placed 7' in from the edge (closest to the transition plots) and ran the length of the field, crossing all 12 cover crop plots (parallel to the 1st and 2nd start strips). Flagged with red flags and ran a tape measure along the plots to create a straight line. See truck book for detailed methods.	Dave S.
1-May	Disked second start plots (both tillage treatments) with McConnell disk and Ford 6600	Farm Crew
4-May	Re-flagged both starts. Tried to base flagging off of the second start because the current tillage reflects those corners. We had problems because we were missing some flags. Used GPS to check the first start. GPS was off by at least 6' (had the one corner of the first plot in the middle of the gravel road).	Dave, Jess, Christy
	Measured the widths for both starts. The first start had adjustments between 1' 5" to 4' 5.4". The second start had adjustments between 2" and 9'	
	Flagged weed seed density plots (1st start) using GPS and plot map. Pink = low, Yellow = medium, Blue = high. First start map's density points correspond with the GPS file.	
	2nd start field map's density points are actually the 1st start density points. Need to find a file that has which points are high, medium, and low.	
	Picked up trash in 2nd start (2 bags)	
8-May	1st start: five random thistle counts per plot using white metal quadrats (4940 cm2). Flipped quadrats so we were able to sample 9880 cm2. Dave S. found and flagged the weed density subplots.	Dave M. Steve K, Mary, Dave S, Jessie, Randa, Christy
	2nd start: density counts and five random weed counts per plot using white pvc quadrat (50.2 cm * 50.9 cm). Included plant in count if meristem was in the quadrat (pertains to weed that may be covered by the quadrat's edge)	
	Placed a purple flag in the corner closest to the gravel road and triangle plot for one of the random counts (same approach as in the weed count procedures). This will now be considered a control background count. Control plots were marked on data sheet so we can track the weed counts over the next two counts. (see truck book for diagram)	
	General observations: full till had hardly any weeds. Seedlings at the thread stage. Soil hard, especially plots 28 and 38. Min till plots had perennial weed clumps throughout the plots. Commonly found weeds when walking through fields with Mary and Dave M. included: chickweed (large clumps), hairy vetch, volunteer timothy, quackgrass clumps, shepherd's purse, dock, pennycress, primrose, yellow mustard, pineapple weed, and dandelion.	
	We still need to do an annual weed count in the first start. Weeds were too small to count them today.	

9-May	Placed permanent markers for each plot border for both starts (45 markers total). Markers consist of a 6' piece of pvc pipe buried flush to the soil. One metal nut was placed in the center of the pipe to aid in finding the markers again at a later date. They were placed in the middle of each drive row and lined up with the flags marking the corners of each plot. Measurements were taken from the center of the pvc pipe to the edge of the plots. There were two flags; the inner represents the actual border of the plots and the outer represents the edges of the tillage treatments. Measurements were made for all four corners for each plot in case we lose some markers later on. (see truck book for diagram and measurements)	Christy, Jessie, Dave S., Steve K
	Found and recorded GPS points for the control sub-plots and marked them on the plot map.	
	Removed the inner plot flags and the weed density flags in the second start	
10-May	Downloaded data loggers that were set up on 3/1/07 to see if they were working properly	Christy
	Removed stones in second start with loader and John Deere 6310	Farm Crew
	S-tined and cultimulched the 2nd start plots (both tillage treatments) with the Ford 6600	
11-May	Planted the corn in the 2nd start (both tillage treatments) new idea planter and Ford 3930 (am) at the rate of 28,000 seeds/acre (30" or 76cm rows)	Farm Crew
	Buried data loggers in start 2 (fields 23/24 and 31/32) right on the border of both plots. Buried them at the plot edge and not where the tillage/planting began (at least 3 ft in from edge of tillage). Sensors crossed the crop rows at a 45° angle with the moisture sensor crossing 2 crop rows and the temperature sensor crossing one. Placed a pvc pole directly behind the weather station so that they are easy to find and won't get run over by the farm equipment. Flagged from the tilled edge to the tip of the moisture sensors with pink flags (see truck book for diagram)	Christy and Jessie
15-May	Re-flagged the second start using the permanent markers. Measured the plot length of some of the plots and moved the marker for 28/38 3" towards 45 and moved the marker for 38 towards the gravel road 4'. Moved 35 flag towards gravel road 3' 11" (need to move marker).	Christy and Jessie
	Half of the markers were found through the use of a metal detector. We will need to add more nuts.	
	Buried the data loggers from the first start in some end fields in the second start. 3/4 station was buried in 26/27 and 13/14 was buried in 36/37. Set up is the same as on 5/11/07.	
	Downloaded data loggers 23/24 and 31/32. Both appear to be working fine	
	Put up the DO NOT SPRAY signs in the two corners along the gravel road (triangle plot and edge of 31) and at the edge of 38 towards the high tunnels. The fourth sign needs to be repaired before it gets put out.	

	Soil is dry. Some areas were moist while digging, usually the grassy areas. When we dug to bury the data loggers, the soil was dry and fell back into the hole.	
18-May	Rained on the 16th	Steve K, Randa, Jessie, Alyssa, Dave S. and Christy
	Performed density counts in the first start (weed density plots flagged on May 8th).	
	Counted the area on the side of the flag closest to the high tunnels and Rt 45. (see protocol for diagram) using a white PVC quadrat with an area of 0.25 m2	
	Created a control plot to compare against density plots by randomly placing quadrat in the field and marking it with a purple flag.	
	Dave recorded GPS points for control plots in first start	
	Some fields had a lot of thistle and hedge bindweed	
	Weeds commonly found included: lambsquarter (lots), thistle (lots), henbit, foxtail, dandelion, chickweed, hedge bindweed (lots), buckwheat, and volunteer corn.	
23-May	Soil sampled both starts. First start: 5 cores/rep and 3 reps/plot (for AAL analysis).	Randa, Dave S., Jessie, Alyssa, Christy
	Second start: 15 cores/rep and 3 reps/plot.	
	Both starts were sampled randomly between crop rows and at least 10' in from the edge of the plot	
	Moved data logger 23/24 to 21/22 so all 4 treatments would be represented. 26/27 was moved to 25/26 and 36/37 was moved to 35/36 for the same reason. Data loggers were stopped prior to removal from the ground. We will toss out the data collected prior to this date.	
	Downloaded 31/32	
	Re-dug a hole for one of the DO NOT SPRAY signs	
	Mowed the grass roadways and field perimeter with the Ford 3930 and brush hog (tires and mower were washed off before mowing)	
30-May	Downloaded and stopped data loggers. Pulled sensors and flags. Wrapped sensors around PVC pole	Dave M., Jessie, Alyssa, Dave S., Christy, Vaughn
	Added metal nuts to the top (~0.25 to 0.5" of soil in the permanent markers)	
	Vaughn rotary hoed 2nd start (all tillage treatments) with the Ford 3930	
	Vaughn cultivated min till plots in the second start (both cover crop histories) with the Ford 3930	
	Mowed off thistle heads in start 1 (pea/triticale) with Bush-hog and Ford 6600	
	Took pics of field as Vaughn rotary hoed	
	Rotary hoe wasn't very effective in 2nd start min till fields. Especially on the thistle, hedge bindweed, pigweed, and volunteer timothy	
	Dave M. decided to have Scott and Vaughn cultivate the corn either today or tomorrow	
	Dave S. pulled out the weed density flags in the first start so he could mow off the thistle tops in the first start with the Ford 6600 and brush hog	

	Barbercheck lab pulled out orange flags in first start (inner, plot border flags)	
	Dave M. suggested tilling the borders of the plots (area between drive path and plot border) to straighten the plot lines	
	Christy mentioned to both Daves about possibly seeding something in the tilled areas to prevent weeds from overtaking that area	
31-May	Re-buried and launched data loggers (drop the 1st ten min. for 25/26 and 35/36 because they were launched before all sensors were buried).	Alyssa, Jessie, Christy
	Picked up trash in both starts	
	Plot 27 has two rows near the back that are almost completely without corn. Possibly a result of the cultivation. This was seen in other areas of the plot and some of the corn was damaged by the cultivation.	
	Weed whacked around edges of the cover crop plots in the triangle field for the June 1 field day	Dave S.
	Weeded thistle out of the corner of plot 1 of the cover crop plots in the triangle field	
1-Jun	Placed signs in cover crop plots to label the different plots for the field day	Dave S.
5-Jun	Flagged 2nd start density subplots using GPS and field map	Dave S.
6-Jun	2nd start weed counts (2nd count this season). 3 density subplots, 4 random, 1 control (counted as random) found with GPS	Steve K, Dave S., Randa, Alyssa, Jessie, and Christy
	Placed white pvc quadrat (0.25m2) on the high tunnel/Rt 45 side of the flag and counted the in and between row weeds	
	Velvetleaf was found near the medium and high seeded densities but weren't within the area we counted based on the flags	
	Plots 21 and 31 were weedier than the min till plots located further down the strips	
	Weeds counted included: pigweed (lots), lambsquarter, bindweed, buckwheat, foxtail (giant, yellow, green), nightshade, thistle, henbit, velvetleaf (more in field than actually counted), ragweed, dandelion, nutsedge, knotweed, purslane, soybean, vetch, timothy, and quackgrass.	
	There is a lot of thistles in the fields but they are patchy, counts may not reflect the density of the thistle	
6, 7-June	Second start fields (all treatments) were cultivated (21-27 and 31-37). Plots 28 and 38 will be cultivated tomorrow (6/7). Dave S. had to follow the tractor throughout the field to make sure the corn wasn't damaged. They had to slow down the tractor to prevent the cultivator from skipping (start 2 is very rocky). Cultivator (Ford 3930) was adjusted to cultivate 1 inch shallower than the 5/31/07.	Vaughn and Dave S.
7-Jun	Stopped data loggers for cultivation	Alyssa, Jessie, Christy
	Took pics of field prior to cultivation	
	Took pics of soil and weeds around the weather stations because these areas are weedier. Partly because it's hard to manipulate the equipment around the weather stations, even though the sensors are pulled up. At least one side of the weather station seems to not receive tillage/cultivation. This may affect soil temp and moisture.	
8-Jun	Re-buried and started loggers	Alyssa, Jessie, Christy
	Took pics of the cultivation	

	Still in-row weeds in the lower min-till plots	
	Weeds where sensors are were cultivated	
11-Jun	Mowed pathways for field day and mowed around the plots using the Ford 3930 and 6' bush hog (washed off according to organic standards).	Dave S.
	Mowed pathway between plots 6/7 and 16/17 in the 1st start and a down the center of the cover crop demo plots	
18-Jun	Mowed buckwheat cover crop plots in triangle fields so that it wouldn't go to seed. Used the Ford 6600 and 12' bush hog (washed off according to organic standards)	Dave S.
	Stopped and removed data loggers for cultivation (a.m.)	Alyssa, Jessie, Christy
	Re-buried and started loggers (afternoon)	
	Cultivated 2nd start plots (all) with Ford 3930.	Farm Crew
19-Jun	Buried pitfall deli containers in the 2nd start. 3/plot, randomly place near the crop row but not in it. (see diagram in truck book) No particular direction, some closest to 45 and some closest to gravel road. A pink flag was placed near the pitfall and at the end of the corn row. When re-entering the flag is to the right of the row that has the pitfall (for each strip)	Randa, Jessie, Alyssa, Dave S., and Christy
21-Jun	Mowed corn that was planted beyond the plot borders	Dave S.
	Re-measured the plot corners and moved the pink flags in so they wouldn't be mowed.	Alyssa, Jessie, Christy
25-Jun	Flagged 2nd start weed density plots using the GPS and plot map	Dave S.
26-Jun	Mowed down the pea/tricale in 1st start and the pea/tricale and cover crop demo plots in the triangle field using the Ford 6600 and 12' bush hog (washed off according to organic standards)	Dave S.
27-Jun	Mowed down missed spots in 1st start and triangle field	Dave S.
	Weed whacked cultivated out corn gaps in 2nd start (plots 26, 27, and 37)	
	Checked pitfalls to make sure the rain didn't cause them to pop out of their holes and pulled pink flags to the edge of the plot	Alyssa, Jessie, Christy
	Corn will need to be mowed down again soon	
29-Jun	Opened pitfalls. Fixed one that sank after rainfall to ensure that soil was flush with the deli container lip.	Alyssa, Jessie, Christy
	Soil is moist from rain over Wed and Thurs. Some fields were muddier than others.	
	Bindweed wrapping around corn and almost to corn apex in spots	
	Some fields have a lot of in row weeds: soybean, grass, pigweed, lambsquarter, and thistle.	
	Checked out seed supply in seed cooler: rye ~250 lbs, corn ~4 bags, soybean ~75 lbs, hairy vetch ~1/3 bag, and red clover ~ 30 lbs	
2-Jul	Weed counts: counted between row and in row weeds but entered them in separate columns. Only counted seedlings that appeared to have germinated after the last cultivation. Density plots, control plots (counted as first random) and 4 random counts	Steve K., Mary, Randa, Jessie, Alyssa, Dave S., and Christy
	Picked up pitfalls. Left deli container and funnel in location and capped container.	
	Downloaded data loggers	

3-Jul	Mowed down the corn located outside of the plot borders (2nd cut) using Ford 6600 and 12' bush hog (washed off according to organic standards)	Dave S.
13-Jul	Thistle and hedge bindweed count with governor's school student (Steve Bond) in 2nd start	Christy and Alyssa
	Found ground hog hole and large rock at the end of plot 24	
	Downloaded data loggers	
17-Jul	Mowed down the corn located outside of the plot borders (3rd cut) and around the edges of start 1 and start 2 using Ford 6600 and 12' bush hog (washed off according to organic standards)	Dave S and Steve K.
	Weed whacked around organic signs and in corn rows that were cultivated out.	
	Removed rock in start 2 and filled in ground hog hole (end of plot 24)	
	Flagged around ground hog hole with purple flag and at the end of the rows	
23-Jul	Collected soil samples in 2nd start. 3 reps/location randomly sampled.	Randa, Alyssa, Jessie, Melissa, Dave S., and Christy
	Min till plots were much harder to get the full 6" (especially plot 33)	
	Downloaded data loggers	
30-Jul	Downloaded data loggers	Christy
	There are a lot of Japanese Beetles in the corn plots on both the silks and tassels. Some silks appear to be eaten away completely	
3-Aug	Mowed 1st start for the second time. Mowed with Ford 6600 tractor and 12' bush hog. Washed equipment off according to organic standards	Dave S.
13-Aug	Downloaded data loggers and replaced cover for loggers	Christy, Alyssa, Melissa
14-Aug	Washed seed room shelves and put dividers up and "organic seed only" sign	Dave S.
	Mowed 1st start for the third time. Foxtail was starting to go to seed. Mowed with Ford 6600 and 12' bush hog. Washed equipments according to organic standards.	
	Flagged start 1 for soil sampling and plowing.	
15-Aug	Soil sampled 2nd start. 3 replicates per plot, 12 cores per replicate.	Christy, Alyssa, Melissa, Randa, Dave S
	Took pictures of thistle patch at the end of field 27. Field is stunted in that location.	
30-Aug	Downloaded data loggers	Christy
	Took pictures of tattered corn leaves, browning corn, and grasshoppers	
4-Sep	Downloaded data loggers	Christy
14-Sep	Downloaded data loggers	Christy
	Took pictures of drying corn and weeds	
20-Sep	Downloaded data loggers	Christy
	Took pictures of corn	
	Took pictures of thistle patch along side of plot 31, near the high tunnels where the fields were tilled and not planted with anything	
	Loggers 3 and 4, plot 4's temperature sensor has started to read -800C (started on 9/16/07)	
22-Sep	Downloaded and stopped data loggers for 3 and 4. Replaced #4's temperature sensor. Restarted and checked readings; appears to be working.	Christy

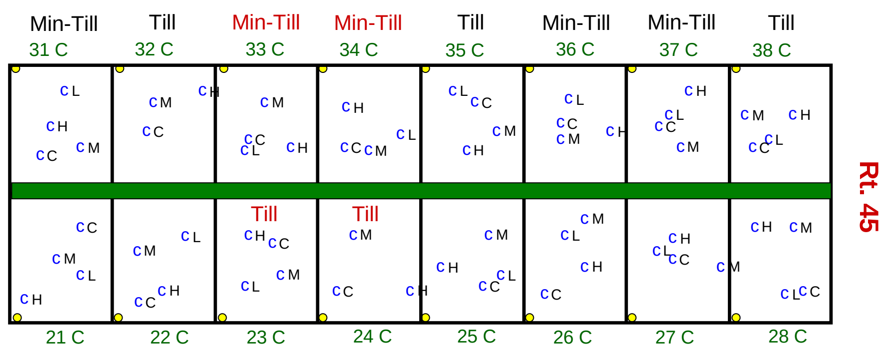
26-Sep	Downloaded data loggers. #4 temperature probe appears to be working.	Christy
	Corn drying down fast	
2-Oct	Soil sampled second start. 3 replicates per plot, 12 cores per replicate. Soil wasn't as dry as expected; it appeared moist in some areas (first strip of 20's). May be a result of heavy rain Friday and Saturday coupled with the cool weather and the plants drying down. Had a problem of weed seeds falling into some of the bags when sampling.	Christy, Alyssa, Melissa, Randa
	Downloaded data loggers	
	Some corn has been pulled down by bindweed. Will have to walk through and assess each plot	
15-Oct	Downloaded data loggers.	Christy, Alyssa, Melissa
	Walked through corn to assess bindweed occurrence and frequency of pulling the corn down. Observations were as follows:	
	21: about 50% bindweed presence, a good number (at least 36) of corn pulled down by bindweed, and some corn was stunted (closer to plot 22).	
	22: hardly any bindweed present, didn't see any corn pulled down. Not a lot of lambsquarter or pigweed.	
	23: hardly any bindweed present, some corn pulled down but it looks more like weak stalks than bindweed. Corn cobs are missing or kernels eaten. Some tops fell at the corn/ear junction.	
	24: present but not a lot, no corn pulled down	
	25: some present but not a lot, no corn pulled down	
	26: some bindweed but not as bad as 21, no corn pulled down. A lot more lambsquarters than bindweed. Only saw about 10 bindweed total.	
	27: a lot of thistle in some parts of the plot, especially where there are missing rows. Hardly any bindweed.	
	28: a handful, some stems fell but appears to be similar to plot 23 but the kernels are still present. Bindweed still green	
	31: ~1/8 to 1/4 bindweed; didn't see any corn stalks pulled down. A few tips were bent but didn't appear to affect kernel set. Also had a lot of lambsquarter, pigweed, and foxtail.	
	32: present but not a lot, still green. Pigweed and lambsquarter more abundant.	
	33: present but not a lot, still green. A lot of lambsquarter and some foxtail.	
	34: ~1/4 bindweed, short corn stalks, a few corn tips started to bend because of bindweed. Those stalks had poor corn production, if any. Pigweed, lambsquarter, bindweed, and thistle the most common weeds. First 1/4 of plot not that weedy.	
	35: Weeds mostly pigweed, didn't see any bindweed. Some thistle. A couple of corn plants down. One had an ear of corn and the other didn't appear to have produced seed	
	36: didn't see any bindweed. Patchy foxtail.	
	37: a lot of foxtail in the first half of the plot. Didn't see any bindweed.	
	38: hardly any bindweed present	

29-Oct	Opened pitfalls. Rained last week so fields were muddy. First frost occurred last night. Opened pitfalls at a temperature of ~31C. Didn't have to fix pitfall traps that were left out since the last sampling in early July. Pitfalls were level with the surrounding soil.	Christy, Alyssa, Melissa
30-Oct	Flagged 6 rows near the center of the plots (usually 13 rows in, not counting row with the orange plot flag) with white flagging tape. Adjusted some plots because of poor corn stand in a row. This occurred in plots **24** and **34**, 24 had a poor stand row. There was also a poor stand in both plots near where the data loggers were located. Plots **27** and **37**. Went in 12 rows and flagged the 12th. 27 also had a poor row stand in row 18 and towards the end of the plot (5 rows away from the orange flag).	Christy, Alyssa, Melissa
	Hand harvested the corn. 11.6' per replicate, 3 replicates per plot. Sampled outside of the flagged area where the combine will sample. 21-2 had poor corn quality and 21-3 was in a thistle patch, corn was shorter and it was harder to find an 11.6 section that didn't have a gap in it.	
1-Nov	Downloaded data loggers and pulled them	Christy and Alyssa
	Picked up pitfalls and pulled traps. Plots 33-2 and 33-3 had animal disturbance. 33-2 had the funnel and cup pulled out, antifreeze in the bottom of the deli container. No apparent antifreeze on ground. 33-3 had its funnel pulled out and a bit of antifreeze spilled into the bottom of the deli container.	
	Used the pink flags from the pitfalls to mark the 6 center rows and removed white flagging tape so it wouldn't get caught in the machinery.	
	Talked to Scott and he said they may start combining corn tomorrow (Friday) or next week. We checked the moisture of the corn and it was 17.8%.	
	Took some sample corn to test hand harvesting machines	
8-Nov	All corn was harvested this morning with the Massey Ferguson 300 combine (Ford 6600) except for the center 6 rows. The center 6 rows' yield was weighed with a weigh wagon.	Farm Crew
14-Nov	Mowed down corn stalks with stalk chopper	Farm Crew

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

Transition to Organic
2007 Experimental Plan

2nd Year Start Transition



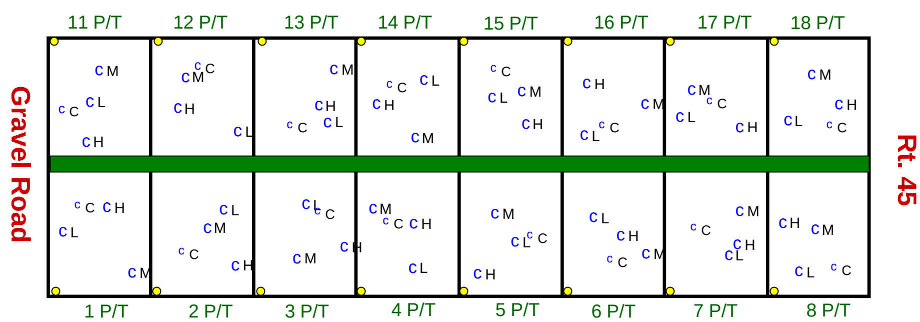
Where: C = Corn
L = Low weed density
M = Medium weed density
H = High weed density
C = Control weed density (started in 2007)

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

= flags indicating plot numbers

Transition to Organic
2007 Experimental Plan

First Year Transition



Where: P/T = Field Pea/ Tricale mix
L = Low weed density
M = Medium weed density
H = High weed density
C = Control weed density (started in 2007)

= field traffic

= flags indicating plot numbers

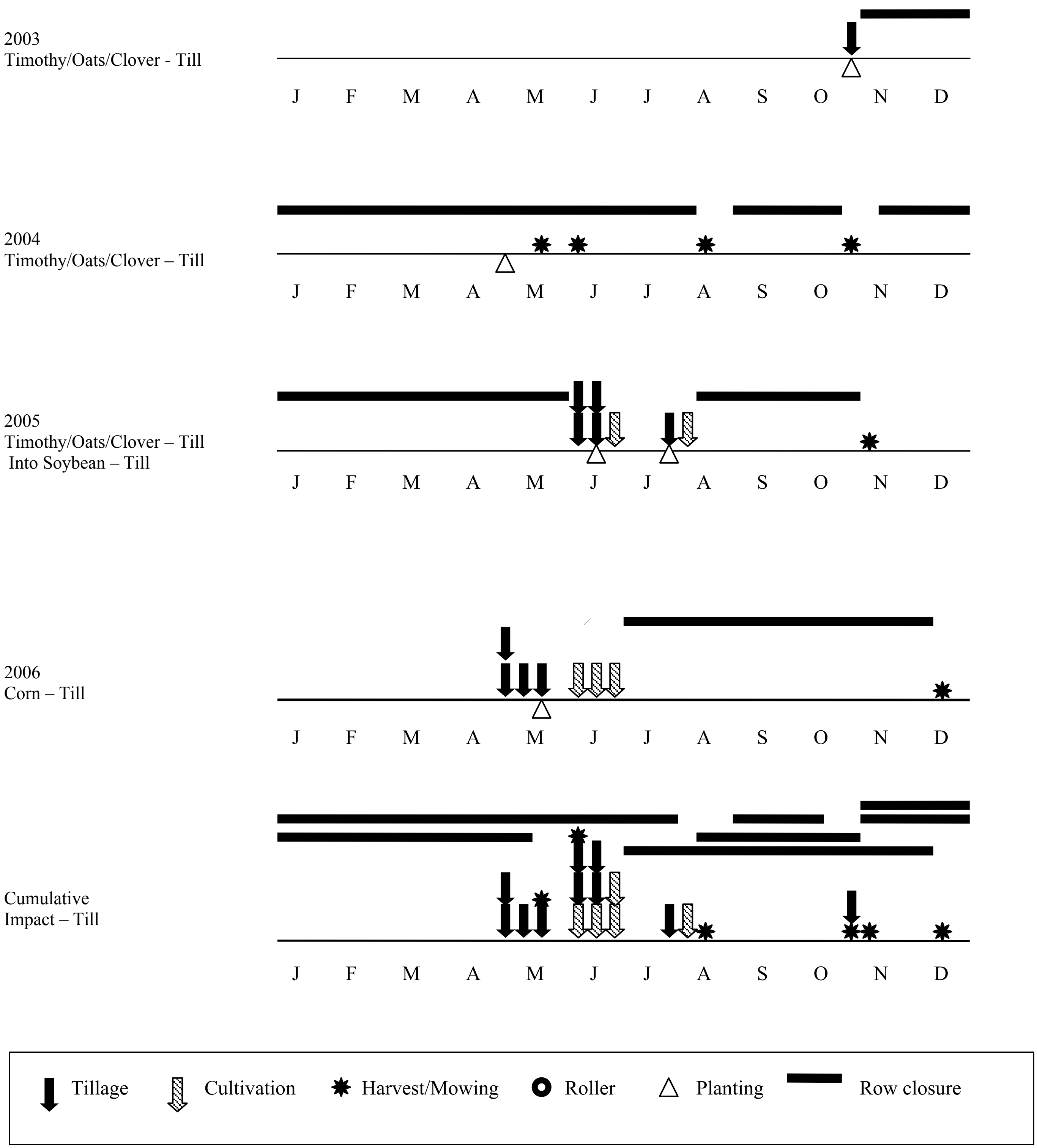
Appendix 3. Cover and cash crop management log during 2003 to 2006 for the first year start's transition to organic where plots were initially planted with either Rye or Timothy/Clover and weed managed with conventional (full) or reduced (min) tillage.

Year	Tim/Clover-Full	Tim/Clover-Min	Rye-Full	Rye-Min	Management
2003	7-Oct	7-Oct	7-Oct	7-Oct	Manure application
	10-Oct	10-Oct	10-Oct	10-Oct	Lime application
	13-Oct	13-Oct	13-Oct	13-Oct	Cultimulcher
	13-Oct	13-Oct	13-Oct	13-Oct	S-tine
	14-Oct	14-Oct	-	-	Planted Timothy/Jay Oats
	-	-	14-Oct	14-Oct	Planted Rye
2004	19-Apr	19-Apr	-	-	Re-seeded Jay Oats
	19-Apr	19-Apr	-	-	Planted Red Clover
	14-May	14-May	-	-	Mowed volunteer Rye
	25-May	25-May	-	-	Mowed volunteer Rye
	-	-	29-Jul	29-Jul	Rye Combined
	2-Aug	2-Aug			Timothy mowed and baled
	-	-	2-Aug	2-Aug	Rye mowed
	-	-	3-Aug	3-Aug	Rye baled
	25-Aug	25-Aug	25-Aug	25-Aug	Compost application
	-	-	26-Aug		Moldboard plowed
	-	-	-	26-Aug	Chisel plowed
	-	-	3-Oct	3-Oct	Hairy vetch planted
	14-Oct	14-Oct	-	-	Timothy/Clover harvest
	-	-	26-May	-	Bushhogged hairy vetch
2005	26-May	-	26-May	-	Moldboard plowed
	-	26-May	-	-	Chisel plowed
	27-May	27-May	27-May	-	Disked
	1-Jun	1-Jun	1-Jun	-	Disked
	1-Jun	1-Jun	1-Jun	-	Cultimulched
	-	-	-	1-Jun	Rolled hairy vetch
	6-Jun	6-Jun	6-Jun	-	Planted soybean seeds
	-	-	-	8-Jun	Flail mowed hairy vetch
	-	-	-	8-Jun	Haybined hairy vetch
	-	-	-	9-Jun	Planted soybeans
	-	-	-	10-Jun	Yetter tool bar no-till coulter set
	-	-	-	10-Jun	Planted soybeans
	15-Jun	15-Jun	15-Jun	-	Rotary hoed
	11-Jul	11-Jul	-	-	S-tined
	12 &13-Jul	12 &13-Jul	-	-	Replanted Soybeans
	20-Jul	20-Jul	20-Jul	20-Jul	Cultivated (half the plots)
	27 & 28-Jul	27 & 28-Jul	27 & 28-Jul	27 & 28-Jul	Cultivated
	27-Oct	27-Oct	27-Oct	27-Oct	Harvested soybeans
2006	Feb/Mar	Feb/Mar	Feb/Mar	Feb/Mar	Bull pen manure application
	19-Apr	19-Apr	19-Apr	19-Apr	Miller disked
	20-Apr	-	20-Apr	-	Moldboard plowed
	-	20-Apr	-	20-Apr	Disked
	28-Apr	28-Apr	28-Apr	28-Apr	Disked
	3-May	3-May	3-May	3-May	S-tined
	3-May	3-May	3-May	3-May	Planted corn
	22-May	22-May	22-May	22-May	Rotary hoed
	31-May	31-May	31-May	31-May	Rotary hoed
	15 & 16-Jun	15 & 16-Jun	15 & 16-Jun	15 & 16-Jun	Cultivated
	5 & 6-Dec	5 & 6-Dec	5 & 6-Dec	5 & 6-Dec	Harvested corn

Appendix 4. Cover and cash crop management log during 2003 to 2007 for the second year start's transition to organic where plots were initially planted with either Rye or Timothy/Clover and weed managed with conventional (full) or reduced (min) tillage.

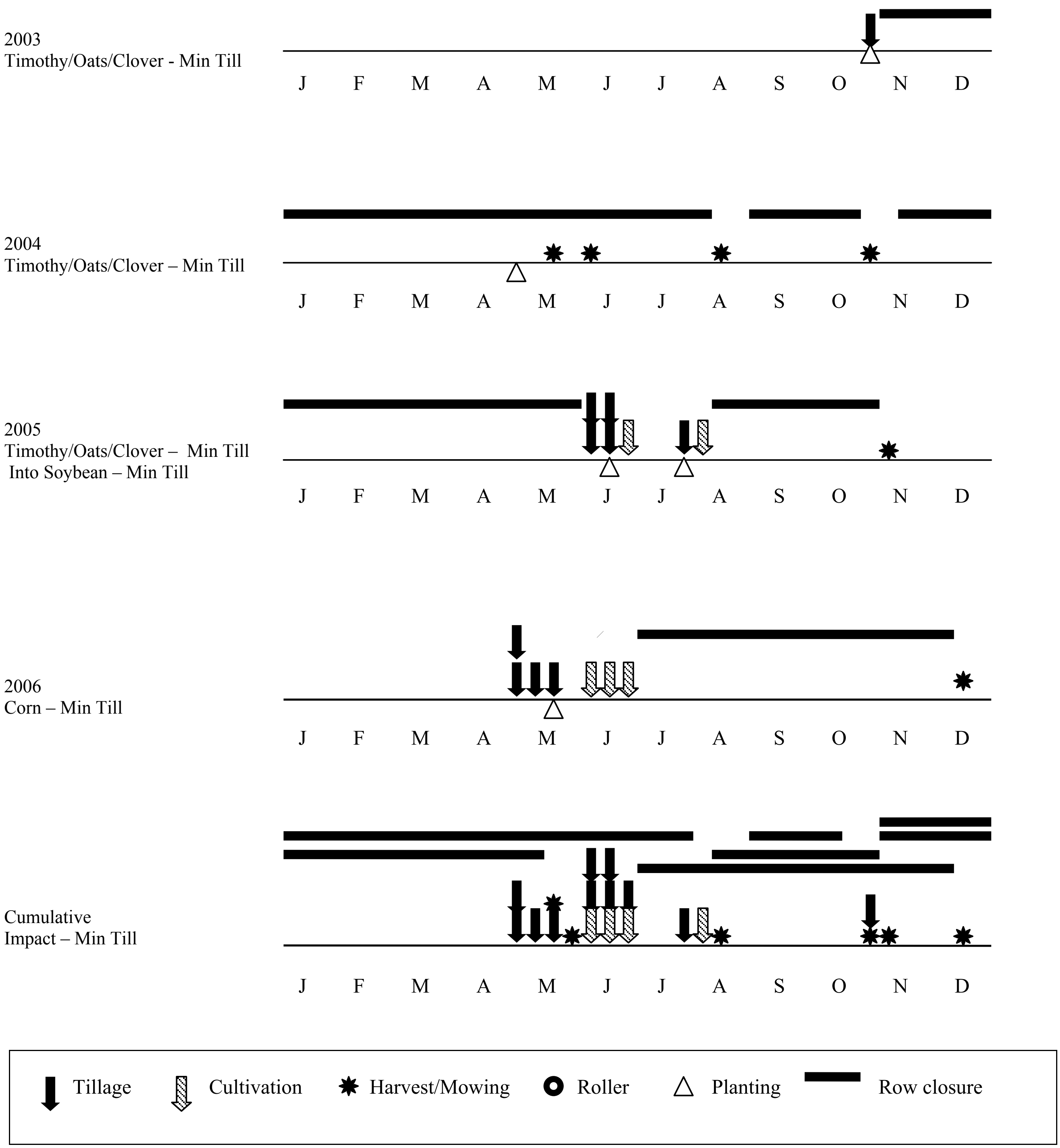
Year	Tim/Clover-Full	Tim/Clover-Min	Rye-Full	Rye-Min	Management
2003	7-Oct	7-Oct	7-Oct	7-Oct	Manure application
	10-Oct	10-Oct	10-Oct	10-Oct	Lime application
	13-Oct	13-Oct	13-Oct	13-Oct	Cultimulched
	13-Oct	13-Oct	13-Oct	13-Oct	S-tined
	14-Oct	14-Oct	14-Oct	14-Oct	Planted Timothy/Jay Oats
2004	19-Apr	19-Apr	19-Apr	19-Apr	Re-seeded Jay Oats
	19-Apr	19-Apr	19-Apr	19-Apr	Planted Red Clover
	30-Jun	30-Jun	30-Jun	30-Jun	Timothy/Clover harvest
	2-Aug	2-Aug	2-Aug	2-Aug	Timothy/Clover harvest
	-	-	22-Sep	-	Moldboard plowed
	-	-	-	22-Sep	Chisel plowed
	-	-	22-Sep	22-Sep	Rye planted
	14-Oct	14-Oct	-	-	Timothy/Clover harvest
2005	14-Jul	14-Jul	-	-	Timothy/Clover harvest
	-	-	21-Jul	21-Jul	Harvested Rye for grain
	-	-	21-Jul	21-Jul	Mowed Rye
	-	-	28-Jul	28-Jul	Baled Rye
	28-Aug	28-Aug	-	-	Timothy/Clover harvest
	2-Sep	2-Sep	2-Sep	2-Sep	Compost
	-	-	15-Sep	-	Moldboard plowed
	-	-	-	15-Sep	Chisel plowed
	-	-	15-Sep	15-Sep	Planted hairy vetch
2006	26 & 27-Apr	-	26 & 27-Apr	-	Moldboard plowed
	-	27-Apr	-	-	Chisel plowed
	2-May	2-May	2-May	-	Cultipacked
	22-May	22-May	22-May	-	S-tine
	-	23-May	-	-	Pittsburgh disked
	23-May	23-May	23-May	-	Planted Soybeans
	-	-	-	9-Jun	Rolled hairy vetch
	-	-	-	13-Jun	Planted Soybeans
	15-Jun	15-Jun	15-Jun	-	Rotary hoed
	-	-	-	16-Jun	Rolled hairy vetch
	6 & 7-Jul	6 & 7-Jul	6 & 7-Jul	-	Cultivated soybeans
	18 & 19-Jul	18 & 19-Jul	18 & 19-Jul	-	Cultivated soybeans
	-	-	-	31-Jul	Ran N-Coulter/attachment
	-	-	-	3-Aug	Cultivated soybeans
	10-Nov	10-Nov	10-Nov	10-Nov	Harvested soybeans
2007	Feb/Mar	Feb/Mar	Feb/Mar	Feb/Mar	Bull pen manure application
	-	23-Apr	-	23-Apr	Chisel plowed
	24-Apr	-	24-Apr	-	Moldboard plowed
	1-May	1-May	1-May	1-May	McConnell disked
	10-May	10-May	10-May	10-May	S-tined
	10-May	10-May	10-May	10-May	Cultimulched (roller harrow)
	11-May	11-May	11-May	11-May	Planted Corn
	30-May	30-May	30-May	30-May	Rotary hoed
	-	30-May	-	30-May	Cultivated
	6 & 7-Jun	6 & 7-Jun	6 & 7-Jun	6 & 7-Jun	Cultivated
	18-Jun	18-Jun	18-Jun	18-Jun	Cultivated
	8-Nov	8-Nov	8-Nov	8-Nov	Harvested Corn
	14-Nov	14-Nov	14-Nov	14-Nov	Stalk Chopper

Transition to Organic
Start 1: Timothy/Oats/Clover – Conventional Tillage

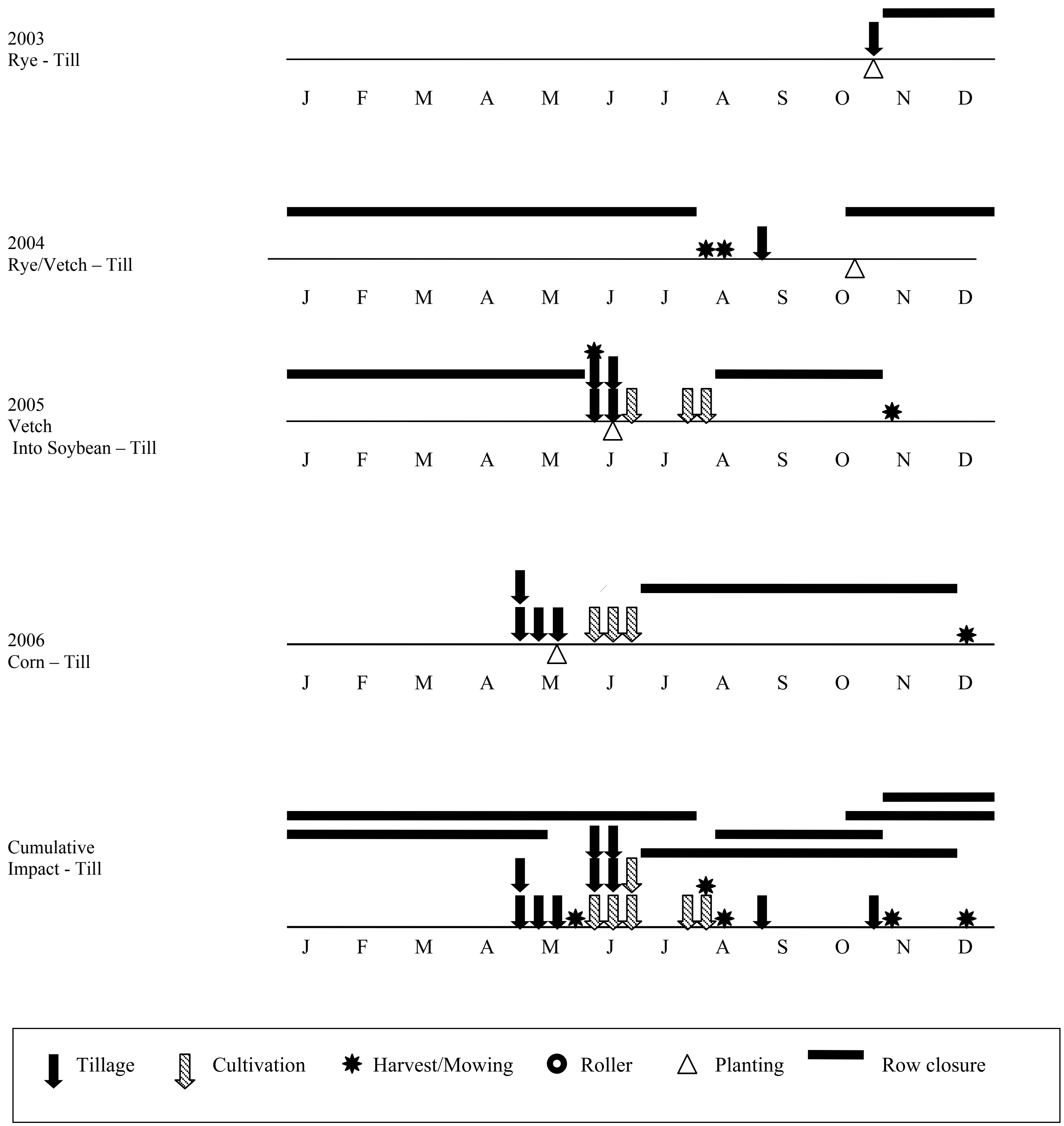


Appendix 5. Management Diagrams.

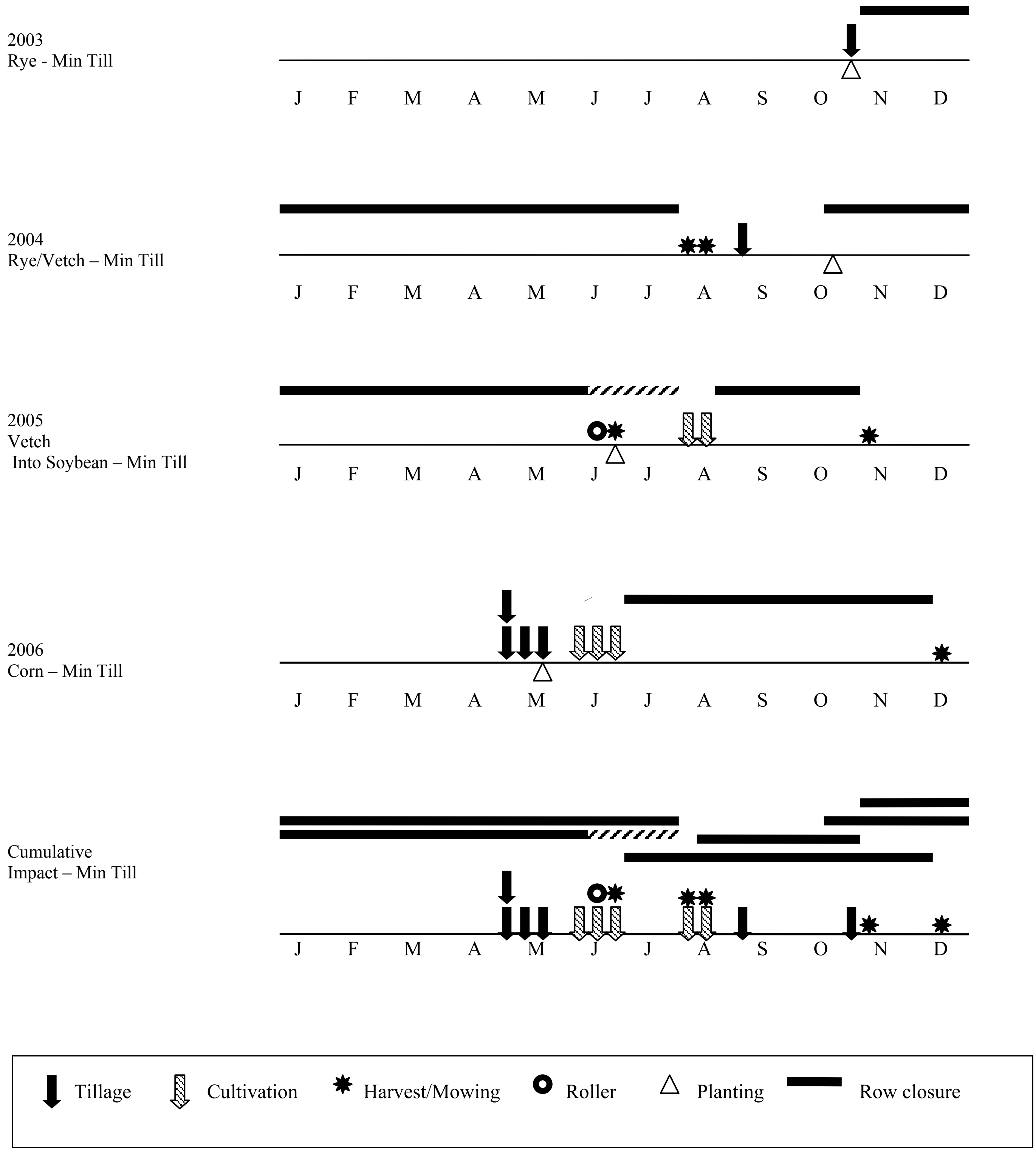
Transition to Organic
Start 1: Timothy/Oats/Clover – Minimum Tillage



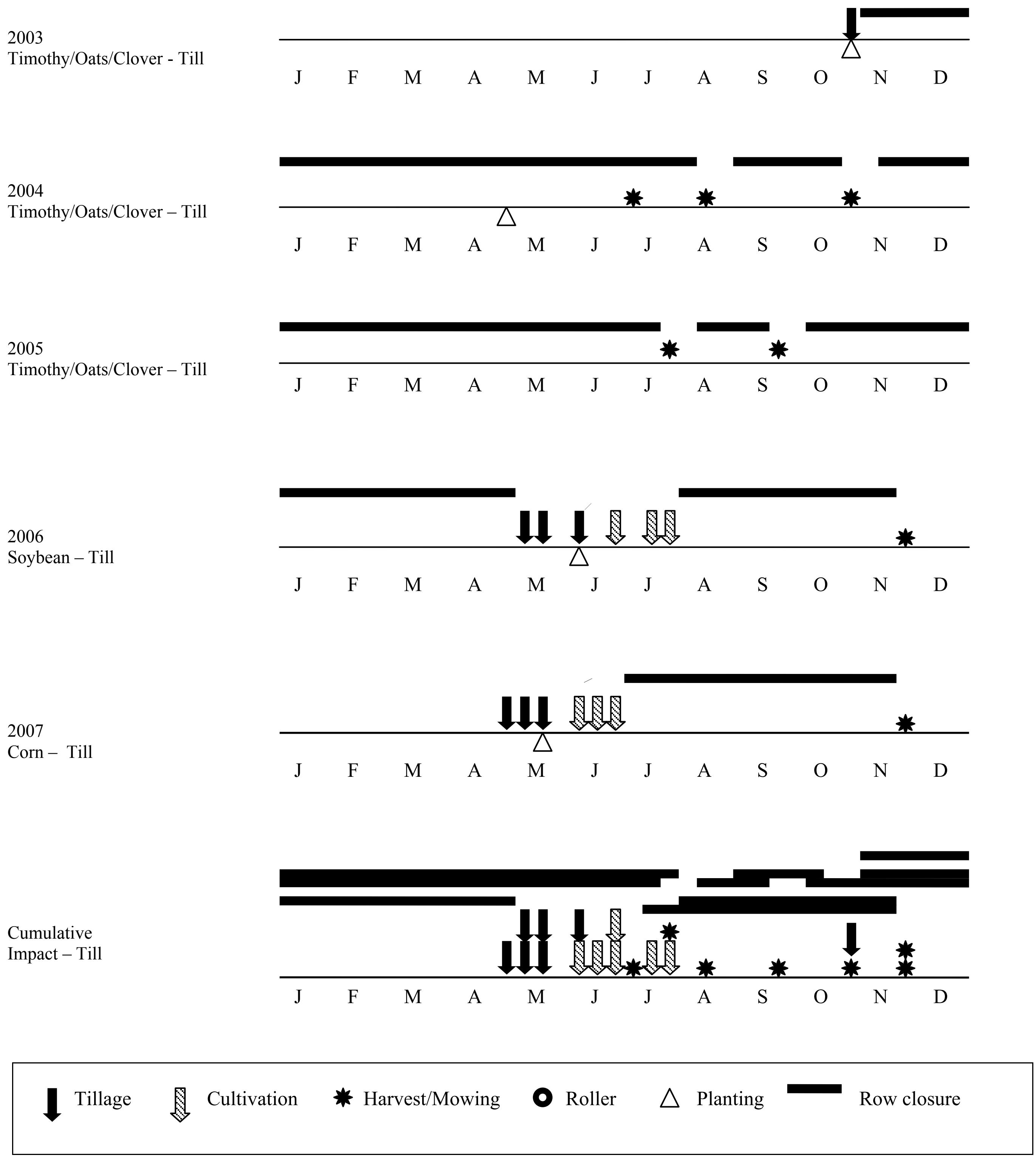
Transition to Organic
Start 1: Rye/Hairy Vetch – Conventional Tillage



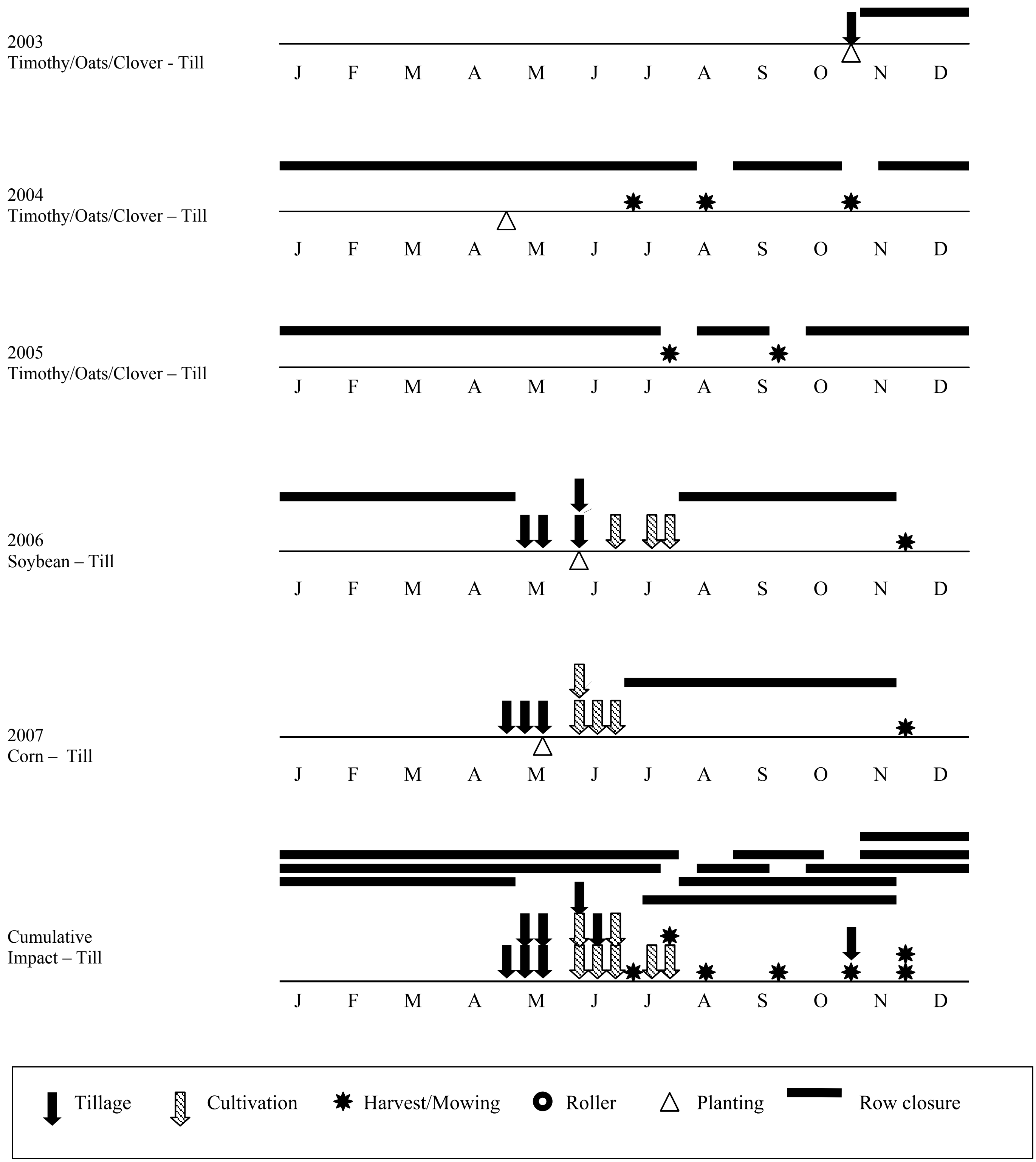
Transition to Organic
Start 1: Rye/Hairy Vetch – Minimum Tillage



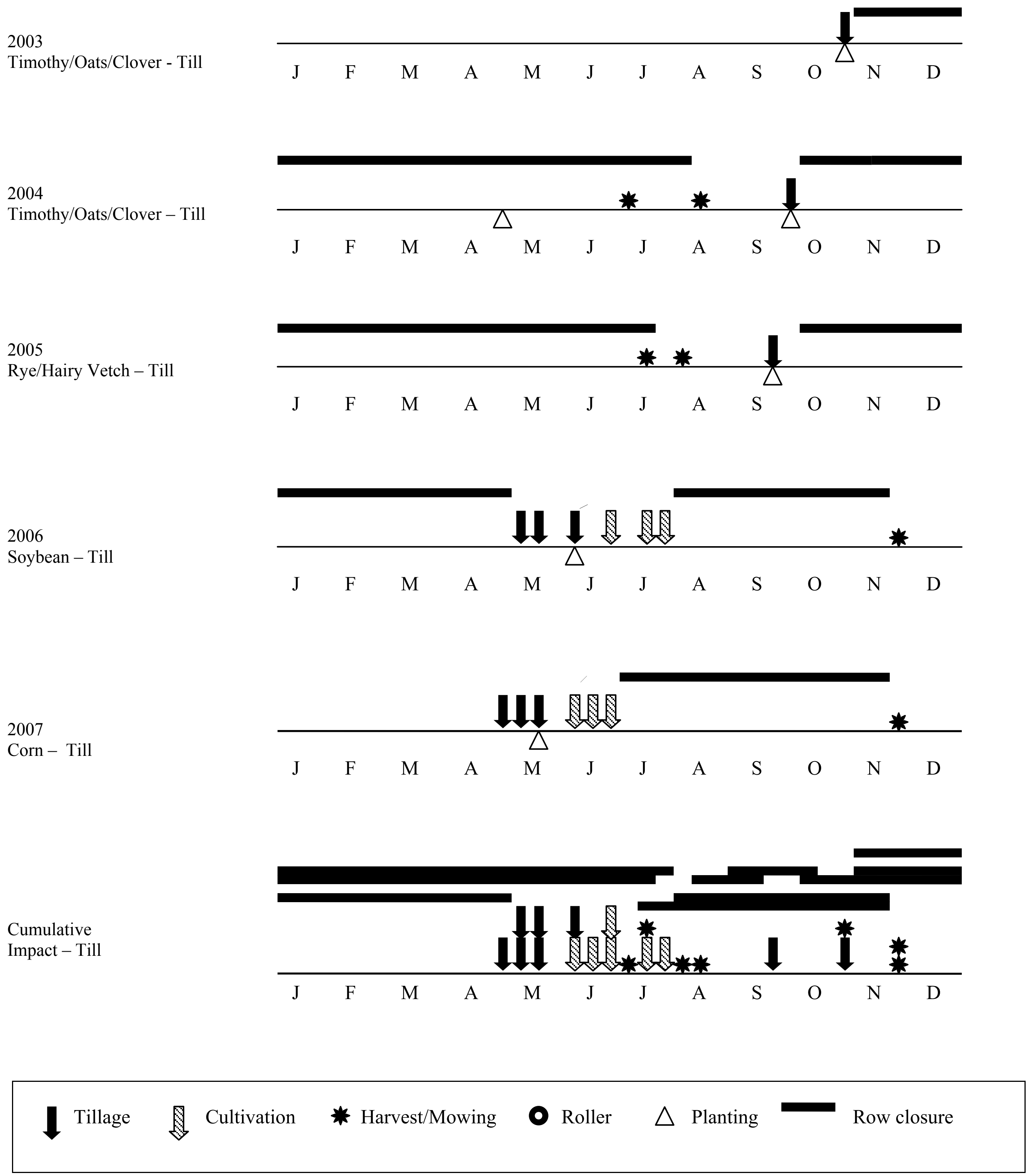
Transition to Organic
Start 2: Timothy/Oats/Clover – Conventional Tillage



Transition to Organic
Start 2: Timothy/Oats/Clover – Minimum Tillage



Transition to Organic
Start 2: Rye/Hairy Vetch – Conventional Tillage



Transition to Organic
Start 2: Rye/Hairy Vetch – Minimum Tillage