The ROSE Review

Reduced-tillage Organic Systems Experiment Newsletter

The Reduced-Tillage Toolbox

Welcome to the latest issue of the ROSE Review! The ROSE Review was started in 2010 to connect project collaborators and stakeholders so we could share the latest news on our USDA Organic Research and Education Initiative (OREI) funded project, *Improving Weed and Insect Management in Organic Reduced-tillage Systems*. In the fall of 2014, we started a new cropping system study that drew on previous successes and tackled persistent challenges related to reducing tillage in organic systems. This study, which we call "ROSE 2.0", is funded by the USDA-OREI (2014-2018) and is entitled, "*A Reduced-Tillage Toolbox: Alternative Approaches for Integrating Cover Crops and Reduced-Tillage in an Organic Feed and Forage System*."

In ROSE 2.0, we follow four different cropping systems (S1—S4) that employ various strategies to reduce the frequency or intensity of tillage in a corn—soybean–spelt annual grain rotation on certified organic land at Penn State's, Russell E. Larson Agricultural Research Center (RELARC). The reduced tillage strategies that we are investigating include: 1) no-till planting corn and soybean into cover crop mulch that was terminated with a roller crimper, 2) underseeding a legume mixture into spelt in late winter, 3) interseeding cover crop mixtures into standing corn using a high-clearance no-till grain drill and 4) no-till planting spelt, which is enabled by the use of shallow-disc manure injection prior to seeding. *A cropping system diagram is located on page 10 of this newsletter*.

In this ROSE Review, we provide several short summaries of the 2016 field season. In many ways, 2016 was a challenging year. Untimely rains prevented prompt blind cultivation in our tilled corn and soybean systems and we continue to struggle with achieving consistent corn and soybean populations when planting into high-residue cover crop mulches. As a result, weeds thrived this year! Nonetheless, we continue to identify important pest and nutrient management dynamics that influence the performance of our reduced-tillage strategies. Finally, we highlight results from our on-farm research with cooperating organic growers at three Pennsylvania locations , which focuses on opportunities for establishing cover crops using relay cropping practices.

By John Wallace

Winter 2017

Inside this Issue:

Have questions or comments about something you've read or seen in *The ROSE Review?*

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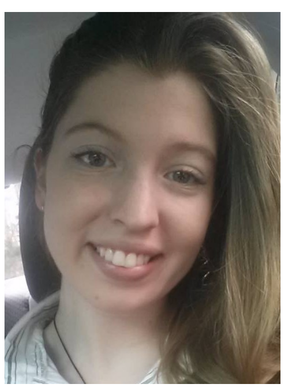
Project Team Updates

Wishing Well. The ROSE team will surely miss our research technician, **Tosh Mazzone**, next field season. Tosh and his wife, Jenny, are off to Charlotte NC to pursue new career opportunities. All multidisciplinary cropping systems experiments need a research technician like Tosh to be successful. On any given day, Tosh could be seen operating specialized farming equipment, assisting graduate students with field work, leading undergraduate student summer interns, and generally pitching in on any and all tasks at the farm. Good luck Tosh and Jenny!

Curt McConnell

Newcomers. In 2016, we welcomed two new graduate students. **Brianna Flonc** is a first-year Master's student studying under Dr. Mary Barbercheck's mentorship. Her research focuses on how *Metarhizium*, an entomopathogenic fungus in soil, varies in abundance under different cover crop treatments. She will also be studying how corn inoculated with *Metarhizium* effects pest arthropods, such as fall armyworm. Brianna obtained a Bachelor's Degree in Biology at Bard College where she completed her Senior Thesis on *Metarhizium* and its possible non-target effects on beneficial arthropods.



Travel Adventures. During the summers of 2015 and 2016, the Rodale Institute hosted teams of Argentinian organic crop producers and certifiers visiting the US to learn about our organic production. Their itineraries included stops at the Reduced Tillage Organic Systems Experiment (ROSE) and the Cover Crop Cocktails (CCC) at Penn State's Russell E. Larson Research and Education Center at Rock Springs, PA. ROSE Project Director, **Mary Barbercheck**, had the opportunity to join a group of US agricultural professionals and visit Argentina to see some organic farms and grain processing and handling facilities in Argentina in November 2016. During the weeklong stay, Mary and others visited organic farms, processing facilities, and delivered presentations at the 17th annual meeting of the Organización Internacional Agropecuaria (OIA), a certification agency for organic products and other specialty labels.

Awards. In January 2017**, Rebecca Champagne** (M.S. Student, Plant Science) and **Sarah Isbell** (Ph.D. Student, Ecology) presented research findings from the ROSE at the Northeastern Plant, Pest and Soils Conference in Philadelphia PA. Both Rebecca and Sarah took home 2nd place in their respective graduate student competitions for top paper. Congratulations Rebecca and Sarah!

Hot of the Press. Former ROSE Ph.D. students, Clair Keene and Ariel Rivers, published papers from ROSE 1.0 in early 2017:

Keene CL, Curran WS, Wallace JM, Ryan MR, Mirsky SB, VanGessel MJ and Barbercheck ME (2017) Cover crop termination timing is critical in organic rotational no-till systems. Agronomy Journal 109:1-11.

Rivers A, Mullen C, Wallace J and Barbercheck ME (2017) Cover crop-based reduced tillage system influences Carabidae (Coleoptera) activity, diversity and trophic group during transition to organic production. Renewable Agriculture and Food Systems. doi:10.1017

Corn News

By Rebecca Champagne (M.S. Student, Plant Sci)

With our second field season under our belts, we continue to see both successes and challenges related to reducing tillage in the spelt to corn transition. Our reduced-tillage strategies include no-till planting corn into rolled hairy vetch and triticale (S1), reducing the intensity of tillage through use of the chisel plow to establish hairy vetch and triticale before tilled corn (S2), or underseeding red clover and timothy into spelt before tilled corn (S3 & S4; **see page 10**). In each system, our cover crops established well; hairy vetch mixtures reached 5,000-7,000 lb/ac at termination, and red clover mixtures averaged about 4,500 lb/ac. Spring weed biomass levels were below 80 lb/ac across all four cropping systems. Our second field season highlighted persistent challenges related to timely weed management practices in organic systems. Untimely weather events prevented blind and interrow cultivation in tilled systems. In the no-till system, we continue to struggle with establishing consistent corn populations in high-residue mulch (**Fig 1**).

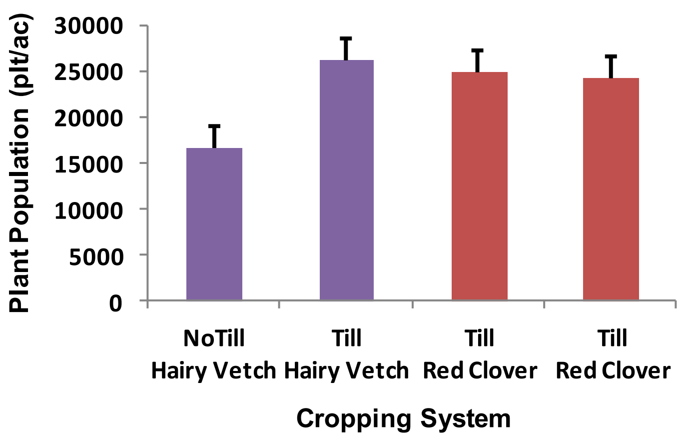


Figure 1. *Mid-season corn populations (plants/ac).*

Late summer weed biomass levels were much higher across systems compared to our first field season, as the weeds really took advantage of the lack of cultivation or gaps in the corn canopy. Weed biomass averaged over 1,000 lb/ac, and weed biomass was consistently higher in the corn row compared to the interrow (**Fig 2**). Due to a combination of these issues, corn yields were lower in 2016 compared to 2015. No-till corn silage after hairy vetch (S1) produced around 9 tn/ac, with the tilled silage after red clover system (S3) yielding higher at 15 tn/ac (**Fig 3**). Grain yields were not different between the tilled hairy vetch before corn system (S2) and the tilled red clover before corn system (S4), averaging around 131 bu/ac (**Fig 4**). This is about a 15 bu/ac difference compared to the 2015 season.

Despite the issues we experienced this past growing season, we are hopeful that 2017 will bring us more positives than negatives. We will continue to examine this data, learn from what does and doesn't work, and use our findings to give recommendations to organic annual grain farmers in the mid-Atlantic region.

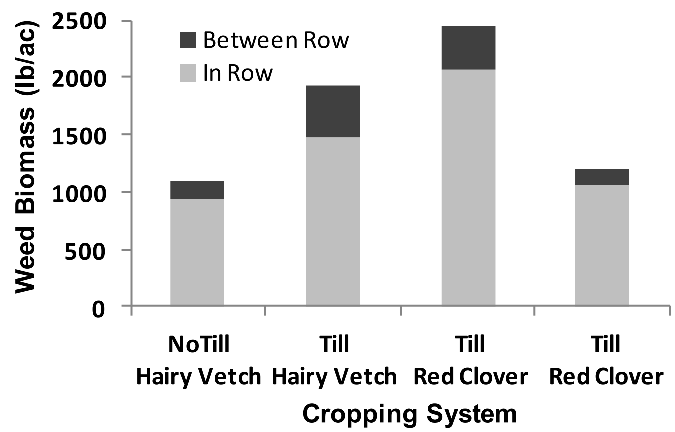


Figure 2. *In-row and between row weed biomass (lb/ac).*

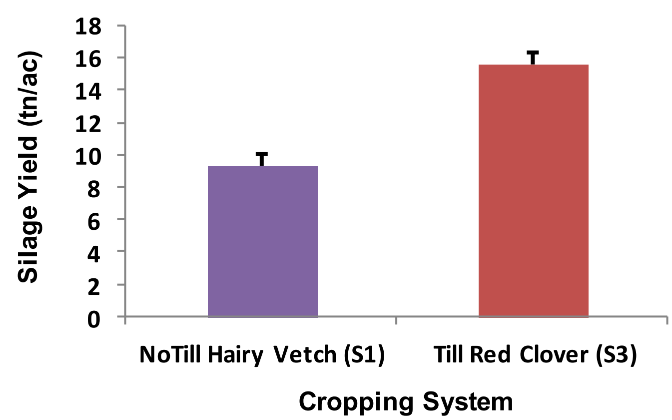


Figure 3. *Corn silage yields (tn/ac) in 2016.*

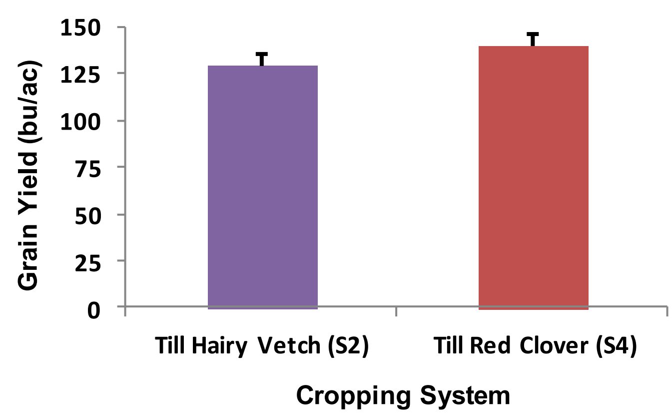


Figure 4. *Corn grain yields (bu/ac) in 2016.*

No-Till Soybean Highlights

By John Wallace

One of the many benefits of cropping system studies is the ability to identify the legacy effects of a management practice on future phases of the crop rotation. In 2016, we saw interesting results in soybean that highlighted two different legacy effects. For a little background, the ROSE has two systems (S1 & S3) where soybean is no-till planted into a rolled cereal rye cover crop (**see page 10**). During the soybean phase, these two systems are managed identically. Prior to soybean, however, corn is no-till planted into a rolled hairy vetch/triticale mixture in S1 and a red clover/timothy cover crop is incorporated with tillage prior to planting corn in S3. Manure is applied prior to planting the hairy vetch cover crop in late Aug (9 mo before corn) in S1 and at the time of cover crop incorporation just prior to planting corn in S3.

Our data suggests that differences in manure and cover crop management in the corn phase in 2015 influenced no-till soybean performance in 2016. We observed higher cereal rye biomass (~ 8,000 lb/ac) in S3 in comparison to S1 (~6,000 lb/ac) at the time of termination (**Fig 1**). We suspect this results from greater nitrogen availability to the cereal rye cover crop in S3, where manure was applied in the spring compared to the previous fall. Greater cereal rye biomass accumulation in S3 led to more difficult planting conditions, particularly in some areas where lodging occurred. As a result, soybean populations were lower in S3 compared to S1 (**Fig 1**) and these lower soybean populations were correlated with lower yields (**Fig 2**). Though soybean yields were higher on average in S1, we observed a good bit of variability. A careful look at the data showed that yield variability across different plots (blocks) was a function of volunteer hairy vetch. Incomplete termination of hairy vetch with the roller crimper before no-till corn leads to volunteer hairy vetch in cereal rye. As a result, volunteer hairy vetch competes with emerging soybean plants (**see picture**). These results highlight some of the management issues related to optimizing cover crop management in no-till corn and soybean systems.

In 2016, however, no-till soybean (S1 & S3) produced higher yields than our tilled soybean (S2 & S4). While we are still working on the data, higher yields can likely be attributed to greater weed suppression and soil moisture conservation in the no-till systems.

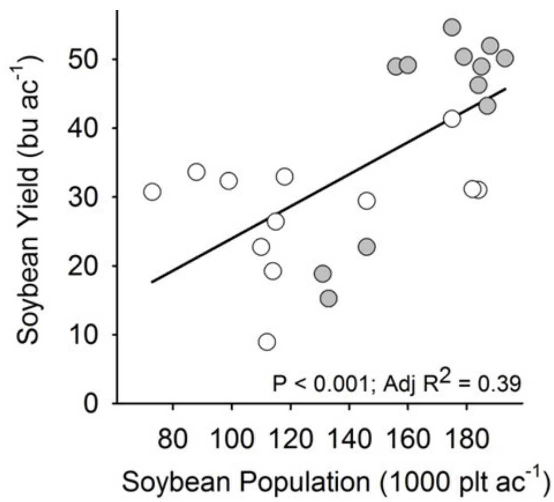


Figure 2. *Relationship between soybean population and yield in no-till soybean systems S1 (grey) and S3 (white).*

Picture. Volunteer hairy vetch competes with emerged soybean in no-till soybean system (S1).

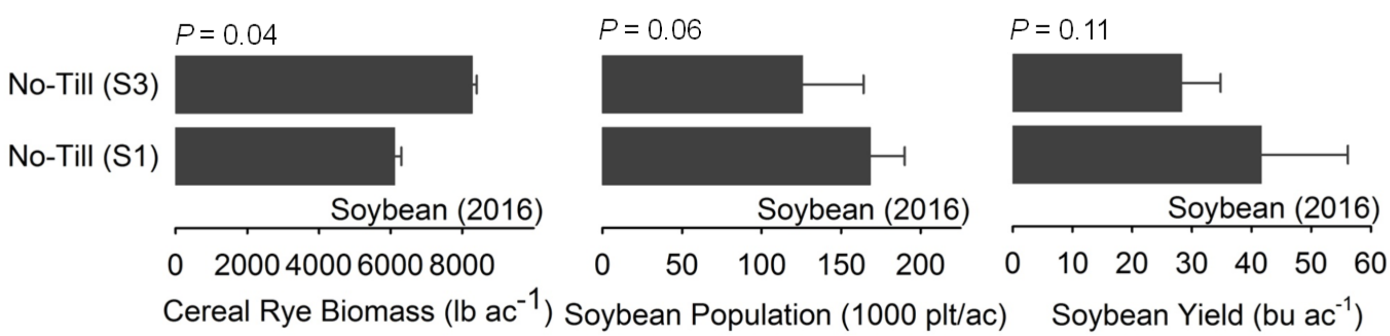


Figure 1. *No-till soybean systems (S1 and S3) comparisons in 2016. See page 10 for systems descriptions.*

Insect Investigations

By Karly Regan (Ph.D. Student, Entomology), Christy Mullen and Mary Barbercheck

The cropping systems (S1-S4) featured in ROSE (**see page 10**) provide blooming opportunities to test the effect of tillage timing and cover crop mixtures on pest damage to crops, as well as biological control of pests by beneficial insects. We focus much of our sampling efforts during early season because seed and seedling damage can translate to decreased plant populations and thus, decreased yield. After corn has been planted, we use emergence traps to measure abundance of seedcorn maggot flies (*Delia platura*) emerging from the soil, where the larvae feed on freshly planted corn seeds. These flies prefer to lay their eggs in freshly tilled soil with high amounts of plant residue, so soil incorporation of cover crop residue in ROSE may pose a risk for these pests. In addition to monitoring seedcorn maggot, we also assess seedling plants for damage from a variety of pests.

Damage varied by system and by type of feeding damage (**Fig 1**). Similar to 2015, slugs caused the highest amount of damage, ranging from 40% to 65% of plants exhibiting slug feeding, though the amount of damage per plant was always very low. Lines of holes left behind by weevils were lowest in S1 where corn is planted no-till and in S4, which is one of two systems tilled following a red clover and timothy cover crop mixture. Cutting damage from black cutworm (*Agrotis ipsilon*) was very low in systems where corn follows hairy vetch and triticale (S1 & S2) and absent from systems where corn follows red clover and timothy (S3 & S4). Chewing damage, which can be done by a variety of insect pests, was significantly higher in the no-till corn system (S1) compared to all other systems, indicating that tillage might have helped control chewing pests early in the season.

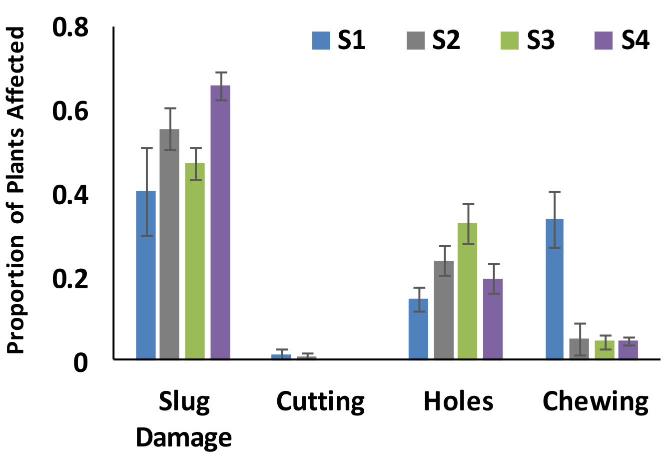


Figure 1. *Early season assessments of corn herbivory by invertebrate pests for each cropping system (S1—S4). See page 10 for system descriptions.*

Under organic management, corn fields can support a wide variety of insects, spiders, and other predatory insects that may feed on pest populations enough to suppress crop damage. To test effects of our management treatments on predatory arthropods in corn, we survey communities using pitfall traps. We use plastic containers buried level with the soil to catch arthropods as they move across the soil surface. At the same time that we conduct pitfall sampling, we also conduct sentinel prey assays to estimate how much predation is being done by any predators. As you may recall from prior editions of the ROSE Review, we tape caterpillar prey onto an index card, place it in the field, and then pick up cards the following morning to see if and how many of the caterpillars have been attacked by predators.

Picture. *A tiger beetle feeds on one of the waxworms during a sentinel prey assay.*

To capture the effect of different management practices employed throughout the corn phase of ROSE, we conduct pitfall trapping and sentinel prey assays three times during the season. We start two weeks before cover crops are terminated to capture the effect of the two different mixtures on arthropod populations. Our second sampling occurs about two weeks after corn emergence to determine the effect of tillage and other seedbed preparation at the time of planting. Finally, we come back in early August to assess the impact of interseeded cover crops on arthropod populations later in the season. In May 2016, predation appeared lower in S1 and S3 than in S2 and S4 (**Fig 2**). In June after corn emergence and in August after interseeded cover crops emerged, predation rate was fairly similar in all

Insect Investigations, cont'd

While plants are sometimes able to withstand early season damage without lasting effects, there are a number of caterpillars that may feed on corn later in the season and affect yield. We focused on sampling two caterpillars, in particular: fall armyworm (*Spodoptera frugiperda*) during late August and European corn borer (*Ostrinia nubilalis*) in early September. As in 2015, fall armyworm damage was very low in all systems. Although no differences in European corn borer larvae or tunneling damage were measured during caterpillar sampling this year, other caterpillars found on sampled plants trended toward being less abundant in plots that had been interseeded (S2 and S4) than plots than had not (S1 and S3). Most caterpillars that weren't European corn borer were corn earworm (*Helicoverpa zea*).

In summary, early season damage levels were similar across all four systems but each system varied in terms of the pests causing damage. Damage by later-season caterpillar pests and caterpillar abundance did not differ by system. Predation rates increased as the season progressed but were also fairly similar across systems, especially later in the season. As we prepare for our final field season, we are busy sorting and identifying the many preserved arthropods that we collect through emergence traps and pitfall traps. Identifying arthropods caught in these traps will give better insight into seedcorn maggot pressure, as well as whether specific predators are conserved by our management practices.

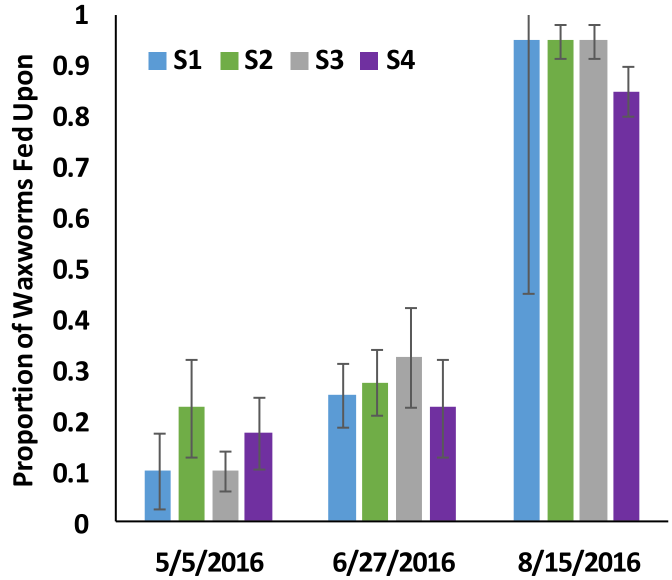


Figure 2. *The effect of cropping system (S1—S4) on predation rate varied through the season, but overall predation was highest in late season. See page 10 for description of cropping systems.*

Picture: *A corn earworm (Helicoverpa zea) munches away on a developing ear of corn examined in the field during caterpillar sampling.*

Nitrogen News

By Debasish Saha, Armen Kemanian & Jason Kaye

The economic and environmental integrity of organic production systems depends on the synchronization between nitrogen (N) availability and its uptake by plants, a critical challenge to reduce plant N stress and N losses. Nitrogen supply through manure, decomposing cover crop residues, and soil organic matter that is in excess of crop demand may lead to gaseous loss of N as nitrous oxide (N_2O) – a harmful gas for our environment as well as an agronomic loss of N. Therefore, the control of N_2O emissions from organic systems depends on the interaction between tillage (time, intensity), residue (cover crop), manure management (application rate, time, and method), and climate variables. Tillage, residue, and manure management are cornerstones of organic systems. We might expect that incorporation of manure and legume-rich cover crops prior to planting corn may create conditions for N_2O emissions early in the corn growing season. This year in ROSE, we conducted extensive monitoring of soil N_2O emissions in corn, soybean, and spelt. Here, we provide an update on the early corn phase.

As a brief background, winter cover crops (hairy vetch + triticale in S2, red clover + timothy in S3 and S4) in the tilled corn systems were mowed on May 19th, followed by liquid dairy manure broadcasting @ 8000 gallons/acre and immediate incorporation by moldboard plowing. Cover crop (hairy vetch + triticale) in S1 was late terminated by roller crimper on June 10th prior to no-till corn planting, without receiving any manure in corn. We measured the soil-atmosphere N_2O flux with a vented, aluminum-foil insulated rectangular chamber (20" × 12").

Picture. *Chamber-based N_20 sampling.*

The N_2O fluxes from the spring cover crops were insignificant until mid-May. The emissions started to increase from 4 to 5 days following cover crop termination and manure incorporation in S2-S4. The peak average emission of 0.5 lbs N/acre/day was observed on June 6th, approximately 20 days after manure and cover crop residue incorporation. However, the emissions during this period were significantly lower in S1, where hairy vetch + triticale cover crops were still growing. The second peak of N_2O emissions was observed from S2-S4in response to precipitation events from June 17th to 24th. The N_2O emissions from the rolled hairy vetch + triticale residues in S1 were also increased during this period. However, they were substantially lower than that in S2-S4. Starting in July, the N_2O emissions decreased to background levels in all systems.

We calculated the total loss of N as N_2O off-gassing during the two month period after manure application and cover crop termination (**Fig 1**). On average, 12 lbs of N were lost as N_2O from the tilled corn systems receiving manure during cover crop termination prior to corn planting (S2-S4). Apart from N_2O being a harmful gas for the environment, the magnitude of loss represents a substantial loss of N as a critical agronomic input in the organic systems. In contrast, only 2 lbs of N were lost as N_2O from the no-till corn system (S1) that received manure in the fall. It is likely that N_2O emissions from S1 will be higher than the other systems when manure is applied in fall prior to cover crop planting. However, in absence of any cover crop residues, we do not expect that the magnitude would ever exceed the level of emissions that we have observed from S2-S4 during early summer.

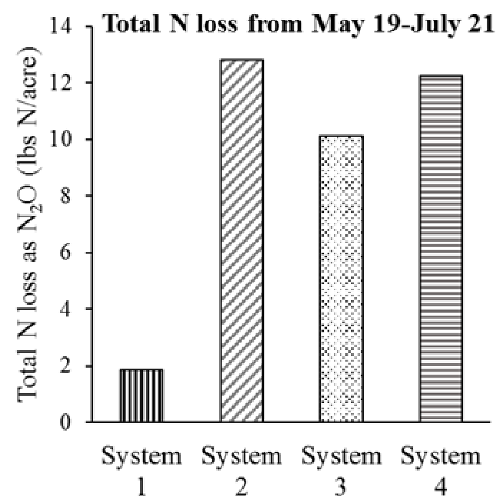


Figure 1. *System comparison of N loss as N_2O. See page 10 for system descriptions.*

We have learned from our 2016 measurements that the risk of N_2O emissions magnifies when manure is applied on fresh legume rich cover crop residues as in S2-S4. This is probably due to the excess supply of N during early summer when the corn N uptake is low, and the fresh supply of carbon for microbial growth. Thus, management practices play a key role controlling soil N transformations and its loss as N_2O. Opportunities exist to fine-tune management practices that preserve the environmental quality and economic outcomes of organic production systems.

On-Farm Research Update

By John Wallace

Recent research conducted by Penn State, Cornell University and the USDA-ARS in Beltsville, MD has demonstrated that relay planting cover crops into standing corn using a high-clearance no-till drill is a viable reduced-tillage strategy with the potential to lengthen cover crop and cash crop growing season windows in conventional no-till corn cropping systems in the Northeast.

We are interested in the potential for this practice to be utilized in organic grain corn systems. Currently, we are in the middle of our second year of conducting on-farm research experiments with cooperating organic growers, Wade Esbenshade (New Holland, PA), Elvin and Michael Ranck (Mifflin, PA), and Harvey Hoover (Hartleton, PA). We are evaluating three treatments at each farm: 1) interseeding cover crops with an Interseeder® no-till drill, 2) broadcasting cover crops with a rotary spreader, and 3) a control in which standard practices in the corn to soybean transition were maintained by cooperating growers. For each cover crop treatment, a mixture of annual ryegrass (10 lb ac^{-1}) + orchardgrass (10 lb ac^{-1}) + forage radish (4 lb ac^{-1}) was established after last cultivation.

The on-farm research component of ROSE has already produced some interesting results, which will help shape future research. A few highlights:

1) We learned that the benefit of interseeding with a grain drill is dependent on the weather. In 2015, we had abundant precipitation in June and July and interseeding with the drill (INT) and broadcasting (BRD) cover crops performed similarly (**Fig 1**). In 2016, June and July were considerably drier and interseeded (INT) cover crops outperformed broadcast treatments (**Fig 2**).

2) We also learned that the method of cover crop establishment may influence the expression of the cover crop mixture. In 2015, forage radish represented a higher proportion of the mixture in interseeded (INT) plots and orchardgrass represented a higher proportion in broadcast (BRD) plots at each site (**Fig 3**). We attribute this trend to seed size.

Beyond these insights, our on-farm research has doubled as a great outreach tool. We have hosted three fall field days to engage organic growers on the potential benefits and constraints of this reduced-tillage practice.

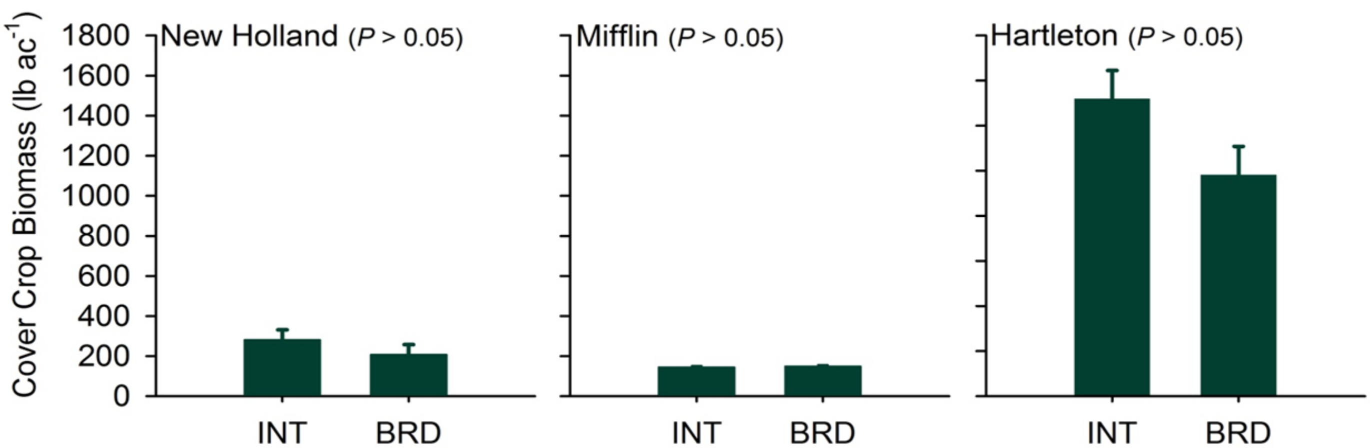


Figure 1. *Cover crop biomass at grain harvest in interseeded (INT) and broadcast (BRD) plots in 2015.*

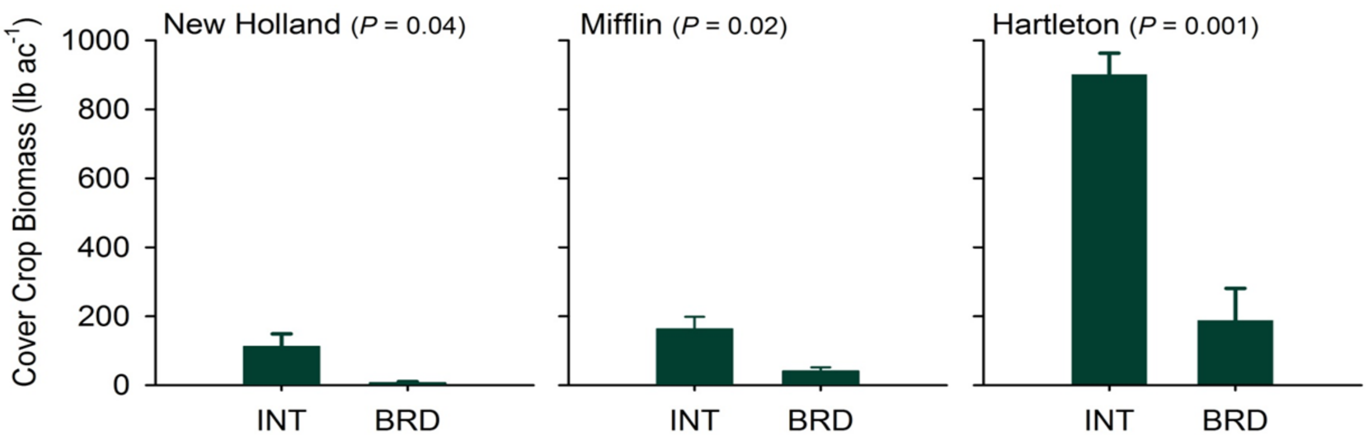


Figure 2. *Cover crop biomass at grain harvest in interseeded (INT) and broadcast (BRD) plots in 2016.*

On-Farm Research Update, cont'd

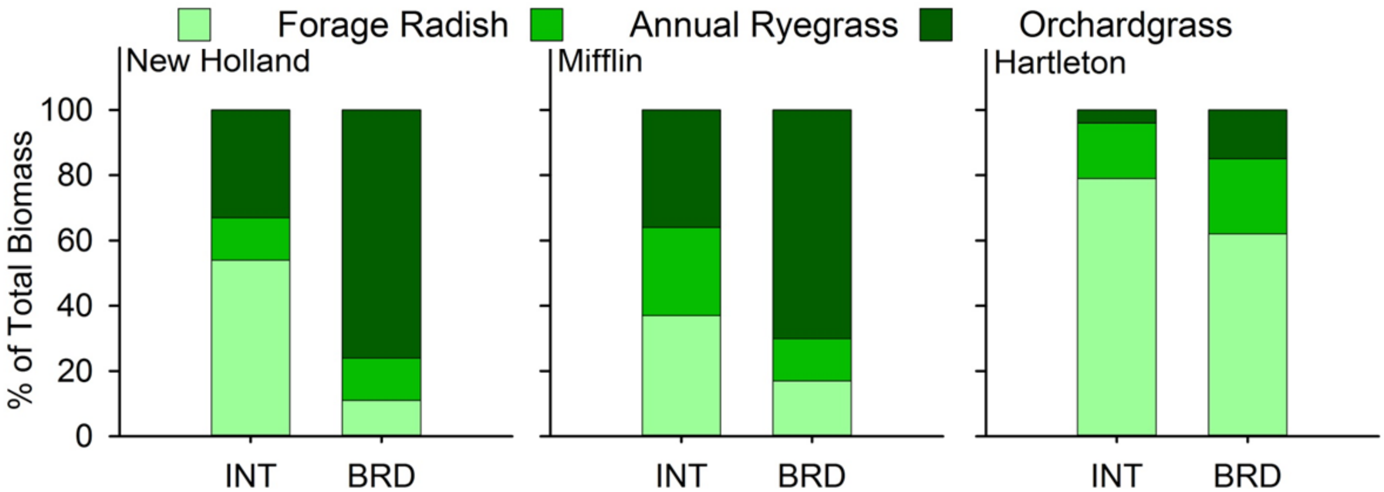


Figure 3. *Cover crop composition at grain harvest in interseeded (INT) and broadcast (BRD) plots in 2015.*

New Research Projects to Start in 2017

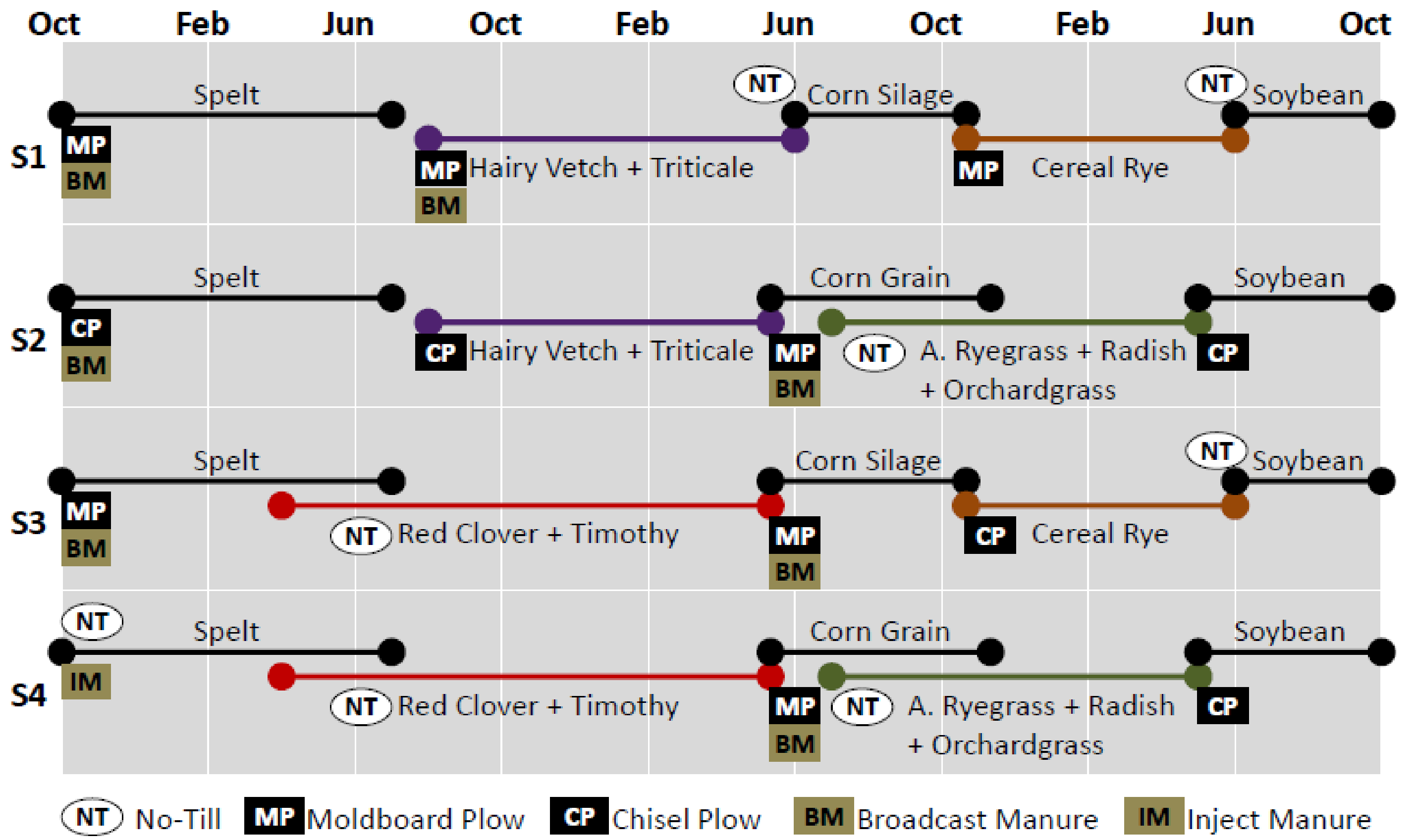
Sarah Isbell, PhD Candidate in Ecology and a graduate research assistant on ROSE, and Dr. Jason Kaye, professor of Soil Biogeochemistry, were awarded a Northeast Sustainable Agriculture Research and Education (SARE) graduate student grant for the proposal "Interseeding cover crops: Evaluating nitrogen retention services provided by plant-microbe relationships." This proposal was developed using the data from ROSE interseeded corn systems as a jumping off-point. The project, slated to begin in May of 2017, aims to evaluate questions about interseeded cover crops and nitrogen dynamics in a field experiment at the Penn State Agronomy Farm at RELARC.

The ROSE project includes cover crops interseeded into corn grain; however, because it is an experiment comparing different cropping systems, it is difficult to tease out the specific effects of interseeding on nitrogen dynamics. In all of the ROSE systems, the effects of interseeding are confounded by differences in tillage, cover crop species, and manure application strategies. Also, preliminary data from years one and two of ROSE suggest that there was low nitrogen availability to the corn throughout the experiment. Because of this low soil nitrogen, we may not be able to see effects of interseeded cover crops on nitrogen retention or other nitrogen dynamics.

The justification for this work is that in order to make scientifically-based recommendations to farmers about interseeding, we must first piece together a picture of the timing and magnitude of nitrogen flow when cover crops are interseeded into corn grain. This new proposed experiment will be able to directly tie effects of interseeding cover crops to nitrogen retention services and to crop yields in fields with differing soil nitrogen levels. Additionally, we will analyze soil microbial communities to find if there are patterns between interseeded and non-interseeded corn at different soil nitrogen levels. By investing in research exploring innovative ways to mitigate nitrogen losses from agricultural systems without sacrificing yields, we can build knowledge with direct links to agricultural sustainability. This work will contribute to reduction of environmental and health risks associated with nitrate leaching into the water supply, the improvement of economic productivity for farmers, and the protection of natural resources.

Picture. *Sarah Isbell soil sampling in ROSE.*

ROSE Cropping Systems Diagram (S1-S4)



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