Sustainable Systems Approach for Improving Soil Health and Managing Soybean Production

2019 Progress Report: Year 2

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Executive Summary:

This project was established in the fall of 2017 to determine the water quality, productivity, soil health and economic benefits of integrating cover crop and tillage systems (no-till, NT, and chisel plow, CP) in a soybean production system. The preliminary findings of this work demonstrated the short-term benefits of cover crop and NT in improving soil health as measured by the improvement of water infiltration and reduction in nitrate leaching under cover crop as compared to non-cover crop treatments. The seeding of cover crop before and after soybean crop in the Des Moines Lobe area is encouraged given the unique cold and wet soil conditions early in the spring. The integration of cover crop in the short-term as well as in the long-term is a good management practice for soil health and productivity, coupled with no-till. Soybean yield was affected by tillage, with CP resulting in a 4.5 bu/ac higher yield than NT. Water quality is improved with the implementation of cover crops, with a reduction in water nitrate as well as soil nitrate by 29% and 44%, respectively. The economic analysis on input costs vs. output costs is not being reported at this time. We will provide more details and additional information at the end of the growing season after data analysis to show the potential agronomic, economic, soil heath, and water quality benefits of incorporating cover crops in a systems' approach to soybean production in central Iowa.

Introduction:

We established this study with the goal to document the water quality, productivity, soil health and economic benefits of incorporating cover crops in a systems' approach to soybean production in central Iowa. This project focused on conducting a field scale research in the Des Moines Lobe to understand and test a systems approach that incorporates cover crop in the existing soybean cropping system of corn-soybean rotation. The research site is in central Iowa to document the performance of the cover crop along with conservation and conventional tillage systems to address the challenges of soil and nutrient losses associated with the current cropping system and soil management for soybean production. With this objective, we conducted the following activities:

Field Work and Data Collection:

Water Quality

1. Weekly leaching using suction Lysimeter
2. Residual soil Nitrate-Nitrogen (NO_3^- -N)

Productivity

1. Weekly Soil Moisture
2. Daily Soil Temperature
3. Soybean Yield

Soil Health

1. Soil Aggregate Stability
2. Soil Bulk Density
3. Water Infiltration
4. Soil Penetration Resistance
5. Soil pH
6. Soil Microbial Biomass-Carbon

7. Soybean Residue Decomposition

2018 End of Season and 2019 Mid-Season Soil Sampling

The end of season samples, which were collected in the fall of 2018, were processed in the lab over the months of December-March. The midseason samples, which were collected in the spring of 2019 were processed in the lab over the months of May-August. Both sets of samples were processed for the above soil parameters as indicated in the proposal protocol.

Water Quality

Lysimeter-collected water for nitrate analysis:

Nitrogen is the most critical nutrient applied to crops to increase yield. It is both environmentally and economically detrimental for nitrogen to leave a field. To measure the amount of nitrogen leaching through the soil profile as nitrate, we buried lysimeters in each plot. Lysimeters have water-permeable ceramic cups at the bottom of them that allows water in the soil two feet deep to be collected. Throughout the spring, when nitrogen is most susceptible to leaching, the water from the lysimeters was collected with a vacuum pump and stored. At the end of the summer, the samples were analyzed for nitrate concentration. As shown in Figure 1, cover crops decreased the amount of nitrate leached by an average of 29%, even months after the cover crops were terminated (March 13).

Using a vacuum pump to collect water from a lysimeter.

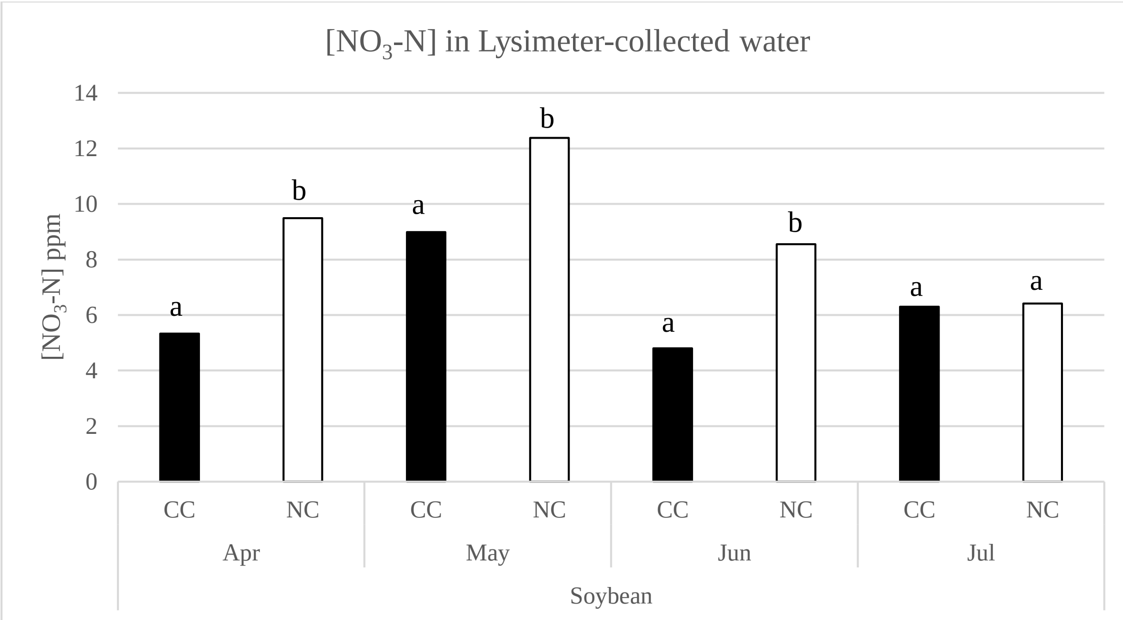
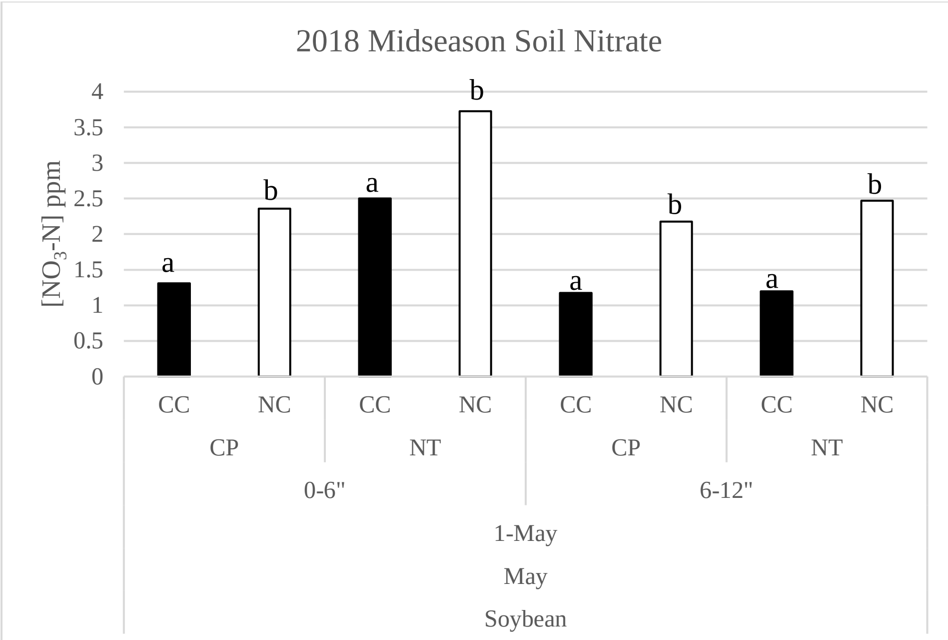


Figure 1. Concentration of nitrate in water collected from lysimeters from April 23, 2019 to July 2, 2019. Treatments were averaged over tillage because there was no effect due to tillage. An average decrease in water nitrate of 29% was observed for each month (CC = cover crops; NC = no cover crops).

Soil Nitrate:

The previous section confirmed in this study that cover crops reduced the amount of nitrate leaching. This should be reflected in the residual nitrate concentration in the soil profile and its potential impact on the following row crops and consideration for proper N application. To address this concern, we measured the amount of nitrate, a form of nitrogen available to the crop, that was present in the soil. As Figure 2 shows, this is a reasonable concern. Cover crops decreased the amount of soil nitrate at depths of 0-6” and 6-12” in the spring of 2018 and 2019. Not included are data from October of 2018, because there was no difference in soil nitrate concentration at that time. In general, the nitrate concentration is very low in both cover and non-cover treatments. However, cover crop reduced nitrate concentration in the soil profile by 44%.



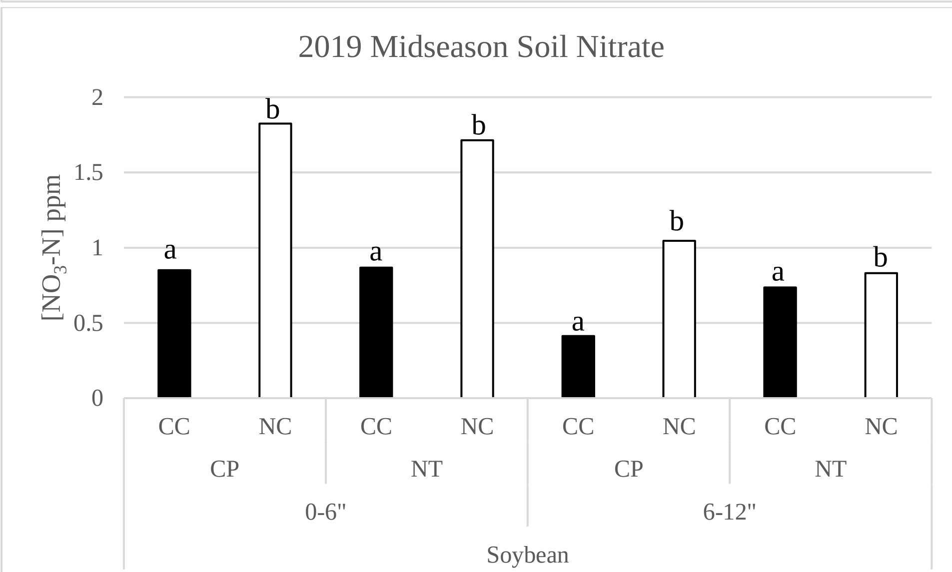


Figure 2. Soil nitrate concentration levels in the spring. Cover crops had a significant impact ($p = 0.0953$) on reducing the amount of nitrate by 45% in both 2018 and 2019 (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Productivity

Soil Moisture:

Soil moisture is an important parameter to consider when planting crops because it effects soil temperature. Moist soils in the spring are cooler than dry soils, which can negatively impact germination. At the time of planting (June 4), tillage decreased soil moisture (Fig. 3). However, the same practices that decrease soil moisture at planting also decrease soil moisture throughout the growing season (Fig. 4). The combined effects of conventional tillage and cover crop can be beneficial in areas such as the Des Moines Lobe, where soil is poorly drained.

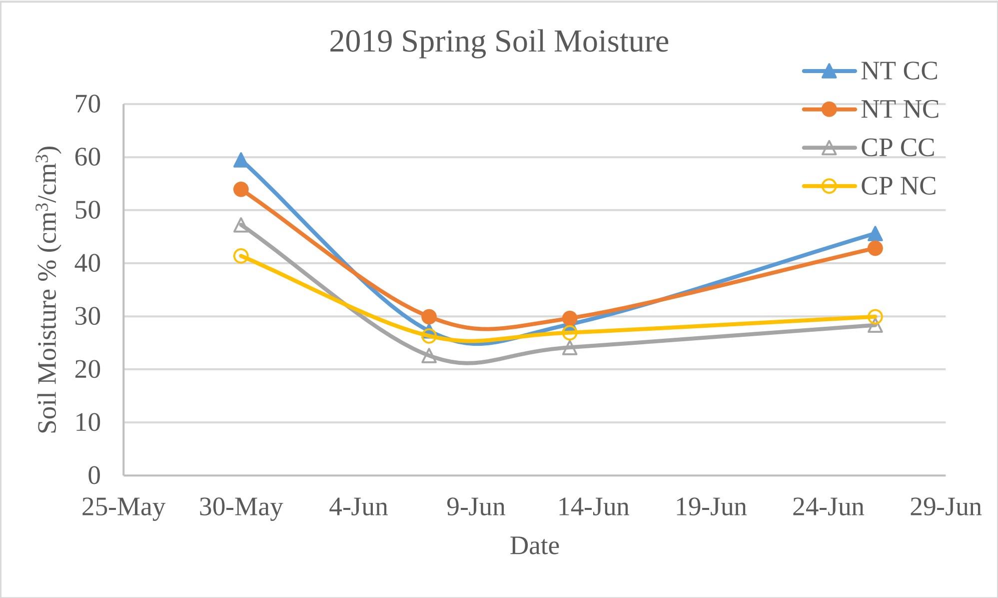


Figure 3. Effect of tillage and cover crops on Volumetric Soil Moisture from May 30, 2019 to June 26, 2019 (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

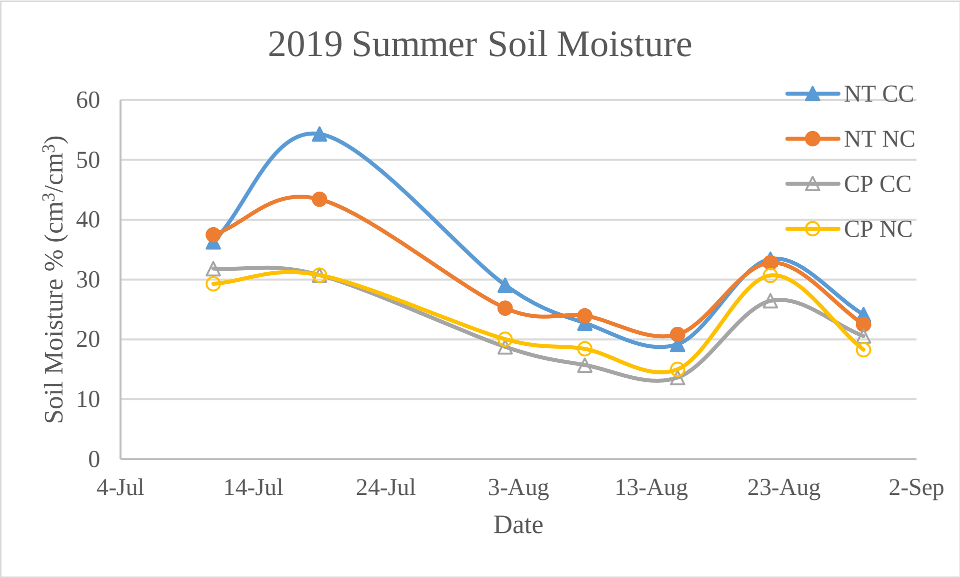


Figure 4. Effect of tillage and cover crops on Volumetric Soil Moisture from July 11, 2019 to August 29, 2019 (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Soil Temperature:

Soil temperature is tightly linked to soil moisture. Data were collected on soil temperature from early March to mid-June to determine the effect of tillage and cover crop on soil temperature. The treatments that had high soil moisture readings had low soil temperature readings, as expected (Fig. 5).

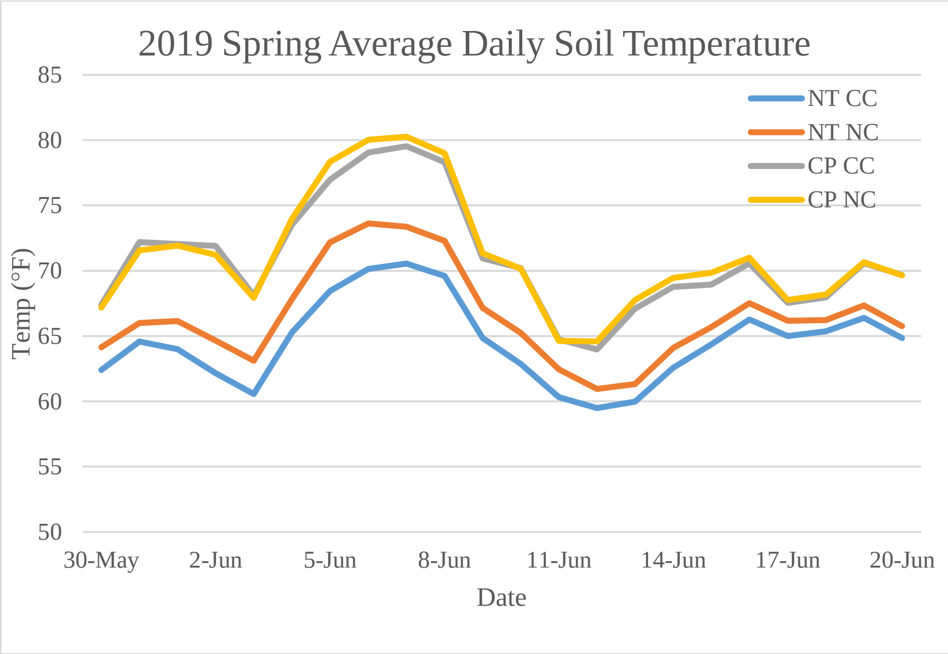


Figure 5. Effect of tillage and cover crops on soil temperature from May 30, 2019 to June 20, 2019 (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Soybean Yield:

Perhaps the most critical piece of data producers want to know when considering the adoption of cover crop and conservation practices is the effect they will have on yield. This study finds what many other similar studies have found, which is a slight decrease in yield when comparing no-till systems to tilled (Fig. 6). We observed a 4.5 bu/ac difference between the two treatments, with chisel plow plots yielding higher than no-till plots. Cover crop did not affect the yield in both systems. Due to the different input costs associated with the tillage treatments, where NT was found to have much less input cost in many studies, this may offset the small yield reduction with NT in the Des Moines Lobe area.

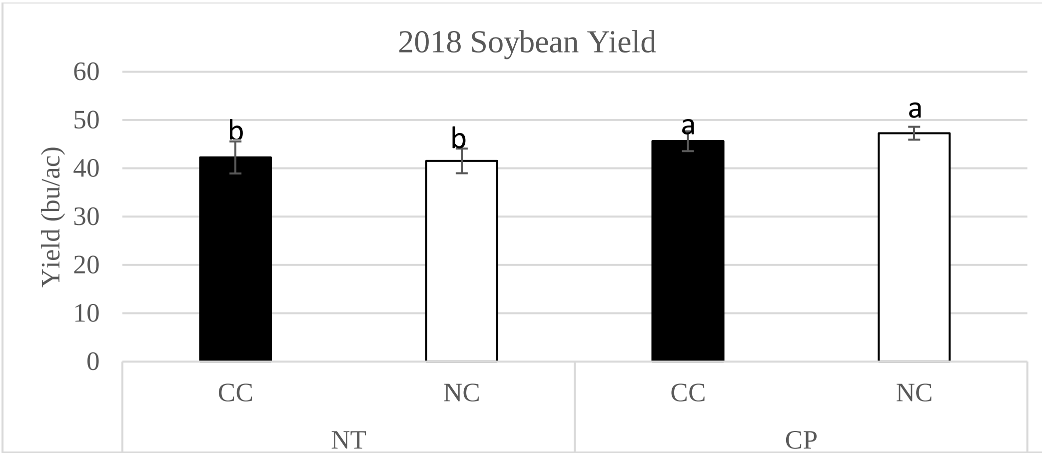


Figure 6. Comparing yields of a commercially available soybean variety in different treatments. A higher yield was recorded for CP plots compared to NT plots (p=0.0633) (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Soil Health

Aggregate Stability:

Aggregate stability is a measure of soil structure strength to resist destructive forces. Generally, no-till and cover crops improve soil structure as measured by the stability of soil aggregates under wet conditions or rain. We tested the strength of soil aggregates in the lab by subjecting undisturbed soil samples from the treatment plots (no-till and chisel plow, with and without cover crop) to rain simulation and measured the resulting fractions of soil in different particle sizes. Generally, the effect of tillage and cover crop on improving the stability of soil aggregate takes a long time, especially with large-sized soil aggregates, which are most sensitive to changes by tillage and other conservation treatments. We observed no significant effects under both tillage systems with and without cover crop as compared to the baseline prior to the treatment establishments (Fig. 7). However, there is slight improvement in soil aggregate stability with cover crop over the baseline for both large (4 mm) and medium aggregates (2 mm). These results are not surprising giving the short-term application of cover crop and NT treatments in this study. As documented by many studies, a long-term application of these treatments is critical in order to achieve significant effect on soil structure stability and sustainability.

Stacked sieves used to collect different fractions of soil for measuring aggregate stability.

Motor and reservoir with stacked sieves inside for measuring aggregate stability.

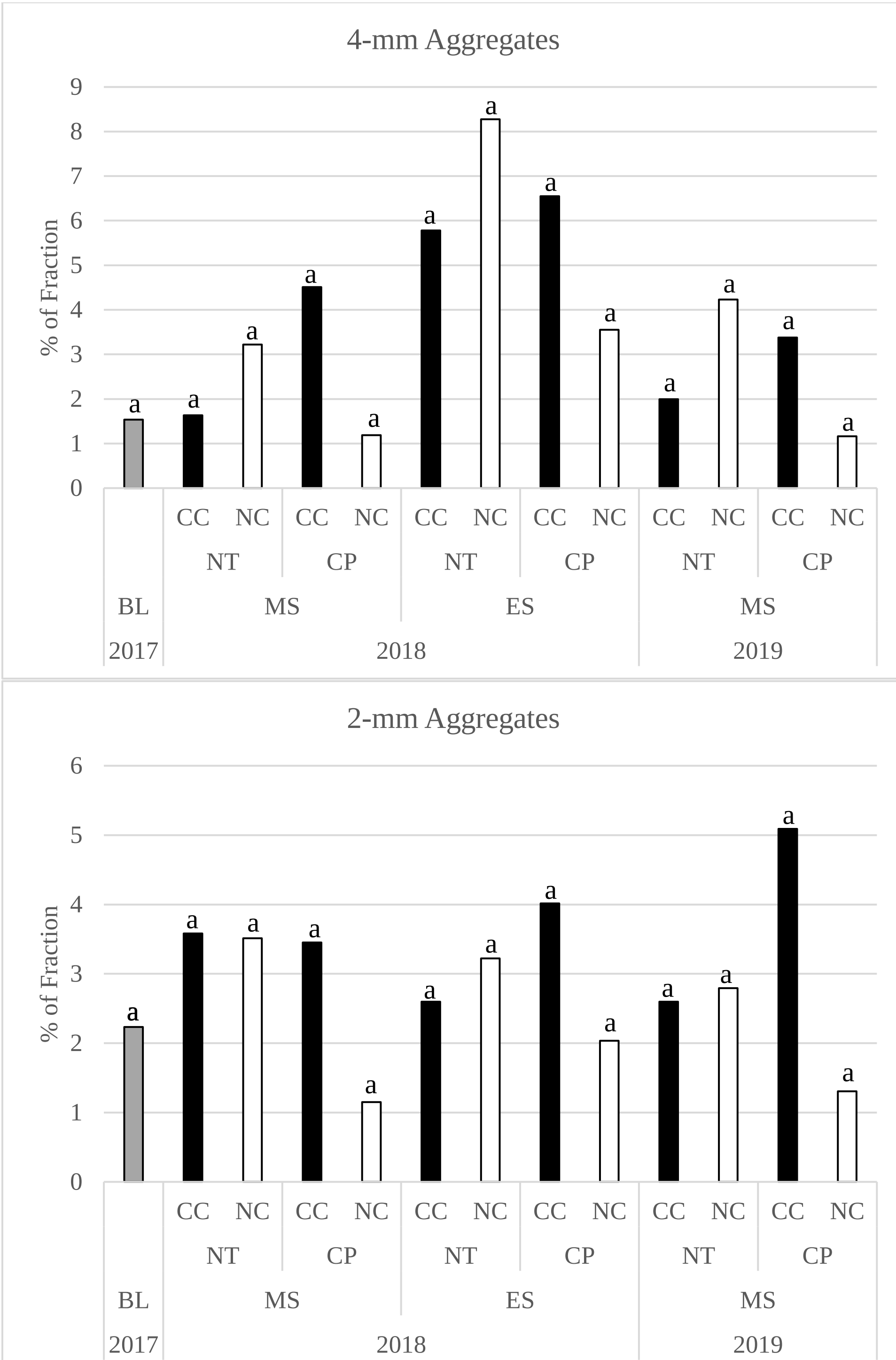


Figure 7. Percent of the soil fraction after rainfall simulation in the 4 mm sieve and the 2 mm sieve under different treatments throughout the duration of the study thus far. No significant differences detected (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop). (BL = baseline; MS = midseason; NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Soil Bulk Density:

Bulk density is a function of tillage and soil structure, which are affected by soil compaction that influences pore size distribution, infiltration, and water holding capacity. Bulk density is a ratio of soil mass over its volume. Higher bulk densities indicate there is little space in the soil for air and water. However, no differences were detected between treatments within a season, as seen in Figure 8. When changing management systems, this shows that bulk density is not always affected, but it should be monitored to maintain favorable growing conditions. Change in bulk density is a long-term process where soil stability will reduce bulk density. In general, cover crop treament in both tillage systems caused a slight reduction in bulk density. This is a desirable outcome to improve water infilteration and reduce surface runoff, which is a main force in soil erosion.

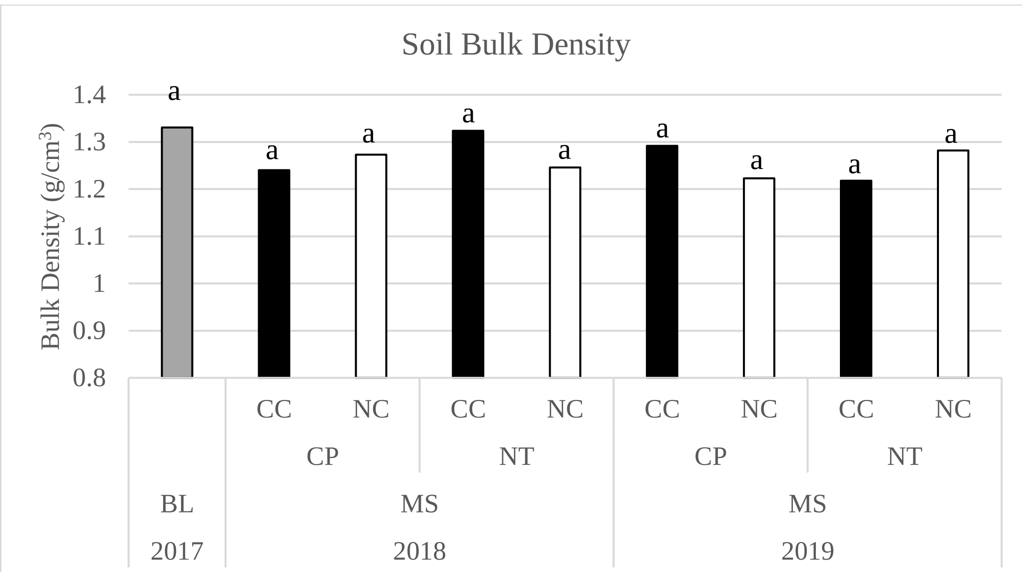


Figure 8. Bulk density for different treatments at different times in the project. No significant differences were detected (BL = baseline; MS = midseason; NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Water Infiltration:

Water infiltration is another indicator of how management practices such as tillage and cover crop affect how fast water enters the soil at the surface and subsequently move through the soil profile. The improvement in infiltration rate leads to reduction in water runoff and sediment loss from fields. An additional benefit of increasing water infiltration is the increase in soil water storage, which becomes invaluable in dry weather conditions during the growing season. The combination of NT and cover crop show slight improvement in water infiltration over other treatments even in the short time of this experiment (Fig. 9).

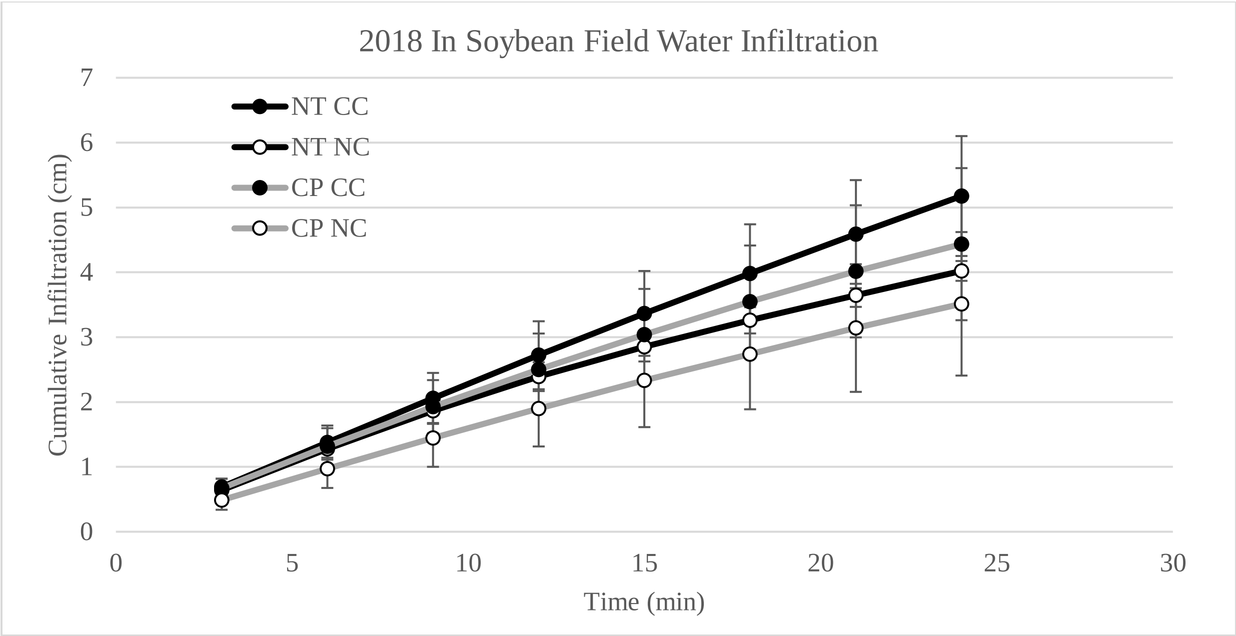


Figure 9. Cumulative infiltration over time for different management treatments (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Cornell infiltrometer used to measure water infiltration in the field.

Soil Penetration Resistance:

Soil compaction is a product of equipment traffic, especially at unfavorable field conditions (wet soils). It can be measured in the field using a penetrometer, such as a Rimik CP-20 (pictured on the following page). It measures the amount of force it takes to penetrate the soil every 25 mm. Less compaction promotes better environments for water movement, soil structure, and root growth. In this study, the rye cover crop had little effect on penetration resistance due to the short-term length of this study and shallow fibrous root structure of winter rye, while tillage appears to decrease the amount of force needed to penetrate the soil (Fig. 10). At the top layer (5 cm), both tillage systems with cover crop have less soil compaction as compared to non-cover crop treatments. Below the soil surface, the soil compaction within the tillage zone is highly affected by tillage system.

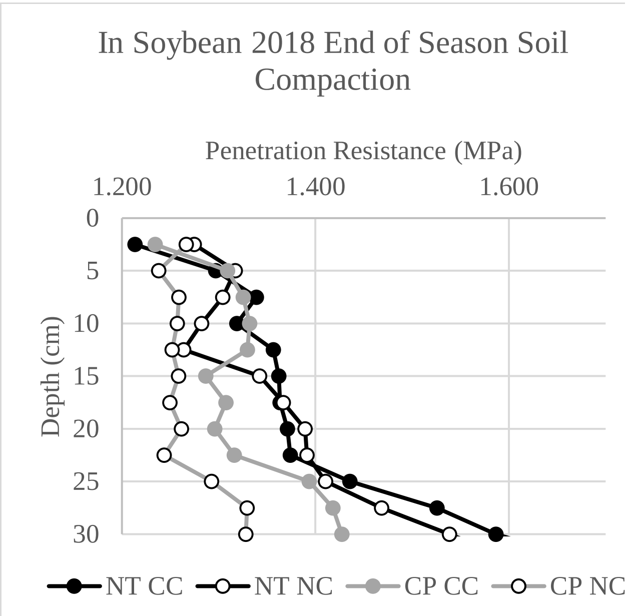


Figure 10. Effects of tillage and cover crops on penetration resistance in November of 2018 (NT = no-till; CP = chisel plow; CC = cover crop; NC = no cover crop).

Rimik CP-20 Penetrometer for measuring soil compaction in the field.

Soil pH:

pH is considered to be the main variable that predicts how favorable soil conditions are for chemical processes to take place. Outside of a certain pH range, crop production is stunted dramatically. The pH of soil is monitored closely to ensure proper timing of lime addition. When changing one management practice, it is important to understand how that influences other management practices. Our study indicates that pH, however, does not behave differently under the different management practices of either tillage or cover crops (Fig. 11).

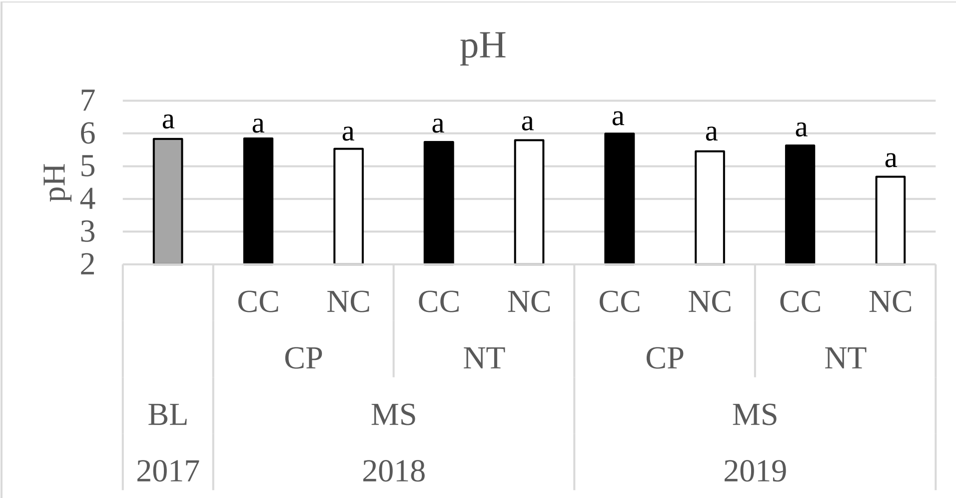


Figure 11. Comparing pH of different management practices across growing seasons. Tillage and cover crop treatment did not significantly affect pH (BL = baseline; MS = midseason; CC = cover crop; NC = no cover crop; NT = no-till; CP = chisel plow).

Soil Microbial Biomass-Carbon:

A strong indicator of soil health is the size and diversity of the microbial community the soil supports. One way to quantify the size of the microbial community is through measuring the amount of carbon that is tied up in organisms. This is accomplished is by collecting soil samples, dividing them, and subjecting one sample to chloroform fumigation, which lyses microbial cells and releases their carbon. The other sample is treated as a control, and the difference between the two is a measure of the size of the microbial community. This indicator is highly sensitive, which means that it is sensitive not only to soil management practices but also to field variability outside of our control. For this reason, we could not determine a significant difference caused by either tillage or cover crops (Fig. 12).

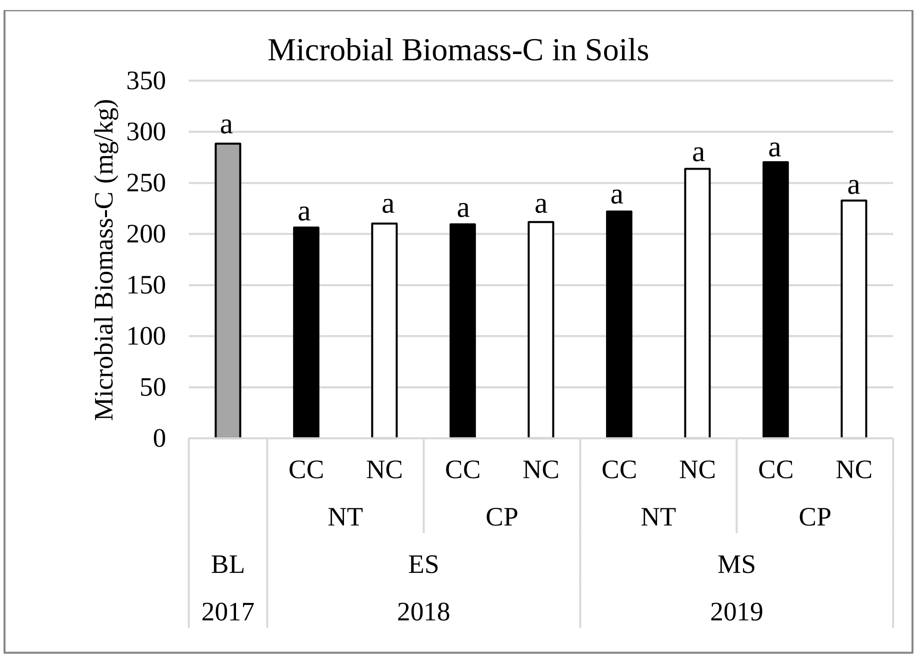
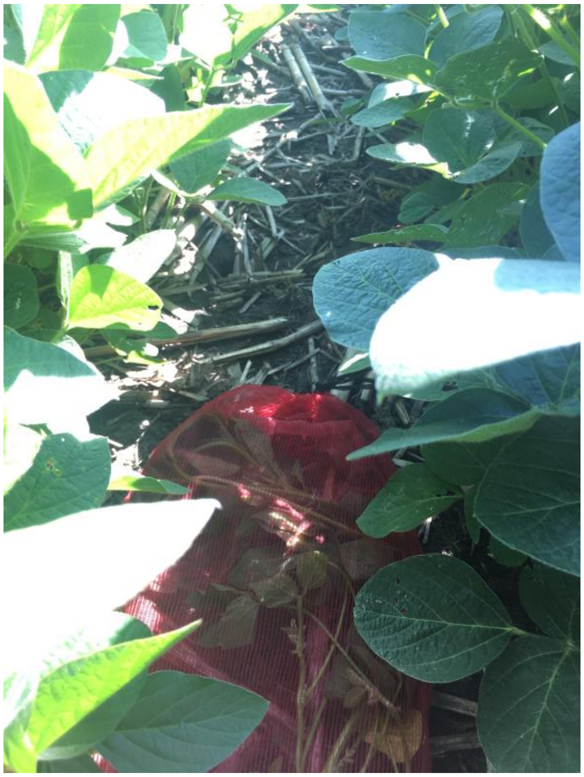


Figure 12. Comparing Microbial Biomass-C of different tillage and cover crop treatments. Due to high variability, no significant differences can be detected (BL = baseline; ES = end of season; MS = midseason; CC = cover crop; NC = no cover crop; NT = no-till; CP = chisel plow).

Residue Decomposition Study:

Three soybean varieties with different carbon to nitrogen ratios (C:N) were compared based on how they decompose in the field. As a general rule, plants with low C:N ratios are decomposed faster than plants with high C:N ratios. The three ratios used here were 47:1, 38:1, and 29:1. All the varieties were at the same maturity stage at the establishment of the experiment. Ten bags of about 100 grams of each soybean variety were weighed and put out in the field in both no-till without cover crops and chisel plow without cover crop treatments. At intervals of one week for the first six weeks and two weeks for the next eight, one bag of each variety in each tillage treatment was collected, brought back to the lab, dried at 60°C for three days, and weighed. At the time of writing this report, data had been collected from the first six weeks. So far, there appears to be no difference between the varieties (Fig. 13), but no-till seems to provide better conditions for residue decomposition than chisel plow (Fig. 14). This may be caused by the increased soil moisture associated with no-till and a lack of disruption of the biological community, both of which lead to higher microbial activity which breaks down the substrate.



A soybean plant that was weighed and put inside a red mesh bag. The bag was then placed in the plot where it came from to be collected later, as pictured on the right.

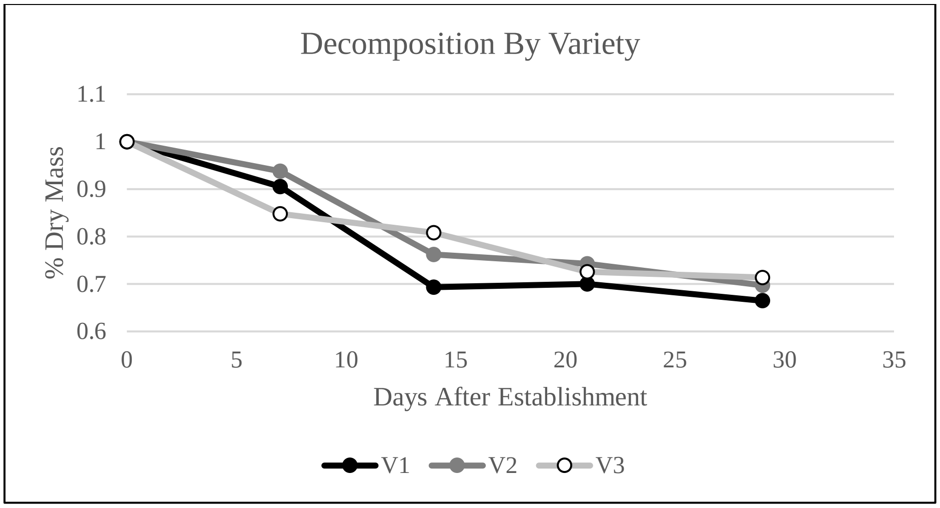


Figure 13. Decomposition averaged over tillage treatments and separated by variety. Despite the difference in C:N ratios, there does not appear to be any clear trends (V1 = Variety 1, C:N =47:1; V2 = Variety 2, C:N = 38:1, V3 = Variety 3, C:N = 29:1).

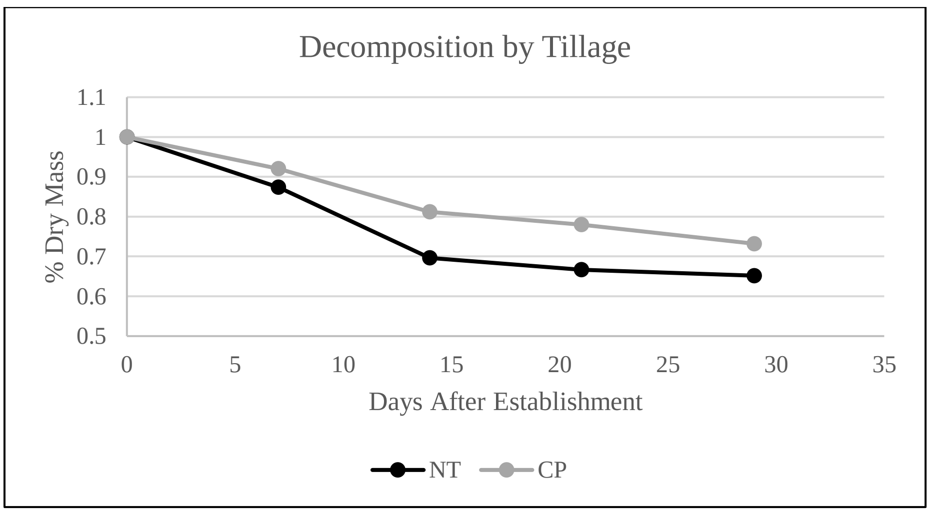


Figure 14. Decomposition averaged over variety and separated by tillage treatments. There is a slight difference in % dry mass remaining, which shows that soybeans placed in the no-till plots were more decomposed than soybeans placed in the chisel plow plots (NT = no-till; CP = chisel plow).

Outreach Activities:

During the period of March 2019 to September 2019, the following activities related to the project were executed:

1. A presentation on soil health and preliminary data from the first year of work from this project was given to farmers at the annual Southeast Iowa Agricultural Research Association.
2. A similar presentation focused on the design and results of this project was given at the Agriculture and Natural Resources Crops Team Fall In-Service located at the Field Extension Education Laboratory in Ames, IA.

3. Presentations related to tillage and soil health were presented during the Agriculture Exploration Day at the Southeast Iowa Research and Demonstration Farm in Crawfordsville, IA. The total attendance was around 200 high school students.

End of Season Field Activities and Parameters to be Completed

1. Soil Sampling for 2019 End of Season
2. Yield 2019
3. Cover Crop Biomass Analysis
4. Soil Ammonium Nitrogen (NH_4^+-N)
5. Total soil C
6. Total soil N
7. Residue Decomposition
8. Economic Analysis

Winter rye grown in CP treatment on May 7, 2019, one week before termination.

Winter rye grown in NT treatment on May 7, 2019, one week before termination.