Sustainable system approach for improving soil health and managing soybean production

First Year Report of the study: fall 2017 to October 2018.

Executive Summary:

This project was established in the fall of 2017 to determine the agronomic, soil health, water quality and economic benefits of integrating cover crop and tillage systems (not-till and chisel plow) in soybean production. 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 aggregate stability, water infiltration, and reduction in nitrate leaching under cover crop as compared to none cover crop treatments. The initial indicators of this systems' approach shows the potential value of cover crop in reducing moisture content and improvement in soil temperature for early soybean germination as indicated by increase in soil temperate by 3-4 ^{o}F. The seeding of cover crop before and after soybean crop in the Des Moines Lobe area is encouraging giving 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. Although we are not reporting soybean yield at this time as we are waiting for the soybean harvest, a long-term study showed that soybean yield and economic return is much greater with no-till as compared to conventional tillage. We will provide more details and additional information at the end of the growing season after data analyses 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 agronomic, soil health, water quality, 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 located 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 field and laboratory activities beginning the fall of 2017 to the present:

Field Work and Data Collection

Establishing of the experiment and treatments

The experiment was established in November 2017 with plots flagged on November 2, 2017 at the Kanawha Research Farm in Central Iowa. Baseline soil sampling was accomplished on November 3, 6 and 7, 2017. The experimental treatments, which include two tillage systems: no-

till (NT) and chisel plow (CP) – chiseling and disking, and the seeding (drilling) of the rye cover crop were established on November 8, 2017. There are 12 plots each of the NT and CP treatments in three (3) replications, giving 24 tillage and cover crops treatments in the experiment. Each replication has four NT and four CP treatments with or without cover crop. Soil temperature sensors and water quality monitoring suction tube/lysimeters were installed in each tillage and cover crop treatments on November 14, 2017. This site was planted with soybean in the spring of 2018 in a corn-soybean rotation system.

Baseline Soil Sampling

The baseline soil samples, which were collected in the fall of 2017 were processed in the lab over the months of December-March and analyzed for the following soil parameters as indicated in the proposal protocol:

1. Soil pH
2. Total Soil Carbon
3. Total Soil Nitrogen
4. Soil Ammonium Nitrogen (NH_4^+–N)
5. Soil Nitrate Nitrogen (NO_3^-–N)
6. Soil Bulk Density
7. Soil Aggregate Stability
8. Microbial Biomass Carbon (MBC)

Laboratory Activities

The following laboratory activities on the baseline soil samples have been accomplished.

1. Analysis for Soil Bulk Density
2. Analysis for Soil Aggregate Stability
3. Analysis for Soil Microbial Biomass Carbon
4. Analysis for Soil pH
5. Analysis for Soil Total Carbon
6. Analysis for Soil Total Nitrogen
7. Analysis for Soil Ammonium-N
8. Analysis for Soil Nitrate-N

During the growing season of 2018, we collected the midseason soil samples. The soil samples were subsequently processed and analyzed in the lab for the above parameters. Also, during the growing season we performed field measurements to determine the rates of soil water infiltration in the cover crop and non-cover crop treatments in both the no- tillage (NT) and chisel plow (CP) treatments. We performed the soil water infiltration experiment by using the Cornel infiltrometer calibrated at a rainfall rate of 0.5cm/min. We also determined the soil penetration resistances

(soil compaction) in the cover crop and non-cover crop treatments in the NT and CP tillage treatments by using the Rimik CP-20 penetrometer.

In August 2018, we collected soybean plant samples from the cover crop and non-cover crop treatments in both tillage treatments to study the rate of soybean residue decomposition (breakdown) in the field. We weighed the total fresh weight of the soybean plant sample per plot and kept the harvested samples in red onion bags at the soil surface in both the NT and CP tillage treatments in the field from August 22, 2018 to the end of the growing season. We retrieved the soybean plant samples from the field periodically for analyses in the lab on the following number of days following the placement of the soybean plant samples in the field: 2, 4, 8, 16, 24, 30 days and end of season after harvest from the date we left the samples in the field. Soybean plant samples retrieved from the field were sent to the lab, processed and oven-dried to determine the sample weight loss for each period.

During the 2018 growing season, we collected hourly soil temperature readings from April to July 2018 by using the B-100 Series Watchdog Temperature data logger (Temp 2K), which was buried at the soil depth of 2 inches in the cover crop and non-cover crop treatments in both tillage treatments (NT and CP). During the same period (April to July 2018), we collected weekly soil moisture readings in both the NT and CP tillage treatments with and without cover crop at the soil depth of 6 inches by using the TDR soil moisture-reading device. The weekly soil moisture readings will continue until soybean senescence prior to harvest.

Extension and Outreach Activities

On September 6, 2018, we organized a Farmers' Field Day at the research site at Kanawha that focused on Cover Crop Management based on cover crops and their benefits in northern Iowa from the perspectives of soil management, weed science, plant pathology and microbiology, and the changes in nitrogen management that are needed when cover crops are used in crop production. Our presentation focused on the: "Tillage and Cover Crop: Soil Health and Yield in Corn-Soybean Rotation." A total number of 55 people attended the September 6, 2018 Farmers' Field Day.

Preliminary Results

Due to continued measurements of data and lab analyses that require additional time to finalize, we will present here some of the immediately available results from the work done in the 2018 growing.

Cover crop biomass establishment and tillage:

Winter rye was used in the study and it was seeded after corn harvest in November 2017. The establishment of cover crop, especially in the Des Moines Lobe area is challenging, giving the cold winter and early spring soil temperatures. Although the early germination and seedling

emergence was slow due to the cold soil temperatures, the warmer spring temperatures however improved the growth and establishment of the cover crop. Therefore cover crop termination was delayed since we are planting soybean and had some advantage to plant late. At the time the cover crop was terminated on June 1, 2018, the winter rye had reached an average plant height of 17.5 inches with NT and 21.0 inches with chisel plow (Fig. 1). The idea was to plant cover crop after corn prior to planting soybean in the growing season to determine the effect of cover crop following corn on soybean growth, yield, and determine the benefits of cover crop to improving the soil health indicators of organic matter, water infiltration and soil aggregate stability. This system will ensure the use of cover crop to improve soil health for the improvement of soybean production in central Iowa. Results from the first year of the study by using winter rye cover crop in the corn-soybean rotation are encouraging due to its tolerant to cold conditions. One of the lessons learned in the first year of this experiment is that winter rye can work within the soybean production system in the Des Moines Lobe.

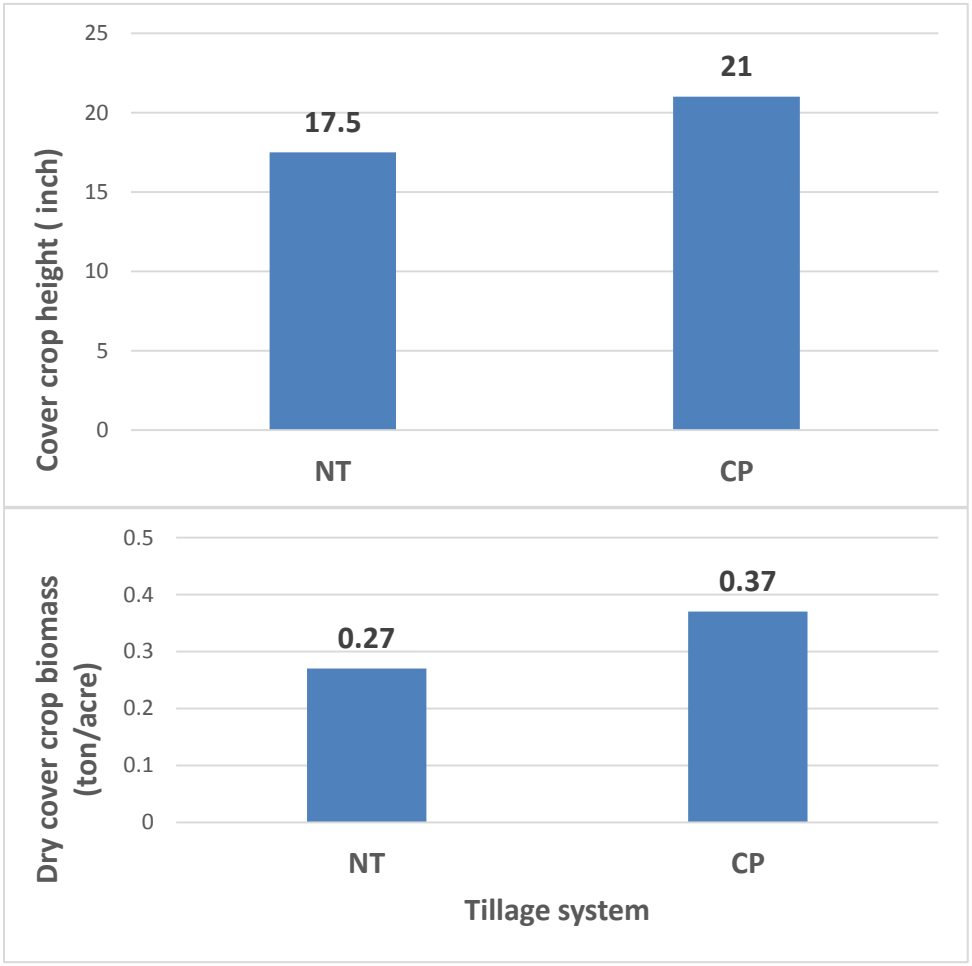

Figure 1. Cereal rye plant height and plant biomass in no tillage and chisel plow tillage systems (NT=No-till and CP=Chisel Plow).

Winter rye seeded in November 11, 2017 at the research site at Kanawha Research Farm.

Winter rye at termination time on June 1, 2018 at the research site at Kanawha Research Farm.

Effect of cover crop and tillage on aggregate stability under soybean:

Aggregate stability is a measure of soil structure strength under different soil management practices such as tillage and the impact of rainfall. Generally, no-till and cover crops improve soil structure as measured by the stability of soil aggregate under wet conditions or rain. In figure 2, we tested the strength of soil aggregate in the lab by subjecting undisturbed soil samples from the treatment plots (no-till and chisel plow, with or without cover crop). 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. Therefore, we observed small improvement or none under both tillage systems with and without cover crop as compared to the baseline prior to the treatment establishments (Fig. 2). Implementing soil conservation practices to achieve a long-term sustainable soil health and productivity is a long-term soil management goal.

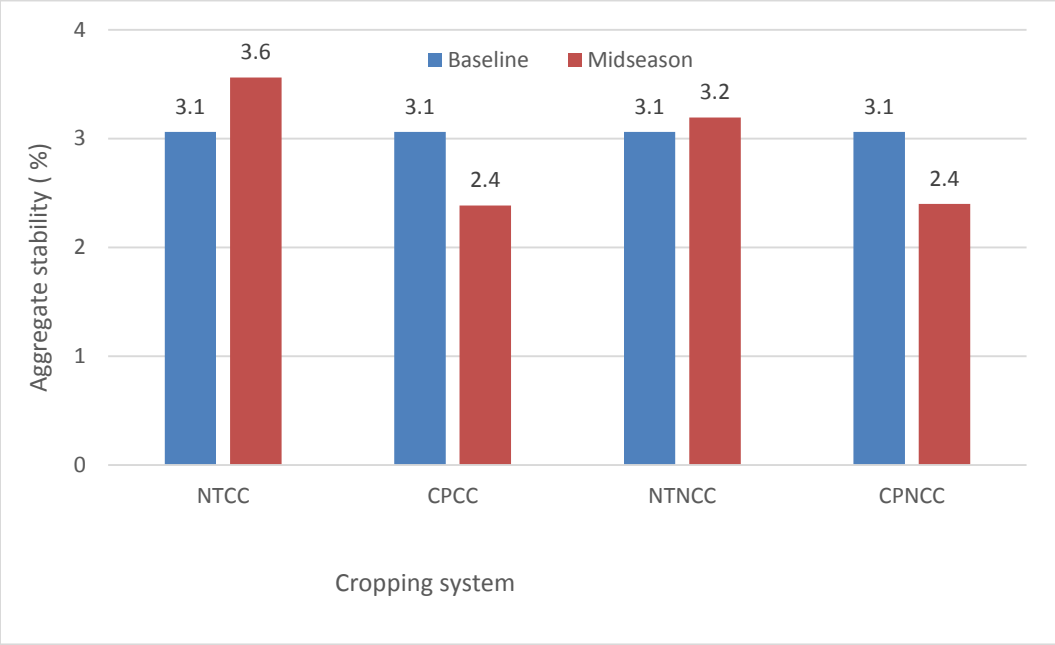

Figure 2. Percent aggregate stability with and without cover crop in no tillage and chisel plow at Kanawha (NTCC=No-till with Cover Crop; CPCC=Chisel Plow with Cover Crop; NTNCC=No-till with no Cover Crop; CPNCC=Chisel Plow with no Cover Crop).

Water infiltration as affected by tillage and cover crop:

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. Plant residue left at the soil surface improves water infiltration, seed germination, seedling establishment, and plant growth. Corn residue left in the field after harvest prior to planting soybean in a no-till system will increase the rate of water infiltration and reduce surface runoff as presented in Figure 3. The combination of NT and cover crop show significant

improvement in water infiltration over other treatments even in the short time of this experiment. This is an important finding, that we can plant soybean in NT with no yield penalty as documented by long-term studies (Al-Kaisi et al, 2016). This quick field measurement enables farmers to evaluate their fields' water conditions. The additional benefit of increasing water infiltration is the increase in soil water storage, which becomes invaluable during dry weather conditions in the growing season.

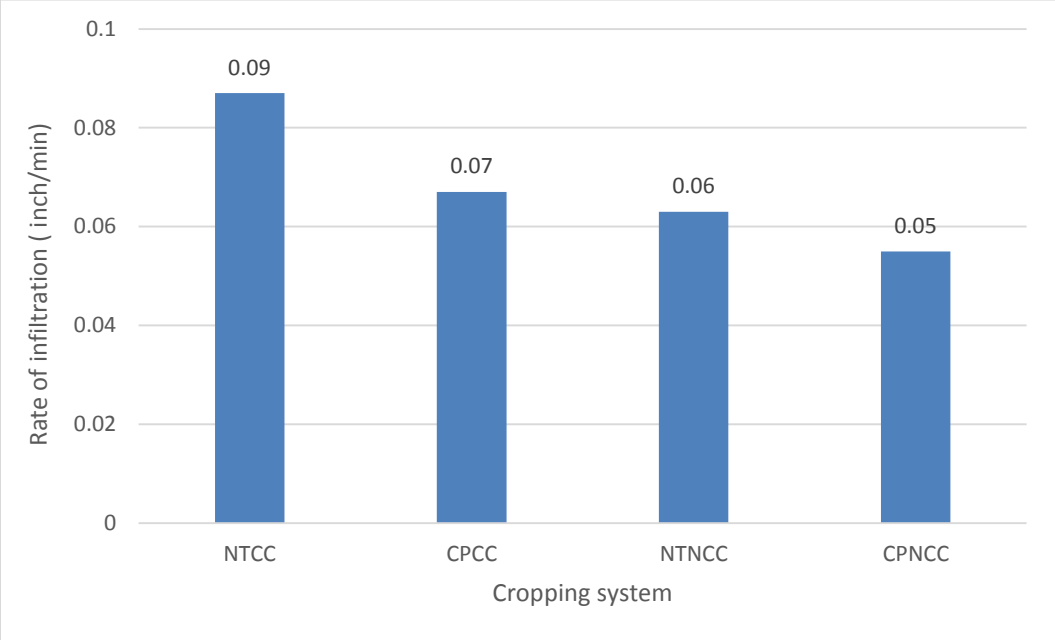

Figure 3. Water infiltration in no tillage and chisel plow tillage system with and without cover crop (NTCC=No-till with Cover Crop; CPCC=Chisel Plow with Cover Crop; NTNCC=No-till with no Cover Crop; CPNCC=Chisel Plow with no Cover Crop).

(Al-Kaisi, M.M., Archontoulis, S. and Kwaw-Mensah, D. 2016. Soybean Spatiotemporal Yield and Economic Variability as Affected by Tillage and Crop Rotation. Agronomy Journal. 108:1-14.)

Cover crop effects on Nitrate leaching:

One of the many benefits of cover crop is the off-season capture of residual soil nitrate and the reduction of nitrate loss to groundwater. Winter rye is well known for its effectiveness in extracting soil nitrate. To monitor the winter rye contribution to the reduction in nitrate leaching within the soybean plots in the two tillage systems (no-till and chisel plow), we installed 2 ft. suction tubes and collected water samples at the 2 ft. soil depth after each rain event (Fig. 4). Figure 4 represents the water nitrate concentration of cover and none-cover crop treatments with NT and CP, where significant reduction in nitrate concentration was observed under no-till with cover crop (NTCC) compared to none cover crop treatments and chisel plow with and without

cover crop treatments. This finding demonstrates the value of cover crop in the short and long-terms as a practice that not only improves soil health, but water quality as well.

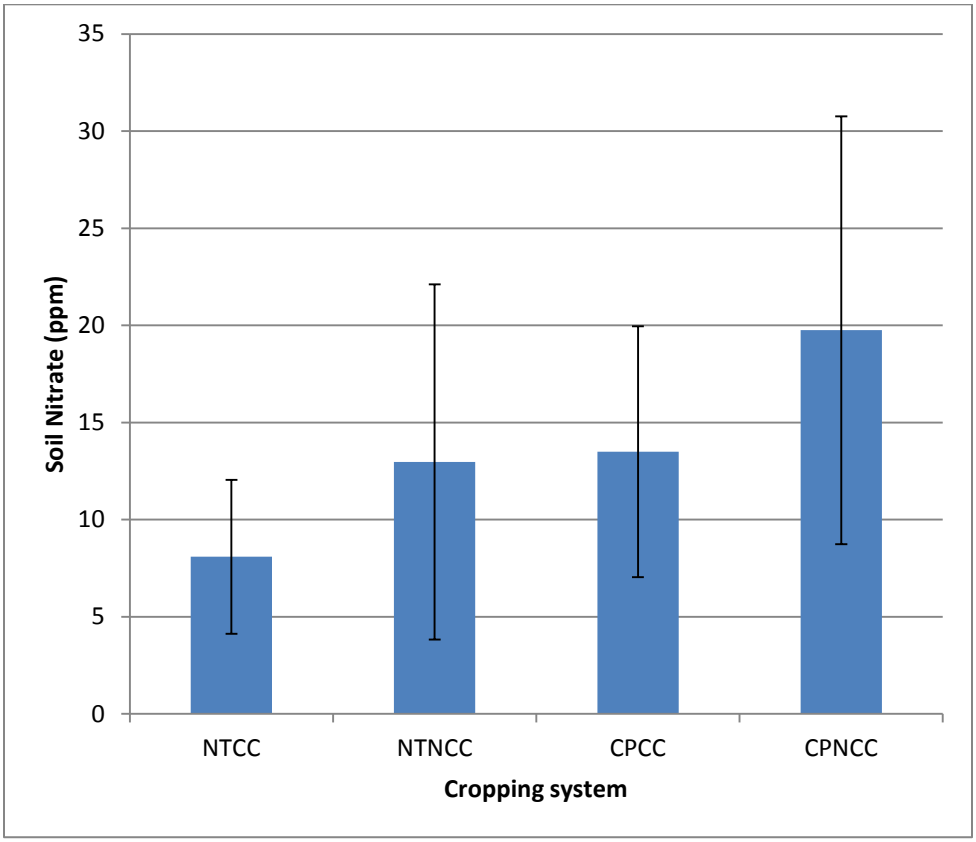

Figure 4. Average soil nitrate (NO^{-3}) leached at 2 ft. depth under tillage and cover crop treatments.

Effect of tillage and cover crop on soil temperature:

Soil temperature is an important factor in soybean germination, especially in the northern and central parts of the state where poorly drained soils and cold soil temperatures delay seed germination. To monitor the effect of both tillage and cover crop on soil temperature at the top two inches of soil depth, we installed temperature sensors in both tillage systems (no-till and chisel plow) with and without cover crop. Generally, tillage can increase soil temperature by increasing soil water evaporation in the tilled-zone of the soil. However, including cover crop with NT or chisel plow can reduce the water content, especially in the early spring where cover crop extracts moisture and that leads to warming the soil at the planting depth (of the seedbed) to improve seed germination (Fig. 5).

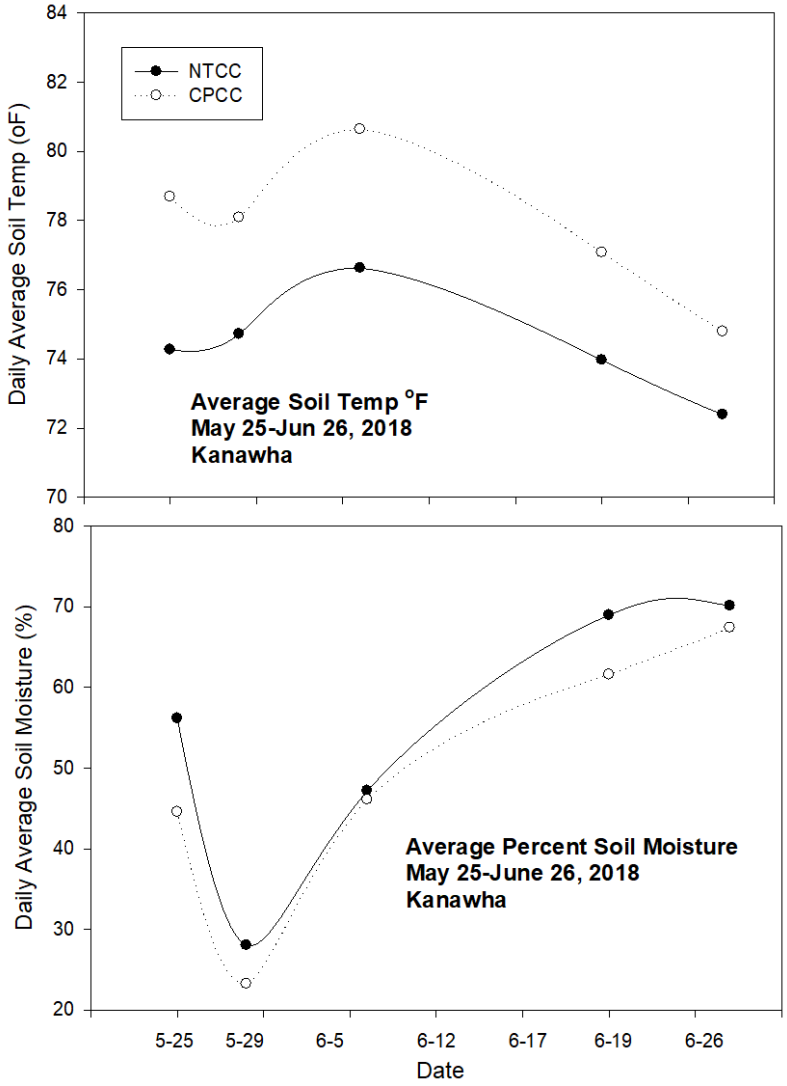

Figure 5. Average soil temperature (top 2 inches depth) and percent soil moisture (top 6 inches depth) in no tillage (NT) and chisel plow (CP) tillage systems with cover crop.

Long-term and short-term benefits of this research to Iowa Soybean Farmers:

The integration of cover crop with tillage system in soybean production can have positive effects on improving soil health and reducing soil erosion. In this project, the initial short-term indicators are showing that there is a great potential for improving soil and water quality in central Iowa, which farmers in other parts of the state can benefit from as well. The system that we used in this study is seeding cover crop before planting and after harvesting soybean. This system can provide benefits to farmers by reducing nutrient loss, especially soil nitrates, which easily leaches through the soil and phosphorous and soil organic matter, which can be lost with soil erosion. From the preliminary data, there is a good potential for using and establishing cover

crop, especially with soybean and extend the termination to a later date in the spring to maximizing the benefits of water and soil quality as demonstrated by short-term results. The initial results will help us fine-tune our management practices such as soil tillage with a cover crop management system. The short-term gains from integrated systems of cover crop and conservation practices can have both agronomic and economic benefits to develop a sustainable long-term return. The development of a more robust soybean production system that has less-negative ecological impacts on soil and water quality, is essential for sustainable soybean production to capitalize on the flexibility of soybean production of late spring planting, to encourage an intensive cover crop biomass for maximum soil and water quality benefits.

To fully understand and develop an integrated system for soybean production that is economically and environmentally sustainable, we need a long-term evaluation to increase the agronomic and economic return of the system. We feel the high productivity of our soils in Iowa can benefits from a well-integrated system, especially with soybean production by using cover crop as a low residue amount crop associated with the soybean crop, where cover crop can play significant role in reducing the potential for soil erosion and its associated negative impacts.

Key Points and Recommendations:

The first year early findings of this research project highlighted a few short-term benefits that we can use to predict the long-term benefits for soybean production using an integrated or stocked practices that include conservation tillage and cover crop. The following are a few key points or take home message from our on-going effort:

- Winter rye has been demonstrated as a good fit for the Des Moines Lobe with good establishment and biomass prior to soybean seeding.
- Managing winter rye to grow for achievable effective biomass to maximize its soil and water quality benefits presented less challenge to planting soybean.
- The integration of cover crop and no-till system in soybean production can have positive impact on soil health and water quality.
- The agronomic and economic return of using cover crop within the soybean production is another indicator we will determine as we finalize the season and obtain yield as a major indicator for fine-tuning our management practices.