**Final Report for #16-393**

1. **Title of Grant**: Incorporating Cover Crops into Soybean Cropping Systems
2. **Period Covered (life of project for final report**): 2016 through 2019
3. **Project Leader and Co-Primary Investigators:** William (Bill) Wiebold
4. **Layman’s Summary (limit to one page):**

Data collection for this four-year project began in 2016. The project used plots that were first established with rotation and cover crop treatments in 2014. The objectives of the project included determining the effects of cover crops on soybean yield and the effects of rotation and cover crops on soil health.

Rotation treatments were: continuous soybean, soybean rotated with corn, corn rotated with soybean and continuous corn. Plots were 40 feet long and 20 feet wide. Commonly used management practices of both crops were employed. Plots were not irrigated unless severe drought occurred. Cover crop treatments were no cover crop and a mixture of cereal rye and radish. Cover crop seeds were broadcast into standing grain crops just before leaf drop of soybean. Rye survived through the winter, but radish was killed by freezing temperatures. Cover crops and any weeds were killed with a spring burndown application of Roundup on a date that ensured timely planting of grain crops. Rye had not produced heads at termination.

Continuous soybean and soybean rotated with corn yield the same in three of the four years. In 2016, continuous soybean yielded 19% less than rotated soybean. Averaged over all four years the mean yields differed by only 0.6 bu/acre and the rotation effect was not significant. Continuous corn yielded less than corn rotated with soybean in three of the four years. Yield penalties were 14, 20, and 6% in 2016, 2018, and 2019. Averaged over all four years the yield penalty from continuous corn was 10%.

The rye/radish cover crop did not affect soybean yield in any of the four years. Averaged over all four years soybean yields were 48.1 and bu/acre and 49.3 in plots without and with cover crops. The effect of cover crops on corn yield was more negative than on soybean yield. Averaged over all four years corn yields were 186 and bu/acre and 176 in pots without and with cover crops.

Neither rotation nor cover crop treatments had much effect on soil health parameters. Changes in microbial populations may change over a longer time frame than what we used in this project. The only soil characteristic affected by the treatments was water stable aggregates (WSA). WSA was greater for corn compared to soybean (35 and 23%). Continuous cropping actually had greater WSA than rotation (32 and 25%). WSA are beneficial because aggregates are an indicator of good soil structure. Aggregates are held together by organic matter and fungi. Because corn stimulated fungi growth it also stimulated the formation of WSA.

Cereal rye is an effective cover crop because it produces large amounts of biomass and survives Missouri winters. However, there is some concern that rye allelopathy could decrease yield. We found no indication of a yield decrease. Soybean farmers should be able to use cereal rye as a cover crop. However, corn yield was decreased by rye. We used an early termination date and substantial nitrogen fertilizer, so the cause of yield decline was probably not nitrogen tie-up. Missouri farmers should be judicious in their use of rye cover crops in corn cropping systems.

1. **State your objectives in question form and discuss how your results answer these objectives.**

Because one of the rotation treatments was soybean rotated with corn, we were able to collect data from corn plots and were able to compare soybean to corn for cover crop management and effects on soybean health. All data, soybean and corn, are included in the tables and this discussion.

1. Determine the impact of appropriate cover crop management on soybean yield.

There have been some reports that the use of cereal rye as a cover crop may decrease grain crop yields. Our cover crop treatment, an equal mixture of rye and radish, did not decrease soybean yield in any of the four years of the project. Averaged over all four years, soybean yields were 48.1 and bu/acre and 49.3 in plots without and with cover crops.

The effect of cover crops on corn yield was more negative than on soybean yield. Averaged over all four years, corn yields were 186 and bu/acre and 176 in plots without and with cover crops. This was a significant yield decrease of 10 bu/acre or about 6%. Similar results have been found in the MU Strip Trial project.

2. Determine if cover crops can correct some of the negative impacts from soybean planted after soybean.

In this experiment, continuous soybean did not decrease yield compared to a soybean – corn rotation except in 2018. In that year continuous soybean yielded 7.1 bushels (19%) less than soybean rotated with corn. Averaged over all four years, the mean yield differed by only 0.6 bu/acre and the effect was not significant. A 3-year mean is provided because of the unusual results for 2016. But, the yield difference between rotated soybean and continuous soybean was only 1.4 bushels/acre and still not significant. In 2018, cover crops had little effect on the continuous crop yield penalty.

Continuous corn yielded less than corn rotated with soybean in three of the four years. Yield penalties were 14, 20, and 6% in 2016, 2018, and 2019. Averaged over all four years the yield penalty from continuous corn was 10%. Cover crops did not decrease the yield penalty for continuous corn. Averaged over all four years, the lowest yield was for continuous corn grown with a cover crop.

3. Determine if soybean intensity in a rotation affects soil health parameters.

We have modified the project to include additional information. The additional information allows for a soil health comparison of soybean and corn as rotation partners. We used the FPLA method for estimating soil health parameters and soil characteristics as measured by the MU Soil Health Laboratory. Soil health microbial parameters included the weights of arbuscular mycorrhizae, other fungi, gram negative bacteria, gram positive bacteria, anaerobic bacteria, actinomycetes, and total organisms. Each of the microbe types was also calculated as a percentage of total organisms. Soil characteristics were bulk density, water stable aggregates, potential mineralizable nitrogen, total organic carbon, and active carbon.

Neither rotation nor cover crop treatments had much effect on soil health parameters. Treatments have been imposed for seven years. Changes in microbial populations may change over a longer time frame than what we used in this project.

Crop type affected the weights of arbuscular mycorrhizae (AMF) and other fungi. Plots with corn planted had greater amounts of both categories of fungi than plots with soybean. AMF are beneficial fungi that infect roots. The larger root system of corn may have resulted in greater AMF. Fungi other than AMF are responsible for residue decomposition. Corn produces much more residue than soybean and this greater residue amount may have stimulated fungi growth.

The only soil characteristic affected by the treatments was water stable aggregates (WSA). WSA was greater for corn compared to soybean (35 and 23%). Continuous cropping actually had greater WSA than rotation (32 and 25%). WSA are beneficial because aggregates are an indicator of good soil structure. Aggregates are held together by organic matter and fungi. Because corn stimulated fungi growth it also stimulated the formation of WSA.

1. **Please answer the following.**
2. **How do your results benefit Missouri soybean growers?**

There has been renewed interest in using cover crops for erosion control and to improve soil health. This project provides important information of the effects of cover crops on soybean yield and soil characteristics.

1. **Estimate financial return for the average Missouri soybean producer.**

Difficult to estimate returns from applied research information.

1. **Do your results benefit the environment?**

Yes, cover crops are an effective method for controlling erosion and the effects of eroded soil on the environment. This project provides important information for cover crop management.

1. **What products or processes can be commercialized from this research?**

Applied research, no products or varieties

1. **List disclosure(s) of inventions or plant varieties submitted to the MU Tech Transfer Office.**
2. **Identify potential disclosure(s) of inventions or plant varieties. *Please note that credit must be given to MSMC for any inventions or discoveries resulting from this research*.**
3. **How would you commercialize these products or processes?**

No products

1. **If no specific products or processes were produced, how do you plan to make your results available to producers or industry?**

Newsletter articles, presentations, extension web site

1. **Is additional time or research required before your results can be used by producers and industry?**

No, however data collection will continue and results my change over time

1. **Where does this research go from here? What are the next steps?** These plots with these rotation and cover crop treatments existed before MSMC project and will continue to exist after the
2. **List publications by type (popular press, thesis, journals, other) written or planned.**

Planned: Jake Young’s dissertation, peer-reviewed article for Agronomy Journal, IPCM newsletter, extension article to be posted on University of Missouri Extension web site.

1. **List cost of original project and actual expenditures. *The U.S. Department of Agriculture requires that we ask for budget information, including the number of hours spent on the project, the number of dollars remaining on account, as well as a breakdown of expenses. You are required to provide this information in your report.* Please also include names and titles/positions of those whose time has been charged to this project.**

A total of $78,308 was requested from MSMC over the four-year life of the project. Total expenses were $78,308. A portion of the funds were used for the GRA of Jake Young. A small portion of the funds were used for salaries of one or more technicians with the MU Variety Testing Program to provide support for the project.

1. **List equipment purchased with MSMC funds, identifying inventory and serial number. (It is not considered equipment unless it costs $500 or more and has a life expectancy of at least 2 years.) Indicate current and future use of this equipment in support of soybean research.**

None

**Appendix of Tables**

Table 1. Yields of soybean grown with two rotation systems and two cover crop treatments for four years, Columbia, MO.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| System | Cover | 2016 | 2017 | 2018 | 2019 | 4-yr | 3-yr† |
|  |  | ------------------------------ bushels/acre ------------------------------ |
| Continuous | Yes | 57.7a§ | 51.3a§ | 38.0b§ | 50.9a§ | 49.5a§ | 46.7a§ |
| Continuous | No | 55.9a | 52.7a | 35.6b | 49.8a | 48.5a | 46.0a |
| Rotated | Yes | 51.1a | 50.4a | 45.0a | 49.8a | 49.1a | 48.4a |
| Rotated | No | 49.5a | 51.3a | 42.7a | 47.8b | 47.8a | 47.3a |
|  |  |  |  |  |  |  |  |
| Means |  |  |  |  |  |  |  |
| Continuous |  | 56.8a¶ | 52.0a¶ | 36.8b¶ | 50.3a¶ | 49.0a¶ | 46.4a¶ |
| Rotated |  | 50.3a | 50.8a | 43.9a | 48.8a | 48.4a | 47.8a |
|  |  |  |  |  |  |  |  |
|  | Yes | 54.4a# | 50.8a# | 41.5a# | 50.3a# | 49.3a# | 47.5a# |
|  | No | 52.7a | 52.0a | 39.2a | 48.8a | 48.1a | 46.6a |

† 3-yr mean does not include 2016 data.

§ Means followed by same letter are not different.

¶ Rotation treatment means followed by same letter are not different.

# Cover crop treatment means followed by same letter are not different.

Table 2. Yields of corn grown with two rotation systems and two cover crop treatments for four years, Columbia, MO.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| System | Cover | 2016 | 2017 | 2018 | 2019 | 4-yr | 3-yr† |
|  |  | ------------------------------ bushels/acre ------------------------------ |
| Continuous | Yes | 122c§ | 198a§ | 150b§ | 189b§ | 164c§ | 179b§ |
| Continuous | No | 149b | 201a | 164b | 191ab | 177b | 186b |
| Rotated | Yes | 151a | 203a | 197a | 196ab | 187a | 199a |
| Rotated | No | 164a | 215a | 197a | 207a | 196a | 207a |
|  |  |  |  |  |  |  |  |
| Means |  |  |  |  |  |  |  |
| Continuous |  | 135b¶ | 200a¶ | 157b¶ | 190b¶ | 171b¶ | 182b¶ |
| Rotated |  | 157a | 209a | 197a | 202a | 191a | 203a |
|  |  |  |  |  |  |  |  |
|  | Yes | 136b# | 201a# | 174a# | 193a# | 176b# | 189a# |
|  | No | 157a | 208a | 181a | 199a | 186a | 196a |

† 3-yr mean does not include 2016 data.

§ Means followed by same letter are not different.

¶ Rotation treatment means followed by same letter are not different.

# Cover crop treatment means followed by same letter are not different.

Table 3. Effect of crop, rotation system, and cover crop treatment on several soil health characteristics including soil water stable aggregates (WSA), arbuscular mycorrhizae (AMF), and other fungi.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Crop | System | Cover | WSA | AMF | Other fungi |
|  |  |  | % | pmol/g | pmol/g |
| Soybean | Continuous | Yes | 25.0c† | 4830bc† | 1007c† |
| Soybean | Continuous | No | 21.0c | 4153bc | 820c |
| Soybean | Rotated | Yes | 25.3c | 4445bc | 870c |
| Soybean | Rotated | No | 19.5c | 3757c | 964c |
| Corn | Continuous | Yes | 46.3a | 6302a | 2083ab |
| Corn | Continuous | No | 37.0ab | 5457a | 1685bc |
| Corn | Rotated | Yes | 27.3bc | 4749bc | 1557bc |
| Corn | Rotated | No | 28.8bc | 5533ab | 2630a |
|  |  |  |  |  |  |
| *Means* |  |  |  |  |  |
| Soybean |  |  |  22.7b‡ |  4296b‡ |  915b‡ |
| Corn |  |  | 34.7a | 5510a | 1989a |
|  |  |  |  |  |  |
|  | Continuous |  |  32.3a§ |  5186a§ |  1398a§ |
|  | Rotated |  | 25.2b | 4621a | 1505a |
|  |  |  |  |  |  |
|  |  | Yes |  30.9a¶ |  5082a¶ |  1379a¶ |
|  |  | No | 26.6a | 4725a | 1525a |
|  |  |  |  |  |  |
| Soybean | Continuous |  | 23.0b# | 4491b# | 913b# |
| Soybean | Rotated |  | 22.4b | 4100bc | 917b |
| Corn | Continuous |  | 41.6a | 5880a | 1884a |
| Corn | Rotated |  | 28.0b | 5141ab | 2094a |

† Means followed by same letter are not different.

‡ Soybean and corn means followed by same letter are not different.

§ Rotation treatment means followed by same letter are not different.

¶ Cover crop treatment means followed by same letter are not different.

# Crop and rotation treatment combination means followed by same letter are not different.