Using cover crops with wheat to improve rotational profitability
Final Report
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Investigator: Dean Baas, Michigan State University Extension

Project summary

Research sites were established in two locations, the MSU Saginaw Valley Research (SVREC) and Extension Center and the MSU Mason Agronomy Farm (Mason), to investigate the impact of rotational diversity and/or cover crops on yield, inputs and soil health. The research plots were implemented with four replications for the resulting 20 treatments for three years, one full cash crop cycle and two cover crop years. Significant yield differences were identified in year three corn at SVREC and year three soybeans at Mason. At SVREC, year three corn yield averaged 19.9 bu/A higher when soybeans were added to the continuous corn rotation, 30.1 bu/A higher when wheat and soybeans were added to the continuous the corn rotation and 10.2 bu/A when wheat was added to the corn-soybean rotation. At Mason, year three soybean yield was 16.8 bu/A higher when corn and wheat were added to the continuous soybean rotation, 17.5 bu/A higher for the corn-soybean-wheat with sorghum-sudangrass followed by cereal rye, 17.1 bu/A for the corn-soybean-wheat with red clover. The corn and soybean yield results suggest that the increases at both locations were probably more the result of diversity than cover crops.

Other than 2016 corn at SVREC and soybeans at Mason, yields were not significantly different for any other years, crops and diversity and/or cover crop treatments. During the three growing seasons, there were no observable differences in weed, insect or disease pressure with no differences in herbicide or pesticide treatment types, amounts or rates within cash crops at either site. With the exception of 2015, where the red clover cover crop treatment yielded a 30 lb/A nitrogen credit at SVREC, all other corn years received the nitrogen rate recommended for yield goal and soil type by the pre-sidedress nitrogen test (PSNT). Other nutrients were applied as recommended by the MSU Soil and Nutrient Laboratory.

Cornell soil health assessments were performed by treatment for both sites. The SVREC and Mason sites soil health overall quality scores remained low to medium with no clear relationships or trends between the overall scores or individual ratings and including diversity and/or cover crops for three years. Cornell suggests additional management changes in addition to the diversity and cover crops including less tillage, manure, sod crops, etc. to correct the low ratings, in particular the low biological ratings. These changes are probably not economical, practical or of interest to farmers within the cropping regions studied. Longer term effects of diversity and/or cover crops cannot be estimated with a single three year, one crop rotation cycle. While it is promising that significant yield differences emerged in year three for corn at SVREC and soybeans at Mason, we know building soil health is a slow process. A longer period under diversity and/or cover crops would be necessary to determine if soil health is improving, declining or remaining constant under the treatments studied.

Background

Historically, crop rotations have been much more diverse than they are at the present time. The lack of more sophisticated crop rotations has resulted in crop yield reductions, increased pest problems and

poor soil quality. A University of Guelph study showed diversifying by including wheat in the rotation provided a 25 bushel per acre (bu/A) yield benefit to corn and four to six bu/A in soybean yield in the corn-soybean-wheat rotation. Including wheat in the rotation also provides an opportunity to further diversify the rotation through the addition of cover crops. When red clover is frost seeded into wheat, the same University of Guelph study found on average an eight bushel per acre increase in corn yield.

Our project evaluated continuous corn, continuous soybeans, corn/soybean and corn/soybean/wheat rotations with and without cover crops at two locations. Using these plots, we evaluated the agronomic performance and soil health changes of rotations with cover crops only, wheat only and wheat with three different cover crops over three years. This design allows us to evaluate the effects of rotational diversity, cover crops and the combination of diversity and cover crops. We believed incorporating wheat and cover crops into the corn and soybean rotation would enhance yields; decrease incidence of weeds, diseases and pests; and increase profits for corn, soybean and wheat growers in Michigan, while improving soil health. This project was funded through the Corn Marketing Program of Michigan, Michigan Soybean Checkoff and Michigan Wheat Program.

Methods

Duplicate trials were established in two locations: the MSU Agronomy Farm (Mason), Mason, MI and the MSU Saginaw Valley Research and Extension Center (SVREC), Frankenmuth, MI (Figure 1). The trials consisted of ten split plot treatments randomized within four replicated blocks. All rotation entry points were tested to evaluate growing season variability. Treatments were split by: 1) with cover crop and 2) a without cover crop control. The three cover crop combinations with wheat studied were frost seeded red clover (RC), oilseed radish (OSR) plus oats (O) mix and sorghum-sudangrass (S) followed by winter cereal rye (R). Winter cereal rye was used as the cover crop after corn and soybeans in the non-wheat rotations and after corn in the wheat rotations. The crop rotations and cover crop combinations by year are given in Figure 2. Typical management practices including reduced tillage were used for all treatments and herbicides used for cover crop termination and weed control. Fertility was be based on pre-sidedress nitrogen test (PSNT) and soil test analyses.

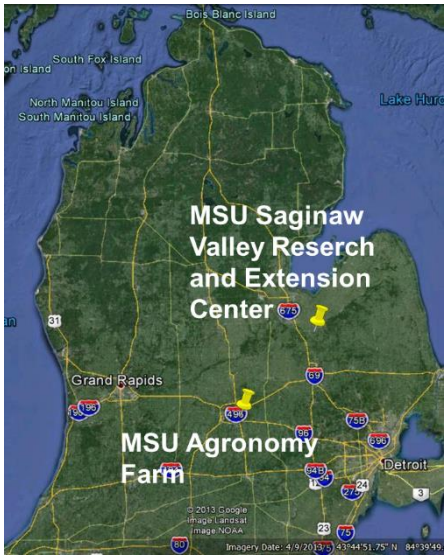

Figure 1. Research locations.

The following data was gathered for analysis across treatments, splits and years:

- Seeding rate (crop and cover crop)
- Cover crop density
- Fall and spring biomass
- Weed assessment (also used to determine herbicide application requirements)
- Disease assessment (also used to determine pesticide application requirements)
- PSNT for corn yield goal N application and cover crop N contribution
- Crop yields
- Cornell soil health assessment

	Year 1 (2014)		Year 2 (2015)		Year 3 (2016)	
Trt	Crop	cover	Crop	cover	Crop	cover
1	Corn	No Cover	Corn	No Cover	Corn	No Cover
2	Corn	Rye	Corn	Rye	Corn	Rye
3	Soybean	No Cover	soybean	No Cover	soybean	No Cover
4	Soybean	Rye	soybean	Rye	soybean	Rye
5	Corn	No Cover	soybean	No Cover	Corn	No Cover
6	Corn	Rye	soybean	Rye	Corn	Rye
7	soybean	No Cover	Corn	No Cover	soybean	No Cover
8	soybean	Rye	Corn	Rye	soybean	Rye
9	Corn	No Cover	soybean	Wheat	Wheat	No Cover
10	Corn	Rye	soybean	Wheat	Wheat	Red Clover
11	Corn	Rye	soybean	Wheat	Wheat	Oats + OSR Mix
12	Corn	Rye	soybean	Wheat	Wheat	Sorghum then Rye
13	soybean	Wheat	Wheat	No Cover	Corn	No Cover
14	soybean	Wheat	Wheat	Red Clover	Corn	Rye
15	soybean	Wheat	Wheat	Oats + OSR Mix	Corn	Rye
16	soybean	Wheat	Wheat	Sorghum then Rye	Corn	Rye
17	Wheat	No Cover	Corn	No Cover	soybean	Wheat
18	Wheat	Red Clover	Corn	Rye	soybean	Wheat
19	Wheat	Oats + OSR Mix	Corn	Rye	soybean	Wheat
20	Wheat	Sorghum then Rye	Corn	Rye	soybean	Wheat

Figure 2. Research treatments by project year.

Progress to date

Year one (2014) of this project established 20 treatments (Figure 2) with four replications in two research locations (Figure 1) in Michigan. Year two (2015) continued the rotations/cover crops established in year one. Year two was the first crop year after the inclusion of wheat and/or cover crops in the rotation. Year three (2016) continued the rotations/cover crops established in year one and continued in year two. Harvest year three represents completion of the three year cash crop rotation and includes two years of cover crop use for the cover crop treatments (T2, T4, T6, T8, T10, T11, T12, T14, T15, T16, T18, T19 and T20).

2016 Growing Conditions

MSU Enviroweather data for accumulated precipitation and growing degree days (GDD) from May – October for the SVREC (Richville/ Frankenmuth station) and Mason (East Lansing/ MSUHRT station) are given in Figure 3. Accumulated GDD were similar for each location. Both locations experienced dry conditions from mid-April through mid-August, when over four inches of precipitation was received in less than a week. Mason site finished the period with 4.5 inches more precipitation than SVREC site.

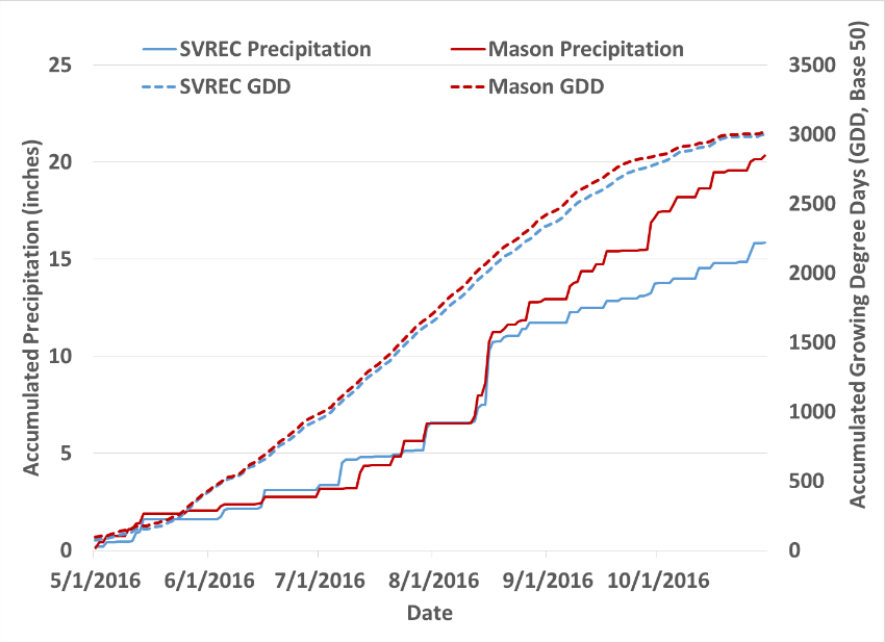

Figure 3. 2016 accumulated precipitation and growing degree days from April through October for the SVREC and Mason sites.

Agronomic Results

SVREC

Yield results for the 2016 growing season are given for the SVREC site in Table 1.

Soybean yields

There was no statistically significant differences in yield between any of the treatments that were harvested for soybeans in 2016. After three years, neither the introduction of cover crops, rotational diversity or the combination of diversity and cover crops impacted soybean yields at the SVREC site.

Wheat yields

There were no statistically significant differences in wheat yield between any of the treatments that were harvested for wheat in 2016. After three years, adding cover crops into a diversified rotation that included wheat did not impact wheat yields at the SVREC site.

Corn yields

Cover crops

There was no statistical difference in yield between continuous corn without a cover crop and continuous corn with a cereal rye cover crop (T1 vs T2).

Rotational diversity

Adding soybeans into the corn rotation resulted on average in a 19.9 bu/A year three corn yield increase (T5 vs T1). Adding both soybeans and wheat into the corn rotation increased year three corn yield on average 30.1 bu/A compared to continuous corn (T13 vs T1) and 10.2 bu/A compared to the corn-soybean rotation (T13 vs T5).

Rotation diversity and cover crops

A corn-soybean rotation with a cereal rye cover crop resulted on average in a 17.5 bu/A year three corn yield increase (T6 vs T1). However, the yield from only adding soybeans (19.9 bu/A) was

not statistically different than the yield from adding the combination of soybeans and a cereal rye cover crop (17.5 bu/A) to the continuous corn rotation.

Table 1. Corn, soybean and wheat yields in 2016 at the SVREC location for the different rotational/cover crop treatments. (Corn p-value = 0.032. LSD, 95% confidence: statistical significance – yields with different letters are different.)
Cover crop key: NC – No Cover, Rye – Cereal Rye, RC – Red Clover, O+OSR – Oilseed Radish and Oats Mix, S/R – Sorghum-sudangrass followed by Cereal Rye.

Crop	Treatment	Rotation	Average Yield (bu/A)	Statistical Significance
Corn	1	Corn-NC-Corn-NC-Corn	157.0	a
	2	Corn-Rye-Corn-Rye-Corn	164.7	a
	6	Corn-Rye-Soybean-Rye-Corn	174.5	b
	16	Soybean-Wheat-Wheat-S/R-Corn	175.3	b
	15	Soybean-Wheat-Wheat-O+OSR-Corn	176.6	b
	5	Corn-NC-Soybean-NC-Corn	176.9	b
	14	Soybean-Wheat-Wheat-RC-Corn	184.2	c
	13	Soybean-Wheat-Wheat-NC-Corn	187.1	c
Soybean	4	Soybean-Rye-Soybean-Rye-Soybean	64.5	d
	19	Wheat-O+OSR-Corn-Rye-Soybean	70.1	d
	3	Soybean-NC-Soybean-NC-Soybean	70.8	d
	17	Wheat-NC-Corn-NC-Soybean	71.4	d
	8	Soybean-Rye-Corn-Rye-Soybean	71.9	d
	18	Wheat-RC-Corn-Rye-Soybean	73.0	d
	7	Soybean-NC-Corn-NC-Soybean	75.3	d
	20	Wheat-S/R-Corn-Rye-Soybean	78.7	d
Wheat	11	Corn-Rye-Soybean-Wheat-Wheat-O+OSR*	76.1	e
	10	Corn-Rye-Soybean-Wheat-Wheat-RC*	76.3	e
	9	Corn-NC-Soybean-Wheat-Wheat-NC	86.2	e
	12	Corn-Rye-Soybean-Wheat-Wheat-S/R*	92.2	e

*Frost seeded RC growth until wheat harvest, O+OSR and S/R planted after wheat harvest.

A corn-soybean-wheat rotation with sorghum-sudangrass followed by cereal rye (T16) or a mixture of oats and oilseed radish cover crop (T15) increased average year three corn yield by 18.3 bu/A and 19.6 bu/A, respectively, compared to continuous corn (T1). A corn-soybean-wheat rotation with a frost seeded red clover cover crop increased average year three corn yield by 27.2 bu/A compared to continuous corn (T14 vs T1). The red clover treatment (T14) increased year three corn yield on average an additional 8.9 bu/A over the sorghum-sudangrass treatment (T16) and 7.6 bu/A over the oats and oilseed radish mixture treatment (T15). However, while the year three corn yield of the corn-soybean-wheat rotation with red clover (T14) was not different than the corn-soybean-wheat rotation without a cover crop (T13), the without cover crop treatment (T13) yielded on

average 11.1 bu/A more year three corn than the average of the sorghum-sudangrass treatment (T16) and the oats and oilseed radish mixture treatment (T15).

Weeds, insects and diseases

During the three growing seasons, there were no observable differences in weed, insect or disease pressure with no differences in herbicide or pesticide treatment types, amounts or rates within cash crops at the SVREC site.

Nitrogen

With the exception of 2015, where the red clover cover crop treatment (T18) yielded a 30 lb/A nitrogen credit, all other corn years received the nitrogen rate recommended for yield goal and soil type by the pre-sidedress nitrogen test (PSNT).

Discussion

After one complete crop rotation and two years of cover crops, at the SVREC site, there were not differences in year three soybean or wheat yields from the addition of cover crops, rotational diversity or the combination of both. Note that treatments harvested for wheat in 2016 had only partial impact from interseeded red clover through harvest and no impact from the sorghum-sudan grass followed by cereal rye or the oats and oilseed radish mixture planted after harvest. This study did not confirm the 4 – 6 bu/A increase in soybean yields at the SVREC site from the addition of wheat seen in the University of Guelph study. Differences were identified in the year three corn yields between rotational diversity and the combination of rotational diversity and cover crops, but not cover crops without rotation diversity. Further analysis indicates that the addition of rotational diversity (soybeans and wheat) to continuous corn probably accounts for these increases to a greater extent than the combination of cover crops and rotational diversity. Year three corn yield for the corn-soybean-wheat without a cover crop (T13) were equal to or higher than the corn-soybean-wheat with red clover (T14), sorghum-sudangrass followed by cereal rye (T16) and a mixture of oats and oilseed radish (T15). After three years, this study did not confirm the additional 8 bu/A increase in corn yield from adding red clover to the corn-soybean-wheat rotation.

<u>Mason</u>

Yield results for the 2016 growing season are given for the Mason site in Table 2.

Corn yields

There were no statistically significant differences in yield between any of the treatments that were harvested for corn in 2016. After three years, neither the introduction of cover crops, rotational diversity or the combination of diversity and cover crops impacted corn yields at the Mason site.

Wheat yields

There were no statistically significant differences in yield between any of the treatments that were harvested for wheat in 2016. After three years, adding cover crops into a diversified rotation that included wheat did not impact wheat yields at the Mason site.

Table 2. Corn, soybean and wheat yields in 2016 at the Mason location for the different rotational/cover crop treatments. (Soybean p-value = 0.132. LSD, 95% confidence: statistical significance – yields with different letters are different.)
Cover crop key: NC – No Cover, Rye – Cereal Rye, RC – Red Clover, O+OSR – Oilseed Radish and Oats Mix, S/R – Sorghum-sudangrass followed by Cereal Rye.

Crop	Treatment	Rotation	Yield (bu/a)	Statistical Significance
Corn	15	Soybean-Wheat-Wheat-O+OSR-Corn	150.8	a
	2	Corn-Rye-Corn-Rye-Corn	152.4	a
	14	Soybean-Wheat-Wheat-RC-Corn	152.7	a
	13	Soybean-Wheat-Wheat-NC-Corn	154.3	a
	5	Corn-NC-Soybean-NC-Corn	154.5	a
	6	Corn-Rye-Soybean-Rye-Corn	156.0	a
	16	Soybean-Wheat-Wheat-S/R-Corn	156.3	a
	1	Corn-NC-Corn-NC-Corn	156.3	a
Soybean	3	Soybean-NC-Soybean-NC-Soybean	29.3	b
	4	Soybean-Rye-Soybean-Rye-Soybean	35.3	b
	8	Soybean-Rye-Corn-Rye-Soybean	35.9	bc
	7	Soybean-NC-Corn-NC-Soybean	36.4	bc
	19	Wheat-O+OSR-Corn-Rye-Soybean	41.8	bc
	17	Wheat-NC-Corn-NC-Soybean	46.1	c
	18	Wheat-RC-Corn-Rye-Soybean	46.4	c
	20	Wheat-S/R-Corn-Rye-Soybean	46.8	c
Wheat	9	Corn-NC-Soybean-Wheat-Wheat-NC	81.8	d
	10	Corn-Rye-Soybean-Wheat-Wheat-RC*	81.8	d
	12	Corn-Rye-Soybean-Wheat-Wheat-S/R*	86.2	d
	11	Corn-Rye-Soybean-Wheat-Wheat-O+OSR*	86.4	d

*Frost seeded RC growth until wheat harvest, O+OSR and S/R planted after wheat harvest.

Soybean yields

Cover crops

There was no statistical difference in yield between continuous soybeans without a cover crop and continuous soybeans with a cereal rye cover crop (T3 vs T4).

Rotational diversity

Year three soybean yield from adding corn into the soybean rotation was no different than continuous soybean yield (T7 vs T3). Adding both corn and wheat into the soybean rotation increased year three soybean yield on average 16.8 bu/A compared to continuous soybeans (T17 vs T3), but was not different compared to the corn-soybean rotation (T17 vs T7).

Rotation diversity and cover crops

Year three soybean yields for a corn-soybean rotation with a cereal rye cover crop (T8), a corn-soybean rotation without cover crops (T7) and a continuous soybean rotation with cover (T4) and without cover (T1) were not different.

The corn-soybean-wheat rotations with sorghum-sudangrass followed by cereal rye (T20) or red clover (T18) cover crops increased average year three soybean yield by 17.5 bu/A and 17.1 bu/A, respectively, compared to continuous soybeans (T3). A corn-soybean-wheat rotation with an oats and oilseed radish mixture did not yield differently than continuous soybeans (T19 vs T3). None of the corn-soybean-wheat rotations with cover crops (T18, T19 and T20) produced year three soybean yields different than the corn-soybean-wheat rotation without cover crops (T17).

Weeds, insects and diseases

During the three growing seasons, there were no observable differences in weed, insect or disease pressure with no differences in herbicide or pesticide treatment types, amounts or rates within cash crops at the Mason site.

Nitrogen

The red clover cover crop treatment (T18) did not yield a nitrogen credit for any of the three cash crop years. All corn years received the nitrogen rate recommended for yield goal and soil type by the pre-sidedress nitrogen test (PSNT).

Discussion

After one complete crop rotation and two years of cover crops, at the Mason site, there were not differences in year three corn or wheat yields from the addition of cover crops, rotational diversity or the combination of both. Note that treatments harvested for wheat in 2016 had only partial impact from interseeded red clover through harvest and no impact from the sorghum-sudan grass followed by cereal rye or the oats and oilseed radish mixture planted after harvest. This study did not confirm the 25 bu/A increase in corn yields at the Mason site from the addition of wheat seen in the University of Guelph study. Differences were identified in the year three soybean yields between rotational diversity and the combination of rotational diversity and both sorghum-sudangrass followed by cereal rye and frost seeded redclover cover crops, but not for an oats and oilseed radish cover crop or cover crops without rotational diversity. Further analysis indicates that the addition of rotational diversity (corn and wheat) to continuous soybeans probably accounts for these increases to a greater extent than the combination of cover crops and rotational diversity. Year three soybean yield for the corn-soybean-wheat without a cover crop (T17) were equal to or higher than the corn-soybean-wheat with red clover (T18), sorghum-sudangrass followed by cereal rye (T20) and a mixture of oats and oilseed radish (T19). After three years, this study did not confirm the 4 – 6 bu/A increase in soybean yields at the Mason site from the addition of corn and wheat without covers to the rotation (T7 vs T17) seen in the University of Guelph study.

Soil Health Results

Soil samples were collected and sent to Cornell University for soil health analysis (http://soilhealth.cals.cornell.edu/extension/test.htm) in the fall of 2014, 2015 and 2016. At each site, five samples from each of the four replications were composited and submitted as one sample per treatment as the cost of the analyses prohibited analyzing each replicate. On the advisement of Cornell, year to year soil health parameters comparisons were not made due to the impact of growing season

moisture and temperature on the results. Within year comparisons between treatments are valid and the 2016 soil health results from samples collected on November 1, 2016 are presented here. Our interest is in indicators for the potential improvements to soil health that could result over the three year rotation from adding only cover crops, only diversity and diversity plus cover crops to continuous corn or continuous soybeans without cover crops.

The Cornell soil health overall quality scores are given for SVREC in Figure 4 and Mason in Figure 5. The ratings for individually measured soil health parameters and overall quality are given for SVREC in Table 3 and for Mason in Table 4. Without replication of the soil health data, significant differences cannot be determined and only general trends can be commented on.

SVREC

After three years, the overall soil health scores remained in the low to medium range at the SVREC site. The chemical ratings were optimum with the exception of pH which ranged from 7.4 – 7.8 which was higher than the optimum range of 6.2 – 6.8 producing constraint to suboptimal ratings for most plots. Of the physical parameters, aggregate stability was rated a constraint or suboptimal for all treatments. Of the biological parameters, Ace soil protein was rated a constraint or suboptimal for all treatments. Other physical and biological parameters varied from suboptimal to optimal with no clear patterns related to yield, diversity and/or cover crops (Table 3).

The SVREC overall quality scores (Figure 4) for corn harvested in 2016, where significant yield differences were identified, show a trend towards the addition of soybeans and wheat in the rotation without cover crops (T13) with a higher score than the other treatments (T1, T2, T14, T15 and T16). This supports the previous observation that the addition of rotational diversity (soybeans and wheat) to continuous corn probably accounts for the year three corn yield increases to a greater extent than the combination of cover crops and rotational diversity.

Mason

After three years, the overall soil health scores remained in the low to medium range at the Mason site. The chemical ratings were optimum with the exception of a few low level and excellent ratings. Of the physical parameters, aggregate stability was rated a constraint for all treatments. Of the biological parameters, all were rated a constraint or suboptimal for all treatments. Other physical parameters varied from suboptimal to optimal with no clear patterns related to yield, diversity and/or cover crops (Table 4).

The Mason overall quality scores (Figure 5) for soybeans harvested in 2016, where significant yield differences were identified, did not show any clear trends. The previous observation for soybeans that the addition of rotational diversity (corn and wheat) to continuous soybeans probably accounts for the year three soybean yield increases to a greater extent than the combination of cover crops and rotational diversity was not supported by the overall quality scores

Discussion

Overall soil quality ratings ranged from 52 – 66 for the SVREC site and 49 – 59 for the Mason site. Ratings of 40 – 55 are considered low and 55 – 70 are considered medium. To attain very high quality

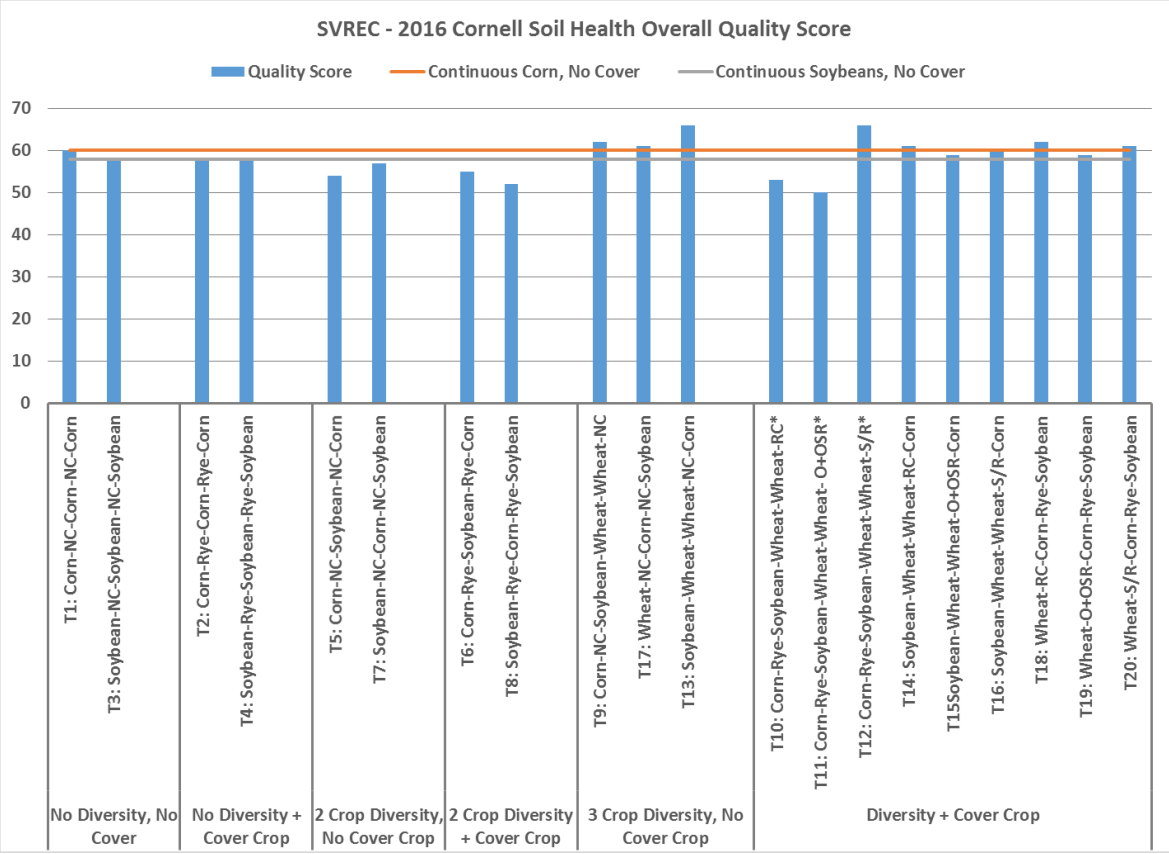

Figure 4. 2016 Cornell Soil Health Overall Quality Rating for the SVREC location for the different rotational/cover crop treatments. *RC growth from frost seeding through 11/1/16 and S/R growth from after wheat harvest through 11/1/16.
Cover crop key: NC – No Cover, Rye – Cereal Rye, RC – Red Clover, O+OSR – Oats and Oilseed Radish Mix, S/R – Sorghum-sudangrass followed by Cereal Rye.

rating, a minimum of 85 is required. Both sites continue to be well below the very high target due to deficiencies in the physical and biological parameters.

Without the statistical power of replicated soil health data, differences between these values cannot be determined. Even if differences existed, the continuous corn without cover and continous soybeans without cover are in the middle of the range for both sites with diversity and/or cover crop combinations above and below. This suggest that after three years either there may have been no change in soil health from the various treatments or it was not measureable with our design and sampling. Regardless, our goal was to evaluate inserting diversity, cover crops or the combination of the two into production systems without changing other typical management practices for the area such as tillage or fertility. Diversity and/or cover crops alone may not be sufficient to improve the soil health at

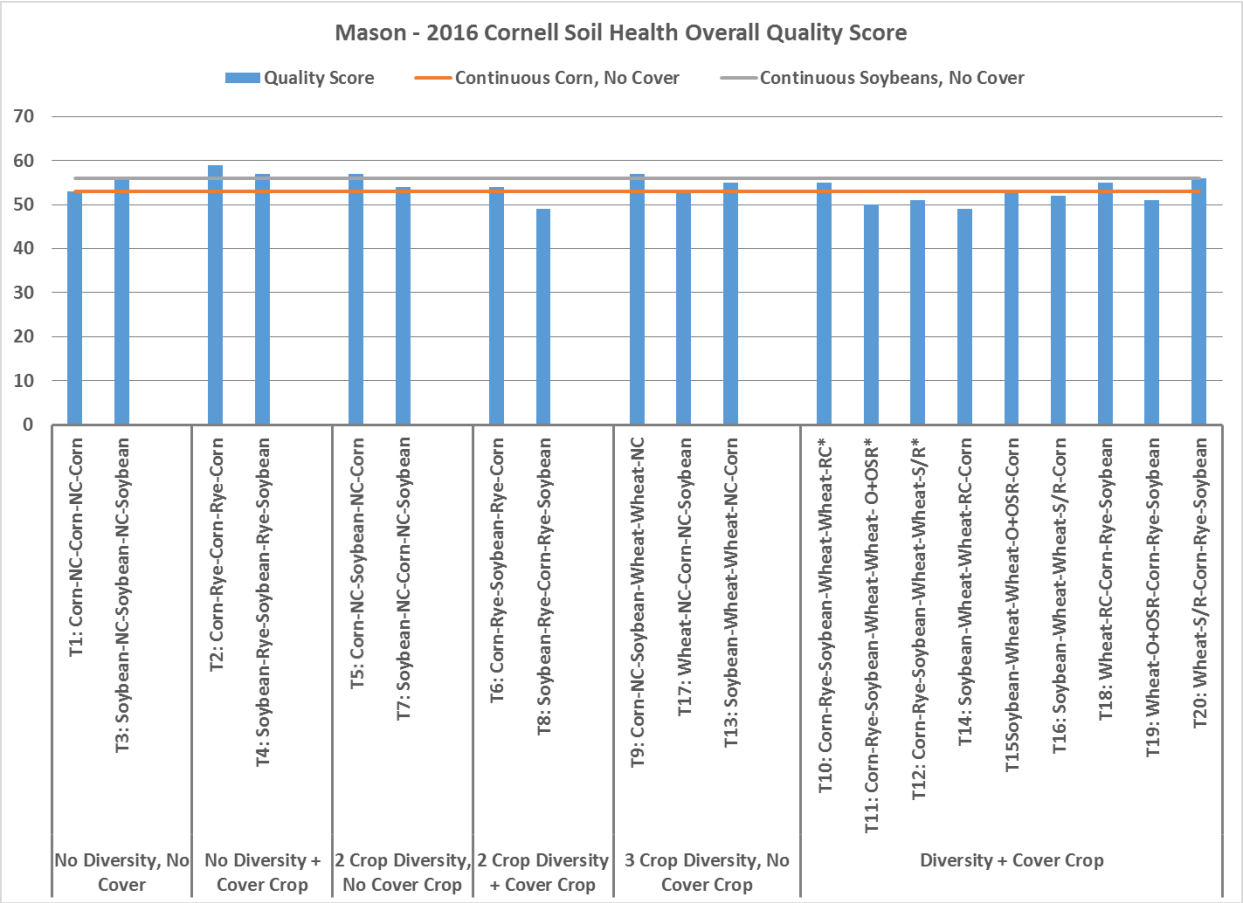

Figure 5. 2016 Cornell Soil Health Overall Quality Rating for the Mason location for the different rotational/cover crop treatments. *RC growth from frost seeding through 11/1/16 and S/R growth from after wheat harvest through 11/1/16.
Cover crop key: NC – No Cover, Rye – Cereal Rye, RC – Red Clover, O+OSR – Oats and Oilseed Radish Mix, S/R – Sorghum-sudangrass followed by Cereal Rye.

these two sites. Cornell makes short-term management suggestions including incorporating fresh organic materials and adding manure, green manure or mulch in addition to diversity/cover crops to correct the low physical and biological ratings. They further suggest long-term management changes of reducing tillage and rotating with sod crops and mycorrhizal hosts to improve these ratings. These types of management and cropping changes may not be economically practical unless yield increases to offset the cost of these changes can be proven. The use of cover crops and/or diversity may prove beneficial over a longer period of implementation, however, after three years of these practices results are inconclusive as to the impact on soil health.

Outreach

This reasearch was highlighted during two major farmer events during the course of the project. In 2014, the SVREC site was included in the tour during the Wheat Field Day with 180 attendees. The site was included as a stop during the inaugural MSU Ag Innovations day in 2016 (Figure 6). During this event, Dr. Lisa Tiemann, Assistant Professor – MSU Plant, Soil and Microbial Sciences and Dr. Dean Baas, MSUE Educator discussed rotation, cover crops and soil health with over 400 farmers.

Figure 6. Lisa Tiemann and Dean Baas present to farmers at the SVREC site during the 2016 MSU Ag Innovations Day.

Conclusions

After three years of investigating the influence of rotational diversity and/or cover crops on yield and soil health in continuous corn, continuous soybean and corn-soybean rotations:

- At the SVREC site:
  - Year three corn yield was 19.9 bu/A higher when soybeans were added to the continous corn rotation, 30.1 bu/A higher when wheat and soybeans were added to the continuous the corn rotation and 10.2 bu/A when wheat was added to the corn-soybean rotation.
  - Corn yield results suggest that the increases were probably more the result of diversity than cover crops.
  - Year three soybean and wheat yields were not significantly different for any of the diversity and/or cover crop treatments.
- At the Mason site:
  - Year three soybean yield was 16.8 bu/A higher when corn and wheat were added to the continuous soybean rotation, not different for the corn-soybean rotation, 17.5 bu/A higher for the corn-soybean-wheat with sorghum-sudangrass followed by cereal rye, 17.1 bu/A for the corn-soybean-wheat with red clover and not different for the corn-soybean-wheat with the oats and oilseed radish mix.
  - Soybean yield results suggest that the increases were probably more the result of diversity than cover crops.
  - Year three corn and wheat yield were not significantly different for any of the diversity and/or cover crop treatments.

- Cornell soil health assessments indicate:
    - For both the SVREC and Mason sites the overall quality scores remain low to medium with no clear relationships or trends between the overall scores and including diversity and/or cover crops for three years.
    - The individual ratings for physical, biological and chemical parameters that contribute to the overall quality score did not show any clear relationships or trends from including diversity and/or cover crops for three years.
    - Cornell suggest additional management changes in addition to the diversity and cover crops in the study including less tillage, manure, sod crops, etc. to correct the low ratings, in particular the low biological ratings. These changes are probably not economical, practical or of interest to farmers within the cropping regions studied.
    - Longer term effects of diversity and/or cover crops can not be estimated with a single three year, one crop rotation cycle. While it is promising that significant yield differences emerged in year three for corn at SVREC and soybeans at Mason, we know building soil health is a slow process. A longer period under diversity and/or cover crops would be necessary to determine if soil health is improving, declining or remaining constant under the treatments studied.

Acknowledgements

We would like to thank the Corn Marketing Program of Michigan, Michigan Soybean Checkoff Program and Michigan Wheat Program for funding this project.

Table 3. Cornell soil health ratings in 2016 at the SVREC location for the different rotational/cover crop treatments. *RC growth from frost seeding through 11/1/16 and S/R growth from after wheat harvest through 11/1/16.

Cover crop key: NC – No Cover, Rye – Cereal Rye, RC – Red Clover, O+OSR – Oats and Oilseed Radish Mix, S/R – Sorghum-sudangrass followed by Cereal Rye.

Treatment	Rotation	Cornell Soil Health Rating													
		Physical				Biological				Chemical				Overall Rating	
		Water Capacity	Surface Hardness	Subsurface Hardness	Aggregate Stability	Organic Matter	Ace Soil Protein Index	Respiration	Active Carbon	pH	Phosphorus	Potassium	Minor Elements		
5	Corn-NC-Soybean-NC-Corn	86.7	58.3	58.9	14.2	37.1	25.5	41.7	62.6	17.9	100	100	100	54	Low
6	Corn-Rye-Soybean-Rye-Corn	41.4	79.7	60.3	26.7	38.7	28.8	34.9	36.6	52.6	100	100	100	55	
2	Corn-Rye-Corn-Rye-Corn	71.1	53.1	47.6	24.0	46.2	26.9	49.2	62.6	23.9	100	100	100	58	Med
15	Soybean-Wheat-Wheat-O+OSR-Corn	86.2	40.5	47.8	10.3	83.8	21.9	38.9	50.2	35.2	100	100	100	59	
1	Corn-NC-Corn-NC-Corn	79.1	64.9	58.9	22.5	39.3	27.1	41.2	58.3	27.1	100	100	100	60	
16	Soybean-Wheat-Wheat-S/R-Corn	88.4	50.0	38.2	10.1	80.7	21.0	35.4	57.2	37.2	100	100	100	60	
14	Soybean-Wheat-Wheat-RC-Corn	78.7	52.0	53.8	19.2	44.5	33.1	45.4	64.8	40.1	100	100	100	61	
13	Soybean-Wheat-Wheat-NC-Corn	87.1	55.3	64.6	15.6	82.6	23.0	37.6	70.2	63.3	100	100	100	66	
8	Soybean-Rye-Corn-Rye-Soybean	43.6	68.1	53.8	21.0	40.8	19.9	35.4	45.6	0.0	100	100	100	52	Low
7	Soybean-NC-Corn-NC-Soybean	47.2	69.1	61.8	16.2	42.0	29.6	40.3	49.0	36.6	100	100	100	57	Med
4	Soybean-Rye-Soybean-Rye-Soybean	40.1	63.3	54.4	14.3	47.0	37.1	58.5	42.5	8.9	100	100	100	58	
3	Soybean-NC-Soybean-NC-Soybean	59.5	61.2	56.1	17.2	43.9	26.5	42.1	42.5	0.0	100	100	100	58	
19	Wheat-O+OSR-Corn-Rye-Soybean	81.6	64.9	53.8	11.1	36.2	27.2	42.6	53.6	36.9	100	100	100	59	
17	Wheat-NC-Corn-NC-Soybean	88.9	65.4	49.7	10.5	75.4	19.8	50.6	55.8	22.6	100	100	100	61	
20	Wheat-S/R-Corn-Rye-Soybean	82.7	74.5	68.3	11.3	40.4	27.6	52.9	61.5	19.3	100	100	100	61	
18	Wheat-RC-Corn-Rye-Soybean	83.7	73.1	54.9	16.9	51.4	25.9	69.1	56.7	20.3	100	100	100	62	
11	Corn-Rye-Soybean-Wheat-Wheat-O+OSR*	30.1	59.9	34.7	15.0	42.6	26.6	45.9	43.7	0.0	100	100	100	50	Low
10	Corn-Rye-Soybean-Wheat-Wheat-RC*	68.2	45.4	39.0	20.5	47.5	31.5	41.7	50.2	0.0	100	100	100	53	
9	Corn-NC-Soybean-Wheat-Wheat-NC	50.1	65.6	51.0	21.8	57.3	33.1	45.4	60.8	63.7	100	100	100	62	Med
12	Corn-Rye-Soybean-Wheat-Wheat-S/R*	54.2	68.1	67.3	30.9	60.1	30.9	51.0	56.7	71.5	100	100	100	66	

Functioning Color Key	Constraint	Low Level	Suboptimal	Excellent	Optimal

Table 4. Cornell soil health ratings in 2016 at the Mason location for the different rotational/cover crop treatments. *RC growth from frost seeding through 11/1/16 and S/R growth from after wheat harvest through 11/1/16.

Cover crop key: NC – No Cover, Rye – Cereal Rye, RC – Red Clover, O+OSR – Oats and Oilseed Radish Mix, S/R – Sorghum-sudangrass followed by Cereal Rye.

Treatment	Rotation	Cornell Soil Health Rating													
		Physical				Biological				Chemical				Overall Rating	
		Water Capacity	Surface Hardness	Subsurface Hardness	Aggregate Stability	Organic Matter	Ace Soil Protein Index	Respiration	Active Carbon	pH	Phosphorus	Potassium	Minor Elements		
14	Soybean-Wheat-Wheat-RC-Corn	69.7	29.5	52.2	9.3	10.3	25.4	20.0	22.8	57.0	100	100	100	49	
16	Soybean-Wheat-Wheat-S/R-Corn	67.7	35.5	52.5	8.3	29.1	14.3	23.1	29.8	100.0	69.778	96.096	100	52	
15	Soybean-Wheat-Wheat-O+OSR-Corn	65.7	47.3	66.5	7.3	31.8	13.6	18.4	26.5	100.0	64.717	95.185	100	53	Low
1	Corn-NC-Corn-NC-Corn	71.6	42.2	47.3	7.7	9.1	22.1	29.8	15.0	100.0	90.755	100	100	53	
6	Corn-Rye-Soybean-Rye-Corn	74.3	45.8	54.4	6.6	33.8	14.4	23.8	21.8	100.0	83.497	100	100	54	
13	Soybean-Wheat-Wheat-NC-Corn	65.7	57.5	67.5	8.5	10.6	18.8	24.6	19.4	100.0	94.276	100	100	55	
5	Corn-NC-Soybean-NC-Corn	76.8	71.5	61.1	8.0	35.1	16.6	17.2	24.0	90.4	90.282	100	100	57	Med
2	Corn-Rye-Corn-Rye-Corn	83.2	69.6	61.1	6.2	34.3	16.8	20.1	29.5	100.0	85.618	100	100	59	
8	Soybean-Rye-Corn-Rye-Soybean	61.9	27.0	49.9	9.2	32.9	14.8	23.5	21.0	100.0	100	100	56	49	
19	Wheat-O+OSR-Corn-Rye-Soybean	73.9	20.5	29.0	7.7	29.2	16.5	19.7	19.3	100.0	100	100	100	51	Low
17	Wheat-NC-Corn-NC-Soybean	79.3	52.8	49.9	7.1	31.3	13.2	15.1	10.1	79.6	100	100	100	53	
7	Soybean-NC-Corn-NC-Soybean	71.4	42.9	59.8	7.9	30.4	14.4	19.0	16.3	100.0	89.335	100	100	54	
18	Wheat-RC-Corn-Rye-Soybean	80.4	42.5	47.6	7.4	32.3	18.0	19.3	21.6	92.1	98.105	100	100	55	
3	Soybean-NC-Soybean-NC-Soybean	85.6	39.0	54.7	6.6	30.8	13.0	23.6	22.1	100.0	100	100	100	56	Med
20	Wheat-S/R-Corn-Rye-Soybean	78.6	42.2	55.6	7.7	30.9	17.6	21.7	22.6	100.0	100	100	100	56	
4	Soybean-Rye-Soybean-Rye-Soybean	79.7	42.5	66.0	6.4	31.1	13.3	18.1	32.3	100.0	100	100	100	57	
11	Corn-Rye-Soybean-Wheat-Wheat	49.3	52.8	41.7	9.0	31.4	17.9	28.5	26.0	100.0	91.629	100	56	50	Low
12	Corn-Rye-Soybean-Wheat-Wheat	46.7	55.4	55.0	8.7	23.3	15.1	26.1	22.3	100.0	73.734	93.117	100	51	
10	Corn-Rye-Soybean-Wheat-Wheat	50.0	42.2	53.3	8.6	31.9	18.7	34.7	29.2	100.0	92.249	100	100	55	Med
9	Corn-NC-Soybean-Wheat-Wheat	54.3	61.8	51.0	9.2	37.3	17.3	32.6	20.8	100.0	100	100	100	57	

Functioning Color Key: Constraint | Low Level | Suboptimal | Excellent | Optimal