On Farm Research to Quantify the Value of Cover Crops for Nutrient Crediting and Soil Health

Supported by North Central Sustainable Agriculture Research & Education (SARE) Program

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Final report submitted by

Aicam Laacouri, Minnesota Department of Agriculture

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Summary

The topic of implementing cover crops and their benefits to soil health has been the focus of much research and discussion. This project engaged and supported three experienced farmers, currently using cover crops, to measure and quantify some of the benefits of cover crops in southern Minnesota. In addition to quantifying the benefits, project partners worked with farmers to share information with other local farmers. All three farmers, in partnership with their local conservation districts, are key members of the Freeborn County Soil Health Team. This Soil Health Team promotes beneficial soil health practices through field days, data collection, and outreach to other interested farmers in the area.

The Minnesota Department of Agriculture lead this project in partnership with the NRCS (USDA-NRCS SSR-10, staff Myles Elsen) and local farmers representing the local soil health team (Freeborn, Mower and Steele Counties). The result of this two-year, multi-field project showed that the successful establishment of cover crops varies year to year and from field to field based on weather conditions and management practices where cereal rye and ryegrass are more likely to overwinter and scavenge soil N. Additionally, this study showed that cover crops do not impact cash crop yield and nitrogen availability for the cash crop. Lastly, cover crops seem to improve soil health, providing more microbial biomass and diversity.

Project Objectives

1. Monitor nutrient levels throughout the cover crop life cycle to establish a procedure for properly crediting cover crop nutrients for subsequent cropping years. If this can be done successfully, there is potential to reduce fertilizer inputs. Reduced fertilizer inputs would in turn save the farmer money and potentially reduce nutrient losses that are impacting water quality.
2. Generate high quality data related to soil health and agronomic variables for this specific geographic area, soils, and climate.
3. Provide education and outreach through field days, factsheets, handouts, etc. This will help local farmers make more informed management decisions regarding cover crops.

Materials and methods

Cover Crop Planting

Data were collected from three corn and three soybean fields that incorporated cover crops in the 2016-2017 or the 2017-2018 seasons. Each of the six fields included in the study had a cover crop planted in late summer or fall of 2016 and was terminated in the spring of 2017 (or 2018). Cover crop species, seeding rate, and seeding method was determined by the farmer operating the land. Each field left an untreated check strip where no cover crop was planted.

This provided the opportunity to compare soil chemistry and crop yield on paired sites, with and without the presence of a cover crop. All planting data were collected for each field. Due to unforeseen weather conditions and the subsequent management changes, not all six fields were sampled each year.

Cover Crop Growth and Nutrient Content Assessment

Several parameters were analyzed to quantify cover crop growth and nutrient content. Cover crop samples were collected from eight randomly assigned locations within each field. The aboveground biomass was collected from one square foot of ground surface and sent to Minnesota Valley Testing Laboratory (MVTL) for analysis. The cover crop samples were analyzed for their carbon, nitrogen, phosphorus, and potassium content, along with their dry matter yield. These analyses were used to calculate the total nutrient uptake in the aboveground biomass of the cover crop at termination. The cover crop analysis also provided the C:N ratio to estimate when the decomposing cover crop would release its nutrients. All the plant data were collected within three days of termination to maximize cover crop growth and nutrient uptake.

Cover crop tissue samples prior to corn planting were collected on May 8-9, 2017. Cover crop tissue samples prior to soybean planting were collected from May 10 through June 7, 2017. Dates ranged based on weather and cover crop termination dates.

Soil Sampling

Soil sampling was also conducted in these six fields. The first sampling period was planned before crops were planted, however, weather challenges prevented this from taking place. The first soil samples were collected in early June, just prior to the time farmers began side-dress nitrogen applications. Soil samples were collected from ten sites in each field and sent to MVTL for analysis. The ten samples were collected in a strategic manner to form five paired sites for comparison. The paired sites had one sampling location within the check strip where no cover crop was established, and one sampling location outside the check strip where a cover crop was present.

The paired sites were located in close proximity, within a common soil mapping unit, and other management techniques held constant. Each soil sample was made up of twelve subsample soil cores and combined to form a single composite sample. Soil cores were sampled to a depth of 12 inches to perform the pre-sidedress nitrate test (PSNT). Composite samples were also analyzed for routine chemistry including; pH, buffer pH, organic matter, phosphorus, and potassium. Soil sampling sites were geo-referenced and revisited later in the growing season for additional sampling. A second round of samples was collected in early August and analyzed for nitrate. In fields where nitrogen fertilizer was banded, special attention was paid to collect subsamples both within the row and between rows.

Soil health was assessed using the comprehensive soil health test from Ward Laboratory (NE) that included the Haney test and the Fatty Acids (PFLA) test, enzyme activity test. Additional soil microbial genome was extracted from the soil and used to map the microbial fauna. Using microbial genome, we were able to determine the presence of specific taxa and functional groups. The soil health test was conducted at the end of the project following fall soil sampling in 2018.

Research results and discussion

- Cereal rye and ryegrass are more likely to overwinter and scavenge soil N
- Cover crops did not impact cash crop yield
- Cover crops did not seem to impact N availability for the cash crop.
- The average soil nitrate levels were lower where there was a cover crop growing
- Improved nutrient cycling (enzyme activity) and microbial activity was observed under cover crops.
- Residual soil nitrate was not different between the cover crop and non-cover crop areas

Cover Crop Yields

Cover crop yields were calculated for five of the six fields where plant tissue samples were collected (Table 1). Cover crop yields varied widely both within individual fields and between field sites. In-field variability seemed to vary due to soil type, landscape position, and moisture availability. Low lying areas with wet soils seemed to inhibit cover crop growth, to the extent that cover crop yield was zero in some areas. Variability between fields can be attributed to several management factors (i.e. cover crop seeding mix and rate, establishment method, seeding and termination dates), as well as environmental considerations (i.e. soil texture, rainfall, and fertility).

Table 1. Cover Crop Yields

Farm Site	Average Yield (lbs./ac)	Range of Individual Site Yields Per Farm (lbs./ac)
Steele East	206.5	0 – 1968.7
Steele West	902.7	0 – 1968.7
Freeborn East	153.7	19.2 – 1267.6
Freeborn West	139.3	19.2 – 1267.6
Mower South	3178.8	2131.9 – 4628.8*
Mower North**	-----	-----

* Does not include individual sites from Mower North, range is for Mower South.
** Cover crop yield was not calculated due to incomplete analysis from MVTL.

Plant Tissue Analysis

Cover crop tissue analysis, in combination with cover crop biomass yields, was used to calculate the quantity of nutrients contained in the aboveground portion of the cover crop. Looking specifically at nitrogen, there seemed to be a direct correlation between the cover crop biomass yield and the amount of nitrogen scavenged and contained within the aboveground biomass. There was relatively little variability in nitrogen concentrations of the various tissue samples, so the highest amounts of plant nitrogen were found at sample sites with the highest cover crop biomass yield.

Another trend was noted when considering C:N ratio and biomass yield. There appears to be a relationship between the two parameters; as biomass yield increased, C:N ratio also increased. This indicates that a mature cover crop with a high biomass yield would break down and flush nutrients more slowly than a cover crop with less vegetative growth, and likely, an earlier termination date.

Soil Analysis

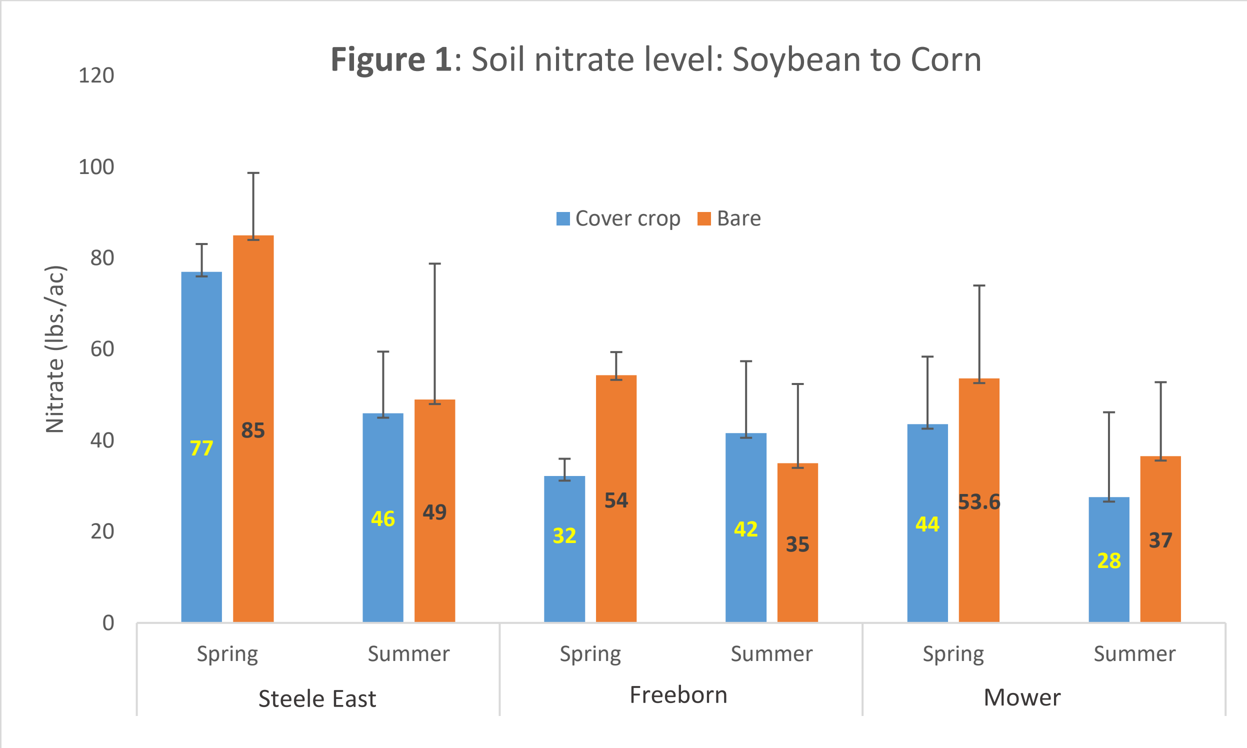
There appear to be some trends in the soil sample analysis from paired sites. The pre-sidedress sampling period showed that average soil test nitrogen levels were lower where a cover crop was growing when compared to the check strip (Table 2).

Table 2. Soil Nitrate at Pre-Sidedress

Farm Site	Average Soil Nitrate within Check Strip (lbs./ac)	Average Soil Nitrate within Cover Crop (lbs./ac)
Steele East	24.8	18.2
Steele West	84.6	76.6
Freeborn East	21.0	11.8
Freeborn West	54.3	32.2
Mower South	53.6	43.6
Mower North	31.2	43.6

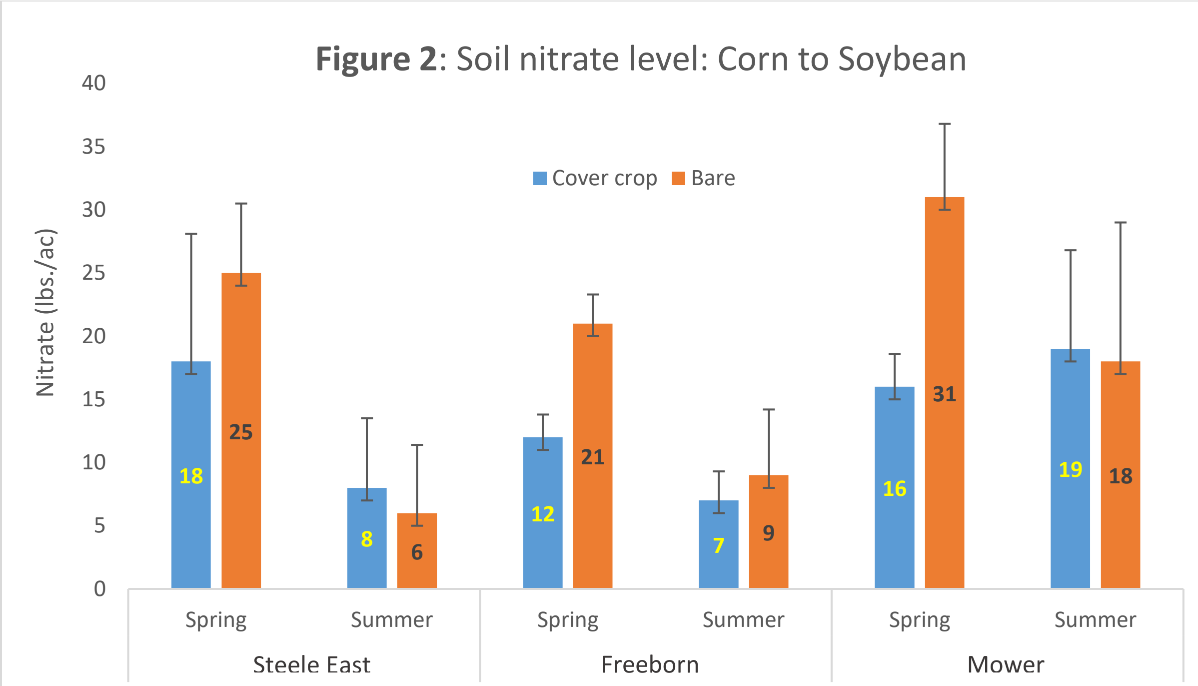
In every case, the average soil nitrate levels were lower where there was a cover crop growing. The August soil nitrate sampling results were much less conclusive.

Cover Crops and Nutrient Cycling

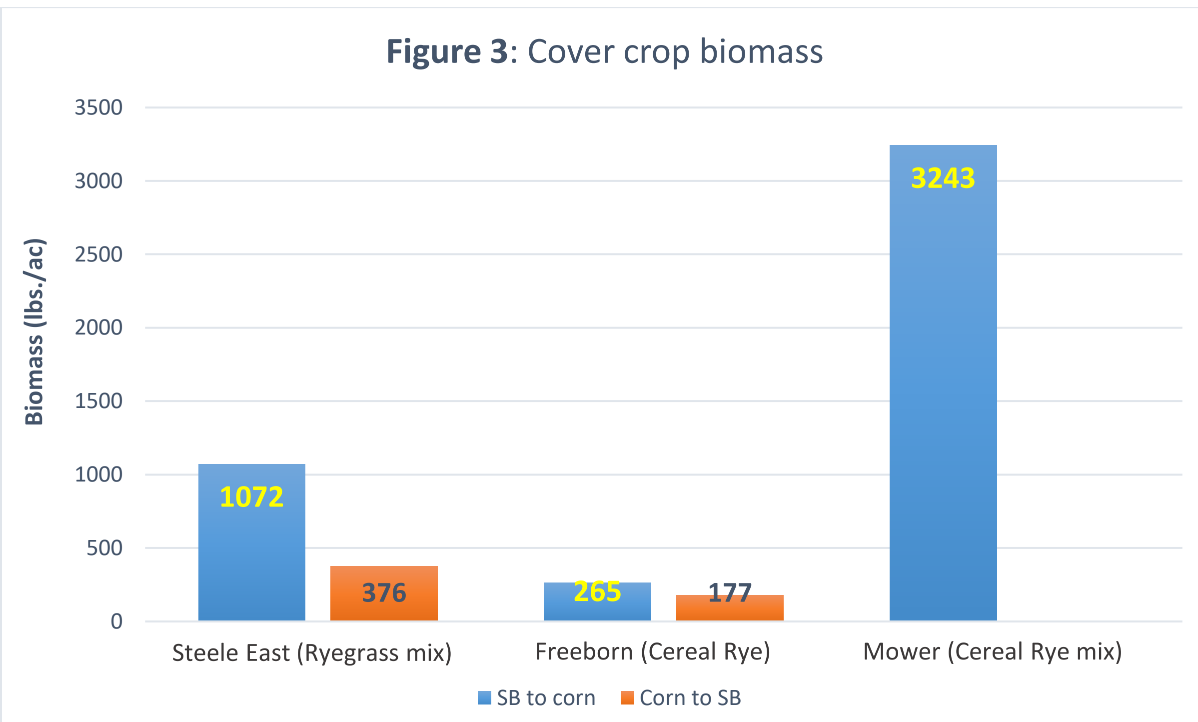


In fields with corn following soybeans, lower spring nitrate N levels were found in zones where cover crops were growing in the fall/early spring (Figure 1). These lower levels likely lead to less N loss via leaching and denitrification. Additionally, the areas of the field with cover crop showed more N available later in the growing season (no signs of immobilization of N).

Cover crops showed the same impact on nitrogen cycling for corn following corn. Areas with cover crops had lower spring nitrate N, with the cover crop areas showing more plant available N later in the growing season and no sign of nitrogen immobilization by soil microbes (Figure 2)



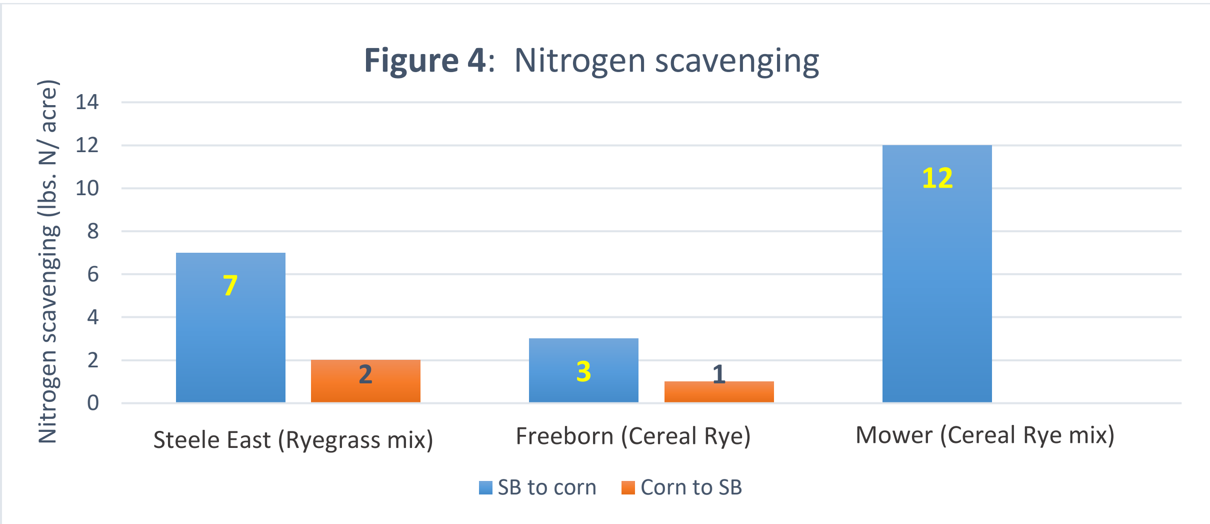
Cover Crop Biomass



Cover crop biomass was assessed in the 2017 growing season and showed that the cover crop mix and cover crop planting time strongly influence the amount of cover crop harvested. Overall, the best result was achieved using a cover crop mix that is based on cereal rye that had enough time to establish (Figure 3). Cereal rye can overwinter under Minnesota winter conditions which explains its performance compared to other cover crops mixes.

Nitrogen Scavenging

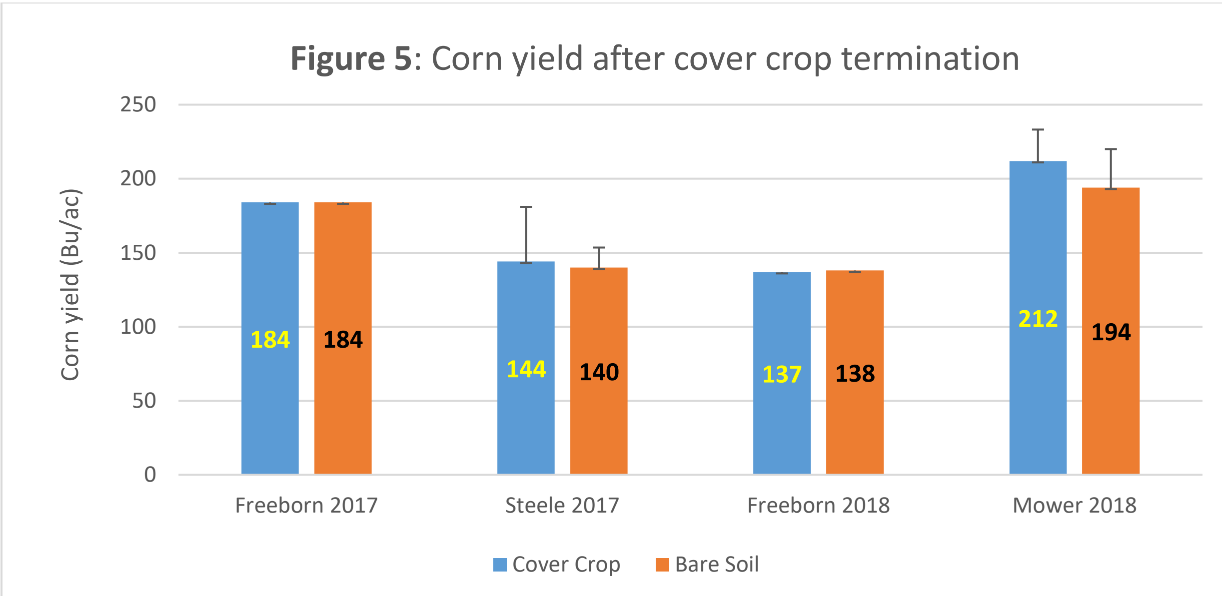
Nitrogen scavenging is directly related to cover crop biomass. In this study, one factor that seemed to impact the scavenging performance is the length of the growing season. The longer the growing season (for the cover crop), the greater the cover crop nitrogen scavenging. Nitrogen scavenging results are included in Figure 4.

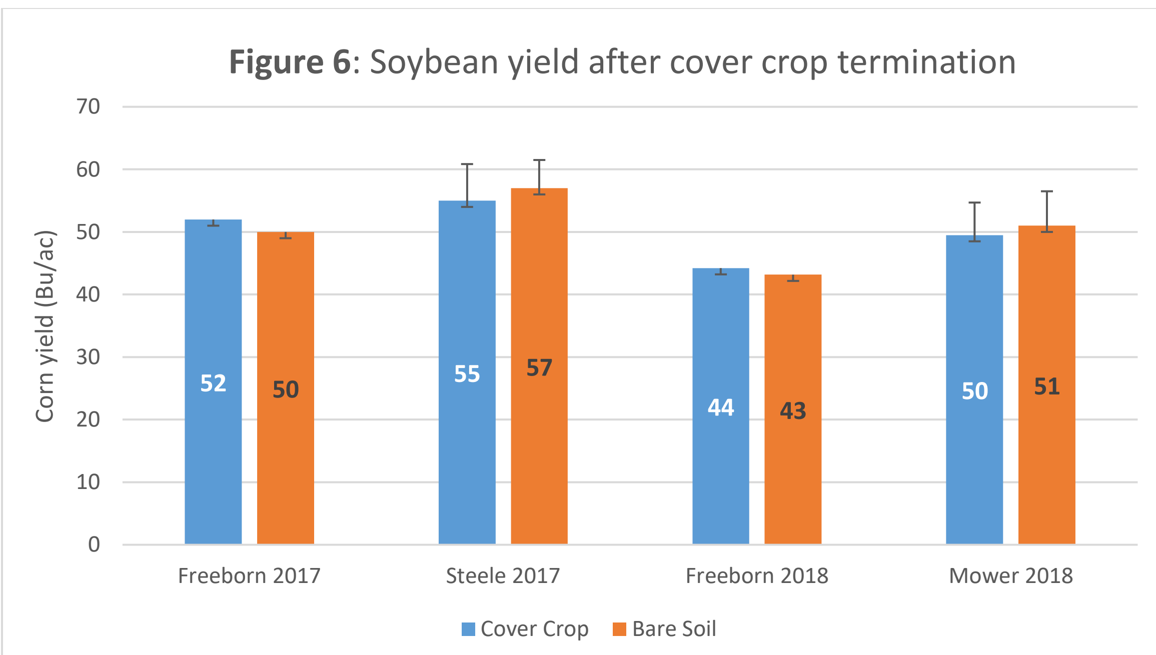


Cover Crop Impact on Cash Crop Yield

For corn (Figure 5), grain yield seems to be impacted by overall growing season weather condition and previous crop. In this study, we found no significant difference in yield between the cover crop and no cover crop areas of the fields assessed.

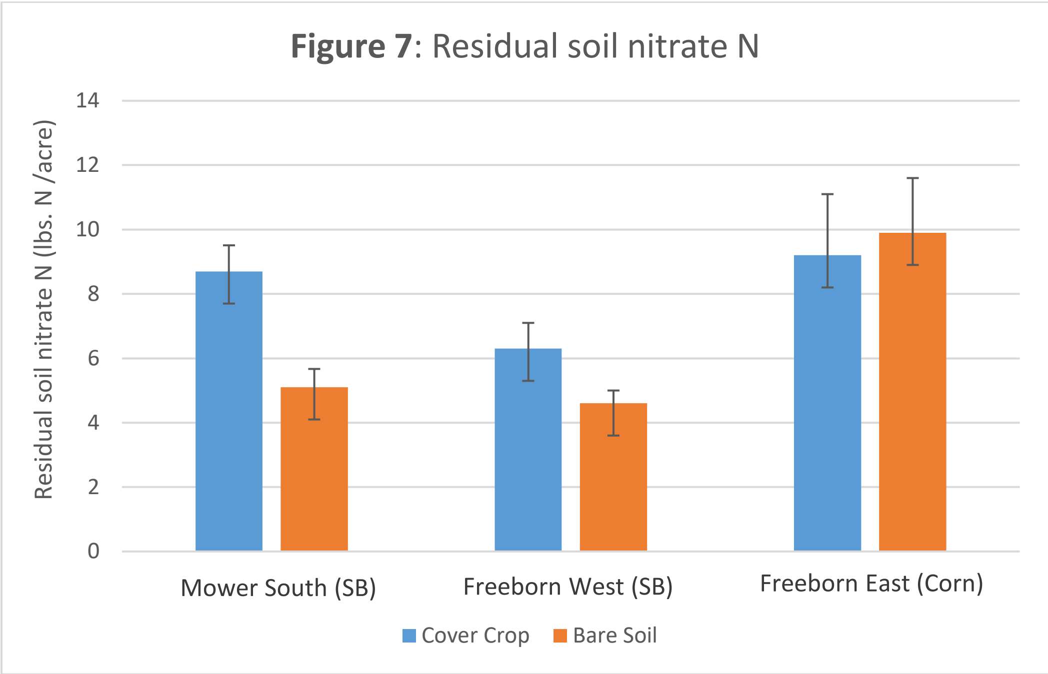
Soybean yield (Figure 6) showed the same trend and showed no impact of cover crop on grain yield which was expected since soybean plants, via rhizobia symbiosis, are able to uptake atmospheric nitrogen and therefore rely less on soil N.





Soil Residual N

Soil residual N is an important indicator of agricultural nitrogen use efficiency and potential loss to the environment. In this study, residual soil N was measured using a four-foot soil sample after harvest of corn and soybeans. Residual N was only assessed on three fields due to logistical challenges. Overall, soil residual nitrate was low under all scenarios (cover crop and no cover crop all had RSN less than 10 lbs./ac, which is considered low) and similar in areas of the field with and without a cover crop. This indicates that the cover crop did not interfere with in-season availability of nitrogen for the cash crop and the cash crop planted after cover crop termination did not experience any in-season soil N disadvantage from the cover crop N (Figure 7). There was no sign of N deficiency in areas of the field where cover crops were grown.

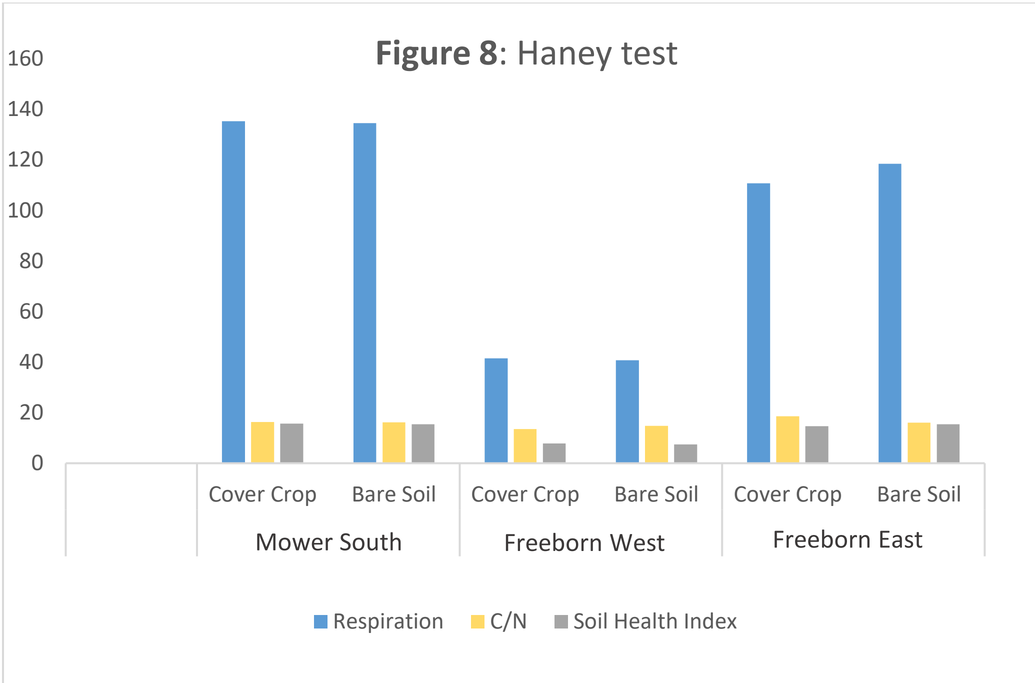


Cover Crop Impact on Soil Health

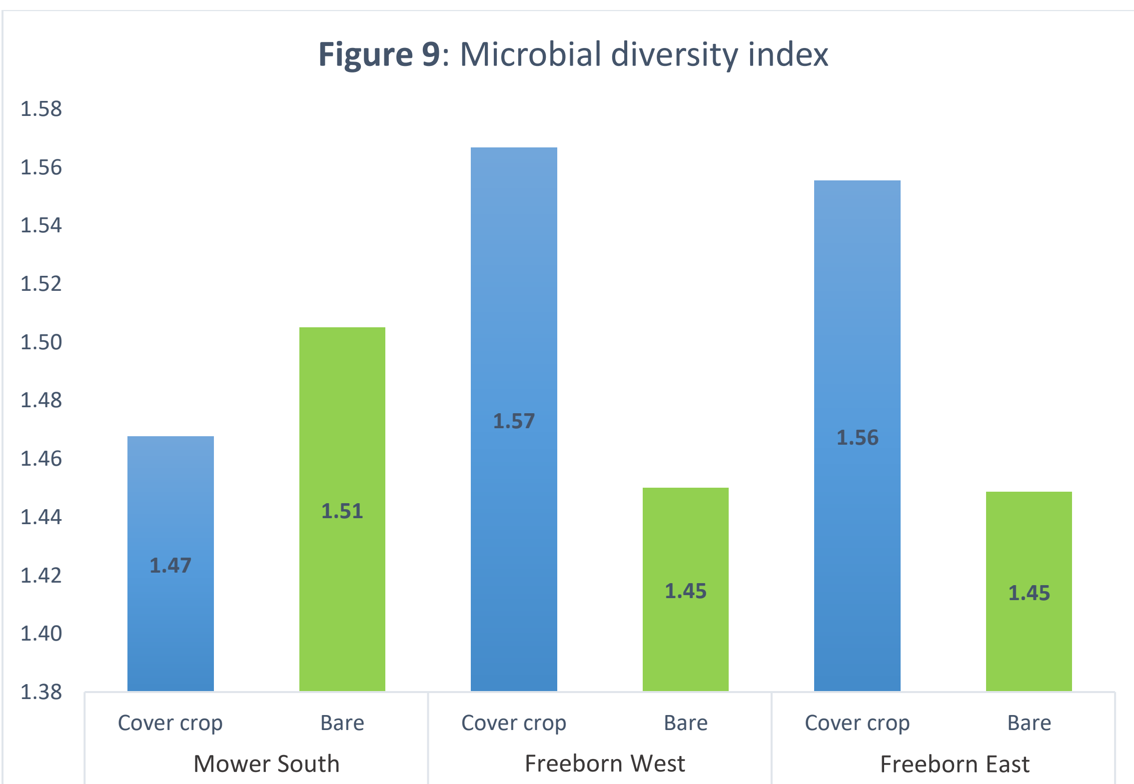
Comprehensive soil health test

The comprehensive soil health test provided by Ward Laboratories includes multiple soil parameters that describe the biological, chemical, and physical properties of the soil and include the Haney test. Soil health was assessed on three fields only due to logistics.

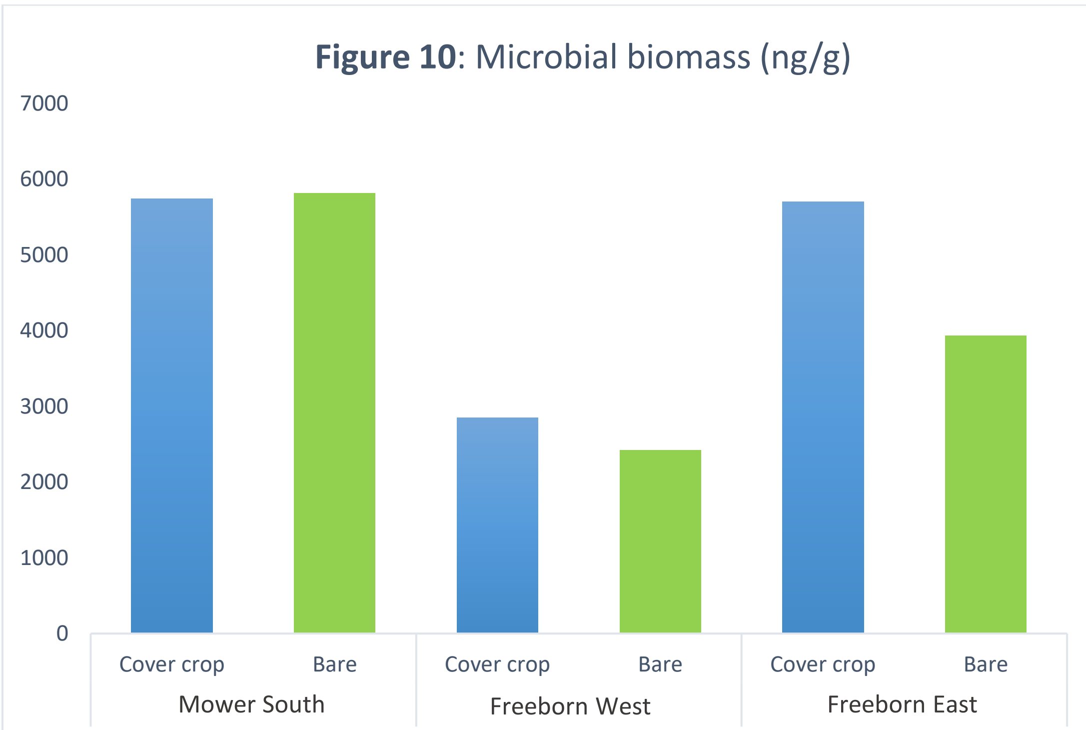
Based on these tests (Figure 8), and more specifically the carbon dioxide respiration (ppm C), the soil health index and the C/N ratio, there seem to be no differences between the soil properties under cover crop management and those of the non-cover crop. This lack of difference could be explained by the short-term duration of this study. Soil health improvement may take longer time to reach a level that is quantifiable.



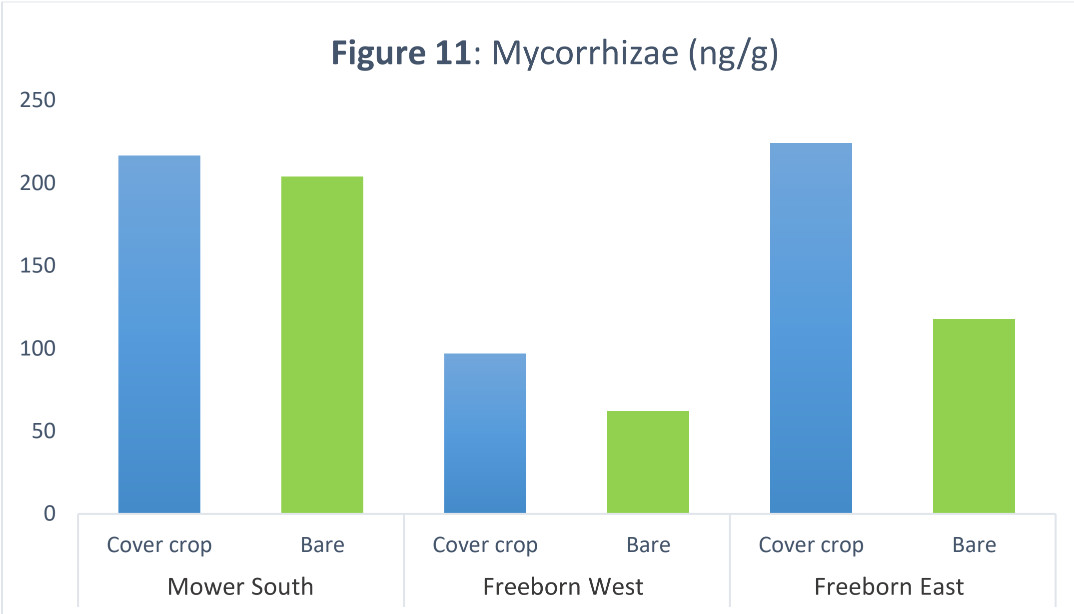
Microbial Diversity

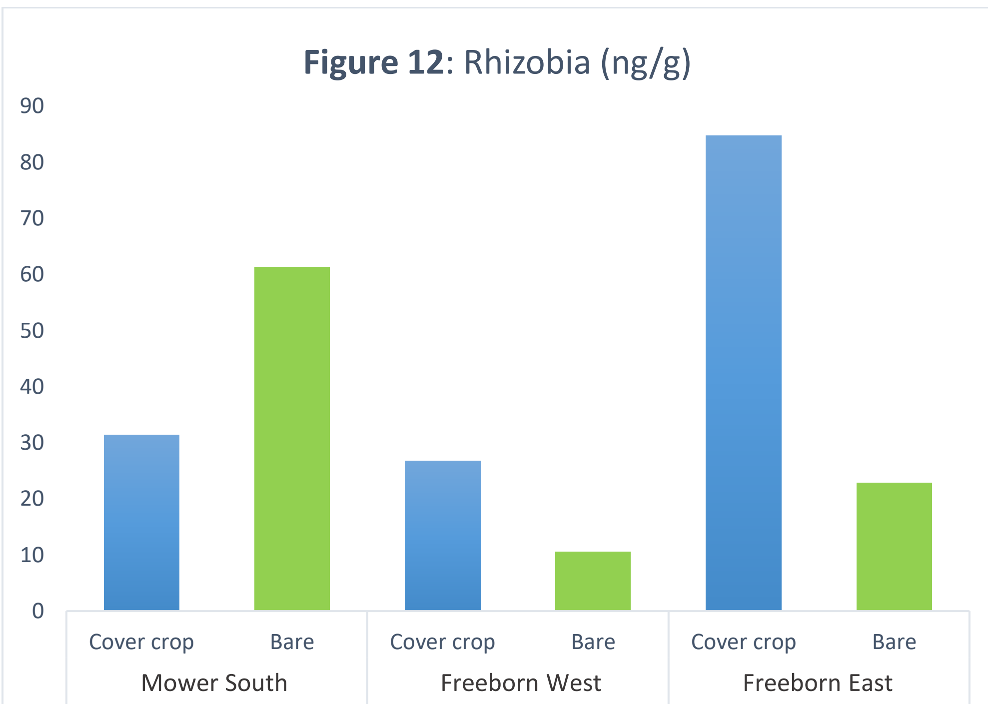


Microbial diversity comparison revealed mixed results (Figure 9). While there was more microbial activity in two fields, the field with conventional tillage did not show improved microbial activity under cover crops. This result is likely a result of the soil disturbance and aeration from tillage that could potentially mask the impact of cover crops. On the other hand, microbial biomass was similar or better under the cover crop system, possibly indicating that cover crop system provides better environment for microbial activity (Figure 10).

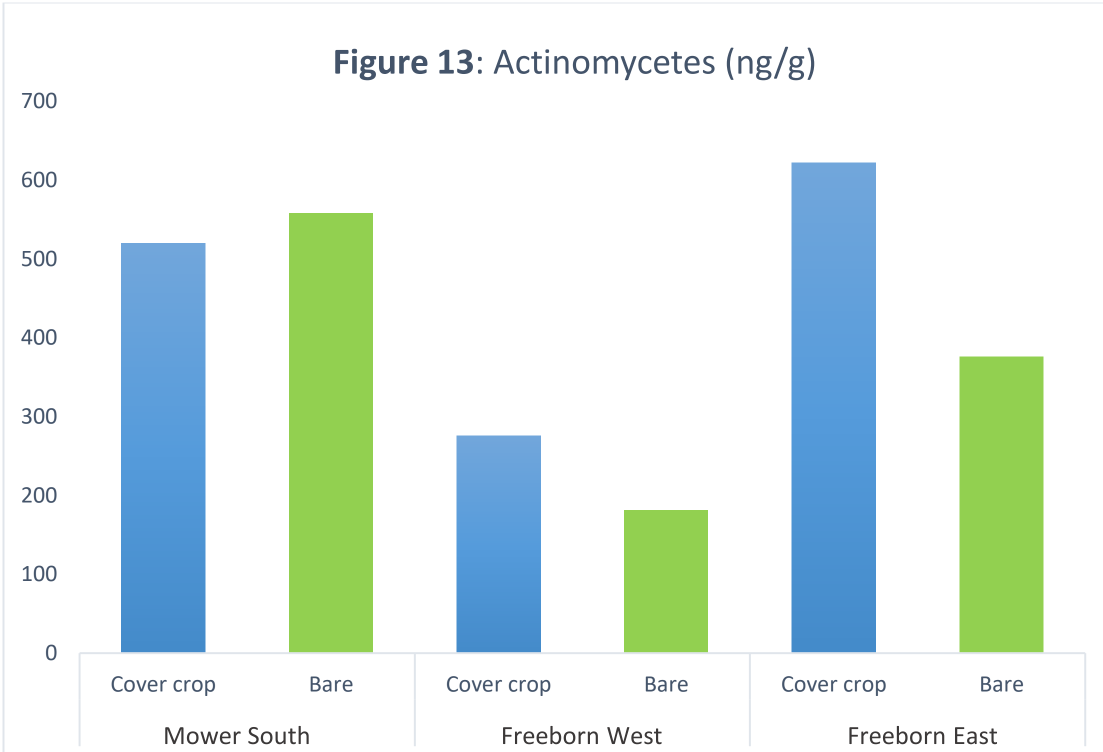


This microbial advantage of cover cropping was especially visible for mycorrhizae (Figure 11) where these phosphorus providers seem to thrive under the cover crop strips compared to the non-cover cropping system. Overall, cover crop practice seems to increase soil mycorrhizae under strip-till (Freeborn West and Freeborn East). Rhizobia presence showed a similar trend (Figure 12) and the cover crop practice seems to increase rhizobia under strip-till (Freeborn West and Freeborn East) providing more N to soybean through biological fixation.



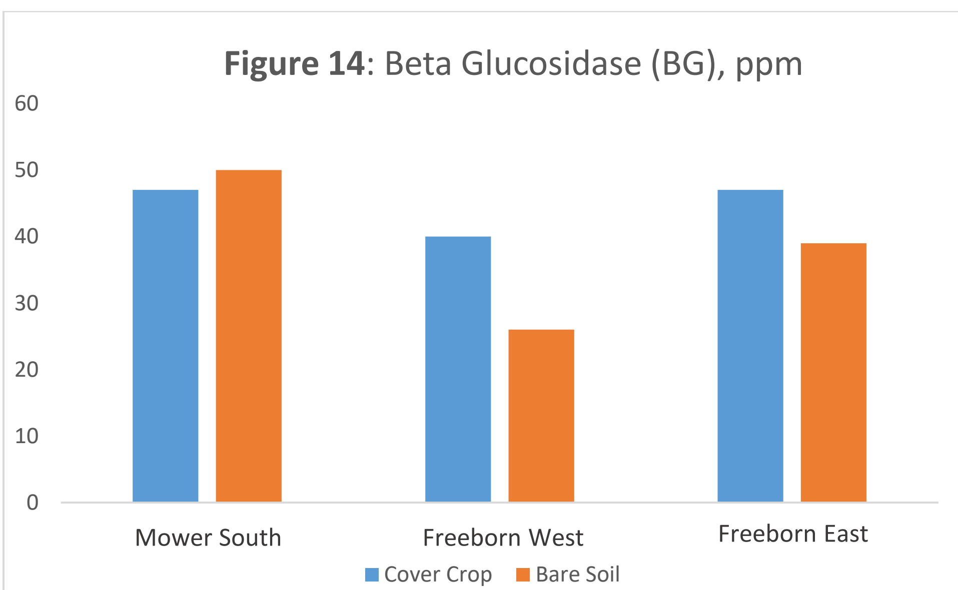


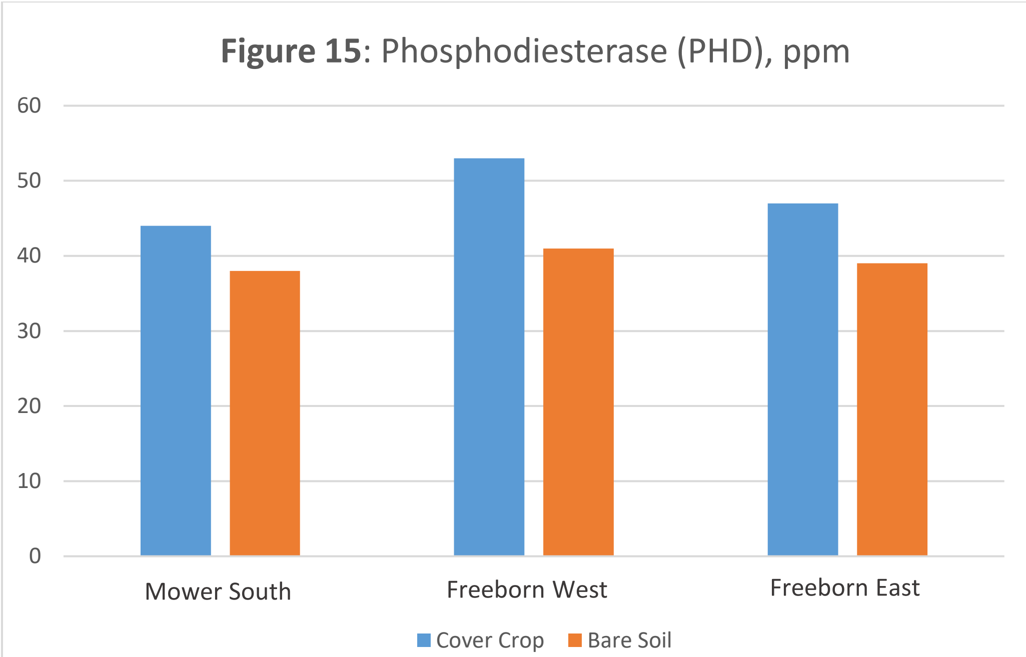
Another important group of microorganisms that helps cycle organic matter in the soil is the actinomycetes. Actinomycetes help reduce soil-borne diseases. In this field study (Figure 13), cover crop practice seems to increase Actinomycetes under strip-till (Freeborn West and Freeborn East).



Soil Enzyme Activity

Enzyme activity in the soil is also used as an indicator of soil microbial activity and overall health. Specifically, the Beta Glucosidase (BG) and Phosphodiesterase (PHD) are known to drive C and P cycling. Usually higher Beta Glucosidase (BG) is an indicator of adequate carbon and nutrient cycling. Overall soil health and cover crop practice seems to increase BG under strip-till (Figure 14, Freeborn West and Freeborn East).





In general, higher PHD is an indicator of more plant available phosphate and, in this field study, cover crop practice seems to increase PHD activity under strip-till (Figure 15, Freeborn West and Freeborn East).

Additionally, both soil nitrate and microbial biomass were stratified, where about 90% were measured in the topsoil (0-8 inches). The slight improvement of microbial activity in this study was further confirmed using genomics. Under the cover cropping system, more microbial taxa were present.

Conclusion

The successful establishment of cover crops varies year to year and from field to field based on cultural practices. Key findings from this study:

- Cereal Rye and Ryegrass are more likely to overwinter and scavenge soil N.
- Cover crops did not impact cash crop yield.
- Cover crops did not seem to impact N availability for the cash crop that follows them (no N immobilization) based on spring and summer soil N levels.
- This microbial advantage of cover cropping was especially visible for mycorrhizae where these phosphorus providers seem to thrive under the cover crop strips compared to the non-cover cropping system. Overall, cover crop practice seems to increase soil mycorrhizae under strip-till.

Although this was a very short field trial, cover crops seem to improve soil health, providing more microbial biomass and diversity. This study showed improved nutrient cycling (BG and

PHD enzyme activity) under cover crops. The increased population of mycorrhizae, rhizobia and actinomycetes needs further confirmation because of the short duration of the study.

Outreach

The three participating farmers shared their results and experience through field days and outreach events. As members on the Freeborn Soil Health Team, they have a presence in the local farming community and held spring and fall field days. Factsheets and educational materials were developed and distributed at local and regional events. Additionally, lessons from this study were shared through a number of local media distributions including newsletters and newspapers.

Acknowledgement

This project was made possible by funding from the North Central SARE Program: Thank you for your support! (Grant obtained by Spencer Hubert and Myles Elsen). Also, thank you to the participating farmers who made this on farm project possible. We look forward to continuing to work together and supporting your leadership on growing cover crops in southern Minnesota.

Project Field Day in 2017