FINAL REPORT

PROJECT TITLE: Best management practices to integrate cover crops and manure
PROJECT NUMBER: 6054-21DD
PRINCIPAL INVESTIGATOR AND CO-INVESTIGATOR(S): Melissa Wilson, Chryseis Modderman, Manuel Sabbagh

ABSTRACT

There is a growing interest in using cover crops for improving soil health and water quality. In cool, northern climates, however, adoption is low due to the short growing season. On the other hand, interseeding cover crops allows more time for growth and is becoming popular. Liquid manure application, which often happens in the fall in this region, is one practice that could benefit from the use of cover crops. Newer injection technologies have made manure application into cover crops possible, but many questions remain. With a mix of on-farm and small plot research, we studied the effectiveness of a variety of cover crop seeding practices into corn and soybean; fall manure application timing versus spring fertilizer treatments with and without cover crops; soil health characteristics; and the impact of the studied practices on the following corn crop yield. We found that getting the cover crop planted as early as possible was beneficial for biomass production. Following sweet corn, cover crops could be drilled, but broadcast seeding into soybean around leaf-drop was better than drilling after soybean harvest. When it comes to manure application, we were able to successfully inject manure into the cover crop, though weather conditions seemed to dictate how well the cover crop recovered in the injection zones. As far as application timing, early fall applications when soil temperatures were above 50°F resulted in a 20 bushel per acre yield reduction compared with spring fertilizer. Waiting until after soils had cooled to below 50°F resulted in similar or better corn yields than spring fertilizer. This trend happened regardless of whether cover crops were planted or not. In the short time of this study (a two-year period in each field), we did not detect any changes in soil health (pH, bulk density, permanganate oxidizable carbon (POXC)) regardless of the practices used. Future research should evaluate these practices over the longer-term. Overall, this information will help farmers incorporate cover crops into their production systems when fall manure application is involved. This research also re-iterates that waiting until soil temperatures are cool in the fall to apply swine manure is a best management practice.

INTRODUCTION

Keeping the soil covered as much as possible is an important aspect for soil health management. Growing cover crops between cash crops is one way to keep the soil covered and depending on the type(s) of cover crops used, can also be a way to keep living roots in the soil.

In cool climates, however, adoption of cover crops has been limited due to the short growing season. For example, in Minnesota cover crops are more popular following early season vegetable crops like peas and sweet corn that allow for more time for establishment. Fewer acres, however, are seeded following commodity crops such as corn or soybeans. Recent research has successfully addressed this seasonal limitation in corn and soybean systems using interseeding in corn early in the growing season (Noland et al., 2018) or overseeding in soybeans in September (Wilson et al., 2013).

Another soil health promoting practice is the use of animal manure in combination with or in place of commercial fertilizers. This is because manure can improve the microbial diversity in the soil along with providing nutrients. Typically, manure is applied in the spring or fall. While spring application allows for less chance of nutrient loss, it is logistically difficult for farmers in Minnesota due unpredictable temperatures and increasingly wet weather. Thus, it is estimated that a large portion of manure is applied in the fall, leading to the potential for significant nutrient losses via leaching, runoff, or denitrification. The addition of cover crops to this practice could reduce these losses as the plants take up available nutrients throughout the fall and spring then slowly release them for the following cash crop. Combining manure applications with the use of cover crops could have additional beneficial effects on soil health as well, improving microbial diversity further than only applying manure or only using cover crops alone.

Farmers that use cover crops and manure traditionally apply manure following cash crop harvest and then plant cover crops. This leaves a significant amount of time for the manure nutrients to be lost before the cover crop is established and scavenging nutrients. Recent on-farm research in Minnesota (Everett et al., 2019) has demonstrated that with improvements in minimal disturbance manure injection, application of liquid manure into an already-growing cover crop is possible following soybeans and silage corn. This study investigated cover crops drilled after the cash crop was harvested, however, and researchers noted that low biomass accumulation, particularly in the more northern sites, resulted in lower fall nitrogen scavenging than reported in studies in warmer climates. Injection of manure into interseeded or overseeded cover crops, which have had more time to grow, may improve nutrient uptake. Timing of manure application may also impact nutrient dynamics in the soil and needs further testing.

Our primary goals were to develop and demonstrate best management practices for the integration of cover crops and liquid manure injection. Secondarily, we evaluated whether the combination of practices had added beneficial effects on optimizing soil nutrient cycling and soil health when compared to each practice alone.

OBJECTIVE AND GOAL STATEMENTS

- Evaluate cover crop seeding practices prior to liquid manure application
- Assess whether timing of manure application into a cover crop is important for retaining nutrients
- Determine whether manure application, cover crops, or the combination of both impact soil health
- Monitor changes in soil nitrogen and estimate nutrient recovery of the cover crop
- Evaluate the impact of these practices on subsequent cash crop yield and nutrient uptake

MATERIALS AND METHODS

We used a combination of small plot and on-farm research for this project. The small plots located at the Research and Outreach Centers (ROCs) allowed us to better control environmental factors and use a more intense sampling regime to determine whether treatments had an impact on soil parameters. The on-farm research allowed us to demonstrate techniques using full-scale equipment.

Task 1 – Small plot experiments – We conducted two small plot experiments at the Southern ROC (SROC) in Waseca, MN, using sweet corn-corn and a soybean-corn rotations. Winter cereal rye was used for the cover crop in both experiments, as this has been widely studied in Minnesota. In the first experiment, we also used oats, alone and in a mix with rye and radish, as the cover crop treatments. This first experiment also tested manure application timing: an early application when soil temperatures were warm enough for nitrogen cycling, where potential nitrogen losses may occur, and a late application when soil temperatures were cool and nitrogen cycling and losses were likely minimized. The second experiment tested overseeding and drilling cover crops into soybeans (in a corn-soybean rotation). Manure was applied in late fall when soil temperatures were cool. In both experiments, liquid swine manure was injected using sweeps to minimize soil surface disturbance. The "control" plots were treated according to standard practices in the region (the same nitrogen rate was applied pre-plant in the spring as the manured plots and P and K fertilizers were applied based on soil test levels). The cover crop was terminated approximately one to two weeks prior to planting the following cash crop.

- *Task 1A – Set up experiment with sweet corn* – Sweet corn was planted, managed, and harvested following typical practices in the region. For the experimental plots, we used a randomized complete block design with split plots and four replications. A new field was used each year of the experiment. The main factors were manure application timing while the subplots were with or without cover crops. Treatments can be found in Table 1. Cover crops were drilled after sweet corn harvest in early- to mid-August. Manure was tested and applied at the necessary rate to meet the nitrogen needs (minus 40 pounds of N at planting) of the following corn grain crop. In the control plots, fertilizers were applied a few days prior to planting in the spring and incorporated via tillage.
- *Task 1B – Set up experiment with soybeans* – Soybeans were planted, managed, and harvested according to typical practices in the region. We used randomized complete blocks with split plots and four replications for the design where the main plots were whether manure or spring fertilizer was applied, and the subplots were cover crop seeding method/timing (see Table 2). Overseeded winter rye was broadcast by hand to simulate directed broadcast by highboy or aerial seeding. The manure application rate was determined by the manure nutrient analysis and the following year's corn crop's nutrient needs (minus 40 pounds of N at planting). In the control plots, fertilizers were applied a few days prior to planting in the spring and incorporated via tillage.
- *Task 1C – Collect and analyze samples for both experiments* – To evaluate the impacts of cover cropping and manure injection practices on nutrient cycling and soil health, we

collected soil and plant samples over time. All samples were analyzed according to appropriate standard laboratory methods.
    - Rye biomass growth was monitored by collecting above-ground biomass samples in late fall and in the spring prior to cover crop termination.
    - Soil health was evaluated around the time of cover crop termination and near the end of the following corn season using several of the USDA-NRCS approved Standard Indicator Soil Health tests (2019).
- *Task 1D – Determine impacts on yield of the following crop in both experiments* – The following cash crop, grain corn, was planted, managed, and harvested according to typical practices in the region. Cash crop yield was determined to assess any impacts of the manure and cover crop treatments.

Table 1. Treatments for small plot experiments following sweet corn at the Southern Research and Outreach Center in Waseca, MN.

Main plots (manure application timing)	**Subplots (cover crop seeding method/timing)**
Early manure (shortly after harvest)	• Drilled winter rye • Drilled oats • Drilled rye/oat/radish mix • No cover crop
Late manure (late October to early November)	• Drilled winter rye • Drilled oats • Drilled rye/oat/radish mix • No cover crop
Spring fertilizer applied prior to planting (no manure)	• Drilled winter rye • Drilled oats • Drilled rye/oat/radish mix • No cover crop

Table 2. Treatments for small plot experiments with soybean at the Southern Research and Outreach Center in Waseca, MN.

Main plots (manure application)	**Subplots (cover crop seeding method/timing)**
Manure applied after harvest	• Broadcast seeding in September • Drilling after harvest • No cover crop
Spring fertilizer prior to planting (no manure)	• Broadcast seeding in September • Drilling after harvest • No cover crop

Task 2 – On-farm experiments – The on-farm experiment was located near Trimont, MN in cooperation with AJ Krusemark. Due to issues with planting cover crops in fall 2019 (an extremely wet season), the experiment was only conducted one time (fall 2020-2021 growing season). We used farm scale equipment in a soybean-corn rotation where the crops were planted, managed, and harvested following typical practices in the region.

- *Task 2A – Setting up experimental strips* - For the experimental plots, we used field-length strips that were arranged in randomized complete blocks with three replications (table 3). We tried to minimize the number of treatments on the farm for logistical reasons and timing of other farm operations. The cover crop mix was chosen by the farmer and included winter rye. It was drilled after soybean harvest. Liquid swine manure was injected with strip tillage. We analyzed the manure for nutrient content and then applied at the necessary rate to meet the P needs of the following crop. Fertilizer was applied in the non-manured plots via strip tillage based on the soil test levels. The cover crop was terminated at two different times in the spring: 1-2 weeks prior to planting and after planting. All remaining N (or full N rate in the fertilizer-only plots) was sidedressed.
- *Task 2B – Collect and analyze samples* – The number of samples collected at these sites was not as intense as the small-plot studies. We monitored the winter rye growth and nutrient uptake by collecting above-ground biomass samples in the spring prior to each termination date. Corn was harvested by hand from each plot from two randomly selected 10-foot section of rows, shelled, then dried to get moisture content.

Table 3. Treatments for on-farm experiment

Experiment	Strip Treatments	Split plots within strips
Soybean – Corn Rotation	Strip-tilled manure + cover crops	Early, pre-plant termination of spring cover crops
	Strip tilled fertilizer + cover crops	Late, post-plant termination of cover crops

RESULTS AND DISCUSSION

Sweet Corn – Corn Rotation – Small Plot Trials

Cover crop biomass – Above-ground cover crop biomass for the oat and mixed cover crop averaged approximately 400 pounds per acre in the fall after planting, while winter rye produced significantly less at 200 pounds per acre (Figure 1). Significant differences were not found for nutrient source/timing. In the spring prior to termination, the oats and radish had completely winter killed but there were no significant differences between rye and the cover crop mix. Nutrient source/timing did not affect cover crop biomass production in 2020, but in 2021, the early-fall applied manure increased cover crop biomass production relative to the plots where nothing had been applied yet (spring fertilizer was applied after cover crop termination). The late-fall applied manure significantly decreased cover crop production, however (Figure 1). This is likely due to drought conditions from mid-fall 2020 through spring 2021 and the late applied manure application did not allow for the cover crops to recover.

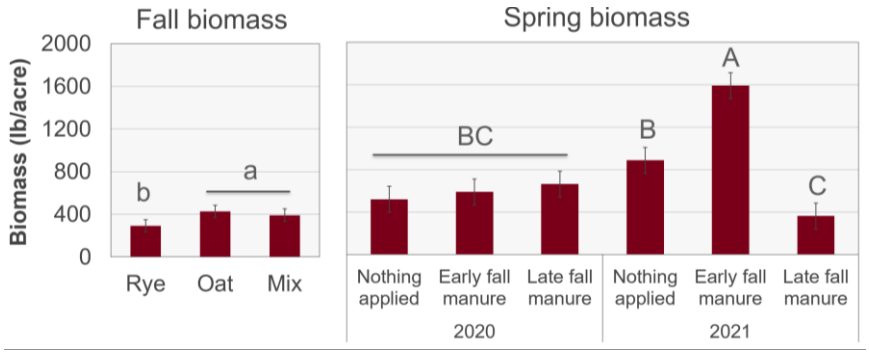

Figure 1. Average above-ground biomass for different cover crops in the fall after planting and the following spring prior to termination. There was a significant year by cover crop type interaction for spring biomass collections. Bars with different letters above them for each season are significantly different (P<0.05).

Corn yield following cover crops – There was an effect of nutrient source/timing and cover crop types on yield, but there was no interaction between the two (Figure 2). In both 2020 and 2021, early-fall applied manure (applied in September when soil temperatures were >50°F) significantly decreased corn yield compared with the spring fertilizer treatment, regardless of whether cover crops were used or not. The yield decrease was approximately 13-15 bushels per acre. On the other hand, the late-fall applied manure (applied in late October or November when soil temperatures were <50°F) increased yield by 33 bushels per acre in 2020 or had a statistically similar yield compared to the spring fertilizer treatment in 2021. There was a drought in 2021, so it is likely that the manure nitrogen did not mineralize as well that year. This really emphasizes the need for applying swine manure at the right time in the fall when the soil temperatures have cooled. A significant amount of nitrogen was likely lost when the manure was applied too early.

Cover crops also affected yield. The oat cover crop treatment yielded similarly to the no cover crop control. The rye and mixed treatments, however, decreased yield by about 19-20 bushels per acre. This was possibly due to two issues. First, the rye had grown very large in the spring and was difficult to properly incorporate. The seedbed was affected, and the seed likely had poor seed-to-soil contact. The other issue was that the incorporated rye may have tied up nitrogen early in the growing season. We observed nitrogen deficiency symptoms (yellowing of lower leaves) in the corn in the treatments with rye.

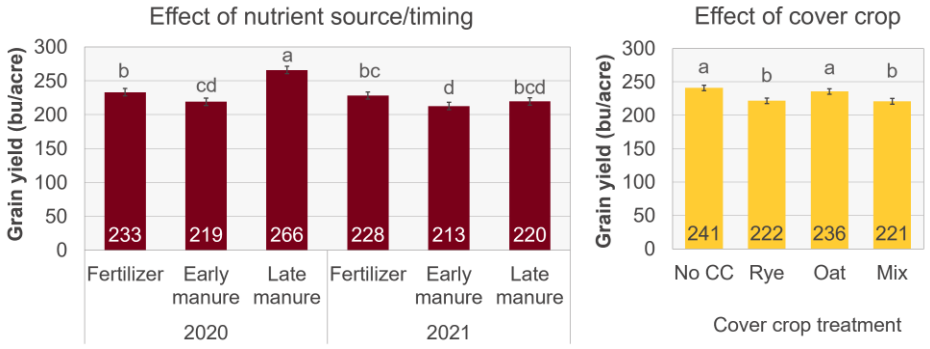

Figure 2. Effect of nutrient source/timing and cover crops on corn yield following sweet corn. For nutrient sources, fertilizer was spring applied and compared with early manure (applied mid- to late-September) and late manure (applied late October). A winter rye, oat, or winter rye-oat-radish mix was compared to a no cover crop control (no CC). Bars with different letters above them for each graph are significantly different (P<0.05).

Soil health parameters – Bulk density was measured every spring, prior to cover crop termination from the 0-6" soil layer. There were no significant differences in relation to the interaction of nutrient source and cover crop treatment (Figure 3). Although no differences were observed, bulk density was in the optimal range for clay loams and fields should not have impacted plant growth.

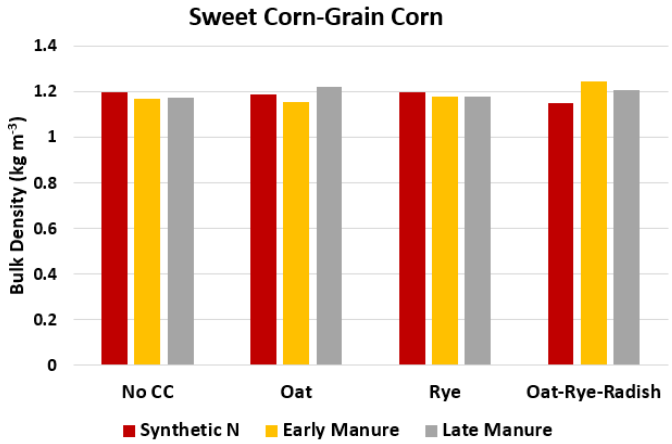

Figure 3. Soil bulk density in the sweet corn-corn rotation from the top 0-6" of soil in relation to nutrient source and cover crop treatment.

Similarly to bulk density, pH was not significantly different in relation to the interaction of cover crops and nutrient source in either spring after cover crops were planted or in fall after the following crop was grown (Figure 4). Soil pH fall in the optimal pH range for soils for crop production (6-7).

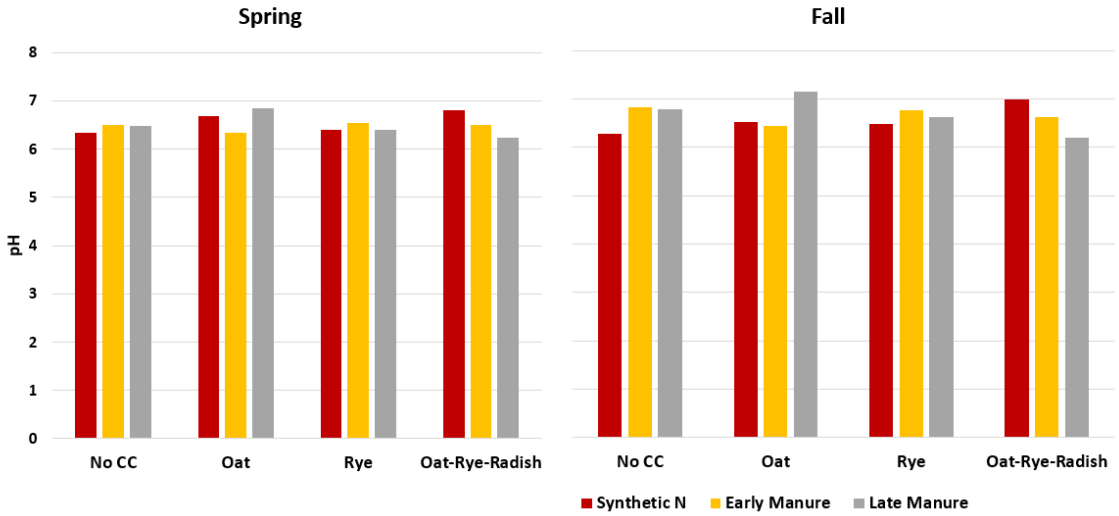

Figure 4. The interaction of cover crops and nutrient source on soil pH in the sweet corn-grain rotation. Soils were taken from the 0-6" soil layer in spring and fall.

Permanganate oxidizable carbon (POXC) measures the labile carbon in soils that can be utilized by microbes. In addition, POXC is a sensitive tool that can track changes in soil carbon quickly when soil management practices change. In both rotations, POXC was not affected by the interaction of cover crops and liquid injected manure in both spring after cover crops were planted or in fall after the following crop was grown (Figure 5). The lack of significant differences across the year may also be the result of the inherently high percent soil organic matter in both these studies. Cover crops may have also not produced enough biomass to have a significant effect in relation to carbon inputs from root exudates and inputs from decomposing biomass.

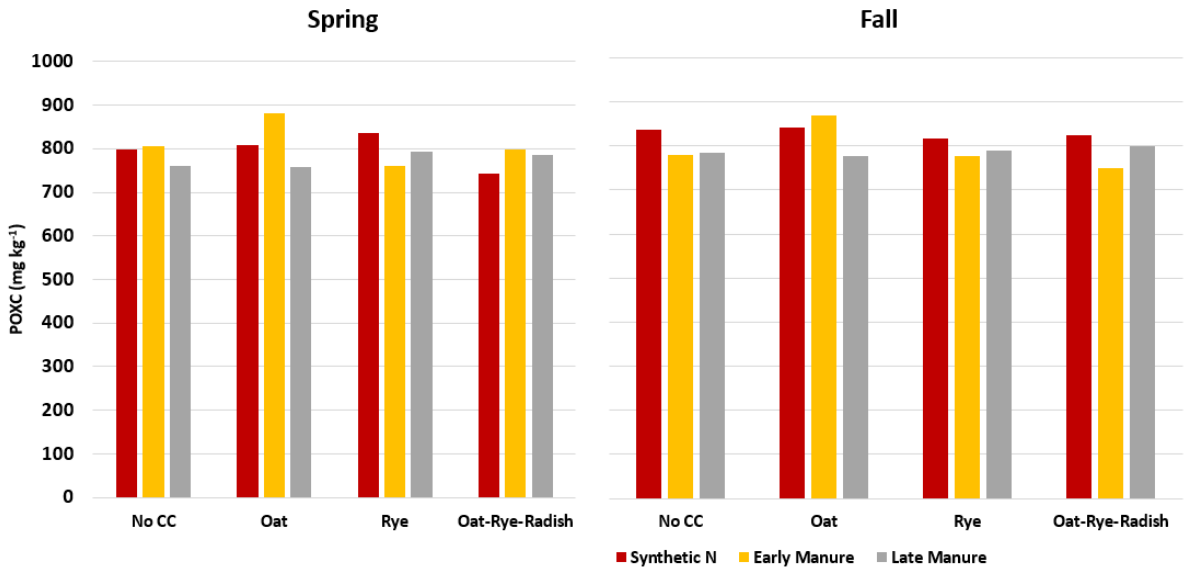

Figure 5. The interaction of cover crops and nutrient source on permanganate oxidizable carbon in soil in the sweet corn-corn rotation. Soils were taken from the 0-6" soil layer in spring and fall.

Soybean – Corn Rotation – Small Plot Trials

Cover crop biomass – Above-ground cover crop biomass production was much lower following soybean than following sweet corn, less than 100 pounds per acre in the fall and less than 400 pounds per acre in the spring prior to termination (Figure 6). Cover crops that were drilled after harvest failed in one of two years, and produced very little biomass in the years that they were successfully established. Overseeding the cover crops around soybean leaf drop was a better method for getting the cover crops established earlier. Manure application affected cover crops in the fall when averaged over both years. By the spring, cover crops had recovered in the manured plots in 2020 but we did not see that trend in 2021. As mentioned above, we had a significant drought develop in late fall 2020 so it is likely that the cover crop could not recover after application with so little moisture in the soil profile.

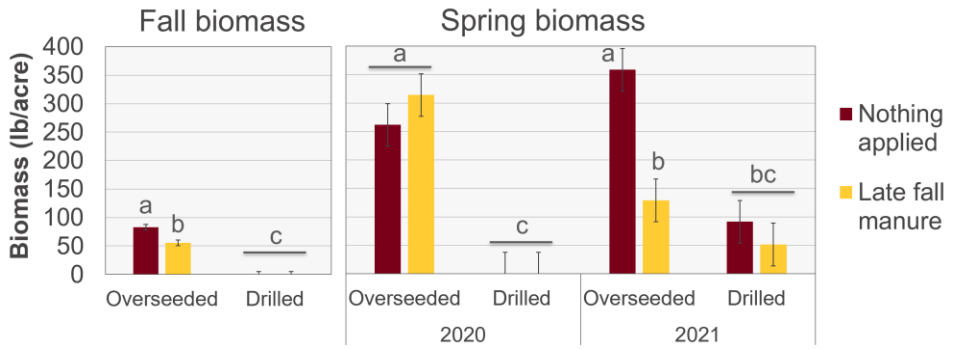

Figure 6. Average above-ground biomass for different cover crops in the fall after planting and the following spring prior to termination. Cover crops (annual ryegrass and winter rye mix) were overseeded at soybean leaf drop or drilled after harvest. In the fall, manure was applied and compared to plots where nothing was applied until spring following cover crop termination. Bars with different letters above them for each season are significantly different (P<0.05).

Corn yield following cover crops – In the soybean-corn rotation, we did not find an effect of fall manure versus spring fertilizer or an effect of cover crop (Figure 7). This is likely because corn following soybean is more resilient when it comes to nitrogen needs. The decay of soybean reside provides some nitrogen to the following crop. As for the cover crops, they did not produce much biomass in this rotation, so it is likely they did not tie up nitrogen or cause seedbed issues like was seen in the sweet corn-corn rotation.

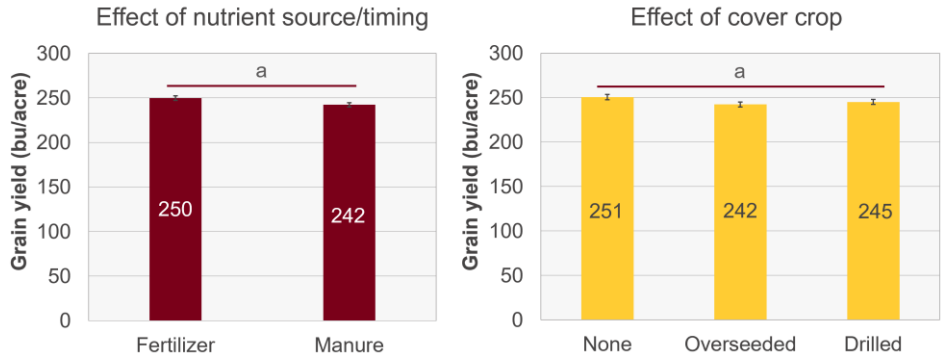

Figure 7. Effect of nutrient source/timing and cover crops on corn yield following soybean. For nutrient sources, fertilizer was spring applied and compared with fall manure (applied late October). The cover crop included a winter rye-annual ryegrass mix. It was overseeded near soybean leafdrop or drilled after harvest. Both were compared with a no cover crop (no CC) control. Bars with different letters above them for each graph are significantly different (P<0.05).

Soil health parameters – None of the treatments affected soil bulk density (Figure 8), pH (Figure 9), or POXC (Figure 10). As mentioned above, the fields in the study had high soil organic matter to begin with, so it was unlikely to see changes to soil health over a small period of time.

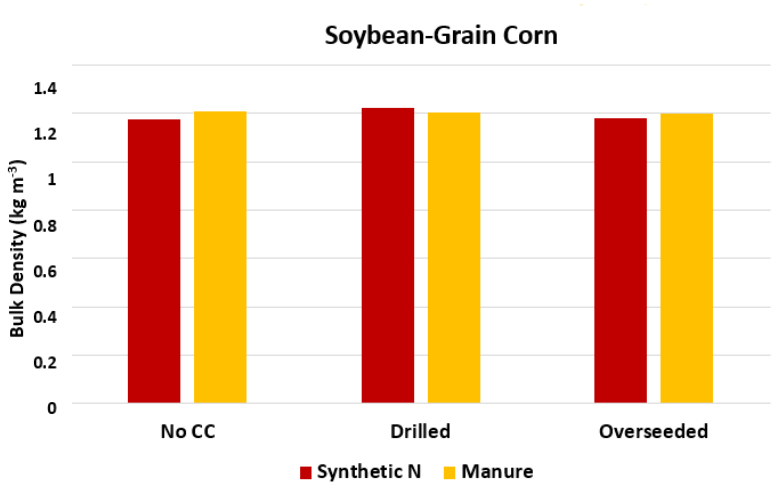

Figure 8. Soil bulk density in the soybean-corn rotation from the top 0-6” of soil in relation to nutrient source and cover crop treatment. Cover crops (annual ryegrass and winter rye mix) were overseeded at soybean leafdrop or drilled after harvest and compared to plots with no cover crop (CC).

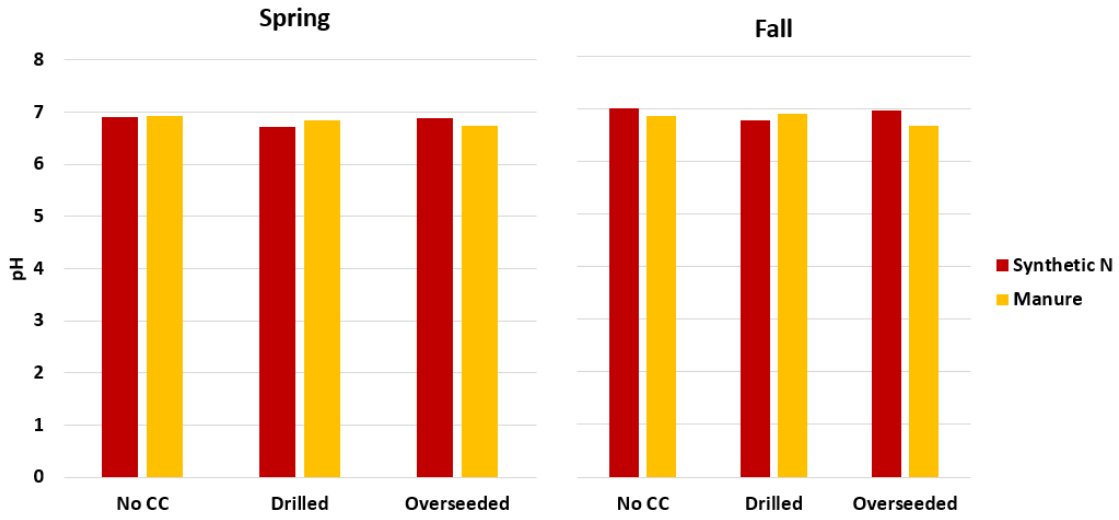

Figure 9. The interaction of cover crops and nutrient source on soil pH in the soybean-grain rotation. Soils were taken from the 0-6” soil layer in spring and fall.

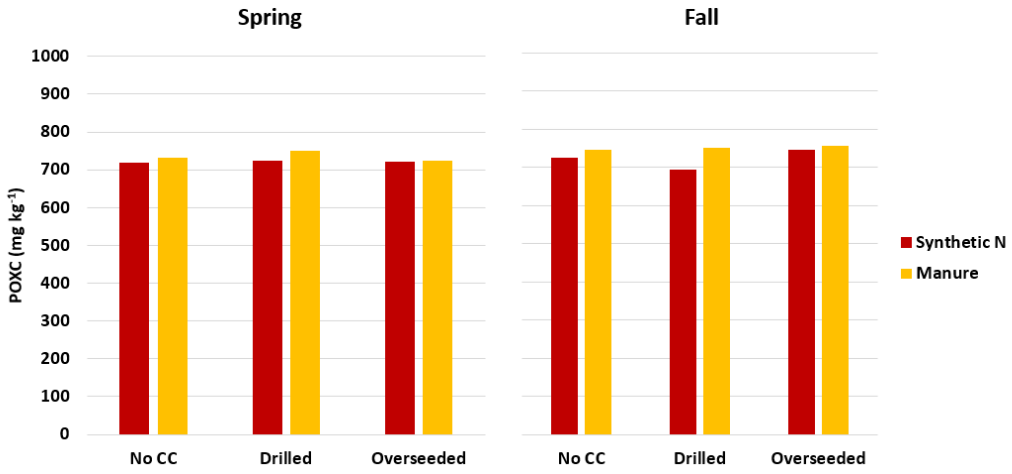

Figure 10. The interaction of cover crops and nutrient source on permanganate oxidizable carbon in soil in the soybean-corn rotation. Soils were taken from the 0-6" soil layer in spring and fall.

Soybean – Corn Rotation – On-farm trial

Cover crop biomass – In this trial, swine manure or commercial fertilizer was strip-tilled in the fall after cover crops were drilled following soybean harvest. In the spring, cover crops were either terminated early (one to two weeks prior to planting) or late (after planting). Samples were collected on May 7, 2021 and May 19, 2021 prior to each termination date. Fertility treatments did not affect cover crop biomass, but termination timing did. There were 352 pounds of above-ground biomass produced by the early termination date and 1,113 pounds of biomass produced by the late termination date, a more than 3-fold increase over 12 days.

Corn yield following cover crops – Fertility treatment (manure versus commercial fertilizer) did not affect corn yield following the cover crop. Interestingly, the late-terminated cover crops slightly reduced yield (179 bushels per acre) compared to the early-terminated cover crops (190 bushels per acre), but the difference was not statistically significant. The lack of a drastic difference was surprising as 2021 was a dry year and we had anticipated that the cover crop would have consumed excess amounts of water.

CONCLUSIONS

Manure can be successfully injected into growing cover crops in different crop rotations. Depending on the year, the injection equipment may damage some of the cover crop stand, but with good growing conditions the cover crop will recover and flourish. We also found that:

- Getting cover crops established as early as possible is important to allow for more time for growth.
- There is a chance that winter rye will slightly decrease the following corn yield, particularly in corn following corn systems. This could be an equipment issue, however, as seedbed issues made planting difficult.
- Applying swine manure too early in the fall will cause significant decreases in yield. Waiting until the soil temperatures were cool (<50°F) helped improve yield.

- Swine manure was a great nutrient source for corn production, similar to or better than commercial fertilizers.
- Soil health improvements were not detected over the short timeframe of this experiment.

EDUCATION, OUTREACH, AND PUBLICATIONS

Conferences

- Sabbagh, M.J., Wilson, M.L., Pagliari, P.H. (2022). Integration of Liquid Injected Manure and Cover Crops and Their Impact on Soil Health and Grain Yield in the Upper Midwest. In: ASA, CSSA, and SSSA 2022 International Annual Meetings. Baltimore, MD. 6-9 Nov.
- Sabbagh, M.*, Wilson, M., Pagliari, P. (2022). Changes in Soil Health in Response to Cover Crop and Manure Integration in the Upper Midwest. In: World Congress of Soil Science. Glasgow, Scotland, UK, 31 Jul- 5 August.
- Sabbagh, M., Pagliari, P.H., Wilson, M.L. (2022) Potential soil health improvement through the integration of cover crops and manure in the upper Midwest. In: Waste to Worth Conference. Oregon, OH. 19-22 April. https://lpelc.org/potential-soil-health-improvement-through-the-integration-of-cover-crops-and-manure-in-the-upper-midwest/
- Sabbagh, M., Wilson, M. L., Pagliari, P. H. (2021). Effects of integrating liquid swine manure and cover crops have on soil health in the upper Midwest. In: ASA, CSSA, and SSSA 2021 International Annual Meetings. Salt Lake City, UT, 7-10 Nov.
- Sabbagh, M., Wilson, M. L., Pagliari, P. H. (2021). Integrating Cover Crops and Manure: Developing Best Management Practices. In: 76th SWCS International Annual Conference. Virtual, 26-28 Jul.
- Sabbagh, M., Wilson, M. L., Pagliari, P.H. (2020). The Impacts Cover Crops and Liquid Manure Have on Soil Health in the Upper Midwest. In: ASA, CSSA, and SSSA 2020 International Annual Meetings. Virtual, 8-11 Nov.

Articles/Other outreach:

- Wilson, M. (2020). Cover crops and manure for soil health [Webpage]. ArcGIS Story Maps. https://z.umn.edu/ManureCoverCrops2020
- Sabbagh, M., Wilson, M. (2022) How does integrating cover crops and liquid-injected manure impact corn yield and cover crop biomass? In: MN Crop News blog. 31 May. https://blog-crop-news.extension.umn.edu/2022/05/how-does-integrating-cover-crops-and.html
- Sabbagh, M. (2022). Manure – waste or resource? In: Foundation for Food and Agricultural Research Blog. 25 Apr. https://foundationfar.org/impact/insights/manure-waste-or-resource/
- Wilson, M., Sabbagh, M. (2021). Injecting liquid manure into a cover crop. In: Minnesota Crop News Blog. 1 Mar. https://blog-crop-news.extension.umn.edu/2021/03/manure-research-update-injecting-liquid.html
- Wilson, M., Stahl, L. (2019). Applying manure in late summer or early fall? Try cover crops. In: Minnesota Crop News Blog. 19 Aug. https://blog-crop-news.extension.umn.edu/2019/08/applying-manure-in-late-summer-or-early.html.

Extension Presentations:

- Wilson, M. L. (2022) Injecting manure into cover crops. In: North American Manure Expo. 14 July. Chambersburg, PA. (*102 in attendance*)
- Sabbagh, M., Wilson, M.L. (2022). Integrating Cover Crops and Liquid-injected Manure: Impacts on grain yield. In: MN Ag Expo. Mankato, MN. 19 Jan.
- Wilson, M., Raman, R., Andersen, D. (2022). Manure Application & Cover Crops: Panel Discussion. In: Iowa Pork Congress. Des Moines, IA. 27 Jan. (*31 attendees*)
- Wilson, M. (2022). Injecting manure into a growing cover crop. In: Wisconsin Agribusiness Classic. Madison, WI. 12 Jan. https://vimeo.com/659707510 (*60 attendees*)
- Loeffler, A., Wilson, M.L., Shea, M., Breen, D. (2021). Cover crops and livestock. In: Midwest Cover Crops Council Conference. Guelph, Ontario but held virtually. 25 Feb. (*1 panel presentation, 95 attendees live*)
- Wilson, M.L. (2021). Cover crops and manure research update. In: MN Corn Growers Research and Promotion Board Summer Meeting. Hastings, MN. 9 Jun. (*14 attendees*)
- Wilson, M. (2021). Manure happens: Can cover crops help? In: Stearns SWCD Manure and Cover Crops Field Day. Virtual. 7 Jan. Available at https://www.youtube.com/watch?v=T89zmPnQzq4 (*62 live attendees, 113 video views*)
- Sabbagh, M., Wilson, M.L. (2020). Integrating cover crops and manure: Best management practices. In: MN Ag Expo. Mankato, MN. 22-23 Jan.
- Wilson, M. L., Hatlewick, H. (2019). Table Talk: Crap and cover crops. In: Conservation Tillage Conference. University of Minnesota Extension. Saint Cloud, MN. 17-18 Dec.
- Wilson, M. L. (2019). Applying Liquid Manure into Cover Crops. In: Crop Pest Management Short Course. Institute for Ag Professionals – University of Minnesota Extension. Minneapolis, MN. 12 Dec.
- Wilson, M.L. (2019). Manure Management in Cover Crops & Side-Dressing Corn. In: Tour de Forage. Midwest Forage Association. Welch, MN. 4 Dec. (*51 attendees*)
- Wilson, M. L. (2019). Manure and Cover Crops: Best Management Practices. In: Soil Health Summit. National Corn Growers Soil Health Partnership. St. Louis, MO. 15 Jan. (*70 attendees*)

Interviews:

- Studying manure and cover crop integration – MN Corn Podcast, Sep. 11, 2022
- Time cover crops, manure in short fall window – Farm Progress, Jul. 25, 2022
- Minnesota Study: How Integration of Cover Crops, Liquid-Injected Manure Impacts Corn Yield, Biomass – Cover Crop Strategies, May 31, 2022
- Study provides insights to how cover crops and manure work together – Brownfield Ag, Mar. 10, 2022
- "Research evaluates soil health benefits of combining manure and cover crops" – MN Corn Blog, Jun. 9, 2020
- "Applying manure to cover crop offers multiple benefits" – MN Farm Guide., Jan. 30, 2019
- "Manure, Cover Crops Fit Well Together" – Successful Farming, Jan. 22, 2019

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