Conservation Innovation Grant—NRCS No. 68-3A75-9-168

Title: Integrating No-Till Cropping, Manure and Cover Crops with Manure Slurry Seeding

Project dates: September 2009-September 2012

Primary Investigator: Tim Harrigan, Associate Professor, Michigan State University
MSU Co:PI's: Dale Mutch and Natalie Rector, Michigan State University
Purdue University Co-PI's: Irene Kladivko, Brad Joern and Jim Camberato

Project Background and Justification

There are many soil and water conservation challenges to the environmentally sound and economically viable use of manures on agricultural land. Soil erosion can be a problem, due in part to the slow adoption of no-till cropping systems by livestock producers because of the need for intensive tillage to incorporate manure for efficient nutrient recovery. On the other hand, liquid manure is often applied on untilled ground after corn silage harvest even though the soil is compacted from harvest traffic and there is little crop residue to protect the soil from runoff and erosion. Although cover crops can trap nutrients and provide a vegetative barrier to overland flow, producers are often too busy with harvest and manure application to seed a cover crop in a timely fashion. There is a need for new manure management options that are compatible with no-till planting and cover crops in livestock-based cropping systems.

Figure 1. Cover crop seed is mixed directly with the nutrient-rich slurry.

A new, no-till compatible manure application and cover crop establishment method--*manure slurry seeding*-- has been developed at Michigan State University. Manure slurry seeding combines low-disturbance aeration tillage, liquid manure application and the seeding of cover crops in one efficient operation. In one pass, cover crop seed that has been mixed with liquid manure in the spreader tank is delivered through drop-tubes to the fractured and loosened soil behind each set of aeration tines. A cover crop soon emerges, capturing nutrients and forming a vegetative barrier to overland flow.


Figure 2. Oats and turnips slurry seeded with swine slurry on August 6, 2010. Picture taken Septermber 17, 2010.

Slurry seeding is an environmentally sensitive option for manure management in no-till cropping systems and soil and water quality improvement in all cropping systems. This new process alleviates seedbed compaction; reduces erosion by increasing surface roughness, improving water infiltration and conserving crop residues; improves nutrient cycling; and mitigates contaminant loss to the environment through tile drains by disrupting the continuity of soil macro-pores. Soil quality is enhanced by reducing tillage intensity and adding organic inputs --manure and cover crops-- that stimulate soil building biological processes. Because slurry seeding combines low-disturbance tillage, manure application and seeding in one operation it provides fuel savings (more than 2 gal per acre) and labor savings (more than 0.35 hr per acre) compared to conventional cover crop seeding practices.

Michigan State University
There are three main types of activities at MSU related to the CIG grant: 1) demonstration sites, 2) presentations and educational activities, and 3) web site and videos. Slurry seeding of cover crops was demonstrated at three 40-acre sites in Michigan in 2011-2012, at the Blight Farm in Albion, MI, at the Bloom Dairy in Coldwater, MI, and at the Bakerlad's Dairy in Clayton, MI.

Michigan Presentations and educational activities
The Michigan Co-PI's organized and presented several educational programs and presentations related to the CIG project.

2010

1- Manure slurry seeding of cover crops. January 15, 2010.
2- Webinar for the Livestock & Poultry Environmental Learning Center.
3- General session National No-till Conference, Des Moines, IA
4- New cover crop strategies No-Till conference, Des Moines, IA
5- Ag Action, Kalamazoo, MI
6- Farmer's Day, Coldwater, MI
7- Cover Crops to protect the soil from eroding, Allegan, MI
8- NAN webinar, e-Organic
9- NW Station think tank, Sutton's Bay, MI
10- International IPM, KBS
11- Michigan Alternative and Renewable Energy Center, Muskegon, MI
12- Great Lakes Expo, Grand Rapids, MI
13- SWCD IN, Auburn, IN
14- National Manure Expo, PA.
15- Tour/Field Day, Blight Farms, Albion MI.

2011

16- Reintegrating Manure and Cover Crops in Livestock-Based Cropping Systems.
    2011 Meeting of the Midwest Forage Association, Wisconsin Dells, WI.
17- Minnesota Organic conference MN
18- Harrigan, T.M. 2011. Integrating Cover Crops, Liquid Manure and Low-Disturbance Tillage. ASABE International Meeting, Louisville, KY. Paper No. 1111392. ASABE: St. Joseph, MI
19- Harrigan, T.M. 2011. Slurry Seeding: A New Technology for Cover Crop Establishment and Nitrogen Cycling. Proceedings of the 2011 Great Lakes Fruit and Vegetable Growers Conference. Grand Rapids, MI. December 6-8.
20- CSS 488 Dr. Renner's Cropping systems class (MSU)
21- Harrigan, T.M. 2011. Integrating Cover Crops and Liquid Manure in No-Till Cropping Systems. Ohio No-Till Council, Minster, Mercer Co., OH August 31. Attendance approx. 140.
22- Harrigan, T.M. 2011. Slurry Seeding and the Cost of Hauling and Transporting Manure. Certified Livestock Manager Training. Ohio Dept. of Agriculture and Midwest Professional Nutrient Applicators Association. Marysville, OH. June 29. Attn: 80.
23- Dundee, MI

24- Frankenmuth, MI
25- Saginaw, MI
26- Benton Harbor, MI
27- Bowling Green, OH
28- Tuscola SWCD, Caro, MI
29- Midwest Professional Nutrient Applicators Meeting, Marysville, OH. June 29.

2012

30. Harrigan, T.M. Cover Crops in Livestock-Based Cropping Systems. Lakeshore-UW Extension Progressive Operators Series, Lakeshore Technical College. January 27, 2012. Cleveland, WI.
31. Harrigan, T.M. Corn Grain Response to Manure and Oil Seed Radish Cover Crop. Midwest Cover Crop Conference, February 29, 2012. West Lafayette, IN.
32. Harrigan, T.M. Maximizing Manure Efficiency with Cover Crops. Purdue Agronomy Center for Research and Extension. Mar 1, 2012.
33. Harrigan, T.M. Maximizing Manure Efficiency with Cover Crops. Dubois Co. SW Indiana Crop Seminar, Jasper, IN. March 2, 2012.
34. Harrigan, T.M. Grassland Renovation with Slurry-Enriched Seeding of Red Clover. Michigan Dairy Review 17(2) 1-3
35. Harrigan, T.M. Hay and Pasture Renovation with Low-disturbance Slurry Seeding of Red Clover. MidWest Forage Association. July 13.
36. Harrigan, T.M. Slurry Seeding of Cover Crops. Soil and Water Conservation Society. 2012 Annual Meeting, Ft Worth, TX July 23
37. Harrigan, T.M. Slurry seeding of cover crops for soil and water quality. Farm Drainage and Nutrient Management Field Day, Quincy, MI Aug 1-2
38. Harrigan, T.M. Cover Crop and Residue Management Field Day, St. Johns, MI. October 4, 2012.

Project Web Site and Videos

The CIG slurry seeding project web page is housed at the Midwest Cover Crops website and maintained by Ms Erin Taylor at Michigan State University. The slurry seeding process and resulting cover crops were documented with video and posted on YouTube and linked to the project website http://www.mccc.msu.edu/SlurrySeeding.html The Blight Farm video documents the slurry seeding process and cover crop growth through November, 2010 http://www.youtube.com/watch?v=3st0qZ_3vH0 A second field day was held at the Blight Farms on August 26, 2011. The video from that event is available for viewing at http://www.youtube.com/watch?feature=player_embedded&v=YUbfg0PXX2M

Cereal rye was slurry seeded in the first week of September, 2010 at the Bloom Dairy near Coldwater MI following corn silage harvest. Cereal rye demonstration plots were established at a 40 acre site on a sandy loam soil. Dairy manure slurry was applied at 7000 gallons per acre. Plots were seeded with: 1) slurry seeding, 2) broadcast seeding followed by a shallow disking and manure slurry application with aeration tillage on the same day, 3) no-till drilling rye followed by manure application with aeration tillage on the same day, 4) broadcast seeding with shallow disking, manure application six weeks later on the established rye cover, and 5) no-till drilling, manure application six weeks later on the established rye. The slurry seeding process and resulting cover crop were documented with video and posted on the project web site with a link to the video at http://www.youtube.com/watch?v=lzvr5miXxZ8

Field Day/Demonstrations
The demonstration plots at Blight Farms, Albion MI were very successful and well located for a plot tour. Natalie Rector coordinated a tour on October 27, 2010 with about 40 attendees. Two of the cooperating farmers (Doug Bloom and Ken Blight) spoke of their experiences with the project and with cover crops in general. Dr. Harrigan, Dr. Dale Mutch/Dean Baas, Roberta Osborne and Natalie Rector contributed to the educational sessions. The on-sight tour provided a backdrop for photographs and interviews with participants and speakers. Michigan Farmer magazine expanded the outreach of this session (14,000 subscribers) with their Dec 2010 issue. Dr. Harrigan was shown on the front page and there were five contributing articles and sidebars on various aspects of cover crops and manure. The farmer cooperators were featured. The articles covered the main points related to cover crop synergism with manure and stress the environmental protection benefits of these planting systems.

A **second field day** was held at the Blight Farm in Albion, MI on August 26, 2011 with 75 attendees. The field day was a scheduled event for the state tour of the Soil and Water Conservation District. The attendees viewed a demonstration of the slurry seeding process and inspected cover crops strips established less than one month earlier as part of the CIG project.

A **third field day** was held in concert with the *Farm Drainage and Nutrient Management Field Day*, in Jonesville, MI on Aug 1-2. Red clover was slurry seeded into a winter wheat crop in April, 2012 with a comparison strip of broadcast red clover. Presentations of slurry seeding cover crops were given each day with a demonstration of the slurry seeding equipment and process and attendees viewed the established red clover cover crops. Handouts were provided. Approximately 500 visitors attended the two-day event.

A **fourth field day** was held in concert with the *Bioenergy, Cover Crops and Corn Residue Management Field Day* in St. Johns in Clinton Co. on October 4, 2012. Cover crops were seeded in mid-September by slurry seeding, no-till drilling and broadcast seeding with incorporation by vertical tillage. The slurry seeding equipment was demonstrated at the field day. Approximately 250 visitors attended the event.

Purdue University (sub-contract)
There are four main types of activities in Indiana:
1- growth chamber analysis of seed germination in contact with swine manure
2- field mini-plot trial on cover crop germination with swine manure
3- field-scale trials with swine slurry seeing of cover crops with three producers
4- discussion of slurry seeding option during Extension talks on cover crops
Specific details of the project have been submitted by the Purdue Co-PI's.

BakerLads Dairy, Lenawee Co., Cadmus Michigan

2010-2011 Cereal Rye Cover Crops

Blaine and Kim Baker manage a 500 cow dairy herd and produce corn and soybeans as cover crops. The farm is approximately 2,000 acres tillable. The soils are predominantly loam with a significant portion of subsurface drained cropland. They frequently sow cereal rye as a cover crop because they like the option of harvesting the crop in the spring for feed for young stock and dry cows.

In 2010 cereal rye was sown following corn silage harvest on Sept 22-23, 2010. The slurry seeding was done by placing 90 lb. /acre cereal rye in the slurry tank with a slurry application of 4000 gal/acre.

The objective of the demonstration was to compare slurry seeding of cereal rye with two common rye seeding methods, no-till drilling or surface broadcast of rye with slurry spreading by aeration tillage. Four treatments were made with three replications of each treatment: 1) slurry seeding, 2) no-till drill rye, dairy slurry applied with AerWay after seeding, 3) broadcast seeding of rye, dairy slurry applied with AerWay after seeding, and 4) no-till drilling of rye, 30-day delay of manure application with AerWay.

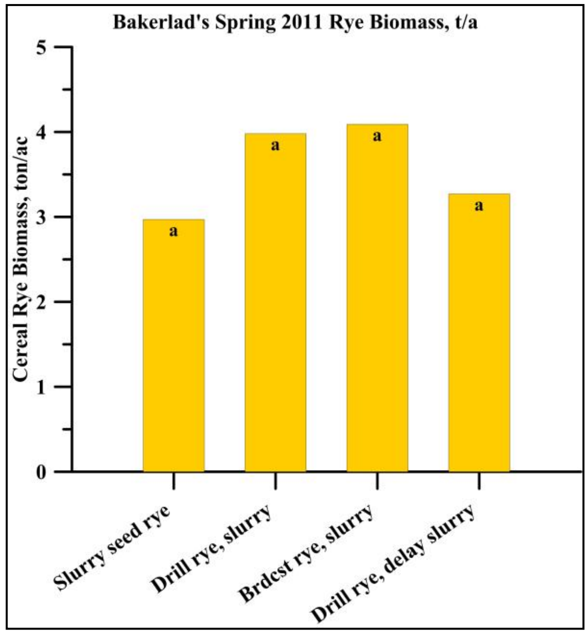


Figure 1. Spring 2011 biomass production for four cereal rye cover crop seeding methods.

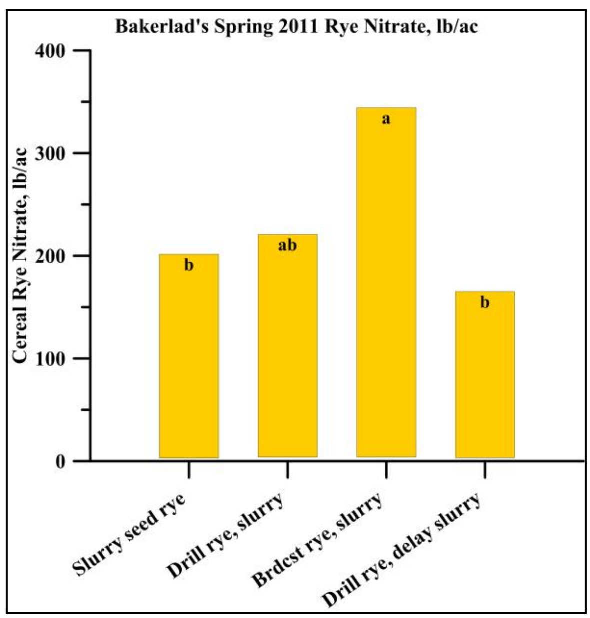


Figure 2. Measured plant nitrate accumulation prior to harvest.

All slurry spreading and slurry seeding were with a 5 degree gang angle on the AerWay. This improved infiltration, established suitable micro-sites for rye germination and growth, and greatly reduced the potential for runoff while the cover crop established. The delay in manure application for treatment #4 was to make the manure application on an established cover crop, thereby reducing the runoff potential. The delayed manure application was done on October 19.

Spring cover crop biomass and plant nitrate measurements were made on May 17, 2011 and the rye was chopped for feed on May 18. The rye biomass yield ranged from three to four tons/acre dry matter. It was dry at seeding but adequate precipitation was received within 10 days of seeding to establish uniform stands. There were no statistically significant differences ($p \leq 0.10$) in dry matter yield although the slurry seeding yielded almost one ton/acre less than the drilled or broadcast with seedings. Cereal rye is a vigorous, rapid starting cover crop that benefits from the manure nutrients at the time of seeding.

Manure slurry application with aeration tillage immediately after no-till drilling cereal rye is a novel approach. The advantages are it provides flexibility in timing the two operations and the seeding can be done on clean ground without tire tracks (preferential flow paths) in loosened ground. The aeration tillage loosens and fractures the soil, improves infiltration and reduces runoff after seeding.

Plant nitrate accumulation in the cereal rye was generally in the range of 175 to 200 lbs. N/acre. Based on this trial the greatest accumulation was with the broadcast seeding of rye followed the slurry application with aeration tillage. Additional testing is needed to verify the repeatability of these results.

Key points from BakerLads in 2010-2011

- Slurry seeding was an efficient method for integrating manure with a cereal rye cover crop.
- No-till drilling of rye with immediate slurry application and aeration tillage did not diminish rye biomass compared to no-till drilling with delayed slurry/aeration tillage on the established crop.
- Based on dry matter yield and plant nitrate concentration a cereal rye cover crop seeded with dairy slurry generally trapped 175 to 200 lb./acre N/

2011-2012 Cereal Rye Cover Crops

Similar to 2010-2011, a cereal rye cover crop was established in a Blount Loam soil following corn silage harvest. The seeding and dairy manure slurry application was done from September 16-18. Cereal rye was seeded at 90 lb. /acre with the addition of 5 lb. /acre oil seed radish (OSR). The dairy slurry was applied at 6,000 gal/acre.

The objectives of this demonstration were to: 1) evaluate the effect of the aeration tine gang angle (a greater gang angle leaves a rougher surface) on crop establishment and yield, 2) compare rye yields from slurry seeding with no-till drilling and manure slurry/aeration tillage immediately after seeding, and 3) evaluate the effect of adding oil seed radish to the rye cover crop.

Figure 3. Slurry seeded cereal rye/OSR cover crop at BakerLads Dairy, November 28, 2011.

Specific comparisons were: 1) slurry seeding, 5 degree gang angle, 2) slurry seeding, 10 degree gang angle, 3) no-till drill rye + OSR, slurry immediately after seeding with aeration tillage at a 5 degree gang angle, and 4) no-till drill rye + OSR, slurry immediately after seeding with aeration tillage at a 10 degree gang angle.

Biomass samples were collected on November 28, 2011 (Fig 3). There were no statistically significant differences ($p \leq 0.90$) in OSR plant population (Fig 4) or dry matter biomass yield (fig 5) due to seeding method/gang angle in 2011. In previous we have observed fewer plants with slurry seeding compared to no-till drilling. Perhaps, in this case, the disturbance of the aeration tillage reduced plant stand compared to what might have been possible with drilling.

Plant dry matter samples included OSR roots, OSR foliage and cereal rye foliage. Oil seed radish roots made a small contribution to forage dry matter compared to OSR planted in early August following wheat at other locations. Radish foliage tended to yield greater with slurry seeding. Slurry seeding with the 10 degree gang angle produced radish foliage yielding significantly greater than either of the drilled treatments. On the other hand, cereal rye foliage tended to yield greater when the crop was drilled. The drilled rye and OSR with slurry applied at a five degree gang angle yielded significantly greater rye foliage than either of the slurry seeded treatments. There was no statistical difference in biomass yield among seeding methods in 2011.

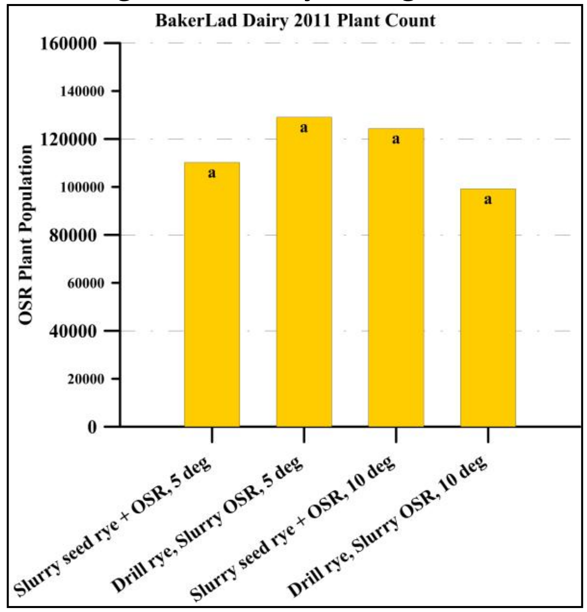


Figure 4. OSR plant population following slurry seeding or no-till drilling with rye.

Oil seed radish thrives in the nutrient rich environment created by slurry seeding. The spatial distribution of OSR plants was not as uniform with slurry seeding as when drilled. Slurry seeding tends to concentrate manure nutrients in the fractured tine pockets along with the OSR seed. It is likely that slurry seeding favored fewer OSR plants and those plants were more vigorous and thereby shaded out the surrounding cereal rye. Perhaps when OSR is combined with manure in a cover crop mix that includes grasses such as cereal rye, annual rye or oats, the OSR seeding rate should be six lb. /acre or less.

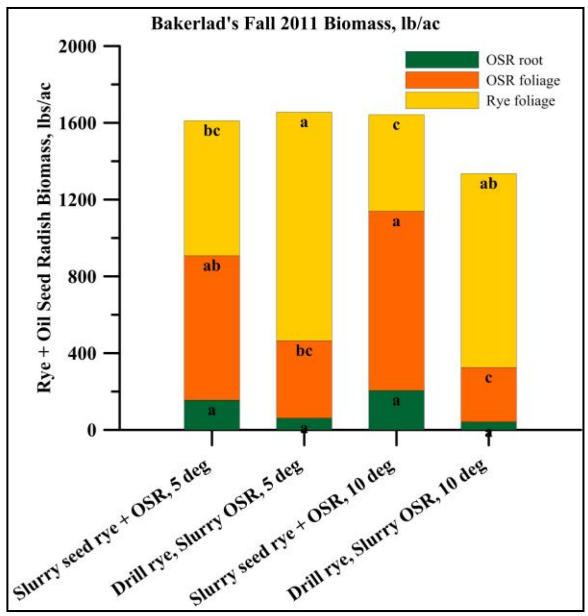


Figure 5. Rye plus OSR biomass at BakerLads in November, 2011.

Key points from BakerLads in 2011-2012.

- There was no difference in plant population due to aeration tillage gang angle.
- There was no difference in plant population between slurry seeding and no-till drilling followed by slurry application with aeration tillage.
- When a cereal rye/OSR mix was combined with a manure application, slurry seeding favored OSR foliage production while no-till drilling favored rye production.
- There was no difference in biomass production due to seeding method in 2011.

Bloom Dairy, Branch County, Coldwater, MI

2010-2011 Cereal Rye Cover Crops

The Bloom Dairy is a 500 cow dairy. They also grow field crops, corn and soybeans. Because their ground is predominantly a droughty sandy loam soil many of their fields are irrigated. The soils are prone to wind erosion so cover crops are a good fit for their cropping system. Their first choice for a cover crop is cereal rye because it provides flexibility in their dairy-based cropping system-- the option to harvest the crop in the spring for feed for young stock and dry cows.

In 2010, cereal rye was sown following corn silage harvest from Aug 30 to Sept. 1, 2010. Dairy manure slurry was applied at 7,000 gallons per acre. The rye seeding rate was 90 lb. /ac.

The objective of the demonstration was to compare slurry seeding of cereal rye with other common rye seeding methods. Five treatments were made with three replications of each treatment: 1) slurry seeding, 7.5 degree gang angle, 2) no-till drilling rye, dairy slurry applied with AerWay after seeding, 3) no-till drilling rye, dairy slurry applied with AerWay six weeks after seeding, 4) broadcast seeding of rye, shallow disking, dairy slurry applied with AerWay after seeding, 5) broadcast seeding of rye, shallow disking, dairy slurry applied with AerWay six weeks after seeding. A 7.5 degree gang angle was used for all manure application on the day of seeding. The gang angle was reduced to 2.5 degrees when slurry was applied to the standing rye cover crop.

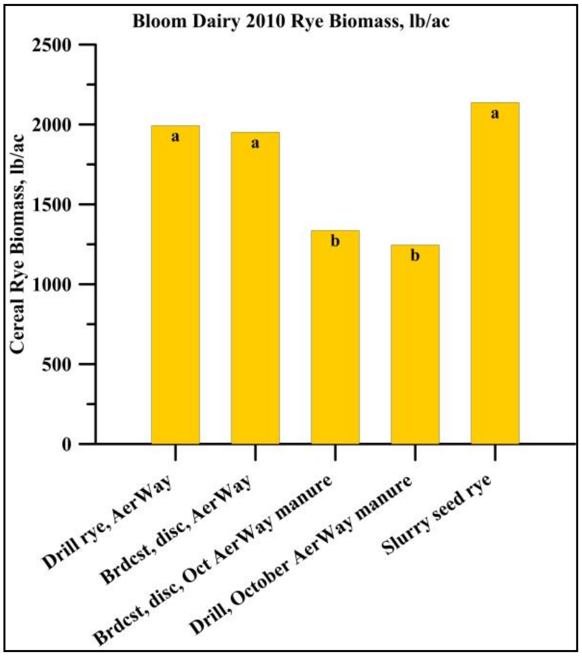


Figure 6. Cereal rye biomass at the Bloom Dairy in October, 2010.

Figure 7. Cereal rye/OSR cover crop, Bloom Dairy, 2011.

Fall biomass samples were collected on December 9. Each seeding method using same-day slurry application yielded about 2,000 lb. /ac (Fig 6). The treatments receiving manure in mid-October yielded about 1,250 lb. /ac. The rye receiving manure immediately after seeded showed more vigorous early growth.

Rye plant nitrate at harvest ranged from 45 to 160 lb. N/ac. The coefficient of variation among treatments was high and there were no significant differences among treatments. The greatest N recovery was from the slurry seeded rye.

Key Points from Bloom Dairy, 2010

- There was no difference in biomass yield between seeding methods when the dairy slurry was applied on the day of seeding.
- Integrating manure and seeding of the rye cover crop increased biomass yield. When manure application was delayed to apply on a vegetative cover reduced fall biomass by about 35%.
- Rye foliage nitrate uptake ranged from 45 to 160 lb./ac.

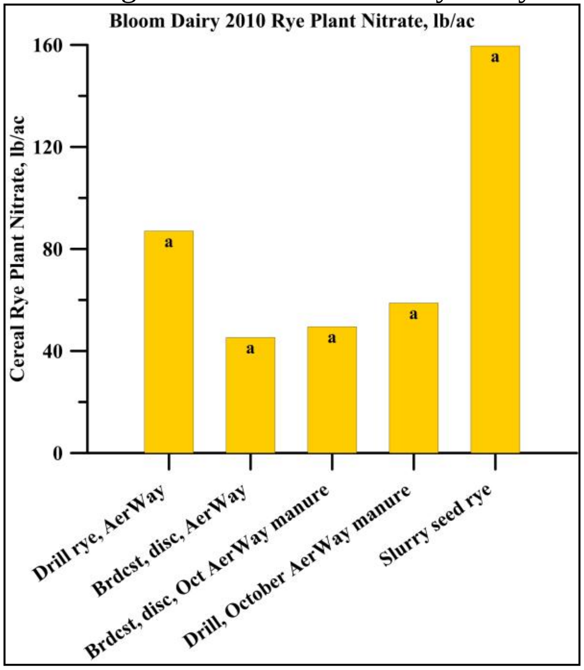


Figure 8. Cereal rye plant nitrate in the 2010 cover crop.

2011-2012 Cereal Rye/OSR Cover Crops

The 2011-12 cover crops were seeded on September 8-12 in corn silage stubble. All treatments were seeded with 90 lb. /ac cereal rye. Oilseed radish was seeded at 6 lb. /ac with the drilled and slurry seeded rye, OSR was drilled at 10 lb. /ac where the broadcast rye treatments were used. The slurry seeding and manure application rate was 7,000 gal/ac. Biomass samples were collected on November 21, 2011.

The objective of this demonstration was to evaluate the integration of manure with common cover crop seeding methods and the addition of OSR with cereal rye as a seed mixture. Specific seeding methods were: 1) slurry seed rye + OSR, 2) drill rye + OSR, AerWay manure, 3) drill rye + OSR, Oct. AerWay manure, 4) brdcst rye, slurry seed OSR, and 5) brdcst rye, disk, drill OSR, Oct AerWay manure.

Biomass dry matter yield tended to be inconsistent across seeding methods in 2011, and yields tended to be less than in 2010. Oil seed radish roots contributed little biomass. The OSR foliage was significantly greater where it was drilled after broadcasting rye with slurry applied about 30 days after seeding. The greatest rye yields followed no-till drilling of rye and OSR with manure slurry applied with aeration tillage after seeding on the same day. This method produced significantly greater biomass than all other treatments.

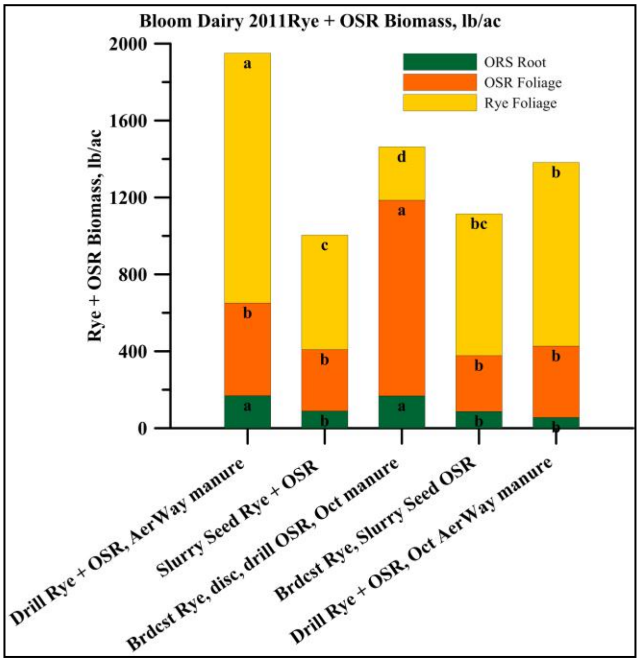


Figure 9. Biomass dry matter yield at the Bloom Dairy, fall 2011.

Key Points from Bloom Dairy, 2011-2012

- Oil seed radish adds little root biomass when seeded in September in southern Michigan.
- Broadcast and disking rye presents a risk of a poor stand. Broadcasting with slurry application by aeration tillage has been more resilient across locations.

Blight Farms, Calhoun County, Albion, MI

Ken and Art Blight have a mixed enterprise farm producing beef, hogs, corn grain and soybeans on approximately 2000 acres. The soil series is primarily a Kalamazoo Loam, a coarse textured loam that tends to be droughty. They did not use cover crops prior to the work with this CIG project.

Figure 10. Slurry seeded OSR, Blight Farm, October 17, 2010.

In 2010, cover crops of oil seed radish (OSR; 12 lb. /ac) or a mixture of oats (2 bu/ac) and forage turnips (2 lbs. /ac) were sown in wheat stubble during the first week of August (Fig. 10). Four cover crop treatments were established in three replicated strips, and one replicated treatment of no cover crop. Liquid swine manure was applied at 3000 gal/acre with aeration tillage (7.5 degree gang angle) after drilling, same day, 2) no-till drill OSR, manure with aeration tillage after drilling, same day, 3) slurry seeding oats + turnips, 4) slurry seed OSR, and 5) no cover crop, manure with aeration tillage. The no cover crop treatment was for visual comparison, no crop material was collected from those areas.

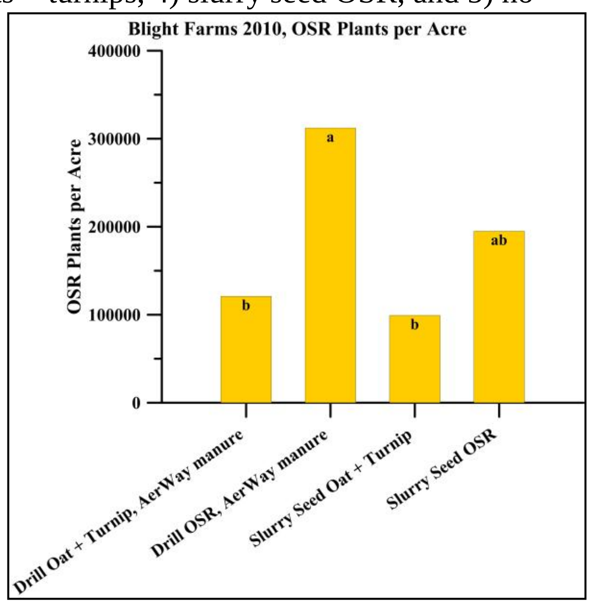


Figure 11. Cover crop plant population at Blight Farms, 2010.

The plant population ranged from about 100,000 to 300,000 plants per acre (Fig 11). There was little difference between the no-till drilled and slurry seeded oat + turnip when manure was applied after drilling on the same day, with aeration tillage. The greatest plant population was with the no-till drilled OSR, but the plant population was not significantly greater than the slurry seeded crop. Oil seed radish is an aggressive starter and greatly benefits from the addition of the manure nutrients.

Biomass yield was evaluated by collecting samples of the OSR and turnip roots, the OSR and turnip foliage or aboveground growth, and the aboveground portion of the oat plants. There was no difference in root yield between the OSR and turnips (Fig 12). Top growth of the no-till drilled OSR was significantly than the oat + turnip mix, but there was no difference ($p \leq 0.10$) between the no-till drilled and the slurry seeded OSR. Total dry matter biomass yield tended to be greater with the oat + turnip mix (2.6 tons/acre) than the OSR, but the yield increase was not statistically significant.

Plant nitrate uptake in the 2010 cover crops was evaluated based on plant biomass yield and nitrate concentration in the plant material. There was a great deal of variability in the samples collected and we were unable to detect statistically significant differences between treatments. Total plant nitrate (fewer nitrates sequestered in the oat roots) ranged from 69 to 169 lbs. /acre (Fig 13).

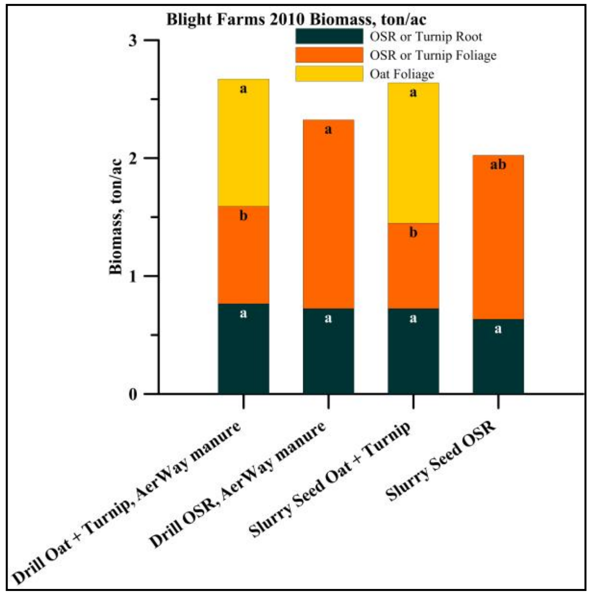


Figure 12. Biomass dry matter yield, Blight Farms, 2010.

Key points from Blight Farms, 2010.

- No-till drilling OSR with manure applied on the same day, after drilling, produced a higher plant population than slurry seeding when OSR was seeded at 12 lb. /ac.
- No-till drilling a mixture of oats and forage turnips with manure applied on the same day and after drilling produced dry matter yields equivalent to slurry seeding when oats were seeded at 2 bu/ac and forage turnips were seeded at 2 lb./ac.
- Nitrate uptake ranged from 69 to 169 lbs. /ac.

Blight Farms, 2011

The 2011 cover crop was seeded from August 3-6 in wheat stubble. Swine slurry was applied at 4,000 gal/ac when either slurry seeding or applying manure after no-till drilling. The objective was to compare OSR with annual rye, oats and cereal rye; with and without manure; and by slurry seeding versus no-till drilling.

Specific cover crop and manure comparisons were: 1) no-till drill annual ryegrass (AR) + OSR, swine manure with aeration tillage after seeding, 2) no-till drill annual ryegrass (AR) + OSR, aeration tillage after seeding, no manure, 3) slurry seed AR + OSR, 4) Slurry seed cereal rye + OSR, 5) slurry seed oats + OSR, 6) no-till oats + OSR, manure after seeding with aeration tillage, 7) no-till oats + OSR, aeration tillage after seeding, no manure.

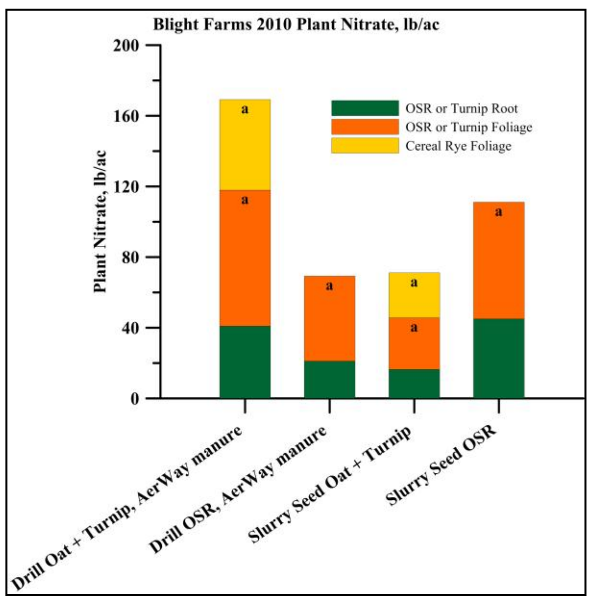


Figure 13. Plant nitrate, Blight Farms, 2010.

Oil seed radish plant population was estimated for each treatment. In general, the greatest plant population resulted from no-till drilling in the absence of manure. Aeration tillage was applied to the drilled plots after drilling, on the same day, both with and without manure. The results at this location indicate that the presence of liquid swine manure decreased plant population compared to drilling alone. When drilled with annual ryegrass, the OSR population was about 40% greater when no manure was applied. When drilled with oats, the OSR population was about 80% greater in the absence of manure. This indicates that there may be crop inhibition due to ammonia toxicity in some situations. Additional work will be required to confirm this finding.

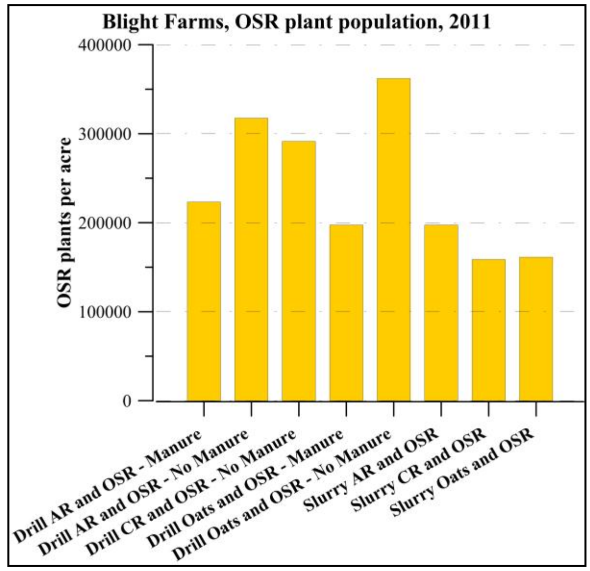


Figure 14. OSR plant population at Blight Farms, 2011.

No-till drilling provided an apparent increase in OSR plant population compared to slurry seeding. When OSR was seeded in a mix with annual ryegrass, the no-till drilled crop population with manure slurry applied after seeding with aeration tillage was about 13% greater than the slurry seeded stand. When seeded with oats, the OSR population was about 22% greater with drilling than with slurry seeding. This reduction in plant population with slurry seeding compared to no-till drilling is consistent with previous field results.

Plant biomass dry matter yields clearly show enhanced cover crop growth when combined with liquid swine manure. When a mixture of annual ryegrass and OSR was no-till drilled, biomass yields were 2.5 times greater when liquid manure was applied. The biomass yield increase of the oat and OSR mixture was about 50% with the liquid manure compared to no manure.

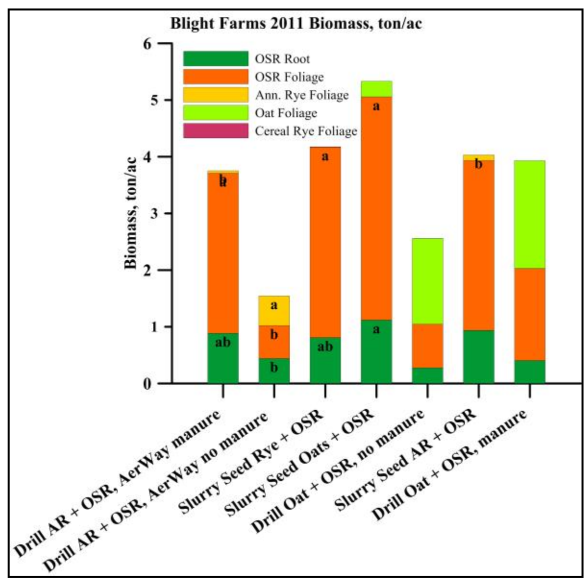


Figure 15. Cover crop biomass dry matter yield, Blight Farms, 2011.

There was no difference in biomass yield between the slurry seeded annual ryegrass and OSR mixture and the no-till drilled crop. Each seeding method yielded about four tons/acre dry matter. The slurry seeded oat plus OSR mix yielded nearly one ton greater than the drilled crop. Slurry seeding concentrates the seed and manure slurry in the fractured ground loosened by the aeration tines whereas no-till drilling places seed more uniformly across the drill width. This concentration of nutrients mimics greater nutrient application and could account for the increased yield.

The oat plus OSR mixture was very compatible with the manure application. The oat crop established rapidly and the upright foliage allowed it to compete for sunlight successfully with the OSR. The annual ryegrass and cereal rye did not compete favorably with the OSR. The

OSR grew rapidly and shaded out the AR and CR, and neither the annual ryegrass nor the cereal rye contributed significantly to cover crop biomass yield.

Key points from Blight Farms, 2011

- Liquid swine manure may inhibit OSR plant population when the manure is applied with aeration tillage on the same day, after drilling.
- When swine manure was applied with aeration tillage after no-till drilling the OSR plant population was 13% to 22% greater than with slurry seeding.
- The cover crop biomass yield increased from 50% to 250% when seeded with liquid swine manure compared to seeding without manure in wheat stubble. Cover crop biomass yields ranged from 1.5 (no manure) to more than 5 tons/acre (with manure).
- There was little yield difference between the cover crops seeded by no-till drilling with manure applied with aeration tillage after seeding and the slurry seeded crops.

Figure 16. When seeded with liquid swine manure the OSR grew aggressively and shaded out low-growing grasses such as annual ryegrass and cereal rye.

- When OSR was seeded with liquid swine manure in the first week of August, the OSR established rapidly and shaded out less aggressive grasses such as annual ryegrass and cereal rye.
- The oat and OSR was a good mixture in combination with liquid manure. The rapid and upright growth habit of the oat allowed it to compete successfully with the OSR.

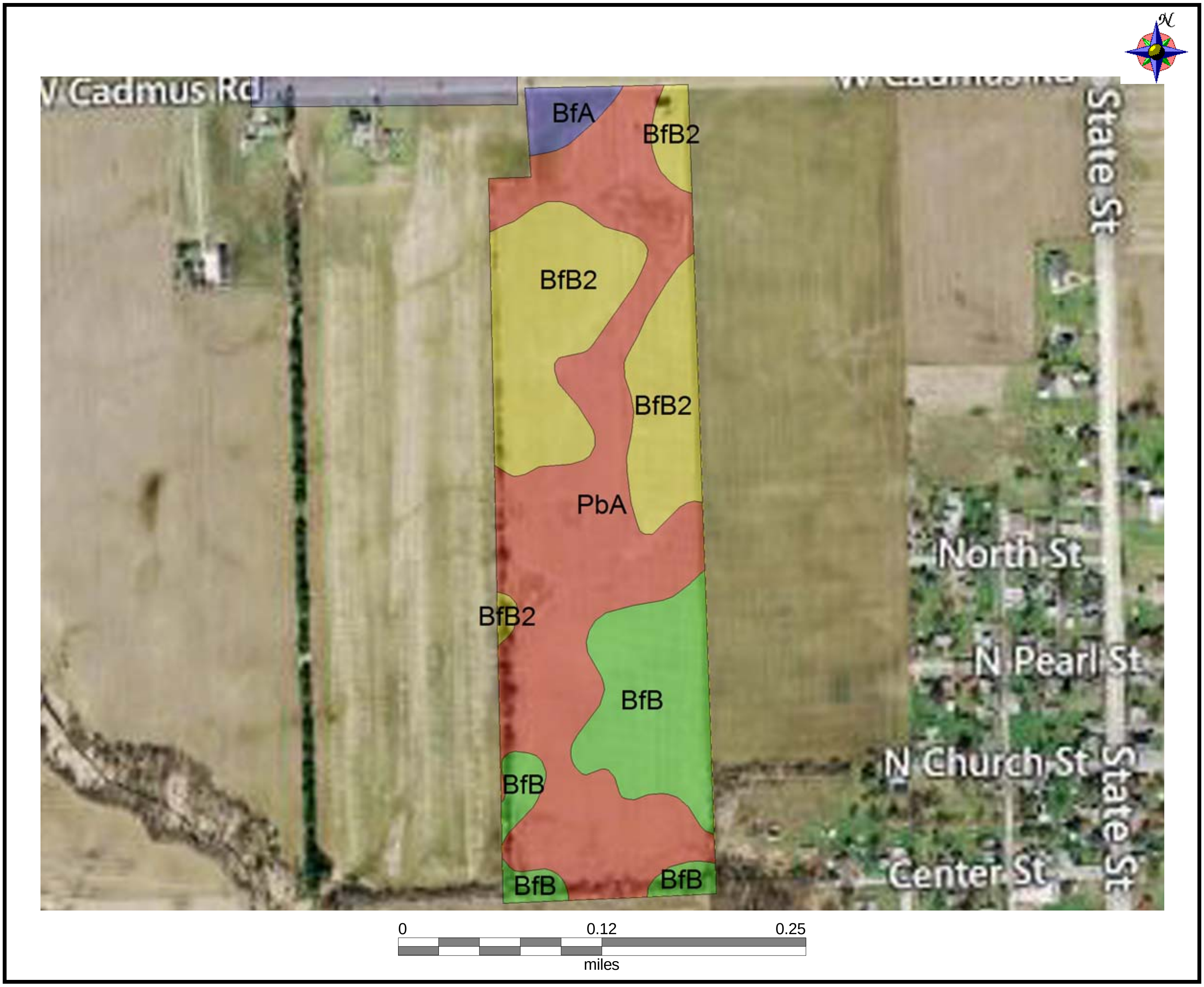
Key Observations and Lessons Learned for Integrating Liquid Manure and Cover Crops

- Slurry seeding is an efficient method for integrating manure, cover crops and low-intensity aeration tillage.
- Excellent cover crops were established with slurry seeding and no-till drilling of cereal rye, annual ryegrass, oats, forage turnips or oil seed radish and applying liquid swine or dairy manure over the drilled crop with aeration tillage immediately after seeding. Cover crop biomass yields ranged from 1.5 ton/acre (no manure) to more than 5 ton/acre (with manure). Biomass yields increased from 50% to 250% when seeded with liquid swine manure compared to seeding with no manure in wheat stubble.
- Broadcasting and disking cereal rye increases the risk of a poor stand compared to slurry seeding or no-till drilling with manure slurry applied after drilling.
- Based on cereal rye dry matter yield and plant nitrate concentration, a cereal rye/oil seed radish mixture sequestered from 69 to 200 lbs./acre of nitrogen by late fall when the seeding was accompanied by manure application. Cereal rye top-growth nitrate averaged about 75 lb. /ac.
- Generally, there was little difference in plant population between slurry seeding and no-till drilling with slurry application by aeration tillage immediately after seeding. In one trial,

drilling OSR with same-day manure application resulted in a 13% to 22% greater OSR population than slurry seeding, but the increase in plant stand did not increase biomass yield.

- When slurry seeding a cereal rye/OSR mixture in a loam soil there was no difference in OSR plant population comparing 5 degree and 10 degree gang angles.
- Liquid swine manure may inhibit the OSR plant population when the manure is applied with aeration tillage on the same day, after drilling, but a reduced plant stand is not likely to result in lower biomass yields.
- Liquid manure application when seeding a cereal rye cover crop increased biomass yield. A delayed manure application on a vegetative cover reduced late fall biomass by about 35%.
- When a cereal rye/OSR mix was combined with a manure application, slurry seeding favored OSR foliage production while no-till drilling favored rye foliage production.
- When OSR was seeded with liquid swine manure in the first week of August, the OSR established rapidly and shaded out less aggressive grasses such as annual ryegrass and cereal rye.
- Oat and OSR is a good cover crop mixture in combination with liquid manure. The rapid and upright growth habit of the oat allowed it to compete successfully with the OSR for sunlight, nutrients growth.

BakerLads 2010 CIG



Primarily Blount Loam, Corn Silage in 2010, Cereal Rye C

- BfA
- BfB
- BfB2
- PbA

BakerLads 2011 CIG

Primarily Blount Loam, Corn Silage in 2011, Cereal Rye C

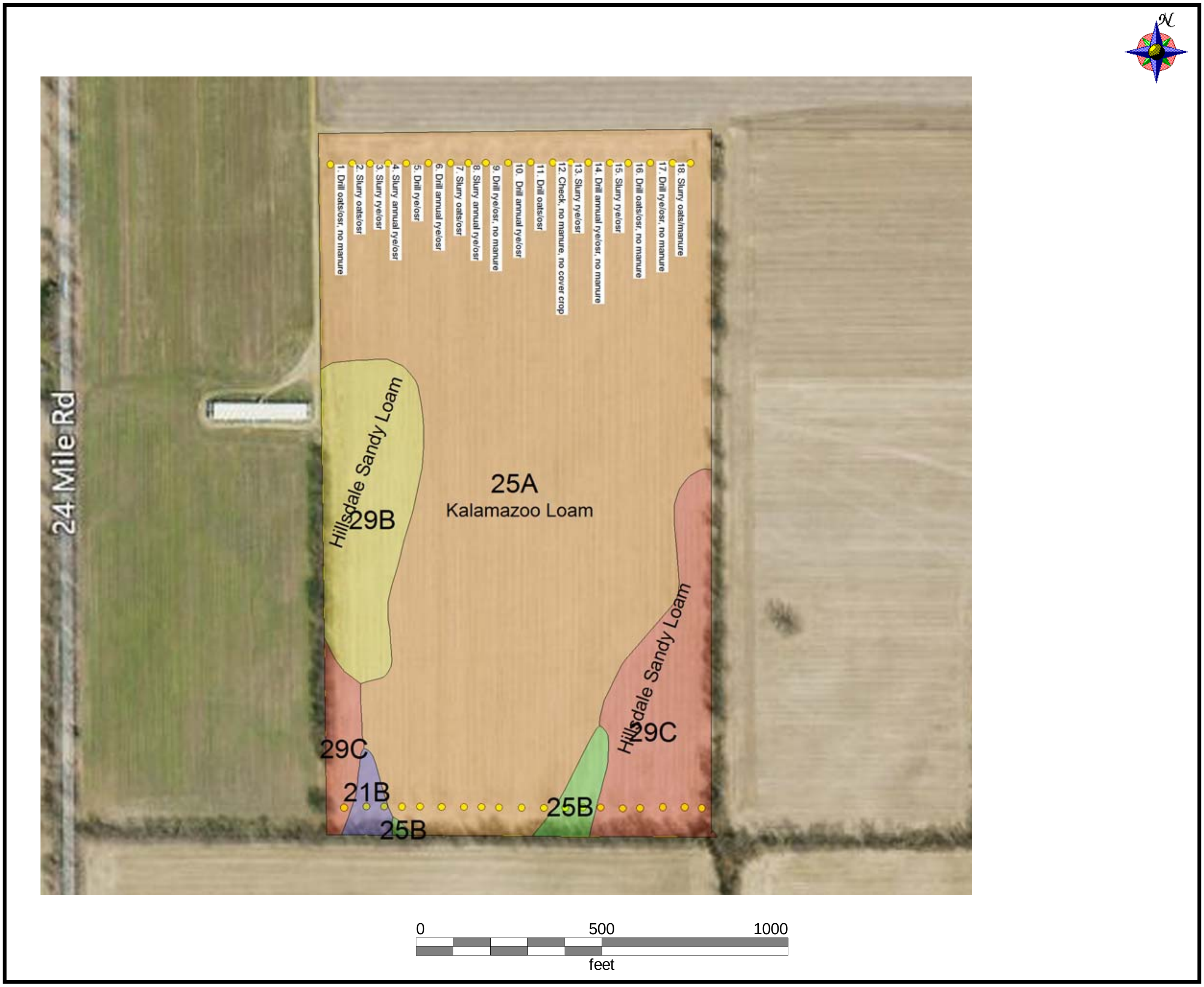
- BfA
- BfB
- GfA
- MhB2

Blight Farm 2010 CIG

Slurry Seeding Cover Crop Site
After wheat in 2010

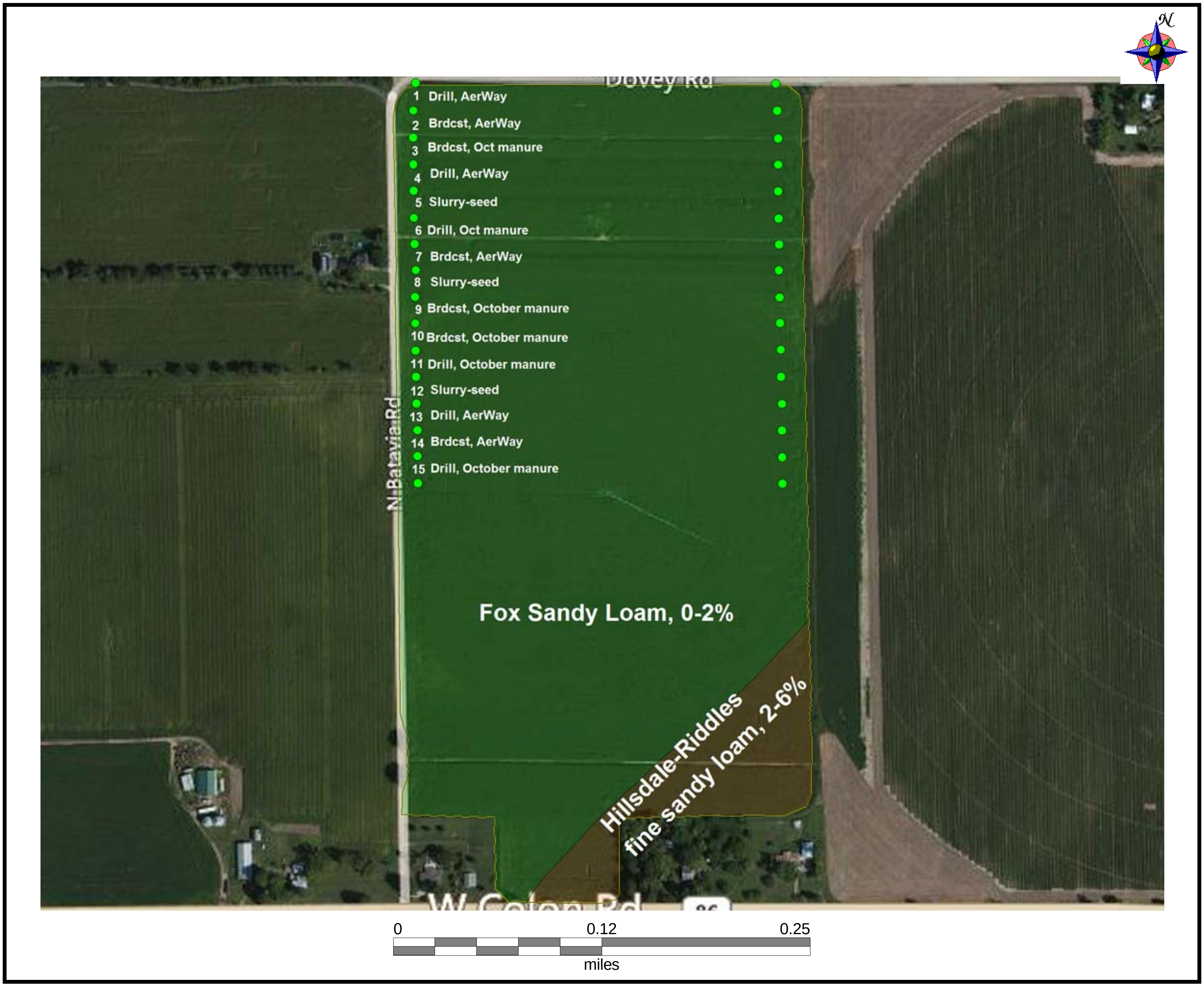
14B	3.24 ac
17C	0.11 ac
25A	0.93 ac
25B	20.58 ac
29B	6.01 ac
29C	10.34 ac

Blight Farms CIG Cover Crop 2011



21B
25A
25B
29B
29C

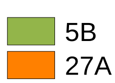
Bloom Dairy 2010 CIG



Primarily Sandy Loam Soil
Corn silage in 2010
Cereal Rye cover in Sept
Cover crop not irrigated

25.000 - 32.000
21.000 - 24.999
17.000 - 20.999
13.000 - 16.999
9.000 - 12.999
5.000 - 8.999
1.000 - 4.999

Bloom Dairy, 2011 CIG



MANURE SLURRY SEEDING COVER CROPS

CONSERVATION JOB SHEET **NEW, FOR REVIEW ONLY**

Natural Resources Conservation Service

Michigan

Figure 1. Seed is placed directly in the slurry tank.

WHAT IS SLURRY SEEDING?

Manure slurry seeding combines low-disturbance aeration tillage, liquid manure application and the seeding of cover crops in one efficient operation. In manure slurry seeding, low-disturbance aeration tillage is used to create an absorptive surface in untilled ground that helps prevent overland flow and soil erosion by fracturing the soil, increasing surface roughness, improving infiltration, and conserving crop residues. In the same pass, cover crop seed that has been mixed in the slurry tank with the manure is placed through drop tubes over the aeration slots behind each set of aeration tines. The nutrient-rich, seed-laden slurry quickly infiltrates the soil matrix and carries the cover crop seed to protected sites in soil cracks and fissures. A cover crop soon emerges, capturing nutrients and forming a vegetative barrier to overland flow.

MACHINERY CONSIDERATIONS

Slurry seeding is one way to integrate cover crops, forages for late season grazing or pasture and grassland renovation with the application of liquid manure. The equipment for slurry seeding is commercially available but the slurry tank and aeration tines must create conditions suitable for seed germination and emergence. Probably the two most important considerations are the ability to distribute seed uniformly in the tank and place the seed-laden slurry directly into the loose and fractured soil directly behind the aeration tines. The best results have been achieved with equipment set up to:

1. *Maintain uniform seed distribution in the tank.* Slurry tank pto-driven pumps are designed to deliver a large volume of liquid through a splash plate at the rear of the tank. The full flow rate is too great for delivery through low-disturbance injectors. The best results will be with slurry tanks that can restrict flow to the manure injectors and return the excess flow to the tank, similar to the bypass flow in a field sprayer. A bypass flow rate of about 800 gallons per minute provided excellent seed distribution in a 3000 gallon spreader tank.

2. *Aeration tillage tines fracture and loosen soil.* The best results were obtained with a drawn or rear-mounted rolling-tine aerator (12 ft., Aer-Way, Holland Equipment Ltd. Norwich, Ontario, Canada)[1] and a SSD (sub-surface

[1] Mention of trade names, proprietary products, or specific equipment is intended for reader information only and

deposition) slurry distribution system. The rolling-tine aerator was ground-driven with sets of four, eight-inch tines mounted helically on a rotating shaft with 7.5 inches spacing between each set of tines. The tines were angled slightly on the shaft to provide lateral movement and loosening of the soil. The angle of the rotating shaft was adjustable in 2.5º increments from 0º to 10º degrees from perpendicular relative to the direction of travel. The 0º gang angle provided little soil disturbance while the 10º gang angle provided the most soil loosening. No additional seedbed tillage or soil firming is recommended.

Figure 2. Aeration tines loosen and fracture the soil and improve infiltration with little loss of crop residues.

3. *Place the seed-laden slurry directly in the loosened and fractured soil.* When seed is placed directly on the soil surface it is exposed to wide swings in temperature and moisture. Emergence is likely to be very poor. It is important to place the seed-laden slurry in a concentrated flow in the loosened and fractured soil directly behind aeration tines. The liquid slurry carries the seed into soil cracks and fissures where there is a protected and suitable environment for germination and growth. Many small-seeded cover crops will emerge from 2-3 inches below the surface in this fractured soil. Do not till, level or firm the soil after slurry seeding. Deeply placed seeds will not be able to emerge from firm consolidated soil. The best results were achieved when passing the seed-laden slurry through a hydraulically driven, rotating chopper/distributor (300 RPM) with radially configured outlets and then through drop tubes to the fractured and loosened soil behind each set of rolling aeration tines.

Figure 3. Cover crop seed-laden slurry is delivered through drop tubes to the loosened soil directly behind the aeration tines.

4. *Aeration tine gang angle and depth of tillage.* The angle of the rotating aeration tine shaft was adjustable in 2.5º increments from 0º to 10º degrees from perpendicular relative to the direction of travel. The 0º gang angle provided little soil disturbance while the 10º gang angle provided the most soil loosening. Excellent results were achieved with a 2.5º gang angle for pasture and grassland renovation. More aggressive gang angles of 5º to 10º were suitable for cover crop seeding in wheat and corn silage stubble. Some growers reported a noticeably rougher seedbed at planting time when using a more aggressive gang angle; however, there was no measureable reduction in corn plant population compared to no aeration tillage. The aeration tillage tines are typically run at the full tillage depth, about eight inches.

5. *Other aeration tine and slurry distribution options*. Aeration tillage and manure distribution equipment can be configured in many ways. Slurry drop tubes can be placed in front of the aeration tines to increase mixing of the slurry in the soil. Manure slurry can be broadcast on the soil surface with splash plates

constitutes neither a guarantee nor warranty by Michigan State University, nor does it imply approval of the product named to the exclusion of other products.

mounted behind the aeration unit and left on the surface soil. While dropping the slurry laden slurry in front of the aeration tines may lead to a suitable cover crop, this process has not been tested and cannot be recommended at this time. Broadcasting the seed-laden slurry on the soil surface without additional, shallow tillage to cover the seed is not recommended.

OTHER CONSIDERATIONS

1. *Soil texture and condition of the seedbed*. The best results have been achieved when slurry seeding in consolidated, untilled ground that fractures into a cloddy structure. This open soil structure provides the protected environment suitable for seed germination and growth. Poor results have been achieved in loose, tilled soils, and sandy, flowable soils. In these conditions the aeration slots backfill before the seed-laden slurry is placed in the soil and the seed remains on the soil surface where it is exposed to wide variations in temperature and moisture, unfavorable conditions for seed germination and emergence.

Figure 4. Thick, viscous slurries tend to infiltrate slowly and may crust over, preventing emergence and root establishment.

2. *Type of manure and manure consistency*. The best results have been achieved with flowable, liquid manure slurries, both diary and swine. Flowable slurries mix easily in the slurry tank, infiltrate quickly in loosened and fractured soil, and carry the seed to soil cracks and fissures where they have a stable and moderate environment compared to the soil surface. Poor results have been achieved with thicker, viscous slurries because they infiltrate slowly, if at all, and may crust over and prevent emergence of the seed.

3. *Seeding rate*. Standard, published seeding rates for various cover crops are generally recommended. Careful evaluation of cover crop emergence and plant population has shown that slurry seeding typically results in stands 30% to 70% of a drilled crop at the same seeding rate. Because the slurry seeded crop is in a nutrient-rich environment, the crop grows vigorously and typically will produce two- to six-time as much biomass per plant as the same crop sown without manure slurry. Slurry seeding typically results in less plants per acre but equal or greater biomass per acre because the plants are much larger.

4. *Seed sensitivity to manure slurry*. Field experience has demonstrated success with a wide range of forages and cover crops with slurry seeding. Some of the crops that have been established include cereal rye, oats, annual ryegrass, wheat, alsike clover, red clover, orchard grass, festulolium, forage turnip, forage rape, oil seed radish and oriental mustard. Crimson clover has not established well with slurry seeding. Most of the current work with slurry seeding has been with dairy and swine slurries typically found on Michigan farms. Caution should be used with slurry seeding with 'hot' swine manure, swine manure that is high in dry matter and nutrient dense with a high nitrogen content. Test the seed/slurry combination on a small area before seeding large acreages. Studies suggest that the seed should be mixed into the slurry tank right before the field application, and not be allowed to sit for hours in the tank before application, to reduce any detrimental effects of the manure on the seed.

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