NCR-SARE Farmer Rancher Grant Program

Final Report Form

Please fill out the final report form and return it to the North Central Region (NCR) Sustainable Agriculture Research and Education (SARE) Office by your project end date. For 2009 projects, the end date is March 31, 2012. The report may be prepared on a computer or handwritten (please write or print clearly).

Project Title: Evaluation of annual cover crops for use as green manures in corn production

Project Number: FNC08-706

Producer/Project Leader: James K. Stute

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Project Duration: April 1 2009 – December 31, 2010
Date: April 22, 2011

PROJECT BACKGROUND

We operate a 170 acre integrated farm in southeast Wisconsin. Our products include: field crops; corn, soybean, winter wheat, oats and hay; fresh market vegetables sold roadside and at farmers markets, and sheep; breeding stock, feeder lambs, direct-market lambs and wool products. Our crops are produced using a "chem-lite" approach to production, maximizing use of management and on-farm resources to limit use of purchased inputs and to protect the farms environment. Our forage-based sheep enterprise uses rotational grazing and supplemental hay. Manure nutrients are recycled in forage production to maintain soil fertility, so cover crops are vital to meeting the nitrogen demand of field crops.

Cover crops are critical for supplying N in grain rotations for those that don't have access to manure, yet want to reduce or eliminate purchase of external inputs. At the same time, they provide additional benefits of soil conservation and building, but these gains are easily negated by tillage to manage the legume. My primary reason for cover cropping is to reduce fossil energy use, improving the farms net energy balance, while capturing the associated benefits. We've used cover crops as the primary source of nitrogen for corn production off and on for the last 15 years and consistently for the past 5.

Red clover, frost-seeded into winter wheat before corn has been a reliable green manure crop for us and others when it can be incorporated with tillage. We converted to 100 percent no-till in

2003, and have subsequently learned how to manage clover residue for successful no-till production. From a farm integration and risk management standpoints, a cover crop should be harvestable as hay should factors reduce yield in established hay fields. Red clover is very difficult to harvest in storable form and has inherent feeding problems, denying this benefit to producers who can only harvest dry hay. For these reasons, we sought an alternative. Our subsequent experience with fall harvest demonstrated it is difficult to harvest dry hay consistently given the highly variable fall weather in Wisconsin. For this reason, we are now focused on optimizing nitrogen fertility in corn following legume cover crops, particularly red clover.

PROJECT DESCRIPTION

Goals: This project builds on a previous farmer grant (FNC06-626) whose objectives were to evaluate 3 annual forage legumes planted after wheat harvest to red clover interseeded (frost seeded) with wheat as green manures to supply nitrogen to a following corn crop. In that project we also evaluated the impact of the green manures and their management on corn yield. Specific objectives of this project were to:

1) Finish the comparison of alternative legumes to red clover for seeding year performance
2) Measure impact on legumes and supplemental nitrogen on corn yield
3) Determine optimum N rate for corn following red clover

Results from the first project have been previously reported but will be included here to capture the full scope of the project with respect to using cover crops as a N source for corn.

PROCESS

A 4-year field study was conducted near East Troy, WI (N42^{o}48.902', W088^{o}29.123') from 2007 and 2010, representing 3 cause-effect cycles of legume cover crop performance on corn yield. Additional nitrogen management treatments were applied to corn phase treatments. Site characteristics and growing season conditions can be found in table 1.

Phase 1 (legume performance)

Wheat (c.v. Kaskaskia) was no-till planted into soybean stubble at a rate of 1.6 million seeds/a. the previous fall. Medium red clover (vns) was frost seeded the following spring at a rate of 10 lb/a. using a spinner type broadcast seeder. The summer seeded annual legumes: berseem clover (vns), annual sweetclover (c.v. Hubam) and chickling vetch (c.v. AC Greenfix) were no-till drilled into wheat stubble following grain and straw harvest at rates of 12, 10 and 50 lb/a. respectively. All seed was treated with the appropriate inoculant strain at seeding, even if the seed was preinoculated. Legumes were allowed to grow undisturbed until early November.

In 2007, one-half of each plot (except the red clover treatment) was harvested as forage in early November. The other half of the plot was left undisturbed. Forage was sampled to determine yield and quality using near infrared spectroscopy (NIR). Plots were also sampled for aboveground biomass production by clipping random areas in the plots (total area 14 ft^2). Samples were analyzed for dry matter (DM) and nitrogen (N) content to estimate aboveground nitrogen production. Conditions unfavorable for forage harvest prevented measurements in 2008 and 2009, but legumes were sampled by hand using the same methods to estimate potential

forage production, quality and N content. The red clover treatments were killed with an application of glyphosate and 2,4-D ester after sampling each year.

Phase 2 (corn performance)
Corn response trials were superimposed over the legume plots of the previous year. Corn was no-till planted into undisturbed plots at a rate of 30,000 seeds/a. in 30-inch rows. Starter fertilizer (6-24-24 or 9-23-30) was applied with the planter at a rate of 100 lb/acre. Weed control consisted of a post emergence application of atrazine and nicosulfuron with adjuvants. Presideress soil nitrate test samples were taken to a depth of 1 foot (3 cores/plot, bulked) at corn growth stage V6. Subplots were split and sidedress N (28-0-0) was applied immediately afterward at either a 0 or 60 lb N/a rate. In a separate N response trial unique to the red clover treatment, 6 rates of N were applied (as ammonium nitrate, 0, 40, 80, 120, 160 and 200 lb N/acre) were applied to subplots measuring 4 row by 30 feet. Grain yield was estimated at physiological maturity by hand harvesting two - 17 foot 5 inch sections of row within each plot. Grain yield is reported at 15 percent moisture.

The experimental design is a strip-plot trial with 4 replicates. Previous legume was the main plot, supplemental nitrogen the sub plot. In 2008 corn yield data used only 3 replicates because of a mistake made during sidedress N application. Final plot size was 18.75 x 75 feet. Data were analyzed using analysis of variance procedures to determine significant main effects and interactions and means separated using a protected least significant difference (LSD) at a 0.05 level of probability. Orthogonal contrasts were used to compare red clover with the summer seeded annuals where appropriate. Not harvesting the red clover forage created an unbalanced design for corn measurements. As a result two separate analyses were conducted: one with only unharvested treatments (all legumes); and one with the 3 summer seeded annual legumes with harvested and unharvested treatments in 2008. Unharvested treatments were compared in all years.

Corn response to red clover with various rates of supplemental N was analyzed using regression methods and optimum N rates determined using the maximum return to nitrogen (MRTN) method employed by UW-Extension.

Table 1. Experimental conditions and dates.

Measurement/ activity	2007	2008	2009	2010
Soil Type		Fox Silt Loam		
Soil test levels				
pH	6.8	6.8	6.8	6.6
OM(%)	2.1	1.8	1.9	1.9
Available P (ppm)	75	88	77	74
Available K (ppm)	134	124	147	106
Precipitation (inches)				
April	3.49	4.09	5.8	2.89
May	1.58	2.50	3.87	3.85
June	3.60	9.82	4.36	8.27
July	3.66	4.75	2.14	6.55
August	11.04	1.07	5.9	3.04
September	1.50	5.12	1.58	2.18
October	2.42	1.88	3.19	1.63
Total	27.29	29.23	26.84	28.41
First Frost	22-Oct	4-Oct	10-Oct	4-Oct
Field operations				
		Phase 1		
Wheat planting (previous year)	18-Oct	13-Oct	12-Oct	
Red clover seeding	7-Apr	4-Apr	30-Mar	
Wheat harvest	15-Jul	26-Jul	3-Aug	
Annual legume seeding	2-Aug	6-Aug	10-Aug	
Biomass harvest/ sampling	5-Nov	4-Nov	16-Nov	
			Phase 2	
Corn planting		6-May	20-May	29-Apr
PSNT/ sidedress N application		21-Jun	27-Jun	-
Harvest		31-Oct	17-Nov	21-Oct

PEOPLE

Kevin Shelley CCA, Senior Outreach Program Manager, UW Nutrient and Pest Management Program, assisted with trial work, data interpretation, and outreach.

Dr. Peg Reedy, Agriculture Agent, Walworth County UW-Extension, facilitated outreach activities at the SARE/ UWEX professional development workshop in 2009 (see outreach)

RESULTS

Phase 1, legume performance

Medium red clover was the most productive cover crop in terms of DM yield and N content in all three years of the study (figure 1). Data is presented by year because of a significant year by legume interaction for these variables. Despite the interaction, contrasts reveled that red clover was significantly more productive compared to the annual legumes as a group.

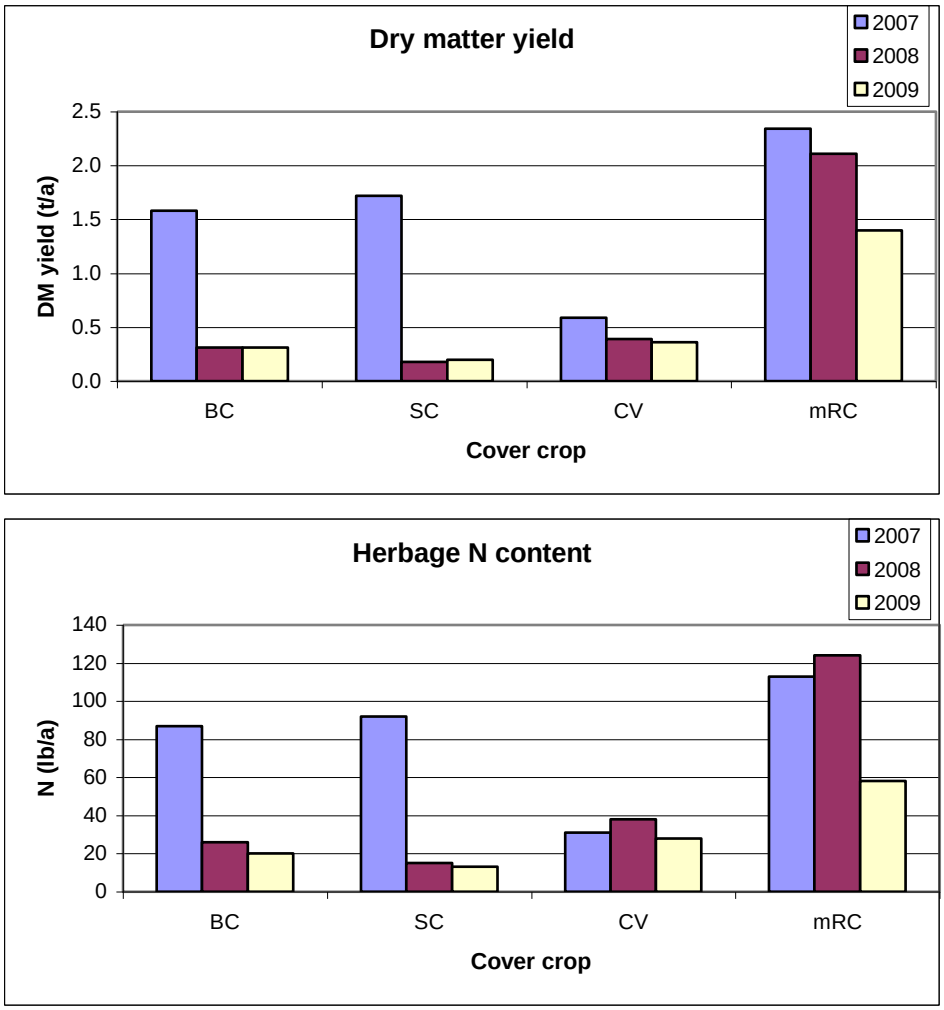

Figure 1. Legume cover crop herbage DM and N content measured in the fall of the seeding year, East Troy WI 2007-2009.

Legume forage yield and quality data is reported in table 2. Field scale harvest was only possible in one of three years (2007) which indicates growing these cover crops with the intent to harvest is risky. Red clover in general has lower forage quality than the annual legumes, presumably because its tissues are more mature at harvest in the fall of the seeding year than the other legumes which were seeded much later.

Table 2. Performance of legume cover crops at East Troy, 2007-2009

	Forage yield and quality							
Legume[(1)]	Yield (t DM/a)	RFQ	CP %	ADF %	NDF %	TDN %	N Yield lb/a	BTD
2007								
Berseem clover	1.58	181	17.1	28.0	34.3	63.4	87	0.95
Annual sweetclover	1.72	114	16.7	35.5	44.1	56.1	92	1.30
Chickling vetch	0.59	142	16.6	31.8	41.4	59.3	31	1.10
Medium red clover	2.34	119	15.2	33.5	41.8	55.7	113	1.55
lsd (0.05)	0.48	34	ns	4.6	5.8	4.3	18	ns
2008								
Berseem clover	0.31	242	26.8	21.5	27.8	71.9	26	
Annual sweetclover	0.18	290	26.2	19.9	23.6	73.2	15	
Chickling vetch	0.39	213	29.6	22.5	31.3	71.0	38	
Medium red clover	2.11	148	18.4	31.7	40.5	63.9	124	
lsd (0.05)	0.66	24	2.6	2.7	3.0	2.2	42	
2009								
Berseem clover	0.31	212	20.8	24.8	32.0	67.0	20	
Annual sweetclover	0.20	239	20.8	22.5	29.8	68.5	13	
Chickling vetch	0.36	254	24.8	23.1	29.9	69.8	28	
Medium red clover	1.40	86	12.9	42.2	52.6	50.0	58	
lsd (0.05)	0.26	17	1.5	1.9	2.1	2.9	16	
Analysis of variance				p>f				
Year	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Cover	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Year x Cover	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
Red clover vs. annuals	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
2007								
Cover	0.0001	0.0059	0.1829	0.0270	0.0208	0.0109	<0.0001	0.1590
Red clover vs. annuals	0.0002	0.0612	0.0427	0.3101	0.3981	0.0366	<0.0001	0.0613
cv (%)	19.4	15.2	7.4	8.9	9.0	4.6	13.8	28.7
2008								
Cover	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	
Red clover vs. annuals	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	
cv (%)	49.8	6.8	6.5	6.9	6.1	1.9	47.2	
2009								
Cover	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0007	
Red clover vs. annuals	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	
cv (%)	28.6	5.4	4.7	4.2	3.6	2.8	33.1	

Abbreviations:

RFQ, relative feed quality — NDF, neutral detergent fiber — TDN, total digestible fiber

CP, crude protein — ADF, acid detergent fiber — BTD, beetles per trap per day

Notes:

N yield is a measure of aboveground N in the herbage.

BTD is a daily measure of rootworm beetle population. The current treatment threshold is 5 BTD.

Phase 2, Corn Response

Corn yield reflected the productivity of the previous legume, red clover significantly greater than the other legumes as a group (Figure 3). Within the annual legumes, corn yield was not significantly different and there's no relationship between yield and previous N content.

Corn responded significantly to added N (60 lb N/a) across all legumes, averaging a 46 percent yield increase (Figure 4). Presidedress soil nitrate tests indicated no difference between the previous legumes, and all would be N responsive (means: 2008, 2.8 ppm; 2009, 6.9 ppm: critical value where no response expected is 21 ppm). Although treatment differences were insignificant, contrasts revealed that the red clover response was greater than the other legumes in aggregate. Greater yields and yield response to added N suggest that red clover has a more positive rotation effect on corn than the other legumes.

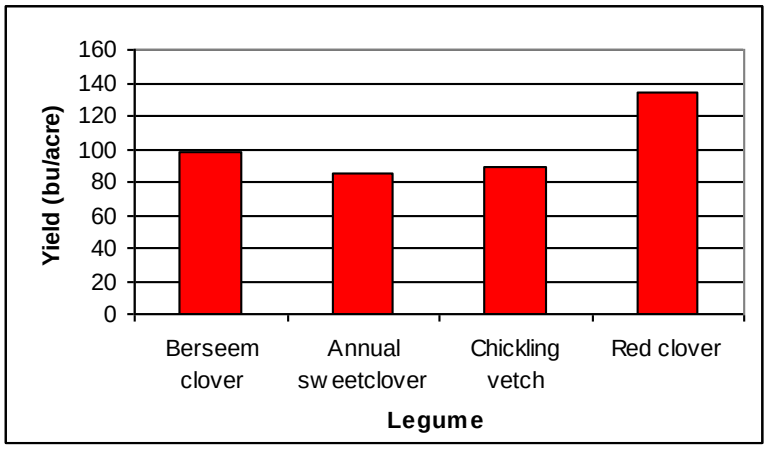

Figure 3. Corn yield following unharvested legume green manures at East Troy, WI 2008-2010.

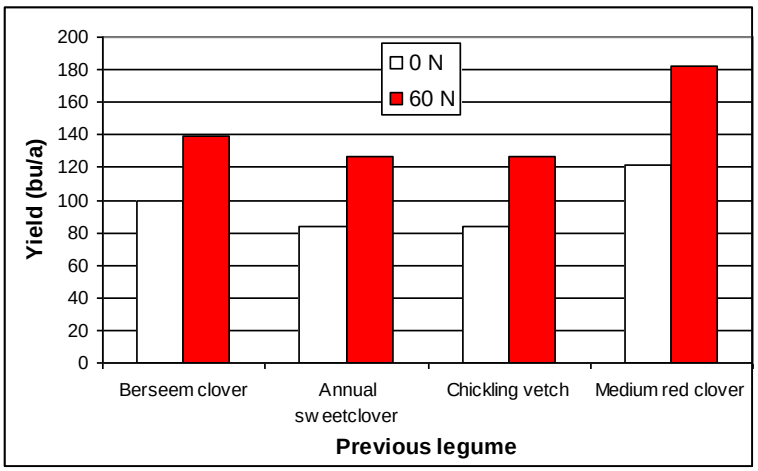

Figure 4. Corn yield following unharvested legume green manures with and without supplemental nitrogen at East Troy, WI 2008-2009.

An accentuated yield response to added N following red clover in 2008 led to a two-year N response trial with multiple rates to determine the maximizing and economically optimum rate, the point where the last dollar spent on N returns a dollar of corn yield. The response to N was significant in both years and when the data are combined, the response curve (figure 3) shows:

1) approximately 70 percent of the maximum yield was obtained with no added N;
2) yield was maximized with 157 lb N/acre;
3) the economically optimum N rate at prevailing prices was 101 lb N/acre.

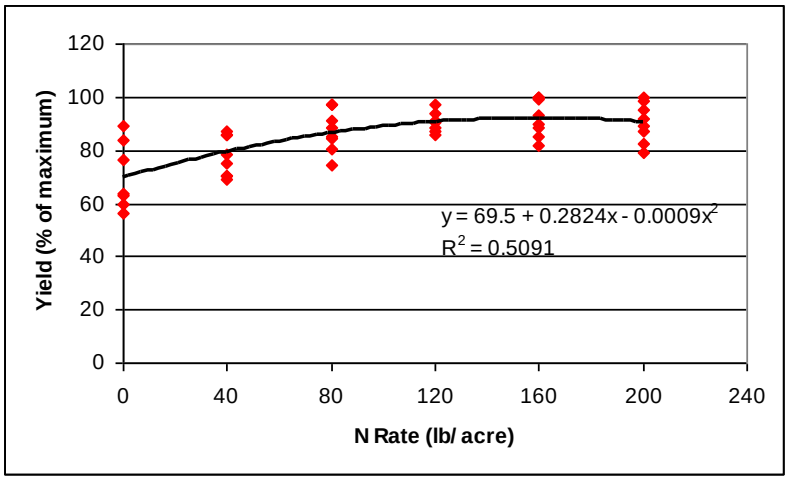

Figure 5. Corn yield response to supplemental nitrogen following red clover at East Troy, WI 2009-2010.

Table 3. Yield maximizing and economically optimum N rate, lb N/acre.

	nitrogen to corn price ratios			
N max	0.05	0.10	0.15	0.20
157	129	101	74	46

DISCUSSION

Lessons learned:

1. Red clover interseeded with wheat is more productive in terms of biomass production and N accumulation than berseem clover, chickling vetch, and annual sweetclover seeded after wheat harvest.

2. Red clover production is more consistent than the other legumes, minimizing the risk of cover crop use and more importantly, failure.

3. Fall harvest of cover crops in Wisconsin is risky based on variable weather. Producers should not plan on routinely harvesting cover crops for forage in fall.

4. Legumes cover crops do not supply sufficient N to optimize corn yield. Additional nitrogen should be applied early in the season to ensure sufficient N availability, especially in cold springs where legume N mineralization may be delayed.

5. Corn yield following red clover was economically optimized at 100 lb N/acre. Based on University of Wisconsin –Extension N recommendations, this suggests a 35 lb/ acre N credit. But: the methods of this trial don't allow for a direct credit calculation and can't quantify the yield enhancement caused by including red clover in the rotation.

6. Red clover can be successfully used in no-till corn production. For success: a) clover should be terminated in fall using a growth regulator herbicide in combination with glyphosate for volunteer wheat control and; b) residue should be "fluffed" in spring to facilitate air movement for soil warming and drying. A rotary hoe or rolling harrow work well for this purpose.

Recommendations:
On-farm trials should include a no cover treatment so that non-nitrogen rotation effects can be measured. Other research in Wisconsin (Stute and Shelley, unpublished) has shown a 10 percent non-N yield response to clover in the rotation. Including this treatment will allow a true economic comparison.

OUTREACH
We held three public events at the farm where this work was toured and discussed. These included two cover crop workshops sponsored by the Michael Fields Agricultural Institute, August 2009 and 2010, and a SARE sponsored Cover Crops Professional Development workshop, October 9, 2009. This workshop was attended by conservation professionals from UW-Extension, County Land Conservation Departments and USDA NRCS. In-total, sixty-two individuals participated.

Data from the project has been incorporated into the master UW-Extension cover crops database, the Midwest Cover Crops Council web-based cover crops decision aid tool (in development) and used at two SARE/ UW-Extension sponsored cover crop professional development workshops in 2011, March 2 (Sparta) and April 13 (Hancock).