Diverse Cover Crop Strategies for Improved Yield and Weed Suppression in Organic Cropping Systems for the Western Corn Belt

The Ceres Trust Organic Research Initiative
Final Research Report

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Abstract

We requested funding to expand research initiated with a 2009 Ceres Trust grant on increasing cover crop diversity for weed suppression and improved soil health and productivity. The certified organic field and crop rotation established in 2009 was be modified in 2012 with new treatments reflecting what was learned in the first three years, including additional cover crop treatments that we hypothesize will further improve yield, weed suppression, and soil health. The first three years showed that a diverse mixture of spring-sown mustard cover crop species can reduce weed pressure in a subsequent row crop when terminated using a sweep plow undercutter. In 2012, we modified the original sunflower–soybean–corn certified organic crop rotation to a winter wheat-corn-soybean rotation and incorporated four new cover crop treatments to improve soil water and nutrient availability and soil health, and further suppress weed populations. Project results will provide innovative solutions for organic farmers seeking increased productivity, profitability, and system resilience by increasing biodiversity and reducing off-farm inputs, and these in combination will improve environmental quality.

Introduction

The 2014 growing season was the final year of a three study for the CERES Trust Organic Research Initiative. The field experiment is being conducted at the Agricultural Research and Development Center (ARDC) near Mead, Nebraska. The 2.8 ha field is certified for organic production. The treatment design includes a three crop rotation of corn, soybean, and winter wheat with each crop present in each year (Table 1).

Table 1. Three phases of organic crop rotation treatments from 2009 through 2014.

Year	Phase I	Phase II	Phase III
2009	Sunflower	Soybean	Corn
2010	Soybean	Corn	Sunflower
2011	Corn	Sunflower	Soybean
2012	Soybean/Winter wheat	Spring wheat	Corn
2013	Winter wheat	Corn	Soybean/Winter wheat
2014	Corn	Soybean	Winter wheat

This three year experiment (2012-2014) includes seven ecological management treatments:

1) No cover crop control (NC)
2) Oilseed radish (*Raphanus sativus*) (RAD) sown with winter wheat
3) Sunn hemp (*Crotalaria juncea*) (GM) planted as a cover crop following winter wheat harvest
4) Hairy vetch (*Vicia villosa*) and subterranean clover (*Trifolium suberraneum*) living mulch (LM) planted with corn
5) Red clover (*Trifolium pratense*) (CLO) sown with winter wheat
6) Three-species spring-seeded mustard cover crop mixture (yellow mustard [*Brassica hirta*], Idagold mustard (*Sinapis alba*), dwarf essex rape [*B. napus*]) (MUS) sown prior to soybean
7) The previous five treatments combined (kitchen sink=KS).

The experimental design is a randomized complete block (RCBD) with four replications. Individual plots measuring thirty feet wide and seventy feet long (9 x 21m) were utilized. The 2014 plot plan can be viewed in Appendix A. Corn (Blue River var. 56M30) was planted at 73,850 plants ha^{-1} on May 20, 2014. Soybean (Blue River var. 24C3) was planted at 617,500 plants ha^{-1} on May 21, 2014 and had a germination rate of 70% (175,000 PPA). Camelot wheat was planted at 121 kg ha^{-1} on October 28, 2014.

In order to determine treatment effects on soil water content, weekly soil surface water readings were gathered via a Theta probe from five random locations within treated plots over an 18 week period. Deep soil water content was measured to a depth of 1 m using a PR1 soil probe biweekly in the wheat with radish, wheat with clover, kitchen sink, and no cover crop treatments. Six soil cores were sampled to a depth of 20 cm from each treatment plot at four times corresponding to at planting, thirty days after planting (30DAP), sixty days after planting (60DAP) and harvest. Samples were analyzed to determine treatment effects on soil nutrient levels (N, P (Bray), K, NH_4, and SOC%). Results were analyzed as an unstructured repeated measures model. To analyze treatment effects on weed growth/competition, 30DAP biomasses were destructively harvested from two randomly selected 0.2 m^2 quadrats per experimental unit and oven dried to constant mass (DM). At 60 DAP, visual weed ratings were also collected to determine weed canopy cover versus crop canopy cover. Treatment effects on yield was also collected. All data sets were analyzed by ANOVA using SAS 9.3 proc glimmix.

Results

Hypothesis 1: Radish cover crop sown with winter wheat

The first hypothesis tested was that large rooted radish sown with winter wheat will produce a substantial soil- and crop-protective canopy that will winter kill, and the rapid degradation of root tissues in spring will allow soil water to be more uniformly available through the soil profile during winter wheat growth, substantially improving wheat yield. To test this hypothesis, a single 5 cm diameter access tube was buried to a depth of 1 m within the wheat RAD, KS and NC plots. Soil water content was quantified using a PR1 TDR probe at depths 10, 20, 30, 40, 60 and 100 cm.

We had some issues seating the access tubes owing to the approach used to install them. As such, we were unable to obtain good data in 2012, and data were more variable than we would have liked in 2013 and 2014. This issue has been resolved for 2015, and we hope to obtain more concrete results this year. Figure 1 shows the deep soil water content in four treatments during the third week of May of each year. Owing to the large variability, no statistical differences were observed in soil water content at any depth or on any date in either year. The trend is that the no cover treatment had greater soil water content, especially below 50 cm depths. We expect that the 2015 results will clarify any differences.

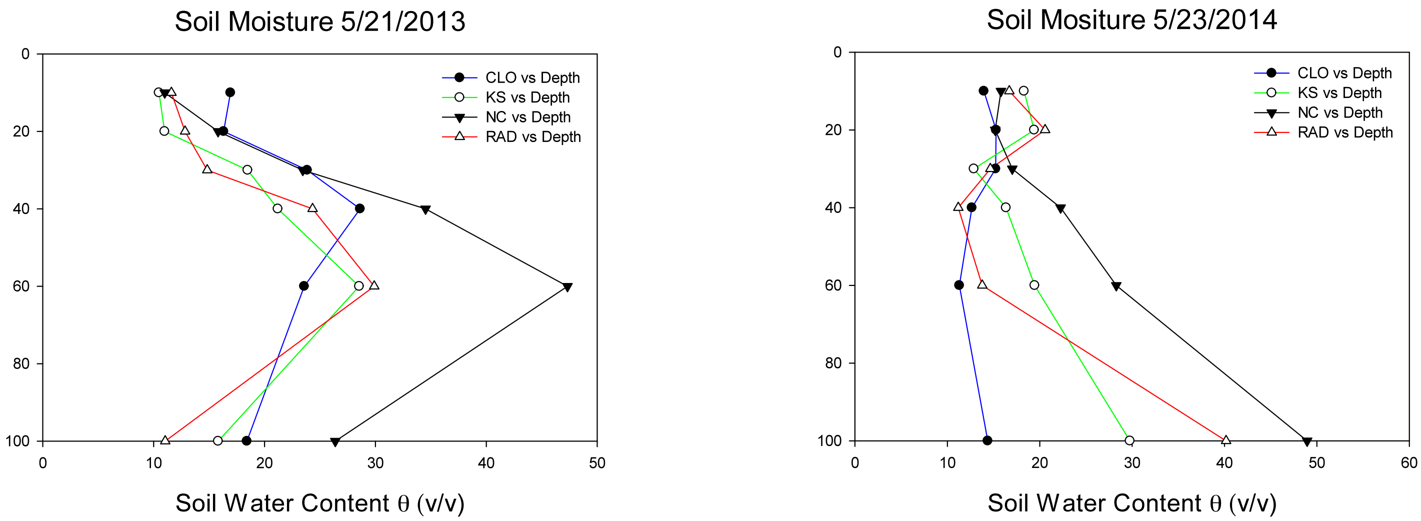

Figure 1. Soil water content in wheat in late May 2013 and 2014. **CLO**: red clover frost-seeded in winter wheat; **RAD**: tillage radish interseeded with winter wheat; **KS**: kitchen sink, all cover crop options; **NC**: no cover crop.

Sunn hemp cover crop green manure following winter wheat

The second hypothesis tested was that the rapidly establishing leguminous sunn hemp (*Crotalaria juncea*) will provide excellent weed suppression following the winter wheat crop and provide substantial benefits to soil nutrient availability and soil health in the subsequent corn crop. The sunn hemp cover crop yield can be found in figure 2.

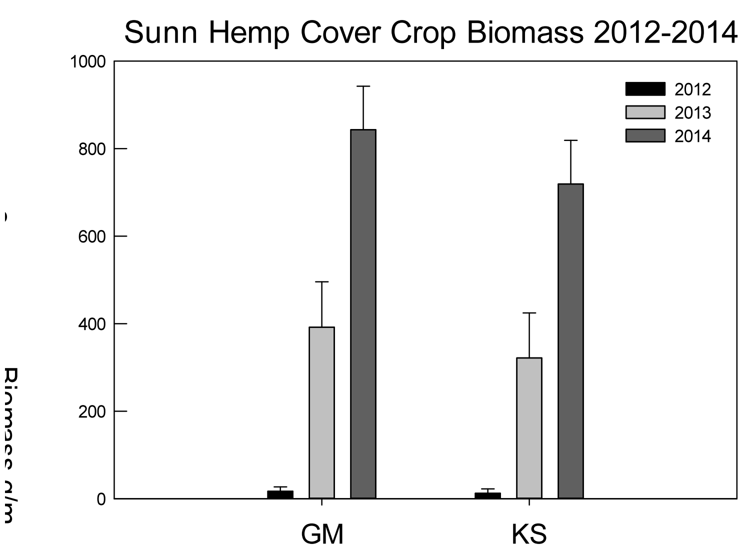

Figure 2. Sunn hemp cover crop biomass in 2012, 2013 and 2014. **GM**: green manure sunn hemp cover crop; **KS**: kitchen sink, all cover crop options.

Very little sunn hemp biomass was produced in 2012 owing to the extreme drought in that year. Sunn hemp biomass increased in 2013 and 2014. To assess the weed suppressive potential of sunn hemp cover crop treatment (green manure, GM) following the winter wheat crop, weed biomass was measured by destructively harvesting aboveground weed biomass within four (0.3 x 0.3 m) randomly placed quadrats and dried to constant mass. Weed biomass following the winter wheat crop can be found in figure 3. There is a trend of declining weed biomass in 2014, which may be associated with the greater sunn hemp biomass, but further analyses will be needed to properly evaluate this trend. Soil samples to be used for assessing soil microbial community dynamics were collected, but are still being processed in the lab.

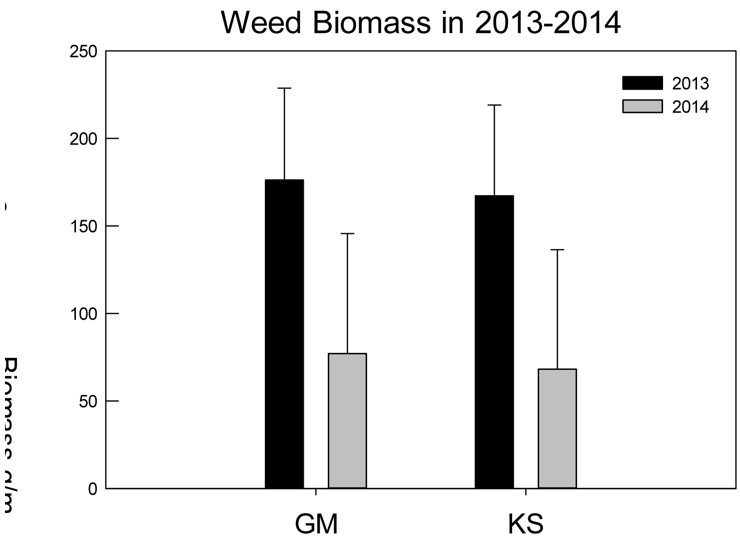

Figure 3. Weed biomasses for the years of 2013 and 2014. **GM**: green manure, sunn hemp cover crop; **KS**: kitchen sink, all cover crop options.

The effect of the sunn hemp cover crop on corn yield, grain yield was determined by hand harvesting and adjusting for grain moisture content in 2013, and using a plot combine and adjusting for grain moisture content in 2014. Corn yield in 2013 and 2014 following the sunn hemp cover crop treatment can be found in figure 4 (there was no sunn hemp planted in fall 2011, so 2012 corn yield is not reported). There appears to be no trend of increased yield in plots containing sunn hemp compared to the no cover control. However, we hope that as we continue to maintain these treatments, long-term effects will become evident. In 2013, the no cover plots where split into two with one half being hoed (no cover hoed, NCH) and the other half not (no cover weedy NCW). No significant difference were observed when comparing the corn yield of the no cover hoed and the no cover weedy ($p>0.05$).

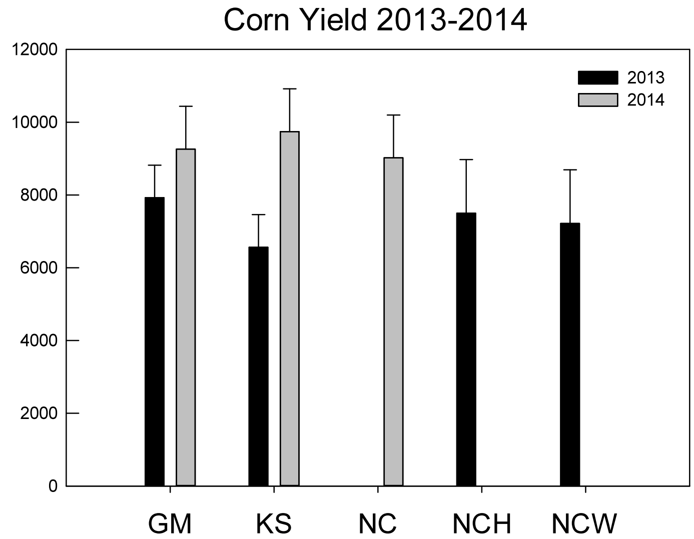

Figure 4. Corn yield for the years of 2013 and 2014. **GM**: green manure, sunn hemp cover crop; **KS**: kitchen sink, all cover crop options; **NC**: no cover crop; **NCH**: no cover crop, hoed; **NCW**: no cover crop, weedy.

Hairy vetch and subterranean clover in corn

The third hypothesis tested was that a living mulch of the leguminous hairy vetch (*Vicia villosa*) and subterranean clover (*Trifolium suberraneum*) (LM) sown with corn will provide substantial weed suppression and benefits to soil nutrient availability and soil health. The living mulch yield can be found in figure 5. Neither species produced much biomass within the corn crop, presumably owing to competition from the crop. As such, we do not expect to see any weed suppression or yield benefit. We found that an oilseed radish and turnip mixture established well within corn during the early part of the season in a side study (data not shown), so this treatment will eliminate the vetch and clover and include radish and turnips beginning in 2015.

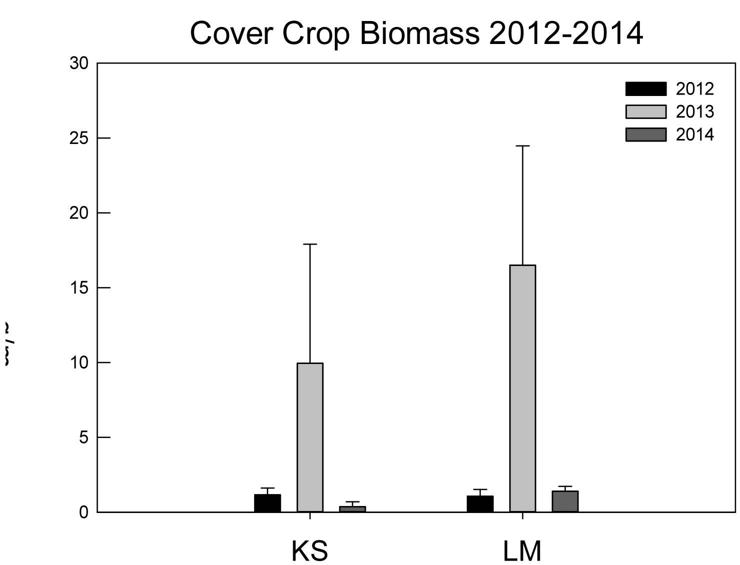

Figure 5. Living mulch cover crop biomasses for the years of 2012, 2013, and 2014. **LM**: living mulch, hairy vetch and subterranean clover plant with corn; **KS**: kitchen sink, all cover crop options.

To assess the weed suppressive potential of the living mulch treatment in corn, weed biomass was measured by destructively harvesting aboveground biomass of weeds within four (0.3 x 0.3 m) randomly placed quadrats and dried to constant mass. Weed biomass can be seen in figure 6. No significant differences were observed when comparing the weed biomass measured in g m^{-2} in plots treated with the living mulch cover crop, the plots treated with the kitchen sink treatment, and the plots with no cover crop ($p>0.05$). We hope that the radish and turnip treatment established in 2015 will have greater early weed suppressive potential.

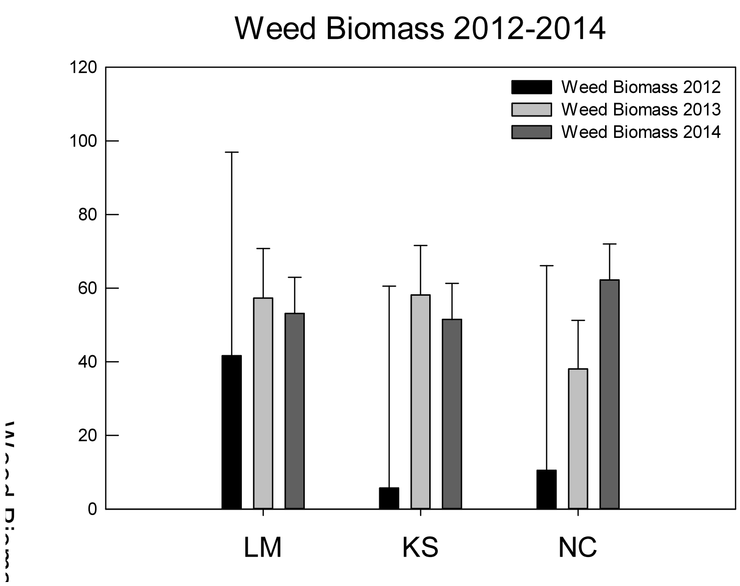

Figure 6. Weed biomasses for the years of 2012, 2013, and 2014. **LM**: living mulch, hairy vetch and subterranean clover plant with corn; **KS**: kitchen sink, all cover crop options; **NC**: no cover crop.

The effect of living mulch cover crop on corn yield, grain yield was determined by hand harvesting ears and adjusting for grain moisture content in 2012 and 2013, and using a plot combine and adjusting for grain moisture content in 2014. Corn yield in 2012, 2013 and 2014 can be seen in figure 7. No significant differences were observed when comparing corn yield in plots treated the living mulch cover crop, plots treated with the kitchen sink, and plots with no cover crop ($p>0.05$).

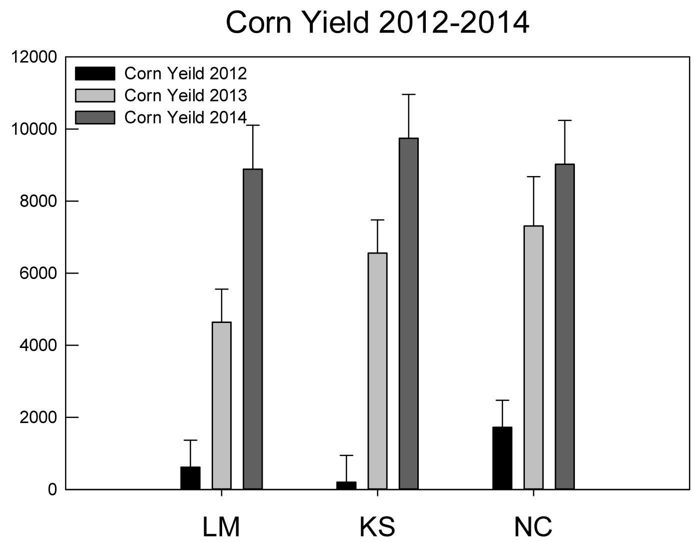

Figure 7. Weed biomasses for the years of 2012, 2013, and 2014. **LM**: living mulch, hairy vetch and subterranean clover plant with corn; **KS**: kitchen sink, all cover crop options; **NC**: no cover crop.

Red clover cover crop in winter wheat

The fourth hypothesis tested was that red clover (*Trifolium pratense*) sown with winter wheat will provide substantial winter cover and protection against winter kill while enhancing soil nutrient availability and soil health during subsequent wheat growth. The red clover cover crop yield can be found in figure 8. 2012 was a transition year, where spring wheat was planted instead of winter wheat. Therefore, there was no red clover production in 2012. Red clover productivity was extremely minimal in 2013 and 2014, presumably owing to competition from the wheat crop. As such, we expect no protection from winter kill, yield benefit, and minimal effects on soil microbial community dynamics in this treatment, though these data are still being processed.

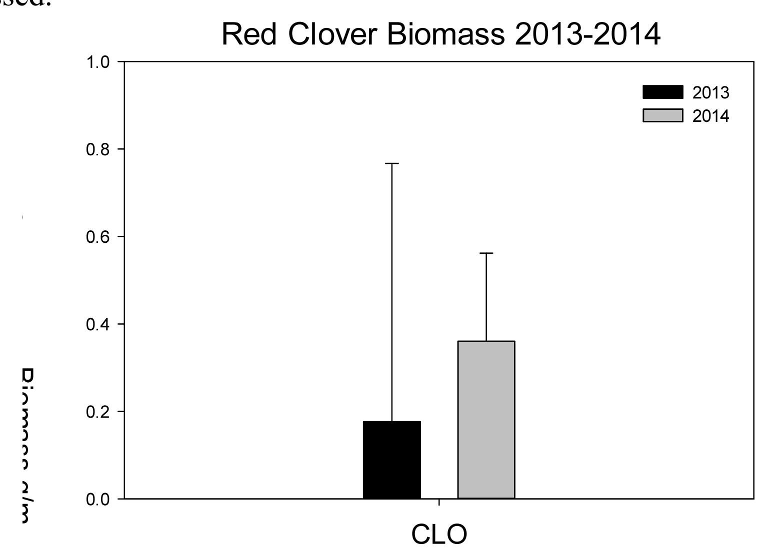

Figure 8. Red clover cover crop biomass for the years of 2013 and 2014. **CLO**: red clover cover crop.

To assess the weed suppressive potential of the red clover cover crop sown in with winter wheat, weed biomass was measured by destructively harvesting aboveground biomass of weed species, taken from four (0.3 x 0.3 m) randomly placed quadrats and sorted by weed species then dried to constant mass. Weed biomass can be seen in figure 8. No significant differences were observed when comparing the weed biomass (g m^{-2}) in plots treated with the red clover cover crop, in plots treated with the kitchen sink cover crop, and plots with no cover crop ($p>0.05$).

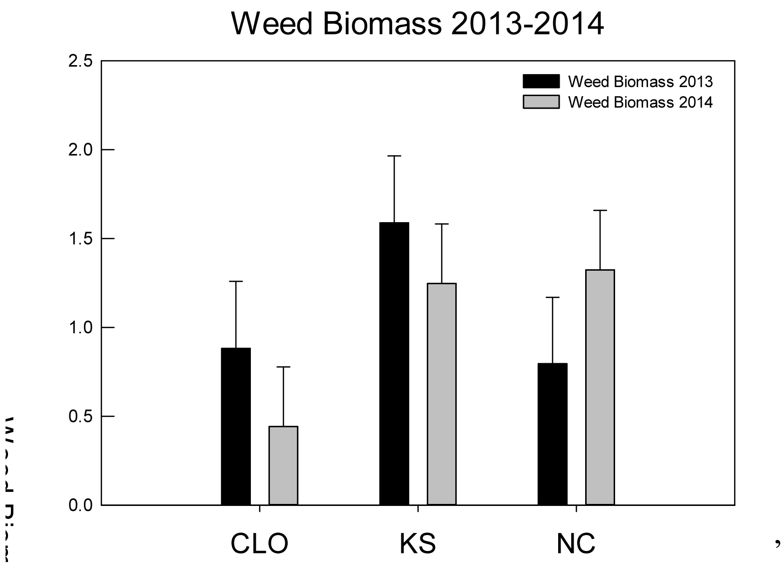

Figure 8. Weed biomass for the years of 2013 and 2014. **CLO**: red clover cover crop; **KS**: kitchen sink, all cover crop options; **NC**: no cover crop.

The effect of the red clover cover crop on winter wheat yield was assessed by harvesting yield in 2012, 2013 and 2014 and adjusting for grain moisture content (figure 9). No significant differences were observed when comparing the winter wheat yield (kg $hectare^{-1}$) in the red clover, kitchen sink, or no cover crop treatments.

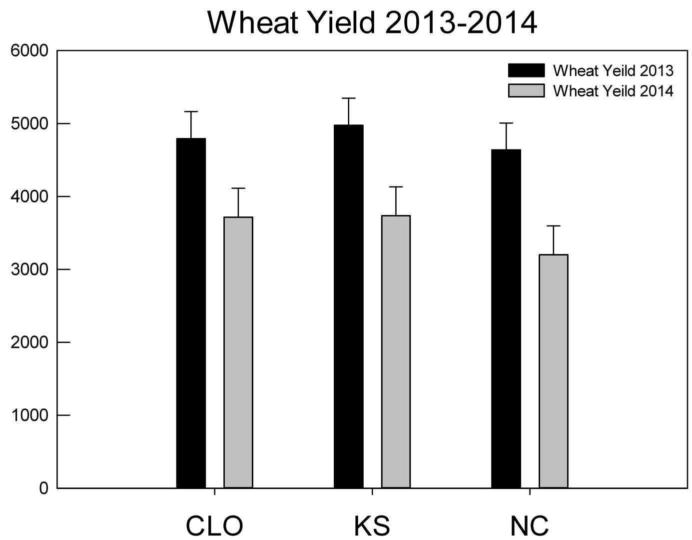

Figure 9. Wheat yield for the years of 2013 and 2014. **CLO**: red clover cover crop; **KS**: kitchen sink, all cover crop options; **NC**: no cover crop.

Outreach

Meetings

Summary results of the three year project will be presented at professional meetings and prepared for use in extension meetings in 2015.

Websites

The web-page developed during the previous round of funding and is part of the larger UNL Organic Working Group website will be maintained and revised as appropriate research-based information becomes available.

http://organic.unl.edu/covercrops.shtml

Farmer Involvement

Angela (Tran) Florence attended organic farming and cover crop meetings in Nebraska (Healthy Farms Conference) and Wisconsin (MOSES Organic Farming Conference). She interacted with farmers attending these meetings developed related collaborative projects with several organic farmers.

On-farm trials were initiated with three selected farmers in 2013. Cover crop treatments used on those farms were fit to the unique operations of each farmer (e.g., ridge till, arid climate, etc.). The goal of this farmer cooperation is to evaluate the optimum mixture of cover crop species for total biomass production following winter wheat, soybean and corn. Results of those collaborations will be included in Angela's dissertation, which should be available by May, 2016.

Publications

We intend to publish the results of this project and Angela Florence's dissertation in peer reviewed journals when sufficient data are available to develop a story.

↑ 70 ↓

NC	**CLO**	**MUS**	**LM**	**NC**	**KS**	**CLO**	**MUS**	**CLO**	**KS**	**GM**	**KS**	**GM**	**LM**	**RAD**	**MUS**	**GM**	**RAD**	**LM**	**RAD**	**NC**
401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421
SOY	**CRN**	**CRN**	**WHT**	**CRN**	**SOY**	**WHT**	**SOY**	**SOY**	**CRN**	**CRN**	**WHT**	**SOY**	**SOY**	**CRN**	**WHT**	**WHT**	**SOY**	**CRN**	**WHT**	**WHT**

←**30**→

NC	**RAD**	**LM**	**NC**	**KS**	**LM**	**KS**	**GM**	**CLO**	**CLO**	**NC**	**KS**	**MUS**	**RAD**	**LM**	**RAD**	**MUS**	**GM**	**GM**	**CLO**	**MUS**
301	**302**	**303**	**304**	**305**	**306**	**307**	**308**	**309**	**310**	**311**	**312**	**313**	**314**	**315**	**316**	**317**	**318**	**319**	**320**	**321**
CRN	**CRN**	**CRN**	**SOY**	**SOY**	**SOY**	**WHT**	**WHT**	**WHT**	**SOY**	**WHT**	**CRN**	**CRN**	**SOY**	**WHT**	**WHT**	**WHT**	**CRN**	**SOY**	**CRN**	**SOY**

N

NC	**NC**	**MUS**	**RAD**	**LM**	**KS**	**CLO**	**KS**	**GM**	**MUS**	**LM**	**MUS**	**GM**	**RAD**	**RAD**	**KS**	**CLO**	**NC**	**GM**	**CLO**	**LM**
201	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**	**211**	**212**	**213**	**214**	**215**	**216**	**217**	**218**	**219**	**220**	**221**
SOY	**CRN**	**CRN**	**SOY**	**CRN**	**WHT**	**CRN**	**CRN**	**CRN**	**SOY**	**WHT**	**WHT**	**WHT**	**CRN**	**WHT**	**SOY**	**SOY**	**WHT**	**SOY**	**WHT**	**SOY**

↑ **35 ft**

KS	**RAD**	**GM**	**NC**	**LM**	**GM**	**MUS**	**LM**	**CLO**	**NC**	**KS**	**GM**	**NC**	**CLO**	**RAD**	**KS**	**CLO**	**MUS**	**MUS**	**RAD**	**LM**
101	**102**	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**	**114**	**115**	**116**	**117**	**118**	**119**	**120**	**121**
CRN	**SOY**	**SOY**	**SOY**	**SOY**	**WHT**	**CRN**	**CRN**	**CRN**	**WHT**	**WHT**	**CRN**	**CRN**	**WHT**	**CRN**	**SOY**	**SOY**	**SOY**	**WHT**	**WHT**	**WHT**

Figure 1. Ecological management study near Mead, NE in 2014. There are seven management treatments and three main crops.
The management treatments are: NC = no cover; KS = kitchen sink (all cover crop options); RAD = tillage radish interseeded with winter wheat;
GM = sunn hemp green manure planted after winter wheat; LM = hairy vetch and subterrenean clover living mulch planted in corn;
CLO = red clover frost-seeded in winter wheat; MUS = spring-seeded mustard mixture before soybean.
The three main crops are corn (CRN), soybean (SOY) and wheat (WHT).