**Increasing Cover Crop Diversity and Weed Suppressive Potential of Soils in Organic Cropping Systems**

**The Ceres Trust Organic Research Initiative**

**Final Research Report**

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**Abstract**

Organic grain cropping systems typically depend on intensive mechanical cultivation for weed control and manure or compost applications to meet plant nutrient demands. However, cover crops may contribute to weed suppression and soil fertility, potentially increasing crop yield and sustainability of the system. The utility of individual cover crop species have been well documented, but the agronomic benefits of diverse cover crop mixtures have received less attention. Cover crop mixtures are an appealing option for farmers, as increasing species diversity has been shown to increase resource-use efficiency, stability, resiliency, and productivity of plant communities. Despite the growing interest in cover crop mixtures, little is known about the effect of increasing cover crop diversity on cropping system performance. Moreover, organic farmers have questions about the most effective method for cover crop mixture termination.

In an effort to increase knowledge about cover crop mixtures and management for the western Corn Belt, an organic cropping systems trial was initiated in 2009 at the UNL ARDC near Mead, NE. Spring-sown mixtures of cover crops, ranging from two to eight species, were included in a sunflower – soybean – corn crop rotation. Cover crops were planted in late-March and terminated mechanically with either a field disk or sweep plow undercutter in late-May. Changes in cover crop mixture influenced cover crop productivity and early-season weed biomass, while termination method drove differences in weed community composition, soil microbial community structure, soil moisture and nitrogen, and crop yield. Interestingly, the management of ambient weed communities as a cover crop led to unique shifts in soil microbial community structure, but did not alter soil nitrogen or crop yield when compared to cover crop mixtures. When considering cropping system performance in combination with potential environmental benefits, diverse cover crop mixtures paired with a sweep plow undercutter for termination seems to be a profitable and sustainable management option for organic grain farmers in the western Corn Belt.

**Research Activities**

**Table 1.** Description of ecological weed management treatments and cover crop termination treatments used in year’s one and two of the study.

|  |  |
| --- | --- |
| Treatment | Practice |
| 2CC | Buckwheat or Idagold Mustard, Hairy Vetch cover crop mixture |
| 4CC | 2CC + Field Pea, Yellow Mustard cover crop mixture |
| 6CC | 4CC + Crimson Clover, Oilseed Radish cover crop mixture |
| 8CC | 6CC + Chickling Vetch, Dwarf Essex Rape cover crop mixture |
| F8 | 8CC + Fusarium lateritium soil inoculant |
| WD | No cover crop or weed control prior to cover crop termination |
| NC | No cover crops or weeds prior to planting summer annual crops |
| Disked | Cover crops terminated with field disk |
| Undercut | Cover crops terminated with sweep plow undercutter |

*Cover Crop Productivity*



**Figure 1.** Cover crop and weed aboveground dry biomass (g m-2) harvested immediately prior to termination. Bars represent the standard error of the mean.

Increasing diversity of the cover crop mixture generally increased biomass productivity in two of three years, highlighting the resilience of diverse cover crop mixtures following management error and severe weather disturbance. Despite differences in productivity, cover crop mixture composition and diversity did not influence soil moisture, soil nitrogen, or crop yield. Instead, differences within these factors were driven by termination method. Cover crop mixtures paired with the undercutter for termination did increase yield and profitability compared to a traditional no cover crop organic cropping system (NC control), but undercutter termination of weed mixtures (WD – undercutter treatment combination) proved to be the most profitable cropping system in this study.

*Weed Suppression*

Changes in weed biomass, density, and community composition were largely driven by the current main crop and differences in cover crop termination strategies. Reduced weed pressure following termination with the undercutter observed here is congruent with the results of others who found reduced weed biomass following cover crop termination with an undercutter compared to a flail mower. Moreover, the stimulation of weed growth commonly observed following termination with the disk and in the no cover control is consistent with previous work demonstrating the risks of using intensive tillage for early-season weed control and seedbed preparation. Use of the undercutter for weed control and cover crop termination has typically been limited to sandier soils of the western US Great Plains. However, these results demonstrate potential for this unique conservation tillage implement in the silty clay loam soils of eastern Nebraska to aid in profitable cover crop and weed management for increased crop yields in organic systems.

The influence of cover crop mixture and increasing cover crop diversity in this study were far more subtle than the impacts of current main crop and termination method. However, changes in weed biomass among cover crop mixtures were detectable early in the growing season in two of three years. The lack of a relationship between cover crop biomass and early-season weed biomass suggests that allelopathic or negative soil microbial feedback mechanisms contributed to weed suppression in this study. While allelopathic mechanisms of weed suppression are well understood for individual cover crop species, future studies should focus on the complex interactions occurring at the plant-soil interface between diverse cover crop communities and weed seed germination and growth.

*Soil Moisture*

Prior to cover crop termination, soil moisture availability decreased in the cover crop plots when precipitation became limiting. However, with regular spring rainfall there were no detectable differences in soil moisture between cover crop and no cover crop controls. Following cover crop termination and main crop planting, differences in soil moisture were due to termination method. In 2009, soil moisture was initially greater in the undercut treatment compared to the disked treatment. Similar to 2009, soil moisture availability was greatest in the undercut treatment compared to the disk treatment for the first three sampling intervals after cover crop termination in 2010. In general, when there was sufficient soil moisture to meet cover crop transpiration demands, the dense cover crop canopy may have conserved soil moisture by reducing evaporative loss from the soil surface occurring in the relatively bare NC and WD treatments. Following cover crop termination, surface soil moisture was not influenced by termination method or DOY in 2011. Instead, soil moisture was influenced by cover crop treatment, where values were greatest in the 8CC mixture (0.275 ± 0.004 cm3 cm-3) and lowest in the NC and WD treatments (0.262 ± 0.006 cm3 cm-3 and 0.254 ± 0.004 cm3 cm-3, respectively) when pooled across the three post-termination sampling intervals (DOY 159 to 186; data not shown). Increased soil moisture in the cover-cropped treatments in the third year of this study may be related to improvements in soil physical structure. Cover-cropping in organic systems has been shown to increase soil water infiltration and soil water holding capacity.

*Soil Nitrate Release*

There were no consistent differences among cover crop mixtures (2, 4, 6 or 8 species) in regard to soil nitrate release at either sampling interval after cover crop termination in 2009. The most consistent result at both sampling dates was the high level of soil nitrate in the undercut “weedy” treatment. Similarly, soil nitrate in the no cover control treatment was greatest at the second sampling interval.

Because this field was amended with liquid animal manure (30 tons ha-1) prior to year one, it is not surprising that soil nitrate levels were greater in the no cover and weedy treatment (the low level of soil nitrate in cover crop treatments is likely the result of increased N immobilization). In 2010, soil nitrate availability at 32 days after termination was greatest following the undercut treatment suggesting that nitrogen immobilization was greater following incorporation with a disk and overall soil nitrogen is becoming limiting in the no cover crop control. Our goal was to identify a cover crop termination method that would allow farmers to “spoon feed” nitrogen to the crop throughout the growing season without stressing the crop, and results suggest the undercutter may be an appropriate tool to accomplish this goal.

*Soil Microbial Community Structure*

While the results for individual fatty acid methyl ester analyses (FAMEs) and overall community composition were sometimes inconsistent with previous studies, it is clear from this work that the type of residue (cover crops vs. weeds) and the method of plant termination and residue management resulted in unique changes to microbial community structure. While tillage is often a strong driver of soil microbial community structure in managed ecosystems, the results of this study highlight the unique influence of weed communities on specific soil microbial function groups and community structure as a whole. Previous studies have found that plant species, community composition, and diversity are relatively weak drivers of microbial community composition, but our results demonstrate the potential influence of plants when comparing different plant classifications (weedy species vs. cultivated crops). Future studies should be directed toward understanding the prominent role of agricultural weed communities in driving microbial community composition and also toward determining the functions of these unique communities and functional groups.

FAME microbial biomass was generally greater following termination with an undercutter compared to the disk, especially following the 2 species cover crop mixture. This result is important because total microbial biomass is often used as an indicator of overall soil health. As expected, the combination of cover crops and the undercutter may be contributing to improved soil health.

*Grain Yield*

**Table 2.** Crop yield (Mg ha-1) ± 1 standard error for corn, soybean, and sunflower as influenced by termination method in the years 2009, 2010, and 2011.

|  |  |  |  |
| --- | --- | --- | --- |
| **Crop** | **2009** | **2010** | **2011** |
| **Corn** | \_\_\_\_\_\_\_\_\_\_ Mg ha-1 \_\_\_\_\_\_\_\_\_\_ | | |
| No cover | 8.41 ± 0.64 a | 5.29 ± 0.64 c | 11.12 ± 0.64 a |
| Disk | 7.37 ± 0.28 b | 6.45 ± 0.28 b | 10.16 ± 0.28 b |
| Undercutter | 8.78 ± 0.28 a | 7.75 ± 0.28 a | 10.97 ± 0.28 a |
| **Soybean** |  |  |  |
| No cover | 2.59 ± 0.18 a | 0.72 ± 0.18 b | 2.51 ± 0.18 b |
| Disk | 1.58 ± 0.08 b | 0.82 ± 0.08 b | 2.11 ± 0.08 c |
| Undercutter | 2.46 ± 0.08 a | 1.11 ± 0.08 a | 2.96 ± 0.08 a |
| **Sunflower** |  |  |  |
| No cover | 2.18 ± 0.15 a | 0.55 ± 0.15 a | 1.46 ± 0.15 a |
| Disk | 1.91 ± 0.07 b | 0.74 ± 0.07 a | 1.40 ± 0.07 a |
| Undercutter | 2.11 ± 0.07 a | 0.74 ± 0.07 a | 1.52 ± 0.07 a |

Soil conservation, quality, and fertility benefits associated with cover crops have been well documented, but increases in crop yield are less commonly reported. The lack of yield benefits typically realized following cover crop plantings may be related to previous knowledge gaps regarding the most effective cover crop termination and residue management strategies. However, novel cover crop management systems, like the winter rye – soybean no-till cropping system, have created opportunities for increased crop yield and profitability. Though unique from the roller-crimper system, results from this study provide support for another effective cover crop management strategy for organic cropping systems. Indeed, termination with the undercutter consistently maintained or increased crop yield relative to disk termination and the more traditional no cover crop organic cropping system. While the utility of the undercutter for cover crop termination and weed management has been previously documented, this is the first evidence of yield benefits associated with a “cover crop – undercutter” organic management system.

**Outreach**

We have presented poster and oral presentations at many professional and Extension meetings throughout the duration of this project. We have also developed Research, Extension and outreach publications to spread our research results via the internet and through societal newsletters (see citations below).

*Peer Reviewed Journal Articles*

Wortman, S. E., R. Drijber, E. Blankenship, and J. L. Lindquist. Relative Influence of cover crop diversity and residue management on soil microbial community structure. (In preparation).

Wortman, S. E., C. A. Francis, M. A. Bernards, E. E. Blankenship and J. L. Lindquist. 2013. Mechanical termination of diverse cover crop mixtures for improved weed suppression in organic cropping systems. Weed Science 61:(in press).

Wortman, S. E., C. A. Francis, M. L. Bernards, R. A. Drijber, and J. L. Lindquist. 2012. Optimizing cover crop benefits with diverse mixtures and an alternative termination method. Agronomy Journal 104:1425-1435.

Wortman, S. E., C. A. Francis and J. L. Lindquist. 2012. Cover crop mixtures for the western corn belt: Opportunities for increased productivity and stability. Agronomy Journal 104:699-705.

*Professional Presentations*

Wortman, S. E., M. L. Bernards and J. L. Lindquist. 2012. Weed biomass and community response to cover crop mixture and termination method. Proceedings of the Weed Science Society of America. 52:353.

Wortman, S. E. and J. Lindquist. 2011. Maximizing cover crop productivity for weed suppression. Proceedings of the North Central Weed Science Society. 66:50.

Wortman, S. E., J. L. Lindquist, R. A. Drijber, M. L. Bernards, and C. A. Francis. 2011. Mulching Cover Crop Mixtures for Improved Weed Suppression in Organic Grain Crops. Weed Science Society of America Annual Meeting, Portland, OR.

Wortman, S. E., M. L. Bernards, R. A. Drijber, C. A. Francis, and J. L. Lindquist. 2011. Impacts of Cover Crop Diversity and Termination Method On Organic Grain Crop Performance. ASA-CSSA-SSSA Annual Meeting, San Antonio, TX. *Accepted.*

Wortman, S. E., R. A. Drijber, and J. L. Lindquist. 2011. Relative Influence of Cover Crop Diversity and Residue Management On Soil Microbial Community Structure. ASA-CSSA-SSSA Annual Meeting, San Antonio, TX. *Accepted.*

Wortman, S. E., J. L. Lindquist, M. J. Haar, and C. A. Francis. 2010. Increased Weed Diversity, Density and Aboveground Biomass in Long-Term Organic Crop Rotations. Weed Science Society of America Annual Meeting, Denver, CO.

Wortman, S. E., J. L. Lindquist, R. A. Drijber, M. L. Bernards, and C. A. Francis. 2010. Mulching Cover Crop Mixtures to Increase Weed Suppression, Soil Moisture and Grain Yield. ASA-CSSA-SSSA Annual Meeting, Long Beach, CA.

Wortman, S. E., J. L. Lindquist, R. A. Drijber, M. L. Bernards, and C. A. Francis. 2009. Increasing Cover Crop Diversity and Weed Suppressiveness of Soils in Organic Cropping Systems. North Central Weed Science Society Annual Meeting, Kansas City, MO.

*Extension/Outreach Presentations*

Wortman, S. E. 2012. Crop Production: Effectively Using Cover Crops. University of Nebraska – Lincoln Crop Production Clinic, Beatrice, NE.

Wortman, S. E., and J. L. Lindquist. 2011. Diverse Cover Crop Strategies for Improved Yield and Weed Suppression. Nebraska Agribusiness Association Research Symposium, Kearney, NE.

Jasa, P., J. Schneider, and S. E. Wortman. 2011. Cover Crops and Their Benefits. University of Nebraska –Lincoln Crop Management and Diagnostic Clinic.

Jasa, P., J. Schneider, and S. E. Wortman. 2011. Cover Crops Field Day. University of Nebraska –Lincoln ARDC Fall Field Day.

Wortman, S. E. 2011. Adapting Cover Crop Management for Nebraska. Nebraska Sustainable Agriculture Research and Education (SARE) Webinar.

Wortman, S. E. 2011. Adapting Cover Crop Management for Nebraska. Nebraska Sustainable Agriculture Society Healthy Farms and Rural Advantage Conference, Columbus, NE.

Wortman, S. E. 2011. Adapting Cover Crop Management for Nebraska. Cover Crop Research Visioning Meeting, Lincoln, NE.

Wortman, S. E. 2011. Cover Crop Mixtures in Organic Farming. “Use of Cover Crops in Organic Farming”. NRCS South Central Nebraska RC&D Workshop, Hastings, NE.

Wortman, S. E. 2011. Cover Crops. “Cover Crops and No-Till in Organic Farming”. NRCS Trailblazer RC&D Workshop, Alma, NE.

Wortman, S. E. 2011. No-Till Without Chemicals. “Cover Crops and No-Till in Organic Farming”. NRCS Trailblazer RC&D Workshop, Alma, NE.

Wortman, S. E., J. L. Lindquist, R. A. Drijber, M. L. Bernards, and C. A. Francis. 2011. Mulching Cover Crop Mixtures to Increase Weed Suppression, Soil Nitrogen Availability, Soil Moisture and Grain Yield. MOSES Organic Farming Conference, La Crosse, WI.

Wortman, S. E., J. L. Lindquist, R. A. Drijber, M. L. Bernards, and C. A. Francis. 2010. Increasing Cover Crop Diversity and Weed Suppressiveness of Soils in Organic Cropping Systems. MOSES Organic Farming Conference, La Crosse, WI.

*Extension/Outreach Publications*

Wortman, S. E.and J. L. Lindquist.2012. Effective Management of Cover Crops. University of Nebraska – Lincoln Crop Production Clinic Proceedings.

Wortman, S. E.and C. A. Francis. 2011. Cover Crops: Increasing Diversity in Nebraska Crop Rotations. Prairie Fire Newspaper 5(8):2, 9, 10, 11, 14.

Wortman, S. E.and R. Drijber. 2011. Considering Reduced- or No-Till Organic? Do it for the Fungi! Organic Broadcaster 19(5):12-13.

Wortman, S. E. 2011. Cover Crop Mixtures: Increasing Diversity and Improving Weed Management in Organic Cropping Systems. Nebraska Sustainable Agriculture Society Newsletter. June 2011 issue.

Wortman, S. E. 2011. Cover Crop Mixtures: Increasing Diversity and Improving Weed Management in Organic Cropping Systems. Organic Crop Improvement Association Communicator Newsletter. June 2011 issue.

Wortman, S. E., J. L. Lindquist, C.A. Francis, R. Drijber, and M. Bernards. 2011. “Mulching Cover Crop Mixtures to Increase Weed Suppression, Soil Nitrogen Availability, Soil Moisture, and Grain Yield.” Cover Crops. Ed. J. Quinn. University of Nebraska – Lincoln. 31 January 2011 <http://organic.unl.edu/covercrops.shtml>.

*Farmer Involvement*

Five on-farm experiments and/or demonstration plots were initiated on two organic farms in year two to test the benefits of cover crop diversity at various phases of grain crop rotations. Larry Stanislav, an organic farmer near Linwood, NE has conducted three on-farm comparative studies within his four year grain crop rotation this past season. In his first experiment, Larry compared a mixture of dwarf essex rape and field pea with a monoculture of field pea as the first component of his green manure crop. In his second experiment, Larry compared a mixture of cowpea and buckwheat with a monoculture of buckwheat as the second component of his green manure phase in the rotation. Lastly, Larry planted a gradient of cover crop mixtures (1, 3, or 5 species) following harvest of his spring wheat this summer and will graze these mixtures later this fall. In each of these experiments, we measured aboveground productivity and plant tissue nutrient content or forage quality. Larry hosted a field tour on August 20, 2011 where local farmers and Extension personnel were able to observe two of these three experiments. We have continued to work closely with Larry as an advisor to our research project and in developing useful on-farm research for his specific operation.

The second set of on-farm experiments were conducted in collaboration with Dave Welsch, an organic farmer near Milford, NE. Dave planted a gradient of cover crop mixtures (0, 1, 3, or 5 species) in the early spring of 2010 prior to planting corn. Aboveground productivity of the cover crop was measured in all of these plots. Dave also planted a 15 acre demonstration plot this summer that includes an 8-species cover crop grazing mixture planted after winter wheat harvest. Dave hosted a pasture walk field day on September 26, 2011 for local farmers to view his cover crop mixture and discuss the benefits of grazing cover crops.

Each of these on-farm studies was replicated at least three times and the results are currently being analyzed. Regardless of the impact of the on-farm research results, the real impact of these on-farm experiments is the interest and attention it generates for cover crops and cover crop mixtures within local farming communities.

In December of 2010, our research results were presented at the UNL State Organic Advisory Committee meeting in Kearney, NE. At this meeting, we engaged in dialogue regarding our project with the panel of 10 organic farmers representing various growing regions within the state. Overall, the feedback from this panel was very positive regarding the direction of our research and they were excited to see some of the preliminary results.