2011 Proceedings of the Midwest Cover Crops Council

MCCC.msu.edu

February 23-24, 2011
Conservation Tillage & Technology Conference
Ohio Northern University, Ada, Ohio





Mizzou University of Missouri
University of Guelph
The Ohio State University
The University of Wisconsin Madison
Michigan State University Extension
Iowa State University
Purdue University
NDSU
University of Illinois Extension
University of Minnesota

Contents

Introduction

About the MCCC 1

Executive committee 1

State Reports

Ohio, USA (2011 host) 2

Indiana, USA 7

Iowa, USA 9

Michigan, USA 19

Ontario, Canada 22

Wisconsin, USA 24

Specific cover crop information

MCCC cover crop selection tool update 29

MCCC cover crop selection tool presentation summary 31

Legumes

Red clover nitrogen contribution for corn (poster) 35

Clover cover crop and nitrogen rate effect on corn 36

Clover cover crop and tillage effect on corn production 38

Legumes for cover crops- What fits your rotation? (presentation) 40

Quantifying nitrogen mineralization and plant available nitrogen concentrations in the soil following crop, cover crop residue and manure incorporation across and organic vegetable rotation (poster) 88

Grasses

Cereal rye cover crop effect on soybean production 45

Cover crop effect on cash crop yield: Year 2 95

Brassicas

Tillage radish to control weeds in horticulture crops 47

Effectiveness of white mustard on spring weeds 49

Results from a Brassica variety trail in MN and MI (scripted presentation) 52

Quantifying nitrogen mineralization and plant available nitrogen concentrations in the soil following crop, cover crop residue and manure incorporation across and organic vegetable rotation (poster) 88

Cover crop influences on soil properties and nutrient availability

Cover crops biomass N credit for rainfed wheat production (poster).......................... 68

Cover crops, composed chicken and cattle manures effect on crop yields, weed control and soil quality in soybean-corn rotations (poster) 69

Biomass N contribution of cover crops for agronomic crop production (poster) 70

Cover crop x nitrogen rate comparison 71

Using cover crops to convert to no-till 73

The biology of soil compaction 81

Quantifying nitrogen mineralization and plant available nitrogen concentrations in the soil following crop, cover crop residue and manure incorporation across and organic vegetable rotation (poster) 88

Cover crop influences on pest management

Field vegetable production: Using cover crops for weed management 89

Tillage radish to control weeds in horticulture crops 47

Effectiveness of white mustard on spring weeds 49

Cover crop influences on yield and economics

Cover crop effect on cash crop yield: Year 2 95

Economics of cover crops (presentation) 98

Miscellaneous

Opportunities to advance carbon sequestration in the Farm Bill 124

Green Lands Blue Waters program summary 126

Introduction

About the Midwest Cover Crops Council

Founded in 2006, the Midwest Cover Crops Council (MCCC) is a diverse group from academia, production agriculture, non-governmental organizations, commodity interests, private sector, and federal and state agencies collaborating to address soil, water, air, and agricultural quality concerns in the Great Lakes and Mississippi river basins. The goal of the MCCC is to facilitate widespread adoption of cover crops throughout the Midwest, to improve ecological, economic, and social sustainability.

Executive Committee

Tom Kaspar
Plant physiologist
USDA-ARS, National Laboratory for Agriculture and the Environment
Ames, IA

Eileen Kladivko
Professor, Agronomy Department
Purdue University
West Lafayette, IN

Dale Mutch
Senior District Extension Educator and Specialist
Adjunct Professor Crop and Soil Science
Michigan State University
Hickory Corners, MI

Alan Sundermeir
Extension Educator
The Ohio State University
Bowling Green, OH

Anne Verhallen
Soil Management Specialist
Ontario Ministry of Agriculture, Food and Rural Affairs
Ridgetown, ON

Donald Wyse
Professor, Department of Agronomy and Plant Genetics
University of Minnesota
St. Paul, MN

Midwest Cover Crop Council: Ohio report 2011

<u>Summary of Cover Crops Research in Ohio, February 2011</u>

OARDC Northwest Branch

1. Cereal rye as a winter cover crop is used in corn-soybean rotation under different compaction levels (0, 10, and 20 tons/axle) and tillage systems (annual subsoiling and continuous no-till) to evaluate the impact of cover crops on reducing soil compaction. PI's: *Randall Reeder, Alan Sundermeier, Jim Hoorman, and Rafiq Islam*

2. Gypsum (0, 1, and 2 tons/a) and oilseed radish are used to evaluate their impact on reducing compaction and improving soil quality. *PI's: Bruce Clevenger and Rafiq Islam*

3. A 26-yr tillage research area is being expanded in 2011 to include cover crops treatments. We'll have up to 6 different cover crops, or combinations, with continuous no-till. PI's: *Randall Reeder, Larry Brown, Rafiq Islam, plus*

4. Radish, Winter Pea, Cowpea, Soybean, planted after wheat harvest. Compare corn yields following year with zero, 80 and 160 lb. nitrogen applied. *PI: Alan Sundermeier*

5. Medium Red clover frost seeded under wheat. Compare corn yields with no-till vs conventional tillage. *PI: Alan Sundermeier*

OARDC-Piketon

4. Cover crops and tillage impact on soil quality and ecosystem services. Cowpea and cereal rye were used as living mulch (cover crops) in No-Till and Conventional Tillage corn-soybean-wheat rotation to reduce N input and emission of Greenhouse Gases (GHGs), enhance C sequestration, improve soil quality, and sustain farm production. *PI: Rafiq Islam*

5. Impact of cereal rye on transformation and off-site movement of manure nutrients in NT and CT corn-soybean rotation. The study focuses on C, N, and P mineralization and fate including nutrient availability to plants, leaching and surface runoff, and emission of GHGs (CO_2, CH_4, NOx, and NH_3). A new method has been developed for simple measurement of NH_3 volatilization. *PI: Rafiq Islam*

6. Several new cover crops were tried at different locations in Ohio. They were: Sun hemp, Phagelia, Mung bean, Teff, and horse bean. *PI's: Rafiq Islam, Alan Sundermeier, Randall Reeder, and Jim Hoorman.*

Collaborative Research with Farmers

7. Oilseed Radish, cowpea, and winter pea were used as cover crops to reduce N input, maximize biomass N contribution, and reduce soil compaction and soil-borne diseases. *PI's: Aaron Lemaster, Yogi Raut, Jim Hoorman, and Rafiq Islam.*

8. Oilseed Radish with different combinations of cover crops was used to maximize biomass N contribution, control weeds, reduce compaction, and improve soil quality. *PI's: Dave Brandt, Randall Reeder, Jim Hoorman, Alan Sundermeier, and Rafiq Islam*

9. Oilseed Radish and winter pea, planted with precision placement, in a controlled traffic system to increase corn yield in the 4 rows at the edges of the permanent tracks. Radish planted at the edges of tracks may break up the soil enough to allow good corn root growth; winter pea in all other rows will provide N. *PI's: Bill Richards and Randall Reeder*

Peer-Reviewed Journal Articles

Henry, D.C., Diedrick, K.A., Mullen, R.W., Dygert, C.E., Sundermeier, A. 2010. Nitrogen contribution from red clover for corn following wheat in western Ohio. *Agronomy Journal*. Vol. 102, no. 1: 210-215.

Presentations by James J. Hoorman

1) January 26-27, 2010 Advanced No-till and Cover Crops, Quebec Canada- 200 farmers Odette Menard Two days of training on soil ecology, nutrient recycling, biology of soil compaction, sustainable crop rotations, homegrown nitrogen

2) February 25-25 Conservation Tillage & Technology Conference, Ada, Ohio The Biology of Soil Compaction – 275, Soil ecology and Nutrient Recycling -250

3) March 12, 13, 22 Mercer Landmark, Trupointe, Soil and Water: Talks on cover crops -91 farmers

4) April 6, 7, 30 Cover Crop Tours, Mercer, Fairfield and Van Wert County – 42 people

5) June 18 Soil Quality and Soil Health, Dayton, Ohio-24 people

6) June 22, Slurry Seeding of Cover Crops for Certified Livestock Managers – 136 applicators.

7) July 26-28 Canadian-Ohio Cover Crop Bus Tour for 45 farmers. Visited 12 Ohio farms using cover crops with Odette Menard from Quebec Canada.

8) August 9, Maria Stein Livestock and Cover crop farmer meeting – 180 farmers

9) August 11, Blanchard Valley coop Cover Crop Tour and meeting – 52 farmers

10) August 13-19 Mercer County Fair, Cover Crop exhibits -250 farmers

11) August 19 Putnam County Manure and Cover Crop Field day- (By Glen Arnold not me) 75-100 farmers

12) August 24, 26, Mercer and Williams County Cover Crop Tours-125 farmers

13) September 7, Darke County Nutrient Management & cover crop tour & Cover Crop Exhibits -65 farmers

14) September 8 Ohio No-till Field Day, Preble County – Cover Crop Exhibits – 103 farmers

15) September 10-11 Trupointe Cover Crop and Agronomy Field days – Cover Crop Exhibits – 140 farmers

16) September 21-23 Farm Science Review- Cover Crop Plots and Cover Crop Exhibits -150 farmers, Talk on Cover Crop Rotations – 60 farmers

17) December 8, Pennsylvania Keystone No-till and Cover Crop Conference –

Soil Ecology and Nutrient Recycling – 120 farmers, Sustainable Cover Crop Rotations -120 farmers

18) January 12-13, 2011 National No-till Conference, Cincinnati, Ohio Soil ecology and Nutrient Recycling to Improve Soil Structure – 840 farmers   Sustainable Crop Rotations – 300 farmers Cover Crop Exhibit – 150 farmers

19) January 19, 2011 Burleigh County North Dakota Soil Health Workshop

Soil Ecology and Nutrient Recycling to Improve Soil Structure – 440 farmers

Sustainable Crop Rotations and Homegrown Nitrogen – 440 farmers

20) January 20, Ohio Soil Pedologist Metro Parks, Columbus – Biology of soil Compaction -45 scientist and soil technicians

21) February 15, 2011 Great Lakes Cover Crop Initiative Dundee, Michigan -25 farmers

22) February 24 Conservation Tillage & Technology Conference – Cover Crops Agenda –expecting 200-250 farmers for sessions all day.

Abstracts:

1) Alan Sundermeier, Randall Reeder, James Hoorman, Yogendra Raut, Norman Fausey, Khandakar Islam, and Stacy Reno. 2010. Crop Rotation and Tillage Impacts on Soil Nutrients [Abstract]. *Proceedings of ASA-CSSA-SSSA 2010 International Annual Meeting*. S04 Soil Fertility & Plant Nutrition/ General Soil Fertility and Plant Nutrition, no. Paper No. 58327. Long Beach, CA, USA: ASA-CSSA-SSSA 2010 International Annual Meeting. (November 2): 314-11.

2) Kenin Barik, Randall Reeder, Alan Sundermeier, James Hoorman, Yogendra Raut, Rafiq Islam, and Stacy Reno. 2010. Tillage and Compaction impact on Soil Aggregate Associated Properties [Abstract]. *Proceedings of ASA-CSSA and SSSA International Meeting*. S06 Soil & Water Management & Conservation/Sustainable Agriculture and Ecosystem Services: Role of Conservation Tillage, Crop Rotation , and Nutrient Management, no. Paper No. 58441. Long Beach, CA, USA: ASA-CSSA-SSSA2010 Annual Meeting. (November 2): 233-8.

3) Hoorman, J.J. 2010. Biological Recycling of Soil Nutrients [Abstract]. *95th Proceeding of The National Association of County Agricultural Agents*. Tulsa, Oklahoma, USA: Sustainable Agriculture Session. (July 13): pg. 167-168.

4) Hoorman, J.J. 2010. Understanding the "Root" Cause of Soil Compaction [Abstract]. *95th Proceedings of The National Association of County Agricultural Agents*. Tulsa, Ohio, USA: Agronomy & Pest Management Session. (July 13): pg 149.

5) Sundermeier, A., Hoorman, J., Reeder, R., and Islam, R. 2010. Using Cover Crops to Convert To No-till, Regional Winner Feature Story [Abstract]. *95th Proceedings of the National Association of County Agricultural Agents*. Tulsa, Oklahoma, USA. (July 11): pg. 123..

6) Sundermeier, A.P., Gastier, M., Hoorman, J.J., Islam, K.R., and R.C. Reeder. 2010. Ohio Cover Crop Team Outreach [Abstract]. *95th Proceedings of The National Association of County Agricultural Agents*. Tulsa, Oklahoma, USA. (July 11): pg. 69-70.

7) Hoorman, J.J. and R.C. Reeder. 2010. Biology of Soil Compaction and Soil Structure [Abstract]. *Procceedings of the American Society of Agricultural & Biological Engineering, 2010*. Abstract No: 1008484. Pittsburg, Pennsylvania, USA. (June 23)

Current Grants

1) 07/2010 - 12/2012. Planting oilseed or tillage radish with winter peas to break up compaction, control weeds, and grow nitrogen for the following corn crop. Conservation Tillage & Technology Conference. (Funded Amount: $2,000.00) PI- Hoorman-Raut

2) 07/2010 - 12/2012. Oilseed/tillage radish inter-seeded into no-till wheat. Conservation Tillage & Technology Conference. (Funded Amount: $4,000.00) Research Grant. PI – Brandt & Hoorman

3) Using cover crops to improve soil compaction. Conservation Tillage and Technology Conference Grants. (Funded Amount: $5,000.00) Research Grant. CO-I: Reeder, R., Hoorman, J.J., Sundermeier, A., and Islam, K.R.

4) Recycling nutrients with cover crops to decrease hypoxia while promoting sustainable crop production. USDA Sustainable Agriculture Research and Extension. (Funded Amount: $10,000.00) Research Grant. PI-Hoorman for PHD & Islam

5) 07/2010 - 12/2011. Successful Transitioning to No-Till Corn-Soybean Rotation with Cover Crops for Home-Grown N, Weed Control, and Soil Quality Improvement. Warner Grant. (Funded Amount: $5,000.00) PI-Hoorman & Raut & Islam

6) 2008 - 2010. Soil Quality Professional Training to Improve Farm Profitability. USDA Sustainable Agriculture Research and Extension. Training Grant. Funded Amount $67,900 PI: Islam, K.R. CO-I: Hoorman, J.J., Sundermeier, A.P., Reeder, R, C.

7) 10/01/2010 - 09/30/2013. Cover Crops and Conservation Tillage Reduce NPS Pollution. US-EPA. (Funded Amount: $968,298.00) Sub-contract. Award Number: EPA-R5-GL210-1 PI: Karen Scanlon, Executive Director, CTIC Role: Collaborator

8) 07/2010 - 06/2013. Mississippi River Basin Initiative (MRBI). USDA-NRCS. (Funded Amount: $1,500,000.00) Sub-contract. Grant/Contract Number: MRBI-Bill Knapke, CoPI Hoorman

9) 07/2010 - 06/2012. Farmer Sustainable Agriculture Research and Extension. SARE. (Funded Amount: $18,000.00) Training Grant. PI: Rasawehr, J. CO-I: Hoorman, J.J.

10) 10/01/2008 - 09/30/2011. Recycling nutrients with cover crops to decrease hypoxia/eutrophication while promoting sustainable crop production. Univ of Minnesota. (Funded Amount: $10,000.00) Training Grant. Grant/Contract Number: GRT00012881 Award Number: H408626309 CO-I: Rausch, J.N., Brown, L.C., Hoorman, J.J.

11) 2009 - 2011. Tranisitioning to Long-term No-till with Cover Crops. Conservation Innovation Grant. (Funded Amount: $150,000.00) Training Grant. PI: Kladvicko, E., Towery, D. and Reeder, R. Role: Hoorman as Consultant

12) 07/01/2010 - 06/30/2012. Controlling Soil Erosion in the Auglaize River Watershed, Paulding County using Cover Crops. USDA-Great Lakes Commission. (Funded Amount: $29,815.00) Training Grant. PI: Lopshire, J. and Hoorman, J.

13) 07/01/2009 - 06/30/2011. Controlling Soil Erosion in the Auglaize River Watershed, Putnam County using Cover Crops. USDA-Great Lakes Commission. (Funded Amount: $29,815.00) Training Grant. PI: Arnold, G. and Hoorman, J.J.

Teaching Awards

1) 2010 1st Place Regional and State Winner, Feature Story on Cover Crops. National Association of County Agriculture Agents (NACAA). Sundermeier, Hoorman, Islam, Reeder

2) 2010 Tools for Teaching 8A Fact sheet, 2nd. ESP. The Ohio State University, Columbus, OH, United States. Subject: The Biology of Soil Compaction Hoorman, Reeder

3) 2010 Tools for Teaching, 9A Home Page on the Web, 2nd. ESP. The Ohio State University, Columbus, OH, United States. Subject: Midwest Cover Crops Council website Sundermeier, Hoorman, Reeder, Islam

4) 2010 Tools for Teaching, 4A Educational Exhibit, Internally Produced, 1st. ESP. The Ohio State University, Columbus, OH, United States. Subject: Cover Crops Roots Display Hoorman

5) 2010 Tools for Teaching 3B Computer Generated Presentation, 1st. ESP. The Ohio State University, Columbus, OH, United States. Subject: The Biology of Soil Compaction Hoorman

6) 2009 2nd Team Teaching, Multi-Disc. 5 or more. Epsilon Sigma Phi (ESP): The Science of Cover Crops at Conservation Tillage & Technology Conference, Ada, Ohio Hoorman, Islam, Sundermeier, Reeder

Midwest Cover Crops Council
State/Province Report for February 23-24, 2011 Meeting in Ada, Ohio

State/Province Name: **Indiana**

Contact Information
Name: Eileen Kladivko
Organization: Purdue University
E-mail: kladivko@purdue.edu
Telephone: 765-494-6372

Research
Some new studies were initiated within the past year, along with continuation of some long term or ongoing studies by a number of researchers at Purdue. New studies include:

1. Slurry seeding of cover crops, as part of larger project with Tim Harrigan at Michigan State. Purdue‟s part includes field trials with annual ryegrass and swine manure, on three farmers‟ fields, as well as mini-plots at research farm, and growth chamber studies on seed germination with exposure to swine manure. (graduate student Edwin Suarez)
2. Sampled various cover crops for biomass and N content on several farmer fields or demonstration plots, as initial information (not replicated) around the state.
3. Greenhouse experiment growing 3 radish varieties at two plant densities and two soil bulk densities, for overall growth, tuber size, overall root growth, top growth, N content. (graduate student Mohammad Amini)
4. New project on organic agriculture, led by K. Gibson (weed scientist, Dept. of Botany and Plant Pathology) with 8 faculty across 5 departments and eventually 6-7 grad students. Cover crops are part of overall management strategy. (graduate student Jessica Garvert working on soils part in Agronomy Dept with Kladivko)
5. New long-term and short-term plots to be established starting spring 2011 (covers to be seeded in fall 2011). This will include some smaller aspects of what we all proposed for AFRI grant proposal, on rye and another cover vs no cover, but we‟ll only use different N rates (3) after 5 years of cover crop growth (ie, build the SOM first, and then test N release). Also will do N sampling in field with radishes, and will likely try small plots with other covers too (still doing final plans for 2011). (new graduate student Kaylissa Horton plus another coming in May).
    a. One of these sites will be as part of a large AFRI-CAP (the $20million program, not the $5million program we tried for) led by Lois Wright Morton at Iowa State, on climate change and corn systems. The cover crop plots will be simply cereal rye vs no rye, on corn-soybean and soybean-corn, with 4 reps, for total of 16 plots. We should encourage some of those participants to become more directly involved with MCCC in the future, but as of now, Kladivko is the "liaison".

Some long-term or always ongoing work continues:

6. Winter wheat cover crop used in tile drainage research project, where nitrate measured in tile drainflow. Long-term (25+yrs) but no simultaneous comparison without cover crop. Could make more measurements related to N cycling, if regional collaboration.
7. Biomass crops, new and old work (Miscanthus, switchgrass)
8. Ongoing work on pest suppression (disease, nematode, weeds) and in vegetable production (Dept. of Botany and Plant Pathology; Dept of Horticulture
9. Always ongoing work on forages for hay or grazing

Extension/Education
There has been a **lot** of activity and interest in cover crops in Indiana the past few years. Several new or greatly expanded efforts in cover crops are occurring through and with many of our partners, including

NRCS, SWCD, Conservation Cropping Systems Initiative, State Dept of Agriculture, along with Purdue Extension.

1. Purdue Extension has been working with colleagues in the MCCC on two major Extension products—the Cover Crop Selector Tool (led by Dean Baas and Michigan State and now on line!) and recently the Cover Crop Pocket Guide (led by Purdue, just starting). The Indiana team for the Selector Tool included Fisher, Towery, Johnson, Robison, Swaim, and Kladivko. The Pocket Guide includes all interested MCCC states/provinces and is scheduled to be drafted within the next month, and available by December 1, 2011.
2. Conservation Cropping Systems Initiative (CCSI)—this new initiative of the Conservation Partnership puts two experienced people on the ground, for working with farmers interested in no-till, cover crops, and other conservation practices. (Hans Kok and Dan Towery). They work with SWCDs, County Extension, ISDA, NRCS and agri-businesses to provide information, education and collaboration to over 4000 producers at over 50 workshops across the state.
3. Demonstration sites on farmers" fields. These are usually initiated by farmer interest but may be facilitated by NRCS, SWCD, Extension, or agronomic consultant. The CCSI will be helping initiate many more of these through a new on-farm network, assisted by CIG funding through the State Dept of Agriculture.
4. Field days and winter meetings. These are sometimes held at the field demonstration sites. Others are part of broader field days or extension meetings. Speakers are usually NRCS, extension, or agronomic consultant, along with the farmer cooperator.
5. County SWCDs again have access to some small grants from Indiana State Dept. of Agriculture (ISDA) through State Soil Conservation Board, to promote cover crops in their counties, through field days, winter meetings, and provision of extension materials from numerous sources.
6. Discussion of cover crops as a way to reduce nitrate leaching to tile drains, is included as a standard part of extension talks on tile drainage and water quality.
7. Indiana NRCS continues making significant investments in promoting Conservation Cropping Systems which include cover crops. To meet the demand for regional expertise and recognize individuals that demonstrate a sound background, enthusiasm and experience in planning and implementing these practices, NRCS Indiana established a cadre of „**Conservation Cropping Systems Specialists**". These employees have received prioritized training in agronomy such as soil quality, No-till/Strip-Till systems, Nutrient Management, and Cover Crops.

<u>Communication</u>

There is usually some local publicity associated with county SWCD education events, as mentioned under extension.

<u>Policy</u>

NRCS in Indiana no longer has the “energy bundle” (due to national restrictions) but does still have EQIP and CSP payments available for cover crops. Additionally, Cover Crops are integrated into the 590-Nutrient Management (High Management) and 633-Waste Utilization (High Management) practices under the EQIP (Regular, MRBI and GLRI). In addition, many counties have some amount of financial assistance available through various programs such as EPA 319 grants, Nature Conservancy, Clean Water Indiana, etc.

State Report for Iowa on Cover Crop Research and Activities for the Combined NCCC211 and MCCC 2011 meeting in Ada, OH on 2-23-2011

Matt Helmers, Dept. Ag. & Biosys. Eng., Iowa State University; mhelmers@iastate.edu

Studies on nitrate-nitrogen leaching benefits of winter rye cover crop within a corn -soybean rotation are being conducted at drainage water quality research sites near Gilmore City and Nashua, IA. Preliminary results indicate positive nitrate leaching benefits of the cover crops even in less than ideal spring growing conditions for the rye. Three publications have been submitted related to this work. One related to soil moisture dynamics under various land uses, another on nitrate leaching characteristics of various land covers, and one related to long-term modeling of hydrology and nitrogen dynamics of a winter cover crop system.

Qi, Z., and M.J. Helmers. 2010. **Soil water dynamics under winter rye cover crop in central Iowa.** Vadose Zone J 9:53-60.

Utilization of cereal rye (Secale cereale L. ssp. cereal) as a winter cover crop has potential benefits for subsurface drainage and NO3 loss reduction. The objective of this study was to quantify the soil water balance components and impacts of a rye cover crop on subsurface drainage in central Iowa. Rye was planted in lysimeters in mid-October and terminated in early June in 3 yr and the lysimeters were left fallow during the summer months. Subsurface drainage water was generally pumped out weekly along with taking soil moisture measurements; however, multiple appreciable rain events in a given week required more frequent pumping. During May through July of the 3 yr, monthly subsurface drainage was significantly reduced by 21% when comparing the rye system to bare soil ($P < 0.1$). Drainage of individual pumping events was significantly lower in the rye lysimeters than the bare lysimeters when averaged across 3 yr ($P < 0.05$). Soil water storage in the rye treatment was also significantly lower than the bare treatment ($P < 0.05$) in all 3 yr. The winter cover crop effectively reduced subsurface drainage, which would then be expected to decrease the NO3 load, which is essential to water quality improvement. During the main growing month, May, estimated evapotranspiration of rye was 2.4 mm d-1, significantly higher than evaporation from the bare treatment (1.5 mm d-1, $P < 0.1$). Soil water depletion by rye in May could reduce the drainage volume and may also help facilitate trafficability, but it is still unknown what impact there may be on crop production in dry years.

Qi, Z., M.J. Helmers, and A.L. Kaleita. 2010. **Soil water dynamics under various agricultural land covers on a subsurface drained field in north-central Iowa, USA**. Agric. Water Manage. 98:665-674.

Modification of land cover systems is being studied in subsurface drained Iowa croplands due to their potential benefits in increasing soil water and nitrogen depletion thus reducing drainage and NO3–N loss in the spring period. The objective of this study was to evaluate the impacts of modified land covers on soil water dynamics. In each individual year, modified land covers including winter rye–corn (rC), winter rye–soybean (rS), kura clover as a living mulch for corn (kC), and perennial forage (PF), as well as conventional corn (C) and soybean (S), were grown in subsurface drained plots in north-central Iowa. Results showed that subsurface drainage was not reduced under modified land covers in comparison to conventional corn and soybean. Soil water storage (SWS) was significantly reduced by PF treatments during the whole growing seasons and by kC during May through July when compared to the cropping system with corn or soybean only ($p < 0.05$). Treatments of rC and rS typically maintained higher SWS than C and S, respectively, during the 3 years of this study. In the spring during a 10–15-day period when the rainfall was minimal, SWS in plots with rye, kura clover, and forage decreased at a significantly higher rate than the C and S plots which were bare. Estimated evapotranspiration (ET) during this period was significantly higher in rS, kC, and PF treatments than C and S. The results of this study suggested that significantly higher ET and similar drainage for modified land covers may increase water infiltration, which would be expected to reduce surface runoff thus to decrease stream flow. Because subsurface drainage reduction was not seen in this study, impact of modified land covers on NO3–N loss needs further investigation.

Mary Wiedenhoeft, Dept. of Agronomy, Iowa State University; mwiedenh@mail.iastate.edu

Evaluating canola *(Brassica napus)* as an alternative oilseed crop and enhancing winter cover in Iowa,

Mary Wiedenhoeft and Stefans Gailans, ISU Agronomy Funded by Leopold Center.

Project description: One of the objectives of this project is to increase the amount of information available to growers about winter canola as a „third" crop in Iowa. Investigators also want to increase information concerning its use as a winter cover crop in Iowa. The team will assess the economical and ecological impact of alternative cropping systems and different crop rotations. Data will be used to make recommendations to farmers

Jeremy Singer, USDA-ARS, National Laboratory for Agriculture and the Environment, Ames, IA; Jeremy.Singer@ars.usda.gov

Self-Seeding

Developing self-seeding cover crop systems that minimize competition with soybean are possible if cover crop growth is restricted to optimize cover crop seed production and dispersal. The objectives of this research were to quantify cover crop seed production, viability, and self-seeding when growing concurrently with soybean. Winter wheat, triticale, and rye were seeded at two rates in combination with three seed dispersal methods (natural seed rain, simulated combine, and mechanical preharvest). Wheat combined with mechanical seed dispersal preharvest exhibited the greatest consistency in self-seeding regardless of initial seeding rate and wheat averaged 51 and 32% green groundcover in the fall of 2007 and 2008. Wheat seed viability (> 82%) exceeded rye and triticale at soybean harvest, approximately 60 to 80 days after seed maturity. Cover crop species or seeding rate did not affect soybean seed yield either year. Averaged across seeding rate and seed dispersal treatments, wheat self-seeding systems exhibit the greatest potential for adoption, although soybean yield was lower in one of two years compared to a no cover crop control. Producers who want to adopt a self-seeding cover crop system should drill wheat between 400,000 and 800,000 seeds/acre after corn harvest in the fall and use some form of mechnical disturbance after wheat maturity the following summer to facilitate seed dispersal prior to soybean harvest.

Coupling Manure and Cover crops

Coupling manure injection with winter annual cover crops can enhance nutrient retention, among other cover crop benefits. The objective of this research was to compare manure injection methods with or without an oat/rye cover crop. Results from the first two cycles indicate that low disturbance manure injection captures the greatest quantity of nitrogen in cover crop shoot biomass. Corn grain yield was lower in one of two years with a cover crop compared to a no cover crop plus manure treatment, regardless of manure injection method. This research will continue through the 2013 growing season.

Cover Crop Species and Corn Seeding Rate

Corn grain yield reductions in winter annual cover crop systems are sometimes related to final corn plant population. The objective of this research was to quantify corn yield growing after contrasting winter annual cover crops at seeding rates between 26,000 and 56,000 seeds/acre to determine if increasing corn seeding rates can mitigate reductions in final corn plant populations following a winter annual cover crop. Corn following Wesley winter wheat, Wheeler winter rye, and a no cover crop control were tested at six corn seeding rates. Results from 2009 indicate that corn grain yield was 10% lower than the no cover crop control, cover crop variety was not significant, and corn grain yield only responded going from 26,000 to 32,000 seeds/acre. In 2010, the no cover crop control yielded 18% higher than Wheeler winter rye and 29% higher than Wesley winter wheat and corn seeding rate was not significant. This study will be repeated in 2011.

Tom Kaspar, Dan Jaynes, Tim Parkin, Tom Moorman, and Jeremy Singer, USDA-ARS, National Laboratory for Agriculture and the Environment, Ames, IA; Tom.Kaspar@ars.usda.gov

Reducing nitrate losses in tile drainage with winter small grain cover crops.

An experimental site was established in the fall with a tile drainage system that allowed continuous measurement of the flow and nitrate concentration of drainage coming from 24 plots near Ames, IA. A corn-soybean rotation was established in 2000 with corn in even years and soybean in odd years. Nitrogen fertilizer was applied at or near corn planting only in the corn years, with 215 lbs N/acre applied in 2002 & 2004, 200 lbs N/acre in 2006, and 175 lbs N/acre in 2008 and 2010. The plots are managed with no-till and rye cover crop plots were established in the fall of 2001 by overseeding into soybean at leaf drop. Rye was also overseeded into corn at black layer in fall of 2002. After 2002, the rye cover crop was established by drilling after harvest. In fall of 2005 an oat cover crop treatment was initiated by overseeding into soybean at leaf yellow. The oat cover crop treatment continued to be established by overseeding into the standing crops before harvest in subsequent years.

The rye cover crop reduced the flow-weighted nitrate concentration of the drainage water by 55% over the entire 9 year period and by 48% from 2006 through 2010 (Fig. 1). A rye cover crop grows and takes up water and nitrogen in both the fall and spring, whereas an oat cover crop only grows in the fall and does not overwinter. In spite of this, the oat cover crop reduced the nitrate concentration of drainage water by 25% from 2006 through 2010 and in 2009 reduced nitrate concentration as much as the rye cover crop (2009). Because the oat cover crop is broadcast seeded into the standing crop it may take up soil N that has already leached downward by the time the rye cover crop is planted after harvest. Additionally 2006 through 2010 had unusually wet falls for central Iowa with fall drainage occurring in each of the these years. This may have increased the relative effectiveness of the oat cover crop compared with the rye. Nitrate load or the amount of N in the drainage water responded to the two cover crops in the same way that nitrate concentration did. The rye cover crop reduced the load of nitrate in the drainage water by 53% over the entire 9 year period and by 46% from 2006 through 2010 (Fig.2). The oat cover crop reduced the nitrate load of drainage water by 37% from 2006 through 2010. The oat cover crop reduced nitrate load relatively more than nitrate concentration because it also seems to have reduced drainage or flow. This is preliminary information and needs to be confirmed.

The results reported in this note are preliminary and have not been error checked or statistically analyzed.

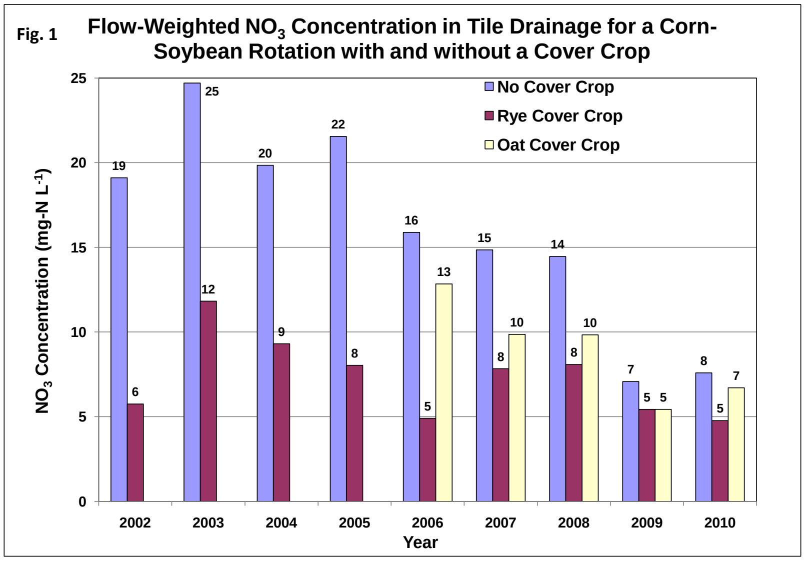


Fig. 1
Flow-Weighted NO3 Concentration in Tile Drainage for a Corn-Soybean Rotation with and without a Cover Crop
No Cover Crop
Rye Cover Crop
Oat Cover Crop
NO3 Concentration (mg-N L-1)
Year
2002
2003
2004
2005
2006
2007
2008
2009
2010
19 6
25 12
20 9
22 8
16 5 13
15 8 10
14 8 10
7 5 5
8 5 7

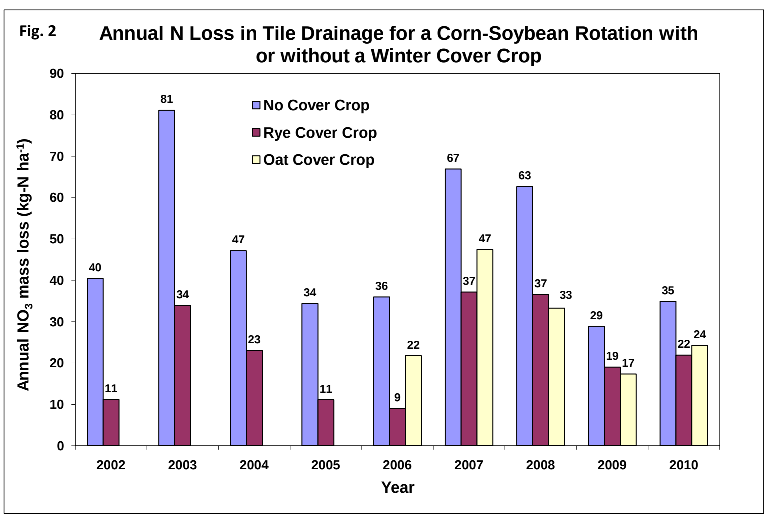


Fig. 2
Annual N Loss in Tile Drainage for a Corn-Soybean Rotation with or without a Winter Cover Crop
No Cover Crop
Rye Cover Crop
Oat Cover Crop
Annual NO3 mass loss (kg-N ha-1)
Year
2002
2003
2004
2005
2006
2007
2008
2009
2010
40 11
81 34
47 23
34 11
36 9 22
67 37 47
63 37 33
29 19 17
35 22 24

Evaluating Various Cover Crop Species for Overseeding into Corn and Soybean in Iowa

Tom Kaspar and Ben Knutson

In late summer and early fall, ten cover crop species or genotypes were overseeded into soybean at two dates (Aug. 25 and Sept 1) in 2009 and four dates (July 16, Aug. 3, Sept. 3, and Sept. 15) in 2010 and into corn at one date (Aug. 25) in 2009 and one date (Sept. 15) in 2010. The species and genotypes evaluated were red clover, mustard, hairy vetch, annual alfalfa, 2 radish genotypes, alsike clover, sweet clover, turnip, and rape.

In 2009, observations were made on Dec. 1. At that time only one of the radish genotypes had shown moderate growth (4-6 in high) and a moderate numbers of plants. No biomass samples were taken but I would guess that biomass was less than or equal to 500 lbs/acre. Turnip, mustard, and the other radish genotype had moderate growth, but fewer plants. No rape plants could be found. We observed that a severe frost on Oct 11 had burned back the vegetative growth on the brassica species and this may have killed the rape plants. Hairy vetch had a moderate number of plants at this time, but they were small and viney. The other legumes had few plants and were very small. Rye overseeded at the same time as the other species had excellent growth and stand. Germination and stand were much better for the first planting date because of rains Aug. 26 and 27 (1.70 in). The next rain was Sept 21. Species planted at the Aug. 25 dates showed some elongation, but soybean leaves began to yellow and fall in early Sept. All species had fewer plants in the combine wheel track, although rye and hairy vetch seemed to tolerate this better. Also, species seeded into corn grew more poorly than when seeded into soybean, most likely because of residue cover after harvest. The winter had continuous snow cover from Dec.7 until March 10 and only the surface inch froze briefly. A few plants of several species overwintered, but most of the hairy vetch and all the rye plants overwintered.

In 2010 the cover crop species were evaluated on Nov. 9. The only legume to show fair growth and a moderate number of plants was hairy vetch, which survived planting at all dates except the July 16 date. The other legumes had almost no survival except at the Sept. 15 planting date in soybean and did very poorly in corn at that same date. Legumes in soybean at the Sept. 15 planting date were small with few to moderate numbers of plants. The brassicas also survived and grew better after the Sept. 15 date in soybean, although mustard also did fairly well after the Sept. 3 date in soybean. The brassicas also did more poorly in corn than soybean at the Sept. 15 planting date. In general mustard probably had the best stand and growth, with the rest of the brassicas close behind. No biomass samples were taken, but mustard probably produced greater than 500 lbs/acre. Only a few isolated plants of any brassica species survived at the Aug. 3 or July 16 planting dates in soybean. In general, all species were affected by combine wheel traffic, with hairy vetch being the least affected. Plants of all species planted before Sept. 15 germinated and emerged well but were elongated and relatively weak plants. These surviving plants, except for hairy vetch, did not seem to be able to grow out from under the residue deposited during harvest.

John Sawyer, Dept of Agronomy, Iowa State University; jsawyer@iastate.edu

Nitrogen Fertilization of Corn Grown with a Cover Crop

John Sawyer, professor
Jose Pantoja, graduate assistant
Daniel Barker, assistant scientist
Department of Agronomy
Iowa State University

Introduction

Objectives of this project are to study corn nitrogen (N) fertilization requirement and corn-soybean yield response when grown in a rye cover cropping system. Multiple rates of N fertilizer are applied, with measurement of corn yield response to applied N and soybean yield with and without a fall planted winter rye cover crop. The study is being conducted at multiple research farms, with the intent for comparison of with and without a cover crop system across varying soil and climatic conditions in Iowa.

Materials and Methods

The first year was in 2009, with locations at the Ag Engineering/Agronomy Research Farm, Ames (Webster silty clay loam); Armstrong Research Farm, Lewis (Marshall silty clay loam); Southeast Research Farm, Crawfordsville (Mahaska silty clay loam); and the Northeast Research Farm, Nashua (Floyd loam). Each location is in a corn-soybean rotation. The winter rye cover crop ("Wheeler" variety) was no-till drill planted at 1 bu/acre in the fall of 2008 and 2009 as soon as possible after corn and soybean harvest (Oct 2-Oct. 20, 2008; Sept. 25-Oct. 9, 2009) after soybean and Sept. 30-Oct. 28, 2009 after corn). The rye cover crop growth was controlled with Roundup in the spring (Apr. 22-May 20, 2009; Apr. 19-23, 2010 before corn and Apr 22-May 20, 2009; Apr. 28-May 10, 2010 before soybean), with the targeted control at least seven days prior to corn planting and at or within one week of soybean planting. The corn and soybean crops were no-till planted in 30-inch rows (April 28- 29, 2010 for corn and May 4-20, 2010 for soybean). Actual rye control and corn-soybean planting occurred as conditions allowed.

Nitrogen fertilizer rates were applied early sidedress as urea-ammonium nitrate (UAN) solution (0, 40, 80, 120, 160, and 200 lb N/acre). The UAN was coulter-injected on 60-inch spacing. The corn hybrid and soybean variety were early season adapted for the location. Pest management practices were those typical for the region and rotations. Corn and soybean were harvested with a plot combine and yields corrected to standard moisture.

Results and Discussion

Rye growth and aboveground biomass (Table 1) was greater in 2010 than 2009 due to warmer spring temperatures. In general, the rye biomass production was greatest following soybean except at Crawfordsville where the rye control before soybean planting was much later due to wet soil conditions. At each location and averaged across locations there was no difference in soybean yield with or without the cover crop (Table 2) in both years, except at Ames in 2009 (Table 2). In 2009, the corn yield difference was 7 bu/acre lower with the cover crop across locations (Fig. 1). The corn grain yield was the same at two locations (Crawfordsville and Nashua) and lower with the cover crop at two locations (Ames and Lewis). Across locations and N rates in 2010, corn yield averaged 20 bu/acre lower when planted in conjunction with the rye cover crop. This difference can be seen in the lower yield at each N rate (Fig. 1). The yield difference was smallest at Nashua and largest at Ames. In 2010, lower corn yield with the cover crop was due to reduced stand establishment (Ames) and cold/wet conditions after planting (especially Ames and Crawfordsville). At Ames and Lewis, a fall armyworm infestation in the corn planted into the rye resulted in some plant damage and necessitated insecticide control. There was no interaction between N rate and cover crop in either year, indicating that the N response was the same either with or without the rye cover crop (Fig. 1). In 2010, the economic optimum N rate (EONR, 0.10 price ratio) was the same with or without the rye cover crop (180 lb N/acre). The EONR was high due to the wet 2010 season.

Acknowledgments

Appreciation is extended to the farm superintendents and their staff for assistance with this project. This project is supported in part by the Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation, through funds appropriated by the Iowa General Assembly.

Table 1. Aboveground winter rye biomass before controlling growth with herbicide, spring 2009 and 2010.

Cover Crop	Year	Ames	Crawfordsville	Lewis	Nashua
		----------------------------	lb/acre	---------------------------	
Before Corn	2009	149	86	309	35
Before Soybean	2009	289	1109	197	188
Before Corn	2010	1460 a	1000 b	1245 a	1020 a
Before Soybean	2010	765 b	2345 a	590 b	665 b

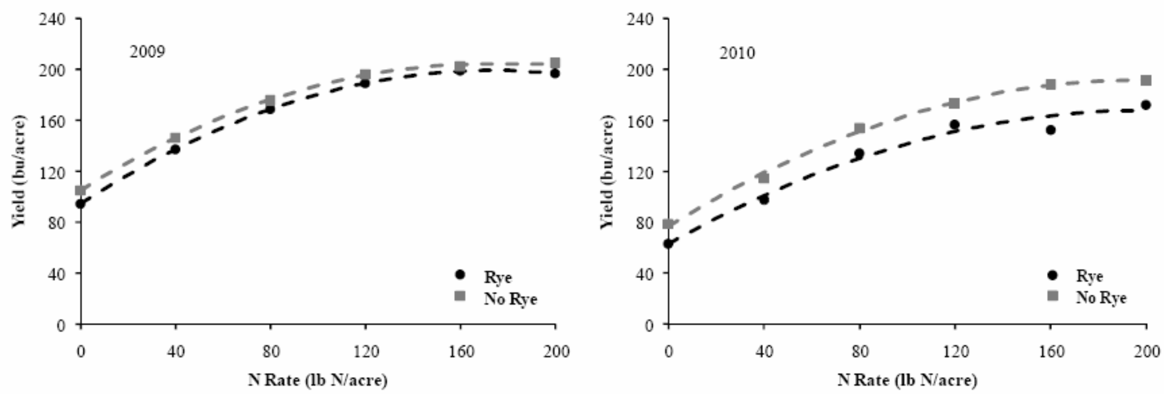
Average dry matter of four replicates. Means at a location within a year followed by the same letter are not significantly different.

Table 2. Soybean grain yield with and without rye cover crop, 2009 and 2010.

Cover Crop	Year	Ames	Crawfordsville	Lewis	Nashua
		---------------------------- bu/acre	----------------------------		
With Cover Crop	2009	58.4 a	69.0 a	65.2 a	56.5 a
Without Cover Crop	2009	54.2 b	69.8 a	66.0 a	57.8 a
With Cover Crop	2010	53.7 a	63.2 a	61.0 a	64.9 a
Without Cover Crop	2010	53.7 a	61.9 a	62.9 a	65.9 a

Yields at a location within a year followed by the same letter are not significantly different.

Figure 1. Corn grain yield response to N rate across locations with and without rye cover crop.



IOWA Learning Farms Newsletter

Mission Statement
The Iowa Learning Farms promote efficient agriculture production systems that result in agronomic, economic, and environmental improvements through increased awareness and adoption of conservation systems and ethics.

Volume 6 Issue 4 Fall 2010

Cover crops are taking off

By *Sarah Carlson, Practical Farmers of Iowa*

Cover crops are a great way to indulge a cash crop. "Retaining precious nitrogen and phosphorus on the farm allows for dying cover crop roots to release nutrients to new cash crop roots next year," says Barry Fisher, Indiana State Agronomist. Not only do cover crops hold those nutrients in place, but they also decrease erosion, keeping Iowa's precious soil on the farm. This fall, Iowa farmers seeded several thousands of acres of cover crops. The momentum for this practice has really been taking off, especially aerially seeded cover crops.

Iowa Learning Farms and Practical Farmers of Iowa, through funding from the Iowa Department of Agriculture and Land Stewardship, have completed the second year of a five year cover crop study with 11 farmers across Iowa. This on-farm research project looks at changes in soil, the yearly yields of cover crop biomass in the spring, and the cash crop yields each fall. Each farmer-partner planted a set of three no-cover strips and three cover-strips in a randomized, replicated design. In the spring, they bulk plant corn or soybeans; in the fall, yields of each plot are measured to see if cover crops are influencing the yields. Because the cover crop is planted in the same place each fall, the cumulative effect of having a cover crop on the same land will be measured.

Why plant cover crops?

Green plants that grow in the "brown" months help protect soil and water quality and maintain natural cycles for water, carbon, nutrients and soil organisms. Since the Midwest agricultural landscape is dominated by corn and soybeans, plants typically only grow for four to six months of the year and often are tilled between harvest and planting. This period without living plants leaves the soil, nutrients and water exposed and unprotected for up to eight months. With good management, this practice can successfully be added to Iowa farms.

Sarah Carlson is the Research and Policy Director at Practical Farmers of Iowa. Contact her at sarah@practicalfarmers.org or 515-232-5661, if you'd like to conduct on-farm research with cover crops or have a story to tell.

For more information on cover crops:
- Watch for the cover crops webinar, sponsored by ILF in early 2011
- Look for ILF's new how-to DVD on cover crops, due out in January
- attend the Iowa Water Conference, Iowa Learning Farms track, March 6-7, 2011, in Ames.

Top 10 cover crop management tips:

1. Overseed cover crops at or before soybean leaf yellowing or black layer of corn.
2. The planting rates for overseeding are 50% greater than the drilling planting rate.
3. Coincide overseeding with rainfall or adequate soil moisture conditions.
4. If fall harvest is early, follow the combine with the cover crop planter.
5. Winter rye/cereal rye is the most commonly used cover crop in Iowa.
6. Don't confuse winter rye/cereal rye with ryegrass.
7. A good alternative to planting winter rye as a cover crop—if corn is to be planted in the field the next spring—is to plant oats in the fall as a cover because they winterkill.
8. Hairy vetch, a legume, can be seeded with winter rye to increase nitrogen to the following crop.
9. Cover crops can decrease the amount of stored feeds needed for cattle when grazed in the spring.
10. Don't forget, cover crops need management. Check spring growth early to avoid too much growth.

IOWA STATE UNIVERSITY
University Extension

LEOPOLD CENTER

Michigan State Report for MCCC 2011

Organic and conventional research being conducted by Michigan State University Extension (MSUE) at the W. K. Kellogg Biological Station (KBS)

by Dale R. Mutch, Ph.D.
Senior District Extension Educator and Extension Specialist,Adjunct Professor CSS
Coordinator, KBS and Extension Land & Water Unit
NCR-SARE PDP State Sustainable Agriculture Coordinator

The MSUE Cover Crop Program at KBS began conducting organic research in 1996. In 1997 we had 12 acres certified organic through OCIA. We now have 15 acres certified organic. On these organic acres we conduct small plot research that is driven by farmer advisory groups.

In 1996 MSU had only a few researchers working with organic farmers. Over the past 15 years, that has changed tremendously. I believe MSU is one of the top Land Grant universities doing research for organic farming systems.

Some of the research projects being conducted at MSUE/KBS are:

1. **Evaluation of an organic no-till system for organic corn and soybean production.** A six-state (Iowa, Michigan, Minnesota, Wisconsin, North Dakota and Pennsylvania) long-term no-till organic cropping system project. We are measuring crop productivity, yields, soil quality and economic performance. The crimper/roller is being evaluated as a tool to enhance organic no-till practices. The crimper/roller (C/R) crushes the cover crop leaving a mulch that shades out weeds and prevents them from germinating. Following C/R we no-till drill or plant soybeans or corn into the mulch. Hairy vetch and cereal rye are being used in this study for both corn and soybean production. The no-till treatments are being compared to more traditional conventional tilled treatments for corn and soybeans. Each state also has the same experiment being conducted on an organic farmer's field. This is the third year of a four-year project.

2. **Controlling weeds using flame heat for organic farmers.** A study was initiated at KBS to evaluate the time of day for the best results of flame burning weeds in corn systems. A six-row flamer was used at 8 a.m., 12 noon, 4 p.m. and 8 p.m. in organic corn. The study was conducted over two years and the results will be presented by Dr. Christy Sprague at this year's MOSES conference.

3. **Evaluation of organic potassium sources for alfalfa.** In 2009 the field had been a crop of organic no-till soybeans with rye, and had cereal rye and clover growing, making it necessary to moldboard plow. In 2010, the first year of this project was spent establishing the alfalfa. A field that had been farmed organically for the past three years was moldboard plowed on March 19. The untreated alfalfa seed was donated to the project by Cisco Seeds.

   The field was planted to alfalfa at 28 lbs/A with a nurse crop of oats at 1 bu/A on April 12. Timely rains and warm weather resulted in good establishment of the oats and alfalfa. The oats became competitive with the alfalfa by late May, from advisement of the forage specialist at MSU, the oats were mowed off and removed on June 11. Weeds overtook the 2-3 inch alfalfa after mowing, and were flail mowed and removed on August 6. An excellent alfalfa stand resulted from these management strategies. In 2011, sulphate of potash (SOP, Great Salt Lake Minerals Corporation) and dairy slurry as potassium sources will be compared to an untreated control for their influence on alfalfa yield and quality.

4. **Evaluation of eight legume cover crops no-till drilled into wheat stubble and their influence on organic corn yield.** Since nitrogen is often a limiting factor for organic corn, a study was conducted to compare several legumes no-till drilled after wheat harvest for their nitrogen contribution to corn the following season. Red clover, hairy vetch and crimson clover resulted in the highest corn yields in 2010 at 117, 105 and 103 bu/A respectively. We drilled Austrian winter pea at two rates, 60 and 90 lbs/A, where the 90 lb. rate resulted in a 5 bushel corn yield gain of 96 bu/A, as compared to 60 lbs/A rate at 91 bu/A. The sweet clover treatment resulted in a corn yield of 97 bu/A, which was comparable to the 90 lb/A Austrian winter pea treatment at 96 bu/A. Vernal alfalfa, chickling vetch and the no cover crop control had the lowest yield of 82, 85 and 84 bu/A respectively.

   Our results indicate that in Michigan on sandy loam soils, red clover provided the best corn yield compared to the other tested legumes.

5. **Brassica mustard as a cover crop for weed control in the spring**. This study involves using two varieties of mustard—Tilney and Ida Gold—which were planted at four separate dates. A quadrant of no cover crop (bare ground) was left in each plot to evaluate weed pressure without cover crops. Biomass samples were taken during the spring. Cover crop biomass was compared to weed biomass. In 2010 we had an early spring and thus allowed us to plant earlier than most seasons. These data should help farmers evaluate mustards as a spring weed control tool. Three states are conducting this experiment—Michigan, New York and Illinois.

6. **Organic dry bean production and weed control.** A dry bean variety and production trial is being initiated in 2011. We have tested 32 varieties of dry beans over the past three years on our certified organic soil. A more expansive research project at KBS and on organic farms will be evaluated over the next four years.

   Other research projects being conducted by the MSUE Cover Crop group at sites other than KBS are organic pumpkins, organic tomatoes, 13 oilseed radish and seven other brassicas variety trial with NRCS and University of Minnesota.

Other Cover Crop Research conducted in 2010:

- Three on farm trials were conducted utilizing the slurry seeding method. Oilseed Radish, oats + turnip and a control without covers were compared. These were field size trials and each treatment was replicated four times. The slurry seeding was compared to drilling the same cover crops and applying liquid manure was the Aerway applicator. One on farm trial; used ceareal rye only which was applied through the slurry seeder.

- An experiment evaluating three rates of nitrogen fertilizer for rye: which was crimped and rolled in the spring, was planted with drilled round-up ready soybeans. There was four replications in a RCB design.

Dr. Dean Baas Cover Crop decision Tool:

- The cover crop decision tool has been completed for Michigan field crops. Four meeting with specialists and educators were conducted to fit cover crop data into the tool for Michigan.
- A vegetable cover crop decision tool has been initiated. We have had one meeting to begin this process.

Dr. Sieg Snapp LTER/KBS cover crop long term research:

- Long-term row crop experimentation at the Kellogg Biological Station Long-term Ecological Research (KBS LTER) has shown that integration of cover crops in a corn-soybean-wheat rotation reduces the nitrogen (N) fertilizer requirement by half. Soil organic matter was enhanced by about 20% after 10 years, and remains higher than conventionally grown crops after 20 years. Experiments are being conducted to test the benefits and challenges associated with growing cover crops at larger scales. This includes a farm-wide experiment at KBS involving 27 fields that are being managed with and without cover crops. Modeling is also being used to evaluate impacts of cover crops on soil and water properties over various temporal and spatial scales.

  Profitability and adoption of cover crops has been investigated, where farmers were asked the extent of payments that would be required to compensate for the opportunity costs of growing cover crops that require a later time frame for planting cash crops. Concerns of farmers - with the notable exception of organic farmers- were substantial regarding the inability to grow long-season, high yield potential varieties of cash crops in a cover crop diversified systems (due to delayed planting after cover crops are incorporated in the spring). There was considerable interest at the same time in conservation tillage cropping systems that combined cover crops with strip or other types of reduced tillage so as to maximize soil organic matter building properties associated with cover crops. New research is being initiated on combining various types of conservation tillage and zonal tillage with cover crop systems.

State/Province Report: Ontario, Canada

Cover crops continue to be used by a wide variety of Ontario growers for diverse reasons: from pest suppression, nitrogen production to wind erosion protection. The pressure on nitrogen costs did renew more interest in using red clover cover crops to produce nitrogen. Timely rains and good growing conditions across much of Ontario resulted in many good stands of clover fall 2010.

In 2010- 2011 cover crops were profiled at a number of venues including:

- brassica cover crop demo at Canada's Outdoor Farm Show
- Cover Crop Open House/plot tour – Ridgetown Campus
- Southwest Agricultural Conference - Ridgetown

Project	**Lead**
Impact of Cover Crops on Processing Tomato: Yield, Quality, Pest Pressure, Soil Health, and Economics.	Dr. Laura Van Eerd, University of Guelph, Ridgetown Campus lvaneerd@ridgetownc.uoguelph.ca
Underseeding cover crops to maximize biomass and ground cover in seed corn.	Dr. Laura Van Eerd, University of Guelph, Ridgetown Campus lvaneerd@ridgetownc.uoguelph.ca
Filling in the knowledge gaps of N dynamics in horticultural-cover crop systems: Utilizing lysimeters. Cucumber rotation	Dr. Laura Van Eerd, University of Guelph, Ridgetown Campus lvaneerd@ridgetownc.uoguelph.ca
Evaluation of zone tillage and cover crops as weed management practices in field vegetables.	National Reduced Risk IWM Vegetable Working Group – Kristen Callow, OMAFRA kristen.Callow@ontario.ca
Assessing biofumigant cover crops: practicality, effectiveness, impact on soil health	Anne Verhallen, OMAFRA anne.verhallen@ontario.ca
Bringing cover crop decision-making tools and knowledge to Ontario growers and agribusiness personnel.	Dr. Laura Van Eerd, University of Guelph, Ridgetown Campus Anne Verhallen, OMAFRA
Cover crops in pepper plasticulture for soil improvement.	Anne Verhallen/Kristen Callow, OMAFRA

Ontario

UNIVERSITY of GUELPH
RIDGETOWN CAMPUS

Publications:

O'Reilly, K.A., D.E. Robinson, R.J. Vyn, and L.L. VAN EERD. 20xx. Weed Populations, Sweet Corn Yield and Economics under Fall Cover Crop Systems. Weed Technology. WT-D-10-00051 Submitted 10 March 2010 –Accepted

AAFC Factsheet
Integrated Weed Management: Using Cover crops in Field Vegetable Production

Revision of OMAFRA Cover Crop Website content underway - **http://www.omafra.gov.on.ca/english/crops/facts/cover_crops01/covercrops.htm**

Ontario

UNIVERSITY of GUELPH
RIDGETOWN CAMPUS

Midwest Cover Crop Council
2011 State/Province Report

State/Province Name: Wisconsin

Contact Information
Name: Ken Albrecht
Organization: University of Wisconsin-Madison
E-mail: kaalbrec@wisc.edu
Telephone: 608-262-2314

Research:

Water balance and nitrate leaching under corn in kura clover living mulch (Tyson Ochsner, Ken Albrecht, John Baker, Todd Schumacher, and Bob Berkevich)

Kura clover living mulch has potential to improve the environmental impact of corn production, especially in the context of corn silage or stover harvest. Our objective was to determine the effects of kura clover living mulch on the water balance and nitrate leaching under corn near Arlington, WI. Treatments in the 2.5-yr experiment were N-fertilized no-till corn following killed kura clover as the control and no-till corn in living mulch with fertilizer rates of 0 and 90 kg N ha^{-1} yr^{-1}. Soil water storage was 37 to 50 mm lower under the living mulch in the spring, while the control experienced 29 to 36 mm greater soil water depletion in the summer. Evapotranspiration was similar across treatments, except in May when it was greater under the living mulch by 11 to 41 mm. The living mulch did not appreciably reduce drainage. Nitrate-N storage in the soil profile and nitrate-N concentrations in the soil solution at 1-m depth were reduced under both living mulch treatments relative to the control. Flow-weighted nitrate-N concentrations were 23 mg L^{-1} for the control, 17 mg L^{-1} for the living mulch with 90 kg N ha^{-1} yr^{-1}, and 6 mg L^{-1} for the living mulch with 0 kg N ha^{-1} yr^{-1}. Total nitrate-N leached was reduced 31% and 74% relative to the control under the living mulch with 90 and 0 kg N ha^{-1} yr^{-1}, respectively.

Evaluating organic fertility management systems for an organic processing vegetable rotation (AJ Bussan and Nick Goeser)

Research focuses on the evaluation of several organic fertility management systems within an organic processing vegetable rotation (potatoes, sweet corn and snap beans) for cover crop residue nitrogen mineralization rates and nitrogen release timing, soil plant-available nitrogen pools, nitrogen leachate losses, in-season crop growth and development, in-season crop nitrogen uptake, crop nitrogen use efficiency, and end of season yield and quality. Fertility management systems utilize combinations of composted poultry manure, fall planted perennial cover crops for use as a green manure, and spring planted annual green manure crops. Over 3 years, results indicate an integrated composted poultry manure with annual cover crop system performs well over several measured parameters including cover crop residue nitrogen mineralization rates and nitrogen release timing, soil plant-available nitrogen quantities available to crops, in-season crop growth and development, in-season crop nitrogen uptake, and end of season yield and quality.

Soil erosion and nutrient losses kura clover living mulch (Arthur Schwab and Ken Albrecht)

We are measuring the effect of kura clover (*Trifolium ambiguum* M. Bieb) living mulch on surface water runoff, soil erosion, and phosphorus and nitrogen losses during simulated large storm events (~3 in. $hour^{-1}$) in southwest Wisconsin at a moderately sloped site (~10%). The experiment consists of four treatments: standard no-till corn silage (*Zea Mays* L.) and corn in kura clover living mulch, each with and without winter rye (*Secale cereale* L.) cover crop. The rye treatments are included in order to compare the environmental effects of kura clover living mulch to those of annual winter rye cover cropping. Simulations were performed throughout the 2010 growing season and a final set of simulations will occur in the spring of 2011. Preliminary results show a large (more than 50%) reduction in both soil erosion and phosphorus runoff between the standard no-till treatment and kura clover living mulch ($p < 0.001$).

Green manure crops for organic systems (Josh Posner, John Hall, Janet Hedtcke)

Green manure crops for organic grain systems (corn-soy-wheat/clover rotation) have been used on the Wisconsin Integrated Cropping Systems Trial (WICST) since 1991 at 2 sites in southern Wisconsin. Inter-seeded red clover drilled into winter wheat (in early spring) was the primary green manure crop until 2004; in 2005, we shifted to a sequential seeding of berseem clover and oats after wheat harvest. Without any summer tillage after wheat harvest, we were finding increasing foxtail and quackgrass pressure in the following corn crop. We anticipated that we would fix less N with the later seeded cover crop and have a period when the field would be ―open" with the potential for increased erosion. However, late July is usually a hot and dry part of the season and an ideal time to break the weed growth cycle—especially to desiccate quackgrass rhizomes. The inter-seeded red clover at plowdown averaged across the 20 site-yrs was 2.4 t DM/a (1.6 t/a aboveground +0.8 t/a belowground) with 127 lbs/a N (16 of the 20 site-yrs had an N credit over 100 lbs/a). The shorter season oat/berseem cover crop (planted in mid-August) resulted in an average of 2.2 t total DM/a and about 80 lbs N/a (80% from oats, 20% from clover). However, in this shorter data set with berseem clover/oats, 2 of 6 site-yrs had biomass yields less than 1.1 t DM/a due to a dry period following planting (less than 1" of rain in the 3 weeks after planting). We did find however that ground cover was quickly re-established due to inclusion of oats in the cover crop mix. Although the comparison in this report is not from side-by-side plots, biomass yields and N levels from a sequentially seeded oat/berseem following wheat (6 site-years) yielded about 80% that of inter-seeded red clover (20 site-years). Although not solely due to reduced weed pressure, organic corn yields from 2002 to 2005 averaged 106 bu/a while from 2006 to 2009 the average was 163 bu/a. Further research on our cover crops is posted on the WICST website: http://wicst.wisc.edu/category/cover-crops-project/

Organically-managed no-tillage rye-soybean systems: Agronomic, economic, and environmental assessment (Emily Bernstein, Joshua Posner, David Stoltenberg, and Janet Hedtcke)

A major challenge that organic grain crop growers face is weed management. The use of a rye cover crop to facilitate no-tillage organic soybean production may improve weed suppression and increase profitability. We conducted research in 2008 and 2009 to determine the effect of rye management (tilling, crimping, and mowing), soybean planting date (mid-May or early June), and soybean row width (76 or 19 cm), on soybean establishment, soil moisture, weed suppression, soybean yield, and profitability. Soybean establishment did not differ between tilled and no-tillage treatments; and soil moisture measurements showed minimal risk of a drier soil profile in no-tillage rye treatments. Rye mulch treatments effectively suppressed weeds, with 75% less weed biomass than in the tilled treatment by mid-July. However, by this time, no-tillage soybean competed with rye regrowth, were deficient in Cu, and accumulated 22% as much DM and 28% as much N compared to the tilled treatment. Soybean row width and planting date within no-tillage treatments impacted soybean productivity but not profitability, with few differences between mowed and crimped rye. Soybean yield was 24% less in the no-tillage treatments than the tilled treatment, and profitability per hectare was 27% less. However, with fewer labor inputs, profitability per hour in no-tillage rye treatments was 25% greater than in tilled soybean; in addition, predicted soil erosion was nearly 90% less. Although soybean yields were less in no-tillage rye mulch systems, they represent economically viable alternatives for organic producers in the Upper Midwest.

Managing spring-seeded legume cover crops in diverse vegetable production systems (Matt Ruark, Kevin Shelley, and Jim Stute

Utilization of spring-seeded legumes to provide nitrogen (N) to vegetables has not been fully evaluated in Wisconsin climates. Short-season vegetables (60 to 90 day growing season) are high value and if managed organically require annual applications of organic N. In 2009 and 2010, field research was conducted in Jefferson County, Wisconsin to evaluate how to best manage spring-seeded legumes to maximize agronomic benefit. The experimental design was a randomized, complete block – split plot with four replications. The main plot factor was N input and there were five main plot treatments: no N input, composted chicken manure, berseem clover, crimson clover and chickling vetch. The legume cover crops were planted in early April. The split plot factor was timing of plow-under. The legumes were plowed under 4, 6 and 8 weeks after planting and crops were planted two weeks after plow-under. The crop rotation evaluated was a buckwheat-red beet-kidney bean rotation. Preliminary results suggest that benefits of spring-seeded cover crops can be maximized after only 4 weeks of growth. Most of the above ground biomass production of the cover crops had occurred by week 4, which produced enough N to satisfy the N needs of the crops (based on the green manure credits suggested from UW-Extension guidelines). During the growing season of 2009 and 2010, soil samples (30 cm) for ammonium and nitrate and whole plant buckwheat samples were collected six to ten times during the growing season to evaluate N dynamics and synchrony between N uptake and soil N availability during the growing season. Samples are currently being processed. Results from this study provides information for fresh market vegetable growers (conventional, CSA and organic) to best manage legume cover crops on their fields.

Developing Carbon-Positive Organic Systems through Reduced Tillage and Cover Crop-Intensive Crop Rotation Schemes (Kathleen Delate, IA; Jeff Moyer, Rodale Inst.; Pat Carr, ND; Erin Silva, WI; Jim Riddle, Paul Porter, MN; Dale Much, MI)

The long-term goals of the project are to maintain and enhance soil quality in organic systems by maximizing cover, minimizing erosion, and improving soil ecology and biological processes to reduce environmental and economic costs and optimize yield stability. Research and on-farm demonstrations will be utilized to develop these goals, in addition to disseminating results in classroom and Extension programs. Cover crops involved in this study include winter rye and hairy vetch.

Removing the Barriers to No-Till Organic Farming (Pat Carr, ND; Erin Silva, WI; Kathleen Delate, IA; Paul Porter, MN)

The negative consequences of tillage on soil health have stimulated interest in no-till organic farming. A coordinated, multi-state effort will be used to establish management recommendations when tillage is eliminated in organic farming systems. Fallvseeded cover crops (rye, hairy vetch, Austrian winter pea, winter barley, and winter triticale) will be screened for early maturity and above-ground biomass production, and farmer-researcher teams will refine a method for killing cover crops consistently and economically in a no-till organic system. The impact of cover crops on soil health and subsequent crop performance will be determined.

Extension/Education:

Ken Albrecht, Jadwiga Andrzejewska and Francisco Contreras-Govea. 2010. *Yield and unique quality characteristics of oat forage in autumn.* Wisconsin Crop Improvement Association, Madison, WI, 1 December. 50 WCIA members attended.

Ochsner, T.E., K.A. Albrecht, T.W. Schumacher, J.M. Baker, and R.J. Berkevich. 2010. Water balance and nitrate leaching under corn in kura clover living mulch. Crops and Soils 29:27-31. https://www.certifiedcropadviser.org/files/certifications/certified/education/self-study/exam-pdfs/257.pdf

Kevin B. Shelley and Jim Stute, 2010, *Why Plant Cover Crops in Wisconsin Crop Rotations.* Presentation at the 2010 Wisconsin Crop Management Conference, January 14, Alliant Energy Center, Madison, WI. 125 Crop production professionals and educators attended

Matt Ruark, Dick Wolkowski, and Kevin Shelley, *Your Cover Crop Options in Wisconsin.* Arlington Agronomy and Soils Field Day, August 25. 100 farmers, educators and crop production professionals in attendance.

Silva, E. 2009. Developing Carbon-Positive Organic Systems through Reduced Tillage and Cover Crop-Intensive Crop Rotation Schemes. UW Organic Agriculture Field Day, Arlington Agricultural Research Station. 100 attendees.

Silva, E. 2010. Rolled Rye/Soybean System Demonstration on a Working Organic Farm. Field days in June 2010 and September 2010 at Ed Knoll's farm in Sparta WI (partner with Vernon County LWCD and MOSES).

Publications:

Ochsner, T.E., K.A. Albrecht, T.W. Schumacher, J.M. Baker, and R.J. Berkevich. 2010. Water balance and nitrate leaching under corn in kura clover living mulch. Agron. J. 102:1169-1178.

Sawyer, J.E., P. Pedersen, D.W. Barker, D.A.R. Diaz, and K.A. Albrecht. 2010. Intercropping corn and kura clover: Response to nitrogen fertilization. Agron. J. 102:1-7.

Bernstein, E. R., J. L. Posner, D. E. Stoltenberg, J. L. Hedtcke. 2011. Organically-managed, no-tillage winter rye-soybean systems: agronomic, economic, and environmental assessment. Agron. J. (In press)

Albrecht, K.A., and J. Andrzejewska. 2010. Intercropping corn in kura clover living mulch. p. 26-28. *In* Proc. Production and Utilization of Corn for Food and Industrial Purposes, Posnan, Poland, 6-7 May 2010.

Shelley, Kevin B. and Paul D. Mitchell, 2010, *Cover Crops and Crop Insurance*, Crop insurance fact sheet series on P. Mitchell website: http://www.aae.wisc.edu/mitchell, Pages 1-2.

Shelley, Kevin B. and Paul D. Mitchell, 2010, *Cover Crops and Crop Insurance*, September 2010 edition of the Wisconsin Crop Manager newsletter: http://ipcm.wisc.edu/.

Shelley, Kevin B. and Jim Stute, 2010, *Why Plant Cover Crops in Wisconsin Crop Rotations*, proceedings of the 2010 Wisconsin Crop Management Conference (January 2010).

Bernstein, E. R., D. E. Stoltenberg, J. L. Posner, J. L. Hedtcke. 2010. Weed suppression in transitional organic, no-tillage winter rye-soybean systems. North Central Weed Sci. Soc. Abstr.

Bernstein, E. R., J. L. Posner, D. E. Stoltenberg, J. L. Hedtcke. 2010. Organic no-tillage winter rye-soybean systems: agronomic, economic, and environmental assessment. Proc. Wisc. Crop Management Conf. 49:152-158.

Bernstein, E. R., D. E. Stoltenberg, J. L. Posner, and J. L. Hedtcke. 2009. Multitactic weed management in organic soybean production systems. North Central Weed Sci. Soc. Abstr. 64:65.

Bernstein, E.R., J.L. Posner, D.E. Stoltenberg, and J.L. Hedtcke. 2009. Organic no-till winter rye-soybean systems: agronomic, economic and environmental assessment. ASA-CSSA-SSSA International Annual Meetings.

MCCC Cover Crop Selection Tool Update

Dean G. Baas
Michigan State University Extension and W.K. Kellogg Biological Station

Abstract

This project is a collaborative effort of the Midwest Cover Crops Council (MCCC), a diverse group from academia, production agriculture, non-governmental organizations, commodity interests, private sector, and federal and state agencies with members from Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, Ohio, Ontario and Wisconsin. The MCCC seeks to significantly increase the amount of continuous living cover on the Upper Midwestern agricultural landscape by building a vital and effective regional collaboration of agencies, individuals and the general public.

Since its inception, the MCCC has been committed to developing a web-based tool (Fig. 1) to support cover crop decision-making. Tool development is based on the SAN/SARE handbook *Managing Cover Crops Profitably* by Andy Clark, detailing cover crops and their application at the national scale. The tool's information is more detailed and specific for the Midwest region and its states/provinces, compiling existing information and research results, gleaned from experts in each state. This web-based tool has been developed to assist farmers in identifying species and production systems appropriate for their locations that meet their goals for using cover crops. Cover crop selections will be suggested that are appropriate within their crop rotation systems and that minimize or identify the agronomic and economic risks associated with their use. Initially the MCCC decision tool has been developed for row crop agriculture. Michigan is leading efforts to develop the tool for vegetable production. The tool is available from the homepage of the MCCC website at www.mccc.msu.edu under Cover crops selector.

Update

Following is a brief update of the status of the MCCC decision tool project:

1. Frost/freeze climate data for the MCCC region has been completed and added to the decision tool.
2. Teams from Indiana, Ohio and Michigan through a series of meetings have completed development of their state databases.
3. The web version of the MCCC decision tool was implemented on February 10, 2011for Indiana, Ohio and Michigan, and is available on the MCCC website.
4. State meetings have been initiated for Minnesota and Wisconsin, and development of their state databases has started.
5. A team has begun development of a vegetable cover crop decision tool for Michigan.
6. Funding is being requested from the Great Lakes Regional Water Program to develop the row-crop decision tool for Illinois and the vegetable tool for Wisconsin.
7. Development meetings need to be scheduled for Ontario and Iowa row-crop decision tools and Ontario's vegetable decision tool.
8. Refinements to the web-based tool are underway and will continue based on feedback from users.

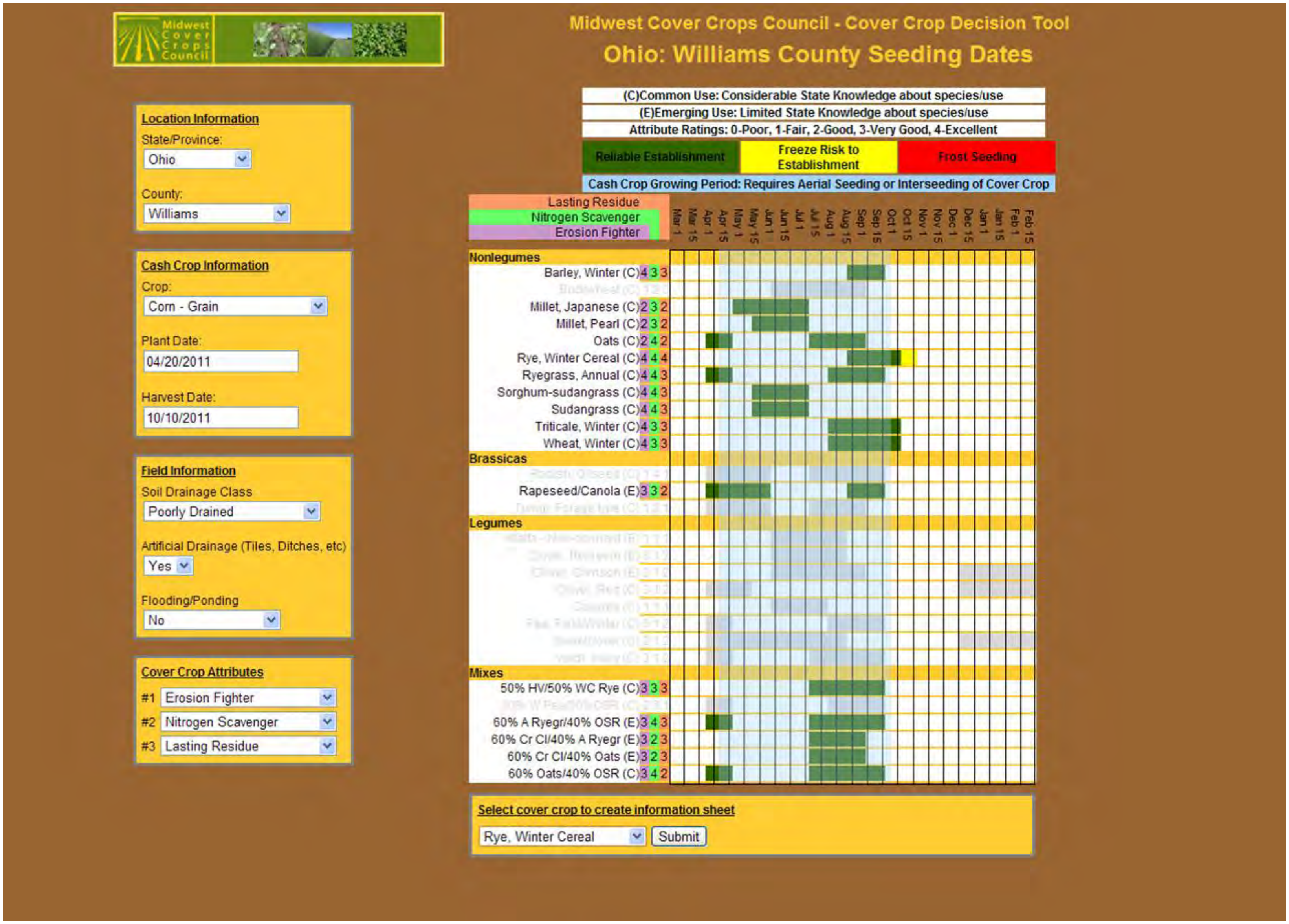


Figure 1: Screen-shot of the web-based cover crop decision tool for Indian, Ohio and Michigan

MCCC Cover Crop Selection Tool Presentation Summary

Dean G. Baas
Michigan State University Extension and W.K. Kellogg Biological Station

Background

This project is a collaborative effort of the Midwest Cover Crops Council (MCCC), a diverse group from academia, production agriculture, non-governmental organizations, commodity interests, private sector, and federal and state agencies with members from Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, Ohio, Ontario and Wisconsin. The MCCC seeks to significantly increase the amount of continuous living cover on the Upper Midwestern agricultural landscape by building a vital and effective regional collaboration of agencies, individuals and the general public.

Since its inception, the MCCC has been committed to developing a web-based tool (Fig. 1) to support cover crop decision-making. Tool development is based on the SAN/SARE handbook *Managing Cover Crops Profitably* by Andy Clark, detailing cover crops and their application at the national scale. The tool's information is more detailed and specific for the Midwest region and its states/provinces, compiling existing information and research results, gleaned from experts in each state. This web-based tool has been developed to assist farmers in identifying species and production systems appropriate for their locations that meet their goals for using cover crops. Cover crop selections will be suggested that are appropriate within their crop rotation systems and that minimize or identify the agronomic and economic risks associated with their use.

Problem Statement

Considerable local cover crop information has been generated by universities, agricultural organizations and farmers, however this information: 1) resides within multiple organizations and systems; 2) varies in form and format; 3) is often difficult to locate; and 4) does not lend itself to making cover crop decisions. A regional system is required that: 1) consolidates local information; 2) provides a common format; 3) implements a database; 4) is web-based; and 5) supports cover crop decision-making.

Funding

Funding for the development of the cover crop decision tool system and the development of Indiana and Ohio row-crop databases were funded through an NRCS conservation innovation grant. Development of the Michigan databases for row-crops and vegetables was funded through a Michigan State University Project GREEEN grant. The Great Lakes Regional Water Program is funding the development of decision tool databases for Minnesota and Wisconsin.

Development Process

The MCCC decision tool system and the state/province databases are being developed with a state/provincial team of cover crop experts including university researchers, extension educators, agency representatives, NGO representatives, agri-business representatives and farmers. These teams meet face-to-face and by Adobe connect to identify information (data, ratings and references) for 104 categories for each cover crop selected for inclusion in their state/province decision tool. The databases have been completed for Indiana, Ohio and

Michigan row-crops. Development is underway for Minnesota and Wisconsin row-crop databases. Michigan has begun developing a vegetable cover crop decision tool and the associated database.

The MCCC Decision Tool

The web version of the MCCC decision tool was implemented for Indiana, Ohio and Michigan on February 10, 2011. It is available from the MCCC website (www.mccc.msu.edu) under the Cover crops selector menu item (see screen shot in figure 1 below). When the Cover crops selector item is clicked, an introduction page and instructions for the use of the decision tool are displayed. The actual decision tool is accessed from this page.

How the Decision Tool Works

Please refer to Figure 1 in reference to the descriptions for the various options for and the displays presented by the decision tool.

Location Information

State/Province and county information must be entered from the drop-down menus. Once entered, seeding date bars are displayed for each of the cover crops included in that state/province database. Bars are displayed with the following colors:

> Green – Reliable Establishment: Cover crops planted during these periods can be expected to reach sufficient growth to produce the benefits from growing a cover crop.
> Yellow – Frost Risk to Establishment: Cover crops planted during these periods will grow, but frost may limit their growth and the benefits that may be produced.
> Red – Frost Seeding: Certain cover crops can be frost seeding during these periods when conditions are right.

Specifying the county adjusts seeding dates based on average spring and fall frost/freeze dates for a hard frost (28 degrees F).

Cash Crop Information

Name, anticipated planting date and anticipated harvest date can be entered for the cash crop to be grown. The period between the two dates is shaded in blue indicating that a cover crop seeded during this period will require aerial seeding or some other interseeding technique.

Field Information

The Soil Drainage Classification can be entered from the County Soil Survey for the field being considered. In addition, Artificial Drainage and Ponding/Flooding can be specified. Upon completion of any or all of these parameters, the decision tool will screen the cover crops graying out the ones that are not appropriate under the specified conditions. The remaining cover crops may be considered for use for this field.

Cover Crop Attributes

Drop down menus are provided to specify up three cover crop attributes that the farmer would like the cover crop to have. These include nitrogen source, nitrogen scavenger soil builder, erosion fighter, weed fighter, good grazing, quick growth, lasting residue, forage value, seed/grain value and interseed w/cash crop. Upon select of 1-3 attributes, the decision tool screens for cover crops that have ratings of at least good for all attributes selected. In addition the attribute rating for each cover crop is displayed to further help in the selection processes. Cover crops with less than a good rating are grayed out. The remaining cover crops may be considered for use for this field to deliver the desired benefits.

Cover Crop Information Sheet

An information sheet can be created from the list of appropriate cover crops. This sheet contains the information specified on the input page and the following information:

- Considerations for using this cover crop in this state/province
- Planting Information
- Termination Information
- Performance and Roles
- Cultural Traits
- Potential Advantages
- Potential Disadvantages
- References
    - Cover crop information from Managing Cover Crops Profitably
    - State, regional and out of region bulletins and publications referring to the use of the selected cover crop

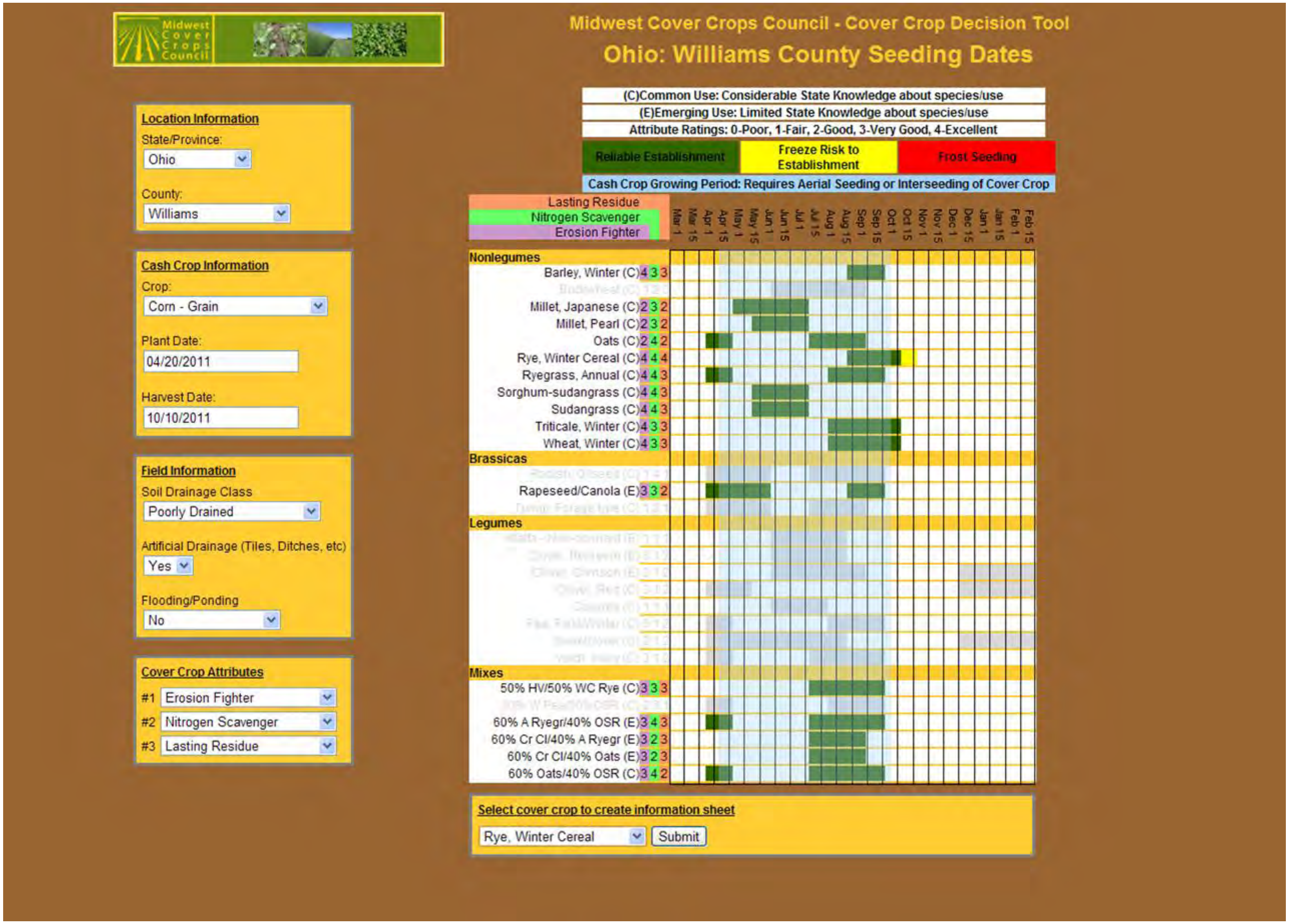


Figure 1: Screen-shot of the web-based cover crop decision tool for Indian, Ohio and Michigan

Red Clover Nitrogen Contribution For Corn

Alan Sundermeier
Ohio State University Extension, Bowling Green, Ohio

THE OHIO STATE UNIVERSITY EXTENSION

Abstract

The use of clover as a nitrogen source for corn production may allow producers to reduce commercial nitrogen rates. To evaluate the effect of clover cover crop and nitrogen rates on corn production, an experiment was conducted at the Ohio State University Research Farm in Wood County, Ohio. The entries were replicated four times in a randomized complete block design. All systems in this comparison were no-till. Medium red clover was frost seeded in wheat on April 18, 2008. After wheat harvest, clover was allowed to grow until 10-29-08 when Roundup and Clarity herbicides were applied to kill the clover. Corn was planted at the same time in all plots as no-till on 5-12-09. Sidedress nitrogen was applied on 6-16-09 at V6 growth stage. All plots harvested the center two rows. Red clover biomass analysis from late fall 2008 showed 120 lb/acre of available nitrogen. Chlorophyll content of corn on 8-8-09 ranged from 24.1 SPADD meter reading for no clover and no nitrogen to 53.1 with clover and 160 lb/acre nitrogen applied. In all comparisons, clover increased chlorophyll content of corn leaves. Soil nitrate nitrogen tested on 8-8-09 ranged from 2.7 ppm for no clover and no nitrogen to 22.7 ppm with clover and 160 lb/acre nitrogen applied. In all comparisons, corn yields were significantly increased when clover was included. An economic analysis showed that when clover was used, corn yield increased 9.9 bu/acre with a net return of $13.65 above costs of clover.

Nutrient Content Red Clover

Red Clover Topgrowth in Fall
1.5 ton /ac

N = 120 lb/ac P = 8 lb/ac K = 77 lb/ac

Corn Yield

2009 NW Ag Research Station

Red Clover, N Rate, No-till

Cover Crop	Sidedress N Rate	Corn Yield	
No clover	0	39.9	A
Clover	0	47.6	B
No clover	80	93.3	C
Clover	80	103.2	D
No clover	160	129.5	E
Clover	160	135.4	E
LSD (0.10)	6.3		

Clover Underseeded in Wheat

A typical method to establish red clover is applying early spring nitrogen fertilizer to wheat with clover seed included. Frost heaving and rain incorporates seed into soil. Clover grows underneath wheat.

Chlorophyll Content

SPADD meter reading 8-8-09

No Clover	O Nitrogen	24.1
Clover	O Nitrogen	26.7
No Clover	80 lb. N	47.9
Clover	80 lb. N	50.1
No Clover	160 lb. N	50.6
Clover	160 lb. N	53.1

Nitrogen in Soil

Soil Nitrate ppm 8-8-09

No Clover	O Nitrogen	2.7
Clover	O Nitrogen	5.2
No Clover	80 lb. N	4.7
Clover	80 lb. N	4.5
No Clover	160 lb. N	13.5
Clover	160 lb. N	22.7

Economics

<u>Cost of Clover Analysis</u>:

At 80 lb/ac sidedress nitrogen clover cover crop increased corn yield by 9.9 bu/ac.

Value of Corn = 9.9 bu/ac x $3.50 /bu = $ 34.65
Cost of clover = 12 lb/ac x $1.75/lb = $ 21.00

Net return on clover = $ 13.65

For more information contact

Alan Sundermeier,
Ohio State University Extension
Wood County
639 Dunbridge Rd., Suite 1
Bowling Green, Ohio 43402
Ph 419-354-9050
sundermeier.5@osu.edu

Clover Cover Crop & Nitrogen Rate Effect on Corn Production

Alan Sundermeier, Agriculture & Natural Resources Extension Agent
Dr. Robert Mullen, Ohio State University Extension Fertility Specialist

Objective

To evaluate the effect of clover cover crop and nitrogen rates on corn production.

Background

Cooperator:	O.A.R.D.C. NW Branch
County:	Wood
Nearest Town:	Hoytville
Drainage:	Tile, well-drained
Soil type:	Hoytville, clay
Tillage:	notill
Previous Crop:	wheat
Variety:	Becks 5335HXR

Soil test:	
Fertilizer:	300 lb/ac 10-27-25, urea at planting, sidedress 28% N
Planting Date:	5-12-09
Planting Rate:	30,000
Row Width:	30 in.
Herbicides:	Lexar, Honcho
Harvest Date:	11-4-09

Methods

The entries were replicated four times in a randomized complete block design. Plot size- 10 x 70 feet each entry. Harvest data was collected from the center rows. All systems in this comparison were no-till. Medium red clover was frost seeded in wheat on April 18, 2008. After wheat harvest, clover was allowed to grow until 10-29-08 when Roundup and Clarity herbicides were applied to kill the clover. Corn was planted at same time in all plots as no-till. Sidedress nitrogen was applied on 6-16-09 at V6 growth stage. All plots harvested center two rows. Wheat straw was chopped and left on plots. At corn planting time, soil moisture levels were similar in all treatments.

Results

Cover Crop	Sidedress Nitrogen Rate	Corn Yield bu/ac	
No clover	0	39.9	A
Clover	0	47.6	B
No clover	80	93.3	C
Clover	80	103.2	D
No clover	160	129.5	E
Clover	160	135.4	E
	LSD (0.10)	6.3	

Summary

<u>Cost of clover analysis</u>:

At 80 lb/ac sidedress nitrogen clover cover crop increased corn yield by 9.9 bu/ac.

9.9 bu/ac x $3.50 /bu = $ 34.65
cost of clover – 12 lb/ac x $1.75/lb = $ 21.00
net return on clover = $ 13.65

At 160 lb/ac sidedress nitrogen, the clover cover crop increased corn yield but it was not significantly different from no clover treatments.

<u>Cost of nitrogen analysis</u>: $ 0.66/lb Nitrogen

No clover	80 lb N = $52.80	93.3 bu/ac x $3.50 /bu = $326.55	$ 273.75 net
No clover	160 lb N = $105.60	129.5 bu/ac x $3.50/bu = $453.25	$ 347.65 net

Positive return from 80 additional lb/ac nitrogen – corn yield increase value = $ 73.90/ac

Clover	80 lb N = $52.80	103.2 bu/ac x $3.50 /bu = $361.20	$ 308.40 net
Clover	160 lb N = $105.60	135.4 bu/ac x $3.50/bu = $473.90	$ 368.30 net

Positive return from 80 additional lb/ac nitrogen – corn yield increase value = $ 59.90/ac

There was a significant benefit from the cover crop at 80 lb/ac.nitrogen. The optimum N rate at 160 lb/ac, however, was similar whether a cover crop was present or not.

For additional information, contact:

Alan Sundermeier
Ohio State University Extension, Wood County
639 Dunbridge Road, Suite 1
Bowling Green, Ohio 43402
Sundermeier5@ag.osu.edu

Clover Cover Crop & Tillage Effect on Corn Production

Alan Sundermeier, Agriculture & Natural Resources Extension Agent

Objective

To evaluate the effect of clover cover crop and tillage on corn production.

Background

Cooperator:	O.A.R.D.C. NW Branch	Fertilizer:	300 lb/ac 10-26-26, urea at planting, sidedress 28% N at 50 gal/acre
County:	Wood		
Nearest Town:	Hoytville	Planting Date:	4-21-10
Drainage:	Tile, well-drained	Planting Rate:	30,000
Soil type:	Hoytville, clay	Row Width:	30 in.
Tillage:	notill vs conservation tillage	Herbicides:	Lexar, Princep,2,4-D, Glyphosate
Previous Crop:	wheat		
Variety:	Becks 5354HXR	Harvest Date:	9-24-10
Soil test:			

Methods

The entries were replicated four times in a randomized complete block design. Plot size- 10 x 70 feet each entry. Harvest data was collected from the center rows. Tillage plots were chisel plowed and then harrowed in November, 2009. Residue in tillage plots was 30 percent. Medium red clover was frost seeded in wheat in April, 2009. After wheat harvest, clover was allowed to grow until November, 2009 when Roundup and Clarity herbicides were applied to kill the clover. Corn was planted at same time in all plots. Sidedress nitrogen was applied on 6-8-10 at V6 growth stage. All plots harvested center two rows. Wheat straw was chopped and left on plots. At corn planting time, soil moisture levels were similar in all treatments.

Results

Cover Crop	Tillage	Corn Yield bu/ac	
No clover	No-till	129.8	A
Clover	No-till	138.6	B
No clover	Conservation Tillage	139.3	B C
Clover	Conservation Tillage	144.8	C
	LSD (0.20)	5.8	

Summary

Cost of clover analysis:

The no-till clover cover crop increased corn yield by 8.8 bu/ac. compared to no-till with no clover.

Value of increase:	8.8 bu/ac x $6.00 /bu (price of corn)	= $ 52.80
Cost of clover :	12 lb/ac x $2.00/lb (price of clover)	= $ 24.00
	positive net return on clover	= $ 28.80

When corn was planted into wheat residue, conservation tillage had a significant effect on increasing corn yield compared to no-till. However, when clover cover crop was added to no-till, corn yields were not significantly different compared to conservation tillage without clover.

Cost of tillage analysis:

2010 Ohio State Custom Rates (average)

Chisel plow	=	$14.00 per acre
Finish harrow	=	$11.50
Total	=	$25.50

When comparing the per acre cost of clover ($24.00) to total conservation tillage cost ($25.50) there is no significant difference in input cost with the same corn yield results. Added benefits of clover cover crop and no-till are soil quality improvements in soil tilth and active carbon.

Acknowledgement

The author expresses appreciation to the staff at the O.A.R.D.C. Northwest Agricultural Research Station for assistance with this research.

For additional information, contact:

Alan Sundermeier
Ohio State University Extension, Wood County
639 Dunbridge Road, Suite 1
Bowling Green, Ohio 43402
Sundermeier5@ag.osu.edu

Legumes for Cover Crops – What fits your operation?

Dave Robison, Agronomist
The *CISCO* Companies

CISCO Seeds had 50+ Cover Crop Plots in 4 states in 2009/2010

Inoculate the legumes

Austrian Winter Peas

Disadvantages

- Best to be incorporated
- Generally Winterkills
- Needs 5-6 weeks growth for best results
- Only one grazing/harvest can be expected

Advantages

- Produces 60-120#/acre N
- Excellent companion to Radishes and Turnips
- Generally Winterkills
- Easy to kill with herbicides

Austrian Winter Peas

Fall 2009

Spring 2010

Austrian Winter Peas have large nodules

Austrian Winter Peas with Radish 2/21/11 – Mercer Co., OH

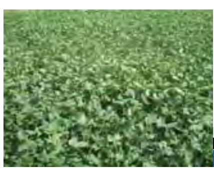
Field Peas

Disadvantages
- Won't grow as late in season as Austrian Winter Peas
- Will not normally overwinter North of I-70

Advantages
- Produces 60-120# N/ac
- Will not normally overwinter North of I-70
- Makes excellent forage
- Very good short-term cover
- Good for weed control

Cowpeas

Disadvantages
- Needs warm soil
- Needs good moisture
- Seed Cost
- Seems to be more reliable South of I-70
- Cannot harvest grain like soybeans



Advantages
- Can produce 60-120 # N/ac
- More reliable in summer than soybeans for nitrogen production

Crimson Clover

Disadvantages
- VNS or older varieties will probably winterkill
- Some hard seed

Advantages
- Can produce up to 140 units of N/acre within 90 days following wheat
- Earthworm "Heaven"
- Easy to kill
- Excellent new (early and winterhardy) varieties are available (limited supply)

Crimson Clover -2

Advantages
- Works very well as a companion to Radishes, Annual Ryegrass, etc...
- Deep and fibrous root system (21" deep in Fulton County, IN sp 2010)

Earthworms love Crimson Clover roots! (April 2010 –Mason, MI)

Crimson Clover's Fibrous roots are loaded with nodules

Medium Red Clover

Disadvantages
- May get too tall in wheat and affect harvest

Advantages
- Produces 75-100# N
- Good root system-soil builder
- Easy to frost seed into wheat
- Often least cost cover crop
- Easily killed
- Excellent for forage

Medium Red Clover

- It is BMP to inoculate seed each year
- Excellent "green manure"

Alsike Clover

Disadvantages
- Seed Cost is generally higher than Medium Red Clover
- Not as good of forage as some other clovers

Advantages
- Produces 60-125# N/Ac
- Lower growing in wheat than Medium Red or Mammoth Red Clover
- Does very well in wetter soils

Berseem Clover

Disadvantages
- Short growing cycle
- Dies at 30-32 degrees
- Seed Cost ~ $50/acre

Advantages
- Produces100-125# N/ac in 60 days
- Possibly use between wheat and other fall crop
- Good soil builder
- Excellent for green manure
- Significant forage produced

Yellow Blossom Sweetclover

Disadvantages
- Known to be a host to soybean cyst nematode
- Little or no seed available for 2011

Advantages
- Can produces 100-200# N/ac
- Biennial
- Top legume for hot weather forage growth
- Good soil builder
- Easy to frost seed into wheat

Hairy Vetch

Disadvantages
- Hard Seed
- Most reliable south of I-70
- Not as quick to grow in autumn as many clovers
- Seed Cost

Advantages
- Produces100-200# N/ac
- Very Good soil builder
- Most of N is produced in the top growth

Chickling Vetch

Disadvantages
- Seed Cost generally higher than many clovers
- Plant 2-3" deep
- Plant 50#/ac

Advantages
- Produces 60-200# N/ac
- Good soil builder
- Very good for forage
- >50% of N is reportedly available for following crop

Alfalfa

Disadvantages
- Cost for short-term cover crop is high
- May need to spray for Potato Leafhopper

Advantages
- Produces 60-200# N/ac
- Excellent soil builder
- Excellent for forage
- Best used in longer term rotation
- Deep Root system

Kura Clover

Disadvantages
- Very little seed production in the world (but we're trying!)
- Up front Seed Cost
- Spreads by Rhizome

Advantages
- Perennial Clover
- Produces 100-200# N/ac
- Excellent soil builder
- Excellent for forage
- Must use in longer term rotation
- Excellent living mulch

Where to get timely updates on cover crops?

www.plantcovercrops.com

A cover crop blog with:
- Research updates
- Agronomic views on cover crops
- Guides and helps
- And so on...

N-Vest® Cover Crops

A Smart *N-Vestment* in the future of your farm
Available through:

*The **CISCO** Company dealers*
daverobison@ciscoseeds.com
www.plantcovercrops.com

Cereal Rye Cover Crop Effect on Soybean Production

Alan Sundermeier, Agriculture & Natural Resources Extension Agent
Jim Hoorman, Agriculture & Natural Resources Extension Agent

Objective

To evaluate effect of cereal rye cover crop on soybean production.

Background

Cooperator:	O.A.R.D.C. NW Branch	Soil test:	
County:	Wood	Fertilizer:	
Nearest Town:	Hoytville	Planting Date:	5-31-10
Drainage:	Tile, well-drained	Planting Rate:	180,000
Soil type:	Hoytville, clay	Row Width:	7.5 in.
Tillage:	notill and conventional	Herbicides:	Glyphomax xtra, 2,4-D, Canopy
Previous Crop:	Corn	Harvest Date:	10-1-10
Variety:	Pioneer 93Y10		

Methods

The entries were replicated four times in a randomized complete block design. Plot size- 10 x 80 feet each entry. Harvest data was collected from the center rows.
On November 6, 2009, cereal rye cover crop was drilled into corn residue at a rate of 1.5 bu/acre. On April 14, 2010 these cover crop plots were killed with Glyphosate, 2,4-D ester spray. Plots were planted with a drill no-till.

Results

Treatment	Yield bu/acre	Significance
Cereal Rye	51.0	A
No cover crop	46.1	B

LSD (.20) = 4.5

Summary

Using a cereal rye cover crop had a significant soybean yield increase when compared to no cover crop.

Per acre economics

Value of soybean yield increase:		
4.9 bu x $12.00 / bu (soybean price)	=	$ 58.80
Cost of cereal rye cover crop:		
1.5 bu x $ 12.00 / bu (seed cost)	=	$ 18.00
Net return from cover crop	=	$ 40.80

For additional information, contact:

Alan Sundermeier
Ohio State University Extension, Wood County
639 Dunbridge Road, Suite 1
Bowling Green, Ohio 43402
sundermeier.5@osu.edu

Healthy Food, Diverse Farms, Vibrant Communities

Cooperator
Mark Quee, West Branch

Project Timeline
August 2009–May 2010

Web Link
www.practicalfarmers.org

Contact
Sally Worley, 515.232.5661
sally@practicalfarmers.org

Funding
SARE, Walton Family Foundation, Green Lands Blue Waters

Tillage Radish to Control Weeds in Horticulture Crops

Abstract

Scattergood Farm near West Branch tested tillage radish for weed control in one of their vegetable fields. They also collected data on seed germination for the cash crop after tillage radishes to observe if the tillage radish had an adverse effect on seed germination. Mean weed counts (34.25 in control and 31.75 in tillage radish plots) combined with statistical analysis indicated no difference in weed control between the tillage radish and control.

Statistical analyses of cash crop germination also illustrated no difference in cash crop seed germination between tillage radish and control plots. Mark Quee, farm manager at Scattergood, said that observations were in line with the data. He thinks tillage radish may have potential to contribute to soil tilth and organic matter, and plans to find out with further research.

Background

Controlling weeds without the use of synthetic chemicals is a priority of Practical Farmers of Iowa's fruit and vegetable members.

Tillage radishes are a quick growing brassica cover crop that winter kills. Steve Groff, Pennsylvania farmer, praises tillage radish for its ability to: alleviate compaction, suppress winter annual weeds, scavenge nitrogen, and leave the soil mellow or soft and loamy.[1]

Mark Quee, manager of Scattergood Friends Farm, trialed tillage radishes for weed control in the farm's vegetable rotation. He also wanted to see if the tillage radishes had an adverse effect on germination of vegetable seeds.

Scattergood students count weeds in quadrats to determine if tillage radish planted the previous fall impacted spring weed germination.

Method

Mark planted two plots of tillage radish into a tilled field on August 25, 2009, with a no-till drill at a rate of 10 pounds/acre. He planted into a field that contained beets the prior season. Mark tilled and left two plots bare for control. Each plot was approximately 10 by 50 feet in size.

Mark tilled up the ground in spring 2010 and planted peas and spinach May 5. Weed and seed germination counts were recorded May 17, 2010.

Statistical analysis of the data was computed as variance of analysis using JMP software.

Farm Cooperators

Scattergood Friends School is a small Quaker boarding school about 15 miles east of Iowa City, with approximately 10 acres of IDALS-certified organic gardens and orchards and about 30 acres of pastures, upon which they grass-finish beef and lamb. Scattergood also raises a few heritage breed Guinea hogs and has a couple Berkshire sows, a small flocks of guinea fowl and turkeys, occasional broiler flocks, and a laying flock of about 100 chickens. Scattergood Farm primarily grows food for its school, but also market through New Pioneer Coop in Iowa City and Coralville, and is trying to support the nascent West Branch farmer's market.

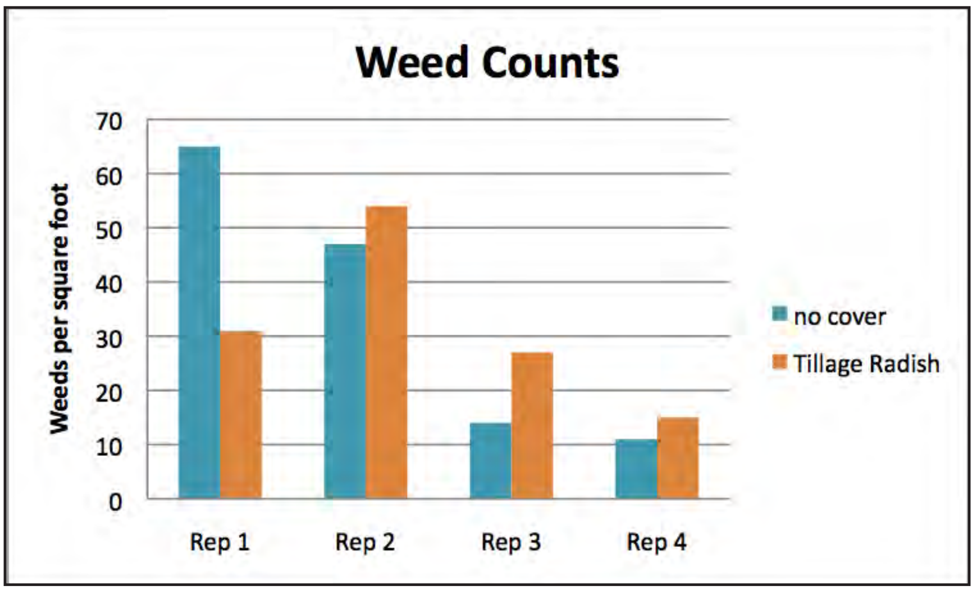
Results

The project hypothesis was that there was no difference between tillage radish and control (no cover) weed counts or cash crop seed germination.

Four samples of weeds were counted per four replications in both control and cover crop plots. Mean weed count where cover had been planted was 31.75 per sample (approximately one square foot) and 34.25 per control sample.

Using an analysis of variance, there was no significant difference in occurrence of weeds between cover and no cover treatments (P=0.8766).

Germination counts were taken for the cash crop that was planted after the tillage radish to determine if tillage radish had an adverse effect on cash crop germination. Using analysis of variance, results show that there is no difference in pea germination between cover and no cover treatments (P=0.9479). Using analysis of variance, results show that there is no difference in spinach germination between cover and no cover treatments (P=0.8968).



Conclusions

Mark's observations were in line with the data; he did not see a noticeable difference in weeds between the control and the tillage radish plot.

He had issues with black rot in his brassicas this year, and is going to be disciplined with crop rotation (he has been using turnips as cover crop as well as for his sheep). Scattergood Farm's sheep readily grazed an oats/tillage radish mix, so they fit well in the farm system for that.

Mark Quee said, "I loved the porosity of the soil after the radishes rotted. The soil has been productive this season. I tilled in the experimental crops and planted two rows of raspberries with mangels. The mangels are really sizing up nicely, indicating good fertility."

While Mark did not notice a reduction of weed pressure due to planting tillage radish, he is curious about their ability to increase organic matter and improve soil tilth on his farm. He is participating in a follow up trial measuring soil compaction that incorporates tillage radish.

References

1. Tillage Radishes, blog by Dan Davidson: http://www.dtnprogressivefarmer.com/dtnag/common/link.do?symbolicName=/free/news/template2&forceNavUpdate=false&topic=DTN/Ag&vendorReference=becab9aa-9415-49dc-a37e-341d21cba9e1__1251378735587

Healthy Food, Diverse Farms, Vibrant Communities

Cooperator
Jason Jones, Pleasant Hill

Project Timeline
September 2009–May 2010

Web Link
www.practicalfarmers.org

Contact
Sally Worley, 515.232.5661
sally@practicalfarmers.org

Funding
SARE, Walton Family Foundation, Green Lands Blue Waters

Effectiveness of White Mustard on Spring Weeds

Abstract

Jason Jones of The Homestead near Pleasant Hill planted white mustard (Sinapis alba) fall 2009 to test its impact on weed germination in spring 2010. White mustard germinated uniformly and winter killed in late November 2009. Weed counts were not statistically different between mustard plots and the bare ground control. Carrot germination was slightly less in the mustard plots than in the bare ground control, but not enough to create a statistical difference.

While results did not show that there was reduced spring weed germination, Jason was satisfied with the cover mustard provided on his field for erosion control. Since the mustard winter killed, no cultivation was necessary in the spring and the bed was clean enough to plant into without a spring tilling.

Background

Weeds are a constant nuisance at The Homestead, a Certified Naturally Grown farm near Pleasant Hill, as they are at many organic and chemical-free vegetable farms.

Cover crops offer many benefits, from added fertility, erosion prevention, improved soil tilth, an additional rotation to break pest-and-disease cycles, and weed control.

The Homestead was interested in all the benefits cover crops offer, but in this case, they wanted to see if there was an impact on spring weed germination after planting a cover crop in the fall.

White mustard (Sinapis alba) mulched into the soil is purported to have biofumigant activities that have the potential to inhibit germination of weed seeds (Suszkiw, 2004).

April 14, 2010: Jason Jones crouches behind a plot of mustard residue that winter killed on left, and the bare ground control treatment on the right.

Method

Jason Jones, farm manager at The Homestead, planted white mustard by hand at a rate of one oz. per 100ft² on September 4, 2009 following garlic and beet crops.

Jason planted the cover crop treatment and a control (bare ground) in randomized strips that were replicated six times across the field and then split those plots the following spring into weedy and weed-free subplots.

Weeds were counted within each subplot four times using a square foot quadrat in the spring on April 14, 2010. Jason cultivated half of the plot using a Williams flex-tine weeder for a weed-free germination bed, and half he left "as is" for the weedy germination treatment. Jason planted carrot seeds April 30 and then measured plant stands on May 14 using four quadrats within each subplot.

Carrot germination was measured in one foot square quadrats. Germination was recorded on both weedy and weed-free plots to determine if the mustard cover crop impacted germination of the cash crop. Carrot germination was quite low in all treatments. Jason unintentionally used one-year-old coated carrot seed for the trial, which could have significantly reduced carrot germ and skewed overall germination results.

The data were analyzed using an Analysis of Variance (ANOVA) to determine treatment effects. All statistical analysis was performed using JMP8.

Farm Cooperator

Jason Jones is farm manager at The Homestead, a living and learning center for people with autism. The campus includes an agriculturally based vocational program for adults with autism that employs 24 campus residents and several people who live in the Des Moines area. They raise Certified Naturally Grown fruits and vegetables, on approximately six acres of land, which they market through community supported agriculture (CSA), the Iowa Food Cooperative, and Farm to Folk. They also grow one acre of apples and raise vegetable transplants for sale in the spring and poinsettias for sale in the winter in their heated 5,000-square-foot greenhouse.

Results

According to Jason's visual observations, the mustard germinated uniformly and created 80-90% cover in the fall. It winter killed late November 2009. Also according to Jason's observations, 40-50% white mustard residue covered the soil in the spring.

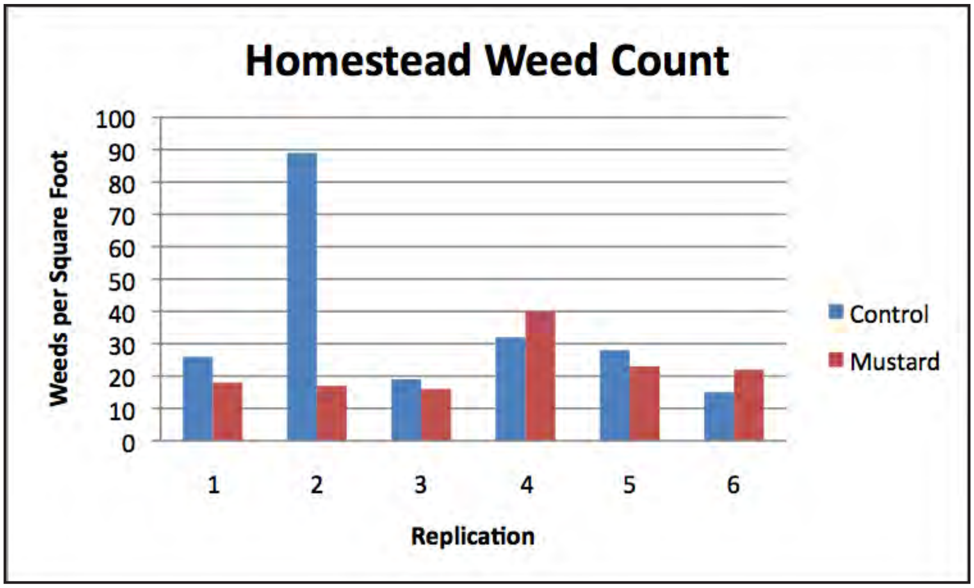


Chart 1. Homestead weed count April 14, 2010.

> ***"The control plot had over 50% more weeds present than the mustard plot."***

Weed counts are reported in chart 1. Total weed counts for the control, or bare ground plots, was 209 plants/ft^2, and total weed counts for mustard, cover crop treatment plots, was 136 plants/ft^2. The control had over 50% more weeds present than the mustard plot. However, as reported in chart 1, the control had one replication with significantly higher weed counts than the other five replications. If this replication is excluded, total weed counts were more similar between the cover crop 119 plants/ft^2 and control plot 120 plants/ft^2.

No significant difference of number of weeds was measured between the mustard and control plots ($p=0.9705$).

Carrot germination was also measured. Chart 2 (pg. 3) reports carrot germination in both the weedy and weed-free treatments. In each instance, germination was higher where the Williams tine cultivator was not used prior to seeding.

Chart 3 (pg. 3) illustrates carrot germination by treatment. Average germination was 72 plants/ft^2 in the control and 62 plants/ft^2 in the mustard plots resulting in 16% greater germination in the control plots. However, this was not statistically significant (p=0.6892).

Conclusions

Although no significant statistical differences were found between the control (bare ground) and the cover crop treatment, (white mustard) plots, Jason observed benefits in planting the cover crop: "It provided a good cover to hold the soil. Even though the data doesn't show it, it looked like there were less weeds where the mustard was planted."

Jason found the seeding of the mustard to be easy and fit into his fall schedule. He does not have a seed drill, but thinks white mustard may have more potential if seeded with a drill, then followed by a cash crop seeded using a drill in the same location.
To reduce potential adverse impacts of a mustard on cash crop germination, Jason plans on using a larger seeded crop such as a legume after mustard. Since mustard winter killed, it created a seed bed clean enough to spring sow the cash crop without needing to spring till.

One challenge white mustard poses as a cover crop is its crop family (Brassicaceae). Since it is a brassica, it may prove difficult to add into a rotation on a vegetable farm that raises a large amount of brassica crops. Jason Jones: "As a result of this trial, mustard is now part of my cover crop 'tool box.' I had not planted mustard as a cover prior to this trial, but plan on continuing to implement it into my cover crop plan."

References

Suszkiw, Jan. "Mustard for Pest Control, Not for Your Sandwich." Agricultural Research. October 2004: 14-15

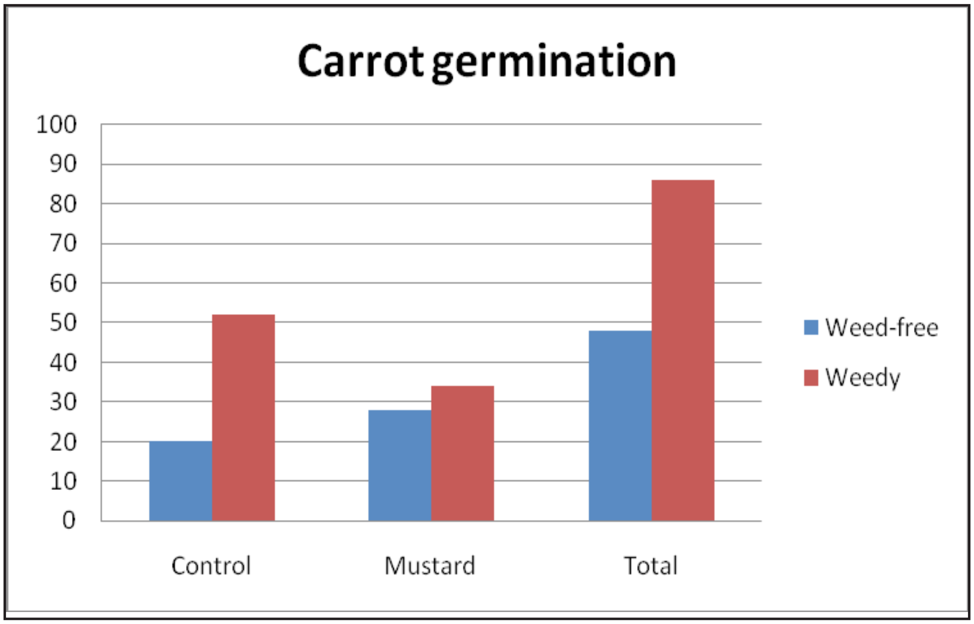


Chart 2. Carrot germination comparing weedy and weed-free areas.

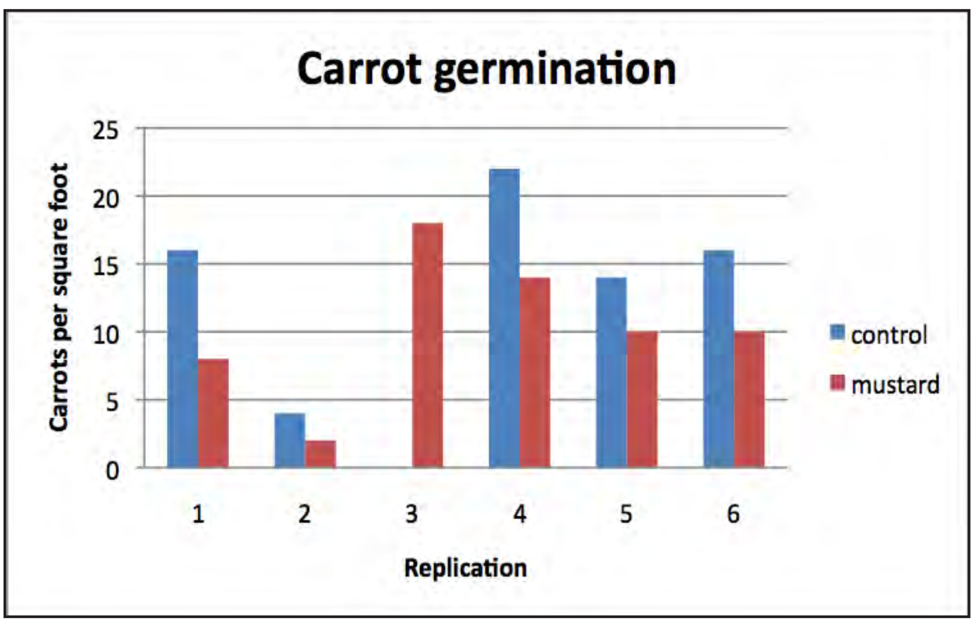
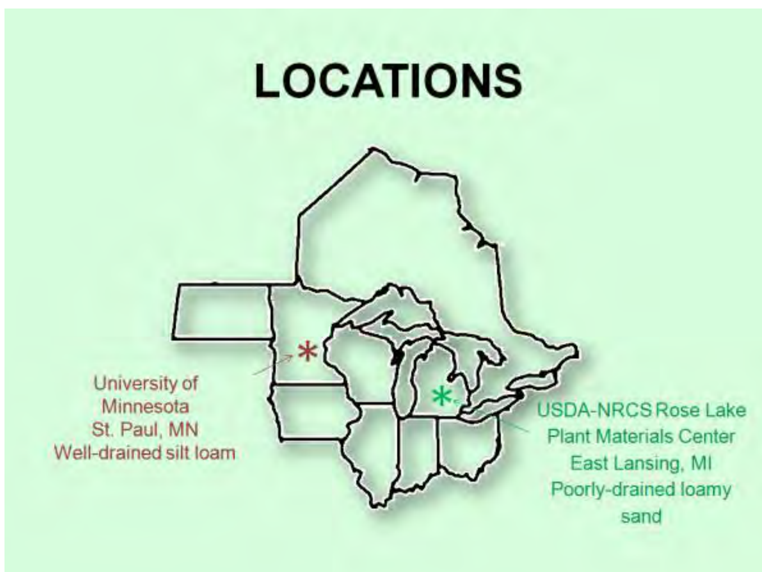


Chart 3. Carrot germination by treatment.

Today's report is presented by John Durling (USDA-NRCS Rose Lake Plant Materials Center (PMC)), Miriam Gieske (Univ. of Minn.), and Victoria Ackroyd (Michigan State Univ. Extension). The speakers helped to conduct a brassica variety trial in Minnesota and Michigan during 2010.



The University of Minn. is in St. Paul, MN. The site's soil is a well-drained silty loam. The USDA-NRCS Rose Lake PMC is in East Lansing, MI. Its soil is a poorly drained loamy sand.

PREVIOUS CROP & CULTURAL PRACTICES

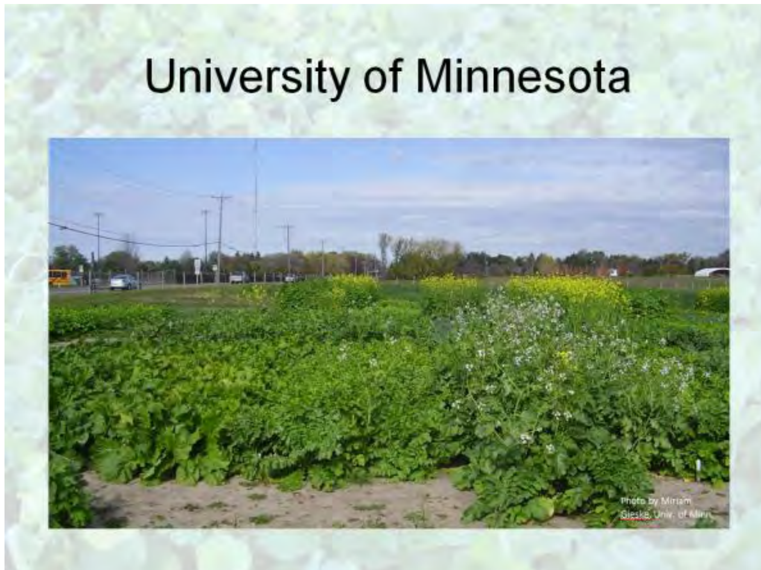
Soybean green manure	Oats
Soybeans mowed August 2010	Grain harvested August 2010
Soybeans (50-60 lbs/acre N) incorporated with tillage	Straw and 30 lbs/acre N incorporated with tillage

At the MN site, the field previously held a soybean crop. The soybeans were mowed in August of 2010, and then incorporated with tillage. The field was credited with 50-60 lbs/A N from the green manure. Oats were grown on the MI field site during the summer of 2010; the grain was harvested in August. The straw was incorporated with tillage and 30 lbs/A of N was applied.

FIELD PLOT DESIGN & MANAGEMENT

Randomized complete block with 4 replicates	
19 or 20 accessions of *Raphanus sativus* and *Brassica spp.*	
Planted 17 August 2010	Planted 13 August 2010
Oilseed and tillage radish @ 10 lbs/acre Mustard @ 8 lbs/acre Rapeseed @ 5 lbs/acre Forage turnip @ 2 lbs/acre	
Hand weeding 7 days after planting	Herbicide to manage volunteer oats
No irrigation	Irrigation

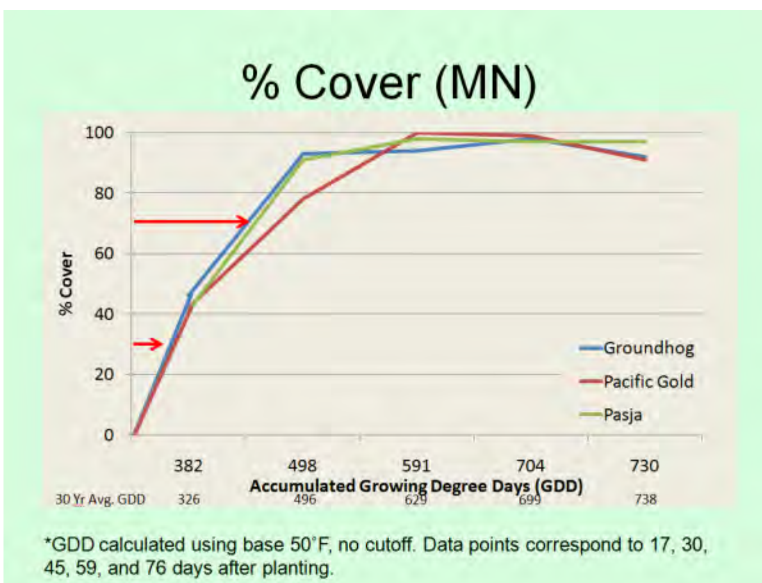
The variety trial experiment was a randomized complete block design with four replicates. Twenty accessions of *Raphanus sativus* and other brassica species were tested (19 at the MN site). Seeds were planted August 17, 2010 in MN and August 13, 2010 in MI. Planting rates for both sites were: oilseed and tillage radish, 10 lbs/acre; mustard, 8 lbs/acre; rapeseed, 5 lbs/acre; and forage turnip, 2 lbs/acre. The MN site was hand weeded seven days after planting to remove mature weeds that survived tillage while herbicides were applied in MI to manage volunteer oats. The MI site was irrigated; the MN site was not.



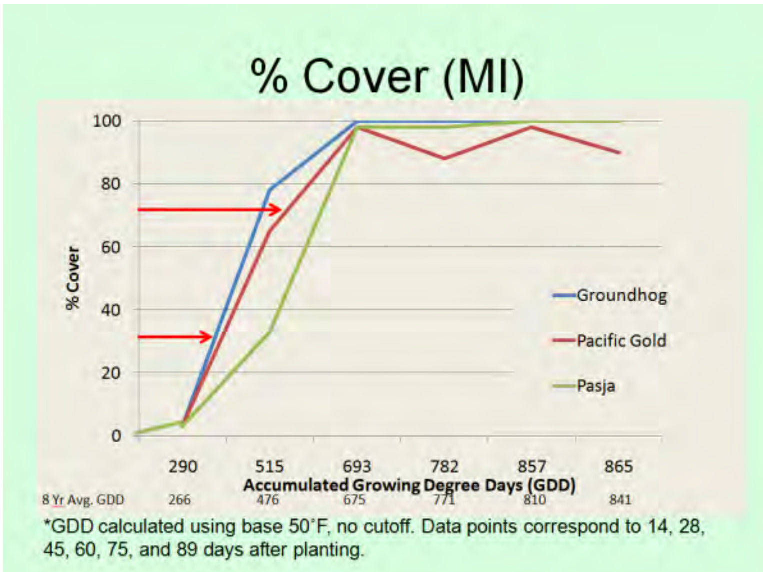
DATA COLLECTION

DATA COLLECTION	
Canopy cover and flowering at 1-2 week intervals late August through mid-November	
Two 0.25 m^2 subsamples	One 2 ft^2 subsample
Biomass and % nitrogen mid-October at 64 days after planting	Biomass and % nitrogen mid-October at 60 days after planting
Other plant growth parameters for crop models	

Data collected include plant canopy cover, plant stand and height, root length and diameter, and flowering at 1-2 week intervals. Other data of use to modelers was also collected. In MN two 0.25 m^2 subsamples per plot were taken to collect biomass data, while in MI one 2 ft^2 subsample per plot was collected. Biomass and % nitrogen data were collected in mid-October (64 days after planting in MN, 60 days after planting in MI).

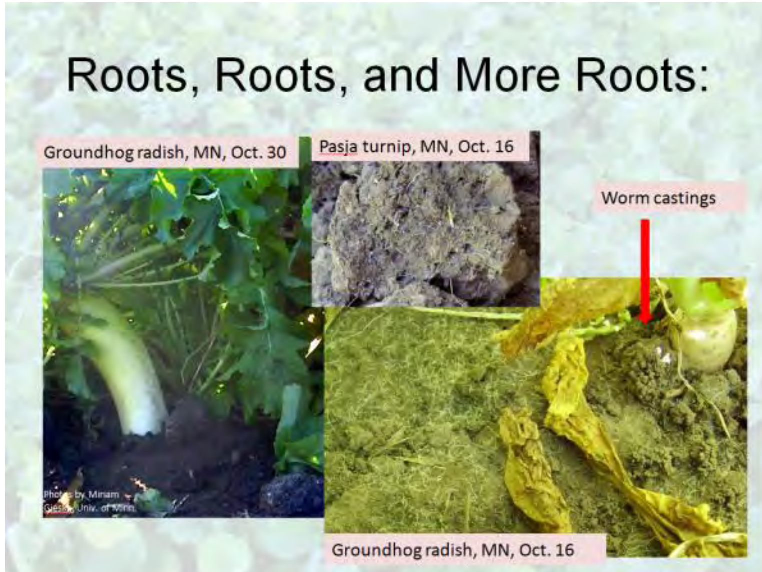


One of the key points of interest was how quickly ground cover could be achieved. Note the x-axis values on the graph are growing degree days (GDD), not data collection dates. This is to emphasize that ground cover is dependent upon multiple variables, temperature being chief among them. The brassicas did cover the ground quickly. Thirty percent ground cover in MN was achieved at around 382 GDD (within 2 ½ weeks of planting); this value is of interest because in some states (and some programs), 30% is the minimum for cost share. Within about a month after planting (498 GDD), 70% ground cover was achieved. Looking at the average GDD, the GDD in 2010 didn't vary greatly from the average.

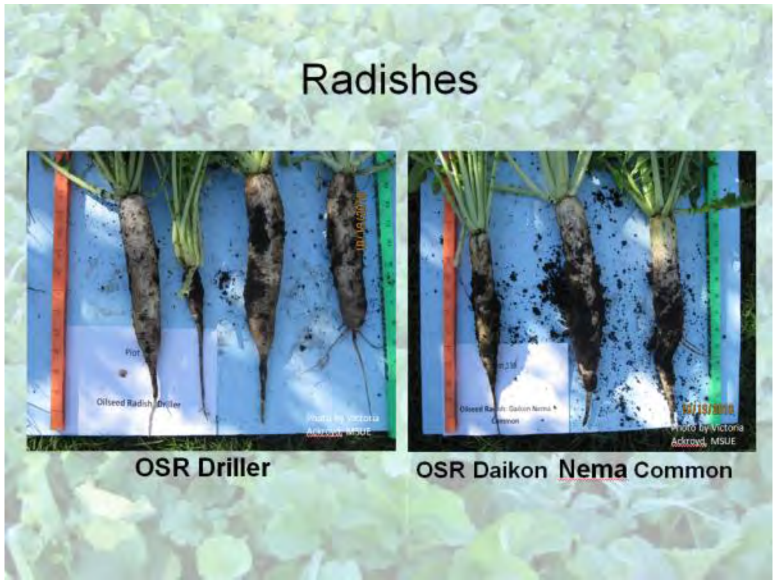


The brassicas in MI achieved roughly 30% cover about 3 weeks after planting, at about 400 GDD; they reached about 70% cover 4-5 weeks after planting. Pasja turnip was slower to cover the ground starting off, but caught up by 6 weeks after planting (at 693 GDD). In both the MI and MN graphs, some of the lines waver between 90 and 100% ground cover. This is indicative of variability in the data. Sometimes, due to weather/planting equipment/etc, cover can be patchy. This experiment had four replicates at each experiment site, but the variability is one of the reasons we plan to run the experiment again in 2011. As a side note, weather information including GDD is typically available at the state level. In MI the website is http://www.agweather.geo.msu.edu/mawn/mawn.html In MN the website to determine GDD is http://climate.umn.edu/cropddgen/cropddgen.asp

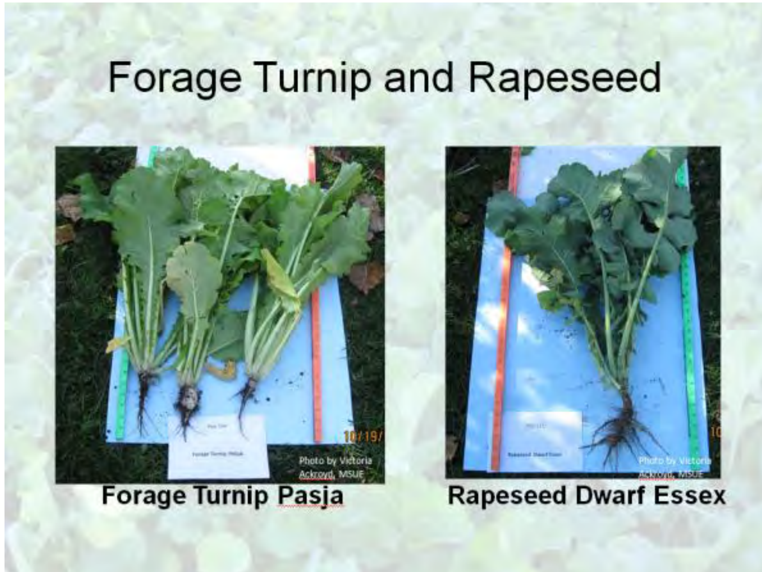
The pictures on this slide are of Groundhog radish planted at 11.1 lbs/A in MN. All were taken Oct. 25, 2010. The later the planting date, the fewer growing degree days the plants get in a given time period and the slower they are to cover the ground. The first three plantings all had very good cover, while a lot of bare ground was still visible in the fourth planting. Percent cover in the fourth planting was visually estimated to be 30%. Note that the fourth planting had almost four weeks to grow, but only 159 GDD. Note also that the first three plantings had slightly fewer than average GDD up to Oct. 25, while the last planting had slightly more GDD than average (September was slightly cooler than average, while October was slightly warmer). For optimal ground cover/erosion control, plant early enough to achieve satisfactory cover.



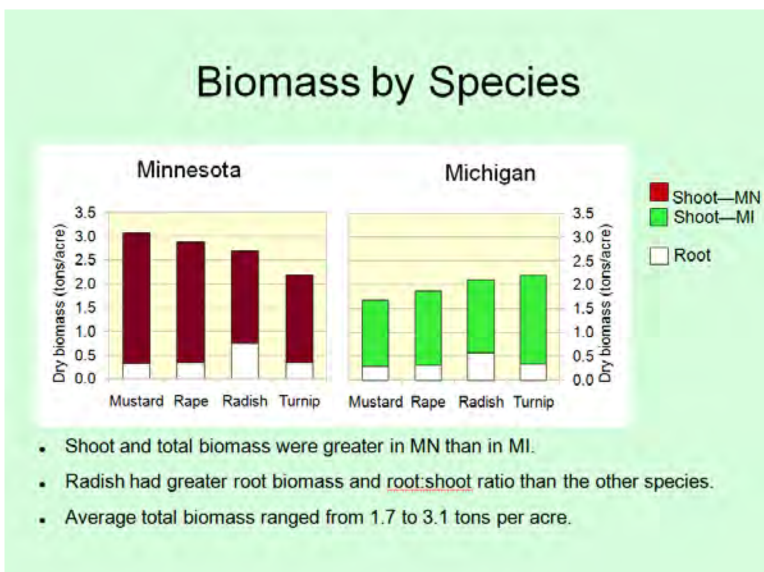
Root structure varies among and even within species. The radishes' large taproots often protrude above the ground. Roots play a role in improving soil structure and preventing erosion. The enlarged taproots on the radishes are impressive, but the fine roots the plants put out may be at least as important. They work their way through the soil (as seen in this soil clod from a Pasja turnip plot) and even form a webbing over the surface when the soil is wet or covered with litter (as seen in this Groundhog radish plot). All four species had a lot of fine roots, which means there may or may not be that much difference between radishes, turnips, and mustards in their effects on the soil.



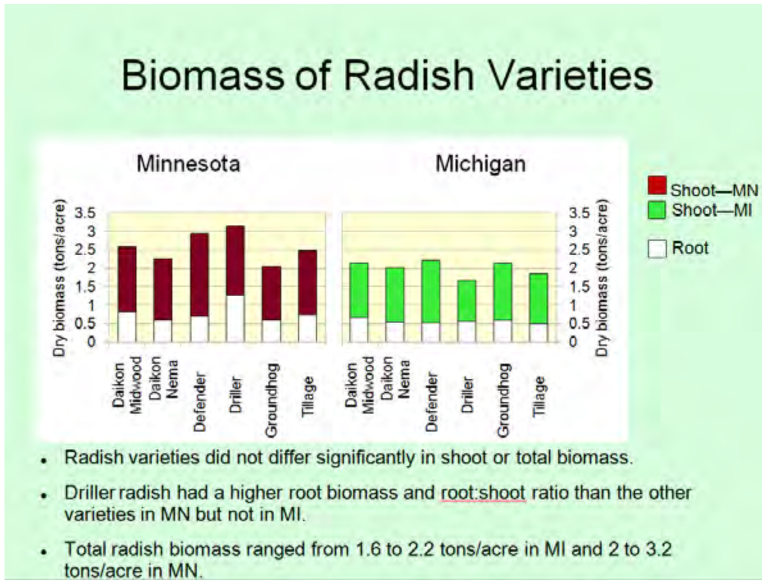
At the same time, sometimes selections from within the same species are hard to tell apart on sight. In these pictures of Driller and Daikon Nema Common radishes the 'classic' oilseed radish root shape can be seen. A lot of claims are made about different varieties, especially of radishes. Part of the purpose of this experiment was to see how much difference there actually is. While intra-specific confusion is understandable, the species themselves are easily distinguishable.



This picture shows a comparison of a forage turnip, with its squat bulbs and a rapeseed, with its more fibrous root system.

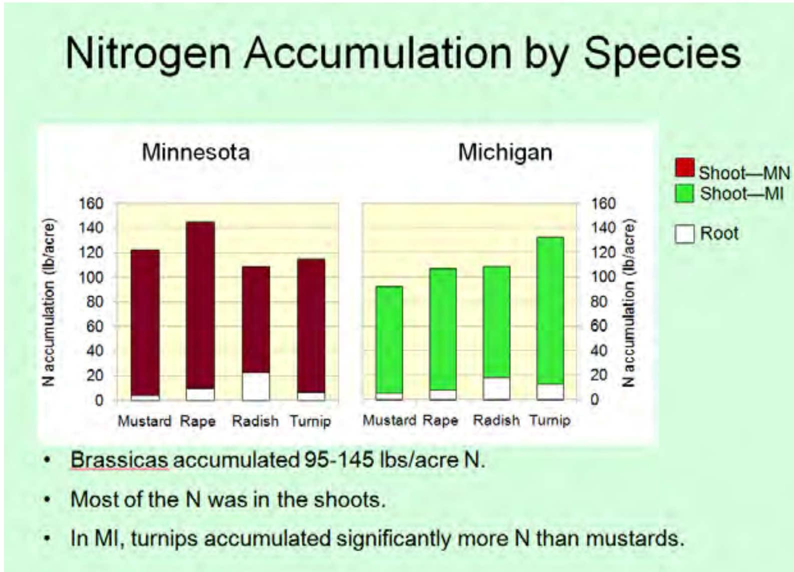


Like ability to provide quick cover, biomass production is also of much interest. Shoot and total biomass were higher in MN than MI. This may be due to the MN field's history of manure application. Radishes produced significantly more root biomass than the mustards, turnips, and rapeseed; they also had a higher root:shoot ratio. Interestingly, the species did not perform the same at both sites. For example, in MN the mustards had the greatest total biomass and turnips had the least, but in MI the turnips had the greatest biomass and mustards had the least.



Among the individual radish selections, varieties did not vary in shoot or total biomass production, though in MN Driller had a higher root:shoot ratio and more root biomass than the other varieties. Results presented are for six radish varieties, but the statistics were run using all the varieties.

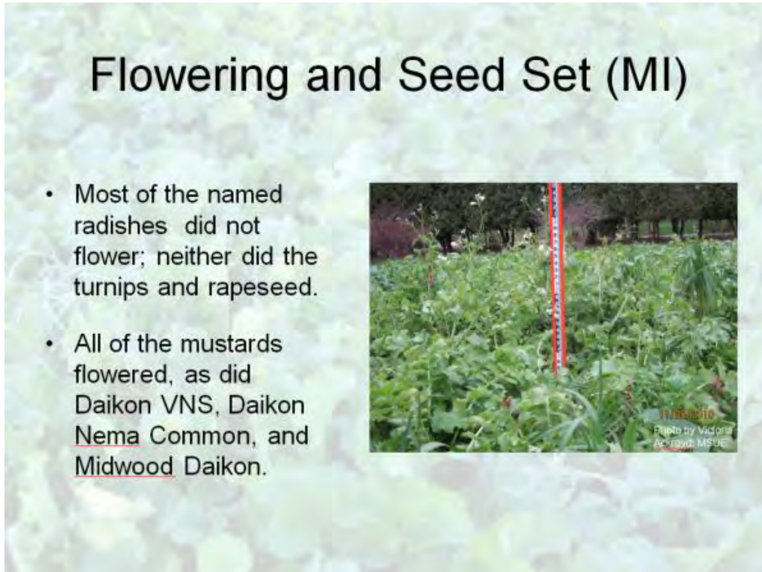
This is a picture of oilseed radish Defender in the field as well as pulled out of the field, followed by a visual comparison of Pacific Gold mustard and Groundhog radish. That the radishes had a higher root:shoot ratio was no surprise.



Nitrogen accumulation is another topic of interest to most people who grow cover crops. The brassica biomass was analyzed for nitrogen content at the Oct. 20 sampling date in MN and the Oct. 12 sampling date in MI. These N values were corrected for percent moisture where necessary, but not for percent ash, which makes them conservative. The brassicas accumulated about 95-135 lbs/acre N in MI and 110-145 lbs/acre N in MN. One thing to notice here is that even for the radishes, the majority of the N is in the shoots, with less than 25 lb/acre N in the roots. In MN, the differences in N accumulation were not statistically significant , probably because only one variety out of each species was analyzed for N and there was a lot of variability within each of those varieties. So even though 50 lb/acre would be a big difference, it can't be determined whether the difference is 'real'/significant or just random luck of the draw. In MI, all samples were analyzed. The turnips accumulated significantly more N than the mustards, while the radishes and rapeseed were in the middle. These differences in N accumulation parallel the differences in biomass production seen in MI.

There are other traits of interest to be found in brassicas. Pollinators love them, especially mustards. This picture was taken Nov. 10, 2010 in MI – after there had been several light frosts and at least one hard frost.

In MN, brown mustard, Ida Gold and Pacific Gold had green seed pods as of Nov. 8. Nema Common Daikon and Midwood Daikon had a few plants with flowers or green seed pods. The rapeseed, turnips, and most of the "named" radishes (e.g. Driller, Groundhog) did not bloom. No selection of the total 19 set seed.



In MI, most of the named radishes didn't flower; neither did the turnips or rapeseed. The mustards did, as did Daikon VNS, Midwood Daikon, and Nema Common Daikon.

Even when pollinators or food for beneficials are of no interest, flowering characteristics may be of concern for two reasons. Firstly, brassicas must not be allowed to set seed due to their high potential as a weed. Secondly, some (especially mustards) are day length sensitive. It isn't a problem for fall cover crops, but some mustards planted in the spring may start blooming before they've had time to put on lots of biomass (due to longer days/shorter nights).

Brassicas will generally tolerate light frosts, but hard frosts will kill them. There are reports of radishes surviving due to snow cover. One topic which we will continue to investigate in the spring is the hardiness of these selections. Of note is the fact that oilseed radish, when it rots, stinks badly of sulfur compounds (rotten eggs). This smell has at least once been mistaken for a gas leak, so farmers with suburban neighbors should be aware of the phenomenon.

We would like to thank Dave Burgdorf, John Durling, Elaine Gerona, Jerry Grigar, Bill Kuentsler, John Leif, and Sergio Pérez of USDA-NRCS; Don Wyse, Bev Durgan, Doug Miller, Brad Kinkaid, Kevin Betts, Joshua Larson, Jackeline Verra, João Benevides, and Miriam Gieske of the Univ. of Minn; and Dale Mutch, Dean Baas, Todd Martin, Tim Dietz, Paul Gross, Victoria Ackroyd, and Christina Curell of Michigan State Univ. and MSU Extension. Our thanks to our funding sources including Project GREEEN and the Great Lakes Regional Water Program.


Thank you. Questions?
Nov. 5, 2010
Pacific Gold mustard (left) and Midwood Daikon.

Cover Crops Biomass N Credit for Rainfed Wheat Production

M. I. Sultani , T. Mahmood S.M. Gill Khandakar Islam

National Agricultural Research Center, Islamabad, Pakistan, University of Arid Agriculture, Rawalpindi, Pakistan, and Ohio State University

Abstract

Legumes used as cover crops to enhance soil fertility and improve crop production are often limited by phosphorus (P) deficiency. To evaluate the effects of P fertilization of substituting leguminous cover crops for nitrogen (N) fertilizer and their effects on soil fertility for rainfed wheat (Triticum aestivum, L. cv. Inqalab 91) production were investigated for successive years. A randomized complete block design with Sesbania (Sesbania aculeata Linn), Rice bean (Vigna umbellate Thunb), Cluster bean (Cyamopsis tetragonaloba L.) and a fallow treatment were factored into 0, 30, 60, and 90 kg P_2O_5 ha^{-1} treatments. Treatments were replicated thrice in 8 x 6 m2 field plots. Sixty days after planting, the cover crops were mowed down two weeks prior to planting wheat as a succeeding crop. The fallow designated as a chemical fertilizer treatment received 90 kg N, P_2O_5 and K ha^{-1}, respectively. Biomass production, N concentration, and labile fraction of cover crops were measured. Results showed that P fertilization and type of cover crops had significant interaction on biomass production, labile fraction, and biomass N concentration of cover crops. P fertilization at $\geq$ 60 kg P_2O_5 ha^{-1} for Sesbania as preceding cover crop significantly improved the growth and yield of succeeding wheat over chemical fertilizer and other cover crops treatments. Linear contrast has shown that cover crops significantly improved rainfed wheat production than chemical fertilization.

Introduction

Cover crops, as one of the important components of the sustainable agriculture, provide organic matter as mulch to reduce soil erosion and evaporation, decrease soil compaction, improve water infiltration, provide N to succeeding crops, recycle subsoil nutrients, and enhance soil quality (MacRae and Mehuys, 1985; Hargrove et al., 1989; Tester, 1990; Hussain et al., 1992; Decker et al., 1994; Mahmood and Aslam, 1999; Islam and Weil, 2000; Choi et al., 2008). While non-legume cover crops can fix CO2, legumes have the ability to fix both CO2 and N in the plant biomass, and are potentially an economic alternative to chemical fertilizers for plant growth (Boddy et al. 1997; Giller 2001). Legumes provide N for succeeding crops by recycling of N-rich biomass and root exudation (Decker et al., 1994; Choi et al. 2008).

Forage legumes such as Cluster bean and Sesbania are known to have beneficial effects by providing substantial amount of N credit to succeeding crops due to their rapid growth, greater biological N fixation capacity, deep root system, and widespread adaptability in nature (SFI, 1980; Hussain and Ibrahim, 1987; Choi et al. 2008). Suitable integration of legumes in crop rotation can enhance the growth and yield of row crops by adding much needed N and organic matter to improve soil quality (Hussain and Ibrahim, 1987; Khan et al., 1996; Malik et al., 2002). Results from several studies have suggested that alternate cropping practices (e.g. cover crops, compost application, etc.) can produce economic yields that are comparable to those of conventional systems and also impart various benefits to soil quality (Drinkwater et al. 1995; Bulluck et al. 2002).

Both N and P are common limiting macro-nutrients in most agricultural soils (Giller 2001; Zingore et al. 2008). Moreover, current high yielding crop varieties have a much greater demand for both nutrients. While the N deficiency could be partially alleviated by using legumes in crop rotation, however, biomass production and quality of cover crops related to N credit for succeeding crops could be influenced by P availability in soil (Olsen and Moe, 1971; Cassman et al., 1981; Khan et al., 2001; Zingore et al. 2008). Biomass N credit for cereal crops can be improved if legumes used as cover crops are adequately fertilized with P (Vesterager et al. 2008). Several studies have reported that P fertilization in combination with organic amendments consistently increased rainfed crops yields (Hussain and Ibrahim, 1987; Azad et al., 1993; Haque and Lupwayi, 1999). Clark (1998) reported that cropping systems that integrated N inputs were more efficient at storing excess N in organic matter than conventional systems. Integration of suitable cover crops into the crop rotation seems appropriate management strategy to shorten the fallow period between growing seasons and provide N and organic matter credit to improve soil quality for economic crop production.

The objectives of the study were to evaluate the (i) effects of P fertilization on biomass production and quality of Cluster bean, Rice bean, and Sesbania as cover crops, and (ii) biomass N credit of cover crops on growth and yield of rainfed wheat.

Materials and Methods

Site Description

The study was conducted at the experimental field of the National Agricultural Research Center (33.38°N and 73.04°E), Pothowar region of Islamabad, Pakistan from 2001 to 2003. Existing farming system is predominance of rainfed wheat, barley, sorghum, millet, maize, and rapeseed production. The soil is a Gujranwala loam (mixed, illitic, hyperthermic, udic haplustalf) which is loess in origin, alkaline in reaction, and extremely low in organic matter, N, and P content to support productive agriculture (Azad et al., 1983). Soil samples were randomly collected from the site at 0-30 cm depth prior to set-up the experiment in 2001, and were analyzed for selected properties by using standard methods. Soil characteristics were pH 7.6, electrical conductivity 280 mS cm-1, organic matter 4.6 g kg-1, total N 0.33 g kg-1, available P 5.1 mg kg-1, exchangeable K 76.2 mg kg-1, bulk density 1.71 g cm-3, total porosity 0.36 m3 m-3, sand 355 g kg-1, silt 300 g kg-1, an clay 345 g kg-1.

Experimental Treatments and Cultural Practices

The RCB design with 4 reps for each treatment was laid-out in the field that had been under fallow. Three annual summer legumes (e.g. Cluster bean, Rice bean, and Sesbania) were used as cover crops treatments. A chemical fertilizer treatment was also included. Four levels of P fertilization (e. g. 0, 30, 60, and 90 kg P2O5 ha-1, respectively) were factored into cover crops treatments. Each replicated plot was 8 x 6 m2 with a 50 cm buffer between plots. The field was plowed with a double disk in last week of June 2001 to laid-out experimental treatments. P from triple superphosphate and a basal dose of 90 kg K ha-1 from Muriate of potash were incorporated to the plowed soil prior to planting of cover crops.

Cover crops were planted by a hand drill with a row-to-row distance of 40 cm in each replicated plot during 3rd week of June 2001. Seeding rate was 50 kg ha-1 for Sesbania, 80 kg ha-1 for Rice bean and 50 kg ha-1 for Cluster bean. At maximum vegetative growth (~ 60 d after planting), the cover crops were mowed down and incorporated into the soil by rotavator prior to planting wheat as a succeeding crop. High yielding winter wheat (variety Inqalab 91) was planted (@ 100 kg seed ha-1) in early September 2001 two weeks after incorporation of the cover crops biomass. No N fertilizer was applied to wheat planted in cover cropped plots. The chemical fertilizer treatment received 90 kg N, P2O5, and K ha-1 from urea, superphosphate and Muriate of potash, respectively. All the fertilizers were broadcasted 2 weeks before planting wheat. Wheat was allowed to grow under rainfed condition. Weeds were manually controlled in all plots throughout the experimental period.

At maturity, the plant height, tiller numbers, spike length and spikelet number spike-1 of wheat were recorded. Wheat was harvested in last week of May 2002, and the grain and straw were separated and measured. Wheat grain yields were reported at around 14% moisture content. The experimental treatments were repeated in 2002-2003 growing season in the same manner as described above.

Sampling, Processing and Analysis of Cover Crops Biomass

Cover crops biomass was sampled from 3 randomly selected 1 x 1 m2 subplots in each replicated plot and their weight were recorded. A sample of biomass was oven-dried at 55°C for 48 h to obtain dry-weight and ground to pass a 0.5 mm sieve. Total biomass N was determined by using micro-Kjeldahl digestion and distillation method (AOAC, 1994). The labile (easily decomposable) fraction of biomass was also determined (AOAC 1994). Total amount of biomass N added to the soil from cover crops was calculated by multiplying their concentration with total amount of dry biomass yield.

Statistical Analysis

Data were analyzed by using ANOVA procedure of the MSTAT-C software. Year was included as replication. The effect of P fertilization and type of cover crops on biomass production and N content were analyzed by following RCB design in 4 x 3 factorial combination. Wheat growth and yield data were analyzed by following RCB design with three cover crops and chemical fertilizer treatments. Simple and interactive effects of predictors on dependent variables were separated and evaluated at p$\leq$0.05 by the LSD test unless otherwise mentioned. Regression of wheat yield on cover crops biomass N content was performed by using treatment mean with standard error.

***For further information:**

Islam.27@osu.edu

Results and Discussion

P Effects on Cover Crops Biomass Production, Quality and N Content

Total dry biomass (TDB) yield, the amount of labile fraction, and biomass N content of cover crops varied significantly by P fertilization and cover crops without an interaction (Table 1 and 2). Among the cover crops, Sesbania produced highest biomass (4.7 Mg ha-1) while Rice bean had the lowest biomass yield (3.7 Mg ha-1). The TDB between Sesbania and Cluster bean did not vary significantly. The P fertilization significantly and quadratically increased cover crops biomass over control. On average, biomass was more than 30% when 90 kg P2O5 ha-1 was applied to cover crops.

The total amount of labile biomass (LBf) was 14 to 25% higher in Sesbania than Cluster bean and Rice bean, respectively. Averaged across cover crops, labile biomass increased significantly in response to P fertilization (Table 2). Sesbania added a greater amount of biomass N (97 to 104%) in soil for succeeding wheat than Rice bean and Cluster bean, respectively. Likewise, the amount of N in labile biomass of Sesbania was significantly higher than Rice bean and Cluster bean, respectively. The P fertilization consistently increased the total and labile N amount of cover crops (Table 3). The amount of fertilizer equivalent total biomass N content of cover crops was significantly higher (30 to 109%) with increasing P fertilization. However, the biomass N did not vary significantly in between 60 and 90 P2O5 ha-1 treatments.

A consistent variation in cover crops biomass is possibly related to their differences in genetics, plant architecture, adaptability, rooting pattern, and, N-fixing capacity (SFI, 1980; Ahlawat and Saraf, 1982; Hussain et al., 1992). Greater potential biomass N credit by Sesbania is most probably due to its ability for efficient N2 fixation through profuse and active root nodulation, and greater biomass production (SFI, 1980; Hussain and Ibrahim, 1987). Significantly higher biomass yield of cover crops in response to P fertilization is most probably associated with deeper root system to facilitate greater uptake of water and nutrients from soil (Hussain et al., 1992; Haque et al., 1996; Khan et al., 2001; Malik et al., 2002). It is reported that P fertilization enhanced biological N2 fixation by increasing active root nodulation of legumes, and resulting in greater production of N-enriched biomass (Olsen and Moe, 1971; Cassman et al., 1981; Ahlawat and Saraf, 1982; O'Hara et al., 1988; Vesterager et al., 2008).

Cover Crops Biomass Nitrogen Credit for Rainfed Wheat Production

Wheat growth and yield except plant height, spike length, and spike number spike-1 were significantly influenced by cover crops and residual P fertilization with an interaction (Table 3). Among the cover crops, Sesbania biomass incorporated plots significantly increase the tiller no. and grain yield of wheat followed by Cluster bean and Rice bean over chemical fertilizer treatment. Wheat grain yield was more than 15% higher in Sesbania biomass incorporated plots than chemical N fertilization. However, the straw yield and harvest index of wheat did not vary consistently. The effects of residual P fertilization significantly increased tiller no., spike length, spikelet no. spike-1, and grain and straw yields. P fertilization at 90 kg ha-1 increased wheat yield (> 30%) over control. The effect of cover crops on grain yield was more pronounced (46%) in Sesbania biomass incorporated plots when fertilized with 90 kg P2O5 ha-1 (Table 3). The linear contrast between the effects of chemical fertilization and cover crops has shown that cover crops biomass incorporation of soil significantly increased the wheat yield (> 12%) over chemical N fertilizer treatment.

There was a significant linear relationship between cover crops biomass N content and wheat grain yield (Fig. 1). Results showed that one kg of total biomass N credit in Cluster bean was able to produce 24 kg wheat grain compared to13 kg wheat grain in Sesbania. Total N credit from Rice bean was intermediate in wheat production.
Significant positive effects of cover crops on wheat growth and yield are possibly due to incorporation of large amounts of N enriched labile organic matter followed by an increase in nutrient availability in soil (Hussain et al., 1992; Khan et al., 1996; Nahar et al., 2002). Furthermore, a significantly higher yield of wheat in cover crops treatments than chemical fertilization is most probably related to beneficial effects of organic matter added as biomass to improve soil quality. Due to low bulk density (0.3 to 0.6 g cm-3) of organic matter, a greater incorporation of cover crops biomass to soil may have facilitated deeper root distribution of wheat in soil, and hence greater nutrient and water uptake to increase yield (Khan et al. 1975, Ekwue 1992, Ohu et al. 1994, Barzegar et al. 2002). A significant linear relationship between wheat yield and the amount of fertilizer equivalent biomass N from cover crops especially Sesbania supported our results.

Table 1: Total and labile biomass, and biomass N content of Cluster bean, Rice bean and Sesbania (Data averaged across P fertilization and year)

Cover Crops	TDB ($Mg\ ha^{-1}$)	LBf	TBN
		($Kg\ ha^{-1}$)	
Cluster bean	4.3ab	1119.7b	57.6b
Rice bean	3.7b	976.8c	59.6b
Sesbania	4.7a	1301.9a	117.5a

TDB=Total dry biomass, LBf=Labile biomass fraction, and TBN=Total biomass N. Means followed by same letters were not significantly different at p<0.05.

Table 2: Phosphorus effects on total and labile biomass, and biomass N content of cover crops (Data averaged across cover crops and year)

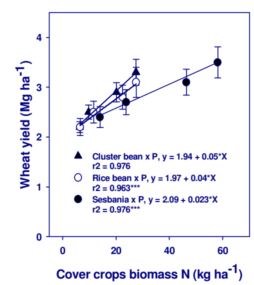
P2O5 Kg ha-1	TDB	LBf	TBN
	(Mg ha-1)	(kg ha-1)	
0	3.8b	649.8c	51.7d
30	4.1b	885.6b	67.2c
60	4.5ab	1512.0a	86.4b
90	4.6a	1559.4a	108.1a

TDB=Total dry biomass, LBf=Labile biomass fraction, and TBN= Total biomass N. Means followed by same letters were not significantly different at p$\leq$0.05.

Table 3: Interaction of cover crops and P fertilization (residual effects) on rainfed wheat growth and yield (Data averaged cross year)

Cover Crops	P2O5 kg ha-1	Plant height cm	Tiller no. m-2	Spike length cm	Spikelet no. spike-1	Grain yield	Straw yield	Harvest index
						__Mg ha-1__		
Cluster bean								
	0	93.9a	270hi	9.2cd	18de	2.2hi	3.8ghi	0.58b
	30	92.3a	292fg	10.1bcd	20bcde	2.5efgh	4.1ghi	0.61b
	60	96a	328cd	11.2abcd	22abc	2.9cde	4.9cd	0.6b
	90	96.2a	354ab	12.2ab	24a	3.3ab	5.5ab	0.59b
Rice bean								
	0	93.6a	271hi	9.2cd	18de	2.2hi	3.7hi	0.59a
	30	94.9a	284fgh	9.8bcd	19cde	2.5efgh	4ghi	0.62a
	60	95.7a	305ef	10.7abcd	21abcd	2.8cde	4.7cdf	0.59b
	90	98.2a	343bc	11.6adc	23ab	3.1bc	5.1ghi	0.6ab
Sesbania								
	0	90.7a	288fgh	9.8bcd	19cde	2.4fghi	4.1ghi	0.59b
	30	93.7a	307ef	10.5abcd	21abcd	2.7def	4.3defg	0.62a
	60	95.1a	339bcd	11.6abc	23ab	3.1bc	5bc	0.627a
	90	98.4a	365a	12.7a	24a	3.5a	5.6a	0.62a

Mg=Megagram, kg=Kilogram, ha=Hectare, cm=Centimeter, m=Meter. Means followed by same upper or lower case letter are not significantly at different p $\geq$ 0.05



Conclusions

P fertilization has shown a significant improvement in biomass production and N credit of cover crops. All the cover crops were found to be equally responsive to P fertilization. However, a greater amount of nutrient-enriched biomass from Sesbania followed by Cluster bean and Rice bean exerted significant improvement in wheat growth and yield over chemical fertilization. P fertilization at 60 kg P2O5 ha-1 for preceding cover crops can be used as a sustainable organic amendments for better N credit and recycling nutrients for wheat as a succeeding crop under rainfed condition.

Cover Crops, Composted Chicken and Cattle Manures Effect on Crop Yields, Weed Control and Soil Quality in Soybean-Corn Rotations

K.R.Islam, S.R.Wright, and Jeff Fisher, OSU South Centers and Extension, Piketon OH 45661

ABSTRACT

Organic manures, as passive by-products of agricultural systems, are important sources of nutrients and organic matter to soils that support sustainable crop production. A RCB design experiment with 6 treatments (4 rep) was established to evaluate the long-term impacts of chicken, cattle and green manures under NT system vs. chemical fertilization under tillage on soil-crop systems. Impacts evaluated include selected soil quality properties; weed suppression; and crop yield in a soybean-corn rotation on 2 farms. Prior to initiation, soil samples were collected from each plot and analyzed selected biological, chemical and physical properties of soil. Results show that initial biological, chemical and physical properties of soil did not vary consistently among treatments. Soil quality properties on Jeff Chatin's farm varied significantly. The values of soil quality index of Jeff Chatin's farm were higher than Paul Bapst's farm. Relatively small changes in soil quality properties did not cause any significant variations in soybean yields. However, as soil properties are responsive to management practices, it is anticipated that the experimental treatments will cause significant changes in soil quality properties and crop yield over time.

INTRODUCTION

Soil organic amendments have received considerable attention in recent years due to reported adverse effects of long-term use of chemical fertilizers and protection on functions of conventionally managed agroecosystems. The N supplied by commercial fertilizers is difficult to manage because of potential loss through leaching, surface runoff, denitrification, and volatilization. Excessive N fertilization and poor soil-crop management practices have decreased economic returns and increased groundwater pollution over time. Understanding the factors that affect crop yields, and the role of management practices in recycling nutrients and controlling weeds and soil-borne diseases through organic amendments to sustain soil quality, are important in defining conservation practices that are productive and environmentally stable (Islam and Weil 2000).

Numerous benefits result from conservation management practices using organic or green manures, as alternatives to commercial fertilizers and herbicides. As a means of disposal and utilization of poultry and animal waste products, chicken and cattle manure have traditionally been applied as a source of nutrients for crops and organic matter to improve soil tilth (Sommerfield and Chang 1985; Roberson et al. 1991). Cover crops, as a source of green manures, may benefit agroecosystems by providing N to grain crops, producing large amounts of organic matter as mulch, and suppressing weed growth and soil-borne diseases through rapid growth and allelopathic effects (Clark 1998).

Proper utilization of manures as alternatives to commercial N fertilizers and chemical protection will be a renewable input approach for sustainable crop-soil management systems. Farmers and producers in the Southern Ohio are concerned about the disposal of millions of tons of cattle manures from locally expanding livestock operations. Local grain farmers have the opportunity to apply cattle manures in their fields at rates very competitive with commercial N fertilizers. Our purpose was to conduct on-farm research and educate farmers on the utilization of valuable organic manures for sustainable soil-crop management practices.

OBJECTIVES

The objectives of the study were to conduct on-farm research trial with a 3-year soybean-corn rotation to:

Evaluate agronomic, soil quality, and environmental aspects of organic manures and cover crops, compared to N fertilizers and herbicides, and demonstrate proper utilization of manures for producing grain crops, and assist farmers to develop sustainable soil-crop management practices, which will supplement, replace, or reduce their need for N fertilizers and herbicides, and sustain soil quality over time.

MATERIALS AND METHODS

The study was conducted at two sites (viz. Jeff Chattin and Paul Bapst's farms) in Pike County. Both farmers are traditional corn and soybean growers. In addition to farming, both farmers collected tons of *lot-scraped cattle manures* from livestock. Soil at Paul Bapst's farm is a somewhat poorly drained Doles silt loam with 0 to 3% slope (Hendershot 1990). The soils at Jeff Chatin's farm are mixture of well-drained Fox loam and somewhat poorly drained Taggart silt loam ,respectively (Hendershot 1990). The slope at the site was 0 to 4%. Over the years, both farms were conventionally plowed their farms for growing soybean or corn.

Experimental Treatment Combinations

A randomized complete block design with six treatments was laid out at both farms. The treatments were replicated in four blocks with 60-m long and 30-m wide plots. A 3.5-m border between treatments and 7-m between replicated blocks were established.The experimental treatments were *(1) Soybean-corn rotation with standard commercial fertilizer rates and herbicide* applications under full-width chisel plow/disk tillage. As first part of the experiment, soybean was planted on May 28, 2002 at a seeding rate of 95 kg/ha. About 222 kg/ka of 9-23-30 (N-P-K) fertilizer mixture and 220 kg lime /ha were applied. Round-up Ultra was applied on June 13 2002, (*2) Soybean-corn rotation with cattle manures equivalent to commercial N fertilizer standard rates and herbicide* applications under full-width chisel plow/disk tillage. About 12.5 tons of cattle manure/ha will be surface applied during the 1st week of May 2003 for growing corn. Round-up Ultra was applied on June 13 2002, (*3) Soybean-corn rotation with composted chicken equivalent to commercial N fertilizer standard rates and herbicide* applications under full-width chisel plow/disk tillage. About 3.3 tons of chicken manure/ha will be surface applied during the 1st week of May 2003 for growing corn. Round-up Ultra was applied on June 13 2002, (*4) Soybean-corn rotation with woolly pod vetch and rye as cover crops.* In late October 2002, about 30 kg of Woolly pod Vetch seed and 10 kg Annual rye seeds/ha were drilled in the soil under no-till conditions to provide N for growing corn, (5) *Soybean-corn rotation with field peas and rye as cover crops.* In late October 2002, about 80 kg field peas and 10 kg rye seeds/ha drilled in the soil under no-till conditions to provide N for growing corn, and (6) *Soybean-corn rotation with mixed cover crops.* In late October 2002, about 20 kg Woolly pod Vetch, 50 kg field peas and 10 kg rye seeds/ha were drilled in the soil under no-till conditions to provide N for growing corn. Composted chicken manures (contained 38 kg/N and 17 kg P/ton) were collected from the Daylay Egg farm. Cattle manures (10 kg N and 0.6 kg P/ton) were collected from Paul Bapst's farm.

Soil Collection, Processing and Analyses

Composite soil samples were collected from the each plot in May 2002 prior to planting of soybeans. The collected soils were gently sieved through a 2-mm sieve to remove stones, straw, chaff and roots, and analyzed to measure selected properties. Total microbial biomass C and N were determined by a rapid microwave extraction method (Islam and Weil 1998a). Soil basal respiration rate (CO_2 evolution), as an index of biological activity, was measured by using in vitro static incubation of field-moist soil. The specific maintenance respiration rates (i.e. loss of C from soil through microbial metabolism) were calculated as basal respiration rate/microbial biomass C/day (Anderson and Domsch 1993). Soil pH was determined in 1:2 soil-E-pure water slurries using a combination glass electrode after 30 minutes shaking. Electrical conductivity was measured in 1:1 soil-E-pure water slurries using EC meter. Soil active C, as a measure of soil quality, was determined based on $KMnO_4$ oxidation (Islam and Weil 1999; Weil et al. 2003). Soil total and soluble C contents were determined using a rapid microwave digestion colorimetric method (Islam and Weil 1998b). Ammonium and nitrate-N contents were determined by using modified indophenol blue techniques. Available phosphorus content of soil was determined by using Murphy-Riley method. Soil bulk density was calculated from the relationship of oven-dried weight of a known volume of soil.. Total porosity of soil was calculated from (bulk density/particle density) relationship. Soil aggregate stability was determined on 1-2 mm sieved air-dried soil by a modified turbidimetric method (Williams et al. 1966).

Calculation of Soil Quality Index

The soil quality index (SQI) was computed using "higher values of soil properties are better indicators of soil quality" concept (Islam 1997) except bulk density and qCO_2. The values of selected soil properties were normalized to a 0-1 scale relative to the maximum value of that property among all the datasets. Equal weight was given for each soil property and the normalized values were then averaged across soil properties to compute SQI and expressed the results in a 0-1 scale.

Statistical Analysis

SAS was used to determine site variability on initial soil properties, SQI, crop yields, and to predict crop yields from SQI or active C test. Treatment means were separated using LSD test with p=of 0.05.

RESULTS AND DISCUSSION

Initial soil analyses show that soil quality properties did not vary consistently among plots (Table 2 to 7). While there was no significant difference in soil microbial biomass C (SMBC) content among the plots in Paul Bapst's farm, there was a significant difference in SMBC among the plots in Jeff Chatin's farm (Tables 2-3). The SMBC as a proportion of total C content of soil did not vary at all. The SMBN content significantly differ among the plots at both sites. Soil basal (BR) and specific maintenance respiration (qCO_2) rates varied significantly among the treatment plots in both sites. The BR rates differed from 6.98 - 13.8 mg CO_2/d/kg soil among the plots in Paul Bapst's farm and 9.5 - 18.4 mg CO_2/d/kg soil among the plots in Jeff Chatin's farm. The qCO_2 as a measure of net loss of C through biological metabolism ranged between 0.04 - 0.087 mg CO_2/mg SMBC/d in Paul Bapst's farm soils and 0.037 - 0.08 mg CO_2/mg SMBC/d in Jeff Chatin's farm soils (Tables 2-3).

Table 1. Soil biological properties of Bapst's and Jeff Chatin's farm

Treatments	SMBC (mg/kg)	qR (%)	SMBN (mg/kg)	BR (mg/kg/d)	qCO2 (mg/mg/d)
Fertilizer	209.8a	1.24a	32.0a	13.8a	0.087a
Chicken manures	220.4a	1.28a	12.5b	9.5b	0.042b
Cattle manures	208.4a	1.47a	19.2b	12.0ab	0.060ab
NT-Rye/Vetch	246.7a	1.48a	16.4b	7.9b	0.040b
NT-Peas/Rye	220.6a	1.24a	34.6a	9.6b	0.045ab
NT-Peas/Rye/Vetch	192.9a	1.25a	11.9b	6.9b	0.047ab
Fertilizer	158.8b	0.92a	41.5b	10.3a	0.072a
Chicken manures	274.2a	1.52a	67.4ab	13.0ab	0.047bc
Cattle manures	251.8ab	1.35a	105.7a	18.4a	0.08a
NT-Rye/Vetch	257.5ab	1.52a	29.8b	9.5b	0.037c
NT-Peas/Rye	264.7ab	1.39a	18.9b	14.8ab	0.057abc
NT-Peas/Rye/Vetch	206.7ab	1.01a	52.5ab	13.9ab	0.067ab

SMBC=Soil microbial biomass C; qR=Ratio of microbial biomass C/TC, SMBN=Soil microbial Biomass N; TC=Total C; BR=Basal respiration; qCO2=Specific maintenance respiration.

Since collection, processing and analytical procedures were identical for all the soils prior to actual imposition of the experimental treatments; the differences in the biological properties and processes among plots in Jeff Chatin's farm can primarily be related with variability within the site and quantitative and qualitative changes in C (Islam and Weil 2000).

Soil pH at both sites did not vary significantly (Tables 4 and 5). The pH of Paul Bapst's farm soil is more acidic than those of Jeff Chatin's farm soil. Soil EC among plots differ significantly in Paul Bapst's farm. Soil soluble-C varied significantly in both sites. Jeff Chatin's soil had more soluble-C than Paul Bapst's soil (Tables 4 and 5). Potassium permanganate ($KMnO_4$) oxidizable C as a measure of active C pool was greater in Jeff Chatin's farm soil compared to that of Paul Bapst's farm soil (Fig. 1) but there was no significant difference in initial contents of active C contents. Total organic C (TC) contents did not differ among the plots in both sites (Tables 4 and 5). The TC content was ranged between 1.42 - 1.85% in Paul Bapst's soils and 1.69 - 2.11% in Jeff Chatin's soils. Ammonium-N content varied significantly in soils among the plots of both sites. Nitrate-N content did vary consistently among the plots of Jeff Chatin's farm. Soil available P content did not vary significantly among the plots (Table 4 and 5).

Table 4. Soil chemical properties of Bapst's farm (Beaver, OH)

Treatments	pH	EC	Sol-C	NH4	NO3	AN	TC	P
Fertilizer	5.9a	291.2a	71.8ab	1.0b	31.0a	32.0a	1.65a	14.1a
Chicken manure	5.8a	275.2a	83.1a	1.83a	40.8a	41.9a	1.80a	16.0a
Cattle manure	6.0a	204.0b	66.8b	1.71a	27.7a	38.8a	1.42a	14.3a
NT-Rye/Vetch	5.9a	225ab	69.7ab	0.64b	31.1a	31.6a	1.63a	14.0a
NT-Peas/Rye	6.0a	279.2a	71.6ab	0.86b	37.8a	38.1a	1.85a	14.7a
NT-Peas/Rye/Vetch	6.0a	231ab	77.5ab	1.59a	39.8a	41.3a	1.62a	17.2a
Fertilizer	7.9a	262.2a	98.4b	0.82a	40.3bc	41.1bc	1.69a	15.9a
Chicken manure	7.9a	261.2a	86.4ab	1.3a	52abc	53abc	1.83a	18.9a
Cattle manure	7.9a	274a	91ab	1.68a	67.4a	69.1a	1.86a	17.4a
NT-Rye/Vetch	7.8a	255a	90.4ab	1.35b	39.8bc	41.1bc	1.73a	16.3a
NT-Peas/Rye	7.9a	274.5a	80.2b	0.90a	31.6c	32.5c	1.94a	15.4a
NT-Peas/Rye/Vetch	7.9a	273.7a	83.3ab	1.23a	55.5ab	56.7ab	2.11a	17.2a

EC=Electrical conductivity; Sol-C=Soluble C; NH_4=Ammonium N; NO3= Nitrate N; AV= Available N; TC=Total C; and P=Available P.

Relatively high soil pH at Jeff Chatin's farm may have resulted from recent application of lime and inherent properties of parent materials. Consistent variations in soluble-C pool suggested that this C fraction is sensitive and early indicators of temporal changes in C_T quality in response to management practices long before the changes detected in absolute amounts of C_T contents because of the possible large background levels of recalcitrant C in soil (Islam and Weil 2000b). Greater amounts of soluble-C or active C in Jeff Chatin's farm soil relative to Paul Bapst's farm soil may explain a higher level of biological activities. The active C pool is of special importance because this is the most biodegradable fraction of C_T, acting as immediate energy and food sources to determine the size of SMBC, nutrient cycling and their activities in soil (Cook and Allan 1992; Blair et al. 1995; Islam and Weil 2000a).

Soil Physical Properties

Soil moisture content was significantly varied among plots in both sites. The bulk density and total porosity of soil in Jeff Chatin's farm varied significantly (Tables 6 and 7). Aggregate stability varied significantly in soils among the plots of Jeff Chatin's farm. The aggregate stability was between 50 to 67% in Jeff Chatin's farm compared to 35 to 58% in Paul Bapst's farm (Tables 6 and 7). Since there were two different types of soil at Jeff Chatin's farm, significant variations in bulk density and total porosity were anticipated. A greater amount of soluble, active and total C pools probably accounts for the increased aggregate stability of soils on Chatin's farm as compared to soils in Paul Bapst's farm. Aggregate stability is one of the core soil quality properties to influence many soil functions, and reflects an interrelationship among biological, chemical and physical properties of soil (Oades 1984; Islam and Weil 2000 and b). Enhanced soil aggregation was expected to increase the availability of C pools for use by SMBC, which in turn, would enhance biological activities, and produce more organic binding and/or stabilizing agents for soil macroaggregation (Oades 1984; Roberson et al. 1991; Angers et al. 1992). Macroaggregation, in turn, may retain and sequester C content in soil that is physically protected from microbial decomposition (Roberson et al. 1991; Angers et al. 1992; Islam and Weil 2000a).

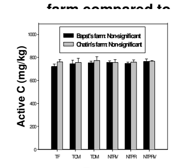
Table 3. Soil physical properties of Bapst's farm (Beaver, OH)

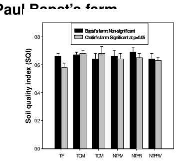
Treatments	Moisture	Bd	Porosity	AS
Fertilizer	15.3bc	1.32a	50.2a	0.35a
Chicken manure	15.6abc	1.35a	49.1a	0.44a
Cattle manure	14.4c	1.32a	50.2a	0.44a
NT-Rye/Vetch	17.2a	1.36a	48.5a	0.51a
NT-Peas/Rye	16.7ab	1.38a	48.1a	0.58a
NT-Peas/Rye/Vetch	15.5abc	1.33a	49.9a	0.47a
Fertilizer	14.2b	1.27ab	52.3ab	0.50b
Chicken manure	15.6ab	1.24b	53.4a	0.64ab
Cattle manure	17.1a	1.23ab	53.5a	0.63ab
NT-Rye/Vetch	15.0ab	1.28ab	51.8ab	0.58ab
NT-Peas/Rye	15.8ab	1.36a	48.8b	0.67a
NT-Peas/Rye/Vetch	15.7ab	1.24b	53.2ab	0.65a

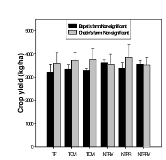
Bd=Bulk density; and AS=Aggregate stability.

Soil Quality and Crop Yield

Since soil quality index is an integrated value from measured soil properties, variations in soil properties would reflect variations in soil quality (Islam 1997). Significant variations in inherent soil quality was found in Jeff Chatin's farm compared to an uniform soil quality in Paul Bapst' farm (Fig. 2). The calculated soil quality index is expected to predict temporal changes in soil quality in response to experimental treatments. A significant difference in soybean yield was observed among the plots in Jeff Chatin's farm and is possibly due to inherent soil quality differences. On an average, about 10% increase in yield was found in Jeff Chatin's farm compared to Paul Bapst's farm







*For further information: Islam.27@osu.edu

Biomass N Contribution of Cover Crops for Agronomic Crop Production.

Y. Raut[1], Jim Hoorman[2], Alan Sundermeier[3], Irfan Aziz[4], and Khandakar R. Islam[1]

[1]The Ohio State University South Centers, Piketon, OH, [2]The Ohio State University Extension Center at Lima, OH, [3]The Ohio State University, Bowling Green, OH, [4]Dept. of Agronomy, University of Arid Agriculture, Rawalpindi, Pakistan

Abstract

Cover crops are important sources of nitrogen. This study was conducted to evaluate Alfalfa (*Medicago sativa*), Austrian Winter Pea (*Pisum sativus*), Cowpea (*Vigna unguiculata*), Crimson clover (*Trifolium incarnatum* L), Hairy vetch (*Vicia villosa* Roth), Ladino White Clover (*Trifolium repens* L), Mungbean (*Vigna radiate*, L.), and Red Clover (*Trifolium Pratense*) as suitable cover crops that would establish quickly, over-winter or winter-killed, and contribute sufficient biomass N for subsequent cereal crops during 2002 to 2006. At their maximum vegetative growth, both above- and below-ground biomass of cover crops were randomly harvested, oven-dried at 550C, ground and analyzed for C and N contents. Above-ground dry biomass production ranged from 1670 (White Clover) to 7830 kg ha^{-1} (Cowpeas). Biomass N concentration ranged from 19.7 (Cowpeas) to 43.2 g kg^{-1} (Mungbean). Alfalfa had the lowest biomass C:N ratio at 11.3:1 while Cowpeas had the highest C:N ratio at 21.6:1. Biomass N contribution ranged from 26.3 (White Clover) to 218 kg ha^{-1} for Alfalfa. Based on biomass production, N content, and suitability of planting and killing, Cowpeas was planted as a cover crop after harvesting wheat in the 3rd week of July in a wheat-corn-soybean rotation with or without chemical N fertilization under conventional tillage (CT) and no-till systems (NT). The Cowpeas biomass was winter killed (1st week of November). Results showed that there was no significant corn yield (7190 kg ha^{-1} vs. 7156 kg ha^{-1}) difference between conventionally-tilled and fertilized treatment (CT-C) vs. no-till cover cropped treatment (NT-CC) with Cowpeas without chemical fertilizer. However, corn yield was significantly lower (4577 and 6575 kg ha^{-1}) in both reduced tillage (RT-C) and no-till (NT-C) treatments with chemical fertilization.

Introduction

Maintaining soil quality for economic crop production is the foundation of sustainable agriculture. Cover crops as one of the important components of sustainable agriculture to provide organic matter as mulch to reduce evaporation, surface runoff and compaction, supply N to succeeding crops, recycle subsoil nutrients, and enhance soil quality (MacRae and Mehuys, 1985; Hargrove et al., 1989; Tester, 1990; Hussain et al., 1992; Decker et al., 1994). While non-legume cover crops can fix tropospheric CO_2, legumes fix both CO_2 and N in the plant biomass.

Legumes cover crops have the ability to supply N for succeeding crops by recycling of N-rich crop residues in soil (Decker et al., 1994). Suitable integration of legumes in crop rotation can enhance the growth and yield of cereal crops by adding much needed N and organic matter to improve soil productivity (Hussain and Ibrahim, 1987; Khan et al., 1996; Malik et al., 2002). An appropriate strategy may be to integrate suitable cover crops into a crop rotation system to shorten the fallow period between growing seasons, improve soil fertility, and supplement the N fertilization for economic crop production. The objectives of the study were to identify suitable cover crops that would establish quickly, over-winter or winter-killed, and contribute sufficient biomass N for subsequent cereal crops in both CT and Ny systems.

Materials and Methods

The study was conducted at the Vanmeter farm (formerly known as the site of the Ohio Management Systems Evaluation Area (MESA) at Piketon (39°02′N and 83°02′W), South-Central Ohio. The site is in the relatively flat Scioto River Valley without water-logging and soil erosion problems. Soil at the site is predominantly Huntington silt loam (fine-silty, mixed, mesic fluventic Hapludoll) containing 21% sand, 55% silt and 24% clay, pH 6.5±0.2, and 1.6% organic C. Averaged across months, air temperatures ranged between 0 to 24°C; relative humidity ranged between 79 - 93%; soil temperature at 15 cm deep ranged between 3 to 30°C; rainfall ranged between 6 to 10 cm; solar radiation ranged between 9981 to 43037 KW/m²; and wind velocity ranged between 5 to 9 Km/h. The mean annual rainfall is 96±20 cm, with about 40% of the precipitation falls during the growing season (May to September).

In 2003, no-till Alfalfa (Medicago sativa), Austrian Winter pea (Pisum sativus), Cowpea (Vigna unguiculata), Crimson clover (Trifolium incarnatum L), Hairy vetch (Vicia villosa Roth), Ladino White clover (Trifolium repens L), Mungbean (Vigna radiate, L.), and Red clover (Trifolium Pratense) were planted. A randomized complete block experiment with 3 replications was laid-out in the field. Each replicated plot was 3 m x 5 m. Fertilizers and pesticides were not applied. At their maximum vegetative growth, both above- and below-ground biomass of cover crops were randomly harvested, oven-dried at 55°C, and calculated for biomass production. A portion of the oven-dried cover crops biomass was ground and analyzed for C and N contents by using CNS elemental analyzer. The experiment continued for 2004 and 2005, respectively.

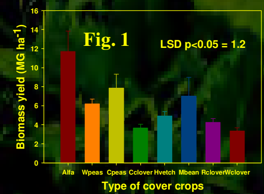
Based on the results of cover crops study, a 2nd experiment was initiated in 2005 to introduce Cowpea as a cover crop after harvesting wheat in the 3rd week of July in a wheat-corn-soybean rotation with or without chemical N fertilization under CT and NT systems. The experiment was set-up in a randomized block design with 3 replications in 15 m x 30 m plots. The cowpeas were allowed winter killed (1st week of November). In 2006, corn was planted in early May within the winter killed cowpea residues without any N fertilizers. The P and K fertilizers were applied @ 150 kg/ha. In chemical treatments, 150 kg N/ha was applied using UAN with 150 kg P and K per ha, respectively. Corn was harvested in the 2nd week of October. The experiment was repeated in 2007.

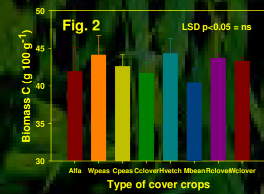
Differences in cover crops biomass production, C and N contents, biomass N contribution, and corn yield in response to experimental treatments were analyzed by ANOVA procedure of the SAS. Using a least significant difference test at a p≤0.05, the treatment means were separated.

Results and Discussion

Biomass Yield:

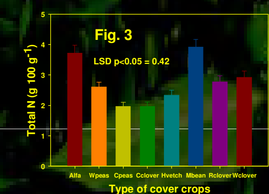
Cover crops species in question showed a significant variation (p≤0.05) in biomass production (Fig. 1). Alfalfa demonstrated the highest performance in biomass yield, followed by Mungbeans, Cowpeas and Winter peas. In contrast, Red clover (Rclover) and white clover (wclover) showed lowest performance. Likewise, variation in yield is associated with the performance of individual species.

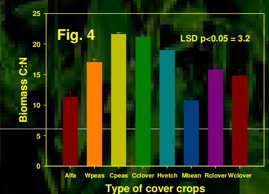




Biomass C, N and CN ratios:

Although, no species came out with a significant difference in organic C contribution, Alfalfa and Mungbeans contained the most total nitrogen (p≤0.05) concentration, and had the lowest C:N ratio (p≤0.05) followed by White and Red Clover, Winter Peas, Hairy Vetch, Crimson Clover, and Cowpeas (Fig. 2-4). Hairy Vetch and Winter peas had the highest C:N ratio while Mungbeans had the lowest C:N ratio.

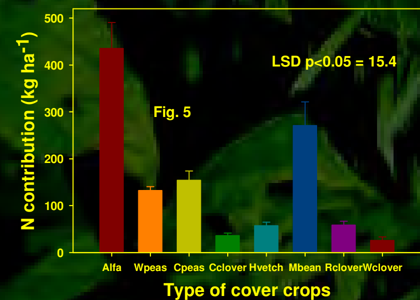


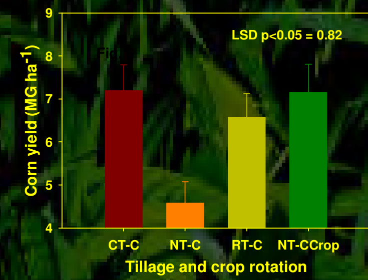


Alfalfa and Mungbean had the highest total N and N contribution followed by Cowpeas and Winter peas (p≤0.05) over time (Fig. 5). Alfalfa was planted and killed after 3-yrs. Only a limited supply of Mungbean was available from Russia, so Cowpeas was used as the main cover crop after wheat because of its high N contribution.

Tillage and Crop Rotation Versus Corn Yield:

Corn yields on conventionally tilled corn (CT-C) using commercial fertilizer (Photograph 1) and NT with Cowpeas as a cover crop (NT-CCrop) without commercial fertilizer (Photograph 2) were not significantly different (p≤0.05). However, the NT-C corn yield was significantly less than the NT-CCrop corn yield. N contribution and the biomass production (especially root biomass) from the Cowpeas significantly improved corn yield in NT-CCrop.





Summary:

Because of greater biomass production and N contribution, Cowpeas was used as a cover crop following wheat. There was no significant yield difference between conventionally tilled corn with commercial fertilizer and NT corn with Cowpeas as a cover crop without commercial fertilizer.

Photograph 1: CT-C

Photograph 2: NT-Ccrop

Cover Crop x Nitrogen Rate Comparison

Alan Sundermeier, Agriculture & Natural Resources Extension Agent

Objective

To evaluate the effect of cover crop and nitrogen rate on corn production.

Background

Cooperator:	O.A.R.D.C. NW Branch	Soil test:	
County:	Wood	Fertilizer:	
Nearest Town:	Hoytville	Planting Date:	4-23-10
Drainage:	Tile, well-drained	Planting Rate:	30,000
Soil type:	Hoytville, clay	Row Width:	7.5 in.
Tillage:	notill	Herbicides:	glyphosate, 2,4-D ester, liquid AMS, Lexar
Previous Crop:	wheat		
Variety:	Pioneer PO518XR	Harvest Date:	10-12-10

Methods

The entries were replicated four times in a randomized complete block design. Plot size- 10 x 70 feet each entry. Harvest data was collected from the center 2 rows. All treatments received the same herbicide. All treatments were no-till planted. After 2009 wheat harvest, all plots had glyphosate applied to control volunteer wheat and weeds. On July 24, 2009 cover crops were planted. Cowpea was inoculated and drilled at 40 lbs/acre. Soybeans were drilled at 50 lb/acre. Soybean variety Pioneer PI93Y51. A White splitter planter was used to plant inoculated winter pea at 30 lb/acre and oilseed radish at 4 lb/acre. Radish was placed in the rows where corn was planted the following spring, with the winter pea 15 inches over from the radish rows. All cover crops had good growth. Cover crops were naturally killed by winter cold temperatures. Corn was no-till planted in all treatments. Nitrogen was sidedress applied at V6 stage with liquid 28% injected.

Results

Treatment	Cover Crop	N-Rate	Corn Yield bu/acre
1	none	0	40.2 A
2	none	140	93.9 B C
3	none	220	104.6 C
4	Radish/Winter Pea	0	49.2 A
5	Radish/Winter Pea	140	86.9 B
6	Cow Pea	0	49.2 A
7	Cow Pea	140	88.3 B
8	Soybeans	0	52.4 A
9	Soybeans	140	99.3 B C

LSD (.05) 14.3

Summary

With the 0 nitrogen rate, there was no significant difference between no cover crop versus any of the cover crops. One can conclude that the cover crops did not add significant amounts of nitrogen to increase corn yields. Also, with 140 lb/acre nitrogen there was no significant difference between no cover crop versus any of the cover crops. The spring of 2010 was very wet which may have leached available nitrogen from the cover crops. In this experiment, there was no advantage to planting cover crops as shown in corn yield. Soil quality improvements from using cover crops were not analyzed.

For additional information, contact:

Alan Sundermeier
Ohio State University Extension, Wood County
639 Dunbridge Road, Suite 1
Bowling Green, Ohio 43402
Sundermeier5@ag.osu.edu

THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

SAG-11-09
AEX-540-09

Using Cover Crops to Convert to No-till

James J. Hoorman
Extension Educator
Cover Crops and Water Quality
Ohio State University Extension

Rafiq Islam
Soil and Water Specialist
Ohio State University Extension
South Centers at Piketon

Alan Sundermeier
Extension Educator
Agriculture and Natural Resources
Ohio State University Extension

Randall Reeder
Extension Agricultural Engineer
Food, Agricultural, and Biological Engineering
Ohio State University Extension

No-till versus Tillage

In the Midwest, about three-fourths of all soybeans and wheat are planted without prior tillage. But before corn is planted at least three-fourths of the fields are tilled in the fall and possibly tilled again in the spring. Farmers are tilling ahead of corn planting because they perceive a yield increase with tillage that is more than enough to cover the added direct costs for machinery, fuel, and labor. Typically, soybeans are no-tilled into corn stalks followed by soybean residue being tilled for corn planting the next year. No-tilling one year (for soybeans), then tilling the next (for corn), is not a true no-till system.

In many situations, corn yields drop slightly after switching to no-till. In Ohio, 10–20% of corn acres are no-tilled. So the question becomes, Why does this occur? Since corn is a grass, it requires more nutrients (especially nitrogen) and water and corn responds well to tillage. Farmers typically see a 5–10% bushel yield decrease for the first 5–7 years after they convert from conventional tilled to no-till. The corn crop benefits from tilled soils due to the release of nutrients from soil organic matter. Tilling the soil injects oxygen into the soil, which stimulates bacteria and other microbes to decompose the organic residues and releases nutrients. Every 1% soil organic matter holds 1,000 pounds of nitrogen. However, continuous tillage oxidizes or burns up soil organic matter and soil productivity declines with time. Thus, tillage results in poor soil structure and declining soil productivity.

Long-term research reveals that 7–9 years of continuous no-till produces higher yields than conventional tilled fields because it takes 7–9 years to improve soil health by getting the microbes and soil fauna back into balance, and start to restore the nutrients lost by tillage. In those transition years, the soil is converting and storing more nitrogen as microbe numbers and soil organic matter levels increase in the soil. For the first several years after converting to no-till, there is competition for nitrogen as soil productivity increases and more nitrogen is stored in the soil in the form of organic matter and humus. See OSU Extension fact sheet Understanding Soil Ecology and Nutrient Recycling.

Cover crops have the ability to "jump-start" no-till, perhaps eliminating any yield decrease. Cover crops can be an important part of a continuous no-till system designed to maintain short-term yields and eventually increase corn yields in the long run.

Cover crops recycle nitrogen in the soil, help to build soil organic matter, and improve soil structure and improve water infiltration to improve no-till corn yields. Long-term cover crops can boost yields while improving soil quality and providing environmental and economic benefits. Growing cover crops is helping farmers adapt faster to a continuous no-till system, one that provides long-term economic and environmental benefits that are impossible to obtain by no-tilling one year at a time.

Ecosystem Functionality

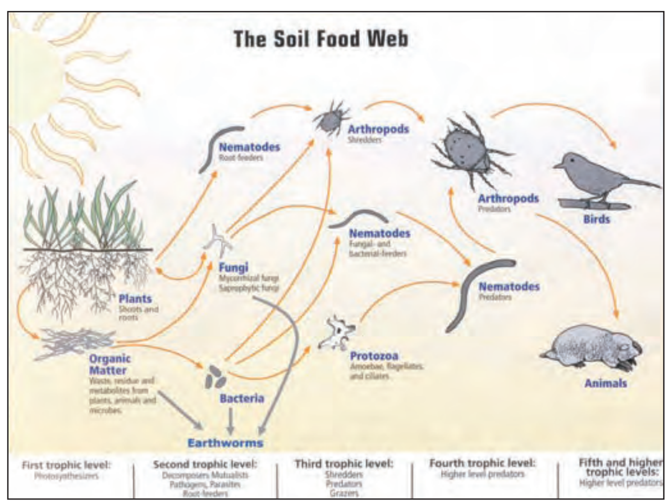
Our agricultural landscape is only green for about 6 months during the year with no living cover for the other 6 months. Corn and soybeans are planted in the spring and harvested in the fall. Fall tillage prepares the seed bed for the following crop but leaves the soil exposed and fallow. The result is a soil surface devoid of plant life for 6 months and a decrease in "ecosystem functionality." In a typical corn-soybean rotation, there are active living roots only a third of the time (Magdoff and van Es, 2001). Typically there are 1,000–2,000 times more microbes (especially bacteria and fungus) associated with living roots because the roots provide active carbon and exudates to feed the microbes (Schaetzl and Anderson, 2006).

Ecosystem functionality means that an ecosystem can sustain processes and be resilient enough to return to its previous state after environmental disturbance. Functionality depends on the quantity and quality of a system's biodiversity. An important characteristic of ecosystem functionality is that it develops and responds dynamically to constantly occurring environmental changes. Tillage is a constant disrupter and biodiversity in the soil decreases as tillage increases.

Tillage releases carbon to the atmosphere by oxidizing the soil organic (carbon based) residues and in the process releases nitrogen. Nitrate leaching typically occurs after the crop is harvested in the fall, winter, and early spring months because after the microbes release the nutrients, there are no live plants to recycle the excess nutrients. Tillage also increases soil erosion and phosphorus losses (phosphorus attaches to clay soil particles) to surface water. Excess nitrogen and phosphorus in the water cause hypoxia and eutrophication in surface waters. Ecosystem functionality decreases because the soil biodiversity decreases and there is less recycling of nutrients in the soil. That explains why the nitrogen use efficiency for commercial N and P fertilizer is only 30–40% for N and 50% for P. By improving ecosystem functionality, farmers can increase their N and P nutrient use efficiency, decrease their fertilizer bill, and improve the environment by decreasing N and P losses to surface water.

In the last hundred years, tillage has decreased soil organic levels by 60–70% with 30–40% soil organic carbon stocks remaining. Carbon stocks (30–40%) correlate directly with nitrogen use efficiency (30–40%) and the two are directly related to each other. To increase nitrogen and other nutrients in the soil, farmers need to increase carbon or organic matter. Carbon is the glue that binds the soil, stores nutrients, and keeps nutrients recycling.

Ecosystem functionality decreases as the soil carbon content decreases because carbon is the food for microbes and the storehouse for many nutrients. Most soil nitrogen (>90%) and available phosphorus (50–75%) is stored in the organic form. Nitrogen use efficiency for corn is directly related to the amount of soil organic carbon in the soil. The soil carbon holding capacity is 2.5 times the amount of carbon dioxide in the atmosphere, so the soil has a tremendous ability to store carbon. Ultimately,



Ecosystem functionality is dependent on a healthy soil food web. Each species has a certain role and function in the soil.

a loss in soil ecosystem functionality reduces the quality of life for the farmer, land owners, our rural communities, and our society.

Continuous Living Cover and No-till

An agricultural system that combines a continuous living cover (cover crops) with continuous long-term no-till is a system that more closely mimics natural systems and should restore ecosystem functionality. A thick layer of plant residue on the soil surface protects the soil from the impact of rain drops, moderates soil temperatures, and conserves soil moisture. Soil microorganisms and plants together produce polysaccharides, and glomalin (a glycoprotein) which acts like glue to bind soil particles and improve soil structure. Living roots increase pore space for increased water infiltration, soil permeability, and increased water holding capacity and recycle soil nutrients (nitrogen and phosphorus) in the soil profile.

In natural systems, the land is not extensively tilled and a continuous living cover protects the soil from rain drop impact (less erosion). By growing a cover crop in the winter, carbon inputs are added to the soil, keeping nutrients recycling within the system. Nitrogen is directly linked to carbon so less carbon losses means more nitrogen stays in the soil rather than being lost through leaching or runoff. Soil nutrients (N and P) are recycled within the natural system. Plant roots and soil residues protect the soil and keep the soil from eroding and reduce P losses resulting in less hypoxia and eutrophication. Microbial diversity and

No-till corn planted into cowpeas as a cover crop with no additional commercial N fertilizer. Photo by Dr. Rafiq Islam.

microbe numbers increase with continuous living covers so that pests (disease, insects, and weeds) can be more effectively moderated. The solution lies in changing agricultural practices to promote greater nutrient efficiency to recycle carbon, nitrogen, and phosphorus in the soil. Improved soil productivity, soil structure, and nutrient efficiency should increase crop yields and farmer profitability.

Nitrogen Recycling

Legume cover crops (cowpeas, Austrian winter pea, etc.) can provide nitrogen to the following crop. Legume cover crops fix nitrogen from the air, adding up to 50–150 pounds per acre of this essential nutrient. Non-legume cover crops recycle leftover nitrogen from the soil, storing it in roots and aboveground plant material, where a portion will be available to the following crop. Every pound of nitrogen stored is a pound of nitrogen prevented from leaching out of the top soil into streams (see OSU Extension fact sheet on Homegrown Nitrogen and Crop Rotations with Cover Crops).

Cover crops can replace nitrogen fertilizer, but not in every situation. After cereal rye, there may not be enough early nitrogen available for the new crop and after a legume, the N will likely not be available until later in the growing season depending upon when the crop decomposes. It all depends upon the carbon to nitrogen ratio.

A C:N ratio less then 20 allows the organic materials to decompose quickly while a C:N ratio greater than 30 requires additional nitrogen and slows down decomposition. Microbes will tie up soil nitrogen if a high carbon-based material with low nitrogen content (cereal rye or wheat straw) is added to the soil. Eventually the soil nitrogen is released but in the short-term the nitrogen is tied up. A low C:N ratio means more nitrogen is available quickly for microbes and plants to convert nitrogen to amino acids and protein.

Microbes generally take up nitrogen faster than plants, so if nitrogen is limiting, the plant will suffer. In no-till corn, corn is sometimes yellow from a lack of nitrogen because as the soil carbon content is increasing, the microbes are using the limited nitrogen stocks before the corn plant. A typical soil

C:N ratio is 10–12 so nitrogen is available to plant roots. If the soil C:N ratio is too high, adding nitrogen to the soil will allow the microbes to decompose the carbon residues and will decrease the C:N ratio and more nitrogen will become available to the plant.

For cereal rye and annual ryegrass before corn, plan to kill it 3–4 weeks before planting (when it is young and lush and the C:N ratio is lower). If it cannot be killed until about 2 weeks before planting, apply nitrogen (as liquid fertilizer or dry fertilizer). Cereal rye and annual ryegrass provide good rooting and soil structure and absorb nitrogen, which can be recycled for the following corn crop but depending upon the C:N ratio, may tie up nitrogen short-term, hurting corn yields.

Cowpeas may supply 120–150 pounds of N to no-till corn. No-till corn (background) planted into cowpeas with no additional commercial fertilizer. Note dark green color indicating good N fertilization. Cowpeas (foreground) drilled into wheat stubble 7 days after planting. Photo by Dr. Rafiq Islam.

Cereal ryegrass rolled before planting soybeans. Some farmers drill soybeans directly into the cereal rye then spray the cereal rye after the soybeans emerge. The cereal rye helps to control weeds and hold soil moisture going into the summer.

Cereal rye or annual ryegrass management is different for soybeans. Soybeans can be successfully no-till drilled into a standing cereal rye cover, even 7 feet tall. The cereal rye gets flattened, helping to smother potential weed growth, and is fairly easy to kill with herbicides (Roundup®) after planting. Annual ryegrass will reach 3–4 feet tall but should not be allowed to go to seed. Since soybeans are legumes and make their own nitrogen, the carbon content or C:N ratio of cereal rye and annual ryegrass does not hurt the soybean growth or yield.

No-till corn generates 14% less CO_2 losses than intensive tillage. Among the advantages are: less fuel used; soil quality and structure improves; better drainage, which can lead to earlier planting. Potential disadvantages include more weeds, more herbicides (to initially kill the cover crops), slower soil drying in spring at least initially (until soils are better aerated) , and more N required in the transitional years until soil compaction is reduced and or drainage is improved. The nitrogen may be provided, at least in part, by manure or cover crops.

Reduced Soil Erosion and Phosphorus Retention

Using a continuous living cover with no-till greatly reduces soil erosion and the loss of phosphorus with runoff. Remember that 50–75% of the available P in soil is organic and our P efficiency is only about 50% with tillage. Since the majority of the phosphorus (P) in the soil is attached to clay particles and organic matter, protecting the soil from rain drops results in less sediment erosion and keeps the P on the soil, rather than as runoff to surface water. Over 90% of P runoff is associated with phosphorus attached to the soil when soil phosphorus levels are below 100 pounds per acre Bray P1. Phosphorus in the soil is quickly tied up by clay particles so tillage incorporates P into the soil and binds P quickly.

In no-till, as the crop residues decompose, they release soluble P, which can flow to surface waters. Growing a living crop with no-till or adding a cover crop allows the soluble P to be absorbed and recycled back into the soil system.

In long-term no-till systems with a continuous living cover (cover crops), P is efficiently recycled on the soil surface so less P fertilizer is needed. A continuous living cover protects the soil from soil erosion, where a majority of the P is lost. With tillage, the P is incorporated into the soil and binds to the soil, but since the soil is not protected, soil erosion may increase sediment and P losses to surface water. When soil erodes, the nutrient-rich portion or the organic matter is the first portion to erode off in sediment because it is less dense than soil particles, floats, and can easily be washed away from the soil surface into surface water.

Soil Temperature

Living cover crops can significantly alter soil temperatures. Cover crops decreased the amplitude of day and night temperatures more than average temperatures resulting in less variability. Cover crop mulches protect the soil from cold nights and slow down cooling. This may be a benefit in hot regions, but may slow growth in cooler regions. Winter cover crops moderate temperatures in the winter. Standing crops have higher soil temperatures than flat crops. Row cleaners help manage residues and improve soil temperatures in no-till fields. Corn responds to warmer soil temperatures so strip tilling in a 10 inch band by moving the top soil residue may increase stand establishment and corn growth initially when converting from conventional tillage to no-till.

No-till soybeans drilled into a cover crop. Cereal rye and annual ryegrass used as a grass cover crops before soybeans, a legume grain crop. Photo by Dr. João Moraes Sá.

Long-term no-till farmers who use cover crops say that their soils are not cold. There are three reasons why this occurs. **First**, in the transition from conventional tillage to no-till, soils tend to be compacted, keeping the soil wet and saturated. Water holds the heat and cold longer than air, which acts like an insulation. Thus, cold soils tend to be wet and insulated from the atmosphere by residue on the soil surface. Cover crops in a no-till rotation allow rainfall and precipitation to infiltrate the soil (soils are more porous) and allow more air into the soil to warm up the soil faster. Grass cover crops can typically penetrate 12 inches of soil compaction per year, so it may take several years to remove soil compaction that is several feet deep.

Second, in long-term no-till with cover crops, as organic residues are added to the soil surface, the soil color changes from light yellow and brown to dark brown and black as organic residues decompose. Dark brown and black organic residues absorb sunlight and heat, warming the soil. This process may take several years to occur.

Third, as even more organic residues accumulate on the soil surface, the intensity of the biologic activity on the soil surface increases. Biologically active organic matter like compost piles give off heat as the microbial decomposition intensifies, warming the soil. In order for this last sequence to occur, a thick layer of residue needs to accumulate on the soil surface. Long-term no-tillers and no-till farmers using cover crops say that the improved soil porosity and dark organic residues promote soil warming.

Cold versus Warm No-till Soils

1. Compaction and poor drainage create cold soils because water holds both the heat and cold more than air. Cover crops improve drainage and aeration in no-till soil so they warm up faster in the spring.
2. Surface residue decomposes, turning black, and absorbs heat.
3. Thick surface residue increases microbial activity and creates heat, like in the center of a compost pile.

Controlled Traffic and Compaction

Soil compaction is a biological problem. Surface and subsoil tillage may physically break up hard pans and soil compaction temporarily but they are not a permanent fix. Good soil structure requires the production of glomalin, formed from polysaccharides produced by plants and fungus in the soil. The plant roots provide the sugar and the fungi provide the protein to form glomalin, a glycoprotein.

Glomalin coats microaggregate soil particles, forming macroaggregates, which improves soil structure and allow soil air and water to infiltrate and move through the soil. Tillage destroys macroaggregates by oxidizing the glomalin. Both cover crops and fungus microorganisms are needed to improve soil structure and decrease long-term soil compaction in the soil. (See the OSU Extension fact sheet: "The Biology of Soil Compaction.")

No-till corn (either in rotation or continuous) offers an opportunity for controlled traffic to manage compaction and provide other savings. Using auto-steering to maintain exact traffic patterns means that earlier planting and more timely harvest are possible because tracks are firm, resulting in higher grain yields. Precise steering means no overlap, which reduces costs of all inputs, including fuel and labor. Using auto-steering with a cover crop and no-till in a controlled system offers the opportunity to manage soil compaction so that it does not hurt crop yields.

Water Infiltration

As a plant grows, the roots create channels and fissures in the soil called macropores. These macropores allow air and water to infiltrate and move in the soil. These macropores also allow water to be stored. A pound of soil organic matter has the ability to hold 18–20 pounds of water. The organic residues stabilize the soil and hold soil moisture. A bare soil that has been tilled has the ability to hold 1.5–1.7 inches of water, while a continuously vegetated soil has the ability to hold 4.2–4.5 inches of water. Organic matter improves water infiltration, soil structure, and macropores in the soil. Living plants, plant roots, organic matter, and the polysaccharides in the soil (glomalin) stabilize the soil and allow the soil to retain more water than a tilled soil.

Cover crops produce more vegetative biomass than volunteer plants, transpire water, increase water infiltration, and decrease surface runoff and runoff velocity. If the velocity of runoff water is doubled in a stream, the carrying capacity of water or the stream competence to transport soil sediment and nutrients increases by a factor of 2^6 or 64 times. So 64 times more sediment and nutrients are lost with moving water when the velocity is doubled (Walker et al., 2006). Cover crops protect soil aggregates from the impact of rain drops by reducing soil aggregate breakdown. By slowing down wind speeds at ground level and decreasing the velocity of water in runoff, cover crops greatly reduce wind and water erosion.

Cover crops decrease soil erosion by 90%, decrease sediment transport by 75%, reduce pathogen loads by 60%, and reduce nutrient and pesticide loads by 50% to our streams, rivers, and lakes. As the price of fuel and fertilizer increases, planting cover crops becomes more and more economical as a way to build SOM and store and recycle nutrients in the soil. See the OSU Extension fact sheet on Using Cover Crops to Improve Soil and Water Quality.

Summary

Agricultural systems that mimic the natural world tend to be more efficient, sustainable, and profitable. Using a continuous long-term no-till system with cover crops or a continuous living cover is an agricultural system that closely mimics the natural world and restores ecosystem functionality. In no-till, a thick layer of residue protects the soil from the impact of raindrops and reduces soil erosion. Soil temperatures are moderated by this residue and soil moisture is retained in the soil profile. Water infiltration is improved and runoff is minimized. Soil nutrients are efficiently stored and recycled in the soil by growing plants or cover crops, allowing carbon to be recycled in the soil and storing nitrogen and phosphorus. Soil pests like weeds, insects, and diseases are controlled because there is a biological diversity, which generally prevents or moderates large increases in one species over another. Growing a continuously living cover with no-till promotes healthy growing crops and reduces the problems

Making No-till Corn Successful

No-till corn production has struggled to be successful in the Midwestern United States. No-till farmers say it takes 7–9 years to transition from conventional farming to long-term no-till. Using a cover crop with continuous long-term no-till shortens the time period to 2–4 years. No-till corn yields are typically reduced 10–20% during those transition years.

This occurs for several reasons. First, initially fewer nutrients are being released from the residues deposited on the soil surface. Tillage allows surface residues to decompose faster, releasing nutrients, but it also destroys organic matter, resulting in less storage of soil nutrients.

Second, in biologically active soils, the microbial biomass is increasing in size and population, accumulating N as amino acids and proteins and P as DNA in microbes. This initially deprives no-till corn of nitrogen and soil nutrients until the soil system becomes stable.

Third, the soil is building humus organic matter, which requires N to decompose and stabilize the organic molecule. Every 1% SOM requires 1,000 pounds of N, so if the N is being tied up and N is not available, the soil microbes will utilize N before the corn. Fourth, soil compaction from the previous tillage causes denitrification from saturated/water-logged fields, losing 40–60% of the available N in the soil.

So to reverse this process, first cover crops are grown to reduce soil compaction and improve the recycling of C and N in the soil. Second, as the microbial and humus organic matter levels build up, N and P are more efficiently recycled in the soil to the corn and no-till corn yields increase, outperforming conventional tilled soils. Third, as water infiltration increases and soils are better aerated, denitrification and N losses decrease, increasing the storage and recycling of N in crop residues and organic matter (humus) and resulting in more soil nutrients (N, P, and S) for the corn crop. See OSU Extension fact sheet Understanding Soil Ecology and Nutrient Recycling.

Reasons Why No-till Corn Struggles

1. Surface residue ties up nutrients and slows down decomposition and release of nutrients.
2. Soil microbes tie up soil nutrients, especially N.
3. Long-term soil organic matter ties up nutrients, especially N.
4. Compaction and poor drainage causes denitrification and loss of N.
5. Cold wet soils limit germination and planting.

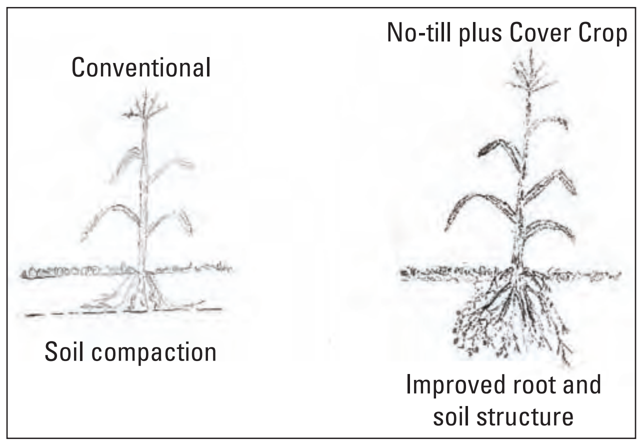


Diagram by James J. Hoorman. Illustrated by Danita Lazenby

Successful No-till Plus Cover Crops

1. Reduces soil compaction.
2. Improves C, N, P recycling.
3. Reduced N Losses from denitrification.
4. Increased nutrient storage in soil from increased SOM

most farmers have in growing crops with tillage (hard soil, cloddy soils, soil compaction, runoff, soil erosion, nutrient losses, annual weeds, insects, soil diseases). Tillage creates problems with soil compaction, water infiltration, soil structure, and nutrient recycling.

However, converting to no-till requires a transition period because the biological diversity has been diminished with tillage. Natural systems are fragile and once they have been disturbed it takes time to restore the ecosystem functionality. As the carbon is decomposed and released to the atmosphere, the capacity to store nutrients in the soil is diminished. The fastest way to build soil organic matter levels is to grow plants continuously using long-term no-till so that the residues are not decomposed. Continuous no-till plus a cover crop mimics natural cycles and promotes nutrient recycling and improved soil structure to improve crop production.

Acknowledgments

This fact sheet was produced in conjunction with the Midwest Cover Crops Council (MCCC). The authors wish to thank Kim Wintringham (Technical Editor, Communications and Technology, The Ohio State University) and Danita Lazenby (illustrations). Outside reviewer: Mark Fritz, Ohio Department of Agriculture.

References

Magdoff, F. and H. van Es. 2001. *Building Soils for Better Crops*, 2nd Edition. Sustainable Agriculture Network. Beltsville, MD. www.sare.org/publications/soils.htm.

Managing Cover Crops Profitably, 3rd Edition, Sustainable Agriculture Network, Handbook Series Book 9, Ed. Andy Clark. 2007 Beltsville, MD, United Book Press.

Schaetzl, R., and S. Anderson. 2006. Chapter 6: Basic concepts: soil organisms. In *Soils: Genesis and Morphology*. Cambridge University Press, p. 96.

Tisdall, J.M., and J.M. Oades. 1982. Organic matter and water-stable aggregates in soils. *Journal of Soil Science, 33*, pp. 141–163.

USDA-NRCS Engineering Field Handbook, Chapter 2, Hydrology.

Walker, D., D. Baumgartner, K. Fritzsimmons, and C.P. Gerber. 2006. Chapter 18: Surface Water Pollution, In *Environment & Pollution Science.* Eds. I.L. Pepper, C.P. Gerber, and M.L. Brusseau, p. 283.

Widman, N., R. Glaze, B. Miller, A. Sundermeier, and R. Reeder, No-till Corn Production, Ohio State University Extension, Food, Agricultural and Biological Engineering, AEX 501-01.

Related OSU Extension Fact Sheets

- Crop Rotations with Cover Crops
- Understanding Soil Ecology and Nutrient Recycling
- Homegrown Nitrogen
- The Biology of Soil Compaction
- Using Cover Crops to Improve Soil and Water Quality

THE OHIO STATE UNIVERSITY EXTENSION

FACT SHEET

Agriculture and Natural Resources

SAG-10-09
AEX-543-09

The Biology of Soil Compaction

James J. Hoorman
Extension Educator
Cover Crops and Water Quality
Ohio State University Extension
Columbus, Ohio

João Carlos de Moraes Sá
Soil Organic Matter and
Fertility Specialist
University of Ponta Grossa
Ponta Grossa, Brazil

Randall Reeder
Extension Agricultural Engineer
Food, Agricultural, and
Biological Engineering
Ohio State University Extension
Columbus, Ohio

Soil Compaction

Soil compaction is a common and constant problem on most farms that till the soil. Heavy farm machinery can create persistent subsoil compaction (Hakansson and Reeder, 1994). Johnson et al. (1986) found that compacted soils resulted in: (a) restricted root growth; (b) poor root zone aeration; and (c) poor drainage that results in less soil aeration, less oxygen in the root zone, and more losses of nitrogen from denitrification.

Subsoil tillage has been used to alleviate compaction problems. Subsoilers are typically operated at depths of 12 to 18 inches to loosen the soil, alleviate compaction, and increase water infiltration and aeration. Subsoiling usually increases crop yields but the effects may only be temporary as the soil re-compacts due to equipment traffic. Some no-till fields never need to be subsoiled, but in other no-till fields deep tillage has increased yields especially if equipment traffic is random. When subsoiling removes a hard pan, traffic must be controlled or compaction will reoccur. If a hard pan does not exist, equipment traffic generally will create one (Reeder and Westermann, 2006).

If the soil is subsoiled when the soil is wet, additional compaction may occur. In a loamy sand, Busscher et al. (2002) found that soil compaction increased with time, and cumulative rainfall accounted for 70 to 90 percent of the re-compaction due to water filtering through the soil and the force of gravity. The fuel, labor, equipment, and time to subsoil makes it an expensive operation. Subsoiling in dry conditions requires even more fuel (Reeder and Westermann, 2006). Two other factors that impact soil compaction are rainfall impact and gravity. In soils that have been tilled, both the velocity of the raindrop impact on bare soil and natural gravity combine to compact soils.

Low organic matter levels make the soil more susceptible to soil compaction. Organic residues on the soil surface have been shown to cushion the effects of soil compaction. Surface organic residues have the ability to be compressed but they also retain their shape and structure once the traffic has passed. Like a sponge, the organic matter is compressed and then springs back to its normal shape. However, excessive traffic will break up organic residues, and tillage accelerates the decomposition of organic matter. Organic residues in the soil profile may be even more important than surface organic residues. Organic matter (plant debris and residues) attached to soil particles (especially clay particles) keeps soil particles from compacting. Organic matter binds microaggregates and macroaggregates in the soil. Low organic matter levels make the soil more susceptible to soil compaction (Wortman and Jasa, 2003).

In the last hundred years, tillage has decreased soil organic levels by 60%, which means that approximately 40% soil organic carbon stocks are remaining (International Panel on Climate Change, 1996, Lal, 2004). Carbon provides energy for soil microbes, is a storehouse for nutrients, and keeps nutrients recycling within the soil. Humus or old carbon (>1,000 years old) is the most stable carbon and binds micro soil particles together to form microaggregates. Humus is non-water soluble so it stabilizes microaggregates and is not readily consumed by microorganisms. Humus is more resistant to tillage and degradation than active carbon.

Active carbon (plant sugars or polysaccharides, glomalin) is consumed by microbes for energy. Active carbon is reduced with tillage but is stabilized under natural vegetation and no-till systems using a continuous living cover. Active carbon is part of the glue that binds microaggregates into macroaggregates and insulates the macroaggregate from oxygen. Soil porosity, water infiltration, soil aeration, and soil structure increase under natural vegetation and no-till systems with continuous living cover. Increased soil macroaggregation improves soil structure and lowers bulk density, keeping the soil particles from compacting.

Microaggregates and Macroaggregate Formation

Microaggregates are 20–250 µm in size and are composed of clay microstructures, silt-size microaggregates, particulate organic matter, plant and fungus debris, and mycorrhizal fungus hyphae: these particles are stable in size. Roots and microbes combine microaggregates in the soil to form macroaggregates. Macroaggregates are linked mainly by fungi hyphae, roots fibers, and polysaccharides and are less stable than microaggregates. Macroaggregates are greater than 250 µm in size and give soil its structure and allow air and water infiltration. Compacted soils tend to have more microaggregates than macroaggregates. See the microaggregate-macroaggregate model (figure 1) and the macroaggregate model and hierarchy (figure 2).

Glomalin acts like a glue to cement microaggregates together to form macroaggregates and improve soil structure. Glomalin initially coats the plant roots and then coats soil particles. Glomalin is an amino polysaccharide or glycoprotein created by combining a protein from the mycorrhizal fungus with sugar from plant root exudates (Allison, 1968). The fungal *"root-hyphae-net"* holds the aggregates intact and clay particles protect the roots and hyphae from attack by microorganisms. Roots also create other polysaccharide exudates to coat soil particles (see figures 2 and 3).

The contribution of mycorrhizal fungi to aggregation is a simultaneous process involving three steps. First, the fungus hyphae form an entanglement with primary soil particles, organizing and bringing them together. Second, fungi physically protect the clay particles and the organic debris that form microaggregates. Third, the plant root and fungus hyphae form glomalin and glue microaggregates and some smaller macroaggregates together to form larger macroaggregates (see figure 4).

In order for glomalin to be produced, plants and mycorrhizal fungus must exist in the soil together. Glomalin needs to be continually produced because it is readily consumed by bacteria and other microorganisms in the

Microaggregates-Macroaggregates Model

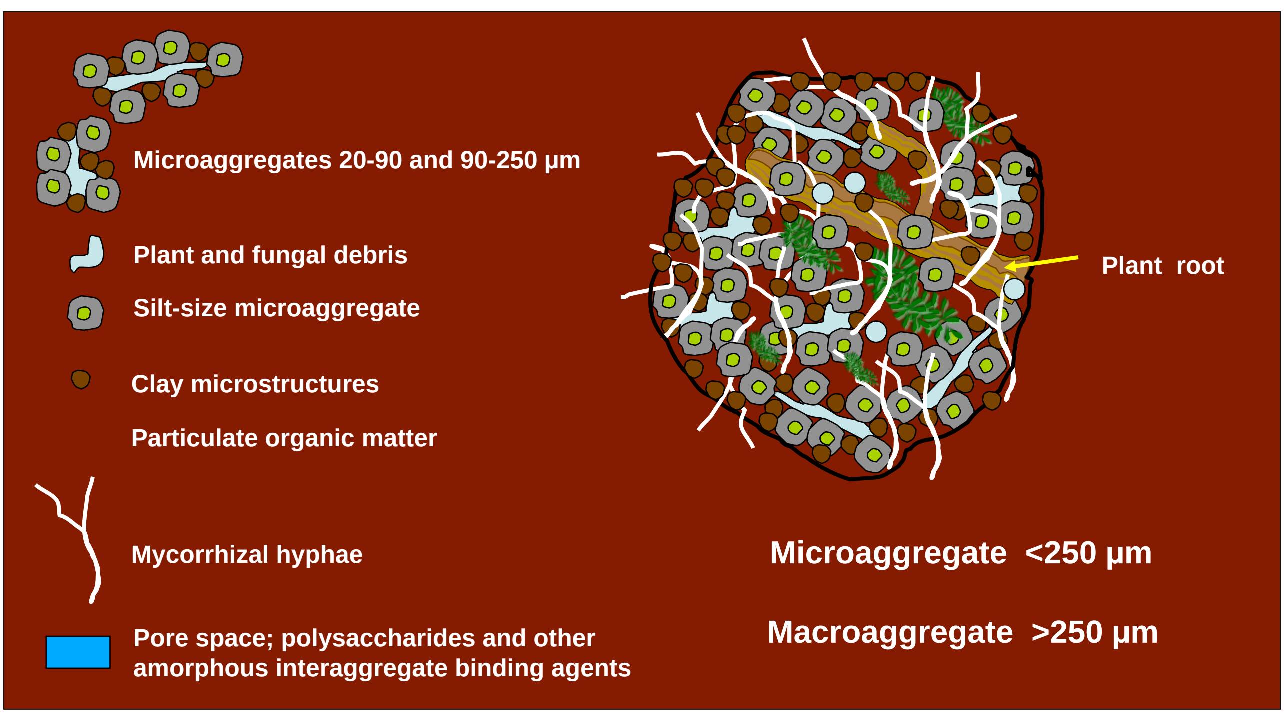


Figure 1. Dr. Charles Rice presentation adapted from Jastrow and Miller, 1997.

Macroaggregate Model and Hierarchy

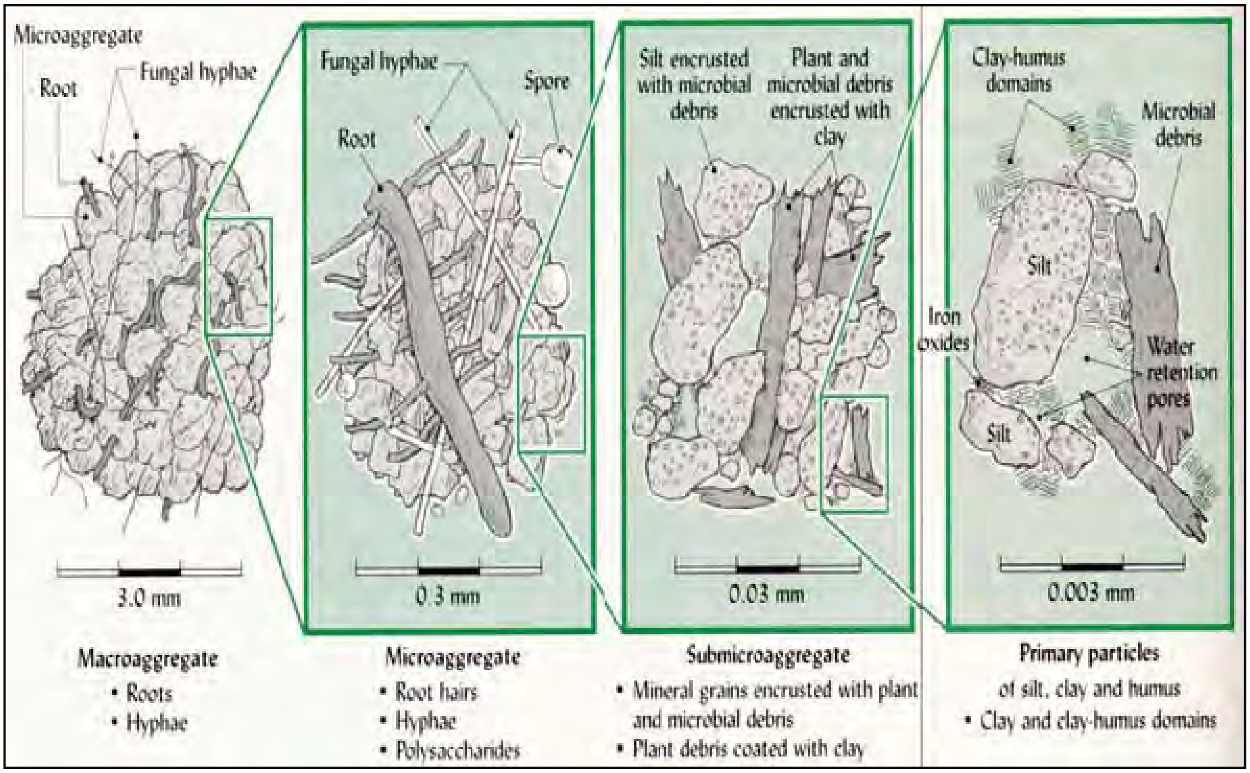


Figure 2. From Tisdall & Oades, 1982.

soil. Bacteria thrive in tilled soils because they are more hardy and smaller than fungus, so bacteria numbers increase in tilled soils. Fungi live longer and need more stable conditions to survive. Fungi grow better under no-till soil conditions with a continuous living cover and a constant source of carbon. Since fungi do not grow as well in tilled soils, less glomalin is produced and fewer macroaggregates are formed. Fewer macroaggregates is associated with poor soil structure and compaction. **Thus, soil compaction is a biological problem related to decreased production of polysaccharides and glomalin in the soil. Soil compaction is due to a lack of living roots and mycorrhizal fungus in the soil.**

In a typical corn-soybean rotation, active roots are present only a third of the time. Adding cover crops between the corn and soybean crops increases the presence of active living roots to 85% to 90% of the time. Active roots produce more amino polysaccharides and glomalin because mycorrhizal fungus populations increase due to a stable food supply.

Surface and subsoil tillage may physically break up hard pans and soil compaction temporarily but they are not a permanent fix. Tillage increases the oxygen content of soils and decreases glomalin and amino polysaccharide production by reducing plant root exudates and mycorrhizal fungus populations. Soil compaction is a result of the lack of active roots producing polysaccharides and root exudates, and a lack of mycorrhizal fungus producing glomalin. In a typical undisturbed soil, fungal hyphae are turned over every 5 to 7 days and the glomalin in the fungal hyphae is decomposed and continually coats the soil particles. Disturbed soils have less fungus, more bacteria, and more microaggregates than macroaggregates. Heavy equipment loads push the microaggregates together so that they can chemically bind together, compacting the soil. Macroaggregate formation improves soil structure so that soil compaction may be minimized. Thus, soil compaction has a biological component (see figure 5).

Cultivation of soils, heavy rains, and oxygen promotes the breakdown of macroaggregates, which give soil structure and soil tilth. Farmers who excessively till their soils (for example, heavy disking or plowing) break down the soil structure by breaking up the macroaggregates, injecting oxygen into the soil, and depleting the soil of glomalin and polysaccharides and a loss of carbon. Greater than 90% of the carbon in soil is associated with the mineral fraction (Jastrow and Miller, 1997). Glomalin and polysaccharides are consumed by flourishing

Figure 3. Roots, fungi hyphae. and polysaccharides stabilize soil macroaggregates and promote good soil structure.
From Dr. João de Moraes Sá.

bacteria populations that thrive on high oxygen levels in the soil and the release of nutrients in organic matter from the tillage. The end result is a soil composed of mainly microaggregates and cloddy compacted soils. Soils composed mainly of microaggregates prevent water infiltration due to the lack of macropores in the soil, so water tends to pond on the soil surface. Farm fields that have been excessively tilled tend to crust, seal, and compact more than no-till fields with surface crop residues and a living crop with active roots to promote fungal growth and glomalin production.

An agricultural system that combines a **continuous living cover (cover crops) with continuous long-term no-till** is a system that closely mimics a natural system and should restore soil structure and soil productivity. A continuous living cover plus continuous long-term no-till protects the soil from compaction in five major ways. **First**, the soil surface acts like a sponge to help adsorb the weight of heavy equipment traffic. **Second**, plant roots create voids and macropores in the soil so that air and water can move through the soil. Roots act like a biological valve to control the amount of oxygen that enters the soil. The soil needs oxygen for root respiration and to support aerobic microbes in the soil. However, too much soil oxygen results in excessive carbon loss from the aerobic microbes consuming the active carbon. **Third**, plant roots

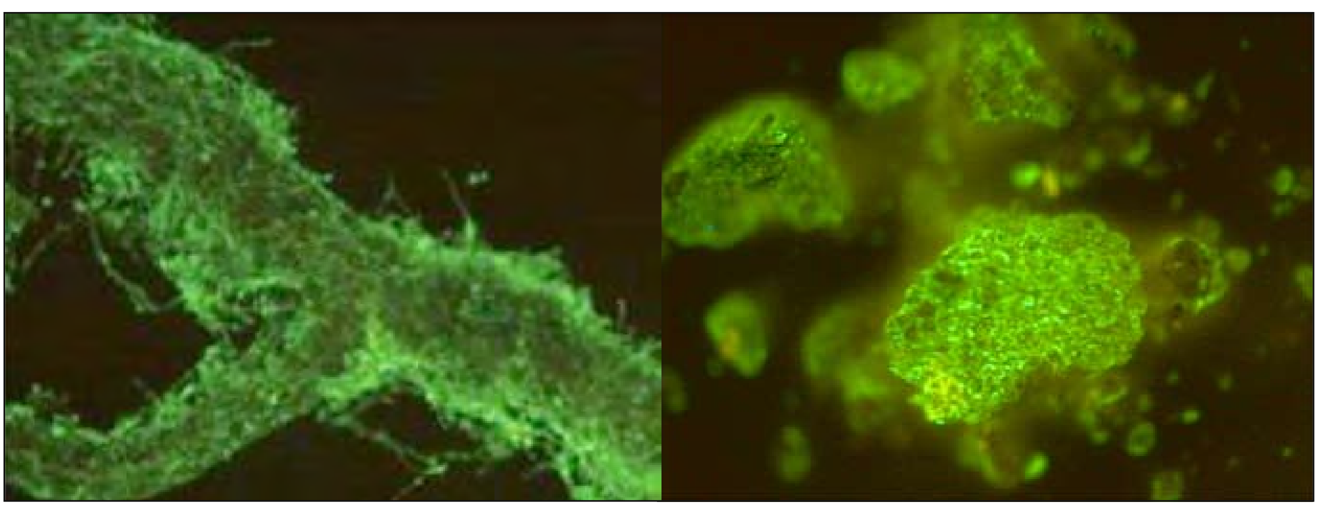


Figure 4. Glomalin surrounding a root heavily infected with mycorrhizal fungi and soil macroaggregates surrounded by glomalin.
Photos by Dr. Sara Wright, USDA-ARS.

What is a clod?

Many farmers complain that their soil is cloddy and hard to work. Clods are manmade and do not usually exist in the natural world. Bricks and clay tile are formed by taking wet clay from the soil, and heating and drying the clay. When farmers till the soil, they perform the same process by exposing the clay to sunlight, heating and drying the clay until it gets hard and turns into a clod. Tillage also oxidizes the soil and results in increased microbial decomposition of organic residues. Organic residues keep clay particles from chemically binding. Clay soils that remain protected by organic residues and stay moist resist turning into clods because the moisture and organic residues keep the clay particles physically separated.

Organic residues act like sponges, absorbing water and soil nutrients, cushioning soil particles. Clods act like bricks, resisting water absorption and making soils hard and compacted. Photo by Jim Hoorman.

supply food for microorganisms (especially fungus) and burrowing soil fauna that also keep the soil from compacting. **Fourth**, organic residues left behind by the decaying plants, animals, and microbes are lighter and less dense than clay, silt, and sand particles. The average bulk density of soil organic matter is 0.3 to 0.6 kg/m^3 compared to soil density of 1.4 to 1.6 kg/m^3. So adding organic residues to the soil decreases the average soil density. **Fifth**, soil compaction is reduced by combining microaggregates into macroaggregates in the soil. Microaggregate soil particles (clay, silt, particulate organic matter) are held together by humus or old organic matter residues, which are resistant to decomposition, but microaggregates tend to compact in the soil under heavy equipment loads. Polysaccharides and glomalin weakly combine microaggregates into macroaggregates but this process is broken down once the soil is disturbed or tilled.

Oxidation and Release of CO_2

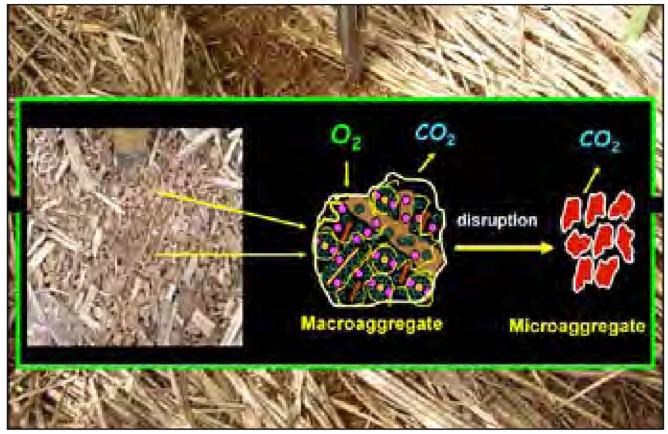


Figure 5. Tillage disrupts the macroaggregates and breaks them into microaggregates by letting in oxygen and releasing carbon dioxide. From Dr. João de Moraes Sá.

Summary

Soil compaction reduces crop yields and farm profits. For years, farmers have been physically tilling and subsoiling the soil to reduce soil compaction. At best, tillage may temporarily reduce soil compaction but rain, gravity, and equipment traffic compact the soil. Soil compaction has a biological component and the root cause of soil compaction is a lack of actively growing plants and active roots in the soil. A continuous living cover plus long-term continuous no-till reduce soil compaction in five ways. Organic residues on the soil surface cushion the soil from heavy equipment. Plant roots create voids and macropores in the soil for air and water movement. Plant roots act like a biological valve to control the amount of oxygen in the soil to preserve soil organic matter. Plant roots supply food for soil microbes and soil fauna. Residual organic soil residues (plants, roots, microbes) are lighter and less dense than soil particles.

Soil compaction is reduced by the formation of macroaggregates in the soil. Microaggregate soil particles (clay, silt, particulate organic matter) are held together by humus or old organic matter residues and are resistant to decomposition. Macroaggregates form by combing microaggregates together with root exudates like polysaccharides and glomalin (sugars from plants and protein from mycorrhizal fungus). Polysaccharides from plants and glomalin from fungus weakly hold the microaggregates together but are consumed by bacteria so they need to be continually reproduced in the soil to improve soil structure. Tillage and subsoiling increases the

continued on page 7

Building Soil Structure

Building soil structure is like building a house. Mother Nature is the architect and plants and microbes are the carpenters. Every house needs to start out with a good foundation like bricks *(clay, sand, silt)* and cement *(cations like Ca++, K+).* When a house is framed, various sized wood timbers, rafters, and planks are used to create rooms (represented by the various sized roots in the soil). Wood and roots give the house and the soil structure, creating space where the inhabitants (plants, microbes, and soil fauna) can live.

Wood in a house is held together by various sized nails *(humus)* and lag screws *(phosphate* attaches organic residues to clay particles). A house has braces to add stability *(nitrogen* and *sulfur* provide stability to organic residues) and a roof to control the temperature and moisture. In the soil, a deep layer of surface residues controls oxygen and regulates water infiltration and runoff. A roof insulates the house and regulates the temperature just like surface residue on the soil surface keeps the soil temperature in a comfortable range for the inhabitants *(microbes* and *plant roots).* Houses need insulation and glue to keep the house together. Root exudates form polysaccharides and glomalin (formed with *mycorrhizal fungus)* to insulate the soil particles and keep the soil macroaggregates glued together. If the roof on a house is destroyed, moisture and cold air can enter the house and rot out the wood and dissolve the glues.

In the soil, organic matter decomposes very quickly when tillage, excess oxygen, and moisture either break down the glues *(polysaccharides* and *glomalin)* or are easily consumed by flourishing bacteria populations. Excess oxygen in the soil (from tillage) stimulates bacteria populations to grow and they consume the polysaccharides as a food source, destroying the soil structure. With tillage, macroaggregates become microaggregates and the soil becomes compacted.

As every homeowner knows, houses need regular maintenance. In the soil, the roots and the microbes (especially *fungus)* are the carpenters that maintain their house, continually producing the glues *(polysaccharides* and *glomalin)* that hold the house together. Regular tillage acts like a tornado or a hurricane, destroying the structural integrity of the house and killing off the inhabitants. Tillage oxidizes the organic matter in the soil, destroying the roots and the active organic matter, causing the soil structure to crumble and compact. If you remove wood supports and glue in a house, the house becomes unstable just like the soil does when you remove the active living roots and active organic residues (polysaccharides). Wood beams in a coal mine stabilize the coal mine tunnel like active living roots and healthy microbial communities give the soil structure to prevent soil compaction. Active roots and macroaggregates give soil porosity to move air and water through the soil in macropores. In an ideal soil, 50 to 60% of the soil volume is porous while in a degraded compacted soil, soil porosity may be reduced to 30 to 40% of the total soil volume. Compacted soil is like a decaying house turning to a pile of bricks, cement, and rubble.

Building Soil Structure is like Building a House

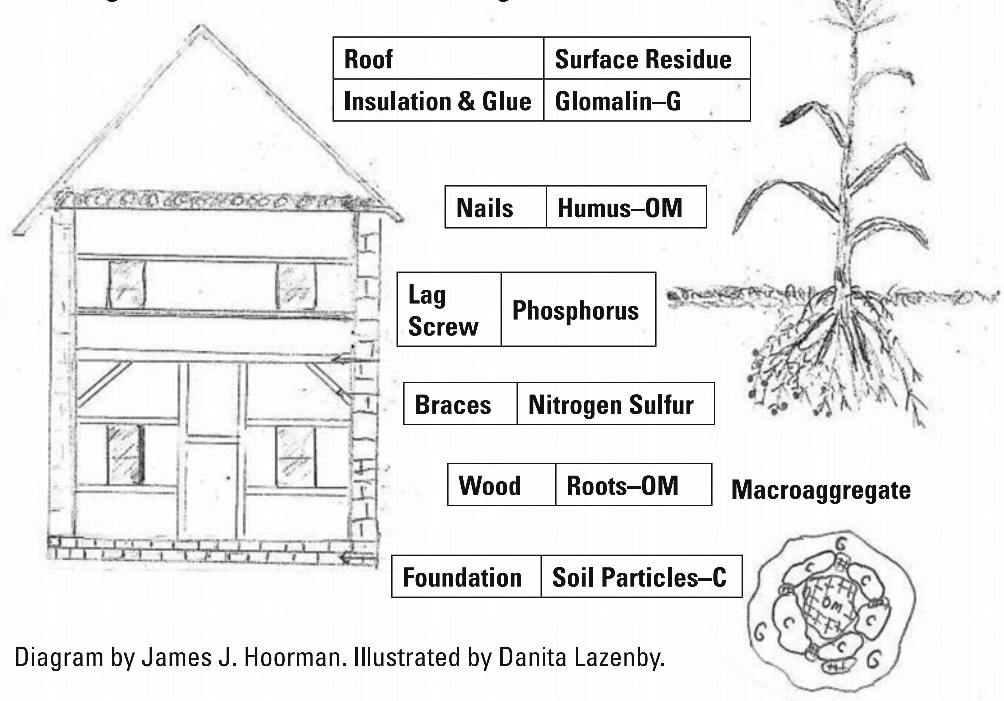


Diagram by James J. Hoorman. Illustrated by Danita Lazenby.

oxygen content in soils, increasing bacteria populations, which consume the active carbon needed to stabilize macroaggregates, leading to the destruction of soil structure. Soil compaction is a direct result of tillage, which destroys the active organic matter and a lack of living roots and microbes in the soil. Heavy equipment loads push soil microaggregates together so that they chemically bind together, resulting in soil compaction.

Acknowledgments

This fact sheet was produced in conjunction with the Midwest Cover Crops Council (MCCC). The authors wish to thank Kim Wintringham (Technical Editor, Communications and Technology, The Ohio State University) and Danita Lazenby (diagram illustrations).

Five Ways Soil Organic Matter Resists Soil Compaction

1. Surface residue resists compaction. Acts like a sponge to absorb weight and water.
2. Organic residues are less dense (0.3-0.6 g/cm^3) than soil particles (1.4-1.6 g/cm^3).
3. Roots create voids and and spaces for air and water.
4. Roots act like a biological valve to control oxygen in the soil.
5. Roots supply exudates to glue soil particles together to form macroaggregates and supply food for microbes.

References

Allison, F.E. 1968. Soil aggregates—some facts and fallacies as seen by microbiologist. *Soil Sci. 106*: 136–143.

Busscher, W.J., P.J. Bauer, & J.R. Frederick. 2002. Recompaction of a coastal loamy sand after deep tillage as a function of subsequent cumulative rainfall. *Soil and Tillage Research 68*: 49–57.

Hakansson, I., & R.C. Reeder. 1994. Subsoil compaction by vehicles with high axle load-extent, persistence and crop response. *Soil and Tillage Research 29* (2–3): 277–304.

Jastrow, J.D., & Miller, R.M. 1997. Soil aggregate stabilization and carbon sequestration: Feedbacks through organomineral associations. In: *Soil Processes and the Carbon Cycle* (ed. R. Lal et al.), pp. 207–223. CRC Press, Boca Raton, FL.

Johnson, B.S., A.E. Erickson, & A.J.M. Smucker. 1986. Alleviation of compaction on a fine textured soil ASAE Paper No. 86-1517. St. Joseph, MI: ASAE.

Lal, R. 2004. Soil Carbon Sequestration impacts on global climate change and food security. *Sci. 304:* 1623–1627.

Reeder, R., & D. Westermann. 2006. In: *Environmental Benefits of Conservation on Cropland: The Status of Our Knowledge,* Chapter 1 Soil Management Practices. (ed. M. Schnepf & C. Cox), Soil and Water Conservation Society, Ankeny, Iowa, pp. 26–28.

Tisdall, J.M., & J.M.Oades, 1982. Organic matter and water stable aggregates in soil. *J. of Soil Science. 33:* 141–163.

Dr. João Carlos de Moraes Sá. 2008. Biological interactions with aggregate formation & carbon cycle in the terrestrial environment. PowerPoint presentations.

Wortman, C., & P. Jasa. 2003. Management to Minimize and Reduce Soil Compaction. NebGuide G896. University of Nebraska–Lincoln Extension.

Wright, S.F., & Upadhyaya, A. 1996. Extraction of an abundant and unusual protein from soil and comparison with hyphael protein of arbuscular fungi during active colonization of root. *Plant Sci. 181:* 193–203.

Related OSU Extension Fact Sheets

- Sustainable Crop Rotations with Cover Crops
- Understanding Soil Ecology and Nutrient Recycling
- Homegrown Nitrogen
- Using Cover Crops to Improve Soil and Water Quality
- Using Cover Crops to Convert to No-till

Quantifying Nitrogen Mineralization and Plant Available Nitrogen Concentrations in the Soil Following Crop, Cover Crop Residue and Manure Incorporation Across An Organic Vegetable Rotation

Nicholas J. Goeser, Alvin J. Bussan, Matthew D. Ruark

THE UNIVERSITY of WISCONSIN MADISON

Introduction

- Adequate nitrogen fertilizer and synchronizing nitrogen availability with crop nitrogen demands are great concerns in organic vegetable production.
- Net nitrogen mineralization quantity and rate varies with cover crop residue and organic amendment chemical composition.
- Our goal was to determine in-situ nitrogen mineralization and plant available nitrogen pools as affected by previous crop, cover crop and fertilizer residues alone and in combination within the soil.

Objectives:

1) Quantify nitrogen mineralized in soils following crop residue, cover crop residue, organic fertilizer incorporation.
2) To determine plant available nitrogen concentrations within the soil, throughout a sweet corn crop growing under four organic fertility management systems.

Materials and Methods

Field Methods

- 2 year study at Arlington, WI from 2009-2010 within a sweet corn cropping system
- Plano silt loam soil (Typic Argiudolls)
- Randomized complete block design-3 blocks- 2 columns/block
- Four organic fertility management systems.
  - *Control*- no inputs
  - *Manure*- manure applied in spring prior to planting, no cover crops- no fertilizer
  - *Plant based*- Field pea and mustard cover crops- no fertilizer
  - *Integrated annual cover crop/manure*- field pea and mustard cover crops, manure applied the previous year

In-situ column methods

- 10.16 cm dia. x 30 cm deep PVC columns with in-tact soil core
- Amendments added and installed at the time of cover crop incorporation
  - Initial soil sample (1cm x 8 cm core from within column)
  - 2 resin ion/anion bags placed at base of column
- Repeated soil sampling and resin bag extraction at time of significant crop growth stages
  - Emergence, V5, VT, VS, Harvest

Data Analysis

- A Levene's test for homogeneity of variances across years was conducted followed by repeated measures ANOVA methods.

Results

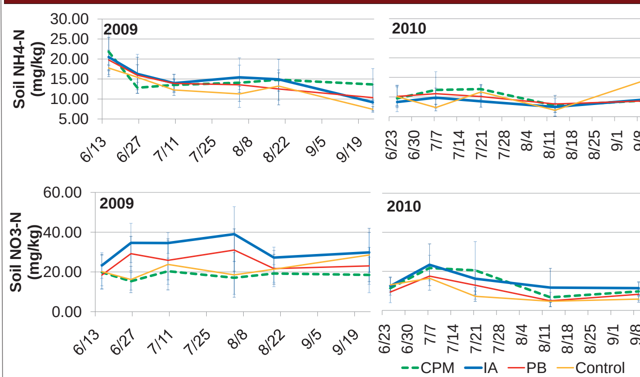


Figure 1: Soil NH_4-N, NO_3-N,throughout 2009 and 2010 by organic fertility management system.

Table 1: Summary of comparable mineralization studies in similar systems. (Adapted from Brye et al. 2003)

Ecosystem	Soil Type	Time Period	N-min Estimate (kg-ha^{-1})	Reference
Dryland Fallow	Loam	April 30-July 22	33.7	Kolberg et al. 1997
	Clay loam	April 30-July 15	26.5	
Fertilized corn	Sandy silt	Aug. 10- Sep. 26	82	Hubner et al. 1991
Wheat-fallow rotation	Sandy loam	2 Weeks	13-19	Qian and Schoenau 1995
Minimum tillage agroecosystem			17-20	
Uncultivated sugarcane	Muck	Annual	149-348	Hanlon et al. 1997
Cultivated sugarcane			13-221	
Sod			63-234	
Cultivated sweet corn			18-123	
Cultivated winter wheat		30 days	153	Ajwa et al. 1998
Wheat-corn-millet rotation	Loam	30 days	32-52	Wood et al. 1990
	Loam clay		39-73	
Cultivated field corn	Silt loam	1 Month	-167 - 58.5	Brye et al. 2002
Our Study	**Silt loam**	**76-100 days**	**4-82**	

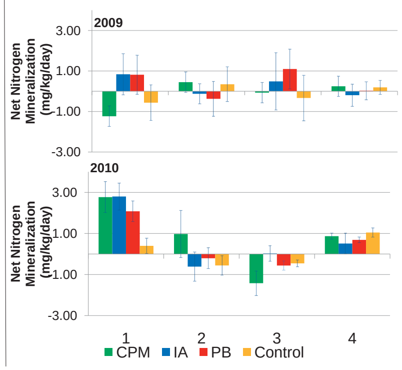


Figure 2: Within season accumulated mineralized NO_3-N, incubation time, year and organic fertility management system.

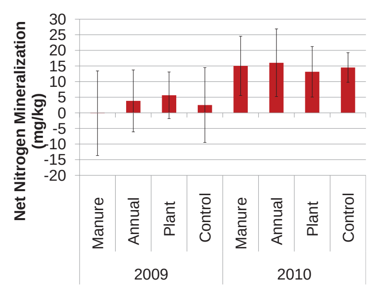


Figure 3: Total mineralized NO_3-N by year and organic fertility management system.

- Soil NO_3-N and NH_4-N values varied by system, incubation time and year.
- Within season mineralized NO_3-N varied by system and year.
- Total growing season mineralized NO_3-N did not vary by system or year
- Net mineralized N values from this study were within published values typical of cultivated systems.

Conclusions

- We were able to quantify nitrogen mineralization within and across a growing season, and while our values were within previously published ranges, the quantities of nitrogen available for plant uptake were insufficient for sweet corn crop growth.
- Field pea incorporation can offset fertilizer requirements in sweet corn.
- Supplemental nitrogen is needed for organic sweet corn production using these fertility management systems.
- There is a need to further research additional manure and plant residue mineralization rates for organic production systems.

Field vegetable production:

Using cover crops for weed management

Weed management is an important crop protection component in vegetable production. Non-chemical weed control options are needed to help growers reduce reliance on herbicides and risk of resistance development. Cover crops (CC) have been identified as an approach to sustainable weed management.

Cover crops serve important functions such as enriching soil organic matter, cycling nutrients, and protecting soil from water and wind erosion. Cover crops have also been used as part of an integrated weed management approach.

However, information on CC approaches, applications and benefits pertinent to vegetable crops grown in Canada is not readily available. Therefore, a literature review was conducted to determine the feasibility of using CC in field vegetable production systems as part of integrated weed management practices to minimize the use of herbicides.

Methodology

Published scientific literature and extension articles on CC research for key vegetable crops (potato, sweet corn, field tomato, carrot, onion, Brassica crops, peas, cucurbit crops, green and wax beans, and lettuce) in North America and other regions with similar climates in Europe were reviewed. From this review, approaches which can be adopted for weed management in field vegetable production in Canada were identified based on:

Figure 1. No-till seeding into a chemically killed rye cover crop

- Economics
- Potential to suppress weeds by allelopathy (inhibition of growth of a plant by a toxin released from a nearby plant of the same or another species)
- Amount of research that has been conducted for the system in temperate regions
- Environmental impact

Economics included establishment costs, impact on crop yield, and potential for the CC to add value through control of weeds (e.g. reduced herbicide input cost), through control of other pests (e.g. increased yield or reduced input cost of other pesticides) or as a product such as forage.

Results

Potential to adopt CC as a weed control tool and reduce herbicide use in vegetables has been demonstrated mostly by studies conducted in the US. There are few scientific studies on CC for weed control in vegetables from Europe or Canada. Full season weed control by CC was rare in the literature. Some additional weed control is usually required later in the season.

Figure 2. Cereal rye in April that was overseeded by aircraft into a standing crop the previous August

Cover crops can lessen herbicide use by:

- Reducing the number of pre-plant or pre-emerge (PRE) applications;
- Switching from broadcast to band application; and,
- Switching from PRE to post-emerge (POST) applications as needed.

Switching to POST usually involves herbicides that are less persistant in the environment than PRE. Savings in herbicide cost compensates the CC cost in some studies but not others. There is wide variability between studies and systems in degree of weed control, crop response and costs. Some systems add value beyond weed control, thereby increasing profitability.

Species of weeds controlled varies widely between and within systems. In general, annuals, and not biennials or perennials are suppressed by CC. Allelopathy is a promising mechanism of control, and is likely to work best where weeds are small seeded, and the crop is not. Rye residues are allelopathic with better efficacy against annual dicots than grasses and have consistently controlled lambsquarters, nightshade, plantain, goosegrass and barnyardgrass. Brassica residues are also allelopathic, depending on stage, and notably provide control of crabgrass and pigweed. Smother crops such as sorghum or sudangrass can provide control of perennials such as quackgrass during growth, but at the expense of about half of the growing season. Sorghum residues also have allelopathic effects, controlling pigweed, barnyard grass and others.

Figure 3. Measuring biomass of forage sorghum

Recommended approaches

Table 1. Four cover crop systems are recommended for sustainable weed management that can be adopted by Canadian vegetable growers:

	Cover Crop Approach	Comments	
A	Fall-seeded cereal rye + hairy vetch mixture, chemically killed before no-till tomato	Rye was selected for these systems because of allelopathy to weeds (Table 2), low seed cost, high availability (in many areas), and compatibility with existing equipment (combine, drill) facilitating home-grown, inexpensive seed. Both rye and vetch grow at low temperature and mixtures provide a number of advantages over monoculture cover crops.	Hairy vetch adds nitrogen value and has a track record of increasing tomato yield and profit.
B	Fall-seeded rye chemically killed before zone-till cucurbits		Zone tillage was selected for this system to avoid delay in crop maturity that can occur with mulches left on the surface.
C	Aerial overseeded rye into late harvested crops such as potato or carrot		This system may not increase profit in the short term (1 yr), but may reduce the weed seed bank over the long term, and provides important off-site environmental benefits such as improved water quality.
D	Summer seeded smother crop of sorghum or sudangrass before or after a short season vegetable such as fresh market cole crops or pea	Sorghum was selected for this system because it is a smother crop, residues are allelopathic to weeds, it is drought tolerant and therefore suitable for summer planting (typically dry), and it has potential to add value as livestock feed or a biomass crop or from control of other pests in the subsequent vegetable such as root rot.	

Conclusions

Growers are encouraged to trial rye/vetch mixtures prior to tomato or rye before cucurbits with minimum or no till planting, or cereal rye overseeded into late harvested crops, or sorghum before late planted or after early harvested vegetable crops. Adoption of these recommended approaches will likely lead to reduced need for herbicides, hence reduced risk from pesticides, better resistance risk management and other economical and environmental benefits.

If using any of these approaches, note:

- Vetch should be planted by September. If available water is limited, it is advisable to burndown the rye or rye/vetch mixture in spring before it uses too much moisture. A tank mix may be needed to kill vetch; in this case, a minimum of two weeks is needed before transplanting the new crop. Reducing nitrogen fertilizer rate to subsequent vegetable according to vetch growth is also advisable.
- Mowing the CC may enhance weed control.
- Row cleaners, also called trash whippers, mounted on seeding equipment can improve crop stands when seeding through CC residues.
- Herbicide requirement will be reduced according to amount of mulch left by the CC, existing weed pressure and the weather - spray as needed.

Table 2.
Seeding rates and seeding costs for recommended cover crop species and cost of selected cultural practices.

Species	Seed Rate		Seed Cost		Planting Cost	
	kg/ha	Source	$/kg	Source	$/ha	Source
Rye - drill	125	Reynolds *et al.*, 2002	0.13	Ontario	$16.20	Reynolds *et al.*, 2002
Rye - drill	120	New Brunswick, Quebec	0.79	New Brunswick, Quebec	$95.00	New Brunswick A&A 2008 (online)
Rye - drill	62-94	Hoffman and Regnier, 2006			$52.00	Wilson, 2005
Rye - aerial	125	Manitoba AFRI online (in potato)				
Rye - aerial	188	Ball Coelho *et al.*, 2005 (in corn)		commodity price, Ontario	$24.70	
Hairy vetch	20-30		2.75		$68.75	VerHallen *et al.*, 2003
Hairy vetch	28-45	Hoffman and Regnier 2006; Abdul-Baki and Teasdale, 2007			$148.00	Wilson, 2005
Hairy vetch	30		4.76		$143.00	New Brunswick A&A 2008 (online)
Rye + vetch	95-125 (rye) 28-45 (vetch)				$105.00	Snapp and Mutch, 2003
Rye + vetch	35 (rye) 28 (vetch)	Groff online				
Rye + vetch	45 (rye) 45 (vetch)	Abdul-Baki and Teasdale, 2007				
Rye + vetch	45-123 (rye) 19-28 (vetch)	Burgos *et al.*, 2006; Masiunas, 2006				
Sorghum sudangrass	15		$1.68	New Brunswick A&A 2008 (online)	$25.00	New Brunswick A&A 2008 (online)
Forage sorghum	15	Wheeler and McKinlay, 2007	$4.84	Ontario	$ 72.60	

Table 3. Example costs of some relevant field operations used in establishing a Example costs of some relevant field operations used in establishing and killing cover crops based on custom rates. nd killing cover crops based on custom rates.

Operation	Cost $/ha	Source
Grain drill	$28	Reynolds *et al.*, 2002
Air seed	$50	Manitoba AFRI online
NT drill	$46	Reynolds *et al.*, 2002
Mow	$12	Reynolds *et al.*, 2002
Incorporation	$11	Reynolds *et al.*, 2002
Spray	$22	2009 retail, ON
Cultivate	$17	Ball Coelho *et al.*, 2003

Table 4. Example input costs from Wallace and Bellinder (1992) study in New York with tomato strip tilled into different cover crop mulches and metribuzin/sethoxydim applied as needed.

Cover crop species	Cover crop kill method	Cost $/ha (seed & kill)	Cost $/ha (herbicide; * 2 applications)
Grain rye	glyphosate 1.1 kg ai/ha	$84	$121
Hairy vetch	mow kill	$193	$230
Annual ryegrass	winter killed, glyphosate / 2,4-D for emerged perennials	$111	$158*
Conventional till	plow, disc	$57	$94

References

Abdul-Baki, A.A., J.R. Teasdale, R. Korcak, D.J. Chitwood, and R.N. Huettel. 1996. Fresh-market tomato production in a low-input alternative system using cover-crop mulch. Hortsci. 31:65-69.

Abdul-Baki, A., and J.R. Teasdale. 2007. Sustainable Production of Fresh-Market Tomatoes and Other Vegetables With Cover Crop Mulches. Farmers Bulletin, 2280 USDA.

Ball-Coelho, B., A.J. Bruin, R.C. Roy, and E. Riga. 2003. Forage pearl millet and marigold as rotation crops for biological control of root-lesion nematodes in potato. Agron J. 95:282-292.

Ball-Coelho, B., A.J. Bruin, R.C. Roy, and A.J. Bruin. 2005. Long-term effects of late-summer overseeding on corn grain yield and nitrogen balance. Can. J. Pl. Sci. 85:543-554.

Burgos, N.R., R.E. Talbert, and K.I. Yong. 2006. Grass-legume mixed cover crops for weed managment, p. 95-125, In H. P. Singh, et al., eds. Handbook of sustainable weed management. Food Products Press, New York.

Groff, S. Smart Cover Cropping [Online] http://www.ibiblio.org/farming-connection/covercrop/groff/coverman.htm

Hoffman, M.L., and E.E. Regnier. 2006. Contributions to weed suppression from cover crops, p. 51-75, In H.P. Singh, D.R. Batish, and R.K. Kohli, eds. Handbook of sustainable weed management. Food Products Press, New York.

Manitoba Agriculture Food and Rural Initiatives (AFRI). Cover Crops on Special Crops Land [Online] gov.mb.ca/agriculture/soilwater/soil/fbd01s08.html (acc May 2010).

Masiunas, J. 2006. Rye as a weed managment tool in vegetable cropping systems, p. 127-158, In H.P. Singh, et al., eds. Handbook of sustainable weed management. Food Products Press, New York.

New Brunswick Department of Agriculture and Aquaculture. 2008. Cover crops /Hay mulching [Online]. www.gnb.ca/0173/30/0173300003-e.asp (acc Apr 2010).

Reynolds, L.B., B.R. Ball Coelho, and J. Potter. 2002. Rotation with Tagetes sp. to control root-lesion nematodes affects flue-cured tobacco growth, yield, quality, and cost of production. Tob. Sci. 44:11-18.

Snapp, S.S., and D.R. Mutch. 2003. Cover crop choices for Michigan vegetables. MSU Extension. Extension Bulletin E. 2896. October. 2003. www.covercrops.msu.edu/general/index.html

Verhallen, A., A. Hayes, and T. Taylor. 2003. Cover Crops: Hairy vetch [Online] www.omafra.gov.on.ca/english/crops/facts/cover_crops01/hairyvetch.htm (acc May 2010).

Wallace, R.W., and R.R. Bellinder. 1992. Alternative tillage and herbicide options for successful weed control in vegetables. HortSci. 27:745–749.

Wheeler B., and J. McKinlay. 2007. Forage Sorghum-Sudan Grass Factsheet [Online]. Available by OMAFRA. www.omafra.gov.on.ca/english/crops/facts/98-043.htm.

Wilson, D. 2005. Getting Started with Cover Crops Selection and establishment tips for on-farm research [Online] rodaleinstitute.org/getting_started_with_cover_crops.

Acknowledgements

The main author, Bonnie Ball Coelho thanks Kristen Callow, OMAFRA (Ridgetown, ON), Robert Nurse, AAFC (Harrow, ON), Diane Lyse Benoit, AAFC (Saint-Jean-sur-Richelieu, QC) and Danielle Bernier, MAPAQ (Québec City, QC) for their collaboration, and recognizes research contributions from former AAFC specialists Robert Roy and Alex More.

This literature review and this factsheet were developed with funding provided by the Pesticide Risk Reduction Program of Agriculture and Agri-Food Canada's Pest Management Centre.

About the *Pesticide Risk Reduction Program* at *Agriculture and Agri-Food Canada*

The Pesticide Risk Reduction Program delivers viable solutions for Canadian growers to reduce pesticide risks in the agricultural and agri-food industry. In partnership with the Pest Management Regulatory Agency of Health Canada (PMRA), the Program achieves this goal by coordinating and funding integrated pest management strategies developed through consultation with stakeholders and pest management experts.

The Pesticide Risk Reduction Program is actively pursuing the development and implementation of strategies which are key to reducing pesticide risks in the agricultural environment. To view Program's current priorities and the issues being addressed, visit: www.agr.gc.ca/prrmup. To consult other factsheets in this series, visit: www.agr.gc.ca/sustainable-crop-protection.

For more information on this study, please contact:

Bonnie Ball Coelho, Ph. D., Research Scientist
Agriculture and Agri-Food Canada
Soil and Environmental Sciences
London, Ontario
E-mail: bonnie.ballcoelho@agr.gc.ca
Tel: 519-457-1470 ext. 217

Aussi offert en français sous le titre : *Production maraîchère : Utilisation des cultures de couverture pour la lutte intégrée contre les mauvaises herbes*
AAFC Number 11408E Catalogue Number A118-42/2011E-PDF
ISBN 978-1-100-17960-5
SPCS (D.K.)

Cover Crop Effect on Cash Crop Yield: Year 2

Cooperators
Bill Buman, Harlan
Devan Green, Conrad
Jim Funcke, Jefferson
Randy Caviness, Greenfield
Rick Juchems, Plainfield
Larry Ness, Whiterock Conservancy, Coon Rapids
Mark Pokorny, Clutier
George Schaefer, Kalona
Rob Stout, West Chester
Jerry Sindt, Holstein
Gary & Dave Nelson, Fort Dodge
Kelly Tobin, New Market

Project Timeline
2008-2013 (Year 2 Report)

Web Link
www.practicalfarmers.org

Contact
Sarah Carlson, 515.232.5661
sarah@practicalfarmers.org

Funding
Iowa Department of Ag and Land Stewardship; Walton Family Foundation; NCR-SARE; and in partnership with the Iowa Learning Farm

Abstract

Cover crops are an important tool farmers may use to decrease soil erosion, improve nutrient cycling and increase soil organic matter. However, many farmers are concerned about the negative effects of this cultural practice on their cash grain yields. After year two of this 5-year study, a winter cover crop positively affected soybeans, had no effect on corn silage and negatively affected corn yield in 2010 and at one location in 2009 but did not affect corn yield in 2009 on three locations.

Background

Cover crops provide multiple benefits to any farming system. Incorporating more "green" plants into the "brown" months will help to protect water quality and maintain natural cycles for water, carbon, nutrients, and soil organisms.

Although cover crops are an excellent practice for farmers to incorporate, few currently use cover crops. Iowa farmers planted cover crops on approximately 17,000 acres of the 23 million corn and soybean acres in the state in 2008. Farmers have not adopted cover crops as a part of their farming system on a broad scale due to timing constraints in the fall following harvest and concerns about cover crop's potential negative effect on the following year's cash crop yield. Research on cover crops' effect on cash crop yield from PFI cooperators' projects since 1987 and refereed journal articles has been mixed. Several studies have been conducted but few have planted the cover crop in the same location for consecutive years. This five-year study will measure the yield of corn and soybeans in cover and no cover plots, that are planted in the same place every year, to determine if the cover crop has a negative effect on the cash grain yield and if consecutive years of cover crops change any negative effects of the cover crop on the cash crop's yield.

Methods & Materials

To study this question, six sites were established in the fall of 2008 and six more in 2009. These sites were located at Harlan (SW), Greenfield (SW), Coon Rapids (West Central), Jefferson (West Central), Plainfield (NE), Conrad (East Central), Clutier (East Central), Fort Dodge (Central), Kalona (SE), West Chester (SE), Holstein (NW), and New Market (SW). Table 1 describes each location's cash crop and cover crop management.

Depending on when they initiated the study all sites planted a winter hardy rye cover crop in the fall of 2008 and/or 2009. Winter rye planted was either sourced through local seed retailers, or farmers used the improved variety 'wheeler,' a variety bred at Michigan State University. Farmers planted cover and no cover strips in a randomized, replicated complete block design in the fall of each year in the same location. Farmers either aerial seeded into standing cash crops, drilled the cover crop following cash grain or corn silage harvest, or broadcast the cover crop seed with dry fertilizer. In the spring, to terminate the cover crop, farmers either used an herbicide as a "burn-down" before or after cash crop planting; mowed plus an herbicide application and then planted the cash crop into a cover crop mulch; or used tillage or a combination of tillage plus an herbicide application before cash crop planting. In the spring before the cover crop was killed, four 1ft^2 quadrates per plot were used to collect samples of the above-ground biomass which were dried and weighed. Nitrogen concentration of the cover crop biomass was measured in spring 2009 to estimate how much nitrogen the cover crop held on the farm. In the fall, farmers combined and weighed grain from individual plots using a weigh wagon or a yield monitor. Yields are reported as: corn in bu/A at 15.5% moisture content; soybeans in bu/A at 13% moisture content; and corn silage in T/A at 35% moisture content. At West Chester, in 2010, the cover and no cover plots were split and an additional sidedressing and no sidedressing of 50 lbs nitrogen/A was applied to the corn June 7, 2010.

Table 1 | On-farm Research Location Description

Location	2009 Crop	2010 Crop	Cover Crop Planting	Cover Crop Termination
Harlan	Corn	Soybeans & Corn	Aerial Seeded	Herbicide
Greenfield	Corn	-	Drilled	Herbicide
Jefferson	Corn	Soybeans	Drilled	Herbicide
Conrad	Corn	Soybeans	Drilled	Tillage
Plainfield	Soybeans	Corn Silage	Drilled	Herbicide & Tillage
Coon Rapids	Soybeans	Corn	Drilled	Herbicide & Tillage
Clutier	-	Corn	Drilled	Herbicide & Soil Finisher
Kalona	-	Soybeans	Aerial Seeded	Mowed & Herbicide
Holstein	-	Soybeans	Broadcast w/ Dry Fertilizer	Herbicide
Fort Dodge	-	Soybeans	Drilled	Herbicide
West Chester*	-	Corn	Aerial Seeded	Herbicide
New Market	-	Corn	Drilled	Herbicide

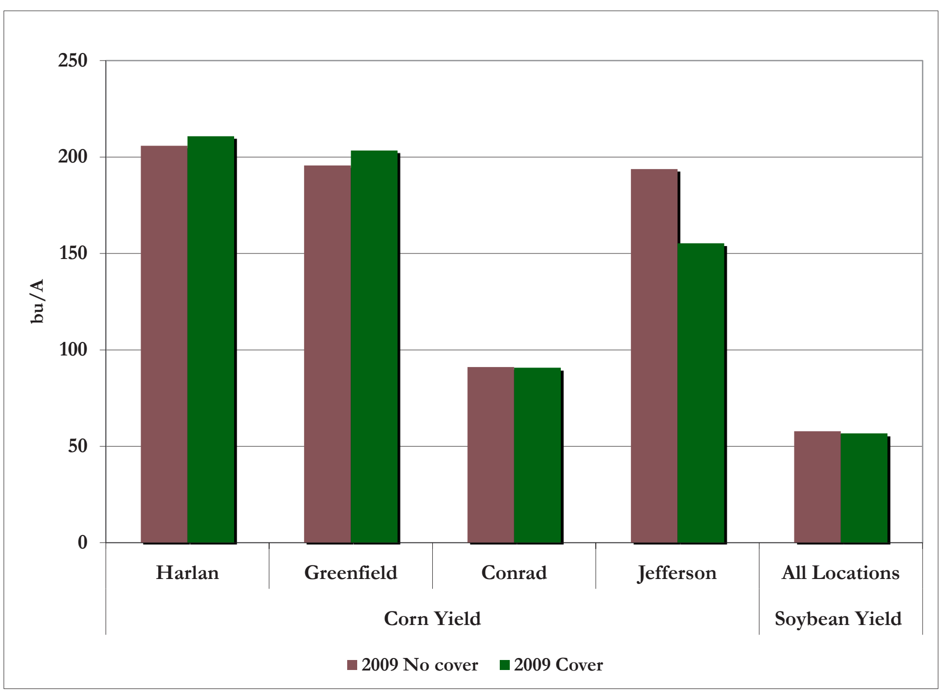
* Data were analyzed separately because an additional Sidedress N treatment was added to the original study. **Indicates a significant difference between the treatments ($p<0.05$).

Analysis

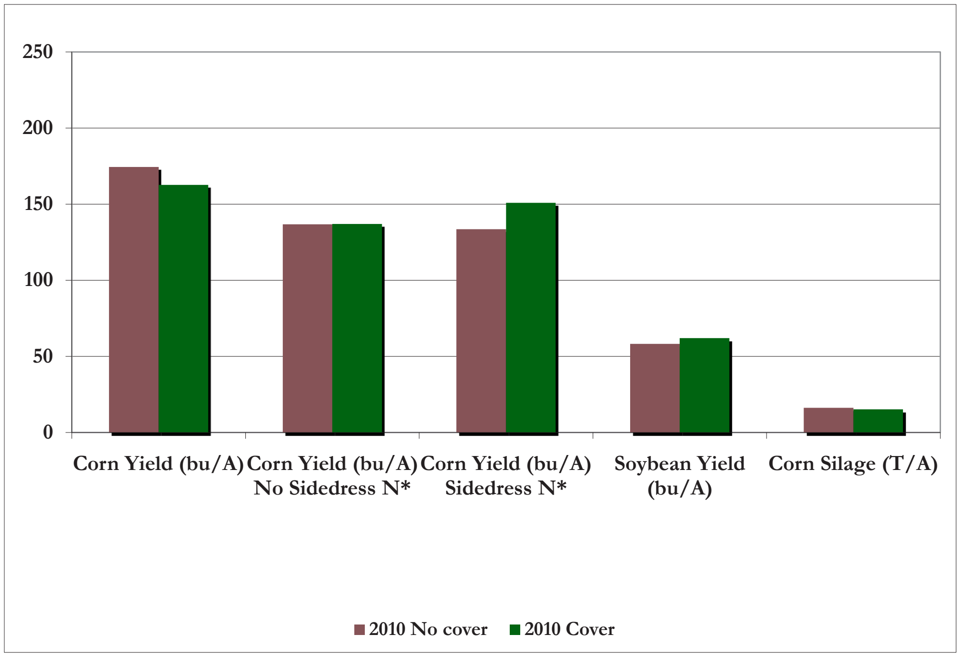
The data were analyzed using a mixed model to determine treatment effects. When effects were significantly different with a $P<0.05$, means comparisons were determined using the Student's T test at a $P<0.05$. All statistical analyses were performed using JMP8. Data from the West Chester site were analyzed and reported separately from the other locations' results.

Results

In 2009, cover crop did not have a significant effect on corn or soybean yield except at Jefferson where poor control by the herbicide Liberty© did not terminate the cover crop. On the cover crop plots the corn yielded 39 bu/A less than on the no cover plots. But all other plots, where the cover crop was terminated did not show a significant difference in corn or soybean yield.



In 2010, corn yield was significantly reduced on the cover plot (163 bu/A) versus the no cover plots (175 bu/A). Soybean yield was positively affected by a winter rye cover crop yielding 4 bu/A greater where cover crops were present. Corn silage yield was not affected by a winter rye cover crop yielding similarly in both the cover crop (15 T/A) and no cover crop (16 T/A) treatments. Corn yield at West Chester, although no statistical differences were measured, where cover crops and an additional application of 50 lbs nitrogen/A were present, corn yield was 15 bu/A greater than without the sidedress or a cover crop treatment.



Conclusion

Yield

Soybeans planted following a winter rye cover crop were positively affected in 2010 and showed no difference in 2009 while corn yield was negatively affected at one location in 2009 and negatively affected at all locations in 2010. Corn silage yield was not affected. The majority of the locations in this experiment that planted corn in 2009 and 2010 had never planted a cover crop on these farms. Our results, that corn yield was negatively affected by a winter rye cover crop in its first couple years of usage on a farm is supported by other university research where a winter cover crop treatment is only planted one year before measuring the following year's cash crop yield. We hypothesize that with additional years of cover crops planted to the same area the affect on corn yield will change.

Extending Cover Crop Coverage

Our results for soybean yield and corn silage yield are supported by the published literature. In addition, at Jefferson, soybeans were planted on 04/23/10 into a living cover crop and then the cover crop was terminated using an herbicide on 05/15/10. Soybean yield was not affected and the cover crop was allowed to continue growing, covering the soil and scavenging nutrients. An average 2000 lbs/A additional biomass was returned to the soil through this management technique. Also at planting, four farms are aerial-seeding cover crops into a standing corn or soybean field to improve fall cover crop growth, which further covers the soil and also increases spring growth.

Economics of Cover Crops

Cost of Tillage Operations/Acre

• Chisel Plow	$14/A
• Disk Tandem	$13/A
• Field Cultivate	$11/A
• Plow	$17/A
• Soil Finishing Tools	$11/A
• Subsoil	$18/A

Ohio Farm Custom Rates 2010
Barry Ward, OSU Economist

To compare the economics of conventional tillage to no-till and cover crops, look at the economics and partial budgets for each system. A partial budget simply looks at economic differences between two systems. For conventional tillage, these are the costs for various tillage operations. Notice, that often several tillage operations are performed before a field is ready for planting. So these costs are additive. The cost of tillage can vary from $35 to $50/A depending on how many tillage operations are performed.

Legume Cover Crop Seed Cost

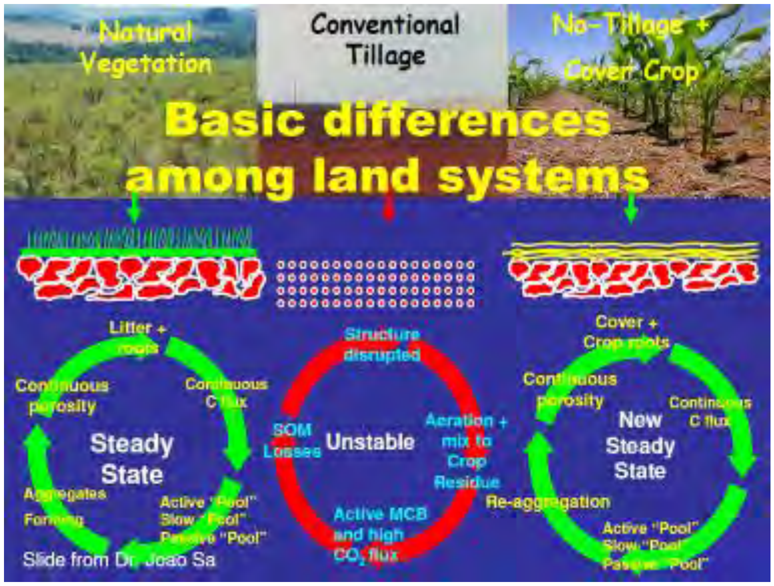
Cover Crop	Seed Price/lb	Pound	Planting	Kill	Total Cost/A.
Cowpeas	$.80	40-50	$14	$0	$46-54
Winter peas	$1.00	30-40	$14	$0-15	$34-$69
Red Clover	$2.00	10-12	$6	$15	$41-$45
Chickling vetch	$1.00	30-70	$14	$15	$59-$99
Sweet Clover	$1.50	10-20	$6	$10	$31-$46
Hairy Vetch	$1.25	15-20	$14	$15	$49-$54

Enclosed are the Legume Cover Crop costs to buy seed, plant, and kill or manage the crops. Costs range from $31 to $99 per acre.

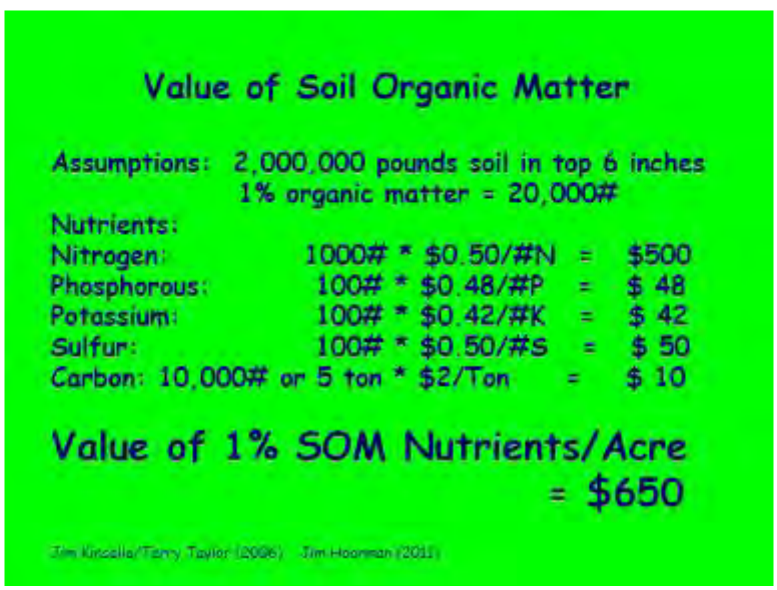
Grass Cover Crop Seed Cost

Cover Crop	Seed Price/lb	Pound	Planting	Kill	Total Cost/A.
Cereal Rye	$.20 $12/bu	60 1 bu	$14	$15	$41
Annual rye	$.80	15-25	$14	$15	$41-$49
Wheat	$.10 $6/bu	60 1 bu	$14	$15	$35
Oats	$.15 $6/Bu	42-63 1-1.5 bu	$14	$0	$20-$23
Brassicas					
Oilseed Radish	$3.00	1-10	$14	$0	$17-$44

Grass and Brassica Cover Crop costs are similar for buying seed, planting, and killing the crop. Grass and Brassica cover crops costs range from $17 to $49/A. Precision planting and drilling are much more efficient and require less seed and expense than broadcast seeding. Good seed to soil contact is critical for good establishment but if adequate rain or moisture occurs, aerial or broadcast seeding has been successful but usually these methods are not as consistent as planting or drilling the seed. How do these costs compare to conventional tillage? Legume Cover crops tend to cost a little more but they also add N.



This graph shows the differences in soil stability. Conventional tillage is in an unstable system because the soil structure is disrupted and the microbial community is in a state of flux resulting in SOM losses. In a Natural vegetation system, the system exists under steady state and the soil keeps nutrients recycling efficiently by keeping the soil porous and helps maintain a healthy microbial community. A no-till system with cover crops mimics the natural system because the soil is not disturbed and the microbial communities are continually fed with new organic matter. Plants act like a solar collector to continually add energy to the soil year round and keep the microbial communities actively fed and recycling plant nutrients like N, P, K, S and micro nutrients. Over 90% of the energy in a soil is recycled by soil microbes so it is important to keep them active, healthy, and growing.



Shows the value of SOM. There is 2 million pounds o soil in 6 inch slice. So 1% SOM has 20,000 pounds or 10 ton. About 50% of SOM is carbon so 10,000# or 5 ton of carbon exist in every 1% SOM. Associated with that 1% SOM is a 1000 pounds of N, and roughly 100 # each of P, K, and S. The value of 1% SOM at today's fertilizer prices is roughly $650 for every 1%

SOM. So what is the value of 2% SOM? $1,300. How about 6% SOM? $3,900. Dark black soils rich in SOM are more valuable than light colored soils with less SOM.

Tillage releases large amounts of N but it is not efficiently utilized and the nutrients may be lost to the environment. Why do no-till yields lag conventional tillage? Most of our soils have lost 60-80% of their SOM. Because the soil has to restore the 4-6% SOM that is lost (4-6K of N) plus supply N for the microbes; the corn may get some of the remaining N for corn production.

Soil Organic Matter Accumulation

- Takes 10 tons of Decomposed Organic Matter to equal 1% SOM
- If start with 40 tons Organic Matter and lose 75% to get 10 tons decomposed SOM
- Accumulate 4-6 tons and lose 75% equals 1-1.5 tons Decomposed SOM or .1-.15% SOM * $560/Acre or $56 to $84/Acre

You are Building Your Soil Fertility with SOM!

How many tons of residues does it take to make 1% SOM? Answer is 10 tons decomposed. How much SOM can we accumulate in a typical year? Answer is about .1 to .15 SOM which is equal to $56 to $84/A in nutrients. This is a minimum value because SOM also has economic value for other things (water storage, soil structure, microbial food etc.)

What happens to the residue when we till the soil. Residue is light and can easily be washed off or float away in a heavy storm. This is a picture taken in 2007 from a chiseled wheat field in NW Ohio on a Hoytville soil. What happened to all this farmers nutrients stored in the wheat straw? Washed away.

The residue caused problems with drainage. This is sometime a huge problem on fields that have been tilled or even no-tilled. Is there a solution? We'll discuss a solution later.

Value of Ton of Topsoil

- Most Biological activity occurs in top 3 inches.
- One million pounds or 500 ton of topsoil in top 3 inches.
- Average Value of Cropland = $5,000/Acre
- Soil Lost at T value = 4-5 ton/acre
- Soil Productivity Value: $5,000/500 = $10/Ton
- Lost value per acre = $10/ton soil loss * 4-5 tons

Losing $40 to $50 per acre.

Another way to value SOM is to look at the price of land. The soil productivity is mostly in the top 3 inches of the soil. If you divide the top three inches of topsoil by the average price of land, you get a value for topsoil of $40 to $50 per acre. If you think that the land still has value for building or for roads, you might say that half the value is in the physical location and the topsoil is worth 20 to $25 per ton of topsoil. For farmers concerned with soil productivity and farming, the value is in keeping the topsoil on the land to produce high yielding crops.

Productivity of SOM

- Michigan study: Every 1% SOM =12% increase in crop yields.
- Baseline Yields: 170 bu corn, 50 bu soybeans

Starting SOM = 3% and add 1% SOM

Soybeans 50 bu * 12% = 6 bu * $10 = $60/A.
.1 to.15% SOM increase/year = $6-$9/yr.

Corn 170 bu * 12% = 20.4 bu * $5 = $102/A
.1 to.15% SOM increase/year = $10.20-$15.30/yr.

A Michigan study found that every 1% SOM equals a yield increase of 12% in crop yields. If we take a typical farm producing 50 bushel soybeans and 170 bushel corn, a 1% SOM increase is equal to $48 to $102/A at current crop prices. Annually, the rate is around $6 to $15/A if you increase your SOM by 0.1 to 0.15 SOM points per year.

Do we get more N loss from inorganic (fertilizer) N or organic N?

- Inorganic (fertilizer) N had significantly higher N losses.
- How much? 31% for fertilizer compared to 13% for crop residue (organic N).
- Crop residue has 73% more retention of N in the soil than fertilizer N (26% retention).
- Suggests slower N recycling in crop residues (or proteins) protects against N losses. (Delgado, 2010)

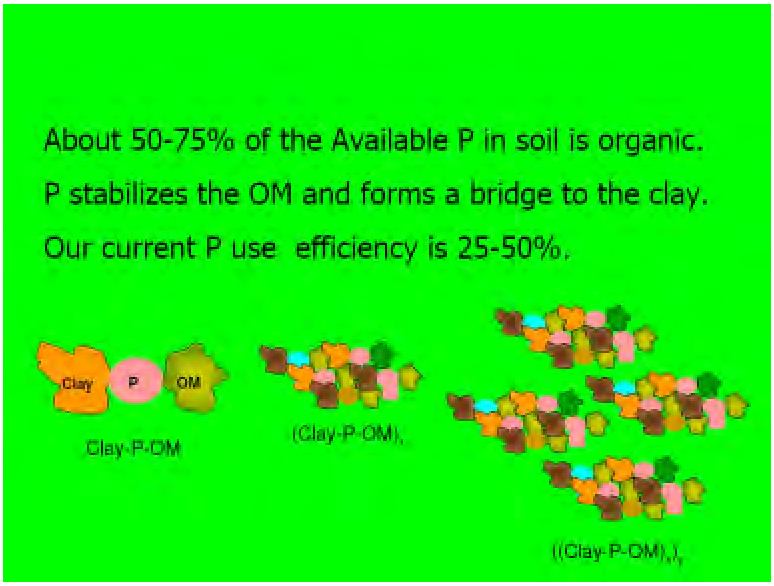
A Common *Myth* about inorganic fertilizers: They feed the plant directly

Fertilizer Nitrogen applied Kg/ha (pounds/ac)	Corn Grain Yield Mg/ha (Bu/ac)	Total N in corn plant Kg/ha (pounds/ac)	Fertilizer derived N in Corn Kg/ha (pounds/acre)	Soil-derived N in corn, in Kg/ha (pounds/acre)	Fertilizer-derived N in corn as percent of total N in corn %	Fertilizer-derived N in corn as percent of N applied %
50 (45)	3.9 (62)	85 (77)	28 (25)	60 (54)	33	56
100 (90)	4.6 (73)	146 (131)	55 (50)	91 (81)	38	55
200 (180)	5.5 (88)	157 (141)	86 (78)	71 (63)	55	43

Source of Nitrogen in Corn in North Carolina on an Enon Sandy Loam Soil Fertilized with Three Rates Nitrogen as NH+4 NO-3 (tagged isotope 15 N)

(Calculated from Reddy and Reddy 1993)
Page 725 13th Edition Nature and Properties of Soil

The majority of inorganic commercial fertilizers are utilized by the soil microbes before it is recycled to the plants. Fertilizer derived N only represents 33% to 55% of the N in a corn plant. Where does the rest of the N come from: The soil organic matter and the soil microbes. Most of the organic nitrogen comes available later in the growing season as soil temperatures increase and rainfall occurs. So if we can increase our SOM and our soil microbial life, we can increase our soil nutrient efficiency. What about P?



Notice how P acts like a lag screw to connect the SOM (wood) to the clay particle (brick). If we lose or decrease the OM, the P is exposed and can easily be lost in a soil in a water solution. SOM protects the nutrients from being easily lost or leached out of the soil profile. P is very reactive so it tends to bind tightly to clay and OM unless it is exposed. Our current P use efficiency is 25-50% in a conventional system. No-till with cover crops increase that P use efficiency by keeping the P tied up in the SOM and the microbes.

Increased Efficiency

Nitrogen Efficiency: 30-50% conventional
Increase to 80-90% with No-till & Cover Crops.

Phosphorus Efficiency: 50% conventional
Increase to 80-90% with No-till & Cover Crops.

N and P efficiency may be increased biologically by no-till and cover crops by actively keeping the N & P recycling until the next crop is planted.

Lime Costs/acre

- 1 to 2 tons of lime per acre * $14/Ton
- Plus spreading cost $6/Acre
- Total lime cost: $34/Acre over 3-5 years
- Cost /Acre/Year: $7-11
- No-till and Cover Crops need less lime because they keep Ca^{2+} circulating

Farmers with no-till and cover crops are using less lime per acre. Why? Because with tillage, the heavier calcium ions tend to precipitate into the subsoil. What is the poor man's way of liming his field? Simply plow a couple of inches deeper to bring up calcium ions. In no-till and cover crops, the calcium is kept in the top soil profile. The plant roots act like an elevator to keep nutrient recycling. The nutrients may decompose as the plant stems and leaves decompose, but the nutrients stay within the top profile. Do natural systems or Mother Nature ever apply lime? So why do farmers have to lime their soils every couple of years? Two major reasons: One they apply N commercial fertilizers which acidy the soil, and second they do tillage which allows the calcium ions to precipitate out of the profile into the subsoil. At $34 per acre, the annual cost is around $7-11 per acre. (Varies by region and soil type).

Legume Cover Crop N Economics

Cover Crop	Total Cost/A.	Pound Of N	Value of N	Total N $	Net Gain
Cowpeas	$46-54	120-150	$.40	$48-60	($2)-$14
Winter peas	$34-$69	120-150	$.40	$48-60	($9) - $26
Red Clover	$41-$45	100-120	$.40	$40-$48	($3)-$7
Chickling Vetch	$59-$99	50-125	$.40	$20-$50	($9-$49)
Sweet Clover	$31-$46	100-150	$.40	$40-$60	($6)-$29
Hairy Vetch	$49-$54	100-200	$.40	$40-60	($9)-$11

These are rough estimates of the value of N from Legumes. This analysis only looks at the value of the N produced from the legume. The net gain or loss is the additional gain or loss of the value of N from planting the legume. The additional benefits from SOM additions are not included in this analysis. Most legumes appear to at least break even on N production but there are more soil benefits than just the N.

Drainage

- $800 to $1000/acre for subsurface drainage.
- Farmers say you pay for drainage every 20 years whether you pay for it or not. Poor drainage costs you in reduced yields.

Keep $1000 in Bank, Collect 2-3% interest

Spend Interest on Cover Crops: $20-30/A.

Still have principal at end of 20 years.

Drainage is critical for good crop yields. Many farmers are looking at splitting their subsurface (tile) drained fields. Putting extra money into tubing is very expensive. Using cover crops and no-till allows the soil to become more porous and improves drainage. The cover crop roots promote drainage by forming channels for water to flow to subsurface (tile lines) drains. Improved earthworm populations also increase drainage of soils. The earthworms benefit from increased SOM and crop residue (food) and from undisturbed soils. Tillage dries out the soil and kills off newly hatched earthworms by desiccating the earthworm eggs. If you put that same $1000 investment in the bank at 2-3% interest you could pay for the cover crop seed and still have your $1000 principal investment left after 20 years.

This is a heavy clay soil (Pewamo no-till soybean field) in Northwest Ohio. This field usually lays wet all winter long due to soil compaction.

On bare soil, the residue can float away. This field had two rains in December that measured 2.5 and 3 inches a week apart. This was on a cover crop demonstration plot. Notice the bare soil in the no-till. What happened to the residue?

It floated off and landed up in the ryegrass plots. Look between the ARG rows. The ARG anchored the residue and kept the OM from floating off. The farmer commented that this field always flooded and stayed wet all winter long, but on this field with ARG, the water was gone within 24-30 hours and the soil stayed drier all winter long.

Water Storage Value

- Every 1% SOM hold 1 acre-inch of water
- Value of an acre-inch of water = $12
- Value of 6% SOM vs 2% SOM =
  4 acre-inches of water * $12/acre-inch=$48
- .1% SOM addition per year =
  .1 acre-inch * $12/acre-inch = $1.2 per year

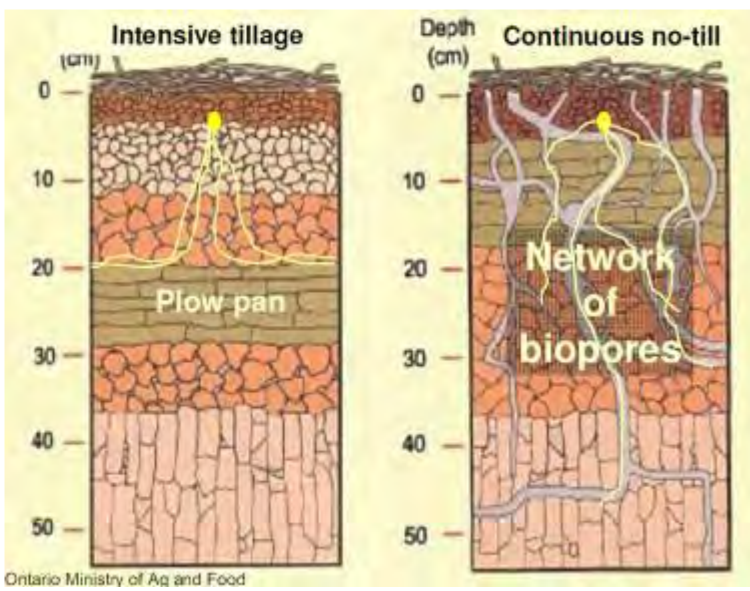
Another way to look at SOM is the improvement in the water storage capacity of soils. Have you ever noticed that after a heavy rain (2-3 inches), farmers want to get the soil dry as quickly as possible. An then a couple days later they start to complain that they need a rain. SOM acts like a buffer to keep the soil aerated and yet holds the moisture. Every 1% SOM holds about an inch of water. Crops need about an inch of water per week for optimal growth. From irrigated areas, an acre-inch of water is worth about $12. A soil with 4% additional SOM is worth $48 more (comparing 6% SOM to 2% SOM). A 6% SOM soil has 6 weeks of water storage compared to a 2% SOM soil with only 2 weeks storage. Notice that during a drought, the high SOM soils (bottom land) are under less stress than low SOM soils (typically on the hills). Hills tend to lose SOM to the bottom land and the darker soils in the bottom, higher in SOM tend to produce the best yields.

Indiana Corn Yields

Planting method	Yield bu/A	
	2002	2003
Conventional (mulch till)	55	136
Conventional (with soil compaction)	23	61
No-till/ryegrass Silt loam soil	138	140
No-till/vetch-ryegrass Claypan soil	83	78
No-till no cover crop Claypan soil	65	49

Corn yield data from Indiana on various types of soils managed different ways during two dry years. Notice the yield increases from no-till and cover crops. Cover crops tend to dry out the soil in the spring but this may be managed by killing them early. Cover crop roots also allow corn roots to go deeper for subsoil moisture during droughts.

Illinois data from Mike Plumer on cover crops and no-till. Notice only 2.3 inches of rain occurred in 2005 from May through September. Look at the difference in yields. For Midwest farmers, 7 out of ten years we have a wet spring with a dry spring occurring on average about 1 out of ten years. Cover crop roots help to dry out the soil and allow for earlier planting.



What is the potential benefit of increased drainage, increased water storage capacity, decreased soil compaction, and increased rooting depth? Increased yields during wet and dry periods.

Cover Crop Benefits in Drought

2005 Illinois Corn Data (2.3 inches rain)

Conventional tillage	82
No-till 124-82=42 bushels * $5/Bu =	$210
No-till + Annual Rye 137-82=55*$5 =	$275

$275/20 years $14 per year

Negative Effects:

Cover crops may excessively dry the soil through respiration in a dry spring. Solution is to kill the cover crop early if the soil is getting too dry.

Weeds

- Farmers promote weed seed by tilling the soil.
- Ways to fight weeds
  1) Hoe or pull them out
  2) Kill with herbicides
  3) Compete for sunlight and nutrients by growing cover crops and reduce weed seed production.
- Farmers with No-till and Cover Crops reduce herbicide cost by 1/3 = $7-$12/A.
- Early weeds reduce crop yields 10% * 50 bu soybeans * $10/A. = $50
- Reduced weeds: cereal rye, oilseed radish, etc.

This graph shows how weeds flourish under tillage due to high soil disturbance and low diversity of plants. Under a system of cover crops and no-till, there is lower soil disturbance and higher plant diversity which leads to more biological activity and less weeds. Weed seed that is buried by tillage is protected by low microbial activity and is often brought to the surface by annual tillage which promotes weeds and more weed seed production. Under no-till and cover crops, there is more competition for weeds and weed seed is buried under residue and more quickly decomposed with high microbial activity.

Insects

Positive: Soybean Cysts Nematodes (SCN)

1) 80-90% Reduction using cereal rye/annual rye
   50 bu * 30% =15 bu * $10 =$150/A

Natural Pollinators:$5 Billion/350 million =$14/A

Negative: Slugs, Cutworm, Armyworm

1) Carabidae beetles or ground beetles are natural predators of soft body insects.
2) Cover crops may be an alternative food source for slugs and may protect corn from damage.

Soybean cysts nematodes (SCN) is the major soybean insect in the Midwest. ARG, cereal (winter) rye, and oilseed radish decrease SCN by 80 to 90%. Soybean yields can be reduced as much as 30% by SCN which could equate up to a maximum of $120 or more per acre depending on the severity of SCN. Natural systems buffer insect infestations and do not allow insects pests to build up to harmful levels.

Natural pollinators contribute $5 billion dollars to our economy in increased yields or an average of $14/A.

Natural predators often use nectar from flowering plants to survive during critical stages in their development so flowering cover crops can contribute to natural predators which control insect pests. Sometimes, slugs, cutworms, and armyworms populations build up in fields recently converted to no-till and cover crops. Ground beetles and fire flies are natural predators of soft body insects but must have continuous cover and food to survive. Ground beetles require large pieces of residue to survive. Bill Richards, Former Chief of Soil Conservation Service is seeing reduced slug damage on his farm around Circleville Ohio with continuous corn due to using winter pea and oilseed radish cover crop. The slugs prefer to eat the winter pea and leave the corn alone until the corn outgrows any potential slug damage from feeding.

Diseases

Diseases that thrive under excess water

- Phytophthora: 20% loss*50 bu=10 bu * $10= $100/A
- Phythium: 5-10% *50 bu=2.5-5 bu*$10= $25-$50/A
- Fusarium: 10% * 50 bu= 5 bu. * $10 = $50
- Rhizoctonia 2-5%*50 bu=1-2.5bu*$10= $10-$25/A

Thrive with less biological activity (tillage)

- Sclertina/White Mold (Bury seed with tillage)

2 to 4 bushel per acre * $10 = $20-40/A

These are soybean diseases that thrive under excess water and soil compaction. Average yield losses of 20% for Phytophthora, 5-10% for Phythium, and 2-5% for Rhizoctonia occur along with 2-4 bushels or more for White mold. These yield losses can be reduced by increasing porosity with cover crops and decreasing soil compaction. These values are maximum damage and the benefit of cover crops is largely unknown. However, if the cover crop enhances microbial predators and improves drainage, some economic benefit may occur by using cover crops.

Some cover crops may be used for seed production and provide additional farm income.

Dairy and cattle farms have the opportunity to grow and utilize cover crops for forage. Oats and cereal (winter) rye makes excellent hay for dry cows and heifers. ARG can only be harvested as haylage (need to wrap it wet because it will not dry) but has an excellent feeding value (RFV=150-175).

Manure Application & Retention

Manure Applied to a Cover Crop

Manure application rates should be based on the available moisture holding capacity of the top 8 inches of soil. Most operators look at their manure management plan and if it says they can put on 15,000 gallons, that is what they apply all in one application. In many cases, the environmentally safe rate is only 5,000 to 10,000 gallons per acre.

Manure Value of Cover Crops

Swine Manure: 95% Water 5% solids
Manure Nutrient Analysis:18-16-14/1000 gallons
Uptake: At 5,000 gallons/A =90-80-70 $33
At 10,000 gallons/A =180-160-140 $44

Dairy Manure: 98% water 2% solids
Manure Nutrient Analysis: 20-15-15
Uptake: At 5,000 gallons/A =100-75-75 $36
At 10,000 gallons/A =200-150-150 $64

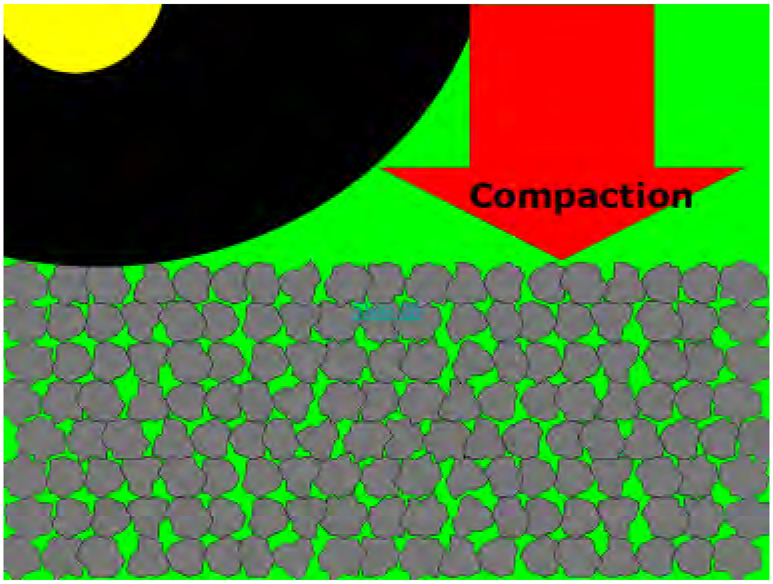
*Absorb 70% N, maximum 20# P

Cover crops efficiently recycle manure nutrients and add value to the soil as a fertilizer. Most grass cover crops absorb 70 to 90% of the N in the manure and up to 20# of N per acre. Often manure has excess P in relationship to N. These cover crops prevent soil erosion and N lost to surface water. Based on these numbers, (70% absorption, maximum 20# P absorbed), the value of the manure is $33 to $64 per acre. Not all N and P that is absorbed are going to be immediately available to the next growing crop, depending on decomposition.

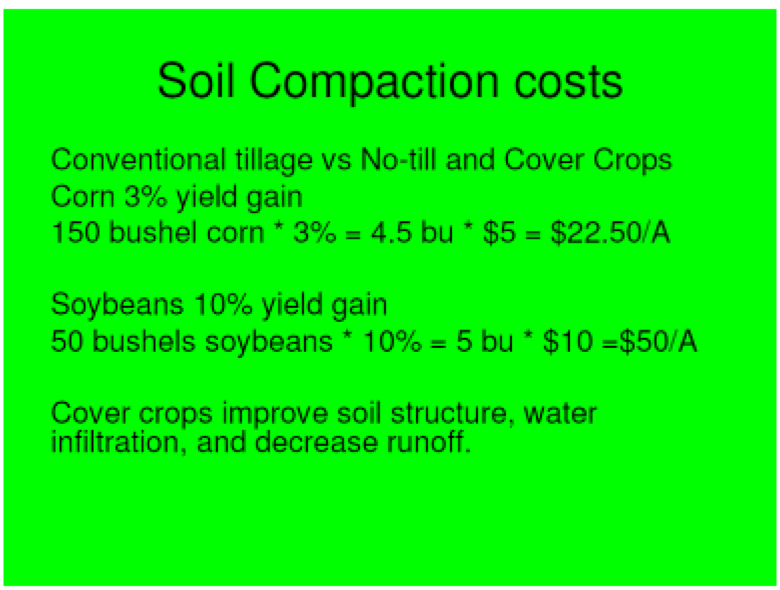
SOM buffers the soil from extreme temperatures. During early frosts, cover crops and residue may keep soil temperatures warmer to prevent freezing temperatures. Cereal rye or a grass cover crop 6-12 inches tall will trap warmer air and prevent freezing at the soil surface like air trapped in a windowpane. The air acts like an insulator to protect new soybean plants susceptible to frost.

Water nutrient runoff from agricultural fields costs down stream users money to restore the water quality. The chemical cost to treat waste water averages $1-2 per 1000 gallons of water. The average person used 161 gallons of water per day, 365 days a year, and we have 310 million people in the USA. At a cost of $1-2/1000 and 85% of the population using treated water versus water from a well (rural people), the cost of water treatment is about $44 per acre on 350 million crop acres in the USA. This is a huge sum of money. This analysis assumes that all of the water treatment costs come from cropland so the number is over stated but it shows the huge costs that occur when agricultural water runs off the soil and is contaminated with excess soil nutrients (N and P and other micronutrients, pesticides). The Army Corp of Engineers also spend $1.345

billion per year dredging channels from soil erosion and sediment from 350 million crop acres which amounts to about $4 per acre. No-till and cover crops reduce soil erosion to practically zero compared to conventional tillage.



Soil compaction is a major cost to farmer yields and farm income.



Ohio No-till corn and soybean fields had yield gains of 3% and 10% when soil compaction was reduced. In conventional fields; a subsoiler increased yields 3% and 10%. In no-till fields; a subsoiler actually reduced yields by 3 and 10% because it disturbed the soil. However, planting cover crops improved soil structure, water infiltration, and decrease runoff. The cost of subsoiling was about $18 per acre.

Government Payments

CSP payments: Range from $10 to $30/Acre

Carbon Credits: Depends on Price $1-2/acre depending on how much carbon is stored in the soil. Currently there is not much of a market for carbon crdits in the USA.

Nutrient Credits: Ohio Miami Conservancy paying $1 per pound for N & P credits.

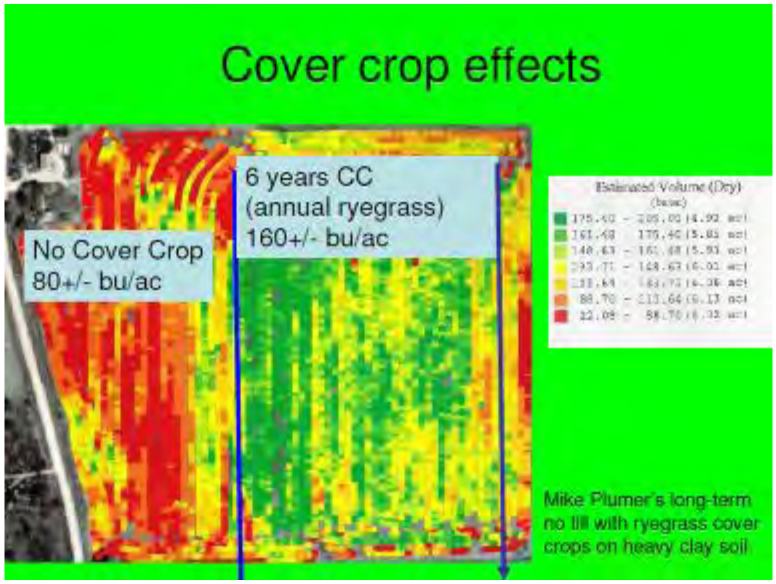
Other Local or Regional Payments

Nitrogen and Phosphorus Credits:

Miami Conservancy (Dayton, Ohio) is paying $50 to $80/A if grow grass cover crop after corn silage (N, P, soil erosion) and apply manure, $20 to $40 after soybeans and wheat (P, soil erosion) if no manure applied.

Grand Lake St. Marys, Ohio: $50-70/A for Cover Crops for manure management.

Some regions of the country are paying farmers to plant cover crops, especially if they have excess nutrients or manure and excess runoff is occurring. In 2010, over 600,000 acres of cover crops were planted in the State of Maryland at $75/A to help control Eutrophication in the Chesapeake Bay.



Mike Plumer's long term no till with ryegrass cover crops yield difference in Illinois.

Yield Benefits

Positive Results for Corn
No-till+CC versus conventional tillage
1) Crimson clover + Radish
235.3 bu – 227.8 bu = 7.5 bu * $5 = $37.50/A
2) Oats + Radish
195.5 bu -186.5 bu = 9 bu * $5 = $45.00/A
3) ARG + Manure on Sandy Soil Leman, IN
20 bushel * $5 =$100.00/A

Included are some yield benefits from various cover crops grown in Indiana.

Corn Yield Losses

1) ARG

227.8 bu– 211.1 bu = (16.7 bu)*$5 = ($83.50/A)

Why: Dry weather may reduce corn yields.

Solution: Kill ARG earlier to reduce water loss.

2) Winter pea + Radish

227.8 bu – 223.1 bu = (4.7 bu)* $5= ($23.50)

However, depending on the spring and summer weather, corn yield losses may also occur. In general, farmers find that after several years of continuous cover crops and no-till, the yield benefits are much greater than yield decreases. Sometimes it takes several years to improve the soil ecology, soil structure, and soil quality enough so that crop yields are maximized. Crop yields are the last indicator to respond to improved soils. Why does this occur? Because plants only get nutrients remaining after the microbes feed first. Plant roots are many times larger than the microbes and are less efficient at scavenging for N and P. In addition, most soils have lost 4-6% SOM over the last 100-150 years, so they have lost 4,000 to 6,000 pounds of N and 400-600 pounds of P associated with the SOM. The decomposing SOM is going to tie up nutrients as it decomposes. So No-till soils need more N and P to build microbial populations and SOM to restore the soil productivity compared to conventional tilled fields.

Golden Goose

Two Farmers with 10 Golden Geese

First Farmer: Wants 10+ eggs/day. Kills one goose to gain 5 eggs inside dead goose. (Conventional tillage)

Second Farmer: Can sacrifice and live with 9 eggs/day. Breeds one goose and hatches eggs. Takes 3-5 years before a mature bird lay eggs. (No-till+Cover crops)

Which farmer is going to be richer and better off after 5-10-20 years?

No-till and cover crops farming is like two farmers who had golden geese. The problem with farmers is that if they really want to produce higher crop yields in the short –term, they can always till the soil one year and get a bumper crop because of the huge release in nutrients.

However, long-term, their crop yields will start to suffer as the soil productivity and soil structure declines. In order to keep the soil productive and have good soil structure, farmers need to feed the soil by keeping the soil covered with live plants and roots year round. Compare the benefits.

Cost Savings and Added Income

Practice	Conventional	NT + Cover Crop
Costs	$35-$50/A	$30-$99/A
SOM	($25-$50)/A	$56-84/A
Soil Erosion	($40-$50)/A	$0
N Efficiency		+30-60%
P Efficiency		+15-65%
Lime	($7-11/A)	
Drainage	($1000/A)	($20-30) + Principal

Cost Savings and Added Income

Practice	Conventional	NT + Cover Crop
Weeds		Maximum $50/A
Insects (SCN)		Maximum $150/A
Diseases	Phytophthora	Maximum $100/A
Diseases	Phythium	Maximum $25-50/A
Diseases	Rhizoctonia	Maximum $10-25/A
Diseases	Fusarium	Maximum $50/A
Diseases	Sclerotinia	Maximum $20-40/A
Seed Prod.		$280-$1400/A

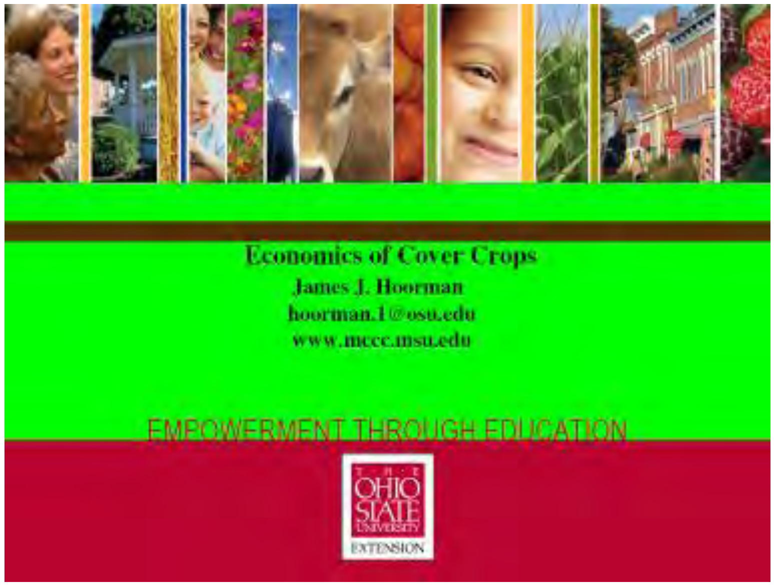
Cost Savings and Added Income

Practice	Conventional	NT + Cover Crop
Forage Production		$200
Manure Value		$33-64/A
Water Treat.	($44/A)	
Dredging	($4/A)	
SOM Productivity		$6-15/A
Water Storage		$14/year
Temperature		$5/Acre
Soil Compaction	($18-$50/A)	

Added Income or Losses

Practice	Conventional	NT + Cover Crop
CSP		$10-$30/A
Carbon		$1-2/A
Local Watershed	For N and P or manure credits	$20-75/A
Yield Gain		$37.50-$100/A
Yield Loss		($23.50-$83.50/A)

These results are not all additive. Each soil and farm are different dependant upon the local environment and soil conditions.


Economics of Cover Crops
James J. Hoorman
hoorman.1@osu.edu
www.mccc.msu.edu
EMPOWERMENT THROUGH EDUCATION
THE OHIO STATE UNIVERSITY
EXTENSION

Opportunities to Advance Carbon Sequestration in the Farm Bill

The Farm Bill offers tremendous opportunity to encourage farmers to increase carbon sequestration and reduce emissions through existing programs

Despite a tight federal budget, the upcoming Farm Bill renewal is a tremendous opportunity to address climate change. The conservation and energy programs in the Farm Bill offer incentives, cost-sharing assistance, and technical assistance to help farm and forest owners reduce greenhouse gas emissions and increase carbon sequestration while addressing vital environmental issues including soil, air and water quality and wildlife habitat. Maintaining funding of vital farm bill conservation programs and increasing the value each dollar spent on conservation will prove necessary to help America meet our goal of 17% emissions reduction by 2020 while meeting our food, fuel, and fiber needs.

The Farm Bill conservation title funds farm practices that have multiple benefits for landowners and their land; not only can these practices offer economic, environmental, and wildlife benefits, but often they also include climate benefits. For example, if farmers in the U.S. implemented cover crops on all of the acres suitable for cover crops (an estimated 185 million acres), we could mitigate up to 4% of our annual greenhouse gas emissions. If farmers implemented resource conserving crop rotations on fields suitable for such (roughly 244 million acres), we could mitigate up to 5% of our annual greenhouse gas emissions. Rotational grazing on pastures (an estimated 118 million acres) could mitigate another 4.5% of annual emissions. **This means we could mitigate 14% of annual emissions from America's working farmland alone, while increasing diversity of crops produced and providing multiple benefits to the environment.**

All of the practices mentioned above are currently supported by two farm bill conservation programs: the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP), both of which are programs that provide technical support and financial incentives to farmers to implement conservation practices. USDA estimates that EQIP and CSP store over 4 million metric tons of CO_2 annually.

The Farm Bill energy title also offers significant opportunities for greenhouse gas reductions. One successful program within this title is the Rural Energy for American Program (REAP), which funds on-farm energy conservation and renewable energy production. Projects include wind turbines, electrical and engine efficiency improvements, anaerobic digesters, and other renewable energy projects. **REAP projects will generate 57 million metric tons of CO_2 reductions over five years.**

Advancing the next Farm Bill to better meet America's needs:

1. *Protect existing conservation programs.* In the current budget climate, funding for the next Farm Bill will be tighter than ever, and funding for current farm bill conservation programs will be especially vulnerable. It is critical that funding for these programs is maintained. These programs not only have soil, water, and wildlife benefits, but they also sequester huge amounts of carbon dioxide. The Conservation Reserve Program (CRP), for instance, pays farmers an

incentive payment to take the most erodible land out of crop production and plant permanent ground cover. This ground cover reduces erosion, provides wildlife habitat, and increases the carbon sequestration of participating lands. A University of Missouri study estimates **CRP increases carbon sequestration by 84 million metric tons of CO_2 each year**. Federal policy must continue to support the multiple benefits of CRP with appropriate application of the program. For example, tree planting should only be encouraged in native forests. Native prairie should be left as grassland, which is better suited to provide better erosion control, wildlife habitat and water quality improvement than an exotic forest. Similarly, the Wetland Reserve Program (WRP) helps farmers protect and restore wetlands, which emit considerable amounts of carbon if converted to cropland. USDA estimates that WRP is responsible for sequestering 184,000 metric tons of CO_2 annually. These programs are extremely popular with farmers; as of August 2010, there was a backlog of almost 300,000 acres waiting to be enrolled in WRP.

2. *Tweak conservation programs to further incentivize carbon sequestration practices*. In some cases, by altering what is incentivized under certain programs, we can better maximize the benefits of these programs. The Environmental Quality Incentives Program (EQIP), for instance, provides cost-share, technical assistance and replaces some forgone income to help farmers implement practices that address environmental concerns. Projects help conserve water, address nonpoint source pollution, reduce emissions, and reduce erosion. Currently, the single largest use of EQIP is support for manure lagoons. When manure is placed in a lagoon it emits methane, which is 23 times more potent of a greenhouse gas. Lagoon methane represents about 1% of United States annual greenhouse gas emissions. Tweaking these payments to pay for capturing and using methane, or avoiding methane creation in the first place by making compost or energy would achieve significant avoided greenhouse gas emissions and the environmental co-benefits of cleaner water and air.

3. *Provide ways to ease the concerns of farmers while transitioning to more climate friendly practices.* The next Farm Bill should provide tools to help farmers make the transition to new methods and carbon sequestration strategies such as cover crops and conservation tillage. One option would be to offer income insurance to farmers willing to try cover crops for the first time. Since cover crops have been shown to maintain or increase commodity crop productivity, the actual cost of this program would be minimal.

4. *Prevent the farm bill from incentivizing destruction of native habitat*. Native grasslands sequester large amounts of carbon, and when these lands are put into agricultural production, that carbon can be released into the atmosphere. Many of these remaining native grasslands are in areas with poor soils, erodible conditions, and frequent flooding, making them a poor choice for crop production. Yet crop insurance subsidies currently incentivize farmers to convert these grasslands to commodity production, protecting farmers from the inevitable consequence of low production and low economic returns. Not only is this a fiscally irresponsible policy, but it releases tons of stored carbon into the atmosphere through the breaking of native grasslands. A more responsible fiscal and environmental policy would include a “Sodsaver” provision in the next farm bill, which would make non-cropland that is converted to cropland ineligible for federal benefits.

Green Lands Blue Water

Program Summary
February 2011

Green Lands Blue Waters is a **consortium** of scientists, policy experts, farmers, and community organizers from over a dozen non-profit organizations and five land grant universities, and collaboration with multiple government agencies in Middle-America, from the Upper Midwest to the Gulf of Mexico. Expanding the number of institutions in the partnership is a priority for 2011. We have formed this collaborative in order to leverage and gain traction with our collective resources in effecting the systemic transformation in the agricultural system that we seek.

The mission of Green Lands Blue Waters is to support the development of and transition to a new generation of multi-functional agricultural systems that integrate more perennial plants and other continuous living cover into the agricultural landscape. In doing so, we strive to maximize the multiple benefits to humans and the environment of natural services, including but not limited to: reducing greenhouse gas emissions, nitrogen, and sediment runoff; sequestering carbon; improving water quality; improving the extent and quality of wildlife habitat; reducing flooding potential; and enhancing human and animal health. We aim to serve as a model of positive agricultural transformation that can inspire and inform agricultural stakeholders and practices across the nation and globally, strengthen the resilience, quality of life, and health of rural communities.

Core Strategies

We are organized around two tiers of complementary and interconnected activities: 1) working groups / communities of practice that serve as hubs for research, and link research with extension and development around the most viable and promising perennials and other continuous living cover systems, and 2) rural development projects that systematically implement locally applicable best practices from all working groups and communities of practice, in concert, on large landscapes, and at scales that are economically significant and ecologically sound.

For the current slate of **working groups and communities of practice**, these are among the primary goals:

- *Agroforestry* – Cultivate agroforestry for multiple purposes including bio-energy, carbon sequestration, wildlife management, forest farming, and improved environmental performance.
- *Grazing / Grass-based livestock* – Build value chains for grass-fed and grass-finished and other animal systems on environmentally sensitive lands and beyond.
- *Perennial grains* – Develop germplasm for commercially viable perennial grain, the production systems, and markets for the harvested products.
- *Biomass* – Create viable perennial and cover crop-based biomass enterprises and markets that yield multiple ecological services benefits.
- *Cover crops* – Develop and implement cover crop systems to improve environmental performance of annual cropping systems.

The GLBW **rural development programs** are intended to overcome the silo affect of the independent working groups. Scaling-up of GLBW is happening for each of the five strategies described above, where the working groups and communities of practice are expanding research and the tools and extension programs needed to increase the production of perennials and other continuous vegetative cover and promote their markets. At the same time, GLBW partners and collaborators are increasingly implementing these strategies in combinations, developing more complex programs on specific landscapes. Significant change at the community level will be realized when we systematically implement the best practices from all five working groups, in concert, at scales that are economically significant and ecologically sound, increasing farm profitability, creating or strengthening local businesses that provide farm inputs and bring the outputs to markets, creating jobs, and generating revenue for community development.

Contact:

Richard Warner
Director, Green Lands Blue Waters
Department of Agronomy and Plant Genetics
University of Minnesota
411 Borlaug Hall
1991 Upper Buford Circle
St. Paul, MN 55108-6026
rhwarner@umn.edu
Tel: 612-625-3709)