GREENBOOK
2018

DEPARTMENT OF AGRICULTURE

GREENBOOK 2018

The Minnesota Department of Agriculture (MDA) is pleased to release the 2018 edition of our annually published *Greenbook*. We are highlighting 25 projects funded through the Sustainable Agriculture Demonstration Grant (SADG) Program, a component of the Agricultural Growth, Research, and Innovation Program. We invested these dollars so grantees could explore new ideas that will make farming in Minnesota more productive and sustainable. We are very proud of this program and the many ways it has impacted farmers and rural communities in Minnesota for the past three decades.

Recipients were awarded up to $25,000 for forward-thinking agricultural initiatives. We believe that the ideas these farmers and researchers are testing are fundamental to the future of agriculture. The SADG is dedicated to improving and shaping the future; many of the SADG's previous projects have focused on practices that have become widely adopted, such as integrated pest management and cover cropping.

In *Greenbook 2018*, you will find results from currently funded on-farm research and demonstration projects. The grantees are focusing on ways to increase energy and labor efficiency, reduce purchased inputs, and improve both the environment and their bottom line.

To learn more about any of the projects, please don't hesitate to get in touch with the grantee. You'll find contact information listed at the beginning of each project summary.

The MDA funded 11 new projects in 2018 and is accepting applications for new projects until December 12, 2018 for funding in 2019. If there's a sustainable farming idea you'd like to try, please keep this opportunity in mind. To apply, you must submit all application materials via the SADG webpage at **www.mda.state.mn.us/sustagdemogrant.**

Dave Frederickson, Commissioner

Minnesota Department of Agriculture | 625 Robert Street North | Saint Paul, Minnesota

September 2018

Agricultural Growth, Research, and Innovation (AGRI) Program

MISSION STATEMENT

The Minnesota Department of Agriculture's mission is to enhance Minnesotans' quality of life by ensuring the integrity of our food supply, the health of our environment, and the strength of our agricultural economy.

Our Sustainable Agriculture Demonstration Grants support innovative on-farm research and demonstrations. They fund projects that explore sustainable agriculture practices and systems that are likely to make farming more profitable, resource efficient, and personally satisfying. In the *Greenbook*, grantees share their observations and experiences so that other citizens can benefit from them.

ABOUT AGRI

The Minnesota Legislature created the Agricultural Growth, Research, and Innovation (AGRI) Program in 2013 to advance the state's agricultural and renewable energy industries.

The AGRI Program awards grants and other types of financial assistance to create agricultural jobs and profitable businesses. Farmers, agricultural businesses, schools, researchers, and county fairs can apply to several different AGRI grant programs.

AGRI grants focus on areas of greatest opportunity and potential economic impact. These investments have resulted in increased production, employment, market expansion, and improved production and processing efficiencies since the program launched in 2013.

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PROGRAM PURPOSE

The Grant Program is designed to demonstrate and publicize the energy efficiency, environmental benefit, and profitability of sustainable agriculture techniques or systems from production through marketing. Grants fund research or demonstrations on Minnesota farms. Funding is from the **Agricultural Growth, Research, and Innovation Program (AGRI)**.

PROGRAM DESCRIPTION

The Department has received over 1,165 grant applications and approved over $4.0 million in funding for 349 projects since the program began in 1989. Project categories include: Alternative Markets, Specialty Crops, Cropping Systems, Soil Fertility, Energy, and Livestock. The active grant projects, being conducted throughout the state of Minnesota in 2017, are described in *Greenbook 2018*.

Grants provide a maximum of $25,000 for two or three year on-farm research or demonstration projects. These projects by Minnesota farmers, educational institutions, individuals at educational institutions, or nonprofit organizations demonstrate farming methods or systems that increase energy efficiency or production, reduce adverse effects on the environment, and show economic benefits for a farm by reducing costs or improving marketing opportunities. A Technical Review Panel evaluates the applications on a competitive basis and makes recommendations to the Commissioner of Agriculture for approval. The Technical Review Panel includes soil scientists, agronomists, postsecondary educators, ag marketing specialists, sustainable and organic farmers, and other agricultural experts.

Summary of Grant Funding (1989-2018)

Year	Number of Grants Funded	Total Funding	Average Grant Size	Ranges
1989	17	$280,000	$16,500	$3,000-25,000
1990	14	$189,000	$13,500	$4,000-25,000
1991	4	$46,000	$11,500	$4,000-23,000
1992	16	$177,000	$11,000	$2,000-25,000
1993	13	$85,000	$6,000	$2,000-11,000
1994	14	$60,825	$4,000	$2,000-10,000
1995	19	$205,600	$11,000	$2,000-25,000
1996	16	$205,500	$12,900	$4,000-25,000
1997	20	$221,591	$11,700	$1,000-25,000
1998	19	$210,000	$11,100	$1,000-24,560
1999	23	$234,500	$10,200	$3,000-21,000
2000	17	$150,000	$8,800	$4,600-15,000
2001	16	$190,000	$11,875	$5,000-25,000
2002	18	$200,000	$11,000	$4,300-20,000
2005	10	$70,000	$7,000	$2,000-11,600
2006	8	$70,000	$8,750	$4,600-12,000
2007	9	$70,000	$7,777	$2,700-12,000
2008	10	$148,400	$14,800	$4,500-25,000
2009	7	$103,000	$14,700	$5,000-20,000
2010	11	$77,000	$7,000	$3,600-10,000
2013	6	$66,000	$11,000	$5,300-20,300
2014	13	$205,000	$15,770	$7,800-25,000
2015	13	$236,000	$18,200	$6,700-25,000
2016	11	$177,030	$16,094	$9,765-24,980
20 17	7	$103,682	$14,812	$5,397-25,000
2018	11	$223,099	$20,282	$12,167-25,000
Total Funded	**349**	**$4,004,227**	**$11,818**	**$1,000-25,000**

*No grants were awarded in 2003, 2004, 2011, and 2012.

New Demonstration Grant Projects 2018

CROPPING SYSTEMS

Cover Crop Effects on Soil Temperature and Soil Moisture

Grantee: Jerry and Nancy Ackermann
Duration: 3 years
Award Amount: $19,078.00
County(ies): Jackson, Nobles (two plots each)

Project Objectives:

Previous research has shown that cover crops reduce erosion, decrease soil compaction, and increase organic matter. However, project partners are unaware of any first-hand data about cover crop effects on soil temperature and soil moisture for southwest Minnesota. Soil temperature and moisture are important for nutrient uptake and plant growth.

1. Determine how cover crops affect soil temperatures and soil moisture.
2. Determine if soil moisture and soil temperatures have an impact on plant growth or nutrient uptake.
3. Provide an educational opportunity for southwest Minnesota farmers and agronomists to help make future management decisions.

Grazing Intermediate Wheatgrass (Kernza) as a Dual Purpose Crop for Forage and Grain Production

Grantee: Alan Kraus, Cannon River Watershed Partnership
Duration: 3 years
Award Amount: $24,965.00
County(ies): Rice

Project Objectives:

Intermediate Wheatgrass or Kernza is a new perennial plant that produces an edible grain and a high amount of biomass relative to annual grains like wheat. This biomass could be used as forage for livestock, supplementing the income from grain. Establishing Kernza as a dual-use forage and grain production crop may help to increase the adoption of Kernza among Minnesota farmers and increase the amount of continuous cover across the Minnesota cropping landscape.

We will establish Kernza on farms where the farmers are new adopters of the crop to:

1. Investigate the impact of fall grazing on subsequent Kernza grain yields in the first three years of production following fall planting of Kernza;
2. Investigate the quantity and quality of the fall regrowth of Kernza biomass, and;
3. Develop enterprise budgets to evaluate the effect of grazing on Kernza production economics.

Agrophenology Project

Grantee: David Abazs, Wolf Ridge Environmental Learning Center
Duration: 3 years
Award Amount: $15,525.20
County(ies): Lake

Project Objectives:

1. Identify and evaluate plant, insect, mammals and migratory animal species to determine their reliability in providing a better planting "calendar" for our domestic crops. Using phenology, the scientific study of the timing of nature will provide a better gage as to when we should plant our crops for maximum plant health and growth.
2. To determine the best phenological indicators for greenhouse/high tunnel production. We know that growing conditions vary greatly between and within greenhouses and high tunnels making it particularly difficult to determine the best planting times. We want to experiment between the phenological observations outside and within the season extension greenhouse/high tunnels by comparing specific indicator species both inside and outside the enclosures.
3. Develop an agrophenological calendar for our region that will serve as a more reliable planting guide for farmers. Even more importantly, the research results will establish an agrophenological methodology with downloadable phenology observation sheets and crop record-keeping documents to provide farmers the tools necessary to assess their own farms' conditions and individualize their own nature-based planting calendar.

SOIL FERTILITY

Perennial Farming and Carbon Sequestration, Ecosystem Services and Innovative Entrepreneurship

Grantee: Michele Manske, Mashkiikii Gitigan
Duration: 3 years
Award Amount: $24,606.29
County(ies): Hennepin

Project Objectives:

1. Evaluate the effectiveness of this perennial system to sequester carbon due to perennial inputs and management practices that promote carbon storage. Switching from conventional to biodiverse/perennial agriculture has, in some cases, been shown to sequester significant amounts of carbon in the soil. Effectiveness will be evaluated by comparing carbon storage in production oriented perennial systems to turf and vegetable production, and exploring the impacts on ecosystem services.
2. Investigate the impact of production-oriented perennial systems on soil contaminant accessibility. Research has shown changes to soil quality and health can decrease contaminant bioavailability and that perennial systems, with deep roots and deciduous leaf fall may increase aeration, microbial activity, and formation of organic matter. Specifically, this project will investigate whether perennial system changes to soil health decrease heavy metal contaminant exposure risk in urban gardens.
3. Evaluate the sustainability of this biodiverse perennial production system to provide innovative entrepreneurial opportunities for urban farmers and populations who face disproportionate contaminant exposures in this urban environment. Through weekly hands-on classes this project will allow us to provide needed training and develop market access strategies.

ENERGY
FRUITS & VEGETABLES

Testing of a Non-traditional Process for Cleanings and Sorting MN Wine Grape Varietals

Grantee: Arlyn Wall, KISS LLC
dba Brookview Farm Winery
Duration: 2 years
Award Amount: $25,000.00
County(ies): Mille Lacs and Stearns

Project Objectives:

1. Testing that a non-traditional method of cleaning and sorting the grape harvest can speed the field work component of grape harvest to reduce labor and pick the crop at the peak of ripeness. As field work is weather dependent and picking grapes off the vine in most MN vineyards is a manual process speeding this component of the harvest is of critical importance.
2. Demonstrate that Material Other than Grape (MOG) removal can be done at the crush pad more effectively than in the field. Increasing marginal quality loads of fruit with Multicolored Asian Lady

Beetles and stunted berry growth mixed with sound fruit by efficiently sorting and cleaning using technology to leave only high quality fruit for the wine maker. Removing Multicolored Asian Lady Beetle is very important as only a small amount in the wine making process can taint the flavor of wine.

3. Prove that MN cold hardy wine grape varieties can benefit from the reorganization of the cleaning and sorting process and the use of modern equipment. This could then pave the way to mechanical harvesting (removing even more field labor) while also elevating wine quality with a proven cleaning and sorting method. This non-traditional method of sorting grapes is used in other wine making regions, but needs to be tested with the physical size, shape and characteristics of the MN varieties.

Cover Crop and Intercropping Alternatives During the Establishment Period of Perennial Fruit Crops

Grantee: Richard Traugott
Duration: 3 years
Award Amount: $16,356.00
County(ies): Benton

Project Objectives:

1. This study will be evaluating and demonstrating alternatives to current production practices used with perennial fruit plant establishment by comparing 12 options. Upon conclusion of this project, farmers will understand which option best maximizes fruit plant growth during the first three seasons of plant establishment for several perennial fruits produced in Minnesota. Combined with the potential added value of the secondary crop, this project may encourage a new establishment paradigm.

2. In addition to emphasizing rapid establishment of the primary fruit plant, this study will evaluate the potential added value of the secondary crop produced. Harvested amounts of the four horticultural crops will determine the relative added value of intercropping. The four cover crops will be cut each month and collected to determine yield.

3. Evaluating and demonstrating the effect of options on the condition of the soil. Soil samples will be recorded in the beginning and at the end of the project.

Evaluating Effectiveness of Sap Analysis to Increase High Tunnel Tomato Yield and Quality

Grantee: Andrew Bernhardt, The Good Acre
Duration: 2 years
Award Amount: $23,558.40
County(ies): Ramsey and Goodhue

Project Objectives:

1. In 2014, a new Sap Analysis test became available in the US offering farmers more insight into crop health. By measuring 21 nutrients with a 1 week turnaround, this test allows farmers to be responsive to crop needs with timely tailored fertigation.

2. Evaluate the effectiveness of Sap Analysis to inform a customized nutrient management system using fertigation throughout the growing season to produce higher yields, better quality and reduced input costs. To accomplish this, we will conduct a 2 year study with three treatments.

   Treatment 1: control, no fertigation and no Sap Analysis.

   Treatment 2: fixed fertigation and no Sap Analysis.

   Treatment 3: Regular Sap Analysis and customized fertigation based on Sap Analysis results.

3. Hold two field days to demonstrate the setup and use of a fertigation system, teach farmers about Sap Analysis, and share any differences in high tunnel tomato production in the three treatments of our study. We will also create outreach and educational materials that we will distribute so that farmers can make informed decisions about whether or not this new crop production strategy is a good fit for their own farm.

SPECIALTY CROPS

Effects of Drip Irrigation on the Yields of Native Seed Production Plots

Grantee: Dustin Demmer, Blazing Star Gardens
Duration: 2 years
Award Amount: $12,983.92
County(ies): Freeborn and Steele

Project Objectives:

1. This project will research the impact of drip irrigation on native prairie seed production. The demand for native seed is increasing for habitat restorations and pollinator habitat, while supply struggles to keep up due to long-term investment returns and lack of grower knowledge.

2. Determine whether drip tape irrigation increases the seed production of four native Minnesota perennial plant species compared to non-drip irrigated seed plots.

3. If we find that drip tape irrigation increases native seed harvest weights, we will then determine whether the increased seed production revenue of each species is more than the added expenses of installing and managing the drip irrigation system.

Minnesota Hops Terroir Identification and Promotion

Grantee: Eric Sannerud, Mighty Axe Hops
Duration: 2 years
Award Amount: $25,000.00
County(ies): Benton

Project Objectives:

1. This project will bring together leaders in the hop growing and beer brewing communities across Minnesota, as well as key sensory analysis experts specializing in these industries, to investigate how we can best evaluate, communicate, and market the specific aroma and terroir of Minnesota grown hops.

2. Evaluate and identify the brewing characteristics, flavor, and terroir of Minnesota grown hops in varieties familiar to the market in order to increase profitability of hops as a local specialty crop, with high potential as a value-added product.

3. Effectively communicate the relevance of Minnesota hops terroir to commercial brewers and farmers in order to increase market opportunities for local hop growers and businesses using local hops.

Peonies for Profitable Cut Flower Production in Northeastern Minnesota

Grantee: Kate Paul, Owl Forest Farm
Duration: 3 years
Award Amount: $23,860.00
County(ies): St. Louis

Project Objectives:

1. The primary objective is to support the production of peonies for use in commercial cut flower production in an area of Minnesota where it has never been done before, but where growing conditions (in USDA zone 3) are potentially ideal.

2. To identify peony varieties, particularly late season cultivars, that will extend the season of their use for cut flowers beyond what is readily available in the industry, thus creating a nitch for sales in later summer (July into September) when supplies are low or nonexistent elsewhere in the lower 48 states.

3. To identify particular peony cultivars that grow well and produce the most cutting stems per plant. In essence, to identify which peony cultivars are most suitable for commercial cut flower production in northern Minnesota.

LIVESTOCK

Comparison of Mobile Confinement and Day-range Production Systems for Pastured Broiler Chickens

Grantee: Randy Kleinman, Seelye Brook Farms
Duration: 2 years
Award Amount: $12,166.60
County(ies): Anoka

Project Objectives:

1. Profitability Comparison - The project will compare the total production cost and profitability of each pastured broiler chicken system and its generated output. This includes comparing feed consumption and infrastructure costs. The project will also track total output of the system by weight of the finished broilers to determine if there is significant difference in feed conversion. Loss to predation and mortality will also be tracked.

1. Labor requirements - The project will track the total labor requirements of each pastured broiler chicken system. This is particularly important for beginning farmers who may be working full- or part-time off-farm jobs, and/or leasing pasture away from their residence where the need to tend to broilers multiple times a day could incur considerable time and transportation costs and make pastured poultry a non-viable or less profitable option.

3. Product Marketability - The project will provide a nutritional analysis of the chicken meat to determine if the different pasture access model is complementary to consumer nutritional demands. Any increase in one of many favorable nutrients (or vice versa for unfavorable nutrients) would potentially be a desirable marketplace advantage.

THANK YOU ...

to the MDA's Agricultural Marketing and Development Division Staff who helped to make *Greenbook 2018* a reality. They include:

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GRANT SUMMARIES

The following project summaries are descriptions of project objectives and methods with activities and results obtained each year of the grant. To find out more details about these projects, contact the principal investigators directly through the listed telephone numbers, addresses, and email addresses.

Developing a Network for Environment and Weather Applications

PRINCIPAL INVESTIGATOR

John P. Jacobson
450 Apple Orchard Rd.
White Bear Lake, MN 55110
651-429-6577
Washington County

PROJECT DURATION

2015 to 2017

AWARD AMOUNT

$19,465

STAFF CONTACT

Cassie Dahl

KEYWORDS

apple, climate, scab, codling moth

Rainwise weather station.

PROJECT SUMMARY

The Minnesota Apple Growers Association (MAGA) is currently evaluating the performance and efficacy of an electronic weather monitoring network that would standardize the data throughout Minnesota. In order to utilize the network, 12 weather stations have been distributed to apple growers around the State. These stations connect to the internet via WiFi and upload data to the Network for Environment and Weather Applications (NEWA) website (www.newa.cornell.edu). Growers may then view the data collected by the weather station nearest their orchard and use the data to forecast different insect and disease models.

We are also evaluating the efficacy of the forecast models to determine if they can accurately predict insect life cycles and disease maturation in the different apple growing climates within Minnesota.

PROJECT DESCRIPTION

Apple growers in Minnesota are located in many different growing regions. For example, growers are located in La Crescent which is in the southeastern part of the State, Grand Rapids which is in the northern part, and many locations in-between. In the past, organizations have used weather stations to collect and evaluate data, but this is problematic. The data may have been formatted differently, corrupt if the weather station malfunctioned, or not shared for proprietary reasons. In order to best serve the growers, a publicly accessible and standardized weather collection system is needed.

The Rainwise weather stations are all calibrated and function identically. The stations connect via the internet to the NEWA network, and can be accessed by anyone. NEWA is maintained by Cornell University, an industry leader in insect and disease forecast models. These weather based forecast models allow the growers to predict different plant and insect diseases from emergence to maturation. Proper prediction allows the grower to use chemicals more effectively by applying them at times when the insect or disease is more susceptible to control.

The evaluation of these models is important for the apple growers in Minnesota. Since, the forecast models were developed in other areas of the United States they need to be researched for accuracy with Minnesota's climate. The weather stations automatically calculate and keep a running total of growing degree days (GDD). They are used to determine the emergence and maturation of plant and insect diseases. Growing degree days are calculated by taking the high temperature for the day adding it to the low temperature, dividing that by 2, and then subtracting the base temperature per the disease or insect. For example, codling moth egg laying occurs at 100 GDD and then first generation eggs hatch at 250 GDD, while the second generation starts at 1,060 GDD. The type of control a grower uses is based on the GDD total which lets the grower know whether to control for eggs, larva, or moths. In addition to using GDD we will use pheromone traps for codling moths and apple maggots, so we can compare the two.

Apple Scab (AS) is another pest that MAGA has been collecting and charting the ascospores for the past 20 years. The progress of the ascopores is done by placing last years infected leaves under an apple tree. Each week leaves are then collected and sent for scientific evaluation to chart the progress of the disease. In comparison, a grower using the NEWA weather network, can click on the weather station closest to their orchard and run the "Apple Scab" forecast model using the data collected by that station. The forecast model will then predict the current level of AS ascospores and recommend if the grower needs to act. The electronic process eliminates many variables in testing, including contamination of samples, improper handling, and delays in testing. The electronic process also allows the growers to check thresholds on a daily basis rather than weekly.

2015 RESULTS

Scab Testing

During this first year of our study one of the issues we had with the NEWA model is that it relies on tree phenology when determining spore development and maturity instead of the dissection of a spore to do so. Crop protection is needed for AS when the disease reaches an activity level of 5% active spores or greater.

The NEWA model has the grower input the date at which McIntosh trees are at 50% Green Tip. This serves as the starting point for the predictive model. NEWA presents this data in a cumulative format. The grower would start protecting at pre-5% and proceed until 95% of the spores had been ejected. Versus the dissection method, which tells the grower the percentage of spores that are currently active on the leaf surface.

Typically the first cover spray would occur when the active spores reach around 3%, thinking that with the next rainfall disease maturity of 5% would be achieved. The grower will need to keep the crop protected until the levels drop back below 5%.

Results from leaf collection and dissection testing (highlighted = currently active).

Location	4/15/15	4/21/15	4/28/15	5/5/15	5/12/15	5/19/15	5/27/15	6/2/15
Tree Stage	Green Tip	TC	Pre-Pink	Bloom	Full Bloom	Petal Fall	8-12MM	20-25MM
White Bear Lake	0.5	7.1	14.3	13.4	11.8	5.3	14.5	12.1
Webster	NA*	1.4	2.2	0.4	25.6	16.9	32	10.7
La Cresent	0.3	2.5	11.6	14.1	26.1	19.8	1.7	0.5
Lake City	NA*	0	5.2	3.3	24.5	8.5	3	0.9

*NA = Not applicable.

NEWA Scab forecast model (highlighted = cumulative percentage of mature spores released).

Location	4/15/15	4/21/15	4/28/15	5/5/15	5/12/15	5/19/15	5/27/15	6/2/15
Tree Stage	Green Tip	TC	Pre-Pink	Bloom	Full Bloom	Petal Fall	8-12MM	20-25MM
White Bear Lake	2%	6%	16%	41%	78%	95%	99%	NA*
Webster	NA*	7%	18%	59%	88%	97%	100%	NA*
La Cresent	2%	6%	19%	54%	87%	97%	100%	NA*
Lake City	2%	5%	13%	50%	85%	97%	100%	NA*

*NA = Not applicable.

There are some fundamental differences in the analysis of these types of scab testing, both of which have positive and negative attributes. Leaf collection and dissection samples show “real-time” activity of spores, they do not show the potential risk for future infection periods. The spores mature during wetting periods, if it doesn’t rain the spores do not mature. Looking at the table using the leaf collection method in Webster, it shows the spores jumped dramatically from 0.4% to 25.6%. This could have had severely damaging consequences if the grower had not anticipated a wetting period and the risk of severe infection. The NEWA model did not accurately predict the end of the scab season. As of 5/19/15 the NEWA model was predicting that 95+% of the scab spores had been released. However, the leaf collection samples proved that the active percentage of scab spores was still greater than 5%. Overall, analysis for more than one season is needed to provide a better basis of comparison.

Codling Moth Lifecycle Evaluation

A codling moth (CM) life cycle model has been developed, and used by growers in different areas across the country for many years. This model utilizes grower insect trap counts to determine a “biofix” date, as a basis to begin a GDD lifecycle tracking program. When a grower traps 5 CM the tracking begins. Using this model the grower can predict the hatch of the CM eggs. The eggs begin to hatch at approximately 220 GDD post biofix. Implementing this model into IPM practices, has allowed many growers to target CM during the peaks of their lifecycle changes. A grower can now target codling moth eggs, larva, or adults at the most opportune times, therefore only spraying the necessary insecticide.

The NEWA website asks the grower to input the date of their first CM catch and then begins running a GDD based model to track the CM lifecycle. While it does not predict how many moths you will catch in your trap, it does track GDD extremely well. It also provides accurate information about what lifecycle stage the insects are in and different pest management strategies.

Currently we are checking our insect traps once a week and recording the trap count numbers. If a grower has a trap with 3 CM on Monday morning, they may not re-visit the trap until next week and this could affect the biofix date. If there is a mid-week heat wave, more moths will emerge and there could be 5 CM by Thursday afternoon, but the biofix date will be the following Monday. In addition, there are many different factors that can influence grower trap counts, such as improper trap placement, pheromone mating disruption, or application of different pesticides. If these trap counts are interpreted improperly the efficacy of pest control will diminish. The NEWA website collects weather data many times throughout the day and applies it to the forecast model, therefore setting the biofix date more accurately. For CM, utilizing accurate weather data and then applying the forecast model may provide a better understanding of what is happening in the orchard.

2016 RESULTS

Scab Testing

This season the NEWA model correctly predicted the emergence of the apple scab fungus at three of our testing sites. The decline of the scab ascospores was charted and predicted accurately. There were a few minor discrepancies, but I feel that they were insignificant enough to cause any crop damage, if using the NEWA model alone. One of the issues we've had this year was maintaining the connection status of the weather stations. Severe weather, internet service interruptions, and NEWA server issues have played a part in technological breakdowns this year.

Results from leaf collection and dissection testing (highlighted = currently active).

Location	4/12/16	4/19/16	4/26/16	5/3/16	5/10/16	5/17/16	5/24/16	6/1/16
Tree Stage	**Green Tip**	**TC**	**Pre-Pink**	**Bloom**	**Petal Fall**	**4-7MM**	**8-12MM**	**20-25MM**
White Bear Lake	3	15	21	28	16	12	23	1
Webster	NA*	0	30	29	19	12	27	3
La Cresent	36	19	25	10	13.5	7	15	0
Lake City	NA*	5	43	22	52	5	4	4

*NA = Not applicable.

NEWA Scab forecast model (highlighted = cumulative percentage of mature spores released).

Location	4/12/16	4/19/16	4/26/16	5/3/16	5/10/16	5/17/16	5/24/16	6/1/16
Tree Stage	**Green Tip**	**TC**	**Pre-Pink**	**Bloom**	**Petal Fall**	**4-7MM**	**8-12MM**	**20-25MM**
White Bear Lake	0	4	10	31	51	79	96	99
Webster	0	3	10	32	76	91	98	100
La Cresent	-	-	-	-	-	-	-	-
Lake City	2	3	12	23	61	84	93	100

Codling Moth Lifecycle Evaluation

This year the NEWA website accurately tracked the evolution of CM throughout Minnesota. Using the grower supplied date of first trap catch, NEWA successfully charted the CM lifecycle. It is important to note that the NEWA model cannot predict the amount of pest pressure in the orchard. Growers who have had high-to-extreme pest pressure in the past, may have prolonged exposure, long after the model has run its course.

2017 RESULTS

Scab Testing

This apple scab season brought new challenges in our testing and sampling process. Large amounts of localized rainfall created vast differences in disease pressure across the state. Southeastern and Central Minnesota saw an extreme amount of early season pressure, while areas north of the Twin Cities experienced mid-to-late season pressure, but in controllable amounts.

The best treatment for apple scab is prevention. Every grower must know their orchard and crop history to prevent damage and infestation before it occurs.

Results from leaf collection and dissection testing (highlighted = cumulative percentage of mature spores released).

Location	4/10/17	4/18/17	4/25/17	5/3/17	5/9/17	5/16/17	5/23/17	5/31/17	6/6/17
Stage	**Green Tip**	**1/2" Green**	**TC**	**Pink**	**Bloom**	**Petal Fall**	**4-6MM**	**10-15MM**	**20MM**
White Bear Lake	3	5	NS	15	24	28	10	6	0.5
Webster	NS	32	37	NS	33	54	21	11	3
La Cresent	21	48	43.5	26	16	6	0.3	NS	NS
Lake City	NS	52	NS	23	NS	25	3	NS	NS

*NS = Not significant.

NEWA Scab forecast model (highlighted = cumulative percentage of mature spores released).

Location	4/10/17	4/18/17	4/25/17	5/3/17	5/9/17	5/16/17	5/23/17	5/31/17	6/6/17
Stage	**Green Tip**	**1/2" Green**	**TC**	**Pink**	**Bloom**	**Petal Fall**	**4-6MM**	**10-15MM**	**20MM**
White Bear Lake	2	8	26	50	77	94	98	100	100
Webster	0	16	20	42	92	99	100	100	100
La Cresent	6	7	17	39	72	96	100	100	100
Lake City	2	9	31	51	82	96	100	100	100

Apple Scab Results Final Year

This is the final year of our project and I believe that the NEWA apple scab forecast model has increased in accuracy every season. This year the model correctly predicted the emergence of apple scab at all locations in our trial. However, there currently are 15 NEWA weather stations located across Minnesota and due to budget restrictions we could only physically test leaves at four locations. I believe that because of the accuracy of the computer model, it is a suitable and viable replacement for the physical leaf testing. This information should be used as a "tool" to help the grower determine levels of scab activity in their orchard. Growers throughout Minnesota must evaluate the economic

impact of apple scab and use whatever tools they have at their disposal to help manage this crop disease. There is no such thing as a "cure-all" or "silver bullet".

Codling Moth Results Final Year

A Codling Moth life cycle model has been developed and used by growers in different areas across the country for many years. The NEWA website collects weather data instantly many times throughout the day and applies the data to the forecast model. There are many different factors that can influence grower trap counts such as improper trap placement, pheromone mating disruption, or application of different pesticides, to name a few. If these trap counts are interpreted improperly, the efficacy of pest control will diminish.

To achieve the best control of Codling Moth the grower must target the egg laying period. Codling Moth eggs are deposited on the underside of leaves, around or near the first peak flight and trap counts. Using the NEWA network to track and predict their emergence will help growers achieve season long control by inhibiting the ability of the pest to establish large yearly populations.

MANAGEMENT TIPS

1. Run forecast models on multiple weather stations in your area. If you are in an area with more than one NEWA station, try running the programs on the other stations in the area to see if there are any differences.
2. Know your own history. Always keep accurate records of pest trap counts, and spray events. These can be a tremendous resource when evaluating pest pressures and chemical efficacy.
3. Scout, scout, scout. The best way to discover what is happening in the orchard is to go and look. Set out insect traps in areas you have avoided in the past, don't place them in the same tree year after year. Always maintain traps based on professional recommendations.

COOPERATORS

Weather Station Locations

Pine Tree Orchards, White Bear Lake, MN

Whistling Well Farm, Hastings, MN

Pepin Heights Orchard, Lake City, MN

Ocheda Orchard, Worthington, MN

Apple Jack Orchard, Delano, MN

Plum Crazy Orchards, Buffalo, MN

U of M HR Station-Grand Rapids, Grand Rapids, MN

Fruit Acres, La Crescent, MN

Pleasant Valley Orchards, Shafer, MN

Country Blossom Farm, Alexandria, MN

McDougall's Apple Junction, Hastings, MN

Nelson's Apple Farm, Webster, MN

Other Cooperators

Juliet E. Carroll, PhD, NEWA, Geneva, NY

Linda Treeful, PhD, Plant Pathologist, White Bear Lake, MN

Christopher Phillips, PhD, Entomologist, St. Paul, MN

PROJECT LOCATION

Please contact John Jacobson for directions to the many orchards.

Evaluating Hybrid Hazel Wood Chips as a Mushroom Substrate

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$9,765

STAFF CONTACT

Cassie Dahl

KEYWORDS

hazelnuts, hybrid hazel, mushroom, Shiitake, substrate, Wine Cap

Chipping hazel branches.

PROJECT SUMMARY

This project tests the idea of using of chipped hybrid hazelnut *(Corylus x)* branches as substrate for growing Wine Cap and Shiitake mushrooms. I am comparing hazel wood chips with standard substrates. I'm hoping to determine whether this by-product of the developing hybrid hazelnut industry can generate an additional income stream for producers and improve overall enterprise profitability.

PROJECT DESCRIPTION

My farming operation, Prairie Plum Farm, is small-scale at 14.5 acres of rolling land in southeastern Minnesota. To generate reasonable income, I need to produce items of high unit value. The entire property is planted to perennial ground cover forages rotationally grazed by my Babydoll sheep and a neighbor's dairy calves. I also have a 26' x 60' hoop house (and other buildings), a 30' x 30' vegetable garden, and a not-yet-bearing planting (2015 and 2017) of hybrid hazelnut trees.

Part of my overall philosophy is to have the "waste" from any one enterprise provide useful inputs into another. As a new hazelnut grower looking at the future management of my planting, I searched for a use for the wood that is typically coppiced (cut back to ground level) periodically to maintain high nut yields. I deliberated about options including burning, burying, and chipping for mulch. I decided that using the wood to produce tasty, nutritious, and valuable food (mushrooms) would be a better

option – IF it works biologically and economically. In addition, the spent mushroom compost could be another value-added product.

Hybrid hazel is a relatively new entity comprised of three component species: American, beaked, and European hazels. Both Wine Cap (*Stropharia rugosa-annulata*) and Shiitake (*Lentinula edodes*) mushrooms are known to colonize close relatives within the birch family, so I am optimistic that my idea of growing mushrooms on hazel wood chips will work.

These two species of mushrooms represent the extremes in input levels but also in value and existing market development. Shiitakes are less competitive requiring sterile substrate but have good market price, product recognition, and demand. Wine Caps grow quite vigorously without the need for carefully controlled climate or substrate sterilization but are less well known.

I'll compare the growth, weight of fruit production, and time to harvest these two mushroom species on hazel chips and on recognized good substrates (Table 1). In 2016 and 2017, Wine Caps were grown in 4' x 4' x 6" beds located in the shade. Beds were filled with substrate, topped with mushroom spawn worked into the top inch of substrate, completely saturated, then covered with straw and watered some more. The beds are kept moist for about 4 weeks during the establishment period (added step in 2017). Beds can be perennial if new substrate is added and mixed in.

Shiitakes were added in 2017. These slow growing mushrooms are grown in bags of sterilized substrate under controlled conditions to avoid contamination with unwanted fungi.

Table 1. Treatments

System	Substrates	Species
Ground bed (2016, 2017)	Hazel wood chips/ straw Boxelder wood chips/straw Straw (Control)	Wine Cap
Sterilized substrate (2017)	Hazel chips/oak sawdust/wheat bran Oak shavings/oak sawdust/wheat bran (Control)	Shiitake

2016 RESULTS

In 2016, I concentrated on the Wine Caps. The Wine Cap ground bed culture produced very spindly mushrooms on the straw beds and the hazel/straw beds. They were 3 weeks earlier than I anticipated and not even recognizable as Wine Caps, so I did not collect or weigh them. It is possible that the beds weren't deep enough (providing inadequate nutrition) or the spawn had deteriorated in storage.

The boxelder chips did not produce any mushrooms at all. The chips were stored in the covered bed of my pickup truck that was stored in a shed, but wild-type fungi colonized the chips. I used the chips anyway, to see what would happen. But after 3 days, the wild-type "feral" fungi had already produced extensive colonies. I suspect that the feral fungi prevented the establishment of the Wine Caps – if that's what those spindly mushrooms were. I'll know more when I repeat the experiment in 2017.

Watering the first three Wine Caps beds.

2017 RESULTS

New beds of Wine Caps were installed on August 23 using dried hazel chips stored through the winter on a cement slab sandwiched within a tarp. There was no sign of contamination. Boxelder chips were freshly chipped from branches cut 5 weeks earlier and allowed to dry with their leaves on. These should work much better than last year's chips which were stored and already colonized when Wine Cap spawn was added. All three treatment beds were watered for about 4 weeks and I saw good mycelial growth at that point in all treatments. Fruiting will not occur until next summer so there is no data yet.

Wine Cap mushrooms

Wine Cap fruits emerged in greater abundance in last year's hazel bed than in the boxelder and straw beds. I attributed this to more moisture for that bed from barn roof runoff. The new beds are located so they have equal access to water.

Shiitake production was added this year and proved to be more complex than anticipated. Because Shiitakes are not competitive, substrates are easily colonized by undesirable fungi. Substrate was sealed in bags, then sterilized in a gas pressure cooker, which was depressurized passively to avoid damage to the bags. After cooling 4 hours, I inoculated the bags in an 8' x 8' plastic covered walk-in space. The space is in the basement in front of a laminar flow air filtering unit. The bags were kept in this space at 70°F to grow for 30-70 days. We were successful. Only one block out of 20 was contaminated prior to removing the bags.

Colonization of the hazel and oak substrates was relatively equal. The bags were removed from the enclosed area and placed under a multi-tiered light stand equipped with two 40-watt bulbs and covered with plastic. A mister provided humidity, but we could only attain 60% humidity, not the 95-100% humidity required for fruit initiation. So, fruit initiation did not go well – no mushrooms. Our second attempt had the substrate bags under inverted 66-quart storage totes where the blocks sat on a cooling rack over a pan of water. Mushrooms developed beautifully, but so did a vigorous green mold. Once fruiting has begun, the relative humidity requirement drops to 60-80%, a condition that we can provide. It's the initiation humidity requirement that is the bottleneck.

Bags of substrate inoculated with Shiitake spawn – Oak/Oak/Bran on left and Hazel/Oak/Bran on right.

Only four of the 20 blocks were taken all the way through the fruiting process. The hazel mix substrate produced more mushrooms more quickly, but the small sample size was not adequate to draw any conclusions. Table 2 shows the results of our experiment with two Shiitake mushroom strains and the two substrates. LE04 and LE236 were selected for optimal growth in bag culture. Substrate LE04 is known to fruit at lower temperatures (55-64°F). The data in the table are from multiple flushes.

Table 2. Shiitake mushroom fresh weights and days to first flush.

Substrate	Fresh wt (g)		Days to first flush	
	LE04	LE236	LE04	LE236
Hazel chips/oak sawdust/wheat bran	305	235	8	13
Oak shavings/oak sawdust/ wheat bran	96	35	10	13

If I decide to continue small scale shiitake culture in bags, I plan to construct a chamber with full room humidification some place other than my basement.

MANAGEMENT TIPS

1. To prevent colonization of your substrate by wild fungi, you can chip and construct beds the same day as cutting; cut branches and allow to age/dry as intact branches before chipping, or store stockpiled chips but keep them dry and off the ground. Leaving the bark on while the branches dry should impede colonization by wild fungi.
2. Maintaining the moisture levels for the first two weeks in the Wine Cap beds is critical to colonization. To accomplish this and to save time throughout the season, either invest in a pump/ pressurized system to expedite water delivery to the mushroom beds or arrange for a completely gravity-based drip or ooze hose irrigation system that can be put on a timer.
3. If you have free range chickens, be sure to cover the beds with chicken netting. If you are producing mushrooms for sale, you'll have to exclude the birds entirely (for food safety reasons).
4. Timing and timeliness are critical when growing mushrooms. Before you begin, be sure you have scheduled enough time to reach a natural stopping point in the process.
5. If you plan to sterilize substrate, quickly scale up to use a thermostatically controlled electric sterilization unit. The labor expense needed for our small pressure LP gas cooker experiment was exorbitant. Adjusting gas flow to stay within necessary temperature and pressure limits was required every 5 minutes at first and every 30 minutes towards end of run.

COOPERATORS

Matt Ratliff, Owner of Ready2Fruit Mushrooms, Fort Ripley, MN

Ken Heidelbaugh, Hazel Producer, Spring Valley, MN

PROJECT LOCATION

From Hwy. 44 in Mabel, turn north on Hwy. 43 for less than .25 mile. Turn left onto 120th St./ Cty. Rd. 28. Farm is about 1.7 miles on right (north) side of road. Address/Fire number 42443.

OTHER RESOURCES

Field and Forest Website. **www.fieldforest.net/default.asp**

Fungi Perfecti Website. **www.fungi.com**

Ready2Fruit Mushrooms LLC Website. **www.ready2fruitmushrooms.com**

Stamets, Paul. 2000. Growing Gourmet and Medicinal Mushrooms, Third Edition. Ten Speed Press, Berkeley, CA.

Breeding, Assessing, and Selecting Nutrient Dense Corn for Poultry Production

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2015 to 2017

AWARD AMOUNT

$24,946

STAFF CONTACT

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KEYWORDS

corn, hybrid, methionine, open pollinated, poultry

Hungry hens in Paradox Farm's feeding trial. Photo by Sue Wika.

PROJECT SUMMARY

While poultry can get methionine, an essential amino acid, from pasture, growers typically have to supplement with synthetic methionine. The goal of our project is to identify a nutrient dense, locally adapted organic corn that is palatable to poultry. We are growing, evaluating, and selecting 20 varieties of nutrient dense corn for high nutrient levels of carotenoids, amino acids, yield, and earliness. We found several varieties with high enough protein that they may reduce or eliminate the need for synthetic methionine in poultry diets. We also conducted palatability tests to find out whether chickens prefer high nutrient organic corn or standard organic corn.

PROJECT DESCRIPTION

We are Sue Wika and Zachary Paige. Sue farms with partner Tom Prieve near Ashby, MN. They raise vegetables and pasture raise heritage breeds of goats, sheep, water fowl, cattle and horses. Zach produces hardneck garlic, potatoes, native corn varieties and squash as well as a few pastured butcher chickens and laying hens on his farm near Ponsford.

Zach is currently working on a Master's degree in plant breeding and Sue is interested in growing a corn that is high in nutrition, palatable for poultry, and that could be beneficial for people as well. A corn rich in beta carotene, fiber, protein and other nutrients could be good for individuals with sensitive stomachs and/or diabetes.

Methionine an amino acid, one of the building blocks of protein. We wanted to find a high-nutrient corn that had an ample amount of methionine so that poultry producers do not have to feed synthetic methionine. Organic farmers are currently allowed to use synthetic methionine, but its use is restricted now and may be phased out in the coming years. We are also interested in lysine and carotenoids, which can produce ultra-bright, nutrient dense yolks during winter when birds do not have access to pasture.

We wanted to find a corn that generally produces and yields well in a northern Minnesota climate.
We also wanted to know if a high nutrient corn is preferred by chickens (there have been some problems with chicken palatability of organic corn in our area).

In the summer of 2015, we grew out several varieties of high nutrient corn obtained from the United States Department of Agriculture Genetic Resources Information Network seed bank and from organic corn breeders. Many of the varieties were particularly high in beta carotene, which gave the corn an orange color. One experiment that looked promising was a hybrid we made from two high-nutrient corn varieties that grew well in western Minnesota. We took a high-carotenoid, open-pollinated flint corn called Dziekujie from Argentina (obtained from North Dakota corn breeder Frank Kutka) and a high protein, experimental open-pollinated dent corn called Dave F12 (from Montana corn breeder Dave Christensen) and crossed the two. The outcome was very exciting because it appeared to have the desirable traits from both the parent varieties and it yielded well.

We also obtained some corn varieties from plant breeder Walter Goldstein, who has been breeding high nutrient corn in southeast Wisconsin for more than 20 years. Walter is mainly producing hybrids and has a strong commitment to producing a high-yielding and high-nutrient corn. According to Walter, some of his varieties have 40% more lysine and methionine amino acid protein than conventional hybrids. We were the first people to trial six of Walter's most promising hybrids in a northern climate – although a lot of the genetics he used to create these varieties have been adapted to a Canadian climate for some time.

In both years, our experiment included 20 varieties of corn, including commercial hybrids (CH), high nutrient hybrids (HNH) and open pollenated (OP) varieties (Table 1).

Sue Wika in her maize trial July 4, 2017.

Table 1. Experimental varieties 2016 & 2017

Variety	Source
Group 1 – Commercial Hybrids (CH)	
Blue River 14A91	Blue River Seed
Blue River 06B21	Blue River Seed
Masters Choice 4050	Masters Choice
Viking .90-91N	Albert Lea Seed
Viking .85-90N	Albert Lea Seed
Viking .87-80N	Albert Lea Seed
Bejm (orange flint)	Commercial Variety from Poland
Group 2 – High Nutrient Hybrids (HNH)	
CG Wigor 2009 x Wigor BC1	Walter Goldstein
PHK05.Ngor.. X LH119..15-2-7-3-6-1	Walter Goldstein
CG SS x LH119.LH132..15-2-7-3-3-1	Walter Goldstein
PHK05.Ngor X BS33 B.E. 2006 191-4-2	Walter Goldstein
PHK05.Ngor X LH119.LH132..15-2-7-3-3-3	Walter Goldstein
Group 3 – Open Pollinated (OP)	
Dziekuje	Frank Kutka
Pete Seeger	Frank Kutka
Dave F12	Dave Christensen
VK RX 2300 Flint	Green Haven
Wapsie Valley	Green Haven
Dublin	Green Haven
MN13	Victor Kucyk

In variety trials, it is useful to have a large number of locations if possible in order to minimize the effects of environmental variation. In 2016, we planted our trials at four locations: Ashby, MN, Ponsford, MN, Lake Geneva, WI and Ames, IA. In 2017 we planted the trials at two sites: Ashby and Ponsford. In both years, we used a randomized complete block design with two replications at each location. We fertilized the Ashby location with composted cow manure in May of both years. At Ponsford, we applied organic calcium nitrate and pelletized poultry manure in April and June of both years, along with Sustâne® fertilizer in May of both years. We did not apply fertilizer to the Lake Geneva or Ames sites.

For each variety, we planted seeds 7” apart in two 17.5’ adjacent rows per block, with two border rows surrounding each block. At Ashby and Ponsford, we planted and weeded by hand, tilling lightly in between the rows. At Ames and Lake Geneva, we planted with a two-row cone seeder on a John Deere MaxeEmerge® planter and used tine weeders and other mechanical cultivation for weed control. None of the locations was irrigated. We recorded data on lodging, animal damage, and pest damage at Ponsford in 2016, Lake Geneva in 2016, and at Ashby in 2016 and 2017. We harvested all plots by hand, dried the cobs to 15.5% moisture, and used the dried cob weight to determine corn yield.

In both years, Zach performed protein analyses using Near Infrared Spectroscopy analysis at Iowa State University. The carotenoid analyses were performed at the University of Wisconsin – Madison.

Palatability Trials

In 2017, we conducted palatability tests using chickens at two locations: Ashby and Ponsford. We trialed five different rations that consisted of cracked barley/field peas, rolled hull-less oats and cracked corn. We used four varieties of cracked corn from our study (Table 2), as well as corn we bought from a feed mill.

We conducted the palatability tests in late fall when there are limited grass and insects for poultry to eat, prompting a need for supplemental carotenoid and protein. In Ponsford, the birds were inside a high tunnel. In Ashby, they were in a structure without access to grass (Table 3).

Table 2. Test Varieties for poultry palatability trial.

Variety	Rationale
Masters Choice 4050 (CH)	High yield, high starch, low protein
CG Wigor 2009 x Wigor BC1 (HNH)	High protein, low starch
Dave F12 (OP)	Lowest total beta carotene
Dziekuje (OP)	Highest amount of total beta carotene

Table 3. Parameters for poultry palatability trial.

Location	Ashby	Ponsford
Dates	Oct. 19 – Nov. 2, 2017	Oct. 19 – Nov. 2, 2017
Chickens	21 5-month old Barred Rock pullets	6 Laying hens: 2 Ameraucana, 4 Rhode Island Red
Ration	1:1:1 cracked barley/pea; rolled hull-less oats; cracked corn	1:1:1 cracked barley/pea; rolled hull-less oats; cracked corn
Timing	Offered at 7 am. Uneaten ration weighed and recorded at roosting (~6:30 p.m.)	Offered at 6 am. Uneaten ration weighed and recorded at same time the next day (~6:00 a.m.)

RESULTS

Corn Yield

The top three yielding varieties across years and locations were, in order: Viking .90-.91N (Commercial), PHK05. Ngor X LH119.LH123.11-2-2-4-2-1 (HNH), and Masters Choice 4050 (Commercial). In general, the commercial varieties yielded higher than the HNH and OP varieties (Table 4).

Protein and Starch

Two of the five varieties with the highest protein content were high nutrient hybrids (CG Wigor 2009 x Wigor BC1 and CG SS x LH119.LH132..15-2-7-3-3-1. Three were open pollinated varieties (Pete Seeger, Dave F12, and VK RX 2300).

The five top performers for starch content were all conventional hybrid varieties: Masters Choice 4050, .90-.91N Viking Hybrid, Blue River Hybrid 14A91, Viking .87-.80N, and Viking .85-.90N.

Statistical analysis indicated that HNH and the OP varieties had higher mean protein content than the CH varieties. However, the CH entries had a higher percentage of starch than the HNH entries. Taken together, hybrids (CH+HNH) had a higher percentage of starch than the OP varieties. We found a negative correlation between protein and starch; that is, varieties with higher starch generally had lower protein, and vice versa.

Table 4. Yield, protein, and starch combined across years and locations.

Variety	Mean yield (Bu/A)	Mean protein (%)	Mean starch (%)
Group 1 – Commercial Hybrids			
Blue River 14A91	119	9.07	70.85
Blue River 06B21	91	10.44	69.47
Masters Choice 4050	141	9.05	71.12
Viking .90-.91N	172	8.80	70.98
Viking .85-.90N	133	10.07	70.51
Viking .87-.80N	107	9.56	70.54
Mean for Group 1	**127**	**9.50**	**70.58**
Group 2 – High Nutrient Hybrids			
CG Wigor 2009 x Wigor BC1	81	12.53	67.20
PHK05.Ngor.. X LH119..15-2-7-3-6-1	86	10.95	68.15
CG SS x LH119.LH132..15-2-7-3-3-1	100	11.53	68.34
PHK05.Ngor X BS33 B.E. 2006 191-4-2	107	10.87	67.72
PHK05.Ngor X LH119.LH123..15-2-7-3-3-3	111	11.53	67.80
PHK05.Ngor X LH119.LH123..11-2-2-4-2-1	151	10.92	68.27
Bejm Hybrid	121	10.82	68.69
Mean for Group 2	**108**	**11.31**	**68.02**
Group 3 – Open Pollinated			
Dziekuje	91	11.19	68.29
Pete Seeger	72	12.18	68.47
Dave F12	68	11.62	65.87
VK RX 2300	83	11.62	69.08
Wapsie Valley	95	10.87	69.56
Dublin	86	11.45	68.71
MN13	74	10.50	69.78
Mean for Group 3	**81**	**11.35**	**68.54**

Carotenoids

In both years, we bulked grain by variety across all of the locations for carotenoid analysis, because at $100.00 per sample, it would have been too costly to test corn grain by individual location and replicate. Therefore, for each of the 20 varieties in our trial, we produced one carotenoid profile for 2016 and one for 2017. Table 5 reports the combined averages for each variety from both years and includes the concentration, in micrograms per gram, of lutein, total beta-carotene, and theoretical vitamin A (an indicator of overall carotene performance). Lutein is of special interest because it plays a role in human eye health, and high lutein poultry diets should produce eggs with more lutein.

Table 5. Carotenoid concentrations (ug/g)

Variety	Lutein	Total beta carotenes	Theoretical vitamin A
Group 1 - Commercial Hybrids			
Blue River 4A91	11.098	0.959	1.324
Blue River 06B21	14.043	0.913	1.286
Masters Choice 4050	17.274	1.128	1.486
Viking .90-.91N	18.397	1.407	1.728
Viking .85-.90N	10.434	1.081	1.325
Viking .87-.80N	11.36	0.862	1.149
Bejm	10.721	1.429	2.043
Mean for Group 1	**13.661**	**1.153**	**1.532**
Group 1 Mean w/o Bejm	**14.249**	**1.097**	**1.43**
Group 2 - High Nutrient Hybrids			
CG Wigor 2009 x Wigor BC1	12.833	1.092	1.814
PHK05.Ngor.. X LH119..15-2-7-3-6-1	17.134	0.791	1.443
CG SS x LH119.LH132..15-2-7-3-3-1	18.6	0.964	1.593
PHK05.Ngor X BS33 B.E. 2006 191-4-2	15.909	0.967	1.659
PHK05.Ngor X LH119.LH132..15-2-7-3-3-3	17.351	0.7	1.375
PHK05.Ngor X LH119.LH132..11-2-2-4-2-1	13.804	0.732	1.1
Mean for Group 2	**15.285**	**0.873**	**1.448**
Group 3 - Open Pollinated			
Dziekuje	12.399	2.642	4.348
Pete Seeger	8.974	0.913	1.205
Dave F12	9.269	0.489	0.835
VK RX 2300	10.232	0.92	1.246
Wapsie Valley	13.265	1.191	1.622
Dublin	12.835	0.985	1.316
MN13	14.476	0.989	1.444
Mean for Group 3	**11.636**	**1.161**	**1.716**
Group 3 Mean w/o Dziekuje	**11.508**	**0.915**	**1.278**

The dark orange Dziekuje (OP) performed well above the rest of all entries for both total beta carotene content and theoretical Vitamin A content, which was more than twice as high as the next highest variety. Bejm, the Polish CH which also has a strong orange color performed above the rest of the varieties in the CH group for total beta carotene and theoretical Vitamin A. Dziekuje and Bejm were unique and determined to be outliers, therefore we report the data both with and without these varieties in Table 5. Viking .90-.91N (CH) produced second highest total beta carotene after Bejm (CH) and came in fourth for theoretical Vitamin A.

We did not observe any correlation between kernel color and lutein content.

Table 6 shows the data we collected during poultry feeding trials at Ashby and Ponsford in 2016. Since this table reports rejected feed, higher numbers are unfavorable, indicating the birds found it less palatable.

Table 6. Poultry feeding trial results at Ashby and Ponsford (lb).

Corn variety used in feed mixture	Masters Choice 4050	CG Wigor 2009 x Wigor BC1	Dave F12	Dziekuje	Corn purchased at feed mill
Total uneaten feed, Ashby	1.0	0.5	0.5	1.0	1.5
Total uneaten feed, Ponsford	1.0	0.5	1.5	0.25	2.0
Total uneaten corn, Ashby	0.33	0.17	0.17	0.33	0.5
Total uneaten corn, Ponsford	0.33	0.17	0.5	0.08	0.5

The feed containing commercial corn from the feed mill topped the uneaten category with 1.5 lb rejected at Ashby and 2.0 lb rejected at Ponsford. It is worth noting that at Ponsford, Dziekuje averaged only 0.08 lb uneaten. Perhaps the darker color orange was attractive to the laying hens in the trial. Finally, CG Wigor 2009 x Wigor BC1 had an uneaten weight of only 0.17 lb at both locations. This variety had one of the highest protein contents.

To share information about our project, we held a field day at the Ashby location in June 2017 and offered participants a hands-on opportunity to help weed the trial. We're also planning to share our results at winter meetings and conferences in the region and are writing articles about it for several organic and sustainable agriculture publications.

CONCLUSIONS

Even though we treated the OPs as a group, we chose each individually for specific reasons: Dziekuje for its dark color and Dave F12 for high protein content and yield. In our study, we found the OP varieties had the highest protein level of all the varieties tested, but they did not generally yield as well as the CH or HNH groups. The exception was Wapsie Valley, which yielded better than grand mean and out yielded a few hybrids.

We found the top variety for overall carotenoid content to be Dziekuje. Further research is needed to determine where these traits are located in its genome so that breeders can use Dziekuje to increase carotenoids in other corn lines. We also think more experiments should be done to determine if there is a specific shade of yellow that correlates to lutein.

In our study, relatively high protein and carotenoid content did not affect the yield of the corn we produced. Although dark orange color is correlated with some specific carotenoids and with total beta carotene, further testing should be done to find out whether there is a more specific, visible pigment that is correlated to lutein content.

In our study, we found that a relatively high protein and high carotenoid content corn variety can perform and yield well in organic production systems. The layer palatability testing showed the birds ate more grain with either brighter orange color or high protein. We can at least surmise that the high nutrient corn is just as palatable – if not more so – than low nutrient corn.

2017 field day at Paradox Farm. Photo by Sue Wika.

MANAGEMENT TIPS

1. Start planning plots out in late March. We got a little rushed around the beginning/middle of May.
2. Corn does not dry down fast enough by simply leaving it out in a shed with fans blowing on it in cool weather. It needs **HEAT**. Building a corn dehydrator in 2017 and leaving a small heater under it with fans blowing help dry down the corn in no time.
3. Label all of the bags two times and throw a label in each bag as well when harvesting. There were a few times when we got confused about which variety was which. Labels get misplaced or get torn off. Putting the label inside each bag is important insurance to help when there are a lot of samples involved.

COOPERATORS

Walter Goldstein, Ph.D, Mandaamin Institute, Lake Geneva, WI.

Frank Kutka, Corn Breeder, Dickinson, ND.

Paul Scott, Ph.D, Iowa State University, Ames, IA

Sherry Tanumihardjo, Ph.D, Chris Davis, and Michael Grahn, University of Wisconsin, Madison, WI.

Wendy White, Ph.D, Iowa State University, Ames, IA

PROJECT LOCATION

Ponsford Farm is located off Hwy. 78 on the west side of the road, about 8 miles South of Battle Lake, MN. Paradox Farm is located at 11643 State Hwy. 78 Ashby, MN.

OTHER RESOURCES

Breeding Non-commodity Corn for Organic Production Systems: **eorganic.info/cornbreeding**

Dave Christensen's webpage: **www.northfrontierfoods.com/Dave_Christensen.php**

Mandaamin Institute: **www.mandaamin.org/research-results**

USDA Germplasm Research Information Network: **www.ars-grin.gov**

Using Precision Ag Data to Maximize Economic and Environmental Benefits

PRINCIPAL INVESTIGATOR

Tanner Bruse, Ag and Conservation Programs Manager (MN)
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PROJECT DURATION

2017 to 2019

AWARD AMOUNT

$25,000

STAFF CONTACT

Cassie Dahl

KEYWORDS

conservation practices, management zones, precision ag, working lands

PROJECT SUMMARY

Recent advancements in ag technology provide new opportunities for farmers to evaluate the performance and profitability of individual acres and examine alternative land use options on underperforming acres to increase both economic and conservation benefits. This project will work with a group of farmers, using Profit Zone ManagerTM, to identify revenue negative zones and to evaluate financial impacts of changes in practices before implementing them.

PROJECT DESCRIPTION

Recent advancements in ag technology, including precision ag practices and software, have created new opportunities for farmers to examine ways to provide environmental benefits while maintaining or increasing profitability on their farms. This new level of data collection has revealed that 3-15% of cropped acres do not return a profit, that is, revenue negative acres. There is huge potential in examining opportunities to adopt alternative practices for these revenue negative acres that combine conservation and increased profitability. In the past, there has been little consideration of the economic performance of conservation practices when working with farmers to enroll these acres in federal or state programs or examples of how conservation and production agriculture can complement one another and generate income.

To demonstrate the power of this new technology and its potential, this project will use a precision platform, Profit Zone ManagerTM (PZM), to incorporate farm technology with business planning principles with up to 12 farmers. A focus on profitability, as return on investment (ROI), will provide these farmers with economic outcomes, acre by acre, to identify revenue negative management zones and alternative practices that combine conservation and more profitable production.

The objectives of this project are:

1. Using precision business planning, identify revenue negative acres at the subfield area to provide farmers with alternative land use options to increase their ROI.
2. Build scenarios where farmers can evaluate the financial impact of alternative practices before implementing them.
3. Provide farmers with a working lands alternative, beyond existing conservation programs that are less restrictive with shorter contracts. This new program would increase both economic performance and natural resource benefits.

Farmer partners will be identified and receive a subscription to PZM. Pheasants Forever (PF) precision ag and conservation specialist will work with the farmer and their trusted advisors to find out the goals for their operations and gather detailed information on their current practices and historic yields. Farmers will choose an operation budget template (established from University of Minnesota data) or create a personal custom budget from actual operational expenses. For each farm, our PF's precision ag specialist will identify the typical three zones found on all farms:

- the revenue zone which is generally 60-90% of the operation, usually with the best soils, where it makes sense to intensify management and direct working capital (highest yielding acres);
- the expense limited zone which is generally 10-30% of the operation where yield fluctuates dramatically year to year; and
- the no cost zone which is generally 3-15% of the operation, also referred to as the revenue negative zone, where uncontrollable variability leads to a negative return year after year.

Scenarios incorporating alternative working lands management and practices such as existing federal, state, and local programs options, planting small grain or forage, establishing or renovating pasture, and introducing cover crops with income potential will be developed for possible implementation on the expense limited and no cost zones of each farm. In addition, on the expense limited zones, opportunities exist to work with the farmers trusted ag advisor to identify agronomic practices to increase profitability. The scenarios will be evaluated for each management zone for economic return on investment.

The working lands program under development will provide each farmer with a seed mix of quick establishing species and offer 3 to 5 year contracts with an upfront rental payment of half the current CRP enrollment rate for their county. Farmers can hay or graze the site after primary nesting season and drive through these areas while planting and harvesting.

RESULTS

The first year of this project has been filled with hiring a precision ag and conservation specialist, spreading the word about the project, and building relationships with farmers, ag retailers, consultants, agronomists, and conservation organizations. We enrolled seven farmers in the program and they are analyzing their 2017 harvest data (in addition with previous years harvest data), beginning the business planning process and developing management scenarios for implementation in 2018.

We built alternative management scenarios (conservation practices, increased crop rotation and forage production) for each management zone, focused on increasing profitability and environmental benefits. We've analyzed some of the data from farmer partners' revenue negative acres and measured the potential of recommended alternative management scenarios to increase profitability on those acres (see table). Of the farms analyzed, the average percent of acres that are revenue negative is just above 30%. The profit increase from implementation of the recommended scenarios was projected at $41.48/A. Farmers are considering the options recommended for their farms and will make decisions on implementation for the 2018 growing season.

Projected impact of implementation of alternative management on revenue negative acres.

Average impacts	
Average Number of Fields per Farmer Where Current Management is Resulting in Negative Revenue	9
Average Total Acres with Negative Revenue	844
Average Percent of Unprofitable Acres	31.2
Average Total ROI with all Scenarios	$86,295.84
Average Total Previous ROI	$70,109.34
Increase in ROI per Acre	$41.48

MANAGEMENT TIPS

1. Because of the intense labor, preparation, and weather dependence in farming, it creates short windows of opportunity to work one on one with farmers and their trusted advisors.
2. Change doesn't happen overnight. A discussion regarding management decisions or alternative options may not be implemented immediately and may take several growing seasons before implementation.

COOPERATORS

We currently have seven farmer cooperators located in various Minnesota counties: Stearns County, Todd County, Jackson County, Chisago County, Redwood County, Freeborn County and Lyon County.

EFC Systems (Brentwood, Tennessee) Previously AgSolver with an office still open in Ames, IA

PROJECT LOCATION

Contact Tanner Bruse for location information.

OTHER RESOURCES

www.efcsystems.com/index.php/agronomicplanningandsustainability

pheasantsforever.org/Newsroom/2017-December/Harvest-More-Buck$-and-Birds-Precision-Ag-Workshop.aspx

Maximizing Profitability in Modular Movable Hoop Houses

PRINCIPAL INVESTIGATOR

Megan Henry
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Brandon, MN 56315
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PROJECT DURATION

2015 to 2017

AWARD AMOUNT

$18,642

STAFF CONTACT

Cassie Dahl

KEYWORDS

hoop house, mobile hoop house, season extension, vegetables

Mobile modular greenhouses are easy to move.

PROJECT SUMMARY

Sundogs Prairie Farm is testing a mobile, modular hoop house to see if it can help maximize mixed vegetable production. Stationary hoop houses are already a proven method of increasing farm productivity and profitability. They maximize solar gain, reduce pest pressure, enhance yield and quality, and extend the growing season. However, a limiting factor is the small growing area that traditional stationary hoop houses provide. Mobile modular hoop houses are a recent innovation from grower Eliot Coleman's Four Season Farm in Maine. These structures can be easily split into short segments, moved around the garden by hand, and reassembled in a new location. This unique mobility allows one structure to cover many field plots in the same growing season.

PROJECT DESCRIPTION

We are inspired by Eliot Coleman's farming technique where mobile hoop houses have been used successfully for many years. Mobile modular hoops let growers move the structure, which greatly increases the options for placement, as shown in the photo above. These structures mean growers can cover more total growing area each year, allowing them to plant more crop rotations, place the hoop house in different locations on the farm during critical growth states of many crops, and greatly increase the overall farm benefits provided by the investment.

Sundogs Prairie Farm produces diverse vegetables on 5 acres for delivery to a local food hub, online market, two farmers markets, and several local restaurants. Before we started this project, we used a traditional hoop house, low tunnels, and row covers to extend our growing season and increase farm profitability. Our cropping system includes open field and plasticulture techniques depending on crop, market, and field conditions. We have an additional 50 acres of land in conservation programs, 17 acres

of pollinator planting, and 60 acres of organic alfalfa rented by a neighbor. We employ extended family members for a significant portion of the labor on our farm and, depending on our needs, we hire up to five additional workers.

In 2016 we added a farm stand and 2 acres of raised beds in the City of Alexandria. We found a location along a low-speed segment of a major roadway that our target market travels. We hope the new location will better engage our local community, raise awareness of small farm viability, and demonstrate mobile modular hoop houses.

2015 RESULTS

Our 2015 cropping strategies focused on maximizing fall crop yields, season extension, and profitability. We compared direct seeded plantings at 10 day intervals, with three treatments per planting. The three treatments were:

- Outside planted crops that remained outside all season.
- Outside planted crops covered with a mobile modular hoop house.
- Crops planted inside a conventional hoop house that stayed covered all season.

We monitored seedling establishment, plant condition and growth, re-growth, yield, and management complexity. The warm late fall probably helped plant growth and condition across all treatments through September and into October. With steady fall temperatures, the effects of shorter day length on growth were very apparent in October, and growth essentially ended in early November.

The crops we planted before September 10 performed well but were occasionally difficult to establish due to wet soil. Protecting beds by covering them with old greenhouse plastic prior to planting stimulated weed seeds and maintained good seedbed conditions. We found that seedlings established more slowly when we direct seeded outdoors after early September. However, once established, outdoor plantings grew very well through late September. After that, growth of most crops slowed, and we covered some beds with the mobile modular hoop house.

We observed that the outdoor seedlings covered by the mobile modular hoop house generally had less disease and much better re-growth than the unprotected outdoor beds. This fast re-growth meant we could take an additional harvest of marketable spinach and leaf lettuce from the protected beds (see table). The protection provided by the mobile modular also allowed crops like Hakuri turnips to remain marketable much longer than in the outdoor beds.

2015 spinach growth across treatments.*

Treatment	First cutting	Second cutting	Third cutting	Total yield (rank)
Outside all season	Good	Fair	None	2
Outside, then mobile modular	Good	Fair	Fair	1
Hoop all season	None	Fair	Fair	3

*Spinach planted on August 10.

Direct seeding in the main hoop house was surprisingly difficult in August. It proved to be a stressful environment for seedlings; those that did establish in August grew poorly until the weather got cooler. When we removed the main hoop house crop of tomatoes (around September 1), ventilation improved and seedlings performed better.

Many species germinated and grew rapidly in the short, cool, fall days. In September, all our direct seeded seedlings in the conventional hoop house performed very well. Most species grew until late October and some even later. Densely seeded kale and mizuna beds that we started on September 1 were harvestable by early October. They re-grew enough for another harvest in late October/early November. Hoop house beds that we direct seeded on September 20 with French Breakfast radishes, Tokyo Bekana, Mizuna, Arugula, and kales were harvested by November 1.

In 2015, our most profitable crops were planted outside and then covered with a mobile, modular hoop house. We observed better plant establishment in the mobile, modular houses and growing conditions enabled those plants to regrow rapidly after harvests. Bed preparation, stale seedbed techniques, seeding, and watering were all

Big winds can mean disaster. After this catastrophe, we modified our anchoring system.

significantly easier outside the hoop house and saved a lot of management time and effort. Because we planted adjoining beds in a 10-day sequence, we were able to shift the mobile, modular hoop house onto crops at the optimal growth stage.

2016 RESULTS

This year we focused on three crop schemes that would complement our existing extended season production and reduce the frequency of planting brassicas in our main hoop.

Weather was a defining factor of 2016; we had the longest growing season ever at our location, extending our fall into November. Our spring started off with a bang as high winds, structural flex, and hardware failure combined as two of the three sections of our mobile modular hoop house broke free and tumbled across the farm as shown in the photo above! One section was destroyed but we were able to salvage the other one. When we looked closely, we saw that some of the fittings had failed. We also saw how the structure had shifted under wind load. We reassembled the structure with a modified anchoring system which attaches directly to the frame and pulls down and out in all directions to counter wind shifting as shown in the photo below.

We modified the earth anchor system to make the mobile, modular hoop house sturdier. Note how soundly Kodiak is sleeping, confident that it won't blow away again.

Cropping Scheme 1

Our first cropping scheme this year was to plant early spring crops in the mobile modular hoop house, which we finished uncovered. We transplanted Chinese cabbage, bok choi, and lettuces on April 10. We direct seeded pre-germinated beets and carrots on April 17. They emerged about 10 days later.

We removed the structure from these crops around May 15 to preheat the beds before planting tomatoes. The combination of heat and cold exposure triggered bolting in most of the Chinese cabbage and bok choi, making them unmarketable. The lettuces grew slowly but complemented our normal production and reached harvest 3 weeks earlier than the outdoor unprotected plantings.

The beets and carrots did well; both crops were ready to harvest in mid-June when our markets had no others available. The carrot yield was about 20% less than in our regular hoop house. (Our earliest carrots had been planted in our main hoop on November 17 the year before. We harvested those in mid-May, only 10 days before the February 14, 2016 planted mobile modular carrots were ready. Each 70' bed yielded 200 bunches

of carrots, helping us beat other area growers to the markets. Creating strong connections with customers early in the marketing season increases traffic at our markets. It also draws purchasing power solidly, helping establish our revenue stream for the year.

Cropping Scheme 2

For cropping scheme two, we used warm season crops. We planted tomatoes into raised, plastic-mulched beds and used dual drip tape. We timed planting to give us a chance to clear the early crop of tomatoes out of our main hoop house by September 1. Preparing the three beds, each 200' long, only took 20 minutes with a bed shaper-mulch layer I rented from another farmer.

We covered the first 35' of the beds with the mobile modular unit for a 2-week soil preheat starting May 15, then spread straw for mulch. On June 1, we transplanted 12" tomatoes into the beds – both in the mobile modular unit and beyond -- into the outdoor bed. We used mainly 72-day varieties and 75-day heat set determinates, which have worked well for us in the past.

The tomatoes grew rapidly in the mobile modular unit compared to the outdoor plants whose initial growth was slow. We had planted similar varieties in the main hoop 3 weeks before, but the mobile, modular tomatoes caught up; they were ready to harvest only 2 weeks after those in the main hoop. The mobile modular tomatoes were ready 20 days before the adjoining outdoor plantings.

We saw less disease and weed pressure in the mobile modular unit, probably due to the fact that the plants were protected from rain. The plants thrived in this environment, producing the blemish-free 12 oz BLT slicing tomatoes our customers love.

Production in the mobile modular unit was very strong in September, which meant we could replant the main hoop earlier than planned, while maintaining the supply of quality tomatoes our customers expect. We harvested the last tomato from the mobile modular unit on October 10.

The mobile modular hoop house protected our crops from the intense rainfall, damaging winds, and hail that damaged our 2016 outdoor tomato plantings. We sold most of what was marketable from the outdoor comparison plantings as canning tomatoes, cutting their value in half.

Cropping Scheme 3

The final cropping scheme we used in the mobile modular hoop house this year was production of fall greens. We transplanted fall lettuces into much of our main hoop house to extend availability. Ordinarily, we would have planted fall greens in the hoop house; we used the mobile modular for the greens instead.

We planted our final outdoor greens beds September 15. The mobility of the mobile modular unit was truly on display when two of us loaded it onto a trailer and hauled it 20 miles to our new site in town. On October 12, we dropped it onto the appropriate beds of greens to protect them from predicted cold weather.

We harvested greens on October 20 and again on November 3. We were able to harvest the mizuna, kale, and arugula beds a third time on November 18. Wet conditions in the mobile modular unit contributed to disease in the leaf lettuce, so we did not harvest lettuce.

First cut yields were high in the mobile modular hoop house at 0.5 lb/bed/ft. The 54' we harvested yielded 26 lb of Asian greens, leaf lettuce, and baby kales. We continued planting in the main hoop until November 5, when we planted the final bed for baby spinach. That baby spinach emerged 10 days later and will overwinter as seedlings for harvest in March of 2017.

We deemed our 2016 summer and fall crops in the mobile modular unit a success. They required minimal labor for the quality and yield they returned. The three crop schemes we demonstrated complemented our existing production. They provided a more consistent supply of carrots, beets, spinach, head lettuce, and tomatoes – which are all high demand items at our markets.

We found these schemes helped us maximize our productivity and maintain availability through our extended harvest without significant demands of labor or capital. This made our revenue stream more consistent and conditioned customers to plan on shopping at our Farm Stand. When customers can fill their basket with items they were hoping to buy everyone is happier.

In total, we spent $2,500 on our 14' x 50' three-section mobile modular hoop house, which covers a 140' bed, while we spent $9,000 on our 30' x 72' gothic style hoop house, which covers a 440' bed.

We are not satisfied with our bed efficiency in either structure – something we hope to address in 2017.

The mobile modular unit can be skidded by two people and moved most places by three so labor isn't a limiting factor, although our labor inputs were high in the spring of 2016 due to the wind incident and the Asian crops that bolted. In fact, for many crops, actual labor per unit of yield was less in the mobile modular unit than either outdoors or in the permanent hoop house. The mobile modular hoop house did experience some disease issues in late fall that we didn't have in the main hoop.

The mobile modular hoop house proved very adaptable in placement, allowing us to respond to actual conditions. If vegetable growers have concerns about short-term land leases, the mobile modular unit may be a good option for them.

2017 RESULTS

A major hurdle this year was the lack of a frost proof water supply near the mobile modular hoop house. Hauling water for hand watering was a struggle compared to our mini-sprinkler systems. The inconsistent watering and soil moisture conditions resulted in spotty carrot emergence in our first planting and yield was down by 25-30%. The dry soil conditions seemed to be magnified by the lack of automated hoop vents and low roof; temps in the mobile modular unit varied more than in the hoop houses.

Cropping Scheme 1

At the end of February we planted one beet and two carrot beds. For this planting we germinated the seeds beforehand to try and get an extra early start. After 3 weeks the mobile modular hoop house was moved and another set of beds was planted. The second and third plantings did not use germinated seed. Beets were planted in 6" x 6" blocks using a dibble roller, and carrots were planted into three rows spaced 7" apart. Comparison outdoor beds were established on the same dates and some comparison carrot beds were established in two standard hoop houses. All the initial crops were planted into stale beds that had been leafy greens the fall before. Following stale bed techniques, the beds were not tilled before planting.

We were pleasantly surprised by the yield and quality of the first planted beets, with harvest starting the first week of May and complete by May 15. The harvest of the first planted carrots began the second week of May; this was more than a week after the hoop house carrots, planted the same date. The first carrots planted outdoors emerged 5 to 6 weeks after planting. I had already given up on them when they finally appeared under the coco fiber blanket covering the bed. Although delayed, these outdoor carrots had a good yield, excellent quality, and minimal labor input. The first planted outdoor beets had a lot of seedling loss, which led to a sparsely filled planting bed. The second and third plantings all germinated and grew well. The mobile modular hoop house allowed us to harvest carrots twice before the carrots in the outdoor bed were ready for harvest. In future years, we may try employing the mobile modular unit strictly to warm and dry the soil, and then move it after seeding to take advantage of rainy spring weather.

Cropping Scheme 2

For the summer crop, we planted tomatoes consisting of two rows of red slicers and one row of red cherry on June 7. The mobile modular hoop house covered the ends of the 150' plastic covered, raised bed with drip tape. The structure was placed adjacent to a major roadway with the doors facing the road. The doors were left open so our community could watch us plant, care for, and harvest the tomatoes. This generated quite a bit of interest in the slicers and about a dozen inquiries for canning tomatoes. Our area was struck by late blight in 2017, which caused the outdoor tomatoes to rapidly turn brown with major scarring on the fruits that did ripen. Inside the mobile modular hoop house only the tomato plants near the open door or under the roof vents showed any signs of the disease. Only about 10 lb of red slicers were harvestable from the 200' row of the outdoor planting. Inside the mobile modular unit red slicer yield was 7 lb/row ft, which was slightly less than inside the hoop house. The red cherry tomatoes were slightly more resistant to late blight and some outdoor plantings were harvestable. The mobile modular red cherry tomatoes yielded well and had good quality. However, they were out produced by the hoop house cherry tomatoes, which were ready for harvest a full month earlier and continued to produce all summer and into fall. Tomato harvest from the mobile modular unit generally complemented the harvest from our main hoop houses with some overlap between harvests. The mobile modular unit with the doors open didn't heat up as much as our hoop houses, but ventilated well enough to allow us to keep the side walls completely closed. The varieties we used were Sakura, Sunstart, BHN 569, BHN 964, and Volante.

Fall greens planted in mobile modular.

Cropping Scheme 3

The final cropping system was fall planted spinach, baby kales, turnips, and Asian greens. To ensure we would have a continuous harvest of the crops, plantings were staggered across the planting block in the mobile modular hoop house. To account for varying crop maturities, the plantings occurred every few days, allowing us to harvest spinach, baby kale, turnips, and Asian greens at the same time. The target harvest date for the first 50' of row was October 1; the next 50' target was October 7. The mobile modular unit extended our fall greens harvest up to 4 weeks beyond the outdoor plantings. Spinach, tatsoi, and turnips withstood nights with temperatures in the teens and regain harvest quality the following afternoon after the unit warmed up.

MANAGEMENT TIPS

1. Position your end earth anchors outside the structure and attach the turnbuckles directly to the framework.
2. Scissor doors and roll up sides do not perform well in high winds. We changed our end walls leaving half of each end covered all summer and we clamped the sides down. We experienced no additional wind damage and ventilation seemed adequate for the short tunnel we have.
3. Harvest or terminate crops promptly at maturity, even if they end up in the compost. Replanting immediately provides the opportunity for an additional harvest and maintains soil health.
4. Ensure a frost-free water supply is available for early season watering and late season harvest washing.

COOPERATORS

Dave Birky, Ag Resources, Inc., Detroit Lakes, MN

Deep Winter Producers Association, Online Community

Local Harvest Market Online Cooperative, Alexandria, MN

Ryan Pesch, U of M Extension, Moorhead, MN

Stearns DHIA Labs, Sauk Centre, MN

PROJECT LOCATION

From Brandon, go north on Cty. Rd. 7 for 7 miles. Turn right (east) onto Cty. Rd. 5 and go 1 mile. Turn right (south) on Chippewa Heights Rd. and go 1.5 miles. Turn left (east) onto Burn Rd. which ends at Sundogs Prairie Farm, 10737 Burn Rd. NW.

Sundogs Farm & Market Stand is in Alexandria, MN at 2200 N. Nokomis (Cty. Rd. 42), next to the Alexandria Golf Course and Voyager Elementary School.

OTHER RESOURCES

Dr. John Biernbaum, Michigan State University. **www.canr.msu.edu/people/dr_john_biernbaum**

Deep Winter Producers Association. **www.facebook.com/DeepWinterProducers**

Eliot Coleman. **fourseasonfarm.com**

Jean-Martin Fortier Workshop. **www.youtube.com/channel/UCFF20WbbyKSiYQe0J6a7HTQ/feed**

Local Harvest Market Online Cooperative. **localharvestmarket.co**

The Market Gardener. **www.themarketgardener.com**

MOSES Conference Recorded Workshops. **www.mosesorganic.org**

SARE Season Extension Topic Room. **www.sare.org**

Perennial Wheatgrass and Legumes for Cropping, Grazing, and Soil Health

PRINCIPAL INVESTIGATOR

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Big Stone County

PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$10,000

STAFF CONTACT

Cassie Dahl

KEYWORDS

intermediate wheatgrass, Kernza®, perennial

We used a no-till drill to plant the intermediate wheatgrass into a well-grazed plot.

PROJECT SUMMARY

Intermediate wheatgrass is a perennial cool season grass that reportedly can provide continuous living cover, produce an annual grain crop, and supply forage for grazing livestock. This project is evaluating the forage, forage quality, and grain yields of an intermediate wheatgrass crop inter-seeded with legumes. Can inter-seeding legumes into intermediate wheatgrass provide the nitrogen needed to both supply an annual grain crop and provide forage for beef cattle?

PROJECT DESCRIPTION

Mike and his family operate a 317 acre diversified farm near Clinton, MN. They have 70 acres of rotationally grazed perennial pasture currently grazed by 85 head of Lowline Angus and Irish Dexter cattle. Another 40 acres (including the 5 acre test plot for this study) are certified organic and used for crop production. They also have 40 acres in transition to organic. The rest of the farm is in a conventional corn/soybean rotation.

The Jorgensons say that planting perennial crops has benefitted their land. They farm fine-textured, silty clay soil. Planting perennial crops has improved soil permeability and reduced soil erosion. The cover and improved soil permeability they provide are especially important during the frequent high intensity, 2"/hr rains common in western Minnesota. Mike and his family were also intrigued by the potential economic benefits of a perennial crop like intermediate wheatgrass, which might provide both a valuable annual grain crop and forage for their beef herd.

Researchers in Kansas started a breeding program for intermediate wheatgrass in 2003. They have patented the name of the grain it produces as Kernza®.

They asked University of Minnesota forage agronomist Craig Sheaffer to cooperate with them on this project. He provided the

intermediate wheatgrass and legume seed and helped design the study. When the time comes, Dr. Sheaffer's lab will analyze forage and grain yields as well as forage quality.

2016 RESULTS

The Jorgensons fenced in the entire 40 acre certified organic field and installed interior fence around the 5 acre test plot. They put the cattle out on that plot and mob grazed the existing cover crop in August and again in September just prior to planting the intermediate wheatgrass. Since this field is certified organic, they could not burn the cover crop down with herbicide. Instead, they used intensive grazing to reduce competition for the intermediate wheatgrass they were about to seed.

Mike planted the intermediate wheatgrass test plot on September 29, using a tractor and the Big Stone County Soil and Water Conservation District's no-till drill. He had hoped to plant the intermediate wheatgrass in late August/early September, but their region received excessive amounts of rain beginning in early July and continuing through the entire fall. The rain delayed intermediate wheatgrass planting considerably. Since the planting date was much later than they expected, Mike and his family did not inter-seed the legumes with the intermediate wheatgrass in fall 2016. They will do that in spring 2017.

The intermediate wheatgrass did not emerge until October 12, although near weekly rainfalls in October provided adequate moisture. Warmer than average temperatures in October and November helped the intermediate wheatgrass establish. In fact, the Jorgensons' beef cattle were able to graze on adjacent ground until November 26.

While the intermediate wheatgrass seed did eventually germinate, it is possible that the stand may have been affected by the cool, wet soil conditions. Then, two rainfall events in December encrusted the frozen field in a sheet of ice. When Mike submitted his annual report, it was the middle of winter. He and his family could only hope the intermediate wheatgrass stand would overwinter successfully.

2017 RESULTS

The intermediate wheatgrass planted last fall was largely winter killed due to heavy late autumn rain leading to ice encrusting the field followed by the lack of an insulating snow cover. Mike observed a 50–60% stand loss. He delayed the decision on replanting until June hoping the stand would improve. There was no improvement and the stand was terminated.

The test plot was moved to a better drained site which was tilled four times over the summer for weed management. The field was seeded on September 8 at the rate of 8 lb/A of intermediate wheatgrass and 5 lb/A of alfalfa, again using the Big Stone County SWCD no-till drill. Both the intermediate wheatgrass and alfalfa emerged and, in early December, were still green. Big Stone County has again experienced a winter without snowfall and we hope that the stand will be viable in the spring. Data on yield of grain and forage as well as forage quality will be collected beginning in the spring of 2018 if the stand is viable.

MANAGEMENT TIPS

1. A no-till drill works well to plant intermediate wheatgrass seed. Many SWCDs have them available for rent.
2. Consider planting in a well-drained area.

COOPERATORS

Blayne Johnson, Big Stone County Soil and Water Conservation District, Ortonville, MN

Craig Sheaffer, University of Minnesota, Saint Paul, MN

PROJECT LOCATION

From Clinton, MN, go 7 miles east on Cty. Hwy. 6. Then go south 2.5 miles on 660th Ave. to 33626 - 660th Ave. Driveway is on the left.

OTHER RESOURCES

The Land Institute. Kernza® Grain: Toward a Perennial Agriculture
landinstitute.org/our-work/perennial-crops/kernza

Baseline Soil Analysis

pH	CEC	OM (%)	Salts (%)	P-O (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)
7.9	36.2	4.2	.4	25	427	998	5,350

Inter-seeding Cover Crop into Standing Corn in June

PRINCIPAL INVESTIGATOR

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Rice, Waseca, and Goodhue Counties

PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$24,400

STAFF CONTACT

Tori Hoeppner

KEYWORDS

corn, cover crops, inter-seeding

Inter-seeded cover crop.

PROJECT SUMMARY

In order for cover crops to establish and grow successfully in Minnesota, they need to be planted before corn and soybean harvest. This project explored inter-seeding cover crops into standing corn in June (V5 to V7 stage corn). Eight farmers in Rice, Goodhue, and Waseca Counties tested this practice on their farms. Each farm designed their own approach to the project (cover crop seed mix, planting equipment, etc.) and had unique field conditions. The results showed that, while weather, herbicide carryover and equipment availability are challenges to inter-seeding cover crops at this stage of corn growth, this method is viable and can be a successful and cost effective method for farmers to establish cover crops.

PROJECT DESCRIPTION

Cover crops can provide significant benefits to both the farming operation and the environment. According to the University of Minnesota, cover crops build organic matter, capture nitrogen, improve soil structure, reduce erosion, reduce soil compaction, increase water holding capacity of the soil, and can provide livestock forage. Environmental benefits include improving water quality by significantly reducing nitrogen leaching and reducing erosion.

In this project, eight farmers located in Rice, Waseca, and Goodhue Counties inter-seeded cover crops into standing corn early in the growing season. The Cannon River Watershed Partnership (CRWP) has a history of partnering with farmers in the Cannon River Watershed to experiment with introducing cover crops into

their operations. One of those farmers suggested this project to study methods of establishing cover crops early in the growing season to help improve stand viability and as a way to address the cost drawbacks of aerial seeding in August. Cost savings could make a significant difference in making cover crops more financially feasible for farmers.

Each farmer designed the specifics of his experiment to implement on their farm, choosing cover crop species to plant and inter-seeding method. Farmers employed a variety of cropping systems, including conventional tillage, strip tilling, and no-till.

2016 RESULTS

Seeding occurred between June 7 and June 24, 2016. Cover crop plots ranged in size from 28-85 acres with a variety of species and different seeding methods into fields cultivated with various tillage practices.

All eight farmers elected to broadcast seed the cover crops. One farmer experimented with broadcast seeding and drilled seeding in 2016 to compare seeding establishment and cover crop growth. The drill seeded cover crop resulted in a much healthier stand. Seed mix, planting methods, and cost/A are provided in Table 1.

We evaluated each field during the summer to determine the status of the cover crops. A large rain event occurred a few days after planting in some fields, washing seeds into pooled areas in a conventionally-farmed field. However, there appeared to be no soil erosion or seeds washed in a no-till field. One field had nearly no germination and growth, likely due to herbicide injury. The drill-seeded plot exhibited good germination and growth, and the rows of cover crop plants were discernible. Only Mark and Jim Purfeerst collected yield data. Mark Purfeerst's cover cropped field yielded 243.4 bu/A compared to 241.2 bu/A in his control plots. Jim Purfeerst's cover cropped field also yielded 243.4 bu/A compared to 241.2 bu/A in his control plots.

2017 RESULTS

In 2017, most farmers inter-seeded with a drill or seeder in June, then lightly incorporated seed into the soil. Three farmers were unable to inter-seed their cover crop in June. One aerial seeded a mix of cover crops into standing corn in July; one broadcast seeded and tilled in cereal rye after soybean harvest in late September; and one broadcast seeded cereal rye after corn harvest in November.

While farmers chose a variety of cover crop species to plant, cereal rye and annual ryegrass were the predominant species. Only two farmers planted mixes of multiple species each year. Seed mix, planting methods, and cost/A are provided in Table 1 on the following page.

Yield data was not collected in several fields during harvest. Jim Purfeerst recorded yield of 254.1 bu/A in his cover cropped field and 253.1 bu/A in his control field that was not cover cropped. John Bonde's yields in cover cropped and control fields were 212.1 bu/A and 214.1 bu/A, respectively. Lyle Dick recorded a yield of 233.5 bu/A in his cover crop trial, but no control data was provided to compare.

Table 2 on the following page shows total costs and cost/A for farmers who inter-seed cover crops into standing corn in both 2016 and 2017. Among this group, aerial seeding cost about $7.00/A more than the other planting methods.

Results of inter-seeding cover crops into standing corn in June ranged from very good for some farmers and failures for others. On successful farms, cover crop seeding was well established early in the growing season and continued to thrive after corn harvest. These farmers indicated they intend to continue to inter-seed cover crops at this stage of corn growth. We found inter-seeded annual ryegrass germinates quickly and maintains vigor for fall regrowth after corn harvest, while cereal rye germinates and then loses vigor under the corn canopy and is unable to regrow after corn harvest.

In total, seven fields were inter-seeded in both 2016 and 2017. In those two years combined, seven of those fields rated good with over 10 cover crop plants/ft^2 during late season observation, four rated poor to fair with 2-9 plants/ft^2, and three rated as failures with 0-1 plants/ft^2.

As a whole, this project showed that inter-seeding into standing corn is an effective method to establish cover crops in Minnesota. All farmers involved in this project intend to continue planting cover crops on their farms in the future. Furthermore, one participating farmer invested in special planting equipment to plant his own acres and began a custom planting business.

Table 1. Cover Crop Plot Review

	Species + rate as lb/A		Establishment method		Total cost $/A*	
Farmer Name	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Lyle Dicke	annual ryegrass @ 11 + red clover @ 2	annual ryegrass @ 14 + turnip @ 2 + radish @ 1	broadcast seeder	no till, aerial	27.2	57.14
Steve Lindstrom	annual rye @ 35	cereal rye @ 56	broadcast seeder	single pass turbo-till seeder	19.87	29.25
Coty Hyllengren	cereal rye @ 56	cereal rye @ 90	broadcast seeder	vertical tillage	21.5	28.18
Nathan Kuball	annual rye @ 15	annual ryegrass @ 18	broadcast seeder	air-seeded with light tillage	25	33
John Bonde	annual rye @ 15	annual ryegrass @ 15	broadcast seeder	air-seeded with light, strip tillage	25	30
Jeremiah Franz	cereal rye @ 60	annual ryegrass @ 11	broadcast spreader wagon	air-seeded with light tillage	21.21	26.5
Mark Purfeerst	rye, winter cereal @ 40 + radish @ 2 + turnip @ 0.5	did not plant in 2017	broadcast seeder	did not plant in 2017	22.35	did not plant in 2017
Brad Spinler	did not plant in 2016	annual ryegrass @ 15	did not plant in 2016	air-seeded with light strip and ridge tillage	did not plant in 2016	30
Jim Purfeerst	rye, winter cereal @ 70 + radish @ 5 + turnip @ 0.6	annual ryegrass @ 8.4 + clover @ 4.8 + radish @ 1.8	drilled and broadcast seeder	drilled into conventional tillage	29.94	45.8

*Cost of seed and planting.

Table 2. Cover Crop Cost Summary

June establishment only			
	Total Cost	**Total Acres**	**Cost/A**
Termination	$5,297.94	438.8	$12.07
Seed	$10,585.65	629.8	$16.81
Planting	$7,384.25	629.8	$11.72
Total	$23,267.84	1,698.4	$40.60

MANAGEMENT TIPS

1. Inter-seed as soon as you are able. Corn may grow rapidly or wet soils may persist and then the opportunity for inter-seeding is gone.
2. Drilled is the best method of establishment. It results in good seed to soil contact necessary for seeds to germinate quickly. Air seeding with direct row placement and mild incorporation of the cover crop seed also results in excellent establishment.
3. Plan the cover crop seeding as thoroughly as you plan the corn planting because it takes planning and management to be successful.
4. Start with a single species cover crop and add more species to the mix as you gain experience.

COOPERATORS

John Bonde, Nerstrand, MN

Lyle Dicke, Goodhue, MN

Jeremiah Franz, Northfield, MN

Coty Hyllengren, Cannon Falls, MN

Nathan Kuball, Waterville, MN

Steve Lindstrom, Red Wing, MN

Jim Purfeerst, Fairbault, MN

Mark Purfeerst, Faribault, MN

Brad Spinler, Morristown, MN

PROJECT LOCATION

Contact Alan Kraus at: 507-786-3913 for locations.

OTHER RESOURCES

Midwest Cover Crops Council. Midwest Cover Crops Field Guide Second Edition. Department of Agronomy, 915 West State St., West Lafayette, IN, (765) 494-4773.

Penn State Extension. 2015. Improve the success of inter-seeding cover crops in corn.
Available at **extension.psu.edu**

University of Minnesota Extension. 2016. Managing risk when using herbicides and cover crops in corn and soybean.
Available at **blog-crop-news.extension.umn.edu**

University of Wisconsin Extension Crop Weed Science. 2014. Herbicide rotation restrictions in forage and cover cropping Systems.
Available at **wcws.cals.wisc.edu**

University of Wisconsin Extension Integrated Pest and Crop Management. 2017. Herbicide considerations for cover crop establishment.
Available at
ipcm.wisc.edu/blog/2017/08/herbicide-considerations-for-cover-crop-establishment/

Evaluation of Winter Annual Small Grain Cover Crop for Forage Production

PRINCIPAL INVESTIGATOR

Daniel Ley
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Stearns County

PROJECT DURATION

2015 to 2018

AWARD AMOUNT

$25,000

STAFF CONTACT

Cassie Dahl

KEYWORDS

cover crops, no-till, soil health

Plot with winter wheat emerging 11/2/16.

PROJECT DESCRIPTION

For years I have been interested in building soil health. In 2006, my wife, Crystal, and I took over full ownership of our family's Century Farm. The farm consists of 321 acres, 50 dairy cows with about 16 replacements, and 33 young stock and calves. We grow corn, small grains, alfalfa, and soybeans. In 2008, we began incorporating cover crops into our already no-till rotation.

In 2013 and 2014, we hosted a cover crop research and demonstration project on our farm funded by Minnesota Corn Research and Promotion Council and the USDA Sustainable Agriculture Research and Education Program. We studied different ways of establishing cereal rye, and demonstrated the performance of a variety of fall planted cover crop mixes. The project was developed and managed by the Stearns County Soil and Water Conservation District (SWCD) and the University of Minnesota Extension. That project made me thirsty for more knowledge and answers. A recurring question that we heard from previous field day attendees was, "How do we make cover crops cost effective?" I partnered with Stearns County SWCD and others to continue to research cover crops. The purpose of this project is to evaluate the short-term economics of winter annual small grains planted in the fall as cover crops and harvested in the spring for silage before planting that year's crop. In addition, we want to achieve soil health benefits from these cover crops in a no-till system.

We hoped to show that cover crops can provide resource protection without short-term economic hardship. The following are soil and water resource issues that I believe the winter annual cover crops will address on my farm and the surrounding area.

- Nitrogen Immobilization - Much of my farm and the surrounding area are listed as having “very high” sensitivity to ground water pollution with bedrock within 50’ of the land surface. I am very interested in using winter annual cover crops with their fibrous root systems to help immobilize nitrogen.
- Increasing Soil Carbon - The winter annual grasses we planted have a high potential to increase soil carbon. The sandy soils in our area are typically low in soil organic matter and increased organic matter will improve nutrient cycling, increase water holding capacity, and reduce wind and water erosion.
- Erosion Control - The cover crops that we planted will be actively growing in the spring. This is important because that is when we get our most erosive wind and rain events. Having established plants will protect the soil during these periods. We use no-till methods for minimal soil disturbance and to protect the residue cover.

The project is right on track, I have planted nearly equal sized strips of cereal rye, winter triticale, winter wheat, and winter spelt in 2015 and 2016 after harvesting the production crop on a 12 acre field near my farmstead. In the spring of 2016 and 2017, I harvested the cover crops for silage at the appropriate time to maximize yield and quality. A check strip was included that did not have a cover crop. We monitored the yield and forage value of the cover crop silage in each strip and converted this data to monetary value. We also monitored the yield and forage quality of the following production crops to determine if the cover crop affected these factors based on the check strip values.

Our partner, Ag Resource Consulting (ARC), collected soil samples for standard soil series tests for phosphorus, potassium, soil organic matter, pH, as well as the Haney Soil Health Tool (Haney test) for both inorganic and organic nutrient availability, and solvita (CO2 burst) for our baseline data. We continued sampling throughout the project to monitor changes. We collected data on other soil factors, such as soil moisture, water infiltration rate, and compaction. A crop consultant monitored weed pressure in the production crop to see if the cover crop had any effect on weed species and abundance. The cover crops were planted after corn silage in 2015 and after soybeans in 2016.

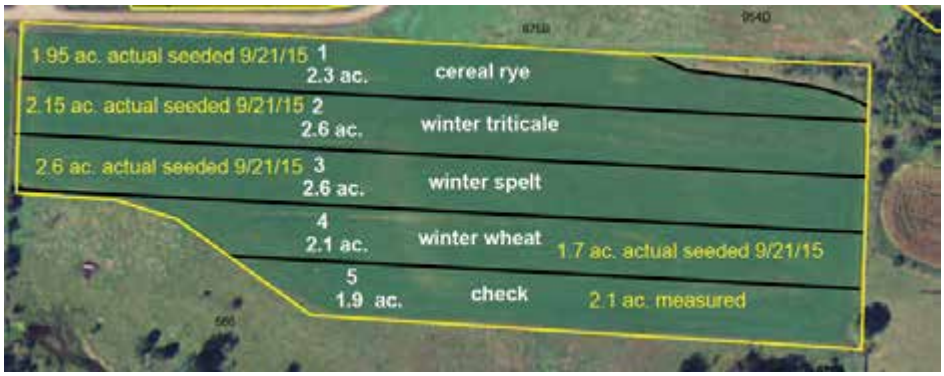
2015 RESULTS

This year soil samples were taken on June 4, 2015. Field monitoring for soil moisture was conducted throughout the growing season. Additional base data including soil compaction, water infiltration rate, and soil temperature was also collected. It will be interesting to see how the data changes as the project progresses. Corn silage was harvested on September 17, 2015 and manure was applied two days later at 5,895 gal/A. Spreader calibration was completed and cover crops were no-till seeded on September 21, 2015.

2016 RESULTS

We harvested cereal rye on May 18 and harvested winter triticale, spelt, and winter wheat on May 24. Soybeans were no-till planted on May 24 and harvested on September 23 followed by a manure application on September 29 at 5,895 gal/A. Cover crops were seeded on September 30. Soybean and cover crop yields were recorded (Table 1 on the following page). We did not see any negative effects of the cover crops on soybean yields.

Field monitoring for soil moisture was conducted periodically throughout the growing season. The main purpose of soil moisture testing was to determine the effect that our cover crops may have on the production crops. Some say that dry conditions caused by cover crops can delay crop emergence and slow early growth. We decided to compare soil moisture in the cover crop strips to the check plot. Our focus was on moisture at production crop planting time and whether or not a moisture deficit recovered during the growing season.



Plot layout with cover crop locations.

We did see somewhat dryer conditions in the cover crop strips versus the check in 2016. This dryer condition seemed to continue into late August or early September. However, we cannot say that it affected yield significantly because all the strips had higher soybean yields than the check.

The economic analysis showed that the cereal rye had a net gain of $7.07/A specific to forage. All other cover crops showed a net loss. The real advantage we saw with the cereal rye was the good yield and the low cost of seed.

Table 1. Soybean and cover crop yields and quality for 2016.

Cover crop	Soybean yield after cover crop (bu/A)	Cover crop wet yield (ton/A)	Cover crop relative feed value	Cover crop relative feed quality	Dry matter yield (lb/A)
Cereal Rye	44. 6	6.0	109	178	4,112
Winter Triticale	41.3	4.2	107	159	3,014
Spelt	46.0	1.8	121	167	1,352
Winter Wheat	35.6	2.9	107	176	2,692
Check	42.8	NA	NA	NA	NA

2017 RESULTS

We harvested the cover crops on May 25. Silage corn was planted on May 26 and harvested on October 2. Corn silage and cover crop yields were recorded (Table 2). Cover crop yields were affected by winterkill except for the cereal rye. As we observed last year with soybeans, there was no significant impact of the cover crops on corn silage yield. In 2017, the soil moisture seemed to parallel the moisture in the check plot much closer. Soil moisture did not seem to vary between the cover crop and the check plots because everything is planted no-till and residue cover was present.

The economic analysis was completed by Dan Martens, U of M Extension Education, Ag Production Systems.

Table 2. Corn silage and cover crop yields and quality for 2017

Cover crop	Corn silage wet yield after cover crop (tons/A)	Cover crop wet yield (ton/A)	Cover crop relative feed value	Cover crop relative feed quality	Dry matter yield (lb/A)
Cereal Rye	13.1	6.1	96	132	3,596
Winter Triticale	14.5	0.54	124	163	365
Spelt	16.0	0.07	129	185	36
Winter Wheat	13.6	1.4	118	167	1,046
Check (No Cover Crop)	12.8	NA	NA	NA	NA

This year cereal rye again had the best economic return compared to the other cover crops though the net return to forage was a little on the negative side this year, mainly due to some winterkill and less dry matter harvested. The rest of the cover crops were way into the negative return. The net returns specific for the cover crops were: rye, -$7.51; triticale, -$110.12; spelt, -$128.62; and wheat, -$68.83. We didn't have a good way to include the value of erosion control, carbon sequestration, and nitrogen immobilization in the economic analyses.

After two years of data collection, we'd hoped to have data to support the positive effects that cover crops have on nitrogen immobilization, increasing carbon sequestration, and controlling erosion. Unfortunately, two years and one replication of the cover crop treatments did not provide enough data to draw conclusions about differences between the treatment plots and the check for soil moisture, infiltration rates, compaction, soil organic matter levels, soil temperatures, or other standard soil tests. The Haney Soil Health Test did indicate that there was less decline in soil health scores in the cover crop plots than in the check. It appears that cover crops might be stabilizing overall soil health.

Cereal rye plot on field day, 5/16/2017.

From this project, it looks clear that cereal rye is the best choice for my farm. It had the economic advantage over the other crops – it yielded well, had more winterkill tolerance, and the seed was less expensive. I will continue to plant cover crops on all my acres.

Cover crop performance can vary significantly year to year and site to site. Farmers should experiment to determine what's best for them.

MANAGEMENT TIPS

1. Keep an open mind when working with cover crops and no-till. I firmly believe the largest obstacle is having the right mindset.
2. Start out small and be ready to adjust and improve until you find what works for you on your farm. The key is just getting started!
3. Be prepared to change your herbicide program. Your weed make up will change as you change your practices and add the cover crop to your rotation.
4. Sometimes you have to look past the hard numbers. Not everything can have a dollar amount attached to it (like erosion control). Economic return is based on your farm operation and how cover crops can add value.
5. Talk to your neighbors, consultants, and feed guys to find out what others are doing; that way you can build off each other's ideas. Another way to be involved is to attend local field days.

COOPERATORS

Stearns County SWCD, Waite Park, MN

Ag Resource Consulting, Inc., Albany, MN

John Dockendorf, Greenwald Elevator, Greenwald, MN

Dan Martens, University of Minnesota Extension, Foley, MN

PROJECT LOCATION

The nearest town is Roscoe, MN. From the intersection of Cty. Rd. 10 and 1st St. (Cty. Rd. 114) in Roscoe head east on 1st St. for 1 mile, turn left onto 246th Ave. for .7 miles. Turn right onto 222nd St. for .7 miles, the field is located at the end of the road on the south side of the mailbox.

OTHER RESOURCES

Midwest Cover Crop Council (MCCC)
www.mccc.msu.edu

No-till Farmer Magazine **www.no-tillfarmer.com**

Stearns County SWCD **www.stearnscountyswcd.net**

Sub-surface Irrigation for Field Crop Profitability and Water and Fertilizer Efficiency

PRINCIPAL INVESTIGATOR

Russell V. Martie
2998 150th St. NW
Monticello, MN 55362
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Wright County

PROJECT DURATION

2015 to 2017

AWARD AMOUNT

$11,937

STAFF CONTACT

Tori Hoeppner

KEYWORDS

irrigation, soil moisture, water efficiency

PROJECT SUMMARY

This project will compare three types of irrigation: 1) Subsurface Drip Irrigation (SDI), which was installed in an existing field in 2014, 2) a non-irrigated field, and 3) a center-pivot field. The objective of this project is to improve yields and profitability while utilizing irrigation water more efficiently and decreasing energy inputs.

PROJECT DESCRIPTION

Russ has been farming for 42 years and grows several crops including corn, hay, and teff grass on about 400 acres. He is enrolled in the Natural Resources Conservation Service (NRCS) Conservation Stewardship Program (CSP), which includes the following activities: multi-species native perennials for biomass and wildlife habitat, wildlife friendly fencing, energy enhancement, water quality enhancement, and soil quality enhancement.

The idea for this project came from reading about SDI projects in Nebraska and other Great Plains states. Russ understands that rain is not guaranteed and knows he could do a better job with controlling the ground water he uses for irrigation. Russ's farm has sandy soil, making it difficult to use water efficiently. Water efficiency is important to Russ in terms of his long-term economic goals and his desire to make his farm more sustainable for the next generation. His goal is to grow 200 bu/A corn while being more efficient with water and electric use and ultimately, provide area farmers with a data set to help them improve resource conservation, increase profitability, and lessen ground water impact.

Buried irrigation tape.

The following pieces of data are collected for this project:

- water used;
- electricity used;
- soil moisture (3 probes per field that are buried at 6", 12", and 18");
- yield rates per field;
- air temperature;
- rainfall per field (rain gauge);
- planting date/rate, and;
- fertilizer rate (same for all 3 fields).

This project runs from April through October. In April, the soil moisture sensors are installed when the soil temperature is suitable, which is around 45°F. In May, sensors in each field are checked for water balance prior to planting. This data is entered into the "ET

Checkbook" to track daily information such as rainfall, irrigation, and air temperature. This information gives other producers an idea of soil moisture levels and water needs based on the stage of their crop. In October, yield rates are collected, final water and electrical use rates are documented, and fields begin to be compared.

2015 RESULTS

Russell believes the SDI style of irrigation was the most efficient in this past growing season. With SDI, the moisture level of the soil was better controlled so that it was saturated but not dry. Where SDI was used, the spikes in soil moisture levels over the season did not vary as greatly as the non-irrigated and center pivot systems.

The center pivot system created some soil moisture consistency, but was not as consistent as the SDI system. When a center pivot system was used between rainfalls, this field consistently had higher levels of soil moisture than the non-irrigated field. The moisture was substantially more variable in the center pivot system than in the SDI system, which leads Russell to believe it is not as effective as the SDI system.

The non-irrigated field had the lowest levels of soil moisture overall and the most variability in soil moisture levels, similar to the field with the center pivot system. When the last sample was taken, the non-irrigated field had higher levels of moisture at all depths than the center pivot system and similar levels to the SDI system. The SDI system had a higher level of moisture 12" below the soil surface, while the non-irrigated field had a higher level of moisture at 6". This means that the SDI system penetrates water into the soil more efficiently, which is important to consider at different stages in the crop's lifecycle.

2016 RESULTS

Table 1.

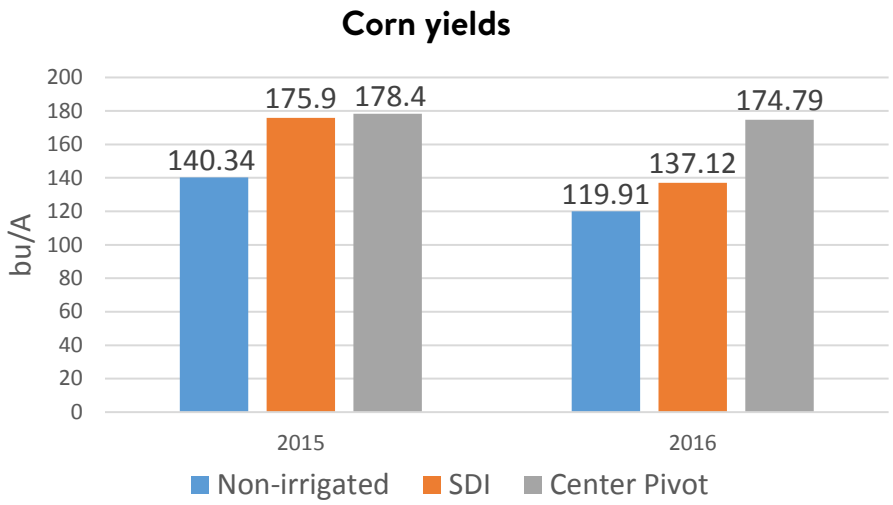


Table 2.

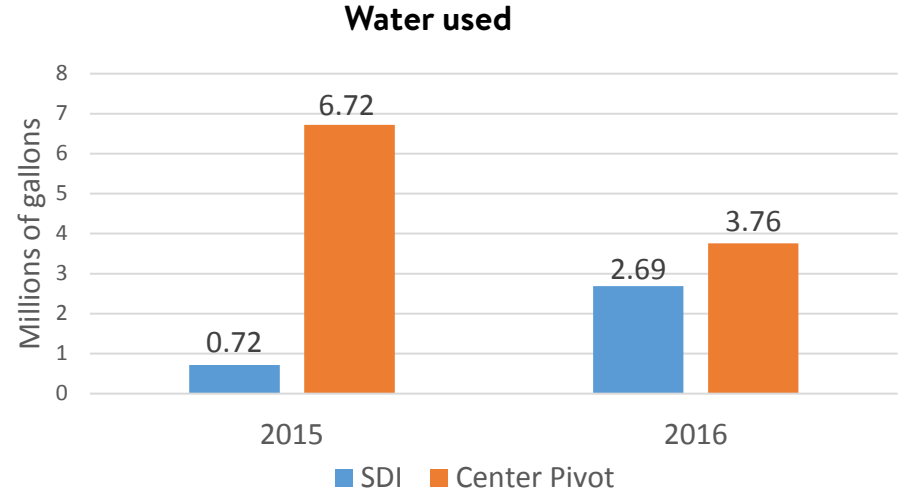
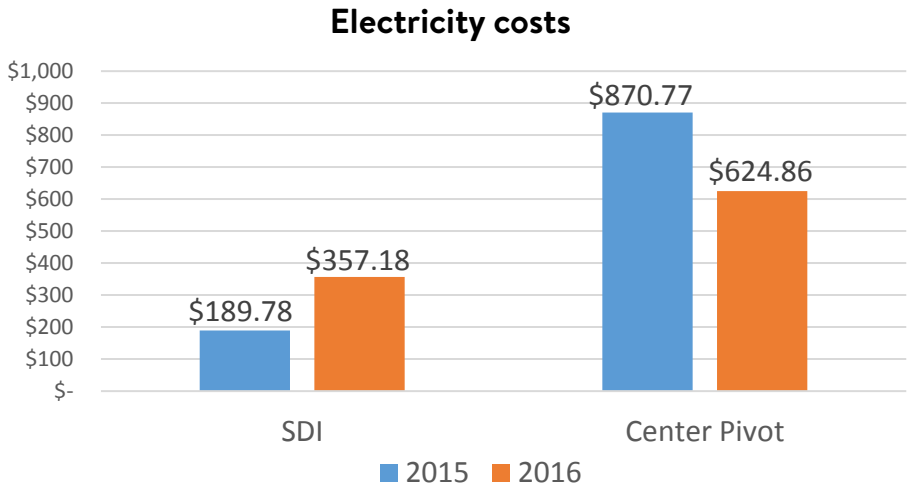


Table 3.



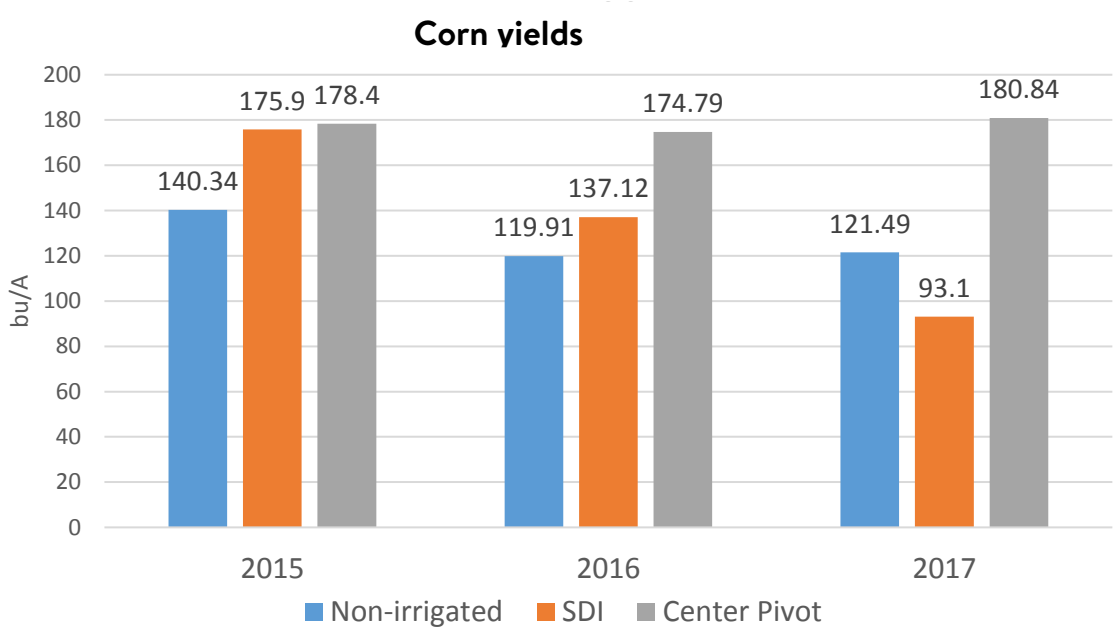
Next year, Russell will check the SDI system right away to confirm it is working correctly and will address any issues as soon as possible. In addition, he will update the ET Checkbook daily and check soil moisture sensors each month to confirm data recorded in the ET Checkbook. In order to maximize yield, he will need to have almost live soil conditions (balancing rain events and needed irrigation). Lastly, he will monitor plant development to ensure his crops receive the correct amount of water for their growth stage.

2017 RESULTS

There were a few items that affected project results. Once again, Russell's well for the SDI system had issues, so he had to hire a new well company, Traut Wells out of St. Cloud, to find the problem and fix it. They found the screen was not fine enough, and sand would eventually reduce the flow, thus an inconsistent amount of water was going through the system. This happened during the stretch of dry weather in June and in the end, Russell took a yield loss.

The weather in 2017 was interesting to say the least. The beginning of spring was a little dry, but they started to get rain and eventually got everything planted. For most of the summer they received rain, aside from 2 weeks in June. The real story was in the temperature; August was an unusually cool month, it never reached 90°F once. Additionally, September and the beginning of October were very wet, delaying harvest.

Table 4.



The data Russell collected gave him a better understanding of how to efficiently use water so it directly waters the crop without evaporating, allowing him to reduce his ground water use and decrease the impact on his aquifer. Furthermore, Russell lives near the small town of Hasty that relies on induvial wells for their drinking water. The SDI project will conserve more of their water supply than a normal center pivot.

Russell found the upfront costs for the SDI system to be much lower compared to the Center Pivot. However, over time he'll have more insight into maintenance costs. Because farming is dependent on many variables (weather, commodity prices, fertilizer and fuel prices), maintaining some consistency with water and electrical use through the SDI system would increase income overall.

Note: Sadly, Sharon Faye Martie, Russell's wife, passed away unexpectedly in January so they were unable to provide data for water and electrical use for the 2017 growing season.

MANAGEMENT TIPS

1. Have background information (collect data – water/electrical use) prior to investing so you understand where SDI can help.
2. Make sure flow of well stays constant, especially in sandy soils.
3. Install soil sensors as early as you can to get good base moisture information. This will help set-up the year and understand what your newly planted field will need if it doesn't rain.
4. If you plan to incorporate fertilizer through your SDI system, start early with your agronomist as there is a learning curve.

COOPERATORS

Scott Wicklund, MIDC Enterprises, Roseville, MN

Johan Oostenbrink, Netafim Irrigation, Fresno, CA

Rod Greder, U of M-Ext Educator, Buffalo, MN

Josh Stamper, U of M Irrigation Specialist, St. Paul, MN

Dan Nadeau, Wright SWCD, Buffalo, MN

Julie Reberg & Katie Evans, Wright NRCS, Buffalo, MN

PROJECT LOCATION

From Minneapolis/St. Paul, go west on I-94. Exit onto Cty. Rd. 8. Turn right onto Cty. Rd. 8. Take the second right onto 150th St. Site is 1 mile down on the left.

Impact of Two Tillage Types on Yield, Economic Profitability, and Soil Health in Polk County Minnesota

PRINCIPAL INVESTIGATOR

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Minnesota Wheat Research and Promotion Council
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Polk County

PROJECT DURATION

2017 to 2020

AWARD AMOUNT

$17,536

STAFF CONTACT

Cassie Dahl

KEYWORDS

conservation tillage, hard red spring wheat, soil health, soybeans, vertical tillage

Vertical Tillage Tool

PROJECT SUMMARY

For the past 100 years, tillage in Northwest Minnesota (NW MN) has involved turning over the soil to create a black seedbed. This research will look at the difference between the conservation tillage method called vertical tillage (VT) and the more conventional chisel plow and cultivation as the primary fall tillage systems. The two tillage systems in a soybean and hard red spring wheat rotation will be compared for soil temperature, soil moisture, compaction, yield, and protein or oil content.

PROJECT DESCRIPTION

The predominant tillage system in NW MN is turning over the soil using a chisel plow and cultivation to create a black seedbed. Conservation tillage systems such as VT reduce compaction, leave more residue over the winter, reduce erosion, and retain more moisture in the soil profile. However, because NW MN has a shorter growing season, fewer frost free periods, and cooler springs and falls, farmers are hesitant to adopt conservation tillage practices which can cause cooler soil conditions in the spring.

Vertical tillage is an option that is not as intensive as strip or no-till yet can still reduce erosion and improve soil health. It is

a good practice to cut crop residue to manageable sizes, lightly incorporate residue, and break up any shallow compaction layers. A VT implement is pulled behind a tractor. It consists of straight, fluted discs set about 10-12" apart. The discs are followed by a section of harrows then a set of rolling baskets. The implement cuts the residue, spreads it across the width of the machine then the rolling baskets crimp and cover the residue. The tool works from 1-5" below the soil, resulting in little soil disturbance.

Our two objectives for this research are:

1. Determine if VT for a soybean/hard red spring wheat rotation is economically viable compared with the conventional tillage practice in the region. We will measure tractor passes (fuel and time), yield, and protein/oil.
2. Quantify soil health factors for the two tillage systems including soil temperature, moisture, and compaction, as well as visible signs of erosion and water runoff.

This research is being conducted on 155 acres at Tim Dufault's farm near Gentilly, MN on the beach ridge of the Red River Valley. Wheat was planted and harvested in 2016. The field was divided into four plots. We worked the wheat stubble in two plots with a VT implement in September and October 2016. The other two plots were worked with a chisel plow twice in September and again in October. All four plots were cultivated and then seeded with soybeans in Spring 2017. Data on crop yield, grain test weight and percent moisture, soil temperature and moisture in the spring, and plant population were collected.

RESULTS

The first year's soybean yield results showed little difference between the VT and conventional tillage plots (Table 1). Stand counts taken at the V3 growth stage showed an average of 10,000 less plants per acre in the VT plots. Soil temperature was an average of 0.5°F cooler in the VT plots than in the conventional tillage plots. There were only slight differences in soil moisture between the two treatments (Table 2). The average grain test weights were 0.366 lb/bu higher in the VT plots and the average grain %.

Table 1. Soybean yield in vertical tillage and conventional tillage plots, 2017.

Tillage practice	Yield* (bu/A)
Vertical tillage	42.34
Chisel plow	43.29

*Average of two plots.

Table 2. Soil temperature and moisture in vertical tillage and conventional tillage plots, 2017

	Temperature (°F)*		Moisture (m3/m3)*	
Date	Chisel plow	Vertical tillage	Chisel low	Vertical tillage
4/11/17	34.4	34.6		
5/4/17	47.0	46.1	0.391	0.395
5/10/17	47.8	47.6	0.422	0.444
5/17/17	51.1	50.0	0.356	0.353
Average	45.1	44.6	0.390	0.400

*Average of two plots.

VT after planting 2017.

Chisel post plant 2017.

Anecdotal observations comparing the two treatments included less mud on the roads and less visual evidence of soil erosion from the VT plots. Tim believes that VT could be the better option for his farm even though he hasn't seen many differences between the two tillage systems. He is starting to feel that VT will come out with the higher return on investment.

Following soybean harvest, the two VT plots were vertical tilled and the conventional plots were chisel plowed. Urea was applied to all plots and cultivated to incorporate.

MANAGEMENT TIP

Changing equipment takes time and money, but VT will use less fuel and time, as well as reduce soil erosion in the long run.

COOPERATORS

Lauren Proulx, Agronomist, MN Wheat Research and Promotion Council, Red Lake Falls MN

Tim Dufault, Farmer, Crookston MN

Melissa Geiszler, Agronomist, MN Wheat Research and Promotion Council, Red Lake Falls, MN

PROJECT LOCATION

From Crookston MN go east on Cty. Rd. 11 for 8 miles, then north 3.5 miles. The farm is in the NW quarter of section 3, Gentilly Township, Polk County.

Economic Feasibility of Spray Foam Insulation in a Hog Finishing Barn

PRINCIPAL INVESTIGATORS

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PROJECT DURATION

2017 to 2019

AWARD AMOUNT

$7,909

STAFF CONTACT

Kevin Hennessy

KEYWORDS

energy, insulation, hog finishing barn, spray foam

Barn construction during summer, 2017.

PROJECT SUMMARY

When we, Vande Ag Enterprises, decided to build a 4,800 head tunnel ventilated custom hog finishing barn, we wanted to incorporate the latest technology and add features that would make feeding pigs and the barn itself as efficient as possible. We looked at this building as a long-term way to transition our farms back into livestock production after many years of being out due to facility obsolescence and weak prices. As part of this determination for maximum efficiency, we started looking at ways to minimize the energy required to operate the barn. We knew propane usage would be a large portion of the energy and could potentially be one of our highest operating costs, especially during times of propane shortages and when the pigs are small and unable to generate enough body heat to keep the barn at a stable temperature. This is where we got the idea to insulate the barn with closed cell spray foam insulation instead of the traditional batt style insulation that is typically used in hog barns. We compared costs between the two types and naturally the spray foam insulation was substantially

higher priced. From this, the question arose, "with the potential propane savings, will the added cost of the spray foam insulation pay for itself over the life of the barn?" We talked to barn contractors and searched the internet for research already done by other producers. We were unable to find much of anything so we decided to go for it and insulate with spray foam. We thought other hog producers and contractors may have some of the same questions we did, so we decided to make a project out of it and share our results.

PROJECT DESCRIPTION

Vande Ag Enterprises consists of three young farmers from two families who grew up on livestock and crop production farms. Both farm families decided to abandon livestock production about 15 years ago because of low prices and facilities that required too much labor. Currently, the members of Vande Ag came back to their family farms after completing school and looked for ways to make their operations sustainable and diversified. Having grown up with livestock, and attractive rates for custom finishing hogs, the idea for a large hog finishing barn continually resurfaced. Also, all three members of the company currently have part-time off the farm jobs and would like to make agricultural production their sole source of income.

Construction of the 4,800 head facility began in early summer 2017 and was completed in late fall 2017.

This project compares the cost effectiveness of different materials used to insulate hog finishing barns. We chose to install closed cell spray foam insulation rather than the traditional batt style insulation. We will compare the propane usage of our spray foam insulated barn with two others similar to it but insulated with batt style insulation. The comparison barns are 2,400 head barns where ours is two 2,400 head barns put together, so the square footage of the actual pig space can easily be used as a comparison. The office and load out space is also the same. The ceiling and roof heights are the same. There will be very similar sized pigs in all barns during the same time period. This is important for accuracy of the comparison since pigs give off a lot of body heat and, as they mature, less supplemental heat is needed to maintain the required temperature. Also, all the barns are using the same temperature curve, meaning that as the pigs get bigger and provide more body heat, the target temperature in the barn decreases. The barns are all located within a ten mile radius of each other, so it is presumed the ambient outside air temperature will be the same at each of the sites. Wind breaks are another factor to consider that could affect the results of this test. Each of the barns being tested is in the open with minimal trees or cover from the weather elements. Results of this will be calculated annually for three years to obtain as accurate of data as possible. The final results will be divided by the added cost of the spray foam and multiplied over the expected useful life of the barn which we hope will be at least 40 years. Two questions to be answered are (a) is spray foam insulation a better product based on how it improves savings on propane, and (b) how many years will it take to pay back the investment with these savings.

The stud walls as well as the concrete stem walls were insulated with spray foam insulation. The batt insulation has an R-value of 19, while the spray foam insulation has an R-value of 21 so it is fairly obvious the spray foam will insulate better, but the question remains, "will it yield enough propane savings to recoup the added cost?" The cost to insulate the barn with batt insulation is $6,076 and the cost to insulate the barn with spray foam is $12,023.

Besides the potential energy cost savings, other benefits of an efficient barn include a smaller environmental footprint from fewer nonrenewable resources being consumed, and a contribution to a more positive overall outlook on the agriculture industry by showing the public our eco-friendly efforts. Some other benefits of spray foam insulation are that it has better longevity in that it won't settle over time or absorb moisture. It also creates an airtight seal over the building and provides superior coverage over batt style insulation. These factors also contribute to the performance of the insulation. Insulation is extremely important in the winter months, but it is also beneficial in the summer. Insulation keeps the hot steel exterior of the building from radiating through to the inside air keeping the temperature lower.

2017 RESULTS

In the summer of 2017, the finishing barn was built and was completed in late fall 2017.

We started recording propane use the day the pigs arrived on November 29, 2017. So far, the barn is using very little propane considering the

pigs are small and winter has set in. We will record propane usage annually for three years in our barn as well as in the test barns. So far, we haven't had pigs in the barn long enough to gather any data to establish trends.

MANAGEMENT TIPS

1. We learned that by spray foaming the above ground concrete stem walls, the walls do not transfer the outside temperature to the inside. For example, on a very cold, winter day, one would expect the temperature of the inside of the concrete wall to be very cold to the touch because of concrete's heat transfer properties. Because of the spray foam on the outside, this is not the case. The inside of the wall nearly matches the inside air temperature when felt. This strengthened our confidence in our insulation choice.
2. The spray foam can continue expanding for a period of time after it is applied so caution should be used when insulating around window and door openings and also a day or more should be allowed between foam applications and covering the foam with plywood so warping doesn't occur.
3. Hog producers need to consider the expected useful life of today's barns. Most of the materials used in barn construction are aluminum, stainless steel, and plastic vs. mostly steel in older barns, which would rust quickly. The contractors and barn equipment suppliers we talked to guess barns built today should last in excess of 40 years, as compared to 25 to 30 years for barns built years ago. This gives an extended period of time for extra investments such as spray foam insulation and the latest technology to pay for themselves. This was a major driving factor in many of our decisions.

Open walls during construction show spray foam insulation after installation.

COOPERATOR

Mike Boerboom, Boerboom Ag Resources, Marshall, MN

PROJECT LOCATION

From Marshall, MN: Go south on Hwy. 59, 1 mile to Cty. Rd. 6, turn east (left) and go 3 miles to Cty. Rd. 9, turn south (right), and go 1.5 miles. The barn is on the west side of the road.

Testing Different Training Systems and Varieties to Improve the Profitability of Gooseberries

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2017 to 2019

AWARD AMOUNT

$6,728

STAFF CONTACT

Cassie Dahl

KEYWORDS

consumer preferences, fruit, gooseberries, trellis systems, varieties

Gooseberry plants on a single post (left) and a double post (right) trellis.

PROJECT SUMMARY

This project is testing eight varieties of gooseberries on three different training systems to determine what works best in Central Minnesota. We will find out which varieties are most disease resistant, most vigorous, easiest to harvest, and most acceptable to consumers.

PROJECT DESCRIPTION

York Farms is a certified organic farm started in 2010 as a vegetable CSA, but now we've shifted to organic fruit production. We have apples, pie cherries, table grapes, apricots, seaberries, strawberries, raspberries, and currants which we market through restaurants and as a fruit share CSA. We planted Hinnomaki Red and Pixwell gooseberries in 2014.

Of all the cold hardy fruits we have tried, we believe gooseberries show the greatest potential. The fruit is nutritious with a unique flavor and is in demand. There are many varieties, but Pixwell the only variety most people know, has a bad reputation because it develops a bitter flavor when ripe. Varieties more acceptable to consumers are needed.

Gooseberries are very difficult to harvest and susceptible to leaf diseases. Fruit is produced very close to thorns on the canes. Different trellis and pruning systems could make picking easier.

This project will compare eight varieties of gooseberries on three different trellis systems. We will collect information on flavor, ease of picking, yield, leaf disease resistance, fruit size, and plant vigor (number of canes and cane heights). In the third year of the project, we will assess consumer variety preference.

2017 RESULTS

We planted 24 plants each of eight varieties this spring (Table 1). We chose the varieties to include both large, dessert quality gooseberries for fresh eating and smaller, more intensely flavored varieties that are best used in baking and cooking.

Table 1. Gooseberry varieties

Gooseberry variety	Berry color
Black Velvet	Red
Captivator	Red
Hinnomaki Red	Red
Hinnomaki Yellow	Yellow
Invicta	Green
Jahn's Prairie	Red
Tixia	Red
Jeanne	Red

Canes were planted 3' apart on rows that are 8' apart on center on April 8. Cane size and root systems varied greatly among the varieties which will likely affect short-term growth. Tixia and Jahn's Prairie were little more than sticks. After planting we spread a layer of wood chips, added drip irrigation then covered the row with 4' wide landscape cloth. While this was extra labor and cost, the mulch and fabric will help with water retention and weed control. A clover cover crop was planted between the rows.

Two different trellis systems were installed mid-summer, one row of each type with 64 plants/row – eight plants of each variety. Discarded 8' metal highway posts for wire attachment were pounded 3' into the ground. One row will be trained to a single wire that runs down the center of the row at 12" and 24". Another row will be trained to two wires at 14" set 1' apart on each side of the plants. The third system, to be installed in Spring 2018, is an intensive cordon system used in Europe. Only one cane is allowed to grow and is headed the first season. Two branches that run parallel to the ground are formed. This delays production one year but has been shown to make picking easier.

Nearly all the plants survived transplanting and most varieties grew quite well. Black Velvet did best, growing 12" or more. All the other varieties grew 3 – 6". Hinnomaki Red produced some berries. We expect to have a crop in 2018 and will begin data collection.

MANAGEMENT TIPS

1. Using wood chips covered with landscape cloth help with water retention and weed management.
2. Using a ripper (Yoeman plow) to create 16" deep furrows reduces shovel work for planting.

COOPERATOR

Thaddeus McCamant, Northland Community & Technical College, Detroit Lakes, MN

PROJECT LOCATION

From downtown Hutchinson, take Hwy. 15 (Main St.) south to the roundabout then go right (west) on Airport Rd./CR115. In a mile, this becomes York Rd. Go another 1.5 miles and the farm is on the left.

Using Juneberries as a Cold Hardy Rootstock for Minnesota Pears

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$14,120

STAFF CONTACT

Cassie Dahl

KEYWORDS

pear, juneberry, rootstock

Trees ready to be planted.

PROJECT SUMMARY

We are testing the viability of using juneberry plants as a rootstock for Minnesota pear varieties. Juneberries have the advantage of being exceptionally winter hardy, and there is some evidence that juneberry rootstocks will make the pear trees shorter and produce blossoms within 2 years after planting. We grafted seven pear varieties onto two species of juneberry rootstocks and two pear rootstocks. At the end of the summer, over half of the pears grafted onto juneberries survived, which was slightly lower than the success rate of pears grafted onto pear rootstocks.

PROJECT DESCRIPTION

There are multiple varieties of high quality pears that are hardy enough to grow in Minnesota. Pears are marginally economical here due to a very long period between planting the tree and harvesting the first crop, and the shape of the trees. Pears naturally have an upright growth habit, but many of the hardy Minnesota varieties like Summercrisp have a columnar form similar to Lombardy poplar, which makes harvesting difficult. Upright growths are managed in other crops with dwarfing rootstocks, but the primary dwarfing rootstock for pears is quince, which is not hardy for Minnesota.

A researcher in Oregon found that juneberries or serviceberries (*Amelanchier spp.*) can be used as a dwarfing rootstock for pears,

giving all the benefits of a dwarfing rootstock: small trees, the potential for high density plantings, and blossoming within 2 years after planting.

We wanted to determine if juneberries would be a compatible rootstock for Minnesota hardy pear varieties. We chose two species of native juneberries: the western serviceberry or saskatoon (*Amelanchier alnifolia*) and the apple serviceberry (*A. x grandifolia*). The saskatoon plants were purchased from Lawyer's Nursery in Plains, Montana. The *A. alnifolia* were seedlings of wild plants native to Montana and were highly variable in size, while the *A. x grandifolia* plants were all about ½" in diameter. For comparison, we used two pear rootstocks: Old Home x Farmingdale (OH x F) 87 and OH x F 97 that were purchased from Cummins Nursery in Geneva, New York. The pear rootstocks were relatively uniform in size.

We chose seven Minnesota hardy pear varieties (rated Zone 4 or hardier): Summercrisp, Harrow Sweet, Clara Frijs, HoneySweet, Ewart, Luscious, and Gourmet. We grafted between 14 and 21 plants for each rootstock/scion combination.

The grafted trees were planted in 3 gal pots with potting soil for the summer at Stone Creek Farm near Taylor's Falls, and the trees were hand watered over the summer. In early November, all trees were planted in fields at the three participating farms. The three farms are Central Lakes Agriculture and Energy Center near Staples, York Farm near Hutchinson, and Stone Creek Farm near Taylor's Falls. The trees at York Farm and Stone Creek Farm were planted as high density orchards, and the trees will be trained to trellises (Photo 2).

2016 RESULTS

All pear varieties successfully grafted onto juneberry rootstocks. Conditions were difficult during grafting, which may have lowered the success rate. About a third of trees that didn't survive died after grafted scions started growing. The plants died at the root level, which indicates poor survival was not due to graft compatibility.

The biggest differences in graft compatibility were not between the saskatoon and pear rootstocks, but between the different varieties of pears. Survival rates in Table 1 include both grafts that did not take and trees that died after grafting, and survival rates varied from 39% for the Harrow Sweet to 88% for Gourmet.

Table 1. Survival rates for each of the different scion/rootstock combinations at the end of the growing season.

	OHxF 87	OHxF 97	*A. alnifolia*	*A. x grandifolia*
Summercrisp	81%	52%	57%	67%
Harrow Sweet	38%	43%	43%	33%
HoneySweet	52%	67%	43%	67%
Clara Frijs	57%	90%	57%	44%
Ewart	95%	71%	64%	56%
Luscious	86%	48%	50%	44%
Gourmet	100%	100%	100%	50%
Average	73%	67%	59%	52%

Planted trees with trellis system.

After grafting, the trees grew rapidly and most were between 2' and 3' tall by the end of the growing season. The growth rates varied a great deal between varieties, but not between rootstocks. The different growth rates appeared to be tied to leaf diseases, especially the disease pear scab, which killed about a third of the leaves on the most susceptible varieties. Clara Frijs, HoneySweet, and Gourmet had almost no scab and good growth. Summercrisp, Harrow Sweet, and Lucious had pear scab and lower growth rates. Ewart had pear scab, but good growth.

The slightly lower survival rates of the juneberry rootstocks compared to the Old Home x Farmingdale rootstocks may not have any bearing on the compatibility of juneberry rootstocks. We used seedling A. alnifolia rootstocks, and some rootstocks were nearly ¾" in diameter while others were close to ¼" in diameter. Second, conditions were poor during grafting, which may have lowered the success rates.

During transplanting in the fall, we did notice a difference in root systems between the rootstocks. The two pear rootstocks and A. x grandifolia all had fibrous root systems, and nearly all pots were root bound. The roots of the A. alnifolia or saskatoon rootstocks did not fill the 3 gal pots. The different root growth on saskatoon plants could be due either to slower root growth or because the plant has a different type of root system, such as a taproot rather than a fibrous root system.

2017 RESULTS

Staples was the coldest site and had the most winter injury with 61% of the trees dying during the winter of 2016-17 (Table 2). In spite of reaching a temperature of -30°F, the site near Hutchinson had the highest survival rate, with over 80% of the trees surviving. At Taylor's Falls, 26% of the trees died. The winter injury in Staples was not surprising since the trees were planted in a site that was exposed to wind and the site was exposed to three cold snaps. High rainfall at Taylor's Falls in November, April, and May could have lowered the survival rate at that site.

Table 2. Survival rates and coldest temperatures of all pears at each site.

Site	Total trees planted	Percent of trees that died	Lowest temperature and date temperature occurred
Staples	56	61%	-35°F, Dec. 18, Jan 6, Jan 13
Taylor's Falls	142	26%	-25°F, Dec. 18
Hutchinson	127	19%	-30°F, Dec. 18

There were large differences in survival rates: between cultivars, between rootstocks, and between the different variety x rootstock combinations. Gourmet had the highest survival rate of the seven cultivars, with Gourmet on Old Home x Farmingdale 87 having a 100% survival rate at all sites (Table 3). In addition to having a high survival rate, the Gourmet trees on OH x F 87 were vigorous and the only trees that grew substantially at the Staples site. The cultivar with the lowest survival rate was Luscious at 61%, but the low survival rate was because only 30% and 40% of the trees grafted onto the two juneberry rootstocks survived. Luscious planted onto OH x F 87 had a survival rate of 83%. HoneySweet appears to be the most suitable for juneberry rootstocks, with a survival rate of 100% when grafted onto A. alnifolia. The lowest survival rate of any rootstock x cultivar combination was Ewart on A. alnifolia, with a survival rate of 13%.

Survival rates of pears grafted to both pear rootstocks were higher than those grafted onto either juneberry species. The survival rate on both juneberry rootstocks was slightly over 50%, whereas the survival rates of trees grafted onto pear rootstocks was over 75%. In addition to having a higher survival rate, there were more trees after the first summer on OH x F 87. When the trees were planted in the field in November 2017, there were 109 trees on OH x F 87, 84 trees on OH x F 97, 76 trees on A. x grandiflora, and 58 trees on A. alnifolia.

Table 3. Survival rate of each cultivar and each cultivar x rootstock combination at all three test sites.

	All rootstocks			*A. alnifolia*	*A.x grandiflora*	OH x F 87	OH x F 97
	Alive	Original	% Alive	Percent of trees that survived 1 year			
Clara Frijs	32	47	68%	63%	50%	79%	71%
Ewart	34	53	64%	13%	67%	76%	75%
Gourmet	47	62	76%	67%	47%	100%	81%
Harrow Sweet	26	36	72%	57%	63%	73%	90%
HoneySweet*	21	32	66%	100%	60%	67%	50%
Luscious	30	49	61%	30%	40%	83%	73%
Summercrisp	35	48	73%	38%	62%	88%	90%
Average			69%	52%	55%	81%	76%

*HoneySweet was not planted at the Staples location.

Pears on juneberry rootstocks differed from pears on pear rootstocks in both growth rates and the production of floral buds. Many trees on both pear rootstocks had excellent growth. At the Hutchinson site most of the trees on pear rootstocks grew between 2' and 3' during the summer of 2017 (see photo). The trees on juneberry rootstocks grew at most 4" to 6" during the same time period. Leaves on trees with juneberry rootstocks tended to be smaller than those on pear rootstocks (see photo).

Most of the growth occurred in the summer of 2016, and leaves are smaller and less healthy than trees grafted on OH x F 87 in neighboring row.

Juneberries appear to be extremely precocious rootstocks when grafted with pears. One pear tree on Amelanchier x grandiflora had two flowers 1 year after grafting. In the fall of 2017, many of the pear trees on both juneberry rootstocks appeared to have floral buds. As expected, some cultivars appear to be more suitable for juneberry rootstocks than others. Honeysweet, Clara Frijs, and Gourmet all had very good survival on juneberry rootstocks.

After 2 years, we do not know if juneberries will be a viable rootstock for hardy pears. Survival rates were low, but acceptable. The low survival rate could have been aggravated by planting the trees directly in the ground in the fall. In the future, we will overwinter the plants in a high tunnel and then plant in the spring. A bigger problem with

Pears on Old Home x Farmingdale 87 at York Farm showing 3' of growth, with healthy leaves 1 year after planting.

Pear on A. x grandiflora at York Farm.

the trees grafted onto juneberry rootstocks was extremely slow growth rates at each site. The slow growth rates were a surprise, because there was no difference in growth rates between trees the year of grafting. Some pear varieties on A. alnifolia and A. x grandiflora grew 2' the summer after they were grafted, but had almost no growth in 2017. We will be carefully monitoring growth rates on the different rootstocks during 2018.

Next year, we will graft more trees onto juneberry plants to fill in places where trees have died.

MANAGEMENT TIPS

1. It is too early to know if A. alnifolia or A. x grandiflora will be viable rootstocks for Minnesota pears.
2. As with apples, one rootstock will not be perfect for every cultivar. Some pear cultivars will do best on specific rootstocks.
3. If grafting in the spring, leave the plants in a protected nursery bed or high tunnel the first year instead of planting into the field.

COOPERATORS

Dan Sheild, Stone Creek Farms, Taylor's Falls, MN

Irene Genelin, York Farm, Hutchinson, MN

PROJECT LOCATIONS

Central Lakes College Agriculture and Energy Center, Staples, MN. From downtown Staples, go north on Airport Rd. to Cty. Hwy. 2. Take a left on Hwy. 2 for .25 miles. The pear trees are in the old agroforestry block just west of the driveway to the office complex.

York Farm, 21161 York Rd., Hutchinson, MN. From Hwy. 15, take Airport Rd. W. to York Rd. York Farms is on the south side of the road.

Stone Creek Farm is located between Taylor's Falls and Shafer. From Shafer, take Redwing Ave. NE to 310th St. Take a right (east) on 310th St. Stone Creek Farm is on the north side of the road next to the solar farm.

OTHER RESOURCES

Cummins Nursery.
Website: **www.cumminsnursery.com**

Lawyer's Nursery.
Website: **www.lawyernursery.com**

This project is in memory of Robert E. Lund, 1922-2016.

Using Essential Oils to Repel Spotted Wing Drosophila in Blueberries

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2017 to 2019

AWARD AMOUNT

$5,397

STAFF CONTACT

Cassie Dahl

KEYWORDS

blueberry, essential oils, spotted wing Drosophila

Northblue blueberry patch where we conducted the experiment.

PROJECT SUMMARY

We are trying to control spotted wing Drosophila (SWD) on our blueberry farm by using repellents made from botanical essential oils instead of insecticides. We grow 1¾ acres of blueberries just north of Stillwater. We primarily market our blueberries as pick-your-own, which draws customers from the Twin Cities metro area. Our customers have requested we follow organic practices. Currently, we use more expensive organic fertilizers and pay for extra mulch and labor for weed control. In 2013, our goal of certifying organic was stopped by the arrival of spotted wing Drosophila. In order to protect our crop we used conventional insecticides during the 2014 and 2015 growing seasons. Wanting to use organic practices, in 2015 we tested lavender oil as a repellant on about 10 bushes outside of our field and had encouraging results. In 2016, we started using lavender oil to repel SWD in our entire field and the results were good enough that we wanted to scientifically test the efficacy of essential oils as a repellant for SWD.

PROJECT DESCRIPTION

Several studies have looked at essential oils as a way to repel or kill SWD adults (Renkema et al., 2016, Jang et al., 2017), and shown that peppermint oils were the most effective. The first

studies were conducted in laboratories and only a few people have tried essential oils to control SWD on commercial fruit farms. We decided to test the efficacy of different essential oils to see if they could keep SWD populations low enough so we would not have to use conventional insecticides. Initially, we were going to compare essential oils to Jet Ag, which is a hydrogen peroxide product that kills the yeast that attracts SWD, but it also contains acetic acid or vinegar, which could attract flies. Therefore, we decided to compare lavender and peppermint oils, both with two differing concentrations.

We tested the essential oils on a block of Northblue blueberries which is separate from the other three fields that are used for pick-your-own (see photo). SWD tend to be worse in Northblue, partly because the variety produces many small berries at the end of the season that are rarely picked. One concern with conducting on-farm pest control research is the possibility of creating a breeding ground that could increase the number of SWD's, and they could spread to the surrounding fields. As a precaution, we monitored 15 plants that were in another section of our property as our control. All three fields of pick-your-own blueberries were sprayed with lavender oil.

The small block of Northblue bushes is divided into a north and south section, each with two rows of 20 to 23 plants/row. The north and south areas were each divided into four sections, and each section received a different spray treatment (Table 1). The order of treatments was alternated on the north and south sections. Each area was sprayed with ½ gal spray solution on a weekly basis, but altered as needed if it rained. For the control, we monitored 15 plants that were in another section of our property, also away from the commercial field.

We monitored for SWD adults using traps baited with yeast and sugar, but we were afraid to place traps in the blueberry field, because in past years the mixture appeared to attract insects. We finally decided to place the traps in a forested area that had wild red elderberries. Traps were checked each week and the adult flies were counted. Males were most present, but are easier to identify due to the distinct spots on their wings. Females lack the wing spot and are difficult to distinguish from common fruit flies without using a hand lens.

Table 1. Different spray treatments for each section of the blueberry patch.

Section	Ingredients
1	¼ tsp Lavender in ½ gal water; ½ Tbsp soda; ¼ tsp NuFilm P
2	½ tsp Lavender in ½ gal water; ½ Tbsp soda; ¼ tsp NuFilm P
3	¼ tsp Peppermint in ½ gal water; ½ Tbsp soda; ¼ tsp NuFilm P
4	½ tsp Peppermint in ½ gal water; ½ Tbsp soda; ¼ tsp NuFilm P
5	Not Sprayed

We began spraying the oils as the first berries started to turn blue. Weather permitting, we continued to spray once a week until we stopped picking for the season. To test for the presence of SWD larvae in berries, we picked ½ cup of blueberries from each block. The berries were crushed and added to a solution of 1 cup salt to 1 gal of water. We placed the crushed berries in the salt solution in plastic bags. After allowing this mixture to sit for ½ hr, the number of larvae that floated to the top was counted (see photo).

To determine if any of the spray treatments were either helping or hurting the fertility of the plants we sent in tissue for testing before and after the picking season. We also sent in a soil sample, which will be compared to a 2018 sample to see if there were changes. In addition, to see if the oils were affecting the taste, we invited guests to do a taste testing of berries from all five plots.

RESULTS

Blueberries started to turn blue in late June, so we started applying essential oils on June 23 and planned to spray weekly. At the time, there were reports of SWD in strawberries in our part of the State. We caught our first SWD on July 6, when our traps had five SWD males. On July 11, our trap had 24 males. On July 24 and 31, the sticky card in the trap had too many SWD flies to count.

The pick-your-own patch opened to customers on July 6 and, thankfully, we did not find any larvae in either the test areas or the commercial blueberries. On July 11, we found one larva in our samples from the unsprayed control and the main field.

Blueberries in solution to float SWD larvae out for counting.

The sections sprayed with ½ tsp of lavender per ½ gal had the lowest numbers of SWD larvae, while sections sprayed with peppermint had about the same numbers as the unsprayed control (Table 2). Also, the south section appeared to have more larvae. Looking closely at the bushes, the bushes in the south section that were sprayed with peppermint oil were denser with a tighter canopy. In the future, we will prune these bushes to become more open in order to improve SWD control.

Our plan to spray the commercial block and the test block once a week was complicated by the weather. We sprayed the test plots on June 23 and June 25, after it rained. We sprayed on July 1, 8, and again on July 12 after the rain stopped. It rained on and off from July 17 through July 21, so we had to wait to spray. We were finally able to spray again the evening on July 21 and then again on July 26.

By July 21, SWD numbers were starting to increase rapidly. On July 28, SWD numbers in the commercial patch were too high to continue picking, so we closed for the season. Fortunately, most of our crop had been sold by then.

At this point, the lavender does appear to reduce SWD pressure. The test blocks sprayed with lavender had less SWD larvae than other treatments and the control, and we were able to harvest most of our commercial fields before the SWD numbers became too high. With SWD, the goal is often to try to keep the problem from getting out of hand rather than to eliminate the pest. In 2017, the lavender appeared to give us at least one extra week of picking.

Taste testing in progress.

After reviewing the 2017 data, the 2018 research will be adapted. Bushes will be pruned as evenly as possible. Lavender will be tested, but Peppermint will be omitted. A review of the latest research will be done to see about testing any new products. So far, we have seen new research on an organic insecticide named Grandevo, which may be an effective option against SWD.

We were pleasantly surprised with the positive response from our guests. Many of them wanted to hear all about the study and had numerous questions. On the taste testing

days, they were willing to take a few minutes to complete the survey (see photo). They were very encouraging of us as we try to use oils as repellents so we can be certified organic. According to our taste tests, consumers could not detect any difference between berries sprayed with an essential oil and berries that were not sprayed.

Table 2. Counts of SWD larvae in 1 cup of blueberries from each treatment.

Sampling date	¼ tsp	½ tsp	¼ tsp	½ tsp	Unsprayed control
July 6, 2017	0	0	0	0	0
July 11, 2017	0	0	0	0	2
July 18, 2017	0	0	6	0	0
July 25, 2017	13	4	31	30	NA
August 1, 2017	18	16	21	29	40

The essential oils are cost effective when compared with other OMRI approved sprays (Table 3), and they have no pre-harvest interval (PHI). The most commonly used insecticide is Spinosad (Entrust), but with current recommendations, should only be sprayed two times during the growing season. However, two times is not enough to prevent SWD numbers from exploding. Spinosad also has a 3 day PHI, which can be inconvenient during the picking season. Growers who want to use essential oils should do some comparison shopping to find a source that is economically viable.

Table 3: Cost of different products used for SWD control in 1 acre of blueberries.

Product	Total cost for package, includes shipping	Amount needed for each spray	Cost per spray	Estimated sprays per year	Annual cost	Restricted-entry Interval	PHI
Grandevo	$450 for 20 lb	3 lb/A	$67.50	6	$405.00	4 hr	None
Lavender	$481.40 for 64 oz	4 oz/24 gal water	$30.09	8	$240.70[1]	None	None
Nu Film P	$75/128 oz	4 oz/24 gal water	$ 2.34	8	$ 18.75	None	None
Entrust	$500/32 oz[2]	6 oz/A	$93.75	2[3]	$187.50	4 hr	3 Days
2 Entrust with 6 Grandevo				2 Entrust with 6 Grandevo	$592.50[4]		

[1] Lavender was sprayed at rate of 1 tsp/gal of water in our field. The above calculation is using 24 gal/A spray volume for Lavender. Annual Cost for 48 gal/A would be $481.40.

[2] Entrust only has a 2-year shelf life. The cost of Entrust may increase if the remaining product is discarded after 2 seasons.

[3] Two is the maximum suggested by the label per season. Two sprays are unlikely to control SWD for one picking season.

[4] The cost of Grandevo could increase significantly because the 20 lb bag is only enough for six sprays.

MANAGEMENT TIPS

1. Prune bushes aggressively to maintain an open canopy.
2. Plan on more time than expected for spraying bushes, testing berries for larvae, and documentation.
3. Order all products before the growing season begins for the year.
4. Lavender oil does appear to reduce SWD pressure.

COOPERATOR

Thaddeus McCamant, Central Lakes College, Staples, MN

PROJECT LOCATION

At I-694 and Hwy. 36 go east towards Stillwater on Hwy. 36. After about 5 miles turn left (north) on Manning Ave./Hwy. 15. Go north 3.5 miles until you get to a roundabout at Hwy. 96/Dellwood Rd. Turn right (east) on Hwy. 96/Dellwood Rd. and go 1 mile. Take a left (north) onto Mendel Rd. N. (by the ponds) and our field is about a ½ mile up the road on your left. You will see our sign there.

OTHER RESOURCES

Renkema, J.M. 2016. Plant essential oils and potassium metabisulfite as repellents for Drosophila suzukii (Diptera: Drosophilidae).
Website: **www.nature.com/articles/srep21432**

Jang, M., Kim, J., Yoon, K. A., Lee, S. H., & Park, C. G. 2017. Biological activity of Myrtaceae plant essential oils and their major components against Drosophila suzukii (Diptera: Drosophilidae). Pest Management Science, 73(2), 404-409.

Developing an Annual Day-Neutral Strawberry Planting System with Biodegradable Mulches

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2017 to 2018

AWARD AMOUNT

$23,212.50

STAFF CONTACT

Ann Kuzj

KEYWORDS

low tunnel day neutral strawberries, biodegradable mulch, winter rye cover crop

Farmer cooperators David Macgregor and Marsha Anklam of Fairhaven Farm in South Haven, MN. They are assisting us with the project on their farm as a demonstration site.

PROJECT SUMMARY

Minnesota farmers need an environmentally acceptable system for producing annual strawberries to increase the supply of this high-value specialty crop. Despite growing consumer interest in local foods, the supply of Minnesota-grown strawberries is extremely limited due to the short growing season and perishability of traditional varieties. We have developed and are currently using a low tunnel production system for strawberries yielding high quality berries that extends the strawberry season into October. Plastic mulch and landscape fabric were integral to our initial system for weed control, a challenge in strawberry production.

In our recent survey of 200 regional farmers, 73% want to learn to grow annual strawberries and 64% want to learn about low tunnels for season extension. However, 57% of farmers surveyed were concerned about our system's use of plastic mulch and landscape fabric because of the negative environmental effects and lack of recycling options. Therefore, to increase local strawberry production and meet the needs of farmers, we are exploring the performance of biodegradable mulches.

PROJECT DESCRIPTION

Strawberry research has been ongoing at the University of Minnesota West Central Research and Outreach Center (WCROC) in collaboration with the Department of Horticultural Science for the past 20 years, both with perennial June-bearing cultivars and day-neutral varieties (grown as annuals). While the traditional June-bearing varieties produce fruit from early June through early July, our day-neutral low tunnel system offers high quality fruit from July to October, which is a non-traditional time of the year in Minnesota. This system for growing strawberries offers great potential for farmers: June-bearing varieties yield an average of 5,500 lb/A of fruit, while the day-neutral low tunnel strawberries produced from 8,600 lb/A in 2017 to up to 17,300 lb/A in 2016.

Since 2013, we have been researching the day-neutral low tunnel strawberry system to determine suitability for Minnesota farmers. We have adapted the system to withstand wind, rain, and heat, as well as establishing irrigation methods and nitrogen best practices. We have also learned that growing a single day-neutral cultivar can lead to pest problems.

The low tunnel system requires hoop-like structures that go over the rows of strawberry plants. In addition, the strawberry plants must be planted into some type of mulch for adequate weed control and to maximize plant growth. In initial studies we used white on black plastic mulch in the row, which is a very effective weed control strategy. However, farmers expressed concern over the amount of plastic used since the plastic mulch cannot be reused. This concern led us to our current project of evaluating the effectiveness of biodegradable mulch in the low tunnel system. We want to determine if there is a more environmentally sustainable alternative to plastic mulch. To further reduce plastic in the system, we evaluated the use of cover crops in place of landscape fabric for weed suppression between the rows of strawberry plants.

Our project consisted of the following objectives:

1. Determine the performance of biodegradable mulches in an extended season annual strawberry production system as compared to our standard white on black plastic mulch;
2. Improve understanding of the effectiveness of sustainable mulches, including biodegradable mulch and cover crops, between crop rows in an extended season annual strawberry system as compared to landscape fabric used between crop rows; and
3. Increase the awareness of the benefits of the extended season annual strawberry system among farmers so they can establish the system on their farms.

In our original proposal, we listed three treatments:

Treatment 1. White-on-black plastic mulch (this is the mulch used in past experiments and is the control);

Treatment 2. White-on-black biodegradable plastic mulch (this is one of the comparisons); and

Treatment 3. Paper mulch approved for certified organic production (this is another comparison).

Treatments 1 and 2 were installed in 2017, but we didn't install Treatment 3. Based on our original research, we were confident that this paper mulch would work when installed with a plastic mulch machine. We tried to install this product with the machine in the Spring of 2017, but failed. During the installation process, the product continually ripped. We made numerous mechanical adjustments to the mulch machine without success. We abandoned the paper mulch treatment and continued to install the other two treatments. In 2018, we will try again with the paper mulch treatment and install it by hand.

One of the objectives of this project was to compare biodegradable plastic mulch with standard white-on-black plastic mulch. The Bio360 biodegradable compostable black plastic mulch was installed on a 6" high raised bed prior to planting dormant strawberry transplants using a plastic mulch machine. Bio360 is made of Mater-Bi®, a plastic that is completely biodegradable and compostable and used in the manufacturing of products having a low impact on the environment. Temperature, humidity, and microorganisms in the ground transform Bio360 into

water, carbon dioxide, and biomass. There is no toxic residue left. The Bio360 biodegradable mulch had the same mechanical and physical characteristics as the white-on-black plastic mulch. Visibly, the Bio360 didn't have quite as tight a fit on the raised bed as the standard white-on-black plastic mulch. Without a tight fit, strawberry transplants initially appeared to have a more difficult time growing through the slit/opening in the Bio360. This led to a slightly reduced number of live plants coming through the Bio360 mulch.

Day-neutral strawberries growing under a low tunnel system on a raised bed. The plastic mulch we are testing here that covers the raised bed is a biodegradable product called Bio360.

The WCROC Horticulture Department has extensive experience in planning, managing, and coordinating research protocols for numerous plant research projects. For this project, we partnered with three grower-collaborators to replicate plantings: Little Hill Berry Farm in Northfield, MN; Tangletown Gardens Farm in Plato, MN; and Fairhaven Farm in South Haven, MN. At each site, we installed and planted two 100' rows of day-neutral low tunnel strawberries. One row was covered with standard white on black plastic mulch, while the other was covered with Bio360 biodegradable mulch. Through these partnerships we will be able to expand our outreach not only to a broader range of producers, but to their customers as well.

Day-neutral strawberries growing under a low tunnel system on a raised bed. The plastic mulch that covers this raised bed is our standard comparison called white on black plastic mulch.

2017 RESULTS

WCROC

In 2017, our yields in lb/A were lower than the yields recorded in 2013 and later, before we started this project. The spring planting date of these day-neutral strawberries was average and the plants appeared healthy. Initially there was some plant loss, but this was corrected by counting plant numbers for yield data. Plant loss might have been from dormant strawberry plants being stored at temperatures that encouraged growth before planting. We have learned that after plants are received from the strawberry plant nursery, storage temperatures should be at 28°F for optimum storage conditions.

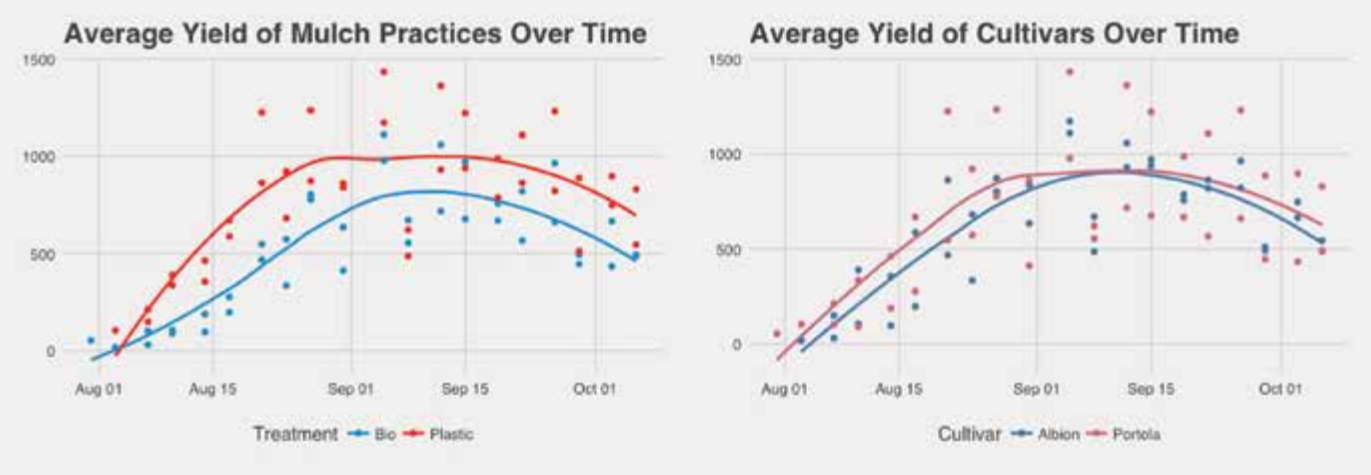
Strawberry harvest was 2 weeks shorter in comparison to cumulative data gathered from 2013 to 2016. This factor could reduce cumulative yield. Although the strawberry yield was lower than we anticipated, berry quality and size were rated good to excellent (Table 1).

Yield and berry size comparison of two within-row treatments, and two strawberry varieties.

Cultivar	Yield (lb/plant)		Cumulative yield (lb/A)		Berry weight (g)*	
	White on black plastic	Biodegradable	White on black plastic	Biodegradable	White on black plastic	Biodegradable
Portola	0.69	0.42	12,628	7,580	18.1a	14.6
Albion	0.41	0.37	7,502	6,829	16.1b	15.7

*Letters within columns indicate significant differences at the 5% level if they are different.

Average yields of mulch and cultivars.



On average, plastic mulch produced higher yields of larger fruit regardless of cultivar, but this difference was especially prominent in Portola. When examining within mulch treatments, Portola showed significantly higher yields and larger fruit than Albion in traditional plastic mulch, but these differences did not appear in biodegradable mulch.

An hourly temperature was recorded at the WCROC site in 2017 using WatchDog A-Series data loggers in the low tunnel beds. The data loggers were suspended 12" above both beds and recorded temperatures as shown in the graph. There were no significant differences in temperatures between the biodegradable and the white on black plastic mulch.

Little Hill Berry Farm

Little Hill Berry Farm in Northfield, MN offers certified organic, pick-your-own blueberries. Their first year growing strawberries was in 2017. In addition to installing the two rows for this experiment, they installed eight rows of strawberries for their pick-your-own operation. Based on their experience with this growing system, they offered their own successes and challenges:

Successes: "We have received positive feedback from customers on the taste and size of the strawberries. During picking, customers found it easy to see the berries. In a typical June-bearing system, there is abundant foliage, which can make finding the berries a bit more challenging. Day neutral strawberries tend to have less foliage, making it easier to find the berries. The plastic that went over the hoop structure of the low tunnels held up well in rain and wind. One of the in-row mulch treatments had biodegradable black plastic mulch (Bio360), which held up well. We did not notice any differences in yield or vigor of the plants compared to the standard white on black plastic, which was the second treatment. Overall, we really like the system and plan on growing more day neutral strawberries next year."

Challenges: "We did experience disease and insect pressures. Portola had some leaf disease issues, and we did have spotted wing drosophila (SWD) under the tunnels. On our farm, we had more SWD in the tunnels than in the rows without the tunnels. The winter rye cover crop, which was planted in between the rows for weed suppression, grew well until the end of July. After that, the rye died out and the weeds took over. This didn't affect our strawberry quality but made for unsightly walk-ways."

Tangletown Gardens Farm

Tangletown Gardens Farm is an integrated biological farm that incorporates plants and animals in a symbiotic environment that allows each to thrive in Plato, MN. They have a 700-member CSA program as well as Wise Acre Eatery and Tangletown Gardens in south Minneapolis.

Successes: "The low tunnel system was the most productive method for growing strawberries at Tangletown. The low tunnel day-neutral strawberries out-performed berries from the other growing methods in both quantity and quality. The white on black plastic mulch produced significantly more strawberries than the black biodegradable plastic (Bio360). We had very little insect damage, and as of mid-August, had not applied any pesticide."

Challenges: "We did experience some minor damage to the plastic that goes over the hoops of the low tunnel. Most of this was due to the fact that we had not rolled up the sides properly at installation, which caused pooling of water. From a timing standpoint, we did not mow the cover crop early enough, which may have prevented the strawberry plants from getting full sun for part of the summer. It also meant that we had to go through later and hand pull the weeds that were growing up against the plastic mulch, which is quite labor intensive."

Fairhaven Farm

Marsha Anklam and David Macgregor run and own Fairhaven Farm, South Haven, MN. They sell their fruit at local farmer's markets and use the berries for jam production. They made the complete switch from growing June-bearing varieties to day-neutral varieties based on their success with the low tunnel system. 2017 marks the third year we have partnered with them on the low tunnel system.

MANAGEMENT TIPS

1. With cooler fall weather, we lowered the plastic sides on the low tunnel system. This helped to maintain a warmer temperature under the plastic hoops providing a more desirable environment for strawberry growth. The lowered sides also prevented excessive moisture. This was important at the Morris site. During the second half of September, the site had over 4" of rain, which is 2" above average. Too much water can cause soft fruit and increase the potential for fruit diseases.
2. The winter rye, which was planted in May 2017 as a cover crop between the strawberry rows, failed to provide adequate cover to suppress weeds for the entire growing season. By mid-August, the winter rye had died off, which allowed weeds to take over between the rows. Our best guess is that the winter rye had met its reasonable life expectancy and died off naturally. Even though the weeds between the rows did not affect fruit quality and quantity, we are reevaluating the use of winter rye as a weed suppressant.

COOPERATORS

Emily Hoover, University of Minnesota Department of Horticultural Science, St. Paul, MN

Andy Petran, University of Minnesota Department of Horticultural Science, St. Paul, MN

Rachel Brockamp, University of Minnesota West Central Research and Outreach Center, Morris, MN

Aaron Wills and Molly McGovern Wills, Little Hill Berry Farm, Northfield, MN

Dean Englemann, Tangletown Gardens Farm, Plato, MN

David Macgregor and Marsha Anklam, Fairhaven Farm, South Haven, MN

PROJECT LOCATION

University of Minnesota West Central Research and Outreach Facility: From Morris, go 1 mile east on Hwy. 329.

Tangletown Gardens Farm: From Norwood Young America, go 6 miles west on Hwy. 212. Turn right onto Cty. Rd. 9. The farm is on the left.

Little Hill Berry Farm: From Northfield, go north on MN-3 for 2.5 miles. Turn left on 320th St. W. The farm is 1/2 mile down on the left.

Fairhaven Farm: From St. Cloud, take Co. Rd. 136. Turn right on Co. Rd. 7 in Fair Haven Township. Turn left on 51st Ave.

OTHER RESOURCES

University of Minnesota Fruit Research Blog. Webstite: **web.archive.org/web/20180406211659/http://fruit.cfans.umn.edu**

University of Minnesota West Central Research and Outreach Center.
Website: **wcroc.cfans.umn.edu**

Relationship of Strawberry Yield with Microclimate Factors in Open and Covered Raised-Bed Production Vol. 60(5): 1511-1525. 2017. American Society of Agricultural and Biological Engineers ISSN 2151-0032.
doi.org/10.13031/trans.12371

Goat Grazing During Winter in Minnesota: Ways to Control Vegetation on a Larger Scale While Saving on Supplemental Feed Costs

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2015 to 2017

AWARD AMOUNT

$24,946

STAFF CONTACT

Cassie Dahl

KEYWORDS

corn, hybrid, methionine, open pollinated, poultry

Farmer Jake Langeslag.

PROJECT SUMMARY

This project will evaluate winter grazing systems that maintain a healthy goat herd and provide control of invasive and undesirable plants during harsh Minnesota winters. Our overall goal is to find that this is a profitable service and meat goat enterprise. The project will assess winter husbandry challenges, including: effective electric mesh fencing, sheltering, watering, and meeting nutritional requirements. The project is also designed to determine if the season's limited browse and forage plants will lessen girdling, so the goats will need to graze a larger land area of invasive and undesirable woody vegetation to get enough to eat. Information gained from this project will benefit farmers with service and meat operations by providing additional income through the extension of the grazing season, plus reduce the costs required when wintering goats in a yard or building. In addition, having the goats graze on frozen soil that is normally wet, fragile, or steep will help protect fragile ecosystems.

PROJECT DESCRIPTION

Jake and Amanda Langeslag own a 10 acre parcel that serves as home base for their goat grazing service and meat enterprise. The service component refers to the contracting of the herd to control invasive and undesirable plants. This provides income as well as additional lands for grazing. During the past year, the operation has contract grazed in Rice, Dakota, and Olmsted Counties on both public and private properties. The meat enterprise has been limited during the early years of the operation due to the desire to grow the herd size. They have increased the herd size from 25 goats in 2013, to over 80 goats now. The Langeslag's have provided support for new graziers and hope what is learned here can benefit new farmers.

Winter is a costly time of year for a service and meat goat enterprise due to feed and supplemental nutrition costs, housing costs, and increased time demands of the herdsman. In addition, it's a time when weight gains are slow and income from service grazing is limited. While addressing these concerns, this project has three overarching goals:

1. Explore the benefits and limitations of grazing goats during winter by increasing our knowledge of electric mesh fence effectiveness, water supply maintenance, and movable winter shelters. We also want to quantify the economic benefit of winter grazing.
2. Assess winter grazing system potential for protection and release of native plant species while controlling invasive and undesirable plants by attempting to influence the goats' preference for undesirable woody vegetation.
3. Monitor indicators of livestock comfort and health by noting their preference for certain shelters and the inside temperatures. In addition, weight change and mortality of goats will be monitored.

There are also ecological considerations that need be explored. Certain sites such as prairies, grasslands, wetlands, and lowlands can be difficult to graze during the growing season. These sites often contain many lush forbs and grasses, which the goats eat along with the brush. This "bogs" the goats down and they are not as willing to go after the woodier vegetation. We hope the goats can be directed to undesirable woody vegetation in the winter due to limited availability of other plants. We also want to focus their attention to undesirable plants by applying several deterrents feeding on preferred native species. If these experiments work out, profitability of the grazing service will increase and a greater land area can be serviced to reduce undesirable woody plants.

2016 RESULTS

Our project is a winter grazing project and 2016 has been used to prepare for the grazing season. There are a few items needed to fully implement the project, but most of the equipment and facilities are in place and ready to go. So far, the fence is maintaining excellent voltage.

2017 RESULTS

Grazing commenced in November 2016 and continued through mid-March 2017. The goats focused on woody vegetation during this time, aggressively stripping

Goat staging area.

the bark from many undesirable species, such as buckthorn. Our anecdotal observation is that 60-70% of the brush/woody plants up to 6" diameter were girdled and will not regrow above the girdled level. The Langeslag's have not seen this aggressive girdling of woody species during summer grazing. The project resulted in less supplemental feed and a shorter period when they needed to provide supplements.

The electro-net fencing contained the goats effectively, with no escapes during the entire winter. The voltage measurements did show increases and decreases with weather and flooding. We think a major factor in the lack of escaping goats is that they were exposed to the fence prior to the winter months and respected the fence.

The round poly-dome huts have benefits for animal comfort as well as ease of moving to new locations, since they are easy to slide or roll. They also maintain a comfortable and healthy temperature and humidity level. Herd health on this site was very good this year. These huts effectively protected the animals to -29°F this past winter with heat from solar gain, as well as heat from the animals.

Game cameras provided evidence of grazing and herd behavior. We intended to also show wildlife damage to the fence with the cameras however, during this grazing cycle this was not a problem.

Winter grazing increased available food in wetter sites during frozen winter months. These sites are often avoided in other seasons. Frequent use of these sites in other seasons can also lead to health and hoof problems that do not occur with winter grazing.

Physical deterrents were used to protect some native desirable plants as well as some buckthorn, which we know are desirable food. Steel reinforcing mesh and galvanized wire mesh, both with rebar stakes, were used; a plastic tube system was also used to protect the trunks of vegetation. Both mesh systems were effective. The lighter weight galvanized wire would be more difficult to re-use due to its flimsiness. These

Cheryl recording species within grazing area.

methods were the most costly. The plastic tubing, while less costly, was less effective, especially when placed on more palatable plants. Goats use their horns to scrape and loosen bark when eating and likewise scraped the plastic tubes off some trees.

MANAGEMENT TIPS

1. Moving shelters and supplemental feed dispersed the goats away from the pens or huts, which increased the size of the grazed area.
2. If you think the grazing area will flood, consider using a stronger fence system along with raising the wires to keep them out of the water.
3. In case of flooding or fencing problems we had holding pens set up. The goats were able to move freely from the pens to the work area.
4. Use caution around goats while using a chain saw. We noticed they aggressively swarm around when we were cutting larger trees and shrubs because it gives them access to berries and tender tree tips.

COOPERATORS

Jake Langeslag, Goat Dispatch, Faribault, MN

Cheryl Culbreath, Landscape Restoration, Inc., Webster, MN

PROJECT LOCATION

From S.E. Faribault take Glynview Tr. S.E., then turn left on 227th St. E., right at the "T", left on 230th St. S.E. to the site at 4640 - 230th St. S.E.

Integrating Silvopasture Practices into Perennial Fruit Production

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$15,000

STAFF CONTACT

Ann Kuzj

KEYWORDS

livestock, perennial fruit, silvopasture

Woven wire fence dividing two orchard blocks.

PROJECT SUMMARY

The purpose of this project is to test the economic potential of grazing animals in perennial fruit systems. We are installing permanent pasture fences and watering systems in the orchards. The farm is currently set up with blocks of fruit trees ranging from 2 to 4.5 acres. The fences will allow each block to act as a paddock for rotational grazing. Although silvopasture systems are being tested globally, there are few projects testing the potential of grazing in fruit production.

To evaluate production and economic potential, we are recording the costs of installation and management of plots over 2 years. Further, we will record the number of animals produced and the corresponding income potential.

PROJECT DESCRIPTION

Hoch Orchard and Gardens is a vertically integrated and diversified food production company. Our primary crop is apples, but we have diversified into other fruit, meat production, vegetable production, and value-added products. We grow, pack, store, market and distribute our products. Our farm is certified organic and certified biodynamic. Our goal is to continually strive to make our farm an independent organism that requires few off-farm inputs.

The purpose of this project is more of a proof of concept rather than an evaluation of a single practice. By implementing this

grazing system on our farm and recording the actual costs and production of meat, we will be able to show the potential of the system. Other farmers will be able to see how this system worked on our farm and be able to adapt it to their own specifications. Additional research may follow this project to evaluate more specific practices.

Although there are many permaculture and silvopasture systems being tested around the world, there are few projects testing the potential of grazing in perennial fruit production systems. There is strong interest in this practice. At Hoch Orchard, we currently rotate sheep, poultry, and hogs through our fruit plots using portable shelters and energized movable fencing. The number of animals we can manage in this system is limited due to the time required to move and maintain this fencing. We can increase production and reduce costs with better infrastructure. Using animals to control the ground cover can reduce energy costs, improve soil quality by increasing biodiversity, and we can produce meat without diverting grains typically used for human food production to feed animals.

Our initial interest in this integration system came from a soil health perspective. Natural systems have both plants and animals contributing to nutrient cycling. Natural ecosystems require an animal component. Wild fruit trees grow in either low-density forests or wooded meadow environments. These systems are conducive to grazing animals. Permaculture systems are often designed for a 60% shade cover at maturity due to the high forage production potential in a partial shade environment. A modern orchard creates similar environment conditions. In conventional orchard systems, the ground covers are mowed regularly and this practice requires large amounts of fuel. We feel there is very high animal production potential and energy savings in this system.

Our three objectives for this grant are:

1. Establish infrastructure;
2. Record establishment and production costs; and
3. Review the data collected about rotation with a final report on time spent and cost to raise the hogs in this system.

Woven wire fence on one of the windbreaks.

Orchard before pigs grazed, numerous apples on ground.

Orchard after pigs grazed, no apples on ground.

2016 RESULTS

We had a project kick-off meeting in April to review the project and allow our cooperators an opportunity to review the plan and provide input. The attendees were Jake Overgaard and Wayne Martin from University of Minnesota Extension, Jennifer Nelson of MOSES, and Ken Meter of Crossroads Resource Center. At the meeting, how to collect the data for the most effective gathering of information was discussed.

From April to December, we began recording the time involved with feeding and watering the pigs. This year, the pigs were rotated around the orchard using the existing pastures that ring the orchard and temporary fences within the orchard. Temporary fences were constructed with ribbon wire or portable electric mesh.

In November, we started building permanent fences. We nailed 42" multi-species wire mesh fence to the windbreaks around the orchard. In addition, we built two fences that were not attached to windbreaks: one six-strand high-tensile fence and one t-post wire mesh fence. In total, we constructed 5,500' of permanent fence this year.

2017 RESULTS

For Year 2, we continued to document the time required to care for the pigs. Time is split among four categories including the construction/deconstruction of any temporary fences, feeding and watering, moving animals from one temporary paddock to the next, and time spent catching pigs that have escaped from temporary fencing. The data from this year will be compared to the first year when the animals were mostly in temporary fencing. The results of the system will be summarized in subsequent articles.

We had a planning meeting in April for our August 17 field day. We also used that time to review the data that was being collected. At the field day we talked about what we learned while testing fencing options. Harry Hoch, Heidi Eger and Steve Jones shared their experiences and some of the data collected on fencing while working with the animals in the perennial fruit system. We also did an orchard walk to look at the pigs and fences.

MANAGEMENT TIPS

1. Schedule time regularly to inspect the fences. The animals are constantly checking the fence, so the farmer should be too!
2. Account for time needed to track data. Be sure the data is entered in a clear and timely manner. We had a change in who was responsible for the animals, so the hand off of data collection did not go as smooth as we expected.

COOPERATORS

Ken Meter, Crossroads Resource Center, Minneapolis, MN

Jake Overgaard, U of M Extension, Winona, MN

Wayne Martin, U of M Extension, St. Paul, MN

Jennifer Nelson, Midwest Organic & Sustainable Education Service, Spring Valley, WI

PROJECT LOCATION

Come into La Crescent on Hwy. 14, then, at the traffic lights, turn west onto South 3rd St. (CTH 6). Turn left (south) onto Elm St. and follow to S 7th St. Turn right (west) onto 7th St. and follow it out of town where it becomes CTH 6. Follow CTH 6 about 5 miles west of La Crescent and turn right (north) onto CTH 16. Take CTH 16 through the valley and up the hill to the top of the ridge and then turn left onto Forster Rd.

OTHER RESOURCES

The USDA National Agroforestry Center (NAC). Website: **nac.unl.edu/practices/silvopasture.html**

Midwest Organic and Sustainable Education Services. Website: **mosesorganic.org/silvopasture**

The Savanna Institute. Website: **www.savannainstitute.org/events.html**

Testing Three Novel Sheep-Specific Pasture Types to Maximize Average Daily Gains in Lambs on Pasture

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2017 to 2019

AWARD AMOUNT

$17,898.50

STAFF CONTACT

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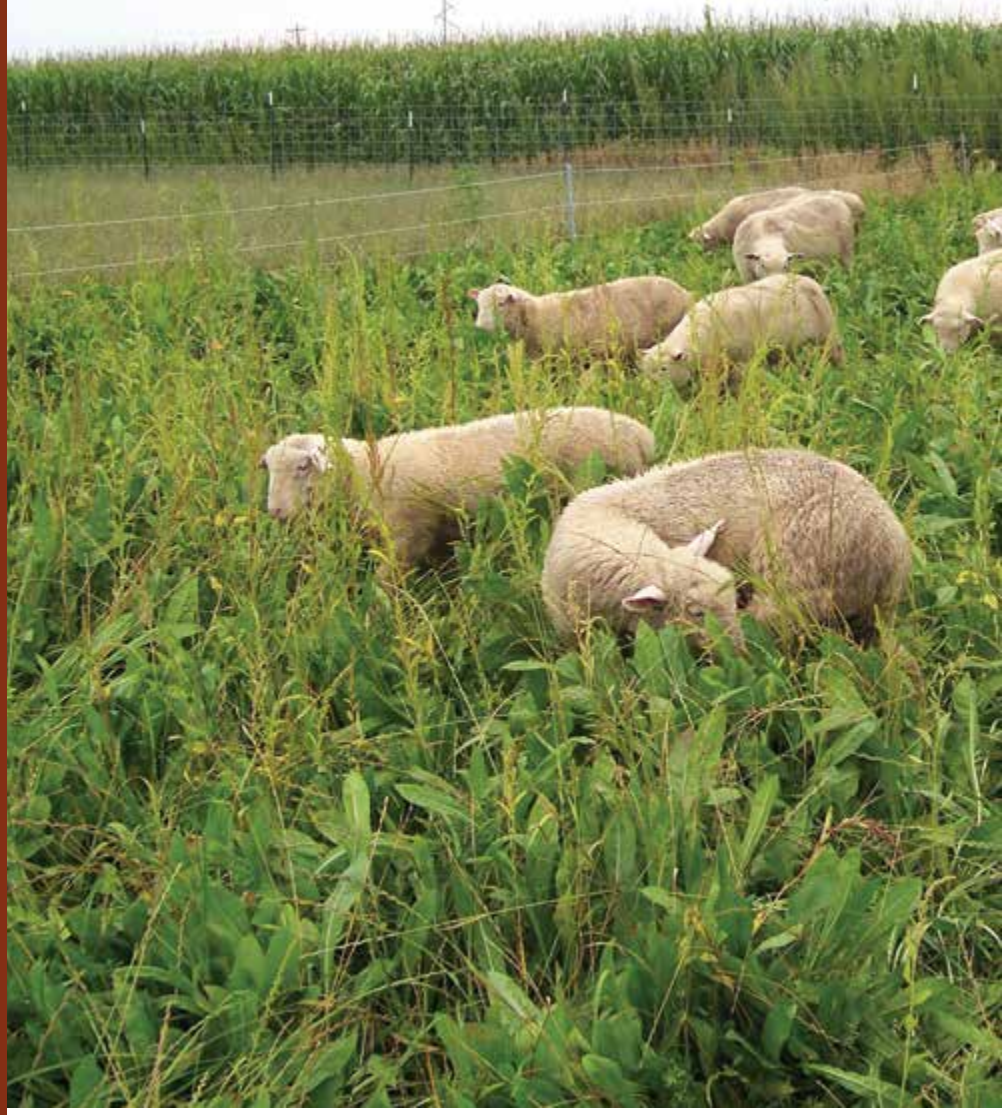
KEYWORDS

sheep, pasture, grazing, average daily gains



Sheep grazing in the non-lignifying pasture.

PROJECT SUMMARY

In the United States, ewes are often grazed, but lambs are almost always raised in feedlots from weaning to market weight. We are trying to determine the most effective pasture types for bringing lambs to market weight within the growing season. There is some research on finishing steers on pasture, but sheep have different forage preferences than steers. In the summer heat, most typical perennial pasture plants lignify, reducing digestibility that results in slower lamb growth and ultimately reduced profitability. Energy is also considered one of the most limiting factors to weight gain on pasture. With these factors in mind, along with our observations of what sheep prefer to eat, we designed three different pasture mixes that were grazed during July and August. Lambs were weighed to determine which mixes maximized average daily gains (ADG).

PROJECT DESCRIPTION

While we have rotationally grazed a few sheep for a number of years, 2017 marks the fifth lambing year where we have become

more serious about growing our flock and raising sheep profitably. Well-managed, rotationally grazed pasture can have excellent water infiltration, leading to less runoff and even manure distribution across the land, resulting in better utilization of nutrients. In addition, well-managed pastures can act as a net carbon sink. We have achieved average daily gains (ADG) in our lambs rotationally grazed on our improved pastures similar to those seen in feedlots, but primarily only through mid-July at the latest. Looking at the numbers, if the lambs were born in mid-April and they maintained the .75 lb/day ADG we have seen in June, they could reach the market weight of 120 lb by the first part of September. Bringing the lambs all the way to finished market weight has the potential to maximize income, as opposed to selling them as feeder lambs. Additionally, finished lambs off of the pasture could potentially be sold for a premium at specialty markets, as they would be 100% grass-fed, with all of the associated health benefits of grass-fed meat.

Our thought was that the decrease in weight gain starting in mid-July may be due to lignification and decreased digestibility of most pasture plants. This study aims to test different pasture types to determine if there is some forage combination that will maintain high ADGs on pasture through the growing season.

If lamb weight gain on pasture can be improved so they reach finished weight in September when pasture growth slows, most or all of the lambs (potentially 2/3 of the animals) could be removed from the pasture and the remaining ewe flock could graze longer into the fall and early winter. This would reduce ewe feeding costs by decreasing hay usage. Raising lambs on pasture is also potentially more family-friendly, as feeding time is spent out in the pasture and even young children can tag along and help while parents are moving polywire. This reduces the use of tractors and feed mixers, and later manure spreaders, to feed and care for the animals. The annual pasture in particular can also add a different "crop" in the rotation if the farm also raises row crops, which can help break up disease cycles and increase profitability in those enterprises.

Based on our observations and research, we designed three different pasture types to try to maximize ADG and profitability. The first pasture type was a diverse annual pasture, heavy on peas and oats, but including a total of 21 different species (Table 1). The thought behind this mix was that both the diversity of plants and the selection of particularly sheep-palatable plants would encourage maximum dry matter intake, leading to high ADGs. The second mix had a heavy component of chicory and white clover (Table 2), plants that are known to not lignify even in summer heat. The third pasture (grain finishing pasture) was planted in two distinct strips that were meant to be rotationally grazed together: one wide strip of alfalfa and one narrower strip of oats that was allowed to mature to grain (Table 3). As the fence was moved forward every two days, the sheep would get a new portion of oats to self-harvest balanced with the protein in the alfalfa, ideally making a nicely balanced ration. The herd was divided into four groups, one in each pasture type with the fourth group used as a control, rotationally grazed on our regular perennial pasture and weighed like the other groups.

The diverse annual pasture, the non-lignifying pasture, and the grain finishing pastures were planted on May 8, May 10, and May 7, 2017, respectively. A grain drill was used to plant the oats and the larger

seeds, and a Brillion seeder was used for the smaller seeds. Seeding details and prices for the three mixes are in Tables 1, 2 and 3. Due to a large amount of competition from green and yellow foxtail grass in half of the non-lignifying pasture, this half was mowed at a height of 3 to 5 inches on June 21. We hoped this would encourage growth of the desired species. Canada thistles in all of the plots were spot sprayed as necessary to avoid flower and seed production.

For the 2017 season, there were 81 lambs and 56 ewes that were part of the experiment. Lambs were weighed on June 29, 2017 at an average of 73 days old. From this data, ADG was calculated for each lamb. Because the lambs would be left with their mothers and to avoid splitting up families, the ADGs of the lambs were assigned to each mother, averaging between twins

Table 1: Seeding details for the diverse annual pasture.

Species	Cultivar	Lb/A	Cost/lb	Cost/A	Total cost
Peas	4010	50	$0.38	$19.00	$104.50
Forage Oats	Everleaf 126 Forage	32	$0.39	$12.50	$68.75
Hairy Vetch	VNS*	3	$1.60	$4.80	$26.40
Lentils	VNS	2	$0.90	$1.80	$9.90
Common Vetch	VNS	2	$1.00	$2.00	$11.00
Sunflowers	Peredovik Black Oil	0.75	$0.60	$0.45	$2.48
Cowpeas	Iron and Clay	2	$0.88	$1.76	$9.68
Grazing Corn	Blue Open Pollinated	4	$2.00	$8.00	$44.00
White Sweet Lupin	VNS	2	$1.62	$3.24	$17.82
Red Clover	Medium	1.75	$2.80	$4.90	$26.95
Italian Ryegrass	Tetilia	10	$0.90	$9.00	$49.50
Turnips	Purple Top	0.5	$1.60	$0.80	$4.40
Turnip/kale	Winfred Hybrid	0.25	$4.68	$1.17	$6.44
Rape	Dwarf Essex	0.25	$1.10	$0.28	$1.51
Kale	VNS	0.25	$4.60	$1.15	$6.33
Sweet Clover	VNS	0.25	$1.50	$0.38	$2.06
Balanza Clover	Fixation	0.75	$2.50	$1.88	$10.31
Crimson Clover	VNS	2	$1.28	$2.56	$14.08
Sorghum-sudan	Viking 200 BMR	4	$0.96	$3.84	$21.12
Sugar Beets	VNS	0.75	$6.50	$4.88	$26.81
Radishes	Tillage	0.5	$1.60	$0.80	$4.40
			Totals	**$85.17**	**$468.44**

*VNS = Variety not stated.

as necessary. The mothers were arranged in order of ADG of their lambs and randomly assigned to four groups. Groups were adjusted as necessary to have a similar number of lambs, ewes, and average ADGs.

Grazing was initiated on the diverse annual pasture on July 12 and on the non-lignifying pasture and the grain finishing pasture on July 22. Each group was moved every 2 to 3 days throughout the study period, depending on forage consumption. Every attempt was made to keep all the groups on the choicest forage available in their respective pastures and not to force them to eat too much coarse/undesirable forage. All lambs were weighed before beginning the treatments and again at the

Table 2: Seeding details for the non-lignifying pasture.

Species	Cultivar	Lb/A	Cost/lb	Cost/A	Total cost
Chicory	VNS*	3	$7.20	$21.60	$118.80
Plantain	Tonic	2.3	$5.85	$13.46	$74.00
White Clover	Alice Grazing/ Ladino	4.6	$5.84	$26.95	$148.25
Alfalfa Coated 66% Pure	Foregrazer	3.3	$4.40	$14.67	$80.67
Red Clover	Medium	1	$2.80	$2.80	$15.40
Meadow Fescue	HDR	7	$2.60	$18.20	$100.10
Festulolium	Spring Green	5	$1.94	$9.70	$53.35
Orchardgrass	HLR	1	$3.88	$3.88	$21.34
Timothy	Barpenta	2	$2.86	$5.72	$31.46
			Total:	**$116.98**	**$643.37**

Table 3: Seeding details for the grain finishing pasture.

Species	Cultivar	Lbs/A	Cost/lb	Cost/A	Total cost
Alfalfa Coated 66% Pure	Foregrazer	13.6	$4.40	$60.00	$270.00
Ladino	VNS*	1.5	$4.00	$6.00	$27.00
Red Clover	Ruby Red	0.5	$2.80	$1.40	$6.30
Alsike Clover	VNS	0.5	$3.80	$1.90	$8.55
Meadow Fescue	VNS	8	$2.60	$20.80	$93.60
Orchardgrass	HLR	2	$3.88	$7.76	$34.92
Timothy	Barpenta	0.75	$2.86	$2.15	$9.65
Hakari Brome	Hakari	3	$3.40	$10.20	$45.90
Oats for Nurse Crop**	BetaGene	1.5	$6.50	$9.75	$43.88
Oats for Grain Portion**	BetaGene	3	$6.50	$19.50	$19.50
			Total	**$139.46**	**$559.30**

*VNS = Variety not stated.

**Measurements and dollars for oats are by the bushel instead of pounds.

end, on approximately August 16. Additionally, the lambs on the diverse annual pasture and the non-lignifying pasture were weighed partway through to distinguish potential differences in gains as the forage composition changed. In the diverse annual pasture, the oats and the peas matured to grain partway through, so the lambs ended up eating a significant portion of grain in their diet instead of just forage. In the non-lignifying pasture, due to previous cropping history, approximately half of the plot was very thick with green and yellow foxtail grass, while the other half had less foxtail, but instead thick with lamb's quarters, water-hemp, and giant ragweed. The third pasture planted, the grain-finishing pasture, was not ready to graze in the same time frame as the annual and non-lignifying pastures, so the group that should have grazed that pasture were combined with those grazing the non-lignifying pasture. Data will be collected from that treatment in the 2018 season.

Table 4. Summary of collected data for the study.

Pasture	Weigh date	Avg lamb age (days) at weighing	Avg wt of lambs beginning of period	Avg wt of lambs end of period	Avg ADG	Days/A normalized for 20 lambs with mothers	Total lamb lb gained in each group/A	Dollar/A of lamb wt gained at $1.50/lb (for the single grazing event for the study)
Control	6/29/17	73	12.2	67.1	0.72	10.2	153.3	$229.93
Control					0.72	10.2	153.3	$229.93
Annual	8/2/17	108	67.6	85.9	0.87	8.1	140.4	$210.58
Annual	8/16/17	122	85.9	93.0	0.51	8.2	84.1	$126.18
Avg total annual					0.73	8.1	118.1	$177.21
Non-lignifying	8/4/17	109	71.1	81.3	0.79	10.2	159.6	$239.45
Non-lignifying	8/19/17	124	81.3	91.2	0.66	11.7	155.3	$232.91
Avg total non-lignifying					0.72	10.9	157.5	$236.18
Grain finishing	The first weighing was omitted because the pasture was uniform throughout the period.							
Grain finishing	8/15/17	118	70.8	86.7	0.66	6.6	86.7	$130.00
Total grain finishing					0.66	6.6	86.7	$130.00

RESULTS

A summary of the collected data appears in Table 4. Lambs on the diverse annual pasture and the non-lignifying pasture maintained gains throughout the period that were similar to those gained on the grain finishing pasture for the first part of the season. Average ADGs were significantly better on both the annual and the non-lignifying pastures than the grain finishing pasture later in the season. At the end of the data collection period, the lambs in the diverse annual pasture averaged the heaviest, at 93 lb (range 71 to 118 lb). The lambs in the non-lignifying pasture were close behind at an average of 91.2 lb (range 61 to 126 lb). Both of these pastures resulted in lambs that were heavier than those in the grain finishing treatment, who averaged 87 lb (range 69 to 103 lb).

As another way to look at the data, when the total pounds gained by the lambs is converted to a dollar amount representative of prices for the 2017 season, the difference seen is large (last column of Table 4). This dollar amount is a reflection of both ADG and the number of acres used. Best attempts were made to optimize acres used while not sacrificing the level of nutrition available on all of the plots when making daily decisions about when to move the fence and how big of a paddock to allocate. With that in mind, even though average ADGs were not that much lower on the control than the annual and non-lignifying, the dollars made per acre were lower because more acres were needed to fulfill their nutritional requirements. Ultimately, seeding costs and pasture longevity need to be figured in to achieve a complete picture of the profitability of each of the pasture types.

The weather in 2017 was unique in some important regards. August was much cooler than normal, to the point that perennial species likely did not lignify as they are usually expected to. This may explain why there wasn't a very large difference between average ADGs in the control vs. the non-lignifying pasture. From our observations from other years, we were expecting the difference to be greater.

For both the diverse annual and the non-lignifying pastures, gains were higher in the first half of the period than the second. This may be due to changes in forage composition, or it may be due to compensatory gain. The diverse annual pasture matured to the point that the peas and oats were all grain and, due to their vigorous growth, the other species were a rather small percentage of the total available forage. Energy was likely not lacking, but protein may have been limiting for gains in the lambs. In retrospect, grazing could have been initiated slightly earlier to have more of the pasture grazed in the vegetative state. Alternatively, the pasture could have been planted in two increments, one to two weeks apart. In our small experimental plots, this is hardly feasible as the area to plant was so small already. If this experiment would be replicated on a larger scale, this might be something to consider.

In the non-lignifying pasture, approximately one half of the plot was thick with foxtail grass, while the other half was thicker with broadleaf weeds that are generally high in protein. Manure was generally looser in the broadleaf weed half, suggesting high protein, and therefore lower energy, which may have limited gains. Alternatively, compensatory gain may be a reason for the differences in ADGs. Before beginning the experimental pastures, all of the sheep were rotated through some unimproved pasture consisting primarily of bromegrass, bluegrass, and burdock with a little bit of birdsfoot trefoil and lesser numbers of at least 10 other species. We were very surprised by the poor gains on this pasture and were not anticipating that they might possibly skew the result of this experiment. It is uncertain whether experimental results were skewed, but it is something to consider when evaluating the data.

It is important to consider how these pasture types fit into the overall farm system and influence profitability for the whole operation. The cost/A figure in Table 4 represents a single grazing event, and only accounts for pounds gained on the lambs. The ewes were also grazed with their lambs and gained some body condition on these acres. Adding body condition to ewes with feed that they harvest themselves is also great for profitability. Better body condition at breeding has the potential to increase the following year's lamb crop, and fat ewes in second trimester can be sustained on cheaper, poorer quality hay midwinter. The ewes grazed the annual pasture a second time in September and again in December, so those acres provided approximately 2.5 total grazings for our flock. The non-lignifying pasture was also grazed an additional time by the ewe flock. Being perennial, we would expect four to five grazing events throughout the growing season once the plot is established.

MANAGEMENT TIPS

1. Rotational grazing is key to success with any animals on pasture, resulting in better pasture utilization, a more balanced ration, and allows the rest of the pasture to be recovering and growing at any one point. This maximizes pasture yield and carrying capacity. Tall, fully recovered plants result in deep roots leading to increased carbon sequestration, water infiltration, and drought resistance. Additionally, there is then habitat and food for birds and pollinators.

2. The barber pole worm parasite must be managed to obtain acceptable ADGs on pasture. Chemical de-wormers cannot be fully relied upon due to decreasing sensitivity on the part of the parasite. For lambs in particular, rotational grazing where the animals are not left in any one paddock longer than three days can help avoid parasites, particularly the barber pole worm. Barber pole worm eggs are shed by the ewes and can hatch in as little as four days if the weather is conducive, which it often seems to be in Minnesota. If the lambs are rotated out of the paddock, they cannot ingest the worm larvae. Anyone is welcome to contact us for more details on our parasite management strategies.

3. Despite what some people will say, we feel that it is important nutritionally for the lambs to remain with their mothers on pasture. Many people will say that the ewes produce so little milk after 40 days or so that it is nutritionally insignificant for the lambs. However, those of our lambs that have been weaned, even as late as 60 days old have done significantly better than their peers. There is also a small body of research that suggests that the small amount of milk that is produced is high enough in fat to lead to a significant difference in ADG in the lambs. Our ewes gain body condition but do not become obese on our pastures mid-season, so our thought is that they must still be working hard for their lambs.

4. It was difficult to set up temporary fences through the diverse annual pasture for rotational grazing. The pea component is so viney that it is hard even to walk through, much less set up a fence. Extra labor needs to be factored in when considering using this pasture type on a larger scale.

5. We used a 3-line polywire fence for all of our rotational grazing. For this to work with sheep who do not feel the shock through their wool, we feel it is essential to spend some time in the early spring training the lambs to the fence. We find that 3-mm black and white polywire provides great visibility, which adds to the psychological aspect of the fence. Even with all of the different groups of sheep on our farm this summer, no one ended up mixing.

COOPERATOR

Dr. Craig Sheaffer, University of Minnesota, St. Paul, MN

PROJECT LOCATION

From Gibbon, travel south out of town on Cty. Rd. 2. Turn west on Cty. Rd. 25 or 300th St., which is the first intersection out of town. We are the first place on the north side of the road.

OTHER RESOURCES

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Trials to Overwinter Nucleus Colonies with a Pause in Brood Rearing

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PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$8,918

STAFF CONTACT

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KEYWORDS

bees, brood, honeybees, nucleus (nuc) colonies, queens, Varroa

Joe Meyer standing next to four nucleus colonies at an apiary in Dayton, MN.

PROJECT SUMMARY

This project aims to evaluate the practice of overwintering smaller honeybee hives, commonly referred to as nucleus or "nuc" hives, to produce new honeybee colonies in our region. I am evaluating two methods of creating nucleus colonies and comparing their effect on Varroa mite populations within a hive. One method interrupts brood rearing long enough to create a period of time when no brood (eggs, larvae, or pupae) are present in the colony. The other method reflects a more traditional approach, with brood always present throughout the summer.

PROJECT DESCRIPTION

Varroa mites are a major contributor to the nationwide decline in honeybee populations. This parasitic mite transfers viruses and bacteria with its bite and weakens the host bee as it feeds.

Current mite management techniques are not sustainable. Since I started keeping honeybee colonies in 2001, the beekeeping industry has cycled through multiple chemical Varroa mite treatments. The mites have adapted and developed resistance to most of them. Three years ago, I founded a business producing queens from bee colonies overwintered in Minnesota and started searching for alternative management techniques that may offer a more sustainable beekeeping model.

Around that time, I met Wisconsin beekeeper Adrian Quiney. He had been successfully implementing many experimental bee management techniques. The techniques Adrian uses to overwinter nucleus colonies and force a break in brood rearing may be the reason he has not had significant losses due to Varroa mites—despite not using any chemical treatments in his hives. In fact, Adrian has been selling surplus colonies for several years.

Few other people have been able to recreate Adrian's success, and he does not monitor mite levels in his colonies. While I think Adrian's principles could prove promising for beekeepers in our area, his methods are a significant departure from conventional wisdom. I undertook this project to see whether I can replicate Adrian's results, and to generate the information needed to encourage other beekeepers to make the jump.

I am conducting my project in two locations; each has two test groups of honeybee colonies, A and B. In May 2016, I set up 30 purchased nucleus colonies—15 in each location—and grew them until they were big enough to split. In early July, I split 23 colonies into 58 nucleus colonies. (Seven had signs of disease or queen issues and did not produce the brood necessary for the experiment.)

I left all 58 of the nucleus colonies without a queen for 8 days. Then, I introduced a mated queen (who could start laying eggs immediately) into half of them (group A). I introduced a queen cell (a pupa that would emerge within a few days, mate, and start laying eggs) into the other half of the colonies (group B). Since it takes about 13 days for a virgin queen to mate and start laying eggs, group B had a period of about 7 days when no capped brood would be present. Mites reproduce in capped brood and therefore evade grooming behaviors of the adult bees.

I took samples containing approximately 300 bees from each colony before I split them, and then once a month from each test colony until fall. I counted the Varroa mite population in each sample after dislodging the mites with an alcohol wash. I plan to compare treatments A and B using Varroa mite count data and winter survival rates.

2016 RESULTS

At the time I wrote my 2016 report, I had counted Varroa mites from all the bee samples but had not yet statistically analyzed them, so I can't report the data in this article. In spring 2017, I will record colony survival rates and sample all the colonies that are still alive.

While I expected some failure among the nucs that I started with queen cells, I did not expect how high the failure rate would be in one of the locations. I expected 90% of queen cells to result in a laying queen. One location had all 16 out of 16 cells succeed (100%). However, in the other, only 8 out of 14 colonies developed a laying queen (57%). In 5 of those 6 colonies where the introduced queen cells failed to produce a laying queen, worker bees started laying infertile eggs. (This happened more quickly than normal since the colonies were without brood.) Once workers begin to lay, the situation is difficult to correct.

Groups of four nucs wrapped together for winter in Long Lake, MN.

In addition, after the split about a dozen colonies became too weak for me to take bee samples. Right from the start, colonies in group B (the ones started with a queen cell) seemed to be weaker than the colonies in group A (which got a mated queen). I believe this was because workers from the group B colonies began to drift to the ones

nearby that already had a queen. This is a problem I plan to address in 2017. I was also unable to take samples from all hives in the fall because my inspections instigated a honey robbing frenzy among the test colonies. Robbing creates excessive stress in an already stressful time of year for hives.

Going into winter, my experiment had 52 colonies, which I wrapped with foil bubble insulation in groups of four. Despite some winter losses, I should have plenty of hives to repeat the experiment as planned in 2017 and improve upon the methods for more consistent sampling of all 64 hives. I am going to place group A colonies approximately 50 yards from those in group B in order to prevent forager bees from drifting to the test colonies that have queens. I will also be making splits a little sooner when more capped brood is present.

2017 RESULTS

The 2016 trials started by splitting purchased colonies that had very low mite counts. Most had no mites in a 300 bee sample, others had only one or two. By fall, a few colonies had climbed as high as 18 but most stayed quite low averaging just three mites per 300 bee sample. I had a 67% survival rate among the test colonies in the spring of 2017. There were no obvious correlations between colonies that underwent a brood break and those that did not. It was my belief that since the mite populations started so low the trial did not produce significant mite populations making it difficult to draw conclusions.

In 2017, 64 test colonies were created by dividing colonies overwintered from the previous year's trial. Colonies were split and began with higher mite levels averaging around two mites per 300 bee sample. By September the lowest mite level was 10 mites per 300 bees and the highest was an astonishing 94 per 300 bees! For perspective, most beekeepers consider treating above 10 mites in a 300 bee sample. Averages can be seen in the following table. No test colonies were alive by spring of 2018.

Further analysis of the mite population growth in all test colonies will be done for my final report. My preliminary conclusion from this project is that forcing a break in brood rearing may inhibit the population growth of mites within a hive slightly, but not enough to prevent lethal levels of mite infestation. However, forcing a brood break creates a vulnerable period for Varroa mites that when partnered with other methods of mite control, such as chemicals or drone comb removal could prove very effective. Despite significant losses during this project, creating and overwintering nucleus hives has a number of benefits. For instance, splits are done at a time when weather allows for local breeding efforts and smaller hive boxes are easier to manipulate and move. I intend to continue attempting to overwinter nucleus hives and experimenting with various methods of Varroa mite control during the break in brood rearing.

2017 mite levels

Location W	Average number of mites per 300 bees		
	Before Split	**September**	**Increase**
15 Queen Colonies	1.51	45.25	**x 32**
16 Cell Colonies	2.28	42.03	**x 18.5**

Location MA	Average number of mites per 300 bees		
	Before split	**September**	**Increase**
16 Queen Colonies	3.9	45.88	**x 11.8**

MANAGEMENT TIPS

1. When you establish nucleus colonies with a brood break, make colonies strong using capped brood and enough young nurse bees to cover it. A large population of older bees may fly to a nearby hive instead of waiting for the new queen to start laying.
2. In the fall, keep hive entrances small, and your inspection time to an absolute minimum.
3. Varroa mites pose a serious risk to all beekeepers. Monitor your mite levels and keep them low. Once mite levels get high (above 10) it requires drastic measures to save a hive.
4. Beehives are heavy and ergonomics are important! Use a stand so you can inspect a hive without being hunched over.
5. This project has lead me to believe that a break in brood rearing should be viewed as an opportunity for mite treatment and not a treatment itself.

COOPERATORS

Chris Kulhanek, Minneapolis, MN

Adrian Quiney, Beekeeper, Hudson, WI

Marla Spivak, Professor, University of Minnesota

PROJECT LOCATION

One apiary is on the north side of Diamond Lake in Dayton, MN. The other is just east of Wolsfeld Lake near Long Lake, MN.

OTHER RESOURCES

OTS Queen Rearing (and other related information). Mel Disselkoen, International Mating Nuc, Inc. **www.mdasplitter.com**

Michael Palmer, French Hill Apiaries, St. Albans, VT. Many presentations posted on YouTube at **www.youtube.com**.

Quiney Honey and Bee **www.youtube.com/channel/UCn6RmZ0om1dMRSBPgBoCSmQ**

Raising Soil pH Effectively in Acid Soils

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2015 to 2017

AWARD AMOUNT

$19,583

STAFF CONTACT

Meg Moynihan

KEYWORDS

amendments, biochar, fertility, lime, pH, soil, soil health, wood ash

A student helps prepare the virgin land before we till the area and add soil amendments.

PROJECT SUMMARY

Soil health, productivity, climate change, and the need to sequester carbon are challenges to building food and farming systems that will be sustainable long into the future. We farm in northeast Minnesota, a region where acid soils are common and present agricultural production challenges. Our goal was to simultaneously raise soil pH and increase soil health on our farm using organic methods. We were specifically interested in comparing the labor, cost, and effectiveness of applying mined lime, wood ash, biochar, and combination applications. We concluded that a combination of biochar + wood ash did the best job of increasing pH of our soils.

PROJECT DESCRIPTION

The Wolf Ridge Environmental Learning Center started an organic farm in 2009. Our goal is to provide all of the vegetables needed to serve 136,000 meals a year at our school cafeteria. We have built a processing facility for cleaning, cooling, and preparing the vegetables for the cafeteria, and we have kitchen gardens and an outdoor timber frame educational space for classes, workshops, and meals. This soil pH project we are undertaking is an essential part of our efforts for a productive, ongoing, price-stabilized local food

source for the school children, teachers, and parents who attend Wolf Ridge each year.

Our soils here are very acidic—the typical pH is less than 5.0. Our need to find a cost effective and sustainable way to raise the soil pH and improve soil health motivated us to do this project. We are currently farming a small parcel of cleared land, and most of our production is in large commercial high tunnel greenhouses. We are in the process of clearing 3.25 acres of land, where we have begun growing potatoes, carrots, onions, beans, broccoli, and squash; this is where we are conducting our soil amendment demonstration. We surrounded this area with deer fence, which is essential for field production of vegetables in our area.

We are using five different amendment treatments (plus a "no treatment" control) on 50 x 50' plots. We are evaluating actual pH change and soil health (nutrient retention, organic matter, and biological health).

In 2015, we established the field and conducted baseline soil testing. We cleared trees and brush, using a chain saw to cut the trees and a backhoe to dig out the stumps. We buried the logs and stumps below the future plow line. We removed large rocks and dug the entire area 3' deep, sifting the soil with the hoe.

In October, we marked out six 2,500 ft^2 test plots and pulled four soil samples from each plot, combining them to make one composite sample for each plot. The results confirmed that our entire demonstration field was uniformly acidic, with soil pH between 4.3 and 4.7.

In 2016, I met with NRCS soil scientists to review the 2015 soil tests and determine the amount of each amendment we should add. We also made calls to several biochar experts. We decided to put 350 lb of lime on plots 1 and 4. We applied 700 lb wood ash on plots 2 and 5. (Our original plan was to apply 1,000 lb, but considering the nutrient dense, high-valued wood pellets used in the Wolf Ridge furnaces, we decided 700 lb was enough.) Three of our plots also included biochar. One biochar expert recommended adding no more than 100 lb of biochar to 2,500 ft^2 plots. All of the biochar experts we consulted recommended that we inoculate the biochar with compost, but we did not. Instead, we added 100 lb dry biochar to plots 3, 4, and 5. Plot 6 was a control (no amendments added).

In the spring and early summer 2016 we finished preparing the area. More than 100 students and dozens of workers dug out tree roots and rocks with shovels and pick-axes. Then we tilled the soil with a walking tractor, following behind to grab roots and rocks that the tractor turned up as it bounced along.

On August 15, 2016 we added the amendments to the plots at the recommended rates (Table 1) and incorporated the amendments with a walking tractor. We then broadcast 8 lb buckwheat seed and tilled it into each plot for our first cover crop. In October, we pulled more soil samples. We allowed the cover crop to grow through fall, leaving the standing crop in the field to protect the soil.

In 2017, we planted a single row of potatoes down the middle of each field and maintained the remaining areas of each field with a rotation of cover crops. On June 20, we used a roto-tiller behind our walking tractor to plant 8 lb buckwheat in each test field. We lightly tilled the seeds in. In early August, we tilled the

Summer Intern Julia Kloehn supervises as David measures biochar.

buckwheat down the last week of July. On August 4 we incorporated 30 lb blood meal and 8 lb each of oats and pea cover crop seed into the soil.

We soil tested at eight spots in each treatment, sent the samples out for chemical testing and performed our own microscope biological assessments using the Berlese Funnel method.

Table 1. Treatments: Inputs and rates applied.

#1	#2	#3	#4	#5	#6
350 lb lime	700 lb wood ash	100 lb biochar	100 lb biochar + 350 lb lime	100 lb biochar + 700 lb wood ash	Control (nothing added)

RESULTS

Soil test data for pH, cation exchange capacity (CEC), calcium (Ca) and magnesium (Mg) showed clear positive results for the biochar + ash treatment (#5) (Table 2). All the plots suffered loss of soil organic matter (SOM), and the treatments that saw the greatest pH change suffered the greatest OM losses.

Table 2. Soil test results.

	Treatment 1 Lime			Treatment 2 Wood Ash			Treatment 3 Biochar		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
% Organic matter	10.5	6.6	8.0	10.3	5.8	5.8	11.1	3.9	4.7
CEC	8.5	6.4	19.2	7.1	9.5	10.3	7.7	4.1	6.1
pH	4.3	5.0	4.4	4.7	5.7	5.2	4.5	5.2	4.6
Mg (ppm)	6.4	54.0	112.0	9.2	92.0	80.0	7.3	52.0	59.0
Ca (ppm)	23.9	623.0	1,186.0	35.5	1281.0	1137.0	29.7	420.0	402.0
K (ppm)	2.6	52.0	122.0	3.4	90.0	112.0	3.3	40.0	61.0

	Treatment 4 Biochar + Lime			Treatment 5 Biochar + Ash			Treatment 6 Control		
	2015	2016	2017	2015	2016	2017	2015	2016	2017
% Organic matter	10.8	4.2	4.0	11.1	1.8	2.6	12.9	2.7	2.5
CEC	6.9	10.1	8.6	6.5	18.5	13.1	6.1	10.8	12.2
pH	4.6	5.3	5.6	4.7	7.1	6.4	4.7	5.5	5.3
Mg (ppm)	9.4	162.0	127.0	9.7	391.0	253.0	10	219.0	225.0
Ca (ppm)	32	1,084.0	1,054.0	36.6	2,976.0	1,886.0	35.3	1,178.0	1,244.0
K (ppm)	2.8	35.0	55.0	2.3	62.0	61.0	2.8	31.0	41.0

NOTE: All inputs were applied August 15, 2016.

SOM

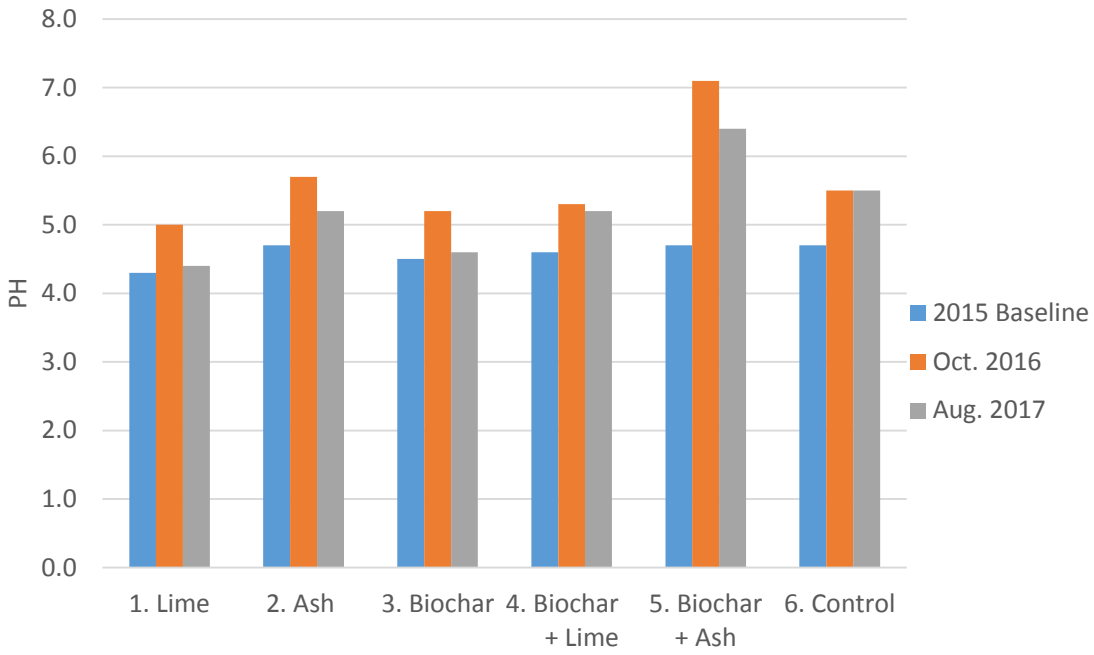
Soil organic matter was one of the wild cards in our study. My best guess as to why we saw such large reductions in SOM is oxidation. Our initial soil sampling in 2015 included the soil profile, which at that time included a leafy top layer that was mixed into the sample (being a forest before we were cropping the fields); I believe that layer was not fully incorporated into the soil profile and probably showed a higher then realistic value.

I also saw that the best pH rises correlated with the most OM being chewed up (oxidized): treatments #4, #5, and #6 showed the greatest loss of SOM while the same fields recorded the best increases in soil pH. Fortunately, the August 2017 sample results showed that all of the fields are beginning to see increases in OM. We credit cover cropping and other current management practices for the increases.

pH

The pH results were clear: only the biochar + ash treatment (#5) was effective in raising the pH levels above the control. In fact, the pH level stabilized and actually rose slightly in our last sampling.

Soil pH changes between baseline test November 2015 and subsequent tests October 2016 and August 2017.



CEC

The cation exchange capacity levels rose in all but the biochar only treatment (#3). From the data it appears that biochar suppressed the CEC levels in the biochar + lime treatment (#4) as well. We're not sure what to assume from these numbers, since the CEC increased in the control plot as well as in most of the treatments.

K

Potassium (K) levels in the lime (#1) and Ash (#2) treatments. Potassium did not increase to the same extent in the biochar-amended treatments and the control (treatments #3-6)

From the chemical analysis data, it was clear that treatment #5 (biochar + ash) produced more beneficial changes than any of the other plots, including treatment #2 (ash only). The ash-only plot had the second most significant change.

Soil Biology

We processed biological soil samples ourselves in 2016 using the Berlese funnel technique, which extracts living organisms, especially arthropods, from soil. We used a microscope to screen the samples to look for both the number and diversity of soil arthropod life.

Unfortunately, we didn't find arthropods in any of the soil samples, and we only found a few worms. My confidence level of the Berlese funnel soil sampling technique was low and did not improve when we used it again in 2017. So far, we have gleaned no useful biological results from this research project. On the other hand, the soil chemical tests produced informative results again in 2017.

The soil test results led us to several conclusions:

- The biochar + ash treatment (#5) produced superior results with regard to pH adjustment and nutrient retention, compared to other treatments.
- The control treatment (#6) showed similar or better pH adjustment compared to all other treatments except biochar + ash treatment (#5), which showed the best results with regard to pH adjustment.
- Soil organic matter was quickly consumed, especially in the biochar + ash (#5) treatment and the control (#6).

We had hoped to compare potato harvest across treatments. Unfortunately, we received 11" of extra rain and beavers built a dam adjacent to our fields. These factors combined to cause excess water to flow through our test plots, making the soil too wet to harvest. Visually, however, we could see that potatoes grown in the ash (#2) and biochar + ash (#5) treatments had grown the best and looked the greenest.

During 2017, our project generated two newspaper stories and a radio interview. In September, nearly 40 people attended a field day. We talked about how important soil health is for plant growth and set up learning stations including soil chemistry, soil biology, and soil physical considerations. Visitors could plainly see that the cover crops growing in the ash (#2) and biochar + ash (#5) treatments were taller, greener, and fuller than the cover crops in the other treatments.

CONCLUSIONS

We think the implications for farming are clear: biochar + ash treatment is clearly the most effective amendment for increasing pH, Ca, and Mg levels while also improving the CEC of our soils.

This conclusion has provided us with a path forward in transforming the remainder of our fields into balanced, rich and renewed soils for future production. Using ash instead of imported mined lime is a huge financial and environmental advantage for our farm. Wood ash is plentiful in our region and the cost is limited to moving it from the school stoves to the farm. On the other hand, the cost of mined lime and the distance it would have traveled to get to us over the next few years are significant.

Sourcing biochar is currently more costly and problematic. We need more research to design and build an efficient system to produce our own biochar. The environmental benefit of using biochar was significant. Not only will biochar increase the success of ash as a soil amendment, but some studies have shown that when biochar is incorporated into the soil, it sequesters carbon dioxide and helps reduce farming's negative contribution to climate change. More research is needed in this field to determine the retention time of the biochar (and carbon) that Midwestern soils typically sequester (hold).

MANAGEMENT TIPS

1. Use multiple biological soil sampling techniques to build confidence in assessing your soil.
2. Shipping costs will probably make biochar expensive, unless you find or create a local source.
3. Use wood or other pure biomass ash to eliminate the risk of heavy metal contamination.
4. Never underestimate the power of beavers! "Our" beavers built a 400' long dam in just a few weeks, flooding an area that had been dry for many years!

COOPERATORS

Mike Walczynski, USDA-NRCS, Duluth, MN

Morgan Williams and John Lavine, Biochar Solutions Inc., Lafayette, CO

Midwest Laboratories, Omaha, NE

DIRECTIONS

From Duluth MN, follow Hwy. 61 north for 66 miles. When you see a large sign marking the turn to Wolf Ridge, take a left on Cty. Rd. 6. Travel 4 miles to Cranberry Rd. Turn left and travel .7 miles; the farm will be on your right. Look for the sign!

OTHER RESOURCES

Cassells, Logie J. Your Essential Honeyberry Guide: Simple Ideas on establishing a healthy and productive orchard. Dartmouth, Nova Scotia: AgriForest Bio-Technologies, Ltd. **www.lovehoneyberry.com/essential-honeyberry-guide** (soils section of this publication is excellent).

Lowenfels, Jeff and Wayne Lewis. 2010. Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web. Portland: Timber Press.

Meyer, John. 2013. Kwik-Key to Soil-Dwelling Invertebrates. Raleigh: Vision Press. **www.cals.ncsu.edu/course/ent525/soil/ident.html**

Smillie, Joe and Grace Gershuny. 1999. The Soul of Soil. 4th Ed. White River Junction, VT: Chelsea Green Publishing, Inc.

The Scientific Basis for Biochar as a Climate Change Mitigation Strategy: Does it Measure Up? Noel P. Gurwick1 Charlene Kelly2 Pipa Elias3. **www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/Biochar-Climate-Change-Mitigation-Strategy-Does-It-Measure-Up.pdf**

Soil Health Research in Southwest Minnesota

PRINCIPAL INVESTIGATORS

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PROJECT DURATION

2015 to 2017

AWARD AMOUNT

$16,814

STAFF CONTACT

Cassie Dahl

KEYWORDS

cover crops, Haney soil test, soil health, soil nitrate

Fall strip-till application on the Christoffer property.

PROJECT SUMMARY

This project was designed to provide southwestern Minnesota farmers with soil health and fertility data to show how cover crops can add value to their farm operations. This research focuses on four farms that have established 50 acre cover crop plots specifically for cover crop research. Soil samples collected and analyzed from the plots over three growing seasons provided sufficient data points to statistically analyze the economic and environmental impacts of cover crop management. The Haney Soil Health Test (Haney Test) and the Nitrate Soil Test were utilized to collect and measure baseline data as well as the changes in soil health and fertility that can be attributed to cover crop impacts.

PROJECT DESCRIPTION

The project is located on four farm sites; two in Jackson County and two in Nobles County. The cooperators on this project consist of four farmers, the Heron Lake Watershed District, and Extended Ag Services, Inc., all of whom are working under an Environmental Protection Agency (EPA) 319 Grant.

Through the EPA 319 project, each farmer established 50 acres of cover crops. Tillage transects, infiltration measurements, and soil samples were taken over three growing seasons to gauge cover crop success. The benefits of cover crops, which include reduced soil erosion and compaction, increased water infiltration to prevent runoff, nitrogen translocation back to the root zone, increased organic matter, and improved wildlife habitat are well documented. We are unaware, however, of any first-hand data about cover crop effects on soil fertility and soil health for southwest Minnesota. The need for first-hand data about cover crop effects is the main reason we applied for this grant.

The cover crops planted at the four project sites included: 30 lb/A cereal rye, 5 lb/A tillage radish, 2 lb/A clover, 2 lb/A purple top turnip, and 6 lb/A oats. Seeding was done in August-September either aerially or drilled depending on the crop in the field and the fall weather. Cover crop termination was completed in late April or early May.

Andy Nesseth, with Extended Ag Services, Inc., collected soil samples from each of the four cover crop sites. Three control samples were taken to develop baseline data. Soil samples were taken from the following sites on each farm:

- a non-agricultural site with perennial grass cover. This site should provide us with optimal soil health characteristics, which provides an indication of where we want our soil health characteristics to be;
- an agricultural site with no cover cropping history. This will provide soil characteristic data similar to our starting point; and
- four agricultural sites with 4-5 years of cover crop history.

Samples from these sites will provide information on the long-term impacts of cover crop management. All soil samples were tested by the Haney Test and the Nitrate Soil Test. The Haney Test was developed to not only test for basic soil nutrient parameters, but also to determine the level of microbial activity in the soil. The different soil parameters tested in the Haney Test are analyzed mathematically to give a Soil Health Condition. The Soil Nitrate Test is an accepted Best Management Practice used to make accurate nitrogen fertilizer recommendations.

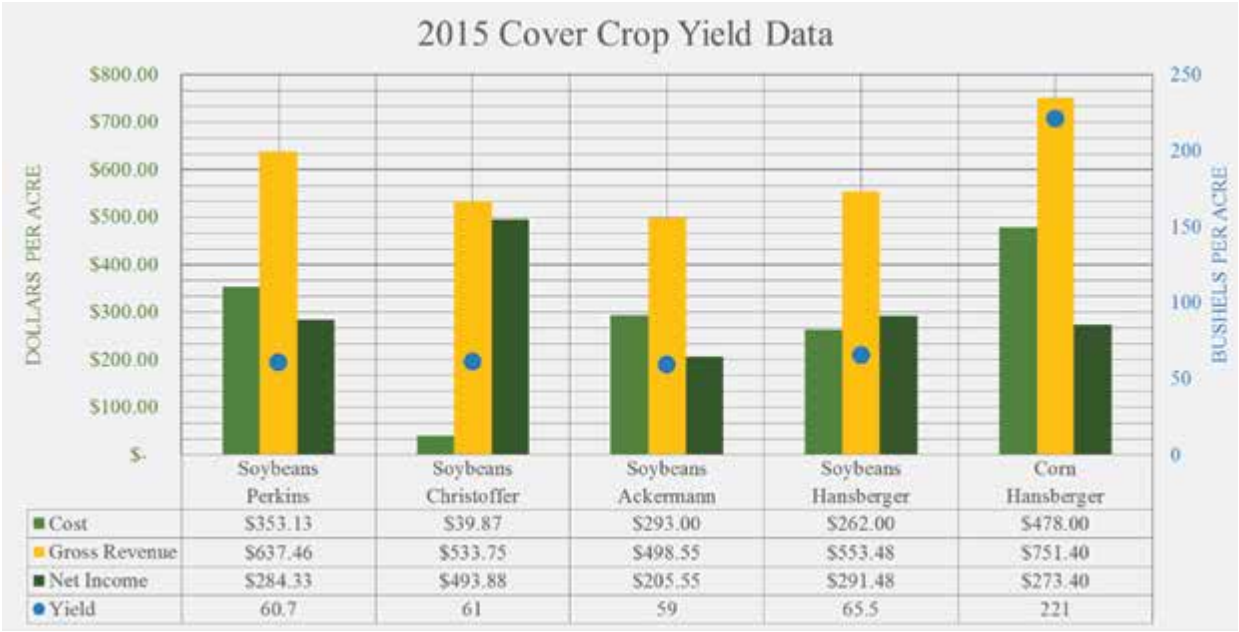
Total crop costs were calculated using the cost of crop seed, fertilizer, herbicides, pesticides, crop insurance, machinery use (fuel, custom farming, and rentals), and cover crop seed including application and termination expenses.

Our four farmer collaborators were:

1. Principal investigators, Jerry and Nancy Ackermann, have been farming for 38 years and are active in pursuing on-farm research and test plot opportunities. Their crop rotation includes corn, soybeans, and alfalfa on 1,050 acres. For the past 11 years, the Ackermann's have incorporated 350 acres of no-till soybeans and 350 acres of strip-till corn in their rotation. They use alfalfa as a cash crop and nutrient management tool in their alfalfa-corn rotation.
2. Dave Christoffer has been farming for 43 years. He farms 220 acres that he converted to strip-till production in 1992. He also rents 300 acres to two different individuals and works with them to incorporate conservation tillage and cover crops in their production systems.
3. Jerry and Terry Perkins have been farming for 40 years. Their farm consists of 627 acres of land. They rent 415 acres to a young farmer who uses no-till practices in his soybeans and strip-till practices in his corn crop.
4. Tim Hansberger has been farming for 10 years. His educational background includes a degree in Agronomy Production from the University of Minnesota. He farms 645 acres of no-till soybeans and strip-till corn.

2015 YIELD RESULTS AND OBSERVATIONS

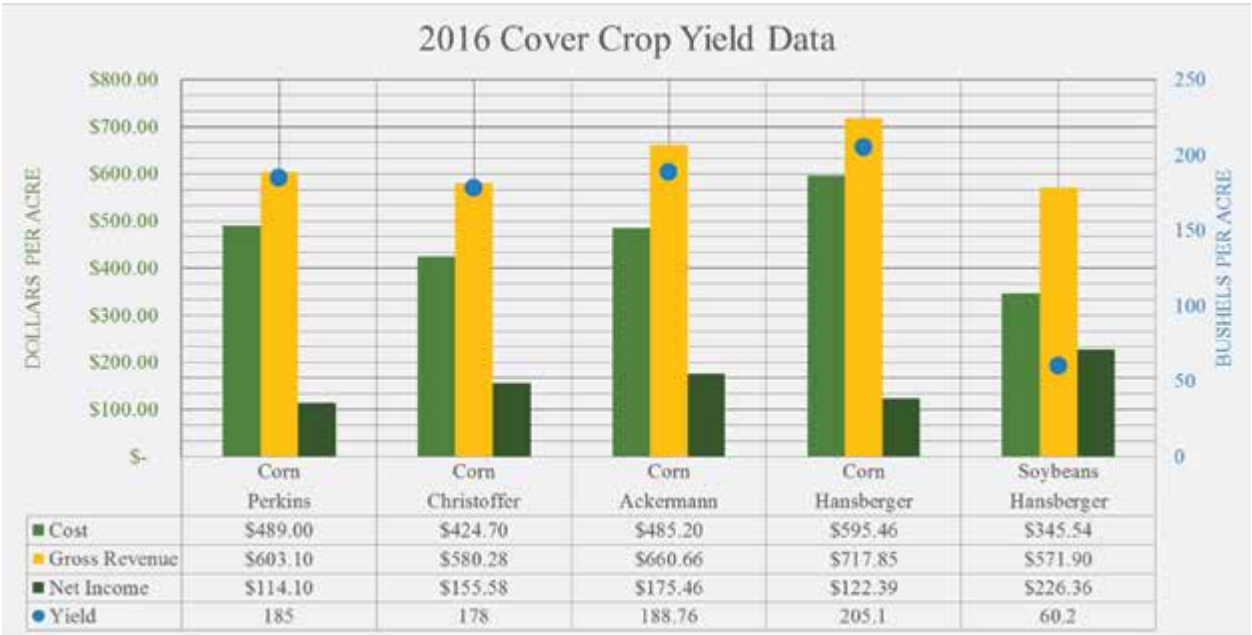
We received 6" of rain in the 10 day period following harvest. There was no ponding of water on the fields where cover crops had been planted, even on areas heavily impacted by trucks and grain carts. Neighboring fields showed ponded water on areas that had been tilled to relieve compaction.



	Soybeans Perkins	Soybeans Christoffer	Soybeans Ackermann	Soybeans Hansberger	Corn Hansberger
Cost	$353.13	$39.87	$293.00	$262.00	$478.00
Gross Revenue	$637.46	$533.75	$498.55	$553.48	$751.40
Net Income	$284.33	$493.88	$205.55	$291.48	$273.40
Yield	60.7	61	59	65.5	221

2016 YIELD RESULTS AND OBSERVATIONS

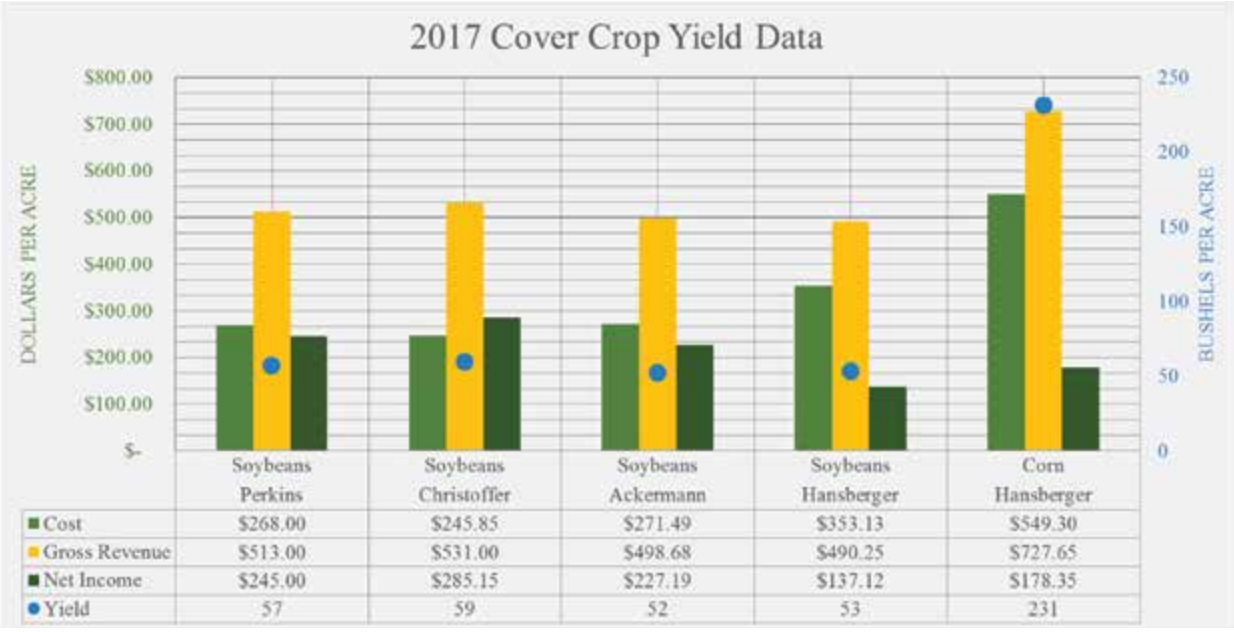
This summer while traveling between farms in the tractor, we noticed cornfield end rows that had a noticeable "dip" in the height of the corn. By that we mean the corn was shorter where trucks and wagons drove and had compacted the soil on the way to the driveway leaving the fields. However, our fields that had a cover crop on the end row previous to planting corn did not display the "dip". We feel this shows that the cover crop had relieved the compaction created by trucks parked in the fields. We also saw a comparison between two of our fields where one had cover crops last year and one that didn't. We again had ponding on the end rows of the field without cover crops before planting this spring.



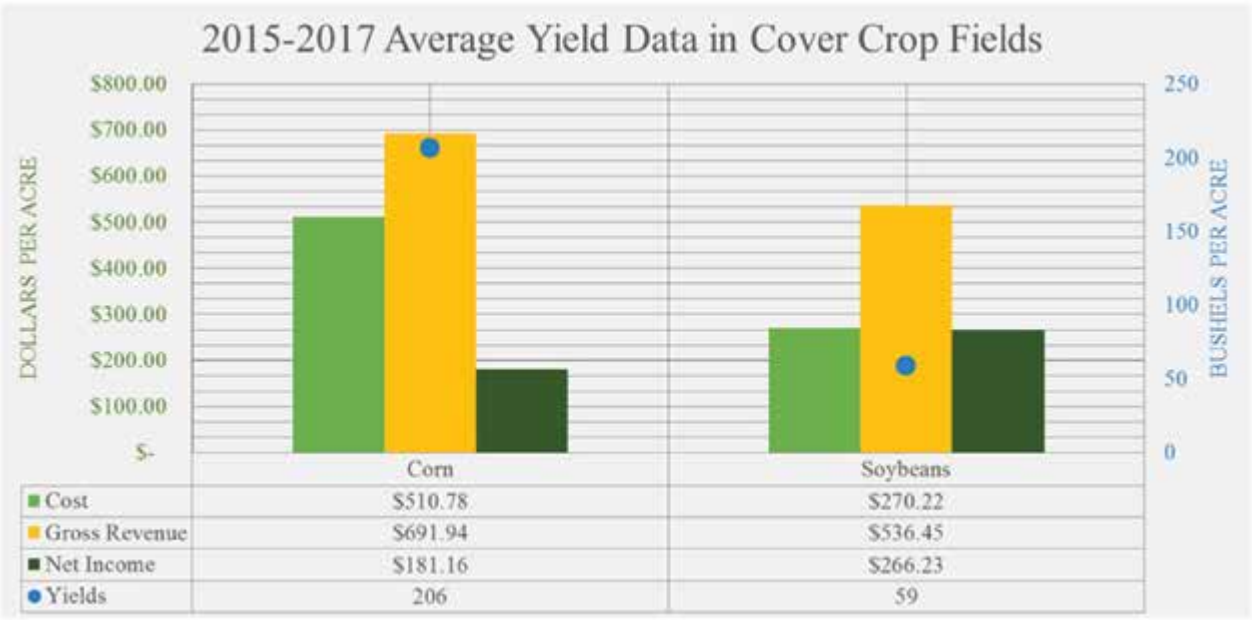
	Corn Perkins	Corn Christoffer	Corn Ackermann	Corn Hansberger	Soybeans Hansberger
Cost	$489.00	$424.70	$485.20	$595.46	$345.54
Gross Revenue	$603.10	$580.28	$660.66	$717.85	$571.90
Net Income	$114.10	$155.58	$175.46	$122.39	$226.36
Yield	185	178	188.76	205.1	60.2

2017 YIELD RESULTS AND OBSERVATIONS

We found that we have great weed control with cover crops and plan to eliminate some of our herbicide applications in 2018. With the wet 2017 fall, having the cover crop cover helped us get the soybeans harvested and get the grain carts and semis into the fields without getting stuck.



	Soybeans Perkins	Soybeans Christoffer	Soybeans Ackermann	Soybeans Hansberger	Corn Hansberger
Cost	$268.00	$245.85	$271.49	$353.13	$549.30
Gross Revenue	$513.00	$531.00	$498.68	$490.25	$727.65
Net Income	$245.00	$285.15	$227.19	$137.12	$178.35
Yield	57	59	52	53	231



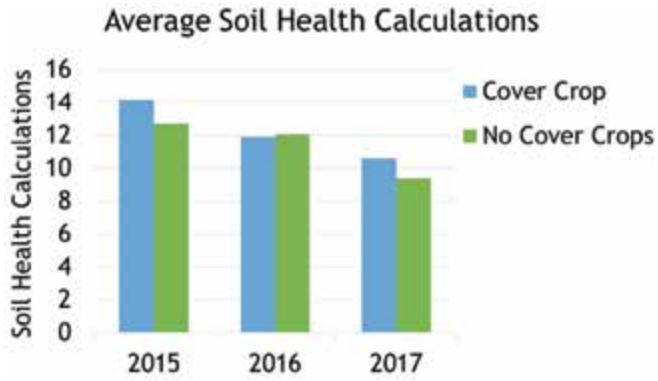
	Corn	Soybeans
Cost	$510.78	$270.22
Gross Revenue	$691.94	$536.45
Net Income	$181.16	$266.23
Yields	206	59

Each field had six to ten soil zones and three control sample zones. These control sample zones included a grass covered site, a site with minimal history of cover crops (less than 1 year), and a site with multiple years (2-5 years) of cover crop history. In November 2015 and 2016, soil samples were collected by Andy Nesseth, Extended Ag Services from each site and submitted to Minnesota Valley Testing Lab.

Haney Soil Test Results

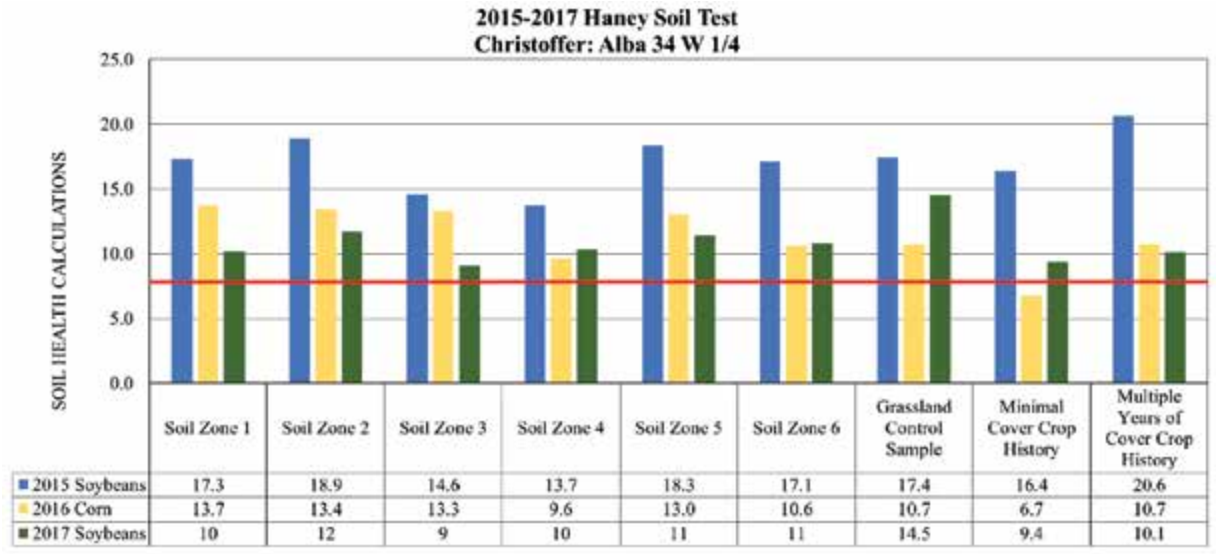
Several samples were analyzed and given an overall "Soil Health Calculation" to determine adequate soil health. A number greater than seven indicates adequate soil health. The majority of samples over the 3 years of the study had soil health number over seven. When comparing all cover cropped fields to fields with no or minimal cover crops, the soil health calculations were higher in the cover cropped field two out of the 3 years. Over the project duration, cover crops had a positive effect on soil health.

When comparing field plots, there is a decline in soil health from 2015 to 2017. The grassland areas used as controls also showed a decline in soil health numbers over the 3 years. The testing methods were not changed from year to year so a lower calculation could be the result of the following factors: increase in water within the soil profile can decrease microbial activity due to lack of nutrient availability and lack of gas exchange; colder soil temperatures; and/or an increase in residue amounts can increase microbial activity.



The individual farm 2015-2017 Haney test results are as follows:

Christoffer Farm



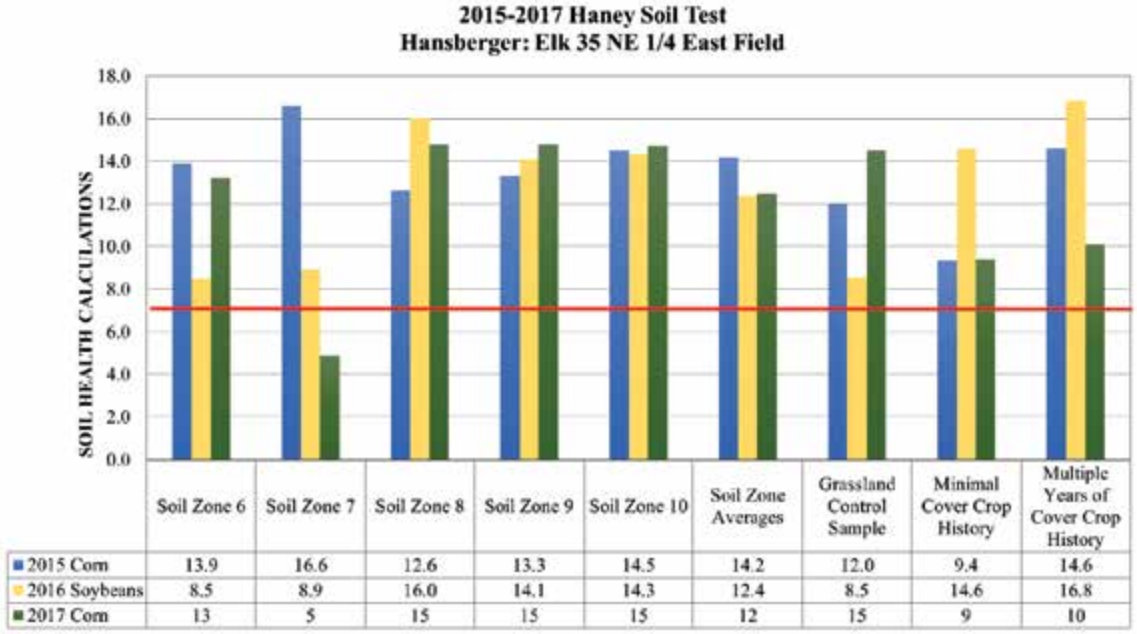
	Soil Zone 1	Soil Zone 2	Soil Zone 3	Soil Zone 4	Soil Zone 5	Soil Zone 6	Grassland Control Sample	Minimal Cover Crop History	Multiple Years of Cover Crop History
2015 Soybeans	17.3	18.9	14.6	13.7	18.3	17.1	17.4	16.4	20.6
2016 Corn	13.7	13.4	13.3	9.6	13.0	10.6	10.7	6.7	10.7
2017 Soybeans	10	12	9	10	11	11	14.5	9.4	10.1

2015: The average soil health calculation for the six soil zones was 16.7. The grassland area was at 17.4 and the highest soil calculation zone was 20.6 for the field with multiple years of cover crop history. The lowest calculation was 16.4 from the minimal cover crop history field.

2016: The average soil health calculation for the six soil zones was 12.3. The grassland and the multiple years of cover crop history sample had a calculation of 10.7. The lowest calculation was 6.7 from the minimal cover crop history field.

2017: The average soil health calculation for the six soil zones was 11. The lowest calculation was found on the minimal cover crop history field and the highest in the grassland area.

Hansberger Farm



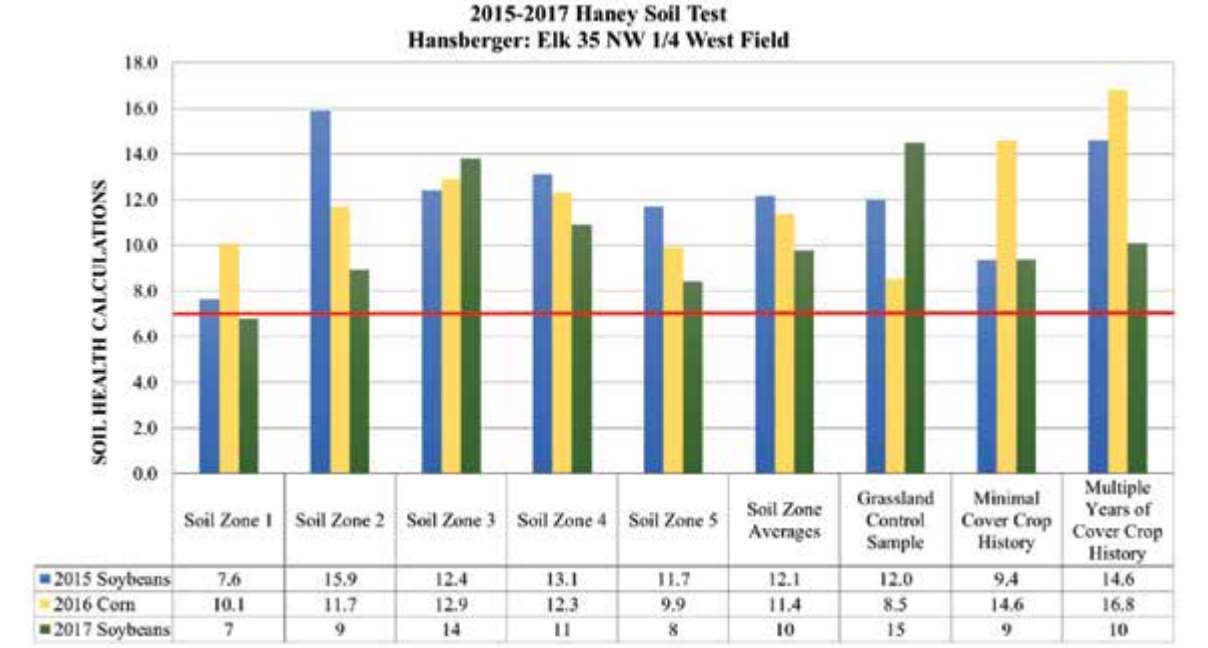
	Soil Zone 6	Soil Zone 7	Soil Zone 8	Soil Zone 9	Soil Zone 10	Soil Zone Averages	Grassland Control Sample	Minimal Cover Crop History	Multiple Years of Cover Crop History
2015 Corn	13.9	16.6	12.6	13.3	14.5	14.2	12.0	9.4	14.6
2016 Soybeans	8.5	8.9	16.0	14.1	14.3	12.4	8.5	14.6	16.8
2017 Corn	13	5	15	15	15	12	15	9	10

2015: The average soil health calculation for the ten soil zones was 13.2. The control zones showed that the grassland area was at 14.6 and had the highest soil health calculation. The lowest control sample calculation was 9.35, from the minimal cover crop history site.

2016: The average soil health calculation for the 10 soil zones was 11.9. The control zones showed that the grassland area was at 8.5 and had the lowest soil health calculation. The minimal cover crop history site showed a result of 14.6.

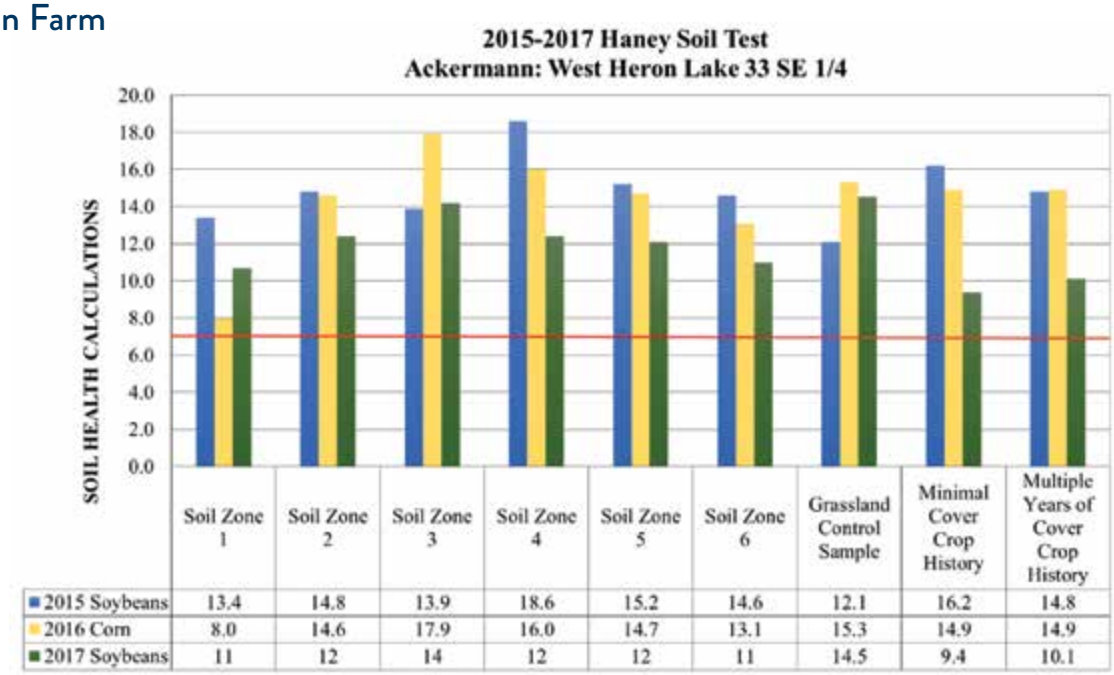
2017: The average soil health calculation for the 10 soil zones was 11.1. As seen the last 2 years, the grassland area had the highest calculation and the minimal crop history the lowest.

Hansberger Farm



	Soil Zone 1	Soil Zone 2	Soil Zone 3	Soil Zone 4	Soil Zone 5	Soil Zone Averages	Grassland Control Sample	Minimal Cover Crop History	Multiple Years of Cover Crop History
2015 Soybeans	7.6	15.9	12.4	13.1	11.7	12.1	12.0	9.4	14.6
2016 Corn	10.1	11.7	12.9	12.3	9.9	11.4	8.5	14.6	16.8
2017 Soybeans	7	9	14	11	8	10	15	9	10

Ackermann Farm



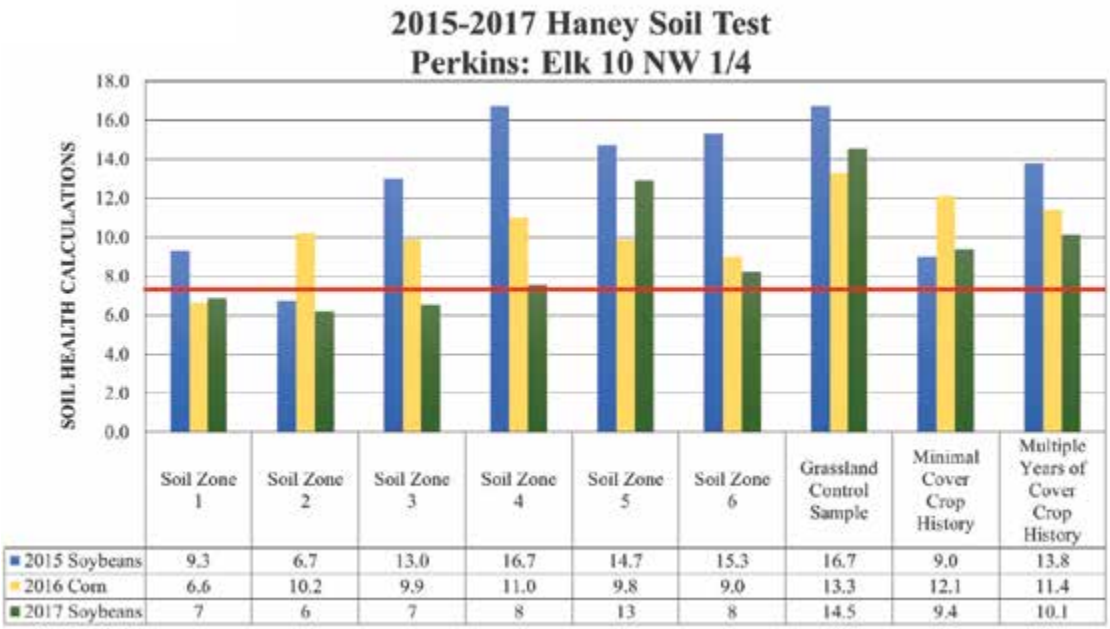
	Soil Zone 1	Soil Zone 2	Soil Zone 3	Soil Zone 4	Soil Zone 5	Soil Zone 6	Grassland Control Sample	Minimal Cover Crop History	Multiple Years of Cover Crop History
2015 Soybeans	13.4	14.8	13.9	18.6	15.2	14.6	12.1	16.2	14.8
2016 Corn	8.0	14.6	17.9	16.0	14.7	13.1	15.3	14.9	14.9
2017 Soybeans	11	12	14	12	12	11	14.5	9.4	10.1

2015: The average calculation for the six soil zones was 15.1. The grassland area calculation was 12.1. The highest soil health calculation of 16 was on the field with the minimal years of cover crop history.

2016: The average calculation of the six soil zones was 14.0. The grassland area was at 15.3. The calculations from the minimal cover crop sample and the multiple years of cover crops sample were the same - 14.9.

2017: The average calculation of the six soil zones was 12.1. The grassland area soil health calculation was the highest at 15. The minimal cover crop sample was the lowest calculation at 9.4.

Perkins Farm



	Soil Zone 1	Soil Zone 2	Soil Zone 3	Soil Zone 4	Soil Zone 5	Soil Zone 6	Grassland Control Sample	Minimal Cover Crop History	Multiple Years of Cover Crop History
2015 Soybeans	9.3	6.7	13.0	16.7	14.7	15.3	16.7	9.0	13.8
2016 Corn	6.6	10.2	9.9	11.0	9.8	9.0	13.3	12.1	11.4
2017 Soybeans	7	6	7	8	13	8	14.5	9.4	10.1

2015: The average soil health calculation for the six soil zones was 12.6. The grassland area calculation was 16.7 and the highest soil health calculation. The field with minimal cover crop history was 8.98.

2016: The average soil health calculation for the six soil zones was 9.4. The grassland area had a reading of 13.3, the highest soil health calculation. The field with minimal cover crop history was 11.4.

2017: The average soil health calculation for the six soil zones was 8.0. This was the lowest reading compared to the three control zones. The grassland area was 14.5 and the minimal cover crop field was 9.4.

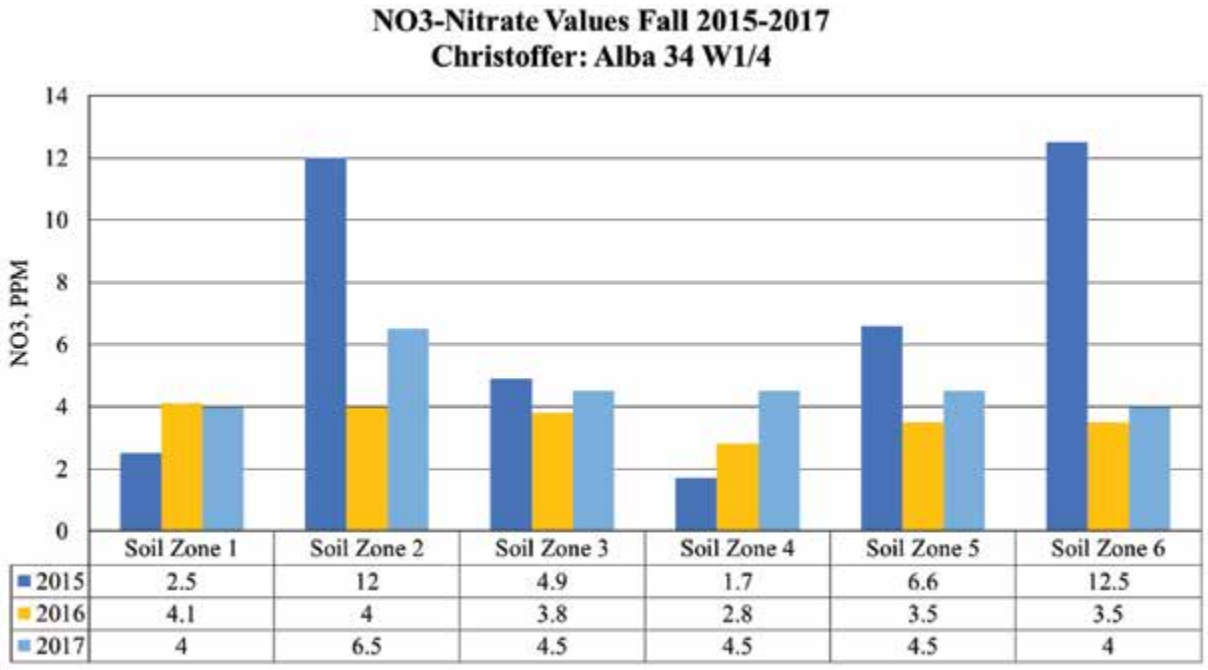
SOIL NITRATE RESULTS

Nitrate values are expressed as parts per million. Soil samples were taken from 0 – 6". Values have been extremely variable across all the zones and farms, which is typical for nitrate sampling.

In 2015 and 2016, all zones 1-6 across the four farms had successful cover crop establishment. Establishment in 2017 was affected by early cold weather and was not as good as the previous 2 years. Overall nitrate values were lower than expected in these fine textured, high organic matter soils. We think that, from the data, cover crops may be immobilizing nitrogen and tying it up as biomass. However, there is no evidence that less nitrogen is needed in the crop following the cover crop indicating that the release of nitrogen from the cover crop is minimal. The lower nitrogen we've seen in our samples is likely in biomass and not in the organic form, NH3 and NH4. There is a possibility that the H3A method we used for extracting inorganic nitrogen was less efficient and the test levels lower than expected from extractions using the ammonium acetate tests for NH3 and NH4.

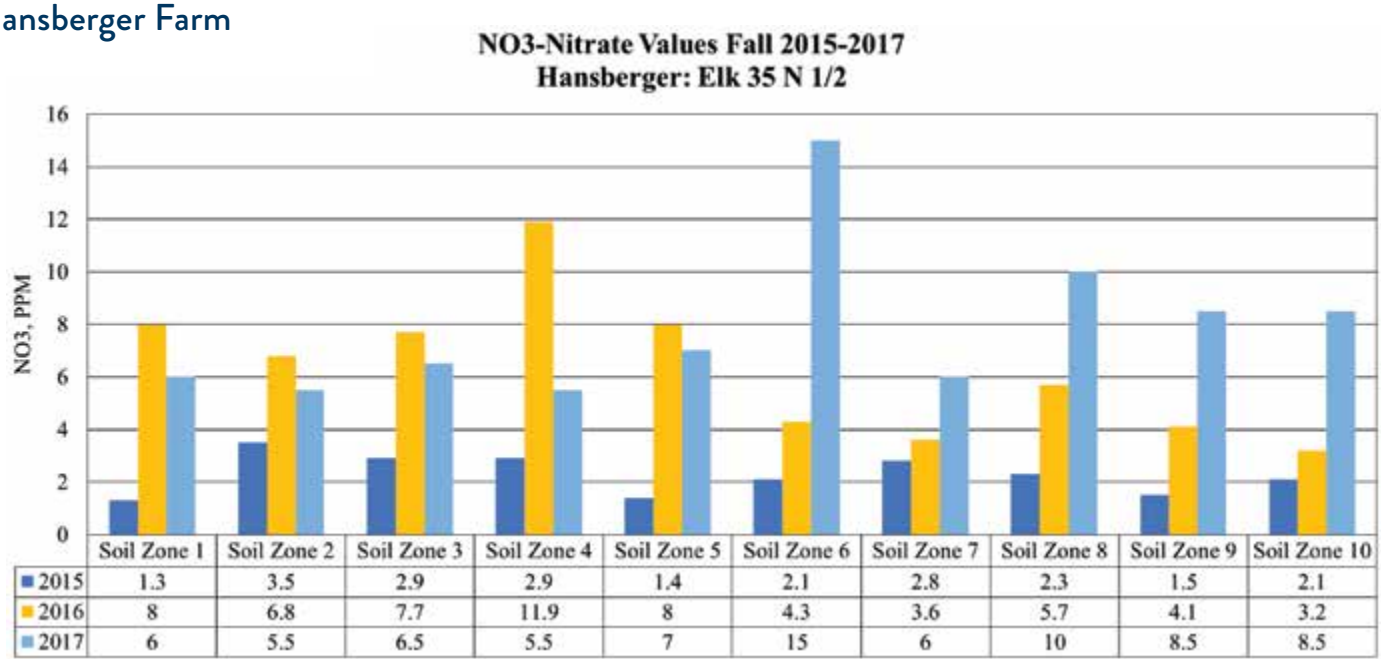
The individual farm 2015-2017 nitrate test results are as follows:

Christoffer Farm



	Soil Zone 1	Soil Zone 2	Soil Zone 3	Soil Zone 4	Soil Zone 5	Soil Zone 6
2015	2.5	12	4.9	1.7	6.6	12.5
2016	4.1	4	3.8	2.8	3.5	3.5
2017	4	6.5	4.5	4.5	4.5	4

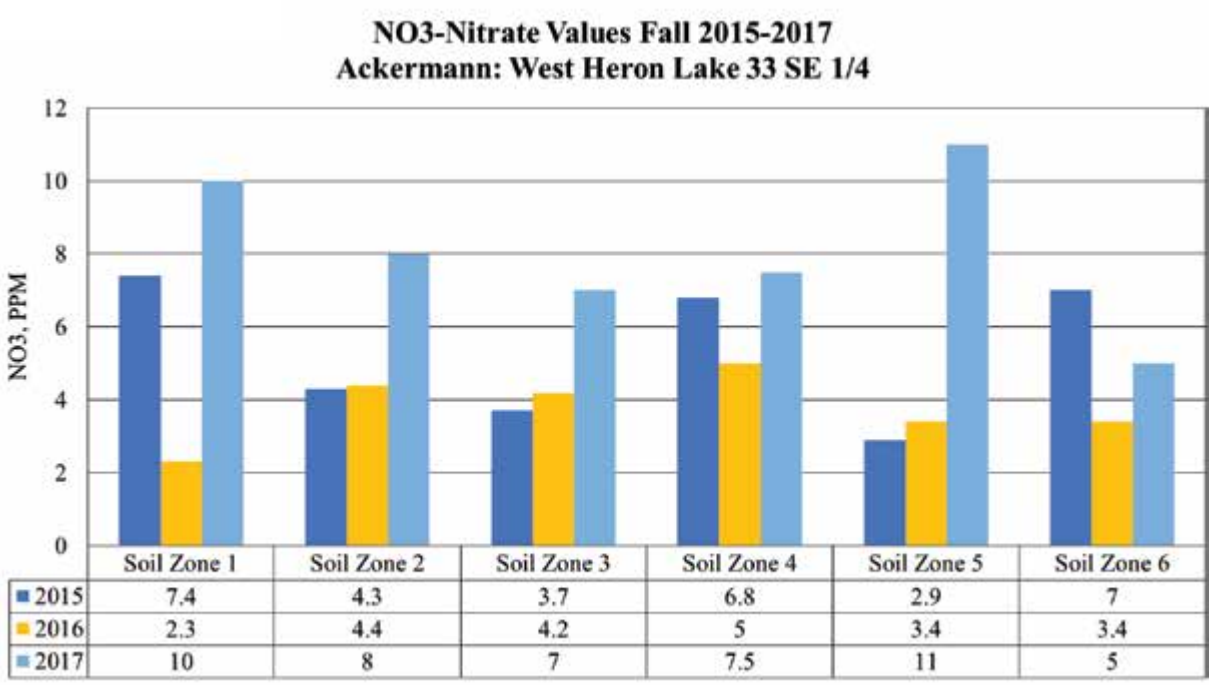
Hansberger Farm



	Soil Zone 1	Soil Zone 2	Soil Zone 3	Soil Zone 4	Soil Zone 5	Soil Zone 6	Soil Zone 7	Soil Zone 8	Soil Zone 9	Soil Zone 10
2015	1.3	3.5	2.9	2.9	1.4	2.1	2.8	2.3	1.5	2.1
2016	8	6.8	7.7	11.9	8	4.3	3.6	5.7	4.1	3.2
2017	6	5.5	6.5	5.5	7	15	6	10	8.5	8.5

Values were fairly consistent across the zones. Zones 4-7 had successful cover crop mix established in August 2015 and persisted with a favorable fall. Zones 1-3 and 8-10 did not have a cover crop planted in 2015. There does not appear to be a strong correlation with measured nitrate levels and cover crop establishment.

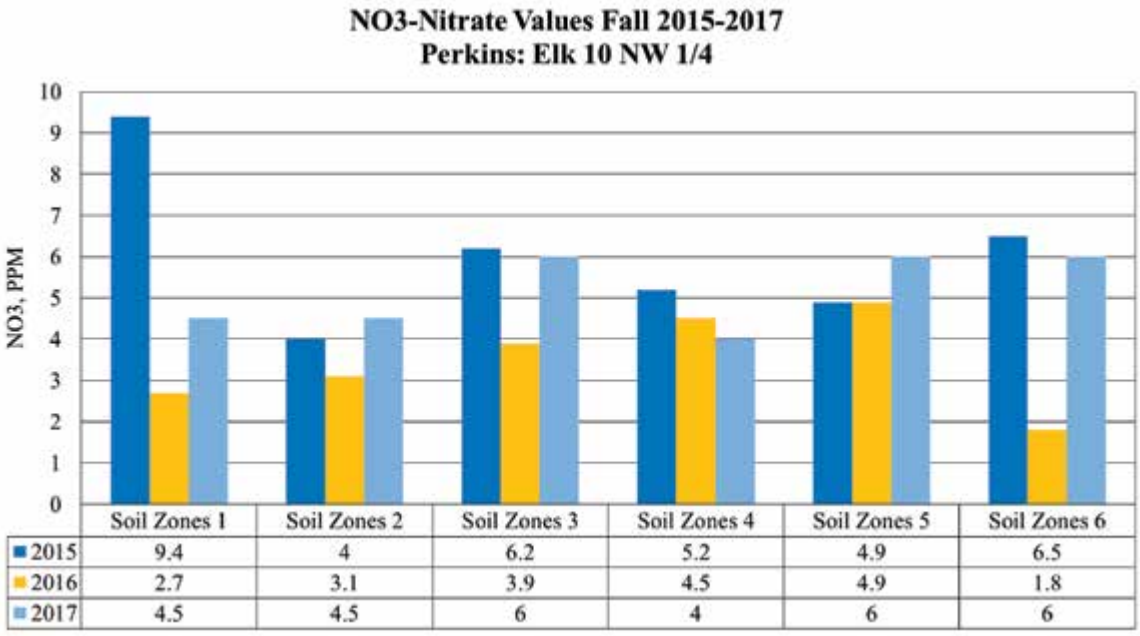
Ackermann Farm



	Soil Zone 1	Soil Zone 2	Soil Zone 3	Soil Zone 4	Soil Zone 5	Soil Zone 6
2015	7.4	4.3	3.7	6.8	2.9	7
2016	2.3	4.4	4.2	5	3.4	3.4
2017	10	8	7	7.5	11	5

On this farm, there does appear to be a correlation with measured nitrate levels and cover crop establishment.

Perkins Farm



	Soil Zones 1	Soil Zones 2	Soil Zones 3	Soil Zones 4	Soil Zones 5	Soil Zones 6
2015	9.4	4	6.2	5.2	4.9	6.5
2016	2.7	3.1	3.9	4.5	4.9	1.8
2017	4.5	4.5	6	4	6	6

There appears to be higher overall nitrate levels in the cover crop zones when compared to the control samples.

MANAGEMENT TIPS

1. Plant multi-species blends to help ensure establishment and provide benefits to the soil biota.
2. Cover crops seem to establish best when planted in early maturing varieties of soybeans. The early leaf drop in these varieties helps in establishment.
3. Cover crop seeding should be done when the soybean leaves are yellowing or during the last week of August.
4. If a drill or ground rig isn't available to do early season seeding into corn, it may be better to wait until August for a high clearance seeder.
5. Cover crops can be very helpful with harvesting in wet falls. They kept our combines, grain carts and semis from getting stuck.

COOPERATORS

Dave Christoffer, Okabena, MN

Jerry and Terry Perkins, Worthington, MN

Tim Hansberger, Worthington, MN

Andy Nesseth, Extended Ag Services, Inc., Lakefield, MN

Jan Voit and Catherine Wegehaupt, Heron Lake Watershed District, Heron Lake, MN

PROJECT LOCATION

Jerry and Nancy Ackermann: From Lakefield, travel 5¼ miles west on Jackson Cty. Hwy. 14 (820th St.). Go ¼ mile north. Cover crop site is on the left.

Dave Christoffer: From Brewster, travel 2 miles south on Hwy. 264. Go east on Jackson Cty. Rd. 14 (820th St.) for 3 miles. Turn north on 340th Ave. The cover crop site is on the right, extending for a mile.

Jerry and Terry Perkins: From Worthington, go 8 miles north on US Hwy. 59. Then travel 1¾ miles west on 170th St. Cover crop site is on the left.

Tim Hansberger: From Worthington, at the intersection of Oxford St. and Hwy. 59, go 4 miles north on Hwy. 59. Go west for ½ mile. The cover crops are seeded on both sides of the tree line in the south half of the field.

OTHER RESOURCES

No-Till Farmer. Website: **www.no-tillfarmer.com**

Farm Journal. The High Yield Conservation section. Website: **www.agweb.com/farmjournal**

Sustainable Agriculture Network. Managing Cover Crops Profitably: Third Edition. Beltsville, MD. 301-504-5236.
Website: **www.sare.org/publications/covercrops/covercrops.pdf**

Demonstrating Vermicomposting for Soil Health in the Upper Midwest

PRINCIPAL INVESTIGATOR

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Stone's Throw Urban Farm
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PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$18,459

STAFF CONTACT

Cassie Dahl

KEYWORDS

compost, garden, produce, transplants, vermicomposting, worms

A neighbor's grandmother serenades us while we add brewery waste and wood chips to the compost pile.

PROJECT SUMMARY

Stone's Throw Urban Farm is building a northern climate vermicompost system to demonstrate the production and incorporation of vermicompost into greenhouse transplant potting mixes. We are building the system to maximize efficiency and savings, using free, locally available waste inputs. Our goal is to develop a system that can be adapted across the scale and geography of organic growing to replace purchased inputs for transplant production.

PROJECT DESCRIPTION

Stone's Throw is a 3-acre certified organic urban vegetable farm. We grow our crops on 16 formerly vacant lots in the Twin Cities. We use intensive growing methods and produce more than 50,000 lb of produce each season. We market through a regional producers' cooperative, sell to several dozen wholesale accounts, operate a 200-member CSA, and attend two weekly farmers markets. In addition to three farm owners, we have two seasonal employees.

On the urban lots we farm, the soil is generally low in organic matter, lacks structure, biodiversity, and nutrient availability. Our limited space, and the fact that we don't own the land we farm, have kept us from investing in amending the soil enough to realize its production potential.

These challenges are not unique to our operation. Finding the most practical and economically viable way to build healthy, resilient soils is a challenge that many growers in urban, peri-urban, and rural areas face. Buying off-farm inputs to manage soils is a major expense and we think it can be reduced by creating on-farm fertility building systems.

Our farm already uses a variety of soil building practices: building thermophilic compost from spent brewery grains, applying generous amounts of compost and composted turkey manure to our fields, using a rotary hoe for less disruptive horizontal tillage, and using crop rotations and cover crops when possible in our limited growing space.

Since 2014 we have been building 20-40 cubic yard compost piles, combining equal parts brewery waste from nearby breweries and wood chips from a local tree care service, and adding excess plant matter from the farm. We've been incorporating this compost in our transplant media and spreading it on our fields.

We first learned about vermicompost as a soil health strategy during an agricultural exchange in Cuba, where vermiculture is an integral piece of an agro-ecological farm system. We have since learned how it can be used in northern climates. For example, Michigan State University horticulture professor John Biernbaum has conducted research and developed a vermicompost system robust enough to process 100,000 lb of cafeteria waste each year.

Originally, we designed a system that involved both digging a tunnel and using windrows. After consulting Dr. Biernbaum as we started the project, we decided to simplify our approach to incorporate vermicomposting into our existing (thermophilic) composting practice. By keeping worms in these larger piles, we should need less maintenance to regulate major variables of temperature and moisture. Worms move around and through piles of this size to find their ideal climate, and using a large pile offers a much greater chance they will survive over winter. Anecdotally, we have found a large number of worms in our compost piles throughout the early spring, which suggests success in sustaining worms through the winter.

2016 RESULTS

We inoculated one of our compost piles with 15 lb of worms and will monitor the compost pile through the winter. We are curious to see how worm population changes and how the addition of worms impacts pile metabolism. Throughout winter we will test activity and metabolism in the pile.

In the spring we will harvest vermicompost from the inoculated pile and incorporate into the potting mix we use for greenhouse transplants. We will create two transplant mixtures, one incorporating vermicompost and the other incorporating inoculated thermophilic compost. We plan to measure chlorophyll, leaf nitrate, and above and below ground biomass of three different crops. We will also evaluate the nitrate content of water draining from flats.

2017 RESULTS

We monitored the compost pile through the winter and the worms were still alive when we began checking our compost piles in the spring. Piles that had been inoculated with worms had broken down more quickly and had lower temperatures.

We then used this vermicompost as an ingredient in our transplant media, compared it to a potting media with composted sheep manure, and a potting media without any added compost. We trialed three trays of each potting media for three different crops: Toscano Kale, Dr. Wyche's Tomatoes, and Alkindus Butterhead Lettuce.

We collected composted sheep manure from a sheep farm in Bloomington, MN. Though we were hesitant to use composted sheep manure in the fields, we were curious if it would make sense as a potting media input. All the potting medium had the same base, which was: 3 bags of Mississippi Topsoil potting soil, 2 cups of Sustane and composted turkey manure. The difference was then based on whether or not sheep manure was added to the mix, or if 5 gal of vermicompost was.

Working with a horticulture student from the University of Minnesota, we recorded plant growth over the course of 4 weeks, and looked at the pH, nitrogen, phosphorus, potassium, organic matter, pH of run off, microbial activity, and electrical conductivity of composts.

By the end of the trial we could see a clear difference between the trays with compost in the potting media vs. those without. Tomato and lettuce trays preformed slightly better with the sheep compost. Kale trays performed slightly

A comparison of potting media. Left tray had composted sheep manure, center tray had vermicompost, and right tray had no compost.

better with the vermicompost. Measurements were taken from 10 random plants in each control group and averaged to create the graph below. Given the relatively small number of trays that we were able to test in our spring greenhouse, it is hard to know how other variables (light exposure, temperature, moisture) may have impacted these results.

Looking at the pH, nitrate level, and electrical conductivity of each potting media helped us obtain other helpful information about each medium. We use pH as a measure for the balance of nutrients available in the media and electrical conductivity is one possible measure of the quantity of nutrient availability in soil.

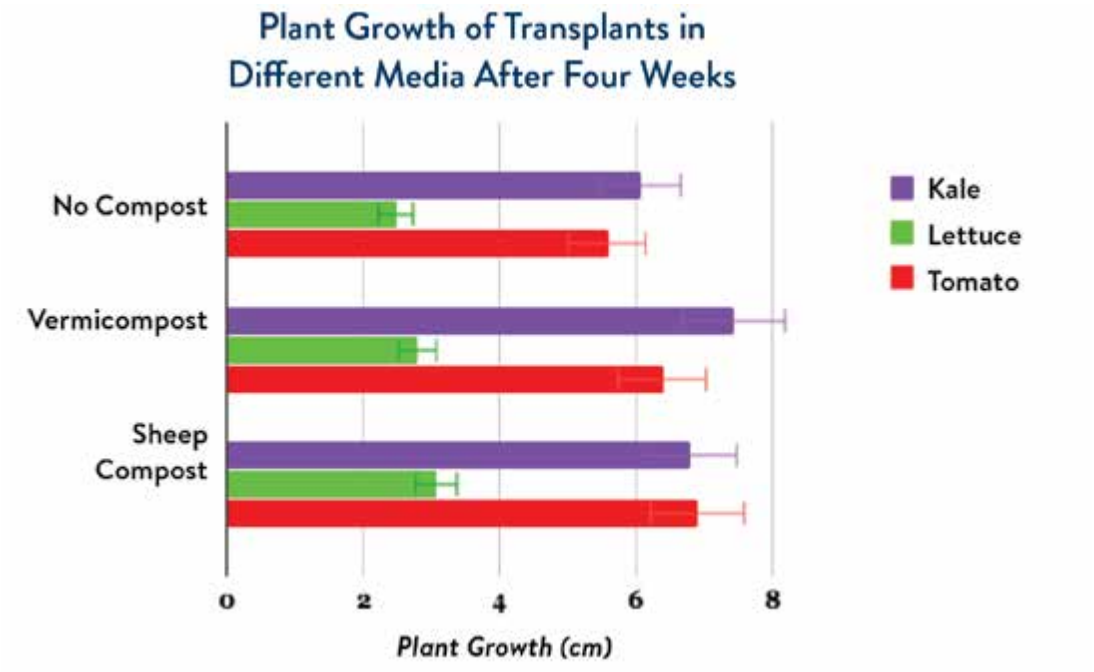
Our thermophillic compost piles were built from wood chips, brewery grains, and vegetable matter. We had been concerned that wood chips might be adding too much acidity to the piles, so it was helpful to know that this was not the case. At 6.3, the vermicompost was an ideal pH. Compared to the vermicompost, the sheep compost was slightly more basic at 6.8 and the potting media without compost was most acidic with a pH of 5.0.

Looking at electrical conductivity, nitrogen, and organic matter levels, on a basic level we could understand that there were higher nutrient levels in the vermicompost (which makes sense in the diversity of inputs: brewery waste, restaurant food waste, vegetable matter, wood chips), but that not all nutrients were available to plants given that the compost was still relatively young.

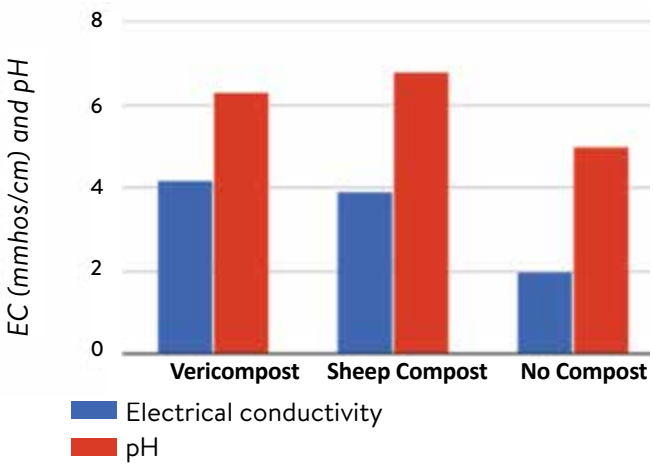
There were limitations to the measurements due to small sample size and the breadth of analyses that we conducted, which are all realities that will continue to be true for small farm based research!

Generally, it was helpful to see that our vermicompost preformed closely to a manure based compost. It would have been ideal to better understand the difference between vermicompost and thermophillic compost piles, but our ability to compare was restricted by our limited ability to create multiple controlled piles on our .3 acre urban lot. We would love to see more support and literature around pragmatic on-farm compost production.

Comparison of plant growth among different potting media.



Electrical conductivity and pH of different compost media



	Electrical conductivity (mmhos/cm)	nitrate (mg/kg soil)	pH
Vermi-compost	4.2	266.49/272.40	6.3
Sheep Compost	3.9	229.41/219.85	6.8
No Compost	2	7.04	5

MANAGEMENT TIPS

1. Professors and farmers have different seasonal down times, so if you need advice, plan accordingly. It was a challenge for us to talk about vermicompost systems design with our advisors before things got busy for our farm in the spring.
2. In urban areas, getting neighbors to buy-in to how compost piles look and smell can be a challenge. We like to engage neighbors, encouraging them to contribute plant-based kitchen matter/non-treated yard matter to the compost piles. We also keep plenty of wood chips on hand to cap any smells.
3. It was nice to receive support from a horticultural student to help us stay on track with data collection and documentation. Our student collaborator was able to come every Friday for a couple of hours. After data collection, she helped us with greenhouse upkeep while getting exposure to our farm culture and objectives.

COOPERATORS

John Biernbaum, Michigan State University, East Lansing, MI

Mark Quee, Scattergood Farm, Brunswick, ME

Mary Rogers, University of Minnesota, St. Paul, MN

Karl Stoerzinger, Fabricator, Minneapolis, MN

PROJECT LOCATION

For directions to the vermicompost site, contact project leader, Caroline Devaney.

RESOURCES

Farmer to Farmer podcast featuring John Biernbaum
www.farmertofarmerpodcast.com/episodes/biernbuam

Biernbaum, John. Research and Guides on Vermicompost Systems
www.hrt.msu.edu/uploads/535/78622/PowerPoint-BasicBiologyEnvironment2014-47.pdf

www.hrt.msu.edu/uploads/535/78622/Vermicomposting-Systems-19pgs.pdf

www.hrt.msu.edu/uploads/535/78622/Vermicomposting-Bio-Enviro-Quality-13-pgs.pdf

Organic Agriculture Centre of Canada. Manual for Vermicomposting in Northern Climates.
http://oacc.info/DOCs/Vermiculture_FarmersManual_gm.pdf

Paul, Lindsay C. and James D. Metzger. 2005. Impact of Vermicompost on Vegetable Transplant Quality. HortScience. 40 (7): 2020-23.

Wisconsin Red Worms, Richland Center, WI.
www.wisconsinredworms.com

Zaller, Johann. 2006. Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. Scientia Horticulturae 112 (2): 191-199.
https://doi.org/10.1016/j.scienta.2006.12.023

Inter-seeding Cover Crops and In Season Nitrogen Application in One Pass

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2016 to 2018

AWARD AMOUNT

$12,500

STAFF CONTACT

Tori Hoeppner

KEYWORDS

corn, cover crops, soil health, yield

Keith Hartmann pictured with inter-seeded rows.

PROJECT SUMMARY

Nitrogen management, soil erosion, and overall soil health are fast growing focal points in Minnesota agriculture. Inter-seeding is gaining more interest, but it comes with many questions and concerns: herbicide use, lower grain yield, and nutrient competition. My project addresses those concerns by inter-seeding cover crops into my corn fields.

Reducing tillage and maintaining a living root system in the soil is the driver for this project. My farm is located in south central Minnesota with heavy clay loam soils. Primary fall tillage is done on nearly all the farm land in my area to break up compaction and to increase water infiltration through the tight soils and flat topography. With primary tillage comes winter wind erosion and black road ditches. Ever since I was a kid, seeing black snow banks and knowing that eroded soil would not return to the field piqued my interest in looking at different ways to increase water filtration and break up compaction without the use of tillage.

PROJECT DESCRIPTION

I seeded a mixture of annual ryegrass and radish into V6 stage corn on July 4 at a rate of 15 lb/A while applying a split nitrogen application of 60 lb/A. I chose those plant species because they each have a different root system with different jobs. The fibrous

roots of annual ryegrass effectively absorb nutrients while radish have large taproots to break up compaction and recycle nutrients that are deep in the soil profile. I removed crimson clover, turnips and rapeseed that I had in my 2016 mix because they didn't perform well under the corn canopy or handle the residual herbicide. Removing those ineffective species lowered the seed cost/A, allowing me to increase the seeding rate from 10 lb/A to 15 lb/A to maintain a seed cost of $15/A.

In 2016, I built an inter-seeder/nitrogen side-dress applicator using a Great Plains NP4000 toolbar with fertilizer coulters, Yetter Strip Fresheners with firming wheels to incorporate the seed, and a Gandy Orbit-Air seeder to meter the seed. Low seeding rates and high seed establishment was the key for this project. That is why I used the Yetter Strip Fresheners to lightly loosen the ground and throw ¼ - ½" of soil on top of the seed followed by a firming wheel for optimum seed to soil contact. The machine worked well injecting a consistent nitrogen band and incorporated the cover crop seed to proper depth achieving an 85% cover crop establishment.

However, machine assembly offered some challenges which led me to the newly released (2017) Yetter Magnum 10,000 fertilizer unit. It has a smooth blade and fertilizer tube that places the nitrogen 4" deep in the soil, trailed by a single shark tooth closing wheel, and finished with an 8" wide firming wheel to seal the nitrogen trench. This single unit achieved all of the goals that I was trying to accomplish with two units: nitrogen placement and soil incorporation and firming. The Magnum also distributed a wider band of cover crop seed. I was confident that I could achieve the same inter-seeding success with the Yetter Magnum 10,000 and simplify the assembly process, increasing farmer adaptability. Therefore, in 2017, I replaced the original injector fertilizer coulters and the Yetter Strip Fresheners with the Yetter Magnum 10,000 units. I positioned the seed tube to distribute the seed at the base of the firming wheel to ensure that the seed was only covered by ¼ - ½" of soil. I was able to achieve better depth control through varying soil conditions with the Magnum vs. the Strip Freshener.

Yetter Magnum 10,000 fertilizer unit.

Through the season, I took measurements, samples and weights from my designated trial plot. The plot was three replicated strips of inter-seeded cover crop and three of no cover crop. Each strip was 1,080' long and 30' wide.

Herbicides applied to these strips are as follows:

- Pre-plant: Dimethenamid-P + Saflufenacil; and
- Post-emerge applied 11 days prior to inter-seeding: Glyphosate and 3 oz Tembotrione.

2016 RESULTS

Warm temperatures and plenty of moisture made for fast cover crop growth and excellent establishment. These conditions made it an excellent year for testing the competitiveness of the cover crop with the primary corn crop.

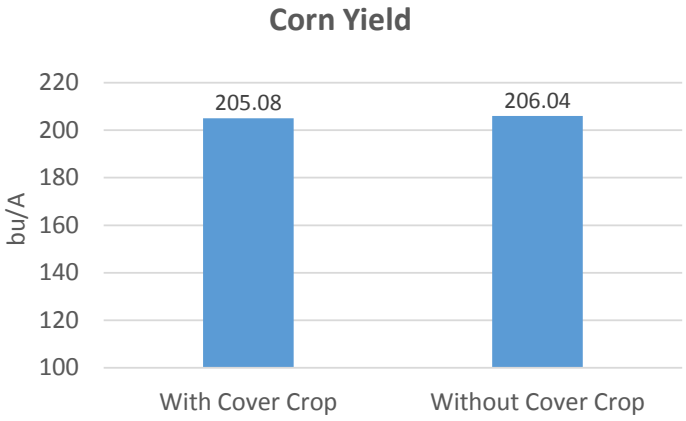
On September 1, the cover crop stand was 25-28 plants/ft^2—an 85% stand establishment. The stand was primarily annual ryegrass, radishes, and rapeseed. The clover and turnips struggled under the shaded corn canopy. In 2017, I may remove those species from the mix to increase stand establishment and potentially lower the seed cost.

I took stalk nitrate samples from each of the six strips on October 6 when the corn reached physiological maturity (black layer). I compared the nitrogen content in the corn plants to see if the cover crop affected yield by taking excessive amounts of nitrogen away from the corn plant. The average of the three strips of cover cropped corn came to 1,211 mg/kg NO3-N. The three strips of control corn was 1,595 mg/kg NO3-N

Although there is a difference of 384 mg/kg NO3-N, both cover cropped and control fell within the optimal range of 700-2,000 mg/kg NO3-N, so this would not be a yield factor.

In mid-November, I harvested each test strip and weighed with a weigh wagon. The average yields of the three strips are show in Figure 1.

Figure 1.



A difference of .96 bu/A is not much in a trial of this size, and I do not think the inter-seeded cover crop had an effect on the corn grain yield. This is significant since the cover crop growth was so aggressive this year.

On November 20, I took 12" deep soil cores to measure the soil nitrate content in the cover crop strips versus control strips. I am comparing how much nitrogen the growing cover crops absorbed. Soil from the cover cropped strips had 5.63 ppm NO3-N, while soil from strips without cover crops measured 5.33 ppm NO3-N.

After reviewing the results, I don't feel this test was a true measure of the cover crops nitrate absorption. With the high amount of rain this field had in 2016 and being late in the growing season, most of the nitrate would be deeper than 12" in the soil profile. A soil core of 24-36" would likely portray the soil nitrate levels more accurately. I will take deeper soil cores in 2017 and 2018.

2017 RESULTS

After seeding, there was no rain for 14 days causing slow, varied inter-seeding growth. At the same time, high temperatures accelerated the corn growth closing up the canopy when the partially emerged cover crop was only 2" tall. I was concerned that the stand would be thin. To my surprise, following the next rain, most of the remaining seed emerged under the canopy. This showed the resilience of annual ryegrass. The radish stand was reduced because of the fast corn canopy, but plants were still present.

On September 7, the cover crop stand was 42-46 plants/ft ^{2}—an 85% stand establishment. The ratio of annual ryegrass to radish at the end was 90/10, respectively.

I took stalk nitrate samples on October 10 when the corn reached physiological maturity (black layer). I compared nitrogen content in the corn plants to see if

Comparison of inter-seeded rows in 2016 and 2017.

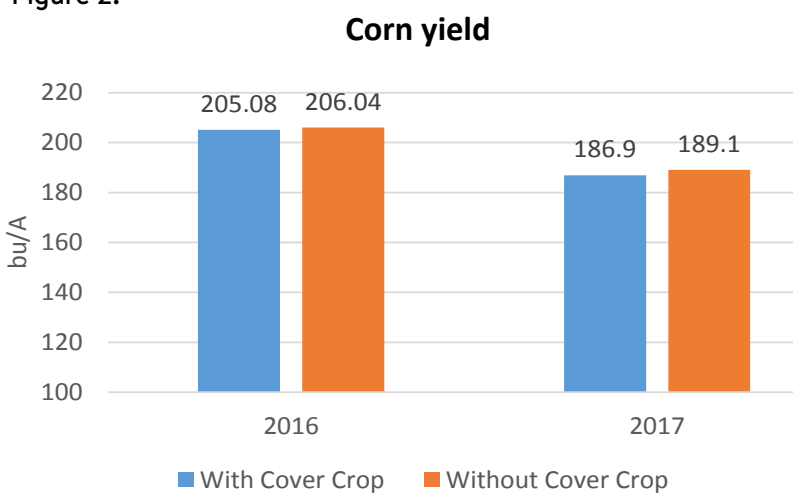
the cover crop affected yield by taking excessive amounts of nitrogen away from the corn plant, ultimately affecting yield. A 15 stalk sample was taken from each of the six test strips. The average of the three strips of cover cropped corn came to 795 mg/kg NO3-N. The average of the three control strips was 414 mg/kg NO3-N.

The range on the six test strips was extremely wide and variable. The variations didn't correlate with the different management practices. Other environmental and weather factors contributed to these varying results as sufficient nitrogen was applied to the corn crop. I do not believe that cover crop increased nitrogen availability to the corn as the results indicate.

On November 1, I harvested each test strip and weighed using a weigh wagon. The average yields of

the three strips with cover crops and the three control strips from 2017 are compared to 2016's yields in Figure 2.

Figure 2.



Removing the clover, rapeseed, and turnips from the mix and increasing the seeding rate from 10 lb to 15 lb/A for even cost ($15/A) demonstrated a higher return on investment by increasing plant establishment, especially in less than ideal conditions. The cover crop remained 2-4" tall in a dormant state, as planned, until September when the corn started to mature and drop its leaves, allowing sunlight to again reach the established cover crop. The cover crop then took off and grew 8" until the first killing frost, after the corn was harvested on November 5. The cover crop growth was less in 2017 than 2016 due to the slow emergence and less vegetative growth of the cover crop prior to corn row closure as shown in Figure 2.

A difference of 2.2 bu/A in 2017 is not statistically different in a trial of this size. The inter-seeded cover crop did not have an effect on corn grain yield. This is the second year that the inter-seeded cover crop has not been shown to compete with the corn crop. That is great to see and positive in advancing this practice.

On November 21, I took 30" deep soil cores to measure soil nitrate content in the cover crop strips versus control strips to compare how much nitrogen the growing cover crops absorbed with their living roots. Soil from the cover cropped strips had 37.5 lb nitrate, while soil from control strips measure 38.5 lb nitrate. A difference of 1 lb is not statistically different.

MANAGEMENT TIPS

1. Seed earlier rather than later. Target V4-V5 corn to inter-seed. That allows the cover crop time to establish and put on some vegetative growth before row closure. This will directly impact the fall growth. From past experiences, I don't think the earlier seeding will increase the cover crop competition with the corn. The lack of sunlight after row closure will still slow the more advanced cover crop growth.
2. Consider residual herbicides when inter-seeding. Most chemical labels do not include an inter-seeding cover crop recommendation. How certain herbicides affect emergence will depend on soil types and trial and error of different types. Keep in mind that weed management and inter-seeding have to work together for this to be a sustainable practice.
3. Seed depth is very important. Small seeded grasses, legumes, and brassicas recommend only ¼ - ½" of soil cover. Err on the shallow side, not deeper.

COOPERATORS

Spencer Herbert, Soil Scientist, Minnesota Department of Agriculture, North Mankato, MN

Chris Schmidt, Soil Conservationist, Natural Resource Conservation Service, Gaylord, MN

PROJECT LOCATION

5 miles south of Gibbon, MN on Cty. Rd. 2.

How Much Can You Afford to Pay for Hay?

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2016 to 2017

AWARD AMOUNT

$9,829

STAFF CONTACT

Meg Moynihan

KEYWORDS

cover crops, Haney soil test, hay soil health, soil nitrate

Aerial photo of the bale grazing study site at Lighthouse Farm.

PROJECT SUMMARY

This study investigated the impact of bale grazing on animal and pasture productivity. After taking all costs and benefits into consideration, what is the value of spent hay litter from purchased hay? How much can a farmer afford to pay for hay used for winter bale grazing?

We monitored changes in hay field and pasture productivity and quality to determine the value of purchased bale-grazed hay. We saw the forage quality of our pasture area improve after we bale grazed it. We also calculated the true net cost and return on purchased hay—in terms of both forage quality and soil benefits.

PROJECT DESCRIPTION

Soil health has become a hot topic in agriculture and has raised interest in pasture management and grazing. At grazing conferences and workshops in the upper Midwest, winter bale grazing (setting bales of hay out on a pasture and grazing them there) is often touted as a great way to add nutrients to the soil because of the spent hay litter left behind after the cattle are done grazing. I've heard statements like, "With what bale grazing can do for your soils, you can afford hay at almost any price!"

Is that true?

Bale grazing is an effective way to increase productivity on grazing land. However, within a fixed acreage, there seems to be little advantage to just moving baled hay from one place on the farm to another. In order to boost productivity quickly, and to be able to produce enough beef to be economically viable, some form of purchased hay may be a producer's best option.

In our region, the cost of winter feed is often a grazier's biggest expense, and making hay is an essential component of producing grass-fed cattle. However, the need to make hay can often limit the amount of grazing land available (and thus the herd size) in a particular year, since some land needs to be hayed for winter feed instead of grazed during the growing season.

But what if hay could be affordably outsourced? If a producer bought all his or her hay, then grass-fed herds could grow larger, because most or all of a farm's land could be grazed. In an attempt to know the true cost and benefit of purchased hay in a bale grazing scenario, we wanted to measure the benefit of that hay litter on the pasture in subsequent years.

The site for this testing and demonstration was a 14 acre pasture at Lighthouse Farm near Milaca. The soil pH is about 6.0. The pasture was established in 1989 and is a mix of timothy, orchardgrass, and smooth bromegrass. We hayed all 14 acres once in summer 2015 and grazed the regrowth in November.

We split the site in half. On the "treatment" side, we set out purchased hay bales and grazed them during the winter of 2015-16. On the "control" side, we didn't do any bale grazing at all. Otherwise, the two halves were managed identically. We recorded everything added to and harvested from the site. We conducted soil tests to monitor changes in soil nutrients and organic matter and forage tests to monitor forage quality.

In spring 2016, we dragged the treatment side to break up hay and manure clumps. We harvested hay off all 14 acres, measuring yield and testing forage quality. We then grazed 14 yearling steers and heifers on the entire site from September 5 to 25, 2016 (20 days). We soil sampled again in fall 2016.

We bought 40 large round bales of hay weighing approximately 900 lb each at $30 apiece and also fed our own hay. After weighing and forage testing the hay, we put them out, 7-10 bales at a time, about 25' apart. We started bale grazing the same 14 animals in December 2016.

In 2017, excessive and untimely rains, (9" over 3 weeks, a ½" at a time) during late July and early August delayed hay harvest. We muddled through, made some poor quality hay during the rainy period, then gave up and waited until drier weather in late September. The delay meant the grasses matured and the hay we made had low digestibility scores. The delay also meant less time for the test site to regrow, so we couldn't fall graze it as we had planned to do.

RESULTS

We soil tested in spring of 2016 and 2017.

Table 1. Soil test results from 2016 and 2017.

Measure	2016		2017		Average change
	Control	Treatment	Control	Treatment	
pH	6.3	5.7	6.4	7.0	n/a
Organic Matter	2.6	2.7	2.6	2.8	0.15
Soil Health Score* (Haney)	8.88	9.23	12.29	14.35	1.12
Nitrogen lb/A	26.2	29.2	23.9	29.5	7.1
Phosphorus lb/A	28.3	30.8	6.7	25.8	10.8
Potassium lb/A	27.9	26.1	26.5	46.4	18.1
Nutrient Value lb/A	$41.74	$43.75	$31.17	$52.13	$11.49

The Haney Soil Health score is an index combining several different measures. The range is 0-50, with higher scores indicating better soil health.* **www.wardlab.com/haney-interpretation.php *According to Ward Labs, most soils do not score higher than 30.*

While forage quality improvements from 2015 to 2016 look impressive (Table 2), it should be noted that we took the 2015 samples 9-10 months after the hay was baled, while the 2016 samples were taken only days after we made hay.

Table 2. Forage quality of hay harvested from the bale-grazed treatment.

Year	2015	2016	2017	Average change
Sampling Date	**April 20**	**July 5**	**August 5**	
Yield (T/A)	2.6	2.8	3.6	+0.6
Crude Protein (dry matter)	7.7%	10.7%	8.8%	+2.1%
Relative Feed Value	80	104	92	+18
Estimated TDN (total digestible nutrients)	55.2%	64.0%	59.6%	+6.6%

In 2016, calves averaged 725 lb at turnout on September 5 and 755 lb on September 25, for an average daily rate of gain of 1.75 lb/day. This number was lower than what we normally achieve on our farm. We think regrowth may have been too short to really allow for efficient grazing. We also suspect that when we split the test group of 14 yearlings off from the rest of the herd, there was a day or two of stress on them from being separated, and they may not have gotten right down to grazing. We hoped that 2017 grazing would help us determine the impact of these effects, but weather prevented us from grazing at all.

Instead of one big field day, we ended up hosting four or five informal farm tours in 2016 and 2017 for people who had heard about the study and wanted to see it. We estimate that more than 50 people visited the farm. Because the season got so late in 2017, we couldn't host a field day showing any significant differences in regrowth between the check site and the test site. Instead, we compiled our key data and learning into a December webinar attended by 15 people.

CONCLUSION

How much can you afford to pay for hay?

This project focused on determining the true value of purchased hay, including both the nutritional value and the value of the benefits to the soil produced by bale grazing the purchased hay.

Using a University of Wisconsin Extension (UW) spreadsheet at: **https://fyi.uwex.edu foragefiles/2014/01/Hay-Pricing-StructureV2.xls** and plugging in the numbers from our forage quality analysis, we get an adjusted nutritional value of $50.05/T for the hay we bought.

The hay cost us $80.00/T, delivered and staged for grazing. This leaves the theoretical value of the remaining hay litter at $80.00 (cost) - $50.05 (feed value) = $29.95/T. Let's try to determine whether the bale-grazed hay adds that much value to the soil.

On average, our cattle grazed 35 tons of baled hay on the 14 acre site in each of two winter grazing seasons. The cattle consumed the nutritional value, but left $29.95/T behind as non-digestible matter, either in manure or in spent hay litter.

So that means we applied 35 tons hay x $29.95/T = $1,048.25 worth of hay litter over 14 acres, or $1,048.25/14A = **$74.88/A**.

Assuming a hay cost of $80/T what did we get for that $74.88/A worth of litter?

Yield Increase Value

Average hay yield increased by 0.5 T/acre.

$80/T x 0.5 T/A = **$40/A**

Protein Value

Crude protein (CP) values increased by an average of 2.1%. Using an average hay yield of 3.6 T/A and UW's valuation of CP at $2.00/1%, the increase in hay quality was worth:

(2.1% x $2.00 = $4.20 and $4.20 x 3.6 T/A = **$15.12/A.**

Feed Value

Relative feed value (RFV) increased by 18 points/T. UW values RFV at $0.25/pt.

So 18 points x $0.25/pt = $4.50/T and $4.50/T *3.6 T/A = **$16.20/A**

Soil Nutrition

We saw an average increase in the value of soil nutrition of **$11.49/A**.

These measures are not necessarily additive, as the dollar value we attribute to the increase in CP is also part of the dollar value increase in RFV.

But we can calculate an estimate for dollar value return of the spent hay litter using either:

A. Yield increase + CP increase + soil nutrition increase

$40.00 + $15.12 + $11.49 = **$66.61**

or

B. Yield increase + RFV increase + soil nutrition increase

$40.00 + $16.20 + $11.49 = **$67.69**

In either case, it comes to about $67.00/A.

To convert to the dollar value per ton, we take

$67.00/A x 14 acres = $938.00 and $938.00/35 tons of hay fed = $26.80/T to get the dollar value of spent hay litter.

In our study, $80.00/T hay contained $50.05/T worth of nutrition and $26.80/T worth of benefit to the soil, for a total value of **$76.85/T**.

So, in answer to the question, "how much can you afford to pay for hay?" our example shows that the $80.00/T we paid is possibly a little high. But perhaps more importantly, we have determined there is significant value to the soil of spent hay litter. Our approach confirms that valuing hay on nutritional value alone is an insufficient measure.

We recommend that farmers use the following formula when considering how much to pay for hay they will bale-graze:

Price (P) = Nutritional Value (NV) + Soil Value (SV)

Where NV is determined by nutrient analysis, plugged into the UW spreadsheet, and SV is estimated to be a 10% yield increase, a 15% RFV increase, and a 20% soil nutrient increase.

There is more work to be done in this area. A more robust testing protocol might include a measure of the percentage of hay that goes unconsumed, rather than just an estimate. Including more test sites and a longer testing window would also help. In the short window of time for this test, weather was too much of a variable factor.

MANAGEMENT TIPS

1. If you use small square bales, you will need some kind of feeder to keep cattle from wasting too much of it. We've used round bale feeders for feeding square bales and it works well.
2. We've put out as much as 3 weeks of feed at a time, with little wastage.
3. We found that 25' between grazing bales was too far, and recommend placing them only 8' to 10' apart. However, you may need to drag the area to bust up manure clumps.

COOPERATOR

Kent Solberg, Livestock and Grazing Consultant, Sustainable Farming Association of MN

PROJECT LOCATION

The study was located 6 miles south of Bock, MN on Mille Lacs Cty. Rd. 1.

Completed Grant Projects

Final Year	Title of Greenbook Article	Grantee
	Alternative Markets and Specialty Crops	
2018	Developing a Network for Environment and Weather Applications	Minnesota Apple Growers Association, JP Jacobson
	Evaluation of Hybrid Hazel (Corylus) Woodchips as Mushroom Substrate	Wholesome Harvest, Sue Weigrefe
2017	Using Compost Tea in Organic Farming	Seeds Farm, Becca Carlson
	Creating Beneficial Habitat for Weed Management & Wildlife Enhancement on Farm Waste Land	Melissa Nelson
	Preserving and Attracting Native Bees while Providing a Habitat that Adds Value to Small Acreage	Noreen Thomas
2016	Reducing Chemical Use and Inputs in a Cold Climate Grape Harvest by Creating New Uses Other than Wine	Locust Lane Vineyards Chad Stoltenberg
	Evaluating Different Depths and Types of Mulches in Blueberry Production	Redfern Gardens, Kathy Connell
2012	Growing Cherries in Central Minnesota	Pat Altrichter
	Organic Mushroom Cultivation and Marketing in a Northern Climate	Jill Jacoby
	Feasibility of Small Farm Commercial Hop Production in Central Minnesota	Robert Jones
2010	Hardwood Reforestation in a Creek Valley Dominated by Reed Canarygrass	Timothy Gossman
	Introducing Cold – hardy Kiwifruit to Minnesota	James Luby
	Growing the Goji Berry in Minnesota	Koua Vang & Cingie Kong
2009	Dream of Wild Health Farm Indigenous Corn Propagation Project	Peta Wakan Tipi, Sally Auger
2008	Developing a Saskatoon Berry Market in the Upper Midwest	Patricia Altrichter & Judy Heiling
2005	Creating Public Recognition of and Demand for "Grass-Fed" Dairy Products through the Development of Brand Standards and Promotion of These Standards to the Public	Dan French
2004	Collaborative Character Wood Production and Marketing Project	Cooperative Development Services, Isaac Nadeau
	Creating Consumer Demand for Sustainable Squash with Labels and Education	Gary Pahl
	Integrated Demonstration of Native Forb Seed Production Systems and Prairie Land Restoration	Michael Reese
	Pride of the Prairie: Charting the Course from Sustainable Farms to Local Dinner Plates	Kathleen Fernholz
2003	Demonstrating the Market Potential for Sustainable Pork	Prairie Farmers Co-op, Dennis Timmerman
	Flour Corn as an Alternative Crop	Lynda Converse
2002	Increasing Red Clover Seed Production by Saturation of Pollinators	Leland Buchholz
	Propagation of Native Grasses and Wildflowers for Seed Production	Joshua Zeithamer
2001	Establishing Agroforestry Demonstration Sites in Minnesota	Erik Streed, CINRAM

Final Year	Title of Greenbook Article	Grantee
	Managed Production of Woods-grown and Simulated Wild Ginseng	Willis Runck
	Midwest Food Connection: Children Monitor on Farms	Midwest Food Connection
	Phosphorus Mobilization and Weed Suppression by Buckwheat	Curt Petrich
2000	Converting a Whole Farm Cash Crop System to Keeping an Eye on Quality of Life and the Bottom Line in Sustainable Agriculture by Using Key Farm Economic Ratios to Aid in Decision-making	Red Cardinal Farm
	Dry Edible Beans as an Alternative Crop in a Direct Marketing Operation	Bruce & Diane Milan
	Native Minnesota Medicinal Plant Production	Renne Soberg
1999	An Alternative Management System in an Organic, Community Supported Market	Candace Mullen
	Cultural and Management Techniques for Buckwheat Production and Marketing	Tom Bilek
	Pond Production of Yellow Perch	John Reynolds
1998	Establishing and Maintaining Warm Season Grasses (Native Grasses)	Pope County SWCD
	On-farm Forest Utilization and Processing Demonstrations	Hiawatha Valley RC&D
1996	Permanent Raised Bed Cultivation for Specialty Crops	Terry & Jean Loomis
1995	Cash Crop Windbreak Demonstration/Development	Phil Rutter
	Cutter Bee Propagation Under Humid Conditions	Theodore L. Rolling
	Red Deer Farming as an Alternative Income	Peter Bingham
	Wildflower Seeds as a Low-input Perennial Crop	Grace Tinderholt & Frank Kutka
1992	Alternative Mulch Systems for Intensive Specialty Crop Production	Ron Roller, Lindentree Farm
	Benefits of Crop Rotation in Reducing Chemical Inputs and Increasing Profits in Wild Rice Production	George Shetka
	Benefits of Weeder Geese and Composted Manures in Commercial Strawberry Production	Joan Weyandt-Fulton
	Common Harvest Community Farm	Dan Guenthner
	Mechanical Mulching of Tree Seedlings	Timothy & Susan Gossman
	Minnesota Integrated Pest Management Apple Project	John Jacobson
Cropping Systems and Soil Fertility		
2018	Raising Soil pH Effectively in Acid Soil	David Abazs
	Soil Health Research in Southwest Minnesota	Jerry & Nancy Ackermann, & Jan Voit
	Maximizing Profitability in a Modular Moveable Cathedral Hoop House	Megan Henry
	Perennial wheatgrass and legumes for cropping, grazing, and soil health	Mike Jorgenson
	Inter-seeding Cover Crops into Standing Corn in June	Alan Kraus
	Evaluation of Winter Annual Small Grain Cover Crops for Forage Production	Daniel Ley
	Demonstrating Vermicomposting for Soil Health in the Upper Midwest	Robin Major & Caroline Devany, Stone's Throw Urban Farm
	Use Sub-Surface Irrigation to Increase Crop Profitability	Russell Martie, Dan Nadeau, Wright Co SWCD

Final Year	Title of Greenbook Article	Grantee
	How Much Can You Afford to Pay for Hay?	John & Lisa Mesko, Lighthouse Farm
	Cover Crops to Replace Fall Tillage in Shakopee Lake Bed	Robin Moore
2017	Nitrogen Capture using Cover Crops in a Cash Grain Rotation	Sherburne County SWCD, William Bronder
	Developing Low-cost Planting Materials and Establishment Methods to Accelerate Agroforestry Adoption for Function and Profit	Happy Dancing Turtle, Jim Chamberlin
	Legume Cover Crops	Paul Kruger
	No-till Cover Crop Rotation vs. Intensive Tillage in Corn-Soybean Rotation	Chad Rollofson
	Planting Short Season Corn for Cover Crop Success	Caroline van Schaik
2016	The Effects of Cover Crops on Water and Soil Quality	Hmong American Farmers Association
	Correcting Soil Structure to Reduce Erosion by Using a Cover Crop Mix with Diverse Root Systems	Bios de Sioux Watershed District
	A Demonstration of Biological Primers on Drought Prone Soils	Sustainable Farming Association of Minnesota
2015	Weed Control in Soybeans	Floyd Hardy
	Comparing the Productivity & Profitability of Heat – Loving Crops in High Tunnel and Quick Hoops Systems	Stone's Throw Urban Farm
2013	Fertilizing with Alfalfa Mulches in Field Crops	Carmen Fernholz
	McNamara Filter Strip Demonstration	Goodhue SWCD, Beau Kennedy & Kelly Smith
	Optimizing Alfalfa Fertilization for Sustainable Production	Doug Holen
2010	Environmentally and Economically Sound Ways to Improve Low Phosphorus Levels in Various Cropping Systems Including Organic with or without Livestock Enterprises	Carmen Fernholz
2009	Establishing Beneficial Bug Habitats in a Field Crop Setting	Noreen Thomas
	Keeping It Green and Growing: An Aerial Seeding Concept	Andy Hart
	Rotational Use of High-quality Land: A Three Year Rotation of Pastured Pigs, Vegetable Production, and Annual Forage	Gale Woods Farm – Three Rivers Park District, Tim Reese
2008	Field Windbreak/Living Snow Fence Yield Assessment	Gary Wyatt
2006	Gardening with the Three Sisters: Sustainable Production of Traditional Foods	Winona LaDuke
	Feasibility of Winter Wheat Following Soybeans in NW MN	Jochum Wiersma
2005	Chickling Vetch – A New Green Manure Crop and Organic Control of Canada Thistle in NW MN	Dan Juneau
	Treating Field Runoff through Storage and Gravity-fed Drip Irrigation System for Grape and Hardwood Production	Tim Gieseke
	Use of Rye as a Cover Crop Prior to Soybean	Paul Porter
2004	Development of Eastern Gamagrass Production	Nathan Converse
	In-field Winter Drying and Storage of Corn: An Economic Analysis of Costs and Returns	Marvin Jensen

Final Year	Title of Greenbook Article	Grantee
	Mechanical Tillage to Promote Aeration, Improve Water Infiltration, and Rejuvenate Pasture and Hay Land	Robert Schelhaas
	Native Perennial Grass - Illinois Bundleflower Mixtures for Forage and Biofuel	Craig Sheaffer
	Northwest Minnesota Compost Demonstration	John Schmidt & Russ Severson
	Potassium Rate Trial on an Established Grass/Legume Pasture: Determining Economic Rates for Grazing/Haying Systems	Dan & Cara Miller
	Woolly Cupgrass Research	Leo Seykora
	Yield and Feeding Value of Annual Crops Planted for Emergency Forage	Marcia Endres
2003	Aerial Seeding of Winter Rye into No-till Corn and Soybeans	Ray Rauenhorst
	Manure Spreader Calibration Demonstration and Nutrient Management	Jim Straskowski
	Replacing Open Tile Intakes with Rock Inlets in Faribault County	Faribault County SWCD
	Soil Conservation of Canning Crop Fields	Andy Hart
	Using Liquid Hog Manure as Starter Fertilizer and Maximizing Nutrients from Heavily Bedded Swine Manure	Dakota County SWCD, Brad Becker & Johnson
2002	Agricultural Use of Rock Fines as a Sustainable Soil Amendment	Carl Rosen
	A Low-cost Mechanism for Inter-seeding Cover Crops in Corn	Tony Thompson
	Annual Medic as a Protein Source in Grazing Corn and Weed Suppressant in Soybeans	Joseph Rolling
	Dairy Manure Application Methods and Nutrient Loss from Alfalfa	Neil C. Hansen
	Evaluation of Dairy Manure Application Methods and Nutrient Loss from Alfalfa	Stearns County SWCD
	Increased Forage Production through Control of Water Runoff and Nutrient Recycling	James Sovell
	Land Application of Mortality Compost to Improve Soil and Water Quality	Neil C. Hansen
	Turkey Litter: More is Not Always Better	Meierhofer Farms
2001	Applying Manure to Corn at Agronomic Rates	Tim Becket & Jeremy Geske, Dakota County Extension & SWCD
	Cereal Rye for Reduced Input Pasture Establishment and Early Grazing	Greg Cuomo
	Establishing a Rotational Grazing System in a Semi-wooded Ecosystem: Frost Seeding vs. Impaction Seeding on CRP Land and Wooded Hillsides Using Sheep	James Scaife
	Living Snow Fences for Improved Pasture Production	Mike Hansen
	Managing Dairy Manure Nutrients in a Recycling Compost Program	Norman & Sallie Volkmann
	Reducing Chemical Usage by Using Soy Oil on Corn and Soybean	Donald Wheeler
	Techniques for More Efficient Utilization of a Vetch Cover Crop for Corn Production	Carmen Fernholz
	Using Nutrient Balances to Benefit Farmers and the Environment	Mark Muller, IATP
2000	Forage Mixture Performance	Itasca County SWCD
	Growing Corn with Companion Crop Legumes for High Protein Silage	Stanley Smith
	Inter-seeding Hairy Vetch in Sunflower and Corn	Red Lake County Extension
	Legume Cover Crops Inter-seeded in Corn as a Source of Nitrogen	Alan Olness & Dian Lopez

Final Year	Title of Greenbook Article	Grantee
	Surface Application of Liming Materials	Jane Grimsbo Jewett
	The Introduction of Feed Peas and Feed Barley into Whole Farm Planning	Ken Winsel
1999	CRP in a Crop Rotation Program	Jaime DeRosier
	Evaluating Kura Clover for Long-term Persistence	Bob & Patty Durovec
	The Winona Farm Compost Strategies	Richard J. Gallien
	Timing Cultivation to Reduce Herbicide Use in Ridge-till Soybeans	Ed Huseby
1998	An Evaluation of Variable Rate Fertility Use on Ridged Corn and Soybeans	Howard Kittleson
	Farming Practices for Improving Soil Quality	Sustainable Farming Association of SC MN
	Sustainable Agriculture in Schools	Toivola-Meadowland School, Jim Postance
1997	Converting from a Corn-Soybean to a Corn-Soybean-Oat-Alfalfa Rotation	Eugene Bakko
	Manure Application on Ridge-till: Fall vs. Spring	Dwight Ault
1996	Base Saturation of Calcium	Randy Meyer
	Biological vs. Conventional Crop Systems Demonstration	Gary Wyatt
	Building Soil Humus without Animal Manures	Gerry Wass
	Controlled Microbial Composting to Improve Soil Fertility	Howard & Mable Brelje
	Legumes as a Protein Supplement in Fall Grazed Corn Stalks	Grant Herfindahl
	Living Mulches in West Central MN Wheat Production	Dave Birong
	Making the Transition to Certified Organic Production	Craig Murphy
	No-till Barley and Field Peas into Corn Stalks, Developing Pastures on These Bare Acres	Jerry Wiebusch
	Weed Control and Fertility Benefits of Several Mulches and Winter Rye Cover Crop	Gary & Maureen Vosejpka
1995	Annual Medics: Cover Crops for Nitrogen Sources	Craig Sheaffer
	Integration of Nutrient Management Strategies with Conservation Tillage Systems for Protection of Highly Eroded Land and Lakes in West Otter Tail County	Harold Stanislawski
	Manure Management/Utilization Demonstration	Timothy Arlt
	Reducing Soil Insecticide Use on Corn through Integrated Pest Management	Ken Ostlie
	Taconite as a Soil Amendment	Donald E. Anderson
1994	Biological Weed Control in Field Windbreaks	Tim Finseth
	Energy Conserving Strip Cropping Systems	Gyles Randall
	Fine-tuning Low-input Weed Control	David Baird
	Flame Weeding of Corn to Reduce Herbicide Reliance	Mille Lacs County Extension
1993	Chemical Free Double-cropping	Jeff Mueller
	Cooperative Manure Composting Demonstration and Experiment	Rich Vander Ziel
	Early Tall Oat and Soybean Double Crop	Charles D. Weber

Final Year	Title of Greenbook Article	Grantee
	Nitro Alfalfa, Hog Manure, and Urea as Nitrogen Sources in a Small Grain, Corn, Soybean Crop Rotation	Carmen M. Fernholz
	Nitrogen Utilization from Legume Residue in Western MN	Arvid Johnson
1992	Demonstration of Land Stewardship Techniques in the Red River Valley	Donald H. Ogaard
	Demonstration of Tillage Effects on Utilization of Dairy and Hog Manure in SE MN	John Moncrief
	Economically and Environmentally Sound Management of Livestock Waste	Fred G. Bergsrud
	Herbicide Ban? Could You Adapt on a Budget?	David Michaelson
	Improving Groundwater Quality and Agricultural Profitability in East Central MN	Steven Grosland & Kathy Zeman
	Modified Ridge-till System for Sugar Beet Production	Alan Brutlag
	Soil Building and Maintenance	Larry H. Olson
	Strip-cropping Legumes with Specialty Crops for Low-cost Mulching and Reduced Fertilizer/Herbicide Inputs	Mark Zumwinkle
	Using Nitro Alfalfa in a No-till Corn and Soybean Rotation	Jeff Johnson
1991	Alternative Methods of Weed Control in Corn	Sr. Esther Nickel
	Hairy Vetch and Winter Rye as Cover Crops	Mark Ackland
Energy		
2016	Increasing Dairy Farm Profitability Through an Energy Efficiency Implementation Model	Fritz Ebinger
	Solar-powered Rainwater Catchment & Distribution System Using Drip Irrigation	Hammers Green Acres, Sharon Utke
2010	Evaluation of the Potential of Hybrid Willow as a Sustainable Biomass Energy Alternative in West Central Minnesota	Diomides Zamora
2009	On-farm Biodiesel Production from Canola	Steve Dahl
2007	Testing the Potential of Hybrid Willow as a Sustainable Biomass Energy Alternative in Northern Minnesota	Dean Current
Fruits and Vegetables		
2017	Developing Profitable Apple Production along Lake Superior's North Shore of Minnesota	Clover Valley Farms, Cindy Hale
	Evaluating Different Depths and Types of Mulches in Blueberry Production	Redfern Gardens, Kathleen Connell
	Controlling Canada Thistle in Organic Blueberry Production	Little Hill Berry Farm, Aaron Wills
2013	Extended Season Marketing of Asian and Latino Ethnic Vegetables Grown in Quick Hoops and a Moveable Greenhouse	Judy & Steve Harder
	Comparison of Strawberries Grown in a High Tunnel and Outside for Quality and Profitability	Debbie Ornquist
	Solar Energy Storage and Heated Raised Beds	Diane & Charles Webb

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2012	Growing Blackberries Organically under High Tunnels for Winter Protection and Increased Production	Erik Gundacker
	High Tunnel Primocane Blackberry Production in Minnesota	Terrance Nennich
	Minimizing the Environmental Impact and Extending the Season of Locally Grown Raspberries	Steve Poppe
	Growing Fresh Cabbage for Markets Using Integrated Pest Management Strategies	Ly Vang, American Association for Hmong Women in Minnesota
2011	Using Solar Energy to Heat the Soil and Extend the Growing Season in High Tunnel Vegetable Production	Dallas Flynn
	Extended Growing Season for Lettuce	Michael Hamp
	Organic Day-neutral Strawberry Production in Southeast Minnesota	Sam Kedem
	Winter Plant Protection of Blueberries in Northern Minnesota	Al Ringer
2010	Intercropping within a High Tunnel to Achieve Maximum Production	Mark Boen
2009	Chokecherry (*Prunus virginiana*) Production in Western Minnesota	Todd & Michelle Andresen
	Winter Harvest of Hardy Crops under Unheated Protection	Kelly Smith
	Insect and Disease Pressure in Unsprayed Apple Orchards in Central and Northern Minnesota	Thaddeus McCamant
2008	Apple Scab Control Project	Rick Kluzak
	Controlling Western Striped Cucumber Beetles Using Organic Methods: Perimeter Trap Crops and Baited Sticky Traps	Peter Hemberger
	Establishing Healthy Organic Asparagus While Utilizing Minimal Labor and Maintaining Proper Soil Nutrition	Patrick & Wendy Lynch
	Novel Preplant Strategies for Successful Strawberry Production	Steven Poppe
2005	Organic Strawberry Production in Minnesota	Brian Wilson & Laura Kangas
2004	Root Cellaring and Computer-controlled Ventilation for Efficient Storage of Organic Vegetables in a Northern Market	John Fisher-Merritt
2003	Evaluating the Benefits of Compost Teas to the Small Market Grower	Pat Bailey
	Research and Demonstration Gardens for New Immigrant Farmers	Nigatu Tadesse
	Viability of Wine Quality Grapes as an Alternative Crop for the Family Farm	Donald Reding
2002	Development and Continuation of a Community Based Sustainable Organic Grower's Cooperative and Marketing System	Patty Dease
	Flame Burning for Weed Control and Renovation with Strawberries	David Wildung
	Good Eating with Little Healing: A Straw Bale Greenhouse	Linda Ward
	Integrating Livestock Profitably into a Fruit and Vegetable Operation	David & Lise Abazs
	Soil Ecology and Managed Soil Surfaces	Peter Seim & Bruce Bacon
	Value Adding to Small Farms through Processing Excess Production	Jeffrey & Mary Adelmann
2001	Bio-based Weed Control in Strawberries Using Sheep Wool Mulch, Canola Mulch and Canola Green Manure	Emily Hoover
	Biological Control of Alfalfa Blotch Leafminer	George Heimpel

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	Cover Crops and Living Mulch for Strawberry Establishment	Joe Riehle
	Sustainable Weed Control in a Commercial Vineyard	Catherine Friend & Melissa Peteler
1999	Development of Mating Disruption and Mass Trapping Strategy for Apple Leafminer	Bernard & Rosanne Buehler
1998	Alternative Point Sources of Water	Joseph & Mary Routh
	Comparison of Alternative and Conventional Management of Carrot Aster Leafhoppers	MN Fruit & Vegetable Growers Association
	Jessenland Organic Fruits Project	MN New Country School
	Propane Flame Weeding Vegetable Crops	Jean Peterson & Al Sterner
	Soil Quality Factors Affecting Garlic Production	Tim King
	Wine Quality Grapes in Otter Tail County	Michael & Vicki Burke
1997	Community Shared Agriculture and Season Extension for Northern Minnesota	John Fisher-Merritt
	Living Mulch, Organic Mulch, Bare Ground Comparison	Dan & Gilda Gieske
Livestock		
2018	Breeding, Selecting and Assessing Organically Grown Nutrient Dense Corn for Poultry Production	Zachary Paige & Sue Wika, Paradox Farm
2017	Acclimating Heifers to Improve Cow Flow on Dairy Farms	Ulrike Sorge
	Utilization of Building for Multiple Livestock Species	Steve Stassen
2013	Determining the Cost of Raising Pastured Pork on a Diet Including Whey and Finishing on a Diet Including Acorns	Lori Brinkman
2011	Determining the Pasture Restoration Potential and Financial Viability of Cornish Cross vs. Red Broilers for a Small Pastured Poultry Operation in Northeast Minnesota	Cindy Hale & Jeff Hall
	Fall Forage Mixture for Grass Finishing Livestock Late in the Fall	Troy Salzer
	Increasing the Profitability of Raising Livestock: An Evaluation of Two Methods to Extend the Grazing Season	Dean Thomas
	Methods to Establish Grazing of Annual Forages for Beef Cows on Winter Feeding Areas	Walker & Mathison
2010	A Comparison between Cornstalk and Soybean Straw for Bedding Used for Hogs and Their Relative Nutrient Value for Fertilizer	John Dieball
2009	Demonstration of How Feeding In-line Wrapped High Moisture Alfalfa/Grass Bales Will Eliminate Our Fall and Winter “Flat Spot” in Grass-fed Beef Production	Donald Struxness
	Diversified Harvest of Integrated Species	Joe & Michelle Bowman
2008	Comparing Alternative Laying Hen Breeds	Suzanne Peterson
2007	Composting Bedded Pack Barns for Dairy Cows	Marcia Endres
	Managing Hoops and Bedding and Sorting without Extra Labor	Steve Stassen
2005	Performance Comparison of Hoop Barns vs. Slatted Barns	Kent Dornink

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	Raising Cattle and Timber for Profit: Making Informed Decisions about Woodland Grazing	Michael Demchik
	Using a 24' x 48' Deep Bedded Hoop Barn for Nursery Age Pigs	Trent & Jennifer Nelson
2004	Comparing Performance of Hoop Buildings to an Older Conventional Building for Finishing Hogs	Kevin Connolly
	High Value Pork Production for Niman Ranch Using a Modified Swedish System	David & Diane Serfling
	Low Cost Fall Grazing and Wintering Systems for Cattle	Ralph Lentz
2003	Can New Perennial Grasses Extend Minnesota's Grazing Season	Paul Peterson
	Enhancement of On-farm Alfalfa Grazing for Beef and Dairy Heifer Production	Dennis Johnson
	Farrowing Crates vs. Pens vs. Nest Boxes	Steve Stassen
	Forage Production to Maintain One Mature Animal Per Acre for 12 Months	Ralph Stelling
	High Quality – Low Input Forages for Winter Feeding Lactating Dairy Cows	Mark Simon
	Pasture Aeration and its Effects on Productivity Using a Variety of Inputs	Carlton County Extension
	Potential of Medicinal Plants for Rotational Grazing	Management Intensive Grazing Groups, Dave Minar
	Programmatic Approach to Pasture Renovation for Cell Grazing	Daniel Persons
2002	Adding Value for the Small Producers via Natural Production Methods and Direct Marketing	Peter Schilling
	Grazing Beef Cattle as a Sustainable Agriculture Product in Riparian Areas	Frank & Cathy Schiefelbein
	Improvement of Pastures for Horses through Management Practices	Wright County Extension
	Increasing Quality and Quantity of Pasture Forage with Management Intensive Grazing as an Alternative to the Grazing of Wooded Land	Michael Harmon
	Supplement Feeding Dairy Cattle on Pasture with Automated Concentrate Feeder	Northwest MN Grazing Group
	Viability of Strip Grazing Corn Inter-seeded with a Grass/Legume Mixture	Stephen & Patricia Dingels
2001	Annual Medic as a Protein Source in Grazing Corn	Joseph Rolling
	First and Second year Grazers in a Year Round Pasture Setting Served by a Frost Free Water System	Don & Dan Struxness
	Low Input Conversion of CRP Land to a High Profitability Management Intensive Grazing and Haying System	Dan & Cara Miller
	Whole System Management vs. Enterprise Management	Dennis Rabe
	Working Prairie – Roots of the Past Sustaining the Future	John & Leila Arndt
2000	Converting a Whole Farm Cash System to Sustainable Livestock Production with Intensive Rotational Grazing	Edgar Persons
	Dairy Steers and Replacement Heifers Raised on Pastures	Melissa Nelson
	Establishing Pasture Forages by Feeding Seed to Cattle	Art Thicke
	Five Steps to Better Pasture in Practice: How does it really work?	Sarah Mold
	Grass-and Forage-based Finishing of Beef, with Consumer Testing	Lake Superior Meats Cooperative
	Low Cost Sow Gestation in Hoop Structure	Steve Stassen

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	Reviving and Enhancing Soils for Maximizing Performance of Pastures and Livestock	Doug Rathke & Connie Karstens
1999	Deep Straw Bedding Swine Finishing System Utilizing Hoop Buildings	Mark & Nancy Moulton
	Extending the Grazing Season with the use of Forage Brassicas, Grazing Corn and Silage Clamps	Jon Luhman
	Home on the Range Chicken Collaborative Project	Sustainable Farming Association of SE MN
	Hoop Houses and Pastures for Mainstream Hog Producers	Josh & Cindy Van Der Pol
	Learning Advanced Management Intensive Grazing through Mentoring	West Otter Tail SWCD
	Management Intensive Grazing Groups	Dave Stish
	Renovation of River Bottom Pasture	Jon Peterson
	The Value Added Graziers: Building Relationships, Community and Soil	Values Added Graziers
1998	Buffalo: Animal from the Past, Key to the Future	Richard & Carolyn Brobjorg
	Marketing Development - Small Farm Strategies Project	Sustainable Farming Association of NE MN
	Pastured Poultry Production and Riparian Area Management	Todd Lein
1997	Butcher Hogs on Pasture	Michael & Linda Noble
	Developing Pastures Using Various Low-input Practices	Ralph Lentz
	Grass Based Farming in an Intensive Row Crop Community	Douglas Fuller
	Grazing Hogs on Standing Grain and Pasture	Michael & Jason Hartmann
	Grazing Sows on Pasture	Byron Bartz
	Low Input Systems for Feeding Beef Cattle or Sheep	Dennis Schentzel
	Raising Animals for Fiber	Patty Dease
	Seasonal Dairying and Value-added Enterprises in SW MN	Robert & Sherril Van Maasdam
	Swedish Style Swine Facility	Nolan & Susan Jungclaus
1996	Dairy Waste Management through Intensive Cell Grazing of Dairy Cattle	Scott Gaudette
	Establishing Trees in Paddocks	Dave & Diane Serfling
	Evaluating Pasture Quality and Quantity to Improve Management Skills	Land Stewardship Project
	Expanding into Outdoor Hog Production	James Van Der Pol
	Grazing Limits: Season Length and Productivity	Doug & Ann Balow
	Rotational Grazing Improves Pastures	MISA Monitoring Team, Dorsey
1995	Backgrounding Rotational Grazing	Frank Schroeder
	Evaluating Diatomaceous Earth as a Wormer for Sheep and Cattle	David Deutschlander
	Intensive Controlled Grazing and Pasture Rejuvenation on Fragile Land	Lyle & Nancy Gunderson
	Intensive Rotational Grazing on Warm Season Grasses	Jim Sherwood
	Rotational Top-grazing as a Method of Increasing Profitability with a High-producing Dairy Herd	Alton Hanson

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1994	Economics of Rotational Grazing vs. Row Crops	Harold Tilstra
	Low Input Range Farrowing of Hogs	Larry Mumm
1993	A Comparison Study of Intensive Rotational Grazing vs. Dry-lot Feeding of Sheep	R & K Shepherds
	Controlled Grazing of Ewes on Improved Pastures and Lambing on Birdsfoot Trefoil	Leatrice McEvilly
	Farrowing and Raising Pigs on Pasture	Charles Cornillie
	Improving Permanent Pastures for Beef in SW MN	David Larsen
	Intensive Rotational Grazing	Chad Hasbargen
	Research and Demonstration of Rotational Grazing Techniques for Dairy Farmers in Central Minnesota	Stearns County Extension
	Winter Grazing Study	Janet McNally & Brooke Rodgerson
1992	A Demonstration of an Intensive Rotational Grazing System for Dairy Cattle	Ken Tschumper
	Intensive Rotational Grazing in Sheep Production	James M. Robertson
	Using Sheep and Goats for Brush Control in a Pasture	Alan & Janice Ringer

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