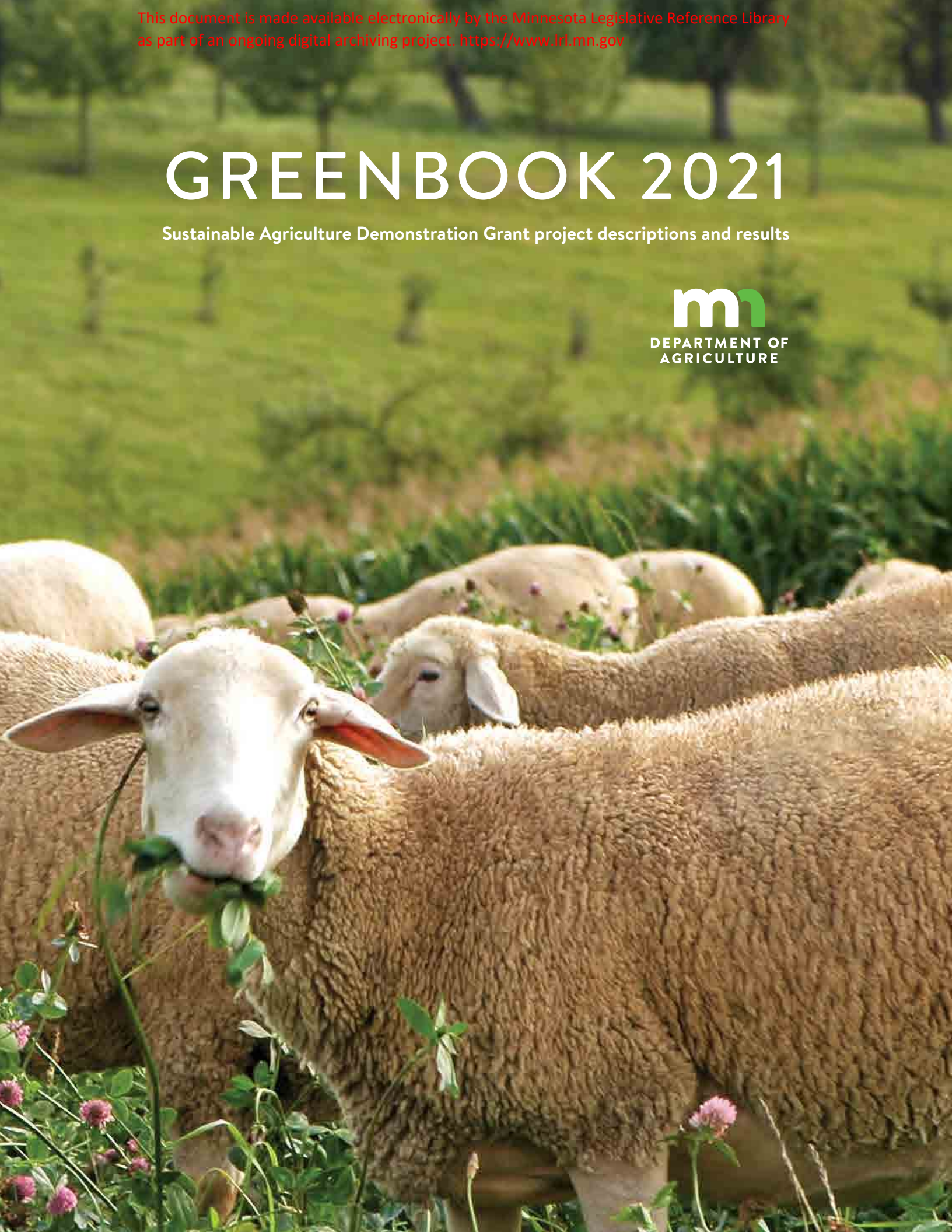
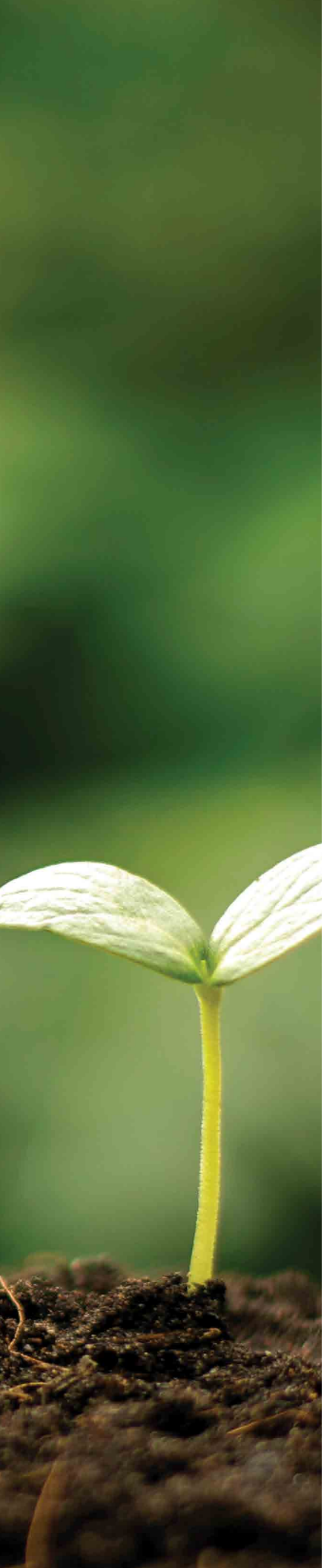
GREENBOOK 2021

Sustainable Agriculture Demonstration Grant project descriptions and results

DEPARTMENT OF AGRICULTURE





GREENBOOK
2021

On behalf of the Minnesota Department of Agriculture (MDA), it is my great pleasure to introduce the 2021 edition of the annual Greenbook. As Commissioner of Agriculture, I'm proud to highlight the important work of the Sustainable Agriculture Demonstration Grant Program, a component of the Agricultural Growth, Research, and Innovation (AGRI) Program. While the COVID-19 pandemic left no area of agriculture unaffected, the projects presented here are great examples of innovative ideas Minnesota farmers and researchers are exploring and testing to make farming in Minnesota more productive and sustainable, and the challenges they've had to overcome during a global pandemic. I applaud their perseverance and dedication.

This year's recipients were awarded a total of $256,890.82 for forward-thinking initiatives that promote sustainability in agriculture. Much as I would love to, I can't highlight every funded project here. But if you read further, you'll see that from examining how to reduce erosion through winter-kill cover crops; to building biodiverse, aerobic composts; to examining the impact of feeds on pastured poultry; to examining no-till alfalfa hay cropping , these projects are fundamental to the future of agriculture. The Sustainable Agriculture Demonstration Grant Program is dedicated to improving and shaping the future; many previous grant projects have focused on practices that have become widely adopted, such as integrated pest management and cover cropping.

In Greenbook 2021, you'll learn about the successes and challenges an enthusiastic group of grantees have encountered while creating nature-based planting calendars, testing whether cover crops can increase nutrient uptake for cash crops, examining the viability of cut-flower peony varieties in Minnesota, and more. In addition to descriptions of new projects, the Greenbook will present final reports on 2018 projects, as well as brief updates on the progress of ongoing projects from 2019 and 2020. To learn more about any of them, please don't hesitate to get in touch with the grantee. You'll find contact information listed at the beginning of each project summary.

If there's a sustainable farming idea you'd like to try, please keep this opportunity in mind. To apply, please submit all application materials via the AGRI Sustainable Agriculture Demonstration Grant webpage at: www.mda.state.mn.us/sustagdemogrant.

Thom Petersen

Thom Petersen, Commissioner
Minnesota Department of Agriculture

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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.

Our Crop Research Grants are intended to generate applied crop research that will improve agricultural product quality, quantity, or value. They fund projects led by professional scientists and researchers that respond to complex questions facing crop producers in Minnesota.

In the Greenbook, we share the recommendations, observations, and experiences collected by grantees so that the public can use this growing collection of information to improve their decision-making on their own farms. We welcome growers with research questions to apply for our grants so that we can address the emergent and on-going challenges facing local agriculture.

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.

Contents

Articles

Alternative Markets and Specialty Crops

Cropping Systems

Contents

Sustainable Agriculture Grant Program

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 1,237 grant applications and approved over $4.6 million in funding for 368 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 2020, are described in Greenbook 2021.

Grants last for two or three years with a focus on on-farm research or demonstration projects. Grantees may receive a maximum of $50,000, with a dollar-for-dollar match required on the amount over $25,000. 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.

GRANT SUMMARIES

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

Sustainable Agriculture Grant Program

SUMMARY OF GRANT FUNDING (1989-2021)

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
2017	7	$103,682	$14,812	$5,397-25,000
2018	11	$223,099	$20,282	$12,167 - 25,000
2019	9	$239,772	$26,641	$11,952-50,000
2020	8	$160,145	$20,018	$11,158- 25,137
2021	9	$256,890.82	$28,543	$9,644-46,937
Total Funded	**368**	**$4,661,035**	**$13,188**	**$1,000-50,000**

No grants were awarded 2003-04, and 2011-12.

Cropping Systems

No-till Vs. Conventional Till for Alfalfa Hay Establishment and Production for a Three-Year Stand

Grantee: Connor McCormick, McCormick Farm
Duration: 3 years
Award Amount: $9,644.00
County: Houston

PROJECT OBJECTIVES

Finding ways to farm more sustainably and economically is essential for smaller operations like ours, because it is hard to compete with the bigger operations that have volume discounts and profit margins on their side. No-till corn and beans have been one practice that we have been adopting and have had success with. We also raise alfalfa hay, and we have yet to try the establishment of alfalfa through no-till. We have always performed a fall tillage, followed by a spring cultivation with a finishing pass before we seed down our alfalfa in the spring. My father believes that good seed to soil contact is vital for a productive 3-year alfalfa stand and that the only way to achieve that is through tillage. However, if we could successfully no-till our alfalfa, we would save three tillage passes, countless labor hours, several gallons of fuel, and acres of degraded soil! The goal of this project is to determine the effectiveness of no-tilling alfalfa.

The purpose of this project is to determine if alfalfa can be successfully established and productive using a no-till drill in corn and bean ground. The vast majority of the farms in our area grow alfalfa for their livestock, but very few have tried no-till as a method for establishing their alfalfa stand, as they still rely on tillage equipment to prepare the soil for seeding. Generally, most farms keep their alfalfa stands for two to five years. If no-tilling can be an effective way to establish an alfalfa stand that will last and be productive for three years, farms could save several hours, gallons of fuel, and tons of soil loss from having to till their ground two or three times before seeding alfalfa. Here in Southeast Minnesota, we have steeper slopes and a lot of water runoff, so it is especially important that we continue to improve our soil management. Also, if we can improve our soil health through practices like this, we will make our soils more productive, and thus more profitable. Through the Haney Soil Test, we will be able to compare our soil health and productivity to determine the extent that no-till may improve our soil health and productivity. I have talked to many local farmers and the majority of responses I have received are that they have yet to try no-tilling alfalfa, mainly due to their lack of experience with it. This project will help with sharing that experience and will guide us to managing our land more sustainably and profitably.

PRIMARY OBJECTIVES

1. **How well does alfalfa germinate, establish, and grow in a conventionally tilled field compared to a no-till field over a 3-year lifespan?**
   There are several factors associated with no-till that may affect this, and it is my goal to observe, record, and demonstrate these differences between no-till and conventional till. Over the 3-year lifespan, I hope to see a significant difference in the total hay health, hay nutrient levels, and total biomass produced between the no-till and conventional till.
2. **Is no-till alfalfa stand more successful in bean ground or corn ground?**
   Our conventional method was to always plow previous corn ground and plant our alfalfa into that the following spring. For this no-till experiment, I'm going to try no-tilling into both corn and bean ground and compare the difference in alfalfa germination, growth, and production over a 3-year lifespan.
3. **Does no-till improve general soil health, soil biological activity, and soil nutrient retention in comparison to conventional tillage?**
   The Soil Haney Test is an accurate measure of these soil characteristics and this project will help farmers learn the differences that no-till may make in their soils.

Comparison of Variable to Uniform Rate Irrigation for Impacts on Groundwater Quality and Quantity

Grantee: Vasudha Sharma, University of Minnesota
Duration: 2 years
Award Amount: $38,000.00
County: Stearns

PROJECT OBJECTIVES

Currently, Minnesota has approximately 600,000 acres of irrigated agricultural cropland, a number that increased by 4 percent from 2007 to 2012 (USDA NASS 2012). Many of these irrigated acres are in Minnesota's Central Sands region. The course-textured nature of the region's soils means that they have a low water holding capacity and a rapid drainage rate. At the same time, many communities in this region depend on groundwater as their sole drinking water source. Balancing agriculture's economic needs while protecting rural drinking water supplies leads to two critical challenges in agricultural watershed management. First, is groundwater quality. Water percolates through the soil profile quickly in the coarse-textured soils. This means that agricultural chemicals (fertilizers) can also leach quickly through the root zone and into groundwater which represents a financial loss to the farmer. Further, fertilizer leaching poses environmental, human health, and economic risks to communities that use groundwater for drinking. Second, is water quantity. High groundwater withdrawals during the crop growing season can temporarily reduce the discharge of groundwater into nearby streams and lakes, impacting aquatic ecosystems as well as causing interference with nearby private and municipal wells.

A meaningful way to address these issues is by implementing proven advanced irrigation management techniques and technologies such as variable rate irrigation (VRI). Our project focuses on addressing both groundwater quality and water quantity by implementing precision irrigation technology and developing an integrated agricultural water management research and extension program in Minnesota.

In this research, we will evaluate the impact of VRI technology on water and nutrient savings, corn yield, and nitrogen (N) leaching in comparison to uniform water management. VRI technology addresses the reality that soil physical properties can vary significantly within a single field–from rapidly draining sands to poorly drained clays. Uniform rate irrigation (URI) does not account for this variability leading to potential over- or under-application of irrigation water. By addressing spatial variability with VRI, we will optimize irrigation for each soil type within a field, maximize crop growth, and minimize negative environmental consequences. The project will address the applicability of VRI technology in Minnesota soils and climate, and its ability to reduce N- loading to groundwater, and total water use. If successful, the project will demonstrate the success of VRI and increase the implementation of VRI in Minnesota through engagement with farmers to share the benefits of this practice, address their concerns, and develop the tools they need to incorporate it into their farming strategy.

A secondary goal of this project is to evaluate the use of nitrate quick test strips to measure nitrate concentration in lysimeter water samples. Lab testing for nitrate can be expensive as well as time consuming. A quick test strip provides inexpensive and instantaneous information about the nitrate concentration in a water sample and will allow farmers to make quick, well-informed decisions about nutrient and water management. The quick test values and lab values for nitrate concentrations will then be compared to see how accurate the test strips are and to generate a calibration curve that could be used for farmers and other agricultural stakeholders to approximate nitrate levels in real-time.

PRIMARY OBJECTIVES

1. Quantify and evaluate the impact of variable rate irrigation (VRI) in comparison to conventional uniform rate irrigation (URI) on nitrogen (N) leaching, grain yield, and crop water use at the field scale. A secondary goal of this objective is to evaluate the use of nitrate quick test strips to approximate nitrate concentration in water samples compared to a lab method. A calibration curve of the quick test and lab values will be generated in this project.
2. Understand the economics of VRI in comparison to URI in an on-farm setting in Minnesota and compare corn crop water productivity to net income.
3. Facilitate extension and engagement through field days, irrigation and drainage workshops, and conversations with farmers to disseminate the project results, promote VRI technology among growers, and develop actionable and practical strategies for adoption. To provide education on VRI to farmers, agricultural professionals, and other agricultural stakeholders through demonstration and extension bulletins/blogs.

2021 New Demonstration Grant Projects

FRUITS & VEGETABLES

Tomato Phosphorus Removal Rates with High- or Low-phosphorus Transplant Solutions and Grafting

Grantee: Charles Rohwer, University of Minnesota
Duration: 2 years
Award Amount: $24,831.00
County: Waseca

PROJECT OBJECTIVES

Vegetable farmers often use manure and compost for fertility. Organic vegetable growers and gardeners are prone to apply more phosphorus (P) than is needed for their crops through repeated application of manure and compost. Soil P after manure and compost application can become high or even excessive because the ratio of nitrogen (N) to P in these fertilizers is often lower than plants require. Soil P in runoff can become an environmental pollutant. Maintaining soil P at a level useful to crops but below excess levels is important in limiting P pollution. This project aims to help vegetable growers increase yield and increase the total phosphorus removed from soils fertilized with organic amendments containing high amounts of P. In previous research, we found that when soil P was adequate for healthy plant growth, adding P at transplant using water-soluble fertilizer increased tomato yield by 18 percent. This practice is common in commercial and home vegetable production. We don't know if the amount of soluble P fertilizer added at transplant in our previous work was subsequently removed from the field at harvest (as tomato fruits), or if more (or less) P was removed than was added to the soil by the soluble fertilizer. In addition, methods to enhance yield without adding additional P would be useful to remove extra P from the soil. Grafting tomatoes onto vigorous rootstocks may be one way to accomplish this. In order to understand these relationships between grafting and soluble transplant fertilizers and their ability to remove P from the soil through harvested tomato yield, we need to study P content and yield of tomatoes.

The primary hypothesis for this project is that adding P fertilizer in transplant solution will increase the soil P removal rate by a tomato crop through increased yield, even in soils with adequate P. We also hypothesize that generative rootstocks will enhance P removal. Improving the ability to remove P from the soil as harvested produce will help vegetable growers to contribute to improved water quality throughout Minnesota. The treatments will be applied to tomatoes in two locations: University of Minnesota SROC in Waseca, and Cedar Crate Farm in Waldorf. Results will be shared through various media channels, a virtual field day, grower meetings, and a peer-reviewed publication.

PRIMARY OBJECTIVES

1. Test whether high-phosphorus (P) or low-P transplant fertilizer solutions enhance yield and P removal rate of field-grown tomatoes, beyond the amount of P added in the transplant solution, especially in conditions of high P fertility.
2. Test ability of generative (fruit-promoting) rootstock to enhance yield and P removal rate of field-grown tomatoes, especially in conditions of high P fertility.

On- Farm Research on Haskap/Honeyberry Production

Grantee: Philip Stowe, Walking Plants Orchard
Duration: 3 years
Award Amount: $16,500.00
Counties: Carlton, Douglas, and Washington

PROJECT OBJECTIVES

We will organize a coordinated research project that looks at honeyberry yield, pollination, and labor requirements in farms in west-central, east-central, and northeast Minnesota. Yield will be measured over three years on eight different cultivars and correlated with site data collected. At each site, there will be soil tests and leaf tissue analyses to hopefully find if honeyberries do better in specific soils. Soil moisture content will be measured to help growers time irrigation.

Honeyberries, or Haskaps, are a popular new fruit crop in Minnesota. Honeyberries have similar uses to blueberries, but honeyberries tolerate a wide range of soils, need no winter protection, and the blossoms are resistant to frost. The fruit is primarily used for processing, and there has been demand among wine makers and distillers. In Canada, it is used to flavor and color ice cream and yogurt. Since it is a new crop, every grower is trying to learn as much as possible, and so far, there has been little coordination between different growers. There is little publicly recorded information on yields, problems that growers have encountered, fertilization requirements, or irrigation.

Some growers who have planted honeyberries have been disappointed by yields that were lower than expected. The low yields could be caused by poor pollination, a lack of flower bud formation, bird damage, cultivar selection, or pollinator proximity. Unlike most fruit crops, honeyberries do not produce extra flowers, and ideally growers want every flower on their plants pollinated. Honeyberries bloom early in the spring before honeybees are active, and therefore bumblebees appear to play a more important role compared to other crops.

During this project, we will collect important production data that may help this fruit crop become more commercially viable in Minnesota.

PRIMARY OBJECTIVES

1. Calculate average yields for eight cultivars grown in three different locations over three years.
2. Correlate yields with blossom production, pollinator activities, climate, soil type, and plant nutrient status.
3. Record managing and harvesting time to help determine production economics.

ALTERNATIVE MARKETS AND SPECIALTY CROPS

Increasing Harvesting and Processing of Wild Rice and Other Small Grains for Small-Scale Growers, NE MN

Grantee: Honor Schauland, Friends of Finland
Duration: 3 years
Award Amount: $35,769.00
Counties: Lake and Cook

PROJECT OBJECTIVES

The harvesting of wild rice requires knowledge of wild rice populations, identifying the correct stage for harvesting, diseases to avoid, and sustainable harvesting techniques. Similarly, the processing of wild rice requires precision to dry, parch, and de-hull the rice kernel while ending with a quality product. The Finland Food Chain will cultivate a new generation of sustainable wild rice harvesters and processors through classes, mentoring, and apprenticeships, while simultaneously exploring dual economic benefits of off-season small grain processing.

The Finland Food Chain, formed in 2018, was founded to support the development of a comprehensive local food system for Finland and the greater Arrowhead Region of Minnesota. In Fall 2020, the Finland Food Chain procured a full line of wild rice processing equipment to establish the Finland Wild Rice Processing Facility. This equipment will be used to explore opportunities for processing and sorting of other small grains. Research clearly shows the potential for local food systems to be major drivers of local economies creating benefits for all who live and work in these communities. The primary objectives of this Sustainable Agriculture Demonstration Grant include the following:

1. **Facilitating the intergenerational transfer of knowledge, skills, and equipment for wild rice harvesting and processing through direct mentorship and apprenticeships.**
   Based on traditional transfer of wild rice skills and knowledge, a group of expert mentors will provide firsthand experience as personal guides for young producers to learn wild rice harvesting and homestead-scale processing skills. For those who wish to develop their skill set further, the apprenticeship program will give aspiring processors a deeper hands-on experience around the technical skills of processing wild rice as a business.
2. **Testing and implementing the use of wild rice processing equipment for the processing of other small grains to support small scale growers in northeastern Minnesota.**
   Small-grain production was once a part of northeastern Minnesota's agriculture, and regional food resilience requires it to be once more. One limiting factor to small-grain production is a lack of grain processing capacity for small producers. The dehulling, winnowing and sorting equipment used for wild rice is similar to that used for small grains, and because the seasonality of processing small grains differs from that of wild rice, there is the potential for one facility to support multiple small grain crop processors. This project will test and demonstrate the technical and financial feasibility of utilizing wild rice processing equipment to also process other small grains with particular emphasis on small scale growers.

3. **Producing and distributing a series of educational modules related to the historical, cultural, environmental, and economic benefits of wild rice in the local food systems and the ecology, harvesting, and processing of wild rice.** The diversity of methods and equipment used by wild rice harvesters and processors along with personal and cultural perspectives, will be reflected in 10 learning modules. Modules will include: a) benefits of wild ricing on individual and community health and economics; b) the natural history and ecology of wild rice; c) technical skills for harvesting and processing wild rice; and d) historic and modern ways of cooking and building meals around wild rice.

   Such work is of vital importance in the face of the challenges posed by climate change, environmental degradation, and the current global pandemic. At a time of increased awareness around sustaining local food systems for food security and resilient local economic systems, the loss of wild ricing knowledge and processing capability must be avoided.

SOIL FERTILITY

Winter-Kill Cover Crop

Grantee: Jason Miller
Duration: 3 years
Award Amount: $30,000.00
County: Murray

PROJECT OBJECTIVES

Miller Farms has already invested in structural improvements to reduce erosion, including three catch-basins installed in 2020, along with extensive gully and drainage repair. To further reduce erosion, they are turning to in-field practices such as cover crops and reduced tillage. Vertical till was used for the first time in Spring 2020 and strip-till will be used for the first time in Spring 2021. An oat cover crop was planted following the 2020 soybean crop. We will investigate soil movement with different tillage practices, especially during the spring and fall when wind and water erosion are extensive on southwest Minnesota's fine-textured soils. Here, we will install replicated strips of two tillage practices, field cultivation and striptillage, and measure soil movement using small mats to collect soil blowing or washing across the land surface. In addition to the erosion data, we will track yield and expenses for two seasons to estimate the partial budget for each system.

Erosion is a primary concern in the farming industry and southwest Minnesota is no stranger to this issue. On our farm, located in Cameron Township of Murray County, erosion has been a constant battle due to various factors such as: the elevation of the adjacent field being higher than ours and the past two years' weather has created extensive runoff due to rapid snow melt and heavy flooding from record rainfalls. The extensive runoff had created large gullies, some as deep as 2-3 feet in depth. These gullies washed away seed, seedlings, and nutrients in the field.

We have been working with our local NRCS staff to decipher the best possible options to reduce erosion and improve the overall soil health of this field. As a result, we determined that the installation of a water and sediment control basin system was the best option for our field, as grass-waterways would continue to erode due to the volume of runoff. In the first year, the basin has performed very well, leaving residue on the surface. In addition, vertical tillage appeared to reduce wind erosion during spring storms in 2020. Next, we want to measure the actual change in soil loss under different tillage systems and see if adding a cover crop improves the soil further.

Reducing loss of sediment from agricultural lands with cover crops and reduced tillage is a key goal in Minnesota's Nutrient Reduction Strategy. However, there is not a lot of on-farm data from testing different tillage strategies' capacity to reduce soil loss. While modeled data is fairly reliable and highly relevant, collecting physical, on-farm data could be a powerful demonstration for other farmers in the area.

Combining these sediment loss measurements with economics is critical for showing other farmers that these systems can be implemented on their farms. Farmers need to see that they can use reduced tillage and cover crops while remaining profitable. Cost-share is available from NRCS and various SWCDs, but is usually short-term, thus farmers need to be prepared to make a transition to a new system over the course of a few years.

1. Evaluating the partial budget of each tillage system. We will track inputs, including tillage costs and labor, seed, fertilizer, as well as crop yield. The partial budget consists of income-expenses.
2. Evaluating the soil loss in each tillage system. We will use small mats, placed and removed seasonally, to estimate soil movement across the field. Soil collected on the mats will be analyzed for total soil carbon and nutrients.

Evaluating Erosion, Yield, and Economics in Different Tillage Regimes After a Crop & Livestock Farmers Building Biodiverse, Aerobic Composts Using the Johnson-Su Method

Grantee: Shona Snater, Land Stewardship Project
Duration: 3 years
Award Amount: $46,937.22
Counties: Mower, Scott, and Winona

PROJECT OBJECTIVES

The Land Stewardship Project seeks funding to work with four farms in Minnesota over two and one-half years to build biodiverse composts using the Johnson-Su method. The project aims to develop recipes with materials and quantities identified to promote the growth of beneficial soil microbes in an aerobic, static compost system that undergoes a full heating cycle. Revitalizing the soil with beneficial microbes has environmental benefits and saves farmers money. Regular monitoring of the composts' temperature, moisture and maturation will be conducted by the farmers. Lab analysis will include meta-DNA bacterial and fungal analysis to show biodiversity and a direct microscopy analysis will give the microbial abundance. Results will compare our Johnson-Su test results to industrial-turned composts to show difference in soil microbial make-up. Outreach to hundreds of farmers will be vital to share Johnson-Su compost recipes to other farmers and reduce their learning curve.

High attendance at Land Stewardship Project events focused on soil microbiology indicates that farmers are invested in understanding the intricacies of healthy soil. Along with 40 other attendees, one of the four farmer-scientists participating in this project took a day-long soil microbiology and microscope course with internationally known soil microbiologist, Dr. Elaine Ingham, hosted by LSP in February of 2017.

Research conducted by Dr. Ingham, Dr. David Johnson, and others have revealed the soil's ability to cycle nutrients and supply them to the plant is dependent upon the bacteria to fungal ratios and the abundance of beneficial, predatory microbes—protozoa, nematodes and arthropods. According to a statement made by Dr. Christine Jones during a presentation, 85 – 90 percent of plant nutrient acquisition is microbially mediated. Cultural management practices common in agriculture today, which include intensive tillage, removal of plant residues, removal of grazing livestock, application of synthetic fertilizers, and bare fallowing of fields, have been shown to have detrimental effects

on populations of microorganisms (Dick, 1992), (McLaughlin & Mineau, 1995), (Wright & Nichols 2002), (Dighton, 2003), (Jangid, Williams, et al. 2008). In some circumstances, creating fields that are devoid of the microbes and fungi necessary to a functioning soil ecosystem. Thus, providing a need to reintroduce them back to our farmland.

Compost that is microbially diverse and fungally dominant can serve as an "inoculant" rather than a soil amendment or fertilizer. Even a small amount of compost can affect and be applied on large acreages either by coating the seeds or applying a liquid extract in the seed trench during planting. Currently, there are many private companies offering "microbial inoculant" products to farmers. We at LSP and the farmers we work with, are interested in ways to make high-quality, bio-diverse products on our own farms. One of the most promising methods is Biologically Enhanced Agricultural Management (BEAM), developed by Dr. David Johnson and his wife Hui-Chun Su. It centers on the use of a Johnson-Su Bioreactor to create a static aerobic compost that requires little management, very little use of large equipment, water and energy, and can produce some of the most microbially diverse and fungally dominant communities.

The Johnson-Su Bioreactor method was developed in New Mexico with locally sourced materials. Therefore, it creates a need to test recipes using materials available to Minnesota farmers. It is important that the compost has a balanced carbon to nitrogen ratio adequate for a full heating cycle up to 165 degrees F, but not so Nitrogen heavy as to cause anaerobic conditions. The compost needs to undergo a heating cycle to kill pathogens, terminate weed seeds, and to promote the growth of beneficial microbes. Farmers currently using this system are having difficulty finding this balance.

Our project seeks to fill in the missing information and develop multiple compost recipes that identify available materials to Minnesota farmers in specific amounts and will result in an aerobic, thermal, biodiverse, and bio-dense compost. To encourage more farmers to use this method, we need clear and proven recipes that will reduce the learning curve.

PRIMARY OBJECTIVES

1. First, we aim to identify compost recipes—made from materials commonly available to Minnesota farmers—to ensure that the resulting composts undergo a full heating cycle, reaching maximum temperatures of 140-165 degrees F and dropping back to ambient temperature. This is to ensure extermination of pathogens, weed seeds and promotion of beneficial soil microbes (Trautmann et al., 2019).
2. We will compare biodiversity and abundance of microbes in Johnson-Su compost using different recipes to industrially produced compost standards from the Olmsted County Recycling Center, Cowsmo Compost, and Vermont Compost Company. Because industrial compost is turned and priority is to finish the compost in a short amount of time, we hypothesize the overall biodiversity and abundance of those industry-produced composts to be lower than compost produced through the Johnson-Su method.
3. The third objective is to educate and share our results with as many farmers in the region as possible. The Johnson-Su compost system is complicated and farmers looking to try out this practice for the first time need step-by-step instructions in order to grow a biodiverse, aerobic compost that has undergone a thermophilic cycle. The demonstration grant findings will be shared in a variety of ways. We also plan to submit the results to the Chico State University Johnson-Su bioreactor registry.

Understanding the Possibilities of On-farm Compost to Reduce or Eliminate Commercial Fertilizer

Grantee: Chad Olsen, Olsen Custom Farms
Duration: 3 years
Award Amount: $25,000.00
County: Lincoln

PROJECT OBJECTIVES

The farm began composting our mono-slope cattle barn manure in September 2020 to fully realize the value of the fertility on all the farm's acres. The nutrient amount generated from the barns was calculated to satisfy all our Phosphorus (P), Potassium (K), and micronutrients, and a quarter of our nitrogen for 11,000 acres. This realization led our farm on the journey to begin producing compost. Making compost is part science and experience; using compost as the hub of a broadacre farm's fertility program is much the same. In order to rapidly close the knowledge gap on using compost on our farm, we intend to conduct a 3-year field study on two soil management environments CT (fall tillage and spring tillage) and NT (mature no till 5+ years). Two treatments will be applied: compost and synthetic fertilizer. From the results of this study we hope to understand the possibilities of compost more fully in our broadacre crop production to greatly reduce our need for synthetic/mineral fertilizer.

This project is very important to our farm because we are transitioning our entire broadacre crop fertility program from the traditional synthetic N-mineral P-and-K system to a carbon-based approach through compost and cover crops. The farm has actively been using cover crops for five years after small grain to increase active soil carbon and provide for following crop nutrients. The initiation of producing compost from our feedlot manure was the next step to close the loop on imported crop nutrients and increase carbon additions into our farm's soils.

By carrying out this project we hope to gain understanding of what possibilities and limits our compost will have to adopting our new broadacre crop fertility system. We also hope this will inspire our peers to consider composting and/or using compost to localize some or all of their farm's fertility. By localizing crop fertility, we can move away from the problems of nutrient export into surface waters in particular and improve broadacre crop production stability with healthier soils. Localizing crop fertility saves on energy needed to manufacture N, mine P and K, and transport commercial fertilizer long distances. By sharing our findings on carbon-based fertility with farmers throughout the region, we hope to produce and use compost on their farms' soils.

PRIMARY OBJECTIVES

1. Quantify the extent of crop production possible using on farm compost in place of commercial fertilizer.
2. Demonstrate the value of compost to soil health as an ancillary benefit over using commercial fertilizer.
3. Inspire peers to consider composting and using compost as part of their broadacre crop fertility.

LIVESTOCK

Evaluating the Impact of Feed on Animal Health, Growth Rates, and Meat Quality in Pastured Poultry

Grantee: Valerie Luhman, Grassfed Cattle Co.
Duration: 2 years
Award Amount: $30,209.60
County: Goodhue

PROJECT OBJECTIVES

Evaluating the impact of corn and soy feed versus corn-free, soy-free feed in pastured poultry production will allow us to understand the impact the two feed rations have on animal health, growth rates, and meat quality. After direct marketing over 1,000 pastured chickens directly to customers in the Twin Cities, many asked us to raise corn-free, soy-free chickens. Many customers explained they choose not to eat pastured chicken because of food sensitivities caused by the meat after the chickens eat corn and soy feed. By assessing the animal health and growth rates between the two groups of chickens, we will provide research for other farmers on the profitability differences between feeding corn and soy feed versus corn-free, soy-free feed to pastured chickens. Lastly, understanding the differences in nutritional composition of the meat between the two groups of chickens, we will provide data for customers, marketing purposes, and a potential new market for farmers.

The purpose of this project is to provide meaningful economical, ecological, and social contributions to farmers and consumers of poultry products. It will improve the environment and landscape on which the chickens are raised, the lifestyle and economics of the farmers who implement these practices, and the health and well-being of the consumers. The project will allow us to do these things in the following ways:

The use of the mobile range coop will benefit farmers by allowing them to run a higher quantity of chickens on pasture more efficiently, producing more meat to sell, and generate more income from their labor and land. This system of raising chickens has a significantly lower investment cost to the farmer than an alternative commercial chicken barn and offers significantly less risk.

The portability of the mobile range coop allows farmers to target areas of land in need of animal impact. The natural impacts of chicken pecking and scratching provides a controlled disturbance on the soil encouraging the growth of new plant species and the density of the forage stand. Manure from the chickens will provide a valuable, natural nutrient source to low-fertility areas and can be a cost-effective way of improving fertility on the landscape. More fertile and productive soil will improve the nutrient density of the food and the profitability of the farm.

Our research on the use of corn-free and soy-free feed rations may also contribute to an increased demand for corn-free and soy-free grains and encourage farmers to include additional crops to their farming systems. One of the principles of soil health is diversity; encouraging a diverse crop rotation will improve the resiliency of individual farms and the agricultural industry.

There have been some studies on non-soy poultry production, however, very little data exists on corn-free and soy-free rations in pastured poultry production. As direct marketers, we have seen a tremendous demand from customers with food intolerances and allergies to soy and corn-fed meat products who desire products raised without corn or soy. This research and data are essential to the expansion of the soy-free and corn-free meat market in order to better serve our communities and customers.

The production system being experimented with in this study provides an enjoyable way of raising chickens that is healthy for both producers and chickens. It allows chickens to express natural behaviors and increase the diversity of their diets through the consumption of plants and insects while positively impacting soil health.

PRIMARY OBJECTIVES

1. **Animal Health** - Assess the impact on mortality, feather growth and animal health between the corn and soy groups and corn-free and soy-free groups. By collecting these observations, we will determine the impact the two feed options have on animal health and profitability for our farm and other farms exploring pastured poultry options.
2. **Growth Rates** - Assess the differences in feed consumption, rate of gain, feed conversion ratios, live weights, and processed weights between the corn and soy feed groups and the corn-free and soy-free feed groups. Data will be collected daily to understand the impact on pastured poultry growth and the profitability differences between the two feed types. The growth rate differences are valuable to farmers meeting customer demand for pastured poultry raised with either type of feed.
3. **Meat Quality** - Evaluate the nutritional composition differences of the meat between the corn and soy feed groups and corn-free and soy-free feed groups to gain data for meeting customer demand, marketing statistics, and farmers adding a pastured poultry enterprise. There is a growing demand for corn-free and soy-free pastured chickens; by understanding the nutritional composition differences, we will be able to differentiate the products and share the new market with other farmers.

Sustainable Agriculture Demonstration Grant Project Updates 2020

The following 2020 project updates contain the purpose for conducting the project, project design, and activities conducted during the first year of the grant project. To find out more about these projects, contact the principal investigators directly through the contact information included in their update. To find out more about the Sustainable Agriculture Demonstration Grant, contact the Grant Administrator with the Minnesota Department of Agriculture.

Alternative Markets and Specialty Crops

- **Diversity Agriculture and Its Feasibility in Minnesota: Sustainable Practices and Marketing**
  Grantee: Dean Current, University of Minnesota
- **Exploring Hulless Seed Pumpkins as a Specialty Crop**
  Grantee: Rachel Sannerud, Pluck Flower Farm

Fruits & Vegetables

- **Expanding the Effectiveness of Non-Chemical Pest Control in Organic Strawberry Production**
  Grantee: Andrew Petran, Twin Cities Berry Company
- **Growing and Evaluating Dessert and Perry Pears on a Tall Spindle System**
  Grantee: Gretchen Perbix, Sweetland Orchard
- **Non-chemical Methods for Managing Colorado Potato Beetle: Feasibility for Diversified Farms**
  Grantee: Natalie Hoidal, University of Minnesota
- **Trialing High-Tunnel Raspberries to Increase Yield and Reduce Spotted Wing Drosophila Pressure**
  Grantee: Aaron Wills, Little Hill Berry Farm

Livestock

- **Control of Wild Parsnip through Rotational Sheep Grazing**
  Grantee: Heidi Eger, Radicle Heart Farm
- **Determining Effects of Prescribed Sheep Grazing on Plant Diversity in Native Pollinator Habitat**
  Grantee: Jake Janski, MN Native Landscapes Heidi Eger, Radicle Heart Farm

Cropping System

- **Grazing Intermediate Wheatgrass (Kernza®) as a Dual-Purpose Crop for Forage and Grain Production**
  Grantee: Alan Kraus, Cannon River Watershed Partnership

Alternative Markets and Specialty Crops

Diversity Agriculture and Its Feasibility in Minnesota: Sustainable Practices and Marketing

Grantee: Dean Current, University of Minnesota
Contact information: 651-238-5226; curre002@umn.edu
Duration: 2 years
County: Ramsey

PROJECT SUMMARY

This project focuses on demonstrating the viability of diversifying sustainably produced agricultural products in Minnesota. Minnesota has a large immigrant population, many with agricultural backgrounds but limited opportunities to work in agriculture. We will work with Bhutanese and Nepali immigrant populations. Crops popular with immigrant populations are not always available. This project focuses on production and markets for lesser known Asian crops common from Bhutan and Nepal. We will: a) conduct qualitative research to identify crop varieties from Nepal and Bhutan; and b) explore the feasibility of growing those crops in Minnesota. The outcome of the study is adding new agricultural products to local markets. The long-term benefit of the project is to introduce innovative crop varieties that contribute to the environment, human health, and the local economy. We will use a change model embracing diversity knowledge to support community-based agricultural micro-enterprises.

PROJECT DESCRIPTION

Contemporary science and technology alone are not enough to resolve our food problems. Diversity in the U.S. is growing, and so is the knowledge base. The purpose of this proposal is to gather and share common information about the varieties of crops that are grown in Nepal and Bhutan and that may be grown in Minnesota. Our diverse immigrant population is not only an incredible human resource, but also a reservoir of cultural knowledge, which, if valued, can provide information for better living. In the Bhutanese Refugee Community, older adults have immense knowledge and understanding of how to live a sustainable lifestyle. Bhutanese, Nepalese, Hmong, and Karen communities share similar agricultural and environmental knowledge. Utilizing and managing this diverse knowledge is a way to generate pro-environmental practices.

Nepal is a pioneer in integrated conservation and development where Dr. Dhakal, one of our researchers, spent almost 20 years working with grassroots communities. This initiative is an effort of Dr. Dhakal to work with Minnesota immigrant communities to identify sustainable options for producing crops important to those communities in Minnesota.

Minnesota immigrant communities bring important agricultural skills that are often not utilized, due to the lack of opportunities for those communities to access land and resources needed to produce and market agricultural products. We plan to demonstrate production of lesser-known traditional agricultural products as a way to improve the diets of the immigrant communities, diversify Minnesota's sustainable agricultural base, and create and strengthen community enterprises to support immigrant livelihoods and improved health outcomes. We will also explore opportunities for immigrant students to attend the University of Minnesota and study agriculture and enterprise development.

Sustainable Agriculture Demonstration Grant Project Updates 2020

PRIMARY OBJECTIVES

1. Research community knowledge of alternative crop varieties.
   We have initiated the project through a survey of Bhutanese community members to identify crops that they were accustomed to producing and consuming in Bhutan, their adaptability to Minnesota and a ranking of crops in terms of interest of the Bhutanese community and the ability to find the crops in Minnesota. We are currently working on objective 1.
2. Introduce innovative crop varieties in Minnesota.
   Based on the survey results, we will identify crop varieties that may be suitable for production in Minnesota but not currently available here, identify seed sources, and establish trials in the community gardens that the Bhutanese are currently utilizing for agricultural production during the 2021 growing season. We will also work with different immigrant communities to identify the potential market demand for those crops.
3. Develop immigrant community capacity to engage in agricultural enterprises for economic development.
   In the second year of the project, we will work with the Bhutanese community to develop the skills to engage in agricultural enterprises based on the innovative crops identified and tested. During the first year, we have identified sources of support for the Bhutanese community to gain those skills.

2020 RESULTS

We have initial plant lists from our surveys. These contain a broad range of plants the communities utilize. From these initial lists, we will develop a list with the crops of greatest interest to the immigrant communities that will be used to develop the trial plantings.

Exploring Hull-Less Seed Pumpkins as a Specialty Crop

Grantee: Rachel Sannerud, Pluck Flower Farm
Contact information: 630-335-5106; pluckflowers@gmail.com
Duration: 2 years
County: Mille Lacs

PROJECT SUMMARY

This project explores growing, processing, and marketing hull-less seed pumpkins, or pepitas, as a value-added product to see if it is a profitable crop for small farmers to grow as a means of diversifying their farm and adding profitability to their farm business.

PROJECT DESCRIPTION

The project will demonstrate the viability of growing hull-less seed pumpkins on small farms and processing them for pepitas to be sold as a value-added product for local markets. This will demonstrate if hull-less seed pumpkins can be successfully grown in Minnesota, if they can be processed as pepitas by the farmer to be sold as a value-added product, and if the whole process will turn a profit. With these results, farmers can make informed decisions on if hull-less seed pumpkins are a crop they would like to grow themselves. If successful, this opens up another specialty crop opportunity for small farms that will boost their profitability.

Sustainable Agriculture Demonstration Grant Project Updates 2020

Objectives

- Assess growing methods of pumpkins: seed variety trials, pest and disease pressure monitoring, plant and fruit performance under cultivation, and mulched plots.
- Assess pumpkin varieties upon harvest: fruit size, quality, quantity, and seed to flesh weight ratio.
- Evaluate harvesting, processing, and packaging of the seeds.
- Evaluate marketing and pricing of the value-added product, pepitas, through market channels: direct to consumer, and wholesale.

Design

Three different varieties of seed pumpkins were started in our on-farm greenhouse and transplanted out to the field plot after danger of frost in June. Each variety will be divided among two weed management strategies in the plot, either into bare ground for mechanical cultivation or into hay mulch.

From June through October the field plot and trials within it will be monitored and tended weekly upon transplanting. Evaluations and plant growth, weed pressure, pest pressure, and disease pressure will be made weekly. Measures used to combat these pressures will be performed and recorded weekly. Plant development, flowering, and fruit set and development will be monitored weekly throughout the growing season.

Prior to harvest in October, each trial variety and weed management strategy will be evaluated for plant size and growth habit, fruit quantity, size, and quality. Through two growing seasons, best practices and equipment for management and harvest of the pumpkin crop will be identified and made into a report.

Upon harvest, pumpkins will be put in the greenhouse to cure and for pumpkins seeds to continue to mature within the pumpkins. Curing of pumpkins will be monitored daily for progression in maturity and will be protected from freezing temperatures as needed.

Once pumpkins are cured in October, pumpkins will be brought to the Sprout MN Marketplace to be processed. Each harvested variety of pumpkin will be weighed whole, and percentage of seeds identified as they were processed.

Evaluation

- How did each seed variety perform? Germination, susceptibility to pest and disease pressure, plant and fruit performance in both cultivation and mulched plots.
- Are any seed varieties suitable or better for a good crop? Compare fruit size, quality, quantity, and seed-to-flesh weight ratio.
- How did harvesting go? What tools were needed? How long did it take to harvest?
- How did processing go? What tools were needed? How long did it take to process and package?
- Are pepitas a value-added product that is in demand in wholesale markets? Direct to consumer? What price was the product sold at in each setting? Is it profitable?

Sustainable Agriculture Demonstration Grant Project Updates 2020

2020 RESULTS

These are results from 2020 and are not in full. More detailed results and conclusions will be made at the conclusion of the project in 2021.

Growing of the three varieties under two cultivation conditions went as planned, for the most part. The crop was relatively low maintenance - no serious disease or pest pressures. The mechanical cultivation crop had to be weeded with hand tools due to rapid plant growth preventing the tractor from fitting between rows. As a result, rows will be spaced further in 2021 to allow for mechanical cultivation. Mulched plot only required 2 hours of hand tool weeding mid-season and had greater fruit yields in comparison to the unmulched plot.

Processing took much longer than expected and without clear guidelines on how to process seeds successfully, yielded no high-quality value-added seed product for sale. The dehydration guidelines from USDA were likely made for seeds with hulls rather than hull-less seeds and as a result all processed seeds had too high of moisture content and were therefore not shelf stable or saleable. Dehydration also took significantly longer than expected and as a result created the greater time spent processing. The yield of pumpkins overall was also higher than expected.

We were impressed to find the high percentage of seeds in the Naked Bear pumpkin variety and less impressed with the Godiva and Styrian varieties, which had a low percentage of seeds but were easier to process overall. In 2021, we will take these results and select varieties that have closer characteristics to Naked Bear, keeping a Godiva/Styrian variety in the trial as well as a representative. The Godiva and Styrian varieties were so similar we feel we do not need to trial both for a second season.

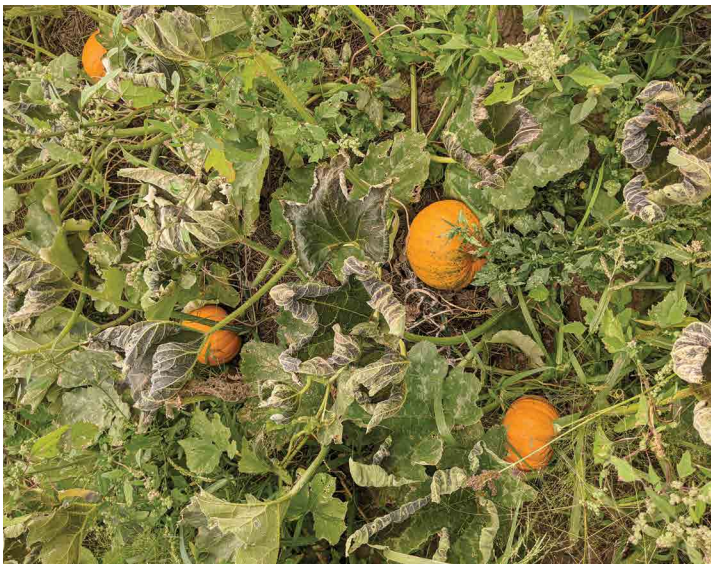
At the end of processing the total yield of seeds was 120 pounds. We anticipate higher seed yield in total in 2021 due to more productive variety trials with increased percentage of seeds in trialed varieties. We anticipate this will be an improvement on the profitability of growing hull-less seed pumpkins for value-added pepita product overall, and will know more at the conclusion of the project.

As a result, marketing was not explored this year and will be done with the 2021 crop when processing has clearer guidance provided by AURI. AURI will provide guidelines for safely roasting the pumpkin seeds, and for testing for shelf stability to yield a value-added product that can be marketed in 2021 and early 2022.

Variety	Germination	Plant Performance	Fruit Assessment	Yield Per Plant	Yield Total	% Seed to Flesh Ratio	Notes
Godiva	Good 360/500	Good	5-10 lb fruit, thinner skin than NB, green/white skin with orange bloom, oblong to round fruit	3-5	2,635 lb	3.7% seed	Best yield by pounds but seed yield mediocre, sprawling plants with large more irregular fruit
Styrian	Good 216/500	Good	5-8 lb fruit, thinner skin than NB, green and white stripe with orange portions, oblong fruit	3-5	1,403 lb	3.4% seed	Average, sprawling plants with more regular fruit than Godiva
Naked Bear	Poor 48/500	Excel-lent	2-3 lb, heavy skinned fruit, orange skin, round fruit	7-12	296 lb	12% seed	Germination may have been affected by placement in the greenhouse, mouse damage etc. Hardest fruit to open for processing, most compact yield per plant

Sustainable Agriculture Demonstration Grant Project Updates 2020

Three varieties of hull-less seed pumpkins were trialed in 2020. From Left to Right: Naked Bear, Styrian, Godiva.



Pumpkins ripening in the field, almost ready for harvest.

Pumpkin plot a day after planting. Foreground is mulched block, background is unmulched block.

Fruits and Vegetables

Expanding the Effectiveness of Non-Chemical Pest Control in Organic Strawberry Production

Grantee: Andrew Petran, Twin Cities Berry Company
Contact information: 847-732-1840; a.petran@tcberries.com
Duration: 3 years
County: Dakota

PROJECT SUMMARY

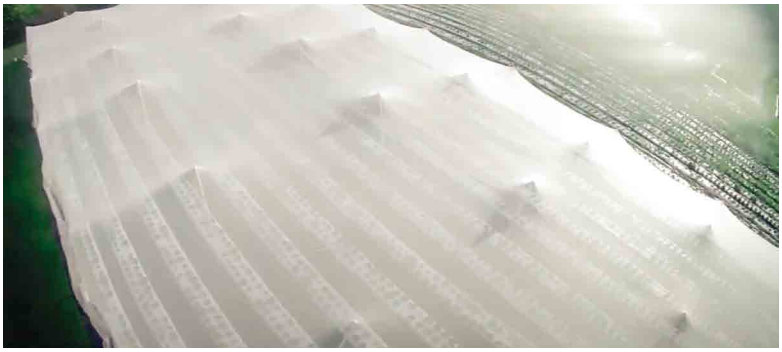
The purpose of this project is to endeavor towards a small fruit production system that is completely spray-free, relatively simple to implement, and financially viable. The project investigates this goal by constructing physical barriers that exclude both fungal and pest pressures with a hybrid of impermeable poly and insect netting completely enclosing the growing area. This is different from most protected culture systems in that 100 percent exclusion is a focal point of construction, whereas common tunnels leave entrances, sides, or ventilation ducts open to the outside environment. Ideally these structures are effective to the point where sprays are no longer needed to control fungal and pest pressures.

The yields of this system will be compared against a 'control' plot of only insect netting, that is relatively less expensive to implement but also not as durable and does not provide relief from fungal pressures like the hybrid system. With this data we can observe if any increased yields from growing in a hybrid system relative to a control netting plot justify the increased costs of implementation and if the system further reduces the need for sprays.

The project was scheduled to begin in 2020 but was delayed due to COVID-related shipping and supply-chain difficulties with Poly-Tex, the greenhouse company that would be working with us to design and construct the hybrid system. We received a one-year extension to begin the project in 2021. During this time, we also decided to change our hybrid structure providers, as Poly-Tex faced increased difficulties due to COVID, to Farmer's Friend, Inc. The structures from Farmer's Friend are more readily available and easier to modify for 100% hybrid exclusion, thus making it easier for other farmers to implement the system in the future. We received our supplies from Farmer's Friend in the last week of January 2021 and look forward to beginning the project in earnest in 2021.

PROJECT DESCRIPTION

Day-neutral strawberry production offers the advantage of a considerably longer harvest season relative to traditional June-bearing types. This works to increase total annual yields and revenue for a farm. However, since day-neutral plants are managed in an annual rotation, any protected culture needs to be relatively easy to disassemble and 'move with the production' to new plots each year. Therefore, our two treatments (traditional and hybrid) are better suited for this type of production than high tunnels, which are more expensive and semi-permanent in nature.



A traditional system set-up; a large insect exclusion netting draped over steel and PVC support poles connected with polyamide wire to make a support grid and held into place with sandbags.

The hybrid system will be a network of 'Gothic Pro' protected culture structures with poly over the top to provide fungal pressure reduction, and modified with insect netting to create a 100 percent exclusion environment to reduce pest pressures. Leafcutter bees will be introduced to each system for pollination purposes.

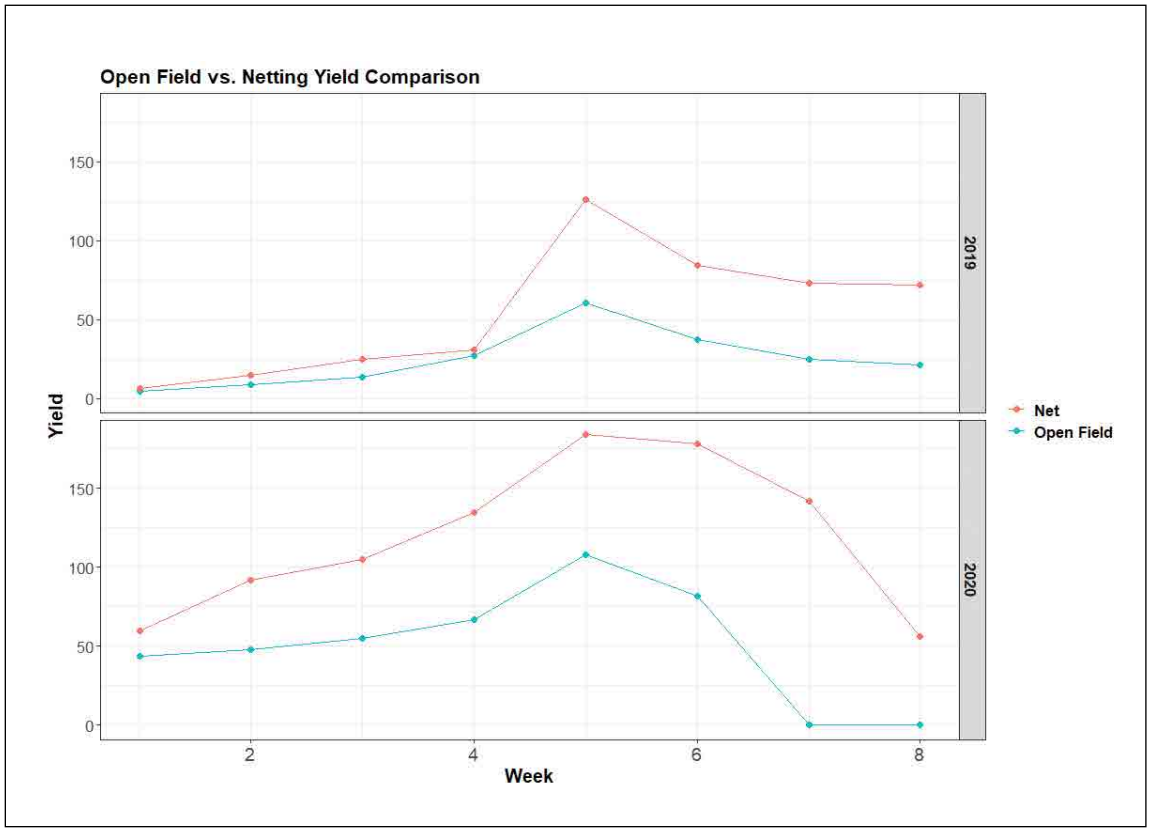
Primary data collection will be total and marketable yields for each plot treatment (traditional vs. hybrid). Yields will be calculated weekly and combined for a cumulative total at the end of each year. Marketable yields will be calculated as the total amount of 'Grade A' and 'Grade B' fruit each week, where 'Grade A' fruit will be sold fresh at market, and 'Grade B' fruit with minor blemishes will be frozen for sale to processors. Comparative yields between each net type will be made. We will also include average yields from open field plots harvested at our farm in 2018-2019 for comparison.

Cumulative spray events within each plot will be documented and compared against the average cumulative spray events in open field plots in 2018 and 2019, as recorded on our farm. Data will be recorded in Microsoft Excel; Figures and statistical comparisons will be made within an R statistical software package.

The economic value of each system will be calculated as well by comparing the cumulative yields of each system to their relative cost of construction. With these figures we can help determine if the hybrid net system is economically worthwhile on our plot.

2020 RESULTS

Due to the one-year extension, we have not compiled results yet for this project. The results below are from a previous two-year project (2018-2019) comparing yields of the netting treatment vs. an open-field control.



As you can see the netting treatment is consistently more productive relative to an open field control. We look forward to seeing if the hybrid system can provide further yield advantages while also completely eliminating the need for sprays.

Growing and Evaluating Dessert and Perry Pears on a Tall Spindle System

Grantee: Gretchen Perbix, Sweetland Orchard
Contact information: 651-252-4337; sweetlandorchard@gmail.com
Duration: 3 years
County: Scott

PROJECT SUMMARY

The purpose of this project is to establish, grow, and evaluate a high-density dessert and perry pear planting (perry is the pear equivalent of fermented cider). Although pears have been historically grown in Minnesota, they are rarely grown at high densities, with the commensurate higher yields and greater profits. The project will commence in spring 2020 with a planting of 300 pear trees on the OHF87 semi-dwarfing rootstock and will include ten dessert varieties and eight perry varieties. A five-wire trellis will be constructed to support aggressive training of the pears in an attempt to limit size and induce precocious fruiting. The trees will be trained and managed in 2020, 2021, and 2022. The project will evaluate hardiness, growth, disease, and yield.

PROJECT DESCRIPTION

The purpose of this project is to establish, grow, and evaluate a dessert and perry pear high-density planting. The project will be assessed in terms of hardiness, growth, disease, and yield. Key findings will indicate if the rootstock/variety combination is hardy, how well the trees are suited for the tall spindle high-density system, and if the trees yield a crop in year three.

This project is important because pears are not usually planted on a high-density system, though there seems to be promise in doing so (Robinson, "High Density Pear Production: An Opportunity for NY Growers"). This project can provide a proof of concept and a feasibility study for Minnesota apple and pear growers. Since a number of pear varieties are hardy in Minnesota – including those varieties developed by the University of Minnesota – the key takeaway points for growers will be in the hardiness of rootstock that many haven't yet worked with, how well the planting worked in the high-density system on trellis, and the hardiness of varieties not commonly grown in Minnesota.

Demonstrating rootstock hardiness is important and has been a key limiting factor to the expansion of pear growing. An eight-year project in New York state demonstrated the hardiness of the OHF87 rootstock being used in this project (Robinson). New York is not Minnesota, however, and so a documented project in Minnesota will help growers better understand their risks in using this rootstock.

Demonstrating the feasibility of the tall spindle planting system is important too. Tall spindle systems crop earlier and harvest higher yields: for example, the aforementioned New York project had an eight-year cumulative yield of 1,000-2,000 bushels of Bosc pears on a low-density central leader system (242 trees per acre) contrasted to 3,000-3,800 bushels of Bosc pears on a high-density tall spindle system (908 trees per acre).

The timing of the project is significant because the growing cider industry provides a new consumer for pear crops. Cidermakers and distillers are currently importing pears and pear juice from out-of-state. Since the law specifies that cidermakers use a majority of Minnesota-grown produce to sell cider in a retail operation, Minnesota-grown pears will be a valuable crop to this industry.

Growers accustomed to operating an apple orchard can easily add pears to their operations, since most growing principles and management practices are the same. For those interested in permaculture in general and new to perennial fruit tree crops, pears are a relatively uncommon specialty crop with excellent marketing possibilities.

Project Design

The pears will be planted in an 80 foot x 300 foot section of the orchard that has been prepared for planting.

All pears will be planted on the OHF87 rootstock, which is semi-dwarfing and cold hardy. Trees will be planted in a tall spindle system. Row spacing will be 12 feet. In-row spacing will be 3 to 4 feet.

Quantity	Pear Variety	Type	MN Hardiness
4	Summercrisp	Dessert	known
4	Sanguinole	Dessert	unknown
4	Dabney	Dessert	unknown
4	Luscious	Dessert	known
4	Magness	Dessert	known
4	Harvest Queen	Dessert	known
4	Bierschmidt	Dessert	known
4	Sucree de Montlucon	Dessert	unknown
4	Blake's Pride	Dessert	unknown
32	Gourmet	Dessert	known
4	Beurre Giffard	Dessert	known
4	Romanian	Perry	unknown
24	Blakeney Red	Perry	unknown
24	Brandy	Perry	unknown
24	Normanishen Ciderbirne	Perry	unknown
12	Thorn	Perry	unknown
36	Yellow Huffcap	Perry	unknown
24	Butt	Perry	unknown
24	Gin	Perry	unknown
24	Barland	Perry	unknown

To accommodate topographic variations in the site, the placement of all of the pear varieties except Gourmet have been randomized by row. Gourmet, as an exception, will be planted in each environment (high, middle, and low elevation). Tree 13 in each row serves as a control and will not be measured as part of the dataset.

The first objective of the project is to evaluate the tall spindle growing system for pears, specifically to assess OHF87 rootstock hardiness, and if the close spacing of the trees provides a sufficiently dwarfing effect.

To evaluate rootstock hardiness, I will observe the trees in spring to early summer to note tree death and to measure tree dieback.

To evaluate the tall spindle system, I will measure the trees in two ways: trunk cross-sectional area and height. I will measure the shortest and tallest trees of each variety per row and, from these measurements, be able to address this growing system for the trees' ability to fill but not exceed the space allotted to them.

The second objective of the project is to evaluate the suitability of pear varieties for Minnesota. Perry varieties that will be evaluated include Barland, Blakeney Red, Brandy, Butt, Gin, Normanishen Ciderbirne, Thorn, and Yellow Huffcap. Dessert varieties that will be evaluated include Bierschmidt, Blake's Pride, Dabney, Gourmet, Harvest Queen, Luscious, Magness, Sanguinole, Sucree de Montlucon, and Summercrisp.

To evaluate hardiness, I will observe the trees in spring to early summer to note tree death and to measure tree dieback.

To evaluate disease, I will scout the planting once per week during the growing season for disease concerns. If potential disease is noted, I will diagnose it and, if needed, send it to the University of Minnesota's plant pathology lab for diagnosis.

To evaluate the growth of the varieties, I will measure the trees in two ways: trunk cross-sectional area and height. I will measure the shortest and tallest trees of each variety per row and, from these measurements, be able to address this growing system for the trees' ability to fill but not exceed the space allotted to them.

Finally, at the end of the third growing season, I will measure each tree's fruit production in terms of fruit count per tree and total harvest weight per tree.

2020 RESULTS

No results yet – the trees were only just planted in 2020.

Non-chemical Methods for Managing Colorado Potato Beetle: Feasibility for Diversified Farms

Grantee: Natalie Hoidal, University of Minnesota Extension
Contact information: 651-395-1492; hoidal016@umn.edu
Duration: 2 years
County: Chisago

PROJECT SUMMARY

Colorado potato beetle (CPB) management is an important priority for diversified vegetable farmers in Minnesota. With increasing insecticide resistance, non-chemical methods are needed for long-term success. Potatoes are an important crop for fresh market growers because customers expect them, and because they provide low-cost season extension. However, they are not a highly profitable crop, and thus farmers need quality information about not just the efficacy of treatments, but the costs, labor requirements, and timing of treatments.

Organic potato growers across Minnesota have relied on the insecticide Entrust (spinosad) for years to manage the CPB. However, spinosad resistance has been documented in other states, and in 2019 Extension educators identified a population of spinosad-resistant potato beetles in Washington County. A diversified approach that includes preventative management strategies is critical for potato farmers, especially organic potato farmers, as they navigate CPB management.

In this study, we aimed to assess five promising cultural control methods for CPB from the perspectives of labor hours, cost, effectiveness in reducing beetle populations, and final plant damage effects. We also aimed to gather qualitative data on how to best implement these strategies, lessons learned, and how the timing of these strategies fits into the flow and workload of a diversified vegetable farm. These strategies included trenches around fields, flaming young plants, using trap crops, row cover, and straw mulch, alongside control plots.

PROJECT DESCRIPTION

While crop rotation reduces CPB infestations, small-scale growers often do not have enough land to adequately rotate away from overwintering populations. Additional preventative control methods are needed; research has shown that various cultural methods effectively reduce CPB populations and increase marketable yield. These include surrounding fields with plastic lined trenches, using straw mulch, planting trap crops around fields, and flaming potato plants when they are young to kill larvae. However, many of these tools have been developed for large-scale systems (growers with hundreds of acres), and no studies have assessed these methods from a labor and cost perspective. Understanding the amount of time and money required to implement these treatments are important for producers as they make management decisions.

PROJECT OBJECTIVES

1. Develop realistic best management practices (BMPs) for potato beetle that consider time, money, labor, and efficacy. The primary goals of these BMPs are the reduction of pesticide applications in potatoes and increased profitability for small-scale potato producers.
2. Engage Big River Farms' cohort of beginning farmers in the process of on-farm research. The goals of this collaboration are to build relationships between beginning farmers and Extension, inspire future experimentation and collaboration, and demonstrate the process of on-farm research.

Project design: Each of the six treatments (control, trench, flaming, straw mulch, row cover, trap crops) were implemented on both partner farms (except the trench was only used at Clover Bee in 2020, and flaming was only used at Big River Farms). Farmers calculated the costs associated with each treatment and kept records of the time spent managing each treatment. The principal investigator visited each farm weekly for six weeks once the first potato beetles arrived and conducted weekly beetle counts. This was not a fully replicated trial, as the primary goal was to understand the labor and time requirements of each treatment. In addition to labor and time, the farmers noted the pros and cons of each management strategy.

The second objective (working with Big River Farms' beginning farmer cohort) was put on hold in 2020 due to COVID-19 restrictions and will be implemented more fully in 2021.

Sustainable Agriculture Demonstration Grant Project Updates 2020

2020 RESULTS

In 2020, row cover, trap crops, and straw were used at both farm sites along with control plots. At Clover Bee Farm, the farmers created a trench around the entire treatment area (encapsulating all other treatments), and also maintained an unbordered control plot. At Big River Farms, an additional flame treatment was included. The cost of supplies and labor hours for each treatment are reported in Table 1, adjusted for a 100 ft row (3 ft beds, 6 ft on center).

Row Cover worked well on both farms. At Big River Farms, row covers were left in the field until 7/22/2020 (75 days after planting). At this point, beetles had begun to break through the fabric, so it was removed. The farmers determined that this was too much time to leave row cover on potatoes, as the humidity was substantially higher, and the potatoes succumbed to greater disease pressure. At Clover Bee, the farmers removed the row cover on 6/23/2020 (46 days after planting) to allow for better weed management. Beetles emerged in the plot almost immediately after removing the row cover, but it successfully kept beetles off the plants for the first 1.5 months of development.

Cost, Labor, and Farmer Perceptions of Treatments

Treatment	Cost of supplies per 1,000 row feet	Labor hours to install per 1,000 row feet	Labor hours to manage
Row Cover	$150	30 minutes - 1 hour depending on wind	3 hours total
Straw	$500 for new straw, laid on fairly thick (1 round bale per 300 row feet), cheaper if reusing	2 hours by hand	0 minutes
Trench*	$12	45 minutes	20 minutes for removal
Trap Crop**	$50	15 minutes	5 minutes
Flaming	• Backpack flame weeder + 2.4-gal tank $317 • Propane for 1000' row feet <$10	40 minutes	0 minutes

*Trench was created around the entire 9,000 sq. ft. area (perimeter 420'). Cost only factors in plastic and assumes the grower already has a tractor and potato hilling implement. Labor is primarily attributed to preparing the equipment and labor time would only increase marginally with a larger field.

**Trap cost crop calculated assuming farm is already starting other transplants indoors, and so additional marginal labor for eggplants is minimal. $50 accounts for the opportunity cost of not selling the eggplants. Management time attributed to planting and maintaining seeds (5-10 plants / 100 ft row).

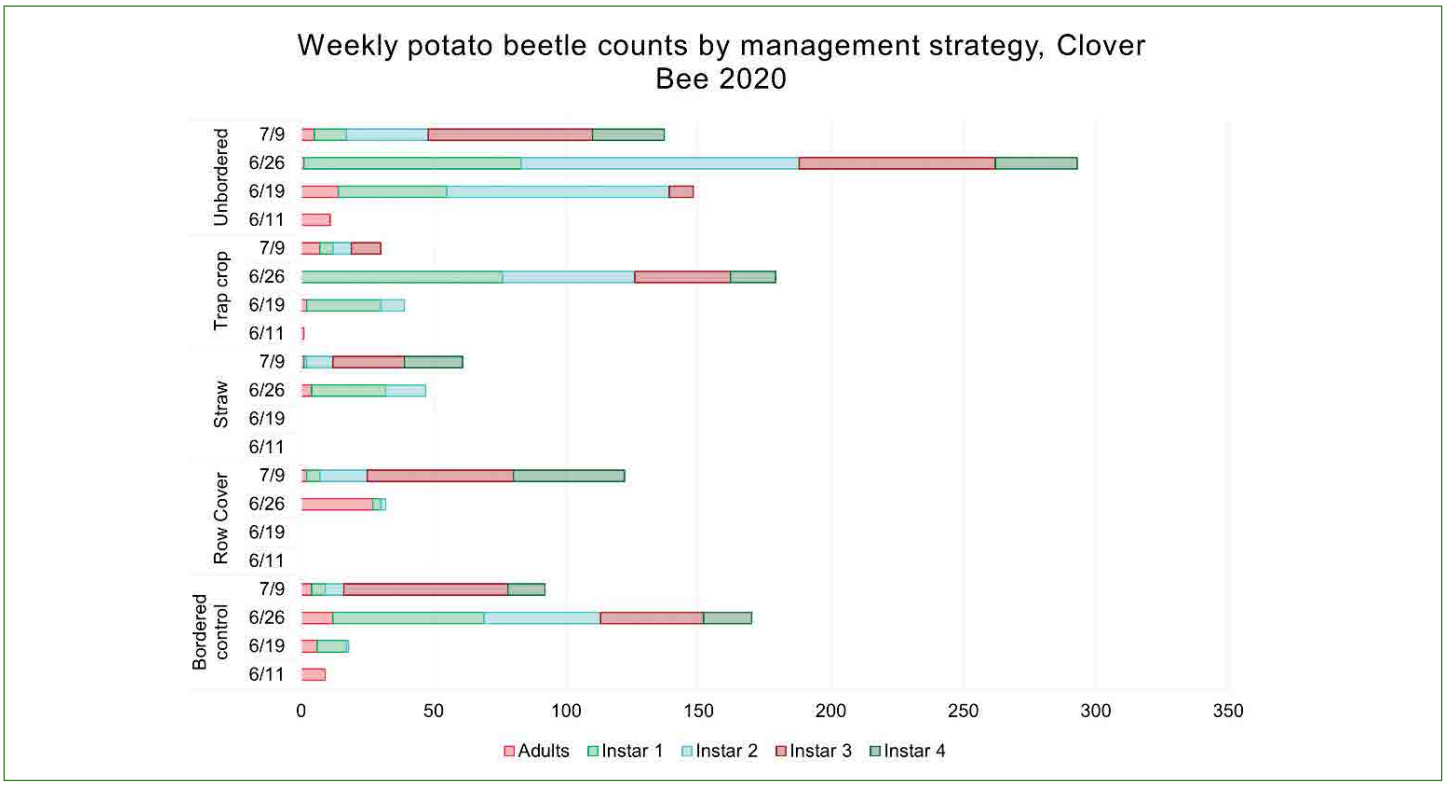
Straw mulched plots had less beetle pressure than control plots or plots with trap crops. At both farms, the straw plots became weedy, and the farmers wished they had applied it slightly later, allowing for an initial cultivation pass. While the straw was effective at suppressing annual weeds, it was not effective at suppressing perennial thistles; this treatment would be best suited to an area with relatively few perennial weeds. Overall, it was affordable and easy to install on a small-scale.

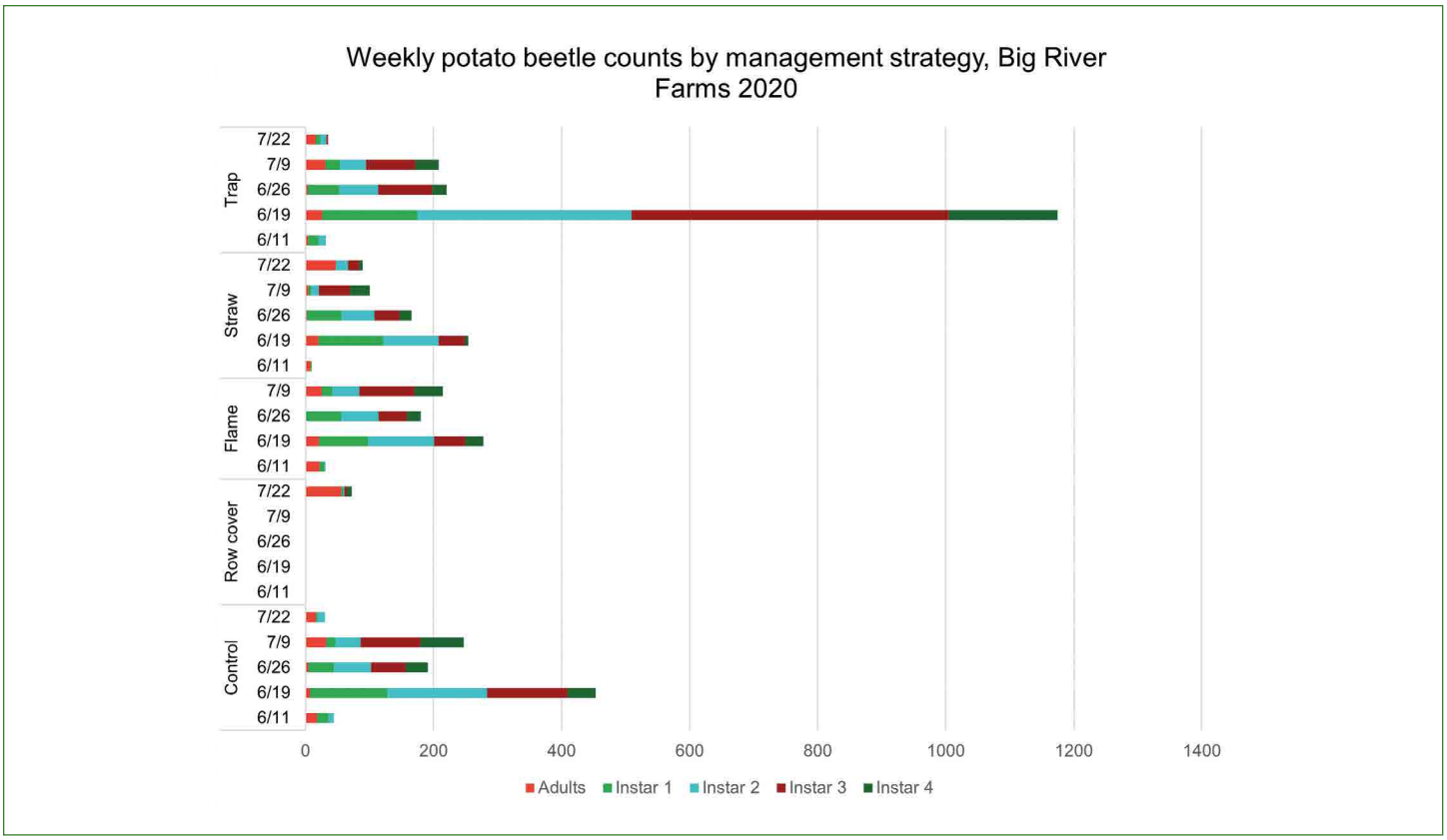
Trench: The trench installed at Clover Bee was quite simple and affordable to install. The farmers used disks on their tractor to dig a trench around the field (2 passes in both directions), lined it with 4 ft by 1000 ft 4 mil plastic mulch, buried the edges, and used landscape staples in the base of the trench every 4-5 ft to keep the plastic in place. Following installation, the trench did not require any maintenance. While we did not notice a substantial number of beetles caught in the trench, there were approximately half the number of beetles in the trenched control area compared to the un-trenched plot at all potato collection dates. We deduced that the trench may have acted more as a deterrent than an actual trap.

Trap Crop: At each farm we planted a trap crop of eggplant seedlings along the edge of the plot that was closest to the prior year's potato planting. While simple enough to install, the trap crop was entirely ineffective. There were often no beetles at all on the trap crop, and there were never more beetles in the trap crop than in the main crop.

Flaming: Flaming was only implemented at Big River Farms, but it was unsuccessful. Overall, the plants appeared to be more damaged than the beetles.

Beetle Counts: Colorado Potato Beetles were collected weekly with a sweep net, based on one pass through the entire treatment area. Planting occurred on May 6, 2020 and counting began when the first beetle was detected. Flaming occurred at Big River Farms on June 15. At Big River Farms, the farm team began manually removing beetles in each plot every two days starting on June 20, and so counts became relatively unreliable after that point. It was determined by the team that the beetle populations were so high that all of the plants would be lost if an additional intervention was not performed. At Clover Bee Farm, Neem was applied to all plots on June 13 and Azera was applied on June 20 for the same reason.





Yields and Leaf Area Index are not reported for a few reasons. At Big River Farms, yields were virtually zero for all treatments as a result of nearly total defoliation. At Clover Bee Farm, the plots were quite weedy compared to the unbordered plot, and the treatment plots had poorer soil with less consistent irrigation. As such, while the team did measure yields, we did not feel that the yield data could be adequately attributed to potato beetle.

Takeaways for 2021 Trials

Both farms decided that flaming and trap crops are ineffective methods for potato beetle management, so these treatments will be dropped in 2021. None of the treatments were entirely adequate on its own, however, trenches, straw mulch, and row cover all showed promise. As such, these treatments, or combinations of these treatments, will all be repeated in 2021.

Trialing High Tunnel Raspberries to Increase Yield and Reduce Spotted Wing Drosophila Pressure

Grantee: Aaron Wills, Little Hill Berry Farm
Contact information: 507-301-7183; info@littlehillberryfarm.com
Duration: 3 years
County: Dakota

PROJECT SUMMARY

This project will test and demonstrate the benefits of growing raspberries in a high tunnel versus traditional open-field growing. Our goal is to determine if high-tunnel raspberries produce greater yield compared to traditional open-field raspberries and if pest pressure, specifically Spotted Wing Drosophila, is reduced. Currently the invasive Spotted Wing Drosophila is a significant challenge for growing raspberries in Minnesota. We will trial four different raspberry varieties, growing them in both a high tunnel and in adjacent open-field production. The information from this project will allow Minnesota growers to assess whether high-tunnel-grown raspberries justify the added expense of building a high tunnel for raspberry production.

Design

We will plant four varieties of primocane fruiting raspberries (fall-bearing raspberries) in both the high tunnel and open field rows that will be located right next to the high tunnel in the Spring of 2019. The varieties we plan to plant are Joan J, Anne, Crimson Night, and Crimson Treasure.

Raspberry Project Plot Diagram				
High Tunnel				
Row	Variety 1	Variety 2	Variety 3	Variety 4
1	Joan J	Anne	N/A	N/A
2	Crimson Night	Crimson Treasure	N/A	N/A
3	Anne	Crimson Night	N/A	N/A
4	Crimson Treasure	Joan J	N/A	N/A
Open Field Production				
Row	Variety 1	Variety 2	Variety 3	Variety 4
1	Joan J	Anne	Crimson Night	Crimson Treasure
2	Crimson Night	Crimson Treasure	Joan J	Anne

Sustainable Agriculture Demonstration Grant Project Updates 2020

Objective 1: Determine if growing raspberries in a high tunnel increases yield over traditional field-grown raspberries and which of the four varieties we trial benefit most from being grown in a high tunnel. We will collect yield data for each of the plots in the high tunnel and the open field production. We keep a clipboard in the high tunnel with harvest sheets developed for this project with spaces for recording yield from each of the plots. Data from these sheets will be entered into a spreadsheet to be tabulated at the end of each year. In addition to total yield for each plot we will calculate the sales value for our value from each plot to show the value of any increased yield. This will help other growers determine if a high tunnel is worth the added investment and increased management time. We will also document visual observations about the growth of the different varieties and comparisons between the high-tunnel plants and open-field plants.

Objective 2: Determine if Spotted Wing Drosophila (SWD) populations and fruit infestation is reduced in high-tunnel raspberries versus traditional field-grown raspberries. As part of each harvest, we will document the level of SWD infestation in each of the plots. We will attempt to quantify the percentage of unmarketable fruit due to SWD damage.

2020 RESULTS

This was Year 1 of our project and our primary goal was to establish our raspberry plantings inside and outside of the high tunnel. Overall, our plants established very well. We were amazed at how quickly the raspberry plants grew and filled in the row compared to our experience establishing blueberry plants. Unexpectedly, we even had a small harvest of raspberries in September.

Throughout the summer there was little difference in plant size and percent of the row filled in between the outdoor and high tunnel plantings. However, starting at the end of August the high-tunnel raspberries continued growing very vigorously while the outdoor rows growth stopped. As shown in the picture on page 37, which was taken on September 17, the high tunnel raspberry plants are noticeably taller, and the rows are thicker, with canes and foliage. Crimson Night performed exceptionally well in the high tunnel compared to outside. Anne was an exception in that the plants were the same size in the high tunnel and outside.

The high tunnel had a higher raspberry yield than the outdoor rows by approximately 50 percent. However, the overall yield was quite small, approximately 50 pints, so next year's yield results will be more useful in terms of comparing yield in the high tunnel versus outside. Fruiting did not start earlier in the high tunnel. The higher yield in the high tunnel came from fruiting continuing later into the Fall and higher fruit quality. The lower fruit quality outside came from increased pest pressure and rain (causing mold). The outside rows were hit hard by Japanese beetles and by tarnished plant bugs, which were both at much lower levels inside the high tunnel. We weren't expecting tarnished plant bug damage, so we will be prepared for them in 2021. For Japanese beetles, we did experiment with BeetleGone and that seemed to be effective against the beetles. We plan to use it again in 2021. We didn't see any SWD pressure this season, but we fully expect SWD to be a major pest to grapple with next year.

One thing we did not do particularly well this year is utilize our trellis system. We installed an Adjustable V Trellis System from Trellis Growing Systems. It was reasonably easy to assemble and install. However, we did not train the canes very well, so when it came time to harvest, we did not have a vertical fruiting wall like we had hoped. This caused harvest to take longer because you sometimes had to search for the berries in the tangle of plants. This will be an area to improve upon in 2021.

ADDITIONAL RESOURCES

For anyone interested in growing raspberries in a high tunnel, I would recommend the Michigan State Extension Bulletin **Organic Raspberry Production in Three Season High Tunnels and the High Tunnel Production Guide for Raspberries and Blackberries 2019** published by Tunnel Berries (a group of universities including Michigan State, Cornell, the U of M, etc.)

Sustainable Agriculture Demonstration Grant Project Updates 2020

Layout of high tunnel with landscape fabric before planting raspberries.

Outdoor raspberries on September 17.

High Tunnel raspberries on September 17.

LIVESTOCK

Control of Wild Parsnip through Rotational Sheep Grazing

Grantee: Heidi Eger, Radicle Heart Farm
Contact information: 612-600-3641; radicleheartfarm@gmail.com
Duration: 3 years
County: Houston

PROJECT SUMMARY

Wild parsnip is an invasive species, and MDA-listed noxious weed, with an exploding population in southeastern Minnesota. Current recommended management strategies include carefully timed mowing and spraying with herbicide. Both methods are expensive, and neither is particularly effective. Organic farmers currently only have mowing or removal by hand as management options. Heidi Eger's flock of 100 percent grass-fed Katahdin/Dorper ewes have shown enthusiasm for grazing wild parsnip plants. The purpose of this study is to measure the effectiveness of managed rotational grazing by sheep to control wild parsnip in a perennial pasture. Effectiveness will be judged by monitoring plant populations along transects and weighing collected seeds in grazed plots and comparing to control plots.

Sustainable Agriculture Demonstration Grant Project Updates 2020

PROJECT DESCRIPTION

The purpose of this project is to measure the impact of a carefully managed sheep flock on a population of wild parsnip. Wild parsnip is listed as a noxious weed by the MDA. As a listed plant, "efforts must be made to prevent the spread, maturation, and dispersal of any propagating parts, thereby reducing established populations and preventing reproduction and spread as required by Minnesota Statutes, Section 18.78." Parsnip is a biennial plant. The first season, it emerges early in the spring and grows as a short basal rosette of leaves. The second season, it sends up a tall flower stalk. Parsnip spreads by producing many seeds per plant.

Wild parsnip is a growing problem across much of Minnesota, especially in the southeast. It outcompetes desirable species by being one of the first species to grow in the spring. When sap from the plant gets on skin, it causes large burn blisters. Wild parsnip is very hard to control. Mowing is expensive and only moderately effective. Spraying the plant with herbicide is expensive, can result in desirable nearby plants being accidentally killed and is dangerous to grazing animals. Organic producers can't spray and can only mow accessible areas. If grazing by sheep provides good control of the plant, it would allow land managers an alternative that is beneficial to the environment and their bottom line.

Heidi's sheep flock has shown a strong preference for parsnip leaves and frequently eats them before other plants in their paddock. Does grazing a plant two or three times in its first season of growth plus grazing it as it sends up a flower stalk weaken the plant enough to reduce the number of seeds blooming? Heidi wants to test the hypothesis that sheep can kill some of the young plants through grazing and trampling and weaken the plants that survive enough that the flowers will produce fewer, smaller, and thus lower quality seeds.

This project will benefit farmers in three ways. First, it would answer the question of whether sheep can impact parsnip populations over two grazing seasons. Second, it would give organic farmers who are unable to spray an effective management tool. Third, it would give sheep producers the option to get prescribed grazing contracts. This option would be especially powerful for beginning farmers without access to land. If shepherds were paid to graze, rather than paying for access to pasture, it would allow them a faster way to a profitable, stable farm business.

Methods

One 5 by 5 meter monitoring plot in each grazing paddock will be established. The monitoring plot location will be chosen strategically so that there is a similar population of parsnip and, as much as is practical, slope, soil type, and surrounding vegetation. Three ungrazed control plots of 5 by 5 meters will also be established and monitored. Plants will be counted at the beginning of the grazing season and on a day during the blooming season.

Sheep will be in each paddock long enough to graze it evenly. This project will test only how sheep control the plant by choosing to graze it. Heidi will not make any effort to force the sheep to overgraze the parsnip. Much of the literature lists parsnip as toxic. Heidi's sheep show a preference for the plant so she is trusting that they know what they can eat. In 2019, she observed no signs of illness in her sheep and the entire season the flock continued to eat parsnip plants before other things in the pasture. She is still careful to give them paddocks with plenty of variety and to move them before all the available food is eaten.

2020 RESULTS

Since this was year one of a two-year study, there are not many results to share yet. Qualitative observations in the test plots vs. the control plots showed taller plants in the control plots and more flower heads were counted in bloom in the control plots than the test plots. Test plot 1 was grazed almost 2 weeks before plots 2 and 3. The sheep showed very little interest in the parsnip from the start of grazing season until May 22. On May 20, it rained for the first time in weeks and on May 22, the sheep were seen demolishing parsnip plants. They were moved into test plot 2 on May 26.

From qualitative observations and counts of flowering plants, test plots 2 and 3 had less parsnip plants flower than plot 1 or the control plots. This makes sense because the sheep barely grazed the parsnip in plot 1 in May.

Heidi is interested to see if the sheeps' interest in parsnip follows a similar timeline in 2021. Do the plants need to reach a certain stage of growth? Was the rain the main factor? Or was it a mineral imbalance in the sheep? Heidi noticed the sheep were eating an unusual amount of their free-choice mineral mix and worked with the local animal nutritionist at Hyview Feeds to experiment with individual free-choice minerals. The flock remained very enthusiastic about both free-choice calcium and the regular mineral mix all grazing season.

Sheep were observed many times using their necks to bend down tall parsnip flower stalks so they could eat the blossoms and young seed heads. The test plots are too thick with parsnip for the plants to really bend so the highest flowers and seed heads are left after grazing. On other patches of parsnip around the farm, only the stalk is left.

Determining the Effects of Prescribed Sheep Grazing on Species Diversity and Density in Restored Pollinator Habitat

Grantee: Jake Janski, Minnesota Native Landscapes
Contact information: 612-490-5992; Jake.Janski@MNLcorp.com
Duration: 3 years
Counties: Chisago, Stearns, Wright

PROJECT SUMMARY

This project seeks to explore prescribed sheep grazing as an alternative management method for planted pollinator-friendly prairie on operational solar farms. Grazing has been shown to effectively control vegetation height at acceptable levels, but we wish to identify the effects of prescribed grazing on plant species diversity and overall prairie health within solar sites, while providing local producers grazing opportunities and expanding locally sourced meat markets.

PROJECT DESCRIPTION

Due to public awareness, permit conditions, and other market factors, pollinator-friendly prairie installations on solar production facilities are increasing. While the prairie provides excellent habitat for birds and pollinators, prairie vegetation may exceed operational heights under solar panel arrays and around sensitive equipment when left unmanaged. While mechanical cuttings and chemical applications may adequately control plant growth, we seek to employ prescribed sheep grazing as a sustainable management method to provide an ecologically friendly and cost-effective alternative. While prescribed sheep grazing has been shown to effectively control vegetation height, its effects on prairie plant species diversity are largely unknown. As an ecological restoration and land management services company, Minnesota Native Landscapes strives to provide innovative, sustainable, and efficient management solutions for our clients while promoting healthier ecosystems. Research on larger ungulates, such as bison and cattle, has shown that prescribed grazing does increase prairie plant diversity. This study will evaluate sheep grazing on those same natural principles.

Six active, utility-scale solar power generation sites, managed with sheep grazing, were planted with pollinator-friendly native seed mixes. Each site has been actively managed with a variety of techniques for at least three full growing seasons and is considered properly established. Sample transects were established in plotted areas of each site and subjected to grazing. A replicated set of transects were established within ungrazed control plots, that were isolated using electric fencing. The sites were grazed under high-intensity, short-duration conditions according to the site's

operational and vegetation management goals. Vegetation sampling using the point-intercept method was conducted on each transect. Alpha diversity and diversity index (Shannon-Weiner) were calculated for grazed and ungrazed plots on each site. This process will be repeated two or three times each growing season for the duration of this grant, and likely beyond.

2020 RESULTS

The 2020 data collection commenced largely according to plan, and prescribed sheep grazing was successfully employed once in the summer season at each of our six sites to meet the ecologist's and owner's vegetation management goals. Two of the 18 estimated initial site surveys shown as "NA" in the tables below were not completed due to active grazing of the site.

The data below was gathered from ungrazed (Table 1) and grazed (Table 2) plots on each site. Each plot consisted of four transects, where point-intercept data was taken every meter for 50 meters, resulting in 200 points per plot. All grass, forb, and woody species were noted, each "hit" was recorded separately. Total vegetative cover was calculated as total vegetation "hits" divided by the 200 points.

This dataset provides us a baseline, and we will compare future surveys to these. As plots are not identical, even within sites, we will compare year-to-year differences within plots, rather than compare the plots to each other. As grazing will likely take many seasons to significantly affect prairie establishment, we did not expect to see significant results immediately, and this season will serve as a solid benchmark to assess gains or losses in total species number, species diversity, and total vegetative cover in the coming seasons.

Table 1. Total species recorded, Shannon-Weiner Diversity index, and total vegetative cover of ungrazed plots at each of our 6 study sites in June, July, and August 2020, respectively.

TABLE 1. Total species recorded, Shannon-Weiner Diversity index, and total vegetative cover of ungrazed plots at each of our 6 study sites in June, July, and August 2020, respectively.

Site #	# Species Recorded	Diversity Index	Total Vegetative Cover
1	24, 18, NA	.71, .75, NA	1.03, 1.27, NA
2	24, 21, 23	.65, .65, .81	.97, 1.00, 1.31
3	16, 13, 13	.67, .58, .66	.81, 1.14, .99
4	24, 23, 23	.77, .73, .73	1.09, 1.25, 1.25
5	19, 16, 18	.70, .68, .76	1.04, 119, 1.09
6	18, NA, 20	.83, NA, .81	1.35, NA, 1.40

Sustainable Agriculture Demonstration Grant Project Updates 2020

TABLE 2. Total species recorded, Shannon-Weiner Diversity index, and total vegetative cover of grazed plots at each of our 6 study sites in June, July, and August 2020, respectively.

Site #	# Species Recorded	Diversity Index	Total Vegetative Cover
1	22, 16, NA	.66, .75, NA	1.00, 1.13, NA
2	24, 23, 22	.67, .79, .54	1.08, .95, 1.22
3	14, 13, 9	.64, .66, .66	1.01, 1.0
4	21, 15, 15	.80, .81, .81	1.13, 1.22, 1.22
5	20, 14, 18	.72, .71, .76	.92, .95, 1.05
6	19, NA, 21	.83, NA, .88	1.27, NA, 1.07

Aerial photo of solar site 6 during grazing.

Aerial photo of the grazed study area (left) and ungrazed control plot (right).

Prairie 2 months post grazing.

Prairie 1 week post-grazing.

Sustainable Agriculture Demonstration Grant Project Updates 2019

The following grant project updates contain the rationale for conducting the project, project design, activities conducted, and results obtained in 2019 and 2020. The information for these updates were obtained from the 2019 grantee's Annual Progress Reports. To find out more details about these projects and management tips, contact the principal investigators directly. Please contact the Minnesota Department of Agriculture (MDA) grants staff for questions or information about the Sustainable Agriculture Demonstration Grant.

Farmer cooperators who worked with Alan Krause of the Cannon River Watershed Partnership and conducted grant project farm trials.

Alternative Markets and Specialty Crops

- **Integrated Hemp and Heritage Farm**
  Grantee: Bridget Guiza and Winona LaDuke, Anishinaabe Agriculture Institute
- **Exploring North Star Farm Tour as a Sustainable Agri-Tourism Model for Small Producers**
  Grantee: Melodee Smith and Wendy Wustenberg, North Star Farm Tour

Cropping Systems

- **Regenerative Agriculture: A Pathway for Greater Farm Profitability and Practice Adoption**
  Grantee: Alan Kraus, Cannon River Watershed Partnership

Fruits and Vegetables

- **Rotational Grazing in an Orchard to Improve Pasture Health, Reduce Energy Input, and Increase Profit**
  Grantee: Robert Blair, Canosia Grove

Livestock

- **Toward Forever Green Poultry Rations**
  Grantee: Jane Jewett, WillowSedge Farm
- **Evaluating Hazelnuts as a Soy-Protein Replacement in Free-Range Poultry Systems**
  Grantee: Wyatt Parks, Main Street Project

Soil Fertility

- **Using Sheep and Cover Crops in a Strawberry Rotation**
  Grantee: Sarah Brouwer, Brouwer Berries

Alternative Markets and Specialty Crops

Integrated Hemp and Heritage Farm

Grantee: Bridget Guiza and Winona LaDuke, Anishinaabe Agriculture Institute
Contact information: 218-280-1720, info@anishinaabeagriculture.com, winona@anishinaabeagriculture.com, bridget@anishinaabeagriculture.com
Duration: 3 years
County: Becker

PROJECT SUMMARY

Anishinaabe Agriculture created an integrated hemp and traditional foods working farm, utilizing rotational planting, natural fertilizers, and greenhouses. The site serves as a demonstration farm, allowing others interested in sustainable industrial hemp cultivation to learn and work on the farm. Our primary audience is tribal members and tribal governments, but we also hosted volunteers and others interested in industrial hemp. Our work was conducted, in part during the COVID-19 pandemic. Our end goal is to create a curriculum that can be used at tribal community colleges. Please contact Anishinaabe Agriculture Institute for a copy of our 2020 Annual Report.

CBD girls growing underneath the wigwam hoop house at the AAI Farm November 2020.

Sustainable Agriculture Demonstration Grant Project Updates 2019

PROJECT DESCRIPTION

Anishinaabe Agriculture is interested in restorative and post petroleum agriculture and the development of an organic hemp economy, with a focus on Indigenous hemp industry development. We know that Indigenous seeds and agrobiodiversity are key to the survival of not only our people, but to all peoples, and we are interested in how we restore Indigenous agriculture, traditional soil amendments and restore a hemp economy in a reduced petroleum agriculture system. We've been at this for decades, and this is our new research initiative.

In the time of the pandemic, we have also become a center for Indigenous youth education programs and the Just Transition, from agriculture to renewable energy. We are serving forty tribal youth from the Red Lake, White Earth, Sisseton reservations and non-Native youth from the nearby communities. Our work has been focused on Anishinaabe culture, farming, Horse Nation, and Just Transition. In the past months, we've worked on an Indigenous curriculum focused on sustainability and are now working on this with groups regionally as well as families. This past year, we built internal and community capacity, grew 20 acres of fiber hemp, researched and negotiated production opportunities for hemp refining, and provided seeds and support to tribal members from five reservations.

With the help of foundation donors, we've grown a small organization, and then we've grown our land base. In mid-2020, we joined into the collaboration of Akiing, the CDC created by Honor the Earth to reduce administrative overhead and allow a cross- coordination between organizations.

We farm on the Anishinaabe Agriculture farm, Winona's Hemp Farm, the Round Lake Farm (WELRP), the Mino Akii farm 20 acres, John Bremerton's farm and tribal landholdings in Pine Point Township. We intend to continue farming in these lands and keep adding good nutrition to the lands to grow more.

Our largest farm production came from Winona's Hemp and the Round Lake Farms from which we provided food for tribal members in the Pine Point community, and food for the produce boxes which White Earth Land Recovery Project delivered monthly. We were able to put up a greenhouse with recycled materials on the Hemp Farm, and by the end of the season, had put up the basics of the Hempcrete Greenhouse.

Objective 1

Hemp is traditionally grown as a monoculture crop. We would like to develop both a rotational plan for hemp and also companion planting plans. End uses of the hemp will define whether it can be grown with other crops, or if it needs to be grown alone.

Results: Hemp as a Crop Rotation

We rotated beans into a field that had hemp in 2019 and cultivated it with horses in 2020. We focused on growing hemp on the parcels of WELRP and small test crops in the Anishinaabe Agriculture and Winona's Hemp farm fields. Hemp requires a significant amount of nitrogen and we found that soil amendments are needed as well as a crop rotation which places beans or alfalfa perhaps prior to hemp. The research by the Rodale Institute found that hemp was best in a three-year rotation. We have also been interested in perennializing hemp, as we have had significant volunteers, and in 2021 plan to test one six-acre field with this opportunity.

In 2020, we met with tribal hemp producers nationally, from the Navajo reservation to the Cheyenne River and Oneida reservations, and worked with colleagues in the hemp agriculture industry to discuss research. This included discussions with the Rodale Institute, which produced a report called Industrial Hemp: A Versatile Crop, with the potential to improve agroecosystem diversity, mitigate environmental degradation and increase farm incomes. Rodale is interested in a collaboration with us in 2022.

Objective 2

Results: Indigenous Hemp Conference

We hosted the third annual Indigenous Hemp Conference in 2020, at Maplelag Resort on the White Earth Reservation, just before the shut down by COVID-19. The conference was attended by over 100 Indigenous farmers from the region. We had workshops on cultivation, varieties, regulations, economics, fiber technologies, hemp batteries, and then went on to work with five tribal communities in supporting their hemp projects. Our focus in 2021 will continue to be building regional capacity and collaboration with tribes in the materials economy.

Results: Tribal Hemp Curriculum

With the help of interns and writers, particularly Lucille Contreras and Kyra Bingham, we've developed a draft tribal hemp curriculum, and are now adding in the work of the Parson's School of Design on Hempcrete, to strengthen this important facet off the work.

In the fall of 2020, we also hosted a Hempcrete Workshop, where we were able to build the beginning of the hempcrete greenhouse. This involved about 25 people from the region.

Objective 3

Continue our tribal internship program by hosting three tribal members at our farm.

We have been able to have ongoing volunteers and interns at the farm and continue to be a place for youth who are interested in learning about farming. In 2020, despite the challenge of COVID-19 we were able to host interns from the University of Toronto, including Kyra Bingham and Ari who worked extensively on farming and food production. We also hired a farm manager, Brianna Crowley, as production increased. We moved to largely local tribal interns in 2020, hosting particularly tribal youth at the farm. In 2021, we will host a new tribal intern.

2020 RESULTS

Hemp Yields: In 2020, the White Earth Land Recovery Project (WELRP) provided Winona's Hemp LLC, a tract of land to grow 20 acres of hemp as an experimental and educational project. The tract of land consisted of 58 acres of land of which 20 acres were farmable. This tract had not been farmed in the last 5 years and was overgrown with a wide range of plants. We used a tractor and a disk and put in a significant amount of organic fertilizer. The seeds were provided by Patagonia, and Steff Fibers. Despite being delayed by the pandemic, we were able to plant and harvest a very good crop. Six varieties of hemp were planted at the rate of 40 pounds per acre on different sized plots.

Amish Horses, Chaga and Beans; pulling production equipment.

The germination of all hemp varieties was good. There were periodic estimates of hemp growth over summer. The photo shows what the hemp looked like in November. We also produced a significant amount of heritage potatoes, squash (400 pounds), and bean varieties. Much of this was consumed locally or sold to the Sioux Chef and Native American Food to

provide traditional meals. This past year, we quadrupled our farming production, largely with the support of a huge group of youth workers and provided food to tribal programs such as those of the White Earth Land Recovery Project. In light of the pandemic, and instability of food systems, we see the need to re-localize our food systems and have found that our work, in collaboration with many other tribal farmers, is critical for food security.

We grew six varieties of hemp which came from European sources under the Winona's Hemp MDA license. Those varieties included Futura 75, Felina, Bio-Uso, Frimon, Fedora, and Monoica. Of these varieties, we found Futura 75 to be the most productive, and we feel it has the best potential for fiber and hurd. Our estimate of the hemp harvest in our Futura field was 2,700 pounds of hemp hurd, and 1,500 pounds of fiber per acre. The entire Futura field of 7.15 acres produced 10,725 pounds of fiber. Production was 19,948 pounds of hemp hurd for the field, the equivalent to 23,770 cubic feet of hurd.

We will continue collecting soil samples that measure soil texture, soluble salts, pH, nitrate, phosphorus, potassium, organic matter, and micronutrients. This will help guide fertilizer applications and timing, and recommendations for crop rotations such as alfalfa and red clover. We will be measuring the ways regenerative agriculture improves soil health, sequesters carbon, and improves farm resilience to climate change.

Exploring North Star Farm Tour as a Sustainable Agri-Tourism Model for Small Producers

Grantee: Melodee Smith and Wendy Wustenberg, North Star Farm Tour
Contact information: 651-212-8099 and 651-246-6332, northstarfarmtour@gmail.com
Duration: 3 years
Counties: Dakota, Faribault

PROJECT SUMMARY

North Star Farm Tour (NSFT) is a 501c3 learning community of family-owned farms with the mission: "Connecting people with agriculture through safe, fun, and educational agritourism." We are pioneers in developing professional, entrepreneurial approaches to agritourism because an educated citizenry is fundamental to a sustainable future for agriculture. Small-scale farmers and agritourism operators run on notoriously thin margins, yet face increasing pressures to improve facilities, ensure product quality, and professionalize their businesses in order to meet consumer demand and regulatory requirements. NSFT is busy networking to find experts, knowledge and resources that can prevent redundant investments or costly mistakes. We will continue to self-fund our annual activities and direct 100 percent of this remarkable grant to the benefit of participating members. Unrestricted block grants will allow members to invest in projects that are important to their farm operation. Longitudinal evaluation administered under

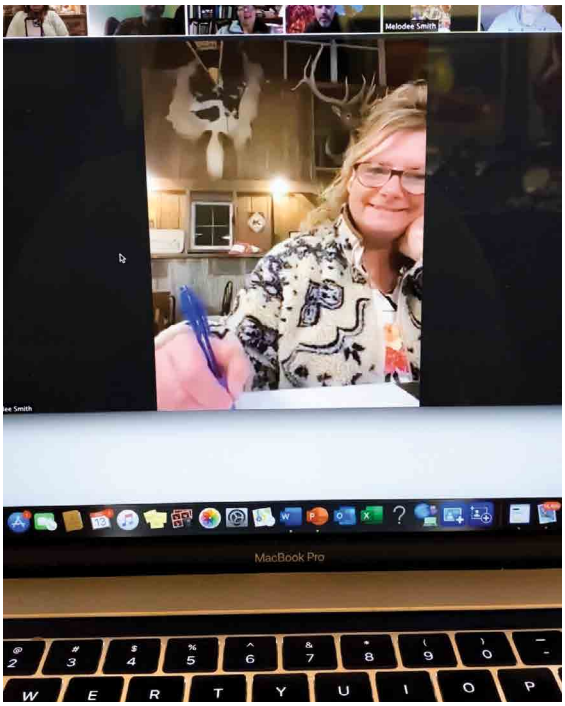
North Star Farm Tour's diversity policy led to a project to translate handwashing posters into 20 languages commonly spoken in the northern region in partnership with the MN Dept of Health, Minnesota Grown, UMASH, and Mayo Clinic Health System. Amharic is commonly spoken by Ethiopian expatriates.

Sustainable Agriculture Demonstration Grant Project Updates 2019

the auspices of Vermont Law School's Center for Agriculture & Food Systems and the University of Minnesota Tourism Center are tracking these investments and analyzing how involvement with our nonprofit experiment influences the profitability and personal wellbeing associated with agritourism. Our intention is to figure out how agritourism can earn its place as a trusted, sustainable agricultural product beneficial to producers and consumers as well as the State economy.

PROJECT DESCRIPTION

North Star Farm Tour is an all-volunteer, educational organization founded in 2017, funded by membership fees, donations, sponsorships, and grants. In 2019, our 20 members produced a wide variety of quality raw, processed & finished fiber products, as well as food and artisan goods, livestock, forages, and other income-producing goods that were sold independently. Members collaborated under the NSFT banner to accomplish three special educational projects and host an annual farm tour in September 2019. The 2019 tour drew 5,000+ people from over 80 Minnesota cities, five states & seven countries to our 16 tour sites. In our 2019 report, we discussed the great demand from visitors for more NSFT programming: farm dinners; wedding venues; events; open-air concerts; farm stays; demonstrations; classes; youth camps; locally grown, sustainably raised products; spring birth experiences; and more.



NSFT President Melodee Smith conducts a board meeting over Zoom from her barn in 2020.

The COVID-19 pandemic compelled NSFT to pivot program priorities, but fortunately that process had begun voluntarily in the fall of 2019. The 2019 Sustainable Agriculture Demonstration Grant survey revealed that the greatest barriers to farm profitability were access to markets and commercializing products. To address those challenges, NSFT contracted with the University of St. Thomas Enactus Club to study entrepreneurship and with Cromie Creative Consultants to survey needs of members and consumers and redesign a new high-profile website. Research was well under way when the pandemic forced closure of public programming in March, and that allowed fast implementation of a three-phase plan that will soon include an e-commerce marketplace and interactive calendar tied to reservations and payments. The website will feature educational content that is central to the nonprofit mission to serve the public good.

NSFT has evolved into a welcoming watering hole for agritourism hosts interested in professionalizing agritourism as a viable, sustainable, profitable, and enjoyable product in the Upper Midwest. Technology is allowing us to build an efficient structure to serve the needs of more agritourism members without expensive overhead. We benefit from the experiences of farm members who joined the grant as cooperators before the Dec. 12, 2018 application deadline. Each member receives an unrestricted micro-grant of $615 each of three years to invest in projects beneficial to the agritourism operation on their farm. In return, each recipient agrees to be on the annual tour (in years when that is possible), serve on at least one NSFT committee, attend the annual meeting, and participate in evaluations. In 2020, after consulting with a grant officer at Minnesota Department of Agriculture (MDA), we opted to reallocate funds from two members who resigned from NSFT toward website consulting services. The Board of Directors consulted with the remaining grant recipients to inquire whether they would rather receive a larger block grant or invest those funds in the expert consulting services of cooperator Alison Cromie. To a person they voted to invest in the website.

Sustainable Agriculture Demonstration Grant Project Updates 2019

PROJECT OBJECTIVES

1. **Incentivize active participation in North Star Farm Tour as a cost-effective, replicable model.** There is much to know about regulations, liability, marketing, effective community education for all ages, emergency preparation, multi-cultural outreach, and much more. State agencies and other stakeholders are generously helping us figure out the content and helping us ensure professional approaches to knowledge transfer.
2. **Encourage members to develop skills as entrepreneurs and agritourism hosts.** As of October 2019, we are benefiting from higher-education partnerships with Vermont Law School's Center for Agriculture and Food Systems, University of Minnesota Tourism Center, and University of St. Thomas Enactus Club (a long-term partnership to accomplish entrepreneurial business plans for each farm and NSFT). We are working with other organizations to develop competencies necessary for hosting the public.
3. **Share what we learn about agritourism as a sustainable product through a "toolkit" of field-tested ideas by the end of 2021.** What we learn we will share to help others shortcut the agritourism learning curve, improve their experiences and profitability, and help define agritourism and professionalize the industry as a whole.

NSFT cooperators and the two voluntary control farms will complete two confidential qualitative and quantitative surveys per year to disclose plans for annual agritourism operations, farm income, detail their business structure, and explain how they invested their portion of each year's block grant. What we learn we will share to help others shortcut the agritourism learning curve, improve their experiences and profitability, and help define agritourism and professionalize the industry as a whole.

RESULTS

During the grant period in 2020, the goals of making farming more profitable and enjoyable became more central than ever. COVID-19 drastically interrupted any plans established at the end of 2019 to expand NSFT programming and required farms that focus on providing agritourism services to adapt their business models to a pandemic. As an organization, NSFT switched gears. Instead of hosting a 5,000+ person farm tour, we:

1. Presented at the UMASH regional conference in August 2020.
2. Coordinated with UMASH to distribute the 20 translations of the handwashing farm safety poster in laminated form via the UMASH clearinghouse.
3. Opted to produce and distribute professional blueprints and a how-to video free of charge for anyone who wants to build a NSFT-designed and state-approved handwashing station.
4. Self-funded first phases of a complete rebuild of the NSFT website, guided by the advice of a professional web consultant, entrepreneurial advice from the University of St. Thomas Enactus Club, and a COVID-19-compliant, facilitated planning retreat. Additional investments will be necessary to complete unique farm pages, an ecommerce portal, calendar/reservation function and development of compelling content for public use at low-to-no cost.

   The website transitioned from GoDaddy to WordPress and is now hosted on a new server. All of the content on the farm safety page is now linked to the agencies that are distributing that information, our YouTube channel, and other social media. The new website has capacity to house an infinite number of videos and other resources to be made available to our members, other farmers, agricultural organizations, public agencies, private corporations, and specific targets within the general public.

Farm Profitability in 2020

Through the 2020 survey, NSFT members identified key barriers to increasing their farm profits. Farms cite four main barriers to increased profitability: (1) Economies of Scale. To make fiber farming profitable, you need large flocks and a significant amount of space. Many farms do not have enough land or the facilities to increase the size of their operation and see greater returns. Especially where farms have high levels of investment in facilities and high-quality animal care, the costs of production cannot be offset through farm products alone. (2) Insufficient Time. Most farms are subsidized through off-farm employment. (3) Lack of Interest in Expansion. (4) Marketing. A major difficulty in business planning is determining the appropriate price for products and farm services. Multiple farms identified a need for an improved business plan, centered on better marketing and adaptation to access consumers. This issue became exaggerated in 2020 as farms were forced to shift business models away from attracting customers to on-farm events to marketing products to consumers virtually.

Wellbeing & Farm Enjoyability in 2020

Of the 11 farmers who responded to questions about wellbeing and meaning, all agreed that their work was meaningful to themselves, their spouse/partner, and to their customers. All but one farmer reported feeling that their work was important to the environment and felt their work was meaningful to their local community. Despite the many challenges facing farmers in 2020, all farmers reported higher levels of satisfaction, wellbeing, and even slight increases in profitability between 2019 and 2020.

Using these grant funds to sub-contract with farmers helped them adapt to the unexpected challenges of 2020, by helping them adapt facilities to provide an improved farm store, hire help to manage socially distanced visitors, purchase equipment to move processing in-house, connect with relevant livestock organizations, and cover the costs of keeping animals during a year when most farms couldn't host events.

Cropping Systems

Regenerative Agriculture: A Pathway for Greater Farm Profitability and Practice Adoption

Grantee: Alan Kraus, Cannon River Watershed Partnership
Contact information: 507-786-3913, alan@crwp.net
Duration: 3 years
Counties: Rice and Goodhue

PROJECT SUMMARY

Cover crops improve water quality by keeping nutrients in the soil and by keeping the soil in the field. The key to growing cover crops profitably is to use the biomass as forage for livestock, and when inter-seeded into corn, provide a source of forage for livestock after corn harvest. Determining if the width of the corn row affects the production of cover crop biomass and corn grain will provide information about how to improve profit. This project will test the effect of corn row width on cover crop biomass and corn grain yields. Four Southeast Minnesota farmers will each plant 20 acres of corn in five replicated plots using three different row widths and a control and then inter-seed a cover crop mix into the corn in late June for the 2019, 2020, and 2021 planting seasons. Cover crop biomass quantity and quality along with corn grain yields compared between treatments will determine the corn row width that optimizes cover crop biomass production, modeled beef performance under field conditions, corn grain yield, and, ultimately, profit.

Sustainable Agriculture Demonstration Grant Project Updates 2019

PROJECT DESCRIPTION

These farm-based experiments and demonstrations will be conducted in collaboration with farmers; Jim Purfeerst, Ed McNamara, Mark Comstock, and John Jaeger; Alan Kraus, Conservation Program Manager for the Cannon River Watershed Partnership; and Dr. Scott Wells, University of Minnesota Agronomy Department.

Beginning in 2019 and ending in 2021, the four collaborating farmers will each plant 16-20 acres of corn into strips (experimental unit) that are 60-feet wide and 725-feet long (1 acre), using on-farm scale equipment (e.g., 24-row planter), modifying their planters to accommodate a prescribed row spacing (treatment). Treatments include 30-inch (Best Management Practices), 30-inch with 2 skip rows every 4th row (i.e., balanced), and 60-inch row (i.e. wide) spacing in a randomized complete block design. A fourth 60-feet wide strip of corn planted in 30-inch rows will function as the control and receive no cover crop. These planting patterns will be replicated four to five times across the test area. The corn seeding population, crop fertility, crop protection, and the cover crop mix and seeding rate will be constant between treatments. High biomass yielding cover crops of good forage quality (e.g., annual ryegrass, kale, and intermediate red clover) will be encouraged. However, the farmers will base their corn hybrid and cover crop species selections on their own experiences and in consultation with cover crop and agronomy experts. Cover crops will be inter-seeded at corn growth stage V3 to V7.

Prior to corn planting in 2019 and after the final harvest of corn in 2021, soil samples will be collected on each experimental unit and analyzed for nitrogen, phosphorus, and potassium content. Soil microbial activity and water infiltration between treatments and controls will also be measured. Cover crop biomass production (forage yield) will be assessed prior to corn grain harvest by obtaining a composite sub-sample from each experimental unit and the quantity (pounds of dry matter per acre) and quality analysis (crude protein, acid detergent fiber, neutral detergent fiber, and relative feed value) will be determined. Corn grain yield from each experimental unit will be measured using a weigh wagon at harvest. The corn grain and the cover crop forage will be valued at current market prices to estimate and compare maximum gross values of production between treatments and partial budget analysis will be used to make profitability comparisons.

2019 RESULTS

All farms experienced statistically significant corn grain yield reductions for row treatments that were wider than the Best Management Practices of 30 inches.

Cover crop biomass yield was maximized under the “balanced” treatment. This treatment utilized a pattern of planting four rows with 30-inch spacing and then skip 2 rows, resulting in a cover crop planting zone of 90 inches. Relative feed value ranged from 145 for the biomass in the 30-inch row treatment to 191 for the biomass in the 60-inch row treatment. Crude protein of the cover crop biomass was identical between treatments at 23 percent.

Analysis by Dr. Bill Lazarus, University of Minnesota Agricultural Economist, determined that high yielding cover crop forages can offset up to 10 percent corn grain reductions (without any value given to soil health or ecosystem benefits) and maintain profitability equal to the Best Management Practices (or the control). The two farmers who were able to allow their cattle to graze the cover crop biomass reported that the cattle completely consumed it and felt that wide-row corn, paired with cover crops that produce large quantities of high-quality forage can provide corn farmers an opportunity to improve profit, soil health, and the environment.

2020 RESULTS

Quantity and quality results of the cover crop biomass samples collected in October pre-grain harvest are pending. The preliminary corn grain yield variances for each treatment from the control for 2020 across all four farms are shown below:

Control	Corn Yield Difference
60 Inch	-11.3%
30 Inch Cover	-3.6%
Balanced	-21.1%

Sustainable Agriculture Demonstration Grant Project Updates 2019

Mid-July 2020 field observations showed robust cover crop growth in 60" and "balanced" treatments, but also significant weed pressure in some plots (photo left). Jim Purfeerst controlled weed pressure by mowing the weed growth in the wide row treatments. September and October field observations on that farm showed excellent regrowth of annual ryegrass with modest brassica regrowth (photo right).

Fruits and Vegetables

Rotational Grazing in an Orchard to Improve Pasture Health, Reduce Energy Input, and Increase Profit

Grantee: Robert Blair, Canosia Grove
Contact information: 218-341-0988, canosiagrove@gmail.com
Duration: 3 years
County: Saint Louis

PROJECT SUMMARY

This project is demonstrating that intensive rotational grazing within an apple orchard can improve pasture, soil, and orchard health, while decreasing manpower and energy inputs in the orchard understory. The synergy between the sheep and the orchard understory is important because it may have the effect of increasing profitability, while simultaneously improving the overall health of our farm.

PROJECT DESCRIPTION

Canosia Grove is a northern Minnesota permaculture orchard and cidery specializing in on-farm production of small-batch, traditional, dry sparkling hard ciders made from local apples. Our unique "North Shore" climate affords us with some of the fastest tree growth rates in Minnesota, and even our thirty-year-old apple trees have no apple scab, apple maggot, or codling moth. We have a small quarter acre of old trees, 1.5 acres of new orchard, and we are planting an additional 5 acres of new apple trees. We are struggling to convert existing fields from reed canarygrass because it can choke out tree growth. We were trying to control the grass by mowing.

Mowing the orchard allows for increased light during establishment of the trees and allows air to circulate, which decreases fungal diseases. It also decreases

Best control of reed canarygrass was when sheep were grazed in early spring.

pressure from rodents. Mowing, therefore, is a critical and valuable function in our orchard. However, it is also the most time-consuming aspect of our farm labor and has a high opportunity cost. We hope that grazing sheep on the reed canarygrass will provide an economically viable farm enterprise and will cut our overall labor inputs dramatically while providing a new income stream for our farm through sales of wool and lamb. Grazing should add value to the pasture soil, by adding nutrients and organic matter from trampling. The increase in soil health should lead to healthier and faster apple tree growth.

The project involves installing traditional sheep fencing for rotation of our Icelandic sheep flock and establishing an additional 5 acres of pasture within an existing apple orchard. We will assess soil health and forage quality within several paddocks prior to and during subsequent years of rotational grazing, and track labor hours related to mowing, understory management, and tree protection over time. The results of monitoring forage quality and soil changes will help demonstrate the amount of time over which former pasture lands that have undergone succession are able to be re-established for rotational grazing. The improved forage quality will support an expansion of the flock, which will lead to additional capacity to build soil health over time.

2019 RESULTS

We started the year using temporary electric fence for the sheep and rotated the sheep over approximately 40 feet by 40 feet sized plots throughout the summer. The best control of reed canarygrass came when we grazed the sheep in early spring. Plant diversity increased dramatically in the first paddocks grazed in spring 2019, with an increase in plants like goldenrod and hawkweed. While not desirable forage, the new plants will be better understory plants in the apple orchard than the solid mat of reed canarygrass. Paddocks grazed in late summer are still over 95 percent reed canarygrass.

In 2019, we acquired the materials needed for full enclosure of our summer and winter paddocks with 4-foot-high, woven wire sheep fencing. We installed 3,200 lineal feet of fenceposts, 44 H-braces, and eight gates in late September and then stretched 800 feet of fence for the winter paddock.

In the summer and fall of 2019, we collected baseline data related to labor inputs, soil health, and forage quality. Approximately four hours per week (on average) were spent mowing the orchards. The baseline soil quality data indicated that we have generally excellent soil rating based on the phospholipid fatty acid test of total living microbial biomass, and slightly above average to good functional group diversity and a balanced bacterial community. Our soils have relatively low phosphorus and potassium. These nutrients are critical for orchards, which presents a paradox: why are we getting such good growth rates in these soils? Will sheep manure, an excellent source of both nutrients, help with these deficiencies after distribution of manure within the orchard?

2020 RESULTS

The fence installed for our winter paddock in 2019 created a secure easy to use space for our sheep all winter. This space also served as an excellent temporary holding area whenever we needed to shear or otherwise work with our flock. In the spring we continued our frost seeding program and finished stretching the remainder of the fence line. We were able to set up multiple paddocks within the pasture and quickly rotate the sheep.

Even if the sheep escaped their internal paddock they were contained within the permanent fence and safe from wandering into our neighbor's farm. We kept our ram and weather along the exterior perimeter of our permanent fence. This kept them better separated from the ewes and helped keep the grass down along the exterior of our fence line.

The individual fencing around each tree we installed kept the sheep from grazing our apple trees. However, eventually the sheep would rub against them and knock them over, then they would graze them. We were forced to keep the sheep in an area without trees. Once the trees reach 1-2 inches in diameter, we will remove the fencing and should be able to graze the sheep though the orchard.

We did learn a few things this year: trees need to be large enough to have their leaves above the brows line of sheep and have a large enough diameter to avoid sheep chewing on bark; use proper fencing tools; and, plastic carabiners allow for easy connections between electronet fencing and woven wire fence.

Livestock

Toward Forever Green Poultry Rations

Grantee: Jane Jewett, WillowSedge Farm
Contact information: Jane Jewett, 218-670-0066, jane@janesfarm.com
Duration: 3 years
Counties: Aitkin, Ramsey, and Rice

PROJECT SUMMARY

We are using three small-flock, seasonal chicken production systems already operating in Minnesota to compare a Forever Green poultry ration to a standard conventional or standard organic poultry ration. Forever Green is a University of Minnesota initiative that seeks to maximize continuous living cover of agricultural production fields through crop rotations and perennial cropping systems. The Forever Green ration will be built on small grains and perennials (alfalfa); some of which could eventually be replaced by Forever Green crops that are currently under development. We will do paired comparisons of bird batches in each of three production systems; collect data on carcass weights, ration disappearance, meat eating quality; and conduct economic analysis of the Forever Green vs. standard rations in order to determine whether a Forever Green ration is economically viable and produces a good bird. Success of a Forever Green poultry ration could help drive perennial cropping system adoption on Minnesota acreage.

PROJECT DESCRIPTION

The objective of this project is to determine the viability of a Forever Green poultry ration built on small grains and perennial crops, for production of small-flock meat chickens. Viability means comparable performance of chickens on the Forever Green ration to an identical batch of chickens raised on a standard ration.

- The three participants have three different seasonal production systems and raise multiple batches of birds per summer:
  - Jane Jewett – Cornish Cross birds raised in a day-range model with conventional feed.
  - Kathy Zeman – Cornish Cross birds raised in a hoop moved daily with organic feed.
  - Wayne Martin – Kosher Kings raised in a chicken tractor model with conventional feed.

We hired Jeff Mattocks of Fertrell to assist in developing our shared ration recipes. For each farm we were able to match the farm's typical rations to their Forever Green ration for crude protein percentage and energy content and use at least 60 percent Forever Green ingredients in each ration.

Sustainable Agriculture Demonstration Grant Project Updates 2019

Each farm selected two chicken batches during their season to split into a "typical feed" sub-batch and a "Forever Green Ration" sub-batch. We collected data on grow-out period, mortality rate, and ration disappearance in each sub-batch. Chickens were processed and we collected data on carcass weights. The intent was to have six paired comparisons.

We worked with Minnesota Institute for Sustainable Agriculture's Executive Director, Helene Murray, and chef Beth Dooley to conduct a taste test of standard ration and Forever Green ration chicken from each farm.

2019 RESULTS

Comparison of average weight per bird: The Forever Green ration birds did not perform as well as the standard ration birds on either Jane Jewett's farm or the U of MN Student Organic farm. We think this was at least partly because the grind on the Forever Green ration was too coarse. On Kathy Zeman's farm, the Forever Green ration birds performed very similarly to the Standard ration birds in each of two batches. We are researching options to get a finer grind on the non-organic Forever Green feed for the next set of feeding trials.

Economic performance of the trial chickens was calculated by tracking feed costs, dressed weight per bird, and sales data of each bird. Contact the grantee to learn about the different economic performances of the chickens fed the Forever Green rations versus the standard rations for each of the farms in the study project.

Taste testing results were very mixed and difficult to interpret.

We found that it was important to protect chickens from predation. On Kathy Zeman's farm, chickens are kept in chicken tractors. On the Student Organic Farm, chickens are in movable small hoop houses that are fully enclosed in chicken wire. On Jane Jewett's farm, chicken's day-range are protected through a combination of overhead netting, electro-netting fence, and night-time enclosures.

2020 RESULTS

Due to COVID-19, this project was paused for 2020. The University of Minnesota's St. Paul campus was strictly limiting the personnel allowed to be on campus from March 2020 onward. This prevented raising chickens on the Student Organic Farm because the required student laborers could not be present. In addition, we could not have conducted our final field day in 2020 because of travel restrictions and COVID-19 safety concerns with hosting a field day on Kathy Zeman's farm.

Both Jane Jewett and Kathy Zeman have butcher dates and chick order dates secured for 2021 trials of this project. The Student Organic Program Coordinator departed in 2020 and there is no possibility of hiring a farm manager or students to work the Student Organic Farm in 2021. So, it will not be feasible to include the Student Organic Farm location in their 2021 trials.

Evaluating Hazelnuts as a Soy-Protein Replacement in Free-Range Poultry Systems

Grantee: Wyatt Parks, Main Street Project
Duration: 3 years
Contact Information: 425-760-2764, wparks@mainstreetproject.org
Counties: Dakota and Rice

PROJECT SUMMARY

We are testing the viability of feeding hazelnuts and hazelnut processing by-products to chickens within our poultry production methods as a substitute for soy-based protein. We want to know if the hazelnuts can provide usable protein in high enough density to maintain the growth and vigor of the birds. We also are exploring the economic potential of feeding waste hazelnuts (small/non-retail quality) to poultry and whether hazelnuts as feed can be price competitive with soy meal or if the chickens can command a higher retail price due to quality.

As hazelnuts become a more viable crop for Midwestern farmers access to these waste products will become much more available and we plan to help develop ways for farmers to capture the value in their by-products rather than simply disposing of them. This is especially valuable if the chickens that are raised on these by-products can command a premium in the marketplace as soy-free or sustainable- raised animal protein.

PROJECT DESCRIPTION

Alternative to soy-based poultry feeds are critical in the development of sustainable food systems in the Upper Midwest. Market conditions through consumer choice and feed cost variations have created conditions favorable to alternative protein sources in poultry feed. Hazelnuts offer a viable alternative in protein content, nutritional value, as well as the potential for value-added products created in the conjunction with poultry feed. Various studies have confirmed the general viability of replacing up to 50 percent of the protein feed in a confinement poultry operation with hazelnut meal, but no research could be found that pertained to free range/paddock raised chickens. Trial groups need to be performed in Minnesota and in non-confinement conditions to validate existing research.

This grant project seeks to determine the viability of feeding hazelnuts and their by-products to chickens as a soy-protein replacement. Due to unforeseen conditions we will be altering the trial group feed regimens to better represent likely situations that farmers would experience. As such we will be running two trial groups with the first being fed the planned 100 percent hazelnut soybean replacement and the second being fed a much more conservative 40-50 percent replacement rate. The hazelnuts fed to the chickens will be run through a chipper that has been adjusted to crack open the hazelnuts. The whole nuts will represent small or deformed nuts that would normally be waste products.

To implement this research, we will be raising three flocks, one control and two trail flocks. All three flocks will receive the same starter feed for the first four weeks of life and will transition feed sources when they begin to roam in the paddocks. All three groups will also receive a blended mix of sprouted grains as a portion of their daily feed. The control group will receive the normal, corn and soy based non-GMO, feed that Main Street Project uses for all flocks. The trail groups will also receive the corn base of the feed with the correct proportion of soy removed. The hazelnuts will be mixed in with the normal feed to limit selection bias when the chickens feed.

The final evaluation will consider the economic results, comparing normal soy-based feed to hazelnut replaced feed. It will also include evaluations of the animals' health and vigor, and if they reach target market weight on time. We are also considering the overall product quality and whether a premium product is being reached that consumers will want to buy.

RESULTS

This project has not started yet because a new site needed to be prepared in 2019 for the research flocks and construction of new coops finished in the spring of 2020. Conducting this project on Main Street Project's Demonstration and Research Farm coops was preferred over rental for one year and then moving the flocks.

In 2020, we discovered the hazelnut meal that is available is either already spoken for and not available for new outlets or is entirely dedicated to supplying human food chains. In addition, hazelnut meal can retail for upwards of $15 per pound while the conventional soybean meal that we use is roughly $.30 per pound. The increased cost of feed cannot be absorbed by the farmer or transferred to the customer in any market we are familiar with. A premium price may be secured for chickens raised with no or reduced soybean feed consumption, making the prospect of feeding B-grade hazelnuts promising; but the economics suggests it will only be cost-effective to a point.

Even with these challenges, we plan to conduct an amended trial with control groups during the 2021 Spring and Summer. Our goal is to gain valuable information about the economic and productive viability of hazelnuts as a soy replacement in poultry systems. Project changes should better reflect the potential situations the farmers in the Upper Midwest are likely to experience when exploring soy alternatives for livestock feed.

Soil Fertility

Using Sheep and Cover Crops in a Strawberry Rotation

Grantee: Sarah Brouwer, Brouwer Berries
Contact information: sarah@brouwerberries.com
Duration: 3 years
County: Kandiyohi

PROJECT SUMMARY

We are testing the effectiveness of sheep grazing on grass cover crops during fallow periods between strawberry rotations as a method of improving soil health, reducing weed pressure, and increasing strawberry poundage per acre.

We hope to increase the profitability of our farm by grazing sheep on cover crops between rotations of strawberries. Sheep, being smaller, will not compact the wet soil around the cover crops the way cattle have in past years, and that if we use strictly grass cover crops, we will be able to reduce weed pressure. We hope the sheep for meat will be profitable as an enterprise, and that the combination of sheep and a specialty crop will be useful for educational outreach.

Sustainable Agriculture Demonstration Grant Project Updates 2019

PROJECT DESCRIPTION

Healthy strawberry plants in 2019.

We rotate the strawberry fields on a regular basis, this is necessary to reduce weed pressure and to minimize the replant diseases called black root rot. We have our strawberries in the ground a little more than three years. The first year is the establishment year, and the second and third years are used for production. At the end of the third picking season (early July), the strawberry plants are plowed under and are planted into a series of cover crops for the end of summer and for the following growing season. We would like to show that grazing sheep on the cover crops will be a profitable use of the strawberry ground in the fallow years while reducing strawberry plant disease and improving the soil for our strawberry plants.

We believe that healthy soil is the key to healthy plants, and that healthy plants can withstand adverse weather conditions. We have a silt loam soil with a pH above 7.2. In some areas of our strawberry field, the plants occasionally become chlorotic due to the high pH. Chlorosis is a major problem for strawberry growers in western Minnesota, where the soils are heavier and often have a pH above 7.0. A high pH is the cause, but other factors like soil compaction, soil health, and organic matter can either aggravate or minimize chlorosis.

For our project, we are looking at the feasibility of grazing sheep in the cover crops that are planted between strawberry rotations. Immediately after plowing a strawberry field down, we are seeding the field to sorghum/sudan. Sorghum/sudan is an ideal cover crop because it is a warm season grass that grows extremely fast, and it has shown to be one of the most effective cover crops for reducing replant diseases and weed pressure. We will evaluate to determine if sales from sheep balance out any losses incurred on our strawberries.

Evaluation:

- Track weeding labor hours per field block.
- Track grazing days and feed cost saving in sheep flock.
- Sap Testing: Using sap tests to target nutrient deficiencies and increase poundage per acre.
- Soil Testing: Using soil tests to track changes caused by grazing and cover crops in soil nutrient levels, organic content, and pH.
- Track student education and social media metrics on the topics of this Sustainable Agriculture Demonstration Grant Project.

Sustainable Agriculture Demonstration Grant Project Updates 2019

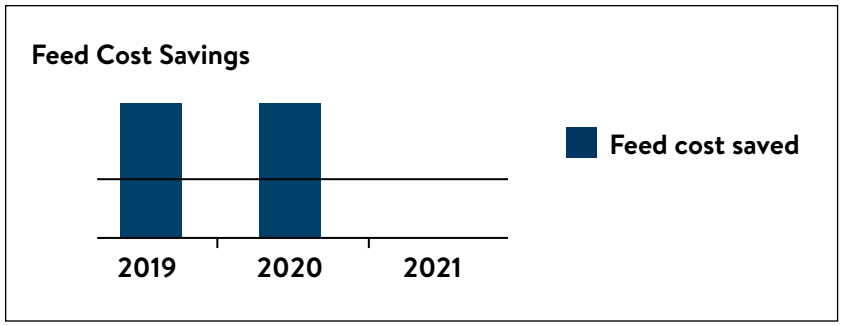
2019 - 2020 RESULTS

Amount of sheep feed cost saved from grazing:

Note that in 2019, there was heavy rainfall, and the cover crop grew rapidly. The sheep were able to eat their fill, thus saving $0.25/head/day. In 2020, there was less rain, and sheep consumption averaged ¾ ration from the field, saving about $0.18/head/day.

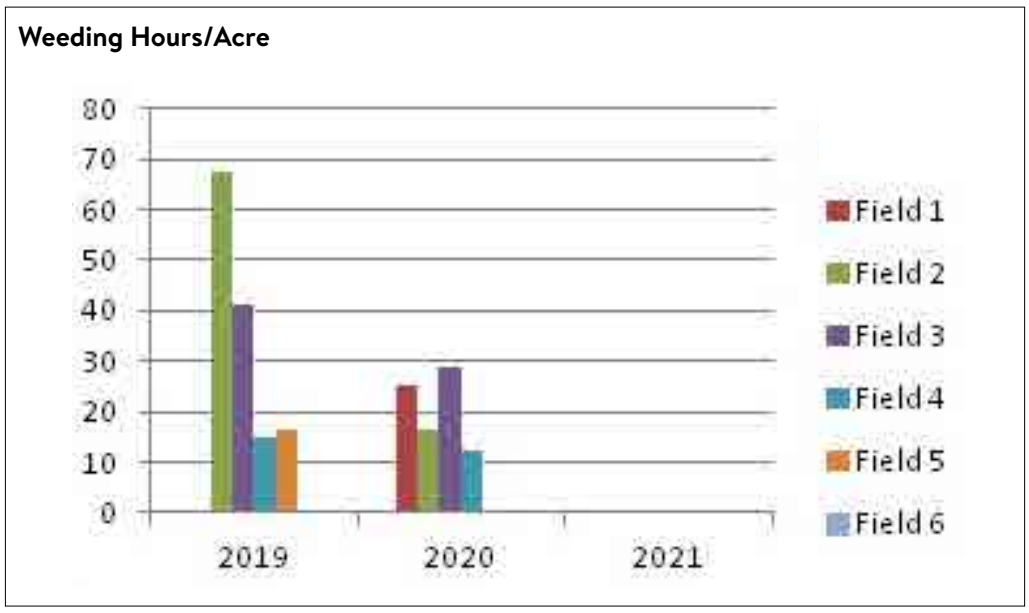
Weeding Hour Comparison of Emergent Fields:

- 2019 Emergent field; planted into cattle grazed land: 40 weeding hr/acre.
- 2020 Emergent field: planted into sheep grazed land: 26 weeding hr/acre.



Poundage Per Acre:

- 2019 strawberry poundage: 3,378 lb/acre. This is an all-time low, due to incessant rain during our harvest.
- 2020: 4,065 lb/acre; better, but still a lot of room for improvement.



Soil and Sap Testing:

Four sap tests per summer informed our foliar feeding regimen throughout the growing season.

Thorough soil analyses were done on all our crop blocks in 2019 and 2020. Strawberry plants start developing chlorosis when the soil pH rises above 7.4, and until recently our pH hovered around 7.5. We had less chlorosis than expected for our soil pH, probably because we also have high organic matter. This past year, we measured a soil pH of 7.1, which takes us out of the danger zone.

2020 STUDENT EDUCATION

In addition to Sustainable Agriculture blog and social media posts, I started as a Middle School Science teacher. I incorporate agricultural sustainability lessons into all of my classes. My students pulled the actual soil samples that were sent to the lab this year and learned how to interpret the data. They are learning about flock genetics, and how to treat a farm as a business, using data to increase profitability. I post what I am teaching onto my farm Facebook pages, and my customers seem genuinely interested.

Dan Brouwer is able to graze sheep on cover crops as late as November 2020.

Sustainable Agriculture Demonstration Grant Project Updates 2018

The following 2018 grant project update is included here because the project will not end before publication of the 2021 Greenbook. The information for this update was obtained from the grantee's Annual Progress Report. To find out more details about this project and management tips, contact the principal investigator directly.

Kernza ® biomass regrowth. Dan Honken Farm October 2020

CROPPING SYSTEMS

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

Grantee: Alan Kraus, Cannon River Watershed Partnership
Contact information: 507-786-3913; alan@crwp.net
Duration: 3 years
Counties: Rice, Goodhue

PROJECT SUMMARY

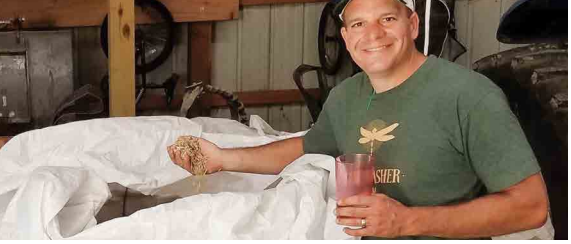
This demonstration grant addresses the needs of grain and livestock managers in the Cannon River Watershed with an interest in grazing Intermediate Wheatgrass (Kernza®). Results of this research are also valuable to a farm audience throughout the upper Midwest. Growers producing Kernza® grain on large and small scales will be provided forage biomass production and quality information to enable grazing on their farms, with a new understanding of whether grazing is beneficial or detrimental for subsequent grain yields (information important for understanding risks associated with the dual use system).

The development of data sets and enterprise budgets made publicly available on the web will enable easy access to key pieces of information important for livestock managers and land use decision makers. The market for Kernza® is expected to grow with new end users like General Mills committing to incorporating Kernza® into their products, and dual use of Kernza® for both grain and forage production could increase the financial returns for Kernza® growers, encouraging adoption of a crop with great potential to increase the productivity and sustainability of Minnesota cropping systems.

PROJECT DESCRIPTION

This project is demonstrating the viability of Kernza®'s dual use for grain and forage production on two Minnesota grain and livestock farms. The viability for a grower to receive feasible financial returns is evaluated by measuring grain and forage yields and calculating returns. The effect of grazing, versus no grazing, on grain production and total returns is evaluated by comparing yields and enterprise budgets among the grazed portion of the field and the exclosures, where grain yields are collected with no grazing treatment (control). Grower comments on labor and livestock performance, as well as the enterprise budgets for each treatment, will be disseminated to the grower community via the CRWP website and at a planned pasture walk event. A brief questionnaire and comment sheet will be disseminated to Pasture Walk participants to elicit comments about the project's outcome, the grower's experience, and participants' perspectives on Kernza® dual use and production.

Prior to each Kernza® grain harvest hand samples are collected by clipping two 0.5-m2 quadrats in each exclosure, and six randomly placed 0.5-m2 quadrats in the grazed portion. Spikes are separated from the straw in the clipped samples and threshed, and grain weighed to determine grain yields. Across the entire field, grain is harvested by either swathing and combining or by direct combining in August of each year.



After grain harvest, Kernza® regrows until approximately 1 ton of biomass (10-12 inches in height) is present in the field and then grazed. Three exclosures of approximately 5 m2 are placed randomly throughout the field and fenced off to prevent livestock access. Biomass production is estimated in the grazed area and in the exclosures (non-grazed area; control treatment) by randomly placing 0.5-m2 quadrats throughout the field and collecting Kernza® biomass to a stubble height of 2 inches. The biomass is weighed wet to calculate forage yield, dried in an oven at 55 degrees C, and weighed dry to calculate dry matter yields and moisture content. Dry biomass is ground and analyzed for forage quality using NIRS. CRWP and UMN researchers work with growers to calculate an appropriate stocking rate, depending on biomass production, livestock forage requirements, and the planned grazing duration. Livestock grazing is managed to leave a short stubble height (<2 inches) by rotation throughout the field via planned paddocks. Livestock behavior while grazing is observed and recorded by the grower. Livestock forage utilization is estimated post-graze in the grazed area by randomly placing quadrats and collecting remaining biomass to 2 inches as described above. Post-graze biomass is dried, weighed, and the proportion to pre-graze biomass calculated, to estimate the percent consumed by grazing livestock.

Grain yields are collected each year in the grazed and non-grazed areas (exclosures). Grain yields and biomass production are compared between the grazed and non-grazed areas to investigate the effect of grazing on Kernza® productivity over time.

2020 RESULTS

Kaleb Anderson Farm 2020

The Kernza® regrowth in early 2020 was excellent allowing grazing from May 15-22 using a stocking rate of 52 animal units on 6.0 acres.

- Pre and post spring grazing forage biomass sample results are pending.
- 5,000 gallons per acre liquid manure was applied post spring grazing.
- Pre-harvest grain samples comparing Kernza® grain yield between grazed and non-grazed Kernza® results are pending.
- Mature Kernza® swathed August 3 and harvested August 8 yielded 600 pounds of uncleaned Kernza® grain (360 pounds of cleaned grain) per acre and 25 1,100-pound round bales of dried Kernza® forage (10.7% crude protein, 53% TDN, 68 Relative Feed Value).
- Excellent regrowth allowed grazing 9 days November 1-10 with 54 animal units on 6.0 acres.
- Pre and post fall grazing forage biomass sample results are pending.
- Grain mycotoxin screen – high level of vomitoxin (deoxynivalenol – DON) detected. Dehulling resulted in DON level within limit for food consumption.
- Kernza® grain sold to Perennial Foods.

Dan Honken Farm 2020

Plot planted in early August 2019 – spring grazing was not an option.

- Grain from this 6.8-acre parcel was planned to increase Kernza® Minnesota Clear Water variety seed, undesirable broadleaf plants were controlled with an application of 2, 4-D in early July.
- Grain harvest on August 18 by direct combining – no swathing prior to harvest – yielded 3,548 pounds (521.7 pounds per acre) of uncleaned seed along with 16 round bales weighing 1,100 per bale.
- Seed sale to Minnesota native Landscapes is pending.
- Moderate vegetative regrowth allowed grazing 36 animal units to begin October 19. but accumulating snow forced removal October 23.
- Pre and post fall grazing forage biomass sample results are pending.
- No fertilizer applied.

Peonies for Profitable Cut Flower Production in Northeastern Minnesota

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2018 to 2021

AWARD AMOUNT

$23,860

KEYWORDS

blossoms, cold hardy, cut flowers, peonies

PROJECT SUMMARY

Peonies (*Paeonia* spp.) are a highly sought-after cut flower around the world. The number of peony stems sold in the international cut flower market has been increasing in recent years. Peonies are winter hardy and incredibly long-lived plants, often living for over a century. Grown in USDA Zones 2 - 8, they need an extended period of cold during the winter in order to go dormant and bloom the next year.

The goal of this project was to grow and evaluate 32 varieties of peonies for cut flower production in USDA Zone 3 in Northeastern Minnesota. This study sought to identify cultivars that produce the most blooms per plant and identify cultivars that would extend the production period, allowing Minnesota growers to meet the demand for peonies after production ends in many other states. This project has the potential to serve as a benchmark for kick-starting a new commercial enterprise in Minnesota that would support small farms and promote USA grown peonies.

PROJECT DESCRIPTION

Owl Forest Farm is a small farm in Iron, MN that supports vegetable, herb, and cut flower production on over 6 acres. Sales of wholesale cut flowers to local flower shops began in 2017. Both annual and perennial flowers are grown on the farm. Perennial species include hydrangeas, lilies, lupin, and peonies. Although it is not certified organic, the farm follows organic practices. The farm's owner, Kate Paul, has an M.S. degree in biology.

In warmer zones in the United States, as well as in Denmark, peonies bloom mainly in May and June. New Zealand's peony market is in November and December. In Chile, peonies are ready for market in January and February. In northern Minnesota (Zone 3), there is potential to grow vigorous peony plants that produce a bounty of blooms during late spring to late summer. This seasonal advantage would help fill a niche in the market when supplies are low or non-existent elsewhere. While this advantage is similar to Alaska's peony market, northern Minnesota grown peonies would have an edge over Alaska due to the proximity of shipping routes within the lower 48 states, which would likely keep costs lower. Peonies grown in northern Minnesota would fill local florist needs and be available for next day air shipments throughout the United States and around the world.

The purpose of the project was to grow and evaluate peony (Paeonia spp.) production in a location where there is great potential for a local, national, and international cut flower peony industry. The project's objective was to identify peony cultivars that perform well overall (measured by average budding/blooming stems per plant) as well as cultivars that bloom the latest during the growing season, thus extending the marketing season.

Peony bare roots were transplanted in the fall of 2018. General maintenance was done on the young plants in 2019, including watering, fertilizing, and monitoring for Botrytis (gray mold). Data collection was done weekly throughout the 2020 growing season while the peonies were blooming. Total mean blooms per cultivar were recorded two times per week. A chart was made showing the timeline of the weeks during which each cultivar was blooming. An ANOVA (analysis of variance) test was done to compare the mean blooms per cultivar during their peak bloom period. A Tukey-Kramer post hoc test was then performed to determine which cultivars had significantly more blooms.

The evaluations and determinations made in this study from data collected during the second season after planting are considered preliminary. However, the data is valuable as an indication of performance of the varieties evaluated. We determined the dates and duration of blooming for each cultivar. We determined the cultivars that bloomed the latest into the growing season. In addition, we determined cultivars that have significantly more blooms during their peak weeks than the others. Those varieties are potentially more desirable for cut flower production. Notes were also made regarding general plant health in 2019 and 2020 to see if there are any cultivars that simply do not do well, as not every variety may be well suited for the growing conditions in this study. This is just as important to know as which varieties perform well.

2018 RESULTS

Soil samples were taken in the spring from the location where bare root peonies were proposed to be planted plus one alternative location. Soil samples were sent to the University of Minnesota Soil Testing Laboratory and measurements were made of the regular series phosphorus, potassium, pH, and percent organic matter. Sulfur, zinc, iron, copper, manganese, boron, calcium, and magnesium were also measured.

Due to the presence of deer that trampled on the previous year's peony plantings in the original proposed location, the alternative location and two additional locations where soil composition was already known were ultimately chosen to plant the peonies. Deer frequently traveled across the proposed location and caused several bare roots to dislodge from the soil. Except for one small area, the locations that were chosen for the 2018 plantings were already protected by deer fencing. The smaller, non-fenced area will be monitored for deer damage in 2019 and fencing will be installed if needed.

Bare root peony divisions were ordered in the early spring from four reputable wholesale companies to secure the varieties needed for fall shipment. Thirty-two different peony cultivars (Table 1) were ordered, all of which had 30 - 50 roots each with 3 - 5 eye roots, for a total of 1,385 bare roots. An equivalent number of early, mid, and late season cultivars were selected. A wide range of colors within each season were chosen including white, light pink, dark pink, red, coral, and yellow.

The field after planting beds have been made.

Landscape fabric covers the planting beds to prevent weeds and to retain soil moisture.

Single: Similar to the wild form of the peony with five or more guard petals arranged around the carpels and pollen-bearing stamens of the flower. This is the fundamental peony flower form.

Semi-double: Five or more outer guard petals with a center of smaller inner petals often decreasing in size as they near the center of the flower. Pollen-bearing stamens may be intermixed with petals or be present in the center of the flower. Occasional transformation of stamens to petal-like structures.

Double: Five or more outer guard petals with a center of stamens and carpels that have more or less transformed into petals - creating the full body of the flower. Occasional stamens may be interspersed throughout the flower.

During the summer of 2018, the ground was prepped for planting by disking, tilling, and applying compost and granulated lime (where it was needed) prior to planting oats as a cover crop. During the last half of September, additional disking and tilling were done to work the cover crop into the soil. Rows 4 feet wide on 9 foot centers were made by using the disc hiller attachment on the tractor to make a trench on both sides of the beds. In all but two beds, hand raking was done to smooth off the bed surface and remove loose soil from the trenches. Six foot wide landscape fabric was laid down on the beds and the sides were secured in the trenches using landscape staples and covered with soil. For each bed,

Table 1: List of peony varieties planted and their characteristics.

Name of Variety	Peak Bloom Season	Flower Color	Flower Form*	Number of Bare Roots Planted
Duchess de Nemours	early	white	double	40
Charles White	early	white	double	50
Festiva Maxima	early	white with crimson flecks	double	50
Premevere	early	white	Japanese	45
Madam Calot	early	cream white/blush pink	double	45
Paula Fay	early	dark pink	semi-double	50
Coral Charm	early	coral	semi-double	50
Allan Rogers	early/mid	pure white	double	50
Pecher	early/mid	light pink fade to white	double	30
Bowl of Beauty	early/mid	pink	Japanese	50
Rachel	early/mid	bright crimson red	double	40
Coral Sunset	early/mid	coral fade to ivory	double	45
Shirley Temple	mid	white	double	45
Lady Alexandra Duff	mid	light pink	semi-double	50
Edulus Superba	mid	pink	double	50
Alexander Fleming	mid	rose pink	double	30
FD Roosevelt	mid	crimson red	double	30
Flame	mid	crimson red	single	50
Kansas	mid	watermelon red	double	40
Adolphe Rousseau	mid	deep maroon	double	50
Henry Sass	mid/late	pure white	double	30
Nick Shaylor	mid/late	white/blush, salmon	double	40
Mme. Emile Debatene	mid/late	salmon pink	double	30
Felix Crousse	mid/late	raspberry red	double	50
Inspector Lavergne	mid/late	dark crimson	double	40
Dr. F.G. Brethour	late	pure white	double	50
Auten's White	late	white	double	50
Auten's Pride	late	blush pink	double	40
Sarah Bernhardt	late	light pink	double	45
Red Sarah Bernhardt	late	dark red/pink	double	30
Best Man	late	red maroon	double	45
Marie Lemoine	late	cream white	double	45

*Description of flower forms:

Single: Similar to the wild form of the peony with five or more guard petals arranged around the carpels and pollen-bearing stamens of the flower. This is the fundamental peony flower form.

Semi-double: Five or more outer guard petals with a center of smaller inner petals often decreasing in size as they near the center of the flower. Pollen-bearing stamens may be intermixed with petals or be present in the center of the flower. Occasional transformation of stamens to petal-like structures.

Double: Five or more outer guard petals with a center of stamens and carpels that have more or less transformed into petals - creating the full body of the flower. Occasional stamens may be interspersed throughout the flower.

We used a stick to measure hole spacing in the landscape fabric.

Sun-Flow irrigation lines at the base of budding peony rows with two drip tape lines supplying each row.

holes were marked 2 feet apart to create a double row for bare root peonies. Using a Bernzomatic torch and the top portion of a metal bucket, 11 inch holes were then burned in the fabric.

2019 RESULTS

The 2019 growing season was mainly maintenance work. Hand weeding was done first thing in the spring to remove early emerging seedlings around the base of each peony plant. Irrigation drip lines were set up and laid down in the early summer. A main water line (1½-inch Sun-Flow Lay Flat Hose) was set up along the base of peony rows with two drip tape lines installed in each 4-foot row (one drip line per single row of peony plants). There are three separate areas of peony plantings, so three main water lines were set up.

Plants were monitored throughout the 2019 season for any signs of disease. The most common disease of peonies is Botrytis blight (gray mold) on the foliage, caused by the fungus Botrytis paeoniae. It is more common in damp, rainy seasons. To prevent blight, we planted the peonies in well-drained soil and provided for proper spacing. As another preventative measure, the early emerging peony tips were sprayed in the early spring with an organic ORMI-listed fungicide, Nu-Cop 50 DF, a copper-based fungicide/bactericide, using an ATV mounted sprayer. It is best to apply fungicides in advance of the disease as a protectant. However, some plants still developed signs of Botrytis during the growing season, so all plants were sprayed with Actinovate, another organic ORMI-listed fungicide, during the summer and after the peonies were done blooming. Affected foliage was also removed from plants as it was observed.

While hand weeding began in early spring, it was early summer before the weeding was complete. Immediately thereafter, a second round of hand weeding began that lasted through the end of the summer. The weeds growing between the 4-foot-wide peony rows were cut using a mulching push lawn mower during the blooming season. Then, during late summer, the areas between the rows were tilled using a tractor, fertilized, and a lawn seed mix was applied using an ATV pulled seeder. Going forward, this seeding will increase soil stability and reduce weeding/tilling between the rows. The dust created from tilling settles on the plants and can contribute to Botrytis and other soil-borne diseases, so it is best to keep the area between the rows in solid cover and mow/mulch.

Deer browsing and trampling were monitored during 2019. Most of the peonies are planted within an area protected by existing deer fencing; however, three rows containing 284 peony plants are located outside the deer fence. This area is closely bordered by deer fencing to the north and a new pole building to the east, so it is somewhat protected and close to human activity. No browsing by deer was noted during the 2019 season and, while deer passed through the area occasionally, there was no noticeable damage to roots.

Permanent markers were installed to identify each peony variety. Variety names were impressed into aluminum plant labels (Amekron Impress-O-Tags) which were then nailed to 5-foot-tall wooden stakes. These are weather resistant and are expected to last for many years.

Aluminum plant labels impressed and attached to wooden stakes for each peony variety.

2020 RESULTS

The maintenance routine in 2020 was similar to 2019 and included water line maintenance and replacement of drip lines in some areas, early season fungicide treatment, weeding, side dressing with fertilizer, mowing between rows, and monitoring plant health. No signs of Botrytis and all plants appeared healthy throughout the season.

Plant tissue samples were collected mid-season from multiple plants in multiple locations. These samples were placed in two bundles and mailed to the University of Minnesota Department of Soil, Water, and Climate for analysis. Tests were performed to obtain a measure of micronutrient levels in the plants. Based on the results and compared to the average nutrient concentration in lower 48 state peony tissue samples, most nutrients were at least moderately low, except for calcium, magnesium, sulfur, and boron (Table 2). The higher levels of calcium and magnesium are likely the result of soil amendments in previous years. The soil was previously used to grow summer and winter squash and brassicas, all of which were supplemented heavily with bonemeal and a calcium and magnesium enriched granular fertilizer. The lower concentrations of other nutrients indicate the need to continue to enrich the soil around the peonies with compost and fertilizer and to also implement a program to spray the foliage with a micronutrient supplement.

Data on the number of harvestable blooms for each cultivar was collected twice per week (3½ days apart) for a total of seven bloom counts. The first bloom-count session was on June 14 after the first blossom appeared. The last bloom-count was conducted on July 5 after which no more harvestable blooms were present. No stems were harvested during the 2020 season so that all harvestable blooms could be counted. A 'harvestable bloom' was defined as any bloom, from buds in the soft marshmallow stage to open flowers in any stage, that appeared would hold up in a vase for several days. This included well-developed blooms, as long as they were not extended or losing petals.

Table 2: Peony Tissue Analysis Results - 2020

Nutrient	Sample 1	Sample 2	Average Concentrations from Lower 48 State Tissue Samples
Nitrogen (%)	1.733	1.606	2.6
Phosphorus (%)	0.198	0.218	0.33
Potassium (%)	0.989	0.958	1.1
Calcium (%)	2.207	2.168	1.3
Magnesium (%)	0.286	0.357	0.36
Sulfur (%)	0.319	0.318	0.23
Iron (ppm)	38.473	41.986	98
Manganese (ppm)	13.713	17.576	44
Copper (ppm)	4.900	4.041	7.0
Zinc (ppm)	20.193	14.519	40
Boron (ppm)	36.868	34.014	25

Total mean blooms per cultivar were calculated for each bloom-count session. A single factor one-way ANOVA (analysis of variance) test was conducted to compare the mean blooms of the 32 cultivars during each of their peak bloom-count sessions. The comparison of blooms during peak count sessions was chosen over the comparison of the total number of blooms for the season because it was probable that some blooms were counted in more than

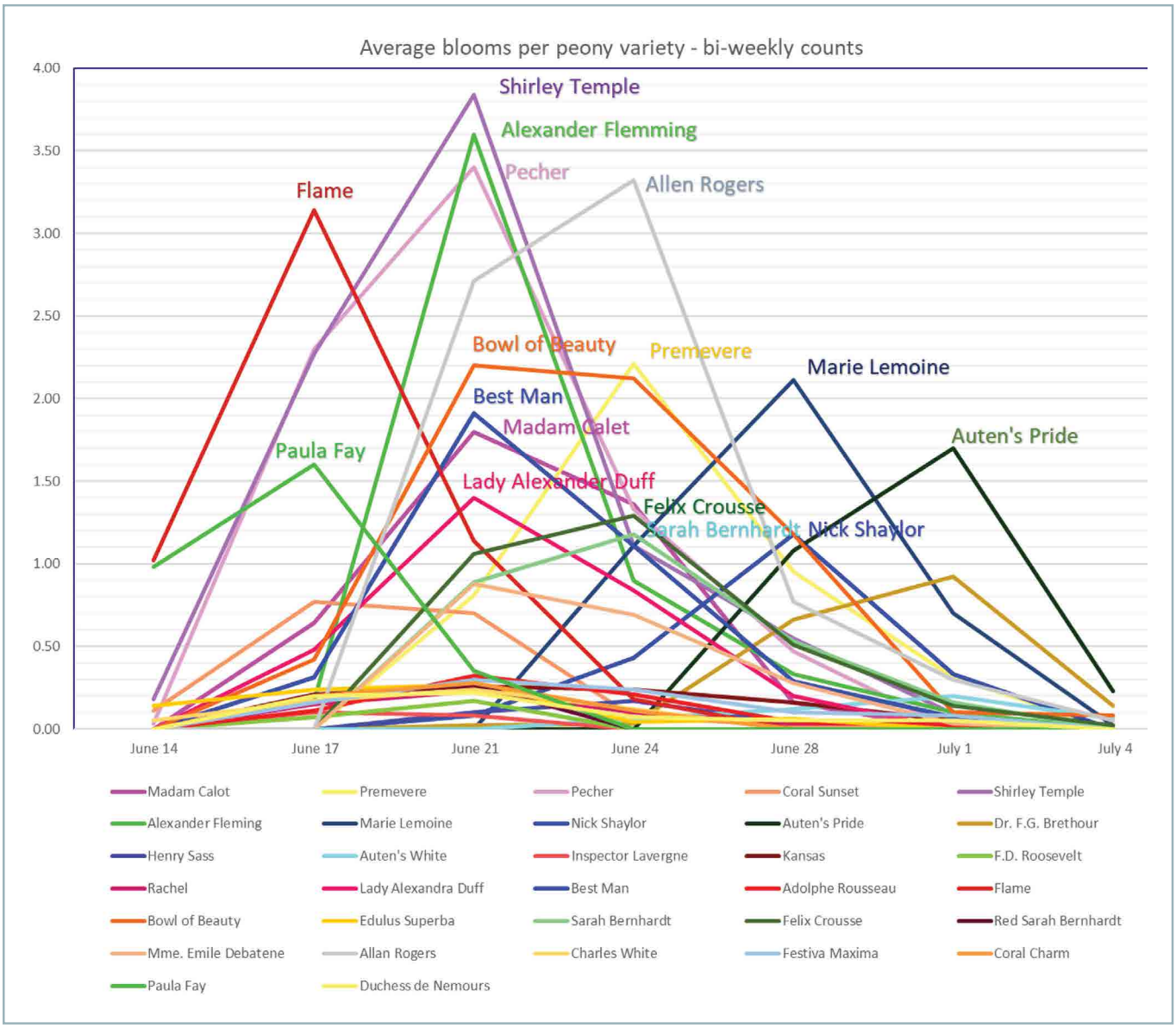
one bloom-count session and this would affect an accurate comparison. The one-way ANOVA tested the null hypothesis that the peak mean bloom count of all cultivars was equal. The ANOVA showed that the hypothesis was rejected, thus revealing there was a difference in means that was statistically significant. A Tukey-Kramer post hoc test was then performed to determine which cultivars had significantly more blooms than others during their peak bloom-count period.

The test results showed that there were two groups of peonies that performed better than the others, but these two groups also have a statistically significant difference between them. The top performing cultivars (Group 1) were Flame, Shirley Temple, Alexander Flemming, Pecher, and Allen Rogers. The next best performing cultivars (Group 2) were Paula Fay, Bowl of Beauty, Best Man, Madam Calot, Lady Alexander Duff, Premevere, Felix Crousse, Sarah Bernhardt, Marie Lemoine, Nick Shaylor, and Auten's Pride. The five varieties in Group 1 outperformed all other varieties, and the 11 varieties in Group 2 outperformed the remaining 17 varieties (Figure 1).

Table 3 displays the total number of harvestable blooms for each cultivar during each of the bi-weekly bloom counts and highlights when each variety was blooming. Peonies from the two high performing groups are also indicated.

Table 3 also displays total number of blooms for the season. The peak overall bloom times were June 21 and June 24. Most cultivars were blooming during this period. This is significant because it verifies that, regardless of the cultivar, bloom time is later in Northeastern Minnesota compared to the majority of the lower 48 states where peonies bloom from April into June. If peonies are harvested during their soft marshmallow stage, stripped of their leaves, and stored

Figure 1: Average (Mean) Blooms per Peony Variety.



dry in a 38 degrees F cooler, stored peonies can last for four weeks. This would make peonies in this climate available for market sales well into July when peony production has ended in many other states. The only other place they are available during this later timeframe is Alaska.

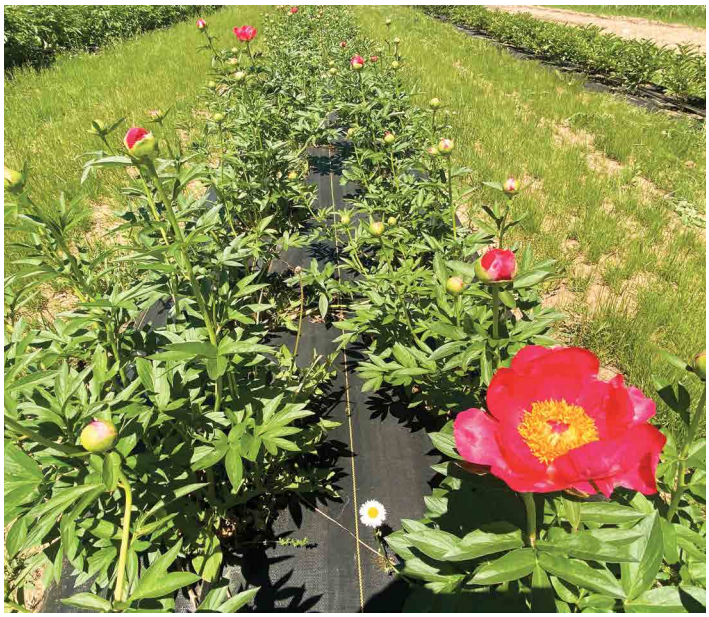
Table 3: Total Harvestable Blooms and Blooming Timeframes.

Cultivar*	June 14 a.m.	June 17 p.m.	June 21 a.m.	June 24 p.m.	June 28 a.m.	July 01 p.m.	July 05 a.m.	Totals
Paula Fay2	51	83	18	0	0	0	0	152
Flame1	52	160	58	9	0	0	0	279
Charles White	2	7	10	5	0	0	0	24
Edulus Superba	7	12	14	2	3	0	0	38
Coral Sunset	5	34	31	3	1	0	0	74
Pecher1	1	69	102	40	14	0	0	226
Shirley Temple1	8	100	169	49	24	4	0	305
Inspector Lavergne	0	4	3	0	0	0	0	7
F.D. Roosevelt	0	2	5	0	0	0	0	7
Red Sarah Bernhardt	0	6	18	0	0	0	0	14
Coral Charm	0	9	13	5	0	0	0	27
Madam Calot2	0	29	81	61	7	0	0	178
Lady Alexandra Duff2	0	12	35	21	5	0	0	73
Alexander Fleming1	0	5	108	27	10	3	0	123
Best Man2	0	14	86	50	13	3	0	166
Festiva Maxima	0	8	15	12	5	4	0	44
Kansas	0	8	10	9	6	2	0	35
Duchess de Nemours	0	8	9	3	2	2	0	24
Rachel	0	6	9	4	1	1	0	21
Adolphe Rousseau	0	5	15	10	2	1	0	33
Bowl of Beauty2	0	21	110	106	59	5	4	305
Premevere2	0	0	34	93	40	13	0	180
Sarah Bernhardt2	0	0	40	53	24	7	0	124
Nick Shaylor2	0	0	3	17	47	13	0	80
Mme. Emile Debatene	0	0	28	22	9	1	0	60
Henry Sass	0	0	3	5	1	1	0	10
Allan Rogers1	0	0	152	186	43	17	3	401
Felix Crousse2	0	0	82	66	26	7	1	154
Dr. F.G. Brethour	0	0	2	3	16	15	4	40
Marie Lemoine2	0	0	0	51	97	32	1	181
Auten's White	0	0	0	3	6	10	3	22
Auten's Pride2	0	0	0	0	43	68	9	120
Total count per session:	126	602	1263	915	504	209	25	3527

*Number following cultivar name indicates the group that cultivar is assigned to based on average blooms per bi-weekly counts.

There were also several cultivars that had an even later peak bloom period, which would extend the production period. For example, Marie Lemoine and Nick Shaylor both had a peak number of harvestable blooms on June 28 and Auten's Pride had a peak number on July 1. These three varieties are included in Group 2 and they performed very well. Cultivars such as these could extend the production period even further and allow Minnesota growers to meet the demand for peonies well after production ends in many other States.

Late-blooming Nick Shaylor peony.



Flame peony from Group 1.

The evaluations and determinations made in this study from data collected during the second season after planting are considered preliminary. Peony plants generally take until their fourth season to produce a large enough number of blooms to start harvesting and many varieties take until their fifth year before optimum productivity is reached. This optimum productivity may then continue for more than 25 years. However, the data in this study is still valuable for other farmers who would like to grow peonies for cut flower production, since it provides baseline performance data on 32 varieties and a picture of overall performance of herbaceous peonies in Northeastern Minnesota.

Now that the grant has ended, we plan to maintain a healthy crop of herbaceous peonies. We have plans to experiment on our own and continue to plant additional cultivars in the upcoming years. We have the space to accommodate more peony plants and the desire to see which varieties perform best in our area as the original planting matures as well as for marketing purposes.

MANAGEMENT TIPS

1. Prior to ordering bare roots, inquire with other growers about suppliers of bare root peonies to find the best quality and ease of handling. For example, the bare roots from one company were very long compared to another company that cut the roots more compactly. The number of eyes was the same, but it was much easier and quicker to transplant the more compact roots. Shipping costs can also be drastically different between companies, so inquire prior to placing your bare root orders.
2. Although deer do not tend to browse on peonies, we discovered from previous plantings that they can trample on the fresh transplants in the fall and again in the early spring, causing some of the bare roots to dislodge from the soil. Because of this, we changed the location of most of the plantings to an area that was already fenced in to keep deer out immediately after transplanting.

3. In preparing beds for the landscape fabric, side trenches were made with the disc hiller attachment on the tractor, but the best results were obtained when the beds were also hand-raked to smooth the bed top and to clean loose soil out of the trenches. It takes more time and is more labor intensive, but the fabric ultimately lays better with a smoother base underneath.
4. Peonies offer more than beautiful flowers. We have discovered that the foliage of many cultivars turns wonderful transitioning shades of burgundy and orange in the fall. These are highly prized by the flower shops we do business with. The fall foliage is not only pretty, but it holds up well in the cooler and in the vase, as well as in the field after light frosts.
5. Keep options open for unique marketing opportunities. Our original plan was to sell peony stems wholesale to one wholesaler and to local flower shops, and we still plan to do this. However, we began offering You-Pick flowers to retail customers in late season 2020, and we have decided to do You-Pick with the peonies in 2021. One foreseen advantage is that the blooms will be harvested in many stages for You-Pick, not just the soft bud stage for selling wholesale. This will decrease our time handling and storing stems and more stems will potentially be sold. For customers, You-Pick is more than just purchasing flowers. It is a fun experience with opportunities to do a self-guided farm tour and take pictures among the flowers.
6. Regarding seeding between the peony rows, we decided against using white Dutch clover as was originally planned and instead used a lawn seed mix. The clover was used between rows of peonies that were planted prior to and separate from this study. We found that during seeding, the round clover seed easily bounced away from the intended areas and into the holes in the landscape fabric with the peonies. Once established, white Dutch clover is difficult to weed out. Also, it blooms prolifically and attracted so many bees that it became difficult to walk between the rows. A lawn seed mix of short grass varieties, in particular red fescue, that contains just a small amount of white Dutch clover was ultimately chosen to seed between the rows for this study.
7. The copper-based fungicide Nu-Cop 50 DF, when mixed and applied, leaves a turquoise-colored residue on foliage that remains through many rain events. We discovered this when applying it on lily foliage. For this reason, we choose to spray the Nu-Cop on emerging peony plants only and not on more mature foliage. The Actinovate fungicide does not leave a colored residue and is thus more suitable for spraying on plants when stems and foliage are to be harvested.
8. Hand weeding the peonies consumed much more time than expected. Our time was more limited while working off-farm jobs, so weeding became a constant task while on the farm. Looking ahead to planting and managing more peony plants in the future, it will be necessary to hire part-time, temporary helpers to keep up with weeding.

COOPERATOR

Kendall Dykhuis, Agriculturalist and Agronomist, St. Louis County Extension Service

OTHER RESOURCES

The Alaska Peony Growers Association is an example of a cooperative with a long list of supported farms. They also host the annual Alaska Peony Conference.

www.alaskapeonies.org

www.alaskapeonyconference.com

Agrophenology Project

PRINCIPAL INVESTIGATORS

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PROJECT DURATION

2018 to 2020

AWARD AMOUNT

$15,525.20

KEYWORDS

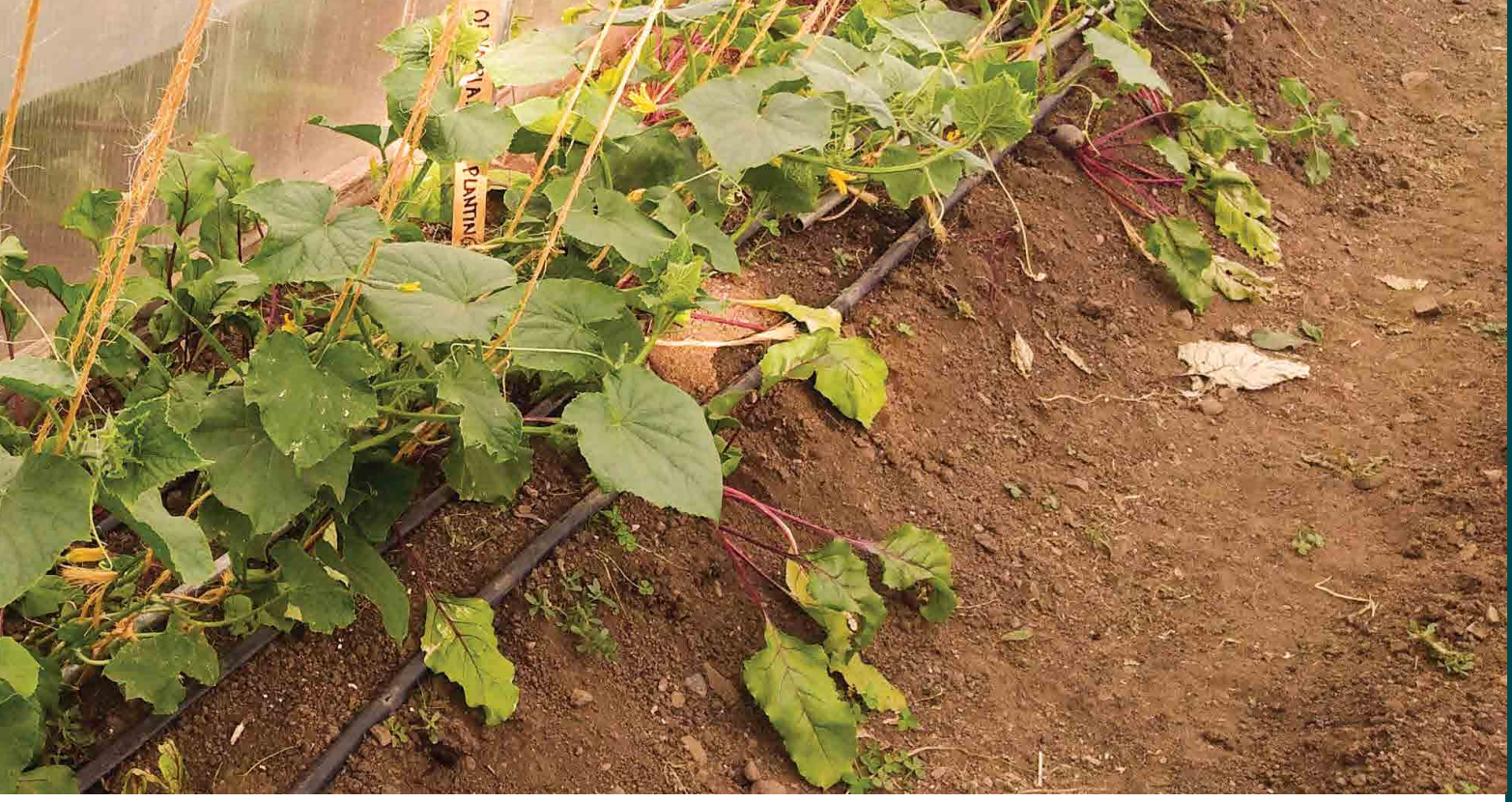
nature-based planting calendar, phenology, wild indicator plant species

PROJECT SUMMARY

Using a standard calendar to determine when we plant our crops has become less reliable due to more variable and extreme weather patterns. Choosing planting times has always been difficult but in today's climate, the risks are greater. Instead of using the standard calendar to determine the best times to plant our crops, we are combining agriculture (the science or practice of farming, including cultivation of the soil for the growing of crops) with phenology (the scientific study of the timing of nature) to create a more useful planting guide. Over the past three years, we have identified the best wild indicator species that provide us with a natural assessment of growing conditions. We experimented with crop plantings as they related to wild indicator species timing to create a nature-based planting calendar that can be more reliable than the standard calendar we use today and possibly provide increased crop productivity. This agrophenology research project has given us another tool in the toolbox to be better farmers on the landscape. Our farm will be using this nature-based planting calendar moving forward.

PROJECT DESCRIPTION

This is a joint Wolf Ridge Organic Farm and Round River Farm project. The Wolf Ridge Organic Farm has been increasing its vegetable production to meet the goal of providing all the vegetables for the 136,000 to 160,000 meals served in the Wolf Ridge Environmental Learning Center (ELC) cafeteria each year. In 2017, we had three high tunnel greenhouses covering 8,640 feet^2 and cleared 3 acres of land to prepare the soil to grow more



Cucumbers growing in a high tunnel.

vegetables like potatoes, carrots, onions, beans, broccoli, and squash. Along with the increased agricultural production, Wolf Ridge runs robust educational programs, additional research projects, graduate farm mentorships, summer internship programs, and adult educational programs. Wolf Ridge ELC closed during COVID-19 but the Wolf Ridge Organic Farm continued to grow crops for food shelves and food relief in the wider community.

Round River Farm, the family farm of David and Lise Abazs, grows vegetables and markets them through the Finland Farmers' Market and Online Marketplace and during the COVID-19 summer of 2020, stopped offering a 65-share Community Supported Agriculture (CSA) subscription. The farm also maintains orchards, livestock, and pastures. The farm grows vegetables on fertile sandy loam soils in an intensive cropping system, using manures, composts, cover crops, plant diversity, and a soil microbe balancing cover crop system. The farm is transitioning some of its fields to seed research and production and is working with regional farmers to grow climate forward tree seedlings for the Forest Assisted Migration Project.

This project's research objectives include:

- Identifying and evaluating plant, insect, mammals, and migratory animal species to determine their reliability to provide a better planting "calendar" for our greenhouse and field crops. Using phenology (the scientific study of the timing of nature) will provide a better guide for when we should plant our crops for maximum plant health and growth.
- Tracking and evaluating our greenhouse and field crops' health and growth in relation to time of planting.
- Developing an agrophenology methodology with downloadable phenology observation sheets, crop record-keeping templates, and a template of the Agrophenology Calendar that growers can use to plant their crops.

For our first year (2018), we established the research protocols for identifying and choosing phenological indicators and their appropriate phenophase (the observable start and end point of a plant or animal life cycle). For example, one indicator could be the period over which open flowers are present on a plant. After initially choosing 10 indicator species of insects, plants, and animals that could be used, we realized that we needed to broaden our diversity and numbers to provide for a more comprehensive timeline to better determine crop planting dates.

We collected physical observations and data on indicator species including timing, minimum and maximum temperatures, light, precipitation, and soil temperature at 7-inch and 17-inch depths. We also looked at GDD/50 (Growing Degree Days above 50 degrees F) and GDD/32 (Growing Degree Days above 32 degrees F) since a significant portion of our northern growing season is below the GDD/50 and many of our crops respond to conditions below 50 degrees F. These physical parameters were used to cull the phenological indicators and helped us focus on the ones that might provide us with the most reliability for the new nature-based planting calendar. We noted other potential indicators and determined that some original ones should be removed from the list and others added. In 2019 we fine-tuned the list to the 23 and further refined the list in 2020 to 28 indicator species to use in this calendar. The list is mostly domestic and wild plant indicators but also included frogs, birds, and an insect (Table 1).

We chose these indicators because:

- They cover most of the typical planting time period in our northern summers.
- They are more likely to be seen or heard on or near our farms.
- They do not mimic the calendar, i.e., some species arrive the same day every year regardless of environmental conditions.
- They do not exhibit radical time swings and inconsistences, e.g., the American crow was removed initially from consideration because it returns to our region over a three-month period with no connections at all to the environmental conditions.

We identified the crop-specific weekly assessment parameters including soil temperature, percent plant survival, average length growth, percent flowering, percent fruiting, percent mature fruit, percent pest or disease damage, and production. Due to the variation and nature of the crops, not all these parameters were used. For example, some crops are vegetative (basil), roots (carrots), tubers (potatoes), or fruit (tomatoes) by nature. Each ended up having different observational consideration. In 2018, we observed varieties of crop species in the field and greenhouse to determine a final list of crops to study.

Table 1. Final 2020 Indicator Species and Phenophases.

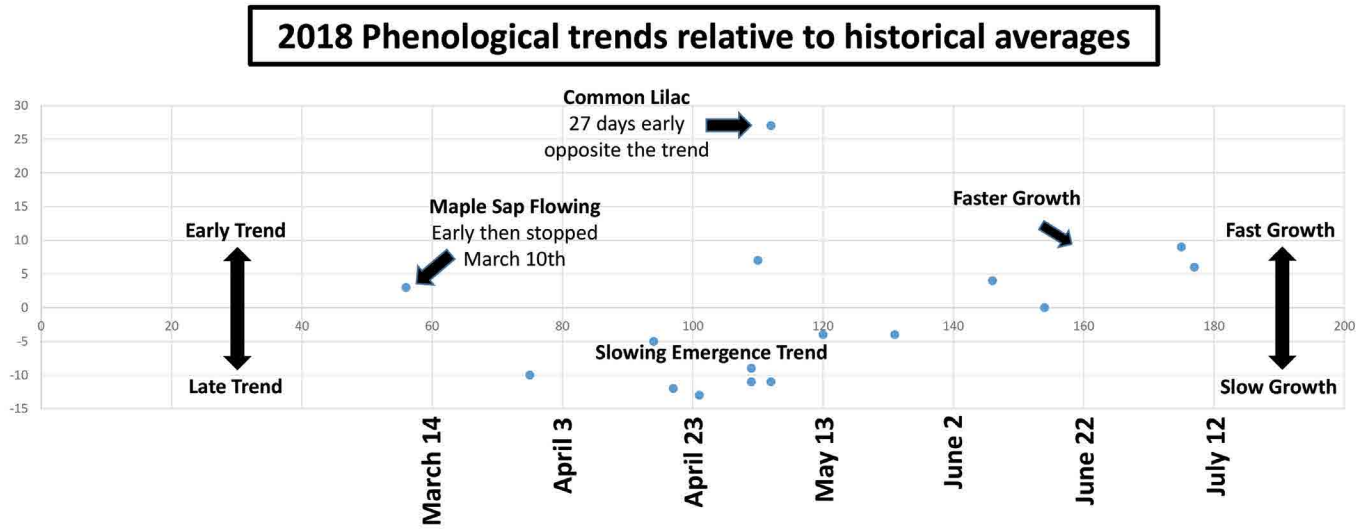
Phenological Indicator Species	Seasonal Indicator
Chickadee	Spring Song
American Crow	First Sighting
Sugar Maple	First Sap Flow
Robin	First Sighting
Speckled Alder	First Catkins Full Expanded
Beaker Hazelnut	First Pollen or Red Stigma
Rhubarb	First Leaves Emerge
Trembling Aspen	First Catkins Fully Expanded
White Throated Sparrow	First Song
Chorus Frog	First Song
Dandelion	First Flower
Marsh Marigold	First Flower
Oven Bird	First Song
American Toad	First Song
Sugar Maple	First Flowers Emerge with Leaves
Juneberry	First Flower
Black Flies	When they get annoying
Common Lilac	First Flower Bush by Solar Panels
Common Lilac	First Flower Bush by House
Red Osier Dogwood	First Flower
Orange Hawkweed	First Flower
Fireweed	First Flower
Black-eyed Susan	First Flower
Canada Goose	First Migration in Small Numbers
Snow Bunting	First Fall Migration Flock Seen
Temperature	First Max Temp Below 32°F
Paper Birch	First Tree Bare of Leaves
Snowshoe Hare	Feet All White

For this study, farming operations at the Wolf Ridge and Round River farms planted exactly what was always planted, but the timing of the plantings was adjusted as we connect the planting schedule to phenological indicators. We performed timed plantings of garlic, peas, beans, potatoes, tomatoes, and cucumbers on one or both farms to help us determine the best time to plant these crops relative to the phenological indicator species. By looking for correlations between our agrophenological observations with crop health and production, we planned to develop a reliable planting calendar.

2018 RESULTS

As we observed and studied the possible phenological indicator species to determine which ones we should use in our study, we realized that many of the migratory birds would not be useful indicators, since their "first sightings" in our location were either drastically variable or too precise. For example, the American crow may show up in January one year and the end of March another year, regardless of any measurable change in seasonal conditions. At the other extreme, hummingbirds are known to arrive in our area on the exact same day every year, basing their migration on day length or star patterns and providing no better insight than using the current calendar.

We ran multiple graphing assessments trying to connect indicators to the physical data points of light, temperature, GDD/50, and GDD/32 but we found no scientifically significant correlations. The lack of correlation is disconcerting but holds promise that the phenological variability may be beyond the understanding and scope of the physical parameters, making the indicator species unique. For example, if the indicator species mimicked temperature then we might as well just use temperature to determine planting times. The fact that they do not match the temperature trends may reveal the hidden secrets that indicator plants "use" to determine when to emerge, send out flowers or leaves. This "uniqueness" aspect may be the way the agrophenological planting calendar can help us in this time of changing climate. We believed that the 22 indicators we tested in 2018 would provide us with broad enough diversity and timing to produce significant and reliable data for the study goals and provide a better chance than our initial plan of identifying 10 indicator species to see clear results as our research progresses.



In this graph, the phenological indicator of maple sap flow started three days earlier than average but stopped due to subsequent changing conditions. During the next few weeks, the indicators emerged later than normal with the delays in the first sighting of robins, rhubarb first leaves, speckled alder first catkins fully expanding, beaked hazelnut first pollen, the first song of the white throated sparrow, and chorus frog first songs, and the later than normal first flowers of the dandelion, common strawberry, and juneberry. This overwhelming slowing of spring was countered by the faster than normal emergence of the first oven bird song and an incredible 27-day early emergence of the common lilac. What is going on there? As the growing season moved into June and July, we saw a shift to earlier than normal arrivals of the first flowers of the orange hawkweed, black-eyed Susan, and fireweed. The spittle bug's first larva emerged exactly on the same day as the historical average.

This graph will be reevaluated and compared to the next two years of observations to see which indicators might best help inform our planting cycles. The work, data collection, and observations that we accomplished this year will provide the baseline for comparison in the years to come.

Based on the results of this season's greenhouse and field observations on both farms, we finalized which crops to study and which parameters we plan to use to assess that crop relative to the timing of its planting. These include five crops that are direct seeded – beans, carrots, garlic (cloves), peas, and potatoes (tubers) – and five crops that are transplanted – basil, cucumbers, pumpkins, summer squash, and tomatoes. For the next season, each of these crops will have multiple plantings, one when we typically would plant them and other plantings before and after. We will then compare each planting with the phenological indicator data to determine the best time to plant them for optimal results in the future. In the final year, we will observe the new planting timings as they relate to the indicator species and see how those adjustments fared with the growth and health of the crops.

We started the experiment with garlic this fall. Our assumption going into this crop assessment is that we should plant garlic when the feet of the snowshoe hare turn white in the fall. We planted identical plots of German and Krasnodar garlic at three different intervals. One set of plots was planted September 20, 2018, a month earlier than typical, another set around the "normal" time of October 18, 2018, and the final set right before the ground froze on November 4, 2018. We continued to observe the differences in crop performance during the 2019 growing season.

We had technical challenges with the temperature capturing devices and computer interface this year. I am thinking we should go "old school" and use min/max temperature gauges so that, once a week, we can have these correlating numbers to compare the two farms with the main data collection site to recognize site specific differences between the locations.

Garlic test plots planted in sequence

2019 RESULTS

Besides continuing to fine tune the indicator species as described above, we performed timed plantings of garlic, peas, beans, potatoes, tomatoes, and cucumbers on one or both farms, measuring production to help us determine the best time to plant these crops relative to the phenological indicator species.

Garlic Trials

In 2019, identical plots of German and Krasnodar garlic were planted on three dates: September 20, 2018, a month earlier than typical; around the "normal" time on October 18, 2018; and right before the ground froze on November 4, 2018.

To our surprise, the results showed that the best time to plant garlic was in mid-September for production, individual bulb size, and survivability (See table below). It was a win/win result to plant the garlic a month earlier than has been traditionally done in our area. We had concerns about planting early because we thought this would result in additional fall growth making the garlic more vulnerable going into winter. We did have an early and deep snow cover which might have helped with the results, but our climate is trending towards more fall moisture and early snow, so the successful results of the early planting of garlic could greatly impact our garlic production.

Based on these results, we will plant garlic after we see the arrival of the snow buntings (typically in mid/late September) instead of waiting until the snowshoe hares' feet turn white (typically mid-October). There are many benefits from this shift. One of the most significant benefits is a greatly increased planting window, allowing us to find better planting conditions (increased chance for dry periods to prepare the field for the planting). With the trend of increased moisture in the fall, this bigger planting window will be very helpful for our management. Increased production, bulb size and survival rate are "icing on the cake."

2018 Fall Planting Timing/2019 Harvest* Results for Garlic.

	German Garlic			Red Krasnoder		
	Planning Date			Planning Date		
	9/20/18	10/18/18	11/4/18	9/20/18	10/18/18	11/4/18
No. Bulbs	58	57	55	59	53	51
Total Wt.	2,960 g	2,821 g	2,320 g	3,137 g	2,288 g	2,593 g
Ave. Size	51.0 g	49.5 g	42.2 g	53.2	43.2	50.8
Size Range	1-1.5" = 0 1.5-2" = 28 2-2.5" = 29 2.5-3" = 1	1-1.5" = 2 1.5-2" = 26 2-2.5" = 29 2.5-3" = 0	1-1.5" = 2 1.5-2" = 40 2-2.5" = 13 2.5-3" = 0	1-1.5" = 0 1.5-2" = 17 2-2.5" = 40 2.5-3" = 2	1-1.5" = 0 1.5-2" = 25 2-2.5" = 28 2.5-3" = 0	1-1.5" = 0 1.5-2" = 14 2-2.5" = 36 2.5-3" = 1

*Harvest: 8/24/19; measurements: 9/22/19.

Potato Trials

Organic French fingerling potatoes were planted two weeks apart based on the juneberry and orange hawkweed indicator species. With the early planting, potatoes were hilled twice. The second planting two weeks later emerged only one week later (likely due to warmer soil) and after only one hilling. The second planting yielded almost as much as the first. The cost saving in labor and energy might be worth looking at a later planting with only one hilling. This indicates that we do not have to panic if we do not plant right after the juneberry trees flowers but should have the potatoes planted by the time the orange hawkweed flowers. Each farmer would have to consider priorities to determine their cost/benefit analysis as they relate to the pros and cons of the planting timing.

Planting Date - 2019*		
	June 2	June 16
Emerged	June 26 (24 days from planting)	July 3rd (17 days from planting)
First Hilling	July 7	July 21
Second Hilling	July 21	-
Harvest	October 20	October 20
Yield (lb)	75.2 (3 lb dirt removed)	70.6 (3 lb dirt removed)
Yield (lb)/Acre	40,962	38,456

*12 Pounds of potatoes planted on each date.

Cucumber Trials

Cucumbers were planted eighteen days apart in one of Round River Farm's unheated high tunnels. Six plants were established in a 4-foot section of the high tunnel. These cucumbers are planted within rows of early crops that will be harvested later. The plants were initially crowded then free when other crops were removed. This intensive management reality plays into yield because space, light, water, and nutrient differences exist, and soil disturbances occur as other crops like beets are removed. Seeds planted on April 21 and transplanted on May 27 yielded 10,065g (42 cucumbers). Seeds planted on May 6 and transplanted on June 6 yielded 7,136g (28 cucumbers). This was a significant production increase of the first planting over the second planting, even though they were planted only nine days apart. Two factors may have occurred in our multi-cropping system: the first planting had more room to grow while the second planting was quite crowded with the larger Swiss chard and beets; and, once the conditions were good, planting early in cold soil did not hinder growth. The high tunnel environment certainly takes away some weather-related variables.

Tomato, Peas, Carrots and Bean Trials

The first tomato planting was seeded indoors on March 31, transplanted on April 21 then planted in the high tunnel on May 27. The second planting was seeded indoors on April 15, transplanted on May 6 then planted in the high tunnel on June 14. There was a significant growth difference between the first planting and the second planting but, for the first time in 30 years at Round River Farm, we did not get tomatoes to ripen before September, leaving us no time to compare production between the two. There was no notable difference in harvest dates and yield.

Round River Farm peas were planted in sequence with three outdoor plantings two weeks apart in the month of May. There was no significant advantage to pushing the season earlier as the later plantings did as good and, in most ways, better than the early plantings. The stands were thicker, and growth was quicker to catch up with the earlier plantings. Carrots appeared to follow the same trend. From these results, we will be looking to plant the peas and carrots after we hear the white throated sparrow sing next year.

Beans were planted every two weeks. The only noticeable difference was that the early planting (like in other years) needed to be replanted because the early planting coincides with the emergence of cutworms. To avoid cutworms, planting a little later after the common lilac by the solar panels flowers would be a better time to plant than after the first juneberry flowers.

2020 RESULTS AND SUMMARY

In 2019, we established optimal planting timings and in 2020 we used these results to plant and confirm the success of the timing. In this process, we also recognized that the 23 indicator species selected from 2019 needed different and additional species, both for early plantings in May and for garlic planting in the fall. Additional species included: chickadee spring song; American toad spring call; red osier dogwood flowers; and Canada geese small group southern migration. We also added a second phenophase of the sugar maple and reestablished the black-eyed Susan to the list to help us with our July timing needs for cover crops. We removed the common wild strawberry first flower and the spittle bug first larva because they are not easily observed and therefore less useful as indicators. The final list is presented in Table 1 earlier in this article.

Garlic Trials

We started the garlic research study planting garlic determined by observing the snowshoe hare feet turning white. We had been happy with that plan for many years. After the 2019 research results showed that an earlier planting time was best for bulb size and planting weight, we shifted to an earlier phenological indicator species, the snow bunting flocks that we saw heading south. In 2020, we found that waiting for the snow buntings was better, but still too late. Our weather conditions were cold, and our soils wet by the time they arrived. From this experience, we are going to plant the 2021 garlic after the first small clusters of Canada geese are seen migrating south.

Potato Trials

Information gained from the research in 2019 indicated that we make different planting timing choices for 2020. If production was our primary consideration, we would have continued to plant potatoes after the June berries flower. Instead, in 2020, we chose to plant our potatoes later, after the hawkweed flowers emerged, to give us cost savings in time and energy because we only hilled potatoes one time instead of two. We were satisfied with the results.

Cucumber Trials

Based on results in 2019, we continued planting cucumbers on the early side in the high tunnels, just after the black flies got annoying, hoping to increase production and growth. 2020 had a bumper crop of cucumbers. Observations over time will help solidify the new timing.

Tomatoes, Peas, Carrots, and Bean Trials

We maintained the timing of the 2019 research for the tomato trial in 2020. We planted tomatoes when the lilac by the solar panels bloomed and had a good tomato crop. We adjusted the timing for planting peas, shifting from the marsh marigold flowering to the flowering of the sugar maple. Carrots were planted later than in 2019, starting when the first rhubarb leaves emerged and continuing through observations of the white throated sparrow and as late as the chorus frog first song. We saw no real advantage and some disadvantages to earlier carrot plantings in often cold soils. In 2020 we planted beans later than in past years, using the red osier dogwood flower emergence, thus avoiding coincidence with the destructive phenophase of the cutworm that occurs with earlier plantings. This was a great success. No second or third seeding was needed to compensate for cutworm damage.

Overall, we were pleased with the additional insight and guidance we gained by using the phenological observations as our planting guide for three years. We believe that we have found a better way to adapt to the changing climate by switching to this nature-based planting calendar using agrophenology. Links to the calendar and indicator checklist can be found in the Other Resources section at the end of this article.

MANAGEMENT TIPS

1. Use the appropriate technology for gathering your research observations and data. Sometimes you can over-engineer or under-engineer your collection process.
2. Develop reasonable daily and/or weekly routines, that give you the time to walk your land to observe what is going on around you and allow you to take the time to record and assess your data.
3. Be patient. Try not to jump to conclusions based on initial observations and perceived trends. Use the gift of time in the winter hours for data assessment to reveal the real trends, (or no trends) that provide you with a greater understanding of what is really happening. You may have been correct with your initial thoughts, but as our work this past year showed, sometimes what looks significant is not actually statistically meaningful. This patience can be helpful over several years to further reveal or confirm your findings.
4. If you use an individual bush or plant phenological indicator, make sure to observe and note other phenological indicators that you could use in its place if something happens to your primary indicator species.
5. It is important to establish your own indicators on your land, in your growing conditions. We found significant differences in the phenology of our indicators between the two research locations. Even though we are just miles apart, the microclimate, soil type and local conditions are significant. We noticed that even on our own land there was a four-day difference of dandelion flowering between our upper pasture and the area where we are growing our crops, 150-feet away. Choose one patch closest to the growing area to observe the dandelions and stick with that one for consistency for ongoing observations.
6. Planting things earlier doesn't always save time and may actually cost you time and money from reduced germination rates and the added time needed to weed the crop. For some crops, we are going to stop pushing them earlier and earlier as some of the negatives outweigh the positives.
7. It pays to pay attention. The benefits we realized through this research were many. On the farming level, we were better at noticing soil moisture levels and cover crop conditions. On another level, we were better in-tune to the natural conditions and trends from carefully observing the phenological trends. All in all, it made farming more enjoyable and interesting, and we feel the results of this nature-based calendar are indeed more useful than our standard calendar.

COOPERATORS

Lise Abazs, Farmer, Round River Farm, Finland, MN

Peter Harris, Science Instructor, Wolf Ridge ELC, Finland, MN

Rod Kuehn, Prairie Track, Ramsey, MN

Sam Anderson and Samantha Krueger, Antioch University/Wolf Ridge ELC, Finland, MN

Tori Dahl, Wolf Ridge Organic Farm, Finland, MN

Rebecca Montgomery, University of Minnesota, Department of Forest Resources, St. Paul, MN

Diane Booth, Minnesota Extension - Cook County, MN

Emily Richie & Kyle Cook, Round River Farm

Sarah Meyer, Wolf Ridge Organic Farm

Federica Ranelli, Wolf Ridge Organic Farm

Graduate Students, farm interns, phenology observations

Finland Community, phenology observations

Lilac bush growing by the solar panels.

American Toad.

OTHER RESOURCES

Agrophenology Calendar Master. Link and copies:
docs.google.com/spreadsheets/d/17dqtIc4F4Xtnj0k7H5mK7wPzBrp48EeY/copy#gid=861266352

Agrophenology Phenological Indicator Check List. Link and copies:
docs.google.com/spreadsheets/u/1/d/14f2jkSYHw8VzTeCk0kSR4X1En3r13BWH/copy#gid=1668027291

Agrophenology Presentation:
www.youtube.com/watch?app=desktop&v=X3QBukP8Bpc

Minnesota Phenology Network:
mnpn.usanpn.org

Phenology Resources on Wolf Ridge phenology webpage:
wolf-ridge.org/fall-phenology-setting-the-stage

Cover Crop Effects on Soil Temperature and Soil Moisture

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PROJECT DURATION

2018 to 2020

AWARD AMOUNT

$19,078

KEYWORDS

cover crops, soil moisture, soil temperature

PROJECT SUMMARY

Previous research has shown that cover crops can reduce erosion, decrease soil compaction, increase water infiltration to prevent runoff, bring leached nitrogen back to the root zone for the following year's crop, and increase organic matter. However, project partners were unaware of any first-hand data about cover crops effects on soil temperature and soil moisture for southwest Minnesota. Soil temperatures and soil moisture are very important for nutrient uptake for plants and plant growth. It is common for farmers to see flooding and drought conditions in the same growing season. The objective of this project was to help determine if cover crops could improve infiltration during wet conditions and water holding capacity during drought conditions. Soil and tissue samples were collected to observe if cover crops can be a tool to help cash crops become more effective at nutrient uptake. With the cost of inputs increasing and water quality declining, this type of project's aim was to assist southwest Minnesota farmers in their farming operations and help improve water quality in local streams.

Over the duration of this project, soil temperatures and soil moisture were measured using soil probes. Weather stations were placed on each plot to measure rainfall, humidity, and air temperatures. Infiltration tests, tissue samples, and soil samples were also collected. The data collected provides a dataset with which to analyze the impact of cover crops on current farm management. In addition, project partners worked together to host a field day at the end of the grant period. This field day and project created an educational opportunity for farmers interested in implementing cover crops in their farming operations and provided firsthand, measurable results in southwest Minnesota.

PROJECT DESCRIPTION

The farmers in southwest Minnesota are looking for better ways to use their costly nutrient inputs as well as protect our water resources. Weather variations are becoming more intense and farmers are looking for a way to protect their crops during flooding and drought conditions within the same growing season. Cover crops have been shown to reduce erosion, decrease soil compaction, increase water infiltration to prevent runoff, bring leached nitrogen back to the root zone for the following year's crop, and increase organic matter. However, project partners were unaware of any firsthand data about cover crop effects on soil temperature and soil moisture for southwest Minnesota. To address the question, soil temperatures and soil moisture were measured in cover crop vs non-cover crop plots in a strip till system and in a conventional tillage system. Weather stations were placed on each research plot to measure rainfall, humidity, and air temperatures. Infiltration tests, tissue samples, and soil samples were also collected. The data collected provides a dataset with which to analyze the impact of cover crops on current farm management. The project provided hands on data for southwest Minnesota. However, there can be no inference of this research data to other sites or other years due to the limited nature of the data, a single site, a single year, and no replication. In the future, it will also provide a way to reach other farmers and share data with them through field days. Note: Extensive additional data and analysis beyond what is presented here are available upon request to Jerry Ackermann.

Project partners included:

- Jerry and Nancy Ackermann have been farming for 47 years and both are extremely active in on-farm research and test plots. The farm is 1,050 acres dedicated to a crop rotation of corn, soybeans, and alfalfa. For the past 16 years, the landowners have incorporated 350 acres of no-till soybeans and 350 acres of strip till corn in the crop rotation. The alfalfa crop is a cash crop and is used in nutrient management for alfalfa-corn rotations.

  Jerry and Nancy have partnered with multiple landowners, the Heron Lake Watershed District, Extended Ag Services, Inc., and University of Minnesota on research efforts. They have hosted numerous field days in the past 7 years.

Strip till before cover crop is terminated.

- Kevin and Dana Schmid are fourth generation farmers and are currently in their 25th year of farming. They have a corn and soybean rotation on 1,680 acres of cropland. Historically, they have used conventional tillage and have no-tilled soybeans from time to time. They also have a wean-to-finish swine operation consisting of three 1,100 head tunnel barns. These were built in 2005 and have allowed them to utilize manure as a fertilizer source in their operation. They are in their fourth year of studying cover crops on 20 acres at home and have added 54 more acres in the last 3 years.
- Bruce Leinen started farming with his father in 1987 and he now farms with his sons. One son farms with him full-time and the oldest son part-time. He currently farms 1,600 acres and grows corn, soybeans, and has started to incorporate some wheat. He has 150 head of cattle and nearly 400 ewes. He also sells feeder lambs and finished lambs.

Extended Ag Services, Inc. collected soil samples in May in 2018, 2019, and 2020. Multiple soil samples were collected in each field plot to accurately demonstrate soil characteristics in each plot. Soil tests helped determine how soil temperatures and soil moisture might affect the availability of nutrients. These samples were used to determine if there were any significant changes in the soil over the grant duration between cover crop vs a non-cover crop management.

Each of the four field plots (two cover crop/strip till plots, one non-cover crop/conventional tillage plot, and one non-cover crop/strip till plot) had a total of four samples collected in each 5 acre plot; there were two sampling zones within each 5 acre plot. Soil samples were collected at depths of 0 to 6 inches and 6 to 12 inches. Soil samples were sent to Minnesota Valley Testing Labs to be tested for baseline nutrients: organic matter (OM), phosphorus, potassium, zinc, calcium, magnesium, nitrate, cation exchange capacity (CEC), soil pH, bulk density, and Solvita carbon dioxide (CO_2) tests. All tests were not performed each year.

OM is the measured percent organic matter in the soil sample. Properties influenced by organic matter include: soil structure, moisture holding capacity, diversity, and activity of soil organisms (both those that are beneficial and harmful to crop production), and nutrient availability. It also influences the effects of chemical amendments, fertilizers, pesticides, and herbicides. The organic matter level is one of the factors used to determine the nitrogen fertilizer recommendation for some crops. Soils with higher organic matter have lower nitrogen recommendations because decomposition of organic matter and the associated release of plant-available nitrogen is a significant source of nitrogen for crops. Soil organic matter is not used in nitrogen recommendations for corn.

Field with no cover crop has water standing. The field next to it had cover crop and infiltration.

pH is a soil test measurement of the acidity or alkalinity of the soil solution. Optimum soil pH (6.0-7.3) improves the availability of nutrients for crop production. Level of plant available phosphorus is measured in parts per millions (PPM) using the Bray phosphorus test in soils with a pH of 7.4 or less and using the Olsen P in soils with a pH greater than 7.4. Potassium (ammonium acetate procedure) and zinc (DTPA procedure) are soil testing procedures used to determine the level of plant available potassium and zinc in soils for crop production measured in PPM.

The CO_2 test helps measure microbial activity below the soil surface. Soil texture was determined by using the Natural Resources Conservation Service (NRCS) Soil Survey for Jackson County (2019 and 2020) and Nobles County (2020).

In general, there was little change in soil fertility at the three locations. The cover crop and strip till plots exhibited the largest change but, given current management, the differences are attributed to soil variability and climatic conditions. The stratification of nutrients in the top 6 inches from the next 6 inches was consistent in 2019 and 2020. (Tables 1 and 2).

There was a consistent change in measured CO_2 (ppm) from 2019 to 2020. This could be due to climatic differences or soil variability – it is unknown at this time. However, the non-cover crop/conventional till plot measured an increase in soil CO_2 respiration. This may be due to soil characteristics – it has the highest clay content of any soil measured. Other factors (not limited to) such as water table depth, surface water runoff, or tillage may contribute to the higher values as well.

Table 1. Soil Fertility Test Results at 0 to 6 Inch Depth from Jackson and Nobles Counties in 2018-2020.

	Jackson County						Nobles County					
	Cover/Strip Till**			No Cover/Conv.**			Cover/Strip Till**			No Cover/Strip Till**		
Test*	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
OM	6	5.4	6.0	5.2	4.8	4.7	5	4.6	4.4	4.5	4.7	4.3
pH	7.1	6.9	7.0	7.5	7.9	8	7.4	6.8	6.8	7.4	6.5	6.4
Olsen P	32	-	-	31	8	8	-	-	-	-	-	-
Bray P	-	47	53	-	5	7	-	17	13	-	15	24
K	163	200	163	133	136	133	132	176	161	116	152	164
Zinc	2	4.7	2.3	1.4	0.6	0.6	1.3	1.6	1.6	2.1	1.5	1.6
Soil N	14	-	13	-	8.5	9.5	42	11.5	13.5	77.5	8.5	11
CO2 Resp	-	144	33	-	56	81	-	124	75	-	-	39
CEC	-	21.8	23.6	-	31.2	32.1	-	19.5	23.1	-	-	-

*OM = Organic Matter as %; Olsen P = Olsen phosphorus as ppm; Bray P as ppm; K = potassium as ppm; Zinc as ppm; Soil N = soil nitrate as pounds per acre; CO2 Resp = carbon dioxide respiration as ppm; and CEC = Cation Exchange Capacity as meq/100g.

**Average of samples taken in each plot

Table 2. Soil Fertility Test Results at 6 to 12 Inch Depth from Jackson and Nobles Counties in 2018-2020.

	Jackson County						Nobles County					
	Cover/Strip Till**			No Cover/Conv.**			Cover/Strip Till**			No Cover/Strip Till**		
Test*	2018	2019	2020	2018	2019	2020	2018	2019	2020	2018	2019	2020
OM	4.6	4.7	5.3	4.9	4.1	4.1	4	4.1	3.9	3.7	4.1	4.1
pH	6.0	7.2	6.9	7.4	7.9	7.9	6.8	7.2	7.4	6.3	6.7	6.6
Olsen P	29	-	-	24	4	4	-	-	-	-	-	-
Bray P	-	22	23	-	2	2	-	5.5	4.5	-	6	6
K	148	112	117	173	120	112	122	101	99	121	92	104
Zinc	2.3	1.5	1.7	1.2	0.5	0.6	1.2	0.8	0.8	1.2	0.7	0.8
Soil N	14.5	10.5	9.5	-	8.5	10.5	41	9	9	80.5	10	9.5
CO2 Resp	-	102	11	-	28	79	-		57	26	-	11
CEC	-	23.2	24.1	-	31.8	32.8	-		21.1	20.2	-	-

*OM = Organic Matter as %; Olsen P = Olsen phosphorus as ppm; Bray P as ppm; K = potassium as ppm; Zinc as ppm; Soil N = soil nitrate as pounds per acre; CO2 Resp = carbon dioxide respiration as ppm; CEC = Cation Exchange Capacity as meq/100g.

**Average of samples taken in each plot.

BULK DENSITY

Bulk density samples were taken to measure pore space in the soil structure. Bulk density soil samples were collected in the fall of 2018, 2019, and 2020. No significant changes in soil bulk density between cover crop and non-cover crop managements were observed despite dramatic differences in seasonal rainfall in 2020.

WATER INFILTRATION

The Heron Lake Watershed District (HLWD) conducted infiltration tests following harvest in 2018 in Jackson County, in 2019 in Nobles County, and in both counties in 2020. Cold and wet weather conditions following harvest made it difficult to conduct infiltration tests in both counties every year.

Infiltration is measured by placing a 6-inch (height) by 8-inch (diameter) ring in the soil 3 inches deep, then adding 16 ounces of water to the inside of the ring. The amount of times it takes to infiltrate 16 ounces of water is recorded as an infiltration rate of inches of rain per hour. The cover crop field had 3 inches of infiltration per hour and the non-cover crop field had less than 1 inch per hour.

In the Jackson County plots in 2018 infiltration was better in the cover crop/strip till management (3 inches per hour) than in the non-cover crop/conventional tillage management system (1 inch per hour). In the Nobles County plots in 2019, wet and cold weather conditions had an impact on infiltration tests. Infiltration rates were 2 inches per hour in the cover crop plot and 1 inch per hour in the non-cover crop field plot. In 2020, precipitation was the lowest over the three-year growth period. Nobles County plots had infiltration rates of 5 inches per hour in the non-cover crop field and 10 inches per hour in the cover crop field. The Jackson County plots showed a higher infiltration rate in the conventional tillage field during the start of the test. After 4 inches, the pore spaces in the soil profile started to fill and the water stopped infiltrating. Whereas the cover crop/strip till plot continued to infiltrate water through the whole hour test. The results demonstrate that infiltration is better in the management system using a cover crop and strip till.

SOIL TEMPERATURE AND MOISTURE

Soil temperatures and soil moisture readings were collected at all four test plots. Soil probes were placed in the ground at 4- and 8-inch depths. In the plots with strip till management, a probe was placed in the tilled row and the non-tilled row. All soil readings were collected at 15-minute intervals over the entire calendar year. Rainfall and air temperatures were also recorded at each test plot during the growing season. Figures 1 and 2 are samples of data collected for soil temperature and soil moisture. Additional data and analysis are available upon request to Jerry Ackermann.

The 2018 Jackson County soil temperatures, on average, were cooler in the non-cover crop/conventional tilled plot versus the cover crop/strip till plot throughout the entire growing season. In 2019, the cover crop plot warmed up sooner than the conventional tilled field. Many farmers perform tillage in the spring to warm up the soil faster. The 2019 research showed that cover crop/strip till management plots warmed the soil up without having to do conventional tillage. Soil temperatures in 2020 were very similar when comparing cover crops vs non-cover crop.

In the 2018 Nobles County test plots, tillage management was the same in the two treatments. The difference was cover crops vs non-cover crop. Temperatures were very similar in May and June, but the cover crop plot showed a slightly cooler reading earlier in the growing season. Throughout the whole growing season, the non-cover crop plot had warmer temperatures on average. Soil temperatures in 2020 were very similar when comparing cover crops vs non-cover crop.

Rainfall in 2018 and 2019 was above average for southwest Minnesota. In 2018 in Jackson County, there was more soil moisture in the non-cover crop/conventional till plot than in the cover crop/strip till plot. However, the cover crop/strip till management proved to be an infiltration benefit throughout the wet growing seasons. In 2018 in Nobles County, the cover crop/strip till and non-cover crop/strip till plots had the same amount of moisture early in the growing season but slightly more in the cover crop/strip till plots throughout the growing season. The 2019 data showed that the cover crop/strip till plots had a higher total soil moisture throughout the entire growing season at both locations. Soil moisture was also higher in the beginning of the planting season even though the soil temperatures were higher. Once the cover crops were seeded in June, there was a decrease in soil moisture. During August, the hottest and driest month of the growing season, the cover crop plots contained more moisture than conventional tillage. This could potentially be a benefit to a growing plant.

In both counties in 2018 and 2019, cover crop plots had less surface moisture due to better infiltration throughout the entire growing season. For example, after a 1 ¾-inch rain moisture levels at 4-inch and 8-inch depths were the same. In comparison, the tilled field was the same as the cover crop plots at the 4-inch level, but it was significantly higher at 8 inches. This would indicate a hard pan just below tillage depth. Our soils from previous 1 hour water infiltration tests had shown that we could handle 11 inches of rain in an hour without water standing on the surface. The cover crops have appeared to break up any hard pan from previous tillage. The non-cover crop/conventional tilled field held on to rainfall and moisture longer and kept soil temperatures cooler than in the cover crop/strip till fields.

In 2020 southwest Minnesota received an average of only 22 inches of rainfall during the growing season following two very wet years. The growing season started with good soil moisture in all four field plots. In Jackson County the cover crop plot showed higher moisture early in the growing season but saw a lower amount during June and July. The opposite was true at the Nobles County sites. The differences between moisture in the cover crops and the non-cover crop sites were very small throughout the whole growing season.

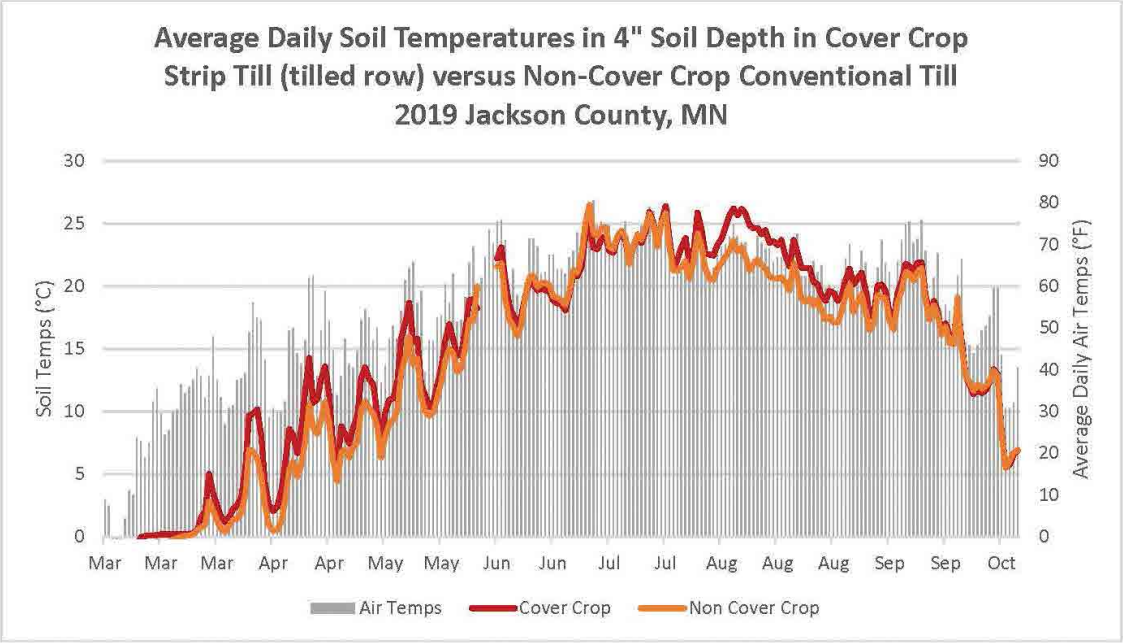

Chart 4. 2019 Jackson County Average Daily Soil Temps

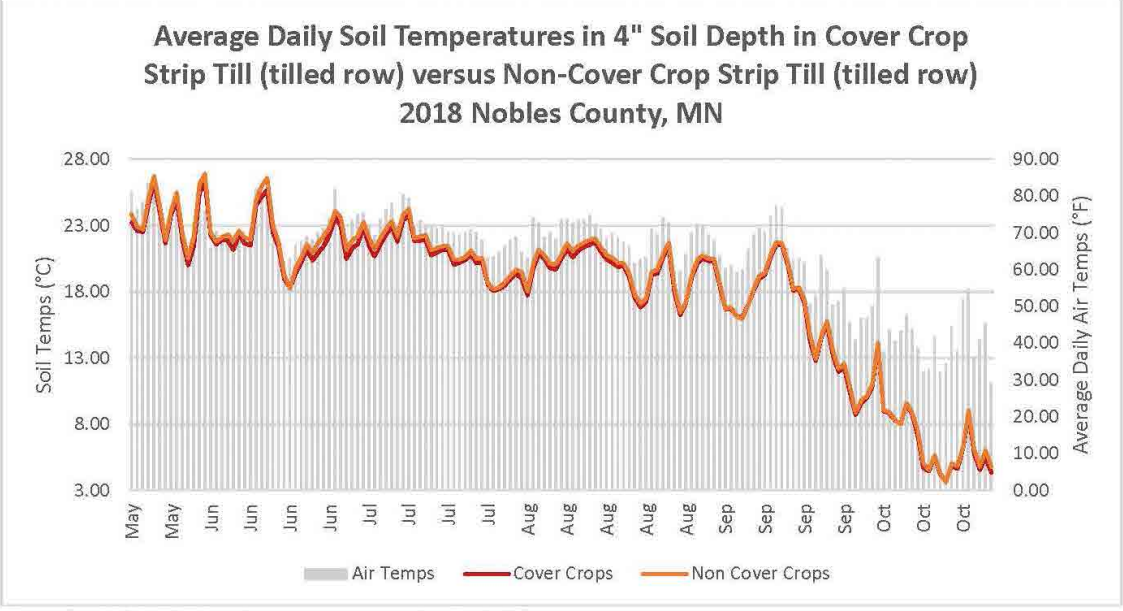

Chart 5. 2018 Nobles County Average Daily Soil Temps

Over the 3-year grant duration, there was a bigger difference between tillage practices when it came to soil moisture and soil temperatures than between cover crops and non-cover crop plots using the same tillage management. In the future, it will also provide a way to reach other farmers and share data with them through field days. While the data collected during this research was helpful to the farmers involved and provides some indications of how cover crops affect the measured parameters, there can be no inference of this research data to other sites or other years due to the limited nature of the data, a single site, a single year, and no replication.

Interseeding visible after the corn harvest.

PROJECT PARTNER COMMENTS

- We plan to continue with cover crops and strip tillage. This project showed us that we have faster soil warm up for early planting which benefits germination. We have seen that the cover crops make it possible to harvest in wet conditions without leaving deep tracks in the field. The cover crop roots and plants also helped carry the planting and harvesting equipment to minimize compaction.
- A previous one-hour water infiltration test on our grant field showed it could handle 11 inches of rain in one hour without standing water. In 2018 and 2019 we were extremely wet with almost double our normal rainfall. Even under these extreme conditions, we had no standing water after heavy rains. Cover crops growing at harvest had the added benefit of being able to carry the combine, grain cart, and semis out of the field without deep ruts. Neighboring farms all had areas drowned out or unharvested until after freeze-up. The year 2020 started fantastic with perfect weather and early planting with no mud. Then starting in July, the rain turned off. We felt the extra water holding capacity of the soil and the cover crop helped the crop conditions better than conventional farming practices.
- Since using cover crops and reduced tillage, we have good weed control, good soil structure, and our soils warm up in the spring before planting. We have a number of neighbors who are adopting strip till, no-till, and cover crops because of the research we have done.

MANAGEMENT TIPS

1. It would have been helpful to have a third moisture probe at approximately the 24-inch level, to compare how much moisture is getting into deeper levels to be stored when conditions turn dry for the following crop to use.
2. The goal is to have people do as little tillage as possible. If strip till is implemented, in the farmer's mind, he is still doing tillage, even though it is just a small strip. Benefits can be seen within a year or two.
3. When seeding cover crops over the crops, it does not seem to matter if it is done aerially or by high clearance equipment as far as germination. Incorporation is better, but that has to be done with a drill or other seeding device after harvest. There generally isn't enough time after harvest for proper germination. Unless there is a cover crop that will overwinter, it would do very little to change anything in the soil.
4. Farmers can do their own infiltration tests. Place a 6-inch diameter ring (any metal or plastic pipe will work) in the soil about 3 inches deep. Place a piece of plastic wrap evenly over the top of the ring. Slowly pour 16 ounces of clean water into the ring on top of the plastic wrap. This will prevent the soil surface from being disturbed. Slowly remove the plastic and measure the time it takes for all the water to infiltrate. Repeat these steps for 1 hour. This will be the infiltration rate in inches per hour. The test should be done on a cover crop and a non-cover crop field for comparison. The infiltration tests are very eye-opening. In our experience, the infiltration rate in cover crop fields is much greater than in non-cover crop fields.

COOPERATORS

Kevin Schmid, Worthington, MN.

Bruce Leinen, Fulda, MN.

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

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

OTHER RESOURCES

Ackermann, Jerry. Cover crop presentations at the Soil Health Workshop in Heron Lake, as well as in Spicer and Porter, Minnesota. He also gave a presentation at the college in Sheldon, Iowa.

Farmer Journal. The High Yield Conservation section. www.agweb.com/farmjournal

No-Till Farmer. www.no-tillfarmer.com

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

Spring strip till into cereal rye that was seeded the previous fall.

Headwaters Agriculture Sustainability Partnership

PRINCIPAL INVESTIGATORS

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PROJECT DURATION

2019 to 2021

AWARD AMOUNT

$50,000

KEYWORDS

dairy, case study, Central Minnesota, conservation, environment, economics, peer-to-peer learning, row crops, sustainability

PROJECT SUMMARY

Dairy farmers are struggling as milk prices are below their cost of production and low crop prices are making many row crop farms unprofitable. This project investigated and created case studies about farming practices that benefit both cost of production for farmers and natural resource conservation (particularly water quality). The project demonstrates the benefits of these practices to Central Minnesota dairy and row crop farmers through peer-to-peer learning and engages and supports motivated farmers in making practice changes through a unique public-private-nonprofit collaboration.

Project partners assisted participating dairy and crop farmers in quantifying the economic and environmental benefits of farming practices such as conservation tillage, crop rotations, improved nutrient management, etc. Project partners helped farmers package their data and stories for communication and demonstration to other farmers, with an emphasis on reaching farmers at existing gatherings.

PROJECT DESCRIPTION

Prevailing market forces are causing the loss of dairy producers and unprofitable economic conditions for crop farmers in Central Minnesota. Assisting farmers in understanding and making practice changes with both economic and environmental benefits will make farms more economically sustainable and protect natural resources that Central Minnesota communities rely on for growth, recreation, and long-term agricultural productivity.

However, much of the available information and research around the environmental benefit and cost of different farming practices is derived from regions with longer growing seasons, does not account for integrated crop and livestock operations, is not presented by farmers to farmers, is intended for scientists, or is otherwise not presented or collected in such a way that it is maximally engaging for a Central Minnesota commodity crop and dairy farmer audience. Absent specific, relatable examples, farmers are understandably hesitant to try practices that are not commonly used among their peers .

The unique collaboration that emerged to solve this problem includes Environmental Initiative, the Minnesota Milk Producers Association, the Stearns County Soil and Water Conservation District, Syngenta, Steve Schlangen (farmer and Chair of Associated Milk Producers Inc.), The Nature Conservancy, Compeer Financial, Steve Peterson (farmer and former Director of Sustainable Sourcing at General Mills), Integrated Crop Management Services, and Houston Engineering Incorporated (collectively, the "Partnership"). The Partnership established a charter with the mission below:

The Headwaters Agriculture Sustainability Partnership (HASP) is comprised of leaders from the private, non-profit, and public sectors of Minnesota agriculture with the mission of deploying solutions that benefit the environment, the economic viability of farmers, and the vitality of our rural communities. We will serve both the agricultural and environmental communities as a forum where innovative ideas can be considered, supported, accelerated and/or implemented with the Partnership's diverse experience, skills, and connections.

The Partnership intended for this project to create a replicable, scalable case study approach for demonstrating how agriculture can have a constructive influence on environmental priorities, especially water quality. If farmers can see in a peer's operation a proven, direct link between farming practices and greater economic and environmental sustainability, they are far more likely to seek assistance in making changes from the organizations in the Partnership.

The on-going goals of the Partnership are to:

- Motivate the adoption of farming practices that achieve short-term cost savings and efficiencies for dairy and crop farmers and long-term regulatory certainty and productivity as well as greater protection and improvement of water quality and soil fertility.

- Motivate practice changes that keep dairy and row crop farms profitable and in business and protect natural resources that Central Minnesota communities rely on for growth, recreation, and long-term agricultural productivity.
- Engage crop advisors and agronomists as secondary audiences so they are more comfortable recommending sustainable farming practices to their clients.
- Create a replicable, scalable model for showcasing sustainable farming practices that can be used to enhance profitability and environmental sustainability for a range of geographies and farm operations.

The objectives of this project are listed below. The grant from the Minnesota Department of Agriculture AGRI Grant Program funded half of Objective 1.

1. Demonstrate, through peer-to-peer farmer education, the alignment between profitable agronomic practices and improved environmental outcomes.
2. Conduct case study assessments of local farmer leaders' operations that quantify the relationship between environmental outcomes and the economics of farming practices.
3. Build a farmer-public-private-nonprofit partnership that will provide advice, services, and resources supporting practice changes by farmers motivated by the case-studies.

This project began with the creation of a cohort of farmers with varying operations, farming practices, and environmental outcomes, starting with integrated dairy and row crop operations, to demonstrate the achievability of different farming practices to improve environmental outcomes and economic returns. The Partnership recruited three dairy farmers:

- Tim Kerfeld runs a dairy farm in Melrose with his family. He is the second generation on the farm and his son will be the third. They milk 250 cows and farm 400 acres, growing mostly corn as well as some soybeans, alfalfa, grass mix, and cover crops. Conservation practices: minimum till up to no-till to reduce erosion; cover crops planted in the fall to capture the last of the nutrients and make forage for cattle; and contour strips, grassed waterways and sediment control basins to decrease the amount of annual soil erosion while increasing the soil carbon.
- Tom Gregory milks 600 cows and farms 450 acres growing corn, alfalfa, and cover crops in Kimball. He owns and rents the land, which is spread over three farms. Conservation practices: stacking slab to prevent leeching from manure into the ground water with capacity for more manure than he needs on his farm so he can supply manure to other farmers in the area; reduce tillage as much as possible using just one pass with a chisel plow and digger; manure application and management has improved soil health and reduced the use of herbicide and insecticide; oats or winter rye cover crops with corn to hold the soil in place through the winter and grow feed for the cattle in the spring. Additionally, filter strips, grassed waterways, and sediment control basins to decrease the annual soil erosion and increased soil carbon.
- Steve Schlangen is a dairy farmer in Albany who milks 65 cows and farms 200 acres. He grows corn, soybeans, alfalfa, and barley. Steve is also chair of the Associated Milk Producers. Conservation practices: buffer strips to improve the water and also provide hay for cattle feed; nutrient management using grid sampling to understand how nutrients are dispersed so he can apply nutrients only where they are needed; and stacking slab mostly for solid manure storage but with some liquid storage capacity, hoping to have capacity to store enough manure for a full season and inject the nutrients into the soil in the fall.

Farm operations were chosen for their similarity to an "average" farm in Central Minnesota, though above average in the success they found in farming for both environmental outcomes and economic returns. The Partnership selected these farmers based on the following criteria: participation in the Minnesota Agricultural Water Quality Certification Program; good financial recordkeeping; and representation of varying sizes of dairy farms with different conservation practices. These farmers agreed to participate in the case study assessments of their farms as well as to help guide the process to ensure that the case studies were relatable to area farmers. They also presented the stories of their farming operations to other farmers and helped identify the guidance, services, and resources needed to help other farmers make similar practice changes.

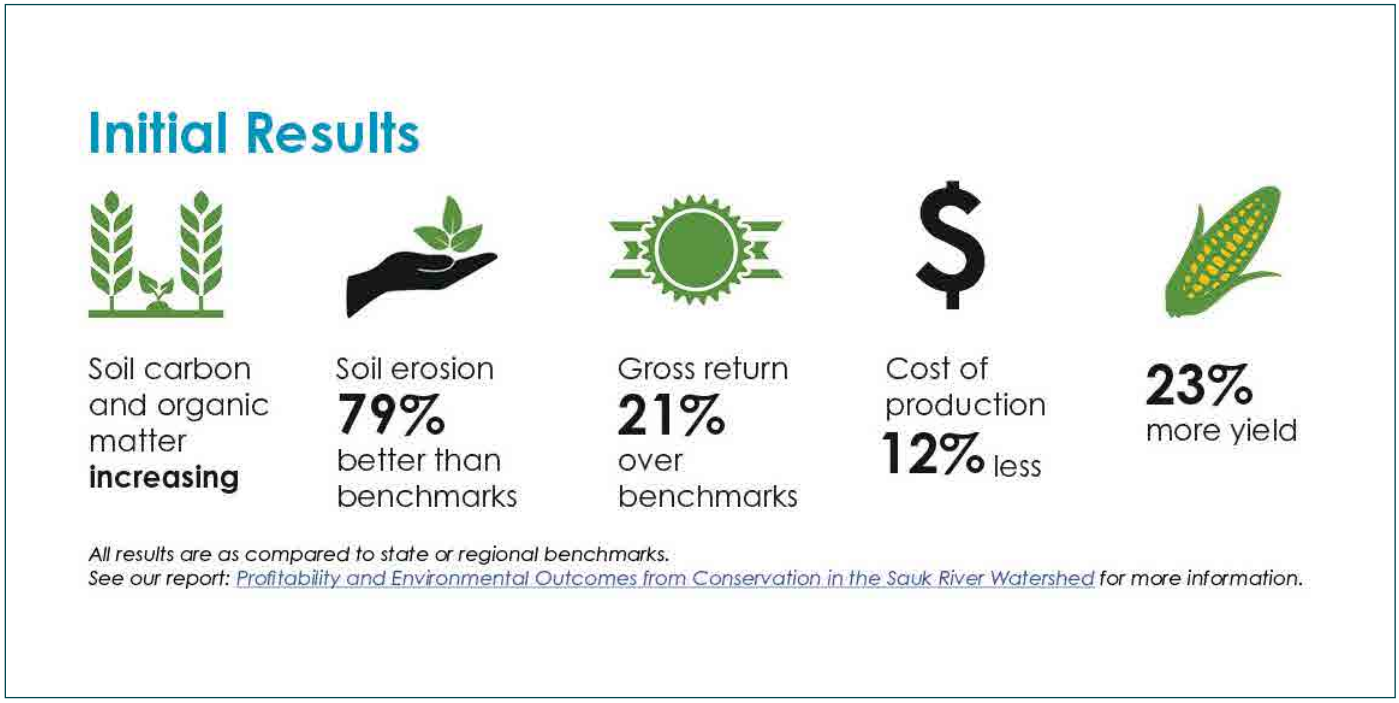
The project developed case studies relevant and motivating for farmers in a similar geography. The project was not attempting to present only "success;" rather, farmer case studies were to reflect the real-world quantification of the economic and environmental impacts of farming practices. If those results showed a negative economic return, that was a result that needed to be communicated to target resources and programs more effectively in Central Minnesota.

Individual assessments of on-farm economics for each farm were conducted and used to quantify and understand the economic impact of practice changes that benefit environmental goals like water quality. Regional farm economic information was compiled and organized to use as a benchmark for the performance of specific conditions found on the operations of case study farmers.

Common environmental assessment techniques such as the Field Print Calculator, the Minnesota Agricultural Water Quality Certification Program, and the Prioritize, Target, and Measure Application (PTMApp) were used to assess the environmental outcomes associated with the farming practices of case study farm operations. Statewide environmental data available through these platforms were used to create benchmark figures for environmental outcomes

RESULTS

Initially, Environmental Initiative convened four in-person Partnership meetings in addition to many conference calls involving a subset of partners. In the meetings, the partners determined roles, developed plans for the project, identified core criteria for farmer participants, and refined the methodology for the collection of data. For efficiency, a sub-group of partners, including the Farm Business Management program, Stearns County Soil and Water, and Houston Engineering worked directly on the assessment. In December 2019, the Partnership developed ambitions to leverage the expertise and reach of the partners to act as a sustainable agriculture project incubator in the Headwaters area, influencing and supporting a wide network of sustainable agriculture projects beyond this case study project. Environmental Initiative supported the partners in this effort, developing a charter and adding more structure to the group. HASP now acts as an advisor and implementor for the All Acres for our Water project in Backes Lake as well as the advisory group for the Ecosystem Services Market Consortium pilot project in Central Minnesota. Environmental Initiative has received separate funds for administrating the Partnership from Compeer Financial and Midwest Dairy.

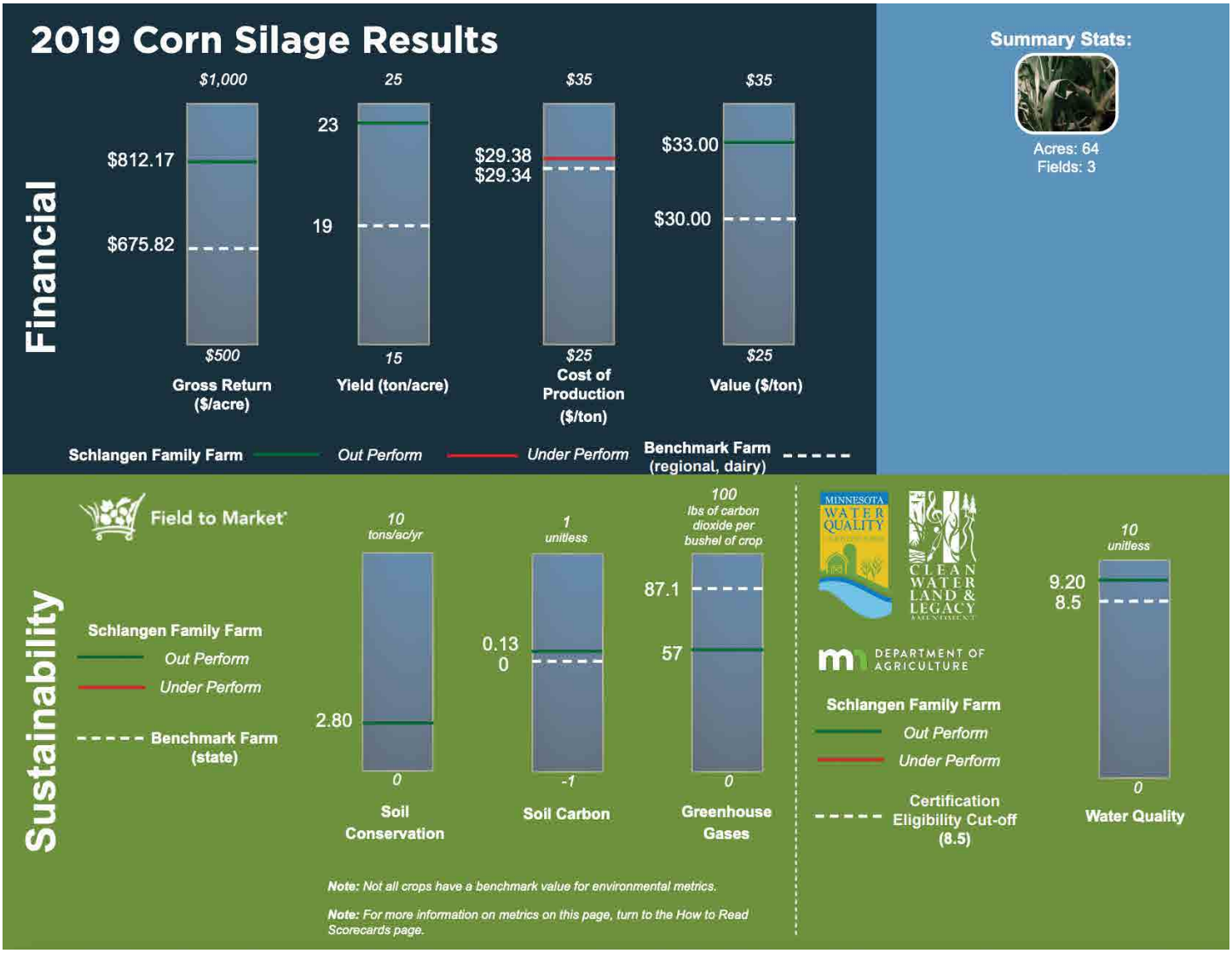


Initial results of Return on Investments in 2019

The bulk of the case study work took place in 2019 and 2020. An economic assessment and an environmental assessment were performed for each farm for both the 2019 and 2020 growing seasons. The economic assessment was completed through enrollment in the Farm Business Management Program at Central Lakes College. The Farm Business Management Program is an individualized program taught at the farm itself and assists farmers in keeping detailed financial records. Instructors visit the farm several times to gain a deep understanding of the farm operation. At the end of each year, the records are analyzed to give farmers a robust picture of their farm's financial health. The data collected is compatible with the FINBIN database and was compared to the average farmer in Stearns County, other dairy farms, and other participants in the Minnesota Agricultural Water Quality Certification Program.

The environmental assessment was managed by Mark Lefebvre at the Stearns County Soil and Water Conservation District, who completed the initial Minnesota Agricultural Water Quality Certification assessment with all farmers. Mark was familiar with their operations and the conservation practices adopted as part of their plan to achieve certification. Mark used the FieldPrint calculator, a national assessment tool several partners have access to through Field to Market, to assess the farms.

After the environmental and economic assessments were completed, Houston Engineering analyzed the data, compared the farms to the average farm in Stearns County, and helped to paint a more detailed picture of the return on investment for on-farm conservation practices. With two years of data, the analysis shows that the farmers who adopt conservation practices have higher average and median net incomes than the average regional farmer. A data summary and sample data charts are found below. The full data can be found in the report Profitability and Environmental Outcomes from Conservation in the Sauk River Watershed.

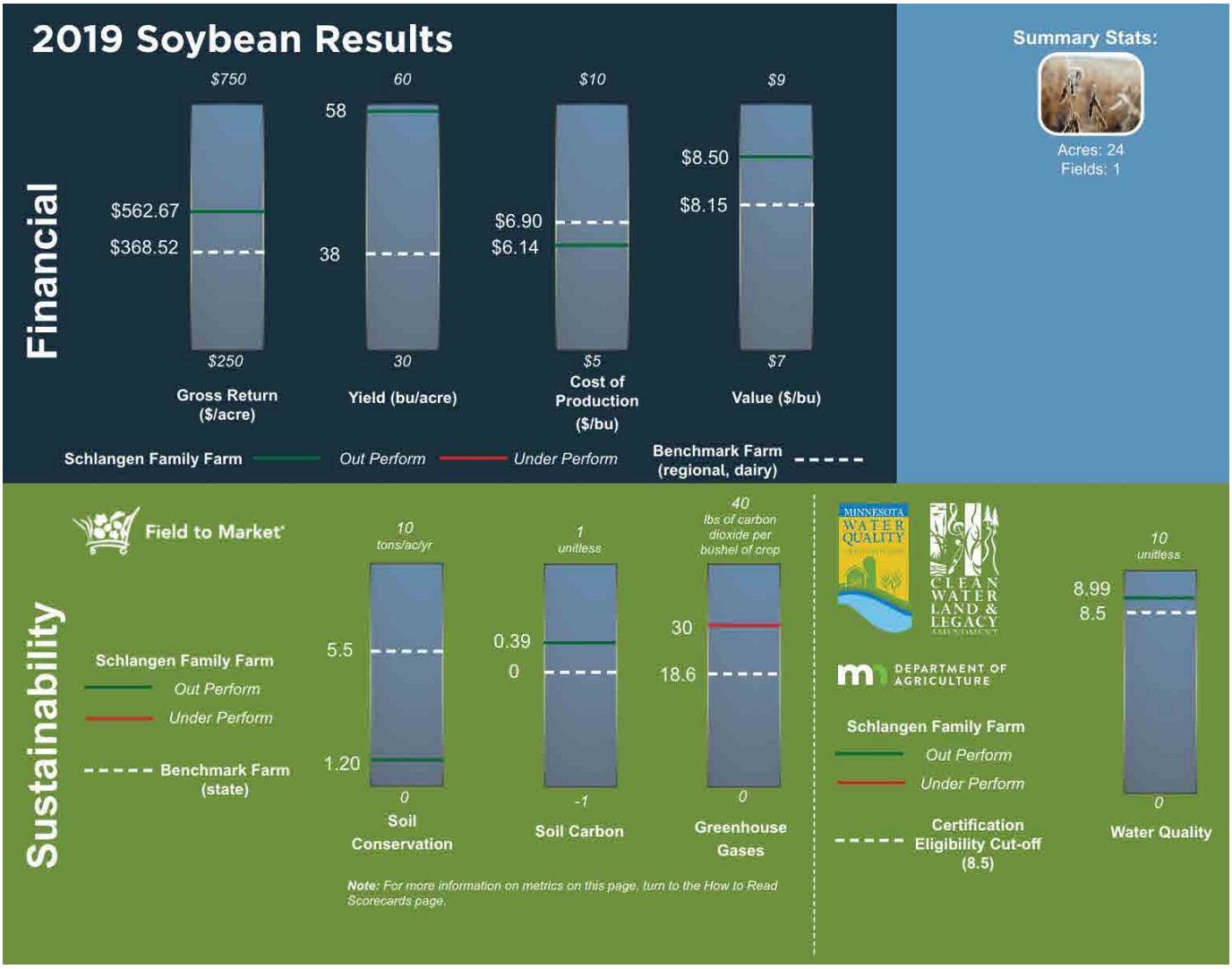


Corn Silage financial and sustainability results obtained in 2019

The peer-to-peer education component of this project will largely take place in spring 2021, after the MDA project ends, due to COVID restrictions. To adapt to COVID, Environmental Initiative contracted Storyboard Films in October 2020 to film a video that highlights the case study farmers' stories with preliminary results. This film will allow farmers to learn about the project without having to be in-person. Environmental Initiative is coordinating partners to participate in webinar events that will encourage farmer-to-farmer discussion this spring and summer. For example, a panel of HASP members participated in the St. Cloud Area Chamber of Commerce Farming Today Conference in March (the recording of the panel is still available). In addition to webinars, Mark Lefebvre plans to use the video as a starting point for meetings with farmers who are interested in soil health. The video and the report are published on Environmental Initiative's website and shared through HASP partner networks.

MANAGEMENT TIPS

1. Regularly convene partners over video call to continue to build working relationships and stay on top of project details. Meeting regularly and strengthening relationships inspires engagement for the project.
2. Adaptability is key, especially as it relates to COVID. A large part of this project was intended to be farmer-to-farmer education on project results. Because in-person gatherings were unsafe, we developed a professional video that captures the highlights of why the case study farmers are engaged in the project, as well as high-level project results. The video was and will continue to be shared in a variety of ways, including as an introduction when farmers express interest in working with the Stearns County Soil and Water Conservation District.



Soybean financial and sustainability results obtained in 2019

3. Keep an open mind about collaborating with other projects in the area. Because some of the farmers in the case study were also engaged in other projects that also use Field to Market's FieldPrint Calculator, we had a difficult time figuring out how to register the projects into the calculator because fields cannot be included in multiple projects. We worked closely with MDA's Minnesota Agriculture Water Quality Certification Program, The Nature Conservancy, and Field to Market to find a solution to the project registration so that we could all access the data necessary for the projects.

Tim Kerfeld of Kerfeld Hillview Farm.

Aerial view of Kerfeld's farm.

Example of cover crops at Kerfeld's farm.

Tim and son looking at field planning technology.

COOPERATORS

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OTHER RESOURCES

Environmental Defense Fund. Farm Finance and Conservation: How Stewardship Generates Value for Farmers, Lenders, Insurers, and Landowners. www.edf.org/sites/default/files/documents/farm-finance-report.pdf

Environmental Defense Fund Blog Post – Conservation Enhances Farm Financial and Environmental Health. http://blogs.edf.org/growingreturns/2019/05/23/conservation-enhance-farm-financial-environmental-health/

Environmental Defense Fund and K Coe Isom. November 2019. How Conservation Makes Dairy Farms More Resilient, Especially in a Lean Agricultural Economy. https://www.edf.org/sites/default/files/content/how-conservation-makes-dairy-farms-more-resilient.pdf

Headwaters Agriculture Sustainability Partnership's Profitability and Environmental Outcomes from Conservation in the Sauk River Watershed: An Analysis of Data for 2019-2020. https://environmental-initiative.org/wp-content/uploads/2020/04/Farm-Storyboard_6.7.21_Final.pdf

Headwaters Agriculture Sustainability Partnership's Profitability and Environmental Outcomes from Conservation in the Sauk River Watershed Farmer Video. https://www.youtube.com/watch?v=Hl1n9YNs4H8

USDA Sustainable Agriculture Research and Education Program. Cover Crop Economics: Opportunities to Improve Your Bottom Line in Row Crops. Technical Bulletin, June 2019. www.sare.org/cover-crop-economics

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

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2018 to 2020

AWARD AMOUNT

$16,356

KEYWORDS

cover crops, intercropping with vegetables, mulching, perennial fruit establishment, secondary crops

PROJECT SUMMARY

Perennial fruits are among the most sustainable and profitable crops for Minnesota farmers but require a significant initial investment. The objective of this three-year study is to determine whether the establishment of the primary perennial fruit crops (apple, blueberry, currants, grapes, and plums) will be affected by the simultaneous production (intercropping) of a secondary crop. Twelve intercropping options were compared to current production practices during the first three years of establishment.

Evaluating the anticipated value of these secondary crops (rutabagas, squash, strawberries, and tomatoes) with the potential delay of establishment or losses of the primary fruit crop during the first three establishment years may help farmers consider whether this intercropping technique is preferable to current production practices in generating profits.

PROJECT DESCRIPTION

Like many small farms providing Community Supported Agriculture and other offerings, our farm is designed to offer a diverse product mix under sustainable production practices. In the next few years, we anticipate that perennial fruits will become a significant portion of our farm's offerings. Over many years, perennial fruit production can be highly profitable. However, under the current production methods practiced in Minnesota for establishing perennial fruits, a significant investment in resources plus the loss of annual revenue

from that land can make adding perennial fruits financially prohibitive. As we considered production alternatives for adding perennial fruits, the idea of intercropping perennial fruits with horticultural crops that could generate revenue during the establishment years seemed to be an advantage, but only if the health and yields of the primary fruit plants would not be significantly decreased.

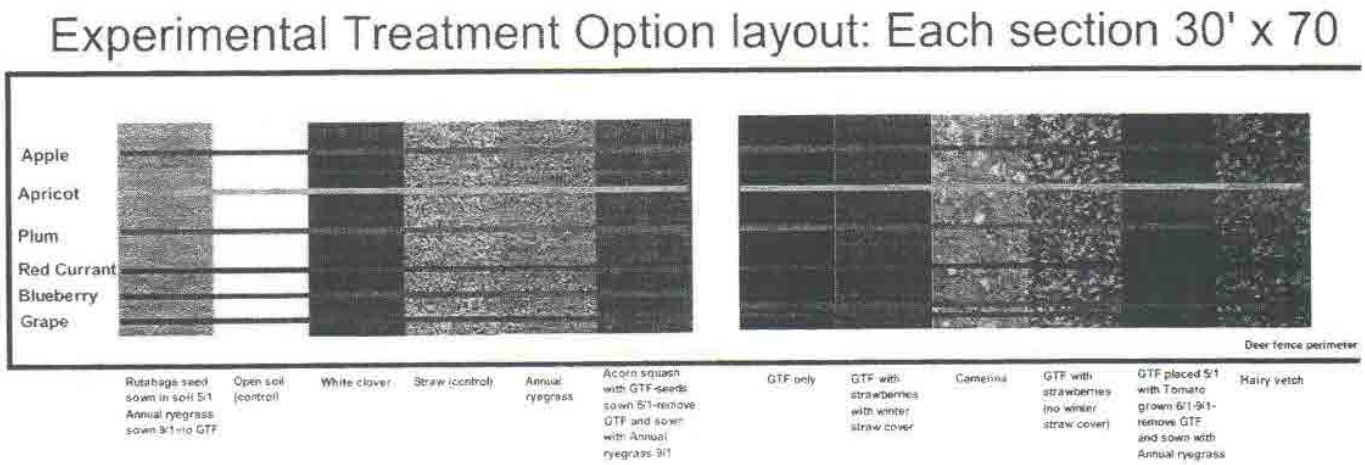
With our other production designs, we have tried to integrate ideas used by other area farmers or learned from past research projects. We have successfully integrated rotational cropping, vertical production, and intercropping with great success in vegetable and herb production. In addition, we extensively use red clover between rows, on our driving paths, as a cover crop, and frequently cut and collect clover to supplement animal feed. We use geotextile fabric and other mulches to reduce labor and increase yields. Each of these ideas seems to offer an advantage over the current production system used during the establishment of perennial fruits in our area. As current practice, perennial fruits are planted in open soil (Plot 2 on field map), in a cover crop such as white clover (Plot 3) or annual ryegrass (Plot 5), or in a non-living mulch such as straw (Plot 4). For small fruits such as blueberries and currants, geotextile fabric (Plot 7) is commonly used.

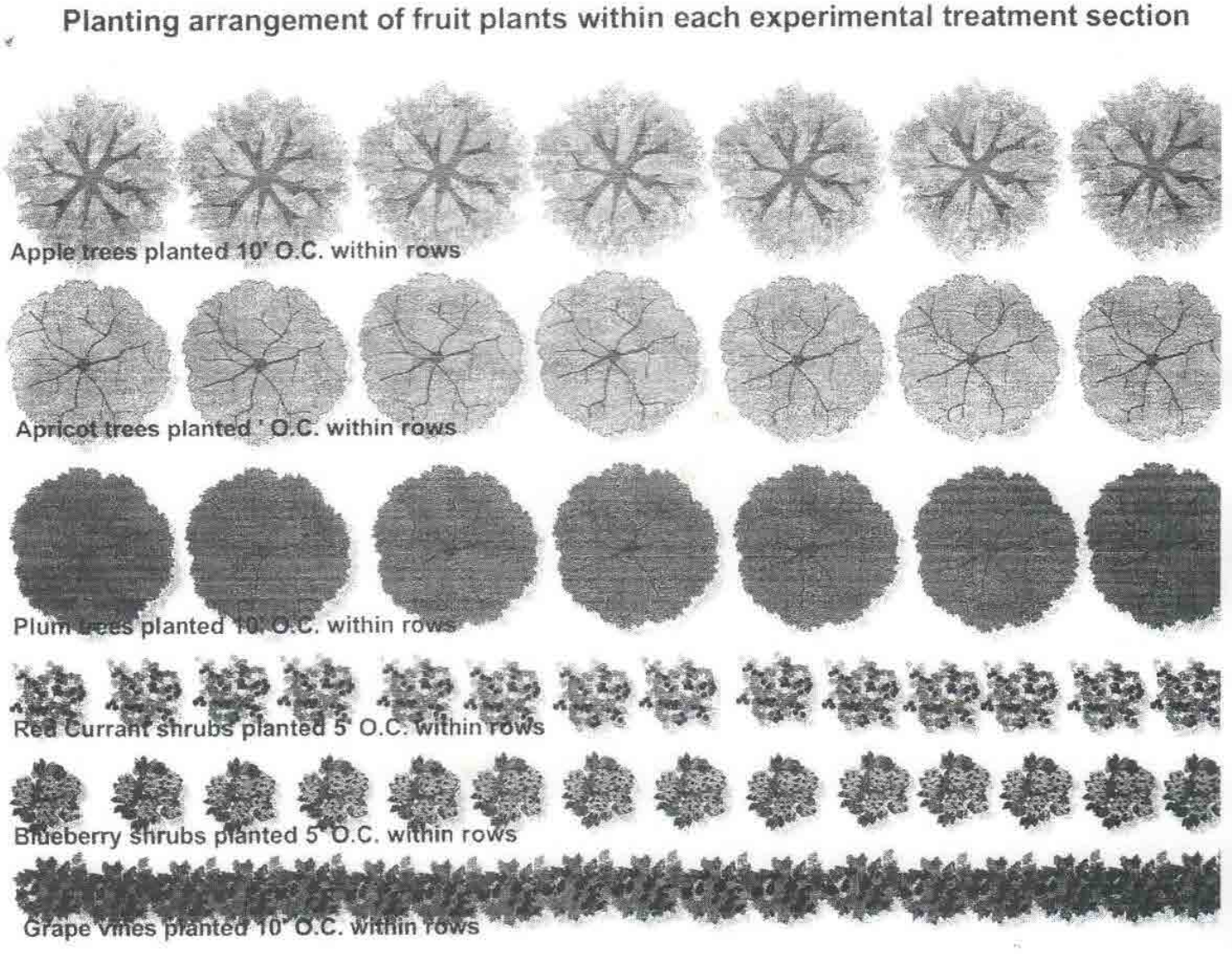
We designed this study to see how horticultural crops (rutabagas, squash, strawberries, and tomatoes) could be intercropped with five commonly produced perennial fruits (apple, blueberry, currants, grapes, and plums). We compared 12 intercropping options with current production practices. We also compared red clover, already used as a cover crop and living mulch on our farm, with rye and hairy vetch because other farmers have had great success with these alternatives. We evaluated the new system for added value from the intercrops and cover crops as well as for soil health effects.

In 2017 in preparation for this project, an acre of fallow land was used in rotation with pastured pigs until about 80 percent of vegetation had been cleared. The pigs were sent through the field twice (May and September). Each time, they were moved after about 30 days. To provide a long-term acidic soil for the blueberry row, oak leaf/pine needles were composted (40 yd^3 finished volume) to be incorporated in 2018.

The 1- acre field for the study measures 105 feet (north to south) by 415 feet (east to west). For easier access, a 15 -foot road surrounds the area and an additional road divides the plot north to south. A deer fence was installed to protect the experiment.

The five perennial fruit species were planted in individual rows with an east to west orientation. Trees (apple and plum) and vines (grapes) were planted 10 feet on center within rows. Shrubs (currants and blueberries) were planted 5 feet on center within rows. Each of the twelve experimental treatments is 30 feet wide running north to south. Six shrubs and three fruit trees or vines of each species were planted within each of the experimental treatment sections. The plot map included in this article outlines the placement of the perennial fruit plants and the twelve experimental treatment options to be compared.





Strawberries were planted 1 foot on center, tomatoes 3 feet on center, and squash 5 feet on center. Rutabaga seed was broadcast as were the cover crop species: white clover, ryegrass, and vetch. These secondary crops were planted as if the fruit trees were not there. As shown in the plot map, except for planting within 24 inches of the fruit plants, secondary plants were planted perpendicular to the perennial plants.

Compost was added around the fruit plants in July to increase fertility and reduce weeds. The secondary crops (rutabagas, squash, strawberries, and tomatoes) were raised without supplemental fertilizer or composting.

To evaluate our project, we planned to measure growth of each fruit and horticultural plant species and survival rates. The value of each treatment section would be calculated depending on growing conditions and survival of plants. The horticultural crop data would include percent of salable and cull items harvested. Cull items would not be given a value, but their weight or percent of harvest would be included. For the harvest of salable vegetables/strawberries, value would be calculated as pounds multiplied by potential dollars produced. The squash/rutabaga would be valued at $1 per pound, Roma tomatoes at $2 per pound, and strawberries at $4 per pound.

We also intend to track the volume of harvested cover crops, the crop analysis, and the value of forages based on $40 per ton (wet). From this data, we would report the relative cost per square foot for each cover crop treatment.

2018 RESULTS

The beneficial effect of the pigs' Manure on the 2018 season greatly reduced the need to add nitrogen throughout the season. There was a significant reduction in rocks, thistle, and saplings in the area formerly occupied by the pigs.

Higher than normal temperatures in the first weeks after planting required nearly daily supplemental watering the first month. High winds required changes to staking design of the apple and plum trees as well as the geotextile fabric. Until growth of the secondary crops provided a micro-climate and helped secure the fabric, keeping narrow widths of fabric in place became an issue.

The effect of the secondary crop on fruit plant growth will be evaluated next spring. Size differences between the experimental plants and the control are not expected the first two years. We are optimistic that any losses over the winter will be low. The greatest concern is winter kill with the small fruit plants. The purchased currant and blueberry plants were disproportional with top growth two to three times the size of roots and were available later than we would have preferred. Excessive early leaf development in May began within days of planting before new rooting had begun. As a result, the secondary crops received more irrigation than would normally be required. In late summer, when the secondary crops did not need irrigation, but the small fruit plants were showing signs of stress, we hand watered the fruit plants to encourage greater root growth for fruit development and to prevent cultural issues with the secondary crop. Managing the different moisture requirements of the two crops could have been more easily accomplished with individual drip emitters for fruit plants, which were not included in this project's design. The early high temperatures and required frequent irrigation presented a challenge going into this first winter, as roots may not be deep enough.

For the secondary crops, rutabagas did not perform well, likely due to excess nitrogen and weed pressure. However, the yields of the other crops closely matched production in areas without perennial fruits, even though these were produced without receiving any supplemental fertilizer. Squash yielded 0.31 pounds per foot^2 with over 90 percent salable produce and a total of 550 pounds valued at $550. The control squash yielded 0.38 pounds per foot^2. The Roma tomato yield in intercropped plots was 7.2 pounds per plant (30 percent cull rate) compared to 9.4 pounds per plant in the control (20 percent cull rate). The 120 tomato plants in the 1,800 foot^2 project area yielded 609 pounds valued at $1,218. Weed pressure in future years should decline so comparison of yields in the two systems will be more useful.

High weed pressure in the cover crops eliminated the chance to harvest and estimate yields this year. The cover crops made up less than one-third of the cut foliage. We anticipate better forage in the next two years of the project.

2019 RESULTS

The year began with disappointment due to losses in the primary fruit crops. Fall 2018 and spring 2019 were exceptionally wet. This, coupled with the effects of the excessive irrigation required during the 2018 season and the standing/frozen water in the plots from October until mid-June, likely resulted in roots rotting and the plant losses. While most of the apple trees initially leafed out in the spring, by the end of June 22 of the 36 apple trees had not survived the first winter. The roots on the surviving apple and plum trees appeared similar in size when they were first planted. Although the row of plum trees was planted next to the apple row, only 5 of the 36 trees were lost. The grapes and currants had minimal losses. We lost 37 of 144 blueberries.

Additional apple trees purchased for this study and planted on the same date in 2018 in other areas on the farm did not experience any losses the first winter. However, these trees did not receive the amended soil in the experimental plot so firm staking was not required. In addition, these trees did not receive previous year's supplemental irrigation from July-September. In the first season, the trees in the experimental plot were firmly staked because winds continued to prevent the trees from remaining straight and little movement was allowed. This may have reduced the stimulation of the roots and possibly reduced root development.

As in the first season, the weeds within the cover crops (ryegrass and vetch) remained but the mixture of intended crop and weeds provided good supplemental feed. The clover showed fewer issues with weeds and provided clean areas around the primary fruit plants. There was a concern that the cover crops would reduce the moisture required for the fruit plants. No supplemental irrigation was used in the 2019 season and the effects of the cover crops or secondary crops did not appear to harm the primary fruit crops. Using any of the cover crops during the establishment period, which is a traditional method, appears to be an effective practice. The low and dense growth habit of the clover, coupled with the option of either weekly cutting or no cutting, makes this an ideal cover crop around the perennial fruit plants. Frequent cutting during the first year will minimize weeds.

The 2019 season was difficult for vegetable producers due to the excessively wet spring. Delays in planting resulted in seeds settling too deep in the tilled soil, rotting of seedlings, and increased weed pressure because of later germination dates. The rutabaga crop had such high weed pressure that we chose to simply mow over and remove this as an option for intercropping this season. After two years of failure with this crop, we are skeptical that the 2020 season will have better results. The initial acorn squash seedlings rotted but this area was replanted with butternut squash seeds. This late crop produced well and resulted in 0.42 pounds per foot^2 with over 95 percent salable product and a total of 760 pounds harvested. The control squash produced 0.38 pounds per foot^2 with 80 percent salable product (damage from mice). Squash seems to be a viable option for intercropping with fruit during this establishment period.

Squash harvested from intercropped plots in 2019.

We decided not to use supplemental irrigation in an attempt to save the primary fruit crop. The remaining primary fruit crops developed good roots. Without irrigation, the few strawberries that developed were too small to be sold and crop considered a complete loss. Strawberries require high levels of both irrigation and fertility, and we determined that this crop is incompatible as an intercropping option when the primary fruit trees need a drier period to establish roots. If the first establishment year only used a cover crop such as clover, strawberries may be introduced in the second year. Because we will be replacing the lost primary fruit plants in 2020 and not be providing irrigation, we will remove the strawberries in the final season. Intercropping strawberries beyond the third year of the establishment period would also become problematic due to shading from primary fruit plants.

We were surprised that the Roma tomatoes performed well despite receiving no supplemental irrigation. The yield was 5.1 pounds per plant (20 percent cull rate) compared to 6.2 pounds per plant in the control group (20 percent cull rate). The snow in the second week of October prevented harvest of additional tomatoes and these were not included in the harvest. The 120 tomato plants in the 1,800 feet^2 project area yielded 490 pounds of salable produce at a value of $980. Determinate tomatoes such as Roma seem to be a viable option for intercropping with fruit during this establishment period.

Roma tomatoes harvested from intercropped plots in 2019.

2020 RESULT

For this final season for the study, we had planned to replace the perennial fruit plants that were lost. However, the apple and plum trees raised in a Wisconsin nursery (similar hardiness zones) were not available until 2021. We decided to wait to replace the blueberries because only small plants were available in the varieties that were hardy in our nearly Zone 3 location. We have ordered replacement blueberries, grapes, and currants for 2021. However, as we learned in 2021, there were still shortages of some plants.

The geotextile fabric was removed, and perennial white clover was sown between the rows of fruit rather than continuing with a secondary crop. There were no vegetables or strawberries raised as a secondary crop this year. Throughout the summer the rows were maintained in anticipation of replacing lost fruit plants in 2021. From the initial planting, we lost 27 of the 36 apples, 8 of the 36 plums, 52 of the 144 blueberries, 5 of the 36 grapes, and 8 of the 72 currants. When the apples were ordered in 2018 for this study, additional trees were purchased and planted away from the intercropping. The growth rate of these apple trees was over twice the size of the study trees that were damaged by the increased irrigation that damaged the roots. We saw no deer damage to these trees, so the fencing was removed.

Although the primary goal of this study was to determine the advantage of intercropping with the perennial fruits to more efficiently use the land for the first years of establishment, the anticipated advantage of raising horticultural crops resulted in significant and unacceptable losses of the primary fruit crop, especially with apple, plum, and blueberries. The grapes and currants, with similar watering needs as the horticultural crops we raised, may be an exception, although the establishment period is only two years before harvesting fruit began with grapes and currants.

It is frustrating to lose time and resources, but learning how critical starting the perennial fruit plants, especially apples and blueberries, with limited irrigation so root development occurs, will help when replacement plants are installed next year. The idea of adding amendments to loosen the soil resulted in the excess irrigation collecting around the roots.

The Cornercopia Student Organic Farm on the UMN St. Paul Campus has used "poultry tractors" to raise chickens for several years. These light-weight structures keep the chickens contained and are designed to be moved across the pasture daily to allow the chickens access to fresh greens. This production model may be a better use for the land around the fruit plants. The chickens may harm fruit and produce near harvest stage due to the spread of manure. Unless there is fruit, we have decided that the space around the fruit plants can better serve as an area to move "poultry tractors." The clover provides a supplemental feed source and our goal next season will be to integrate hens within the study area to find a better method of "intercropping."

After the three establishment years of this project, we've learned a lot. Perennial fruits are an option for a profitable crop to expand the offerings of a farm. However, the attempt to intercrop with horticultural crops that have different management needs from the primary fruit plant during the establishment years has resulted in unacceptable losses, at least with apples and blueberries. However, the land between rows can provide value if the farm integrates livestock into the production model. In 2020, the clover between the rows of fruit plants was bagged and used to supplement the feed for pigs. In 2021, we intend to use the clover to supplement the feed of hens by moving "poultry tractors." Wayne Martin at the Cornercopia Farm has successfully used these poultry tractors for several years. We have a similar design that will be used next season around the perennial fruit plants.

We planned to replace lost perennial fruit plants in 2021 but found that there are shortages so will replace what we can find. The amended soil originally used for apple and plum trees will be mixed with native soil to bring the amended amount to half that originally used. The pathways between rows will remain in perennial white clover and be "mowed" with poultry tractors moved daily over the clover. After the poultry tractor is moved, the clover will be given about a week to produce new growth. The daily movement of the poultry tractors will provide supplemental feed for the chickens and provide a better use of this land as the primary fruit crops become established.

MANAGEMENT TIPS

1. If you chose to grow secondary crops, until those crops provide a micro-climate and help secure geo-textile fabric, keeping narrow widths of geotextile fabric in place will be an issue.
2. Managing the moisture requirements with the two crops could be more easily accomplished with individual drip emitters for fruit plants.
3. Use clover as a ground cover in the initial year of establishment. Limit the irrigation for the clover to the first few weeks to ensure that the fruit plants develop healthy roots.
4. During the establishment year, squash (or other vine crops) or determinate tomato varieties may provide a suitable intercropping option if the irrigation to the primary fruit crops is considered and controlled. Using strawberries may be an option in year two and three.
5. Staking of fruit trees should be monitored. Once roots have developed, allow for some movement to stimulate roots. Amending soil for apples and pears may discourage roots from spreading into native soil and allow water to collect and rot the roots.

COOPERATOR

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Wayne Martin, U of M Extension

Dr. Emily Hoover, U of M

OTHER RESOURCES

Cornell University Fruit Resources: www.fruit.cornell.edu

Minnesota Extension: www.extension.umn.edu

National Sustainable Agriculture Coalition: www.sustainableagriculture.net

Testing Two Pasture Types to Efficiently Finish Lambs on Pasture in a Single Growing Season and an Evaluation of Meat Quality from Each

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PROJECT DURATION

2019 to 2021

AWARD AMOUNT

$24,368.46

KEYWORDS

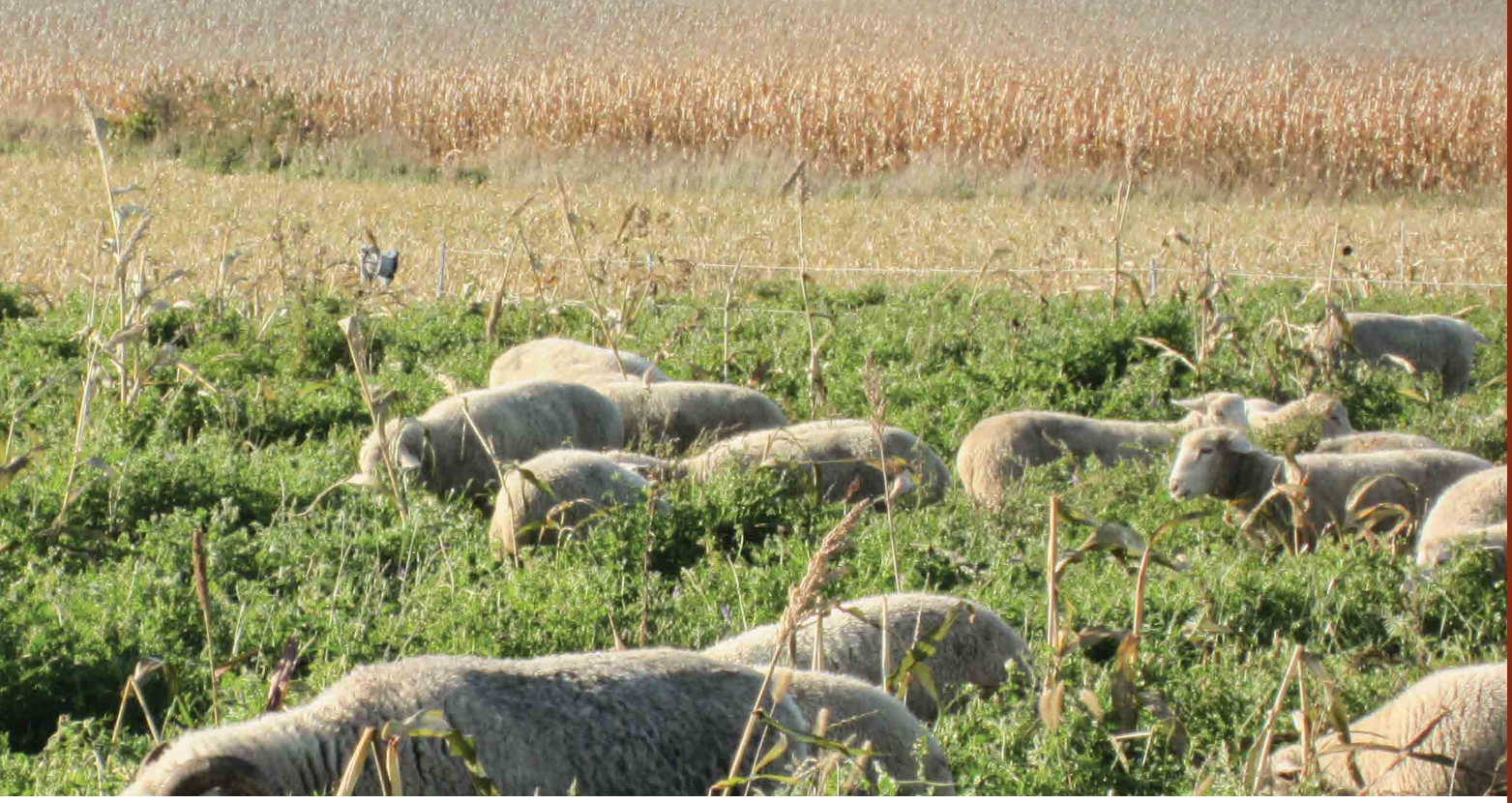
average daily gains, grassfed, grass finished, grazing lambs, pasture mixes, rotational grazing, sheep

PROJECT SUMMARY

This two-year project tested two different pasture types to determine if they effectively maintained average daily gains (ADGs) in lambs on pasture from approximately the end of August until finished weight. In our rotational grazing system, ADGs have usually decreased to economically unfeasible levels after that, which we theorized may be due to decreasing daylength and sunny days. We attempted to test two pasture mixes that can "store sunlight" and compared those to a standard feedlot ration. The first was a mix containing turnips and sugar beets. The second mix contained peas and small grains. Weather led to less than ideal growing conditions in 2019 and we experienced a major flood in 2020. The two pasture mixes did not work exactly as planned, but we were able to gather some data. The meat analyses also revealed some differences in meat quality between the pasture-finished and feedlot ration-finished lambs.

PROJECT DESCRIPTION

This project tested different pasture types to determine if they efficiently pasture-finish lambs in one growing season. In our years of rotationally grazing sheep and lambs, we have achieved average daily gains (ADGs) similar or greater than those reported for lambs in a feedlot for most of the growing season until approximately the end of August. After that, ADGs have dropped well below 0.5 pounds per day, which exponentially increases the length of time it takes the lambs to reach finish weight. This requires large amounts of pasture at a time of year when pasture growth is slowing and the cost per pound of gain rises significantly.



Sheep grazing the Turnip/Hairy Vetch plot in 2019.

Most lambs in the U.S. are raised in feedlots. Feedlots concentrate nutrients in manure, which can have negative environmental effects. This system also relies on monoculture crops (corn and soybeans) for the ration, which can have negative effects on soil health, water quality, bird and wildlife habitat, etc. Machinery and fuel are required to deliver the ration to the animals and remove manure from the feedlot. Well-managed, diverse, rotationally grazed pastures can lead to improved water infiltration and quality, sequester carbon, provide wildlife habitat, and increase the health of the soil, while using less equipment and fossil fuel resources. For these reasons, a viable, efficient way to raise and finish lambs on pasture could provide many ecosystem services while at the same time allowing the farmer to make a living. The purpose of this project is to provide data on the advantages and disadvantages of alternative lamb finishing options that can offer greater environmental benefits and potentially allow producers to tap into additional markets and increase farm profitability.

Meat from pasture-raised animals can be heart-healthy, including a better balance of Omega-3 to Omega-6 fatty acids. Various vitamins and minerals can also be higher in pasture-raised meat than in feedlot raised meat. Additionally, many consumers place increased value on animal welfare and are willing to pay more for both the increased health benefits and the way the animals are raised. Having a financially viable way to efficiently finish lambs on pasture could allow farmers to tap into this growing market, increasing farm profitability.

Through our reading and exploring the research of others, we concluded that there may be two main reasons why ADGs decrease in late August. First, perennial plants are triggered by decreasing day length to increase storage of sugars to their roots, leaving fewer sugars in the leaves. There appears to be a strong correlation between plant sugar levels (brix) and ADGs has in grazing ruminants, so this theory has merit. A second reason for decreasing ADGs this time of year is the declining hours of daily sunlight and the decrease in number of sunny days. Plant brix levels are lower on cloudy days than sunny days, which makes sense as sun drives photosynthesis and photosynthesis makes sugars. So, production of fewer sugars and increased storage of sugars in the roots would then lead to low ADGs.

Following this logic, we planted a pasture with turnips and sugar beets, as these both have large storage roots that store sunlight in the form of sugars. Production of grain is also a method that plants use to store sunlight, this time in the form of starches, so our second pasture treatment included a high percentage of peas and small

grains that have matured, allowing the sheep to harvest their own grain. As you will read, weather and other factors led to changes in original pasture mixes and species abundance in treatment pastures.

In 2019, lambs were sorted into three groups on September 26. In 2020, lambs were sorted and the treatment period started on September 1. Prior to this date, all lambs were rotationally grazed with their mothers on our existing perennial and/or annual pastures. The treatment period ended when the lambs were big enough to harvest and sell. We had planned to have two pasture groups (a turnip/sugar beet pasture and a small grain pasture) and a third feedlot group that would receive a standard corn/concentrate/roughage diet. However, as described in the Results section, weather was a challenge, and we were unable to graze lambs on the pasture types as planned – for example, the turnip/sugar beet treatment became the turnip/hairy vetch treatment, and, in 2020, the planned treatment pastures were lost and data was collected from one of our existing pastures. Lambs were weighed at the beginning and end of the treatment period. We were unable to graze lambs on the small grain pasture in 2019.

When lambs were divided into their groups, lambs in the turnip/hairy vetch treatment were kept with their mothers. We designed the experiment in this way for several reasons:

1. Ewes will teach the lambs how to harvest turnips.
2. Never weening the lambs is standard procedure for our system.
3. Grazing pasture is generally agreed to be the most economical way to feed livestock and excellent pasture will put more fat on the ewes backs and reduce winter feed costs later.
4. And, high quality pasture this time of year will increase body condition of the ewes to increase breeding efficiency and likelihood of multiple births.

Conversely, the lambs in the feedlot group were removed from their mothers, the standard procedure for feedlot finished animals.

The lambs and ewes in the turnip/hairy vetch treatment were rotated to fresh paddocks every 3 days in 2019. In 2020, lambs and ewes were initially rotated every day before moving them to a larger pasture where they could pick whichever plants they wanted. In 2019, lambs in the feedlot group were kept on pasture and the corn/concentrate mix was gradually introduced to them. Once they were fully acclimated, the corn/concentrate mix was fed free-choice. Pasture quality was initially of moderate quality and gradually reduced in quality as they acclimated to the grain ration to encourage maximum corn/concentrate intake. In 2020, lambs were put directly on cement after sorting and fed hay while gradually acclimating to a corn/concentrate diet.

Planting Specifications

We felt that diversity was key to success for both mixes. This increases soil health, animal health, beneficial ecosystem services, and the likelihood of a successful planting; that is, if one species fails, there are others to fill in. This theory manifested itself in the what was originally planned to be the turnip/sugar beet pasture.

Treatment 1: Turnip/hairy vetch.

The specific quantities of each component of this mix are outlined in Table 1. The initial plan was that turnips and sugar beets would provide the main energy of this pasture, but it became the turnip/hairy vetch treatment. Red clover is loved by lambs and has been shown to have a compound that increases appetite. It, along with hairy vetch, will boost the protein levels to allow the rumen to make the most of the energy from the turnips and beets. Italian ryegrass is a high energy grass that will not form heads and lose quality and will provide needed fiber. We also added a few oats so that the mix would go through the grain drill. This mix was planted on May 17, 2019 and June 9, 2020 using a grain drill.

Treatment 2: Sheep-harvested small grains and legumes.

The specific quantities of each component of the mix used in 2019 are outlined in Table 2. A mix of peas, oats, beardless barley, beardless triticale, and proso millet provide the main energy of this pasture. Protein is essential for starch digestion in ruminants, so several clovers were planted as well. In 2019 the plot was planted on June 2 with a grain drill. Clovers were seeded with the small grains, but to avoid the possibility that the small grains might compete with the clovers, 10-foot-wide strips of the clover mix were planted between 10-foot-wide strips of small grains. Substantial competition from water hemp and other weeds proved this to be a less-than-effective way to plant.

After observing how the mix and plantings performed in 2019, they were modified for 2020. With the goal to extend the effective grazing season of the plot, the plantings in 2020 were modified with the traditional cool-season small grains planted early (April 26, 2020) and the other half of the plot planted later (June 17, 2020) with proso millet as the small grain (Table 3). The traditional small grains typically mature around the beginning of August and our observation was that the part of the plot grazed at the end of October would decrease significantly in quality. Additionally, traditional small grains cannot be planted later with the hope of maturing later, as they do poorly in the heat of summer. Proso millet is a warm season small grain that can be planted in hot weather and mature just before frost. In 2020, the clover was underseeded with the small grains.

For the meat analysis, five lambs from each group were randomly selected from the ones to be butchered. From these five lambs, a thin slice was taken from each shoulder, a thin slice from each sirloin, and a thin slice from each leg. These 15 pieces of meat were pooled to make one sample from the turnip/hairy vetch group and the other 15 pooled to make one sample from the feedlot ration group. The two samples were frozen until they were delivered to Minnesota Valley Testing Laboratory in New Ulm, MN for analysis. This was done in 2019 and 2020.

2019 RESULTS

The 2019 growing season presented some challenges. The planting window was tight and less than ideal, particularly for small grains, resulting in the small grain plot planted later than we would have liked. Additionally, just after we finished planting and just before it rained on the plot, a huge windstorm came through and we wondered if it blew away, or at least relocated, many of the small clover seeds. Also, our method of planting a strip of small grains

Table 1. Planting mix for the turnip/hairy vetch plot - 2019 and 2020

Cultivar	Plant	LB/A
Purple Top	Turnip	1.75
Barkant	Turnip	1.75
Medium	Red Clover	2.5
True Italian	Italian Ryegrass	10
VNS*	Hairy Vetch	4
VNS*	Sugar Beet	1.75
VNS*	Oats	6.25
*VNS = Variety not stated		

Table 2. Planting mix for the cool-season small grain/legume plot – 2019 and 2020

Cultivar	Plant	LB/A
Var. 4010	Peas	50
VNS*	Oats	25
Beardless	Barley	20
Beardless	Triticale	20
VNS*	Buckwheat	7
VNS*	Hairy Vetch	8
VNS*	Red Clover	2
VNS*	Balansa Clover	2
True Italian	Italian Ryegrass	5
*VNS = Variety not stated		

Table 3. Planting mix for the warm-season small grain/legume plot – 2020

Cultivar	Plant	LB/A
VNS*	Proso millet	24
VNS*	Sunnhemp	2.4
VNS*	Buckwheat	7
VNS*	Hairy Vetch	6
VNS*	Berseem Clover	1.5
Medium	Red Clover	1.2
Fixation	Balansa Clover	1.6
True Italian	Italian Ryegrass	5
*VNS = Variety not stated		

(underseeded with clovers) next to a strip of clovers and ryegrass without small grains did not work. We were hoping that this method would lead to a vigorous stand of clovers/ryegrass between the small grains to decrease the shading by the small grains as they would be if they were just underseeded. However, there was significant weed pressure mostly from water hemp with a bit of giant ragweed that competed vigorously with the clovers. Perhaps this was due to some seed being blown away after planting. Ultimately, the weed pressure was so great that we ran our entire flock of sheep through the plot to eliminate the problem and eliminated this treatment for data collection.

Based on the problems this year, we plan to modify our planting procedures in 2020 (see 2020 Results section). Additionally, from our 2019 observations, it seems that it would be better for the grazing sheep if some portion of the small grain plot could mature later. As it was, the small grains mature in August and they likely degrade in forage quality as the season progresses and they become rained on and perhaps blown down. Typical small grains (oats, barley, triticale, wheat) are cool-season plants and do not do well planted later, so we can't just stagger the planting dates for the plot. In 2020, we plan to plant half the plot as the planned small grain mix and plant the other half later with proso millet, a warm season small grain that the sheep also like, as the main grain mixed with warm season legumes instead of the peas. Ideally, this would mature as the sheep are finishing the other small grain mix and would be top-quality for the rest of the finishing stage.

The turnip/hairy vetch plot also had some challenges, but we were able to graze it as planned and collect data from it. Planting went as planned and a couple weeks after planting we observed a great stand of turnips, decent amounts of ryegrass, red clover, and hairy vetch, but few sugar beets. As the growing season progressed, everything looked good, but around the time the turnips started to make bulbs, the edges of many of the leaves started turning brown and dying. By the time we started grazing in September, very few turnips could be found, few sugar beets, and the hairy vetch was nearly waist high. Small amounts of ryegrass and red clover were still present. What was supposed to have been a turnip/sugar beet diet ended up being an experiment on grazing hairy vetch.

We are not exactly sure what caused the turnips to fizzle and what to do in 2020 to change that. Our cooperator, Janet McNally, suggested trying a different variety of turnip. We sought advice from others, including Albert Lea Seed House where the seed was purchased, and no one seemed to have much insight. Careful examination of the plants revealed Alternaria leaf spot, caused by Alternaria brassicola, but we are not convinced that this could be the whole problem. We also observed a purpling of the midveins of the leaves, which is reportedly a sign of phosphorus deficiency. This could be a limiting factor for growth, as our soil overall has a high pH that results in tied-up phosphorus. If this is the case, adding phosphorus will have limited efficacy.

The basic costs associated with feeding the turnip/hairy vetch group are presented in Table 4. Some costs are missing (most notably, the cost of land) and each producer must figure these on his/her own. Depending on the producer, that could be land rent, property tax, or any fraction of these costs if the producer could have used these acres for another purpose (other grazing/haymaking, cash crops such as small grains, etc.).

Overall, the lambs in the turnip/hairy vetch group had slightly higher ADGs than the feedlot group (but ADGs in both groups could have been higher. We have a little (but not a lot) of experience transitioning lambs from pasture to a corn/concentrate diet. The transition period did not go smoothly, and some growth potential was likely lost during that period. There is a delicate balance between getting them on full corn as soon as possible so they can realize their maximum growth potential and going slow enough so they do not get sick from overeating corn. Perhaps a producer more experienced in this area would achieve better ADGs with the feedlot ration group than we did.

We were impressed with the ADGs from the turnip/hairy vetch group, as the average ADG was higher than any we had observed in previous years on pasture at this time of the year. We are not sure if this was something special with hairy vetch or if there might have been enough turnips to make

Table 4. Costs associated with feed turnip/hairy vetch lambs - 2019

Seed cost/A	$42.89
Planting cost/A	$25.00
Acres eaten per day (34 lambs, 28 ewes)	0.204
Theoretical no. of lambs if ewes were all lambs	69
Cost/day to feed one lamb (no labor)	$0.20
Labor in dollars/day (40 minutes every 3 days (.22 hr/day), $19/hr)	$4.22
Labor cost per lamb per day (for the actual 34 grazed)	$0.12
Total cost per day for the lambs	$0.32
Value of feed consumed by one lamb	$6.40

a difference in their diet. Alternatively, it may be due to amount of sunshine this fall. September into October was exceptionally sunny compared to most years. Perhaps the greater amount of sunshine allowed the plants to produce more sugars that led to the higher gains. Additional data from 2020 should offer some insight.

Further results from 2019 are included below with the data from 2020.

2020 RESULTS

2020 was also a challenging growing season due to the weather. The cool-season small grain pasture (Table 2) was planted early, but then it hardly rained enough to sprout the seeds. Then the weather turned unseasonably hot and dry for May. The pasture looked okay, but the small grains were noticeably stressed. The warm season millet mix (Table 3) seemed to do okay in spite of the dry weather, although germination could have been better. We liked how the maturation timing of the two plots seemed to be progressing. However, on the night of June 28-29, our spring drought was broken with just under 6 inches of rain, putting part of the cool-season small grain plot under water and stressing the legumes. Then, on July 25, our farm received 10 inches of rain, putting the whole cool season small grain plot and part of the warm season portion under water for a week, killing any remaining legumes and reducing quality of the grain itself. There was little worthwhile left to graze, so we were unable to collect data from this plot in 2020.

We planted the turnip/hairy vetch plot later in 2020 than in 2019, per suggestions by various people, to improve turnip growth. Germination was poor for lack of rain. Random patches looked pretty good and the Barkant turnip variety seemed to do a little better than the ordinary purple top turnips. However, excessive weed growth (particularly giant ragweed) occurred where seeds did not germinate. Giant ragweed, a plant native to Minnesota, makes great sheep forage, but has been designated a noxious weed in Sibley county, so we had to destroy the plot before the ragweed set seed and before the planned grazing period for the study. We contemplated mowing the overstory of ragweed to leave the turnips to graze for the later study period; however, driving anything over turnip bulbs tends to smash them, rendering them useless for later grazing. Our whole sheep flock happily worked together to destroy this plot. Because of the ragweed, we were not able to collect data from this plot in 2020.

While not the original treatment planned for the study, we grass-finished a group of lambs on perennial pasture and the meat sample was taken from these animals. From the start of the study period on September 1 until September 26, this group was rotationally grazed (daily moves) with the ewe flock on a diverse grass/alfalfa/chicory/clover perennial pasture. From September 26 until November 4 when they were harvested, lambs were separated off as their own group and given access to a large area of pasture (mostly alfalfa, but some grasses, chicory, and other species) and they chose whatever plants they liked best, with the thought that this method might allow for good average daily gains. This method made it difficult to accurately assess the number of acres used (cows later used the remaining forage). Costs were estimated by using the average weight of the lambs for the study period, estimating consumption at 3.5 percent of their bodyweight, and valuing forage at the cost of a $60 per round bale (see Table 5).

The ADG differed between the groups (Table 6). In 2019, the feedlot lambs had a lower than expected ADG. In retrospect, they probably consumed more forage than is optimal for corn-fed lambs. Basically, when ruminants consume large amounts of corn, it turns their rumens acidic. An acidic rumen is inefficient at digesting fiber (grass is full of fiber). On pasture, even low quantity pasture, lambs attempt to fill their rumens with forage, which just sits undigested, making them feel full and not inclined to eat more corn. We were hoping that the pasture had so little forage left that the lambs would just eat the corn and concentrate ration, but the ADG suggests that they persisted in eating forage. In

Table 5. Estimate of costs associated with feeding the grass finished lambs in 2020

Average starting weight of one lamb (lb)	90.9
Average ending weight of one lamb (lb)	116.6
Average weight (from start to end) of one lamb over the period (lb)	103.8
Total pounds of feed eaten/day/lamb if eat 3.5% of bodyweight	3.6
Total lb eaten/lamb for the whole period	228.8
Number of 1,100 lb round bales eaten/lamb	0.208
Value of feed consumed by one lamb ($60 per 1,100 lb bale)	$12.48

2020, we put the lambs on cement right away and carefully regulated the amount of forage they had available. The ADGs in 2020 were close to what the feed salesman said should be expected. While the ADGs for the grassfed groups were slightly less than the feedlot lambs in 2020, the cost per pound of gain was much less for the grassfed group, and the meat analyses suggest that the grassfed lambs had an Omega-6 to Omega-3 ratio that is far more healthful to human health than the corn-finished lambs (Tables 7 and 8).

Infrastructure costs are missing from the total cost per pound of gain figures in Table 6. These are highly dependent on the situation of each individual producer. Examples of infrastructure commonly needed to feedlot-finish lambs are: feedbunks, cement, skid loader/tractor loader for scraping manure, tractor and manure spreader, and feed mixer. For the grassfed group, necessary infrastructure may include: polywire and posts to build temporary paddocks and/or permanent fence, fence energizer, and adequate available land base for grazing. At first glance it seems that the feedlot finishing uses a great deal more infrastructure, but the land base required to finish lambs could make the grassfed option unfeasible for some producers, as land costs can be quite high. Alternatively, a lamb feedlot does not require much land. Each producer should evaluate the data presented here and find what works for his or her circumstances.

Another hidden cost that should be, but is often not, considered is the environmental impacts of each finishing method. These are hard to put a dollar value on, but they are still very real. We had a relatively small number of animals confined on cement, so manure concentration and runoff were minimal. But scaling this up could have disastrous environmental impacts for water quality. Rotationally grazing the lambs across the landscape allows for light and even manure distribution, making manure a fertilizer, not an environmental hazard. Finishing the lambs on pasture forage does require more land, but considering potential environmental impact, the animals should never be separated from the land and concentrated on a relatively small piece of cement (or dirt) yard.

Pasture can be one of the cheapest ways to put weight on lambs, as long as the pastures are adequate quality and the producer is knowledgeable enough to effectively raise lambs on pasture so that they are gaining weight (parasites are often an issue). If lambs are not gaining weight fast enough, then the cost per pound of gain can become high enough to become unprofitable. Then, it would make economic sense to use the pasture to feed the ewe flock and purchase feed for the lambs.

For example, say a producer needs to put 25.7 pounds of weight on a group of lambs (the weight our grassfed lambs gained in 2020 – see Table 6). If they gain 0.41 pounds per day, as ours did in 2020, then it takes 63 days to achieve desired weights. If, however, the group of lambs only gained 0.2 pounds per day, then it would take 129 days for the lambs to gain the same 25.7 pounds. If they still ate 3.5 percent of their body weight every day, the same as figured for our 2020 grassfed lambs (Table 5), then the feed cost would jump to $25.45. Labor costs would at least double to $7.60 per lamb, because the producer must tend the lambs for approximately twice as many days. This leads to a total cost per pound of gain of $1.29, approximately double the $0.63 cost per pound of gain we achieved for the 2020

Flooding of major portions of the small grain plots in July 2020.

Table 6. Summary and comparison of pasture finished to the feedlot-fed groups in 2019 and 2020					
	2020 Feedlot group (first sold) 1	2020 Feedlot group (second sold) 1	2019 Feedlot group	2019 Turnip/ hairy vetch group	2020 Grassfed group
Number of lambs	13	26	35	34	8
Average starting weight (LB)	70.3	65	98.5	101.3	90.9
Final weight (LB)	125.5	121.2	120.9	113.8	116.6
ADG for life prior to study period (LB)	0.49	0.45	0.56	0.58	0.6
ADG for study period (LB)	0.5	0.46	0.31	0.37	0.41
Days in the study period	111	131	63	32	63
Average pounds gained/lamb in study period	55.2	56.2	22.4	12.5	25.7
Total feed cost/head	$38.98[2]	$43.83[2]	$17.64[2]	$6.40[3]	$12.48[4]
Cost/LB of gain (feed only)	$0.71	$0.78	$0.79	$0.51	$0.49
Cumulative total time/lamb to feed (hours)	1.13	1.98	0.60	0.21	0.20
Cost of labor (if $19/hour)	$21.47	$37.62	$11.40	$3.97	$3.80
Cost/LB of gain (feed and labor)	$1.10	$1.45	$1.30	$0.83	$0.63

[1]In 2021, the feedlot group was sold in two groups (as they grew big enough), so the groups were separated for analysis.
[2]In 2019, corn was valued at $3.50/bushel and the lamb grower concentrate averaged $0.27/lb. In 2020, corn was valued at $3.75/bushel and the lamb grower concentrate averaged $0.297/lb.
[3]See Table 4.
[4]See Table 5.

grassfed group. Depending on markets, even this low ADG could be profitable, particularly if the producer has a grassfed market that offers a premium. However, available acres of land and snow and ice can become an issue if the producer is in Minnesota. Furthermore, if the producer's only market is the commodity market, this may not be profitable, as the price of finished lambs commonly drops below $1.29 per pound. For these reasons, it might make economic sense to use the pasture to feed the ewe flock and consider putting the lambs on a feedlot ration so that they gain weight profitably. We feel that it is a shame to put ruminants on a monogastric diet on cement, but it is also a shame to not be profitable raising sheep. This is the whole premise of this study and, hopefully, other producers can learn from our experiments and achieve profitable ADGs on pasture.

From the analyses of meat samples from 2019 and 2020, there were strong differences in the fatty acid profiles between the corn finished and grassfed samples. The most notable differences are presented in Table 7, and further summarized in Table 8 related to an actual 6-ounce serving of lamb. Results were similar between years for the corn-finished lambs and the grassfed lambs. Differences between the two groups were greater in 2020 than in 2019. This could be due to several factors. In 2019, the corn-finished lambs consumed more pasture than the lambs in 2020. Additionally, the lambs in 2019 started out heavier, and therefore spent only 63 days on feed versus 111 in 2020. It was interesting that, even after a life of consuming only pasture, with only 63 days eating corn (in 2019), the fatty acid profile was significantly altered.

Saturated fat and monounsaturated fat content were very similar between the corn-finished and grassfed lambs, but polyunsaturated fat (a fat termed "essential" because our bodies cannot produce it) was higher in the grassfed samples, particularly in 2020 (1.6 times greater than the 2020 corn-finished sample).

Conjugated linoleic acid (CLA) has been much studied, and, although sometimes inconclusive, there is some thought among the health-conscious population that CLA helps maintain a healthy weight (maybe even lose

Table 7. Fat composition of meat samples from corn-finished and grassfed lambs- 2019 and 2020					
		Corn-finished		Grassfed	
		2019	2020	2019	2020
	% Total fat in sample	18.87	24.58	12.48	6.41
% of total fat	Saturated Fat	50.49	49.29	53.45	51.84
	Monounsaturated Fat	35.9	39.57	34.46	34.85
	Polyunsaturated Fat	5.57	5.29	6.89	8.41
	Conjugated Linoleic	0.576	0.413	1.049	0.834
	Total Omega-6	4.426	4.452	4.989	5.708
	Total Omega-3	0.118	0.035	0.359	0.625
	Omega-6:Omega-3 Ratio	37.5:1	127.2:1	13.9:1	9.1:1

weight), can fight cancer, and is generally beneficial to health. In both 2019 and 2020, the grassfed meat samples tested higher than the corresponding corn-finished samples (1.8 and 2.0 times higher, respectively).

The designation as an Omega-6 or an Omega-3 fatty acid is not conclusive for some fatty acids, as the exact chemical structure of every fatty acid has not been consistently determined. The current thought is that there are 11 different types of fatty acids that are considered Omega-3s and at least four types of fatty acids that are considered Omega-6s. For this study, the fatty acid profile received from the lab included 42 different fatty acids. This is not all the fatty acids that are known to exist. For example, seven of the eight "lesser known" Omega-3 fatty acids and alpha-Linolenic acid (ALA), a well-known Omega-3 that occurs primarily in plants, were not included in the analyses. So, for the purpose of this study, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) were the only fatty acids included in the "Total Omega-3s" in Tables 7 and 8. For Omega-6s, linoleic acid (LA), gamma-linolenic acid (GLA), arachidonic acid (ARA), and conjugated-linoleic acid (CLA) were included in the "Total Omega-6s" in Tables 7 and 8.

In both years, the total amount of Omega-6s was slightly higher in the grassfed than the corn-finished sample (1.1 and 1.3 times higher in 2019 and 2020, respectively). The Omega-3 content was even higher in the grassfed samples (3.0 and 17.9 times higher in 2019 and 2020, respectively). It is thought that most Americans get too many Omega-6s and not enough Omega-3s, giving the impression that Omega-6s are bad. However, research seems to suggest that Omega-6s are very important (CLA is an Omega-6), but they must be in an appropriate ratio with Omega-3s to be optimally useful. The corn-finished lamb contained very little Omega-3 fatty acids, particularly in the 2020 sample. In particular, the levels of DHA in the corn-finished sample in 2020 were below levels of detection. The grassfed samples in 2019 and 2020 had much better Omega-6: Omega-3 ratios than the corn-finished samples.

Table 8 is included to give a real life, real eating view of what a person can expect to eat when consuming a typical serving of the two types of lamb. The amount of total fat was adjusted from the percentages in the actual samples for two reasons. First, the samples were gathered at two separate butcher shops. Both shops were given the same set of instructions, but the corn-finished sample, particularly in 2020, was visibly very fatty, as if the samplers had specifically sliced off the fatty bits to include in the sample. In retrospect, we should have given more clear instructions about the sample being representative of the overall fattiness of the animals. Another reason to adjust the fat content for Table 8 was that most lamb is sold with much of the outside fat trimmed off. So, whether the animal was under-finished or over-finished, by the time it reaches the consumer, it is basically the same. Intramuscular fat cannot be trimmed and may be greater in corn-finished animals, so, for Table 8, it was assumed that the corn-finished lambs contained slightly more fat. Our grass-fed lambs looked and felt nicely finished, so this may not be the case, but this assumption was used for this analysis. Even assuming that the corn-finished lamb contains more fat, the total Omega-3 content was still greater in the grassfed samples than the corn-finished samples in both 2019 and 2020 (2.5 and 14.9 times greater, respectively.) The mineral composition was not very different between the treatments and years (Table 9). It seems the mineral stores in the meat are not as affected by the feedlot diet as the fat composition. However, there was a general trend of slightly higher mineral content in the grassfed samples. Most of the mineral values were higher than most published values for lamb meat.

Ultimately, the question is, "what is the best way to finish lambs?" The answer is not simple, and involves a complex interaction between the producer's abilities and resources, markets, and human health considerations. We hope that the data presented here will help each producer to make an informed decision for his or her farm and circumstances. Pasture finished meat has real, quantifiable health benefits over corn-finished meat. The environmental benefits are also real. Farmers can use our information to inform the consumer about the value of grassfed lamb to the extent that they are willing to pay more for it. This would allow small farms to make a living raising healthy, environmentally responsible meat.

We will continue to finish lambs on pasture and will continue to explore both perennial and annual options. This study allowed us to try some feed options and we learned enough to get better at finishing lambs each year. We will also make the nutritional information available to our direct market lamb customers and, hopefully, gain more customers.

Table 8. Fat composition of a 6-oz serving of lamb trimmed to 20g total fat (11.8%) for grassfed and 24g total fat (14.1%) for corn finished

	Corn-finished		Grassfed	
	2019	2020	2019	2020
Total Fat[1]	24	24	20	20
Saturated Fat[1]	12.1	11.8	10.7	10.4
Monounsaturated Fat[1]	8.6	9.5	6.9	7.0
Polyunsaturated Fat[1]	1.3	1.3	1.4	1.7
Conjugated Linoleic[2]	138.2	99.1	209.8	166.8
Total Omega-62	1,062.2	1,068.5	997.8	1,141.6
Total Omega-32	28.3	8.4	71.8	125.0

[1]Measured in grams.
[2]Measured in milligrams.

Table 9. Vitamin and mineral composition of a 6-oz portion of meat from each of the treatments in 2019 and 2020

	Corn-finished		Grassfed	
	2019	2020	2019	2020
Total Fat[1]	24	24	20	20
Saturated Fat[1]	12.1	11.8	10.7	10.4
Monounsaturated Fat[1]	8.6	9.5	6.9	7.0
Polyunsaturated Fat[1]	1.3	1.3	1.4	1.7
Conjugated Linoleic[2]	138.2	99.1	209.8	166.8
Total Omega-62	1,062.2	1,068.5	997.8	1,141.6
Total Omega-32	28.3	8.4	71.8	125.0

[1]Measured in grams.
[2]Measured in milligrams.

The layout of the Small Grain/Legume plot in 2019, with the strips of small grain planted between strips of legumes. As mentioned in the text, the legumes did not grow well, and the legume strips ended up being primarily waterhemp and giant rageweed, as seen in the photo.

Ultimately, the question is, "what is the best way to finish lambs?" The answer is not simple, and involves a complex interaction between the producer's abilities and resources, markets, and human health considerations. We hope that the data presented here will help each producer to make an informed decision for his or her farm and circumstances. Pasture finished meat has real, quantifiable health benefits over corn-finished meat. The environmental benefits are also real. Farmers can use our information to inform the consumer about the value of grassfed lamb to the extent that they are willing to pay more for it. This would allow small farms to make a living raising healthy, environmentally responsible meat.

We will continue to finish lambs on pasture and will continue to explore both perennial and annual options. This study allowed us to try some feed options and we learned enough to get better at finishing lambs each year. We will also make the nutritional information available to our direct market lamb customers and, hopefully, gain more customers.

MANAGEMENT TIPS

1. Extreme and abnormal weather was a key contributor to things not working as planned. Some experts predict that effects of climate change will only increase in coming years and crazy weather will become the norm. Perennial pasture does not need to be planted every year and can include a mix of species that can withstand both drought and flooding, making it the most practical to include in the grazing plan for finishing lambs.
2. Finishing lambs on perennial pasture as we did in 2020 worked fairly well and our method of set-stocking on a large pasture worked well from the pasture and parasite side of things because it was fall. This method should not be used in the spring or summer because the sheep will re-ingest the actively reproducing parasites and would die of parasites if not closely monitored and treated. In the colder fall, parasites go dormant and are not re-infecting the lambs. Also, in the summer when the pasture is actively growing, the lambs would repeatedly take second bites of their favorite plants, weakening the plants and hindering overall pasture yield for the rest of the season. In the late fall, growth is so slow (or non-existent) that this is not a concern. This method requires a lot of acres for a small number of lambs, but we were able to run our cows (a lower maintenance group) through and use the remaining lower quality forage to sustain them. To make this strategy work, a larger group of lower-maintenance animals must be available to utilize the rest of the pasture.
3. Counter to what any expert or book says, hairy vetch, planted in the spring, is excellent forage for sheep. The standard recommendation is to plant hairy vetch no earlier than August and several cover crop references claim that the forage value is zero and the grazing value is zero. The way the sheep snarf up hairy vetch suggests otherwise, and the results of our experiment indicate that hairy vetch, planted in the spring, is indeed good forage for sheep.
4. On pasture, adding more lambs does not linearly increase the amount of time spent but decreases the amount of time spent per lamb. This could further reduce the cost per lamb.
5. Some producers who raise their lambs mostly on pasture and finish them the last bit on corn are losing all the health benefit of grassfed meat. Producers should be aware of this and be careful not to (unintentionally) mislead customers that their animals are grassfed if they are fed corn at the end. Our results show that there is a significant difference in the fat composition of the meat.

COOPERATORS

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Sheep in the Small Grain/Legume plot in 2019. The oats, wheat, and triticale are visible, but weeds made up a large portion of the total grazing available.

Perennial Farming and Carbon Sequestration, Ecosystem Services, and Innovative Entrepreneurship

Research plot.

PRINCIPAL INVESTIGATOR

Michele Manske
Project with Mashkiikii Gitigan/
Pillsbury United Communities
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PROJECT DURATION

2018 to 2020

AWARD AMOUNT

$24,606.29

KEYWORDS

perennial fruit and vegetable systems, urban farming

PROJECT SUMMARY

What once was a vacant, un-managed lot has been transformed into a food producing green space within the city of Minneapolis. Sheet mulched, bio-charred, raised beds produce annual vegetables for the Minneapolis Lead Free housing project and the Waite House's food shelf and community cafe. Fruit trees, flowers, and medicinal herbs support medicine-making and 'grow your own' classes. Neighbors stop by to relax under the honey locust tree or to watch the University of Minnesota (UMN) students gather data and admire the abundance around them. In this multi-tiered growing environment, we evaluated the perennial system's ability to sequester carbon, affect soil contaminant levels, and provide entrepreneurial opportunities.

Bulletin board with plot map and planned activities at entrance to farm site.

PROJECT DESCRIPTION

This project came to be through an interest in learning more about ecosystems and designing a landscape to mimic natural systems with edible perennials. I wanted to start this project for many years because I believe that accessible agriculture is an important strategy for public health and improving the urban environment, serving as a tool for community engagement, and as a direct way to address food security. The economic intentions of growing in this specific location are to train interested community members to potentially profit from selling the produce once we had addressed the most significant barriers. Using this model, the vision is to scale from one urban lot to tackling the broader Minneapolis food system. Ultimately, I view this project as a way to inform city officials of the value of green, edible spaces in urban environments as a catalyst for climate change policy and urban agriculture.

The farm site for this project is part of an urban farm consisting of three city lots, started with the Mashkiikii Gitigan (Ojibwe for "Medicine Garden"), part of the 24th Street Farming Coalition made up of the following organizations focused on urban food production: The Native American Community Development Institute; the Native American Community Clinic; the Indian Health Board; the Women's Environmental Institute; Ventura Village; Pillsbury United Communities; the University of Minnesota; Our Saviour's Lutheran Church; and interested neighbors. The mission of the Coalition, now in its seventh year of operation, is food justice and food security for the Phillips neighborhood. The vision for incorporating a perennial food system into the work being done by the Coalition was to provide economic opportunities from tree crops, relief from urban heat through increased tree canopies, improved air quality, education about healthy/organic food production, plant medicine, and cultural connection (to name a few).

We had four main research objectives:

1. Evaluate the sustainability of a perennial system in an urban environment and, more specifically, the effectiveness of a perennial system to sequester carbon.
2. Investigate the impact of production oriented perennial systems on soil contaminants/heavy metals.
3. Assess the biodiversity on this site and its potential to provide innovative, entrepreneurial opportunities for urban farmers and populations who face disproportionate toxic exposure in the urban environments.
4. Determine the potential of a perennial system to provide increased economic prosperity, with particular interest in tree crops.

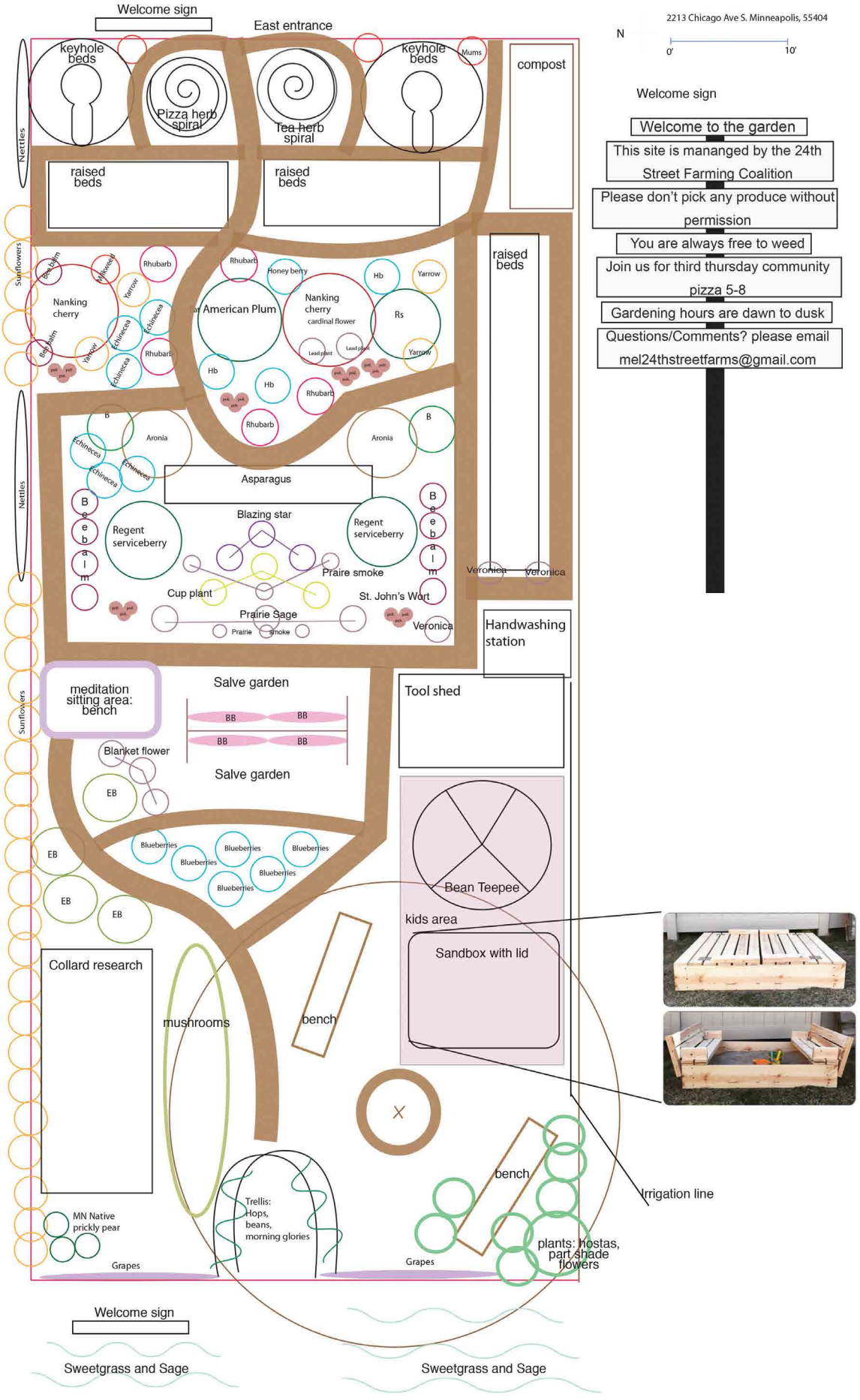
This site, as with all our farm sites, had been exposed to arsenic contamination and is in one of the most polluted neighborhoods in the Twin Cities. For this reason, all our plant beds are raised and have imported soil. Most of our water is metered and purchased from neighbors or the city.

The farm was designed with community input and evolved every year throughout the three years of the project duration. The plan was updated in February 2020. The farm was designed to mimic a multi-tiered, natural eco-system containing differing crop functional types including mushrooms, herbs/native flowers, and fruit-bearing shrubs/trees (See Farm Map). Collectively, these plant products command higher profit margins than vegetables at market, and a perennial system has the potential to generate sustained, lasting benefits to soil and environmental quality. The perennials were planted so that they were mutually supportive, but not in direct competition. Each plant had its own niche. For example, Fragaria x ananassa (strawberry) was planted around the fruit trees as an edible ground cover and weed suppressor. Nitrogen fixing species were included in the system and meant to be cut two to three times throughout the growing season and placed around fruiting species as green manure or mulch to enhance nitrogen availability to surrounding plants. To encourage mycorrhizal symbiosis and enhanced nitrogen fixation, Baptisia species were inoculated with Rhizobia. Fungal species incorporated into the system included the edible Red Wine Cap (Stropharia *rugosa-annulata*), which required inoculation on a layered bed of hardwood mulch and straw.

Trellising to support vining plants.

We planned to rely heavily on fast-maturing fruit crops (Rubus sp.) and mushrooms the first year of the project then begin harvesting other crops chosen for their quick maturity rates (1-3 years) in 2019. By the third season, we planned to have reliable produce to bring to market.

Data was collected in a communal notebook kept on site in the garden shed. We collected information on people passing through, volunteers, their experiences, pollinator species, weather, labor inputs, yields, and weeds. Harvest records included: time spent on harvest (includes setup and cleanup); what was harvested and how; washing, packing, and where produce was sold. We surveyed the overall social impact and growing capacity. We used QuickBooks™ and an accountant to track the economics for the project.


Welcome sign
East entrance
keyhole beds
keyhole beds
Mums
Pizza herb spiral
Tea herb spiral
compost
Nettles
raised beds
raised beds
raised beds
Sunflowers
Bee balm
Milkweed
Rhubarb
Yarrow
Nanking cherry
Bee balm
Yarrow
Echinacea
Echinacea
Echinacea
Rhubarb
American Plum
Rhubarb
Honey berry
Nanking cherry
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Aronia
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Asparagus
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Beeb alm
Regent serviceberry
Blazing star
Regent serviceberry
Beeb alm
Praire smoke
Cup plant
St. John's Wort
Prairie Sage
Prairie smoke
Veronica
Veronica
Veronica
Handwashing station
Tool shed
Sunflowers
meditation sitting area: bench
Salve garden
BB
BB
BB
BB
Salve garden
Blanket flower
EB
EB
Blueberries
Blueberries
Blueberries
Blueberries
Blueberries
Blueberries
EB
EB
EB
Bean Teepee
kids area
Sandbox with lid
Collard research
mushrooms
bench
X
bench
Irrigation line
Trellis: Hops, beans, morning glories
MN Native prickly pear
Grapes
Grapes
plants: hostas, part shade flowers
Welcome sign
Sweetgrass and Sage
Sweetgrass and Sage
2213 Chicago Ave S. Minneapolis, 55404
N
0'
10'
Welcome sign
Welcome to the garden
This site is mananged by the 24th Street Farming Coalition
Please don't pick any produce without permission
You are always free to weed
Join us for third thursday community pizza 5-8
Gardening hours are dawn to dusk
Questions/Comments? please email mel24thstreetfarms@gmail.com

In addition to our data collection, Nic Jelinski's University of Minnesota team collected data on a wide range of ecosystem service indicators such as: water infiltration rates, community services, soil biology, pollinator diversity, mineral leachate, and overall soil health. They compared the data from our site with several other collaborator sites across the Twin Cities metropolitan area (Contact Nic Jelinski for more information on his research and data).

2018 RESULTS

This year we transitioned most of the site from annual vegetables to perennials and fruit trees. We removed the back half of the row crops to create poly-cultured perennial beds. We built and installed trellis supports for blackberries, a separate blueberry and bearberry bed, and purchased drip line irrigation for precision watering. Results were affected by a late snowstorm (April 13-16, 2019). Although we still produced food, I considered this to be a transition year to establish a new system.

Working in the perennial urban farm plots.

The benefits that the farm brought to the community were many. We had one of the most diverse bee populations (data collected from our community partners), a weekly box of fresh produce to help families who were in transitional housing while their homes were being treated for lead, a very successful plant medicine class using plants from the garden, new research being conducted on the benefits of bio-char, and co-hosted a weekly garden-based class with a registered dietician.

This project has reduced the use of non-renewable resources and inputs in the following ways:

1. Drip irrigation improved water management.
2. A higher percentage of perennials will eventually reduce the labor for this site and therefore reduce costs, making it more economical to manage.
3. Small farm size reduced use of fossil fuels for equipment. Ninety-five percent of the site was sheet mulched and heavily wood chipped without the use of fossil fuels.
4. Sale of produce in local markets and nearby restaurants reduce transportation costs and fetch higher prices.

2019 RESULTS

The research design matured in this second year of the project. In addition to our data collection, our University partners (working through a USDA-Sustainable Agriculture Research and Education grant) began collecting information from our demonstration including crop yield and quality, water quality, water infiltration rates, nutrient cycling, biodiversity assessments, and cultural (education, aesthetics, and discovery) services as part of a larger study. Data was collected to compare plots planted with collard greens (using three urban agricultural management practices) with turf grass plots on an urban farm or adjacent to farms in open space or boulevards. (Contact Nic Jelinski for more information on his research and data). The three management practices were:

1. No amendments.
2. Compost amendment from a single source municipal food waste compost which provides a high application rate based on crop N demand.
3. "Growers Choice" practice, in this case our perennial agriculture and brewer's mash.

We also collaborated with Julie Wisenhorn (UMN) to determine the best annual flower species for pollinators by tracking which flower varieties increase green pepper production. We had three plots: flowers interplanted with the peppers; flower patches at the end of pepper rows; and a control area with no flowers. We are still waiting for the results, but we had beautiful flowers while supporting many pollinating species. The peppers went to community cafe.

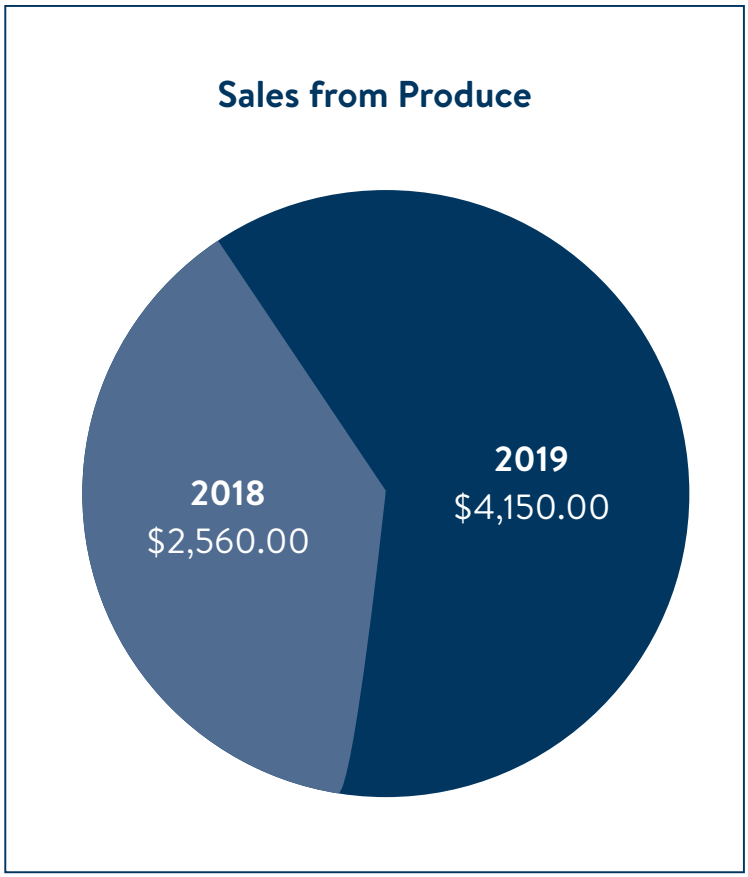
While our research and demonstration collaborations expanded, so did our weed problems. There was an influx of bindweed that nearly choked out half of the plants. We had to weed weekly which affected labor inputs and cost needed at this site. However, if we had not had the bindweed to pull, labor hours would have been lower this year as we decreased annual production and the perennials became the majority species at this site. I spread winter rye hoping that its allelopathic properties would subdue the weeds.

Flowers were seen on the larger fruiting species - plum, Nanking cherry, chokecherry, elderberry, honeyberry and Aronia - but the only notable harvest was the 8 pounds of chokecherries, which were sold to the Indian Health Board for their nutrition program. While we did have plant losses from the bindweed, we did have more product to sell this year than last (see pie chart). The honeyberries were producing, but not enough to harvest. The asparagus will be ready to harvest next year and is prolific. About 10 pounds of rhubarb was harvested and given to the neighbors. Strawberries, started as a ground cover around the larger fruit crops, produced a few handfuls this year. We expanded our customer list and, as we start seeing more fruit next year, our sales will increase. We worked to increase income for some local entrepreneurs through farm work, youth programs made possible by the existence of this site and creation of partnerships for community members to make value-added products (salves, tinctures, teas, preserves) from the site.

Preliminary data from Nic Jelinski's research indicates that water infiltration rates have increased at our site. With all of the flowering species and natural habitat, this site was supporting pollinators in an urban environment. We also increased our use of renewables including wood chips, compost, biochar, beer mash, and recycled metal signs used for trellising.

Data from this study in 2018 and 2019 locations in northern Minnesota, the Twin Cities, and Osceola, WI showed no statistically significant differences in yield that supported interplanting flowers with peppers versus planting a flower patch nearby. Control plots and test plots yielded similar quantities of peppers.

The second piece of our project is community engagement and innovative economic opportunities with our Urban Farming Program. When I started this project, I had hoped it would be an easy, automatic buy-in from the community. Although people love the space, more outreach is needed to get involvement. I will continue to form more partnerships with other organizations and always give any passerbys a tour or produce from the farm if they are interested. We hosted several events to engage the community including: a presentation by the City of Minneapolis about their community gardening program; a blood lead testing event; a plant giveaway in the Spring; and classes about growing perennial crops and business strategies to support urban farmers. We worked with Our Saviour's church to redesign their annual plant areas to perennials.

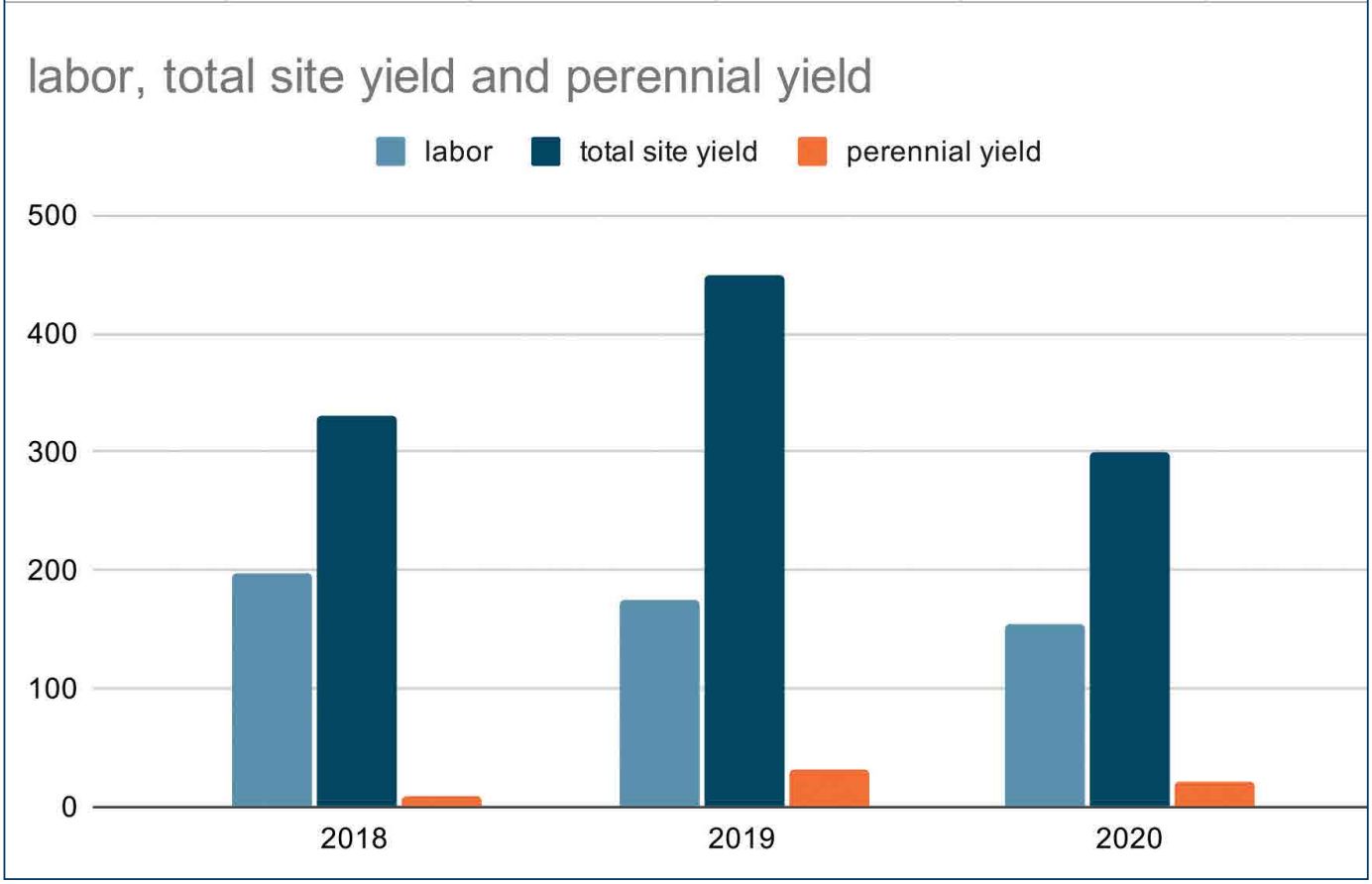


2020 RESULTS AND SUMMARY

COVID-19 and the transition to a new farm manager affected this year's project. Getting the community involved in the site for education and events was restricted and training the new farm manager took a lot of time. Reviewing our progress over the three years of the project has shown several things:

1. The project has not yet improved markets. The fruit trees are still maturing and there is strong evidence that as they do, input costs will be reduced while income will increase. We still rely mainly on annual crops in the meantime. Annual crop production has decreased from 97 percent in year one to 93 percent in 2020 as perennial crop volume has increased gradually each year (see chart). Eventually, our program has the potential to provide more families with a diverse, fresh, and healthy diet.
2. Labor hours have remained relatively consistent though we expected a decrease with the change to perennials. The unforeseen curse of this site has been the bindweed that showed up during year two. This has had an enormous impact on both production and labor (see chart). Also, I underestimated the amount of time needed to build community around this project.
3. Community education and knowledge around food production has increased, and people are finding healing in this space. We feel confident that urban perennial agriculture can provide economic opportunities to community growers, provide ecosystem services such as canopy coverage, better air quality, improved water infiltration, green space, and increased wildlife and biodiversity. Soil health has increased with an associated decrease in lead availability.

	labor	total site yield	perennial yield		
2018	196.5	330.75	10		
2019	176	450	32		
2020	155.2	300	22		



Challenges remain for urban agriculture. There is little guarantee of permanence for use of urban lots for agriculture. We continue to have issues of site security, though signs did help reduce trash and other problems. Many urban sites are contaminated with lead and have poor soil for growing food. Soil must be brought in from outside sources for the first couple years before you can grow enough of your own compost. However, the possibilities offered by perennial agriculture far outweigh the challenges.

The perennial garden will continue to grow and Pillsbury United will continue to explore the economic possibilities as well as the environmental and social impacts that a perennial system can offer. This project paved the way for important questions for city planning regarding community health, city zoning for agricultural purposes, the importance of green spaces within the city, recycling urban waste streams, and community partnerships.

MANAGEMENT TIPS

1. Take a slower approach to installing a perennial system. Get to know the plants and their needs rather than a crash course on numerous new plants. Do extensive site prep. It takes a few years to establish good, weed free healthy soil and it is well worth the wait.
2. Educate everyone on how you would like things planted, even if they say that they understand, still show them the steps. I found that although people told me they had experience, some plants were planted way too deep and others too shallow. Do not give people more than one weed to pull/identify at a time. Even if they say they have planting experience, chances are they will pull things that are not supposed to be pulled unless you are simple and explicit.
3. Lay all potted plants out where you want them when working with a large group of volunteers for planting.
4. Do a weekly walk-through of the site without tools in your hand. This helped me notice things that were not working, catch pests or diseases at the start, and take time to enjoy my work.
5. Purchase a scale for each site. Volunteers can weigh and record everything immediately, so no data gets lost.
6. I know this will not pertain to everyone, but I like to give gifts of gratitude to the people who help me. They do not have to be expensive. It could be a simple thank you card, some flowers, a little chocolate treat (this is a favorite), or a cold lemonade on a hot day. It goes a long way.
7. Install drip irrigation on a timer if possible.
8. Invest in educational material (write into initial grant). Signage and rules (especially if you are in an urban area) help people know what is going on. It is beneficial to your project to set guidelines for the public and volunteers (Can they openly pick? Do you have hours that you are onsite? In our case, where does the food go? What type of research is being conducted?).
9. Plan to work outside of the traditional 9-5 hours if you want community involvement. This means nights and weekends.
10. Let everyone be involved. People want to feel useful, and they want to help. There is always something to do and gardening is very therapeutic.
11. Beer mash (spent grain from the brewing process) is free, readily available, and a wonderful garden amendment. It has increased our carbon stock dramatically, fulfills all our nitrogen needs, builds organic matter, and the smell keeps people out of the hoop houses.
12. I wish I had known more about fruit tree care and site preparation before beginning this project. Learning as you go is fine but be prepared to lose some species.
13. Rabbits can be an issue to woody species. They can take an entire bush to the ground. Install chicken fencing/ some protection around all plants.

COOPERATORS

Dr. Nic Jelinski, Department of Soil, Water and Climate, University of Minnesota, St. Paul, MN

Kat LaBine, University of Minnesota, St. Paul, MN

Jennifer Nicklay, University of Minnesota, St. Paul, MN

Jim Doten, Environmental Services, City of Minneapolis, Minneapolis, MN

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Maria Dahmus, Sustainable Communities Partnership Director, University of St. Thomas, St. Paul, MN

Julie Wisenhorn, University of Minnesota Extension, St. Paul, MN

Martha Schwehn Bardwell, Our Saviour's Lutheran Church, Minneapolis, MN

Melissa Anderson, 24th Street Farming Coalition, Native American Community and Development Institute, Minneapolis, MN

Steve Dryer, Ventura Village

Jenny Breen, Chef, Minneapolis, MN

Claire Baglien, Homegrown Minneapolis, Minneapolis, MN

OTHER RESOURCES

Agriculture's Role in Climate Change and Human Health. https://youtu.be/8jSdj8UGDRA

Bradley, Fern Marshall. Find It Fast: Answers for Your Vegetable Garden.

The Center for Agroforestry at the University of Missouri. Annual symposium, podcast, and resources for perennial farming. http://www.centerforagroforestry.org/

Environmental and Social Aspects of Urban Perennial Farming. https://youtu.be/0LdkYtQ3rsg

Farmer to farmer podcast.com: Interviews of farmers about their processes.

Homegrown Minneapolis. City of Minneapolis resource for community gardens. www.minneapolismn.gov/sustainability/homegrown

How to Make Your Yard Pollinator Friendly. Yard and Garden News | UMN Extension

Kimmerer, Robin Wall. Braiding Sweetgrass.

Kujawski, Jennifer. The Week-by-week Vegetable Gardener's Handbook: Make the Most of Your Growing Season.

Minnesota Extension. www.extension.umn.edu

- Karl Hakanson – Hennepin County Extension, khakanso@umn.edu
- Natalie Hoidal - hoida016@umn.edu
- Twin Cities Urban Growers Meetings

Minnesota Horticultural Society. Roseville, MN.

Permaculture Institute. https://permaculture.org

Pillsbury United Communities. Overview of urban agriculture program. https://www.youtube.com/watch?v=DJXtZI4OnmU

Savanna Institute. Information, webinars, conferences, and networking on perennial farming including an online guide to starting a perennial farm. https://www.savannainstitute.org/

Stone, Curtis. The Urban Farmer.

Toensmeier, Jacke, Dave, and Eric. Edible Forest Gardens. Volumes 1 and 2.

The Urban Agriculture Toolkit. https://alliance1.org/web/resources/pubs/maximizing-urban-agriculture-toolkit.aspx

Podcasts from all types of farmers. www.Urbanfarm.org

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
Alternative Markets and Specialty Crops		
2021	Peonies for Profitable Cut Flower Production in Northeastern Minnesota	Owl Forest Farm, Kate Paul
2020	Minnesota Hops Terroir Identification and Promotion	Mighty Axe Hops, Eric Sannerud
	Effects of Drip Irrigation on the Yields of Native Seed Production Plots	Blazing Star Gardens, Dustin Demmer
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

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
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
	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

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
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		
2021	Agrophenology Project	Wolf Ridge Environmental Learning Center, David Abazs
	Cover Crop Effects on Soil Temperature and Soil Moisture	Jerry and Nancy Ackermann
	Headwaters Agriculture Sustainability Partnership	Environmental Initiative, Sacah Seymour
	Perennial farming and carbon sequestration, ecosystem services and innovative entrepreneurship.	Mashkiikii Gitigan- contract w/ Pillsbury United Communities, Michele Manske
2020	Using Precision Ag Data to Maximize Economic and Environmental Benefits	Pheasants Forever, Tanner Bruse
	Impact of Two Tillage Types on Yield, Economic Profitability, and Soil Health in Polk County, MN	Minnesota Wheat Research and Promotion Council, Melissa Geiszler
2019	Interseeding Cover Crops and In Season Nitrogen Application in One Pass	Keith Hartmann
2018	Raising Soil pH Effectively in Acid Soils	David Abazs
	Soil Health Research in Southwest Minnesota	Jerry & Nancy Ackermann & Jan Voit
	Maximizing Profitability in a Modular Moveable Cathedral Hoop House	Megan Henry

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
	Perennial wheatgrass and legumes for cropping, grazing, and soil health `	Mike Jorgenson
	Interseeding 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
	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	Bois 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

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
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
	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

Completed Grant Projects

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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
	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

Completed Grant Projects

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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
	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

Completed Grant Projects

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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
	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

Completed Grant Projects

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Energy		
2020	Economic Feasibility of Spray Foam Insulation in a Hog Finishing Barn	Vande Ag Enterprises, Ryan Vandendriessche & Jordan Vandeputte
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		
2021	Cover Crop and Intercropping Alternatives During the Establishment Period of Perennial Fruit Crops	Richard Traugott
2020	Testing of a Non-traditional Process for Cleaning and Sorting MN Wine Grape Varietals	KISS LLC dba Brookview Winery, Arlyn Wall
	Testing Different Training Systems and Varieties to Improve the Profitability of Gooseberries	Good Courage Farm, Jen Blecha
	Evaluating Effectiveness of Sap Analysis to Increase High Tunnel Tomato Yield and Quality	The Good Acre, Andrew Bernhardt & David Van Eeckhout
2019	Developing an Annual Day-neutral Strawberry Planting System with Biodegradable Mulches	Steve Poppe, University of Minnesota
	Using Essential Oils to Repel Spotted Wing Drosophila in Blueberries	Blueberry Fields of Stillwater, Bev O'Connor
	Using Juneberries as a Cold Hardy Rootstock for Minnesota Pears	Thaddeus McCamant, Central Lakes College
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

Completed Grant Projects

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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
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

Completed Grant Projects

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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
	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 MN	John Fisher-Merritt
	Living Mulch, Organic Mulch, Bare Ground Comparison	Dan & Gilda Gieske

Completed Grant Projects

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Livestock		
2021	Testing Two Pasture Types to Finish Lambs on Pasture and an Evaluation of Meat Quality from Each	Keith and Anna Johnson Farm, Anna Johnson
2020	Comparison of Mobile Confinement and Day-range Production Systems for Pastured Broiler Chickens	Seelye Brook Farms, Randy Kleinman
2019	Goat Grazing During Winter in Minnesota: Controlling Vegetation While Saving on Feed Costs	John Beckwith, Hiawatha Valley Resource Conservation & Development
	Integrating Silvopasture Practices into Perennial Fruit Production	Jackie & Harry Hoch, Hoch Orchard
	Testing Three Novel Sheep-specific Pasture Types to Maximize Average Daily Gains in Lambs on Pasture	Anna Johnson
2018	Breeding, Selecting and Assessing Organically Grown Nutrient Dense Corn for Poultry Production	Zachary Paige & Sue Wika, Paradox Farm
	Trials to Overwinter Nucleus Colonies with a Pause in Brood Rearing	Four Seasons Apiaries, LLC, Joseph Meyer
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

Completed Grant Projects

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2005	Managing Hoops and Bedding and Sorting without Extra Labor	Steve Stassen
	Performance Comparison of Hoop Barns vs. Slatted Barns	Kent Dornink
	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

Completed Grant Projects

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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
	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

Completed Grant Projects

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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
1994	Economics of Rotational Grazing vs. Row Crops	Harold Tilstra
	Low Input Range Farrowing of Hogs	Larry Mumm

Completed Grant Projects

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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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