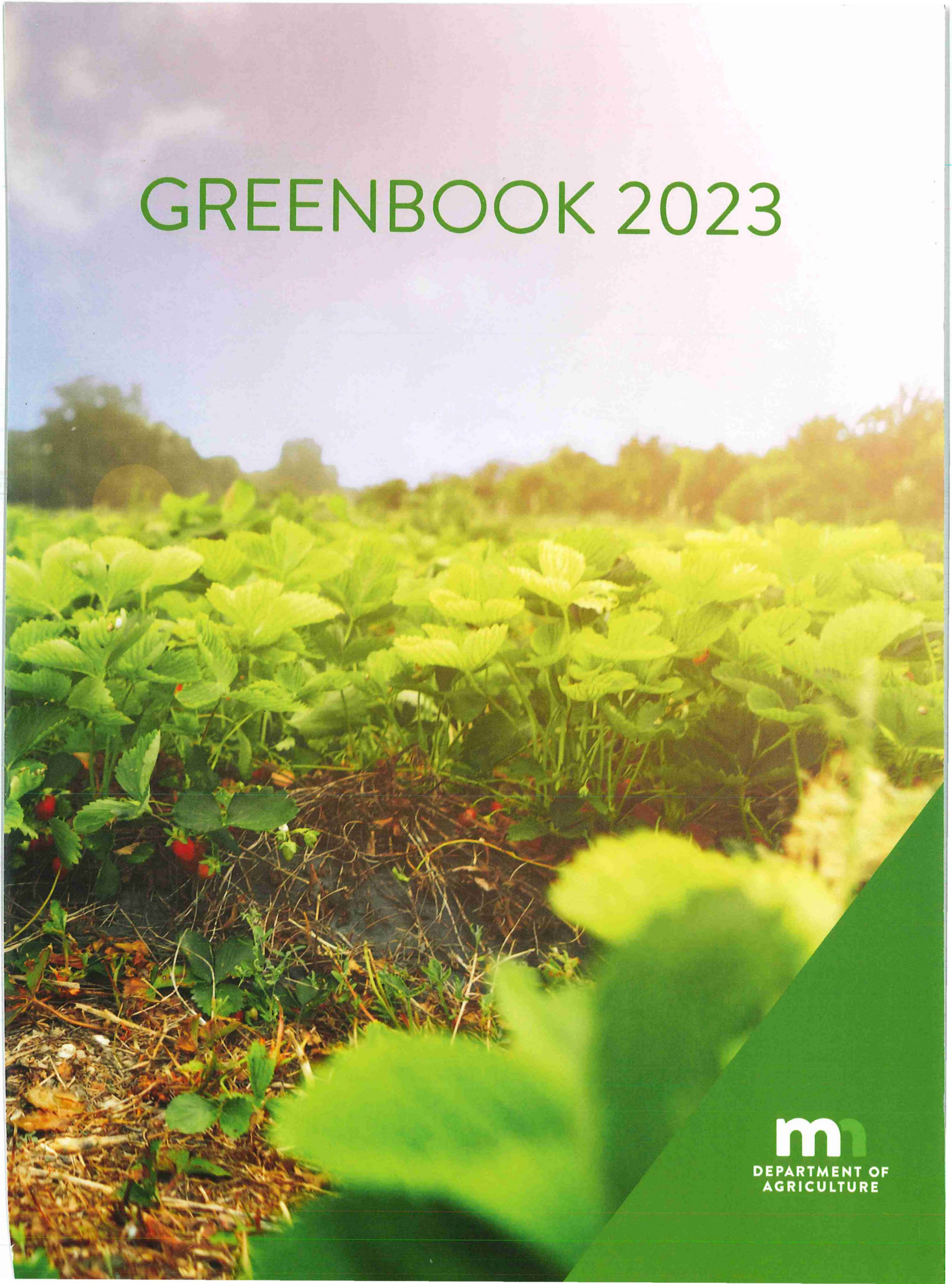
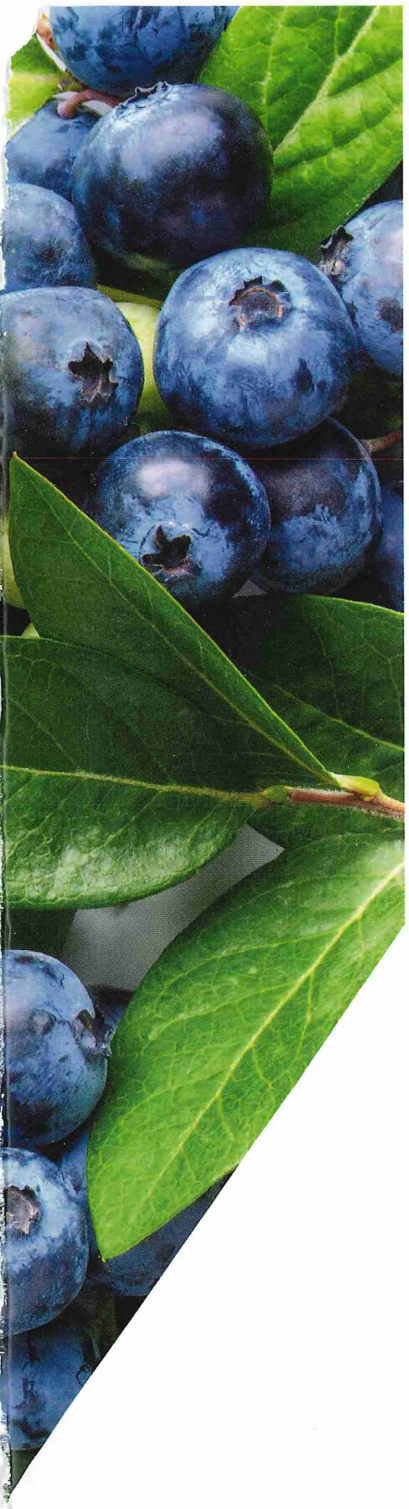
GREENBOOK 2023



DEPARTMENT OF AGRICULTURE



GREENBOOK
2023

On behalf of the Minnesota Department of Agriculture (MDA), it is my great pleasure to introduce the 2023 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 MDA's Agricultural Growth, Research, and Innovation (AGRI) Program. The projects presented here are great examples of the innovative ideas Minnesota farmers and researchers are studying to make farming in our state more productive and sustainable.

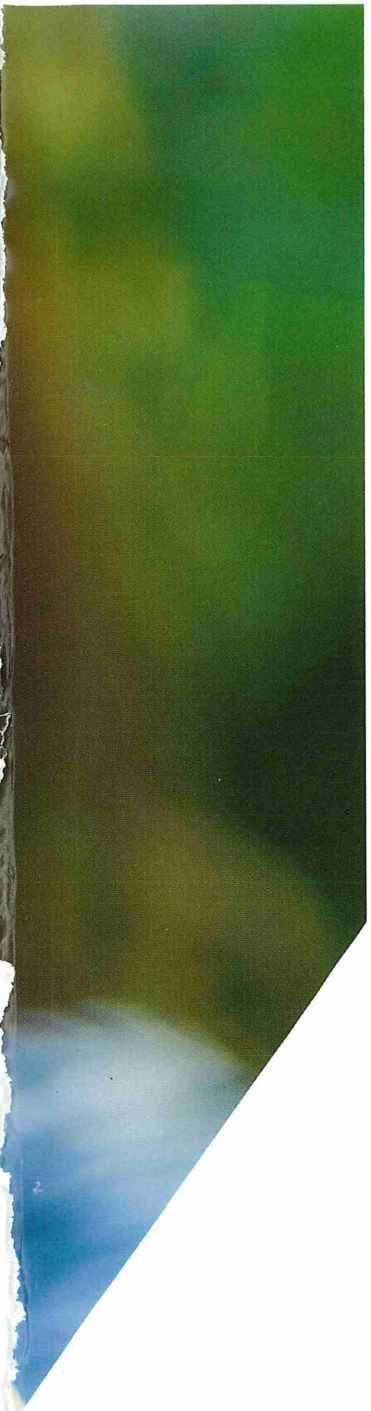
This year's grant recipients were awarded a total of $196,962.78 for forward-thinking initiatives that promote sustainability in agriculture. In the pages ahead, you'll read more about these projects that are exploring an ex citing and wide array of topics, from a comparison of no-till soil management methods to the viability of growing new specialty crops in Minnesota. The Sustainable Agriculture Demonstration Grant Program is dedicated to improving and shaping the future of ag; many previous grant projects have focused on practices that have become widely adopted, such as integrated pest management and cover cropping. I look forward to seeing how the practices being researched by 2023 grant recipients will be adopted in a similar way.

In Greenbook 2023, you'll learn about the successes and challenges an enthusiastic group of grantees have encountered while finding ways to increase energy and labor efficiency, reduce purchased inputs, and improve both the environment and farmers' profitability. In addition to descriptions of new projects, the Greenbook will present final reports on eight projects, as well as brief updates on the progress of ongoing projects from 2021-2022. To learn more about 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 grant 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



Minnesota Department of Agriculture
625 Robert Street North
Saint Paul, MN 55155

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MISSION STATEMENT

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

Our Sustainable Agriculture Demonstration Grants support innovative on-farm research and demonstrations. They fund projects that explore sustainable agriculture practices and systems that are likely to make farming more profitable, resource efficient, and personally satisfying.

In the Greenbook, 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 ongoing 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.

Sustainable Agriculture Grant Program

PROGRAM PURPOSE

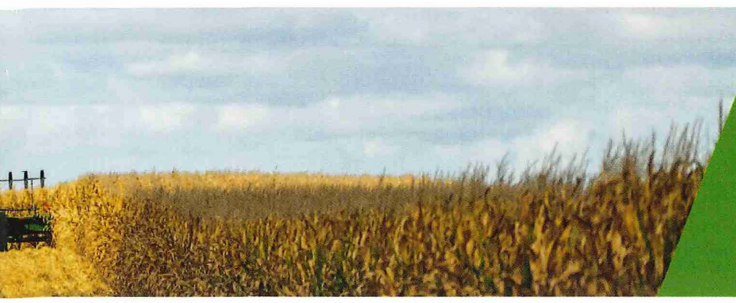
The Grant Program is designed to demonstrate and publicize the energy efficiency, environmental benefit, and profitability of sustainable agriculture techniques or systems from production through marketing. Grants fund research or demonstrations on Minnesota farms. Funding is from the Agricultural Growth,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

PROGRAM DESCRIPTION

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, agriculture 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 (1989-2023)

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	$256,891	$28,543	$9,644-46,937
2022	8	$241,757	$30,220	$7,314-38,629
2023	8	$196,963	$21,885	$13,413-50,000
Total Funded	**384**	**$5,099,755**	**$13,756**	**$1,000-50,000**

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

New Sustainable Agriculture Demonstration Grant Program

The following new demonstration grant project introductions describe the summaries and objectives for the projects in the first year of the grant.

ALTERNATIVE MARKETS AND SPECIALTY CROPS

Explore Methods to Benefit Cost and Production of Indigenous-Raised Meat Entering Local Halal Markets. Anishinaabe Agriculture Institute, Winona LaDuke

Viability of Peat-Free Soil Mixes for Potted Native Plant Production, Blazing Star Gardens, LLC, Dustin Demmer

Exploring the Value and Utility of Coppiced Hazel Wood in the Upper Midwest, Nine Hazels Farm, Paul Mairet

Growing Organic Wild Simulated Ginseng and Ginseng Seed Utilizing Sustainable Agroforestry Practices, North Circle Seeds, Zachary Paige

Establishment and Long-Term Health of Mixed Sainfoin and Meadow Fescue Stands in Non-Calcareous Soil, Fundamental Feed, LLC, Don Prohaska

SOIL FERTILITY

Comparison of No-Till Management Methods to Improve Poor Pasture, Bashcap Bend Farm, Holly Pearson DeVries

Composting the Past for the Future, Garden Magic, Melissa Borer

Applying Bionutrient Food Association Soil Health Principles to a Twin Cities Area Farm, Taylor Ventures, Oredola Taylor

New Sustainable Agriculture Demonstration Grant Program

Explore Methods to Benefit Cost and Production of Indigenous-Raised Meat Entering Local Halal Markets

Principal Investigator
Grantee: Winona LaDuke
Organization/Farm: Anishinaabe Agriculture Institute
Email: winona@anishinaabeagriculture.com
County: Wadena

Project Duration
2023-2026, 3 years

Award Amount
$50.000

PROJECT SUMMARY

The purpose of our project is to explore affordable pathways for goat and sheep meat to enter the halal market while employing the resourcefulness of Indigenous post-petroleum agriculture and exploring climate smart approaches to feeding animals and people. The importance of our project lies in filling a demand for culturally relevant food, with a local supply, raised by Native farmers. At present, the average goat consuming household is purchasing frozen goat meat shipped from New Zealand and Australia. We want to see the market localized and the regional access to foods secured. We want this food to be accessible to the general public yet still profitable for our farming and ranching operations.

There is also potential for goats in grazing opportunities available through the Minnesota agencies seeking to develop options for noxious weed management. By starting to employ this type of land management into our farm systems, we will gain experience that will prepare us for future income-generating opportunities. Lastly, we hope the successes of our project, demonstrating sustainable methods, will inspire neighboring farmers who have expressed difficulty in finding a way around the use of industrial agriculture practices. We are excited about the potential of regenerative agriculture to restore land that has been cleared of its biodiversity, and to build a resilient land base for rural and urban communities.

PRIMARY OBJECTIVES

1. Focus on exploring marketing options to make goat meat affordable and accessible to the Muslim community in Minnesota.
2. Focus on integrating hay, grain, fiber, and high-density grazing from operations at our other farm sites into animal diets, both to supplement the nutrition of our goats and also to further reduce fossil-fuel emissions and costs.

No-Till Management Methods to Improve Poor Pasture

Principal Investigator
Grantee: Holly Pearson DeVries
Organization/Farm: Bashcap Bend Farm LLC
Email: bashcapbend@gmail.com
County: Isanti

Project Duration
2023-2025, 2 years

Award Amount
$13,413.81

PROJECT SUMMARY

The purpose of this project is to compare three no-till management methods for improving soil health and pasture quality side-by-side to see what is the most efficient way to see forage improvement. The information from this project will help other farms and conservation professionals make better decisions about which no-till methods could work to improve and restore their land. We are passionate about putting carbon in the ground. This project aims to improve soil and forage quality, allowing for more successful grazing which also improves farm profitability.

PRIMARY OBJECTIVES

1. Improve farm profitability by demonstrating low-input methods of pasture improvement.
2. Increase forage quality and carrying capacity of our pastures.

New Sustainable Agriculture Demonstration Grant Program

Viability of Peat-Free Soil Mixes for Potted Native Plant Production

Principal Investigator
Grantee: Dustin Demmer
Organization/Farm: Blazing Star Gardens LLC
Email: dustin@blazingstargardens.com
County: Steele

Project Duration
2023-2025, 2 years

Award Amount
$18,039.20

PROJECT SUMMARY

The purpose of this project is to research alternatives to peat-based soil mixes for potted native plant production. Greenhouses most commonly use sphagnum peat-based soil mixes for growing perennials and annuals in pots and other containers.

There is a growing movement to move away from peat-based soil mixes in horticulture because of adverse environmental impacts. The peat bogs where peat moss is harvested have been identified as an important store of atmospheric carbon, and the draining, harvesting, and production of peat-based soil mixes is contributing to the release of this stored carbon — a major greenhouse gas — back into the atmosphere. There are also concerns about habitat destruction and the sustainability of peat bog harvesting since it regrows very slowly. Customers are becoming more aware of these issues and have voiced their concerns to us. It is important that we research peat-free soil alternatives to not only reduce our adverse environmental impacts but to also listen to what customers want.

We hope our project can help other plant growers in Minnesota by researching and documenting different peat-free soil mixes and how well plants grow in them. By researching peat-free soil mixes in the production of native perennial plants, we will try to get ahead of the curve and provide customers with quality plants grown in a more sustainable growing medium.

PRIMARY OBJECTIVES

1. Create two peat-free soil mixes for testing by mixing peat alternatives with other common soil mix components such as perlite, bark, and fertilizer.
2. Test the efficacy of the two new soil mixes in 3 inch pots and plug trays against the standard peat-based potting mix.

Establishment and Long-Term Health of Mixed Sainfoin and Meadow Fescue Stands in Non-Calcareous Soil

Principal Investigator
Grantee: Don Prohaska
Organization/Farm: Fundamental Feed LLC
Email: donprohaskahealer@gmail.com
County: Dodge

Project Duration
2023-2026, 3 years

Award Amount
$24,718.00

PROJECT SUMMARY

Sainfoin, known colloquially as holy hay, is a legume that was well known for its advantageous qualities and widely grown and used for horses preceding the industrialization of agriculture. However, the transition period of the Third Agricultural Revolution (The Green Revolution) during the 1950s and 1960s saw the popularity of high-yield crop varieties, chemical fertilizers and herbicides, and the mechanization of farming become the norm. Because sainfoin did not have the same potential yield of other crops and did not grow well in a chemically altered environment, it fell out of favor. Now, with the advent of the AAC Glenview seed and some similar varieties, it is seeing a renaissance with farmers and consumers as they realize the innumerable benefits of sainfoin respective to its competitors.

Sainfoin is also a beneficial crop for small farms that lack the resources to compete with large-scale operations. It does not require nitrogen fertilizers due to its nitrogen-fixing capabilities, and the AAC Glenview seed has higher regrowth potential. A clear method for successful stand establishment is needed to help bring that information to farmers and consumers alike. Sainfoin has many great qualities that make it a top choice for health and nutrition as well as a sustainable crop of the present and future.

PRIMARY OBJECTIVES

1. Demonstrate the viability of sainfoin as a forage crop in Minnesota.
2. Develop recommendations for seeding and fertilization rates for new sainfoin plantings.
3. Determine baseline soil health measurements for future plot development and testing.

New Sustainable Agriculture Demonstration Grant Program

Composting the Past for the Future

Principal Investigator
Grantee: Melissa Borer
Organization/Farm: Garden Magic
Email: Melissa.Borer@gmail.com
County: St. Louis

Project Duration
2023-2025, 2 years

Award Amount
$23,457.00

PROJECT SUMMARY

The purpose of this project is to develop multiple compost products from Garden Magic's existing composted material. We currently produce Grade B compost, which is considered "fill" compost. We will further develop this enterprise to create Grade A compost, and a compost tea for people to use as foliage spray. Grade A compost is compost that has been finely sifted and is a generally more standardized nutrient level and overall cleaner/sought after product.

The Grade A compost will benefit our existing customers that are looking for a cleaner, finer product, as well as the orchardists that we support with a foliage spray. Our work doesn't just support farm businesses. This project also supports other businesses by relieving them of their waste, which can be a huge expense for them.

PRIMARY OBJECTIVES

1. Increase the amount of compost we can produce and prevent organic material from entering the waste stream.
2. Develop Grade A sifted soil that can be used for potting soil and/or garden top dressing, as well as a compost tea and foliage spray for orchardists and local garden keepers.
3. Demonstrate on-farm composting and compost tea production that can be used by other small farms.

Exploring the Value and Utility of Coppiced Hazel Wood in the Upper Midwest

Principal Investigator
Grantee: Paul Mairet
Organization/Farm: Nine Hazels Farm
Email: ninehazelsfarm@gmail.com
County: Wabasha

Project Duration
2023-2026, 3 years

Award Amount
$17,913.65

PROJECT SUMMARY

This project will provide information to help growers determine whether using/selling their coppiced hazel wood and/or craft products is of greater value than other options such as renting a forestry mulcher for their coppicing needs, giving them a functional crafting guide should they decide to explore options further. As we work to develop a sustainable production system for hybrid hazels, investigating the potential of value-added products derived from already present renewable resources and maintenance activities benefits all farms involved with or considering hybrid hazels.

The practice of cyclical coppicing and crafting appears uncommon in the U.S. currently, but its potential role in sustainable agriculture is tremendous. We will determine which traditional crafts are suited to hybrid hazels and also investigate novel uses. As interest in coppice craft and hybrid hazels grows in the U.S., this project will make an increasingly valuable contribution to sustainable agriculture.

PRIMARY OBJECTIVES

1. Coppice (cut to the ground) hazel plants and detemine the size and number of usable rods per plant.
2. Produce at least five different craft prototypes and test markets for various products.
3. Develop a guide to crafting with coppiced hazel wood to distribute to the public.

New Sustainable Agriculture Demonstration Grant Program

Growing Organic Wild Simulated Ginseng and Ginseng Seed Utilizing Sustainable Agroforestry Practices

Principal Investigator
Grantee: Zachary Paige
Organization/Farm: North Circle Seeds
Email: zacharypaige@gmail.com
County: Otter Tail, Becker, and the White Earth Reservation

Project Duration
2023-2026, 3 years

Award Amount
$25,390.32

PROJECT SUMMARY

Wild ginseng (Panax quinquefolius), also known as American ginseng, was once abundant in Minnesota. From 1859 to 1862, there was a 'Ginseng Rush' that exported over 200,000 pounds from Minnesota each year. However, in part due to this mass over-harvesting, ginseng has currently become a species of "special concern" in the state, meaning it is extremely uncommon in Minnesota and has unique or highly specific habitat requirements that deserve careful monitoring of its stature. The purpose of this project is to bring ginseng back to Minnesota utilizing the original sustainable practices used by the Ojibwe, Dakota, and other Native American tribes in Minnesota territory for hundreds of years.

After establishing a ginseng plot on North Circle Seeds farm, we will further increase ginseng dispersal through seed and root distribution to Minnesota growers, along with educational resources on regulations on how to market, sell, and plant in our Minnesota climate. Multiple and compounded benefits of growing ginseng will include:

- Utilizing land that was not previously utilized for farming.
- Benefiting from ginseng for family health
- Increasing the sustainable cultivation of a high-value, sustainably grown crop into a Minnesota landscape.
- Increasing plant populations through seeding.
- Educating by writing UMN Extension articles and publications.

PRIMARY OBJECTIVES

1. Train two to four farmers annually in the growing and cultivation of ginseng.
2. Host annual field days throughout the project to demonstrate the cultivation of ginseng on the farm.
3. Present findings at the Indigenous Farming Conference and equip up to 30 attendees with the materials needed to plant their own ginseng.

Applying Bionutrient Food Association Soil Health Principles to a Twin Cities Area Farm

Principal Investigator
Grantee: Oredola Taylor
Organization/Farm: Taylor Ventures
Email: taylorventures@zohomail.com
Counties: Washington, Chisago

Project Duration
2023-2025, 2 years

Award Amount
$24,030.80

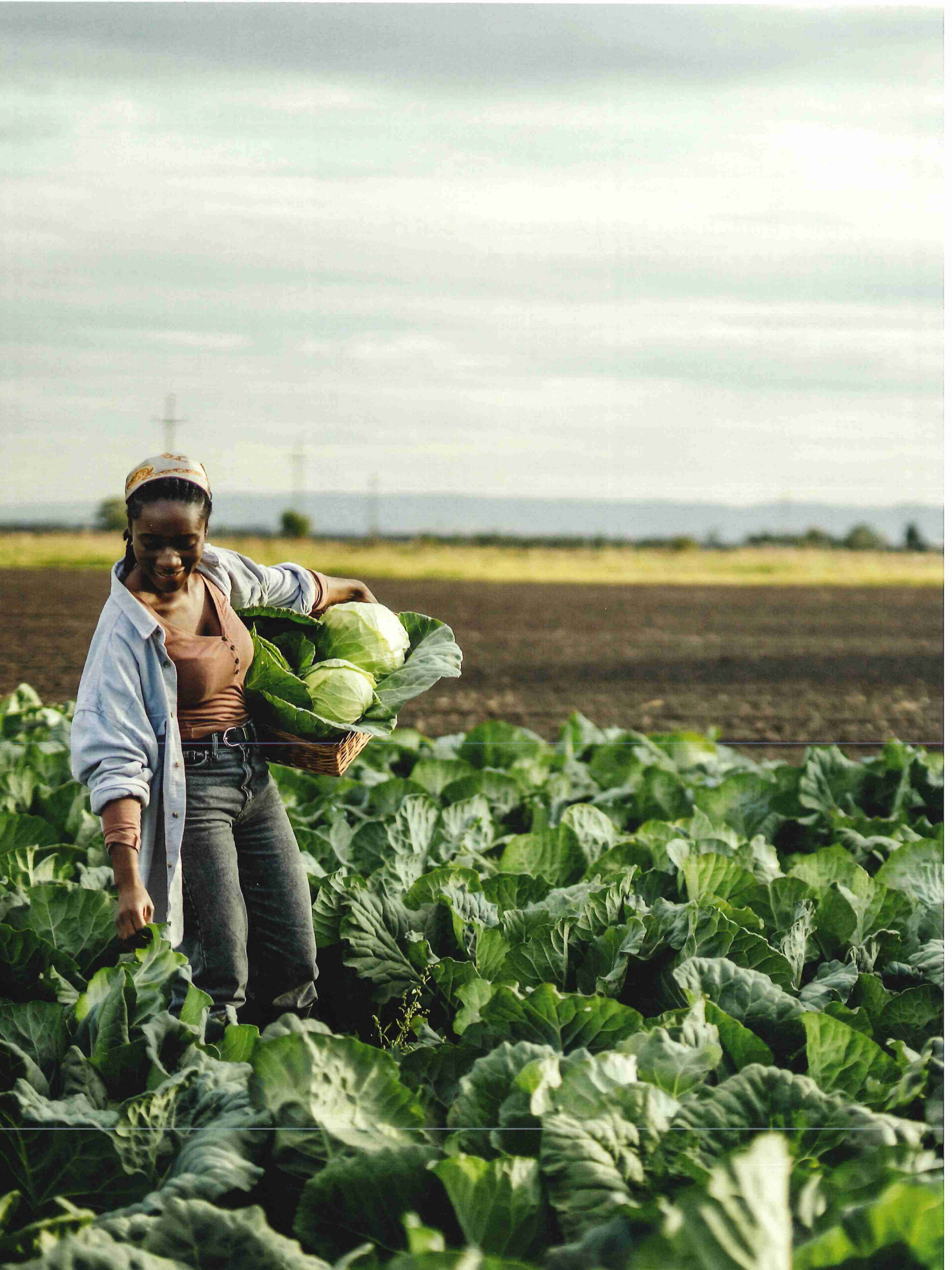
PROJECT SUMMARY

The Bionutrient Food Association (BFA) is a nonprofit organization established in 2010. Partnered with organizations like USDA, it is at the forefront of educating growers about how creating healthier soil ecosystems results in healthier plants. Plants grown using BFA principles give higher-quality food in terms of flavor, aroma, and shelf life with the full spectrum of micronutrients required to positively impact consumer health. These same micronutrients contained in the plants make them more pest and disease resistant, resulting in greater yields and lower costs of production. As the plant becomes more nutritious, it incorporates complex molecules that make it indigestible to organisms like insects, fungus, and bacterial pests.

Bionutrient Food Association principles are environmentally sound. They promote only organic matter and naturally occurring minerals for soil nutrition and no chemical fertilizers, fungicides, herbicides, etc. The association promotes minimal soil disturbance and practices that maximize the soil's water retention capability.

PRIMARY OBJECTIVES

1. Apply Bionutrient Food Association (BFA) practices to demonstrate measurable increases in crop nutrient density, disease resistance, and increases in yield.
2. Share the BFA principles with other farmers through discussions and demonstrations.



Sustainable Agriculture Demonstration Grant Project Updates 2021-2022

The following 2021 and 2022 project updates describe the project design and activities conducted during the first and/or second year of the grant project. To find out more details about these projects, contact the principal investigators.

ALTERNATIVE MARKETS AND SPECIALTY CROPS

Developing The Right Seed Mix for Solar Grazing in Minnesota
Grantee: Cannon Valley Graziers, Arlo Cristofaro-Hark

Baseline Carbon Market Value of Intermediate Wheatgrass
Grantee: Great River Greening, Brad Gordon

Specialty Crop and Season Extension Research by Emerging Farmers
Grantee: Prairie Rose Farm, Verna Kragnes

Increasing Harvesting & Processing of Wild Rice & Other Small Grains for Small-Scale Growers
Grantee: Friends of Finland, Honor Schauland

FRUITS AND VEGETABLES

Tomato phosphorus removal rates with high- or low-phosphorus transplant solutions and grafting
Grantee: University of Minnesota, Charles Rohwer

Documenting Temperatures on Fruit Trees in Winter Protection
Grantee: Stone Creek Farm, Daniel Sheild

On Farm Research on Honeyberry Production
Grantee: Walking Plants Orchard, Philip Stowe

CROPPING SYSTEMS

Farming Practices for Improved Soil Health: An Evaluation of the Impact of No-Till with Chemical Control of Weeds vs. Super-Shallow Tillage and No Chemical Control of Weeds on Soil Health
Grantee: University of Minnesota-Crookston, Katy Chapman and Lindsay Pease

Evaluating Soil Health and Farm Profitability with Perennials and Poultry in Corn Production Systems
Grantee: Minnesota State University, Mankato, Mriganka De

No-Till Vs. Conventional-Till for Alfalfa Hay Establishment and Production for a 3-Year Stand,
Grantee: McCormick Farm, Connor McCormick

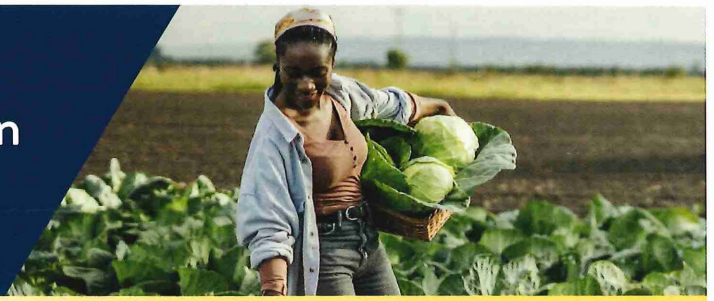
Interseeding Clover Into Pumpkins
Grantee: University of Minnesota, Charles Rohwer

SOIL FERTILITY

Understanding the Possibilities of On-Farm Compost to Reduce or Eliminate Commercial Fertilizer
Grantee: Olsen Custom Farms, Chad Olsen

Crop & Livestock Farmers Building Biodiverse, Aerobic Composts Using the Johnson-Su Method
Grantee: Land Stewardship Project, Shona Snater

Sustainable Agriculture Demonstration Grant Project Updates



Increasing Harvesting and Processing of Wild Rice and Other Small Grains for Small-Scale Growers in Northeastern Minnesota

Principal Investigator
Grantee: Honor Schauland
Organization/Farm: Friends of Finland
Email: honor@friendsoffinland.org
Counties: Cook, Lake, Saint Louis

Project Duration
2021-2024, 3 years

Award Amount
$35,769.00

PROJECT SUMMARY

Traditional wild rice harvesters and processors are getting older, retiring, and/or passing on, taking with them generational knowledge and skills. Consequently, wild ricers are traveling further afield for processing, leading to a reduced interest in wild rice harvesting. Harvesting wild rice requires knowledge of wild rice populations, identifying the correct stage for harvesting, knowing diseases to avoid, and practicing sustainable harvesting techniques. Similarly, processing wild rice requires precision to dry, parch, and dehull the rice while ending with a quality product. The Finland Food Chain was a project formed in 2018 with the goal to support the development of a comprehensive local food system for the Finland area and the greater Arrowhead region of Minnesota. It will cultivate a new generation of sustainable wild ricers and processors through classes, mentoring, and apprenticeships while exploring dual-economic benefits of off-season small grain processing. In this work, we will facilitate intergenerational transfer of knowledge, skills, equipment, and cultural appreciation for the economic, physical, and spiritual sustenance that wild rice provides for future generations.

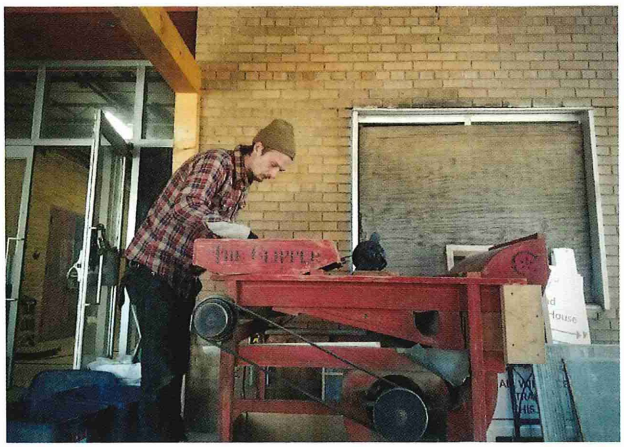
PROJECT DESCRIPTION

The project is intended to support small-scale diversified farms in northeast Minnesota that aspire to add wild rice and other small grains to their farm enterprises. Wild rice (manoomin/psin) is a high-value, high-quality grain that also carries immense cultural value, as it has been considered sacred and central to indigenous cultures (Anishinaabeg and Dakota) in Minnesota and the Great Lakes region for millennia and an important food source for European settlers and homesteaders for the past two centuries. Tribal and non-tribal elders are repositories of the skills needed for harvesting & processing, as well as knowledge related to wild rice ecology and the stewardship practices that are needed to sustainably harvest this important wild crop. The passing of this generation is ongoing, leading to an increased risk of losing these lessons. We intend to harness them before they are lost, through mentorship and education modules to be reproduced and shared as a public resource. Other small grains for human consumption are also in great demand; however, growers are limited by a lack of grain processing capacity for small producers. Small-grain production was once a part of northeast Minnesota agriculture, and regional food resilience requires it once again. This project will test and demonstrate the technical and financial feasibility of utilizing our wild rice processing equipment with other small grains, placing particular emphasis on small-scale growers and grains typically grown in our region.

Sustainable Agriculture Demonstration Grant Project Updates

OBJECTIVES

1. Initiate and facilitate a mentor/apprenticeship program. 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. Research and test the feasibility of wild rice processing equipment to process small grains with support from regional growers. 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.
3. Develop education modules to further reinforce the transfer of intergenerational knowledge and skills to ensure continuity into the future. The diversity of methods and equipment used by wild rice harvesters and processors, along with personal and cultural perspectives, will be reflected in 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.



Adjusting rice processing equipment.

Project participants carving wild rice/manoomin knocking sticks

2022 RESULTS

In the beginning of 2022, the Manoomin/Wild Rice Project began increasing publicity and recruitment for the second year of the mentorship program, and as a result, this objective took front stage in the project this year. Informational brochures were designed, online forms were created and shared through posts on Facebook and the program website (finlandwildrice.com), interviews for applicants were written, and sign-up sheets became available at all public community events. Nineteen mentees and seven mentors participated in the program. Of those mentees, all but three were under the age of 50, and most reside permanently in the Arrowhead region of Minnesota. A full weekend of workshops and

Checking wild rice/manoomin for maturity.

Sustainable Agriculture Demonstration Grant Project Updates

Parching wild rice after harvesting.

events was held and offered to mentees leading up to the ricing season, which was attended by 16 adults and five children. Five processing apprenticeship openings were then advertised and almost immediately filled by full or part-time local residents. Each apprenticeship provided five days of onsite training at the Manoomin/Wild Rice House, our processing facility. All three of the mentees from 2021 ended up going out on their own in 2022.

The Finland Wild Rice House processing facility was built for this project in 2021. As the first year in operation under the new timber frame awning, with both parchers running and extra help from the team of apprentices, 2022 saw a dramatic increase in business and activity. By the end of the harvest season, our team had parched, dehulled, and separated over 13,000 pounds of rice, up from only 2,000 pounds in the first year. Throughout the season, there were five tours given of the processing facility, and two of those outreach events inadvertently resulted in some of the bigger insights and successes gained in 2022 in regards to the small grains objective. One of the tours was given to 25 farmers attending the Finland Farm Tour, hosted by the Lake Superior Sustainable Farming Association. Connections were made there that led to another tour, given to a Sustainable Food Systems undergraduate class from the University of Minnesota (UMN) Duluth campus, where five students chose the Manoomin/Wild Rice Project and its small grains processing objective as the topic for their semester project. They worked with the project coordinator to identify a need for input from local farmers, and then conducted interviews and research to answer questions that would help the project refine its focus for 2023. The findings that were most helpful were those that identified which grains are specifically most desired by farmers in the area, and which equipment would be needed to make efficient processing a reality here. There were also several new small grain/food crops presented by a participating farmer, Kaare Melby, to the processor for testing, including winter wheat, rye, and sunflower seeds. The first two showed enough potential for efficient processing through the manoomin/wild rice machines that Melby and David Abazs (Round River Farm) started planning for next year's crop on a bigger scale.

The educational series started strong in 2022 with a webinar presentation by (then) project coordinator Abby Roweder at the UMN Horticulture Seminar, titled "Manoomin/Wild Rice in Finland, Minnesota: Building Bridges Between Communities to Save the Staple Grain." Many connections and tentative plans had been made the previous year for other internet-based learning events. However, with the easing of COVID-19 tensions, the changing of project coordinators, and the arrival of warmer weather, the focus of the program naturally shifted toward more in-person events. The modules presented consisted of:

- Manoomin/wild rice-related demonstrations held for the public at the Finland Farmers' Market:How to "Puff" Manoomin/Wild Rice (led by the 1854 Treaty Authority), How to Make Fried Manoomin/Wild Rice Cakes (led by Dan Cahill Matthews and new project coordinator Meghan Mitchell), and Ricing 101 and Equipment Basics.

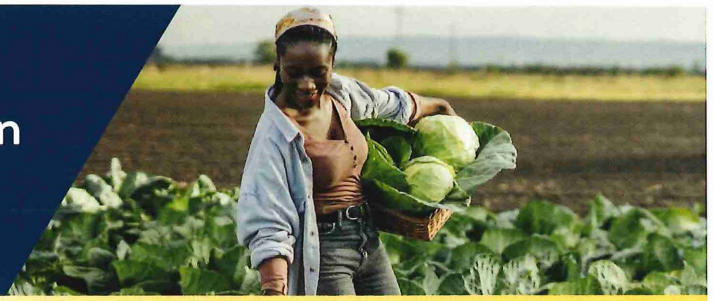
Sustainable Agriculture Demonstration Grant Project Updates

- Post-season taste-testing demo showing the difference between cultivated paddy rice and real manoomin/wild rice.
- One instructional video (created for and distributed to mentees) on how to prepare for ricing season.
- Two days of classes, workshops, and events held for mentees including: Ricing 101, Scouting Basics, Push Pole Harvesting, Ricing Responsibly, Push Pole and Knocker Carving, and others.
- Four informational tours given of the processing facility and its machines.

In December, a strategic planning meeting was held with the project coordinator and four other collaborators to brainstorm and plan for a more diverse and inclusive educational series in the final year of the project, with a goal to include topics that create bridges and links to connect community members with already existing learning opportunities, especially those involving area tribal communities and organizations.

Ricing in canoes.

Sustainable Agriculture Demonstration Grant Project Updates



Crop & Livestock Farmers Building Biodiverse, Aerobic Composts Using the Johnson-Su Method

Principal Investigator
Grantee: Olivia Blanchflower
Organization/Farm: Land Stewardship Project
Email: oblanchflower@landstewardshipproject.org
Counties: Scott, Mower, Winona

Project Duration
2021-2023, 3 years

Award Amount
$46,937.22

PROJECT SUMMARY

The Land Stewardship Project (LSP) is working with four farms in Minnesota over two and a half years to build biodiverse composts through the Johnson-Su method using materials readily available on farms. Revitalizing the soil with a wide range of beneficial microbes holds many environmental potentials as well as economic savings for the farmer. The goals of this project are to:

- Utilize ingredients commonly found on farms to develop and test compost recipes that promote the growth of beneficial soil microbes in an aerobic, static compost system that undergoes a full heating cycle.
- Compare our Johnson-Su test results to standard, industrial-turned composts to show the difference in soil microbial make-up.
- Conduct outreach to hundreds of farmers to promote the Johnson-Su method and share our detailed recipes and best practices to help interested farmers enhance the biology of their soils using a tested and accessible method.

PROJECT DESCRIPTION

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 impact large acreages either by coating seeds or applying a liquid extract in the seed trench during planting. Currently, there are many private companies offering "microbial inoculant" products to farmers. The Land Stewardship Project (LSP) is interested in developing ways to make high-quality, bio-diverse inoculants using materials found on Minnesota farms. One of the most promising methods is Biologically Enhanced Agricultural Management, developed by Dr. David Johnson and Hui-Chun Su, which uses a bioreactor to create a static aerobic compost that requires limited management and very little use of large equipment, water, and energy, and can produce microbially diverse and fungally dominant communities.

Sustainable Agriculture Demonstration Grant Project Updates

The Johnson-Su bioreactor method was developed in New Mexico with locally sourced materials. Therefore, recipe testing is necessary to use this method with materials available to Minnesota farmers. It is important that the compost have a balanced carbon to nitrogen ratio adequate for a full heating cycle up to 165 degrees Fahrenheit, but not so nitrogen-heavy as to cause anaerobic conditions. Compost must undergo a heating cycle to kill pathogens, terminate weed seeds, and promote the growth of beneficial microbes. Farmers currently using this system are having difficulty finding this balance.

LSP's project seeks to fill in this missing information by developing multiple, measurement-specific compost recipes that utilize materials available to Minnesota farmers and will result in an aerobic, thermal, biodiverse, and bio-dense compost. The clear and proven recipes developed under this project will reduce the learning curve for farmers seeking to implement the Johnson-Su method in our state.

DESIGN

LSP staff, along with five farmer-members of the organization, constructed aerobic compost bioreactors following the Johnson-Su Composting bioreactor method. Four of the five farmers/couples — Tom Cotter, Dale and Carmene Pangrac, Jon and Ruth Jovaag, and Wazupi Tribal Gardens, — live and farm in Minnesota and used compost-starting materials geographically accessible to their farms. With the help of LSP soil health organizers, each farmer built two Johnson-Su composting bioreactors on their farms in 2021 and two more in 2022, resulting in 10 compost recipes replicated twice for a total of 20 compost bioreactors over the course of the grant. Analysis of the resulting composts included direct microscopy and genetic sequencing at about the fourth or fifth month of the composting process and after one year.

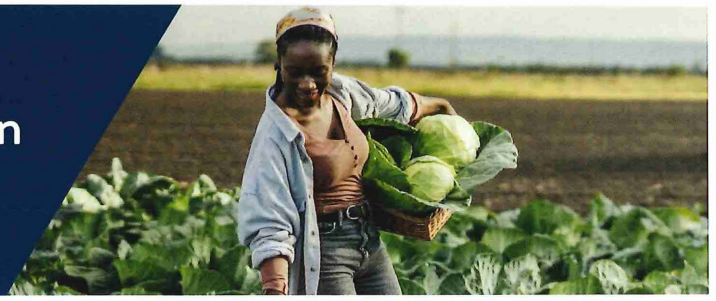
PRIMARY OBJECTIVES

1. Develop Johnson-Su compost recipes using locally available materials.
2. Compare biodiversity of microbes in composts developed under this project with commercially available composts.
3. Promote the findings of the project among farmers in Minnesota.

2022 RESULTS

LSP's farmer-led project to develop Johnson-Su compost recipes using locally available materials is part of an emerging area of focus for sustainable agriculture in our region. This year, LSP received the first genetic sequencing results from eight bioreactors on four participating farms. While these are early results from a small sample size, the analysis of compost developed under this project is encouraging.

Sustainable Agriculture Demonstration Grant Project Updates



Key findings:

Seven out of eight bioreactors showed good nutrient cycling and six out of eight showed moderate to ideal ratios of bacteria to fungi.

- The bioreactors Jovaag 1, Pangrac 2, Good Turn 1, Wozupi 1, and the Preston woodchip compost provided good numbers of protozoa and nematode populations and yielded the overall best composts in terms of microbe diversity.
- One of our bioreactors, Pangrac 2, despite being outside of the ideal range for bacteria to fungi ratios, hit benchmarks for numbers of flagellates, amoebas, ciliates, and nematodes.

Table 1. A table featuring the results of the Soil Food Web Lab (SFWL) in New York and their analysis of soil microbiology.

BIOREACTOR ID	JOVAAG 1	JOVAAG 2	PANGRAC 1	PANGRAC 2	GOOD TURN 1	GOOD TURN 2
Compost Ingredient Ratios	1 Chicken Bedpack: 1 Sheep Bedpack: 1 Pig Bedpack	1 Pig Manure: 1 Wood Chips: 1 Soil	1 Hay: 1 Cow Manure: 1 Barley Straw: 1 Compost Bedpack	1 Bedpack: 1 Forest Soil: 1 Cow Manure: 1 Corn Stalks	1 Forest Soil: 1 Leaves: 1 Bale (grass/alfalfa mix): 1 Rye Straw	1 Forest Soil: 1 Leaves: 1 Bedpack: 1 Rye Straw
Biomass of Total Fungi µg/g	2,495.87	2,831.68	1,403.93	1,162.11	1,784.14	853.59
Biomass of Total Bacteria µg/g	1,861.69	1,808.8	1,791.69	1,711.05	1,400.98	1,413.72
Fungi:Bacteria Ratios	1.34	1.57	0.78	0.68	1.27	0.60
Flagellate Count #/g	102,228.45	138,676.6	142,244.12	165,191.46	75,057.72	116,066.89
Amoeba Count #/g	2,120.08	8,348.9	8,563.68	20,636.38	3,752.07	11,606.69
Ciliate Count #/g	51.62	17,324.04	1,775.74	100.42	157.01	14,499.54
Nematode Count #/g	8.68	281.92	9.88	16.92	39.45	9.01
Peak Temperature	140	100	98	85	140	140
Lab Notes:	Nutrient cycling is excellent, but protozoan diversity should be more balanced.	Nutrient cycling is good, and fagellates levels are very high. Ciliate levels are very high, which indicates there are anaerobic conditions in the pile.	Aq1	Protozoan populations and nutrient cycling are excellent.	Nutrient cycling is good, but protozoan diversity should be more balanced. Excellent nematode population is present, but diversity should be better.	Nutrient cycling is good, and fagellates and amoebae levels are very high. Ciliate levels are very high, which indicates there are anaerobic conditions in the pile.

Key items to notice are the fungi to bacteria ratio, for which it is ideal to have a ratio of 1 or higher. High numbers of ciliates indicate anaerobic compost and the potential of pathogens.

- In general, bioreactor composts showed higher diversity of fungi than industrially produced composts. Interesting to note that while high loads of fungi were reported in the Cowsmo compost Soil Food Web Lab (SFWL) results, the diversity of the fungal species was considerably lower than the bioreactor composts according to the University of Minnesota Genomics DNA sequencing. This indicates that while numbers may be high for industrial composts in the microbial counts, this measure does not give a clear picture of diversity for fungi, bacteria, and protozoa.

COTTER 1	COTTER 2	WOZUPI 1	WOZUPI 2	VERMONT COMPOST	COWSMO COMPOST	PRESTON COMPOST	ORGANISM COUNT IDEALS
1 Worm Compost: 2 Wood Chips: 1 Cattle Manure: 1 Corn Stalks: 1 Fresh Hay: 5 gallon bucket soil innoculant	1 Worm Compost: 1 CRP straw: 2 Wood Chips: 1 Chicken Manure: 5 gallon bucket wood soil innoculant: 1 Fresh Hay	1 Chicken Manure: 1 Chicken Compost: .5 Wood Fines: .5 Potting Soil: 4 flats Pea Shoot Leftovers : 4 cups Carp Liquid	1 Chicken Manure: 1 Chicken Compost: .5 Wood Fines: 1 Native Prairie Straw: 4 flats pea shoots: 5 gallon bucket with fish	Multi-manurail compost (turned)	Cow Manure Compost (turned)	woodchips compost (static)	
979.89	786.2	830.15	783.81	763.74	1,272.79	1,150.37	>300
1,541.16	1,037.85	1,365.91	1102.9	1,472.63	1,935.45	2,070.6	>300
0.64	0.76	0.61	0.71	0.52	0.66	0.56	
86,372.34	82,501.36	60,226.73	59,040.07	114,877.78	97,441.66	84,923.97	>10,000
2,599.05	4,966.92	614.74	5,904.86	690.86	16,187.56	25,477.8	>10,000
1,078.25	2,482.56	0	979.53	0	4,871.03	42.88	<649
2.94	0.67	5.1	3.32	6.86	9.45	4.76	>10
missing	missing	111	103	n/a	n/a	n/a	
Nutrient cycling is good, but protozoan diversity should be more balanced.	Nutrient cycling is good, but protozoan diversity should be more balanced.	A better diversity of protozoa is needed but the very high levels of fagellates are providing good nutrient cycling.	A better diversity of protozoa is needed but the high levels of fagellates is providing very good nutrient cycling.	A better diversity of protozoa is needed but the very high levels of fagellates are providing good nutrient cycling.	Excellent protozoan populations are leading to very good nutrient cycling.	Excellent protozoan populations are leading to very good nutrient cycling.	

Sustainable Agriculture Demonstration Grant Project Updates

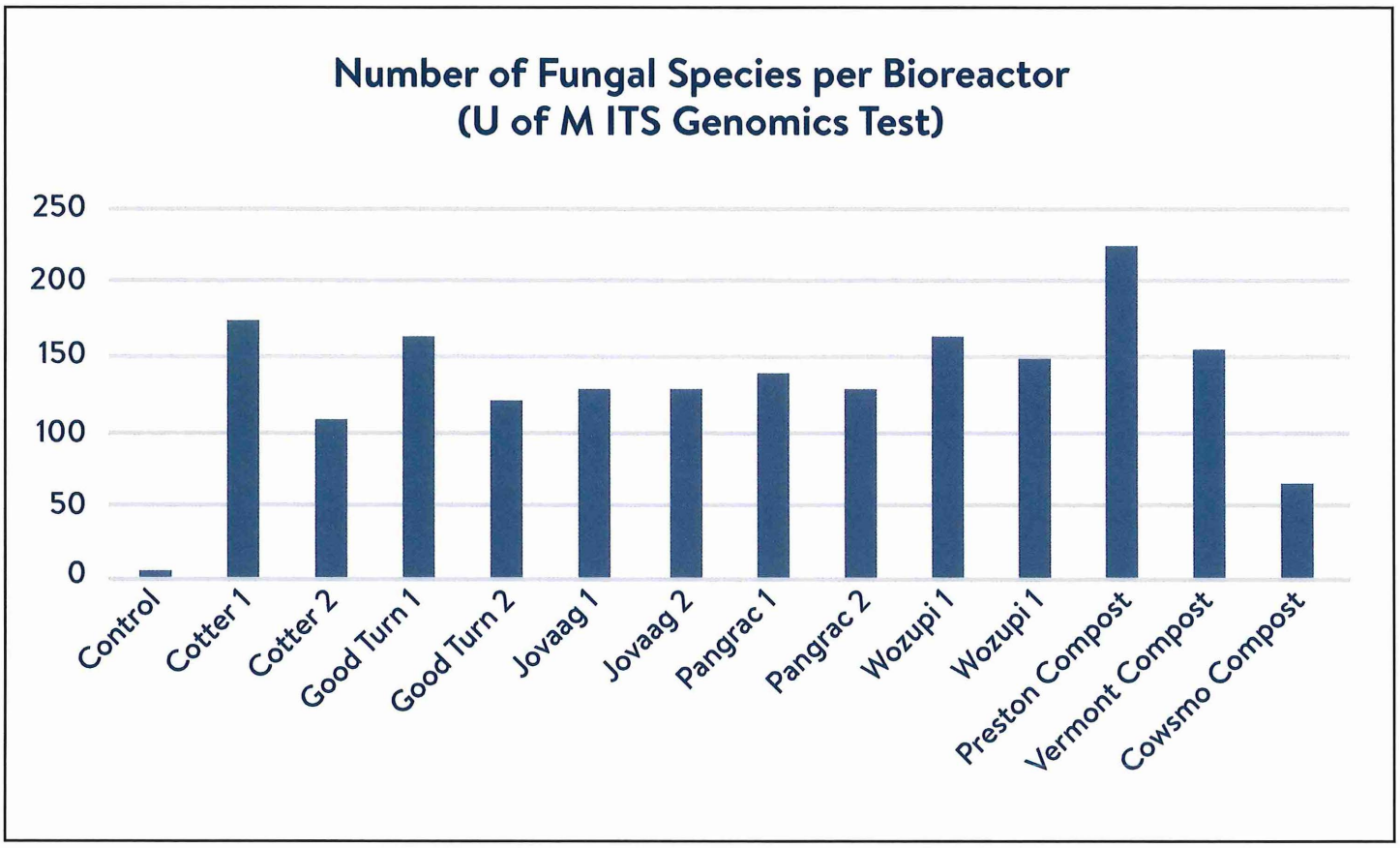


Figure 1. Fungal Species Number. A bar graph highlighting the number of fungal species found within each compost. The higher the number, the more diversity of fungi.

ADDITIONAL RESOURCES

For more information about this project, please see the following resources:

LSP Ear to the Ground Podcast #266: Activating Soil Life

LSP Blog: Getting a Bio-Reaction from Soil

Ear to the Ground 271: Focusing on Fungi

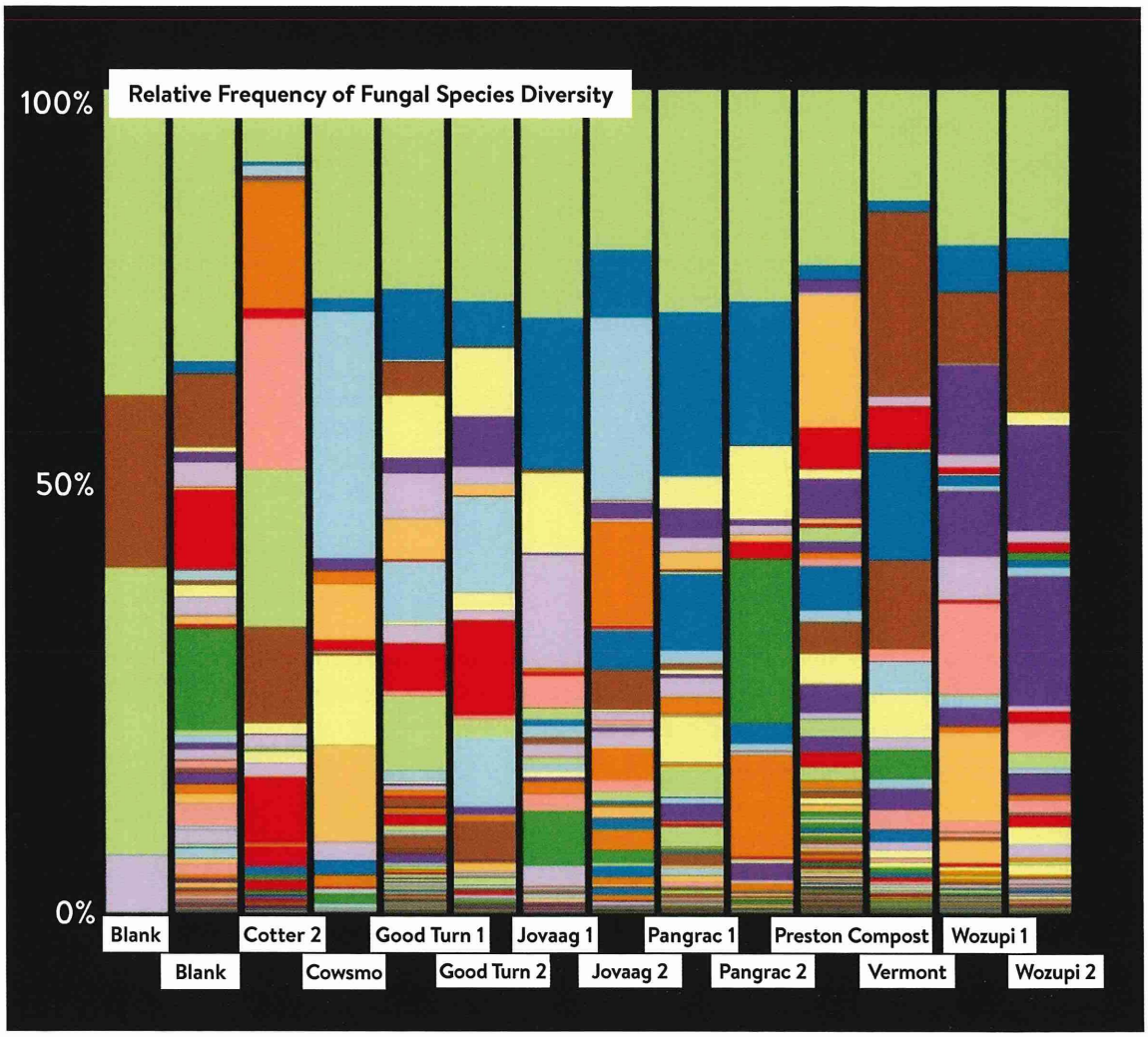


Figure 2. Fungal Relative Frequency. A bar graph showing the relative frequency of the different species of fungi found within that compost.

Sustainable Agriculture Demonstration Grant Project Updates

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

Principal Investigator
Grantee: Connor McCormick
Organization/Farm: McCormick Farm
Email: mccormic.38@gmail.com
County: Houston

Project Duration
2021-2023, 3 years

Award Amount
$9,644.00

PROJECT SUMMARY

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. Many of the farms in our area in southeast Minnesota 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. If no-tilling can be an effective way to establish an alfalfa stand that will last and be productive for at least 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. Southeast Minnesota generally has 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, resilient to extreme weather, and more profitable and attractive for farmers adopting more sustainable practices.

Connor McCormick kneeling in new seeding plot of alfalfa in the spring of 2022.

PROJECT DESCRIPTION

If this study continues to show that alfalfa can be successfully established and productive over a three-year span by using solely no-till equipment, this will significantly improve farmers' profit margins, fuel consumption, soil loss minimization, and overall soil productivity. In addition, if we can determine a difference in success between planting into corn or bean ground, this will help farmers plan their crop rotations and may open more flexibility for diverse crop rotations rather than the normal corn-bean-corn-hay rotation.

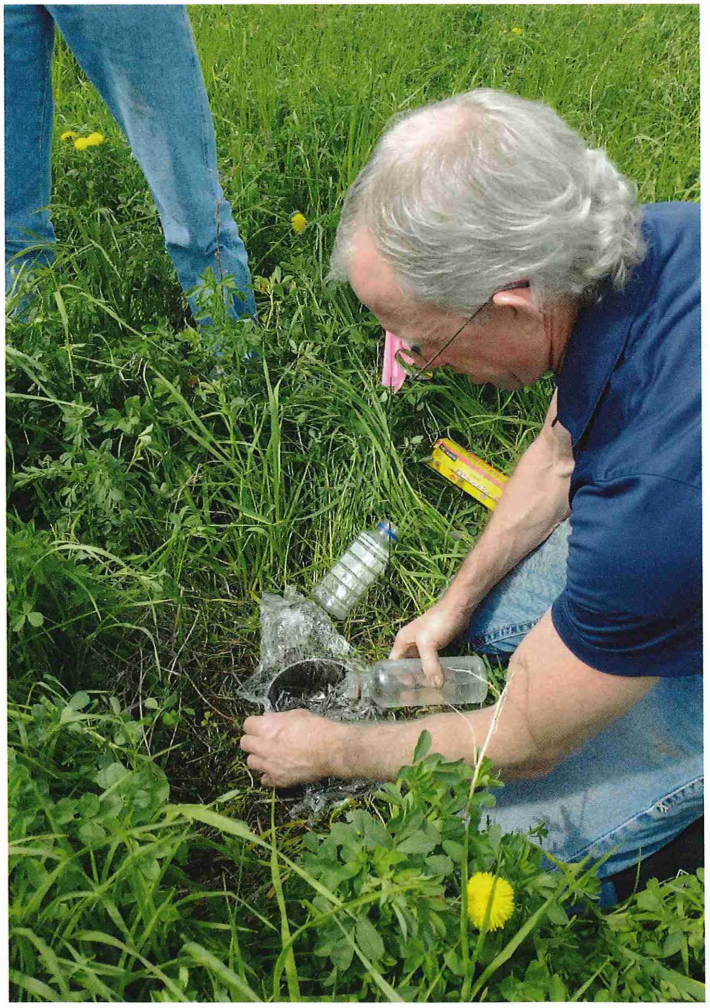
Sustainable Agriculture Demonstration Grant Project Updates

Tests will be conducted on the same day for all fields, and testing dates are as follows:

- August 15, 2021
- June 1, 2022
- July 1, 2022
- June 1, 2023
- July 1, 2023

The first and last test dates (August 15, 2021, and July 1, 2023) will begin with collecting 10 random soil cores from each of the eight field parcels in order to conduct a Haney soil test. This test will give us a comparison of general soil health and biology activity between the fields and will show us if the no-till had an effect on our soil health and biology over the three-year period. The 10 soil cores will be mixed for each of the eight fields, labeled, and sent into Ward Laboratories in Kearney, Nebraska.

A side-by-side comparison of the alfalfa planting in corn ground May 2022. On the left is where the corn ground was direct no-tilled seeded, and on the right is where the corn ground was tilled and finished prior to seeding.



Root River Soil and Water Conservation District technician Bob Scanlan taking a water infiltration test in the no-till alfalfa plot during summer 2022.

Sustainable Agriculture Demonstration Grant Project Updates

On all five test dates, we will complete the following:

1. Alfalfa stand count
We will use five random plot locations, at least 100 feet apart, throughout each field. At each location, we will use a square yard rectangle and place it on the ground. We will then count the number of individual alfalfa plants in this square yard. This will give us a way to compare the alfalfa germination and survival between the fields throughout the three-year study.

2. Alfalfa biomass
We will use the same random square yard plot as the alfalfa stand count test. After the alfalfa plants are all counted, we will then cut all the stems off at two inches above ground level, place the cuttings in a labeled bag, and weigh the net contents of each bag in order to determine the wet alfalfa mass. We will then air dry the samples for a minimum of 72 hours and then weigh the dry samples once again. We will calculate moisture weight of each sample using the following formula:

(fresh weight - dry weight / fresh weight) × 100 = moisture weight

After calculating moisture weight, we will subtract that weight from the fresh weight of the plants in each plot to estimate dry weight and actual biomass of alfalfa for each location. After calculating alfalfa biomass, we will be able to calculate approximate tons per acre that each field has on it.

3. Alfalfa nutrient analysis
On or near each test date, we will collect a random sample of alfalfa for a nutrient analysis in each of the fields. These samples will be labeled and sealed in bags and then sent to the University of Minnesota Labs for analysis. We will record this data and will use it for comparing alfalfa feed value, nutrient uptake and availability, and overall profitability for each field over the course of the study.

Root River Soil and Water Conservation District technicians Bob Scanlan and Dan Wermager taking scissor cutting tests in alfalfa plots during summer 2022.

Sustainable Agriculture Demonstration Grant Project Updates

PRIMARY OBJECTIVES

1. Determine how well alfalfa germinates, establishes, and grows in a conventionally tilled field compared to a no-till field over a three-year lifespan.
2. Determine if a no-till alfalfa stand is more successful in previous bean ground or corn ground.
3. Determine if no-till practices improve general soil health, soil biological activity, and soil nutrient retention in comparison to conventional tillage.

2022 RESULTS

In 2022, McCormick's results again were rather close in comparisons across all samples between the no-till and tilled alfalfa fields. Alfalfa stand counts, biomass production, and water infiltration were measured and recorded as shown in figures 1, 2, and 3 respectively. These data will be used as core data and used as a comparison for the remainder of the project.

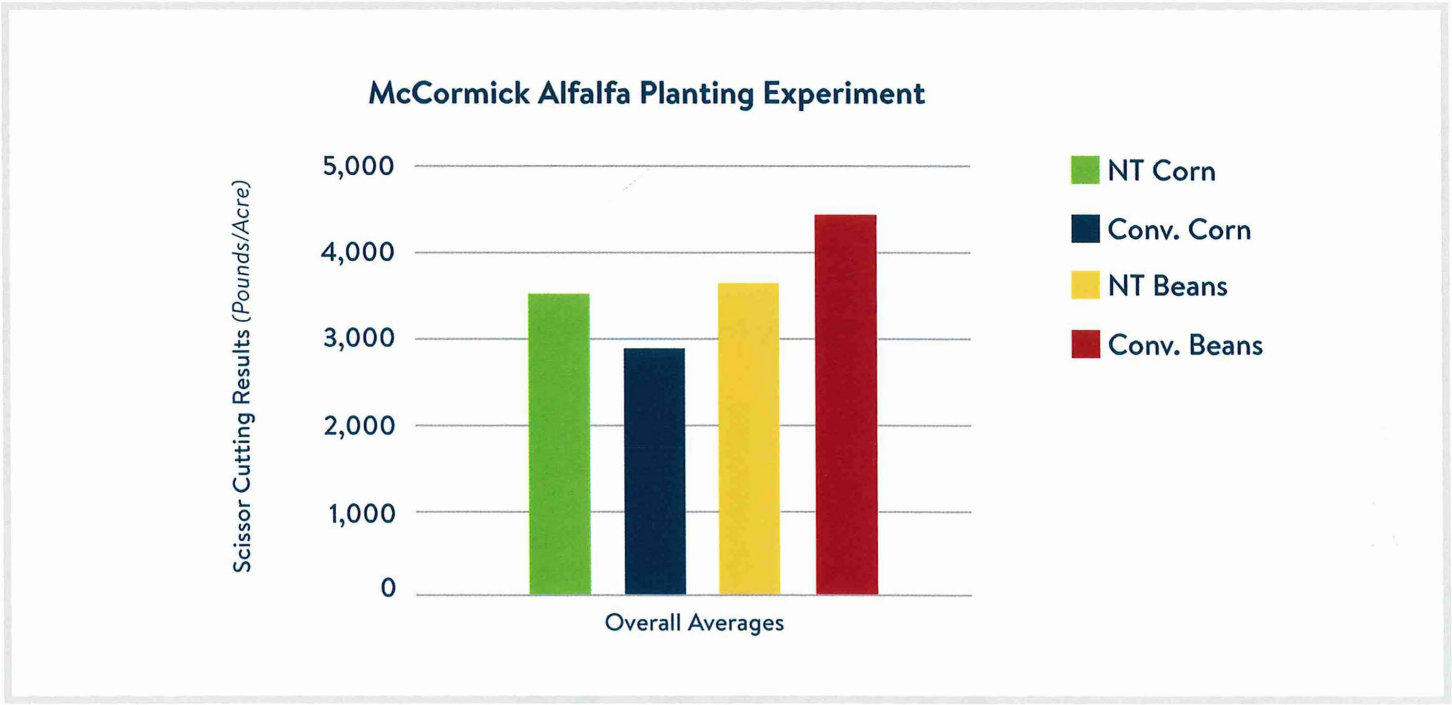


Figure 1. Average amount of hay biomass in pounds/acre produced in each of the trial fields during the second summer of the experiment. Hay biomass was measured by taking scissor cuttings at random sample locations in each field by using a 1/50th acre ring and then allowing samples to air dry. Biomass measurements showed that the no-till corn fields and tilled bean fields had a slightly higher average biomass production during the summer of 2022.

Sustainable Agriculture Demonstration Grant Project Updates

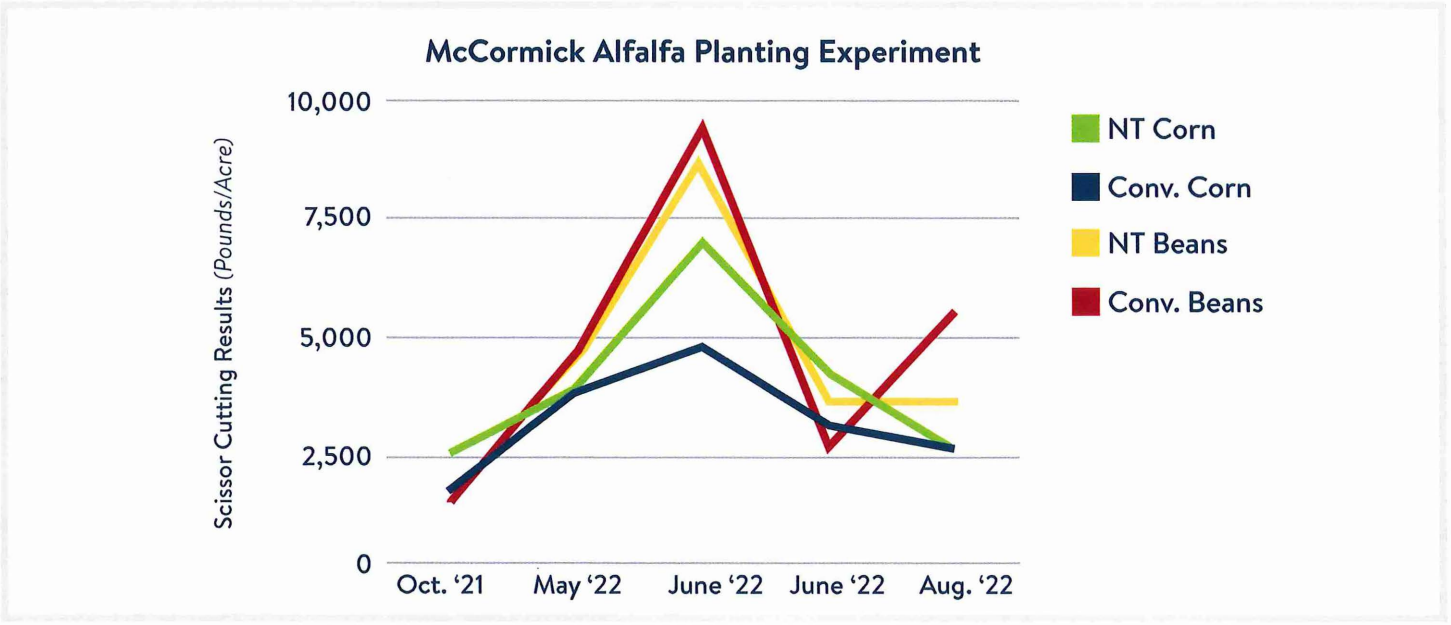


Figure 2. Average biomass production of alfalfa in each of the fields throughout the summer of 2022. The conventionally tilled bean fields appeared to show the highest biomass production throughout the duration of the summer.

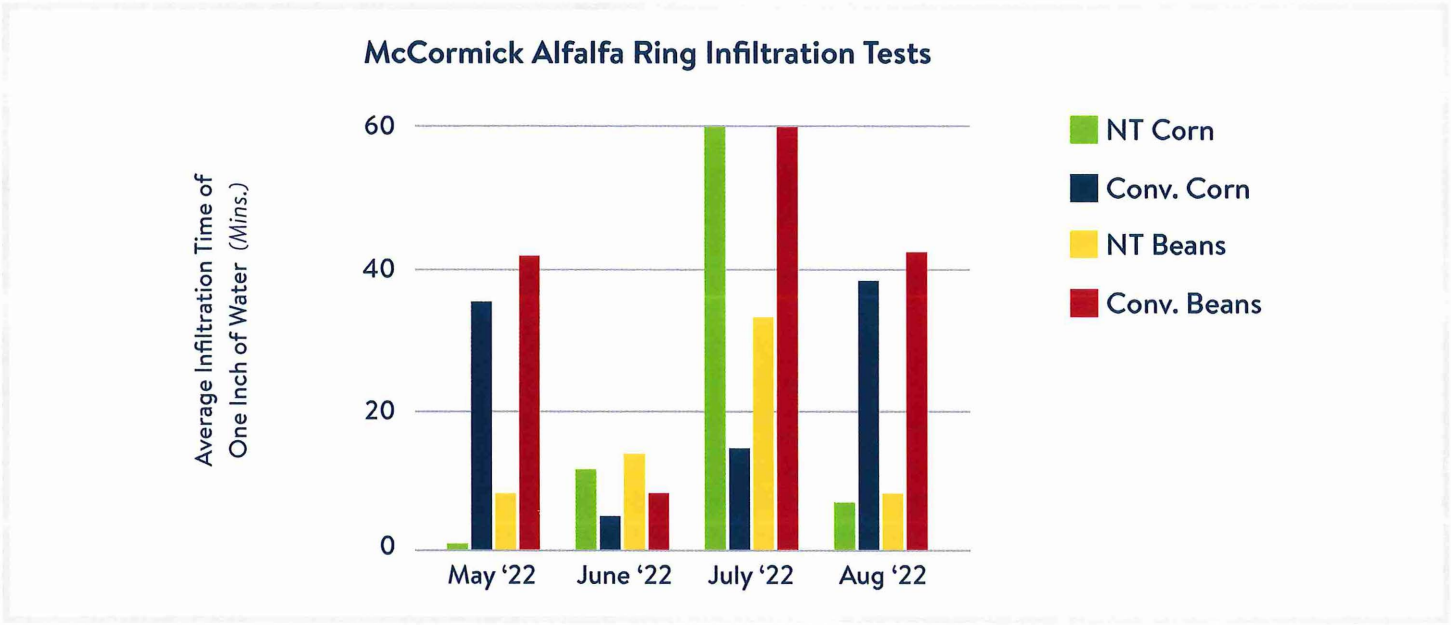


Figure 3. Average water infiltration rate in each of the fields. Although there was a lot of variability in infiltration rate throughout the summer of 2022, the conventionally tilled bean field showed the fastest infiltration times throughout

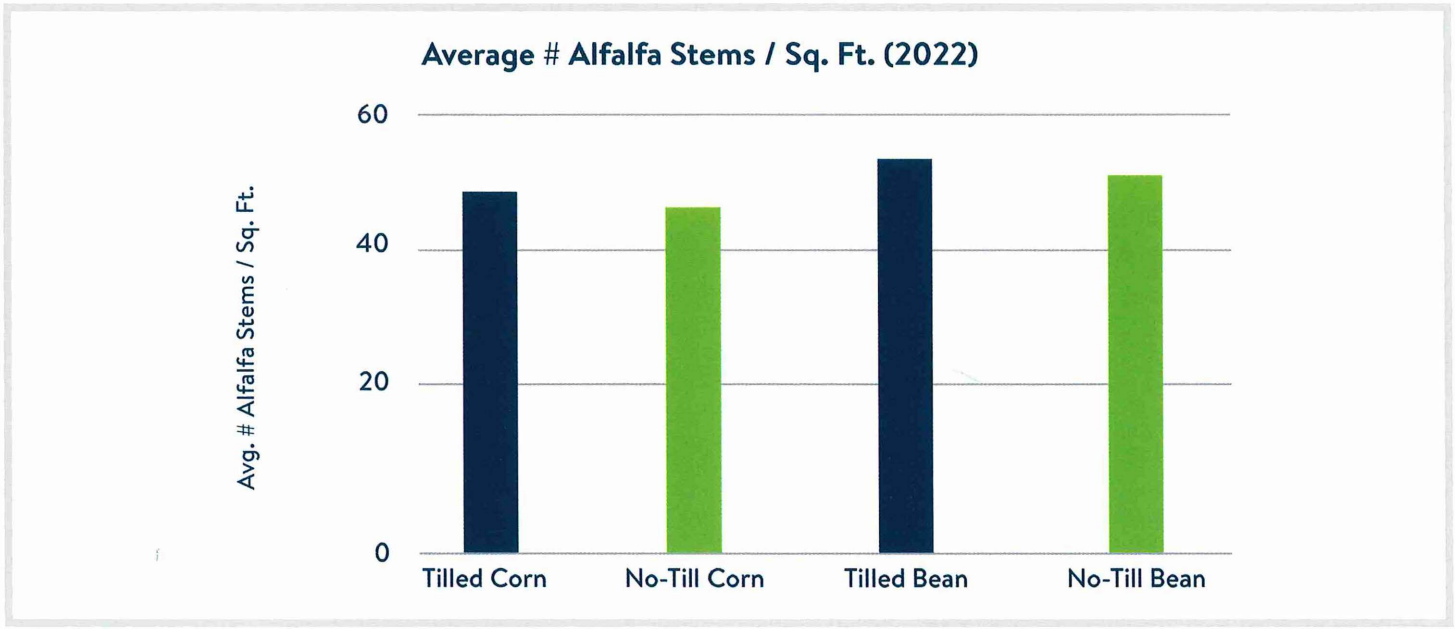


Figure 4. Represents the average number of alfalfa stems counted/ sq. ft in each of the fields. Alfalfa plant establishment was initially measured in August 2021 and will continue to be recorded throughout the duration of the experiment. Alfalfa stem establishment was relatively close between the different fields, with the tilled fields having slightly higher counts in both the corn and bean ground.

ADDITIONAL RESOURCES

Land Stewardship Project's Ear to the Ground Podcast, Episode 267:

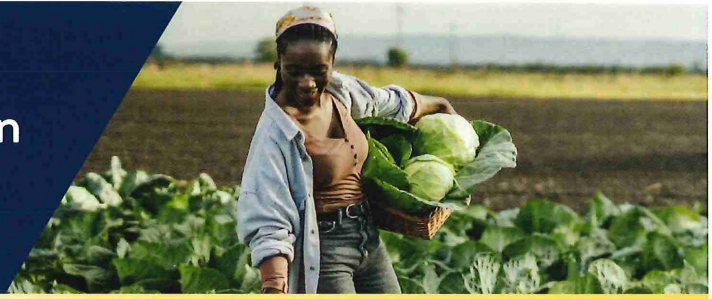
https://landstewardshipproject.org/podcast/ear-to-the-ground-267-bringing-science-back-to-the-farm/

https://fyi.extension.wisc.edu/forage/alfalfa-stand-assessment-is-this-stand-good-enough-to-keep/

https://hayandforage.com/article-2671-checking-in-on-those-new-alfalfa-seedings.html

https://cropwatch.unl.edu/2020/evaluating-alfalfa-stands-part-1-using-hay-square-method

Sustainable Agriculture Demonstration Grant Project Updates



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

Principal Investigator
Grantee: Chad Olsen
Organization/Farm: Olsen Custom Farms LLC
Email: colsen@olsencustomfarms.com
County: Lincoln

Project Duration
2021-2023, 3 years

Award Amount
$25,000.00

PROJECT SUMMARY

Methods to reduce synthetic fertilizer use on broadacre crops like corn can provide many benefits to the farm and landscape, such as higher net returns to the farmer, less nutrient loss to surface and ground water, and a lower carbon footprint through energy savings related to production and transport of synthetic fertilizer. On-farm composting of livestock manure and carbon residues could provide all or most of a farm's fertilizer needs, but its limits or possibilities are not well understood due to few operations currently using on-farm compost over hundreds of acres. This study aims to find out how far our compost can go towards eliminating commercial fertilizer for our farm's broadacre crops and improving soil health.

PROJECT DESCRIPTION

This project is very important to our farm because we are transitioning our entire broadacre crop fertility program from the traditional synthetic nitrogen (N), phosphorus (P), and potassium (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 seed crops 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 an understanding of the 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 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. Sharing our findings on carbon-based fertility with farmers throughout the region hopefully provides a path to produce and use compost on their farms' soils.

Two field locations are being used for the study, one with fall and spring tillage and the other being mature no-till (5+ years). The conventional tillage field is in a three-crop rotation: Corn/oats (2021), soybeans/corn (2022), oats/soybeans (2023). The no-till field is also in a three-crop rotation: Soybeans (2021), oats (2022), corn (2023) (Photo 3).

Sustainable Agriculture Demonstration Grant Project Updates

Compost thermometer used for recording compost temperatures.

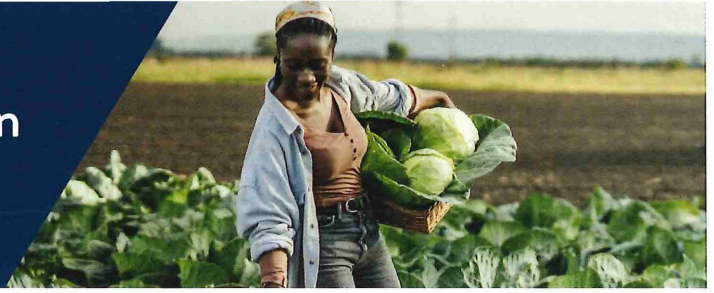
Spreading the compost in the oat plots during the fall of 2022.

Oats in the no-till plots in June, flag leaf emerged.

2022 RESULTS

Olsen Custom Farms LLC completed their second year of a three-year study to understand the possibilities of on-farm compost to reduce or eliminate inorganic fertilizer on broadacre crops. Some similarities exist to year one of the study. The farm experienced a warmer and drier summer, but more timely rain events allowed for overall better crop yields, and this included the study plots. Olsen's composting operation got off to a slower than expected start because windrows made in the fall of 2021 were left on the site over winter. Late spring rains created saturated compost windrows which were slow to dry, so reaching the ideal composting temperature range of 130-160 degrees Fahrenheit was delayed by a few weeks. The farm was able to produce over 5,000 tons of compost, which was applied to oat and soybean fields post-harvest. Fields receiving compost did not receive any inorganic phosphorus or potassium dry fertilizer in the spring of 2023, which is consistent with the goal of the grant study.

Sustainable Agriculture Demonstration Grant Project Updates



Measuring soil carbon dioxide in corn plot.

One challenge with compost production is the initial synchronization of the compost feedstocks to reach the composting temperature quickly. Differences in manure creates challenges to get the desired carbon to nitrogen ratio (25-35:1) along with the correct moisture.

When implementing the two treatments in the study — compost versus inorganic fertilizer — plot by plot fall soil tests were used to determine fertilizer rates based on University of Minnesota recommendations. Each plot received nitrogen, phosphorus, and potassium based on its own unique soil test to satisfy a set yield goal (220 bushel corn, 140 bushel oats, and 60 bushel soybeans). The fertilizer was weighed out and broadcast applied. Compost treatment plots received two tons per acre rate via the broadcast spreader the previous fall. The compost was the only added fertility to the compost treatment plots except the second-year nitrogen credit for cover crop residues following oats. The minimalist approach with respect to the compost treatment is again seeing how great compost contributes toward our broadacre crop fertility.

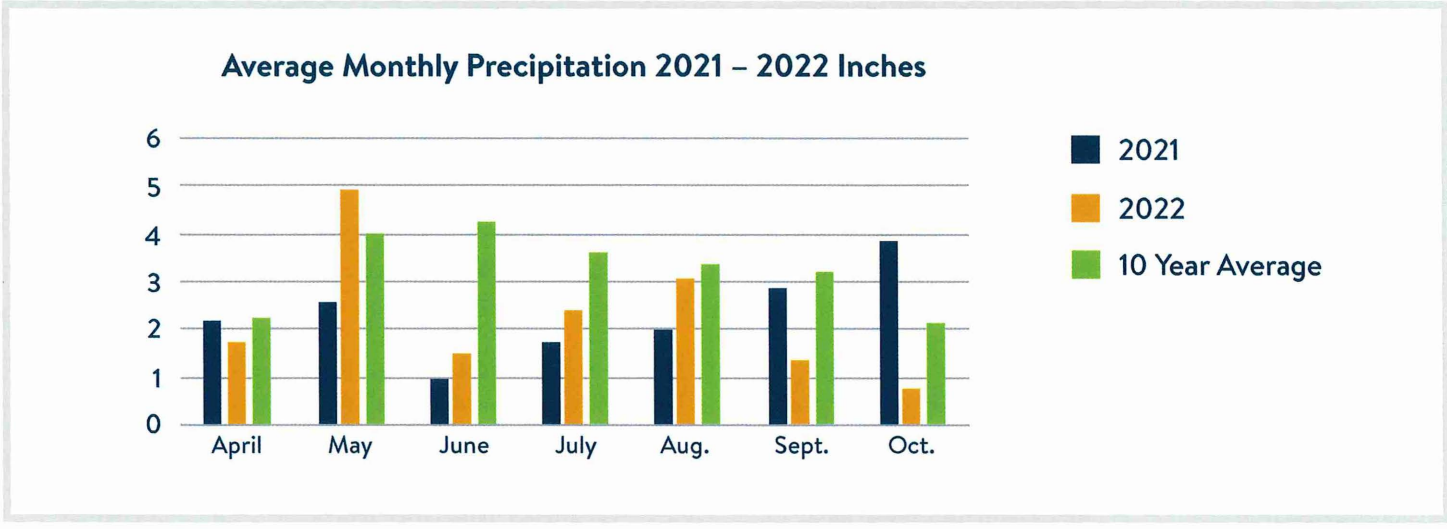
The two soil systems revealed similar trends in terms of soil moisture and temperature. No-till soil is consistently cooler and maintains higher moisture levels as would be expected. The tilled soil environment experienced very high soil temperatures, especially in June when the crop canopies are not fully shading the soil surface. Temperatures above 85 degrees Fahrenheit are never beneficial, since soil microbial communities are limited or die off which can lower crop performance outcomes. Shallow compaction layers three to six inches below the soil surface are still prevalent in all the plot areas as shown by reduced two-inch rainfall infiltration simulations. Water infiltration was quickest in the corn plots based on previous fall disk-ripping, reducing the shallow compaction layers. The no-till plots with oats and the soybeans (spring high-speed disk) created or maintained the shallow compaction layer. We hypothesize that continuous applications of compost would help reduce the likelihood of shallow compaction by the addition of more active fraction organic matter, thus improving soil aggregation (soil physical structure) and ultimately water infiltration. Also increasing the frequency of cover crops from once every three years to every year could help alleviate shallow compact layers.

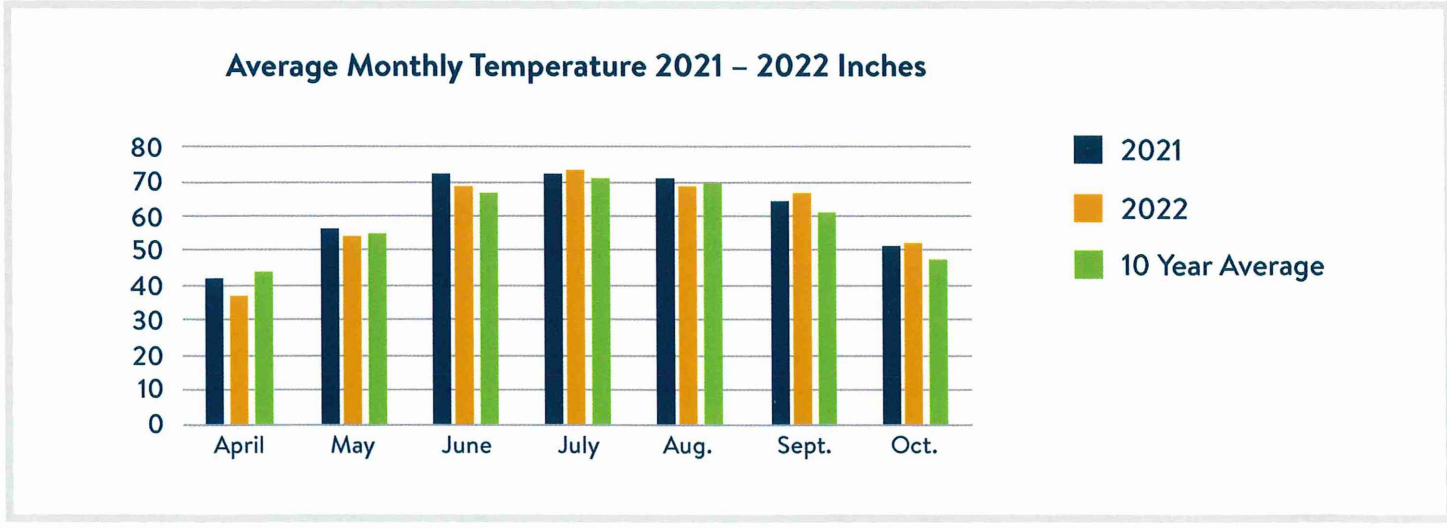
Soil Environment

Some significant differences in soil chemical and biological properties were found in the tilled soil occupied by the 2022 corn and soybean. The properties affected were similar, but not by treatment. Fall soil phosphorus was higher in the fertilized corn plots which were given diammonium phosphate (DAP) applications, while the fall soil phosphorus in the fertilized soybean plots was lower than the compost. The compost had a good phosphate level thus attributed to the higher phosphorus level, while the fertilized plots did not receive DAP applications based on the previous fall soil test. Soluble salt was higher or lower depending on treatment and illustrates that both fertilizer or compost can create unacceptable salt levels when overapplied, possibly disrupting cation exchange capacity, soil structure and soil water movement. The reported sodium values were acceptable levels in all the plot locations.

Sustainable Agriculture Demonstration Grant Project Updates

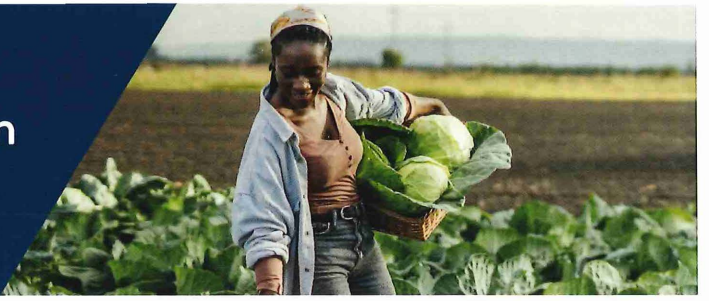
Soil biology activity was higher in the fertilized plots based on soil respiration values. This value was most likely elevated by added inorganic nitrogen increasing microbial activity. The higher microbial activity often results in greater mineralization of organic matter to supply the crop with nutrients. Soil temperature and moisture (data table not included) had few or no significant differences among all dates sampled throughout the growing season. Where a difference was detected, it was likely from a larger crop canopy creating more shade on the soil surface.





Figures 1 and 2. Seasonal Climate conditions for first two years of the study were drier and warmer than the short-term averages. June weather repeated itself as being very dry and warm.

Sustainable Agriculture Demonstration Grant Project Updates



Broadacre Crop Response

Plant tissue analysis produced some significant differences in the corn, while in the soybeans it was limited to just higher boron levels in the compost-treated soybeans. The oats grown in the no-till soil plots produced no significant differences in all plant measured parameters.

Corn sampled at the V6 and R1 growth stages showed that several nutrients were higher in the compost-treated plots. The fertilized corn produced a result often seen from high nitrogen, phosphorus, and potassium fertilizer applications. Plant nitrogen at V6 was higher with lower phosphorus, potassium, zinc, iron, manganese, and molybdenum. It is known that the trace elements, zinc, iron, manganese, and molybdenum are antagonized by high nitrogen, phosphorus, and potassium applications. Nitrate conversion relies on molybdenum while photosynthesis needs adequate early iron. Corn sampled later at R1 did not show trace nutrient differences, only lower nitrogen phosphorus and sulfur on the compost plots which would seem likely given no applied inorganic fertilizer. Lower nitrogen in the compost plants did not result in significantly lower yields. In fact, when trace elements are in balance (seen in V6), tissue nitrate conversion is more efficient for healthy growth and not luxury growth common with high nitrogen applications. Several sampling dates had a statistically significant higher plant chlorophyll for the fertilized corn plots which would correlate with the tissue nitrogen results.

Soybeans exhibited no differences in trace or macro nutrients other than boron. The lack of differences can be attributed to high residual soil test levels in the fall of 2021, thus no additional fertilizer was applied based on soil test critical levels. The two systems were exhibiting a "balanced soil" and the final yields reflect the situation. Boron is often shown to be limiting in tissue tests. Boron increases calcium uptake, which ensures good fruit development. Soybeans being a fruiting crop can take advantage of a boron addition by not aborting seed developing in pods. Boron associated with the compost ensures plants have an adequate level.

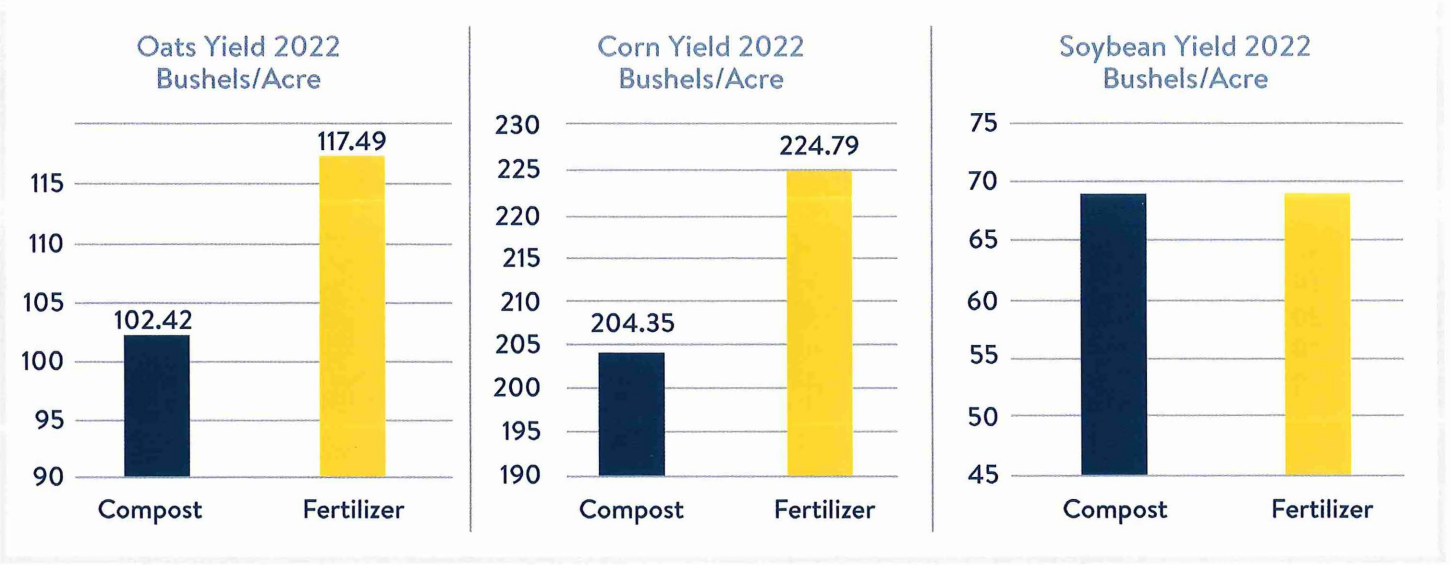


Figure 3. 2022 Crop Yield Averages from Compost and Fertilizer Treatments

Yields reported for all crops were statistically not different at the P>.05, although corn and oats had higher averages with fertilizer (Figure 3). The two ton per acre application of compost cost the farm about $75 per acre (manufacturing, transportation, and application costs) while the fertilizer application for oats was $110 per acre and corn was $90. Fertility cost

Sustainable Agriculture Demonstration Grant Project Updates

per acre is similar, but the key difference is the compost was sourced on-farm. Usually corn fertility would be much higher but the plot field had high residual macronutrient levels and a preceding cover crop biomass credit. The experiment compost application rate of two tons per acre with a reduced amount of supplemental nitrogen could possibly have maximized crop yields.

Table 1. Measured chemical & biological soil and plant parameters ANOVA table.

SAS ANOVA TABLE / 2022 FIELD DATA
*Signficant at .10 Level **Signficant at .05 Level

	CROP	OATS	SOYBEANS	CORN
SOIL PARAMETERS				
pltsqft.		NS	NS	NS
Inch01		NS	NS	NS
Inch02		NS	NS	NS
Yldbu/acre		NS	NS	NS
Grn Mst		NS	NS	NS
pH		NS	NS	NS
SolSalt		NS	**	**
SOM		NS	NS	NS
Nit0-6		NS	NS	NS
Nit6-24		NS	NS	NS
Olsen P		NS	**	**
Kppm		NS	NS	NS
Cappm		NS	NS	NS
Mgppm		NS	NS	NS
Nappm		NS	*	*
Sulfppm		NS	NS	NS
Znppm		NS	**	*
Feppm		NS	NS	NS
Mnppm		NS	NS	NS
Cuppm		NS	NS	NS
CEC		NS	NS	NS
SRespCO2		NS	*	*
WExtN		NS	NS	NS
OrgN		NS	NS	NS
TotOrgC		NS	NS	NS
NH4H20		NS	NS	NS
NO3H20		NS	*	*
OMSHA		NS	NS	NS
PSHA		NS	NS	NS
KSHA		NS	NS	NS
ZnSHA		NS	NS	NS
FeSHA		NS	NS	NS
MnSHA		NS	NS	NS
CuSHA		NS	NS	**
SSHA		NS	NS	NS
CaSHA		NS	NS	NS
MgSHA		NS	NS	NS
NaSHA		NS	NS	NS
WSAg		NS	NS	NS
MAC		NS	NS	*
OCON		NS	NS	NS
ONRel		NS	NS	NS

	CROP	OATS	SOYBEANS	CORN
PLANT PARAMETERS				
PltFe		NS	NS	NS
PltMn		NS	NS	NS
PltCu		NS	NS	NS
PltB		NS	*	NS
PltMo		NS	NS	**
PltN		NS	NS	**
PltP		NS	NS	**
PltK		NS	NS	**
PltCa		NS	NS	NS
PltMg		NS	NS	*
PltS		NS	NS	*
PltZn		NS	NS	**
PltFe		NS	NS	*
PltMn		NS	NS	**
PltCu		NS	NS	NS
PltB		NS	NS	NS
R1N		NS	NS	**
R1P		NS	NS	*
R1K		NS	NS	NS
R1Ca		NS	NS	NS
R1Mg		NS	NS	NS
R1P		NS	NS	NS
R1K		NS	NS	NS
R1Ca		NS	NS	NS
R1K		NS	NS	NS
R1Ca		NS	NS	NS
R1Mg		NS	NS	NS
R1S		NS	NS	*
R1Zn		NS	NS	NS

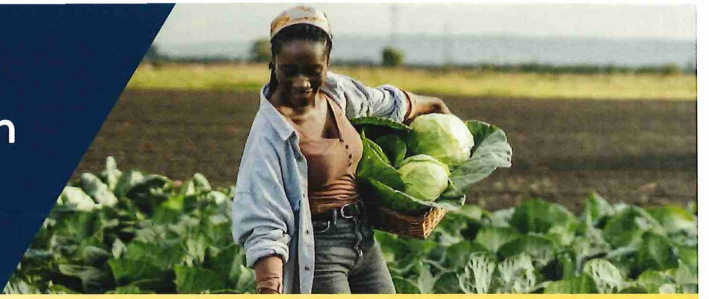
*Treatment Differences between compost or inorganic fertilizer at the 0.05** or 0.10* level.*

Table 2. 2022 Compost Values

COMMON COMPOST ANALYSIS VALUES FOR OCF

NUTRIENT	LBS./TON	NUTRIENT	LBS./TON
Organic N	27.7	Magnesium	12.3
Nitrate N	.0	Sodium	6.3
NH4N	0.4	Zinc	0.3
Total N	28.1	Iron	6.8
Total C	366.5	Manganese	0.5
C:N Ratio	13.5	Copper	0.1
Phosphorus	29.5	Boron	0.1
Potassium	49.5	Soluble Salts	46
Sulfur	10.4	pH	7.9
Calicium	35.8	Moisture %	35.28

Sustainable Agriculture Demonstration Grant Project Updates



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

Principal Investigator
Grantee: Charlie Rohwer
Organization/Farm: University of Minnesota
Email: rohw0009@umn.edu
County: Waseca

Project Duration
2021-2023, 3 years

Award Amount
$24,831.00

PROJECT SUMMARY

Vegetable farmers often use manure and compost for fertility. Soil phosphorus (P) levels 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. In previous research, we found that when soil and fertilizer P was adequate for healthy plant growth, adding inorganic P at transplant using water-soluble fertilizer increased tomato yield. The primary hypothesis for this project is that adding fertilizer containing organic P in transplant solution will increase the soil P removal rate by a tomato crop through increased yield, even in soils with a history of organic fertilizer or high P. We also hypothesize that generative rootstocks will enhance P removal.

Grafted and not grafted tomato transplants used in this study.

Watering transplanted tomatoes with "starter" fertilizer.

Sustainable Agriculture Demonstration Grant Project Updates

PROJECT DESCRIPTION

Phosphorus (P) from agricultural land contributes to P pollution in Minnesota waters. Vegetable growers and gardeners often over-apply P fertilizer as compost and manure. Understanding and improving how harvested produce removes P from the soil will help vegetable growers and gardeners contribute to improved water quality throughout Minnesota.

The University of Minnesota Southern Research and Outreach Center (SROC) in Waseca and Dan Zimmerli of Cedar Crate Farm in Waldorf are collaborating on the project and using both locations as study plots to obtain a more complete data set. Both locations have Webster clay-loam soil, but Cedar Crate has been fertilizing organically and the SROC has not.

OBJECTIVES

1. Test the impact of organic water-soluble "starter" fertilizer on the amount of P harvested from tomato plants in a full season, considering the amount of P added by the fertilizer; and
2. Test the ability of a generative tomato rootstock to enhance tomato yield and P removal from the soil.

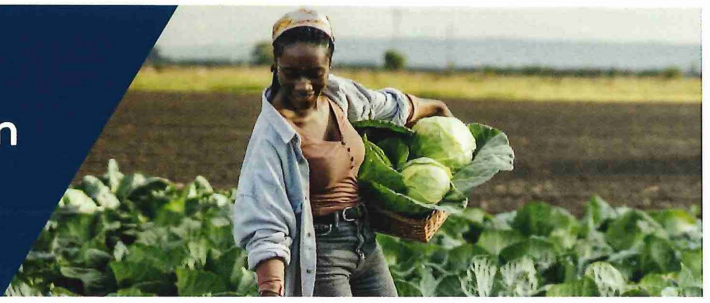
2021-2022 RESULTS

Results were averaged across years when possible, but many analyses were done separately for each location. The plants at Cedar Crate yielded 41%–80% less marketable fruit in 2022 compared to 2021. There were diseases that impacted plant health at Cedar Crate in both years, but yield impacts were most apparent in 2022. Conversely, regular pesticide application at the SROC in both years likely helped to maintain plant health. Overall, marketable yield was only 9% lower at SROC in 2022 compared to 2021. Eighty-seven percent of Galahad fruits and 91% of paste fruits were marketable. Within the Mountain Fresh Plus variety, grafting reduced the marketability of fruits (87% vs. 96%).

Cultivar differences in yield and fruit size were apparent, but the focus of this project was to determine which treatments can enhance yield and P removal from the field. In 2021, we found that grafted plants removed an average of 4.7 pounds more P per acre from the soil (26 pounds per acre) than not-grafted plants (21 pounds per acre). That was partly due to about 6.5% higher P concentration in fruit from grafted plants (~25 mg P per 100 grams fresh tomatoes). Galahad plants removed about 4 pounds more P per acre than Paisano in 2021, and the high-P starter fertilizer treatment removed about 5 pounds less P per acre than plants given no starter P. P removal results from 2022 are still being analyzed, but preliminary results suggest grafted plants removed more P than not grafted plants in 2022 at one location but not the other, with no consistent impact of starter fertilizer.

There were no yield, fruit size, or marketability effects of starter P treatments. However, grafting did increase marketable yield at the SROC by 3 pounds per plant, but maturity was delayed by 10 to 14 days. Yield at Cedar Crate was not increased by grafting, possibly because grafting delayed maturity. In fact, in 2022 — a more challenging year at Cedar Crate — grafting reduced marketable yield by 28%. Earlier harvest would have been more important at Cedar Crate, where diseases became a major impediment to yield as the season progressed. Cost for seed, commercial transplant production, grafting, and shipping was approximately $2.58 per grafted plant and $1.46 per not grafted plant.

Sustainable Agriculture Demonstration Grant Project Updates



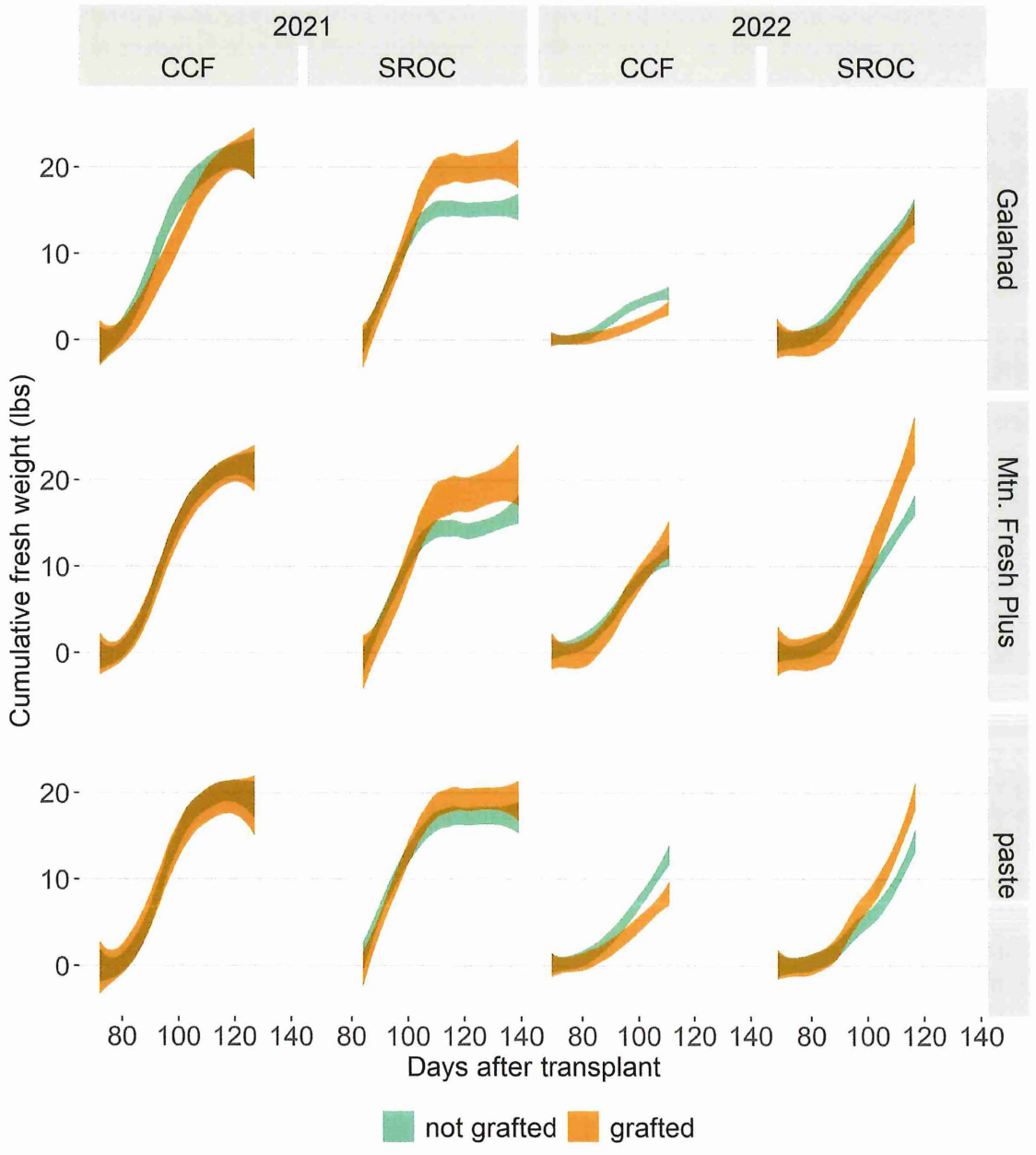


Figure 1. Yield of tomato fruits (marketable, unmarketable, and fruits harvested green on the final harvest) throughout the season at two locations: Cedar Crate Farm (CCF) in Waldorf and the University of Minnesota SROC in Waseca. Yield of three cultivars is shown, with grafted and not-grafted treatments shown separately.

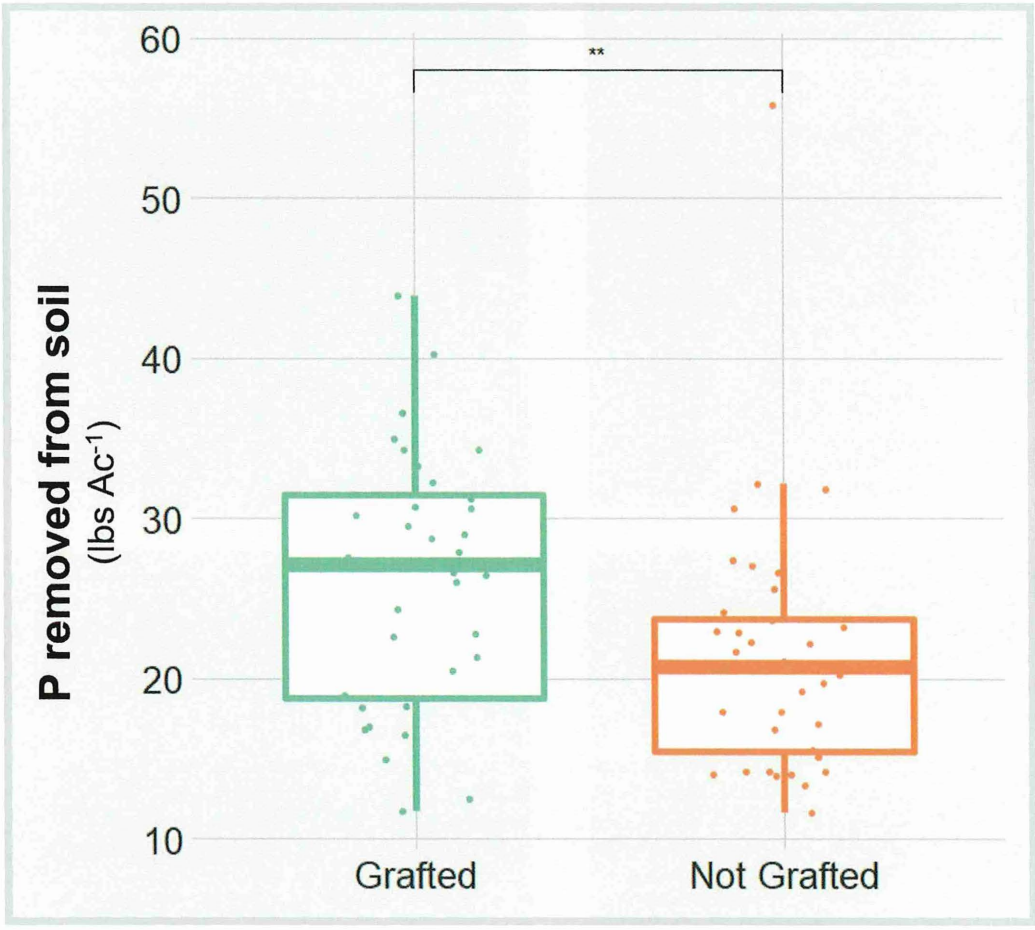
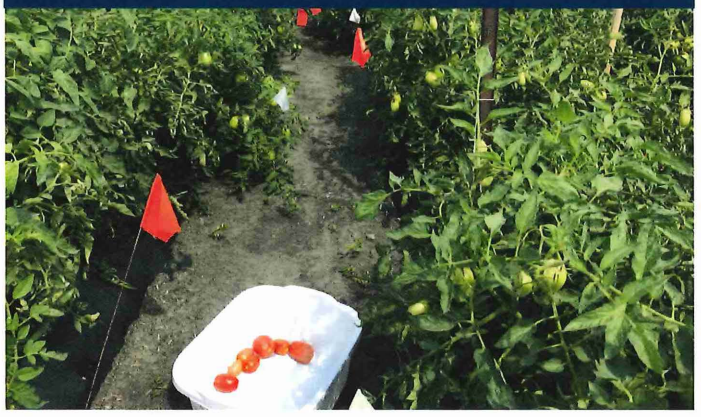


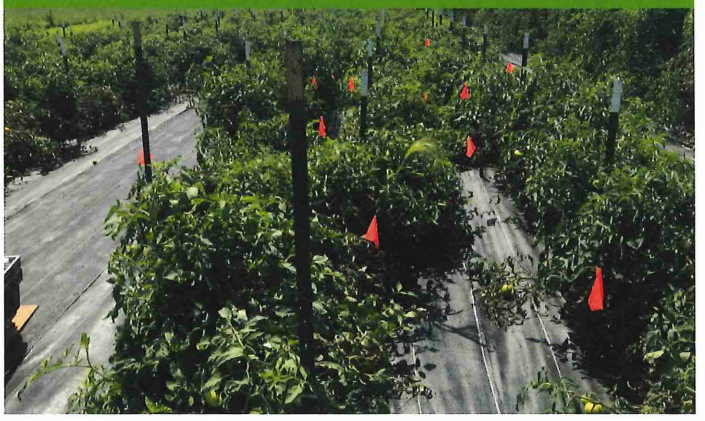
Figure 2. Phosphorus (P) removed from soil in 2021 by harvesting tomato fruits. P concentration in fruits was measured in subsamples of harvested tomatoes. Total P harvested was calculated by multiplying P concentration by total yield, and P added by soluble "starter" fertilizer was subtracted to calculate P removed from the soil. Tomatoes were either grafted onto Estamino rootstocks or not grafted. Boxplots display median, 25th and 75th percentiles, and 1.5×IQR. Individual data points are shown from plots with both high and low rates of starter fertilizer.

Sustainable Agriculture Demonstration Grant Project Updates

16 AUGUST, SROC



17 AUGUST, CCF



31 AUGUST, SROC

31 AUGUST, CCF

Tomatoes growing at the University of Minnesota SROC in Waseca and at Cedar Crate Farm (CCF) in Waldorf in 2022. Mid-August, the plants at both locations appeared healthy. By the end of August, the plants at CCF were suffering from diseases. Yield at CCF in 2022 was substantially lower than in 2021.

ADDITIONAL RESOURCES

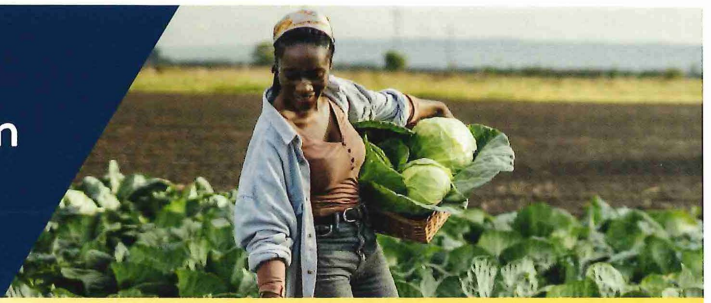
Nutrient management recommendations for fruit and vegetable crops in Minnesota: *https://hdl.handle.net/11299/197955*

Nutrient management for fruit and vegetable crop production: Using manure and compost as nutrient sources for vegetable crops: *https://hdl.handle.net/11299/200639*

USDA-funded vegetable grafting portal, with videos: *http://www.vegetablegrafting.org/*

Ohio State University grafting guide: *https://u.osu.edu/vegprolab/grafting-guide*

Sustainable Agriculture Demonstration Grant Project Updates



On-Farm Research on Haskap/Honeyberry Production

Principal Investigator
Grantee: Philip Stowe
Organization/Farm: Walking Plants Orchard
Email: phil@walkingplants.com
Counties: Carlton, Douglas, Washington

Project Duration
2021-2023, 3 years

Award Amount
$16,500.00

PROJECT SUMMARY

Haskaps/honeyberries are a new crop for Minnesota fruit producers. Over three years, this project will gather and compare haskap production data from three different farms. The farms are in three different Minnesota locations: west-central, east-central, and northeast Minnesota. Cultivar yields and other production data will be collected and compared.

PROJECT DESCRIPTION

The haskap species is circumboreal, with many of the plants being introduced to North America having origins in Russia or the northern islands of Japan. The name "haskap" is derived from the Japanese word for the crop. The name "honeyberry" refers to the subspecies of Russian origin. The small, dark blue fruit is acidic and intensely flavored. The earliest cultivars ripen in June, before strawberries, and provide growers the opportunity to sell local fruit when there are few alternatives. Some cultivars ripen in mid to late July.

Honeyberries thrive in Zone 3 climates and are one of the few fruit crops with frost-tolerant flowers. As with all crops, growers are trying to develop the most efficient growing techniques and ways to increase their yield. Minnesota honeyberry growers lack yield data for our area. If yields are lower than expected, we do not know if the low yields are due to poor growth, poor flower formation, poor pollination, or fruit loss prior to harvest. Honeyberry growers do not know how often the plants should be irrigated. There are a dizzying number of cultivars that produce differences in flowering time, pollination compatibility, fruit size, fruit shape, yield, flavor, ripening times, and growth habit.

Three established honeyberry growers from three different growing regions in Minnesota are participating in this project. Walking Plants Orchard is near the town of Osakis in central Minnesota and has eight cultivars on 1.5 acres with a silty clay loam soil. Haskap Minnesota is near Stillwater and has two cultivars on 2 acres with a silt loam soil. Farm Lola is near the town of Wrenshall in northeast Minnesota and has 14 cultivars on 11 acres with a sandy loam soil. All three farms have blocks that are mature enough to record production data starting with the 2021 growing season.

Sustainable Agriculture Demonstration Grant Project Updates

Being a new crop, we are hoping to learn more about fertilizing, irrigating, and harvesting honeyberries. Soil tests were taken at all three sites. Throughout the summer, leaf samples were taken and sent to Midwest Laboratories for tissue nutrient analyses. We wanted to see if there was a relationship between soil and leaf nutrients. Weather stations from Spectrum Technologies were installed at all three sites to record temperature, relative humidity, dewpoint, and soil moisture throughout the growing season.

To record yield, a subset of cultivars of roughly the same age were selected for the study at each participating farm. Haskap Minnesota recorded yields on the cultivars Beauty and Beast planted in 2018. Walking Plants Orchard recorded yields on Beauty, Beast, Blizzard, and Honeybee planted in 2018. Farm Lola recorded yields on Aurora planted in 2016, Blue Banana planted in 2019, and Strawberry Sensation planted in 2019. All three farms recorded the amount of time spent harvesting.

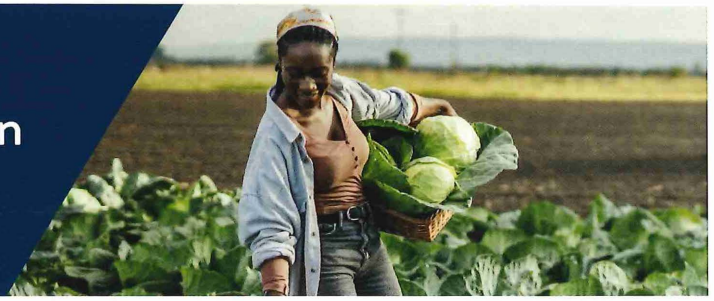
2022 RESULTS

Yield was calculated by dividing the total pounds harvested for a cultivar and dividing it by the number of plants. In 2022, yields varied from 0.82 to 3.60 pounds per plant. As expected, yields at all three farms increased from 2021 to 2022, but the most dramatic increases were at Haskap Minnesota, while Farm Lola had a modest increase of 20%. Four cultivars had yields over 3.5 pounds per plant.

Orchard	Cultivar	Year Planted	2021 Lbs /Plant	2022 Lbs /Plant	Increase
Farm Lola	Aurora	2016	2.20	2.44	11%
Farm Lola	Blue Banana	2019	0.80	0.96	20%
Farm Lola	Strawberry Sensation	2019	0.85	1.02	20%
Walking Plants Orchard	Blizzard	2018	0.93	1.70	83%
Walking Plants Orchard	Beauty	2018*	1.22	2.30	89%
Walking Plants Orchard	Honeybee	2018	1.97	3.60	83%
Walking Plants Orchard	Beast	2018*	1.29	3.60	179%
Haskap Minnesota	Beast	2018*	0.32	1.20	275%
Haskap Minnesota	Beauty	2018*	0.32	0.82	156%
Walking Plants Orchard	Aurora**	2015	2.16	3.50	62%
Walking Plants Orchard	Indigo Gem**	2014	3.54	4.20	19%

**2018 Beauty and Beast cultivars were in pots in May 2018 and transplanted to the field. Plants at Walking Plants Orchard were transplanted to the field in September 2018. Plants at Haskap Minnesota were transplanted to the field in June 2019.*

***Plants were not officially part of the study.*



Honeyberry productivity varies with the height of the plants and the number of canes per plant. As the plants grow each year, production increases. Cultivars at Haskap Minnesota and Walking Plants Orchard were planted in 2018 while Farm Lola planted in 2019. Yields at Haskap Minnesota were lower than Walking Plants Orchard both years, likely due to transplanting to the field nine months later in June of 2019. Haskap Minnesota also had the largest increase from 2021 to 2022.

Pollinator activity appears to be sufficient. All three growers walked the fields during bloom to look for bees, and we all found about four large bumblebees as well as numerous smaller bees and honeybees. We will continue to monitor pollination patterns in coming years.

In 2022, we saw a return to more average precipitation patterns after the intense summer drought of 2021. All three farms had sufficient rainfall in May, which is when honeyberries do most of their growing, and when plants need water to adequately fill the fruit. Stillwater entered a period of drought in June and July, but there was no difference in growth rates between Stillwater and the two locations with normal rainfall. Likewise, the summer drought of 2021 did not appear to lower yields in 2022. Like all trees and shrubs, honeyberries do almost all their growing in early summer, and the early season drought is a bigger problem than a late season drought.

	APRIL		MAY		JUNE		JULY		AUGUST		TOTAL	
LOCATIONS	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Osakis	3.88	2.94	0.86	6.77	1.54	2.54	1.81	3.34	5.07	.94	13.16	16.53
Stillwater	3.13	4.08	2.96	4.39	1.95	1.64	1.37	1.16	6.72	5.89	16.13	17.70
Wrenshall	3.08	3.42	2.63	5.80	2.55	3.37	1.77	2.37	2.77	2.01	12.80	16.97

Table 2. Rainfall (in inches) at the three sites during the growing season.

We have been sending in tissue samples every year to try to determine what the sufficient levels are for each nutrient. Although some plants showed very low levels of potassium and phosphorus, we have not seen any symptoms of nutrient deficiencies, and low levels of potassium or phosphorus do not appear to harm the crop so far. We will have more data on nutrients next year.

HARVESTING

The three growers are using different approaches to harvest honeyberries. Haskap Minnesota and Walking Plants Orchard use mechanical assistant tools and equipment to speed the harvest process. The equipment is used for removing and cleaning the berries. Both farms' fruit is primarily sold wholesale for processing. Harvesting for wholesale is more costly as compared to pick-your-own harvesting.

Farm Lola sold most of the 2022 crop to pick-your-own customers. Farm Lola is using nine cultivars that ripen over a period of four weeks in their pick-your-own section. When customers arrived at the farm, they were given samples of multiple cultivars, and after choosing their favorite, they were walked to the correct row. Although the nine varieties are very different, the customers did not have a strong preference to one variety. Customers did prefer taller cultivars so that they did not have to bend over much to pick, and Aurora had the tallest plants. Customers disliked Reuben because it has short plants with canes lying on the ground, and it will no longer be planted. Farm Lola also sold pick-your-own strawberries, which allowed customers to pick both strawberries and honeyberries at the same time and helped increase sales of both fruits.

Most honeyberry cultivars ripen before spotted wing drosophila (SWD) typically becomes a problem. All three farms have late cultivars that ripen when SWD numbers are peaking. All of us were planning on trying different methods of control, but SWD numbers were extremely low in 2021 and 2022, and as a result, none of the three participants lost any crop due to the pest.

Powdery mildew is the most common disease in honeyberries and is quite common in states to our south. We have seen a few mild cases of powdery mildew in late summer, but it has not been severe enough to lower yields or cause premature defoliation. At this point, we do not recommend fungicides for mildew.

Other than birds, honeyberries have few major pests. Each farm has different bird protection. Walking Plants Orchard uses over-the-row netting. Haskap Minnesota has installed overhead netting. Farm Lola uses sonic deterrence aimed toward nearby trees.

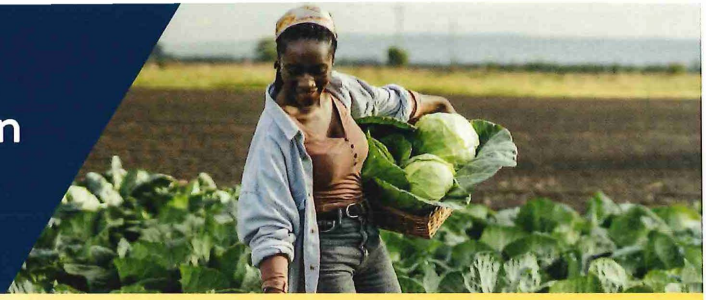
Haskap Minnesota reported an infestation of a scale insect in 2021, which appears to be a species of Lecanium scale, most likely Parthenolecanium corni. The farm tried some organic sprays in 2022 to kill the scale, and we will see for sure if the scale were killed next year.

ADDITIONAL RESOURCES

University of Saskatchewan's fruit program

Honeyberry USA

Sustainable Agriculture Demonstration Grant Project Updates



Developing The Right Seed Mix for Solar Grazing in Minnesota

Principal Investigator
Grantee: Arlo Hark
Organization/Farm: Cannon Valley Graziers
Email: arlo@cannonvalleygraziers.com
Counties: Dakota, Rice, Steele, Fillmore, Waseca

Project Duration
2022-2025, 3 years

Award Amount
$24,396.90

PROJECT SUMMARY

Over the last five years, "solar grazing" (the practice of using sheep to manage vegetation on utility-scale solar sites) has become widely and rapidly adopted across the United States. Through paid contracts with solar developers, solar grazing has the potential to have a tangible, positive impact on the viability of both large- and small-scale sheep farms in the Upper Midwest.

Our project seeks to advance the widespread adoption of solar grazing in Minnesota by developing and testing a ground cover seed mix for use in solar grazing systems. Over a three-year period, we will compare four distinct seed mixes on four separate test sites and measure their effectiveness in four categories: a) ease of establishment; b) cost-effectiveness; c) climate resilience; and d) benefits to pollinators and sheep. The precise objective of this project is to provide the public with an effective, Minnesota-specific solar grazing seed mix that can be used across the state in a variety of applications.

PROJECT DESCRIPTION

Our project aims to support the further development of solar grazing in Minnesota by creating a biome-specific, multi-purpose seed mix that meets the needs of solar developers, meets county-level pollinator scorecard requirements, and provides adequate forage for solar graziers.

Minnesota is on track to develop thousands of acres of utility-scale solar gardens in the coming decade. With this development comes a unique and significant opportunity for Minnesota to become a leader in solar grazing. As Cannon Valley Graziers continues to scale our operation, it is imperative that we are able to create efficient and sustainable systems that will facilitate the long-term success of our farm business and the success of solar grazing more broadly. In order to further advance the co-location of sheep and solar in the Upper Midwest, we need a seed mix that is easy to establish, resilient, meets pollinator habitat scorecard requirements, and provides adequate forage to sustain healthy flocks of solar-grazing sheep.

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The successful development of a Minnesota-specific solar grazing seed mix has implications for the widespread adoption of solar grazing throughout Minnesota. As we have seen in recent years, shepherds across the country have been struggling, and many long-time sheep producers are folding under the stressors of extreme drought and poor market conditions. Solar grazing offers a compelling opportunity for the shepherds of the Midwest to diversify their revenue stream and can help promote the viability of both large- and small scale-sheep operations. In developing a widely adoptable seed mix, we are laying the groundwork for the market expansion of solar grazing in the Upper Midwest.

OBJECTIVES

1. Evaluate the cost, cost-effectiveness, establishment, and climate resiliency of different seed mixes.
2. Measure the benefits of seed mixes for sheep, pollinators, and the environment using the "Pollinator Scorecard."
3. Develop "Minnesota Fuzz and Buzz" seed mix for solar developments.

2022 RESULTS

For the first year of this grant, we worked with Natural Resource Services to develop an approach to finding the right seed mix for solar grazing. We worked together to successfully install seed and graze sites with four distinct seed mixes. Two of the four sites had been previously established with a native pollinator seed mix. One of the two sites previously established with a native pollinator seed mix was grazed with sheep in 2021 (its first year of establishment) as well as 2022. One site was seeded later than planned and grazing was not advised, as site installation and establishment was delayed due to supply chain constraints.

A ewe with her lamb grazing under solar panels.

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Vegetation after grazing under solar panels.

We gathered baseline data on animal body condition and overall health and welfare from our flock mid-season to compare with year two and three data. The ability to gather more precise weights from the whole flock was impractical this year based on our current corral equipment, thus we gathered data from a small sample size. In order to gather more precise weights, the use of a more sophisticated mobile corral system is necessary.

We gathered baseline data on ground cover and species diversity for each site included in year one activities. Our primary method of gathering data was observational – a general species survey was performed on each site, with photos to illustrate species present that include both desirable native and non-native species as well as "weedy" and undesirable species. We noted sheep selection for or against each species present. We also gathered baseline observational data on how each site performed in variable weather conditions. Some sites were in locations that experienced high-intensity drought, while others were in areas of increased seasonal precipitation. Due to a decentralized approach, our operations were mostly unaffected by local drought conditions.

Overall, no significant conclusions can be drawn from year-one activities.

ADDITIONAL RESOURCES

American Solar Grazing Association: *www.solargrazing.org*

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Fall-blooming asters in a pollinator-friendly solar planting.

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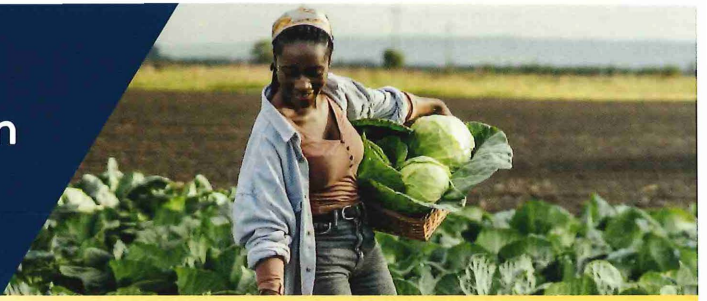

Documenting Temperatures on Fruit Trees in Winter Protection

Principal Investigator
Grantee: Daniel Sheild
Organization/Farm: Stone Creek Farm
Email: grafted73@gmail.com
County: Chisago

Project Duration
2022-2025, 3 years

Award Amount
$7,314.29

PROJECT SUMMARY

This project will use data loggers and heat sensors inside two existing high tunnels to determine the minimal amount of energy input through a heat source (electric heat tape) needed to protect peach flower buds throughout the winter. The data kept through the night during descending temperatures will indicate when the heat source is activated, allowing us to thermostatically control temperatures above the kill zone (16 to 23 degrees Fahrenheit below zero). This will also help determine how quickly supplemental heat must be applied inside the tunnel and the lowest amount of energy needed for heating to ensure fruiting. If the use of electricity can be reduced from 12 to 3 hours, for instance, this would save 75% of cost and energy. Both inside and outside temperatures will be monitored in two high tunnels and two outdoor locations near the tunnels to determine the lowest indoor and outdoor temperatures under which the system works. This data could reveal what other parts of Minnesota could grow peaches, apricots, and plums consistently with this system.

PROJECT DESCRIPTION

After many manifestations of systems attempting to grow peaches in harsh Midwest conditions, I discovered that growing a tree in a sunlight- and wind-proof shelter in the winter with a small supplemental heat source for only the coldest days in my back yard worked the best. I transferred those principles to a larger system on our farm in a 34 feet by 72 feet high tunnel covered with silage tarp in the winter and had great success, having now had peaches here for seven years running. It works far better than I imagined. Wanting to be more sustainable and use little or no electricity, I incorporated four heat sensors and a data logger to store data to determine when a heat source was needed (if any). Initially I intended to have two heat sensors in two tunnels and one outside to record outside temperatures, but I added one more in an empty tunnel as a control with no extra heat at all. I'm researching as if this is the model for the future of peach growing in the Upper Midwest, so I'm also reviewing 43 types of peach cultivars for crop load, brix, precocity, size, sequence of ripening, and winter hardiness in the system.

Three temperature sensors inside of three high tunnels and one temperature sensor outside will observe and record temperatures to determine if added supplemental heat is needed to keep the flower buds alive, or if the geothermal from the ground will be enough to maintain the life of the flower buds. Temperature will also be monitored when supplemental heat is needed to determine the minimal amount of heat and energy needed for success in the system.

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The information will be sent to a data logger and transferred via cellular network to be accessible on a desktop computer and cellular phone so data can be stored and printed for a future presentation.

OBJECTIVES

Document the data from the data loggers and sensors monitoring the electrical input to determine the lowest possible electricity use compared to fruiting ability and crop success.

2022 RESULTS

Because of supply issues, the sensors and data loggers didn't come until late summer and the technician wasn't available to install them until late September. As a result, summer numbers weren't recorded. So far for winter temperatures, each of the tunnels have varied slightly from each other. Factors like the size of the tunnel, snow load, shade in the afternoon, amount of or size of trees, and moisture differences in each tunnel may be responsible for the different readings. Tunnel one has varied 18-22 degrees above the outside temperatures during the coldest part of the day or night. Tunnel two has been the warmest, ranging 20-26 degrees above the ambient temperatures, and tunnel three the coldest, at 8-16 degrees above ambient.

Tunnel two showed the greatest difference from ambient, followed by tunnel one then three, but they all mirrored the outside sensor with their respective averages, especially when temps descended. In December 2022, we had an unusual amount of snow with over 20 inches on the ground even after some melting. This provided insulation to the ground around the tunnels and over the tops of the tunnels with 3 to 10 inches. Each year will vary differently from others depending on many factors, but this year the difference between inside and outside has been the greatest, which I attribute to deep snow.

ADDITIONAL RESOURCES

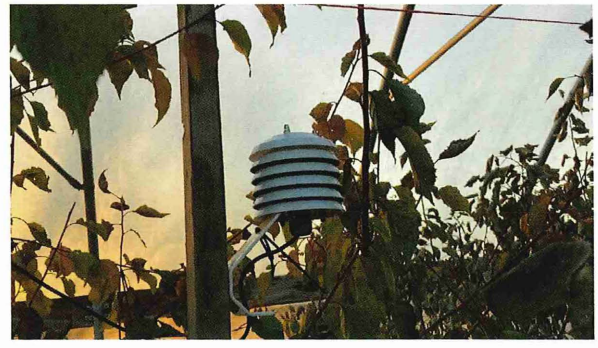
Minnesota Grown Peaches: *www.cbsnews.com/minnesota/news/peaches-grown-in-minnesota/?intcid=CNM-00-10abd1h*

America Fruit Grower Magazine March 2005, pg. 54 Chinese Peaches, Past and Present

Chinese Protected Fruit Cultivation Desmond Layne- Everything About Peaches Video

Instagram: Dan Sheild Stone Creek Farm, username: @dan_sheild

Temperature sensor and data logger outside the high tunnel.



Temperature sensor inside the tunnel with peach trees.

Minnesota-grown high tunnel peaches.

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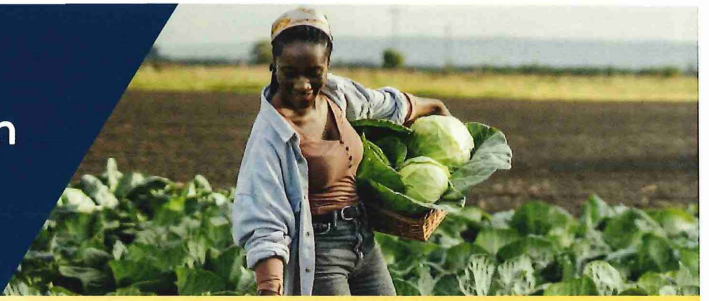

Baseline Carbon Market Value of Intermediate Wheatgrass

Principal Investigator
Grantee: Brad Gordon
Organization/Farm: Great River Greening
Email: bgordon@greatrivergreening.org
County: Nicollet, Scott

Project Duration
2022-2025, 3 years

Award Amount
$34,655.45

PROJECT SUMMARY

Eastern Nicollet County has become a hub for new crops and rotations trialed in Minnesota. One of those crops is Intermediate Wheatgrass (Kernza®). Many local growers desire more confirmation of market opportunities before growing this new crop themselves. A new market that has recently come to the forefront is carbon. This project will demonstrate the profitability of Kernza® when including carbon payments. Before this market is applicable, measurements of carbon sequestration in soil are foundational for setting expectations for revenue per acre. To date, there is very little data on Kernza®'s carbon sequestration in the soil surrounding its deep roots. This project will measure changes in soil carbon over three years in Kernza® fields and control corn/soy fields. The results will be conveyed to interested farmers, community members, the scientific community, and carbon buyers. If farmers can have a baseline value of what they could potentially make per acre from selling Kernza®'s sequestered carbon, they will have a better idea of return on investment for this crop compared to others. Adding carbon to Kernza®'s grain and hay/grazing value could make it even more competitive.

PROJECT DESCRIPTION

Kernza® is still a fairly new crop in Minnesota but has been growing in popularity due to its environmental benefits and flavor as a grain and milled flour. It is the first perennial grain crop in the world and one of the few perennial crops in Minnesota. Its deep roots restore soils, retain water, improve infiltration, increase carbon sequestration, and improve habitat. It has been increasing in acres slowly in order to establish markets and evaluate risks. Now that a cooperative has been developed, discussions about finding the balance between price establishment and market demand have been moving quickly to make it a profitable crop for farmers and an affordable grain for buyers. One element in the value establishment that could make Kernza® more profitable for farmers than other present crops is its potential in carbon markets and other ecosystem services. Organizations that are already buying carbon in Minnesota have been paying between $3 and $20 per metric ton of carbon stored in the soil. These payments are usually for cover crops and no-till or strip-till practices, but some buyers are focusing on retired farmland as well. At this time, there are not enough data for carbon sequestration from Kernza® to enter the carbon markets even though it is well known that the crop will be competitive with other practices for carbon tonnage stored, if not exceedingly more effective at carbon storage. The purpose of this project is to establish baseline data for carbon sequestration in Kernza® fields. Soil samples were collected across five fields at multiple depths to measure carbon

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change across three years of growth in typical tillage depth and lower due to Kernza's® deeper roots. Two fields have been established with Kernza,® where we will measure the sequestration beyond the second year of growth. One more field was planted with Kernza® in fall 2023, so measurements observe the change in soil carbon in the first year. Two other fields, including an FFA field, with soy/corn rotations adjacent to and containing the same soil types as the two established Kernza® fields were sampled as controls.

If a baseline of carbon sequestration is estimated, farmers will have an idea of what to expect from carbon markets. As they calculate returns on investment, they can calculate a better comparison between Kernza® and the more common crops — corn and soybeans. Results from this project will be communicated to farmers in the area, especially in Drinking Water Supply Management Areas (DWSMAs) where conservation practices are urgently needed, and to others in the agricultural community of southern Minnesota to discuss the value of this new crop.

OBJECTIVES

1. Measure and calculate carbon tons per acre to determine how much Kernza® sequesters in its first year and in later years of growth.
2. Evaluate the tonnage of carbon stored, communicate with carbon buyers, and determine whether a profitable market could be established for Kernza® growers.
3. Consider the interest of farmers in the area to grow Kernza® and community members to buy and support it.

Kernza® field that has been recently baled with a demonstration patch left unharvested.

2022 RESULTS

In October of the first year of the project, Great River Greening collected soil samples across five fields, with 10 sample sites per field and three depths at each site. Samples were analyzed for Total Organic Carbon (TOC) percentage and bulk density. Results for bulk density are still pending, but TOC measurements are complete. Trends cannot be measured in the first year, but each site's TOC was similar to its expected value. The sandier soils (BPK and BPF) were lower TOC than the loam soils (LPC, LPK, and BK). The oldest stand of Kernza® (BPK) was a slightly higher TOC than its neighboring corn/soybean field, but conclusions cannot be drawn at this time. The other existing Kernza® field (LPK) will be compared to the adjacent corn field (LPC). LPK is only one year old, so its TOC is expected to increase. BK will be planted in Kernza® in fall 2023, but its current TOC is relatively high to begin.

ADDITIONAL RESOURCES

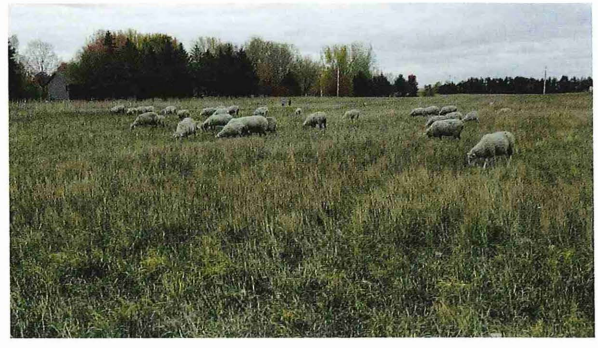
Here are some websites from carbon buyers whom we have been in contact with:

Truterra: *www.truterraag.com/Carbon*

Bayer: *https://bayerforground.com/farmers/carbon-initiative*

Cargill: *https://www.cargillag.com/grow-with-cargill/RegenConnect*

Indigo: *www.indigoag.com/carbon/for-farmers*



Kernza® is a perennial grain that can be harvested when mature or grazed, as seen here with sheep.

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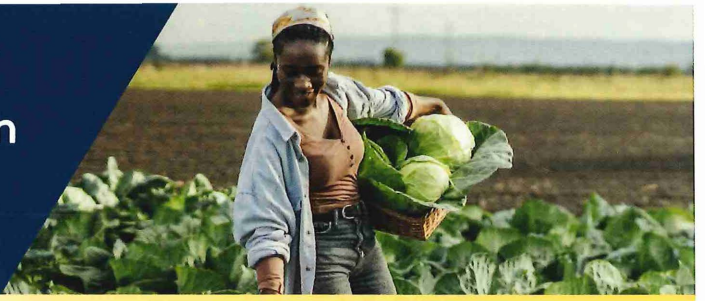

Evaluating Soil Health and Farm Profitability with Perennials and Poultry in Corn Production Systems

Principal Investigator
Grantee: Dr. Mriganka De
Organization/Farm: Minnesota State University, Mankato
Email: mriganka.de@mnsu.edu
County: Faribault

Project Duration
2022-2025, 3 years

Award Amount
$37,474.30

PROJECT SUMMARY

Corn growers are always looking for new management techniques to improve soil and environmental health while also improving farm profitability. Integrating perennial ground cover (PGC) and poultry (P) in corn production systems has the potential to achieve that goal. The proposed project will determine the impact of corn grown with PGC alone and/or PGC–P systems (60-inch row width) on soil health, crop yield, and farm profitability over three growing seasons in an on-farm setting. We hypothesize that corn grown (60-inch row width) with PGC and/or PGC–P systems will increase soil health, grain yield, and farm profitability compared to conventionally grown corn (30-inch row width) without PGC and P. The knowledge gained will be shared with producers and researchers via field days, social media, extension blogs, presentations at an ag-based conference, and a peer-reviewed journal publication. The proposed project hopes to increase the adoption of an innovative and sustainable corn production system with PGC and P suitable for Minnesota corn growers to serve our communities and customers better while positively impacting soil and environmental health.

PROJECT DESCRIPTION

The corn (Zea mays L.) production system in the Midwest is important because corn is used for livestock feed, agricultural exports, consumer products, and biofuel production. Nearly 40% of the world's corn and over half of the U.S. corn production comes from the four Midwestern states (Iowa, Illinois, Nebraska, and Minnesota). Among these, Minnesota alone produces about 9% of the nation's corn production and has become the fourth largest producer of corn in the U.S. In 2021, the average corn yield in Minnesota was 178 bushels per acre, with a slight decrease of 14 bushels per acre from 2020. However, U.S. corn production in 2021 was up 7% from 2020 and was the second highest on record. Despite the higher yields, intensive corn production with increasing removal of corn stover for cellulosic biofuels has caused negative impacts on soil and environmental health. These impacts are aggravated due to monocropping (predominantly corn) and a lack of actively growing rooting systems, leaving the soil exposed to wind and water erosion for more than half of each year. When agricultural fields are left fallow — especially early spring and late fall, nutrients (e.g., nitrogen and phosphorus) lost from farms can impair water quality and be an economic loss to farmers. Hence, it would be essential to eliminate the extended periods of bare soil in the intensive corn production system to improve soil and environmental health, farm profitability, and resiliency for a more sustainable production system in the region.

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Annual cover crops have shown promise to protect and improve soil health between regular row crop (e.g., corn) production, but low adoption illustrates the need for alternatives. One alternative management strategy might be intercropping grass and legume species as a perennial ground cover (PGC) into annual row cropping systems to eliminate fallow soil and minimize the impact on erosive soils. Unlike annual cover crops grown in a relay cropping system, PGC can be grown as a companion crop with corn and does not need to be replanted or terminated every year, thus requiring minimal management. Moreover, intercropping PGC into annual row cropping systems can increase continuous soil surface cover while providing numerous ecosystem and ecological benefits such as reducing soil erosion and surface runoff, herbicide use, nitrogen leaching, weed management and increasing microbial biomass/activity, moisture retention, and the supply of nutrients to the annual row crops. These benefits can be achieved by building or maintaining healthy soils through sustainable soil management practices (e.g., adding PGC).

Along with establishing PGC into annual row crop systems, livestock integration (e.g., poultry) might be an innovative and sustainable method for corn growers to alleviate some of the need for fertilizer application, especially in light of rising fertilizer costs and environmental concerns. Furthermore, the PGC–P system will provide an enjoyable way of raising healthy poultry to express their natural behaviors and increase the diversity of their diets through the consumption of plants and insects. Thus, the integrated approach could improve soil health, reduce off-farm inputs and investment costs, increase farm profitability, and provide producers with sustainable corn production options.

Previous studies have used annual ground cover as a relay crop in row crop systems, but studies establishing PGC and P into row crop systems are limited. Therefore, this study hopes to develop an innovative and sustainable corn production system with PGC and P suitable for growers to better serve our communities and customers while positively impacting soil and environmental health.

We hypothesize that corn grown with PGC–P systems (60-inch row width) will not cause a yield reduction but will increase soil health and farm profitability compared to conventionally grown corn (30-inch row width) without PGC and P.

Experimental Design

To test our hypothesis, a field study was conducted at the Blue Dirt Farm in Faribault County. The experimental design was a randomized complete block design on 2.4 acres of land with four different treatments (three PGC + one control) and four replications for each treatment (i.e., a total of 16 plots = 4 treatments × 4 replications). The control treatment was planted traditionally (i.e., 30-inch rows for a total of 12 corn rows per plot) with no cover crops. For better ground cover, PGC was planted as companion crops with corn on 60-inch rows for a total of six corn rows per plot. Three PGC treatments included i) grass and corn; ii) legume and corn; and iii) grass, legume mix, and corn. Grass and legume species included the following: white clover (Trifolium repens), birdsfoot trefoil (Lotus corniculatus), festulolium (xFestulolium sp.), and bluegrass (Poa sp.).

A 1-inch diameter soil probe was used at each experimental plot to collect eight soil cores to create one composite sample from the 0- to 6-inch depth. Soil cores were collected twice throughout the growing season (before planting and after harvest), processed, and analyzed for physical, chemical, and biological soil health indicators.

Twenty soil plant analysis development (SPAD) Meter readings (a measurement of "greenness" which directly relates to chlorophyl content) per plot were taken at V5/V6 growth stage. Each reading was on a separate plant, randomly selected from the total number of plants per row. A week before harvesting, 12 randomly selected corn ears from each plot were used to calculate percent pollination, number of kernels per ear, kernel weight, and ear weight. The center two rows of each experimental plot were harvested separately and weighed using a test plot weigh wagon for yield analysis. In addition to grain yield comparison, an annual cost-benefit analysis will be conducted to compare the return on investments among the treatments and determine the success of the study.

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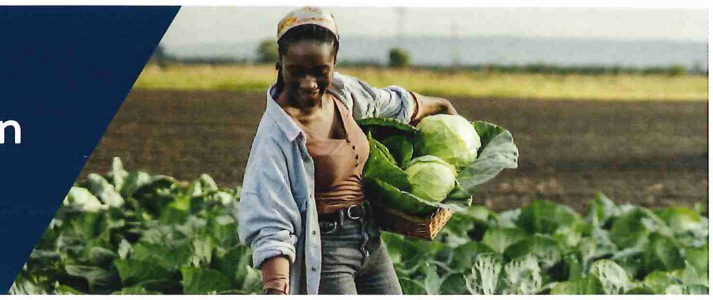

All statistical analyses (e.g., descriptive statistics and one-way analysis of variance [ANOVA] assessment with the Tukey test to determine significance [$p<0.05$] between treatments) were done with Sigma Plot 12.5 and Statistix 10 software.

OBJECTIVES

1. Quantify and evaluate the changes in physical, chemical, and biological soil health indicators with PGC and P integration.
2. Quantify and evaluate the impacts of a PGC-P system on crop performance.
3. Conduct a cost-benefit analysis to compare the return on investments among the treatments and determine the success of the financial aspect of the study.

2022 RESULTS

In 2022, baseline measurements were taken to evaluate soil and crop performance across the different treatments. Table 1 and figures 1 through 3 show the results of data collected to measure soil (physical, chemical, and biological) and corn plant quality and yield.

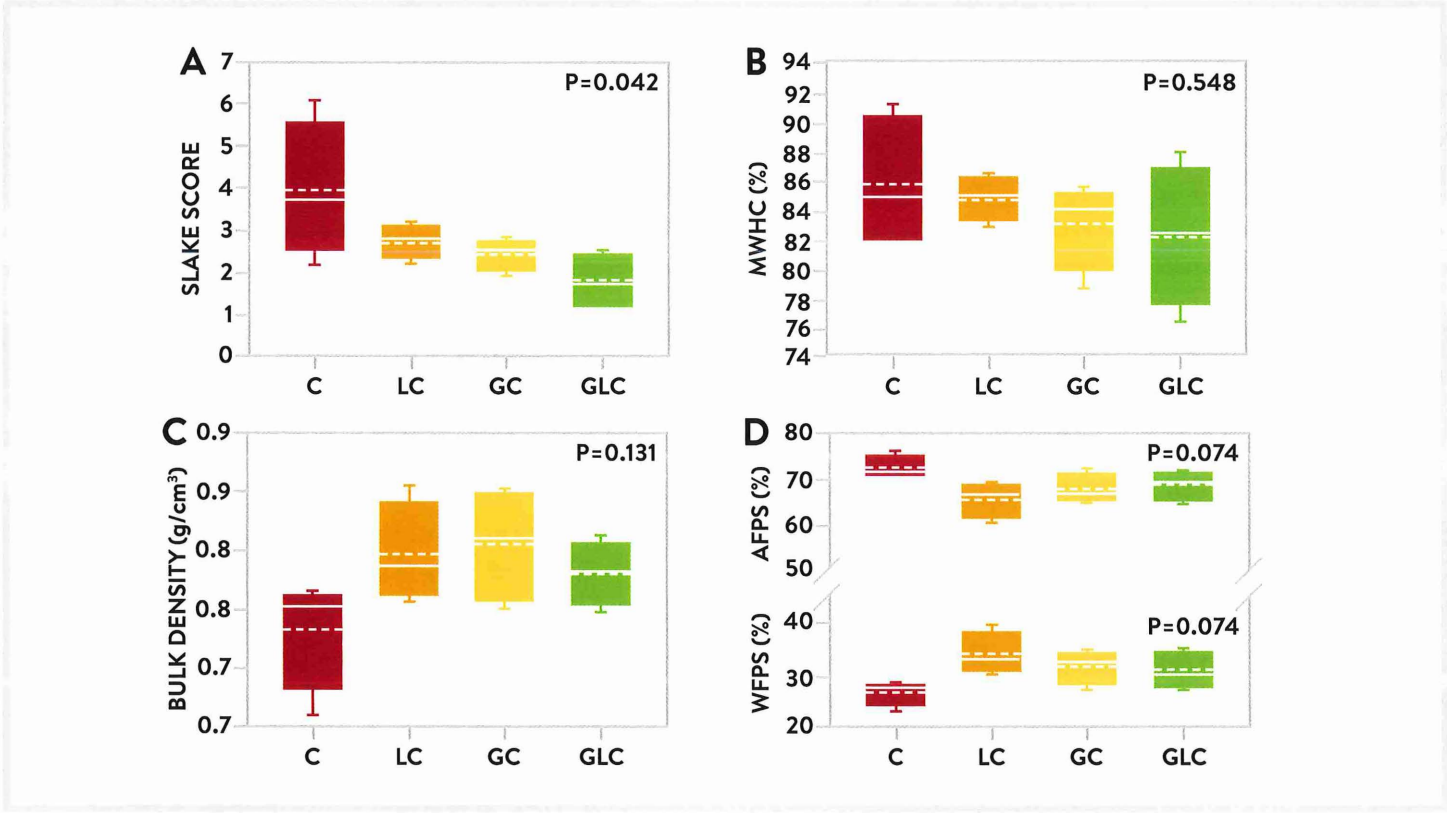

Figure 1: Box plots showing selected physical soil health indicators: A) SLAKE score (lower is better), B) maximum water holding capacity (MWHC), C) bulk density (lower is better), and D) water filled pore space (WFPS) and air-filled pore space (AFPS) collected from control (C) and perennial ground cover treatments (LC: Legume Cover; GC: Grass Cover; and GLC: Grass and Legume Mixture) with P values, median, 10th, 25th, 75th, and 90th percentiles. Means are shown as solid dashed lines.

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Table 1: Selected soil chemical indicators collected from control (C) and perennial ground cover treatments (LC: Legume Cover; GC: Grass Cover; and GLC: Grass and Legume Mixture) in fall 2022.

PARAMETERS	C	LC	GC	GLC
pH (1:1)	6.7	6.4	6.5	6.5
Electrical Conductivity (EC, mmho cm^{-1})	0.26	0.23	0.32	0.30
Cation Exchange Capacity (CEC, me $100g^{-1}$)	27.5	25.2	24.9	25.0
Soil Organic Matter (SOM, %)	6.8	7.2	6.8	7.0
Mehlich P-III (P, mg kg^{-1})	22.5	18.3	21.0	19.3
Potassium (K, mg kg^{-1})	226.0	209.5	221.3	211.0
Calcium (Ca, mg kg^{-1})	3,910.8	3,471.5	3,604.0	3,648.5
Magnesium (Mg, mg kg^{-1})	707.8	627.5	648.3	652.3
Sulfate-S (SO4-S, mg kg^{-1})	3.7	3.2	2.9	3.5
Zinc (Zn, mg kg^{-1})	1.6	1.4	1.3	1.4
Iron (Fe, mg kg^{-1})	52.6	51.9	43.4	42.9
Manganese (Mn, mg kg^{-1})	9.9	9.7	8.3	7.9
Copper (Cu, mg kg^{-1})	2.2	1.8	1.6	1.5
Boron (B, mg kg^{-1})	1.3	1.4	1.2	1.3
Sodium (Na, mg kg^{-1})	9.8	8.5	9.3	9.0

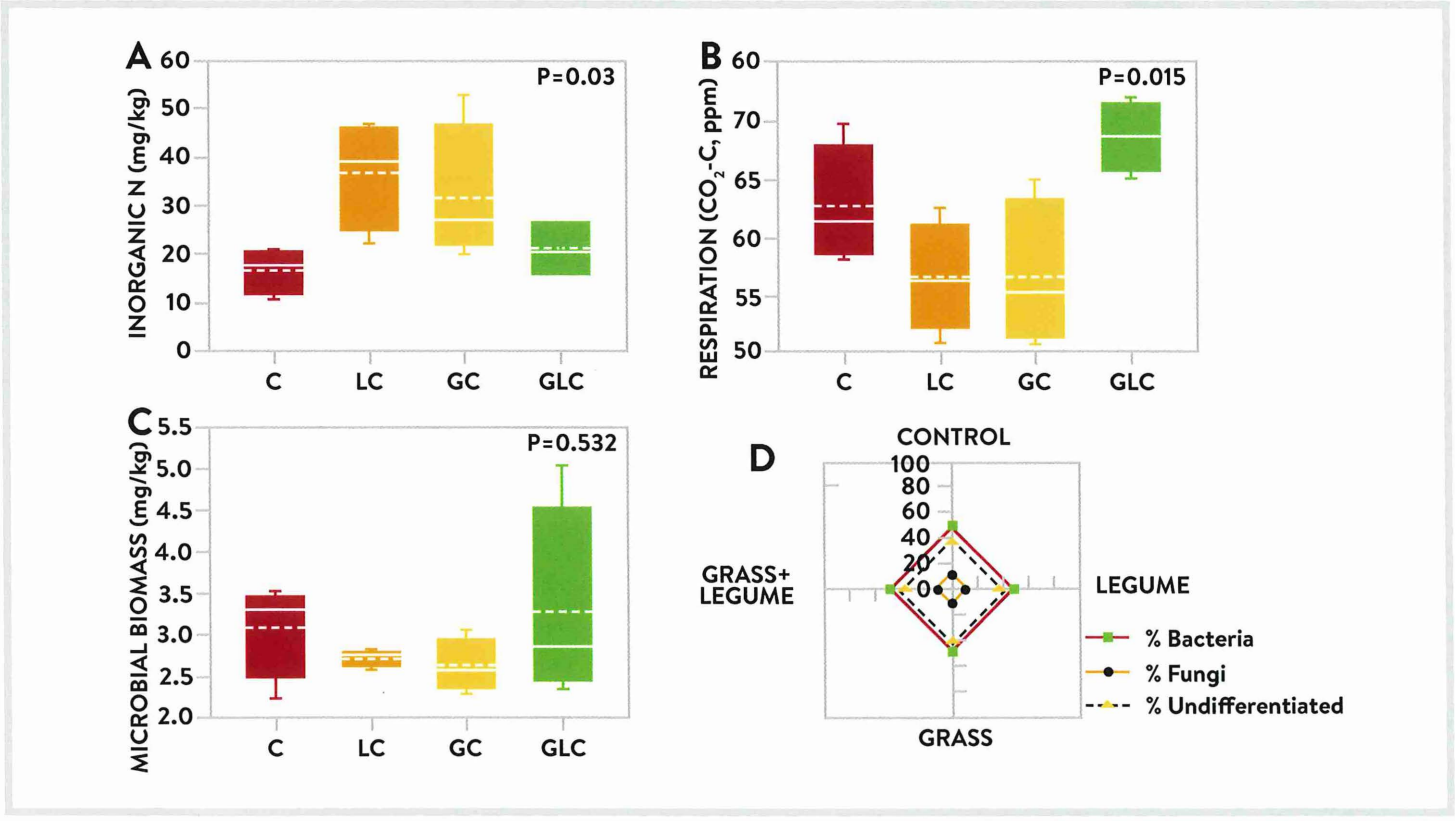
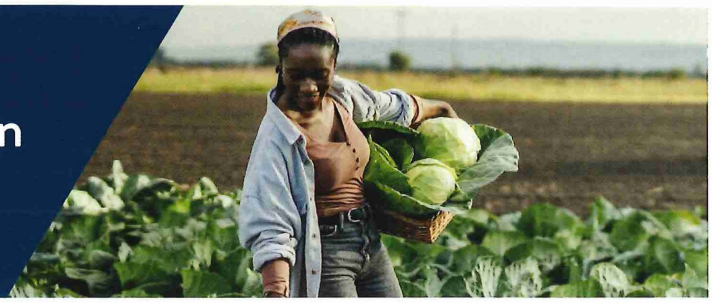
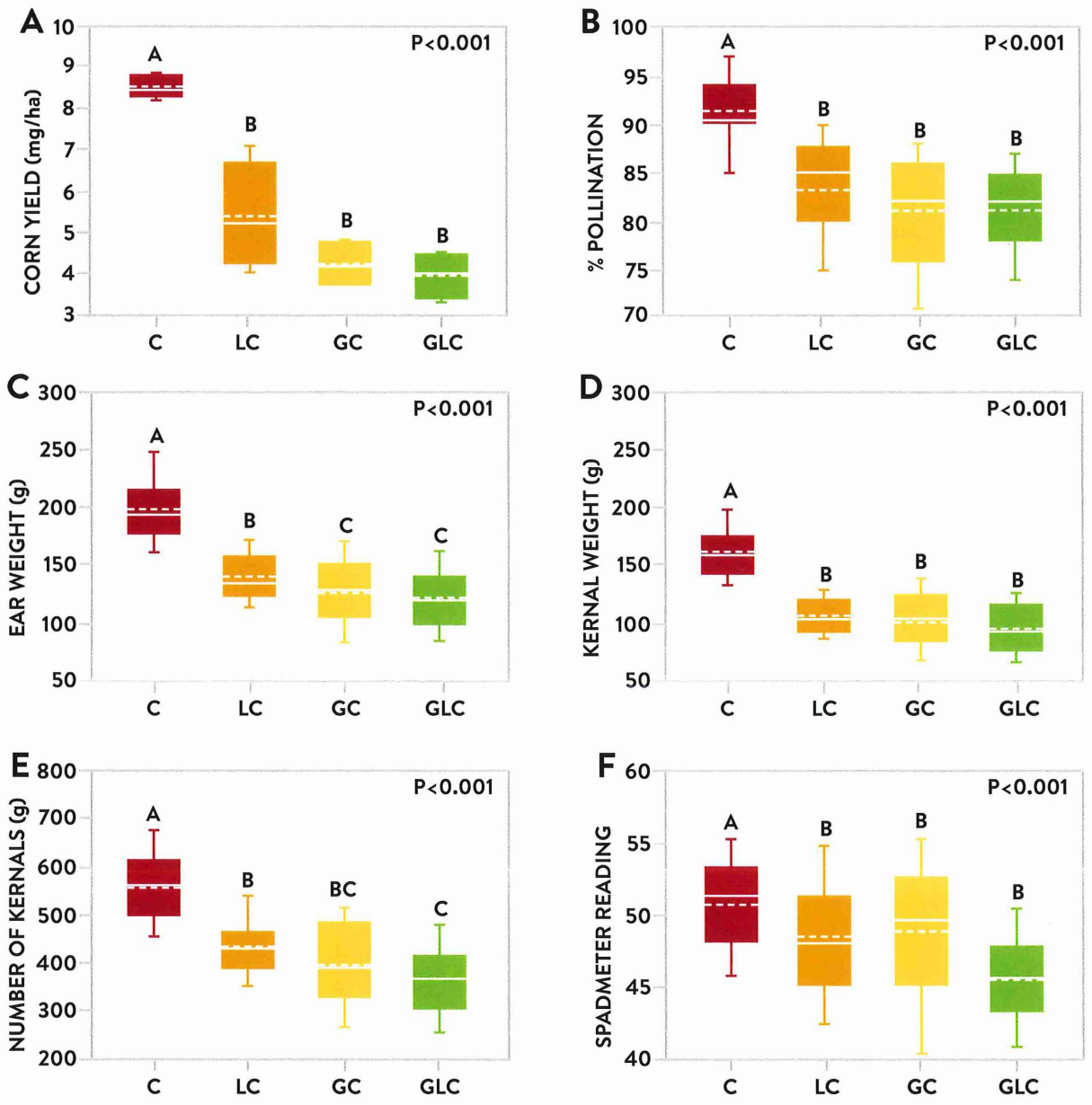


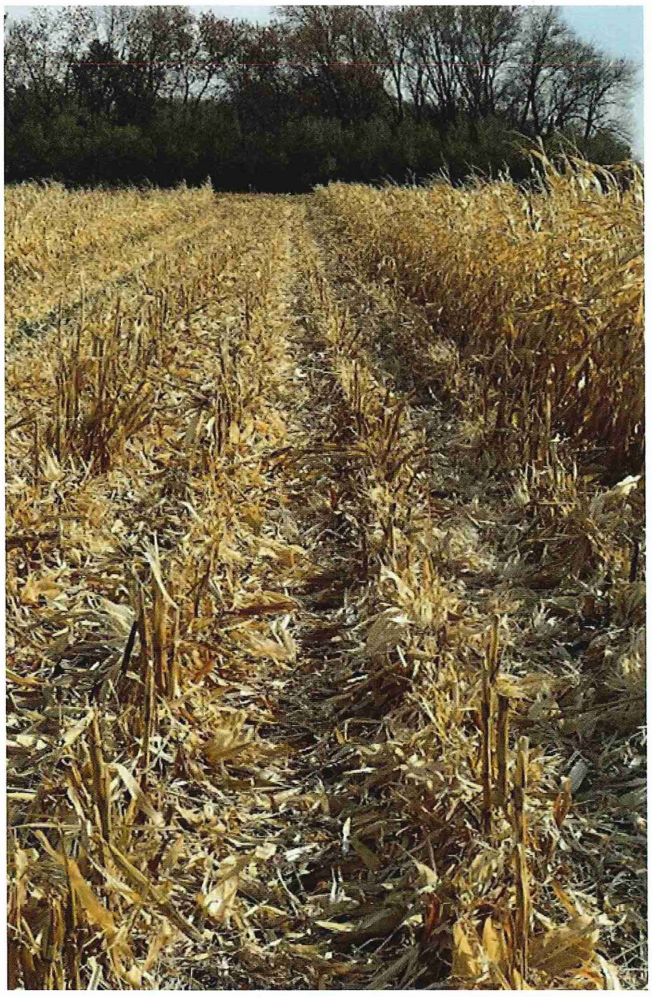
Figure 2: Box plots showing selected biological soil health indicators: A) total inorganic nitrogen, B) soil respiration, C) total living microbial biomass, and D) percent distribution of bacterial biomass, fungal biomass, and undifferentiated biomass of the total living microbial biomass collected from control (C) and perennial ground cover treatments (LC: Legume Cover; GC: Grass Cover; and GLC: Grass and Legume Mixture) with P values, median, 10th, 25th, 75th, and 90th percentiles. Means are shown as solid dashed lines.





Fugure 3. Box plots showing selected physical soil health indicators: A) SLAKE score (lower is better), B) maximum water holding capacity (MWHC), C) bulk density (lower is better), and D) water filled pore space (WFPS) and air-filled pore space (AFPS) collected from control (C) and perennial ground cover treatments (LC: Legume Cover; GC: Grass Cover; and GLC: Grass and Legume Mixture) with P values, median, 10th, 25th, 75th, and 90th percentiles. Means are shown as solid dashed lines.

Sustainable Agriculture Demonstration Grant Project Updates



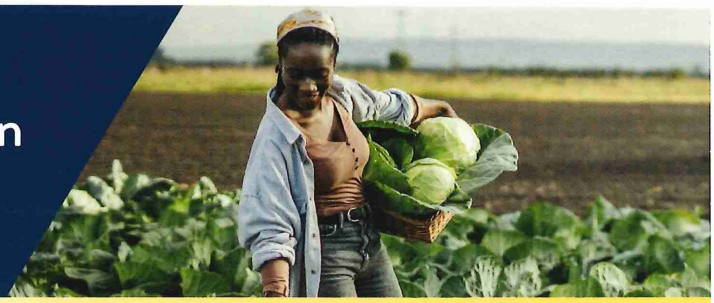
Corn was harvested with a John Deere 9770 Combine Harvester with 8-row cornhead. Combine harvested two central rows for 60-inch row spacing corn and four central rows for 30-inch row spacing corn. Grain moisture content was estimated by grain yield monitor on the combine and weighed on a seed tender with Weigh-Tronix scale.

Overall, control (C) treatment performed better than the perennial ground cover treatments and did not support our hypothesis. However, grass and legume mixture (GLC) has the potential to improve soil physical (e.g., lower SLAKE score; Fig 1A) and biological health (e.g., higher soil respiration, total inorganic N, and total living microbial biomass; Fig 2) than the grass and legume only treatments. Hence, it is too early to make a conclusion based on initial data. Having patience can be helpful to determine what real trend would be over several years.

ADDITIONAL RESOURCES

Project updates, photos, and videos were shared through Dr. De's Twitter account (@MrigankaDe2) and are available for free download from Dr. De's lab website: *https://mrigankade.wixsite.com/soilecology/about-me*

Sustainable Agriculture Demonstration Grant Project Updates



Interseeding Clover Into Pumpkins

Principal Investigator
Grantee: Charles Rohwer
Organization/Farm: University of Minnesota
Email: rohw0009@umn.edu
Counties: Waseca, Brown

Project Duration
2022-2025, 3 years

Award Amount
$14,785.00

PROJECT SUMMARY

Cover crops can improve soil health. Legume cover crops, like clover, can fix nitrogen and make it available to subsequent crops. Crimson clover, for example, can be sown between rows of corn in our region, because it can tolerate some shade from the corn. Pumpkins are grown with much wider row spacing than corn (7 to 12 feet instead of 2.5 feet), and pumpkin foliage doesn't fill in between rows until later in the season than corn. The area between rows of pumpkins is generally kept weed-free with tillage and herbicides, or a killed cover crop like rye is used as mulch. The primary objective of this project is to learn what kind of clover can grow well between rows of pumpkins and fix nitrogen for the crop that follows pumpkins (often corn). Eleven types of clover and three clover mixes were planted between pumpkin rows before vines started to elongate. Pumpkins were harvested and weighed to determine if clover reduced the yield of pumpkins. While clover was still growing, but after pumpkin leaves were killed by frost, clover was harvested to measure biomass. Separately, six clovers were sown in soil treated by five common pumpkin herbicides at two locations in southern Minnesota to determine if clover can be grown even though the soil was treated with herbicides. The ultimate goal is to reduce fertilizer use and improve soil health in rotations with pumpkins.

PROJECT DESCRIPTION

The experiment was carried out at the University of Minnesota Southern Research and Outreach Center in Waseca. We have grown pumpkins in our clay-loam soil before. We have used tillage between rows to keep weeds at bay, but we were interested instead in growing a legume that a) wouldn't compete with pumpkins and b) would provide nitrogen to the corn grown in the year following pumpkins to reduce external fertilizer inputs. We trialed 14 types of clover planted between pumpkin rows, seeding them before pumpkin vines extended. We weighed all pumpkins from each 540-square-foot plot, and measured biomass between pumpkin rows after vines died in the fall. Comparisons were made to plots where no clover was grown, and the experiment was replicated three times (0.6 acres total) using Cotton Candy pumpkins for all plots. In 2022, there was tremendous weed pressure in one replicate (mostly waterhemp), and poor clover germination and a lot of purslane in another replicate. Clover only grew well between pumpkin rows in the third replicate, where moisture in the clay-loam soil seemed to be highest. No herbicides were used between pumpkin rows in 2022. When a clover mix was grown under the taller canopy of Kronos pumpkins in un-replicated plots nearby, it grew well and survived beyond pumpkin harvest (observation).

Sustainable Agriculture Demonstration Grant Project Updates

We intended to study clover nitrogen content but instead decided to use 2022 results to inform plans for 2023. Also, we will extend the project to 2024 because clover only grew well in one replicate in 2022 and we'd like two years of replicated data. In a separate study where herbicides (Dual Magnum, Curbit, Prefar, Sandea, or Strategy) were used 30 days before planting small plots of clover, there were no effects of herbicides on clover growth at one trial location (Waseca). At another location of the herbicide trial (Guldan Family Farms), clover failed to germinate because of dry weather and very sandy soil. Based on the results of the 2022 trial, we focused on a smaller number of clovers in 2023 (red, crimson, berseem, and Persian), used both Kronos and Cotton Candy pumpkins, and we broadcast Strategy herbicide between pumpkin rows. Clover emergence between pumpkin rows has been very good, and the herbicide has been effective in reducing weed growth. Pumpkin emergence in 2023 was variable due to very dry weather for weeks after planting. We are repeating the herbicide trial at both locations in 2023.

OBJECTIVES

1. Generate and share information about and demonstrate use of clover as a nitrogen-fixing interseeded "living mulch" cover crop, with specific relevance for cucurbit growers.
2. Assess pumpkin yield when intercropped with common clovers just prior to vine elongation.
3. Assess impacts of pumpkin-labeled herbicides on clover germination in two soil types.

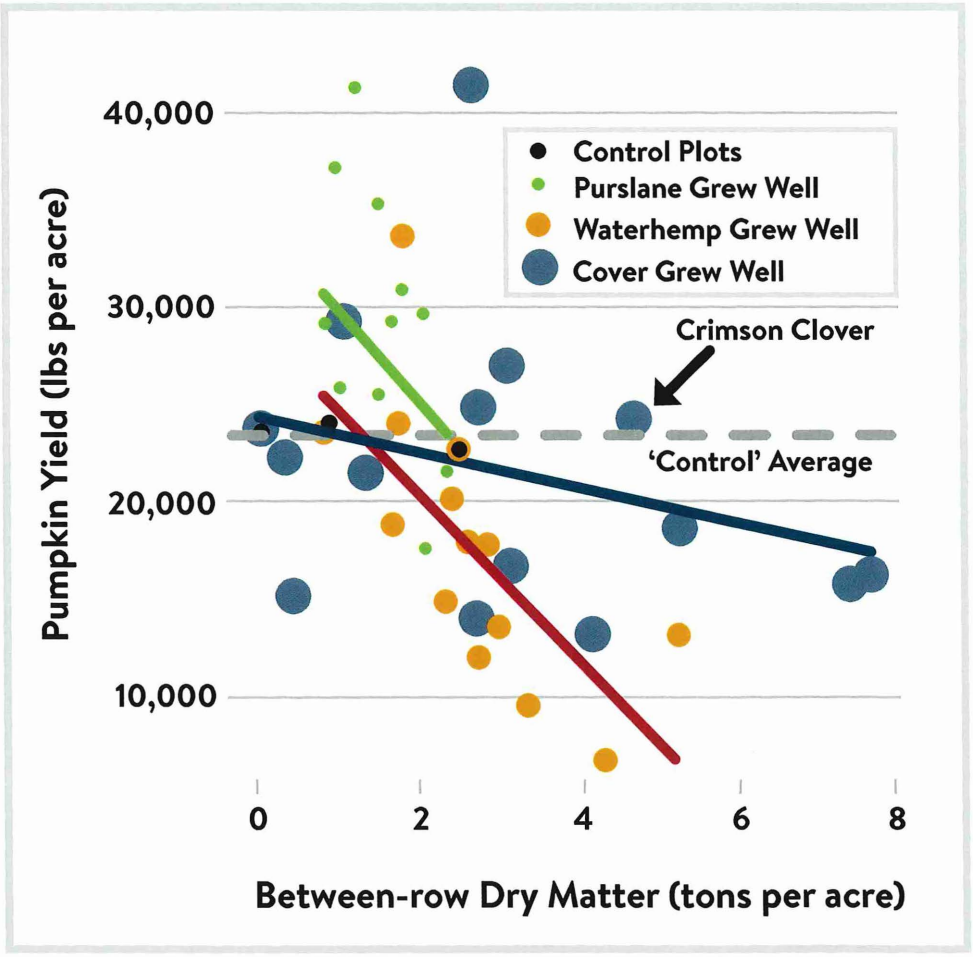
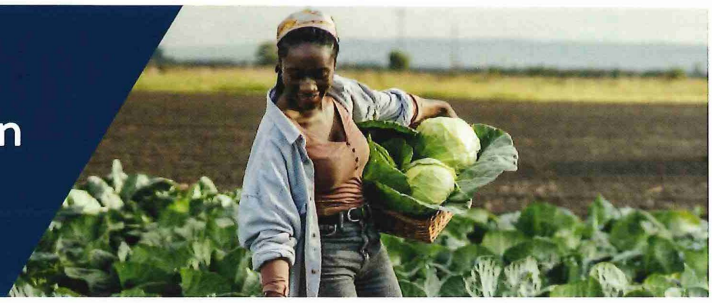


Figure 1. Pumpkin yield based on between-row dry matter.

Sustainable Agriculture Demonstration Grant Project Updates



2022 RESULTS

In 2022 (the first year of this project) in Waseca, pumpkins were hand-planted in rows 10 feet apart on May 23. Germination was very poor due to cold soil, seed predation, and seedcorn maggots. Pumpkins were re-planted on June 14. At harvest, there was tremendous weed pressure in one replicate (mostly waterhemp), and poor clover germination and a lot of purslane in another replicate. Clover only grew well between pumpkin rows in the third replicate, where moisture in the clay-loam soil seemed to be highest. Across all replicates, control plots (hand-weeded, without clover) yielded 23,437 pounds of Cotton Candy pumpkins per acre and 7.0 pounds per pumpkin, which was no different from any clover treatment. Within the replicate where the clover generally grew well, Crimson clover generated 4.7 tons of dry matter (d.m.) without reducing pumpkin yield. Berseem clover got especially tall and seemed too competitive (7.6 tons d.m.). In the study where herbicides (Dual Magnum, Curbit, Prefar, Sandea, or Strategy) were used 30 days before planting clover, there were no effects of herbicides on clover growth at one trial location (Waseca). At another location for the herbicide trial (near New Ulm), clover failed to germinate because of unusually dry weather and very sandy soil. Based on the results of the 2022 trial, we focused on a smaller number of clovers in 2023, used both Kronos and Cotton Candy pumpkins, and used Strategy herbicide on pumpkins.

ADDITIONAL RESOURCES

Midwest cover crop council: Guide for cover crops in Minnesota: *www.midwestcovercrops.org/statesprovince/Minnesota/*

SARE: Building soil for better crops: *www.sare.org/resources/building-soils-for-better-crops/*

SARE: Managing cover crops profitably: *www.sare.org/resources/managing-cover-crops-profitably-3rd-edition/*

University of Minnesota Soil Health Twitter, @MnSoil

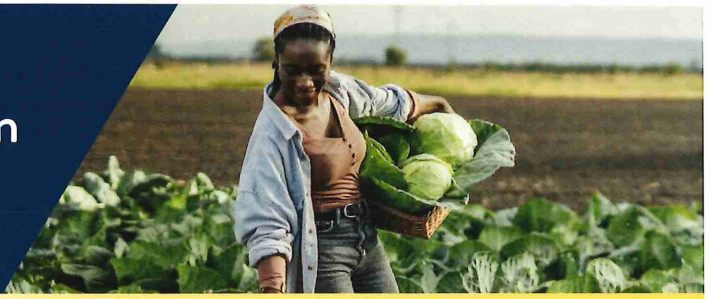
Clover growing between rows of pumpkins.

Sustainable Agriculture Demonstration Grant Project Updates

After pumpkin vines have died, clover is still growing well.

Persian clover growing among other clovers in the herbicide trial.

Sustainable Agriculture Demonstration Grant Project Updates



Farming Practices for Improved Soil Health: An Evaluation of the Impact of No-Till with Chemical Control of Weeds vs. Super-Shallow Tillage and No Chemical Control of Weeds on Soil Health

Principal Investigator
Grantees: Katy Chapman and Lindsay Pease
Organization/Farm: University of Minnesota
Email: katys@umn.edu
County: Polk

Project Duration
2022-2025, 3 years

Award Amount
$38,629.00

PROJECT SUMMARY

To face emerging challenges in food security, rising input costs, and environmental stewardship, agriculture needs to be both highly productive and sustainable. Over much of the past century, agricultural innovations have prioritized higher yields over long-term sustainability. This has led to important technological innovations in both physical (tillage, planting, and harvesting equipment) and chemical (fertilizers, herbicides, and pesticides) management. However, as these technologies developed, soil biological responses were often overlooked. Understanding how soil management decisions affect soil biology and fertility responses is critically important to long-term sustainability. Intensive tillage is a solution to two management challenges: 1) it reduces pesticide spraying and slows the development of pesticide resistant weeds; and 2) it incorporates fertilizer into the soil to prevent loss to the environment. However, use of tillage comes at a cost. It results in the degradation of soil health and the soil microbiome. This project seeks to identify solutions for growers wishing to balance these considerations. We will evaluate impacts of turkey litter placement on crop nutrition and yield, soil fertility, and soil health. We will also be evaluating the effectiveness of a foliar spray (SOURCE) at stimulating soil microbiology during the growing season. Determining which placement and fertility practices best support soybean production and soil health will provide the information growers need to meet multiple goals. This will contribute to lower carbon footprints of farm production and reduce the need for commercial fertilizers while promoting soil health, thus making it easier for soybean farmers to be successful.

PROJECT DESCRIPTION

Fertilizer placement has shown impacts on greenhouse gas emissions in past studies, and poultry litter is an underutilized nutrient source in Minnesota. This project will compare the effects of different poultry litter placement practices and SOURCE (a foliar applied product marketed to improve the microbial community associated with plants) on crop yield and soil health in soybean-wheat rotations on a silty clay loam in northern Minnesota.

This project is a significant deviation from our originally proposed project. However, due to the late spring in 2022, we were unable to plant into the field that had been no-till in order to evaluate different tillages. We plan to look at the residual impact of the poultry litter in 2023 on a wheat yield. In this trial, we will have plots that were tilled and plots that were not tilled in the fall of 2022. Our focus on soil health remained in the modified project, but moved to a later planting date crop in the rotation (soybeans), and we were unable to incorporate tillage due to having to move fields in order to get the trial in this year.

Sustainable Agriculture Demonstration Grant Project Updates

OBJECTIVES

1. Evaluate the influence of poultry litter placement and a foliar applied product on yield in a soybean-wheat cropping system in Minnesota.
2. Monitor soil health and greenhouse gas emissions in the cropping system.
3. Demonstrate and disseminate project results to local farmers.

2022 RESULTS

In year one, we collected baseline soil information including fertility, carbon, and microbial activity levels. Throughout the growing season, we monitored soil moisture, greenhouse gas emissions, and soil temperatures. At harvest, we collected soybean production metrics including yield, percent oil content, and percent protein content.

All of northwest Minnesota experienced significant challenges going into the 2022 growing season due to cool temperatures and wet soils. Our field trial on the LaPlante farm was no exception. In addition to the challenges brought by a late spring, we had difficulty securing turkey manure for our trial due to the avian influenza outbreak in the state. Luckily, we were able to find a farmer cooperator with an uninfected flock and a composted manure pile to supply us with turkey manure for the trial (Photo 1).

Photo 1: Composted turkey manure which was purchased for use in our trial.

Sustainable Agriculture Demonstration Grant Project Updates

We applied fertility treatments and planted soybeans at the LaPlante farm on June 11, 2022. We compared four turkey manure placements: 1) surface broadcast, no incorporation; 2) surface broadcast with incorporation; 3) in-furrow placement with a custom applicator; and 4) no manure placed as a control. The in-furrow applicator was supplied by collaborating scientists from USDA-ARS in Auburn, AL.

Poultry manure applicator designed to inject manure into the soil. This equipment was designed, supplied, and operated by collaborating research scientists from USDA-ARS in Auburn, AL.

Following fertilizer application and soybean planting, we received heavy rainfall at the study site. It is likely that this negatively affected soybean establishment, leading to below-average yields. We expected to see a significant response of fertilizer placement, at least when compared to our control which had no fertilizer applied. We did not see a statistically significant effect of fertilizer placement on yield, oil content, or protein content for 2022. The foliar spray we used did not have a significant effect on yield or protein content, but our results suggest it significantly decreased oil content (Table 1).

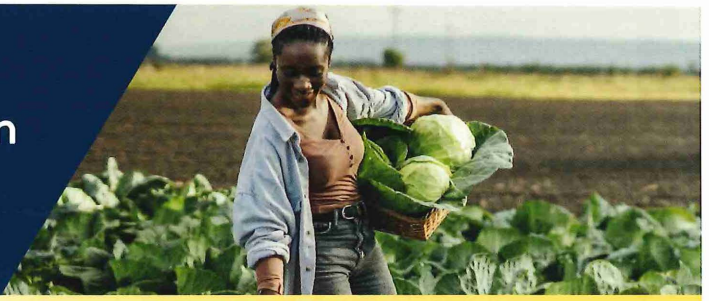
Sustainable Agriculture Demonstration Grant Project Updates

Table 1: Summary of yield metrics (grain yield, oil content, and protein content) by treatment observed during the 2022 growing season.

Fertilizer Placement	Foliar Biological Stimulant Application	Grain Yield (bu/ac)	Oil Content (%)	Protein Content (%)
No Manure		26.8	18.4	34.4
Banded Furrow		34.0	18.3	34.6
Broadcast & Incorporated		33.7	18.3	34.6
Broadcast		30.0	18.2	34.8
	None	31.8	18.4 A*	34.4
	Foliar	30.5	18.2 B	34.8
Placement x Foliar Interaction	**Foliar Biological Stimulant Application**	**Grain Yield (bu/ac)**	**Oil Content (%)**	**Protein Content (%)**
No Manure	None	27.7	18.5	34.1
	Foliar	25.9	18.2	34.7
Banded Furrow	None	33.9	18.3	34.6
	Foliar	34.2	18.3	34.6
Broadcast & Incorporated	None	33.6	18.3	34.6
	Foliar	33.8	18.3	34.7
Broadcast	None	32.0	18.3	34.5
	Foliar	28.1	18.1	35.2
(LSD $p < 0.1$)				
Placement x Foliar			ns	ns

**Means separated by different letters, indicating a statistically significant difference at a=0.10*

Sustainable Agriculture Demonstration Grant Project Updates



Specialty Crop and Season Extension Research by Emerging Farmers

Principal Investigator
Grantee: Verna Kragnes
Organization/Farm: Prairie Rose Farm
Email: verna.kragnes@gmail.com
County: Clay

Project Duration
2022-2025, 3 years

Award Amount
$47,002.34

PROJECT SUMMARY

Refugee immigrant farmer members in New Roots Farm Incubator Cooperative working with Prairie Rose Farm will 1) develop skills in season extension methods; 2) trial and produce African eggplant, white sorghum as grain or flour, and sweet sorghum for syrup as high-value crops; and 3) develop, test, and market these valued-added products of interest in Asian and African communities. The focus of the first year is the trial and selection of both white and sweet sorghum seeds to be grown in the context of three individual farms. Four open-pollinated varieties of white sorghum and three varieties of sweet sorghum will be selected for agronomic and syrup characteristics.

Individual farmers will evaluate and integrate preferred new crops into their farming businesses. Year two will be an expansion of farmers' preferred seed(s) and the first yield of syrup and flour for market sales. Year three will be an expansion of production and direct marketing of grain, flour, and syrup through individual farms or farmer cooperatives. Outreach will showcase immigrant leadership and voice as educators and mentors for their peer farmers, and as presenters for digital media, field days, hands-on workshops, and conferences.

PRIMARY OBJECTIVES

1. Trial and select seeds of white and sweet sorghum for agronomic and syrup characteristics.
2. Process African eggplant, white sorghum grain or flour, and sweet sorghum syrup as high-value crops; test, and market them to Asian and African communities.
3. Expand production and direct marketing of grain, flour, and syrup through individual farms or farmer cooperatives.
4. Evaluate project benefits and impacts including income and profitability, market opportunities, business enterprise opportunities, and implications for crop production and farm management, while increasing access to culturally significant food.

Sustainable Agriculture Demonstration Grant Project Updates

2022 RESULTS

Our first year successfully involved Caliton Ntahompagaze and Simeon Bakunda — two of the New Roots Farm Incubator Cooperative participants near Moorhead, MN — in research on white and sweet sorghum. Learning from this first year included developing a better understanding of the concept of research and building the capacity for working as a team.

White Sorghum

With support and seed provided by NDSU's Dr. Burton Johnson, the following four varietals of white sorghum were planted: SARE 10, SARE 14, SARE 17, and P1574595. Due to a couple of planting errors, these varieties were not compared against each other for taste and other characteristics.

Sweet Sorghum

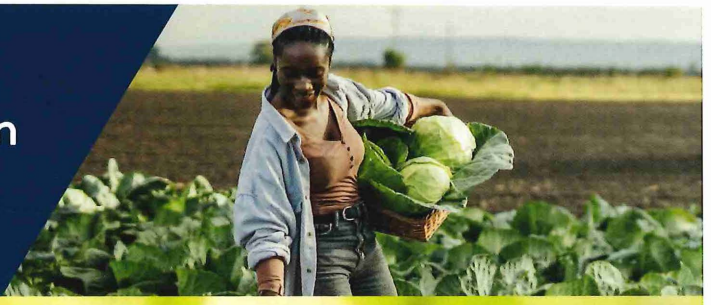
Four varieties of sweet sorghum were planted. This seed, along with technical assistance, was provided by Dr. Thomas Michaels. Brix measurements were taken on September 15, 2022; the results of which are summarized in Table 1. NDSU provided harvesting and processing assistance and Northern Crops Institute (NCI) provided support by grinding samples into flour. Noreen Thomas, of Doubting Thomas Farms, introduced Caliton to potential markets, including a miller from South Dakota. The experiment with no-till planting of sorghum was abandoned due to the weed growth that had been established on the planned field plot while waiting for soil temperatures to rise sufficiently to germinate seeds. Three different sorghum plots were established, with two of them located fairly near each other at Prairie Rose Farm and Simeon's about five miles away. Simeon's was located near trees and sustained significant bird damage. While there was some damage at Prairie Rose Farm, it was much less significant.

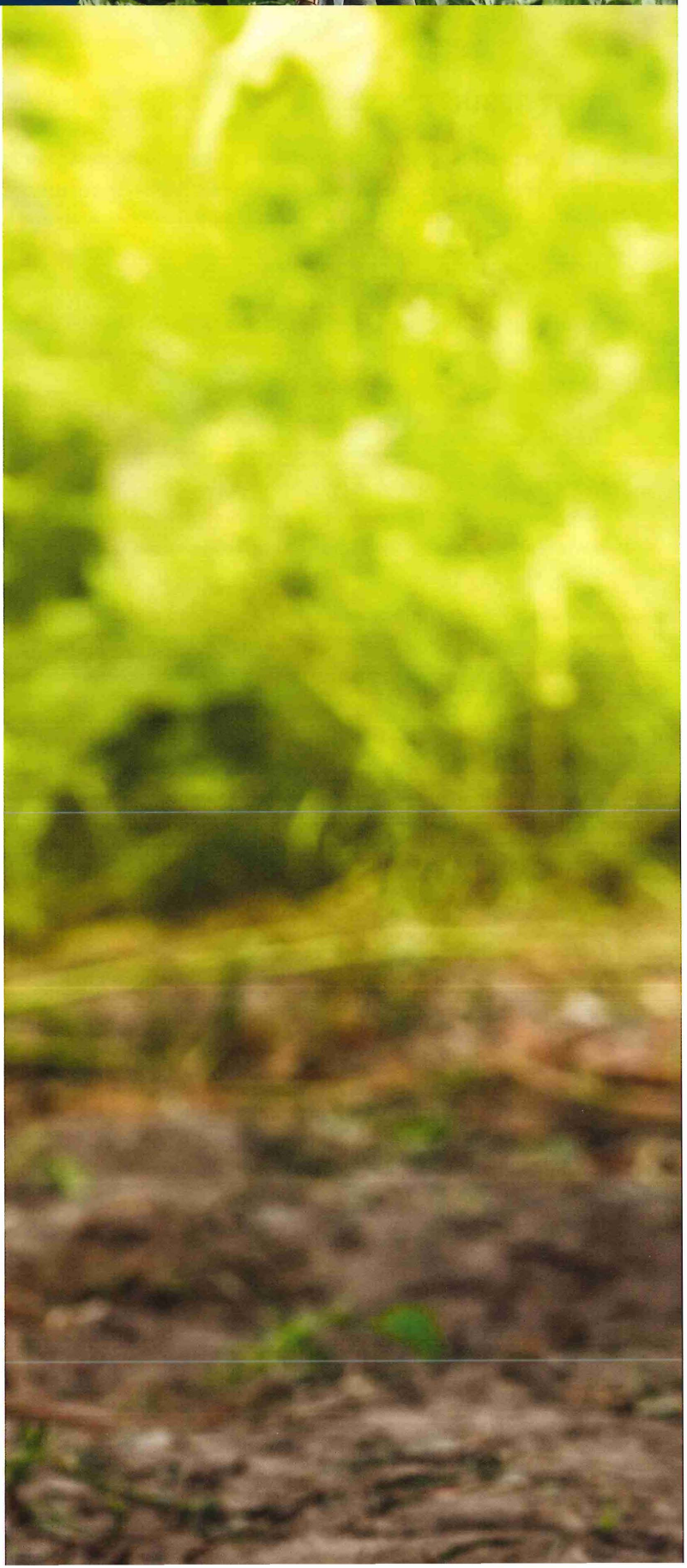
Table 1. Brix measurements for sweet sorghum varieties.

Variety	Brix Measurement
Rox Orange	11
Mennonite	12
Ames Amber	10
MN Ames Amber	11

Dr. Michaels loaned us the equipment to press sorghum sap and provided guidance on the pressing and boiling process. The low brix numbers indicated that delaying pressing would be preferable. The Sorghum was pressed on the last weekend of September, just before a frost. Boiling was completed at a fall festival open to the public. The syrup was put into sterilized jars and then sealed by bringing a cooled syrup to boil and processing it in a hot water bath canner. This prevented the development of the "air space" that consistently comes with the syrup being bottled hot and then cooled. A label was made so the syrup could be sold as a product of the farm. Goals for 2023 include training the team in the preferred bottling methods and using a larger press.

Sustainable Agriculture Demonstration Grant Project Updates





Eggplant

Simeon elected not to be involved in eggplant research. However, Caliton significantly advanced his dreams of establishing Red River Valley Eggplant through the development of a saleable frozen packaged product and the development of his farm label. The path to this success was long. The initial plan for eggplant blanching, freezing, and vacuum sealing according to UMN Extension guidelines resulted in an inferior product. Multiple calls to the Minnesota Department of Agriculture, Extension, and food safety resource contacts failed to find a solution. Jason Robinson from Agricultural Growth and Research Institute (AURI) suggested that we try a blast freezer. This provided the solution we needed. The only one available in the Fargo/Moorhead area was at NCI. Caliton was allowed to test production using the blast freezer, resulting in a saleable product. Consultation with Ryan Pesch has provided support for integrating African eggplant into his business plan, which allowed him to successfully secure a Farm Service Agency loan and purchase his own property. Caliton also tried a comparison of eggplant on plastic to a regular mulched bed and found a 20% increase in production as well as improved weed control. However, he expressed concerns about the cumbersome planting by hand into plastic, and due to the fact that there were only a couple of rows, the wind would catch the plastic edges and it would need to be straightened frequently.

Research on African eggplant in a high tunnel was postponed to the following year. Construction of the first caterpillar high tunnel was attempted in March 2022, but then the season got intense and farmers' team members could not be diverted to this construction project. Additionally, the tunnel proved to be harder to build than had been anticipated. Later in the season, Mason Berube, a Prairie Rose Farm intern, identified construction issues and successfully built a tunnel for use in 2023.

Sustainable Agriculture Demonstration Grant Project Updates

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

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PROJECT DURATION

2020-2022 / Three years

AWARD AMOUNT

$25,000.00

KEYWORDS

immigrant farmers, sustainable agriculture, crops, community gardens

PROJECT SUMMARY

University of Minnesota (UMN) researcher Dr. Dean Current and Central Lakes College urban agriculture instructor Dr. Narayan Dhakal focused on working with Minnesota's Bhutanese and Nepali immigrant populations to demonstrate the viability of diversifying sustainably produced agricultural products in Minnesota. The state has a large immigrant population, many with agricultural backgrounds but limited opportunities to work in the sector. Furthermore, crops popular with immigrant populations are not always available in Minnesota. This project focused on production and markets for lesser-known Asian crops common from Bhutan and Nepal by a) conducting qualitative research to identify crop varieties from Nepal and Bhutan and b) exploring the feasibility of growing those crops in Minnesota. The long-term benefit of the project would be the introduction of innovative crop varieties that contribute to the environment, human health, and the local economy. The project used a change model that embraced the knowledge of diverse populations to support community-based agricultural micro-enterprises.

PROJECT DESCRIPTION

RATIONALE

Contemporary science and technology alone are not enough to resolve the world's food problems. Diversity in the U.S. is growing and so is the knowledge base. Modern technology allows for greater production and enjoyment of material goods without considering pressure on the natural environment. The purpose of this project was to gather and share common information about the varieties of crops that are grown in Nepal and Bhutan which could potentially be grown in Minnesota. The results may guide policies promoting better health, environment, and social justice among every group of citizens and enable development of a synergy to fight against increasing pressure on our natural resource base.

Minnesota's growing 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. Many immigrants can recall their childhood memories of being engaged in organic agricultural production and consumption. As immigrants assimilate into a new culture here, that knowledge, which could contribute to the health of their populations and our agricultural production, is often lost.

In his work with representatives of the Bhutanese Community Organization in Minnesota (BCOM) and the Bhutanese Refugee Community (BRC), Dr. Dhakal identified new community needs. In the Bhutanese Community, older adults have immense knowledge and understanding of how to live a sustainable lifestyle. In their homeland, these subsistence farmers had enjoyed cultivating healthy foods and vegetables for their families as well as trading the surplus produce. Bhutanese, Nepalese, Hmong, and Karen communities share much of the same 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, and it's where Dr. Dhakal spent almost 20 years working with grassroots communities. He worked closely with the communities of Baghmara and Kumroj Community Forest adjacent to the Chitwan National Park. This was the first community forest dedicated to coupled biodiversity conservation and economic development. Dr. Dhakal worked to promote an understanding of the long-term impact of forest conservation amid climate change. Within five to six years, the local community understood the importance of the forest and began to develop forest-based micro-enterprises. The success of this initiative led Dr. Dhakal to adopt a similar practice working with communities which share the same language.

Minnesota's immigrant communities possess important agricultural skills and knowledge that aren't fully utilized because they lack the opportunities to access land and the resources to grow and market agricultural products. This project demonstrated 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.

OBJECTIVES

1. Research community knowledge of alternative crop varieties. Through collaborative and qualitative methods, work with the Bhutanese and Nepali communities in the Twin Cities metro area to identify those crop varieties common in their traditional diets but that were not available in Minnesota or not in the quantities necessary to meet the demand of those immigrant populations.

2. Introduce innovative crop varieties in Minnesota by identifying varieties of interest to immigrant populations, and seed sources and sustainable cropping methods to produce those crops in Minnesota. Test the viability of growing those crops in Minnesota to provide another source of crops essential to the diets of immigrant populations and make those crops more generally available here.

3. Develop minority community capacity to engage in agricultural enterprises for economic development. Work with the Bhutanese farming community to identify resources to assist them with land acquisition, sustainable cropping methods, and forming and managing a community enterprise helping them acquire the resources to do so. (The work was primarily conducted with the Bhutanese community as they are the group with agricultural skills. The Nepali community would provide a market for the new products.)

2020 RESULTS

Dr. Current and Dr. Dhakal concentrated on organizing the work through coordination between BCOM and the UMN and initiating collection of information on the crops and agriculture systems of the Bhutanese farmers associated with the BCOM. BCOM provided access to the farmers they worked with, and Dr. Dhakal interviewed the selected farmers. As this was the initial collaboration between the University and BCOM, establishing communication and collaboration was part of the initial work. This was especially challenging given the limitation imposed by the outbreak of the COVID-19 pandemic in 2020.

2021 RESULTS

The researchers were able to identify the crops that were being grown by the Bhutanese community in their community gardens on Rice Street in St. Paul. (Photo 1). Dr. Dhakal prepared a report, "Traditional Asian Food Wisdom: Perspective from Bhutanese Refugee in Minnesota," that was completed in January of 2021.

Rice Street Community Gardens in St. Paul, MN.

Field Day food.

A few of the Field Day participants.

The field day provided the opportunity to discuss the crop production plans/progress as well as the possibility of their losing the Rice Street garden plots. At the time of writing this report, some Bhutanese community members were exploring ways to raise funds to purchase the garden plots.

Dr. Dhakal developed a list of resources and provided those to the Bhutanese community. Also, through his position with Central Lakes College as their urban agriculture farm business management instructor, he would be able to continue to offer resources and training opportunities to the Bhutanese community.

Much of the work was developing a working relationship with the Bhutanese community and better understanding their gardening activities and the challenges they face. Based on the project work, the researchers identified areas where they can continue to support the Bhutanese community and connect them to resources to improve their efforts.

MANAGEMENT TIPS

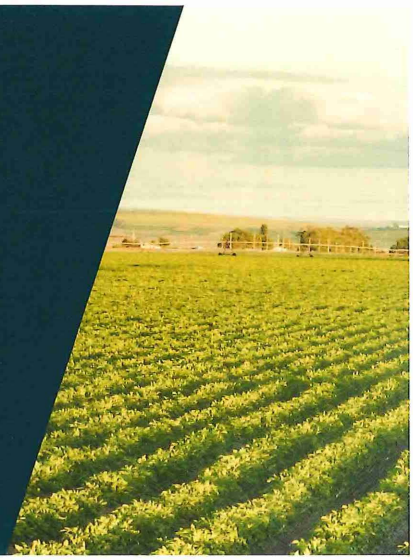
1. It is important to understand the function of the gardens at the community level. In the initial discussions with the leaders of the community gardens, there was an expressed interest in commercialization of community garden produce. However, there were also participants who used these plots as a family garden and also bartered produce with other growers. It is important to look for opportunities for both options.
2. The cultural connections, in this case the garden produce raised, are important to promote to immigrant communities and also to consumers interested in sustainable production and social impacts.
3. Communication is the key to successful collaboration with immigrant communities, especially when faced with unexpected challenges such as the COVID-19 pandemic.
4. Try to encourage ideas from the grassroots level. As this project was implemented, it was often the UMN partners talking either to the administrators/leaders of BCOM or to the individual farmers. Bringing the larger group together would have provided more opportunities to discuss issues and hear broader perspectives and ideas.

COOPERATORS

Kumar Tamang, Seniors Program Coordinator, Bhutanese Community Organization of Minnesota

Puspa Bhandar, Executive Director, Bhutanese Community Organization of Minnesota

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



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PROJECT DURATION

2021-2022 / Two years

AWARD AMOUNT

$38,000.00

KEYWORDS

variable rate irrigation, corn, electrical conductivity, soil type, soil moisture sensors, precision irrigation, nitrate, nitrogen, leaching

PROJECT SUMMARY

Two critical challenges facing Minnesota's agricultural watersheds are nitrate leaching into groundwater supplies and competition over limited groundwater resources. The majority of Minnesota communities depend on groundwater for their drinking water supply, which is threatened by increasing concentrations of nitrate. Variable rate irrigation (VRI) has the potential to improve water use efficiency and reduce the risk of nitrate leaching into groundwater. The purpose of this field study in Stearns County was to evaluate the impact of VRI in comparison to conventional uniform rate irrigation (URI) management on nitrogen (N) leaching, grain yield, and water use efficiency. The University of Minnesota (UMN) Extension also conducted field days and conversations with farmers to disseminate the research results, promote the VRI technology, and develop actionable strategies for adoption.

PROJECT DESCRIPTION

RATIONALE

More than 25% of Minnesota's groundwater supply is pumped for irrigating agricultural crops. This makes irrigation the second-largest user of groundwater in the state (Freshwater Society, 2013). Currently, Minnesota has approximately 600,000 acres of irrigated agricultural cropland, a number that increased by 4% from 2007 to 2012 (USDA National Agricultural Statistics Service, 2012). Many of these irrigated acres are in Minnesota's Central Sands region. The coarse-textured (sandy) soil of this region has 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 of central Minnesota. This means that agricultural chemicals, such as fertilizers, can also leach quickly through the root zone and into groundwater. Fertilizer loss represents a financial loss to the farmer as nutrients are leached beyond the root zone. Further, fertilizer leaching poses environmental, human health, and economic risks to communities that use groundwater for drinking. Many irrigated regions of the state have groundwater with nitrate-nitrogen concentrations exceeding the 10 milligrams per liter (10mg/L) health standard for drinking water.

The second challenge 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 (Watson et al., 2014; MN DNR, 2016) 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 VRI.

Dr. Sharma's project focused 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, she evaluated the impact of VRI technology on water and nutrient savings, corn yield, and nitrogen (N) leaching in comparison to uniform water management. The information gained from the project addressed the applicability of VRI technology in Minnesotan soils and climate, its ability to reduce N loading to groundwater, and its ability to reduce total water use in comparison to URI.

VRI technology addresses the reality that soil's physical properties can vary significantly within a single field — from rapidly draining sands to poorly drained clays. URI does not account for this variability, leading to potential over- or under-application of irrigation water. By addressing spatial variability with VRI, the goal of the project was to optimize irrigation for each management zone within a field, maximize crop growth, and minimize negative environmental consequences. A secondary goal of this project was to evaluate the use of nitrate quick test strips to measure nitrate concentration in lysimeter water samples as compared to traditional lab values. Lab testing for nitrate can be expensive as well as time consuming. A quick test strip provides 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. A quick test strip alone is also significantly less expensive than a lab test. Part of this project is focused on using a nitrate quick test strip to measure nitrate concentration, while sending a subset of water samples to an analytical lab to get an exact value. The quick test values and lab values for nitrate concentrations were compared to assess the accuracy of the test strips and to generate a calibration curve that could be used for farmers and other agricultural stakeholders to approximate nitrate levels in real-time.

OBJECTIVES

1. Quantify and evaluate the impact of VRI in comparison to conventional URI on N leaching, grain yield, and crop water use at the field scale. A secondary goal of this objective was 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 were to 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. Provide education on VRI to farmers, agricultural professionals, and other agricultural stakeholders through demonstrations and extension bulletins/blogs.

The study was conducted on a 120-acre field in Stearns County near Belgrade, Minnesota, during the 2021 corn growing season. The field was located within the coarse-textured soils area defined by the MDA, but still had spatial variability of soil types that made the site uniquely suited for investigating the fundamentals of site-specific irrigation management. The spatial variability of soil electrical conductivity (EC) within the field is shown (Figure 1), with the dominant soil type being a somewhat excessively drained sandy loam. The experiment included two irrigation application strategies. Two treatments were assigned in three blocks in a randomized complete block design, resulting in six individual experimental units (two treatments replicated three times). The two irrigation treatments were VRI management and URI management. The research site had advanced hydraulic and variable rate sprinkler irrigation systems in the field.

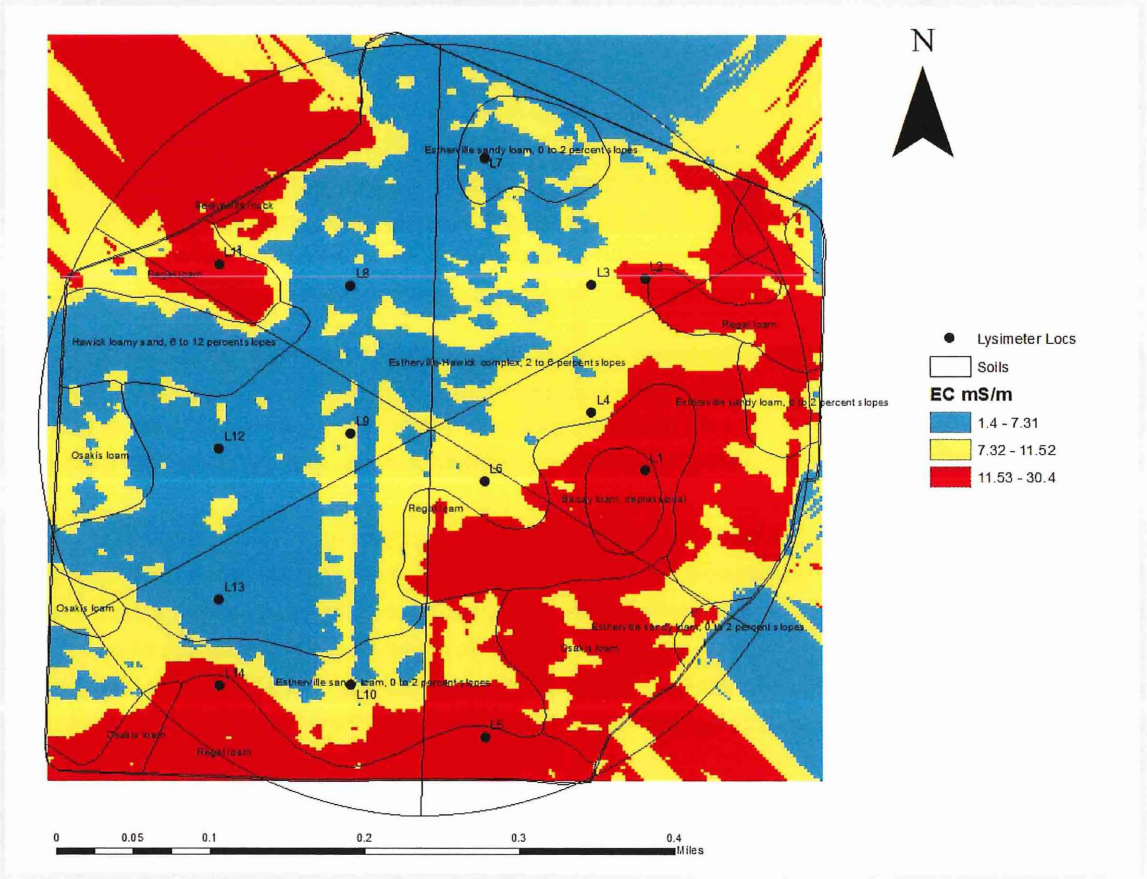

Figure 1. Field map representing different irrigation zones based on the soil EC (three colors). The black dots are the lysimeters locations. The soil moisture sensors were installed at locations 1, 3, 5, 6, 7, 8, 10, 11, and 12 in year 1 and at 2, 4, 5, 6, 7, 8, 10, 11, 12, and 14 in year 2. Different colors represent different EC ranges.

Management zones for VRI management were created based on soil EC, soil type, and elevation. As shown in Figure 1, EC range from 1.4 to 7.31 millisiemens per meter (mS/m) is Zone 1, EC range from 7.32 to 11.52 mS/m is Zone 2, and EC range from 11.53 to 30.4 mS/m is Zone 3. Irrigation events were scheduled based on the soil moisture sensors (see photo) installed in each treatment. When sensor-measured water content in the lowest EC (Zone 1) locations (sandy soils with low water holding capacity) dropped close to 50% of available water holding capacity, irrigation was triggered (Figure 2). In each irrigation event, the irrigation amount was based on the water holding capacity as well as irrigation system capacity. From the literature, Dr. Sharma knew that the management zone with the lowest EC requires the most water, so the irrigation trigger was based on the soil moisture measurement from those zones and then was reduced accordingly for other management zones within the VRI treatment. In 2021, the two higher EC zones (Zones 2 and 3) received 70% and 50% irrigation, respectively, until the end of June and then 50% and 20%, respectively, after that. In 2022, the two higher EC zones (Zones 2 and 3) received 70% and 30% irrigation, respectively, until mid-July and then 70% and 50%, respectively, after that. An irrigation rate of 100% was applied across all URI plots regardless of the soil variability. The 100% irrigation replenished the root zone to 100% field capacity when the soil water level in the lowest EC zones dropped to 50% of available water holding capacity. In each URI, plot 2 to 3 suction cup lysimeters at a depth of 1.2 meters below the root zone were installed to capture any nitrate leaching from the root zone. In each VRI plot, one lysimeter per management zone was installed, except one plot in Zone 2 which was very small. A water sample from each tube was collected on a weekly basis and was measured for nitrate concentration using a nitrate quick test strip and spectrophotometer in the lab. The two datasets were used to generate a calibration curve for the nitrate quick test values.

Photo 1. Soil moisture sensor installed in the field.

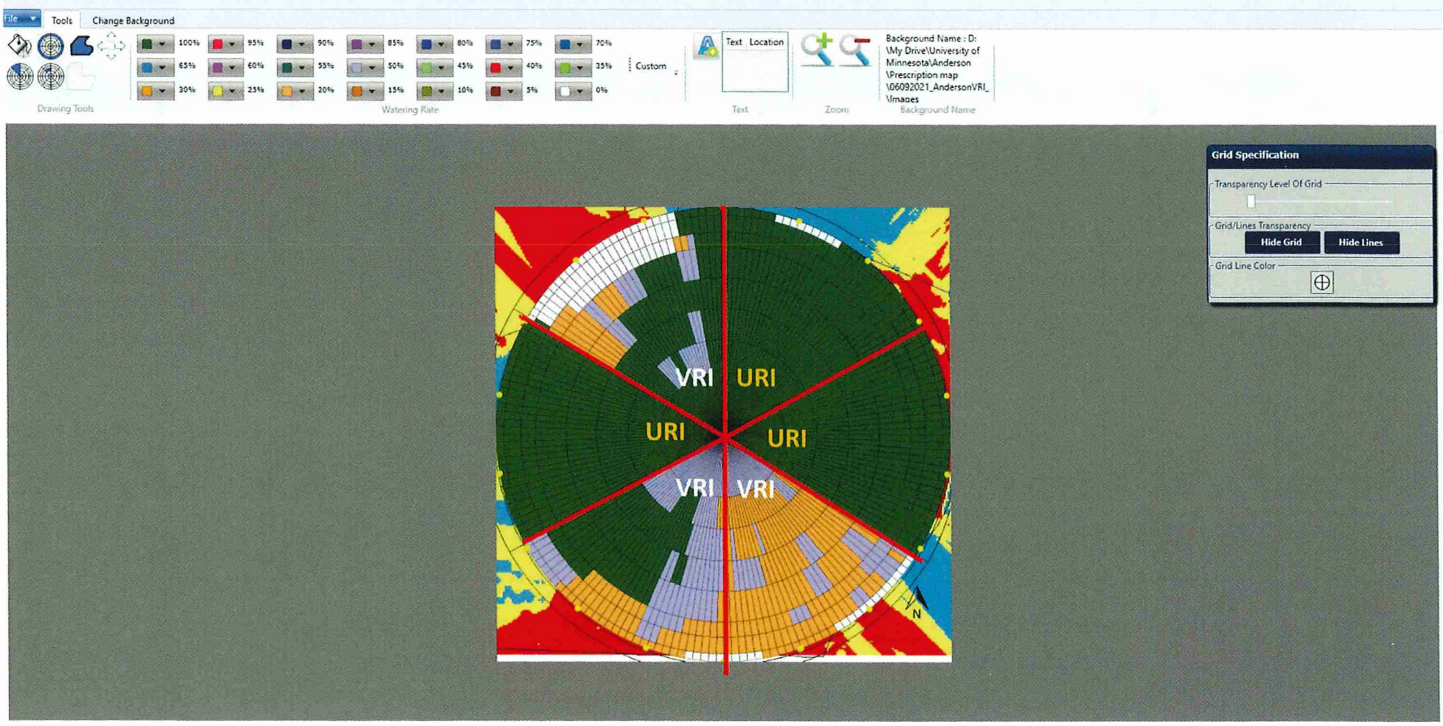

Figure 2. Prescription map for variable rate irrigation. Irrigation water application rates are indicated by different colors on the map. The VRI treatment received irrigation based on the EC zones whereas URI treatment received uniform irrigation throughout.

2021 RESULTS

Figure 3a and Table 1 show corn yield with various irrigation treatments and management zones in 2021. The yield varied from 250 to 259 bushels per acre in management Zone 1, 243 to 259 bushels per acre in Zone 2, and 234 to 255 bushels per acre in Zone 3. Comparing these three zones, the lowest yield was obtained in Zone 3, which was a high EC zone with loamy soil and very low elevation. Because of lower elevation in Zone 3, the soil was mostly above the field capacity in both VRI and URI plots, resulting in lower yield in these areas. The highest yield was obtained in management Zone 1 in both VRI and URI. These results indicated that the yield distribution within each irrigation treatment followed a similar pattern in that the management zones with lower EC had higher yield. Overall, because of very dry conditions in the growing season (below average precipitation), higher irrigation in URI plots did not cause any significant grain yield loss as the water use (crop evapotranspiration) by the crop was high. However, if the weather conditions would have been normal or precipitation would have been in the normal range, Dr. Sharma would have expected higher yields in VRI plots and lower yield in URI. In 2021, in terms of irrigation water application (Figure 4 and Table 1), the VRI treatment used an average of 43% less water compared to URI while producing almost similar yield. On average, the URI treatment produced 258 bushels per acre and VRI produced 242 bushels per acre while using 11.6 inches and 7 inches of water, respectively. Partial economic analysis with corn price to be $5.00 per bushel and irrigation price to be $16.00 per acre-inches showed that both VRI and URI had almost the same net income (Table 1). These results indicate that VRI could be beneficial in terms of saving water and reducing irrigation-induced environmental pollution. Irrigation water productivity (IWP) in the VRI and URI treatments was also calculated (Figure 3b). The IWP equals the amount of grain produced (bushels per acre) by the irrigation water divided by the amount of irrigation water applied (inches). In 2021, the IWP in VRI treatment was 65% higher than the IWP in URI treatment. On average, the IWP was 35 bushels per acre-inches in the VRI treatment and 22 bushels per acre-inches in the URI treatment. The results were statistically analyzed using SAS® software (SAS Institute, 2011). In 2021, there was a significantly higher yield under URI compared to VRI. However, no significant difference was observed between zones in each treatment. The IWP was significantly higher in VRI Zones 2 and 3 as compared to URI Zones 2 and 3, respectively.

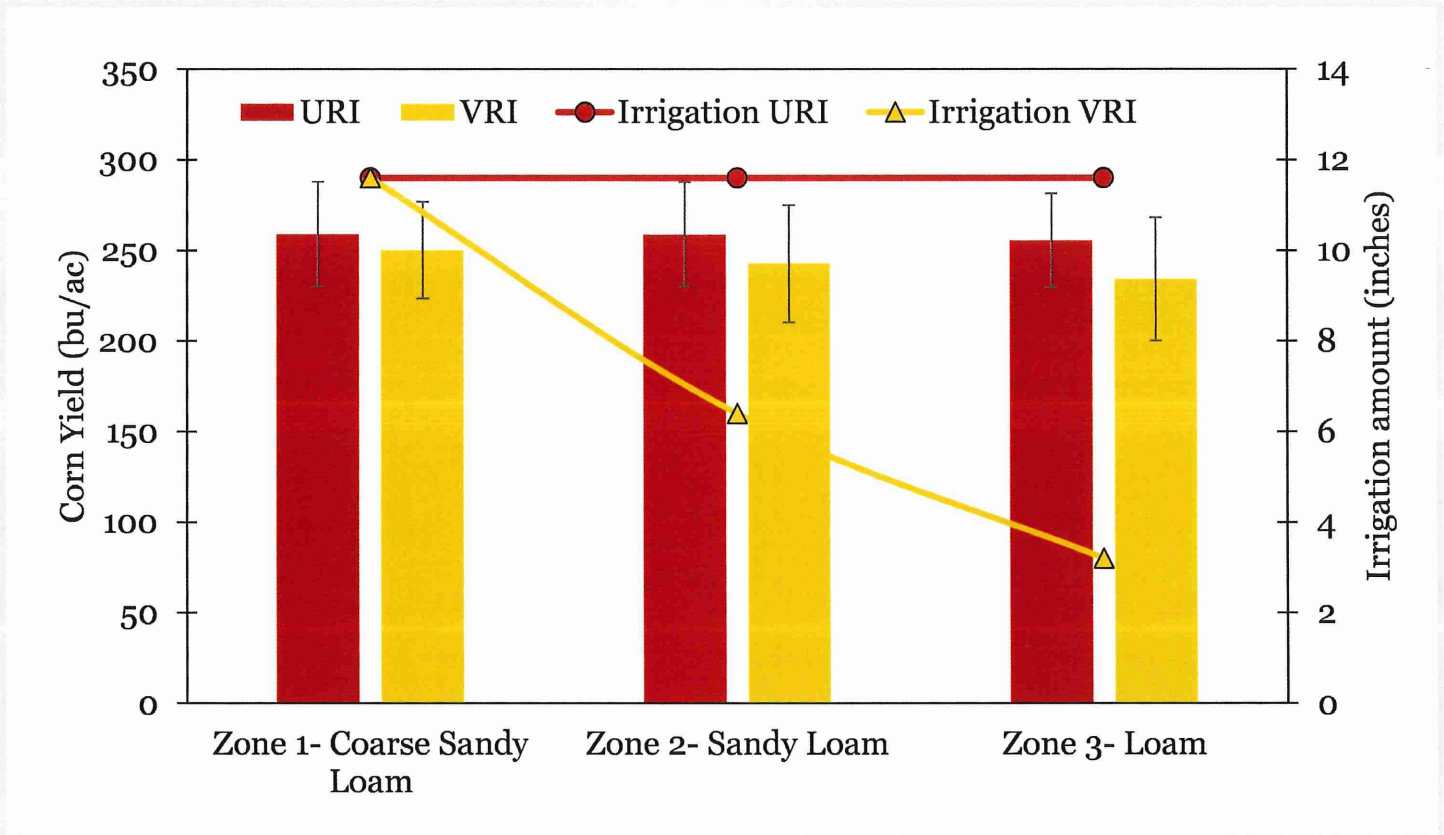

Figure 3a. Corn grain yield (bu/ac) 2021. The lines on each graph indicate irrigation amount in each zone and treatment.

Table 1. Seasonal irrigation amounts (inches) applied, yields (bu/acre), irrigation water productivity (IWP), gross income ($), and net income ($) in each irrigation treatment and zone in 2021.

	URI				VRI			
	ZONE 1	ZONE 2	ZONE 3	AVER-AGE	ZONE 1	ZONE 2	ZONE 3	AVER-AGE
Irrigation (in)	6.5	6.5	6.5	**6.5**	6.5	4.7	3.08	**4.76**
Yield (bu/ac)	227.8	228.7	222.4	**226.3**	226.5	224.4	225.1	**225.3**
Irrigation Water Productivity (bu/ac-in)	35.1	35.2	34.2	**34.8**	34.8	47.7	73.1	**47.3**
Gross income ($)	$1,139	$1,144	$1,112	**$1,358**	$1,132	$1,122	$1,125	**$1,352**
Net Income ($)	$1,035	$1,040	$1,008	**$1,254**	$1,028	$1,047	$1,076	**$1,276**

Seasonal irrigation amounts (inches) applied, yields (bu/acre), irrigation water productivity (IWP), gross income ($), and net income ($) in each irrigation treatment and zone in 2021.

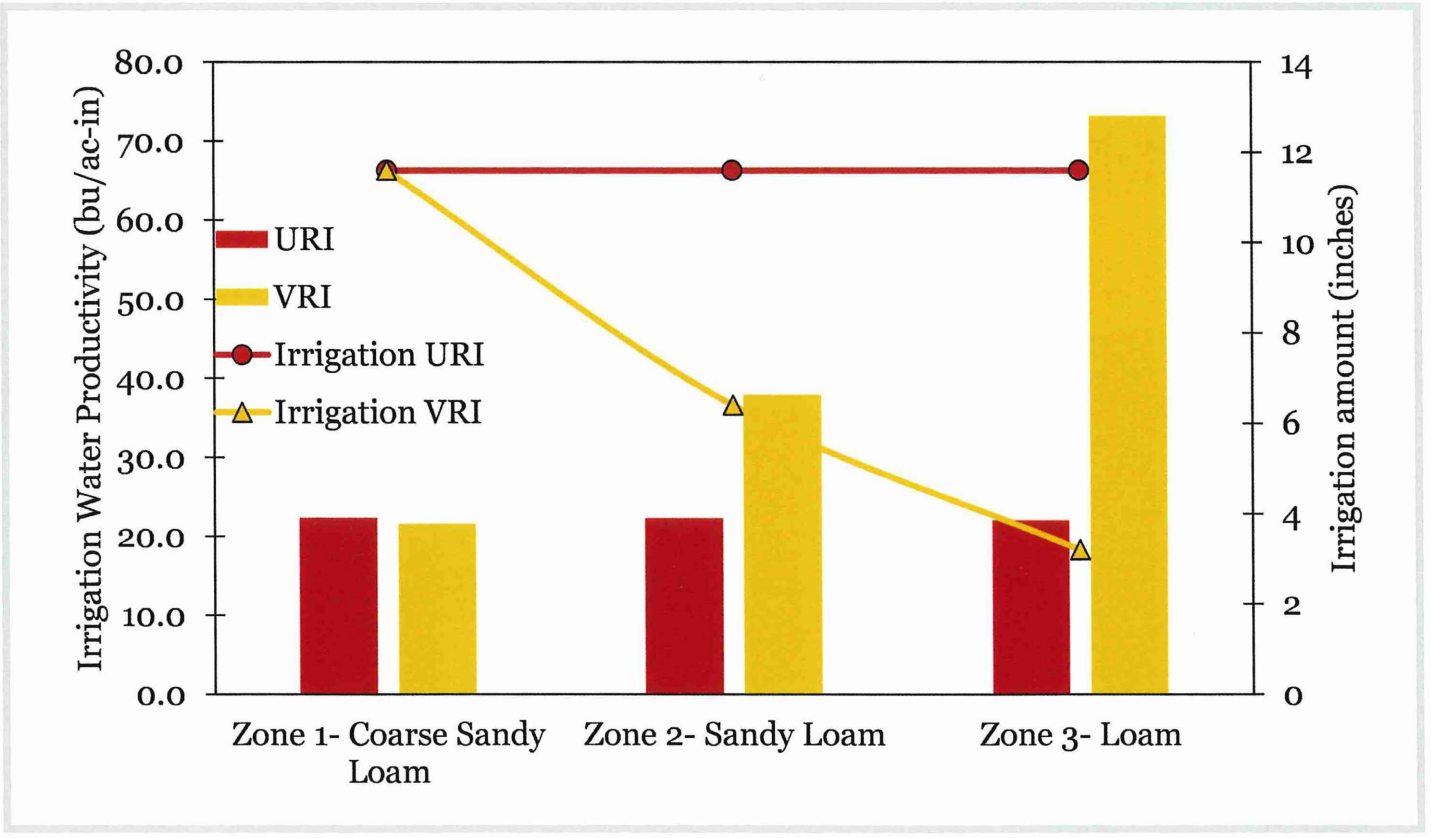

Figure 3b. Irrigation water productivity (bu/ac-in) in 2021. The lines on each graph indicate irrigation amount in each zone and treatment.

2022 RESULTS

Similar results were obtained in 2022, which was also a dry season as compared to normal growing seasons. Figure 3c and Table 2 show corn yield with various irrigation treatments and management zones in 2022. The yield was slightly lower in 2022 compared to 2021, possibly due to reduced irrigation in 2022 than in 2021 (approximately five inches lower irrigation in URI) and slightly lower temperatures in 2022. The yield varied from 226.5 to 228 bushels per acre in Zone 1, 224 to 229 bushels per acre in Zone 2, and 225 to 222 bushels per acre in Zone 3. On average in 2022, the lowest yield was obtained under Zone 3 in URI and Zone 2 in VRI treatment. Statistically, the yields were not significantly different from each other in 2022. There was no significant yield difference between zones within a treatment. On average, the IWP for URI was 35 bushels per acre-inches, which was 30% lower than the VRI IWP of 47.3 bushels per acre-inches. In terms of irrigation amounts, on average, VRI reduced the irrigation amount by 27% compared to URI with only one bushel per acre reduction in corn yield.

Over both years, the yield between URI and VRI management was not significantly different, whereas the IWP was significantly higher in VRI compared to URI, indicating the water use efficiency and superiority of the VRI system in fields similar to the study field.

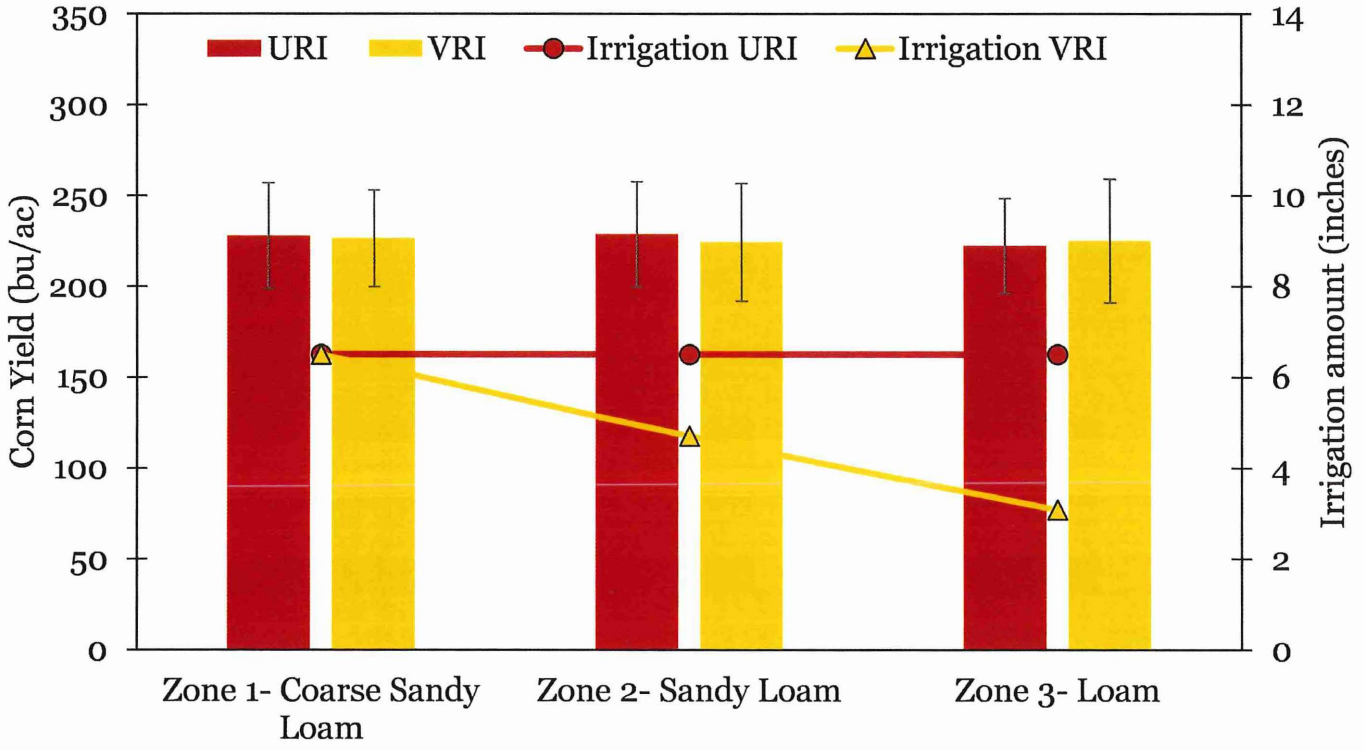

Figure 3c. Corn grain yield (bu/ac) in 2022. The lines on each graph indicate irrigation amount in each zone and treatment.

Table 2. Seasonal irrigation amounts (inches) applied, yields (bu/acre), irrigation water productivity (IWP), gross income ($), and net income ($) in each irrigation treatment and zone in 2022.

	URI				VRI			
	ZONE 1	ZONE 2	ZONE 3	AVER-AGE	ZONE 1	ZONE 2	ZONE 3	AVER-AGE
Irrigation (in)	11.6	11.6	11.6	**11.6**	11.6	6.4	3.2	**7**
Yield (bu/ac)	258.9	258.8	255.5	**257.7**	250.2	242.7	234.2	**242.4**
Irrigation Water Productivity (bu/ac-in)	22.3	22.3	22	**22.2**	21.6	37.9	73.2	**34.6**
Gross income ($)	$1,295	$1,294	$1,278	**$1,289**	$1,251	$1,214	$1,171	**$1,212**
Net Income ($)	$1,109	$1,108	$1,092	**$1,103**	$1,065	$1,111	$1,120	**$1,100**

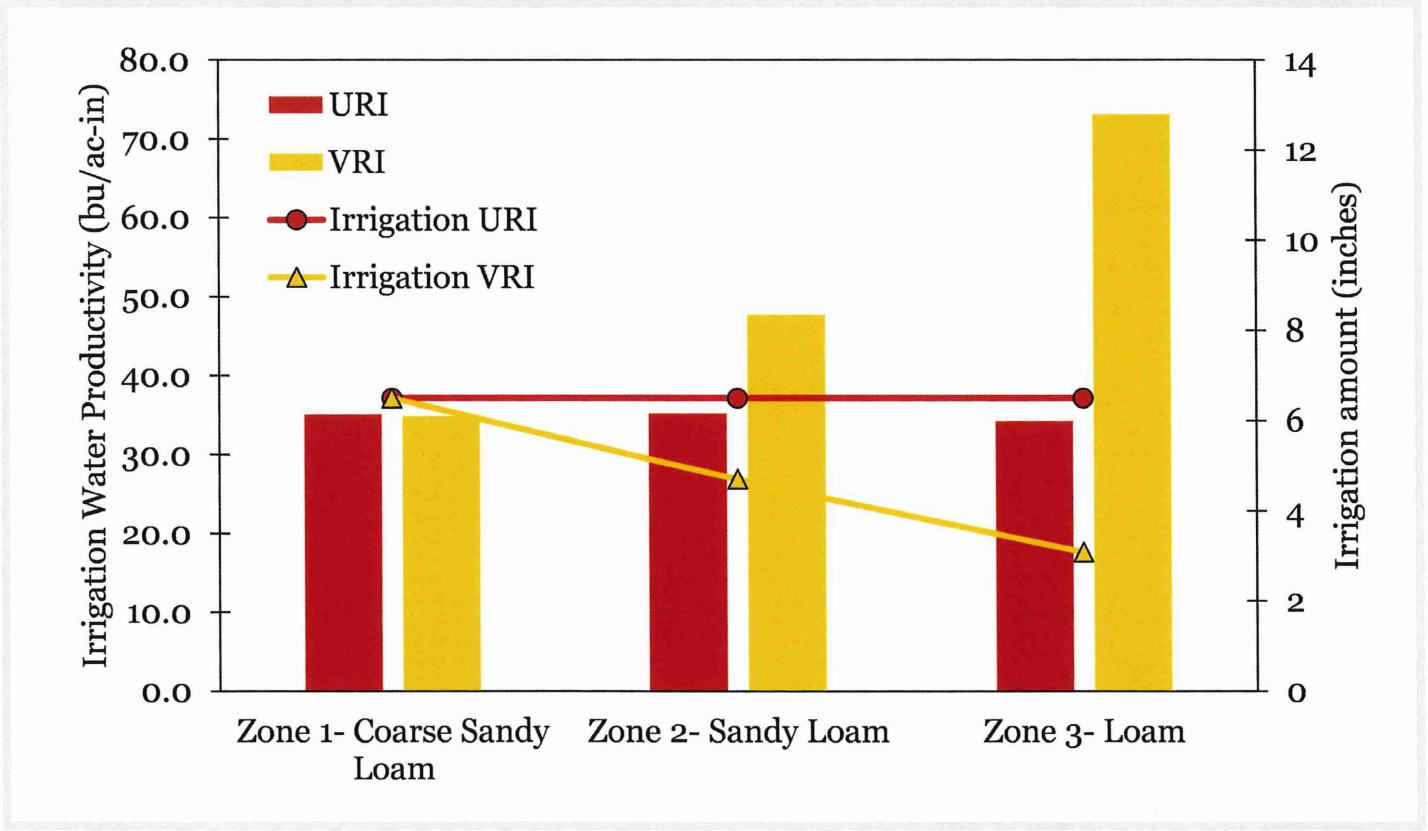

Figure 3d. Irrigation water productivity (bu/ac-in) in 2022. The lines on each graph indicate irrigation amount in each zone and treatment.

Analysis of water samples collected in lysimeters did not show a statistically significant difference between the nitrate concentrations in the VRI versus URI zones. Averaged across the entire season, soil water in the VRI treatment contained 59 parts per million (ppm) and 12 ppm in 2021 and 2022, respectively, while in the URI treatment soil water contained 54 ppm and 19 ppm in 2021 and 2022, respectively. Although the nitrate concentrations in the VRI zones were not different between managements, this could be explained by several factors. The VRI zones received less irrigation than the URI zones (Table 1). The nitrate levels are a concentration measurement, so less water entering a system with the same amount of nitrogen in the soil would be expected to have higher concentrations of nitrate in the water leaving that system. The volume of water percolating the soil in the URI system was much higher and might have a reduced concentration of nitrate, but the net nitrate loss might be higher under URI.

Another goal of this project was to compare nitrate concentrations from the use of nitrate quick test strips to the lab analysis (Figure 4). The colorimetric scale of the nitrate test strips is limited to a maximum concentration of 50 ppm, so for the sake of analysis, only data with lab nitrate values under the threshold of 50 ppm were used. For those select values, there was a curvilinear relationship and 60% of the variation in the lab nitrate values can be explained with the readings by the nitrate test strips. This suggests that nitrate test strips might be useful for making management decisions as an alternative to time-consuming and expensive lab tests, but more research is needed.

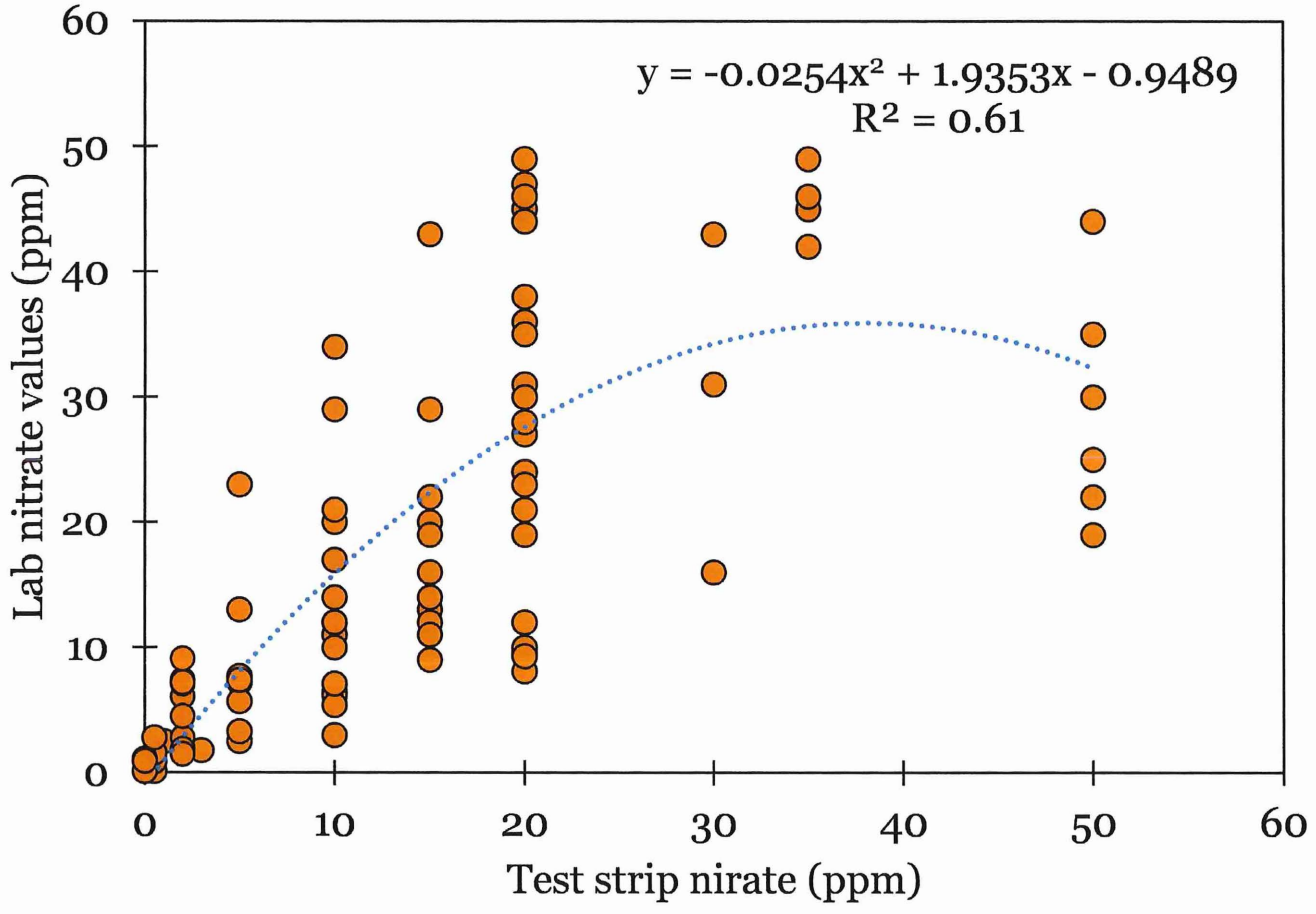

Figure 4. Comparison of Nitrate Test Strip values with the Lab Nitrate values from the same water sample. Data was collected from both VRI and URI plots (ppm is equivalent to mg/L).

MANAGEMENT TIPS

1. For variable rate irrigation and efficient irrigation management, the first and foremost thing is to know your field. Gather information about different types of soils that exist in the field, their water holding capacities, crop water use of the crop you are growing, yield potential, and then based on the spatial variability that exists in the field, manage irrigation.
2. For the first year of using VRI, install as many soil moisture sensors as possible, at least one per management zone. Once familiar, moisture sensors can be reduced to fewer locations in the coming years.
3. It is important to monitor the data collected from the soil moisture sensors on a daily basis in order to schedule irrigation. In addition, monitor the field throughout the season and make changes to the irrigation prescription maps as required.

COOPERATORS

Grant Anderson, Farmer, Stearns County

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Troy Schmidtke, Chief Executive Officer, EarthScout

Anne Nelson, Extension Educator, University of Minnesota

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OTHER RESOURCES

Up-to-date irrigation information from the University of Minnesota Extension
https://extension.umn.edu/soil-and-water/irrigation

Irrigation Management Assistant (IMA) Tool *https://ima.respec.com*

Irrigators Association of Minnesota *https://mnirrigators.org*

USDA Natural Resource Conservation Service (NRCS) irrigation cost share program
https://www.agcentric.org/rcpp-precision-irrigation

Comparing High Tunnel versus Outside Row Raspberry Production for Increased Yield and Reduced Spotted Wing Drosophila Pressure

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2020-2022 / Three years

AWARD AMOUNT

$17,535.00

KEYWORDS

raspberry, raspberries, high tunnel, open field growing, Spotted Wing Drosophila

PROJECT SUMMARY

Principal investigator Aaron Wills (Little Hill Berry Farm) and his crew tested and demonstrated the benefits of growing raspberries in a high tunnel versus traditional open field growing. The goal was to determine if high tunnel raspberries produced greater yields compared to traditional open field raspberries and if pest pressure, specifically the Spotted Wing Drosophila (SWD) fruit fly (Photo 1), was reduced. The invasive SWD has been a significant challenge for growing raspberries in Minnesota. In 2017, Minnesota's raspberry growers lost $2.3 million in sales to SWD damage, according to data from the University of Minnesota (UMN). Wills trialed four different raspberry varieties, growing them in both a high tunnel and an adjacent open field. The trial results would provide valuable information to Minnesota growers and allow them to assess whether high tunnel grown raspberries justify the added expense of building a high tunnel for raspberry production.

PROJECT DESCRIPTION

OBJECTIVES

1. Determine if growing raspberries in a high tunnel would increase yield over traditional field-grown raspberries and which of the four varieties would benefit most from being grown in a high tunnel. Wills collected yield data for each of the plots in the high tunnel and the open field production. In addition to total yield for each plot, he calculated the sales value from each plot to show the value of any increased yield. This would help other growers determine if a high tunnel is worth the added investment and increased management time.
2. Determine if SWD populations and fruit infestations are reduced in high tunnel raspberries versus traditional field-grown raspberries. As part of each harvest, Wills documented the level of SWD infestation in each of the plots and quantified the percentage of unmarketable fruit due to SWD damage.

RATIONALE

Raspberries are a popular berry crop in Minnesota. Many farmers across the state offer pick-your-own raspberries and sell the fruit at farmers' markets, roadside stands, and to wholesale customers. Due to the introduction of an invasive fruit fly, Spotted Wing Drosophila (SWD), raspberry production in Minnesota has become increasingly difficult. According to research released by the UMN in May of 2019, raspberry growers in Minnesota lost an estimated $2.3 million in sales to SWD in 2017. Raspberry growers reported the highest level of infestation among the state's berry growers with a median damage of 20%. Twenty-four percent of raspberry growers said they would "probably" or "definitely" reduce acreage the following season as a result of SWD infestations. SWD infests undamaged, ripening, or ripe fruit, whereas the common fruit fly will only infest overripe or rotting fruit. SWD lays eggs in the fruit. The eggs hatch into larvae which feed on the flesh of the fruit, turning it mushy and unmarketable. SWD populations build quickly in the summer months – taking just over a week to develop from egg to adult and producing more than 10 generations in a single growing season. According to the UMN research, the high tunnel environment might prevent SWD development due to higher air temperatures compared to open field plots and could be a viable management strategy for SWD.

In addition to possible reduced SWD pressure, high tunnels may offer the opportunity for a significant increase in raspberry yields compared to open field production. A 2009 variety trial conducted by UMN researcher Carl Rosen in Grand Rapids, Minnesota, compared high tunnel raspberry yields to open field yields. This study showed that raspberries grown in high tunnels produced greater yields than raspberries in open field production. However, this study was conducted in northern Minnesota (Grand Rapids, which is in USDA Hardiness Zone 3b), and Little Hill Berry Farm is located in southern Minnesota (Northfield, Zone 4b), which has very different growing conditions. Also, many new raspberry varieties released in the last 10 years were specifically bred for high tunnel growing that Wills wanted to trial. These new varieties had not yet been compared in Minnesota and needed to be trialed before farmers here could adopt them for high tunnel production. Additionally, SWD was not present in the state when the UMN study was conducted, so the growing conditions for raspberries had changed dramatically.

Spotted Wing Drosophila on raspberry (photo courtesy of UMN Extension).

DESIGN

In the spring of 2019, Wills planted five varieties of primocane fruiting raspberries (fall-bearing raspberries) in both the high tunnel and in open field rows located right next to the high tunnel. (Figure 1). The varieties planted were Polana, Joan J, Anne, Crimson Night, and Crimson Treasure. Each of the five varieties were planted in two plots in both the high tunnel and the open field to ensure the results weren't skewed due to better soil or better care in one part of the high tunnel or open field versus the other.

RASPBERRY PROJECT PLOT DIAGRAM				
HIGH TUNNEL				
ROW	VARIETY 1		VARIETY 2	
1	Joan J		Anne	
2	Crimson Night		Crimson Treasure	
3	Anne		Crimson Night	
4	Crimson Treasure		Joan J	
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

Figure 1. Raspberry varieties.

2020 RESULTS

In the first year of the project, the primary goal was to establish raspberry plantings inside and outside of the high tunnel. Overall, the plants established very well. Wills reported how quickly the raspberry plants grew and filled in the rows compared to his experience establishing blueberry plants. Unexpectedly, he even had a small harvest of raspberries in 2020.

Throughout the summer, there was little difference in plant size and percent of the row filled in between the high tunnel and open field plantings. However, starting at the end of August, the high tunnel raspberries continued growing very vigorously while the open field rows' growth stopped. As shown in photos 2 and 3, taken on September 17, 2020, the high tunnel raspberry plants were noticeably taller and the rows were thicker with more canes and foliage than the open field rows. Crimson Night performed exceptionally well in the high tunnel compared to the plants grown outside. Anne was an exception in that the plants were the same size in the high tunnel and the open field.

The high tunnel had a higher raspberry yield than the open field rows by approximately 50%. However, the overall yield was quite small, approximately 50 pints, so the anticipated 2021 yield results would be more useful in terms of comparing yield in the high tunnel versus the open field. 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 in the outside rows was caused by increased pest pressure and rain which caused mold. The open field rows were hit hard by Japanese beetles and by tarnished plant bugs, which were both at much lower levels inside the high tunnel. Wills wasn't expecting tarnished plant bug damage, so he would need to be prepared for them in 2021. To combat Japanese beetles, Wills and his crew experimented with beetleGONE! spray, which seemed to be effective against the beetles and they planned to use it again in 2021. While they didn't observe any SWD pressure during the 2020 season, they fully expected SWD to be a major pest to grapple with in 2021.

The crew had installed an Adjustable V Trellis System from Trellis Growing Systems, but Wills felt it wasn't utilized to its full potential. While the trellis was reasonably easy to assemble and install, they didn't train the canes very well, so at harvest time they didn't have a vertical fruiting wall like they had hoped. This caused the harvest to take longer because they sometimes had to search for the berries in the tangle of plants. They planned to improve upon the trellising in 2021.

Outdoor raspberries on September 17.

High tunnel raspberries on September 17.

2021 RESULTS

In year two of the project, Wills and his crew harvested raspberries for the first time and were able to compare yield and SWD pressure in the high tunnel raspberries versus raspberries grown out in the open field. Overall, the yields in the high tunnel were nearly 2.5 times higher. They harvested the equivalent of 1,365 one-pint clamshells (0.5 pounds each) in the high tunnel versus 574 from the open field rows. See Figure 2 for a calculation of revenue from the high tunnel versus the outside rows. The approximate cost of the 30-by-98-foot high tunnel was $10,000. At the increased income shown in the figure, Wills estimated the high tunnel would pay for itself in about two years.

	Yield in Clamshells	Price Per Clamshell	Total Income
High Tunnel	1,365	$8.00	$10,920
Open Field	574	$8.00	$4,592
Increased Income from High Tunnel			$6,328

Figure 2. Raspberry yield in 2021 in clamshells and the total income from raspberries for both inside and outside the high tunnel.

A few factors contributed to the dramatic yield advantage for the high tunnel versus outside production:

- The number of canes in the high tunnel was much higher. Even after the canes were thinned, there were approximately double the amount of canes per row-foot in the high tunnel.
- Harvest in the high tunnel started July 27, 2021, compared to outside which started August 23. Each variety started yielding three to four weeks earlier in the high tunnel. Starting harvest for each variety three to four weeks earlier provided a longer harvest window before the fall freeze that ends berry harvest, which happened around October 22.
- In the open field rows, significant yield was lost due to damaged berries. Damage was caused by mold or soft berries from morning dew, wind blowing berries off the canes, and Japanese beetles. The high tunnel mitigated all of these issues.

Wills estimated that there were 1.5 times as many overall berries produced in the high tunnel, but as stated above, marketable yield was 2.5 times higher in the high tunnel because almost no yield was lost to damaged berries.

However, there were some challenges with the high tunnel that are worth noting:

- It was very hot in the high tunnel, so the crew would try to complete the day's harvesting by 10 a.m. They found that after 10 a.m. it was too uncomfortably hot inside, even with the tunnel sides rolled up and the ends open.
- Bee activity was easier to cope with when harvesting outside than when in the high tunnel. In the open field there was much more space for bees and people to coexist, but in the close quarters of the high tunnel, some crew members were uncomfortable harvesting past 10 a.m. because as the temperature warmed up, the bee activity increased.
- Pest pressure was lower overall on the farm in 2021, including pressure from SWD. However, there was still SWD pressure in the raspberries. Wills' general observation was that SWD pressure was about half as much in the high tunnel versus outside. Japanese beetles were a more significant pest during this season than SWD. They used beetleGONE! as they had the previous season, but this year found it ineffective. The beetles did not abate so the crew resorted to hand picking beetles off of the plants two to three times per week in the open field rows. While effective, it was very labor intensive. The Japanese beetle pressure was significantly less in the high tunnel where they hand-picked only once per week. At the end of this season, they tried using a small handheld vacuum to suck the beetles off the plants. This proved very effective and much quicker, so they planned to trial this method as a primary management strategy in 2022.

VARIETY DATA AND OBSERVATIONS

The Polana raspberry variety was the highest yielding — both in the high tunnel and the open field. That was followed by Joan J, Crimson Night, and then Anne. The lowest yielding variety by a significant amount was Crimson Treasure. The order of highest to lowest yielding varieties was the same in the high tunnel and outside field.

Polana was the earliest maturing variety. The canes were strong, therefore it needed less trellis support and was easier to harvest. Again, it was the highest-yielding variety. The flavor was good, but not as good as the other varieties.

Joan J flavor was fantastic. The canes were very floppy, which made it hard to keep contained to a trellis and hard to harvest. The floppy canes also likely contributed to the mold issues that developed as the plant fell in on itself and thus the berries weren't able to dry out from the sun and wind.

Crimson Night, a newer variety available in Minnesota, had wonderful flavor and attractive berries. The canes were strong, so it grew very upright and was easy to harvest. Its only downside was it had significant thorns — a characteristic disliked by some of the crew during harvest.

Anne, like Joan J, was very floppy. It also had mold issues in open field production as well as a small amount of mold in the high tunnel. The flavor was tasty, and many customers liked having some yellow raspberries mixed in the container. It did not perform as well in the high tunnel as the other varieties. Compared to the Crimson Night variety, Anne's yield was similar in the open field rows but 25% less inside the high tunnel.

Crimson Treasure was another new variety to Minnesota. Its flavor was possibly the best of all the raspberries Wills trialed. A shorter, bushy variety, it was also very easy to harvest. However, its ripening stage probably comes too late to grow successfully in Minnesota. Harvesting didn't start until September 3 in the high tunnel and September 29 in the open field. Consequently, its yields were much lower than the other varieties.

Based on one year's data and observations (Figure 3), Wills recommended Polana, Joan J, and Crimson Night for high tunnel growing. He recommended the Polana and Crimson Night (and perhaps Anne) varieties for growing in an open field.

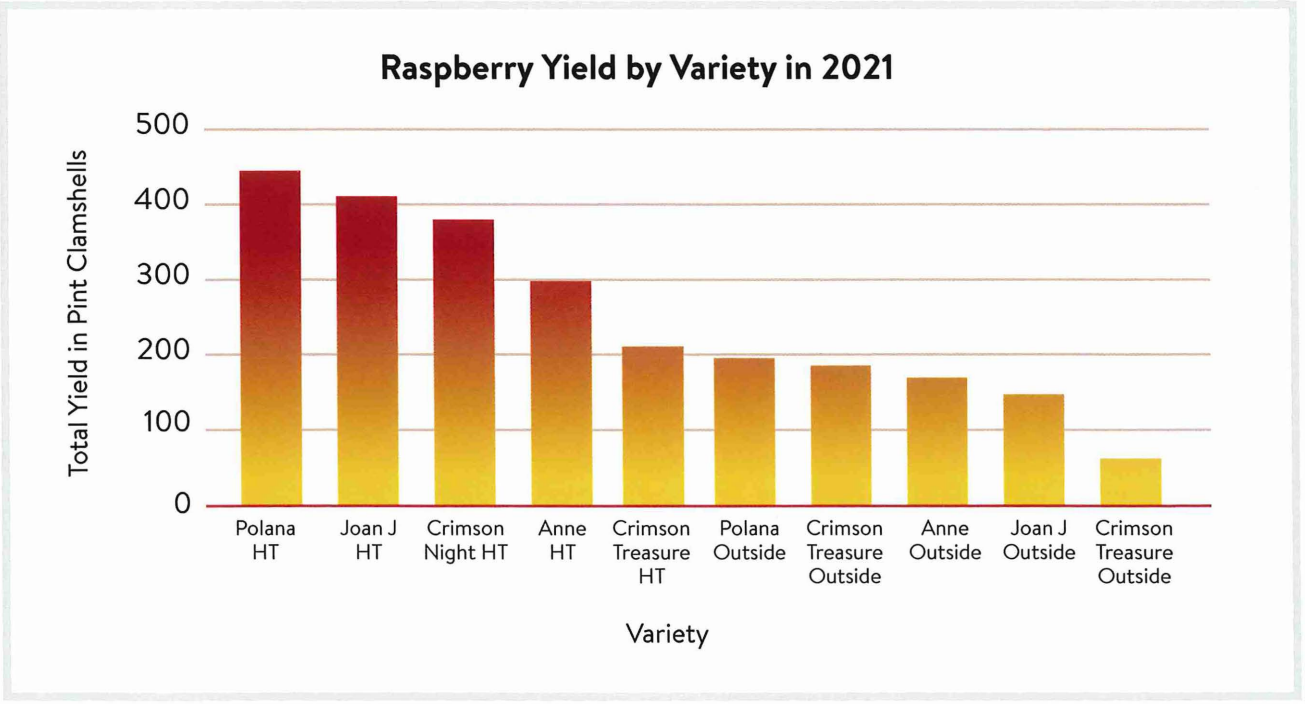


Figure 3. 2021 raspberry yield by variety and location in the high tunnel or open field.

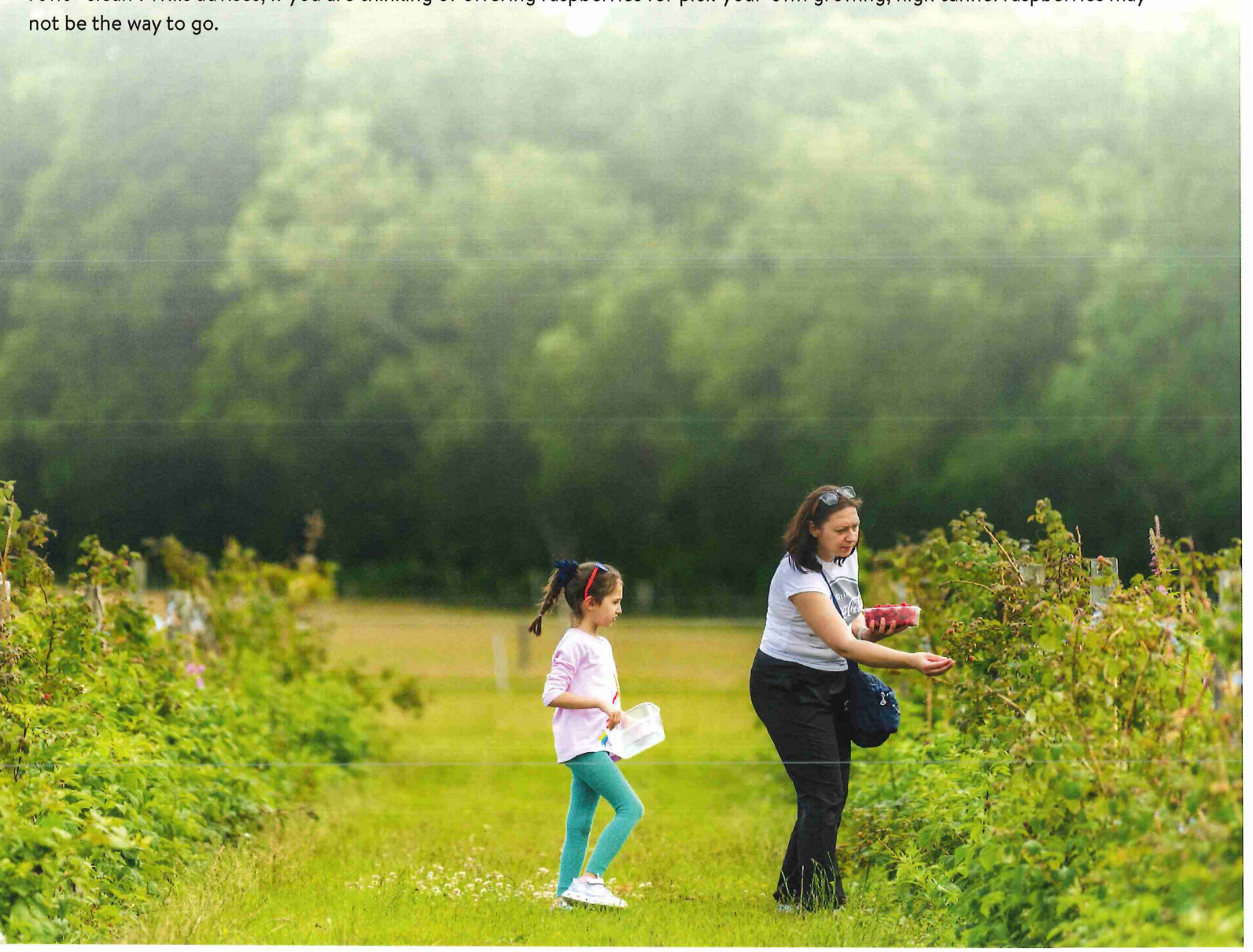
2022 RESULTS

The 2022 results were very similar to 2021. Overall, the yields in the high tunnel were 2 times higher than the outside rows. Yields in the high tunnel were a little lower than in 2021 due to a slower start in the spring. Yields on outside rows were higher than in 2021 possibly due to the plants getting better-established and improved trellis management. Wills and his crew were able to get the canes more upright in the outside planting in 2022 which reduced mold issues and led to a greater percentage of berries being saleable. After two years of harvest the increased yields from growing in the high tunnel paid for the $10,000 high tunnel investment.

	Yield in Clamshells	Price Per Clamshell	Total Income
High Tunnel	1,275	$8.00	$10,200
Open Field	650	$8.00	$5,200
Increased Income from High Tunnel			$5,000

Figure 2. Raspberry yield in 2021 in clamshells and the total income from raspberries for both inside and outside the high tunnel.

Wills experimented with offering pick-your-own raspberries in 2022. He found that the high tunnel raspberries do not work as well for pick-your-own. Most customers would rather pick outside for a number of reasons. It's a more beautiful setting. There is more room to move around outside. The high tunnel feels claustrophobic to some people and it is too cramped for kids. Also, there are so many berries in the high tunnel rows that it is difficult for customers to pick all of the berries or pick the rows "clean". Wills advises, if you are thinking of offering raspberries for pick-your-own growing, high tunnel raspberries may not be the way to go.



PEST PRESSURE

The SWD observations mirrored what was seen in 2021. SWD pressure was about half as much in the high tunnel versus outside.

Japanese beetle pressure was reduced in 2022 compared to 2021. Wills and his crew utilized small, handheld shop vacs to suck the beetles off the plants and set out traps/lures around the perimeter of the raspberry field a couple hundred feet away. The traps seemed to intercept the beetles flying in to the raspberry field. The traps needed to be emptied twice per week, but it was found to be an effective strategy. The beetles that did make it to the raspberry field were captured with the shop vacs. Beetle pressure in the high tunnel continued to be minimal.

VARIETY DATA AND OBSERVATIONS

The varieties that performed best were Joan J along with Crimson Night. Polana was not as productive in 2022. Based on two year's data and observations, Wills recommends Joan J and Crimson Night and possibly Polana. He expects Polana's yield to be better in future years, but it's flavor and berry size is not as good as Joan J and Crimson Night. Wills does not recommend Crimson Night for pick-your-own because it has large thorns. Particular attention needs to be paid to trellising for Joan J as it is very "floppy" and needs a lot of support. Crimson Treasure is not a good variety for Minnesota. It yields too late to provide a decent yield. Anne is a good option for a yellow raspberry, although it will have a lower yield. It is also quite "floppy" like Joan J and so attention needs to be paid to trellising.

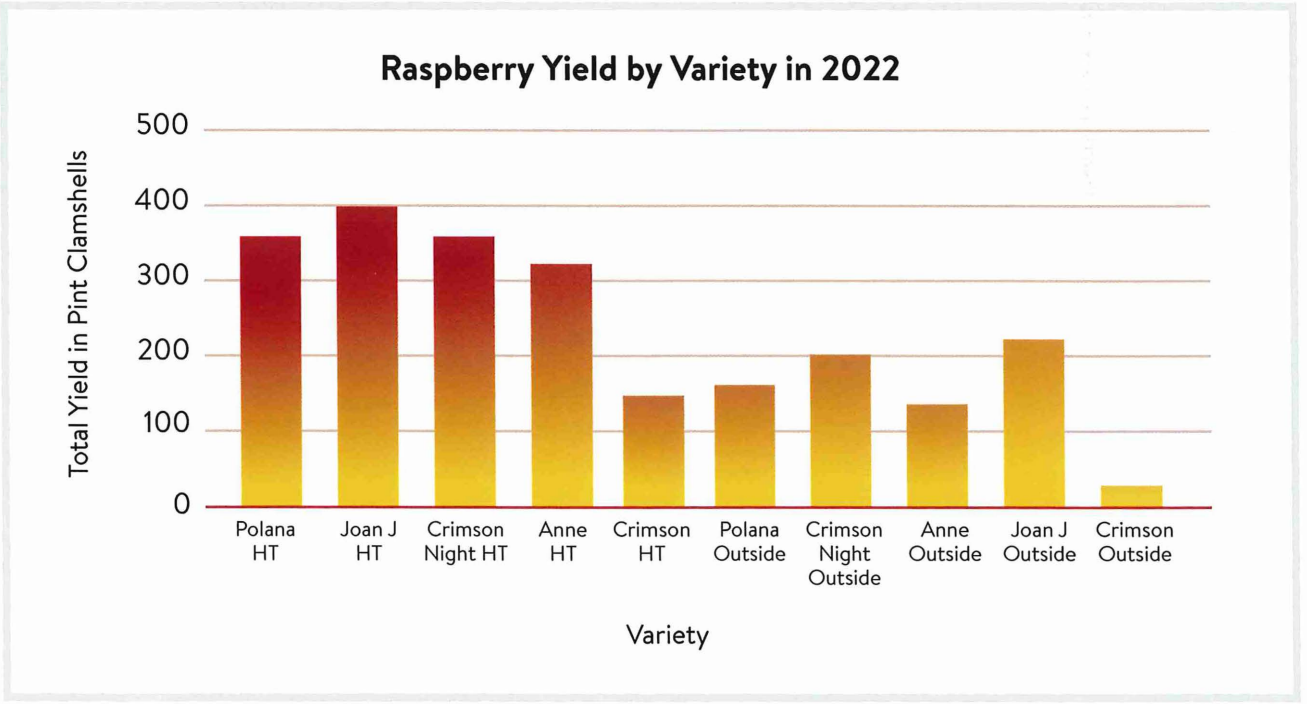
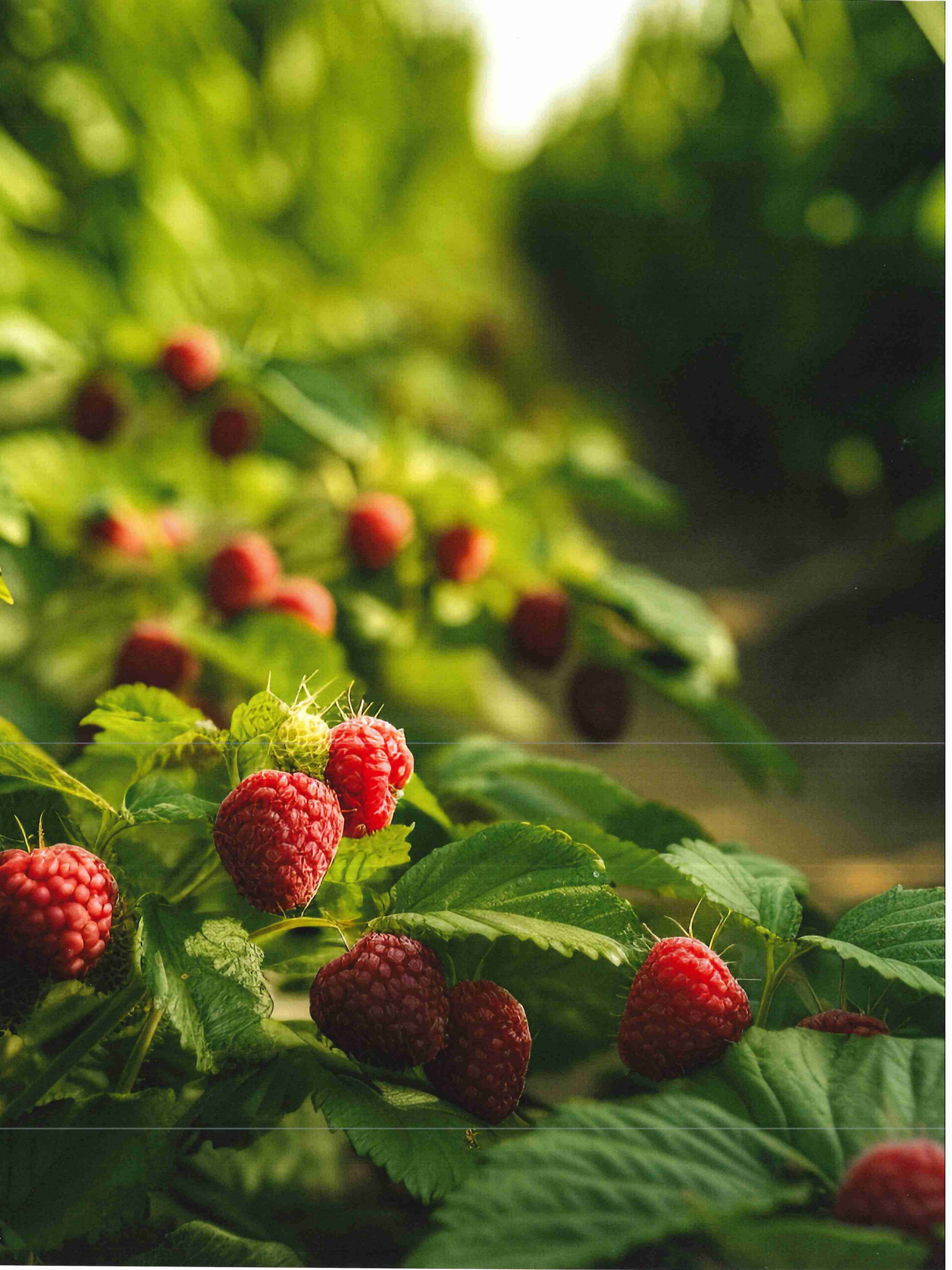


Figure 5. 2022 raspberry yield by variety and location in the high tunnel or open field.



MANAGEMENT TIPS

1. Use landscape fabric in the aisles for effective weed control (Photo 4).

High tunnel layout with landscape fabric.

2. It is extremely important to train plants to a trellis to save on labor when harvesting. Varieties with strong canes, such as Polana or Crimson Night, were good for trellising and easy to train.
3. Be sure to thin out the raspberry canes grown in a high tunnel. Some rows were thinned during the trial and some weren't. The yield was not higher in the unthinned rows, and they were more difficult to manage and harvest because they were so crowded with canes.
4. Japanese beetles can be a significant pest for raspberries. Have a plan for how to control them. The beetleGONE! spray was effective in year one but not year two, so growers will need to experiment on their own to determine what will be effective against Japanese beetles.

COOPERATOR

Annie Klodd, Assistant Extension Professor – Fruit and Vegetable Production, University of Minnesota

OTHER RESOURCES

Michigan State Extension Bulletin Organic Raspberry Production in Three Season High Tunnels *https://www.canr.msu.edu/foodsystems/uploads/files/high_tunnel_raspberry_production.pdf* and High Tunnel Production Guide for Raspberries and Blackberries 2019 *http://www.hort.cornell.edu/fruit/pdfs/high-tunnel-brambles.pdf* published by Tunnel Berries (a group of universities including Michigan State, Cornell, and UMN).

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

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2020-2022 / Three years

AWARD AMOUNT

$22,593.70

KEYWORDS

dessert pear, perry pear, high-density pear planting, hardiness, tall spindle planting system

PROJECT SUMMARY

The purpose of Gretchen Merryweather's project was 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 commenced in spring 2020 with a planting of 300 pear trees on the OHF87 semi-dwarfing rootstock and included ten dessert varieties and eight perry varieties. A five-wire trellis was constructed to support aggressive training of the pears in an attempt to limit size and induce precocious fruiting. The trees were trained and managed in 2020, 2021, and 2022. The project evaluated hardiness, disease, and yield.

PROJECT DESCRIPTION

The purpose of this project was to establish, grow, and evaluate a dessert and perry pear high-density planting. Pear tree hardiness, disease, and yield were assessed. Because pears are not typically planted on a high-density system, results of this project would provide potentially valuable information for future proof of concept and a feasibility study for Minnesota pear and apple growers.

Since a number of pear varieties are hardy in Minnesota — including those varieties developed by the University of Minnesota — the key takeaway points focused on the hardiness of rootstock that many growers hadn'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 significant limiting factor to the expansion of pear growing. An eight-year project in New York state (Robinson, "High Density Pear Production: An Opportunity for NY Growers") demonstrated the hardiness of the OHF87 rootstock that was used in this project. New York is not Minnesota, however, so a documented project in Minnesota would help local growers better understand their risks in using this rootstock.

Demonstrating the feasibility of the tall spindle planting system was 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 to 2,000 bushels of Bosc pears on a low-density central leader system (242 trees per acre) contrasted to 3,000 to 3,800 bushels of Bosc pears on a high-density tall spindle system (908 trees per acre). The timing of the project was significant because the growing cider industry provides a new consumer for pear crops. Cidermakers and distillers currently import pears and pear juice from out-of-state. Since Minnesota law specifies that cidermakers must use a majority of Minnesota-grown produce to sell cider in a retail operation, Minnesota-grown pears are 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.

2nd leaf pear tree on a tall spindle system.

OBJECTIVES

1. Evaluate the tall spindle growing system for pears, which is characterized by the following attributes: planting large, feathered trees; row spacing of 12 to 14 feet; tree spacing of 3 to 4 feet; and use of dwarfing or semi-dwarfing rootstocks. Pears grown in Minnesota are not being grown in high-density systems, so the first objective is specifically to assess rootstock hardiness and if the close spacing of the trees provides a sufficiently dwarfing effect.

2. Evaluate a number of pear varieties in terms of suitability for Minnesota. In particular, perry pear varieties are unproven in the state. Perry varieties that were evaluated included Barland, Blakeney Red, Brandy, Butt, Gin, Normanishen Ciderbirne, Romanian, Thorn, and Yellow Huffcap. Dessert varieties included Beurre Giffard, Bierschmidt, Blake's Pride, Dabney, Gourmet, Harvest Queen, Luscious, Magness, Sanguinole, Sucree de Montlucon, and Summercrisp.

DESIGN

The pears were planted in an 80-foot by 300-foot section of the orchard that was prepared for planting.

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

Table 1. Pear tree varieties and numbers of each planted.

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 the pear varieties except Gourmet was randomized by row. Gourmet, as an exception, was planted in each environment (high, middle, and low elevation). Tree 13 in each row served as a control and was not measured as part of the dataset.

EVALUATION PROCESS

To evaluate **rootstock hardiness**, Merryweather observed the trees in spring to early summer to note tree death and to measure tree dieback.

To evaluate the **tall spindle system and the growth of the varieties**, Merryweather measured the trees in two ways: trunk cross-sectional area and height. She then measured the shortest and tallest trees of each variety per row and, from these measurements, was able to assess this growing system for the trees' ability to fill, but not exceed, the space allotted to them.

To evaluate the **suitability of pear varieties for Minnesota**, Merryweather evaluated Perry varieties, which included Barland, Blakeney Red, Brandy, Butt, Gin, Normanishen Ciderbirne, Thorn, and Yellow Huffcap. Dessert varieties included Bierschmidt, Blake's Pride, Dabney, Gourmet, Harvest Queen, Luscious, Magness, Sanguinole, Sucree de Montlucon, and Summercrisp.

To evaluate **disease**, Merryweather scouted the planting once per week during the growing season for disease concerns. If potential disease was noted, she diagnosed it and, if needed, sent it to the University of Minnesota's plant pathology lab for confirmation.

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

2022 RESULTS

Although the trees have not been in the ground long enough to assess the success of the high-density planting system, it was possible to recommend which pear varieties to plant based on mortality results. As exhibited in Table 2, four perry varieties survived with mortality rates between 12% and 36%. Thorn, with a mortality rate of 36%, may be a questionable variety to plant. Yellow Huffcap trees had the lowest mortality rate (12%) and had exhibited growth. Barland's mortality rate is 15% and Blakeney Red's is 23%. All four perry varieties merit observation over the next three-year period. Unsurprisingly, a number of dessert varieties survived the trial planting. Gourmet, Luscious, and Summercrisp are already proven in our climate. Additional dessert varieties that survived the trial planting included Dabney, Sanguinole, and Sucree de Montlucon.

Table 2. Recommended pear varieties to plant.

PEAR VARIETY	TYPE	MORTALITY RATE
Barland	Perry	15%
Blakeney Red	Perry	23%
Thorn	Perry	36%
Yellow Huffcap	Perry	12%
Dabney	Dessert	0%
Gourmet*	Dessert	10%
Luscious	Dessert	0%
Sanguinole	Dessert	0%
Summercrisp	Dessert	0%
Sucree de Montlucon	Dessert	0%

**These trees arrived particularly small, thus contributing to their failure to establish themselves.*

Table 3 represents the varieties that did not survive the trial planting. The failure of these varieties to establish themselves was obvious with mortality rates between 75% and 100%. Brandy, Butt, Gin, and Normanishen Ciderbirne are not recommended for planting. Surprisingly, some dessert varieties also failed to survive the trial, including Bierschmidt, Blake's Pride, Beurre Giffard, Harvest Queen, and Magness.

Table 3. Recommended pear varieties to avoid planting.

PEAR VARIETY	TYPE	MORTALITY RATE
Brandy	Perry	100%
Butt	Perry	100%
Gin	Perry	100%
Normanishen Ciderbirne	Perry	92%
Bierschmidt	Dessert	75%
Blake's Pride	Dessert	75%
Beurre Giffard	Dessert	100%
Harvest Queen	Dessert	100%
Magness	Dessert	100%
Sucree de Montlucon	Dessert	0%

As previously stated, the high-density planting system was simple to establish but the planting had not been in the ground long enough to evaluate its success.

MANAGEMENT TIPS

1. When planting trees, never take any shortcuts as they will come back to bite you.
2. Prepare your planting site by loosening the soil and digging out a portion of it.
3. Keep the tree roots soaking in water until it's time to put them into the ground.
4. Thoroughly water newly-planted trees as soon as possible but no later than by the end of the day they are planted.
5. Water them the equivalent of one gallon per week if precipitation (1 inch of rain per week) is inadequate.

COOPERATOR

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

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PROJECT DURATION

2021-2023 / Three years

AWARD AMOUNT

$22,349.47

KEYWORDS

strawberry, strawberries, pest control, non-chemical

PROJECT SUMMARY

Small fruit farmers in the Upper Midwest are looking for new solutions to effectively control increases in pest, disease, and environmental pressures. In addition to their high cost and questionable effects on pollinator health, organic sprays are proving an unfit solution to these problems. However, non-chemical management alternatives are beginning to show promise for local fruit production. Andrew Petran with Twin Cities Berry Company had observed significantly higher total and marketable organic strawberry yields under insect netting compared to open field controls that were managed with traditional organic sprays, mostly due to the complete physical exclusion of pests. However, the netting could not protect against disease and rains in 2019, the wettest water year on record in Minnesota. For this project, Petran compared the netting they were currently using against a new hybrid net/plastic system that covered more area than a traditional high tunnel, was lower in cost, would exclude pests, and that could also potentially reduce disease, all without using sprays.

PROJECT DESCRIPTION

The idea for this project began as part of the mission of Twin Cities Berry Company: to design and research high yielding, environmentally benign cultural practices that are resilient against the increasing environmental pressures of climate change. The company strives to produce small fruits that are not reliant on sprays to combat growing pest and disease pressures in the Upper Midwest.

Petran successfully tested the use of insect netting for multiple years and was happy with its performance as a non-chemical practice to significantly reduce pest pressures in strawberries. However, the netting was unable to combat the increased disease pressures that are becoming more prevalent in the open field. Therefore, he designed this project to test insect netting (resistant to pest pressure) against caterpillar tunnels modified for pest exclusion (resistant to both pest

and disease pressure). This three-year project proposed to determine if the increased costs of tunnel production result in increases in total and marketable yields compared to netting production. The project was initially slated to begin in the 2020 field season, but due to constraints with suppliers caused by the COVID-19 pandemic, the project instead began in 2021.

OBJECTIVES

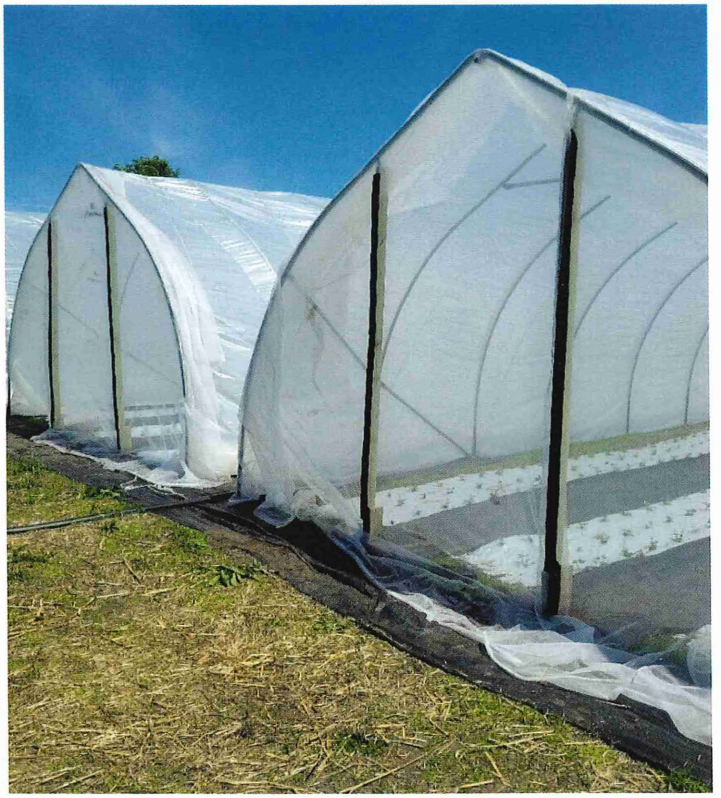
1. Test and demonstrate effectiveness and profitability of improved exclusion environments for local strawberry production.
2. Measure environmental benefits of the proposed system by documenting every spray event in each plot (current and proposed) and comparing those to average spray events in an open field system, based on previous documentation of spray events in open field plots on Petran's farm in 2018 and 2019.
3. Compare labor energy savings by documenting total construction time in labor hours for each system and comparing it to labor hours needed to maintain open field plots, such as spray events and walkway maintenance through mowing or weed whacking.

Petran evaluated the project by measuring total and marketable yields, the number of spray events, and construction time of the netting and tunnel treatments in 2021 and 2022. The data collected was also compared against historical yields and spray events in the open field plots in 2019.

Outreach efforts included presentations at conferences (COVID permitting), blog/YouTube/social media documentation, and participation on advisory boards for other organic small fruit grant projects. With this data, Petran hoped to demonstrate whether modified caterpillar tunnels were a viable method of small fruit production that is resilient against increasing climate instability for small farmers.

2021 RESULTS

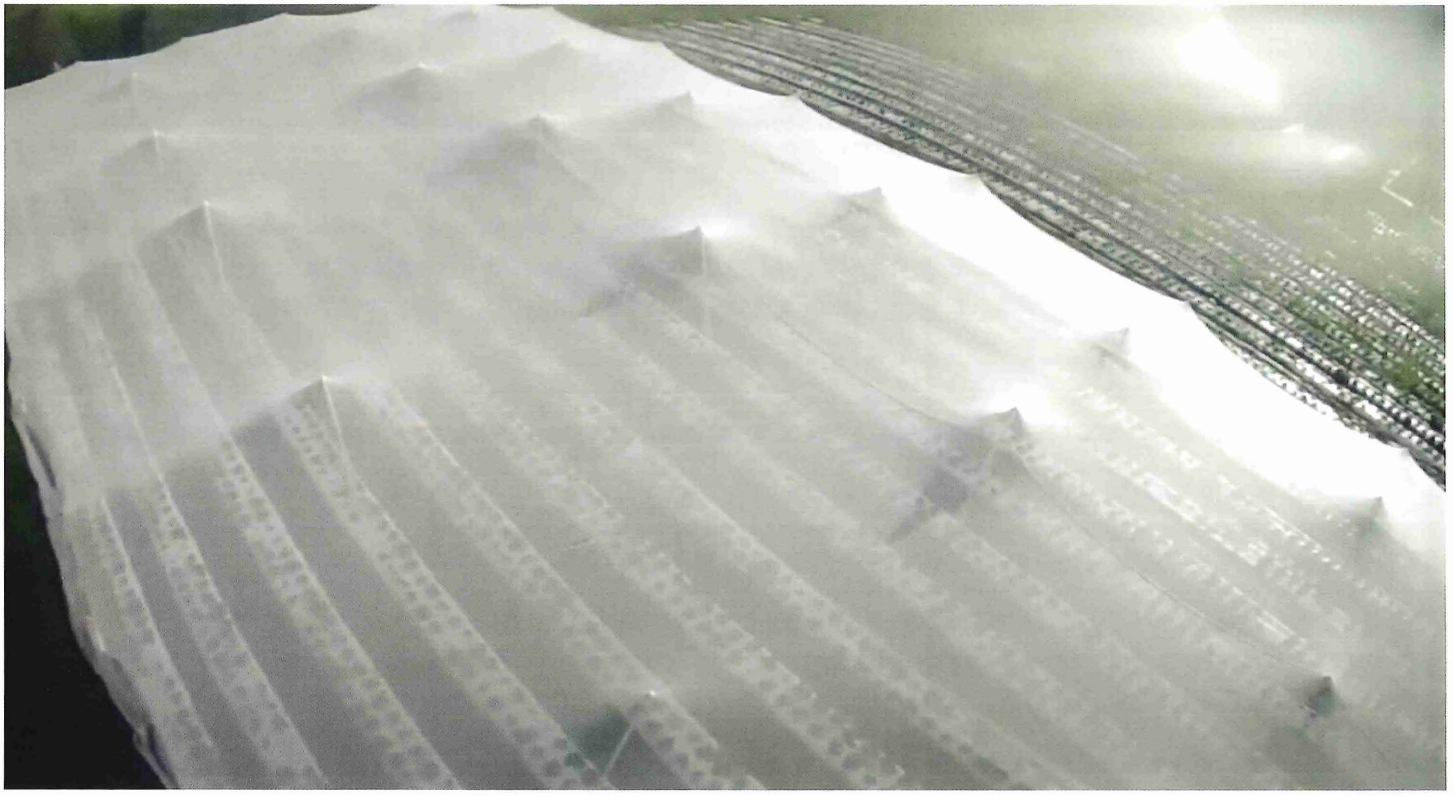
In 2021, Petran constructed 16-by-100-feet Gothic Pro caterpillar tunnels and modified them for insect exclusion by constructing netted endwalls on each tunnel. Each tunnel contained approximately 900 plants, with three 100-foot flat beds, and each bed containing three rows of strawberries planted at 12-inch spacing (Photo 1).



Exterior of 2021 tunnel modified for pest exclusion.

The netting treatment consisted of approximately a half-acre of raised bed plasticulture strawberries grown in 14 beds that were 220 feet long with 5-foot bed spacing, each bed containing two rows planted in a staggered-row formation and 12-inch plant spacing. Construction of the netting consisted of a perimeter of 2-inch galvanized steel poles that were 10 feet in length and placed 3 feet into the ground, 15 feet apart.

Polyvinyl chloride (PVC) interior poles were used to reduce overall cost, and polyamide wire was strung among all poles to form a grid support system for the top of the netting. Netting was then pulled over the entire plot, supported by the poles and wires, and held in place with sandbags around the perimeter of the field (Photo 2).



Netting pulled over entire plot.

Videos documenting the construction process were made for the project and uploaded to Twin Cities Berry Company's YouTube channel: *https://www.youtube.com/watch?v=JTSkQl9mt4k https://www.youtube.com/watch?v=m79ob9CsrtY*

YIELD

2021 summary statistics for total and marketable yields can be seen in Table 1.

Table 1. Total and Marketable Yields of Caterpillar Tunnel and Netting Treatments, 2021.

TUNNEL	TOTAL YIELD (LBS)	YIELD (LB/PLANT)	YIELD (LB/SQ. FT)	AVERAGE % MARKETABLE YIELD
1	287.25	0.33	0.18	81.49
2	341.16	0.39	0.21	84.48
3	236.94	0.25	0.15	84.98
4	111.75	0.13	0.07	81.33
NET	2,184.25	0.75	0.14	83.41

By looking at total and per-plant yields, it appeared to Petran that the netting treatment resulted in significantly higher and more beneficial yields compared to the tunnels, making the extra cost of the tunnels unviable. However, he considered that planting within the tunnels had a considerably higher density than what was possible inside the net. This was due to being able to utilize flat bed plasticulture instead of a raised bed, meaning three rows of plants could be placed within each bed row instead of two, as seen in Photo 1. Measuring total yield on a per-foot basis instead of a per-plant basis controls for this difference in planting density, and Table 1 shows that analyzing the yields this way shows a total yield advantage in three out of the four tunnels compared to the netting treatment. Percent marketable yield was high among all treatments.

Environmental circumstances in 2021 must be considered when looking at the yield data in Table 1. First, temperatures were incredibly high, especially at the beginning of the field season, including several days with highs above 100 degrees Fahrenheit in May and June, and many more above 90 degrees Fahrenheit. These high temps caused over 80% of the first flush of flowers to abort, resulting in suppressed early-season yields (Figure 1), especially among the tunnel treatments where temperatures were even higher. It could be assumed that in seasons with more normal, lower early-season temperatures, total yields would be considerably higher.

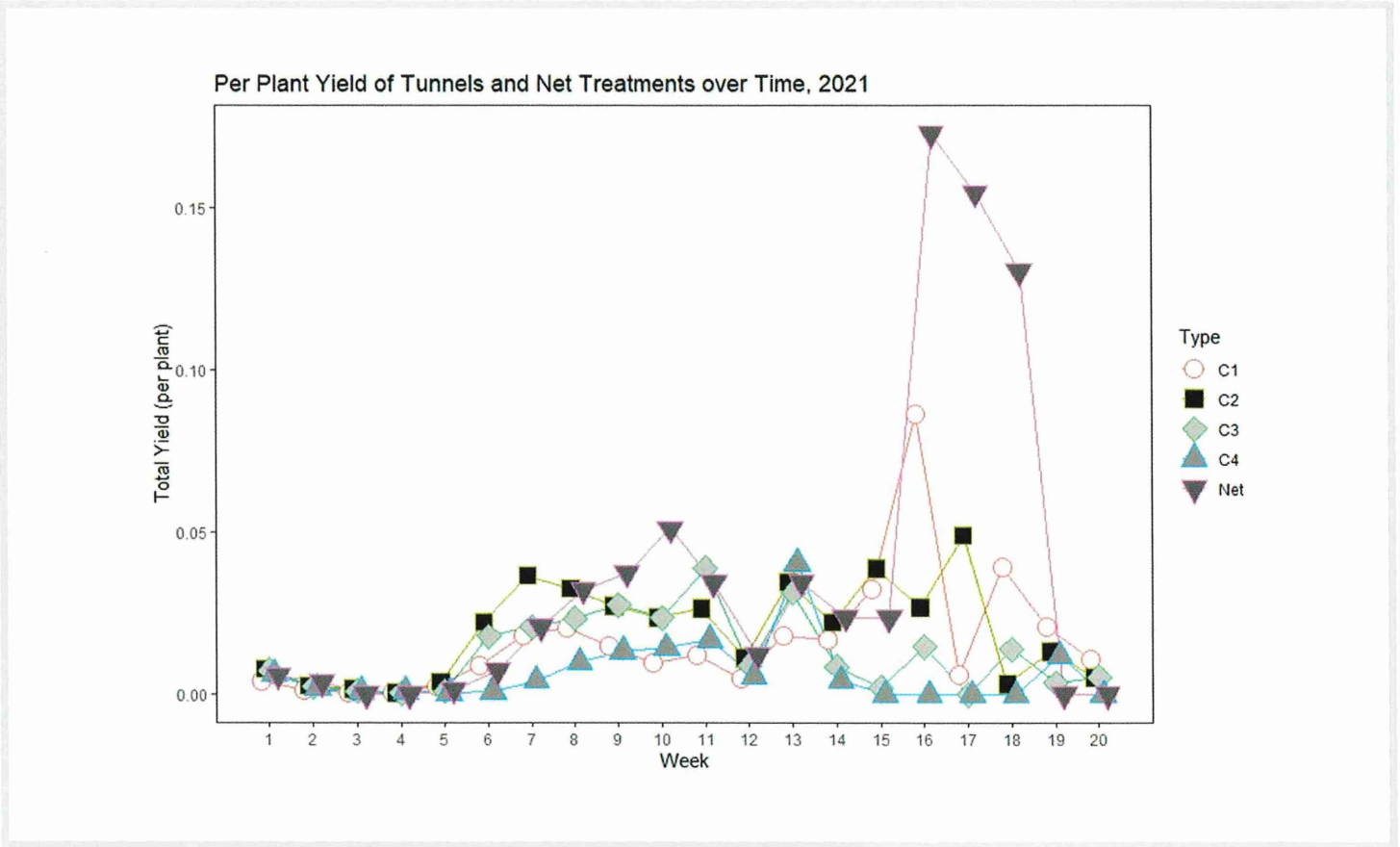


Figure 1. Per-plant weekly yield of tunnel and net treatments, 2021.

One of the driest growing seasons in Minnesota history was 2021; a stark contrast to the 2019 season which was the wettest on record. It could be assumed that in years with more precipitation, the disease pressure in the netting treatment would be higher, leading to a greater separation in average percent marketability between the tunnel and net treatments. Petran ascertained that a stark difference in soil quality explained the large amount of difference in yields among the tunnel treatments seen in Table 1. The soil these strawberries were growing in was of poor agricultural quality and was classified as pastureland by the MDA. Specifically, the soil where the fourth tunnel was located had a crop productivity index of 31 out of 100, likely leading to its poor yield performance observed in Table 1. In better quality soils, it could be inferred that higher yields with lower variability could easily be achieved.

SPRAY EVENTS

Each tunnel and the netting treatment was sprayed exactly three times throughout the 2021 field season, for an average of 0.125 spray events per week. This was considerably less than the one to two sprays per week frequency that was needed to maintain completely open field management on the same plot as recorded in the 2019 field season. It could be inferred that both the netting and tunnel treatments offered value as a strong non-chemical control option for pest management in small fruits. Sprays utilized were Pyganic 5.0 mixed in a backpack sprayer, applied at the rate of three ounces Pyganic per acre for every spray event.

LABOR/ENERGY

Preliminary data showed the tunnels took more time to initially construct, while the netting took more time to maintain throughout the season. The tunnels provided greater resilience against high winds than the netting treatment, something many growers should consider when growing within the windy prairie lands of the Upper Midwest.

2022 RESULTS

The year 2022 was fraught with difficulty on the farm. In early 2022, shortly after planting, a severe storm event with high winds knocked out and tore the netting treatment system, completely destroying it. It was therefore impossible to quantify yields for this treatment in 2022 and therefore reverted to an open field control treatment. The open field treatment was also hit with pesticide drift early into harvesting, severely hampering yields. This unfortunate incident further highlighted the advantage of growing in tunnels, which were not affected by the drift despite being located immediately next to the open field treatment. The tunnel treatments, on the other hand, survived the storm without any damage, due to modifications to strengthen these structures against wind damage. An outreach video showing how to modify tunnels for wind pressure was created and posted on YouTube: *https://www.youtube.com/watch?v=8Fs16O1YYIE*

Combining in-ground with gutter production in a single tunnel.

Due to the constant threat of storm damage destroying the netting treatment, Petran does not recommend the netting for permanent use on-farm and suggested modifying caterpillar tunnels instead, as was investigated in this project. Another improvement to the tunnel systems in 2022 was trialing the use of vertical, gutter production in addition to in-ground strawberries, using container production kits from Meteor Systems (Photo 3). This was done in one of three tunnels and will be expanded in future projects in collaboration with the MDA. Production in this way greatly increases planting density within the tunnel, going from 900 to 2,400 plants in the same physical space.

YIELDS

In early September, after 14 weeks of successful harvest in the gutter tunnel, an accident left the irrigation system turned off for several days, killing every gutter plant inside. A more resilient set of operating protocols would have to be implemented to protect gutter plants moving forward. Therefore, the yield numbers will only encompass the first 14 weeks of harvest, up to the first week of September (Table 2).

Table 1. Total and Marketable Yields of Caterpillar Tunnel and Netting Treatments, 2021.

TUNNEL	TOTAL YIELD (LBS)	YIELD (LB/SQ. FT)	MARKETABLE YIELD (%)
1	140.25	0.09	69.63
2	224.69	0.14	73.11
3 (GUTTERS)	435.98	0.27	79.22
OPEN FIELD	116.5	0.04	13.78

Even without the September harvest, which could account for up to 35% of total annual yields, the advantage of netted tunnel production over the open field was quite clear, in addition to the advantage of adding gutters to the tunnels for increased production. Yield per square foot in a guttered tunnel was 6.75 times greater than in the open field and up to three times greater than a typical netted tunnel, with considerable marketable yield increases as well. Best practices for guttered tunnel production merits further investigation and will be done so in collaboration with the MDA Specialty Crop Block Grant in 2023, Project B0423F91268X. In general, this project highlighted the importance of protected culture production for strawberries. Netted tunnel production, with gutters especially, resulted in higher yields of better-quality fruit on smaller pieces of land with reduced pesticide input. The tunnels provided passive protection from storm pressure, pest pressure, fungal pressure, and even pesticide drift from other farms.

MANAGEMENT TIPS

1. If not using netting in an annual rotation, more permanent methods of keeping the netting secured such as wiggle wire are preferred to sandbags.
2. Removing plastic from caterpillar tunnels during the wintertime is easier than doing so for high tunnels. This is recommended to protect the structure from snow load or wind damage.
3. Landscape fabric for between-row weed control is necessary for extended-season strawberry production. It reduces pest habitat within the field and saves approximately 150 labor hours per acre per year compared to maintaining green walkways through mowing or weed whacking.
4. Consider implementing netted tunnel production for high-value horticultural crops on your farm. The tunnels are passively climate resilient and cost accessible, which is a rare combination, and merits implementation on almost any small farming operation.

OTHER RESOURCES

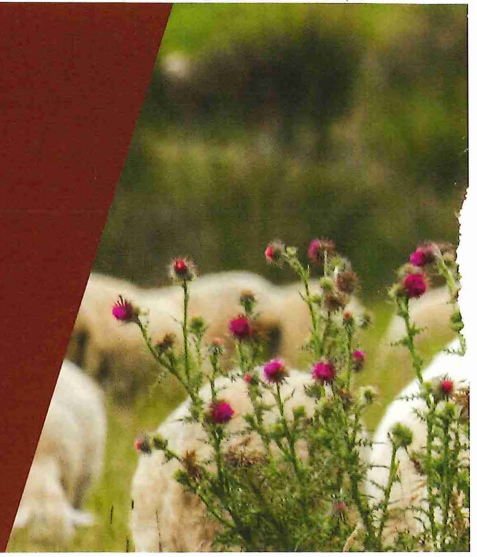
Andy Petran Named 2021 Compeer Groundbreaker of the Year for Pioneering Methods for Small Farmers:
https://www.compeer.com/press-releases/2021/march-2020/2021-groundbreaker-of-the-year

Twin Cities Berry Company YouTube page: *https://www.youtube.com/channel/UCbNnvv8fo2q3d17ItmT442Q*

University of Minnesota Extension articles:
https://blog-fruit-vegetable-ipm.extension.umn.edu/2020/03/want-to-try-day-neutral-strawberries.html

U of M blog on Spotted Wing Drosophila
https://fruitedge.umn.edu/spotted-wing-drosophila

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



PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2020-2022 / Three years

AWARD AMOUNT

$25,137.50

KEYWORDS

sheep, prescribed grazing, pollinator habitat, solar, prairie

PROJECT SUMMARY

Principal investigator Jake Janski is an employee of MNL, formerly Minnesota Native Landscapes. With assistance from researcher Jeremy Gilbertson, they set out 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 heights at acceptable levels, but they wanted to identify the effects of prescribed grazing on plant species diversity and overall prairie health within solar sites while providing local producers with grazing opportunities and expanding locally sourced meat markets. It has been proven that high-intensity, low-duration grazing can improve overall plant vigor in large pasture settings, but this practice had yet to be tested in pollinator-friendly solar sites.

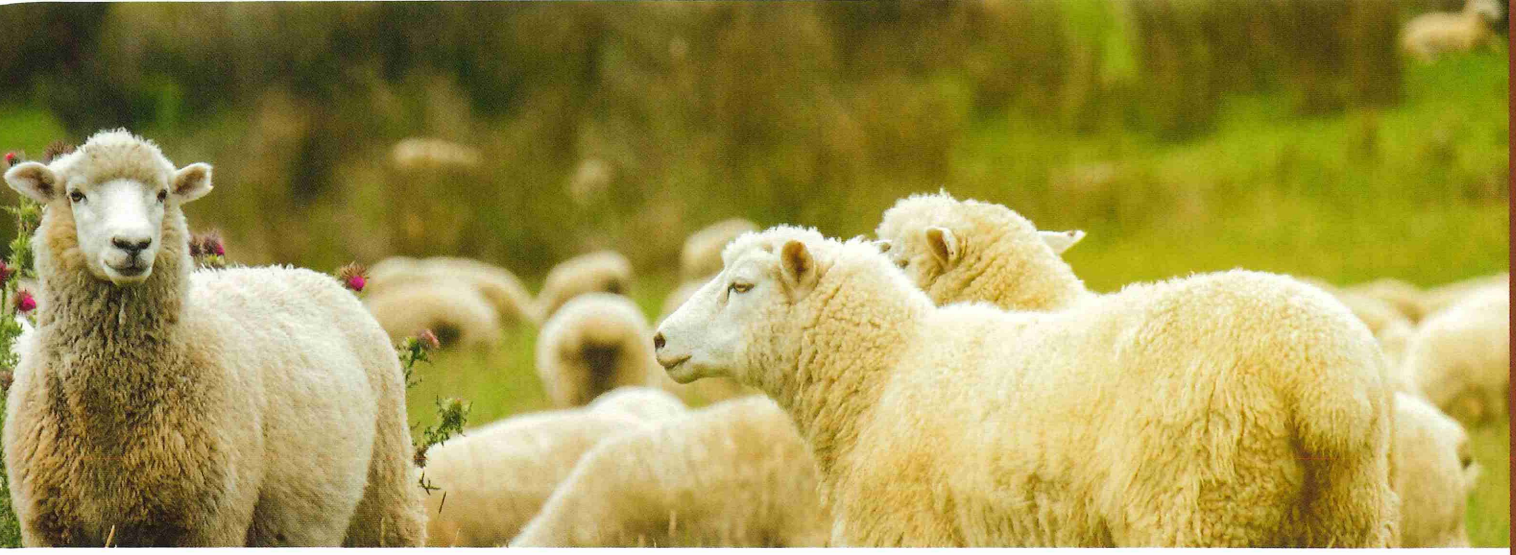
PROJECT DESCRIPTION

OBJECTIVES

1. Identify the effects of prescribed grazing on plant species diversity and overall prairie health within solar sites.
2. Provide more grazing opportunities for local producers resulting in expanded locally sourced meat markets.

RATIONALE

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 — when left unmanaged — may exceed operational heights under solar panel arrays and around sensitive equipment. Mechanical cuttings and chemical applications may adequately control plant growth, but MNL sought to deploy prescribed sheep grazing as a sustainable management method to provide an ecologically friendly and cost-effective alternative. While prescribed



Pollinator-friendly solar sites.

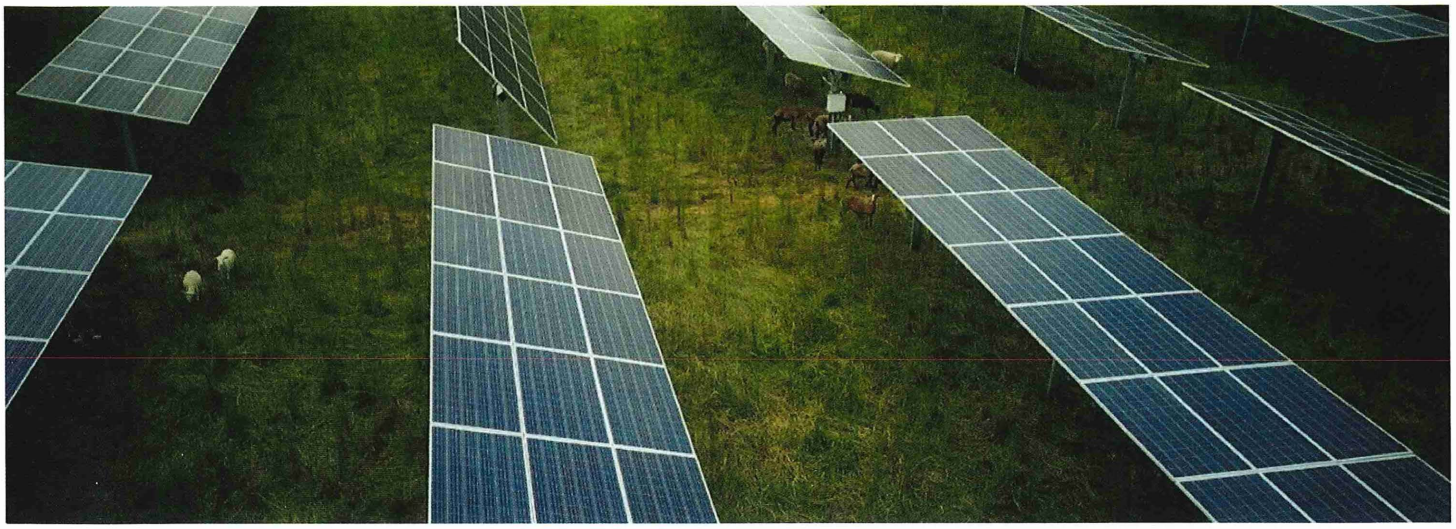
sheep grazing has been shown to effectively control vegetation height, its effects on prairie plant species diversity are largely unknown. As an ecological restoration and land management services company, MNL strives to provide innovative, sustainable, and efficient management solutions for its clients while promoting healthier ecosystems. Research on larger ungulates such as bison and cattle have shown that prescribed grazing does increase prairie plant diversity. The MNL study evaluated 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 was actively managed with a variety of techniques for at least three full growing seasons until properly established. Sample transects were established in plotted areas of each site and subjected to grazing in 2020, 2021, and 2022. A replicated set of transects was 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 (measures how diverse a single sample is) and the Shannon-Wiener Diversity Index (a measure of both species diversity and evenness in a community) were calculated for grazed and ungrazed plots on each site. This process was repeated two or three times each growing season for the duration of the project.

Demonstrating the effectiveness of sheep grazing for solar vegetation management. Sheep will reliably graze native and invasive forbs, including thistle, to manageable levels.

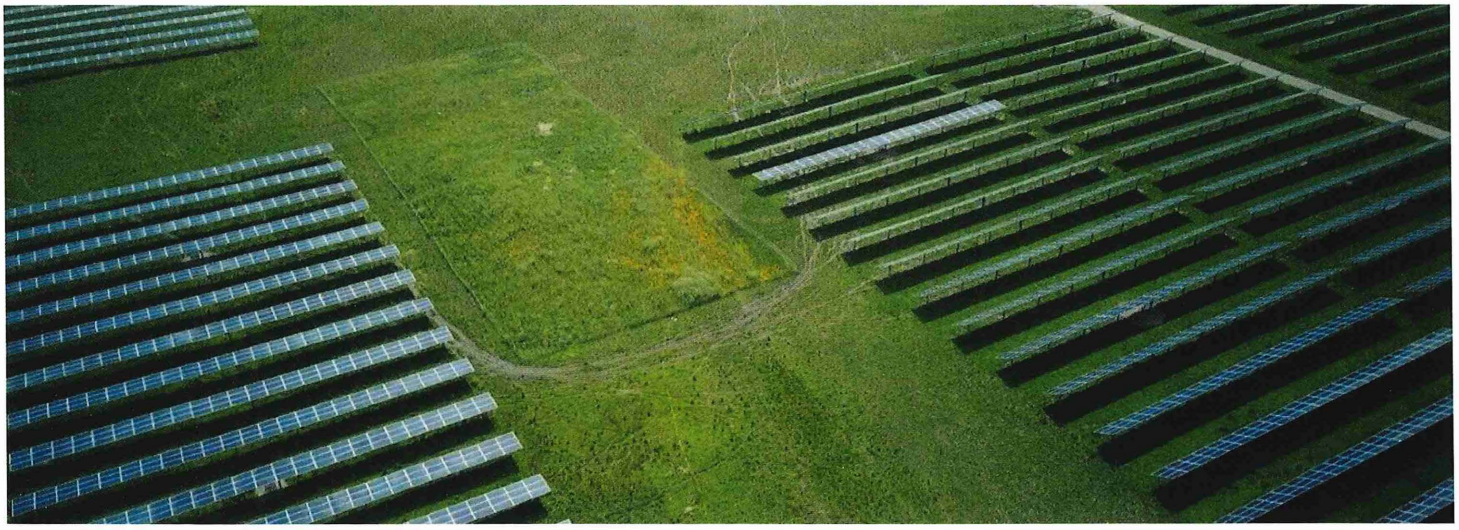
2020 RESULTS

2020 saw the implementation of the excluded plots, great grazing rotations, and the first round of baseline data collection for the study. MNL collected data from three periods over six sites, and although it was too early to see trends in the data, it showed that they could successfully qualify vegetative diversity and cover in the grazed and ungrazed plots.



Aerial photo of solar site #6 during grazing.

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



Prairie one week post grazing.

2021 RESULTS

2021 data was successfully collected in the same manner as in 2020 on all sites in June, July, and August. While MNL had collected a significant amount of data on this project to date, they believed it premature to examine trends in test plots as significant change in prairie ecosystem compositions expected to be a longer-term process. For this reason, 2021 results were not compared statistically with 2020 results. Figures 1 and 2 below show samples of the data collected to that point. These plots illustrate diversity as measured by the Shannon-Wiener Diversity Index and the total species present across the six plots in 2020 and 2021 in the month of June. MNL recorded this dataset — along with measures of vegetative cover — in June, July, and August on each of the six study sites. Throughout the study, MNL hoped to see more significant changes in diversity, evenness, and vegetative cover between plots from year to year. The data collected in 2021 represents one of the first snapshots of this process.

While the changes may take several years to surface, MNL could visually confirm what appeared to be greater cover in the grazed plots versus ungrazed. The summer of 2021 also had its challenges with the state plunging into extreme drought. This could have affected the data in unpredictable ways. It's possible the sheep had altered forage preferences considering the conditions. Additionally, the prairies withstood the drought and came back strong in 2022, but perhaps seed production and dispersal were also hampered.

Although it was too early to see trends in the data at this point, MNL staff and student interns presented preliminary research and hypothesized outcomes to industry peers and academia with the intention of increasing the awareness of grazing as an ecologically-friendly management alternative in industrial settings similar to this, and inspiring future research and collaboration on the subject.

A clear look at grazed and ungrazed plots immediately after a high-intensity, short-duration grazing session.

Grazed and ungrazed study plots side by side. Can you spot the difference? Although it may appear grazing initially harms the plant communities, the grazed plants on the right rebounded more than before.

2022 RESULTS

MNL saw slight trends in the study data by 2022. While the changes of plant community compositions can take place over the span of a decade or more — and MNL plans to continue this study well into the future — they were able to begin interpreting the data thus far. Over three years, diversity (using the Shannon-Wiener Diversity Index), total species present, total cover, and relative cover data points were collected. The difference between the 2020 and 2022 value of each metric was calculated for each site and each time period. These differences were then averaged to give a composite result of the change in each site over the three year study. Total Species: On average, ungrazed plots decreased by 2.85 total present species, while grazed plots decreased by only 2.083 species. Although decreasing total species counts could be explained by a number of factors such as site establishment, preferential grazing, etc., this trend still supported their hypothesis that grazing would encourage greater diversity. Shannon-Wiener Diversity Index: Interestingly, they saw an average increase in diversity in ungrazed plots of .0782, and a decrease of .1304 in grazed plots. This result diverged from their hypotheses, though the difference in values was so small, it warranted continued study before conclusions were drawn. Total Cover and Relative Cover: Total cover (total positive plants counted per 200 points) and relative cover (vegetated points versus bare ground) both increased more in grazed than ungrazed plots. Ungrazed plots increased 7.8% in total cover and 3.1% in relative cover, while grazed plots increased 18.5% and 4.8%, respectively. Again, a greater increase in vegetative cover on grazed plots supported their hypothesis that grazing would positively affect prairie cover. Anecdotally, the researchers also noticed that grasses and forbs in grazed plots appeared more robust and were more difficult to dislodge due to increased root structure development. These characteristics would also contribute to greater soil health and sediment control benefits.

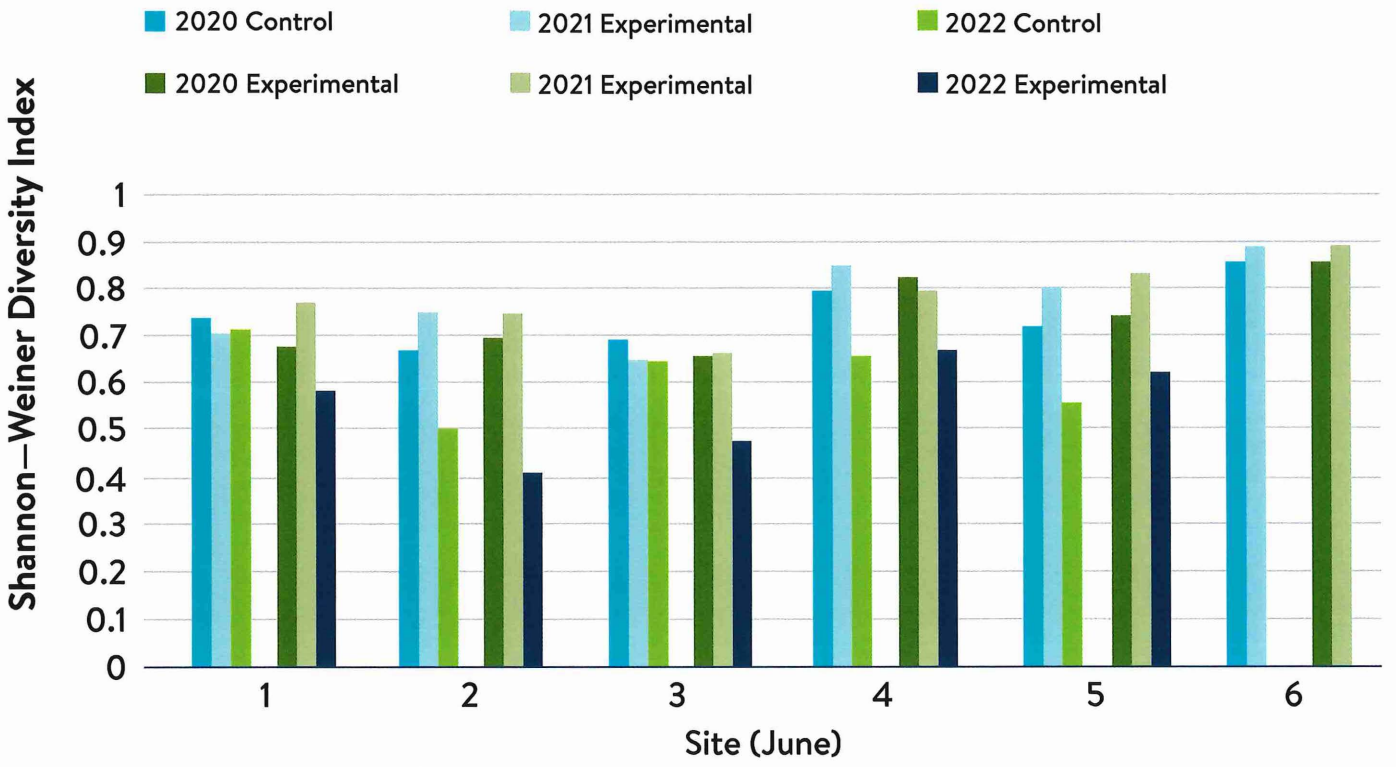


Figure 1. Shannon-Wiener Diversity indices of control (ungrazed) and experimental (grazed) plots in June of 2020, 2021 and 2022 at six pollinator-friendly solar sites.

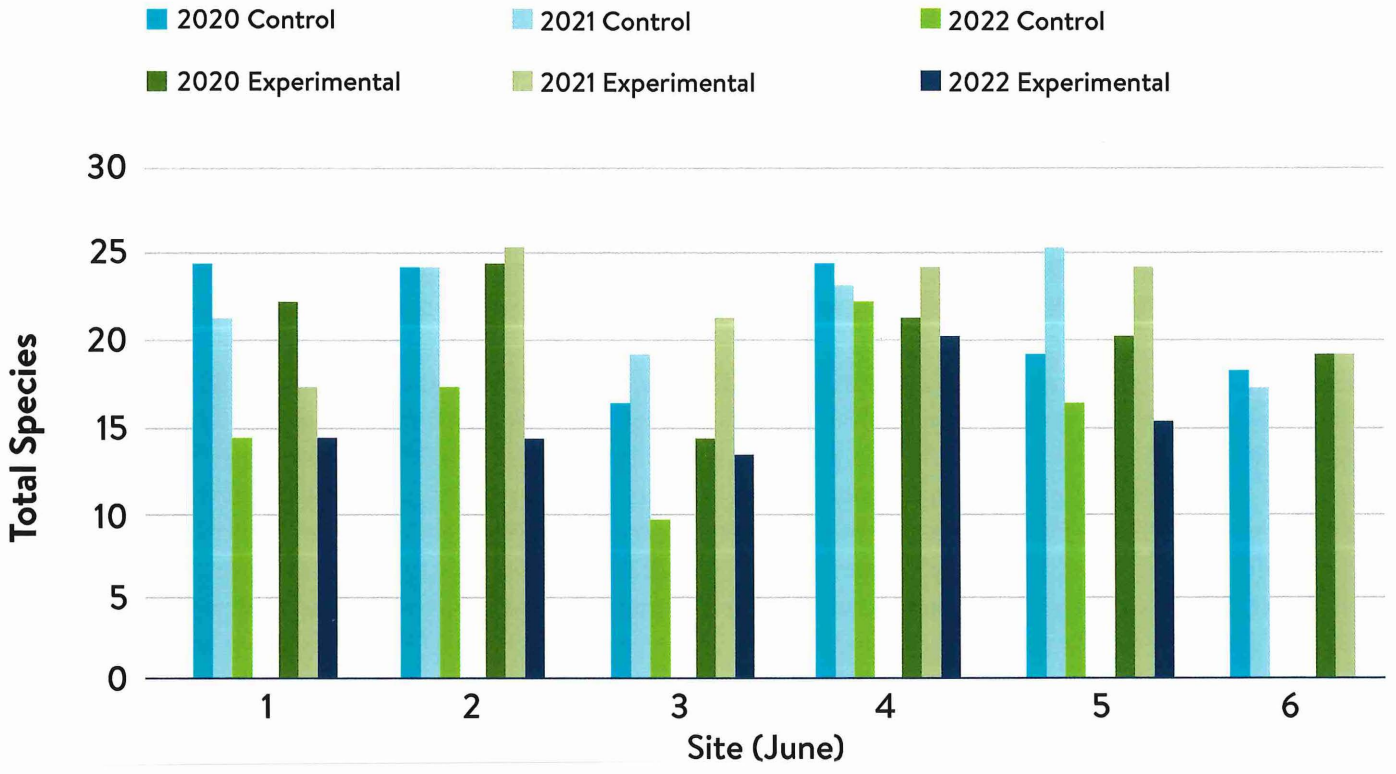


Figure 2. Total plant species counts of control (ungrazed) and experimental (grazed) plots in June of 2020, 2021, and 2022 at six pollinator-friendly solar sites.

Field day at the site.

MANAGEMENT TIPS

1. Permanent rather than temporary fencing would be a better option for paddocks that remain unchanged from year to year. While temporary electric net fencing works very well for animal containment and can be used all year on numerous paddocks, it was not optimal. Meanwhile, though the initial investment is greater, the setup of permanent fencing is a one-time investment and can occur outside of the busy field season.

2. You may need to make a significant change in the grazing duration to help reduce the thatch layer that accumulates in prairie ecosystems. Prescribed burning is not an option in this situation, so grazing for thatch removal is a great alternative. However, in order to achieve the desired results, you may need to increase the deployment time on these sites. This needs to be accounted for in seasonal scheduling.

3. If you plan to replicate this survey, schedule only two surveys per year instead of three. Immediately after grazing, most vegetation becomes unidentifiable, so two surveys would have been sufficient. Two surveys proved to be enough of a sample to provide the data desired and would have saved the time and expense of trying to collect data too soon after grazing had occurred.

COOPERATOR

Enel Green Power, Hardwick, MN

Control of Wild Parsnip Through Rotational Sheep Grazing

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2020-2022 / Three years

AWARD AMOUNT

$18,154.00

KEYWORDS

Wild parsnip, invasive, noxious, weed, rotational grazing, sheep

PROJECT SUMMARY

Wild parsnip (*Pastinaca sativa* L.) is an invasive species with an exploding population in southeastern Minnesota. Recommended management strategies include carefully timed mowing and spraying with herbicide. Both methods can be costly, and neither is particularly successful. Organic farmers only have mowing or removal by hand as management options. Heidi Eger of Radicle Heart Farm noted that her flock of 100% grass-fed Katahdin/Dorper ewes showed enthusiasm for grazing wild parsnip plants. The purpose of this study was to measure the effectiveness of managed rotational grazing by sheep to control wild parsnip in a perennial pasture. Effectiveness was judged by monitoring plant populations in grazed plots and comparing populations to control plots.

PROJECT DESCRIPTION

The purpose of Eger's project was to measure the impact of a carefully managed sheep flock on a population of wild parsnip. Wild parsnip is considered a noxious weed in Minnesota and is listed on the Minnesota Department of Agriculture's *Noxious Weed List*. 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.

RATIONALE

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 also 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 standards prohibit farmers from spraying the weed and they can only mow accessible areas. If grazing by sheep provided good control of the plant, it would allow land managers an alternative that is beneficial to the environment and to their bottom line.

Eger's sheep flock showed a strong preference for parsnip leaves and frequently ate them before other plants in their paddock. Would grazing a plant two or three times in its first season of growth, plus grazing it when it sends up a flower stalk, weaken the plant enough to reduce the number of seeds blooming? Eger wanted to test the hypothesis that sheep can kill some of the young plants through grazing. She also wanted to see if trampling can weaken the surviving plants enough that the flowers would produce fewer, smaller, and thus lower-quality seeds.

This project would 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 beneficial to beginning farmers without access to land. If shepherds were able to get paid to graze, rather than paying for access to pasture, it would allow them a faster way to a profitable, stable farm business.

DESIGN

One five meter by five meter monitoring plot in each grazing paddock was established. Monitoring plot locations were chosen strategically so that the parsnip population in each was of similar size and — where possible — similar slope, soil type, and surrounding vegetation. Three ungrazed control plots of 5 meters by 5 meters were also established and monitored. Plants were counted at the beginning of the grazing season and on a random day during the blooming season.

Sheep would graze each paddock long enough to graze it evenly. This project tested only how sheep control the plant by choosing to graze it. No effort was made to force the sheep to overgraze the parsnip. While much of the literature on wild parsnip identifies it as a toxic plant, Eger's sheep showed a preference for the plant, so she trusted that they instinctively would know what they could eat. In 2019, she observed no signs of illness in her sheep, and during that entire season the flock continued to eat wild parsnip plants before other plants in the pasture. She was careful throughout the project to ensure the sheep had access to paddocks with plenty of variety and to move them before all the available food was eaten.

2020 RESULTS

Since this was year one of a two-year study, Eger didn't have many results to report. Qualitative observations in the test plots versus the control plots showed taller plants were growing 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 two weeks before Test Plots 2 and 3. The sheep showed very little interest in the parsnip from the start of the 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 fewer parsnip plants flowering than Plot 1 or the control plots. This made sense because the sheep barely grazed the parsnip in Plot 1 in May.

Eger was interested in seeing if the sheep's interest in parsnip would follow a similar timeline in 2021. Would the plants need to reach a certain stage of growth? Would rain be the main factor? Or was it a mineral imbalance in the sheep? Eger noted the sheep were eating an unusual amount of their free choice mineral mix and worked with a local animal nutritionist at Hy View Feeds to experiment with individual free choice minerals. The flock remained very enthusiastic throughout the grazing about both free choice calcium and the regular mineral mix.

The 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 were too thick with parsnip for the plants to really bend, so the highest flowers and seed heads were left after grazing. On other patches of parsnip around the farm, only the stalk was left.

2021 RESULTS

Parsnip rosettes were counted in May before grazing in both 2020 and 2021 (Table 1). Based on these counts, there appeared to be a decrease in basal rosettes in the grazed plots. Based on additional observation, there were far fewer parsnip seedlings in the test plots than the control plots.

Parsnip Rosettes Counted in May before Grazing				
NUMBER	2020		2021	
	CONTROL	TEST	CONTROL	TEST
1	88	113	125	35
2	109	123	80	45
3	87	87	41	32

In 2020, the plots were grazed every six weeks. In 2021, the plots were grazed only in the spring and in the fall. At the height of the summer and the height of the drought, a number of the ewes and lambs started to develop skin irritation on their ears and noses.

Ewe with her mouth open shows severe sunburn. Her brow ridges and nose are missing hair, and her face and ears are scabbed (left).

Back of both sheep's ears are badly scabbed and the eyelids are red (right), July 2021.

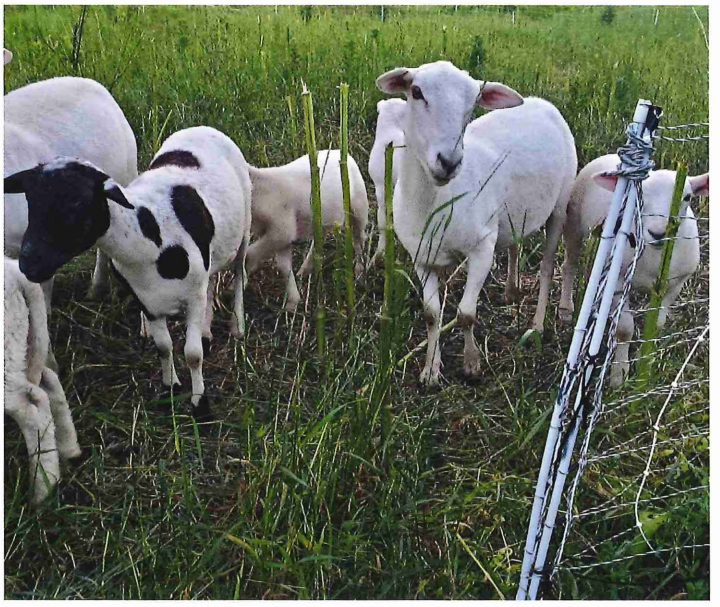
Study cooperator Charlie Wray, a sheep breeder and producer, inspected the flock and rendered his professional opinion that the afflicted sheep were severely sunburned. Only sheep that had been brought in from a new breeder were affected. As a result of the sunburn, the sheep were moved to graze under the shade of the trees instead of grazing the test plots when the plants were in full bloom. After a few weeks in the shade, the sheep's skin had healed. They returned to grazing areas with parsnip and had no further signs of sunburn. The veterinarian hypothesized that the parsnip caused the sunburn, but there was no way to tell for sure. The drought may have caused the plants to produce more of the phototoxic chemicals (furanocoumarins), or the new sheep may have had less genetic resistance or less built-up resistance to the plant than the original flock of sheep.

Other information to note:

During the summer, the sheep were grazing on rented land also being grazed by another farmer's herd of goats. The goat herd accidentally grazed a portion of Test Plot 2 at the edge of the woods. In early spring, a hired forestry mower accidentally scraped down to the soil on Test Plot 3 even though it was 50 feet from the mowing area. In addition, there was inadvertent utility task vehicle damage through all three control plots. As a result of this, there is no replicate data for the test plots.

At all plant stages, the sheep chose to eat the parsnip before eating anything else in their paddock. When the plants were in bloom, the sheep ate every leaf and flower. The sheep had an impact on the parsnip plants, but there weren't end-of-season quantitative measures of the impact.

Area grazed by sheep in the foreground. The stripped stalks are wild parsnip that was in full bloom, June 2021.



Ewe stands by stripped parsnip stalks with her lambs, June 2021.

Left side of the mowed path shows parsnip in flower grazed twice by the sheep. Right side of the path shows taller, more mature parsnip that had already set seed. The right side was grazed once in early spring by the other farmer's goats, August 2021.

2022 RESULTS

No data were collected in 2022. The grant term was extended, allowing Eger to attend the Invasive Species Conference and present an educational poster on the project.

MANAGEMENT TIPS

1. Remember to take photographs of your control plots at the same times as your test plots.
2. Use more marking flags than you think you will need, as they get bumped by the sheep and can disappear into the forage.
3. Don't locate the monitoring plots right on the edge of the paddocks. Then if the animals knock the fence down, it won't be on top of your plot.

COOPERATOR

Charlie Wray, sheep breeder and producer, Caledonia, MN

Evaluating Erosion, Yield and Economics in Different Tillage Regimes After a Winter-Kill Cover Crop

PRINCIPAL INVESTIGATOR

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PROJECT DURATION

2021-2022 / Two years

AWARD AMOUNT

$13,141.65

KEYWORDS

Cover crops, erosion, no-till, sediment, strip-till, tillage

PROJECT SUMMARY

Jason and Monica Miller, owners of Miller Farms, had previously invested in structural improvements to reduce erosion, including three catch basins installed in 2020 as well as extensive gully and drainage repair. To further reduce erosion, they turned to infield practices such as cover crops (no-till) and reduced tillage.

Vertical tillage (a practice that smooths out and levels the seedbed in one pass, which saves time and fuel costs) was used for the first time in spring 2020, and strip tillage (a practice in which narrow strips are tilled in crop stubble, with the area between the rows left undisturbed) was used for the first time in spring 2021. An oat cover crop was planted following the 2020 soybean crop.

The Millers examined 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. They installed replicated strips of two tillage practices — field cultivation (also referred to as tilled fields) and strip tillage — and measured soil movement using small mats to collect soil blowing or washing across the land surface. In addition to the erosion data, they tracked yield and expenses for two crop seasons to estimate the partial budget for each system.

PROJECT DESCRIPTION

OBJECTIVES

1. Evaluate the partial budget of each tillage system by tracking inputs — including tillage costs and labor, seed, and fertilizer — as well as crop yield. The partial budget consisted of income/expenses.
2. Evaluate the soil loss in each tillage system using small mats which were put in place and then removed seasonally to estimate soil movement across the field. Soil collected on the mats was analyzed for total soil carbon and nutrients.

RATIONALE

Protecting the soil and reducing erosion by using no-tillage methods has been one of the main principles of conservation agriculture for more than 20 years. Tillage generally degrades soil quality, which can result in decreased productivity. Research has shown that by not tilling plant residue into the soil and by planting cover crops, soil health is improved and soil carbon is increased.

Example of mat used to collect soil movement.

Strip-till machine used for project.

Strip-till tillage practice.

2021 RESULTS

The Millers measured corn yield in the combine via a yield monitor. There was no statistical difference in yield, though the average of tilled fields was slightly higher at 205 bushels per acre compared to strip-tilled fields at 201 bushels per acre. (Figure 1).

The project's technical cooperators — Liz Stahl, Extension educator, and Anna Cates, PhD from the University of Minnesota (UMN) — measured sediment movement as an indicator of erosion in three subplots of each tillage treatment. The method used was erosion mats pinned to the ground between planting and post-emergence herbicide applications, and collected approximately once every four weeks. The sediment collected from the mats was dried and weighed at the UMN and scaled to estimate pounds per acre of sediment moving. (Figure 2). There was more sediment moving in tilled plots (1,074 pounds per acre) than strip-till plots (449 pounds per acre), a difference that was marginally statistically significant (P = 0.06, 2-sample T-test).

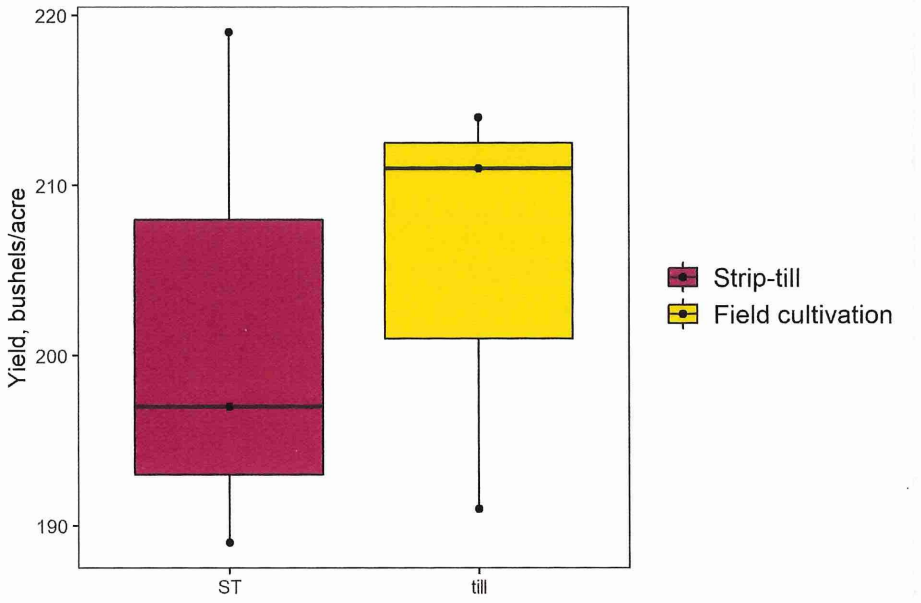


Figure 1. 2021 yield data of bushels per acre for strip-till vs. field cultivation in test strips.

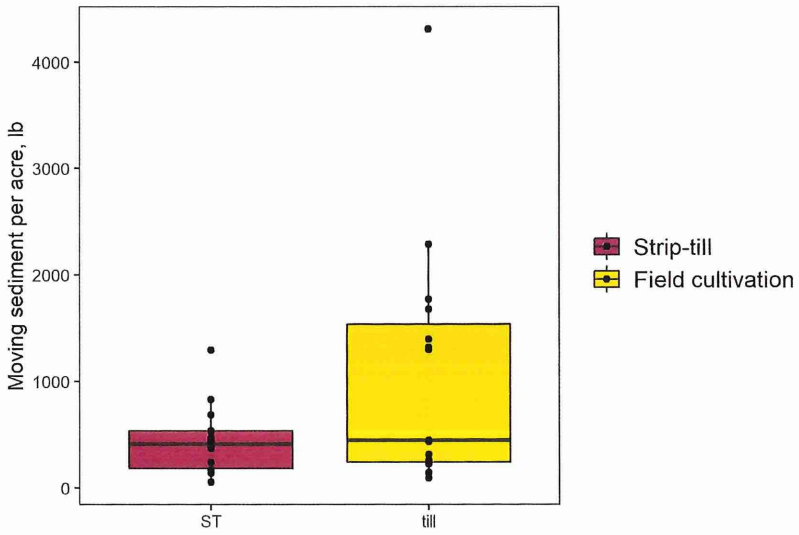


Figure 2. 2021 soil movement comparison of strip-till vs. field cultivation.

Photo 4. Mat with soil movement collected. Photo taken on collection day of mats.

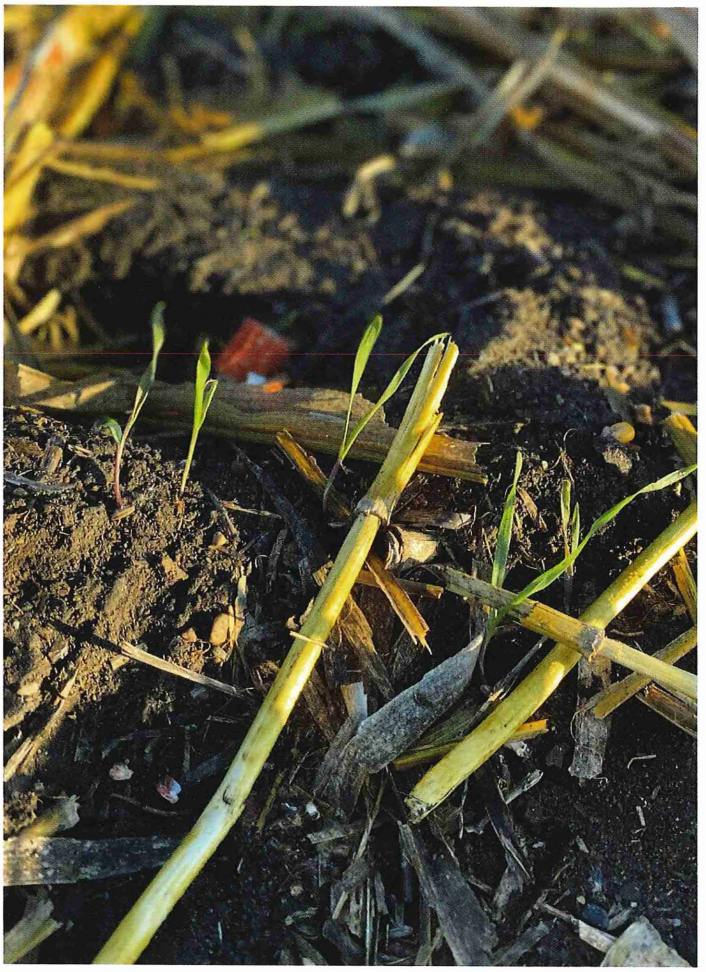


Photo 5. 2021 cover crop emergence after harvest.

Miller Farms analyzed the nutrient content of sediment collected on erosion mats in 2021. They did not have sufficient samples to statistically analyze the data by treatment, but all sediment was relatively high in nitrate, Bray-P, and K. Figure 3 shows how the eroded sediment tends to be high in nutrients.

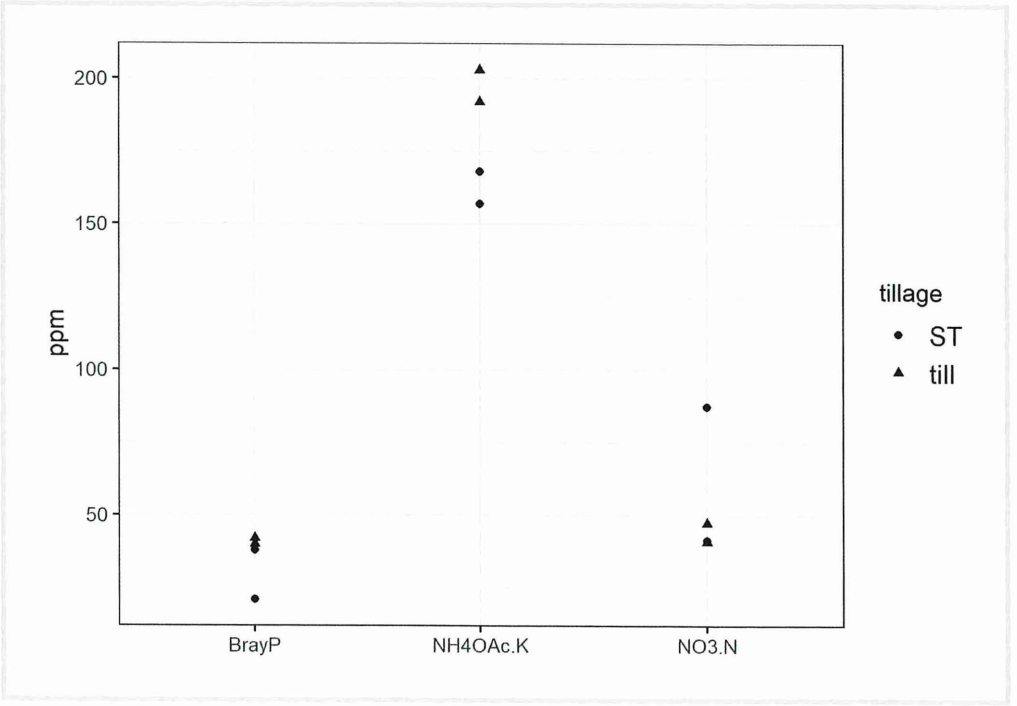


Figure 3. 2021 Soil Nutrients.

2022 RESULTS

The 2022 season presented a challenge with this project. The spring began with far more moisture than predicted, with the fall leading to nearly record drought conditions throughout the area. Due to the wet conditions in the spring, Miller Farms was unable to terminate the cover crop in an appropriate time frame. As a result, they resorted to renting a strip-till machine to remove the crop residue to allow the soil to adequately dry out and plant the season's soybean crop. Issues arose with the strip-till machine getting plugged up with soil due to soil moisture. Heavy rains then persisted after planting which resulted in the cover crop going to seed stage, causing competition in growth through the emergent and early stages of the soybean crop.

There was no statistical difference in yield by tillage treatment (Figure 4). All yields were somewhat low in 2022 due to a drought in southwestern Minnesota. The soybean yields averaged 44.6 bushels per acre in no-till and 45.3 bushels per acre in strip-till.

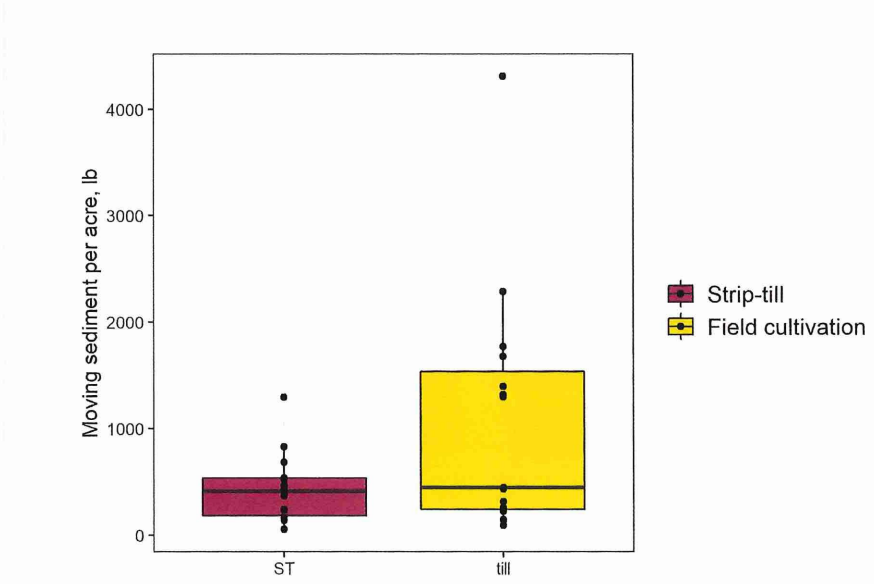
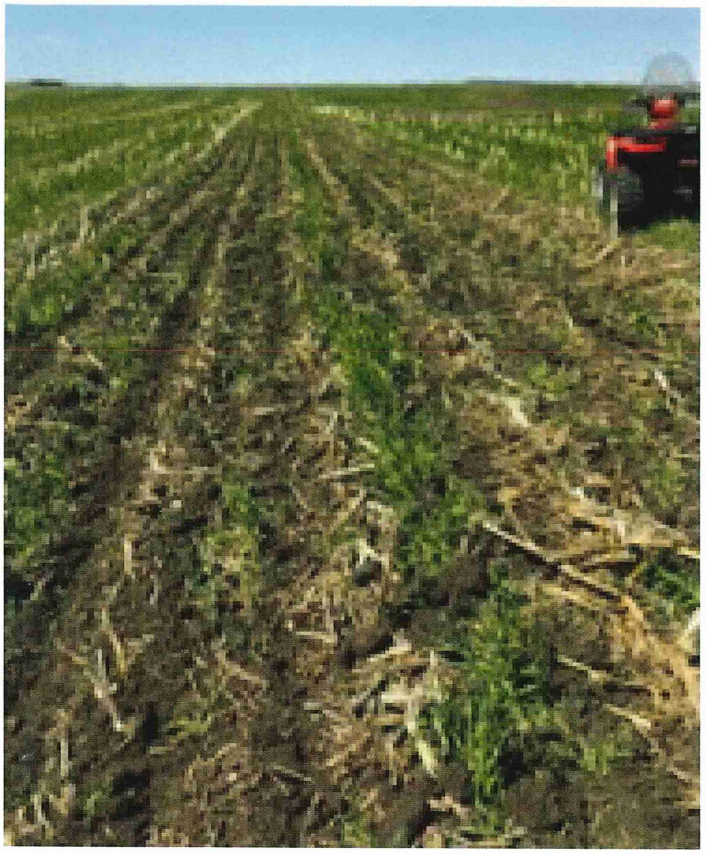
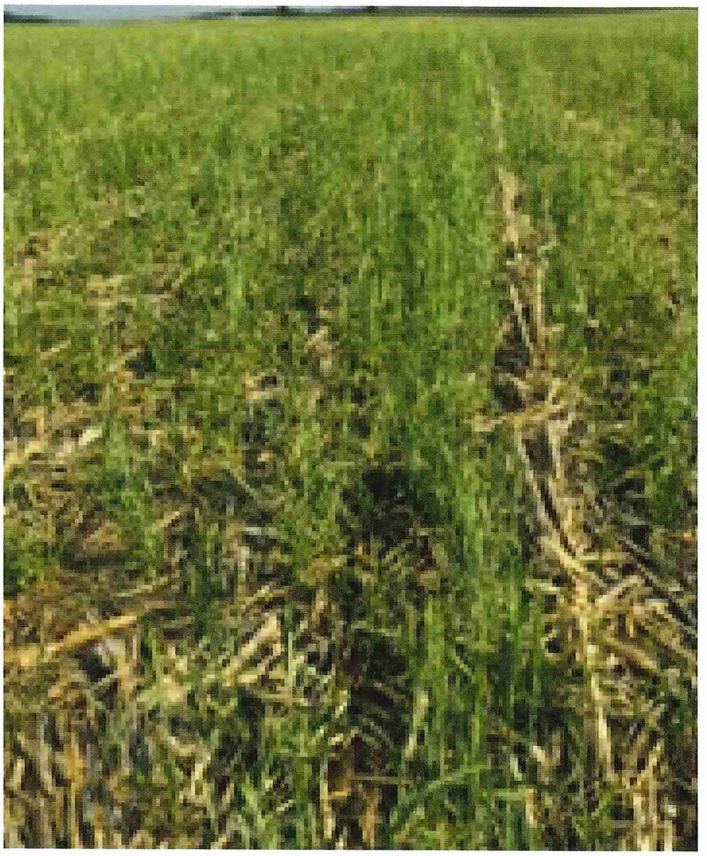


Figure 4. 2022 Yield Data.

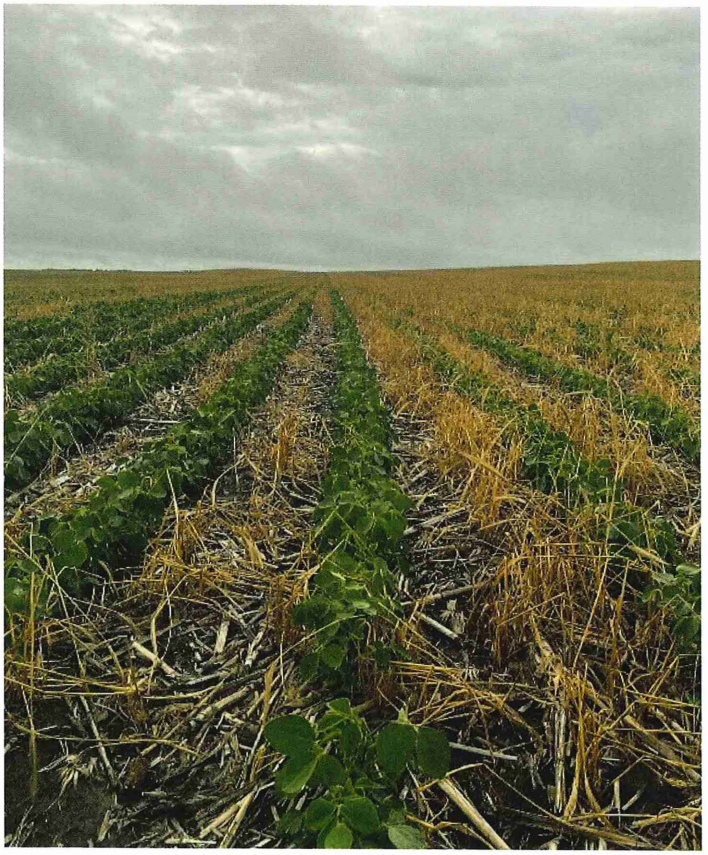
Overall, the project did identify that the no-till acres resulted in lesser tillage costs. Furthermore, throughout the project, there were no substantial yield differences identified between tillage treatments. Unfortunately, the Millers were unable to obtain sufficient samples within erosion mats in the fall of 2022 due to late placement and drought. However, they were confident that the cover crop provided season-long residue cover to reduce soil movement from wind and water erosion at this project site.



Strip-till test strips before planting.



Cover crop and no-till planting.



Strip-till vs. no-till.

Cover crop competition with crop.

As a final presentation of this project, the Millers collaborated with the Murray County Soil and Water Conservation District and presented a slide show and tri-fold brochure about the project during the Murray County Fair in August 2022. Jason and Monica spoke with many fair attendees about their project. An estimated 75 brochures were distributed during the event, with many fairgoers expressing interest in the project and soil conservation practices.

During the project, the Millers were recognized with the Murray County Conservationist of the Year award. The Millers' nomination for this award was a great achievement, and an acknowledgement of their hard work on this project as well as their continued commitment to improving soil health and crop production in their area.

MANAGEMENT TIPS

1. Although the different tillage practices did not result in a major yield benefit, reduced tillage costs would likely result in a better profit. Financial analysis should be conducted to determine profitability differences between practices.
2. Have a "Plan B" when nature does not allow you to do what you desire to do.
3. Don't be afraid to try something new as you'll never know what may result if you don't try.

COOPERATORS

Anna Cates, University of Minnesota, erosion data collection and analysis, outreach.

Liz Stahl, UMN Extension, research plot setup and erosion data collection, outreach.

OTHER RESOURCES

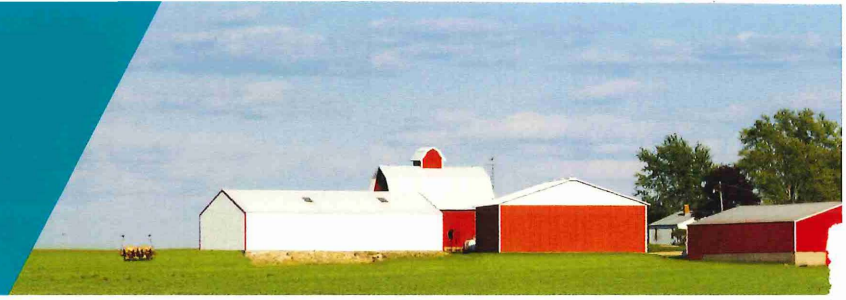
Murray County Soil and Water Conservation District
507-836-6990, Ext. 3
http://murrayswcd.org/

USDA Natural Resources Conservation Service, Slayton Field Office
507-836-8933
http://nrcs.usda.gov (serving Murray, Nobles, Pipestone, and Rock counties)

UMN Extension, Murray County
Melissa Runck, Extension Educator, Ag Production Systems
mkrunck@umn.edu
507-836-1143
http://extension.umn.edu/local/murray

Minnesota Office for Soil Health
http://mosh.umn.edu/
MN Soil Health Coalition
http://mnsoilhealth.org

Completed Grant Projects

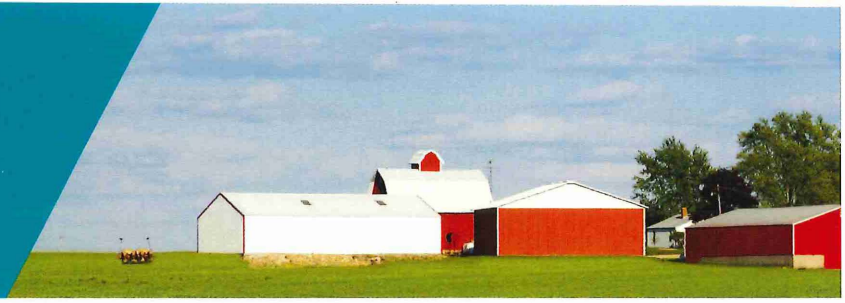


Final Greenbook Article	Title of Project	Grantee
	Alternative Markets and Specialty Crops	
2022	Exploring Hull Less Seed Pumpkins as a Specialty Crop	Pluck Flower Farm, Rachel Sannerud
	Exploring North Star Farm Tour as a Sustainable Agri-Tourism Model for Small Producers	North Star Farm Tour, Melodee Smith
	Integrated Hemp and Heritage Farm	Anishinaabe Agriculture Institute, Winona LaDuke
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

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
2010	Hardwood Reforestation in a Creek Valley Dominated by Reed Canarygrass	Timothy Gossman
	Introducing Cold-hardy Kiwifruit to Minnesota	James Luby
	Growing the Goji Berry in Minnesota	Koua Vang & Cingie Kong
2009	Dream of Wild Health Farm Indigenous Corn Propagation Project	Peta Wakan Tipi & Sally Auger
2008	Developing a Saskatoon Berry Market in the Upper Midwest	Patricia Altrichter & Judy Heiling
2005	Creating Public Recognition of and Demand for "Grass-Fed" Dairy Products through the Development of Brand Standards and Promotion of These Standards to the Public	Dan French
2004	Collaborative Character Wood Production and Marketing Project	Cooperative Development Services, Isaac Nadeau
	Creating Consumer Demand for Sustainable Squash with Labels and Education	Gary Pahl
	Integrated Demonstration of Native Forb Seed Production Systems and Prairie Land Restoration	Michael Reese
	Pride of the Prairie: Charting the Course from Sustainable Farms to Local Dinner Plates	Kathleen Fernholz
2003	Demonstrating the Market Potential for Sustainable Pork	Prairie Farmers Co-op, Dennis Timmerman
	Flour Corn as an Alternative Crop	Lynda Converse
2002	Increasing Red Clover Seed Production by Saturation of Pollinators	Leland Buchholz
	Propagation of Native Grasses and Wildflowers for Seed Production	Joshua Zeithamer
2001	Establishing Agroforestry Demonstration Sites in Minnesota	Erik Streed, CINRAM
	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

Completed Grant Projects

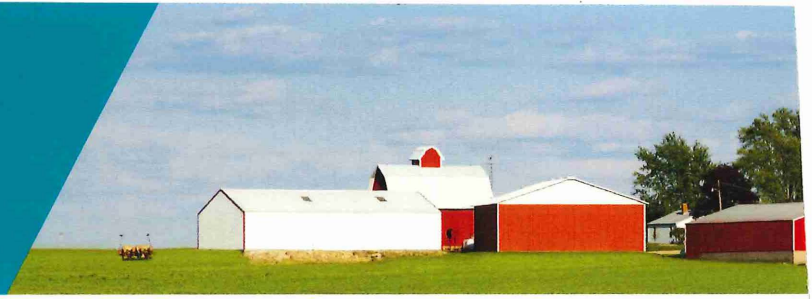


Final Greenbook Article	Title of Project	Grantee
2000	Converting a Whole Farm Cash Crop System to Keeping an Eye on Quality of Life and the Bottom Line in Sustainable Agriculture by Using Key Farm Economic Ratios to Aid in Decision-making	Red Cardinal Farm
	Dry Edible Beans as an Alternative Crop in a Direct Marketing Operation	Bruce & Diane Milan
	Native Minnesota Medicinal Plant Production	Renne Soberg
1999	An Alternative Management System in an Organic, Community Supported Market	Candace Mullen
	Cultural and Management Techniques for Buckwheat Production and Marketing	Tom Bilek
	Pond Production of Yellow Perch	John Reynolds
1998	Establishing and Maintaining Warm Season Grasses (Native Grasses)	Pope County SWCD
	On-farm Forest Utilization and Processing Demonstrations	Hiawatha Valley RC&D
1996	Permanent Raised Bed Cultivation for Specialty Crops	Terry & Jean Loomis
1995	Cash Crop Windbreak Demonstration/Development	Phil Rutter
	Cutter Bee Propagation Under Humid Conditions	Theodore L. Rolling
	Red Deer Farming as an Alternative Income	Peter Bingham
	Wildflower Seeds as a Low-input Perennial Crop	Grace Tinderholt & Frank Kutka
1992	Alternative Mulch Systems for Intensive Specialty Crop Production	Ron Roller, Lindentree Farm
	Benefits of Crop Rotation in Reducing Chemical Inputs and Increasing Profits in Wild Rice Production	George Shetka
	Benefits of Weeder Geese and Composted Manures in Commercial Strawberry Production	Joan Weyandt-Fulton
	Common Harvest Community Farm	Dan Guenthner
	Mechanical Mulching of Tree Seedlings	Timothy & Susan Gossman
	Minnesota Integrated Pest Management Apple Project	John Jacobson

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
	Cropping Systems and Soil Fertility	
2022	Grazing Intermediate Wheatgrass (Kernza®) as a Dual Purpose Crop for Forage and Grain Production	Clean River Partners Inc (formerly Cannon River Watershed Partnership), Alan Kraus
	Regenerative Agriculture: A Pathway for Greater Farm Profitability and Practice Adoption.	Clean River Partners Inc (formerly Cannon River Watershed Partnership), Alan Kraus
	Using sheep and cover crops in a strawberry rotation	Brouwer Berries, Sarah Brouwer
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
	Perennial Wheatgrass and Legumes for Cropping, Grazing, and Soil Health	Mike Jorgenson
	Interseeding Cover Crops into Standing Corn in June	Alan Kraus

Completed Grant Projects

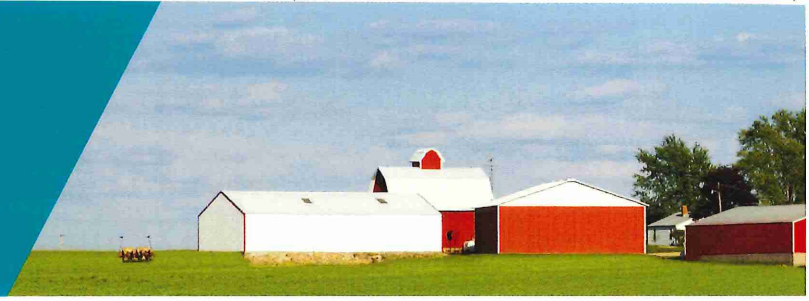


Final Greenbook Article	Title of Project	Grantee
	Evaluation of Winter Annual Small Grain Cover Crops for Forage Production	Daniel Ley
	Demonstrating Vermicomposting for Soil Health in the Upper Midwest	Robin Major & Caroline Devany, Stone's Throw Urban Farm
	Use Sub-Surface Irrigation to Increase Crop 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	Bios de Sioux Watershed District
	A Demonstration of Biological Primers on Drought Prone Soils	Sustainable Farming Association of Minnesota
2015	Weed Control in Soybeans	Floyd Hardy
	Comparing the Productivity & Profitability of Heat-Loving Crops in High Tunnel and Quick Hoops Systems	Stone's Throw Urban Farm
2013	Fertilizing with Alfalfa Mulches in Field Crops	Carmen Fernholz
	McNamara Filter Strip Demonstration	Goodhue SWCD, Beau Kennedy & Kelly Smith
	Optimizing Alfalfa Fertilization for Sustainable Production	Doug Holen
2010	Environmentally and Economically Sound Ways to Improve Low Phosphorus Levels in Various Cropping Systems Including Organic with or without Livestock Enterprises	Carmen Fernholz

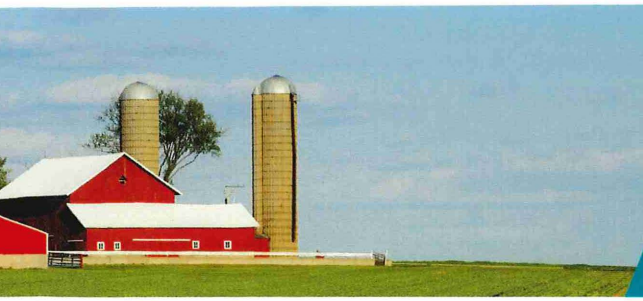
Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
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
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

Completed Grant Projects



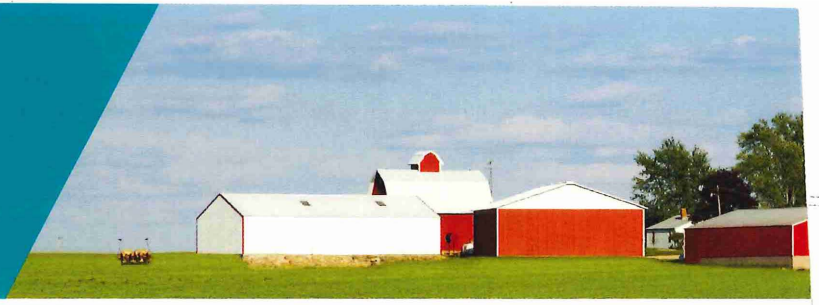
Final Greenbook Article	Title of Project	Grantee
	Using Liquid Hog Manure as Starter Fertilizer and Maximizing Nutrients from Heavily Bedded Swine Manure	Dakota County SWCD, Brad Becker & Johnson
2002	Agricultural Use of Rock Fines as a Sustainable Soil Amendment	Carl Rosen
	A Low-cost Mechanism for Inter-seeding Cover Crops in Corn	Tony Thompson
	Annual Medic as a Protein Source in Grazing Corn and Weed Suppressant in Soybeans	Joseph Rolling
	Dairy Manure Application Methods and Nutrient Loss from Alfalfa	Neil C. Hansen
	Evaluation of Dairy Manure Application Methods and Nutrient Loss from Alfalfa	Stearns County SWCD
	Increased Forage Production through Control of Water Runoff and Nutrient Recycling	James Sovell
	Land Application of Mortality Compost to Improve Soil and Water Quality	Neil C. Hansen
	Turkey Litter: More is Not Always Better	Meierhofer Farms
2001	Applying Manure to Corn at Agronomic Rates	Tim Becket & Jeremy Geske, Dakota County Extension & SWCD
	Cereal Rye for Reduced Input Pasture Establishment and Early Grazing	Greg Cuomo
	Establishing a Rotational Grazing System in a Semi-wooded Ecosystem: Frost Seeding vs. Impaction Seeding on CRP Land and Wooded Hillsides Using Sheep	James Scaife
	Living Snow Fences for Improved Pasture Production	Mike Hansen
	Managing Dairy Manure Nutrients in a Recycling Compost Program	Norman & Sallie Volkmann
	Reducing Chemical Usage by Using Soy Oil on Corn and Soybean	Donald Wheeler
	Techniques for More Efficient Utilization of a Vetch Cover Crop for Corn Production	Carmen Fernholz
	Using Nutrient Balances to Benefit Farmers and the Environment	Mark Muller, IATP
2000	Forage Mixture Performance	Itasca County SWCD
	Growing Corn with Companion Crop Legumes for High Protein Silage	Stanley Smith



Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
	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

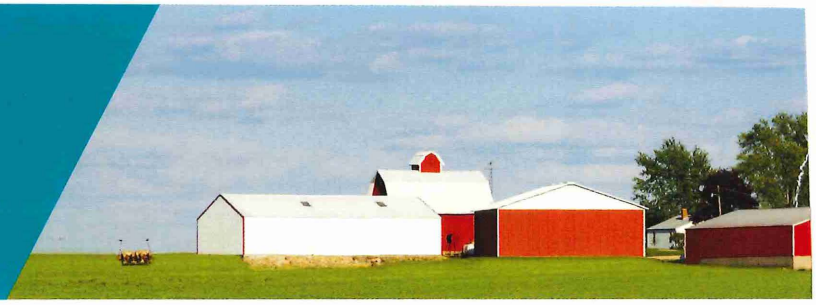


Final Greenbook Article	Title of Project	Grantee
1995	Annual Medics: Cover Crops for Nitrogen Sources	Craig Sheaffer
	Integration of Nutrient Management Strategies with Conservation Tillage Systems for Protection of Highly Eroded Land and Lakes in West Otter Tail County	Harold Stanislawski
	Manure Management/Utilization Demonstration	Timothy Arlt
1994	Reducing Soil Insecticide Use on Corn through Integrated Pest Management	Ken Ostlie
	Taconite as a Soil Amendment	Donald E. Anderson
	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

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
	Using Nitro Alfalfa in a No-till Corn and Soybean Rotation	Jeff Johnson
1991	Alternative Methods of Weed Control in Corn	Sr. Esther Nickel
	Hairy Vetch and Winter Rye as Cover Crops	Mark Ackland
	Energy	
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	
2022	Non-chemical Methods for Managing Colorado Potato Beetle: Feasibility for Diversified Farms	University of Minnesota, Natalie Hoidal
	Regenerative Agriculture: A Pathway for Greater Farm Profitability and Practice Adoption	Canosia Grove LLC, Robert Blair
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

Completed Grant Projects

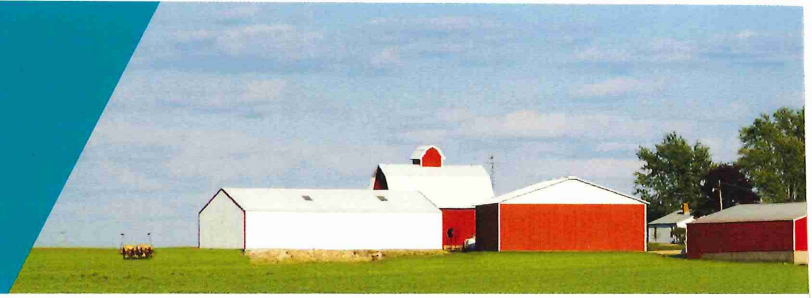


Final Greenbook Article	Title of Project	Grantee
2019	Developing an Annual Day-neutral Strawberry Planting System with Biodegradable Mulches	Steve Poppe, University of Minnesota
	Using Essential Oils to Repel Spotted Wing Drosophila in Blueberries	Blueberry Fields of Stillwater, Bev O'Connor
	Using Juneberries 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
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

Completed Grant Projects

Final Greenbook Article	Title of Project	Grantee
2009	Chokecherry (Prunus virginiana) Production in Western Minnesota	Todd & Michelle Andresen
	Winter Harvest of Hardy Crops under Unheated Protection	Kelly Smith
	Insect and Disease Pressure in Unsprayed Apple Orchards in Central and Northern Minnesota	Thaddeus McCamant
2008	Apple Scab Control Project	Rick Kluzak
	Controlling Western Striped Cucumber Beetles Using Organic Methods: Perimeter Trap Crops and Baited Sticky Traps	Peter Hemberger
	Establishing Healthy Organic Asparagus While Utilizing Minimal Labor and Maintaining Proper Soil Nutrition	Patrick & Wendy Lynch
	Novel Preplant Strategies for Successful Strawberry Production	Steven Poppe
2005	Organic Strawberry Production in Minnesota	Brian Wilson & Laura Kangas
2004	Root Cellaring and Computer-controlled Ventilation for Efficient Storage of Organic Vegetables in a Northern Market	John Fisher-Merritt
2003	Evaluating the Benefits of Compost Teas to the Small Market Grower	Pat Bailey
	Research and Demonstration Gardens for New Immigrant Farmers	Nigatu Tadesse
	Viability of Wine Quality Grapes as an Alternative Crop for the Family Farm	Donald Reding
2002	Development and Continuation of a Community Based Sustainable Organic Grower's Cooperative and Marketing System	Patty Dease
	Flame Burning for Weed Control and Renovation with Strawberries	David Wildung
	Good Eating with Little Healing: A Straw Bale Greenhouse	Linda Ward
	Integrating Livestock Profitably into a Fruit and Vegetable Operation	David & Lise Abazs
	Soil Ecology and Managed Soil Surfaces	Peter Seim & Bruce Bacon
	Value Adding to Small Farms through Processing Excess Production	Jeffrey & Mary Adelmann

Completed Grant Projects



Final Greenbook Article	Title of Project	Grantee
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
	Livestock	
2022	Evaluating Hazelnuts as a Soy-Protein Replacement in Free-Range Poultry Systems	Main Street Project (Sharing Our Roots), Wyatt Parks
	Toward Forever Green Poultry Rations	WillowSedge Farm, Jane Grimsbo Jewett
2021	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

Completed Grant Projects

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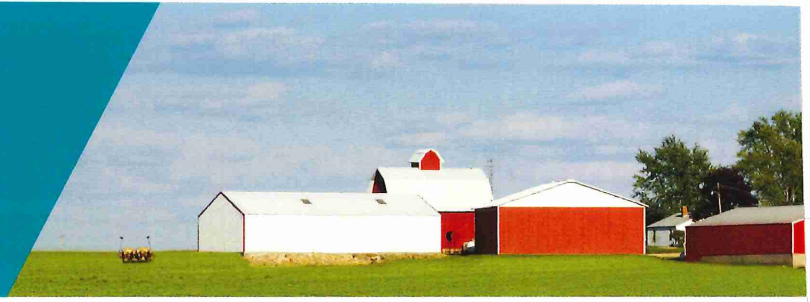
	Integrating Silvopasture Practices into Perennial Fruit Production	Jackie & Harry Hoch, Hoch Orchard
	Testing Three Novel Sheep-specific Pasture Types to Maximize Average Daily Gains in Lambs on Pasture	Anna Johnson
2018	Breeding, Selecting and Assessing Organically Grown Nutrient Dense Corn for Poultry 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
	Managing Hoops and Bedding and Sorting without Extra Labor	Steve Stassen

Completed Grant Projects



Final Greenbook Article	Title of Project	Grantee
2005	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

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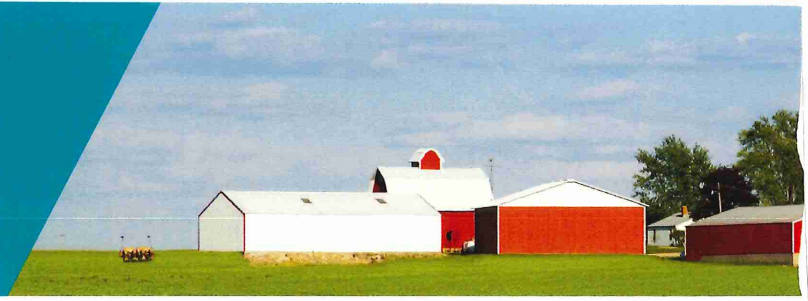
	Viability of Strip Grazing Corn Inter-seeded with a Grass/ Legume Mixture	Stephen & Patricia Dingels
2001	Annual Medic as a Protein Source in Grazing Corn	Joseph Rolling
	First and Second year Grazers in a Year Round Pasture Setting Served by a Frost Free Water System	Don & Dan Struxness
	Low Input Conversion of CRP Land to a High Profitability Management Intensive Grazing and Haying System	Dan & Cara Miller
	Whole System Management vs. Enterprise Management	Dennis Rabe
	Working Prairie – Roots of the Past Sustaining the Future	John & Leila Arndt
2000	Converting a Whole Farm Cash System to Sustainable Livestock Production with Intensive Rotational Grazing	Edgar Persons
	Dairy Steers and Replacement Heifers Raised on Pastures	Melissa Nelson
	Establishing Pasture Forages by Feeding Seed to Cattle	Art Thicke
	Five Steps to Better Pasture in Practice: How does it really work?	Sarah Mold
	Grass-and Forage-based Finishing of Beef, with Consumer Testing	Lake Superior Meats Cooperative
	Low Cost Sow Gestation in Hoop Structure	Steve Stassen
	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

Completed Grant Projects



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1998	Buffalo: Animal from the Past, Key to the Future	Richard & Carolyn Brobjorg
	Marketing Development - Small Farm Strategies Project	Sustainable Farming Association of NE MN
	Pastured Poultry Production and Riparian Area Management	Todd Lein
1997	Butcher Hogs on Pasture	Michael & Linda Noble
	Developing Pastures Using Various Low-input Practices	Ralph Lentz
	Grass Based Farming in an Intensive Row Crop Community	Douglas Fuller
	Grazing Hogs on Standing Grain and Pasture	Michael & Jason Hartmann
	Grazing Sows on Pasture	Byron Bartz
	Low Input Systems for Feeding Beef Cattle or Sheep	Dennis Schentzel
	Raising Animals for Fiber	Patty Dease
	Seasonal Dairying and Value-added Enterprises in SW MN	Robert & Sherril Van Maasdam
	Swedish Style Swine Facility	Nolan & Susan Jungclaus
1996	Dairy Waste Management through Intensive Cell Grazing of Dairy Cattle	Scott Gaudette
	Establishing Trees in Paddocks	Dave & Diane Serfling
	Evaluating Pasture Quality and Quantity to Improve Management Skills	Land Stewardship Project
	Expanding into Outdoor Hog Production	James Van Der Pol
	Grazing Limits: Season Length and Productivity	Doug & Ann Balow
	Rotational Grazing Improves Pastures	MISA Monitoring Team/Dorsey
1995	Backgrounding Rotational Grazing	Frank Schroeder
	Evaluating Diatomaceous Earth as a Wormer for Sheep and Cattle	David Deutschlander
	Intensive Controlled Grazing and Pasture Rejuvenation on Fragile Land	Lyle & Nancy Gunderson
	Intensive Rotational Grazing on Warm Season Grasses	Jim Sherwood
	Rotational Top-grazing as a Method of Increasing Profitability with a High-producing Dairy Herd	Alton Hanson
1994	Economics of Rotational Grazing vs. Row Crops	Harold Tilstra
	Low Input Range Farrowing of Hogs	Larry Mumm

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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

The Greenbook is dedicated to the farming families of Minnesota. Their innovation, cooperation, and persistence are creating a more sustainable agriculture.

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