Final Abstract

Final Report Approved on December 15, 2025

M.L. 2022 Project Abstract

For the Period Ending June 30, 2025

Project Title: Sweetening the Crop: Perennial Flax for Ecosystem Benefits

Project Manager: Neil Anderson

Affiliation: U of MN - College of Food, Agricultural and Natural Resource Sciences

Mailing Address: 1970 Folwell Avenue 305 Alderman Hall

City/State/Zip: St. Paul, MN 55108

Phone: (612) 624-6701

E-mail: ander044@umn.edu

Website: https://cfans.umn.edu/

Funding Source:

Fiscal Year:

Legal Citation: M.L. 2022, Chp. 94, Sec. 2, Subd. 03l

Appropriation Amount: $490,000

Amount Spent: $490,000

Amount Remaining: -

Sound bite of Project Outcomes and Results

Perennial flax is a new, multiuse crop for farmers and will benefit Minnesotans with many traits, such as oil seed (health benefits); fiber (spinning, weaving, biofuels, landscapes); pollinator services (off season flowering); ornamental value (cut flowers, herbaceous perennials). Market potential will be enhanced by product versatility throughout the supply chain.

Overall Project Outcome and Results

The perennial flax flowering season (May-November) provides pollinators (honeybees, bumble bees, native bees, syrphid flies) with nectar and pollen during “gaps” when other crops are not flowering. Lines with high nectar and sugar content were identified.

Crop establishment and weed control are critical for successful production, due to the small leaf size and lack of shading weeds. The best conventional weed control strategies use pre- and post-emergent herbicides while, for organic production, summer and winter cover crops were effective in weed control. We developed a best method for mechanical harvesting oil seed perennial flax with the application of a pre-harvest drying agent, windrows, and combining. Twice as many harvests are possible. Second year plants had yields of 63-335#/A, significantly lower than

annual flax (~969#/A). Organic production had lower yields than conventional. A 44-77% seed loss occurs, demonstrating a need for breeding for non-shattering.
Perennial flaxseed had a moderate fat content of ~28% with oil rich in polyunsaturated fatty acids, particularly alpha-linolenic acid (an omega-3 compound). It has a high level of omega-3s (alpha-linolenic acid), making it suitable for human consumption; vitamin E levels are also high. The low water content (5%) supports storage stability. Mechanical (cold) pressing yields 48% recovery. Perennial flax protein properties were superior to commercial protein ingredients. Perennial flax seed coats become sticky in water (mucilage) which can be used as an emulsifier, foamer, and stabilizer in food manufacturing.
Perennial flax fiber requires rotting (water retting) before 'tow' (short, coarse) and "linen" (high-quality, thin, strong) fiber separation. Assessment of straw for fiber, energy and feed value, biomass potential, process development for pressing oil from seed, seed compounds, and pressed oil, as well as storage conditions for seed and pressed oil showed total carbon at 42.23% and total nitrogen at 1.24%.

Project Results Use and Dissemination

Perennial flax represents a promising and sustainable alternative to conventional crops, offering multifunctional benefits across food, flower, fiber, feed, horticultural, and ecosystem services markets. Perennial flax is attractive in regenerative agricultural systems because of its extended flowering season for pollinator species to feed on when other plants are not flowering, and continuous living cover to stabilize soils. Its seeds can be processed into nutrient-rich food products and oil, while the stalks offer valuable fiber, broadening its market footprint. Emerging interest from the food, bioindustrial, and cut flower sectors points to scalable applications for this climate-resilient cro

Environment and Natural Resources Trust Fund

M.L. 2022 Approved Final Report

General Information

Date: December 19, 2025

ID Number: 2022-266

Staff Lead: Lisa Bigaouette

Project Title: Sweetening the Crop: Perennial Flax for Ecosystem Benefits

Project Budget: $490,000

Project Manager Information

Name: Neil Anderson

Organization: U of MN - College of Food, Agricultural and Natural Resource Sciences

Office Telephone: (612) 624-6701

Email: ander044@umn.edu

Web Address: https://cfans.umn.edu/

Project Reporting

Final Report Approved: December 15, 2025

Reporting Status: Project Completed & Additional Update Approved

Date of Last Action: December 15, 2025

Project Completion: June 30, 2025

Legal Information

Legal Citation: M.L. 2022, Chp. 94, Sec. 2, Subd. 03l

Appropriation Language: $490,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to produce, select, and evaluate how perennial flax provides pollinator and other ecosystem services while enhancing yield for oilseed, fiber, and honey production.

Appropriation End Date: June 30, 2025

Narrative

Project Summary: We will produce, select, and evaluate how perennial flax provides ecosystem (pollinator) services for the environment while enhancing yield for oilseed, fiber, and nectar/honey production.

Describe the opportunity or problem your proposal seeks to address. Include any relevant background information.

Lack of food resources (flowers) is a leading cause of declines in pollinator populations and pollinator health. Current cropping systems do not provide adequate resources for pollinators. The University of Minnesota is breeding perennial flax to replace historic annual flax production. We seek funding to provide early stage crop development data, before direct commercialization. Establishing perennial flax as a reinvigorated oilseed and fibercrop and a new honey crop has the potential to improve seed/fiber/honey yield for farmers (2x harvest/yr.) and provide ecosystem services for pollinators (flowering May-November) within conventional cropping. The early/long flowering provides an unparalleled opportunity to provide resources to hundreds of pollinators. We will experimentally test the effectiveness of perennial flax for ecological services (pollinators, honey production) and realizable harvestable units for oilseed (yield, chemicals, proteins) and fiber types. This will provide critical selection data/breeding directives for the best lines for crop launching. We will communicate the economic potential of perennial flax oilseed/fiber/honey cropping with market pathway and supply-chain analyses. Communication of research findings and best practices with field days, farm demonstrations, and "AURI connects: Fields of Innovation" programming will support adoption of perennial flax to benefit Minnesotans.

What is your proposed solution to the problem or opportunity discussed above? Introduce us to the work you are seeking funding to do. You will be asked to expand on this proposed solution in Activities & Milestones.

A variety of benefits, particularly ecosystem services, are realizable with perennial flax, which we aim to research and generate data during the 3-year period: pollinator services (pollen/nectar sources enhance pollinator activity late into the fall), yield and chemical contents of harvestable products (oilseed, fiber, pollen, nectar/honey), and increased yield (two harvests/year instead of one with annual flax). Experimental and outreach plans include: Activity 1 involves breeding/selecting/evaluating perennial flax for pollinator/landscape services and yield for food product analyses (honey, oilseed, fiber and chemical constituents). Activity 2 concentrates research on perennial flaxseed yield and human/animal nutrient contents for oil, protein, amino acid, and meal. In Activity 3, the business development team will establish supply chain opportunities and investigate new markets for perennial flax, the technical team of process engineers, food scientists and analytical scientists will analyze perennial flax for food product development, assessing flax seed, oil, and honey. Finally, in Activity 4, outreach to stakeholders and clientele groups will build awareness, education and promote discussion of perennial flax in field days and programming. Results will guide future development with businesses for commercialization of perennial flax-based products.

What are the specific project outcomes as they relate to the public purpose of protection, conservation, preservation, and enhancement of the state's natural resources?

Our project will use methods and channels to conduct research, share findings and build awareness of environmental benefits and market potential of perennial flax: identifying valuable end use(s) with value to MN farmers and citizens, enhanced pollinator services, high oilseed, protein, fiber, & gene pool enhancement. Reports will be available via U of M and AURI websites. Project partners will present at events with broad and varied audiences: perennial flax field days, annual AURI "Fields of Innovation". We will engage with print, broadcast, internet media to seek project coverage and build public awareness.

Project Location

What is the best scale for describing where your work will take place?

Region(s): SW, SE, NW, Central, Metro,

What is the best scale to describe the area impacted by your work?

Statewide

When will the work impact occur?

During the Project and In the Future

Activities and Milestones

Activity 1: Producing, evaluating and selecting perennial flax for pollinator services, nectar components

Activity Budget: $180,343

Activity Description:
Flax may be a unique nectar source for bees (native, honey) for pollinator / ecosystem services and a new source of nutrient-rich honey. Objectives of this research are to quantify honey bee and native pollinator activity in perennial flax fields, nectar production, potential for honey production, and chemical constituents with nutritional value for bees. Yr. 1 walking surveys (sweep netting; observational) will be conducted in established fields to survey diversity and abundance of foraging bees and if they are collecting pollen and/or nectar. Existing honey bee colonies will be placed at plot edges to measure weight gain; the proportion of colony pollen diet from flax. Nectar production data from sampling flax flowers (microcapillary tube spinouts) includes volume, nectar chemistry (sugar types, concentrations, content). Yrs. 2-3 will focus on flax selections identified (Yr. 1) with high levels of nectar/pollen to conduct additional pollinator activity surveys, examine nectar/pollen for nutritional and nutraceutical components (lipids, proteins, phytocompounds), evaluate whether these compounds impact pollinator health and assess honey value for human consumption. AURI (Activities 3-4) will use yield and economic data on pollen/nectar sources to enhance pollinator activity and harvestable products (nectar, honey) to create business development

Activity Milestones:

Description	Approximate Completion Date
Quantify pollinator activity, such as rate/frequency of visitation (field, year 1)	December 31, 2023
Determine nectar and pollen production per plant or field plantings (field and lab; 2 yrs.)	December 31, 2024
Determine pollen, nectar & honey nutritional, nutraceutical components in flax (lab; years 1-3)	June 30, 2025

Activity 2: Evaluation of yield for high value perennial oilseed to provide oil, proteins and meal for human/animal nutrition

Activity Budget: $78,372

Activity Description:
There is a global challenge to address food security and preserve land/water resources; consumers seek transparency and sustainability in their food supply. Food industries are interested in commercializing products formulated with ingredients derived from such crops; farmers are motivated to plant a crop with a strong market. As an oilseed, flaxseed is high in oil, fat, proteins, and flax meal is a useful byproduct. The proposed work involves a concerted effort from breeders, food scientists, and engineers to lead perennial flax development as a viable source of plant ingredients. Specific objectives are: Measure flowering/seed ripening periods (Yrs. 1-3); mechanical harvesting 2x/yr at 4 sites (St. Paul, Rosemount, Lamberton, Morris) will determine seed yield in Yrs. 1-3 (wt., size, oil, omega-3 content, meal); wherein protein extraction methodologies will be developed to produce protein isolates; followed by screen breeding lines for protein profile, structure, and functionality (Yrs. 1-3). Residual plant material will be used to study fiber potential in Activity 3. Generated data will direct the breeding program. AURI (Activities 3-4) will use yield and economic data on oilseed sources to enhance harvestable products (oilseed, oils, proteins, amino acids, omega-3s, meal, fiber) to create business development model(s).

Activity Milestones:

Description	Approximate Completion Date

Grow, harvest, determine plant growth (flowering, etc.) and seed or fiber yield components (field; Yr. 1)	December 31, 2023
Oilseed extraction, chemical/nutritional profile determinations (lab; Years 1-2)	December 31, 2024
Breeding line evaluations of yield components (oil, proteins, fiber) (lab; Years 1-3)	June 30, 2025

Activity 3: Assess value-added processes and products to support development of economically sustainable supply-chains for perennial flax in Minnesota.

Activity Budget: $132,233

Activity Description:
Work in this activity will examine uses of perennial flax and support the development of sustainable supply chains through technical assistance, commercialization, and stakeholder engagement. Using residual plant material harvested in Activity 2, an additional objective is to determine flax fiber yield (biomass, fiber type, length/width, tensile strength), suitable harvesting methods (hand harvest/rolling, mechanical) and determination of fiber potential in perennial flax based on these characteristics. Food uses of seed proteins, oils, nectar/honey, etc. derived from flax will be determined to provide an initial assessment of possible venues for commercialization. These will be basic studies (cooking, baking) with cooks and chefs to promote later startups in creation of perennial flax food derivatives and recipes. Providing ecosystem services and economically-valuable products from perennial flax requires investigations into business development. We will use yield and economic data generated on pollen/nectar sources to enhance pollinator activity late into the fall and harvestable products (oilseed, fiber, nectar and honey, fiber) to create business development model(s). The business development team will establish supply chain opportunities and investigate new markets for perennial flax by engaging with private businesses (food, feed, bio-based materials) and other key value chain stakeholders.

Activity Milestones:

Description	Approximate Completion Date
Determine economic potential (lab; Years 1-3)	June 30, 2025
Identify market opportunities (supply chains) of the various derived products (lab, Years 1-3)	June 30, 2025
Determine food product uses to enhance cooking/baking uses (lab; Years 1-3)	June 30, 2025
Assess fiber potential; determine fiber lengths and types and potential uses thereof (lab; Years 1-3)	June 30, 2025

Activity 4: Education and outreach on perennial flax production

Activity Budget: $99,052

Activity Description:
AURI staff will help organize and participate in two perennial flax field days over the grant period to assist in building awareness and educating key stakeholders about perennial flax with demonstrations to highlight perennial flax production and environmental benefits to farmers, beekeepers, government officials, local businesses, educators, and students. In addition to the field days, AURI will also include perennial flax programming at one "AURI Connects: Fields of Innovation" event each year during the project to facilitate discussion, build awareness, and disseminate information about perennial flax and its market potential. We will communicate results derived from Activities 1-3 so beekeepers, farmers, and processors can be informed on requirements to produce/process perennial flax, as well as the environmental and economic benefits of production (oilseed, fiber, and nectar/honey). Potential nutraceutical benefits of flax oilseed and honey will also be highlighted.

Activity Milestones:

Description	Approximate Completion Date
Provide summary of market potential and supply chains (field; Years 2-3)	November 30, 2024
Present economic findings (field days) (field; Years 2-3)	June 30, 2025
Relay market opportunities (field, publications; Years 2-3)	June 30, 2025
Provide summary of market potential and supply chains in Minnesota (field; Years 2-3)	June 30, 2025
Discuss market opportunities and supply chain findings of perennial flax (field; Years 2-3)	June 30, 2025

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Donald Wyse	University of Minnesota, Department of Agronomy & Plant Genetics	Co-project Lead for perennial flax breeding & research; all activities	No
Kevin Betts	University of Minnesota, Department of Agronomy & Plant Genetics	Researcher on perennial flax; field production, maintenance, harvest for all Activities	No
Constance Carlson	University of Minnesota, Forever Green Initiative (FGI)	Engaged with MN Sustainable Farming Association and UMN Extension: Regional Sustainable Development Partnerships, market development, industry engagement, education and outreach, primarily working with Activities 2 - 4	Yes
Bareem (Pam) Ismael	University of Minnesota; Plant Protein Innovation Center	Protein analysis of seed samples, Activity 2; help with Activities 3-4	Yes
Marla Spivak	University of Minnesota, Department of Entomology	Pollinators, honey bee behavior, pollinator habitat, Activity 1; help with Activities 3-4	No
Daniel Cariveau	University of Minnesota, Department of Entomology	Native, wild pollinators, ecology, pollinator habitat Activity 1; help with Activities 3-4	No
Clay Carter	University of Minnesota, Department of Plant and Microbial Biology	Analyses of nectar, honey Activity 1; help with Activities 3-4	No
Colin Cureton	University of Minnesota, Forever Green Initiative (FGI)	FGI Commercialization team; economics of perennial flax production with emphasis on profitability for growers; support pilot production; organize scale-up; advise future IP and release strategies. Activities 3,4	Yes
Michael Stutelberg, Harold Stanislawski, Matthew Leiphon, Jennifer Wagner-Lahr, Alan Doering, Riley Gordon, Abel Tekeste, Nan Larson, Erik Evans, Shelby Thooft	AURI	Lead supply chain activities (primarily Activities 3, 4 but also aiding personnel in Activities 1, 2), AURI scientists for analytical testing (engineering, chemistry, fiber, oil, seed and fiber processing), commercialization, supply chain, networking, events associated with this project	Yes

Dissemination

Describe your plans for dissemination, presentation, documentation, or sharing of data, results, samples, physical collections, and other products and how they will follow ENRTF Acknowledgement Requirements and Guidelines.
AURI and FGI staff will help organize and participate in two perennial flax field days over the grant period to assist in building awareness and educating key stakeholders about perennial flax with demonstrations to highlight perennial flax production and environmental benefits to farmers, beekeepers, government officials, local businesses, educators, and students. FGI staff will coordinate with Dr. Ismail's UMN Plant Protein Innovation Center's Research Spotlight Forum to share perennial flax protein characterization research with global food and beverage industry leaders. In addition to the field days, AURI will also include perennial flax programming at one "AURI Connects: Fields of Innovation" event each year during the project to facilitate discussion, build awareness, and disseminate information about perennial flax and its market potential. We will communicate results derived from Activities 1-3 to inform farmers and processors on requirements to produce/process perennial flax, as well as the environmental and economic benefits of production (oilseed, fiber, and nectar/honey). Potential nutraceutical benefits of flax oilseed and nectar will also be highlighted. Two end-use application bulletins associated with supply chain opportunities and new markets for perennial flax (food, feed, bio-based materials) will be developed to communicate findings to industry stakeholders, 1) a summary the nutritional and functional characteristics of perennial flax seed, oil and meal and near term food applications, 2) a summary of the protein characteristics and functionality for use in product development. In all verbal and written communications, we will acknowledge this funding through use of the ENRTF logo, tagging ENRTF on social media and/or specific attribution language. For verbal communications, the following language will be used: "Funding provided by the Minnesota Environment and Natural Resources Trust Fund." whereas for written communications, we'll acknowledge ENRTF funding by stating that "Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR)." When possible, additional wording will be added on to include specific of the ENRTF funding, such as the recommended wording: "The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources." - or - "Currently 40% of net Minnesota State Lottery proceeds are dedicated to growing the Trust Fund and ensuring future benefits for Minnesota's environment and natural resources."

Long-Term Implementation and Funding

Describe how the results will be implemented and how any ongoing effort will be funded. If not already addressed as part of the project, how will findings, results, and products developed be implemented after project completion? If additional work is needed, how will this work be funded?
This research is part of the Forever Green Initiative, a coordinated effort to develop the next generation of perennial crops to protect Minnesota's environmental resources. Clean Water Funds allocated to the Forever Green Initiative are used for the basic breeding and early research to develop new crops. LCCMR funds are crucial for studying the environmental aspects of new crops and supporting field-scale deployment of perennial flax – which we have demonstrated from previous LCCMR appropriations. LCCMR funds help Minnesota citizens realize the environmental and economic benefits of new Forever Green crops. Related projects are supported by federal grants and industry.

Other ENRTF Appropriations Awarded in the Last Six Years

Name	Appropriation	Amount Awarded
Enhancing Pollinator Landscapes	M.L. 2014, Chp. 226, Sec. 2, Subd. 06a	$864,000
MITPPC #7: Tools to Distinguish Native from Exotic Reed Canary Grass	M.L. 2015, Chp. 76, Sec. 2, Subd. 06a	-
MITPPC 12: Developing Robust Identification Assays for Amaranthus Palmeri in Seed Mixtures	M.L. 2015, Chp. 76, Sec. 2, Subd. 06a	-

Data-Driven Pollinator Conservation Strategies	M.L. 2016, Chp. 186, Sec. 2, Subd. 03a	$520,000
Bee Pollinator Habitat Enhancement - Phase II	M.L. 2016, Chp. 186, Sec. 2, Subd. 08a	$387,000
Pollinator Research and Outreach	M.L. 2017, Chp. 96, Sec. 2, Subd. 03n	$500,000
Farmer-Led Expansion of Alfalfa Production to Increase Water Protection	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04i	$500,000
Using Perennial Grain Crops in Wellhead Protection Areas to Protect Groundwater	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 04j	$250,000
Develop BioMulch to Replace Plastic Soil Covering in Vegetable and Fruit Production to Increase Yield and Reduce Waste	M.L. 2018, Chp. 214, Art. 4, Sec. 2, Subd. 08b	$310,000
Accelerating Perennial Crop Production to Prevent Nitrate Leaching	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04k	$440,000
Farm-Ready Cover Crops for Protecting Water Quality	M.L. 2019, First Special Session, Chp. 4, Art. 2, Sec. 2, Subd. 04l	$741,000

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount	$ Amount Spent	$ Amount Remaining
Personnel										
Faculty, Dr. Baraem Ismail / Salary and Fringe		Conduct, analyze seed protein research, Activity 2; consult with Activities 3-4; advise 1-M.S. student and 1-PostDoc / Yr. 1: 1%=$1387; Yr. 2: 1% pay=$1415; Yr.3: 1% pay=$1443;			36.5%	0.03		$5,794	-	-
Professional and Admin, Constance Carlson / Salary and Fringe		Engaged with MN Sustainable Farming Association and UMN Extension: Regional Sustainable Development Partnerships, / market development, industry engagement, education and outreach, primarily working with Activities 2 - 4			36.5%	0.24		$32,598	-	-
Professional and Admin, Colin Cureton / Salary and Fringe		FGI Commercialization team / economics of perennial flax production with emphasis on profitability for growers; support pilot production; organize scale-up; advise future IP and release strategies. Activities 3,4			36.5%	0.15		$19,558	-	-
PostDoc and Research Specialist (to be determined) / Salary and Fringe, 20% of $50K salary		Protein analysis of seed samples / Activity 2; help with Activities 3-4 "			25.4%	0.3		$26,148	-	-
M.S. Food Science graduate student, 50% RA, Yrs. 2-3 / Salary + Tuition (Academic Yr.) + Fringe (Academic		Conduct Activity 2 research experiments / coordinate harvests with engineers/staff for Activities 3-4			19.9%	1		$92,232	-	-

Summer) - Grad Students (Acad/Summer)										
Undergraduate Students / 1-3 undergrads at $12/hr.; 5-10 hrs/wk during semesters; possibly FT in summers; $8660.33/yr		Conduct Activity 1 research experiments and coordinate harvests with engineers/staff for Activities 1-3 " NOTE: Rebudgeted $961 from this account (reduced by that much) to a new Services and Subawards (internal) budget line			0%	0.75		$33,200	-	-
Civil Service, Honey bee technician, 25% time @ $55,000/yr / Salary + Fringe		Pollinator studies / Activity 1			31.8%	0.75		$55,463	-	-
							Sub Total	**$264,993**	**$264,993**	**-**
Contracts and Services										
Agricultural Utilization Research Institute (AURI)	Service Contract	Technical staff for Activities 3-4; Michael Stuteberg: Lead supply chain activities, Scientist (chemist) analytical testing; Rod Larkin: fiber, seed; Harold Stanislawski: Economics, fiber processing; Matthew Leiphon: Project manager, AURI; Jennifer Wagner-Lahr: Commercialization for AURI; Riley Gordon: Engineer, Fiber and seed processing; Abel Tekeste: Fiber/seed processing; AURI Dir. Innovative Networks				1.92		$139,894	$139,894	-
Contracts and Services (nectar chemistry)	Internal services or fees (uncommon)	Activity 1 Nectar and honey chemistry analyses - replaces 100% of the deleted Activity 1 personnel line for "Civil Service, 25% technician (nectar chemistry; $50k base) / Salary + Fringe" AND replaces $960.76 of the modified				0.75		$33,911	$33,911	-

		Activity 1 personnel line for "Civil Service, Honey bee technician, 25% time @ $55,000/yr"								
							Sub Total	**$173,805**	**$173,805**	**-**
Equipment, Tools, and Supplies										
	Tools and Supplies	Field Supplies	weed control (herbicides, cultivation), harvesting supplies ($3,584/yr x 3 yrs); Yr. 1: Pollen traps (6 colonies/ 9 locations = 54 traps, $65 each)=$3510; Sweep nets ($30/each x 5)=$150; Pollen Substitute: MegaBee patties $2.00/colony x 135 colonies fed 2x/mo, 4 mos=$2160/yr x 3 yrs.;					$20,892	$20,892	-
	Tools and Supplies	Lab Supplies	plant protein analyses ($5K/yr x 2 yrs.); Soxhlet extractor (lipid analysis)=$440; Supplies (recurring, Yrs.1-3): Pollen analysis supplies, 10 boxes 100 glass slides (Glycerine, Calberla's solution)= $840/yr; Protein and Fat analysis, Individual colony samples @ 12/site x 9 x 5 alternate month x $10 = $5,400/yr x 2 yrs; Nectar chemistry analyses (amino acids and sugar types, concentrations, content): Nectar amino acid analyses (19 genotypes x 3 reps x 2 years x 3 sites x $30/sample for LC MS time) = $10,260 ($5,130/yr); Reagents & supplies for sugar analyses =					$27,330	$27,330	-

			$1,500 ($500/yr); None of these are lab fees to use a lab, rather supply costs to run machines. Thus, the $30/sample is used to calculate the supply needs for this analysis.							
							Sub Total	**$48,222**	**$48,222**	**-**
Capital Expenditures										
							Sub Total	**-**	**-**	**-**
Acquisitions and Stewardship										
							Sub Total	**-**	**-**	**-**
Travel In Minnesota										
	Miles/ Meals/ Lodging	Travel by Activities 1-4 Research Teams: $0.56/mile x 4068 mi./yr, M&EI @$55/day @$x 40 d/yr (Lamberton, Morris, Rosemount), lodging @$99/day (Crookston), @$x 12 d/yr	Travel to/from sites for all Activities and all Personnel; field production, irrigation, herbicide applications, data collection, seed.fiber harvests, pollinator studies					$2,980	$2,980	-
							Sub Total	**$2,980**	**$2,980**	**-**
Travel Outside Minnesota										
							Sub Total	**-**	**-**	**-**
Printing and Publication										
							Sub Total	**-**	**-**	**-**
Other Expenses										
							Sub Total	**-**	**-**	**-**
							Grand Total	**$490,000**	**$490,000**	**-**

Classified Staff or Generally Ineligible Expenses

Category/Name	Subcategory or Type	Description	Justification Ineligible Expense or Classified Staff Request

Non ENRTF Funds

Category	Specific Source	Use	Status	$ Amount	$ Amount Spent	$ Amount Remaining
State						
			State Sub Total	**-**	**-**	**-**
Non-State						
In-Kind	Overhead rate, 55% of total (minus tuition costs of $35,212); calculated as: $490,000 - $35,212 = $454,788 x 0.55 = $250,133.40	none - this isn't being paid to the University of Minnesota;	Potential	$250,133	-	$250,133
			Non State Sub Total	**$250,133**	**-**	**$250,133**
			Funds Total	**$250,133**	**-**	**$250,133**

Attachments

Required Attachments

Visual Component

File: 9620ca1e-667.pdf

Alternate Text for Visual Component

Overview. The University of Minnesota is breeding perennial flax to replace historic annual flax production in MN. Establishing perennial flax (Linum spp.) as a reinvigorated oilseed/fiber and a new honey crop has the potential to improve yield for farmers (with 2x harvest/yr.) and provide ecosystem services for pollinators (flowering May-November). We seek funding to provide early-stage crop development data before direct commercialization and have assembled a state-wide team of experts to ...

Supplemental Attachments

Capital Project Questionnaire, Budget Supplements, Support Letter, Photos, Media, Other

Title	File
Cover Letter, University of Minnesota	2071ec6d-938.pdf
Perennial Flax LCCMR 2021- AURI Subrecipient Commitment Form	01a3424c-d7a.pdf
AURI Scope of Work	f7d77019-c24.pdf
AURI Subcontract Budget	dc347834-57f.pdf
AURI Subcontract Budget Justification	77df534f-302.pdf
Background Check Certification	98de3802-b57.pdf
Responses to Revision Requests	a0374eb9-abf.pdf
Approved Research Addendum	059b501a-778.pdf
Perennial Flax Market Assessment	5bddf23b-eba.pdf
AURI Final Research Report	64b27d2b-a04.pdf
Perennial Flax Field Day Flyer	8985deeb-f3c.pdf
AURI Flax seed, flax meal, and flax oil report	84a24e3d-58b.docx
Flax Protein Report, Plant Protein Innovation Center	628d7132-654.docx
Perennial Flax Enterprise Budget	710b1a3e-892.xlsx

Difference between Proposal and Work Plan

Describe changes from Proposal to Work Plan Stage

Due to budget reductions, we dropped several sections of the grant which included breeding/selection for non-shattering, the molecular SNP and GWAS research (primarily Activity 2; these include dropping 1-Ph.D. student, 1-research scientist, field/greenhouse charges), as well as eliminating amino acid analysis in nectar chemistry (Activity 1). AURI contract was reduced in most areas across all activities.

Additional Acknowledgements and Conditions:

The following are acknowledgements and conditions beyond those already included in the above workplan:

Do you understand and acknowledge the ENRTF repayment requirements if the use of capital equipment changes?

N/A

Do you understand that travel expenses are only approved if they follow the "Commissioner's Plan" promulgated by the Commissioner of Management of Budget or, for University of Minnesota projects, the University of Minnesota plan?

Yes, I understand the UMN Policy on travel applies.

Does your project have potential for royalties, copyrights, patents, sale of products and assets, or revenue generation?

Yes

Do you understand and acknowledge IP and revenue-return and sharing requirements in 116P.10?

Yes

Do you wish to request reinvestment of any revenues into your project instead of returning revenue to the ENRTF?

No

Does your project include original, hypothesis-driven research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

Do you understand that a named service contract does not constitute a funder-designated subrecipient or approval of a sole-source contract? In other words, a service contract entity is only approved if it has been selected according to the contracting rules identified in state law and policy for organizations that receive ENRTF funds through direct appropriations, or in the DNR's reimbursement manual for non-state organizations. These rules may include competitive bidding and prevailing wage requirements

Yes, I understand

Work Plan Amendments

Amendment ID	Request Type	Changes made on the following pages	Explanation & justification for Amendment Request (word limit 75)	Date Submitted	Approved	Date of LCCMR Action
1	Amendment Request		a) Re-budget funds of $12,540.00 from the categories of: Postdoc Salary $10,000 and Fringe $2,540. We would like to re-budget these funds for Lab Supplies and Other Non-Capitalized Equipment (lab supplies and reagents for protein extraction, analysis) to complete the protein-related objectives. b) Request approval to re-budget funds in the amount of $1000 from the travel line to 720300 (General Operating Services). The original scope of the work stays the same.	May 2, 2024	Yes	May 22, 2024
2	Amendment Request	• Budget • Other • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences	Re-budget request to move $6,367 from travel to personnel, leaving the total travel request of $2,981 (as changed in the budget line item). We would like to rebudget this amount to complete Activities 1 and 2. Additional personnel time is required for seed sample processing and data analyses this year. This will not impact accomplishment of any Activities as the travel costs were streamlined by the Personnel involved, minimizing trip costs significantly.	February 26, 2025	Yes	March 26, 2025
3	Amendment Request	• Budget - Personnel • Budget - Professional / Technical Contracts	Rebudget Activity 1 funds remaining = $33,910.76 from "salary/fringe" to "contracts and services" (in LCCMR terms). The reason this is needed is that one of the faculty members retired and the remainder of the funds will be spent in another lab for the same purpose to conclude the nectar chemistry and pollinator activities. No loss of data	June 6, 2025	Yes	June 17, 2025

			collection and experimentation would occur; we would end with the same information from the research.			
4	Completion Date	Previous Completion Date: 06/30/2025 New Completion Date: 12/31/2025	Temporary change by LCCMR staff to allow for amendment request submittal	June 17, 2025	Yes	June 17, 2025
5	Completion Date	Previous Completion Date: 12/31/2025 New Completion Date: 06/30/2025	Change by LCCMR staff to allow for amendment request submittal	June 17, 2025	Yes	June 17, 2025
6	Amendment Request	• Budget • Budget - Personnel • Budget - Professional / Technical Contracts • Budget - Capital, Equipment, Tools, and Supplies • Budget - Travel and Conferences	Due to billings that finally hit the accounts, the following changes (emailed Lisa about this, too) are: Move $8190 out of supplies (remaining balance) Move $7231 out of Contracts & Services. (remaining balance) Move $1 out of travel (overage) Moved $8181 into personnel (undergraduates): extra spending accumulated here for students to process samples, enter data, finish field work & lab analyses; moved $7241 into personnel (postdoc & res. spec.): late billing came in show slight overspending for thepersonnel	September 26, 2025	Yes	November 7, 2025

Additional Status Update Reporting

Additional Status Update August 20, 2025

Date Submitted: December 11, 2025

Date Approved: December 11, 2025

Overall Update
Our project concluded research on pollinator services (nectar, pollen collection; timing; visitation; chemical constituents), oilseed production (mechanical harvesting), high oilseed protein yields and nutraceutical content, fiber, forage, and biomass uses of perennial flax straw, market potential and development for the crop of value to MN farmers / citizens-at-large, and holding perennial flax field days with broad and varied audiences at local, upper midwest regional, and national meetings to build public awareness and gauge interest.

Activity 1
This activity was previously marked complete.
(This activity marked as complete as of this status update)

Activity 2
This activity was previously marked complete.
(This activity marked as complete as of this status update)

Activity 3
This activity was previously marked complete.
(This activity marked as complete as of this status update)

Activity 4
This activity was previously marked complete.
(This activity marked as complete as of this status update)

Dissemination
Scientific research papers (5+), extension publications (5+), and webinars (2-3) have been developed or are in their draft phase. Three end-use application bulletins associated with supply chain opportunities and new markets for perennial flax (food, feed, bio-based materials) have been developed to communicate findings to industry stakeholders: 1) nutritional and functional characteristics of perennial flax seed, oil and meal and near term food applications, 2) protein characteristics and functionality for use in product development, 3) market development. We anticipate filing for IR-4 pre- and post-herbicide registration for perennial flax (conventional production). These will continue to enhance industry and R&D interest (farmers, beekeepers, government officials, local businesses, educators, and students) and support for future product testing and development and aid market development and enhancement.

Additional Status Update Reporting

Additional Status Update August 20, 2025

Date Submitted: August 20, 2025

Date Approved: November 7, 2025

Overall Update
Our project concluded research on pollinator services (nectar, pollen collection; timing; visitation; chemical constituents), oilseed production (mechanical harvesting), high oilseed protein yields and nutraceutical content, fiber, forage, and biomass uses of perennial flax straw, market potential and development for the crop of value to MN farmers / citizens-at-large, and holding perennial flax field days with broad and varied audiences at local, upper midwest regional, and national meetings to build public awareness and gauge interest.

Activity 1
This activity was previously marked complete.
(This activity marked as complete as of this status update)

Activity 2
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Activity 3
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Activity 4
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Dissemination
Scientific research papers (5+), extension publications (5+), and webinars (2-3) have been developed or are in their draft phase. Three end-use application bulletins associated with supply chain opportunities and new markets for perennial flax (food, feed, bio-based materials) have been developed to communicate findings to industry stakeholders: 1) nutritional and functional characteristics of perennial flax seed, oil and meal and near term food applications, 2) protein characteristics and functionality for use in product development, 3) market development. We anticipate filing for IR-4 pre- and post-herbicide registration for perennial flax (conventional production). These will continue to enhance industry and R&D interest (farmers, beekeepers, government officials, local businesses, educators, and students) and support for future product testing and development and aid market development and enhancement.

Status Update Reporting

Final Status Update August 14, 2025

Date Submitted: August 20, 2025

Date Approved: November 7, 2025

Overall Update
Our project concluded research on pollinator services (nectar, pollen collection; timing; visitation; chemical constituents), oilseed production (mechanical harvesting), high oilseed protein yields and nutraceutical content, fiber, forage, and biomass uses of perennial flax straw, market potential and development for the crop of value to MN farmers / citizens-at-large, and holding perennial flax field days with broad and varied audiences at local, upper midwest regional, and national meetings to build public awareness and gauge interest.

Activity 1
Flowering season is from May to November, with buds opening after a hard freeze (<30F), providing pollinators with food during "gaps" when other species are not in bloom. Thus, perennial flax offers interesting season extension for ecosystem services. Pollinator, native, and perennial seed mixes are popular for home gardens and conservation plantings, but perennial flax has not been included in these mixes; perennial flax may be a plus for this market sector. Pollinator frequencies, preferences, and visitation (honey bees, bumble bees, native bees, syrphid flies) for oilseed, cut flower, and fiber lines was higher in early morning in both organic and conventional production. Small bees the most frequent visitors in late May to early June, whereupon honey bees and flies predominated into September.
Pollen, nectar & honey nutritional, nutraceutical component studies of nectar analysis for glucose, fructose, hexose, sucrose revealed that total sugar content is low and highest in hexose; however, sucrose makes a higher grade of honey. Low sucrose production could be a causal reason that perennial flax is less attractive to pollinators. Lines with the greatest mmol sugar content were CF7, CF6, CF3, CF16 and Linum perenne x L. austriacum hybrids.
(This activity marked as complete as of this status update)

Activity 2
For the first time, an efficient and scalable flax extraction process was successfully developed for proteins (seed), while ensuring high protein extraction yield, purity, and functionality. Perennial flax protein was successfully and efficiently extracted from perennial varieties following an innovative and effective extraction process. Perennial flax protein solubility and emulsification properties were superior to commercial protein ingredients, giving this protein a competitive edge in the food market. The gelation of the protein from annual flax was superior to all tested protein including that of the commercial protein isolates. These findings are unique and will provide a new high value market for perennial flax, incentivizing farmers to adopt the production of this environmentally sustainable crop.
Harvestable yield (#/A) and % moisture were recorded. Percent moisture levels ranged from 6.2% (no defol., swath-combine, Yr.3) to 41.5% (no defol., seed stripper, Yr.2), differing by locations and years. Yr. 2 yields were highest for hand-harvesting (190-335#/A) compared to mechanical harvests (63-229#/A), although in Yr.3 one mechanical method exceeded hand-harvests. All oilseed yields were significantly lower than annual flax; a 44-77% mechanical harvest seed loss occurred. The need for improved mechanical harvesting as well as breeding for non-shattering types
(This activity marked as complete as of this status update)

Activity 3
Perennial flax cultivars support pollinators, improve soil stability by providing continuous living cover, and can be harvested for multiple end uses. Beyond grain production, perennial flax shows promise as a cut flower and ornamental plant. This is due to its winter-hardy resilience, long blooming season, postharvest longevity, and sought-after pale blue flowers which can be cut twice per season. Potential bioindustrial applications include fuel derived from oilseed feedstock and biomass, sustainable animal and pet food ingredients, and fiber for use in artisan crafts, fine papers, and

biocomposite materials. The University of Minnesota engaged AURI technical services to assess straw for fiber, energy and feed value, biomass potential (BMP), process development for pressing oil from seed, proximate analyses of seed and pressed oil, and storage parameters for seed and pressed oil.
While breeding efforts have developed high yielding, low shattering seedlines, best agronomic practices need to be concurrently developed to successfully launch this as a viable, perennial oilseed crop. Our research tested mechanical harvesting methods' and desiccants' influences on oilseed yield. Linum perenne 'Appar' were direct seeded in non-irrigated 1A fields (10#/A) in three locations, spring 2021 divided into ½A conventional vs. organic production systems.
(This activity marked as complete as of this status update)

Activity 4
Perennial flax is attractive in regenerative agricultural systems because of its extended flowering season for pollinator species to feed on when other plants are not flowering, and continuous living cover to stabilize soils. Its seeds can be processed into nutrient-rich food products and oil, while the stalks offer valuable fiber, broadening its market footprint. AURI conducted interviews with key stakeholders in the potential value chain to create market indicators that could guide the way forward to grower adoption once the crop achieves technical and market readiness, contingent on market demand and supply chain investment.
Future market potential and enterprise budgets are promising, given a growing demand for plant-based proteins, biodegradable materials, alternative feed and fuel feedstocks, and increased biodiversity on the landscape as a climate-resilient crop. Emerging interest from the food, bioindustrial, and cut flower sectors points to scalable applications. Our perennial flax field day (3 June 2025) had numerous firms and farms interested in potentially all applications. However, building a stable supply chain for perennial flax faces key challenges. These include limited agronomic research, limitations once at scale for processing straw into industrial or textile fiber applications, and uncertainty in future grower adoption due to its immature market.
(This activity marked as complete as of this status update)

Dissemination
Scientific research papers (5+), extension publications (5+), and webinars (2-3) have been developed or are in their draft phase. Three end-use application bulletins associated with supply chain opportunities and new markets for perennial flax (food, feed, bio-based materials) have been developed to communicate findings to industry stakeholders: 1) nutritional and functional characteristics of perennial flax seed, oil and meal and near term food applications, 2) protein characteristics and functionality for use in product development, 3) market development. We anticipate filing for IR-4 pre- and post-herbicide registration for perennial flax (conventional production). These will continue to enhance industry and R&D interest (farmers, beekeepers, government officials, local businesses, educators, and students) and support for future product testing and development and aid market development and enhancement.

Additional Status Update Reporting

Additional Status Update August 14, 2025

Date Submitted: June 6, 2025

Date Approved: June 17, 2025

Overall Update
no updates at this time

Activity 1
no updates at this time

Activity 2
no updates at this time

Activity 3
no updates at this time

Activity 4
no updates at this time

Dissemination
no updates at this time

Additional Status Update Reporting

Additional Status Update February 25, 2025

Date Submitted: March 24, 2025

Date Approved: March 26, 2025

Overall Update

Our project is conducting research on pollinator services (data collection of nectar, pollen collection; timing; visitation; chemical constituents), oilseed production (mechanical harvesting), high oilseed protein yields and nutraceutical content, fiber, forage, and biomass uses of perennial flax straw. Current season results are still in progress with updates herein to continually increase shared awareness of the market potential for the crop of value to MN farmers and citizens-at-large. Project partners continue to present at events with broad and varied audiences at local, upper midwest regional, and national meetings to build public awareness and gauge interest.

Activity 1

We quantified frequencies, preferences, and pollinator visitation (honey bees, bumble bees, native bees, syrphid flies) for oilseed, cut flower, and fiber lines (St. Paul, Rosemount,r Morris) in 2024. Pollinator visitation was higher in the early morning (0800HRS) in both organic and conventional field production. Visitation rates dropped off precipitously as the morning progressed. Small bees the most frequent visitors in late May to early June, whereupon honey bees and flies predominated into September. This classifies perennial flax as an alternative, rather than primary, pollinator crop, providing food sources when alternative crops are not flowering.

Perennial flax flowers into November, with buds opening after a hard freeze (<30F). It is rare that any plant flowers after <30F, except for witch hazel (Hamamelis virginiana). Thus, perennial flax offers interesting season extension for ecosystem services.

Pollen, nectar & honey nutritional, nutraceutical component studies repeated nectar analysis for glucose, fructose, hexose, sucrose. Total sugar content is low and highest in hexose; however, sucrose makes a higher grade of honey. Low sucrose production could be a causal reason that perennial flax is less attractive to pollinators. Varieties with the greatest mmol sugar content were CF7, CF6, CF3, CF16 and Linum perenne x L. austriacum hybrids.

Activity 2

Research on the evaluation of yield for high value perennial oilseed to provide oil, proteins and meal for human/animal nutrition continues. Forty-four oilseed selections were grown and tested for seed morphological measurements using Marvin seed analysis equipment. This allowed for screening and selection of large-seeded oilseed types for shattering/non-shattering studies in 2024. The degree of shattering among oilseed accessions varied widely, producing 0 to 10 seeds/capsule (10=max. possible). Highest seed set (non-shattering) types included homomorphic L. baicaulense and several hybrids. Fiber extraction was enhanced with lengthy retting periods to break down fibers. Protein extraction methodologies (hydraulic pressing @ 16,000 psi for 24 hrs.) and development of standards to enhance breeding lines for increased seed proteins and nutraceuticals were tested. The mass balance extraction timeline included protein extraction, dialysis, freeze drying, and Dumas protein analysis. Protein purity and yield were highest at pH=8 or 9 with no heat/no enzyme treatments. Estimated protein purity of L. austriacum ‘Maple Grove’ =85.9%. Current research focuses on increasing protein isolate production, as well as comparison of structural, functional, and nutrition properties of perennial and annual flax protein isolates for food applications.

Activity 3

Best harvesting methods, analysis of flax fiber yield, and retting research continued for assessment of value-added processes and products to support development of economically sustainable perennial flax supply-chains. Perennial flax (Linum perenne ‘Appar’) mechanical harvesting for oilseed yield was highest using Defol 5 as a desiccant, followed by combining. These harvest methods did not affect appreciable stand losses the following year (comparing 2023 vs. 2024

yield). Herbicide evaluation for IR-4 registration was completed. Safe and effective pre-emergent herbicides at tested rates included Treflan (trifluralin), Prowl (pendimethalin), Spartan (sulfentrazone), Dual Magnum II (metolachlor), and Raptor (imazamox). For post-emergent herbicide applications, Stinger (clopyralid), Raptor (imazamox), Accent (nicosulfuron), Select (clethodim), and Assure II (quizalofop) were effective without eliciting damage. Selection and breeding for non-shattering oilseed types identified several high-yielding lines which have been crossed to enhance this trait. Use of chemical mutagens are currently in the testing phase to identify non-shattering mutants. Molecular screening for genes related to non-shattering is also in process. Decortication produced significantly higher fiber yields (fiber length, type) following extensive retting for potential use in the weaving industry. The business development team continues to establish supply chain opportunities.

Activity 4

Education and outreach on perennial flax production included multiple perennial flax field days in connection with the 2024 Horticulture Nights at the North Central Research and Outreach Center (NCROC), Grand Rapid, MN, and at the West Central Research and Outreach Center (WCROC), Morris, MN. Presentations were made to the Forever Green Initiative meetings in December 2024. Additional education/outreach events with perennial flax presentations in 2025 include the CFANS Research Symposium. The Spotlight Science: Genetic Engineering event at the Bell Museum of Natural History (2024) included multiple perennial flax presentations and demonstrations.

Dissemination

Dissemination activities are in the writing phases for several peer-reviewed journal articles from Activities 1-3.

Status Update Reporting

Status Update March 1, 2025

Date Submitted: March 24, 2025

Date Approved: March 26, 2025

Overall Update

Our project is conducting research on pollinator services (data collection of nectar, pollen collection; timing; visitation; chemical constituents), oilseed production (mechanical harvesting), high oilseed protein yields and nutraceutical content, fiber, forage, and biomass uses of perennial flax straw. Current season results are still in progress with updates herein to continually increase shared awareness of the market potential for the crop of value to MN farmers and citizens-at-large. Project partners continue to present at events with broad and varied audiences at local, upper midwest regional, and national meetings to build public awareness and gauge interest.

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Activity 2

Research on the evaluation of yield for high value perennial oilseed to provide oil, proteins and meal for human/animal nutrition continues. Forty-four oilseed selections were grown and tested for seed morphological measurements using Marvin seed analysis equipment. This allowed for screening and selection of large-seeded oilseed types for shattering/non-shattering studies in 2024. The degree of shattering among oilseed accessions varied widely, producing 0 to 10 seeds/capsule (10=max. possible). Highest seed set (non-shattering) types included homomorphic L. baicaulense and several hybrids. Fiber extraction was enhanced with lengthy retting periods to break down fibers. Protein extraction methodologies (hydraulic pressing @ 16,000 psi for 24 hrs.) and development of standards to enhance breeding lines for increased seed proteins and nutraceuticals were tested. The mass balance extraction timeline included protein extraction, dialysis, freeze drying, and Dumas protein analysis. Protein purity and yield were highest at pH=8 or 9 with no heat/no enzyme treatments. Estimated protein purity of L. austriacum ‘Maple Grove’ =85.9%. Current research focuses on increasing protein isolate production, as well as comparison of structural, functional, and nutrition properties of perennial and annual flax protein isolates for food applications.

Activity 3

Best harvesting methods, analysis of flax fiber yield, and retting research continued for assessment of value-added processes and products to support development of economically sustainable perennial flax supply-chains. Perennial flax (Linum perenne ‘Appar’) mechanical harvesting for oilseed yield was highest using Defol 5 as a desiccant, followed by combining. These harvest methods did not affect appreciable stand losses the following year (comparing 2023 vs. 2024

yield). Herbicide evaluation for IR-4 registration was completed. Safe and effective pre-emergent herbicides at tested rates included Treflan (trifluralin), Prowl (pendimethalin), Spartan (sulfentrazone), Dual Magnum II (metolachlor), and Raptor (imazamox). For post-emergent herbicide applications, Stinger (clopyralid), Raptor (imazamox), Accent (nicosulfuron), Select (clethodim), and Assure II (quizalofop) were effective without eliciting damage. Selection and breeding for non-shattering oilseed types identified several high-yielding lines which have been crossed to enhance this trait. Use of chemical mutagens are currently in the testing phase to identify non-shattering mutants. Molecular screening for genes related to non-shattering is also in process. Decortication produced significantly higher fiber yields (fiber length, type) following extensive retting for potential use in the weaving industry. The business development team continues to establish supply chain opportunities.

Activity 4

Education and outreach on perennial flax production included multiple perennial flax field days in connection with the 2024 Horticulture Nights at the North Central Research and Outreach Center (NCROC), Grand Rapid, MN, and at the West Central Research and Outreach Center (WCROC), Morris, MN. Presentations were made to the Forever Green Initiative meetings in December 2024. Additional education/outreach events with perennial flax presentations in 2025 include the CFANS Research Symposium. The Spotlight Science: Genetic Engineering event at the Bell Museum of Natural History (2024) included multiple perennial flax presentations and demonstrations.

Dissemination

Dissemination activities are in the writing phases for several peer-reviewed journal articles from Activities 1-3.

Status Update Reporting

Status Update September 1, 2024

Date Submitted: September 10, 2024

Date Approved: October 1, 2024

Overall Update
Our project is conducting research on pollinator services (data collection of nectar, pollen collection; timing; visitation; chemical constituents), oilseed production (mechanical harvesting), high oilseed protein yields and nutraceutical content, fiber, forage, and biomass uses of perennial flax straw. Current season results are still in progress with updates herein to continually increase shared awareness of the market potential for the crop of value to MN farmers and citizens-at-large. Project partners continue to present at events with broad and varied audiences at local, upper midwest regional, and national meetings to build public awareness and gauge interest.

Activity 1
Data analysis quantified frequencies, preferences, and pollinator visitation rates (honey bees, bumble bees, native bees, syrphid flies, etc.) for 'Appar' (1A-Morris, 1A-Rosemount) and fiber lines (St. Paul, Rosemount) during the 2024 flowering period (May-onwards). We are retesting the identified five varieties of cut flower/fiber selections with the highest pollinator visitation (primarily honeybees) found in 2023 to quantify pollen vs. nectar foragers. This season's challenges of cold weather, a late spring, and excessive precipitation meant many weeks wherein data could not be collected due to a lack of pollinator activity and/or excessive soil moisture preventing traversing the fields. Pollinator visitation remains highest in early morning (0800 HRS) in organic and conventional fields, dropping off significantly as morning hours progressed. Small bees continue to be the most frequent visitors in June, followed by honey bees and flies. Fall data has not yet been collected to determine the predominant pollinator. Pollen, nectar & honey nutritional, nutraceutical components studies repeat nectar analysis on the most visited varieties for the predominant compounds, e.g. glucose, fructose, hexose, and sucrose.

Activity 2
Research on the evaluation of yield for high value perennial oilseed to provide oil, proteins and meal for human/animal nutrition continues. Additional oilseed selections have been made and were tested for seed morphological measurements using new equipment (Marvin). Breeding and selection for nonshattering has commenced to improve yield of all oilseed crops. We are currently determining the degree of shattering among all oilseed accessions to direct future breeding efforts. We continue to use the developed protein extraction methodologies (hydraulic pressing @ 16,000 psi for 24 hrs.) for perennial and annual (comparison) flax to obtain protein isolates, mass balance with scientists in two labs. Development of standards to enhance development of breeding lines for increased seed proteins and nutraceuticals is being tested. New oilseed selections are being tested to determine the range of expression in protein purity and pure protein yield, along with other essential components, e.g. crude fiber, linoleic acid, Omega 3s and alpha-linoleic acid. These data and standards will aid in the development of harvestable products to create business models.

Activity 3
Research assessing value-added processes and products to support development of economically sustainable supply-chains for perennial flax focused on flax fiber yield and best harvesting methods. Perennial flax (Linum perenne 'Appar') mechanical harvesting at two non-irrigated sites in Lamberton and Morris, MN (1/2A organic, 1/2A conventional) to determine oilseed yield (lbs/A) will only occur once this year. This is due to the unseasonably cold and wet weather which has negated the late fall harvest for this year. Seed harvests have occurred and the seed is being cleaned for yield estimated.
Since perennial flax has not been selected for non-shattering types, yield decreases in comparison with annual flax are realized (>33% yield losses). As a result, we are selecting and breeding for increased seed yield with the incorporation of

non-shattering of the capsules (see above).
Additional fiber selections have been made and retted (trialed for the first time) prior to analysis to determine fiber production for potential use in linen material. Additional selections have been submitted for decortication to determine whether there are improvements in fiber length and type in comparison to annual flax. The business development team continues to establish supply chain opportunities.

Activity 4
Education and outreach on perennial flax production to date in 2024 included two perennial flax field days in connection with the annual Horticulture Nights at the North Central Research and Outreach Center (NCROC), Grand Rapid, MN in July 2024 and at the West Central Research and Outreach Center (WCROC), Morris, MN in July, 2024. The Spotlight Science: Genetic Engineering event at the Bell Museum of Natural History (March, 2024) included multiple perennial flax presentations and demonstrations. Other research for the perennial flax market potential and supply chain formulation are waiting for data from Activities 1-3 to relay market opportunities.

Dissemination
Dissemination activities are preparatory for several peer-reviewed journal articles from Activities 1-3.

Status Update Reporting

Status Update March 1, 2024

Date Submitted: March 8, 2024

Date Approved: May 22, 2024

Overall Update

Our project is conducting research on pollinator services (nectar, pollen collection; timing; visitation; chemical constituents), oilseed production (mechanical harvesting), high oilseed protein yields and nutraceutical content, fiber, forage, and biomass uses of perennial flax straw. Year 2 results are being shared to build awareness of the market potential for the crop of value to MN farmers and citizens-at-large. Project partners continue to present at events with broad and varied audiences at local and national meetings to build public awareness and gauge interest.

Activity 1

Data analysis quantified frequencies, preferences, and pollinator visitation rates (honey bees, bumble bees, native bees, syrphid flies, etc.) for 'Appar' (1A-Morris, 1A-Rosemount) and fiber lines (St. Paul, Rosemount) during the 2023 flowering period (May-Nov.). Varieties with highest pollinator visitation were found. Five varieties of cut flower/fiber selections had high visitation; these include ones with flower patterning, star-shaped flowers/curved petals, large diameter flower sizes and those with the highest bloom-retention. Pollinator visitation was highest in early morning (0800 HRS) in organic and conventional fields, dropping off significantly as morning hours progressed. During the growing season, pollinator activity was highest in June and then July, corresponding with floral display. Small bees were the most frequent visitors in June, followed by honey bees and flies. In early August, fly visitation exceeded that of small bees and honey bees. In late fall, honey bees were the predominant pollinator. Pollen, nectar & honey nutritional, nutraceutical components studies found varying levels of sugars/flower (glucose, fructose, hexose, sucrose). Plans for 2024 field research will repeat surveys of pollinators (primarily honeybees) on varieties with the highest/lowest frequency of visitation in 2023 to quantify pollen vs. nectar foragers; repeat nectar analysis on the most visited varieties.

Activity 2

Our research on the evaluation of yield for high value perennial oilseed to provide oil, proteins and meal for human/animal nutrition progressed for all objectives. We developed protein extraction methodologies for perennial and annual (comparison) flax to produce protein isolates with scientists in two labs showing that mucilage (water-soluble polysaccharides) require removal prior with soaking or enzymes to protein extractions, followed by drying. Hydraulic pressing of seeds at 16,000psi for 24hrs, followed by grinding and defatting, followed by protein extraction determined mass balance. ‘Perennial Blue’ flax had 81.3% protein purity and yielded 26% pure protein. One perennial flax accession, Linum lewisii ‘Maple Grove (2.2g)’, had similar 1000 seed weights to annual flax (4.5-5.3g); all other varieties were significantly lower (1.1-1.6g) Thus, seed filling is an important trait for improvement. ‘Maple Grove’ had higher levels of crude protein (26.2%), crude fiber (21.2%), linoleic acid (17.5g/100g), Omega 3s (50.45g/100g) and alpha-linoleic acid (50.45g/100g) than annual flax. Data will be used to set standards and enhance development of breeding lines for increased seed proteins and nutraceuticals, thereby enabling development of harvestable products to create business models.

Activity 3

Research assessing value-added processes and products to support development of economically sustainable supply-chains for perennial flax focused on flax fiber yield and best harvesting methods. Perennial flax (Linum perenne ‘Appar’) 2023 oilseed yield (lbs/A) for mechanical harvesting methods at two non-irrigated sites in Lamberton and Morris, MN (1/2A organic, 1/2A conventional) had the highest yield as follows. Conventional production in comparison with the hand-harvest check (253 lbs/A), had the highest yields with direct combining with (241-262 lbs/A) and without (201 lbs/A) desiccants. Organic production had significantly lower yield, with the highest occurring with direct combining (130

lbs/A). Yield decreases are primarily due to shattering (>33% yield losses). Preliminary flax fiber sampling (decorticator) showed an insignificant amount of fiber length and type in comparison to annual flax. Perennial flax straw has a similar energy value to wood (8,225 BTU/lb.) with a high energy content for solid biomass fuel source. Feed value (livestock) studies have low nutrient content as a roughage for livestock production. Similar to orchardgrass hay, perennial flax straw is high in acid detergent and natural detergent fibers which limits consumption in livestock. Business development team is establishing supply chain opportunities.

Activity 4

Education and outreach on perennial flax production planning for 2024 includes organization of two perennial flax field days, incorporation of perennial flax into this year's annual AURI Connects: Fields of Innovation event, as well as other activity-specific events. The Spotlight Science: Genetic Engineering event at the Bell Museum of Natural History (March, 2024) will include multiple perennial flax presentations and demonstrations. Other research for the perennial flax market potential and supply chain formulation are waiting for data from Activities 1-3 to relay market opportunities.

Dissemination

Dissemination activities have included published abstracts and posters/talks at three local MN (Plant Protein Innovation Center) and national (Crop Science Society of America; American Society for Horticultural Science and the American Floral Endowment - National Floriculture forum) meetings.

Status Update Reporting

Status Update September 1, 2023

Date Submitted: September 5, 2023

Date Approved: September 27, 2023

Overall Update
Field and lab research continues in this year's growing season for the Activities in this proposal. While the drought conditions have been challenging we have managed to keep the plantings alive for field research objectives. The high temperatures have often caused the need to continuously reschedule planned field research activities since the plants are flowering and progressing much faster than usual. Nonetheless, we have made great strides in our research efforts on all fronts. Activity 1 teams have spent many hours in the fields assessing pollinator visitation and nectar/pollen collection using electronic pads in the fields. Technical information regarding flower opening times and petal drop have been recorded with videos. Nectar droplets have been visualized.

Activity 1
Research has focused on the objectives of quantifying the rate and frequency of visitation and preference of different pollinator groups (honey bees, bumble bees, native bees, syrphid flies, etc.) for different lines of perennial flax (Rosemount) throughout the flowering/harvest periods. Species visitation varies throughout the flowering time. The team has been studying this at three locations using large plantings of perennial flax in St. Paul, Rosemount, and Morris, MN. The types of rewards sought (nectar, pollen) have been documented. Chemical analyses are progressing well in the labs. By the end of the year, there will be sufficient data for AURI to use in developing a business development model.

Activity 2
Evaluation of yield for high value perennial oilseed to provide oil, proteins and meal for human/animal nutrition is well underway for Activity 2. The drought and heat conditions across the state have severely impacted plant growth throughout the season this year, particularly since most of our fields are not irrigated. Established plants have survived but most new (2023) plantings either failed to germinate, germinated poorly, or later did not establish due to drought. In our irrigated reference plot, the same issues arose since our ability to irrigate is on a weekly basis and the high temperatures/drought conditions quickly removed the irrigation effects before it could be repeated. Additional challenges have been that the high temperatures meant reduced yields during the first mechanical harvesting experiments. Given the continued drought, we estimate that the later fall harvests may have to be abandoned due to lack of seed set at high temperatures. Mechanical harvesting (1st harvest) has occurred at 4 sites (St. Paul, Rosemount, Lamberton, Morris) to determine seed yield. These seed lots will be cleaned and analyzed for yield components prior to being tested for oil and omega-3 content. Protein extraction methodologies continue to be tested to produce protein isolates.

Activity 3
Flax fiber yield (biomass, fiber type, length/width, tensile strength) preliminary studies provided the basis for studies this year for more in-depth data collection. Fiber analyses will be done, post-mechanical harvesting (Activity 2) using residual plant material bulked by seed lot or variety. Mechanical harvesting methods were retested again this year for accumulated seed yield/A (hand harvest/rolling, mechanical). Food use analyses of oilseed (seed proteins, oils, nectar/honey, etc.) continue. Initial data from two labs showed that some perennial flax lines exceeded or equalled annual flax for specific proteins or oils which provides positive assurance of their use for commercialization. Basic cooking, baking studies will be conducted next year with cooks and chefs. Business development objectives will be started once sufficient data is generated.

Activity 4

Several perennial flax extension activities have been accomplished to inform potential growers or producers and end users of products. These events included the following. We displayed flax plants and presented informational posters at the 7 June 2023, 11 July 2023 and 15 August 2023 events for St. Paul Garden Club, the Minnesota Agricultural Water Quality Certification Program, Minnesota Department of Agriculture and the Clean Water Council, respectively. Perennial flax benefits were presented to the Archer Daniels Midland (ADM) company representatives on 21 August. Oilseed and other crop attributes were presented during the Minnesota State Fair in the Forever Green Initiative booth, 24 August - 4 September, 2023.

Dissemination

n/a

Status Update Reporting

Status Update March 1, 2023

Date Submitted: March 24, 2023

Date Approved: March 24, 2023

Overall Update
The entire perennial flax team meets regularly to ensure the entire set of objectives are being met and cross-sharing of data and input for research ideas are being communicated. The separate groups also meet on a recurring basis to contact joint research endeavors. We anxiously await new findings for all objectives during 2023!

Activity 1
Activity 1: breeding/selecting/evaluating perennial flax for pollinator/landscape services and yield for food product analyses (honey, oilseed, fiber and chemical constituents). We have conducted preliminary, investigative research on pollinator visitation for pollen and nectar in perennial flax at three sites in 2022 which has led to a finalized method of approach for 2023 field and greenhouse studies involving pollinators. Pollinators do visit perennial flax, although the time day or during the season make a big difference. Usually morning pollinator is the highest since the flower petals have not fallen off; seasonality varies as to the type of pollinators visiting the crop, particularly honey bees and native pollinators. The 2023 research priorities will provide quantitative data to help guide the breeding program. New polllinations have already been made for hybrid evaluation this year. We are making excellent progress with the entire pollination team!

Activity 2
Activity 2 concentrates research on perennial flaxseed yield and human/animal nutrient contents for oil, protein, amino acid, and meal. Two labs and their group of researchers (the Plant Protein Innovation Center, U of M; the Agricultural Utilization Research Institute or AURI) are conducting initial experiments with flax seed to determine constituent content levels. First we are studying perennial flax seed that is on the market, along with annual flax comparisons to set a base line from which we will move to testing our own breeding lines to make selections for future endeavors.

Activity 3
Activity 3 is beginning their work connected with perennial flax, although this team is waiting for data inputs from the other objectives (1,2) before any tangible formulation of potential business development strategies can be developed to create supply chain opportunities and investigate new markets for perennial flax.

Activity 4
Activity 4 outreach to stakeholders and clientele groups to build awareness, education and promote discussion of perennial flax in field days and programming is underway. We anticipate launching a field day and additional outreach events to gauge interest with farmers for commercialization of perennial flax-based products. To date, all input received from outreach-related queries have been positive from farmers and/or other firms connected to the potential supply chain.

Dissemination
We plan on presenting a poster on perennial flax seed (plus any new, accompanying data) at the 2023 UMN Plant Protein Innovation Center's Research Spotlight Meeting to get input from global food and beverage industry leaders.