Environment and Natural Resources Trust Fund

2021 Request for Proposal

General Information

Proposal ID: 2021-421

Proposal Title: Protecting Minnesota Waters with Biodegradable, Controlled-Release Fertilizers

Project Manager Information

Name: Brian Barry

Organization: U of MN - Duluth - NRRI

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Project Basic Information

Project Summary: We will develop a biodegradable lignin-based fertilizer coating for granular urea fertilizers to replace non-biodegradable plastic coatings or non-coated fertilizers currently used by the agricultural sector.

Funds Requested: $260,000

Proposed Project Completion: 2023-06-30

LCCMR Funding Category: Methods to Protect, Restore, and Enhance Land, Water, and Habitat (F)

Project Location

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

Region(s): NE

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

Statewide

When will the work impact occur?

In the Future

Narrative

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

The application of nitrogen-containing fertilizers to crops is necessary for high yields but this has severe consequences for Minnesota watersheds. Nitrogen, in the form of nitrate, is highly mobile and is easily washed from agricultural fields into lakes, rivers and wetlands. High levels of nitrates in surface waters cause algal blooms (eutrophication), which deplete water oxygen levels killing aquatic animals. High level of nitrates in drinking waters has negative health impacts for infants and is known to be responsible for methemoglobinemia or blue baby syndrome. Finally, the high rates of nitrate runoff necessitate over application of nitrogen fertilizers, which produces nitrogen dioxide, a powerful greenhouse gas, from soils.

To combat these negative effects, Minnesota has implemented policies aimed at reducing agricultural runoff through wetlands preservation and increased buffer strips around fields. Another way to reduce fertilizer runoff is to coat fertilizer particles in a material that controls water diffusion so that the nutrients are released in a controlled manner over time, giving the crop roots a chance to absorb the fertilizer before percolation and runoff can remove the product. Current coated fertilizers available on the market utilize non-biodegradable plastics which results in environmental microplastic contamination.

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

We are developing a solution that will both reduce nutrient runoff and eliminate the use of non-biodegradable plastics; a controlled-release fertilizer coating made from lignin, a byproduct of cellulosic ethanol production. Lignin has properties that allow it to be processed like a plastic, yet is a 100% biodegradable wood-based material. This program will demonstrate coating formulations that can be coated onto urea fertilizers to control the rate of dissolution thereby aligning nutrient release with the plant's needs throughout its growth stages.

Nitrogen fertilizer is applied to soils as granular urea either prior to or during seeding. It begins releasing nitrogen into the soil immediately which is suboptimal for minimizing nutrient runoff. While nitrogen is needed by the plant in all growth stages, the requisite amount of nitrogen increases as the plant matures, with peak nitrogen uptake occurring, in corn for example, at 60-80 days after planting. When applied to urea, our coating slows water access to the urea granules thereby slowing the timing of release. This timing can be manipulated by varying the thickness of the coating. During this project, we will optimize the coating thicknesses by monitoring nitrogen release in both controlled laboratory, and real-world field conditions.

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?

Current nitrogen fertilizer best practice impacts both Minnesota waters (high nitrate levels) and soils (non-biodegradable microplastic introduction). Our solution of engineering a non-toxic, biodegradable, controlled-release fertilizer addresses both of these issues. By creating fertilizers coated with variable thicknesses, we can tailor the amount and timing of released nitrogen into soils to be compatible with plant's needs throughout their growth stages, minimizing runoff. Additionally, our coatings utilize a waste byproduct generated from cellulosic ethanol production, bringing the cost of this renewable fuel alternative down, making it more competitive with fossil fuel prices.

Activities and Milestones

Activity 1: Develop formulations and coating process for granular fertilizers and scale production for greenhouse and field trials.

Activity Budget: $150,000

Activity Description:
We will generate a 5x4 matrix (20 total products) of coated urea samples with 5 different porosities and 4 different coating thicknesses. These protocols will be based on our internally-funded proof of concept work generating continuous, lignin-based coatings on granular urea fertilizers. In these experiments, a novel, lignin-containing solution was prepared and sprayed onto tumbling urea particles in a spheronizer, and coated urea granules were generated upon solvent evaporation. We have learned that the porosity of the resulting coatings can be regulated by varying the water content of the spray-on solution and the thickness of the coatings can be adjusted by the quantity of solution applied.

We will measure the porosity and surface area of these coatings by mercury intrusion porosimetry and BET surface analyses, and the hydrophobicities using contact angle measurements. We will measure film thicknesses from images generated by scanning electron microscopy. Upon development of successful protocol for repeatability, we will generate adequate quantities of the previously described 20 samples to be used for activity 2. Results from the greenhouse studies will inform selections of 3 finalists to be carried forward in activity 3.

Activity Milestones:

Description	Completion Date
Generation of porosity and film thickness data	2021-12-31
Production of 5x4 matrix (20 samples) of coated fertilizer products required for greenhouse studies.	2022-03-31
Scaled-up production of 3 coated fertilizers products selected for field trials.	2022-05-31
Report on the range of coating properties produced through these methods.	2023-02-28

Activity 2: Characterize coated fertilizer performance in greenhouse conditions.

Activity Budget: $55,000

Activity Description:
The release of plant available nitrogen (N) from coated urea-based fertilizers will be monitored periodically for 60 days after incorporating fertilizer samples into low nitrogen soils. Soils will be sampled at select intervals to track the release of nitrogen into soils over time and will be compared relative to an uncoated fertilizer control and a secondary control of soil with no fertilizer added. Subsequent studies will monitor plant growth using wheat as an indicator plant. Plant growth indices will include plant height, number of tillers, biomass accumulation after 60 days and nitrogen concentration. In addition to monitoring plant growth in these studies, the soils will be monitored at various stages of plant growth (e.g., early vegetative, at flag leaf, soft kernels, and physiological maturity). Soil measurements at these stages will consist of measuring nitrogen in both the form of extractable ammonium and nitrate. All greenhouse studies will use a low N soil as the potting mix, will have at least 4 replicates and be repeated twice.

Activity Milestones:

Description	Completion Date
Generation of nitrogen release vs. time data in soil only for matrix of 20 samples and controls	2022-09-30
Generation of growth index data for wheat in matrix of 20 samples and controls	2022-11-30
Generation of nitrogen release vs. time data in soil with wheat plant growth	2022-11-30

Data interpretation to select 3 samples to be carried forward for field trials	2023-02-28

Activity 3: Demonstrate coated fertilizer performance under field conditions.

Activity Budget: $55,000

Activity Description:

Pilot-scale field testing will assess agronomic crop (wheat) response to surface incorporation of lignin-coated fertilizers (3 varieties) and will be compared to uncoated fertilizer and zero fertilizer addition controls, mimicking the greenhouse studies in a real-world test environment. Crop above ground biomass, nitrogen concentration (vegetative, R1 and grain), nitrogen uptake and yield will serve as plant response indicators. Along with plant response monitoring, soils will also be examined over the course of the plant growth stages. Soil samples will be collected at two depth increments (0-15; 15-30 cm) at the beginning, vegetative, anthesis, and at the end of the growing season, which will be assessed for extractable nitrogen. Plots with low nitrogen availability will be chosen for this phase of the study to more clearly demonstrate causality should trends in plant growth indices or soil nitrogen levels arise. All plot scale treatments will be arranged with a randomized complete block design with four replicates and repeated to provide at least three-site years.

Activity Milestones:

Description	Completion Date
Analysis and summarization of field trials	2023-06-30
Generation of soil nitrogen content data from addition of 3 varieties of coated urea fertilizers	2023-06-30
Generation of plant response data from addition of 3 varieties of coated urea fertilizers	2023-06-30

Project Partners and Collaborators

Name	Organization	Role	Receiving Funds
Dr. Jane Johnson	United States Department of Agriculture	Soil scientist- Dr. Johnson will perform plant and soil assessments at the greenhouse and pilot scale on soils treated with coated fertilizers.	Yes

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 be funded?

One of the deliverables from this project will be to determine a relationship between the coating thickness and the amount of time this delays the release of nitrogen into soils. Once this has been established, future work will focus on generating mixtures of coated fertilizers specific to the needs of different crop species. Another focus will be to examine how regional differences in soils affect the rate of coating degradation and therefore the timing of nitrogen release. To attract funding for these future efforts, we are seeking relationships with fertilizer companies as well as proposals to federal agencies.

Project Manager and Organization Qualifications

Project Manager Name: Brian Barry

Job Title: Chemistry & Materials Science Program Leader

Provide description of the project manager's qualifications to manage the proposed project.

Dr. Barry has a history as principal investigator of funding from various granting agencies (both state and federal) over his career thus far. As such, he has ample experience managing experimental design, personnel and budgets. His background in chemistry & materials science (Ph.D. in chemistry) has been critical to the successful development of formulations for the proof-of-concept experiments which produced results that inspired this proposal submission. He also has a proven track record of fruitful collaborations, which is particularly relevant to this proposal as various expertises (soil scientist e.g.) will need to be pulled together in order to produce quality results.

Organization: U of MN - Duluth - NRRI

Organization Description:

The Natural Resources Research Institute (NRRI) is an applied research organization that works to develop and deliver the understanding and tools needed to utilize our mineral, forest, energy and water resources in a balanced and environmentally responsible manner. NRRI is a unique, multidisciplinary, applied research institute focused on Minnesota's many natural resources. Associated with the University of Minnesota Duluth with research facilities in Duluth and Coleraine, NRRI is a leading research arm of the greater University of Minnesota community. The Institute was created to be an economic development engine for the state. NRRI delivers solutions to allow responsible use of Minnesota's resources, provides information and tools for sound environmental decisions and assists existing and entrepreneurial business and industry evolve and prosper. Ultimately, NRRI is here to collaborate broadly in creating resilient, vital Minnesota communities.

Budget Summary

Category / Name	Subcategory or Type	Description	Purpose	Gen. Ineligible	% Benefits	# FTE	Classified Staff?	$ Amount
Personnel								
Brian Barry (Research Project Specialist 3)		Principal Investigator			26.7%	0.3		$37,480
Eric Singsaas (Research Director 1)		Co-Principal Investigator			26.7%	0.2		$37,885
Oksana Kolomitsyna (Researcher 5)		Coatings formulation and characterization			26.7%	0.4		$30,238
Sergiy Yemets (Researcher 6)		Coatings formulation and characterization			26.7%	0.4		$31,898
							Sub Total	**$137,501**
Contracts and Services								
USDA Agricultural Research Services	Sub award	The USDA ARS will be responsible for performing soil and plant assessments on the bench top and field scale for soils treated with coated fertilizer				2.48		$108,319
							Sub Total	**$108,319**
Equipment, Tools, and Supplies								
	Tools and Supplies	Analytical lab reagents	Purchase of solvents, certified standard samples & instrumentation disposables for characterizing coating films					$1,234
	Tools and Supplies	Solvents, supplies and reagents for scaling up production of coated fertilizer	Purchase of fertilizer, solvent and reagents needed for the generation of coated fertilizer products					$9,135

							Sub Total	**$10,369**
Capital Expenditures								
							Sub Total	**-**
Acquisitions and Stewardship								
							Sub Total	**-**
Travel In Minnesota								
	Miles/ Meals/ Lodging	NRRI personnel visit to ARS in Morris, MN	Collaborative efforts on research design of experiment					$3,428
							Sub Total	**$3,428**
Travel Outside Minnesota								
							Sub Total	**-**
Printing and Publication								
							Sub Total	**-**
Other Expenses								
		Shipping of samples	Shipping of coated fertilizer samples to ARS in Morris, MN					$383
							Sub Total	**$383**
							Grand Total	**$260,000**

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
State				
			State Sub Total	**-**
Non-State				
In-Kind	UMN unrecovered indirect costs are calculated at the UMN negotiated rate for research of 55% modified total direct costs.	Indirect costs are those costs incurred for common or joint objectives that cannot be readily identified with a specific sponsored program or institutional activity. Examples include utilities, building maintenance, clerical salaries, and general supplies. (https://research.umn.edu/units/oca/fa-costs/direct-indirect-costs)	Secured	$45,937
			Non State Sub Total	**$45,937**
			Funds Total	**$45,937**

Attachments

Required Attachments

Visual Component

File: 114517a3-84c.pdf

Alternate Text for Visual Component

Graphic is divided into three sections: Problem, Innovation and Impact. The problem section has a graphic to represent farmland runoff into Minnesota waters causing eutrophication. The Innovation has visuals depicting the transformation of Minnesota forest resources into a coated fertilizer product. Lastly, the Impact section lists the economic and environmental benefits this solution offers the state of Minnesota.

Optional Attachments

Support Letter or Other

Title	File
Sponsored Projects Transmittal Letter	66b1e407-3eb.pdf
Letter of Collaboration-Jane Johnson USDA	2a9fe89b-5c7.pdf

Administrative Use

Does your project include restoration or acquisition of land rights?

No

Does your project have patent, royalties, or revenue potential?

Yes,

- Potential revenue generated or net income from the sale of products or assets developed or acquired with ENRTF funding
- Patent, Copyright, or Royalty Potential

Does your project include research?

Yes

Does the organization have a fiscal agent for this project?

Yes, Sponsored Projects Administration

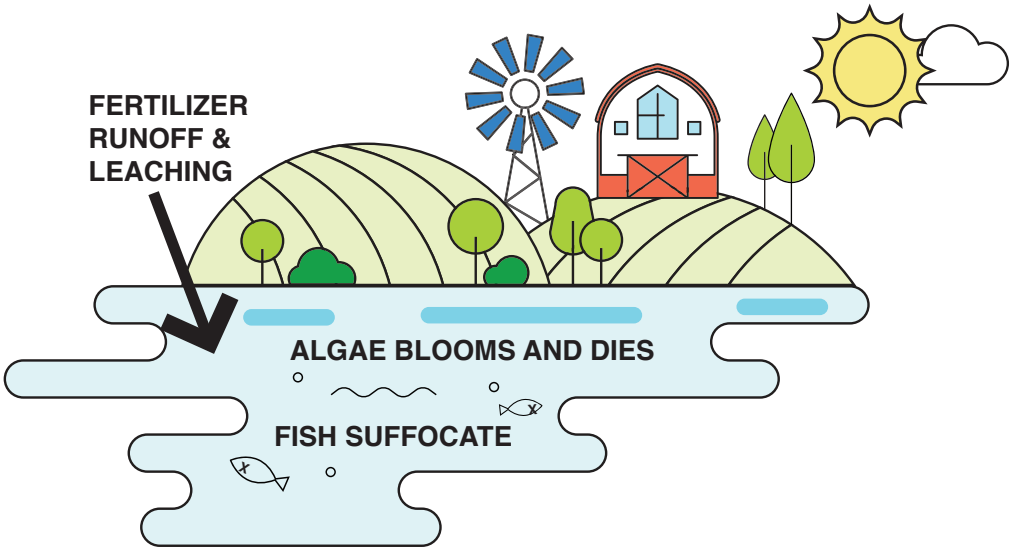
Natural Resources Research Institute
University of Minnesota Duluth
Driven to Discover

PROJECT DESCRIPTION:

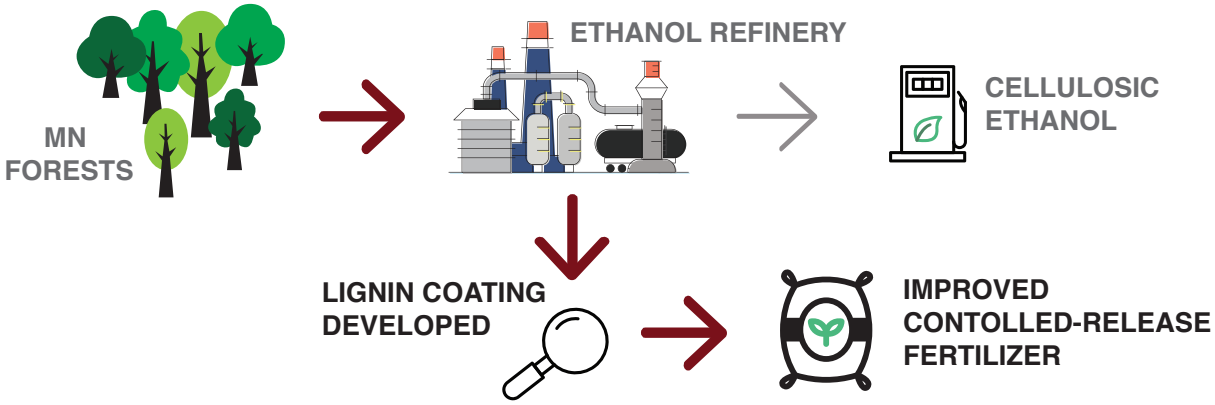
Biodegradable fertilizer coating designed to slow runoff, improve water quality and eliminate environmental microplastic introductions.

Problem: Eutrophication

Due to fertilizer runoff MN lakes and streams are overloaded with nitrogen (nitrates).



Innovation: Biodegradable coating for fertilizer slows runoff



Impact: Reduces fertilizer runoff, directly impacts MN water quality. Replaces non-biodegradable, plastic coatings with natural wood-based product.

- Utilizes a natural byproduct made by Minnesota biorefineries
- Empowers fertilizer applicators to use less overall fertilizer
- Reduces non-biodegradable microplastics in environment
- Addresses Minnesota's environmental need to reduce fertilizer runoff
- Agricultural application process remains the same

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