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Application Summary

Competition Details

Competition Title:	2025 South Dakota Nutrient Research and Education Council Invited Proposals
Category:	SDAES
Cycle:	2025
Submission Deadline:	10/15/2024 5:00 PM

Application Information

Application Title:	Evaluating Selected Soil Health Indices for Predicting Nitrogen Fertilizer Requirement for Winter Wheat in Western South Dakota (Year 3)
Application ID:	3443
Submission Date:	10/9/2024 5:14 PM

Personal Details

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Application Details

Proposal Title

Evaluating Selected Soil Health Indices for Predicting Nitrogen Fertilizer Requirement for Winter Wheat in Western South Dakota (Year 3)

Proposal Abstract

Efficient nitrogen (N) use provides an opportunity to boost profitability of a farm. Several soil health tests are proven to indicate availability of soil nitrate-N to the crop, thus can potentially aid to revise N requirements for winter wheat. This study will evaluate if integration of these soil health tests in the standard N recommendation module will economically benefit wheat growers in Western South Dakota. The funding requested is for the continuation of funding for year 3 (final year) of the project.

2025 Total Budget Request

51,257

Acknowledgment

Acknowledgement of Terms and Conditions

[Acknowledged] I have read and agree to abide by the South Dakota Nutrient Research and Education Council Terms and Conditions attached to this RFP.

Title: Evaluating Selected Soil Health Indices for Predicting Nitrogen Fertilizer Requirement for Winter Wheat in Western South Dakota (Year 3)

PI and Collaborators

Principle Investigator: Christopher Graham, West River Research Farm Manager, Department of Agronomy, Horticulture, and Plant Science, South Dakota State University, christopher.graham@sdstate.edu, (605) 394-2236

Co-PI: Shyam Solanki, Research Associate III, Department of Agronomy, Horticulture, and Plant Science, South Dakota State University, shyam.solanki@sdstate.edu, (605) 688-5032

Summary: Efficient nitrogen (N) use provides an opportunity to boost profitability of a farm. Several soil health tests are proven to indicate availability of soil nitrate-N to the crop, thus can potentially aid to revise N requirements for winter wheat. This study will evaluate if integration of these soil health tests in the standard N recommendation module will economically benefit wheat growers in Western South Dakota. The funding requested is for the continuation of funding for year 3 (final year) of the project.

Goals and Objectives:

The primary goal of this research is to update fertilizer nitrogen (N) recommendations for winter wheat under dryland conditions by predicting crop available N status in soil using selected soil health indices (SHIs). The specific objectives of this project are:

1. Measuring SHIs such as soil protein (Acid Citrate Extractable Protein or ACE Protein), potentially mineralizable nitrogen (PMN), soil nitrate-N, soil organic N (SON), soil organic matter (SOM), soil carbon-nitrogen ratio (C:N), soil enzymes related to carbon (C) and N-cycle (beta-glucosidase, beta-glucosaminidase) and soil organic N mineralization genes as predictive tools for crop-available N before and during the cropping season.
2. Evaluating how SHIs, crop stress indicators (CSIs) such as proline (osmolyte generated during drought stress), chlorophyll content, and leaf-area index (LAI) at 'Feekes 9' (F9) growth stage (anthesis) affect nitrogen use efficiency.
3. Assess how overall soil health influences crop N requirement
4. Correlating SHIs to CSIs and economic yield to revise the fertilizer N rate recommendation for winter wheat (*Triticum aestivum* L.)

Justification Statement:

Nitrogen is the single most expensive input in crop production systems (Robertson and Vitousek, 2007) and excess N (water soluble nitrate-N) in soil, leaches down to the groundwater and other water bodies polluting and disturbing the agroecosystem. Therefore, modern agriculture must economize the use of fertilizer N through efficient utilization by the crops and effective regulation of the rate and time of N application. To determine the N requirement for a cash crop, generally soil nitrate-N, the inorganic, water-soluble form of N, is considered. But in reality, organic N sources can significantly contribute to crop N availability (Drinkwater, 1997). We believe that unless we consider N availability from these organic sources during the growing season, we cannot manage N efficiently, supporting many published research on efficient N management (Drinkwater 1997; Hurisso et al. 2018; Jilling 2018).

Soil health, defined as the ability of the soil to perform its functions, influences the release of N from organic sources into a crop available form. The healthier the soil, the larger the nutrient reserve, the higher the microbial activities, the easier the N release from organic compounds. This project is designed to evaluate if the fertilizer N requirement for wheat can be determined more precisely considering the levels of several soil health indicators such as ACE Protein, PMN, SON, soil C: N, C and N-cycle enzymes and soil N-cycle genes that regulate N dynamics in soil and determine how much N will potentially be available to the winter wheat crop. Outcomes of this project will indicate if a different soil parameter or set of parameters should be considered while calculating fertilizer N requirements for wheat in addition to or in place of soil nitrate-N. This project will also analyze how different parameters regulating soil available N are correlated among themselves to formulate a practical understanding of these attributes.

Additionally, when starved for N, crops show stress symptoms that are connected with N metabolism in the plant system. By studying crop stress indicators (CSIs) that are established and accepted by most researchers, we can fine tune crop N need and eventually reduce N application rate, saving excess N from polluting environment. Additionally, this project will also provide essential information on how different SHIs and CSIs are correlated, and are impacted by N fertilization schemes.

Work Plan:

Experimental Plan and Layout

This will be the third year of field trials at two different locations in western SD, one location is at the SDSU West River Research farm located near Sturgis and the other in a winter wheat grower's field near Wall. The first two years of winter wheat plots were planted in September and harvested in July. Figure 1 and 2 show the average yields at increasing N rates from each site. Interestingly, both sites in Year 1 had an average pre-plant soil N of 54 lbs/ac in the top 24." However, the Sturgis site required less N than Wall to achieve maximum site yield (~40 lbs N/ac at Sturgis vs 95 lbs N/ac at Wall) with significantly higher overall yields. The Sturgis site also had much higher ACE-Protein levels, which suggests that this soil was able to utilize soil N more effectively, hence requiring less applied fertilizer. These are the types of correlations that we hope to build on and incorporate to improve our N recommendations after multiple years of study.

In 2024, unfortunately we lost our Wall site due to a cooperator error in spraying herbicide. At Sturgis, however, we did not see a significant yield increase with increasing N rates as in the previous year (Figure 2). Starting soil N was much higher at ~90 lbs N/ac, which is a large factor in the small yield increase. This site provides valuable data to compare soil N supply to other more responsive sites using the new soil health parameters.

This proposal is for the third season of this trial. The same winter wheat variety will be fertilized with the same four N rates i) 0 lbs. N/acre (Control), ii) 50 lbs. N/acre, iii) 100 lbs. N/acre and iv) 150 lbs. N/acre with each N rate treatment replicated four times in a randomized complete block design (RCBD).

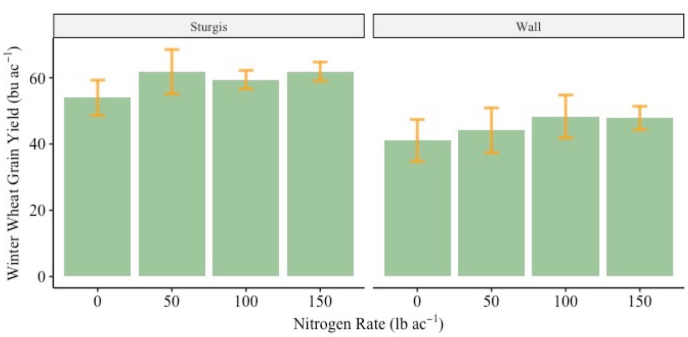

Figure 1. Winter wheat grain yield at increasing N fertilizer rates for 2023 (Year 1).

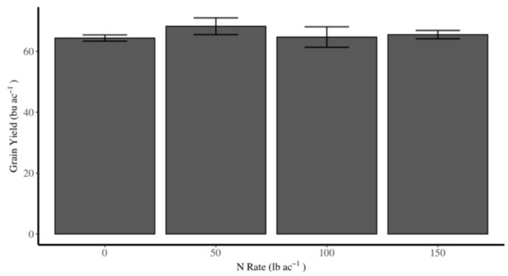

Figure 2. Winter wheat yield for the Sturgis location in Year 2 (2024)

Soil and Plant Tissue Sampling Protocol

Similar to the previous years, composite soil samples will be collected from each field plot, i) before winter wheat planting, ii) at the jointing growth stage, and iii) after wheat harvest for subsequent analysis in the lab. Soil samples will be analyzed for ACE-protein, soil enzymes, soil microbial genes, PMN, and POXC in the SDSU lab, while the rest of the soil tests will be sent to a commercial lab for analyses. 0-24" soil profile core will be collected using a hydraulic soil probe and will be divided into 0-6" and 6-24" soil profile samples. For soil nitrate-N, we will analyze both soil profiles, but for soil health indicators we will use only 0-6" samples. Soil samples will be air-dried and sieved for chemical analyses. Soil health assays will be performed using the protocols reported in the Comprehensive Assessment of Soil Health (CASH) published by Cornell University Moebius-Clune et al. (2016).

The youngest fully mature wheat leaves from each field plot will be collected for measuring proline levels in our lab at F9 (flowering) growth stage. The leaves will be dipped into liquid nitrogen, crushed using pestle and mortar, and then collected in collection tubes. The proline content will be measured using the protocol reported by Woodrow et al. (2017). Chlorophyll content and leaf area index (LAI) will be determined from wheat canopies at F9 growth stage. These measurements will serve as stress indicators to help elucidate if the SHI's are still valuable across a range of stress levels. The wheat crop will be harvested for grain yield and quality (protein content) at harvest maturity stage.

Extension and Outreach

Significant outcomes of this project are continuously shared with growers and other stakeholders in western SD through extension meetings, publications, and conference presentations. Preliminary findings have been shared each year with farmers at the West River Research Farm tour. Combined findings from the 2023 and 2024 seasons will be presented this winter at the SDSU Crop Hour discussions. Research articles will also be published in peer-reviewed journals explaining major outcomes from this project. The value to the farmer from this project is that these data will take various "soil health" tests that are currently available to farmers and integrate them with the current standard nitrate test to evaluate whether these tests add economic value to wheat production in South Dakota.

Potential Impacts:

- Better judgement on N availability to the wheat crop throughout the season
- Economized and efficient N fertilizer application potential profitability for wheat growers
- Validate the effectiveness of soil health assays in N fertilizer recommendation
- A modified equation predicting optimum N fertilizer rates for Winter Wheat
- Adjusted timing of N fertilizer application to facilitate N availability at critical growth stages
- Minimized nitrate pollution from excess N fertilizer application and better water quality
- Healthier environment and healthier product

Project Timeline: This project will hopefully span three winter wheat growing seasons, 2022-23, 2023-24 and 2024-25 to provide robust comments on the research outcomes. Please see the table for detailed timeline for the third winter-wheat season.

Table 1. Timeline for the third winter-wheat season (2024-25)

Project activities per quarter of a year	**2024**		**2025**		
	Jul-Sep	Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sep
Selecting potential field locations	***				
Designing experimental layout	***				
Starter N application		***			
Top-dressing of N			***		
Soil and Plant Tissue sampling		**		***	***
Winter wheat planting	*	***			
Winter wheat harvest					***
Laboratory analyses			***	***	***
Data analysis			**	**	***
Outreach activities				*	**

Number of asterisks (*) shows the intensity of effort during the specific months in a year

Project Budget: A total of $51,257 is requested in year 3 (2025). This will cover the graduate student and research technician funding; charges for acreage for the site, planting, and harvesting; soil and plant sampling and analysis; supplies needed to conduct the analyses, and travel. Please see the following table for details:

Budget Justification: Evaluating Selected Soil Health Indices for Predicting Nitrogen Fertilizer Requirement for 2025.

Second Year (2024)		
Categories	**Cost**	**Description**
Salaries and Wages total	**$22,169**	
Graduate Assistant	$20,411	Salary for graduate assistant who will coordinate the fieldwork and sampling for this project
Intern Salary	$1,550	Salary for interns who will help in sampling and processing soil, plant tissue, and residue samples. They will also help in running field trials and soil health tests in the lab.
Fringe benefit	$208	Fringe benefit for interns
Travel (Domestic) Total	**$2,136**	This cost is for travels to the research plots, NREC meetings and to present findings at one regional conference.
Other Direct Costs Total	**$26,952**	
Materials and Supplies	$12,140	Cost for lab supplies, reagents, equipment, bags, and other consumables Please see table 2 for details.
Contractual	$6,750	
Tuition Remission	$8,062	
2024-25 total	**$51,257**	

Table 2. Material and supply costs

Tests/Assays	Number of samples	Cost/sample ($)	Total Cost ($)
Potentially Mineralizable N	150	20	3000
ACE Protein (in-house)	150	20	1500
Extracellular Soil Enzymes*	225	20	4500
Nutrient Analysis	75	30	2250
Proline assay (in-house)	24	20	480
Soil gene expression (in-house)	150	20	3000
Other Supplies: Seeds, Tracer Fertilizer, Plant Protection Chemicals, Fuel, Machine Parts and Repairs			4160
18,890			

*we will study two different enzymes

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