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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:	How does nitrogen fertilizer and no-tillage impact the soil health of hard winter wheat in South Dakota? (Locations in SD: Winner; Dakota Lakes Research Farm (DLRF) Pierre; Brookings)
Application ID:	3455
Submission Date:	10/14/2024 4:09 PM

Personal Details

Applicant First Name:	Keerthi
Applicant Last Name:	Mandyam
Applicant Degree(s):	PhD
Email Address:	Keerthi.Mandyam@sdstate.edu
Phone Number:	(605) 688-5590
Primary Organization:	South Dakota State University
Primary Appointment Title:	Associate Professor
Contact Person's Name:	
Contact Person's Email Address:	
Contact Person's Phone Number:	

Co-Applicant(s)

Name	Email	Affiliation
Sunish Sehgal	Sunish.Sehgal@sdstate.edu	South Dakota State University

Application Details

Proposal Title

How does nitrogen fertilizer and no-tillage impact the soil health of hard winter wheat in South Dakota? (Locations in SD: Winner; Dakota Lakes Research Farm (DLRF) Pierre; Brookings)

Proposal Abstract

The SDSU hard winter wheat variety trials are conducted under 0N and 150N fertilization under long-term (20+years) no-tillage (regenerative agriculture practice) at Pierre and Winner, and with tillage at Brookings, SD, respectively. In the 2023 trial, 29 wheat varieties (including high-yielding varieties tested for over 5+ years like SD Andes, SY Wolverine, and Winner) were evaluated. These trials report agronomic characteristics, grain quality, and disease ratings. Soil health and the beneficial root colonizing arbuscular mycorrhizal fungal (AMF) colonization (which contributes to soil health) are not quantified. Regenerative agriculture positively impacts both soil health and AMF. So, the aim of this study is to quantify the soil health and root AMF at heading and harvest stage for six high-yielding varieties from three locations under nitrogen amendment and their inter-annual variation. The outcomes are expected to help understand the soil health metrics associated with released high-yielding hard winter wheat.

2025 Total Budget Request

19,040

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.

2025 SD NREC Proposal

Title: ***How does nitrogen fertilizer and no-tillage impact the soil health of hard winter wheat in South Dakota?*** (Locations in SD: Winner; Dakota Lakes Research Farm (DLRF) Pierre; Brookings)

PI: Dr. Keerthi Mandyam (Associate Professor, Soil and Plant Microbiology and Soil Health), Agronomy, Horticulture and Plant Science (AHPS), South Dakota State University (SDSU), Brookings, 57007; email: Keerthi.mandyam@sdstate.edu; Phone: 605-688-5590 (Office)

Co-PI: Dr. Sunish Sehgal (Associate Professor and Winter Wheat Breeder), AHPS, SDSU, Brookings, 57007

Summary: The SDSU winter wheat variety trials are conducted under no-tillage and with and without N fertilizer (0N and 150N) at Pierre and Winner, SD, and with tillage at Brookings, SD. The long-term (20+ years) no-till cultivation of wheat at Winner and Pierre (DLRF) is a regenerative agricultural practice and is expected to positively impact soil health. Root colonizing arbuscular mycorrhizal fungi (AMF) are obligate mutualists found in 80% of land plants including wheat and benefit the host plants by facilitating P, N, and K uptake. Additionally, they promote plant health and improve plant tolerance to biotic (pathogens) and abiotic (drought and heat) stressors. AMF mycelium or biomass in the soil is a carbon sink as plants globally allocate 1.07Gt of carbon to AMF mycelium. Interestingly, global terrestrial plant C accounting for 1/3rd of global anthropogenic CO_2 emissions is allocated to the mycorrhizal mycelium in soils. Nitrogen fertilization and agricultural intensive practices are known to reduce plant dependence on AMF, in turn reducing the AMF contribution to soil nutrient dynamics. The SDSU winter wheat variety trials conducted under no-tillage and different N rates provide the opportunity to quantify both the wheat soil health and root AMF. The winter wheat variety trials conducted annually by the winter wheat breeding program and the SDSU Agriculture Extension https://extension.sdstate.edu/sites/default/files/2023-08/S-0002-2023-01-WW-Regional%20Summaries.pdf evaluates varieties for agronomic characteristics (relative heading, height, lodging and winter hardiness), grain quality (yield, protein and baking quality) and disease ratings (stripe rust, stem rust, leaf rust, wheat streak mosaic virus, tan spot, bacterial leaf streak and Fusarium Head Blight). Soil health and root AMF of wheat varieties will provide additional vital insights into varietal performance.

Goals and Objectives: This proposal addresses the 2025 SD NREC topic of *"Research and update NPK fertilizer recommendation in no-till crop production system of small grains (Wheat)"*. The overarching goal of this project is to evaluate the soil health and AMF associated with six widely grown winter wheat varieties that are also evaluated in regional variety trials. The objectives are

1. To test and compare the soil health of six winter wheat varieties from three SD locations over two years under 0N and 150N.
2. To compare the AMF root colonization of six winter wheat varieties from three SD locations over two years under 0N and 150N.

Justification Statement: The overall root AMF data from heading stage of six released wheat varieties collected in May 2024 showed that the AMF colonization varied by locations: AMF was significantly higher in both Winner and Pierre compared to Brookings; but Winner and Pierre were not different. Overall, from three locations, varieties *SY Wolverine* and *Winner* under 0N showed significantly higher AMF than under 150N whereas other varieties showed no significant AMF differences under 0N and 150N. Within each location, AMF under 0N and 150N for *SY Wolverine* was significantly higher only in Brookings and Pierre but not in Winner, whereas the variety *Winner* under 0N and 150N was significantly different only in location Winner (**Figure 1**). Overall, the top two highest AMF root colonization under 0N of 67% and 62% was seen in variety *Winner* and variety *SY Wolverine* respectively, and the least colonization of 14% and13% were seen in variety *SD Andes* and *SD Pheasant*, respectively. Within the locations, under 0N variety *Winner* had the highest AMF colonization of 72% in Winner and Pierre, whereas *SY Wolverine* had the highest AMF colonization of 68% in Pierre (**Figure 1**). Expanding the AMF quantification under harvest stage coupled with soil health assessment is expected to provide supplementary data that could be considered in future breeding programs. The impact of regenerative practice of no-tillage and N fertilizer on soil health can be quantified and potential environmental benefits accrued can be postulated for subsequent investigations. Long-term soil health benefits of regenerative practice and specific variety interaction with AMF and its outcomes need to be communicated to the producers.

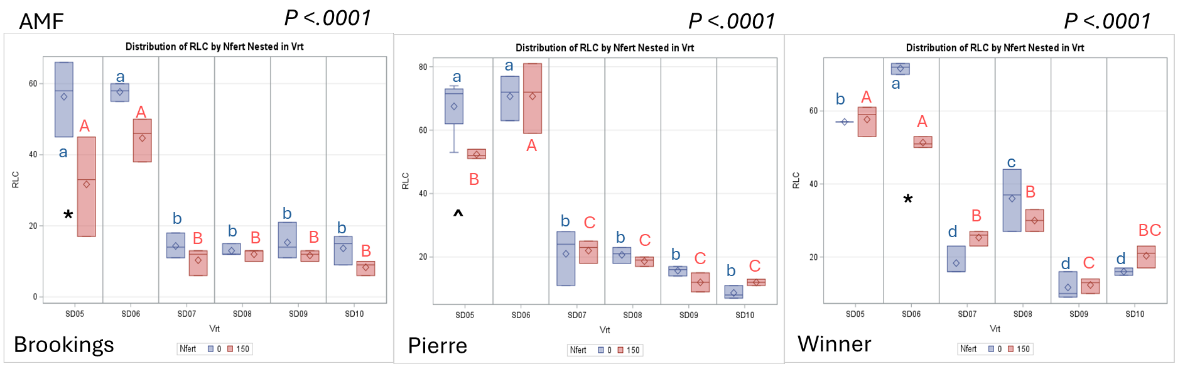

*Figure 1 Arbuscular mycorrhizal fungi (AMF) in wheat varieties at heading stage under 0N and 150N. Data from May 2024. Significance set at P=0.05. Blue=0N, Red= 150N. Varieties: SD05= SY Wolverine, SD06=Winner; SD07=AP Clair; SD08=LSC Chrome; SD09=SD Andes; SD10=SD Pheasant. * significant difference between 0N and 150N for a variety. Significance set at P=0.05; Treatments are significant if they do not share a letter. ^ significant difference between 0N and 150N for a variety P>0.05 < 0.1.*

Work Plan:

Objective 1: *To test and compare the soil health of six winter wheat varieties from three SD locations over two years under 0N and 150N.*

Soil samples and wheat roots of six winter wheat varieties (*AP Clair*, *LCS Chrome*, *SD Andes*, *SD Pheasant*, *SY Wolverine* and *Winner*) cultivated at three SD locations [Brookings (Eastern Trial location) and Pierre and Winner (Central Trial Location)] will be collected at two time points (heading and harvest) in years 2025 and 2026. The total number of samples = 6 varieties × 3 blocks × 2 N treatments × 2 stages × 3 locations × 2 years = 432. The soil samples will be air dried, sieved with 2mm sieve, and subjected to soil health assessment.

The Soil Health Assessment (SHA) includes the following tests namely, 1:1 pH, 1:1 soluble salts, organic matter (OM) %LOI, WDRF Buffer pH, Water Extract of total organic carbon, organic nitrogen, total nitrogen, ammonium and nitrate N; soil tests like P, K, S and micronutrients like Zn, Fe, Mn, Cu, Ca, Mg, Na), soil respiration CO_2-C (also known as C_{min} or 24h potentially mineralizable C), % microbially active carbon (MAC), organic C: organic N, organic N release, organic N reserve and % water stable aggregates (WSA). The soil analyses will be carried out by Ward Labs (Kearney, NE). A published study in 2023 by Bagnall et al. from Soil Health Institute utilizing 2032 experimental units across North American long-term agriculture found that the soil organic carbon concentration, 24h potential carbon mineralization or C_{min} and the soil aggregate stability were the most effective soil health indicators responsive to agricultural management practices including tillage, reflecting soil health rather than inherent soil properties; and capable of linking soil functions to ecosystem

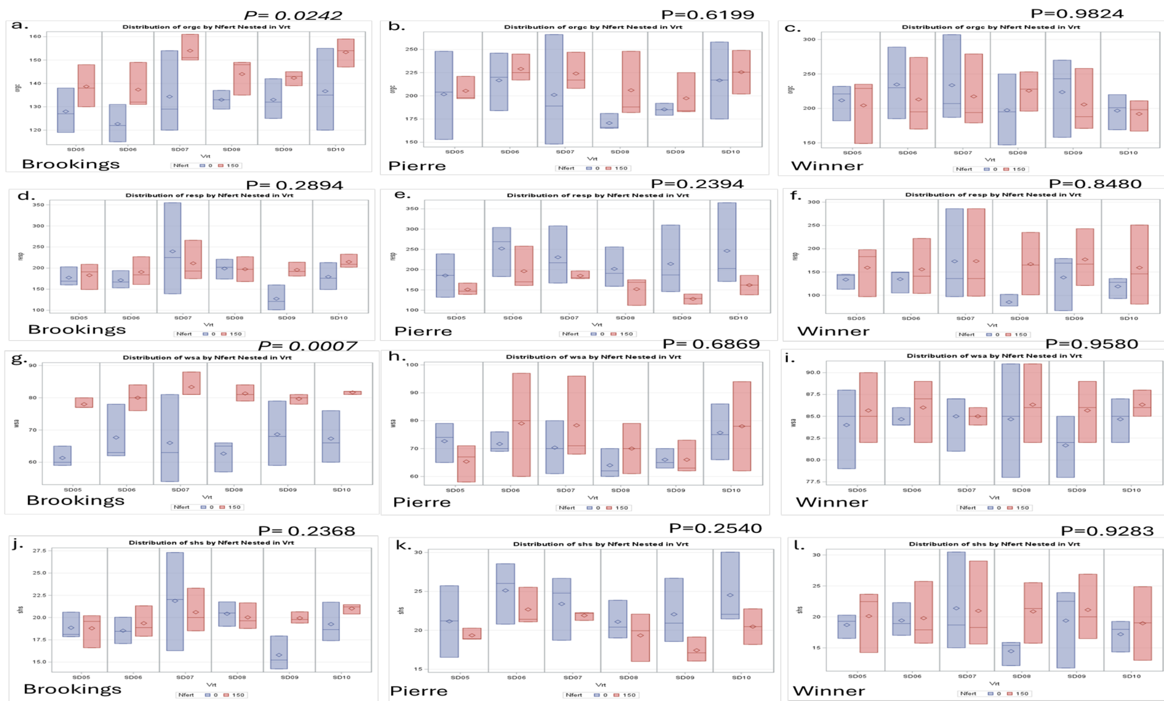

Figure 2 Soil Health Assessment of six wheat varieties at harvest from three locations in 2024. a-c. Water extractable Organic Carbon (WEOC) ppm C; d-f. soil respiration or C $_{min}$ ppm CO_2-C; g-i. Water stable aggregates %; j-l. Soil health score. Significance set at P=0.05. Blue=0N, Red= 150N. Varieties: SD05= SY Wolverine, SD06=Winner; SD07=AP Clair; SD08=LSC Chrome; SD09=SD Andes; SD10=SD Pheasant.

services. Another publication in 2023 from the same team (Liptzin et al.) showed that C $_{min}$ and soil organic carbon could be used as a proxy for N cycling. Utilizing these minimum soil health indicators responsive to North American agriculture practices, SHA test incorporates two biological tests (C $_{min}$ or microbial respiration, water extractable C and N with calculation of % microbially active carbon (%MAC)), one chemical (macro and micronutrients), and one physical test (modified water stable aggregates test). A soil health score (**Figure 2 j-l**) can be calculated from the soil respiration, water extractable organic carbon (WEOC), water extractable organic nitrogen (WEON) and the C:N ratio, and this can serve as a quick reference regrading soil health comparisons of different management systems. This score usually ranges from 0-50 with most soils not scoring higher than 30. **Figure 2** provides a comparison of the soil organic carbon concentration, 24h potential carbon mineralization or C $_{min}$, the soil water aggregate stability and soil health score of the six varieties from harvest in 2024. The soil health scores, and C $_{min}$ were not significantly different for locations but was numerically the highest for Pierre followed by Brookings and followed by Winner. <u>The soil health score for all six varieties was consistently the highest in Pierre for 0N. The highest score of 25 was seen for varieties *Winner* and *SD Pheasant* (**Figure 2k**)</u>. However, the organic carbon and water stable aggregates were significantly different with Winner highest for both compared to Pierre and Brookings. Collecting data for the six varieties in 2025 and 2026 is vital to ascertain inter-annual variation in soil health as impacted by annual environmental variation. Also, ascertaining soil health at heading and harvest will help capture any changes in soil health as impacted by wheat physiology.

Objective 2: *To compare the AMF root colonization of six winter wheat varieties from three SD locations over two years under 0N and 150N.*

Wheat root samples collected during heading and harvest will be cleaned in water, cut into 1-cm pieces, cleared with potassium hydroxide, stained with trypan blue and percent root length colonized (%RLC) by AMF will be quantified by microscopy. The total number of samples = 6 varieties × 3 blocks × 2 N treatments × 2 stages × 3 locations × 2 years = 432. Statistical analysis will be carried out using statistical analysis software (SAS, 9.4 version) to discern if the soil health properties and wheat mycorrhiza are impacted by location, N treatment, varieties, plant stage, and their interactions. Correlation regression analysis will be carried out to discern if the root mycorrhiza are driven by the soil N, P, and K. Principal component analysis (PCA) of the dataset will be carried out to understand the principal drivers of wheat soil health.

Plans to communicate results to stakeholders: The data will be presented annually at conferences like the Tri-society annual meetings; winter wheat workers workshop; U.S. Wheat Associates and National Association of Wheat Growers, etc. The data will be presented at the SDSU Annual field days at the three locations. Peer-reviewed journal articles when published will be shared.

Potential Impacts: The anticipated impacts of this study are listed below: (1) ***New data will be collected to augment plant and yield data from hard winter wheat annual field trials.*** The soil health data and wheat mycorrhizal colonization data under regenerative practice of long-term no-tillage has not been recorded and reported for the wheat varieties released by the SD State Hard Winter Wheat (HWW) Breeding Program. Since these varieties offering a combination of high yield and resistance to biotic stress and/or abiotic stress occupy nearly 40% of wheat acres in South Dakota, it is vital to ascertain their impact on soil health and their mycorrhizal colonization. A multi-year study will help capture soil health under annual environmental variation. The resultant data can potentially be utilized in ongoing breeding efforts to further improve yield and plant resistance to environmental and pathogen stress. (2) ***Wheat yield, Nitrogen fertilization, and Soil health evaluated collectively to make informed decisions.*** Soil health data under 0N and 150N will help quantify the impact of fertilization on soil health in a no-tillage system. Questions this study will help address are *Can wheat yield significantly increase by Nitrogen amendment without negative impact on soil health under a long-term no tillage system? Among the high yielding varieties, which varieties are accompanied by better soil health scores, and finally how are these scores impacted by locations?*

Timeline: The root AMF and soil health data will be collected for two years (2025 and 2026) to account for any possible environmental impact. Soil and root samples will be collected during heading and harvest (May through July).

Project Budget: The estimated budget for two years is outlined in **Table 1**.

Table 1 Proposed project Budget

	Year 1	Year 2	Total
Soil analysis	$ 14,040.00	$ 14,040.00	$ 28,080.00
Consumables	$ 1,500.00	$ 1,500.00	$ 3,000.00
Shipping	$ 500.00	$ 500.00	$ 1,000.00
Travel	$ 3,000.00	$ 3,000.00	$ 6,000.00
Total	**$ 19,040.00**	**$ 19,040.00**	**$ 38,080.00**

Budget Justification: Soil analysis: 6 varieties × 3 blocks × 2 N treatments × 2 stages × 3 locations × 2 years × $65.00/sample=$28,080. Consumables: Sieve, paper bags, Ziplock bags, chemicals, glassware, boxes, tissue cassettes, etc. Shipping: Shipping of soil samples to Ward Labs Inc. (Kearney, NE). Domestic Travel: Travel of graduate student and PI to the Tri-society annual conference in 2025 and 2026. A graduate research assistant stipend ($20,000/year) will be covered by SD State, so only operational funds are requested.