



2025 Research Report



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2025 NDSC Research Report – Leader Letter

Meeting Today’s Challenges, Preparing for Tomorrow

Soybeans remain North Dakota’s leading crop, forming the foundation of the state’s agricultural economy and supporting farm income, rural employment, and community growth. Through the farmer-funded soybean checkoff, decades of research and innovation have transformed the crop from a regional specialty into a statewide economic driver, now grown across the state from the Red River Valley to western North Dakota.

2025 has presented significant challenges for soybean farmers. Extreme weather events, including late frosts, summer storms, hail, and variable rainfall, affected production across the state. Producers also faced market pressures from low commodity prices, limited market access, and high production costs, all of which eroded profitability. These challenges underscore the importance of farmer checkoff investments in research, innovation, and education, which provide practical tools and information to help farmers manage risk and stay productive.

The North Dakota Soybean Council invests farmer checkoff dollars in a broad range of programs and projects to address these challenges. Investments in the NDSU Public

Soybean Breeding Program, Integrated Pest Management, cover crops, soil health, livestock production, agronomy, and precision agriculture provide farmers with locally adapted varieties and tools for managing weeds, diseases, and environmental stresses. Checkoff-funded research partnerships with regional and national organizations leverage funding and expertise to strengthen long-term success. NDSC also uses checkoff resources to invest in new uses research, developing innovative products from soybeans and their by-products, adding value,

expanding markets for North Dakota soybeans, and supporting the state’s agricultural economy.

Looking ahead, continued farmer checkoff support for research, innovation, and market development is critical to sustaining North Dakota’s soybean industry. By combining strong research, practical tools, and strategic market development, made possible through the soybean checkoff, the NDSC and its partners are helping ensure a resilient and competitive soybean industry for North Dakota.



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Agricultural Solutions

Kristi Jean, New Uses Consultant

Hans Kandel, Ph. D., Research
Consultant

On The Cover

Pictured from left to right are Carlos Pires, Ph.D., Assistant Professor and Extension Soil Health Specialist; Ana Carcedo, Ph.D., Extension Agronomist for Broadleaf Crops; Wade Webster, Ph.D., Assistant Professor and Extension Soybean Pathologist; Brady Goettl, Ph.D., Assistant Professor of Soil Science and Extension Soil Science Specialist; and Lindsay Malone, Ph.D., Assistant Professor of Conservation Agronomy.

These early-career researchers and Extension specialists represent the next generation of soybean research and outreach in North Dakota. Their work focuses on advancing soybean production through research in soil health, conservation agronomy, nutrient management, and integrated pest management systems. Through applied field research and grower-focused Extension, this team is delivering practical, science-based solutions that support soybean productivity, sustainability, and long-term profitability for North Dakota farmers.

Determining the Optimum Irrigation Amount and Timing for Enhanced Soybean Yield, Quality, Water Productivity and Soil Health in Semiarid Western North Dakota

Principal Investigator: Gautam Pradhan, Ph.D., North Dakota State University (NDSU) Williston Research Extension Center

Funded Project
\$26,200

Importance to North Dakota Soybean Farmers

Water availability is an increasing challenge for soybean farming in western North Dakota. Farmers face more pressure to conserve water while maintaining healthy crops. This project demonstrates exactly when soybeans need water. By understanding the key times to irrigate, farmers can reduce water use without affecting their harvest or seed quality.

Research Conducted

In summer 2024, a soybean field study was conducted at the Nesson Valley Irrigation Research Site near Ray, North Dakota. Some plots were fully irrigated; some plots received no irrigation (rainfed); and others had water withheld during specific growth stages, such as vegetative (V), flowering (F), pod development (P), seed filling (S), maturity (M), and combinations of these stages. Drones were used during the season to monitor plant growth and to look for signs of stress.



Figure 3. A researcher operates a drone to capture aerial images of soybean fields during the irrigation study in western North Dakota (08-08-2024).

Findings of the Research

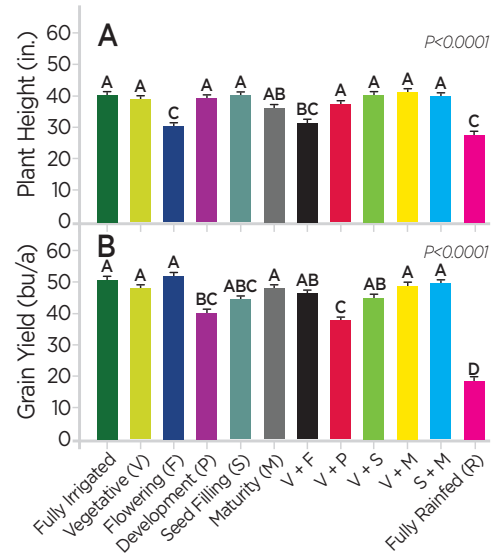
Research results showed that pod development is the most critical period for irrigation. Skipping irrigation during this stage caused a yield drop up to 26%. Soybeans tolerated limited water during the flowering or maturity stages, with yields comparable to full irrigation. Rainfed soybeans had the lowest yields and the shortest plants, producing about 63% less yield than fully irrigated plots. This finding highlights the need for some irrigation during dry years.

The grain's protein and oil levels varied with the timing of water stress: the protein was highest when seeds were small due to stress at seed filling, and oil increased when the stress occurred during pod development. Drone imagery effectively detected plant stress and can help improve irrigation decisions.

Benefits for North Dakota Soybean Farmers and the Industry

Farmers should focus on irrigation during pod development when the soybeans are most sensitive to water stress. Deficit irrigation during flowering or maturity can help conserve water with a minimal effect on yield. Use drone technology to monitor crop health and to make timely irrigation

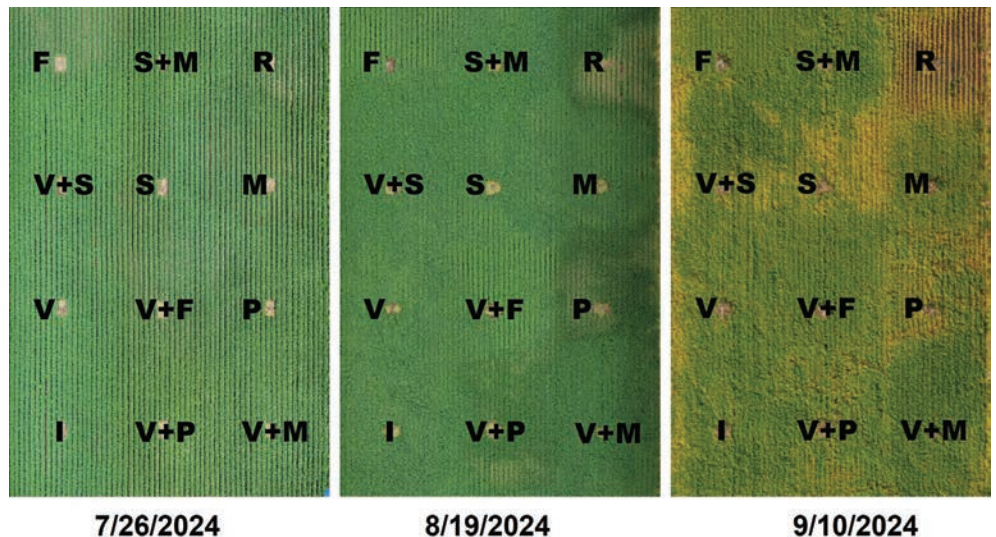
Figure 1. Effects of different irrigation schedules on the soybean's plant height and grain yield in western North Dakota.



Irrigation Treatment (withholding irrigation at different growth stages)

decisions. These findings can assist North Dakota farmers to grow soybeans more efficiently, saving water and staying profitable.

Figure 2. Aerial drone photo showing how withholding irrigation at different stages affected soybean development in western North Dakota.



Characterization of Microbes in the Suppressive Field Soil Against Soybean Cyst Nematode in North Dakota

Principal Investigator: Guiping Yan, Ph.D., North Dakota State University (NDSU) Department of Plant Pathology

Funded Project
\$26,230

Why this Research is Important to North Dakota Soybean Farmers

Soybean cyst nematode (SCN) is one of the most damaging pathogens for soybeans in North Dakota. Its infestation is growing throughout the state. There are management options, such as crop rotation and the use of resistant varieties, but they have limitations. Finding an alternative way with a biological approach such as suppressive soil could be an option for sustainable SCN management.

Research Conducted

This study was conducted to verify the suppressive soil from soybean fields in North Dakota and to characterize the microbes present in those soils. Soils from four fields were collected, including SCN-suppressive Fields 2 and 3 as well as non-suppressive Fields 1 and 4, based on our previous research. Greenhouse experiments, with the susceptible soybean variety 'Barnes', were done to verify the previous results for the suppressive soil using four treatments each in four replications. By sequencing the amplicons of bacteria and fungi, we characterized the microbes with potential biocontrol properties in the soybean's rhizosphere in the suppressive soils as compared to two other conducive soils.

Figure 1. Reproduction factor for SCN in two suppressive field soils from the growth-chamber experiments. A and B represent Field 2 (ID- HG 64) and Field 3 (HG 21-2A). The reproduction factor is the ratio of the soil's final SCN density to the initial SCN density in the experiment.

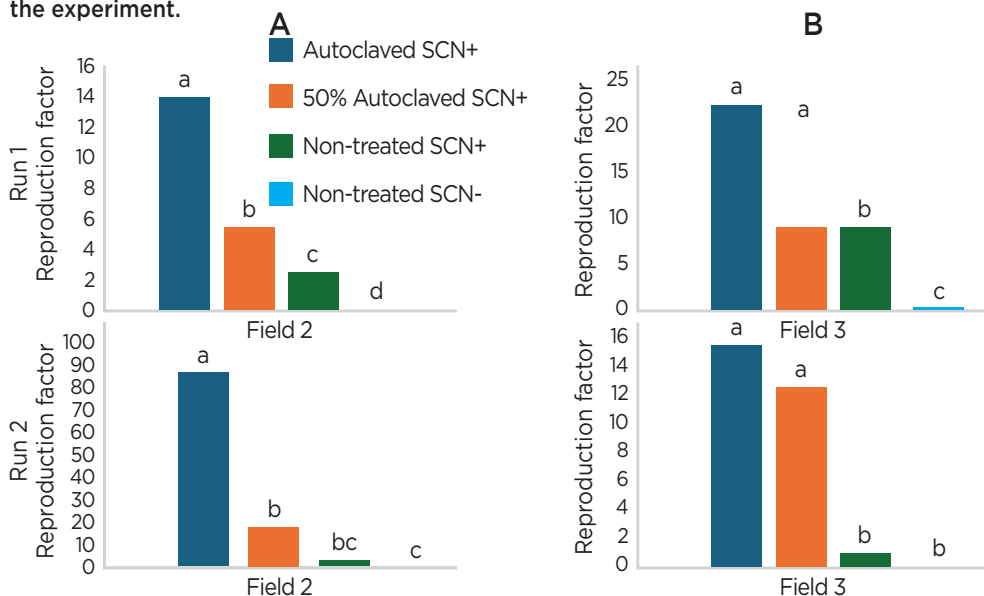
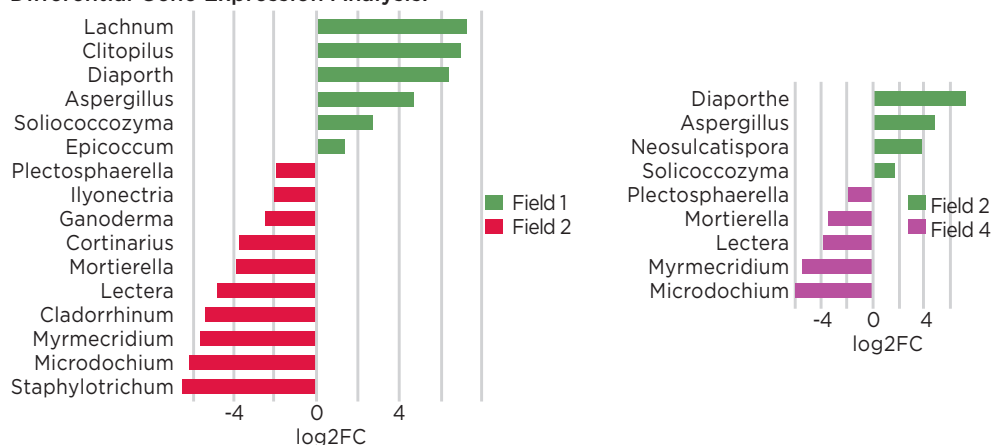


Figure 2. Significantly enriched fungal genera in SCN-suppressive field soil (Field 2) and in non-suppressive field soils (Fields 1 and 4) when two fields were compared with Differential Gene Expression Analysis.



Findings of the Research

The data from the greenhouse experiments confirmed the suppressiveness in Fields 2 and 3 against SCN. The profiling of bacterial and fungal communities was revealed for the soil samples collected from the SCN-suppressive and non-suppressive fields. The sequencing analysis showed Proteobacteria and Ascomycota as the predominant bacterial and fungal groups, respectively, in the suppressive soils. Variation with the composition of fungal and bacterial communities among the soils,

indicated by significant differences in beta diversity indexes, could be the key factor in suppression. The specific enrichment of bacterial and fungal taxa with potential SCN suppressiveness was identified in the suppressive soils. Among these, the fungal genera, such as Lachnum, Diaporthe and Aspergillus, as well as bacteria orders, such as Burkholderiales and Actinomycetales, identified in this study were previously documented to suppress SCN.

Benefits for North Dakota Soybean Farmers and the Industry

This study characterized the SCN-suppressive soil microbiome from fields in North Dakota, warranting further investigation regarding their potential nematicidal properties to advance SCN management strategies. The information about the biocontrol agents will be helpful for managing SCN. Biocontrol agents can be reared in mass scale and used with the SCN-infested fields. Bionematicides, which are specific to target nematodes and eco-friendly, could be developed from the microbes' metabolites or secretions for the sustainable management of SCN.

Enhancing Diagnostic Capabilities for Soybean Root and Stem Rot Diseases

Principal Investigators: Suzette Arcibal Baldwin; Febina Mathew, Ph.D.; and Wade Webster, Ph.D., North Dakota State University (NDSU) Plant Pathology

Funded Project
\$34,730

Why the Research is Important to North Dakota Soybean Farmers

Soybean farmers in North Dakota face serious challenges from soybean root and stem diseases caused by a complex mix of soilborne pathogens, including *Fusarium*, *Rhizoctonia*, *Phytophthora* and *Pythium* species. These pathogens can produce similar symptoms, such as yellowing and wilting, and root rot, making it difficult to identify the exact cause of the disease. Without a clear diagnosis, farmers are unable to select effective management strategies, and that situation can lead to lower yields and higher costs. This research, conducted by the Plant Diagnostic Lab at North Dakota State University, aims to improve how soybean root and stem diseases are identified by developing and validating advanced molecular tests called multiplex real-time PCR assays. These tests can detect and measure multiple disease-causing organisms in a single step, making diagnosis faster and more accurate.

Research Conducted

To support this effort, existing primers are being evaluated, and new ones are being designed to target specific pathogens. Samples were gathered from soybean

fields across North Dakota, as well as from diseased plants which were submitted, to ensure that the tests are effective and relevant to local farming conditions.

Findings of the Research

Primers have been successfully validated for major species of *Fusarium* and *Phytophthora*, confirming their value for accurate, species-level identification. Work is also underway to develop tests for *Pythium* and *Rhizoctonia*, using next-generation DNA sequencing to find stable genetic regions that can be used with future diagnostics.

Benefits for North Dakota Soybean Farmers and the Industry

These new tools can detect disease-causing pathogens more quickly and precisely than traditional methods. Timely and accurate

diagnostic tests will give North Dakota soybean growers faster, more reliable information about diseases affecting crops.



Figure 1. Suzette Baldwin, Ph.D., in her lab, shows why rapid detection of soybean diseases matters for treatment and future management.

Collaborative Research for North Central Soybean Farmers: The Role of the NCSRP

Funded Project
\$250,000

The North Central Soybean Research Program (NCSRP) is a regional initiative funded by 13 states, including North Dakota, that advances soybean production through collaborative, science-based research. By bringing together researchers, extension specialists, and state soybean boards, the NCSRP identifies regional priorities and funds multi-state projects, enabling larger-scale studies with widely applicable results. For North Dakota farmers, this collaboration ensures research addresses local conditions while benefiting from insights and expertise across the region, providing practical, research-based solutions to challenges facing the North Central soybean industry.

Projects funded for Fiscal Year 2025

included:

- Advancing Soybean Health: Field Trials to Decision Support Tools to Maximize Disease Management
- Boots on the Ground 2: AI-Driven Tools for Maximizing Soybean Yield and Profitability
- Management Tactics and Tools for Insect Pests in the North Central Region
- SOYGEN3: Building Capacity to Increase Soybean Genetic Gain for Yield Through Combining Genomics-Assisted Breeding with the Characterization of Future Environments
- SoyRenSeq: A Novel Approach for Disease Resistance Gene Discovery and an Application for Soybean Improvement
- The SCN Coalition: A Checkoff-Led,

University-Driven, Industry-Supported Partnership Battling Soybean's Biggest Underground Threat

These projects demonstrate the breadth of research supported by the NCSRP, addressing both above-ground and below-ground threats while integrating new technologies for yield improvement.

By supporting collaborative, multi-state research, the NCSRP builds a knowledge base that addresses current and emerging soybean production challenges. North Dakota farmers benefit from science-based recommendations; access to research-tested technologies; and management strategies that improve decision-making, profitability, and long-term sustainability.

Sampling Program to Screen for Herbicide Resistance in North Dakota Weeds

Principal Investigator: Zack Bateson, Ph.D., National Agricultural Genotyping Center

Funded Project
\$44,491

Why the Research is Important to North Dakota Soybean Farmers

Herbicide-resistant (HR) weeds are a recurrent problem in the U.S. with more unique cases reported here than in any other country. Herbicide resistance is a moving target for many growers because some weed species emerge throughout the growing season and can quickly spread to new locations every year. Normally, HR is tested in greenhouse trials during the winter by using seeds from the previous year. Now, genetic testing can provide faster results during the growing season by using leaf samples. In partnership with NDSU weed scientists, the National Agricultural Genotyping Center (NAGC) created a statewide program to check for HR in pigweed and kochia. The goals were as follows: 1) to help uncover why certain herbicides failed; 2) to create maps showing where resistant weeds were found; and 3) to track Group 14 resistance in kochia, which is a considerable problem in North Dakota.

Research Conducted

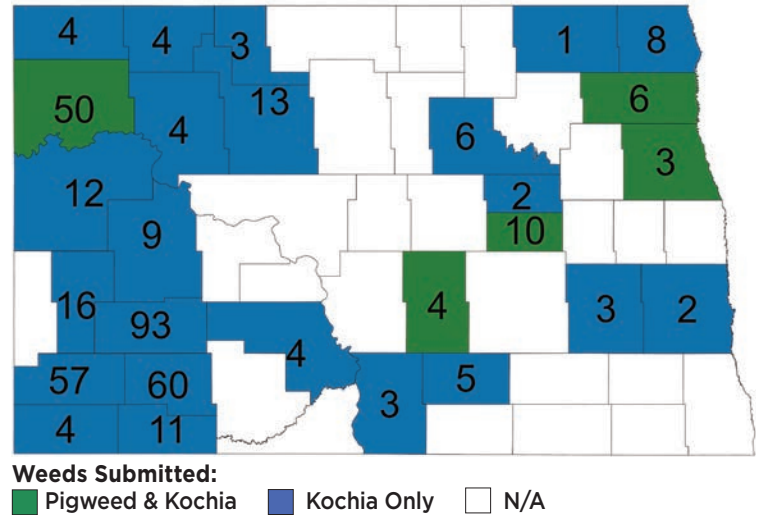
The NAGC sent 877 collection kits to NDSU Extension offices, crop advisers and researchers. Each kit could be used to submit four pigweed or kochia samples. After the samples arrived at the NAGC, they were tested for genetic markers related to resistance to three herbicide groups: Group 2 (ALS inhibitors), Group 9 (glyphosate) and Group 14 (PPO inhibitors).

Test results were sent back to the submitter within seven days after the samples arrived to create county-level maps.

Findings of the Research

A total of 397 weed samples came from 27 counties. Most weeds were kochia (96%), with only 14 pigweed samples. Of the 191 total HR tests performed, 39% detected at least one resistance marker. Across the samples, the Group 9 resistance marker was the most common (found in 55% of samples), followed by Group 14 (38%) and Group 2 (24%). Within individual plants, 43% had one HR marker; 26% had two; and 7% were stacked with all three HR markers. These results underscore the importance of genetic diagnostics for real-time monitoring, guiding localized management recommendations and informing statewide resource allocation for resistance mitigation.

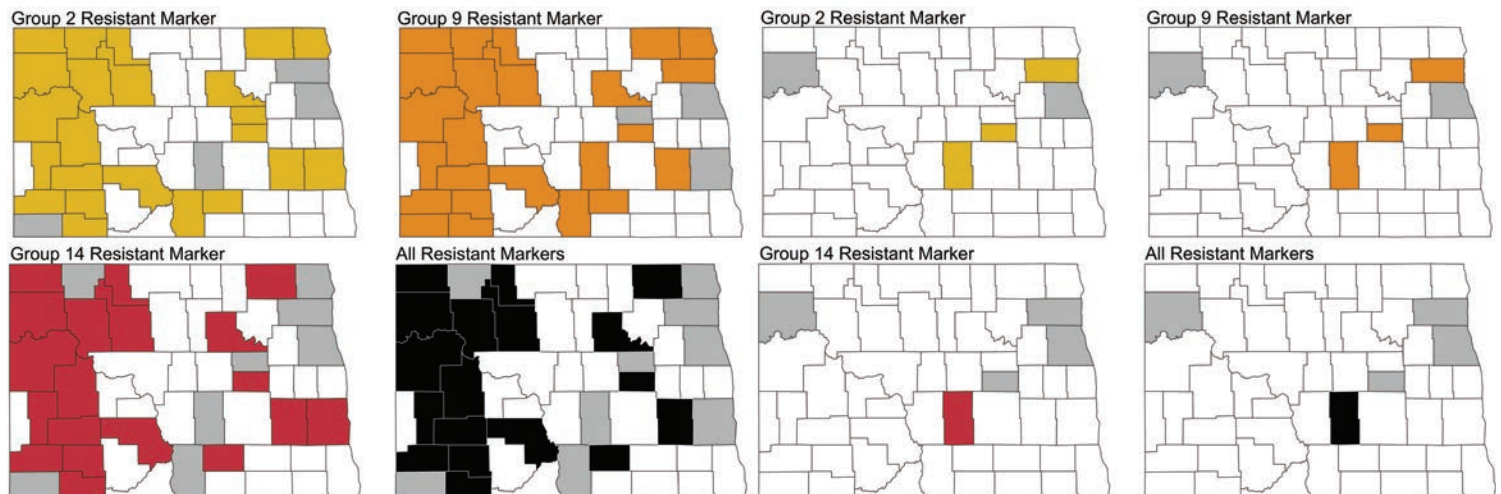
Figure 1. North Dakota map showing the county origins for the pigweed and kochia samples that were submitted to the NAGC for HR genetic testing during the Fiscal Year 25 survey. The numbers indicate the total weeds tested in each county. No weeds were submitted from the counties in white.



Benefits for North Dakota Soybean Farmers and the Industry

The annual survey confirmed widespread HR weeds, especially kochia. Nearly 3 of every 4 weed samples carried at least one HR marker. Group 2 and 9 resistances remained prevalent, but Group 14 resistance was at nearly 40% of the kochia sampled. Although pigweed submissions were low, past surveys showed that resistance was already widespread.

Figure 2. Counties with weeds containing genetic markers associated with resistance to Group 2, 9 and 14 herbicides in kochia (left panel) and pigweeds (right panel). Grey counties indicate where samples were collected but did not contain the specific HR marker. The lower-right map in each panel shows herbicide-resistance hotspots, where black counties had all three resistance markers detected.



Monitoring the Changing Virulence of Soybean Cyst Nematode Populations and Assessing Soybean Breeding Lines for Resistance

Principal Investigator: Guiping Yan, Ph.D., North Dakota State University (NDSU) Department of Plant Pathology

Funded Project
\$52,076

Why the Research is Important to North Dakota Soybean Farmers

Soybean cyst nematode (SCN) is the most destructive soybean pathogen in the U.S. Preliminary data indicate a concerning shift in virulence, with HG type 2.5.7 becoming increasingly dominant. The shift is particularly alarming because this population can reproduce on soybean lines derived from 'PI88788', the most widely used source of SCN resistance in commercial varieties. It is critical to evaluate the resistance responses of breeding lines with evolving SCN populations when developing varieties with durable resistance to ensure the long-term productivity and sustainability of soybean production.

Research Conducted

Soil samples were collected from soybean fields in North Dakota. Twenty-one fields that were SCN positive were tested for virulence types (HG types). Each SCN population was inoculated onto seven standard differential lines and a susceptible check, 'Barnes', to determine the HG type. Ninety breeding lines from the NDSU soybean breeding program were screened for resistance to two SCN populations. Each breeding line was inoculated with 2,000 eggs, and the

experiment was conducted in four replicates. After harvest, SCN females from the roots and soil of each plant were extracted and counted. The Female Index (FI) was calculated to determine resistance levels.

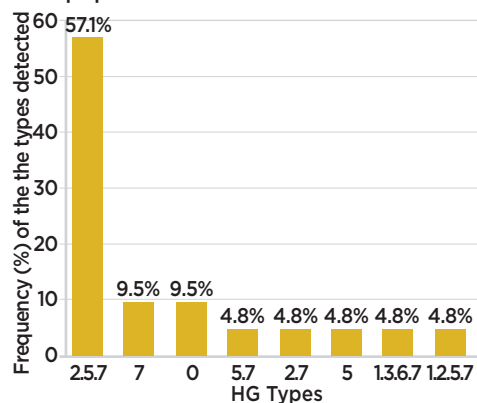
Findings of the Research

Eight HG types were detected. The highest frequency was HG type 2.5.7 (57.1%), followed by HG 7 and 0. HG types 5, 2.7, 5.7, 1.2.5.7 and 1.3.6.7 had the lowest frequency. New HG types 1.3.6.7 and 5 were found, but they were not recorded in our previous survey. Variations for SCN reproduction were observed among the 90 breeding lines tested. For HG 2.5.7, none of the lines were resistant; 54 lines were moderately resistant; and the remaining lines were moderately susceptible/susceptible. Among the 30 lines that were resistant to HG 7, 29 lines were moderately resistant and 1 line was moderately susceptible to HG 2.5.7, suggesting that HG 2.5.7 is more virulent.

Benefits for North Dakota Soybean Farmers and the Industry

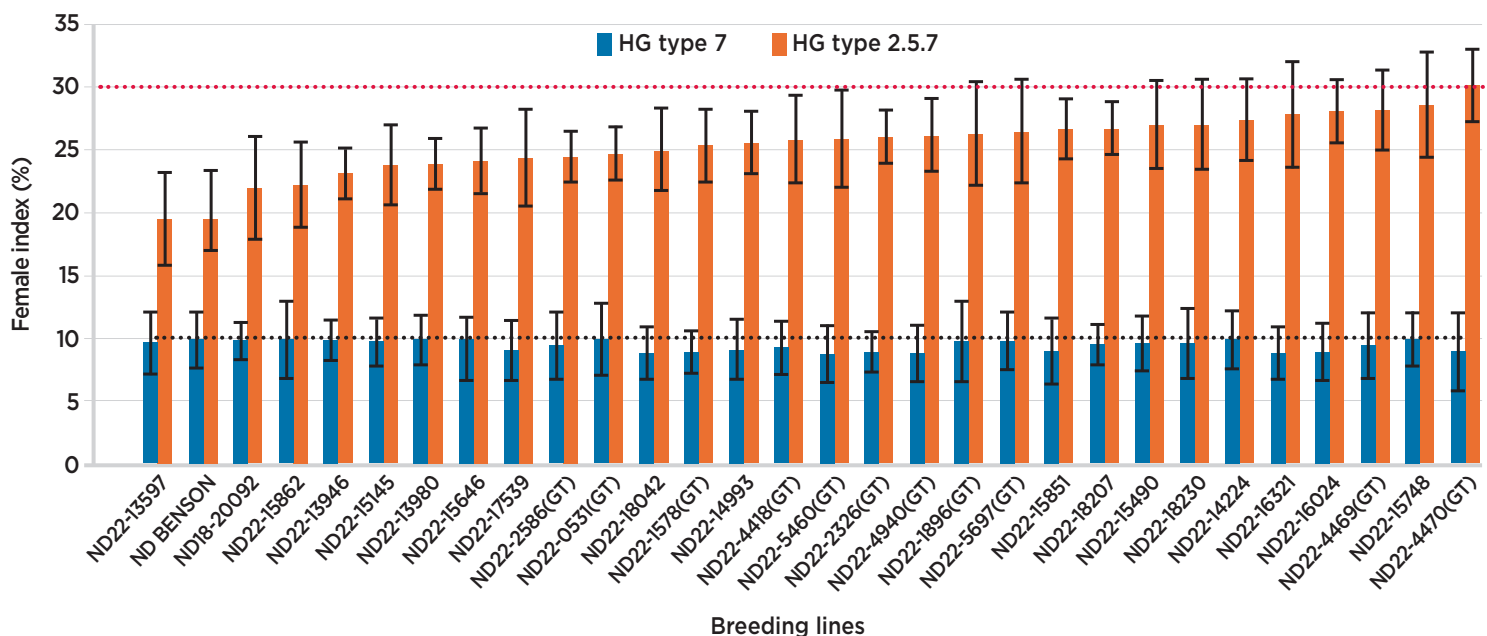
We identified eight virulence phenotypes from 21 field SCN populations and demonstrated HG 2.5.7 as being the most prevalent. We identified 54 breeding lines with resistance or moderate resistance to

Figure 1. Frequency of the HG types detected in North Dakota from the 21 field SCN populations tested.



two widespread HG types in North Dakota. These lines offer immediate benefits for breeders aiming to develop SCN-resistant varieties and give farmers better options for reducing yield loss and maintaining productivity. Identifying prevalent and emerging HG types would lead to better selection and development of soybean varieties with durable SCN resistance.

Figure 2. Variation for the resistance among 30 soybean breeding lines that were classified as resistant to HG type 7, showing differential responses when evaluated for HG type 2.5.7.



Soybeans Interseeded with Cover Crops in Western North Dakota

Principal Investigators: Leandro Bortolon, Ph.D.; James Rogers, Ph.D.; North Dakota State University (NDSU) North Central Research Extension Center; Charlemagne Lim, Ph.D., NDSU Williston Research Extension Center

Funded Project
\$27,370

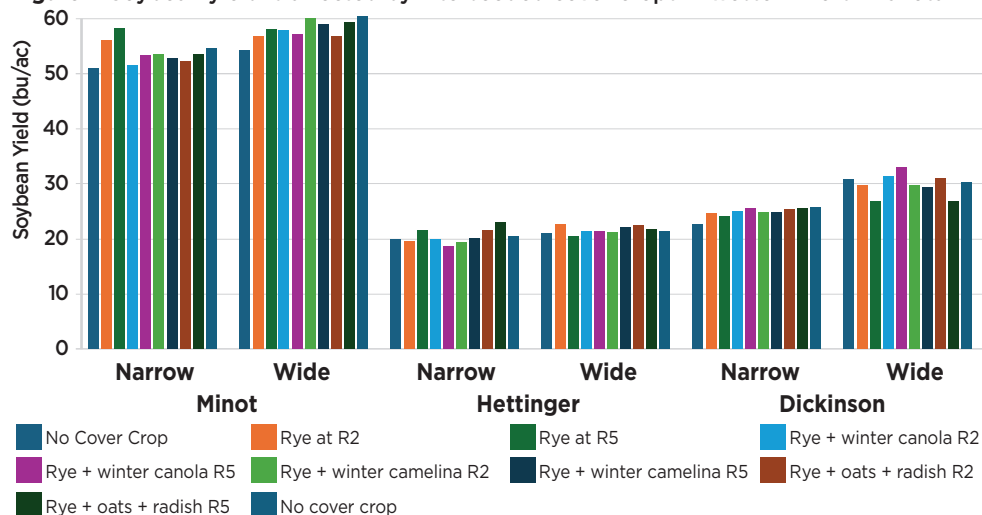
Why the Research is Important to North Dakota Soybean Farmers

Soil erosion is a major problem in western North Dakota due to the low residue and the stubble left in the soil. Keeping the soil covered is key for improving soil health by preventing soil losses from wind and runoff erosion. There is a lack of information regarding the effect on soybean yield when cover crops are established into standing soybeans in western North Dakota. This research aimed to investigate the influence of cover crops interseeded into standing soybeans in western North Dakota.

Research Conducted

Cover-crop trials were done with narrow and wide row spacing for soybeans. Cover crops were broadcasted into standing soybeans at the reproductive stage. Five cover-crop treatments were investigated: no cover crop, winter rye, winter rye + winter canola, winter rye + winter camelina and winter rye + oats + radish. Soybean yield, test weight, oil and protein were recorded. The cover crop's soil cover and biomass, along with soil moisture, were evaluated 30 days after soybean

Figure 1. Soybean yield is affected by interseeded cover crops in western North Dakota.



harvest. The return on the investment (ROI) was calculated as $ROI = \text{gross income (yield} \times \text{commodity price)} - \text{treatment cost}$.

Findings of the Research

The results showed that interseeding cover crops into standing soybeans in western North Dakota does not affect soybean yield. Establishing cover crops is highly dependent

on soil moisture and precipitation patterns. Cover-crop biomass increased the soil's cover even with low amounts of biomass observed across locations. Soil moisture was not affected by cover crops across all locations. The ROI using a cost-sharing program can offset the farmers' cost to establish cover crops with soybeans.

Variability of Soybean Yield Related to Soil Acidity in Western North Dakota

Principal Investigator: Leandro Bortolon, Ph.D., North Dakota State University (NDSU), North Central Research and Extension Center

Funded Project
\$27,370

Why the Research is Important to North Dakota Soybean Farmers

Soybean acreage has been increasing in western North Dakota, mostly with no-till methods. Soil acidification has become an issue for the long-term, no-till soils that receive nitrogen fertilizer, especially when wheat is planted. Long-term nitrogen application has led to acidification of the soil surface for the top 3 inches of no-till soil. The soil acidification can affect nutrient (e.g., phosphorus) activity. However, there is gap in information regarding the variability of soil acidity that influences soybean yield. The relationship among soil

pH, soil aluminum, soil organic matter and soybean yield must be investigated in order to improve the lime recommendation for soybeans with no-till conditions in western North Dakota.

Research Conducted

Twenty-five soybean fields were sampled for this study. Fields with the following characteristics were selected across several counties in western North Dakota: the fields must have no-till conditions for at least 10 years; the fields must have both a low-pH soil and an adequate or high soil pH within the field. Relationships among the relative

grain yield, soil pH, soil aluminum and aluminum saturation were analyzed.

Findings of the Research

We studied 25 long-term, no-till soybean fields across western North Dakota to see how soil acidity—especially low pH and aluminum levels—affects yield. Surprisingly, in these no-till systems, we found no clear link between soybean yield and either soil pH or aluminum concentration. Even fields with low pH and high aluminum produced strong yields, particularly when the organic matter levels were high.

Optimizing the Fungicide's Spray Volume for Improved White Mold Management in Soybeans

Principal Investigator: Michael Wunsch, Ph.D., North Dakota State University (NDSU)
Carrington Research Extension Center

Funded Project
\$40,210

Why the Research is Important to North Dakota Soybean Farmers

Applying fungicides in spray volumes that exceed 10 gallons per acre (gal/ac) and at optimal Delta T (a measure of the evaporative potential of spray droplets) is widely recommended to improve the fungicide's efficacy against white mold and other diseases, but data about the effect of these management strategies are lacking. This research aims to improve white mold management for soybeans by examining how the fungicide's spray volume affects effectiveness. The project also evaluates how spray conditions, including canopy wetness from dew and evaporative potential (Delta T), influence the fungicide's performance. Finally, the study investigates whether the spray volume's influence

depends on spray conditions.

Research Conducted

Spray volumes of 5.0, 7.5, 10.0, 12.5 and 15.0 gal/ac were tested for a single application versus two sequential fungicide applications that targeted white mold in irrigated soybeans which were seeded to narrow (14-inch) rows in Carrington from 2022 to 2024 and in Oakes from 2022 to 2023. In 2024, the full range of spray volume treatments was tested under optimal and marginal spray conditions: preferred Delta T and a dry soybean canopy, low Delta T and a canopy wet with dew, and intermediate Delta T with the bottom half of the canopy wet with dew. The fungicide Endura (5.5 ounces per acre) was applied with a tractor-mounted sprayer, and the spray droplet's size was calibrated relative to canopy closure. The pulse width was modified,

as needed, to maintain the same nozzles, application pressure and driving speed across the spray volume treatments.

Findings of the Research

Applying fungicides with good spray conditions had a much larger influence on fungicide performance than spray volume. Increasing the spray volume from 10 to 15 gal/ac did not improve white mold disease control or soybean yield under white mold pressure, and decreasing the spray volume from 10 to 5 gal/ac was only associated with a weak trend of reduced fungicide efficacy. When a single fungicide application was made, applying the fungicides early in the morning when the canopy was wet with dew and the relative humidity was high (low Delta T) resulted in sharp reductions for white mold

Figure 1. Carrington, and Oakes, ND (2022-2024): The influence of the fungicide's spray volume on white mold management in soybeans. The fungicide Endura (5.5 oz/ac) was applied either once or twice (7 to 11 days apart).

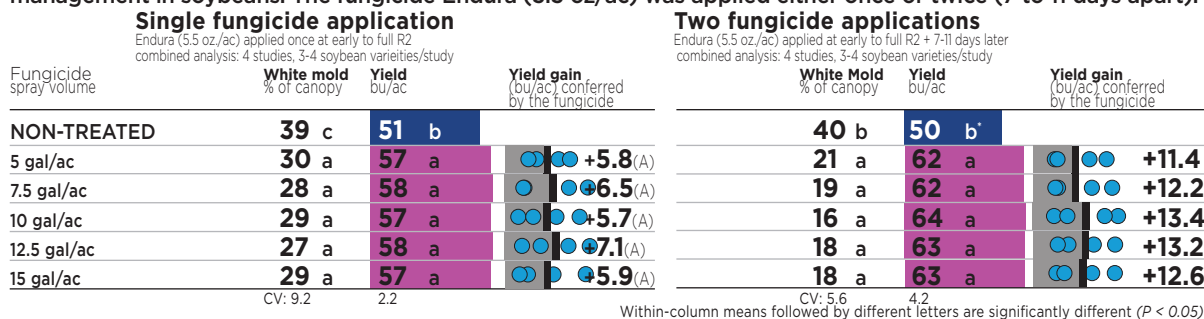


Figure 2. Carrington, ND (2024): Response to spray conditions with one versus two applications of the fungicide Endura (5.5 oz/ac) targeting white mold in soybeans. The average response across all spray volumes tested (5 to 15 gal/ac) is shown.

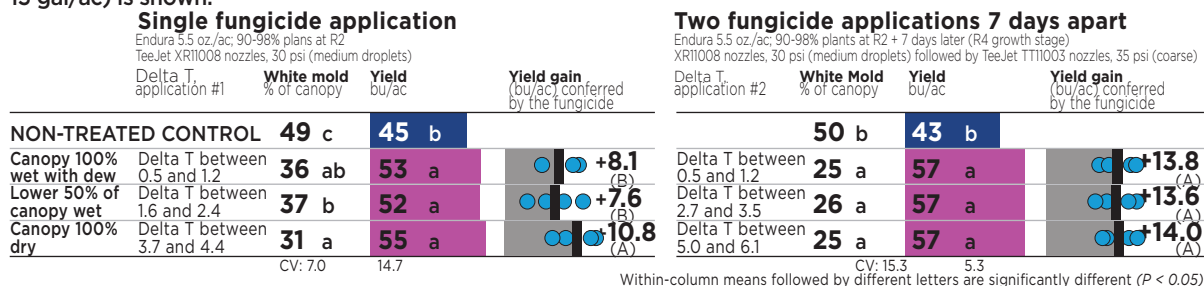
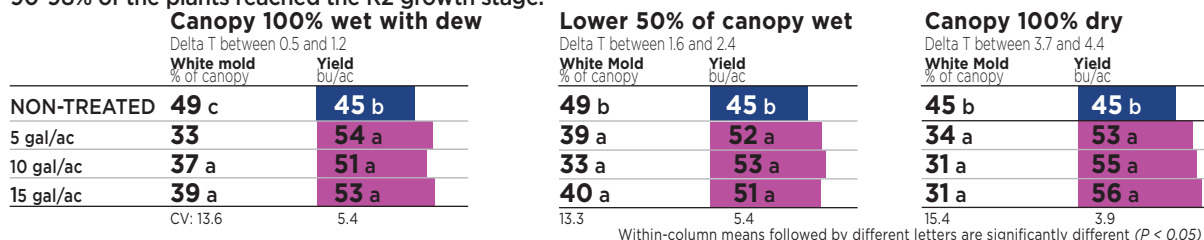


Figure 3. Carrington, ND (2024): The influence of the fungicide's spray volume on white mold management in soybeans relative to spray conditions. A single application of the fungicide Endura (5.5 oz/ac) was applied when 90-98% of the plants reached the R2 growth stage.



management. The effect of applying fungicides with poor spray conditions was mitigated by making a second fungicide application 7 days later and not by increasing the fungicide's spray volume.

Benefits and Recommendations for North Dakota Soybean Farmers and the Industry

The results indicate that the profitability of fungicide applications targeting white mold in soybeans can be improved by limiting the spray volume to 10.0 gal/ac and by delaying morning applications until the canopy is no longer wet from dew and until Delta T values have reached preferred levels.

Mitigating the Salinity Influence: Spring-Planted Cover Crops Boost Soybean Yields in North Dakota

Principal Investigator: Sergio Cabello-Leiva, Ph.D., North Dakota State University (NDSU)
Carrington Research Extension Center

Funded Project
\$11,585

Why the Research is Important to North Dakota Soybean Farmers

Soil salinity affects over 1.9 million acres in North Dakota. For soil with a salinity above 2.2 mmhos/cm, soybean production can decrease by 50% or more. Despite the increased soybean acreage in the state, salinity continues to pose a significant challenge. The adaptation of winter cover crops, such as winter rye, camelina and barley, creates a green mulch that can tolerate salinity. This mulch prevents excessive soil evaporation, improves drainage and boosts soil microbes. Implementing these practices may help to reduce salinity and to increase soybean yields.

Research Conducted

In 2024, research was done in Carrington, North Dakota, on dryland saline soil with electrical conductivity (EC) from 0.6 to 3 mmhos/cm. The study used a randomized, complete block design with treatments: soybeans alone, soybeans with winter rye, winter barley, winter camelina and a cover crop mix. Each cover crop was seeded at 66% and 33% of the recommended rate. Cover crop termination took place at the soybean reproductive 2 (R2) stage and with no termination.

Findings of the Research

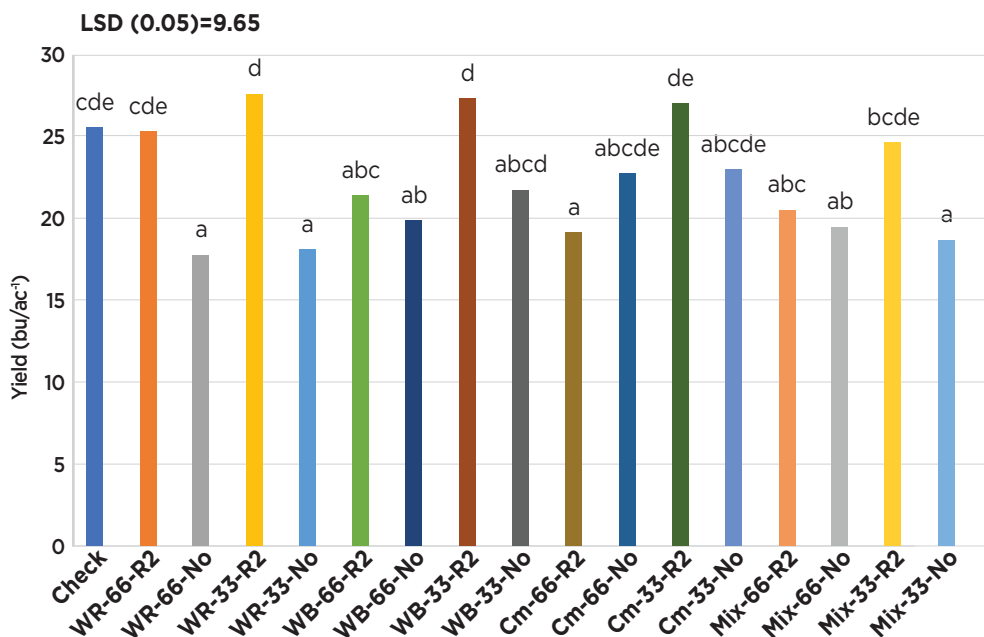
Soil salinity greatly affected soybean growth. When the EC was above 1.8 mmhos/cm, yields dropped by more than 50% compared to less saline fields (EC 0.63 mmhos/cm). Figure 1 illustrates the yield variation with salinity.

Different cover crop treatments affected soybean yields. Winter camelina, winter barley and winter rye yielded 2-3 bushels more per acre than no cover crop when they were terminated at the R2 soybean stage, representing a 5-8% increase. Although not statistically significant, these results suggest that adjusting the seeding rates and termination timing could

Cover crops established at experimental site.



Figure 1. Soybean grain yields under different cover crop treatments, Carrington, North Dakota, 2024.



improve yields. Cover crops seeded at a 66% rate and terminated after the R2 stage will significantly reduce soybean yields.

Benefits for North Dakota Soybean Farmers and the Industry

The adoption of winter barley and winter rye, terminated at the soybean's R2 stage with a seeding rate of 21.45 lb/acre, can boost yields by approximately 8%. Although this increase was not statistically significant, it suggests that modifying the seeding rates and timing can be beneficial.

Our initial results also show that cover crop seeding at 33% of the recommended rate and terminating by the soybean's R2 stage will not negatively affect soybean yield or quality. Planting green soybeans reduces the influence of soil salinity on yield, opening new alternatives for soybean planting. More research is ongoing, but early findings are promising.

Potential for Combatting Iron Deficiency Chlorosis with the Soybean Microbiome

Principal Investigator: Barney Geddes, Ph.D., North Dakota State University (NDSU)
Microbiological Sciences

Funded Project
\$24,720

Why the Research is Important to North Dakota Soybean Farmers

Iron deficiency chlorosis (IDC) remains a major challenge for soybean production in North Dakota, limiting yields and profitability. Current options, such as iron fertilizers, are costly, and many high-yielding soybean cultivars are still IDC sensitive. This project explores the soybean microbiome as a novel biological tool for IDC mitigation, with the goal of developing cost-effective microbial inoculants tailored to North Dakota conditions.

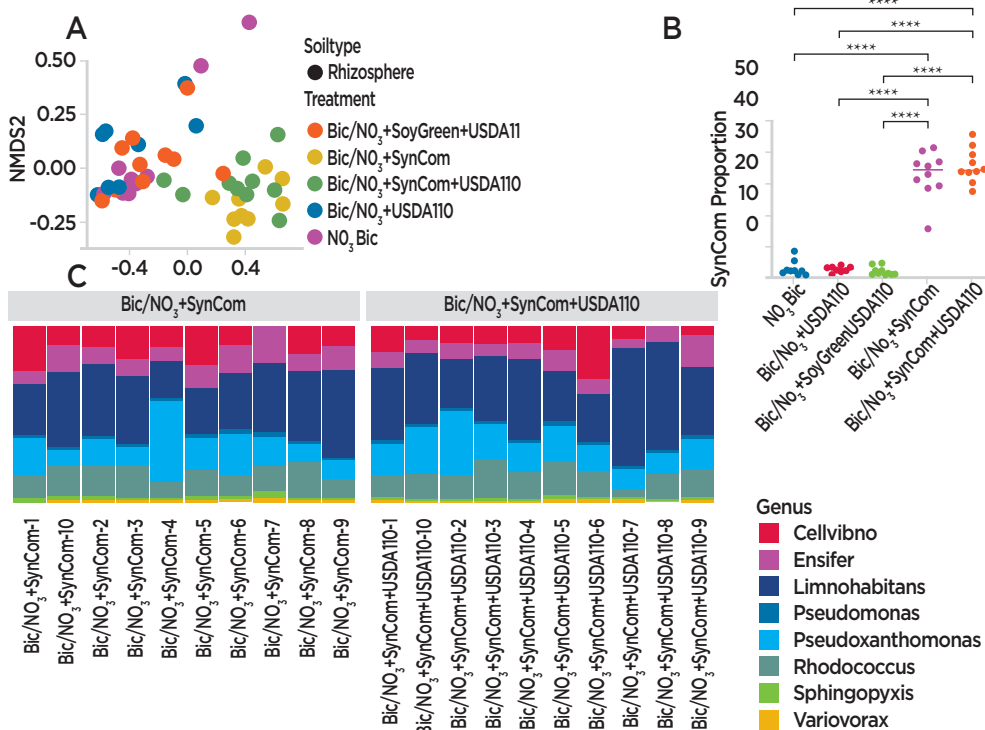
Research Conducted

This study assessed a synthetic microbial community (SynCom) made of 11 IDC-responsive root microbiome isolates. The aim was to determine their ability to reduce IDC in soybean plants and to compete with native microbes for colonization of the soybean microbiome. Greenhouse and growth-chamber experiments were conducted with iron-deficient conditions, utilizing IDC-inducing soil that was amended with nitrate and bicarbonate to trigger IDC symptoms. IDC symptoms in soybeans, both inoculated and non-inoculated, were evaluated to investigate the effectiveness of the isolated microbiomes from our soybean microbiome collection to reduce IDC.



Figure 1. A graduate student from Dr. Geddes's lab conducting field trials.

Figure 3. The same plants treated with a cocktail of 11 IDC-responsive microbial isolates.



Findings of the Research

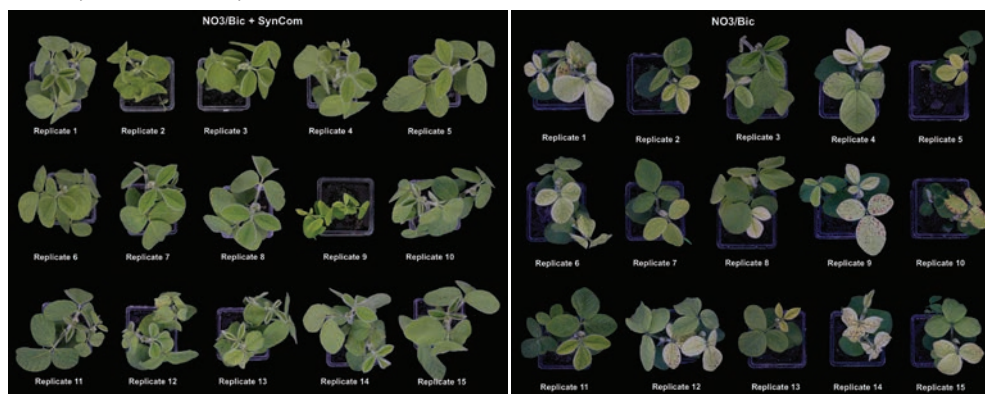
The SynCom significantly reduced IDC symptoms, achieving results comparable to the Soygreen treatment. While some individual isolates showed effectiveness for reducing IDC, extensive testing revealed that a community of microbes was the most effective and reliable treatment. Nodulation was not observed in greenhouse trials due to nitrate suppression, indicating that field conditions are necessary to assess symbiotic enhancements. Profiling the microbial community from soybeans grown in unsterilized field soils showed that

SynCom members successfully colonized the rhizosphere, with five genera dominating the community. These results supported the viability of SynCom inoculants for field testing.

Benefits for North Dakota Soybean Farmers and the Industry

This research provides a strong foundation for developing a biologically based tool to manage IDC. The identified SynCom offers a potential low-cost, integrated solution that could be co-formulated with existing rhizobial inoculants.

Figure 2. Plants grown in a growth chamber's pot assay with IDC-producing soil from Hunter, North Dakota, with NO₃ and bicarbonate.



Evaluation of Seed Treatments to Manage Combined Infections of Interveinal Chlorosis-Causing Pathogens and Soybean Cyst Nematode

Principal Investigator: Venkataramana Chapara, Ph.D., North Dakota State University (NDSU)
Langdon Research Extension Center

Funded Project
\$6,140

Why the Research is Important to North Dakota Soybean Farmers

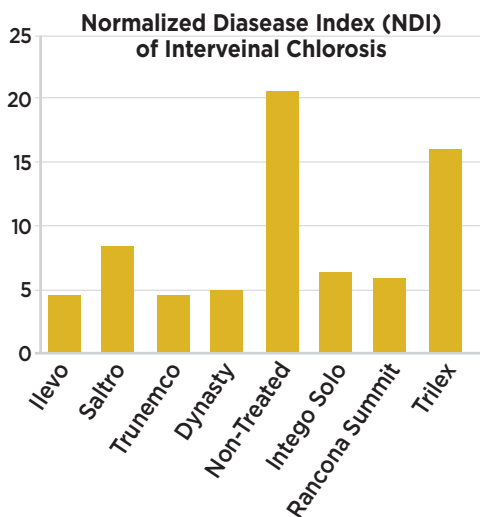
This research is designed to evaluate seed treatments for managing interveinal chlorosis in soybeans, particularly when associated with soybean cyst nematode (SCN) and fungal pathogens such as *Phialophora gregata*, the causal agent of brown stem rot (BSR). Interveinal chlorosis—characterized by yellowing between leaf veins and leaf necrosis—can be caused by several pathogens, including BSR, sudden death syndrome (SDS) and red crown rot (RCR). These diseases share similar foliar symptoms, making field diagnosis challenging. Compounding the issue, SCN infestations can exacerbate yield losses when present alongside these pathogens.

With no effective foliar fungicides for BSR, seed treatments are among the few viable management options. Identifying effective treatments provides practical tools for farmers to reduce disease pressure, to protect yields and to sustain soybean profitability in the state.

Research Conducted

In 2024, a field trial was conducted at the NDSU Langdon Research Extension Center using the soybean cultivar 'GT210086T20.' Seeds were treated with Trunemco®, Ilevo®, Saltro®, Dynasty®, Intego Solo®, Trilex® and Rancona Summit®, and the treated seeds

Figure 1. The Normalized Disease Index observed on the seed treatments tested under field condition at Langdon Research Extension Center, Langdon, North Dakota.



were compared with untreated seeds. The trial used a randomized, complete block design with four replications. Disease incidence (DI) and severity (DS) were measured at the R6-R7 growth stages to calculate a normalized disease index (NDI). Yield, plant stand and vigor were recorded, and pre-plant soil samples had SCN populations averaging 200 eggs per 100 cubic centimeters (cc) of soil. Symptomatic tissue was cultured in the lab to identify the causal pathogen.

Findings of the Research

The results indicated that Trunemco®, Ilevo® and Dynasty® had the lowest NDI. The seed treatments of Trunemco® followed by Intego Solo®, Dynasty® and Rancona Summit® yielded significantly more than untreated seed. Ninety percent of the cultured samples proved to be *P. gregata*, the BSR-causing pathogen. The interveinal chlorosis and pith were usually attributed to Type A of *P. gregata*. Even low SCN levels contributed to symptom severity and potential yield loss.

Benefits for North Dakota Soybean Farmers and the Industry

Seed treatments such as Trunemco®, Ilevo® and Dynasty® offer practical management options for fields with BSR and SCN. Continued BSR monitoring in North Dakota will guide proactive disease-management strategies.

Figure 2. The soybean yield (bu/ac) obtained in the seed treatment trial that was evaluated under field condition at Langdon Research Extension Center, Langdon, North Dakota

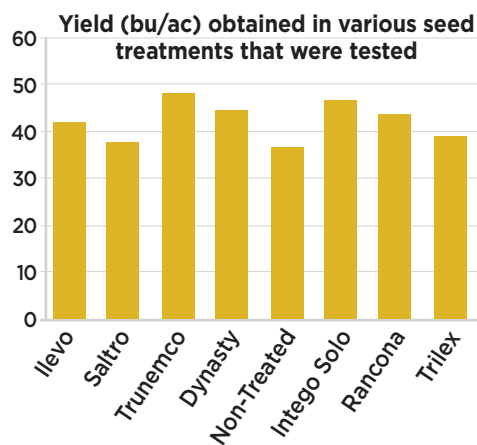


Figure 3. Summer interns taking stand counts at 4-leaf stage of the crop in the soybeans seed treatment trial conducted in Langdon, North Dakota.



Visual Ratings for Iron Deficiency Chlorosis in Soybeans

Principal Investigator: Carrie Dottey, Ph.D., North Dakota State University (NDSU)
Department of Plant Sciences

Funded Project
\$28,995

Importance to North Dakota Soybean Farmers

Iron deficiency chlorosis (IDC) is a common yield-limiting factor for soybeans grown in the calcareous soils of eastern North Dakota. Given the region's unique soil property, growers need reliable, region-specific IDC ratings to guide varietal selection. This project provides independent, third-party evaluation of IDC tolerance across hundreds of public and commercial varieties.

Research Conducted

Between 2020 and 2025, more than 1,200 entries were evaluated across multiple IDC-prone field locations using replicated hill plots and standardized visual scoring on a 1-5 scale. Positive and negative control varieties were included to benchmark symptom severity. Starting in 2024, soil samples were collected at multiple depths and were analyzed for pH, electrical conductivity, carbonates and nitrate. Aerial drone imagery was also utilized to explore high-throughput IDC phenotyping.

Findings of the Research

IDC severity varied by site and year, but control varieties allowed for consistent score interpretation. In severe IDC years (2022, 2024), fewer lines met resistance thresholds. By 2023, improvements with field selection

Figure 1. Clara Mvuta, NDSU master's student, thinning the IDC hills from 8 plants to 3 plants, which is done by hand to ensure score precision.



and publication transparency, including the use of checks, led to clearer interpretation. Soil data suggested that high carbonates and salinity were associated with increased IDC symptoms. Drone image modeling for IDC scoring is in early development.

Benefits for North Dakota Soybean Farmers and the Industry

This project delivered trusted, North Dakota-specific IDC ratings that both farmers and private companies rely on to guide soybean variety selection. By providing transparent and timely data through NDSU's A-843 bulletin and an online platform, the project helps growers reduce yield loss and improve profitability by choosing varieties which are well-suited to their fields. Its

Figure 2. Carrie Dottey, Ph.D., in a soybean field at Agronomy Seed Farm in Casselton.



credibility and practical value have made it a dependable resource for the industry while financial support from private companies has ensured the project's self-sufficiency. This long-term stability highlights both the success of the research and its continued importance for North Dakota's soybean production.

Figure 2. IDC scores are represented by colors.

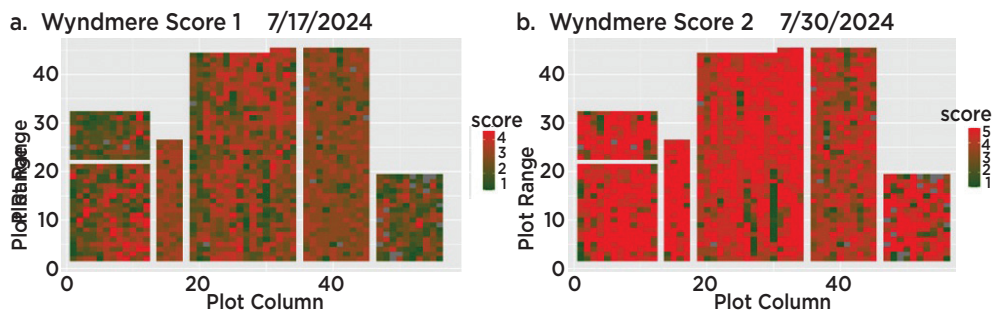


Figure of IDC scores represented by color. Green = IDC score 1 (no symptoms) Red = 4.5 (severe necrosis and chlorosis). Gradient between colors are scores between 1-4.5. a. Depiction of all IDC experiments in Wyndmere location 2024. Score results from 7/17/2024. b. Depiction of all IDC experiments in Wyndmere location in 2024. Score results from 7/30/2024. visual representation of IDC scores over time shows the intensity of IDC progression in Wyndmere in a two-week period where almost all plots were affected with severe IDC.

Modern Breeding Methodologies to Expedite Elite Variety Release

Principal Investigator: Carrie Dottey, Ph.D., North Dakota State University (NDSU)
Department of Plant Sciences

Funded Project
\$140,505

Why the Research is Important to North Dakota Soybean Farmers

This research directly benefits North Dakota farmers by accelerating the development and release of soybean varieties which are both agronomically superior and aligned with current herbicide technologies. With the successful acquisition of Liberty Link and Enlist traits, this project ensures that public varieties will remain compatible with production systems.

Research Conducted

The Liberty Link trait was acquired in 2024, followed by the Enlist trait in 2025. Crosses were performed in growth chambers with tailored day lengths to synchronize flowering. Pollinations in this system are ongoing and show promise. In parallel, a genomic prediction model was developed using 2022-2023 intermediate and advanced yield-trial data. A genomic best linear unbiased prediction (GBLUP) model

Figure 2. Enlist cross explanation.



This photo shows the first Enlist cross made. In the red circle, the flower bud has petals removed exposing the stigma or female part of the plant. The blue arrow points to the male anthers from the Enlist donor that were placed next to the stigma to force the pollination. This plant will be grown in the growth chamber shown in the background until the seed is fully developed and ready for harvesting.



Figure 1. Crossing Enlist lines.

was run in ASReml-R to evaluate multiple levels of complexity.

Findings of the Research

The Enlist trait has the highest priority in the breeding pipeline, with cross attempts conducted weekly. Preliminary genomic prediction models yielded moderate accuracy (0.4 for yield, 0.45 for maturity), supporting the models' initial development. The main limitations include a small training population and a lack of multi-year phenotypic data. Plans are in place to incorporate data from national trials (North Central Soybean Research Program (Soygen) and U.S. Department of Agriculture's Uniform Trials) and 2025 field data in order to improve model accuracy and to broaden applicability.

Benefits for North Dakota Soybean Farmers and the Industry

Genomic prediction will, ultimately, allow breeders to identify top-performing lines before extensive field testing, significantly reducing the time and cost required to release new varieties. This project supports a public breeding program that is capable of meeting the rapidly evolving grower needs and market demands.

Increasing Soybean Yield Under Drought Through Enhanced Symbiotic Nitrogen Fixation

Principal Investigator: *Carrie Dottey, Ph.D., North Dakota State University (NDSU)
Department of Plant Sciences*

Funded Project
\$38,018

Why the Research is Important to North Dakota Soybean Farmers

Low water conditions are a major cause of soybean yield loss in western North Dakota, where limited rainfall and a lack of irrigation infrastructure exacerbate stress on crops. Traditional drought-tolerance traits often reduce yield with well-watered conditions, creating trade-offs. Sustained symbiotic nitrogen fixation (SNF), a trait that allows soybeans to fix atmospheric nitrogen even during drought, can enhance yield and does not carry the same yield drag. This project explores integrating sustained SNF into northern soybean germplasm to improve performance with low water conditions.

Research Conducted

In 2023, thirty advanced NDSU lines, two Arkansas SNF-positive controls and one negative control were tested with dryland and irrigated trials at Nesson Valley. Nodule count, nodule weight and ¹⁵N isotope ratios were measured. Greenhouse trials with drought treatments (80%, 55%, 30% and 0% watering) were conducted using selected high- and low-nodule lines to refine the SNF phenotyping protocols. Simultaneously, three populations were developed between Arkansas SNF donors and elite NDSU lines, with F6 populations developed by 2025 and genotyped for northern maturity by

using marker-assisted selection.

Findings of the Research

Field results confirmed that the nodule dry weight and nodule dry weight-to-count ratio may be useful indicators of SNF under drought. Several NDSU breeding lines outperformed positive controls for SNF, highlighting a strong potential for trait improvement. While ¹⁵N measurements showed high variability and greenhouse trials faced technical limitations, breeding progress was substantial. In just two years, 181 F6 lines were developed, with 12 confirmed as well-adapted to North Dakota conditions. These lines will advance to additional SNF screening in 2025.

Figure 2. R01-416F, an Arkansas line carrying the sustained nitrogen fixation trait, was used both as a breeding parent and as a positive control for our experiments.

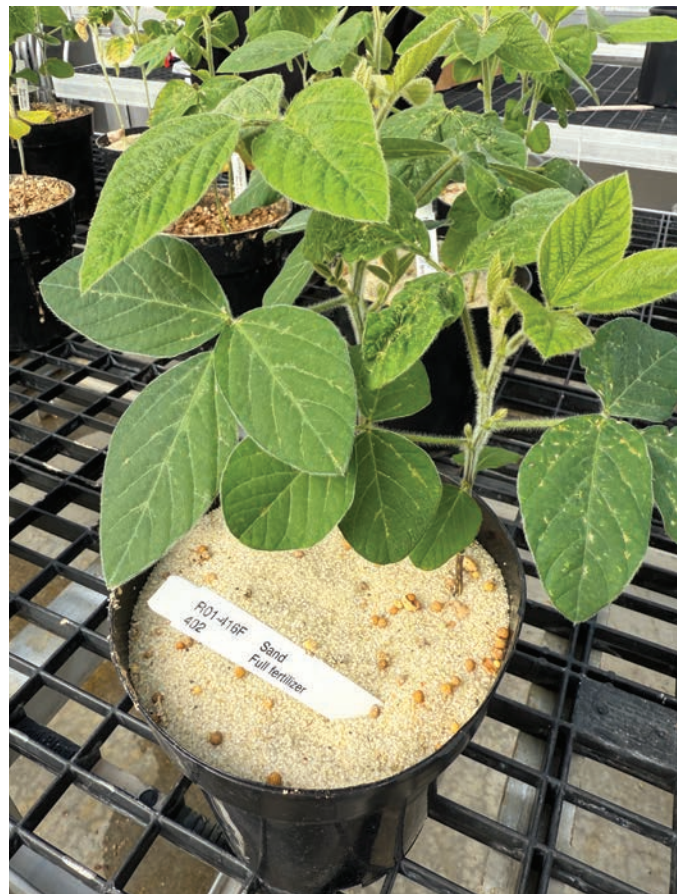


Figure 1. Digging up roots in Nesson Valley, 2023.



Benefits for North Dakota Soybean Farmers and the Industry

This work provides a new pathway for drought resilience without sacrificing yield potential with well-watered conditions. Once validated, sustained SNF will offer farmers varietal solutions for nitrogen management with water-limited environments.

“Field results confirmed that the nodule dry weight and nodule dry weight-to-count ratio may be useful indicators of SNF under drought.”

Breeding, Evaluation and Maintenance of NDSU Core Germplasm

Principal Investigator: *Carrie Dottey, Ph.D., North Dakota State University (NDSU)
Department of Plant Sciences*

Funded Project
\$329,120

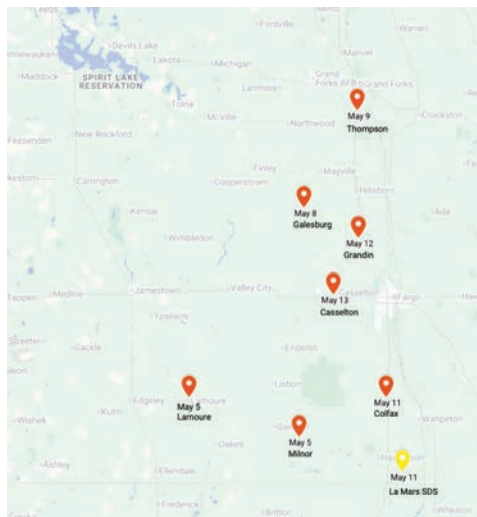
Why the Research is Important to North Dakota Soybean Farmers

This project aims to ensure the long-term success of soybean production in North Dakota by developing soybean varieties which are specifically suited to the state's unique growing conditions. These conditions include short growing seasons and common challenges, such as iron deficiency chlorosis (IDC), soybean cyst nematode (SCN) and sudden death syndrome (SDS). The Core Germplasm program also assists farmers by producing food-grade soybean lines, such as the ones used for tofu and natto, which provide opportunities for premium value.

Research Conducted

The research team completed a full breeding cycle, from crosses to multi-location yield trials and increasing breeder seed. From 2024-2025, thousands of experimental lines were evaluated. Yield trials were conducted at seven locations each year in partnership with cooperating growers. Selection decisions were based on agronomic performance, disease resistance, and seed composition traits such as protein and oil. For the first time, a genomic selection model was integrated into the parent selection process to improve breeding efficiency. A Near-Infrared (NIR) spectroscopy system, which is a rapid, non-destructive method used to measure protein and oil content in various samples, including agricultural products such as soybeans, was added to the combines to collect protein and oil data for all plots during harvest.

Figure 1. Map of the 2025 yield trial locations and the planting dates. Orange pins indicate traditional yield trials; yellow pins indicate specialty yield trial for disease management: soybean sudden death syndrome (SDS).



Findings of the Research

The project generated 305 new experimental lines adapted to North Dakota by using high-yielding genetics from Illinois and Nebraska. Those lines are entering yield

Figure 3. Visiting scientist Tonny Obua checking the seed's planting depth.



trials. Three lines are in their fourth year of testing, and one glyphosate-tolerant line is due for release in January 2026, owing to yield performance and SCN resistance.

Figure 2. Collaborating with Dr. Wade Webster to plant soybean cyst nematode field trials. Dr. Webster is shown with NDSU breeding team members Ben Harms, Cole Williams and Gabe Dusek.



Optimal Temperature for Drying Soybeans

Principal Investigator: Clairmont Clementson, Ph.D., North Dakota State University (NDSU)
Agricultural and Biosystems Engineering

Funded Project
\$36,782

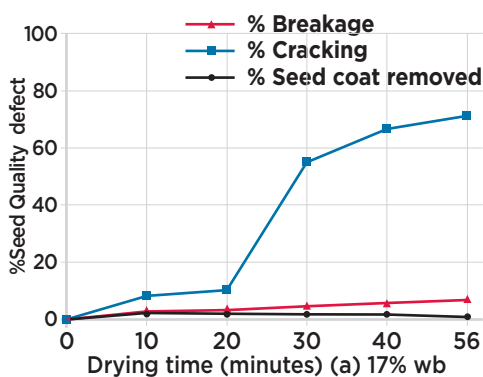
Why the Research is Important to North Dakota Soybean Farmers

Soybeans are a critical crop in North Dakota; they are valued for their high protein content and versatile applications in food and non-food industries. However, unpredictable harvest conditions, such as early frost or excessive rain, in the Northern Plains often require soybeans to be harvested at elevated moisture levels (>20% wet basis (wb)), making field drying impractical. This research addresses the urgent need for reliable, modern drying guidelines which are tailored to North Dakota's unique climatic challenges and updated soybean cultivars.

Research Conducted

A laboratory-scale study was conducted at North Dakota State University using a fixed-bed dryer that was developed to evaluate the effect of the drying temperature, airflow rate and initial moisture content on the soybean's drying behavior and seed quality. The soybeans were conditioned to three initial moisture levels (17%, 20% and 23% wb) and dried at three temperatures (21.1°C, 40.6°C and 60°C) under two airflow rates (45 and 70 cubic feet per minute

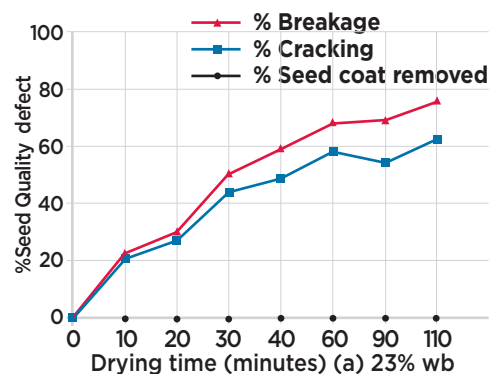
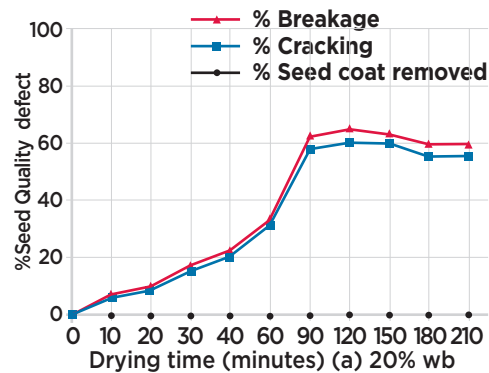
Figure 2. Variation of the quality parameters during the drying time.



per bushel). Quality assessments included measurements of the drying time and rates for the kernel breakage, cracking and seed coat scarring.

Findings of the Research

The findings revealed that drying temperature and initial moisture content were the most influential factors affecting both drying time and seed quality. Higher temperatures significantly reduced drying time but led to increased cracking and breakage, especially at initial moisture levels $\geq 20\%$. In contrast, the airflow rate had



a minimal effect on the drying duration. Importantly, optimal drying conditions were identified at temperatures below 27°C and initial moisture contents of 19-20% wb. Under these conditions, seed integrity was preserved, supporting better long-term storage and market quality.

Benefits for North Dakota Soybean Farmers and the Industry

These findings highlight the potential to implement efficient, quality-preserving off-field soybean drying strategies in the northern U.S. production zone. Such practices can help farmers and processors maintain high-quality soybeans for global markets, supporting premium pricing and improved storage stability. Additionally, this approach enhances operational efficiency by informing energy requirements for quality maintenance during drying.

Figure 1. Grain bins of NDSC Research Committee member Joe Ericson in Barnes County.



Evaluating Phosphorus Needs for Soybeans in North Dakota

Principal Investigator: Lindsay Malone, Ph.D., North Dakota State University (NDSU)
School of Natural Resource Sciences

Funded Project
\$51,790

Why the Research is Important to North Dakota Soybean Farmers

North Dakota's soybean acres have increased from one million to nearly six million acres in the last two decades. New production regions are largely in north-central and northwestern North Dakota. Current recommendations for phosphorus

(P) fertilizer application have been developed from data collected in eastern North Dakota. These recommendations support P application on fields with low (under 7 parts per million (ppm)) soil test phosphorus. This research will support updated soybean fertility recommendations.

Research Conducted

Eight P-trial locations were deployed across North Dakota in both 2023 and 2024, for 16 total site years with low-P fields. Five P rates (0, 23, 46, 69 and 92 pounds per acre) were replicated four times at each location.

Findings of the Research

P fertilizer increased the relative yield for 3 of the 16 trials, Minot and Mohall in 2023, and Milnor in 2024, with small yield increases. Other factors, such as rainfall, may have been yield-limiting at other sites, or soybeans in those fields were able to scavenge enough P despite low soil test values. Considering data from all 16 sites, plots that had increased soil test phosphorus to at least the moderate range (8-14 ppm Olsen) after fertilization had higher relative yield than the plots with lower soil test phosphorus.

Benefits for North Dakota Soybean Farmers and the Industry

More research is needed to develop accurate P-fertilizer recommendations, especially in regions where growing soybeans is relatively new and where the native soil's P is low.

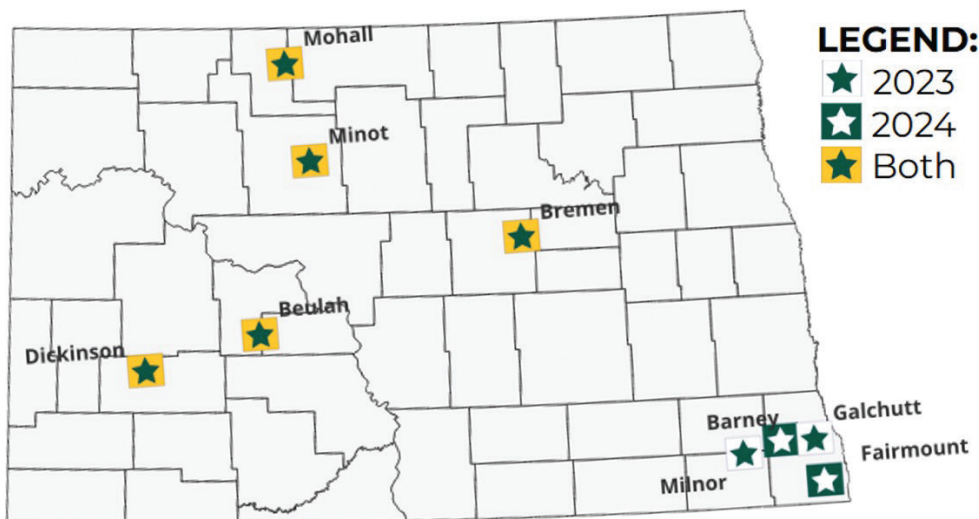


Figure 1. Map of the phosphorus-rate trial sites. Star color indicates the study year. Sites outside southeast North Dakota are indicated with a single point due to their proximity.

Figure 3. Relationship of Olsen fall P and relative yield across all North Dakota trials ($n = 315$). Classifications with the same letter at the top have statistically similar mean relative yields ($\alpha = 0.05$).

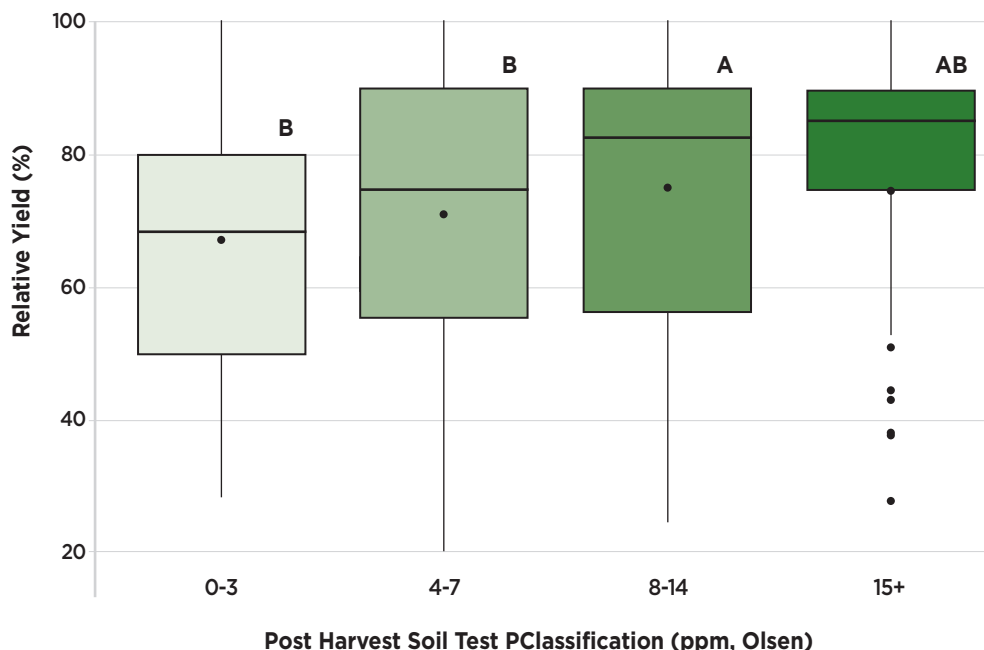


Figure 2. NDSU graduate student Dayne Tallier collecting early season soil samples for this phosphorus-rate trial. This project supported Mr. Tallier's master's research.

Biology and Managing the Seedling Pathogens in North Dakota

Principal Investigator: Febina Mathew, Ph.D., North Dakota State University (NDSU)
Plant Pathology

Funded Project
\$43,358

Why the Research is Important to North Dakota Soybean Farmers

This research is important to North Dakota farmers because it addresses critical gaps for managing soybean seedling diseases and sudden death syndrome (SDS), both of which can significantly reduce yields. Currently, management options are limited to a few seed treatments and some SDS-tolerant varieties. This study enhances disease diagnosis by determining the prevalence of *Fusarium* species associated with seedling diseases and SDS as well as distinguishing these from similar diseases, such as brown stem rot.

Research Conducted

The objectives were to (1) investigate the prevalence of seedling pathogens associated with soybeans in North Dakota, (2) assess the influence of seed treatments on *Pythium*, and (3) evaluate soybean accessions for resistance to *Rhizoctonia solani* and *Pythium* spp.

A soybean disease survey was conducted across 17 counties in North Dakota, assessing 102 fields for seedling pathogens, SDS and other diseases. Soil and diseased plant samples were collected for pathogen isolation and identification.

Figure 1. Soybean accession 'Williams 82' (A) is susceptible while 'PI 79648' (B) shows lower susceptibility when inoculated with *Rhizoctonia solani* AG 2-2 IIIB (A = 'Williams 82' and B = 'PI 79648').



To evaluate seed treatments containing fungicides, a field trial was conducted on June 10, 2024, at NDSU's Research Station in Fargo. The trial plot was inoculated with a single isolate of *Globisporangium* (*Pythium*) *ultimum* at planting. Researchers screened 203 accessions for *Rhizoctonia* resistance and 217 accessions for *Pythium* resistance in the greenhouse trials, using susceptible checks 'Williams 82' and 'Williams'.

Findings of the Research

Fusarium was the most dominant genus infecting soybean roots. SDS was confirmed in two new counties—Cass and Dickey—expanding its known presence beyond Richland County. Additionally, *Clonostachys*

Figure 2. Accessions with significantly lower disease severity compared to the susceptible check 'Williams' when inoculated with *Globisporangium* (*Pythium*) *ultimum* (1 = 'PI 238921', 2 = 'PI 438500', 3 = 'PI 437970', 4 = 'PI 326580' and 5 = 'Williams').

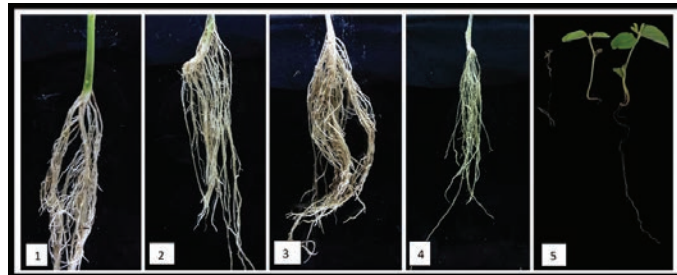
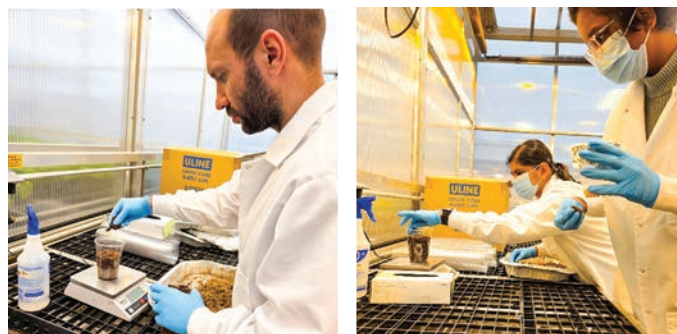


Figure 3. Dr. Mathew's team (Dr. Denis Colombo, Dr. Milsha George and Bijula Mankara Sureshbabu) established greenhouse experiments to screen soybean accessions for resistance to *Rhizoctonia solani* AG 2-2 IIIB and *Globisporangium* (*Pythium*) *ultimum*.



rosea, which causes root rot, was detected in Cass, Richland and Dickey Counties.

Field trials evaluating the efficacy of seed treatments containing fungicides against *Pythium* demonstrated up to a 12% increase for plant emergence compared to the non-inoculated control.

Thirty-five accessions had significantly lower disease severity to *Rhizoctonia solani* AG 2-2 IIIB and 37 to *Globisporangium* (*Pythium*) *ultimum*.

Benefits for North Dakota Soybean Farmers and the Industry

This research has strengthened diagnostics, enabling faster and more accurate identification of the organisms causing the seedling diseases and SDS. The results also provide practical management solutions: seed treatments can improve seedling emergence in pathogen-prone fields. The resistance sources identified in this study have promise for developing resistant soybean varieties.

North Dakota Soybeans and Pollinators: Beginning to Investigate The Potential Interactions and Mutual Benefits

Principal Investigator: Dillon Fogarty, Ph.D., North Dakota State University (NDSU)
School of Natural Resource Sciences

Funded Project
\$16,754

Why the Research is Important to North Dakota Soybean Farmers

Soybeans are a crucial part of North Dakota, so are pollinators, including honey bees. Unlike other plants, soybeans do not require pollinator visitation to successfully reproduce. Thus, we do not always think that soybeans and pollinators have much to do with each other. Recent research suggests that this might be a missed opportunity because pollinators sometimes increase soybean productivity, and flowering soybeans can provide food for pollinators. This research is designed to study these relationships in North Dakota because we do not know very much about the types of bees which contribute to pollinating soybean plants or how that pollination affects the soybean industry.

Research Conducted

We surveyed bees in and around soybean fields at the Central Grasslands Research Extension Center near Streeter, North Dakota, in 2023 and 2024. We used two complementary sampling techniques: active

and passive. First, in 10-minute intervals, we freely searched for bees within 18 two-acre sections of our soybean field. We captured, photographed and swabbed all bees for pollen samples and bee identification. Second, we passively caught bees in blue vane traps to see what other bee species were in and around the soybeans. All bees in the traps that had visible pollen on their body were swabbed for a sample. These pollen samples will be identified with an algorithm to see if any of the bees had soybean pollen on them, which would indicate that the bees are, therefore, contributing to soybean pollination.

Findings of the Research

Within our active sampling, we found honey bees and bumble bees visiting flowers during both years. We found additional bee groups (sweat bees, longhorn bees, mining bees, leafcutter bees, etc.) flying through the fields and in the passive sampling traps, supporting the idea that there is higher bee diversity in and around the fields than what we are directly observing on the flowers.

It was a positive result to find so many types of bees associated with the soybean field because that fact indicates how these bee communities have the opportunity to visit and to pollinate soybean flowers. Additionally, we found a high abundance of sweat bees during early flowering in the soybean fields as well as high abundances of bumble bees and longhorn bees during later flowering, indicating that soybean flowers may be valuable for bees that are active in July and August.

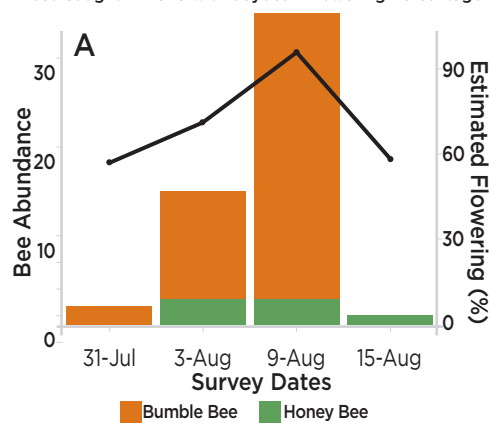
As we continue to use our combined sampling methods and to identify the pollen samples taken from the bees, we will better understand the relationship between pollinators and soybeans as well as how they can benefit each other in North Dakota.

Figure 1. The number of bees within each bee group caught on active surveys along with the flowering period for each survey date in (a) 2023 and (b) 2024.

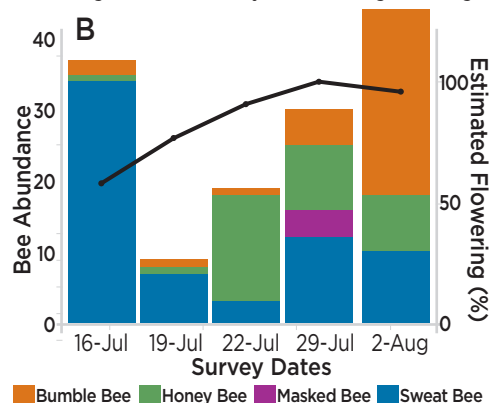


Figure 2. A technician setting the passive, blue vane traps on the edge of the soybean field.

Bees Caught in 2023 with Soybean Flowering Percentage



Bees Caught in 2024 with Soybean Flowering Percentage



Management of Pyrethroid-Resistant Soybean Aphids and Soybean Gall Midge Survey

Principal Investigator: Janet Knodel, Ph.D., North Dakota State University (NDSU)
Entomology and Extension Entomologist

Funded Project
\$12,062

Why the Research is Important to North Dakota Soybean Farmers

Pyrethroid-resistant soybean aphids continue to threaten the effective management of soybean aphids in eastern North Dakota. The first goal of this research is to provide tools for soybean growers to control pyrethroid-resistant soybean aphids as well as to reduce the risk of insecticide-resistance development for other insecticides and for other insect pests. The second goal is to survey for the invasive soybean gall midge, a new, economic insect pest for soybeans in North Dakota. A broad range of registered insecticides, with different modes of action, were tested in the field.

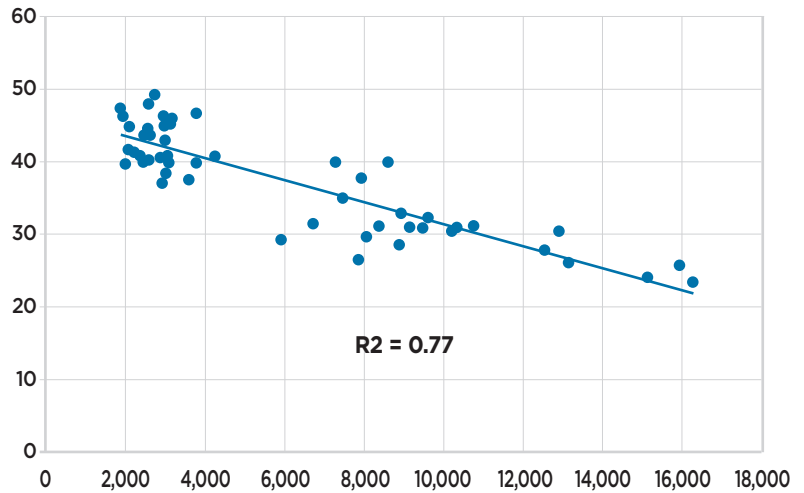
Findings of the Research

The most effective insecticide treatments that reduced the number of soybean aphids were insecticides that only targeted aphids (called aphid specifics), followed by combination insecticides with two active ingredients (usually in different modes of action). The least effective treatment was an insecticide group called pyrethroid insecticides. Yield and net returns were

the highest with the aphid specifics, followed by combination insecticides and then the pyrethroid insecticides.

Soybean gall midge was discovered in Sargent County, North Dakota, in 2022. Detection efforts in 2023 and 2024 were all negative, suggesting that the soybean gall midge is not established or reproducing in North Dakota soybeans. These results could be due to the extended drought, which increased mortality for the overwintering midge in the soil. Future survey efforts are critical for the early detection of new insect pests in soybeans.

Figure 3. Correlation between cumulative aphid days and yield for Fargo, 2024.



Benefits to North Dakota Soybean Farmers and the Industry

This research identified the best insecticide groups to control pyrethroid-resistant soybean aphids and determined the pest status for the soybean gall midge in North Dakota. By understanding the increasing risk of insecticide-resistant soybean aphids, insect management can be optimized through Integrated Pest Management (IPM) and, in turn, can increase soybean producers' profits.

Figure 1. Average cumulative aphid days for each insecticide type at 19 DAT in Fargo, 2024.

Cumulative Aphid Days by Insecticide Type at Fargo, 2024

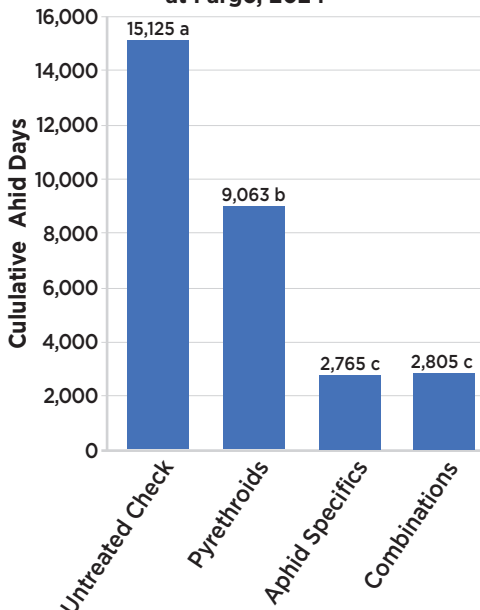


Figure 2. Average yield for each insecticide type at Fargo, 2024.

Yield by Insecticide Type at Fargo, 2024

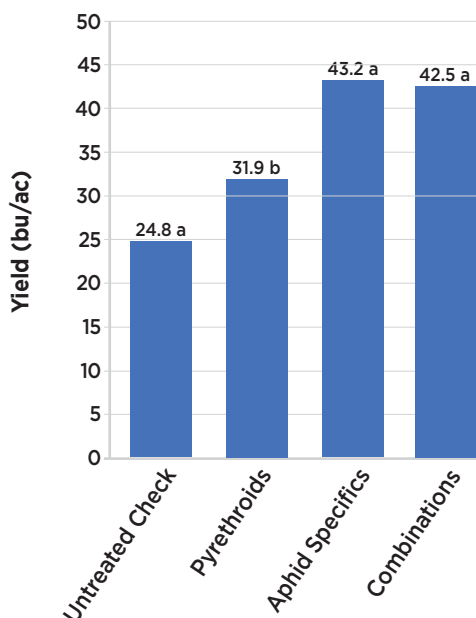


Figure 4. Janet Knodel, Ph.D., and Research Specialist Patrick Beauzay check soybean plants for aphids.



Validation and Optimization of Management Tools for White Mold with Soybean Production in North Dakota

Principal Investigator: Wade Webster, Ph.D., North Dakota State University (NDSU)
Plant Pathology

Funded Project
\$42,621

Why the Research is Important to North Dakota Soybean Farmers

White mold, caused by *Sclerotinia sclerotiorum*, is a major threat to soybeans in North Dakota, particularly during seasons with cool and wet conditions during soybean flowering. This disease has the potential to decimate yields, but the unpredictable nature makes it difficult for farmers to know when to apply fungicides, many of which can be quite an expensive investment. This research focuses on improving the management of white mold by enhancing disease-prediction tools and identifying soybean varieties with resistance to the disease.

Research Conducted

In 2024, we evaluated 27 farmer soybean fields, walking in a “W” pattern to assess the presence of white mold inoculum and to look for infected plants. Then, we assessed our field data from 2023 and 2024 combined relative to multiple predictive models previously developed for predicting white mold risk using weather data. Additionally, we screened 194 genetically diverse soybean lines in greenhouse conditions by infecting plants with a highly aggressive isolate of *S. sclerotiorum* to identify resistant ones. A field trial in Oakes, North Dakota, tested some of these lines, with another trial planned for 2025 in conditions that encourage white mold development.

Table 1. The observed accuracy of the white mold risk-prediction models determines if fungicide applications should be made. The collected data were either grouped by individual years (2023 or 2024) or combined to encompass data from both years. Then, the data were evaluated for accuracy in predicting the development of white mold at a disease incidence of 10% for each of the evaluated action thresholds (20%, 25%, 30%, 35% and 40%). Highlighted cells indicate the highest observed accuracy for each data grouping.

Year	Accuracy of Predicting White Mold (%)				
	20%	25%	30%	35%	40%
2023 and 2024	46.3	51.2	63.4	75.6	75.6
2023	62.5	50.0	68.8	81.3	75.0
2024	36.0	52.0	60.0	72.0	76.0

Findings of the Research

Over the past two years, the predictive risk models projected white mold risk with 75.6% accuracy. This level of accuracy confirms that these models are able to help a farmer decide when fungicide applications are needed and when they are unnecessary, so people can avoid wasteful applications. One more year of field validation took place during the 2025 growing season.

In the greenhouse, 28 soybean lines showed strong resistance, with one line, ‘PI194639’, standing out as highly resistant, offering hope to develop new soybean varieties. However, the 2024 field trial had challenges because uneven plant growth limited disease development. The 2025 trial tested 12 promising lines with high disease pressure to confirm their resistance. The soybeans identified in this research will be used to develop new soybean breeding populations that are resistant to white mold.

Benefits for North Dakota Soybean Farmers & the Industry

These findings provide North Dakota farmers with a reliable tool to make smarter spraying decisions, reducing both costs and environmental effects. As new, resistant soybean varieties become

Figure 1. Greenhouse screening of soybean PI lines for resistance to *Sclerotinia sclerotiorum*. The bleached lesion on the soybean stem is being measured using a digital caliper to determine the level of white mold development.



available, farmers can better manage white mold, leading to higher yields and farm productivity.

Figure 2. Wade Webster, Ph.D., scouts a soybean field for white mold.



Evaluating Metribuzin and Sulfentrazone Rates for Crop Injury and Weed Control Across North Dakota

Principal Investigator: Joe Ikley, Ph.D., North Dakota State University (NDSU) Plant Sciences

Funded Project
\$60,000

Why the Research is Important to North Dakota Soybean Farmers

Herbicide-resistant kochia and waterhemp continue to spread and are problematic for many North Dakota soybean farmers. Effective postemergence herbicide options are becoming more limited as resistance to glyphosate and dicamba is becoming more frequent for these weeds. Soil-residual

herbicides are an important component to manage weed populations with resistance to multiple herbicide sites of action. Metribuzin and sulfentrazone are two older soil-residual herbicides that can be effective against most problematic broadleaf weeds. Many farmers might choose to use lower rates for each herbicide due to cost constraints or potential crop injury.

Findings of the Research

For the crop-safety trials, no crop injury was observed at any rate or combination of metribuzin and sulfentrazone at all sites except for Glyndon, Minnesota, and Minot, North Dakota. Less than 10% visible injury was observed at the Glyndon and Minot locations, and the injury was attributed to metribuzin. None of the injury at these locations resulted in soybean yield loss. Conversely, no injury was observed at the Fargo, North Dakota, location.

Research Conducted

This research was conducted to determine if standard rates of metribuzin and/or sulfentrazone can be applied across several North Dakota sites to provide weed control without compromising crop safety. A standard 1X (0.25 pound active ingredient metribuzin and/or 0.125 pound active ingredient sulfentrazone) and 2X rate for each active ingredient was applied alone and in combination at each site. Separate crop-safety and weed-control trials were established.

For the weed-control trials, treatments of either metribuzin or sulfentrazone alone provided 78% to 82% control of kochia at Hettinger, North Dakota, 6 weeks after planting. Metribuzin provided 74% to 84% control of kochia at Carrington, North Dakota. All herbicide combinations provided 74% to 100% control 6 weeks after planting at both sites.

Green foxtail control ranged between 75% and 91% at Hettinger. Yellow foxtail control was 39% to 85% with metribuzin at 0.25 to 0.5 pounds active ingredient, respectively, at Minot. Yellow foxtail control was 10% to 38% with 0.125 to 0.25 pounds sulfentrazone, respectively, at Minot. Product combinations resulted in 49% to 91% control of yellow foxtail 6 weeks after planting.

Waterhemp control at the Glyndon location ranged between 12% and 50% across all combinations 6 weeks after planting. In Fargo, control ranged from 19% to 86%, with the best control observed when using combinations of metribuzin and sulfentrazone, regardless of rate.

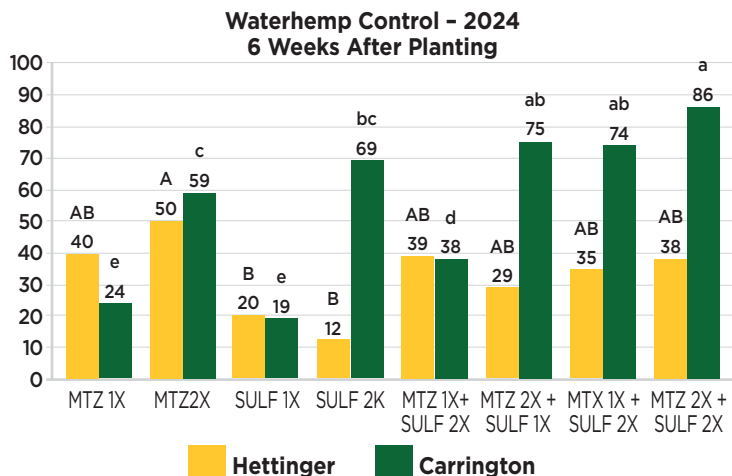
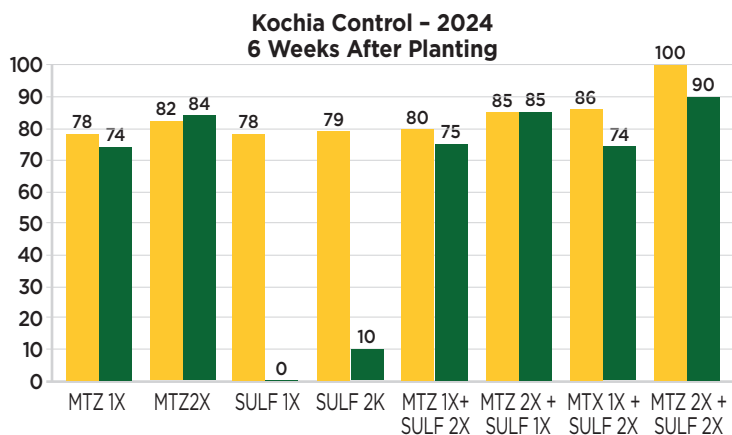
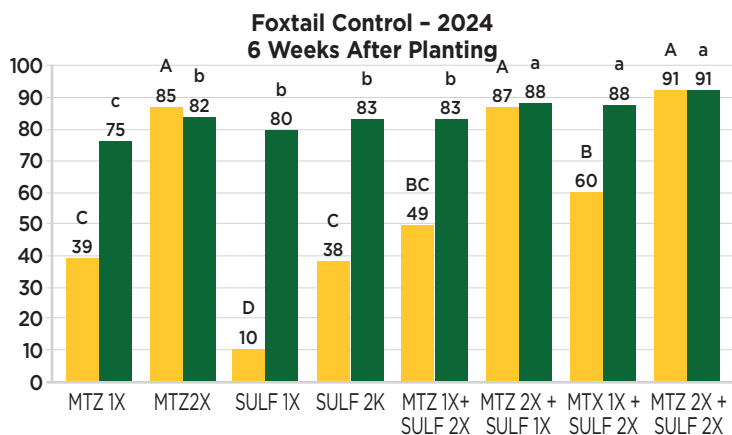


Figure 1. Joe Ikley, Ph.D., and his team work with farmers to tackle weed challenges and protect crop production.



Residue Management for the Future: Planting Technology to De-Risk No-Till Soybean Production

Principal Investigator: Lindsay Malone, Ph.D., North Dakota State University (NDSU)
School of Natural Resource Sciences

Funded Project
\$28,448

Why this Research is Important to North Dakota Soybean Farmers

This research provides guidance for North Dakota soybean farmers who want to transition to reduced tillage and are considering planter-modification options. Managing corn residue while planting no-till differs in our region compared to much of the U.S. because frigid winters and cool,

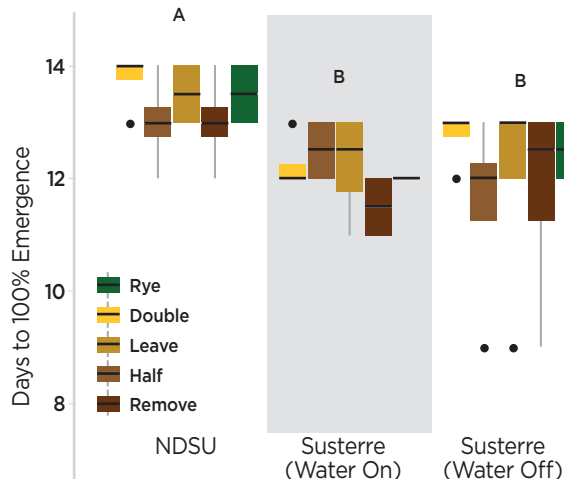
wet spring weather limits decomposition. Planter modifications, such as ultra-high-pressure water jets for cutting through residue, are one option for residue management, but those options have a significant upfront cost. Region-specific research can help guide people looking to transition to no-till soybean production.

The research objectives are as follows: to compare soybean productivity outcomes (emergence rate, final stand and yield) between the Susterre water-jet planter and the conventional no-till system across varying residue levels.

Findings of the Research

There were nominal differences for emergence between the two planters, with the typical converted planter taking one more day to reach 100% emergence than the water-jet planter. The typical converted planter treatment resulted in reduced soybean yield with the heaviest residue treatment compared to the no-residue treatment. The water-jet planter did not have improved yield when the water jets were turned on or off. The somewhat poorer performance of the typical converted planter in high-residue plots demonstrated the mechanical limitations of standard no-till tools under these conditions. However, the ultra-high-pressure water-jet planter did not improve yield or emergence, and is a costly option for converting a planter for no-till production.

Figure 1. Soybean seed yield for the three planter treatments (NDSU typical converted no-till planter, and Susterre’s waterjet planter with the jets on and off) colored by five corn-residue treatments. Treatment combinations with the same letter are statistically similar ($\alpha = 0.05$).



Research Conducted

The study took place in 2024 at the Grand Farm Innovation Campus near Casselton, North Dakota. Researchers tested two types of planting equipment: a traditional no-till planter and an ultra-high-pressure water-jet planter. These planters were tested with different levels of crop residue from complete removal to heavy corn residue. Soybean emergence and yield were measured. Soil-nutrient data and greenhouse-gas emissions are still being studied.

Benefits for North Dakota Soybean Farmers and the Industry

No-till soybean production can be successful, but it requires appropriate planting technology that is capable of cutting through residue without sacrificing planting depth or seed-soil contact. There are many options for modifying planters to be more suited for no-till work, and the cost of those modifications should be considered.

Figure 2. Soybean seed yield for the three planter treatments (NDSU typical converted no-till planter, and Susterre’s waterjet planter with the jets on and off) colored by five corn-residue treatments. Treatment combinations with the same letter are statistically similar ($\alpha = 0.05$).

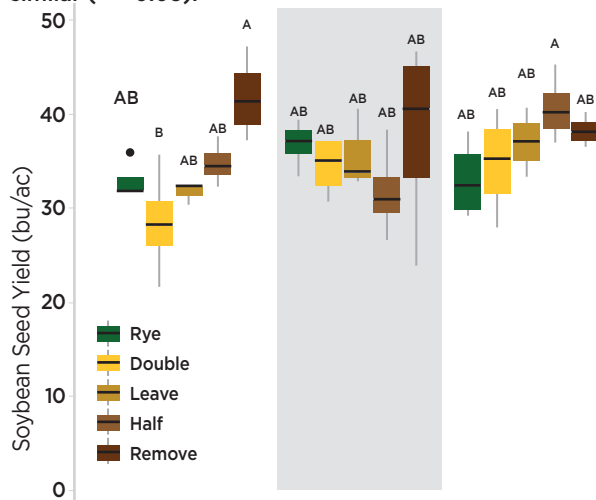


Figure 3. NDSU research specialist Mike McKenna planting with the “typical converted” no-till planter into a heavy-residue plot.

Evaluation of Soybean Cyst Nematode Reproduction on Commercial Soybean Varieties

Principal Investigator: Wade Webster, Ph.D., North Dakota State University (NDSU)
Plant Pathology

Funded Project
\$34,490

Why the Research is Important to North Dakota Soybean Farmers

This research conducted field evaluations for the amount of resistance present in commercial soybean varieties to manage soybean cyst nematode (SCN) and the capacity of this pest to reproduce during the growing season. Because SCN is the most damaging soybean pest in North Dakota, optimal management is critical. Resistance is the most effective management tool available to farmers, but the effectiveness depends on the source of resistance and the native SCN populations in a field. This work will help to give up-to-date information about the commercial resistance available in North Dakota.

Research Conducted

During the 2024 field season, 10 soybean varieties within maturity group 0 were evaluated under naturally infested SCN field conditions at two sites. Severe iron deficiency chlorosis at the Colfax site

prevented useful data collection, so results are presented from the Absaraka location, where the native SCN population was HG type 2.5.7. This HG type is especially concerning because it is known to overcome PI88788 resistance, likely due to long-term reliance on this resistance source. SCN reproduction and yield were measured across the resistance backgrounds.

Findings of the Research

The Absaraka site, with an SCN population of HG type 2.5.7, showed that Peking varieties generally suppressed SCN reproduction better (average reproductive factor (RF) of 0.75) while 'PI88788' varieties allowed for higher SCN reproduction (average RF of 2.2). The soybean variety with no SCN resistance had the highest SCN reproduction (RF of 15.2). Yields ranged from 28.6 to 47.9 bushels per, with no strong association with the SCN reproductive factor, possibly due to moderate initial SCN levels. These findings

“The soybean variety with no SCN resistance had the highest SCN reproduction (RF of 15.2). Yields ranged from 28.6 to 47.9 bushels per, with no strong association with the SCN reproductive factor.”

provided critical data about effective resistance sources for North Dakota farmers and highlighted the need to include a diversity of resistance sources and soybean varieties for SCN management.

Table 1. Ten commercial soybean varieties were evaluated for their response to SCN at Absaraka, North Dakota, in 2024.

Brand	Variety	Relative Maturity	Source of Resistance	Herbicide Trait	Rnd of Season SCN Count (eggs/100cc)	SCN RF ¹	Yield (bu/ac)
Peterson Farms Seeds	PFS-2309	0.9	Peking	E3	3,730	8.2	28.6
Dairyland Seed	DSR-0481E	0.4	PI 88788	E3	890	2.0	30.6
Pioneer	PO2A78E	0.2	Peking	E3	420	0.9	32.3
Peterson Farms Seeds	PFS-2405	0.5	PI 88788	E3	1040	2.3	32.4
Alloy	A09E33	0.9	Peking	E3	330	0.7	32.4
Pioneer	PO7T59E	0.7	Peking	E3	100	0.2	38.7
Pioneer	PO6A85E	0.6	PI 88788	E3	1,300	2.9	39.8
Pioneer	PO4A98E	0.4	None	E3	6,870	15.2	40.7
Dairyland Seed	DSR-o585E	0.5	Peking	E3	540	1.2	43.6
Asgrow	AG07XF4	0.7	PI 88788	XF	750	1.7	47.9
	Mean	0.6	~	~	1,597	3.5	36.7
	LSD ² (α=0.05)	-	-	-	3,548	7.8	11.0

Investigating *Phytophthora sojae* Populations Across North Dakota's Soybean Production Systems

Principal Investigator: Wade Webster, Ph.D., North Dakota State University (NDSU)
Plant Pathology

Funded Project
\$50,821

Why the Research is Important to North Dakota Soybean Farmers

Phytophthora root and stem rot (PRSR), caused mainly by the oomycete pathogen, *Phytophthora sojae*, can destroy soybean crops, leading to substantial yield losses in North Dakota, especially in warm, wet conditions. Early planting, which is common in the state, increases the risk of PRSR, and a new threat, *Phytophthora sansomeana*, may also harm soybeans. This research, in its second year, aims to identify which *Phytophthora* species are present in North Dakota fields, to check if resistance genes for soybeans still work, and to improve breeding and farmer strategies to fight PRSR. By understanding these pathogens, the study helps farmers choose better soybean varieties and protect their crops, boosting profits and sustainability.

Research Conducted

In 2024, researchers sampled soil and plants from 64 fields and 11 symptomatic soybeans across eastern North Dakota. The soil was dried, stored and later flooded to draw out *Phytophthora*, using soybean leaves to capture the pathogens. These leaf tissues were then placed on selective growth media to isolate the pathogens present. The pathogen isolates were then evaluated with microscopy and DNA sequencing to identify their species.

Findings of the Research

Surprisingly, no *P. sojae* was found in the 2023 or 2024 samples, suggesting that it may be less common than previously believed or that the previously developed isolation methods need improvement. However, five isolates of *P. sansomeana* were found, and three were confirmed to cause stem rot in greenhouse tests, marking the first report of this pathogen infecting soybeans in North Dakota. The presence of this pathogen also raises the need for soybean breeding programs to begin integrating *P. sansomeana* resistance genes into their soybean varieties.

Benefits for North Dakota Soybean Farmers and the Industry

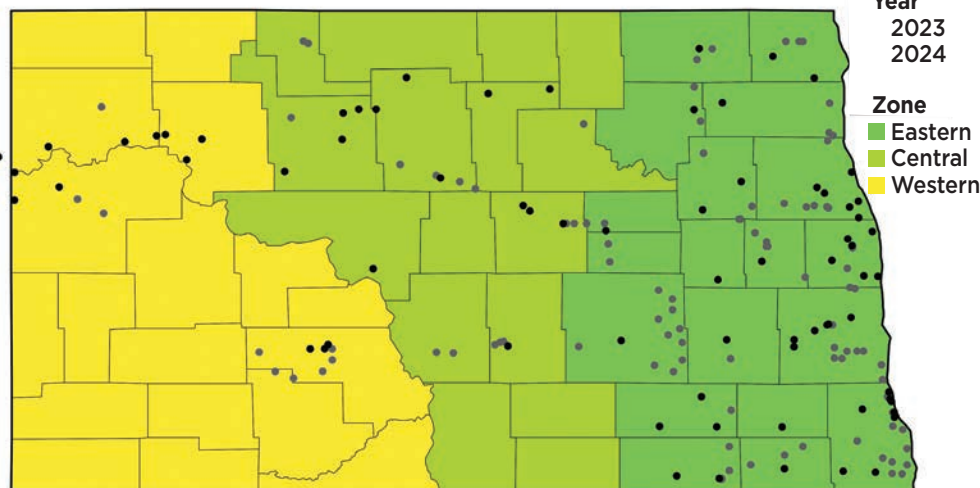
The study's early results show that

Figure 2. Soil sampling for *Phytophthora* root rot.



Figure 1. Map of sampled locations across North Dakota during the 2023 and 2024 field seasons.

Soil Samples Collected in 2023 and 2024



P. sansomeana is a new concern for North Dakota farmers because current resistance genes don't work against it. This finding could mean that past PRSR cases blamed on *P. sojae* were caused by other oomycete pathogens such as *P. sansomeana* or *Pythium* spp. The ongoing 2025 field sampling and seedling tests will help identify all harmful oomycete pathogens which are present.

Farmers should test fields for *Phytophthora*, choose varieties with effective resistance genes for *P. sojae* where it's present and stay updated about new breeding efforts for *P. sansomeana* resistance. This research helps farmers make smarter choices, protecting yields and supporting sustainable soybean farming as new pathogen threats emerge.

Investigating Soybean Seed Treatments and Their Integration into Cropping Systems to Manage Soybean Seedling Diseases in ND

Principal Investigator: Wade Webster, Ph.D., North Dakota State University (NDSU) Plant Pathology

Funded Project
\$67,990

Why the Research is Important to North Dakota Soybean Farmers

Soybean farmers in North Dakota face challenges from early season insect pests and seedling diseases caused by *Pythium* spp., *Phytophthora* spp., *Rhizoctonia solani* and *Fusarium* spp., especially when planting early in cool, wet soils to boost yields. These pests and diseases can harm young plants, reducing crop success and profits. This research, in its first year, tested seed treatment programs to protect soybeans, explored the interaction with different planting dates and seeding rates, and examined their role with cover crops. This work aimed to help farmers prevent disease development, reduce yield losses and maintain profitability.

Research Conducted and Findings of the Research

In 2024, nine seed treatment programs, combining fungicides and insecticides, were tested at three sites: Fargo, Oakes and Williston. For these studies, we counted the

emerged plants, recorded root-rot severity levels, measured yields and evaluated partial profitability to compare treatments.

In eastern North Dakota (Fargo and Oakes), treatments with multiple active ingredients increased the plant stands, yield and profits compared to non-treated seeds, with some seed treatment programs covering their costs through higher returns. In western North Dakota (Williston), non-treated seeds, surprisingly, had the highest stands, yield and profits, suggesting that seed treatments may not always be needed in dry conditions, although some treatments lowered the yield, possibly due to issues of phytotoxicity.

A second study explored how seed treatments work with early or late planting and with two seeding rates (130,000 and 170,000 seeds/acre) in Fargo, and Carrington, North Dakota. Early planting led to higher root-rot severity, but treatments with three active fungicide ingredients reduced disease levels better than those with

Figure 2. Graduate student Vanessa Louks planting the soybean-seed treatment trials at Gardner, North Dakota.

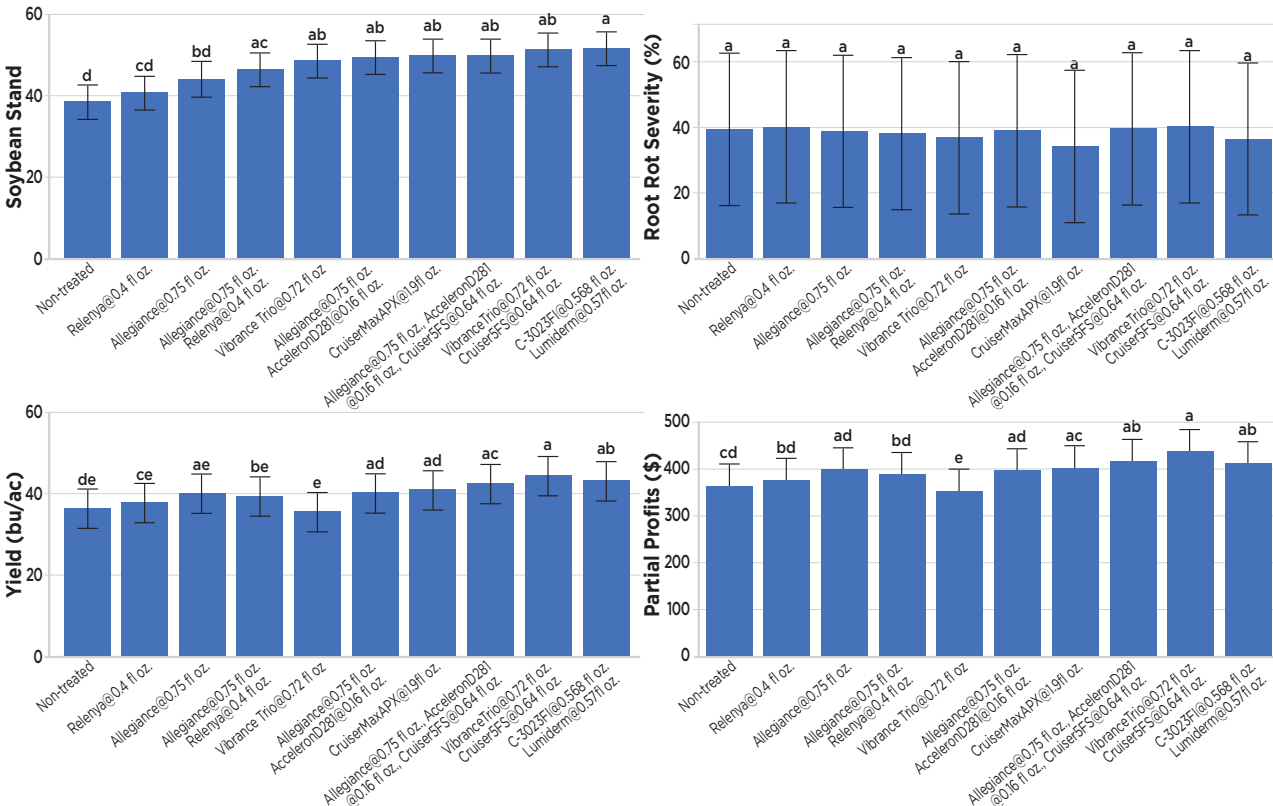


fewer products. Specifically, one product with high levels of efficacy against *Fusarium* spp. played the greatest factor in managing root-rot levels. At lower seeding rates with early planting, non-treated seeds yielded as well as the treated ones, suggesting that early planting can offset losses due to disease pressure. However, at higher seeding rates, seed treatments did boost yields and partial profits.

These trials were repeated in 2025 and were running smoothly. Additionally, three trials

with winter rye cover crops were started in Gardner, Dickinson and Minot, with soybeans planted in 2025 after rye termination by glyphosate. Early soybean growth looks promising, with data collection ongoing.

Figure 1. Effect of soybean-seed treatment programs on soybean stand, root rot severity (%), yield (bu/ac) and partial profits (\$/ac), assuming a \$9/bu grain-sale price point. These data are from two site years in Fargo, and Oakes, North Dakota, during the 2024 season. Seed treatment programs that share a letter do not statistically differ as determined by Fisher's least significant difference (alpha = 0.05).



Benefits for North Dakota Soybean Farmers and the Industry

So far, these trials indicate that seed treatments have positive effects in some, but not all, environments. Further site years are needed to draw larger conclusions and recommendations for North Dakota farmers.

Soybean Cyst Nematode Sampling Program (2024) and Evaluation of SCN Reproduction on Commercial Soybean Varieties

Principal Investigator: Wade Webster, Ph.D., North Dakota State University (NDSU) Plant Pathology

Funded Project
\$34,490

Why the Research is Important to North Dakota Soybean Farmers

Soybean cyst nematode (SCN) is a microscopic worm that attacks soybean roots, silently causing up to 30% yield losses in North Dakota before any signs appear above ground. This destructive pest has been spreading across the state since its first report in 2003, threatening farmers' soybean crops and profitability. This research helps farmers by providing free soil testing to detect SCN presence and severity, creating maps to track SCN's spread and testing soybean varieties with the greatest SCN resistance.

Research Conducted

In 2024, over 5,000 soil sampling bags were distributed to farmers through county Extension offices and Extension events,

such as field days and the Big Iron Farm Show, encouraging farmers to test their fields for SCN. Farmers submitted 687 samples which were analyzed for SCN egg counts.

Findings of the Research

Results showed that 30% of the samples tested positive for SCN (greater than 200 SCN

Figure 2. Cumulative distribution and egg levels for soybean cyst nematode in North Dakota, as determined by the North Dakota Soybean Council/NDSU Extension sampling program between 2013 and 2024.

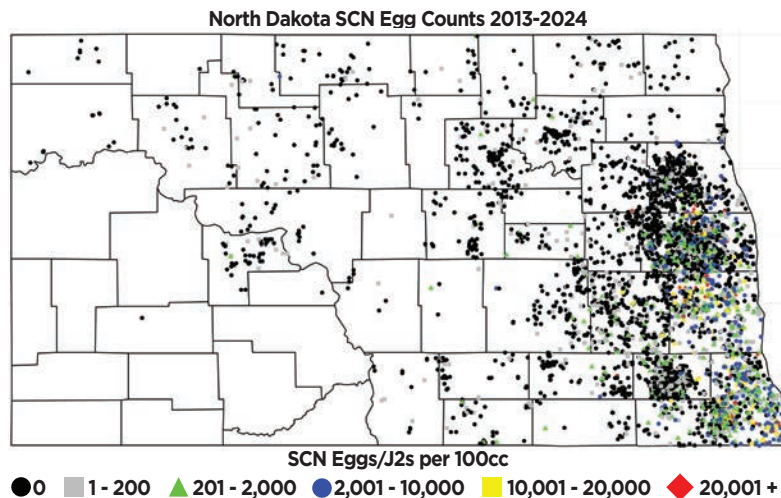
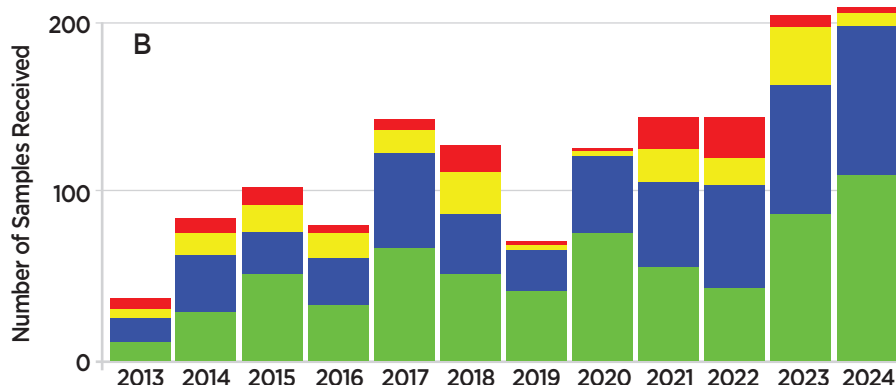
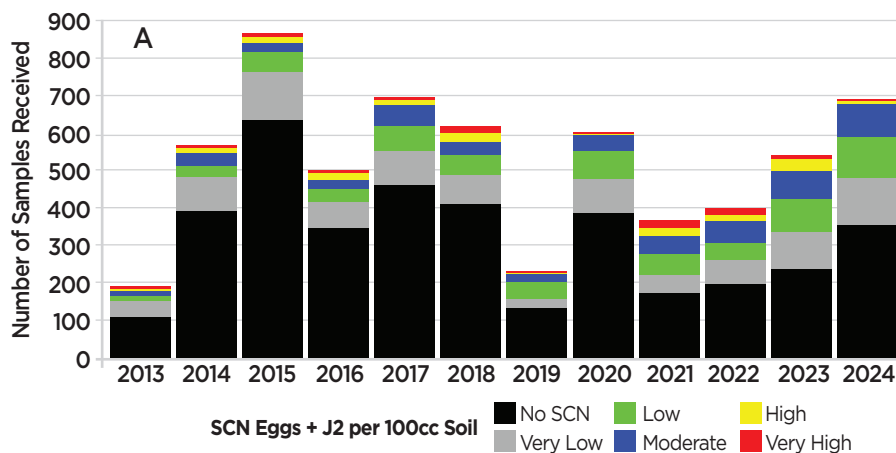


Figure 1. Submitted SCN samples from the North Dakota SCN sampling program between 2013 and 2024. Samples are classified based on their egg counts as No SCN (0 eggs + J2/100 cc), Very Low (1-200 eggs + J2/100 cc), Low (201-2,000 eggs + J2/100 cc), Moderate (2,001-10,000 eggs + J2/100 cc), High (10,001-20,000 eggs + J2/100 cc) or Very High (greater than 20,000 eggs + J2/100 cc). Figure 2A represents all submitted samples, with a total of 6,237 observations, and Figure 2B illustrates samples with SCN counts greater than 201 eggs + J2/100 cc.



eggs/100cc of soil) and that 52% of the samples tested negative for SCN. General SCN trends were also examined, revealing that the proportion of submitted samples with no SCN has been decreasing from over 65% in 2013-2016 to around 50% in 2021-2024. This finding indicates that SCN is becoming more common and severe, with more fields having a greater number of low and moderate egg levels. Updated maps were created to show SCN's spread without identifying specific farms, and Extension materials were shared at field days and meetings to raise awareness and to guide farmers about managing this pest effectively.

Benefits for North Dakota Soybean Farmers and the Industry

This work helps farmers protect their yields and income by detecting SCN early and by guiding effective management decisions. The research also strengthens the soybean industry by slowing SCN's spread as well as supporting the long-term sustainability and competitiveness of North Dakota production.

Farmers should regularly test the soil, choose SCN varieties such as the ones with Peking sources of resistance for better SCN control and use Extension resources to stay informed, therefore protecting crops and profits.

Optimizing Fungicide Application Timing, Fungicide Droplet Size and the Soybean Seeding Rate for Improved White Mold Management in Soybeans

Principal Investigator: Michael Wunsch, Ph.D., North Dakota State University (NDSU) Carrington Research Extension Center

Funded Project \$40,210

Why this Research is Important to North Dakota Soybean Farmers

Previous research demonstrated that small adjustments to the fungicide’s application timing and the spray droplet’s size confer sharp improvements for white mold management in soybeans at little or no additional cost. That research tested the optimal timing for a single fungicide application which targeted white mold, and the study assessed the optimal spray droplet size for fungicide when using TeeJet and Wilger nozzles in soybeans seeded to narrow (14-inch) and intermediate (21-inch) rows. This research also evaluated the optimal timing for the first application of a two-application fungicide program as well as the optimal droplet size for fungicide with Hypro nozzles and soybeans seeded to wide (28-inch) rows.

Research Conducted

Application timing for one versus two sequential fungicide applications was assessed with five applications 2 to 4 days

apart in irrigated soybeans that were seeded to narrow and wide rows. The fungicide’s droplet size was evaluated by testing each application timing with three droplet sizes and with a study evaluating TeeJet versus Hypro nozzles. A single fungicide application delivered with TeeJet and Hypro nozzles emitting fine, medium and coarse droplets was tested on soybeans seeded in intermediate and wide rows at 100,000; 140,000; and 180,000 viable seeds per acre. The fungicide Endura (5.5 ounces per acre (oz/ac), fungicide timing studies; 8.0 oz/ac, droplet size studies) was applied at 6.0 mph in 15 gallons per acre (gal/ac) with a tractor-mounted sprayer equipped with a pulse-width modulation system. Testing was conducted in Carrington and Oakes.

Figure 3. Soy white mold fungicide application



Findings of the Research

The fungicide application timing that optimized white mold management differed for a single application versus the first treatment of a two-application sequence. Fine droplets optimized white mold management with TeeJet nozzles when the canopy was very open, irrespective of row spacing (narrow and wide rows); the optimum droplet size increased as the canopy closure increased; and the fungicide droplet size that optimized white mold management was similar for TeeJet

versus Hypro nozzles in soybeans seeded to intermediate rows but not wide rows. Lowering the seeding rate to 100,000 viable seeds/ac reduced white mold severity and had little-to-no effect on soybean yield under white mold pressure.

Benefits and Recommendations for North Dakota Soybean Farmers and the Industry

The results suggest that white mold management in soybeans can be improved by adjusting the fungicide’s application timing, using the right spray droplet size for the crop canopy and nozzle type (and possibly row spacing), and lowering the soybean seeding rates.

Figure 1. Oakes, North Dakota (2024): When conditions favored white mold as soybeans entered bloom, the management of white mold in soybeans was optimized with a single fungicide application made when 89-98% of plants were at the R2 growth stage or with the first of two sequential applications made when 29% of plants were at R2. The fungicide Endura (5.5 oz/ac) was applied.

Application date application #1	Application #2 application	Application #1 Growth stage	Single fungicide application			Two fungicide Applications		
			Canopy closure 14" rows	28" rows	White mold (%)	Yield (bu/ac)	White mold (%)	Yield (bu/ac)
Non-treated control					26 c	59 b	25 b	60 b
July 17	July 29	54% in bloom, 5% R2	59%	14%	15 b	64 a	8 b	65 a
July 20	Aug. 1	78% in bloom, 29% R2	78%	24%	16 b	63 a	6 a	66 a
July 23	Aug. 3	94% in bloom, 89% R2	91%	69%	9 b	64 a	7 a	65 a
July 25	Aug. 6	100% in bloom, 98% R2	99%	86%	9 a	65 a	10 a	65 a
July 28	Aug. 9	80% in bloom, 20% R3	100%	98%	11 a	64 a	8 a	64 a
CV:			16.6	5.2	24.7			

Within-column means followed by different letters are significantly different (P < 0.05)

Figure 2. Carrington, and Oakes, North Dakota (2024): The influence of seeding rate on white mold severity and soybean yield. The combined analysis across results from Carrington and Oakes is shown; the response to the seeding rate was similar across locations.

White mold (%)	White mold (%)			Yield (bu/ac)	Yield (bu/ac)		
	21" rows	28" rows	Combined analysis		21" rows	28" rows	Combined analysis
100,000 Viable seeds/ac	8 a	25 b	9 a	64 a	58 a	60.9 a	
140,000 Viable seeds/ac	11 a	12 b	11 ab	65 a	58 a	61.5 a	
180,000 Viable seeds/ac	13 b	12 b	12 b	65 a	58 a	61.3 a	
CV:	25.0	12.8	25.0	2.9	2.0	2.0	

Within-column means followed by different letters are significantly different (P < 0.05)

Soy-Based, Biodegradable Super-Absorbent Polymers for Personal-Care and Agricultural Products

Principal Investigator: Dean Webster, Ph.D., North Dakota State University (NSDU)
Coatings and Polymeric Materials

Funded Project
\$10,672

Why the Research is Important to North Dakota Soybean Farmers

Super-absorbent polymers (SAP) have a wide application for disposable personal-care products and for many agricultural and civil engineering applications. The most common commercial SAPs are crosslinked polyacrylic acid salts. Due to environmental concerns, there is a demand to replace petroleum-based materials in disposable products with bio-based, biodegradable and renewable materials.

Research Conducted

The soy-based super-absorbent copolymer was developed from chemically modified soybean oil, acrylic acid and soy meal powder. The polymer was synthesized by the emulsion polymerization method in an aqueous medium; then, the polymer was extracted from the water dispersion, thermally crosslinked and neutralized with a base solution. The composition of the soy-based copolymer was optimized to achieve maximum monomer conversion and stability for the polymer dispersion.

Findings of the Research

The polymer with an optimized composition containing 57 weight percentage of both soybean oil and soybean meal showed excellent water absorption, reaching a value of 74 grams of water per gram of polymer. The extraction process for dry SAP from the



Figure 1. Corn seeds coated with a soy-based SAP adhesive. Left: film-coated seeds, middle: encrusted seeds, and right: germinated film-coated seeds.

polymer-water dispersion was optimized, and the polymer sample obtained with the freeze-drying process had a higher water absorption rate than the air-dried polymer. For biodegradability testing, the neutralized soy-based SAP demonstrated the same rate of degradation in the soil as the starch reference while the same polymer in the form of a polyacid showed a slower rate of biodegradation.

The soy-based copolymer was tested as a bio-based adhesive for a moisture-preserving seed coating. The germination test showed no delay with germination for the film-coated corn seeds and the

antifungal properties of the soybean coating.

Benefits for North Dakota Soybean Farmers and the Industry

With this project, a new concept of using a polymer made from soybean oil and soybean meal for SAP was demonstrated. We showed that the soy-based polymer can have applications for disposable personal-care products and agricultural products. Considering the environmental concerns, the new biodegradable, soy-based polymers have great potential to replace the synthetic and non-biodegradable SAPs on the market.



Figure 2. Dry soy-based SAP sample (left) and the same polymer sample swollen in water (right).



Figure 3. Dean Webster, Ph.D., leads cutting-edge research on soy-based coatings and polymers.

Polyethylene Terephthalate (PET)-Analogue from Soybean Gallic Acid

Principle Investigator: Ali Alshami, Ph.D., University of North Dakota (UND) Chemical Engineering

Funded Project
\$18,319

Why the Research is Important to North Dakota Soybean Farmers

This project's goal was to create new, high-value uses for soybean-processing byproducts by converting them into sustainable plastics. We focused on developing a soybean-based alternative to polyethylene terephthalate (PET), the plastic widely used in bottles, coatings and food packaging. Using gallic acid extracted from soybean byproducts, we successfully produced renewable polymers known as vitrimers. These materials are durable, heat resistant, and can be reshaped and reprocessed, offering an eco-friendly alternative to petroleum-based plastics.

Research Conducted

We synthesized new bio-based plastics using gallic acid, ethylene glycol and succinic acid. Two versions of the material were developed: non-vitrimer epoxy esters and vitrimeric versions that included a zinc catalyst. Laboratory characterization confirmed the successful creation of these polymers. We used thermal analysis and chemical spectroscopy to assess stability, recyclability and purity. While planned antibacterial and 3D printing evaluations could not be completed due to equipment and biosafety limitations, the project successfully delivered on its primary objective: demonstrating that soybean byproducts can serve as the foundation for PET-like plastics.

Findings of the Research

Our findings confirmed that soybean-based plastics exhibit strong heat resistance and durability, which are comparable to conventional PET. The vitrimer versions also showed recyclability advantages because they can be reshaped and reprocessed more easily than petroleum-based plastics. The zinc catalyst improved re-processability, although it slightly reduced heat resistance, highlighting a trade-off that can be optimized with future work.

Benefits for North Dakota's Soybean Farmers and the Industry

This project demonstrates that North Dakota soybean byproducts can be transformed into renewable plastics with strong market potential. The work creates an opportunity to increase the demand for soybeans while adding value to processing waste.

Figure 2. Alshami lab members.



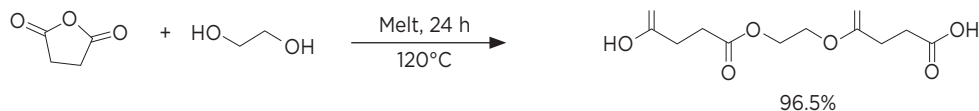
Table 1. Thermal-property data for the synthesized non-vitrimeric and vitrimeric epoxy esters

Polymer	Zn(acac) ₂ % ^{a)}	Epoxy: curing agent ratio	T _{onset} (C°) ^{b)}	T _{20%} (C°) ^{c)}	T _{50%} (C°) ^{d)}	Residual mass	T _g (C°)
NV _{1,1}	0	1:1	344.0	368.0	393.0	13.22	68.2
NV _{1,2}	0	1:2	324.0	368.5	385.2	4.85	--
NV _{1,0.75}	0	1:0.75	330.5	354.0	368.2	0.00	--
V _{1,1,0.02}	2	1:1	331.0	364.0	388.0	21.10	62.2
V _{1,1,0.06}	6	1:1	327.0	352.0	373.0	23.20	55.8
V _{1,1,0.10}	10	1:1	305.0	334.0	363.0	24.10	51.1

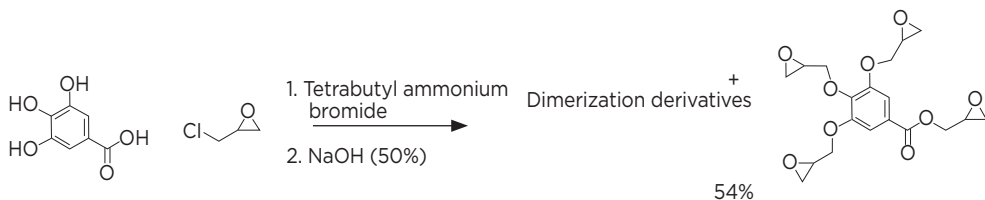
^{a)} mol% to COOH ^{b)} Decomposition temperature at 5% weight loss; ^{c)} Decomposition temperature at 20% weight loss; ^{d)} Decomposition Temperature at 50% weight loss; ^{e)} Residual mass at 650°C.

Figure 1. Synthesis schemes for 1) ethylene glycol diacid diester and 2) GA-based glycidylated monomer.

Scheme 1. Synthesis of Ethylene glycol Diacid Diester



Scheme 2. Synthesis of GA-based glycidylated monomer



Soybean Extracts as Green Corrosion-Inhibiting Additives for Fluoropolymer Coatings

Principle Investigator: Eugene Caldon, Ph.D., North Dakota State University (NDSU)
Coatings and Polymeric Materials

Funded Project
\$40,852

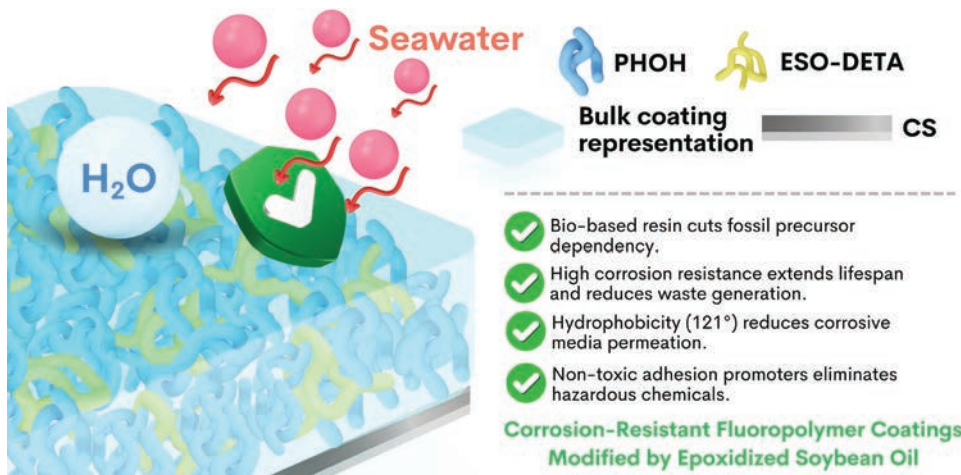
Why the Research is Important to North Dakota Soybean Farmers

This project introduces a new use for soybeans in the coating industry. Fluoropolymer coatings (i.e., Teflon) are excellent for resisting chemicals and heat, but, by themselves, these coatings do not stick well to metals. We used epoxidized soybean oil (ESO), a renewable oil from soy, to help glue the coating onto steel. Therefore, tanks, pipes and other metal parts can be better protected from rust with a coating that contains soybean oil.

Research Conducted

We first treated a fluoropolymer polyvinylidene fluoride-co-hexafluoropropylene (PVDF-HFP) to add hydroxyl (OH) groups, making it highly available for chemical bonding. We blended this modified polymer with varying amounts of ESO and a curing agent and then coated the steel panels. The coatings were first cured at room temperature and then by heating. We used techniques such as infrared spectroscopy to confirm the occurrence of chemical reactions, measured how water-repellent the coatings are and tested corrosion resistance by immersing the samples in salt water. We also performed cyclic corrosion tests to

Figure 1. Schematic overview of the corrosion protection mechanism for the epoxidized soybean oil-modified fluoropolymer coating system.



simulate long-term exposure.

Findings of the Research

The soy-based additive significantly improved the fluoropolymer coatings' performance. The coatings with ESO adhered to steel approximately three times stronger than the unmodified fluoropolymer. This level of adhesion is considered strong enough for durable, long-term coating performance.

The best-performing formulation,

containing 0.25 grams of ESO, maintained a high level of corrosion resistance even after 7 days of immersion in saltwater, effectively blocking rust-causing ions. Furthermore, with cyclic corrosion testing, steel coated with this formulation showed no visible rust until the fifth test cycle while the uncoated and unmodified samples had visible corrosion almost immediately. Moreover, the addition of ESO enhanced the coatings' water repellency.

North Dakota Soybean Council Partners with Airable Research Lab

Funded Project
\$150,000

The North Dakota Soybean Council (NDSC) partners with Airable Research Lab to accelerate the development and commercialization of new industrial and consumer products made from soybeans.



Airable Lab has had a hand in the development of several soybased products including DeWalt bar and chain oil.

Airable Research Lab, located on the campus of Ohio Wesleyan University in Delaware, Ohio, operates as a business line of

the Ohio Soybean Council, a Qualified State Soybean Board. NDSC is one of six state soybean boards, along with Missouri Soybeans, the Kentucky Soybean Board, the Iowa Soybean Association, the Michigan Soybean Committee, and the Illinois Soybean Association, supporting Airable's work to expand soy-based innovation and market demand.

Airable works directly with commercial and industrial partners to develop soy-based solutions that meet specific performance and sustainability goals. By conducting early-stage research at no cost to clients, the

lab helps reduce risk and speed the path from concept to market.

Through this partnership, NDSC supports efforts to diversify soybean end uses, increase the value of soybean oil and byproducts, and strengthen long-term demand for soybeans.



Barry McGraw founder of Airable Research Lab.

Anaerobic Digestion of Soybean Meal for Biogas and Biofertilizer Productions: A Life-Cycle Assessment

Principal Investigator: Iris (Xiaoyu) Feng, Ph.D., North Dakota State University (NDSU)
 Bioenvironmental and Structural Engineering

Funded Project
 \$34,704

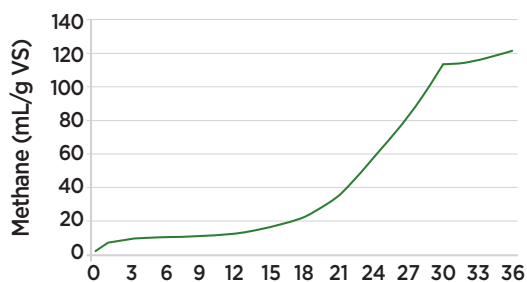
Why the Research is Important to North Dakota Soybean Farmers

With more soybeans being grown in North Dakota and new soybean crushing plants opening, more defatted soybean meal is being produced. Defatted soybean meal is a by-product that currently has limited uses. This research looks at how defatted soybean meal can be turned into something valuable—renewable energy and natural fertilizer—so that farmers can make more profit from the soybeans they already grow while also reducing waste.

Research Conducted

In this research, we tested how well defatted soybean meal works in a process called anaerobic digestion. We mixed defatted soybean meal with cow manure and placed the mixture in controlled tanks

Figure 1. Methane production during a 33-day anerobic digestion period.

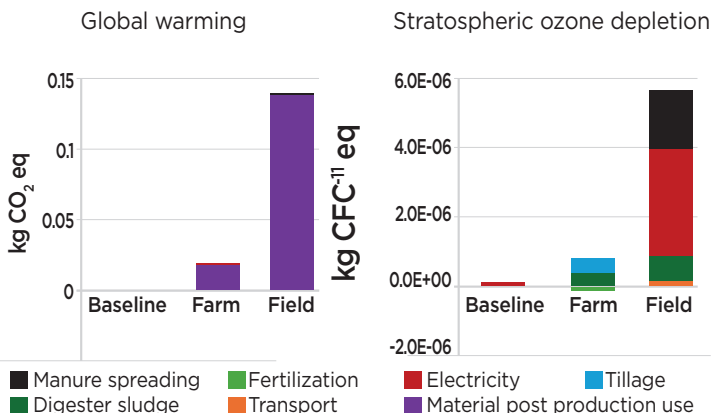


to measure how much biogas was produced. We also looked at the nutrients left after digestion to see if the material could be used as fertilizer. In addition, we used computer models to compare the environmental effects for three scenarios: using defatted soybean meal as animal feed, digesting it and throwing away the waste, and digesting it and using the waste as fertilizer.

Findings of the Research

The results showed that defatted soybean meal can produce good amounts of biogas, with methane levels rising steadily over time. The gas was clean and had very low levels of harmful substances. The leftover digestate had more nitrogen as well as stable phosphorus and potassium levels, making the digestate useful as a natural fertilizer. The computer

Figure 2. Global warming and stratospheric ozone depletion for three soybean-meal use scenarios.



modeling showed that using defatted soybean meal for both energy and fertilizer is better for the environment than the other two options.

Benefits for North Dakota Soybean Farmers and the Industry

This research shows that defatted soybean meal, a common by-product of soybean processing, can be turned into two valuable products: renewable energy and biofertilizer. Therefore, farmers can reduce costs for fuel and fertilizer while creating less waste.

Highly Soy-Based Pressure-Sensitive Polymer Adhesives

Principal Investigator: Andriy Voronov, Ph.D., North Dakota State University (NDSU)
 Coatings and Polymeric Materials

Funded Project
 \$45,342

Why the Research is Important to North Dakota Soybean Farmers

Pressure-sensitive adhesives (PSAs) bond with light pressure and can be cleanly removed from substrates with minimal force. Incorporating “soft” and functional soy-based fragments provides the right balance of viscous and elastic properties, enabling multiple bonding and debonding cycles across different surfaces.

This research advances the use of soybean oil and high-oleic soybean oil to synthesize emulsion polymers for sustainable PSAs. Commercializing these new materials has the potential to add value to soybeans,

increasing profitability for North Dakota farmers. The resulting soy-based PSA products could strengthen the soy value chain and expand market opportunities.

Research Conducted

This project investigated the feasibility of developing PSAs with very high soy-based content. The project’s main goal was to develop new soy-based pressure-sensitive adhesives from latex polymers derived from various soy components: soybean oil-based vinyl monomer (SBM), high-oleic soybean oil-based vinyl monomer (HOSBM) and soybean oil-based polymer surfactant (SBPS).

Figure 1. Coatings and Polymeric Materials graduate student Mariia Usiichuk (left) and summer student Yuliia Romaniuk synthesize highly soy-based latex PSAs.

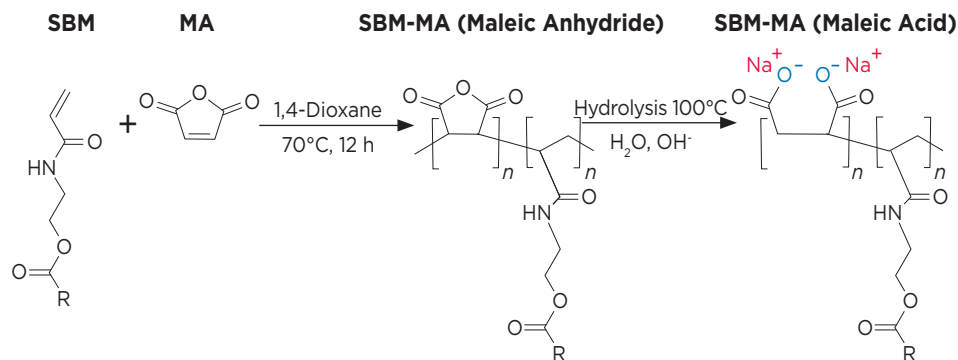


Findings of the Research

We developed synthetic procedures for SBM, HOSBM, and SBPS; formulated latex polymers thereof; and evaluated the properties and adhesion for the resulting highly soy-based polymeric materials. The newly synthesized, soy-based PSAs showed superior adhesion performance across all metrics (peel, tack, and shear), excellent film forming, and enhanced colloidal and solvent resistance.

The suitability of using various combinations/ratios of SBM and HOSBM to make latexes, which are stabilized by SBPS during mini emulsion polymerization, has been demonstrated. The resulting polymeric

Figure 2. Synthesis of soy-based polymeric surfactant (SBPS) - SBM-MA (R = soybean oil's fatty acid components), with subsequent hydrolysis.



materials, containing SBM, HOSBM and SBPS, possess the prospective properties

and performance needed for PSAs on multiple substrates.

Designing High-Performance Materials by Using Soybean Meal as a Functional Feedstock

Principle Investigator: Surojit Gupta, Ph.D., University of North Dakota (UND)
Biomedical Engineering

Funded Project
\$44,350

Why the Research is Important to North Dakota Soybean Farmers

Finding large-scale, new uses for North Dakota soybeans is important to farmers because it can diversify the market and can reduce dependency on specific sectors (e.g., animal feed and oil). New options also increase the demand for soybeans, potentially leading to higher crop prices and increased profitability for the farmers. Opening new soybean processing plants in North Dakota heightens the need and urgency to search for new soybean uses. This project's goal is to develop a fully bio-based and room-temperature-curable soy protein adhesive with excellent pre-pressing, dry and wet bonding strength, as well as good mildew resistance and flame retardancy, via a dual crosslinking strategy.

Research Conducted

In this project, we developed a wood adhesive with soy protein as the main feedstock and used the adhesive to successfully produce high-density wood particle boards (high strength and stiffness, suitable for furniture and construction applications) and foamed particle boards (lightweight, suitable for insulation and packaging). We measured the adhesive's strength before it was fully cured (pre-press strength) as well as its dry strength (fully cured) and wet strength (after water immersion). We conducted burning and mold-growth tests of the adhesive.

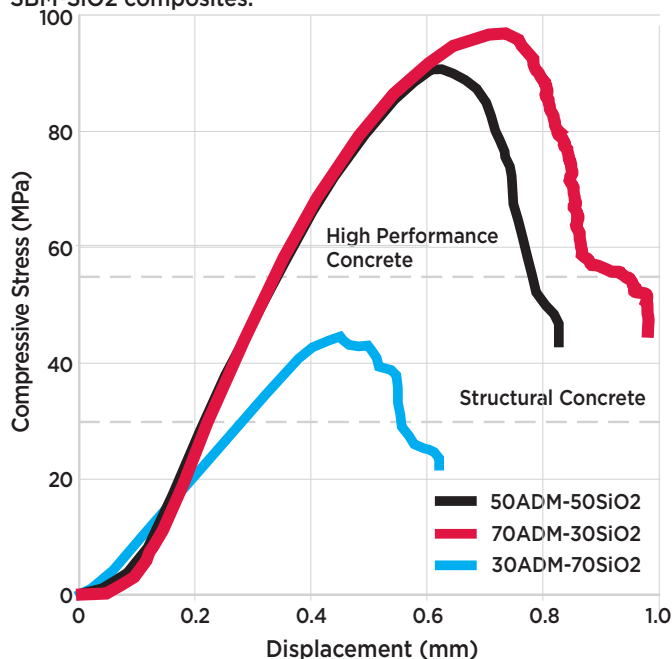
Based on the tests' results, we optimized the adhesive's formulation and application conditions. The adhesive can cure at room temperature, and it shows flame-retardance and mildew-resistance properties. It is also stronger under both dry and wet conditions than many other bio-based adhesives.

Findings of the Research

Via a dual crosslinking strategy, this research developed a fully bio-based, room-temperature-curable soy protein adhesive with high bonding strength (both dry and wet), outstanding mildew resistance and good flame retardance. The developed adhesive can be successfully used as a biobinder for fabricating particle and foam boards. Further investigations with the bonding mechanism and combustion properties of the prepared adhesive as well as the mechanical properties of the prepared particle and foam boards will be beneficial for the adhesive's industrial adoption.

Benefits for North Dakota Soybean Farmers and the Industry

Figure 1. Compressive stress versus a displacement plot for SBM-SiO₂ composites.



In 2023, the global wood adhesive market was valued at \$7 billion (USD) and was estimated to grow at a compound annual growth rate of 8.6% from 2024 to 2030. Due to government regulations and rising consumer awareness, the demand for bio-based, volatile-organic-compound-free green adhesives has continued to increase. The soy-based adhesive from this project is expected to take advantage of this market trend and, therefore, has a high market potential.

Soy-Based Baling Twine with High Digestibility: Further Development

Principal Investigators: Long Jiang, Ph.D., North Dakota State University (NDSU) Mechanical Engineering; Zachary Carlson, Ph.D., NDSU Animal Sciences; and Mark Bauer, Ph.D., NDSU Animal Sciences

Funded Project
\$18,019

Why the Research is Important to North Dakota Soybean Farmers

Polypropylene (PP) twine is widely used to bail hay for livestock feed. Animals often consume the twine, which can cause serious health issues and even death because the plastic cannot be digested. In a project completed a year earlier, we blended biodegradable plastic polylactic acid (PLA), soymeal (SM) and other additives to create a new twine material. The material was extruded into filaments and twisted into twine to produce a twine product with improved digestibility. For this project, a lower-cost soyhull (SH) was used to replace the SM to develop new twine formulations as well as the associated processing techniques and parameters. The new twines' properties were extensively investigated.

Figure 1. Tensile testing of a PLA/SH ribbon.

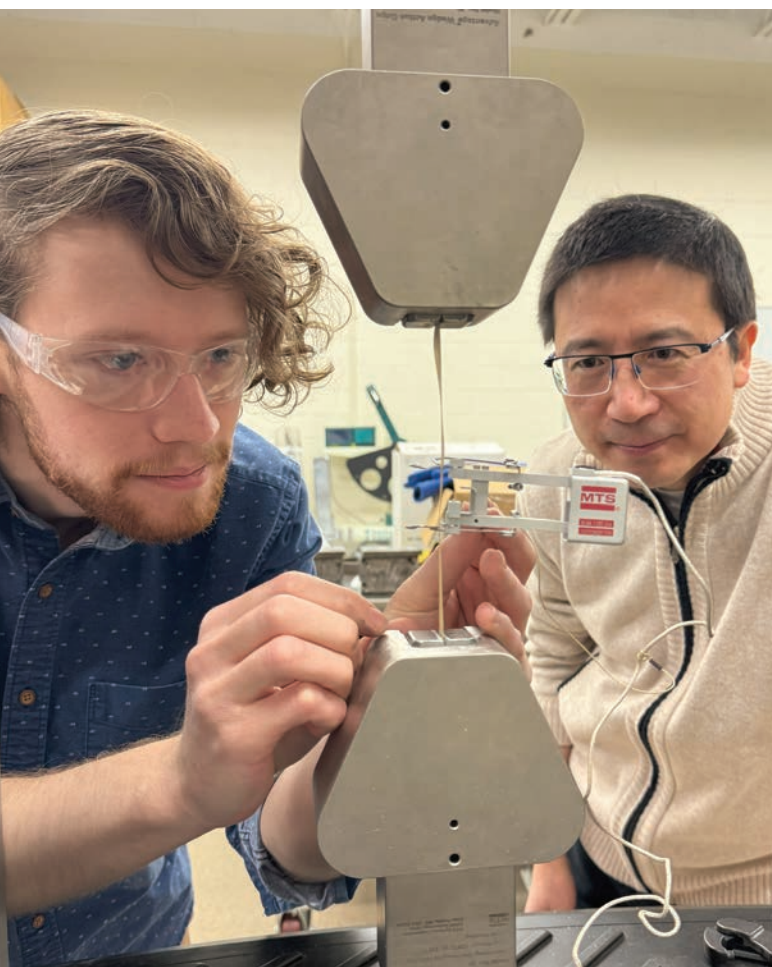
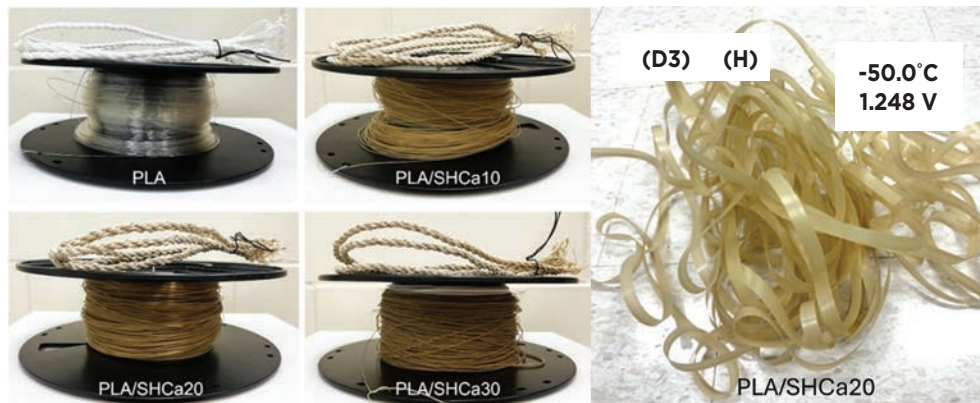


Figure 2. Samples of PLA/SH twine and ribbon.



Research Conducted

A series of formulations and processing techniques were explored to produce twine and packing ribbons. The formulations'

main ingredients include PLA, SH and small amounts of processing aids. The SH content was increased from 0% (i.e., pure PLA) to 30%. The new products were investigated for their processability, mechanical properties, microstructure, thermal stability, UV resistance and digestibility using industrial-standard testing procedures.

Findings of the Research

The PLA/SH twines showed similar

tensile properties to the PLA/SM twines with the same soy content. The digestibility and UV resistance for the new PLA/SH products increased with their SH content. PLA/SH twines and ribbons exhibited different mechanical properties when produced using the same formulations. The tensile strength and extensibility/toughness of the twines decreased with the SH content. However, for the ribbons, the extensibility/toughness of the formulations containing up to 20% SH was up to four times higher than the pure PLA. The different behaviors may be ascribed to the pre-tension on the twines caused by filament twisting. Commercial PP twines are made with slit PP film instead of twisting filaments.

Benefits for North Dakota Soybean Farmers and the Industry

In summary, SH was blended with PLA to produce twine and ribbons for many agricultural and industrial applications. Compared to the PLA/SM products developed last year, the new formulations have an innovative application for a low-value soy by-product and can potentially increase the income for soy farmers.

“ Compared to the PLA/SM products developed last year, the new formulations have an innovative application for a low-value soy by-product and can potentially increase the income for soy farmers. ”

Transforming Soymeal and Soyhull into Building Materials

Principal Investigators: Long Jiang, Ph.D., and Shraboni Sarker, North Dakota State University (NDSU) Mechanical Engineering

Funded Project
\$22,418

Why the Research is Important to North Dakota Soybean Farmers

Soybean meal and soybean hulls, by-products of soybean processing, are currently used primarily as animal feed. Converting them into building materials offers a higher-value use and the potential to increase revenue for soybean farmers. This project builds on our lab's previous work with soy protein isolate (SPI) to develop a cost-effective adhesive using soymeal. Unlike many traditional wood adhesives that release harmful vapors, this new adhesive provides a safer, more sustainable alternative.

Research Conducted

For this project, we first developed a natural adhesive that was mainly made from soymeal, which is more accessible and less costly than soy protein isolate. To enhance the soymeal's strength, water and mold resistance, and to address fire safety concerns, additional natural ingredients, such as calcium carbonate, phytic acid and tannic acid, with the latter two derived from plants, were incorporated at various loading levels and through different fabrication methods. The resulting formulations' adhesion strength

was systematically tested to identify the optimal formulation and process. The selected formulations were further utilized to make particleboard, a widely used wood product, by gluing and compressing soy hull powder under heat.

Findings of the Research

The soymeal-based adhesives developed for this project demonstrated high dry and wet adhesion strength as well as good mildew resistance. The particleboard made using the adhesive and soy hull also exhibited high strength. Foaming the board to create insulation products has been explored. We continue to investigate the selection of the best foaming agent and the foaming process to achieve a uniform foam cell size and even distribution for the cells.

Figure 2. Particleboards made of soy hull and soymeal-based adhesives.



Figure 1. Dry and wet shear strength for the soymeal-based adhesives.

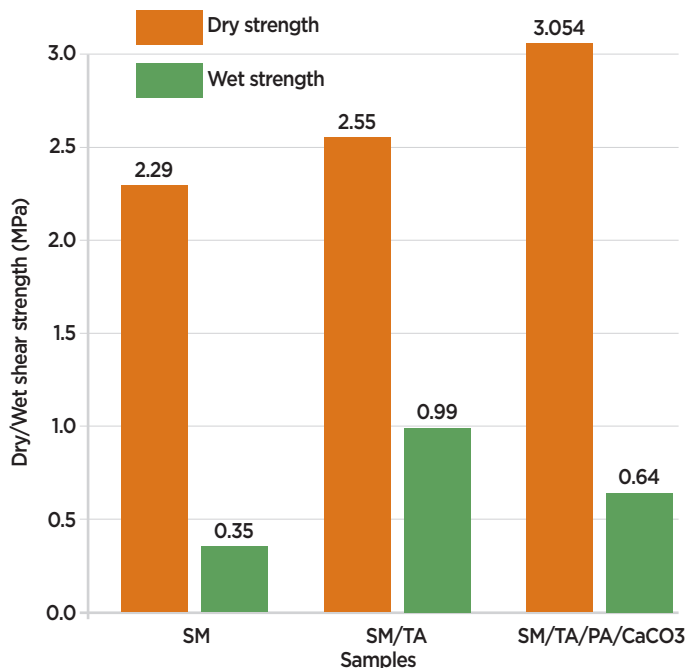


Figure 3. Shraboni Sarker, NDSU graduate student, preparing samples for mechanical testing.



The Effects of Soybean Meal Supplementation Frequency on the Growth Performance of Beef Cattle in an Extensive Winter Grazing System for Backgrounding Cattle

Principal Investigators: Kendall Swanson, Ph.D., North Dakota State University (NDSU) Animal Sciences; Jaime Chambers, NDSU; Grady Gullickson, NDSU; Madeliene Nichols, NDSU; Yssi Entzi, NDSU Animal Sciences; Jessie Syring, NDSU Animal Sciences; Joshua Wianecki, NDSU; Lydia Trandem, NDSU; Garrett Havelka, NDSU; Zachary Carlson, Ph.D., NDSU Extension; and Miranda Meehan, Ph.D., NDSU Animal Sciences

Funded Project
\$43,943

Why the Research is Important to North Dakota Soybean Farmers

Producers have increased the use of extensive winter grazing systems, such as bale grazing, to decrease input costs. Infrequent supplementation in a bale grazing system can reduce labor and inputs. Recent research about soybean meal in cattle diets is lacking. This study will contribute to the utilization of soybean meal as a supplement for winter grazing systems.

Research Conducted

A bale grazing study evaluated the differences for growth performance and soil health between dried distillers grains plus solubles (DDGS) and soybean meal (SBM): supplementation frequency, daily or three times weekly; soil health; forage production; and forage quality. Seventy-two (year one) and 65 (year two) backgrounding calves were supplemented at 0.75% of their body weight. Body weights and blood were collected every 28 days. Soil and forage biomass samples were collected from 3 bale locations: 0', 5', 10' and 15' from the bale center in each paddock.

Findings of the Research

There were no effects for the supplementation treatment on calf average daily gain. In year one, there was a tendency for SBM-fed paddocks to have higher dry matter intake (DMI), whereas in

year two, DMI increased for the daily fed paddocks compared to the alternate. Following year one, there was increased soil total nitrogen, total carbon and total organic carbon for the SBM-fed paddocks compared to the other treatments. After grazing, there was no difference for the soil's bulk density between the bale-grazed and ungrazed paddocks. During the first growing season, there were no differences in forage biomass between bale-grazed and ungrazed paddocks.

Benefits for North Dakota Soybean Farmers and the Industry

No differences due to supplementation treatment were observed, suggesting that producers can utilize SBM or DDGS as supplements, depending on cost and availability, and can reduce the frequency of supplementation. When managing soil nutrients, SBM supplementation resulted in greater increases for nutrients compared to DDGS, which will benefit forage biomass and quality.

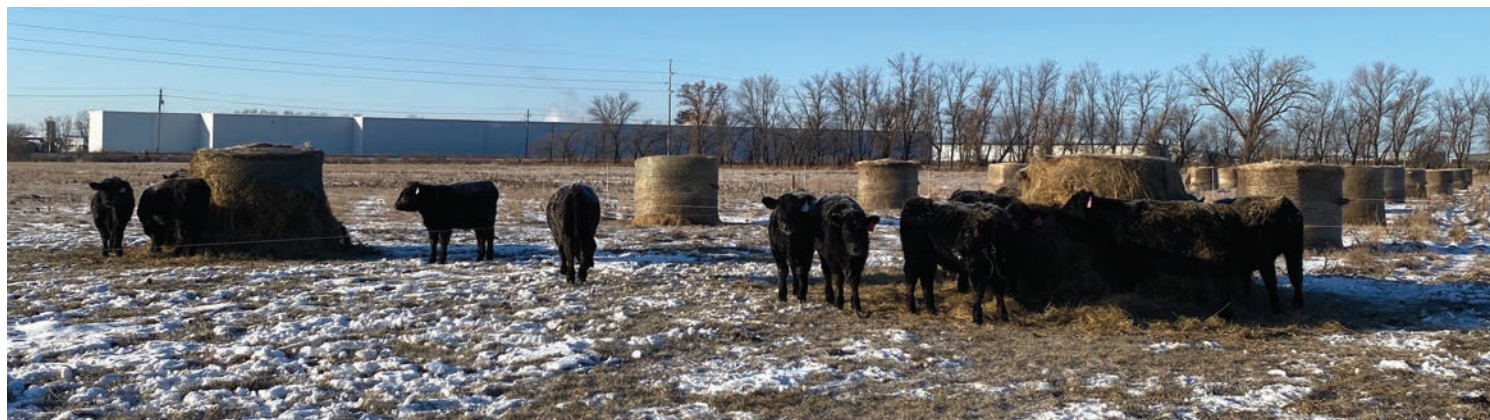
Figure 2. Bale site in the summer during the forage growing season after the first year of grazing.



Figure 3. A graduate student collecting forage biomass samples from the bale sites.



Figure 1. Cattle grazing in the paddocks during the project's second year.



Pelleted Protein Supplements for Cattle Fed Forage-Based Diets

Principal Investigator: Kendall Swanson, Ph.D., North Dakota State University (NDSU)
Animal Science

Funded Project
\$37,450

Why the Research is Important to North Dakota Soybean Farmers

North Dakota now processes much more of its soybeans locally. This scenario creates a steady supply of soybean meal and soyhulls: valuable co-products that can be used to feed cattle. Using these products for beef-cattle diets can help reduce costs, support local agriculture and add value to the soybeans grown in the state.

Research Conducted

This study looked at how cattle responded to different protein supplements: soybean-based (52.5% soybean meal and 47.5% soyhulls) vs. dried distillers grains (DDGS) and pelleted (also known as cake or cube form) vs. meal form. We fed these supplements to steers eating medium-quality hay. We measured how much the cattle ate, how well they digested nutrients, how efficiently they used protein and how much gas (i.e., methane) they produced.

Findings of the Research

All supplements improved digestibility and energy use compared to hay alone. DDGS supplements resulted in greater crude protein intake and nitrogen retention. Soybean-based supplements also performed well, especially when pelleted. Pelleting improved the overall digestibility but tended to increase the nitrogen excreted in urine, showing that the physical form can affect how cattle process protein. Methane energy losses were lower for the supplemented cattle, and DDGS tended to reduce the losses more than the soybean-based feeds.

Benefits for North Dakota Soybean Farmers and the Industry

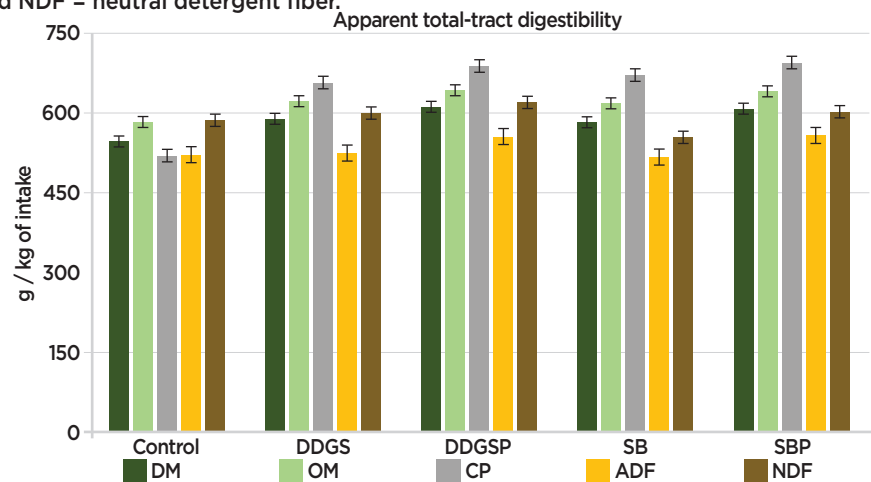
This research shows that soybean meal and soyhulls are valuable feed options for beef cattle. Pelleted soybean-based supplements performed well and could be a strong local alternative to DDGS. While DDGS showed higher nitrogen retention, this advantage was largely due to the higher protein level. More studies using equal protein levels

are needed to better compare the efficiency of these feeds and to demonstrate the full potential of soybean-based supplements. With further research and balanced formulations, soybean co-products can support a more sustainable, regional feed supply, bringing economic and practical benefits to North Dakota soybean growers and the cattle industry.

Figure 1. A steer consuming soybean meal and soybean hulls cubes.



Figure 2. Influence of the supplement's source and form on total tract digestibility. DM = dry matter, OM = organic matter, CP = crude protein, ADF = acid detergent fiber and NDF = neutral detergent fiber.



Items	P-value		
	Supplementation	Source	Processing
DM	<0.001	0.549	0.010
OM	<0.001	0.679	0.008
CP	<0.001	0.210	0.003
ADF	0.228	0.764	0.010
NDF	0.527	0.006	0.004

Remediation of Brine Spills with Soybean Fiber-Activated Materials

Principal Investigator: Jiale Xu, Ph.D., North Dakota State University (NDSU)
Civil, Construction and Environmental Engineering

Funded Project
\$43,900

Why the Research is Important to North Dakota Soybean Farmers

Brine spills are a serious problem from the oil and gas industry in North Dakota. The high concentration of salt at hundreds of grams per liter can have a negative influence on soil and groundwater quality. This research develops a adsorbent material from soybean hulls to effectively remove metals and salts from the brine spills' contaminated water.

Research Conducted

We used the pyrolysis method with the spike of multiple elements to convert soybean hulls into carbon quantum dots, a novel carbon material. The material was tested using a fluorescence analysis to confirm the formation of nanomaterials. The elemental groups were also examined using X-ray photoelectron spectra. The adsorption was conducted using salt and other metals. Last, the cost was analyzed to provide a feasibility test.

Findings of the Research

Soybean hulls were successfully converted into a nanomaterial carbon quantum dot. The adsorbent material had a significant fluorescence signal, suggesting that the

nanostucture was formed. X-ray photoelectron spectra showed that carbon, nitrogen, silica and sulfur functional groups existed to provide adsorption sites. The adsorption test illustrated that these nanomaterials can effectively remove salt and metals from brine spills with high efficiency. The total cost of remediating water was lower than the conventional method, suggesting that this method is feasible for brine spill treatment.

Figure 1. Fluorescence results of carbon quantum dot material.

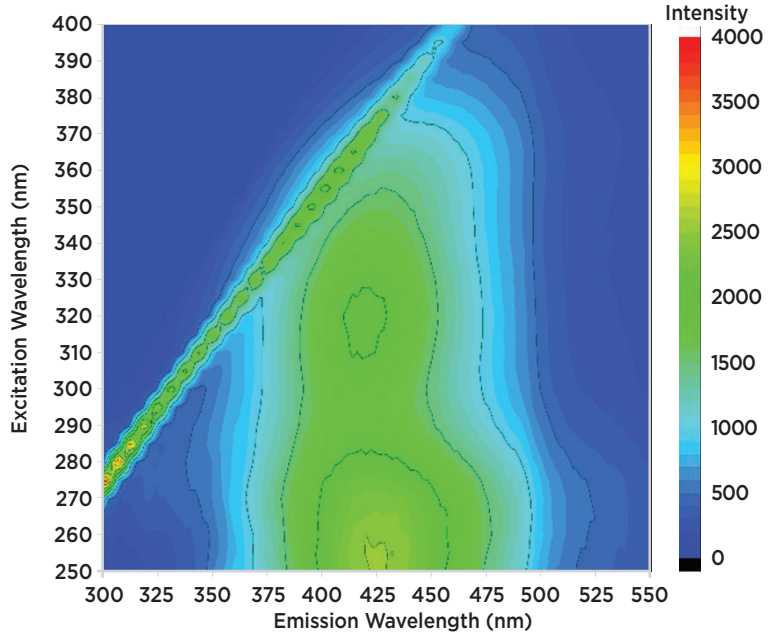
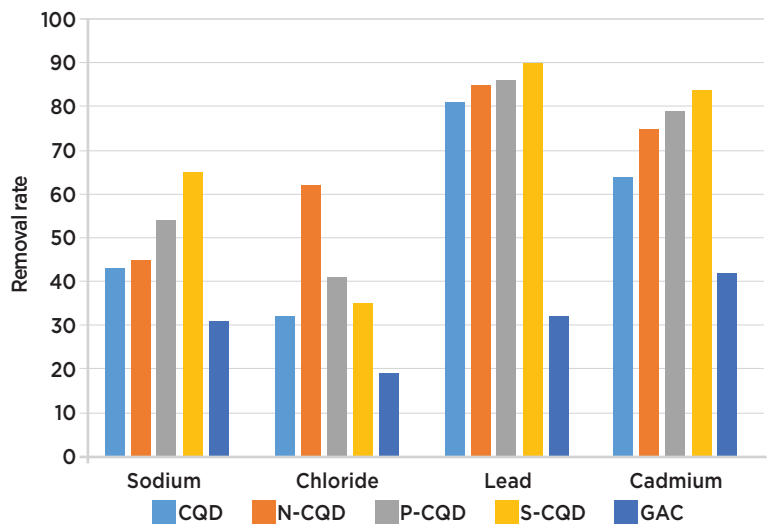


Figure 2. Removal of salt, lead, and cadmium.



“The adsorption test illustrated that these nanomaterials can effectively remove salt and metals from brine spills with high efficiency. The total cost of remediating water was lower than the conventional method, suggesting that this method is feasible for brine spill treatment.”

A Novel Soybean Selection Method for Tofu Production Using Machine Learning

Principal Investigator: Minwei Xu, Ph.D., North Dakota State University (NDSU) Plant Sciences

Funded Project
\$18,019

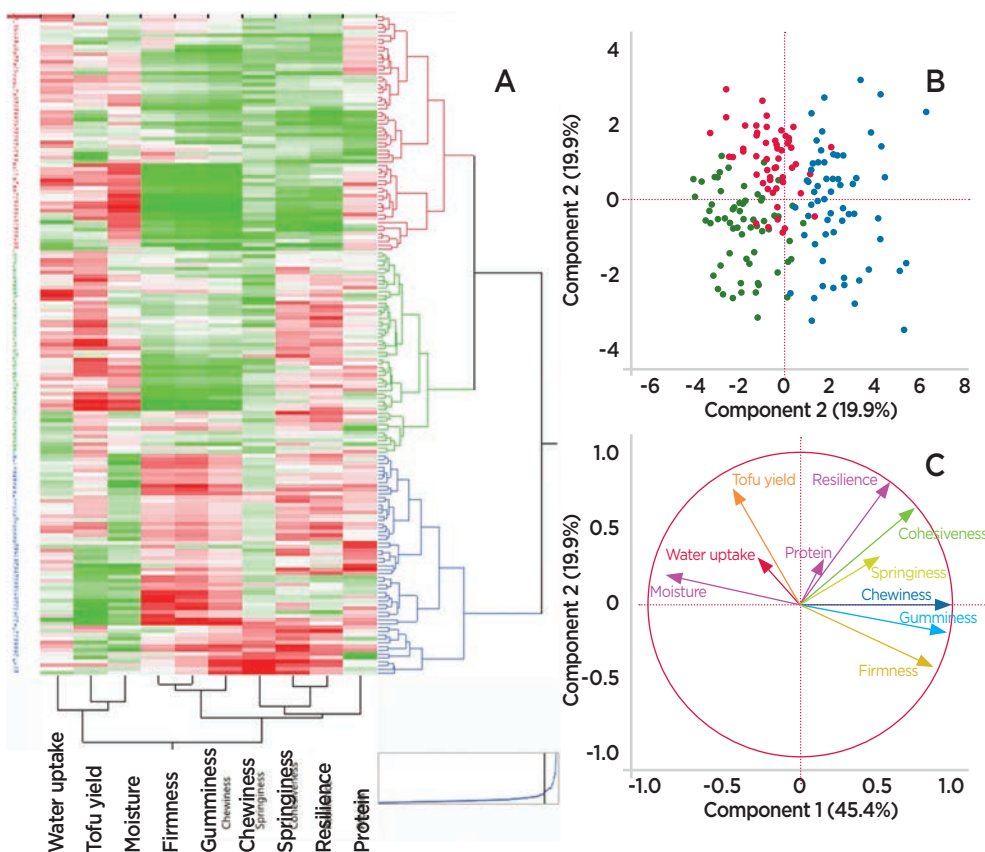
Why This Research is Important to North Dakota Soybean Farmers

Soybeans are one of North Dakota's most valuable crops, but their potential for high-value products, such as tofu, remains underutilized. Tofu quality depends on specific protein characteristics in the soybeans, yet farmers lack the tools to identify which soybean varieties produce the best tofu. This research bridges that gap by using cutting-edge technology to pinpoint the traits that improve tofu quality, helping North Dakota farmers grow premium soybeans to meet the global market's demands.

Research Conducted

The research analyzed 172 soybean varieties that were collected from east Asia and North America. Using advanced protein profiling techniques (SDS-PAGE) and machine learning, the team identified critical soybean protein subunits, particularly the 11S/7S ratio and the 11S A3 subunit, that influence tofu quality. Soybeans were

Figure 1. Classification of soybean seeds based on tofu quality: (A) Hierarchical Cluster Analysis (HCA) of tofu, (B) PCA loading plot and (C) PCA score plot. Class 1 is depicted in red, Class 2 in green and Class 3 in blue.



classified into three quality groups based on water uptake, tofu yield and texture. The most accurate predictive model, K-Nearest Neighbors (KNN), was developed to forecast tofu quality based on the protein subunit's profiles.

Findings of the Research

The study demonstrated that higher 11S/7S ratios and the presence of the 11S A3 subunit produce firmer, higher-quality tofu. The KNN model accurately predicted tofu quality for over 80% of the samples, helping identify soybeans that are suitable for firm or medium tofu. These findings highlighted how protein profiles influence the tofu's quality and the ability of machine learning to optimize variety selection.

Benefits for North Dakota Soybean Farmers and the Industry

This research provides North Dakota soybean farmers with tools to produce premium-grade soybeans specifically for tofu production, opening new markets and

increasing profitability. The predictive model and protein profiling method can guide breeding programs and can help farmers select varieties tailored for high-value uses. By focusing on soybeans with the right protein characteristics, North Dakota farmers can strengthen their competitive edge in domestic and international markets.

Figure 2. SDS-PAGE image automatically processed by Computer Vision: Computer Vision automatically processed the SDS-PAGE image, segmenting the protein profile of each soy protein into 200 contours. Adjacent contours were consolidated into bands, and the intensities of these selected bands were exported to predict tofu quality.

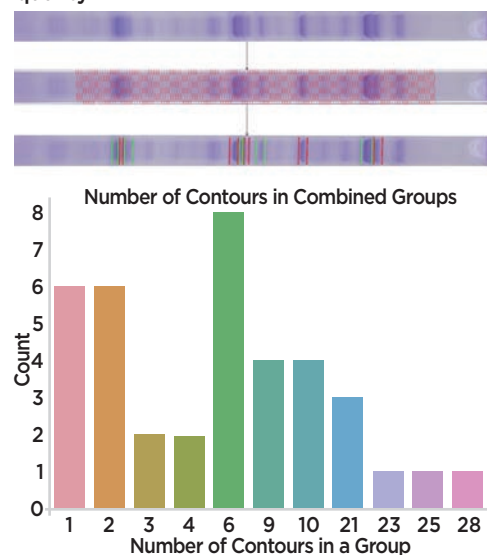
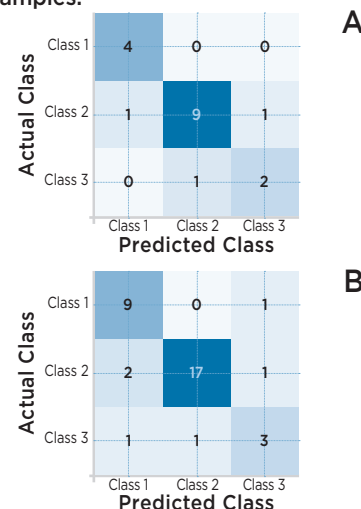


Figure 3. Confusion matrix for (A) testing the KNN model and (B) external verification of samples.



Converting the Insoluble Fiber in Soybean and Okara with Twin-Screw Extrusion and the Effect on Nutrition Factors

Principal Investigator: Minwei Xu, Ph.D., North Dakota State University (NDSU) Plant Sciences

Funded Project
\$37,413

Why the Research is Important to North Dakota Soybean Farmers

This research is significant for North Dakota soybean farmers because it explores how leftover soybean by-products—such as soybean meal and okara—can be transformed into high-value goods. By improving the fiber content and reducing antinutritional compounds, these by-products have a greater potential for use in both food and animal feed. This option creates opportunities to reduce waste, to add value to existing production, and to increase profitability for farmers and the broader soybean industry.

Research Conducted

This project explored how twin-screw extrusion can transform soybean meal and okara—two by-products of soybean

Adding ingredients to the extruder's feeder.

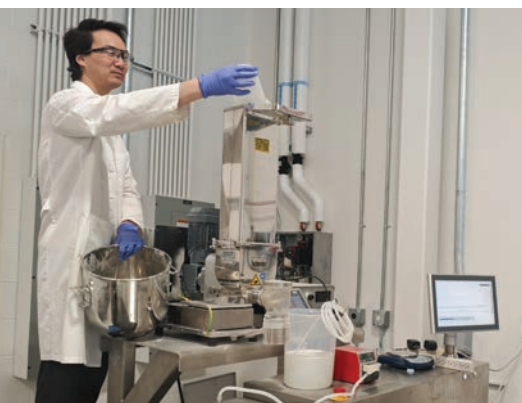
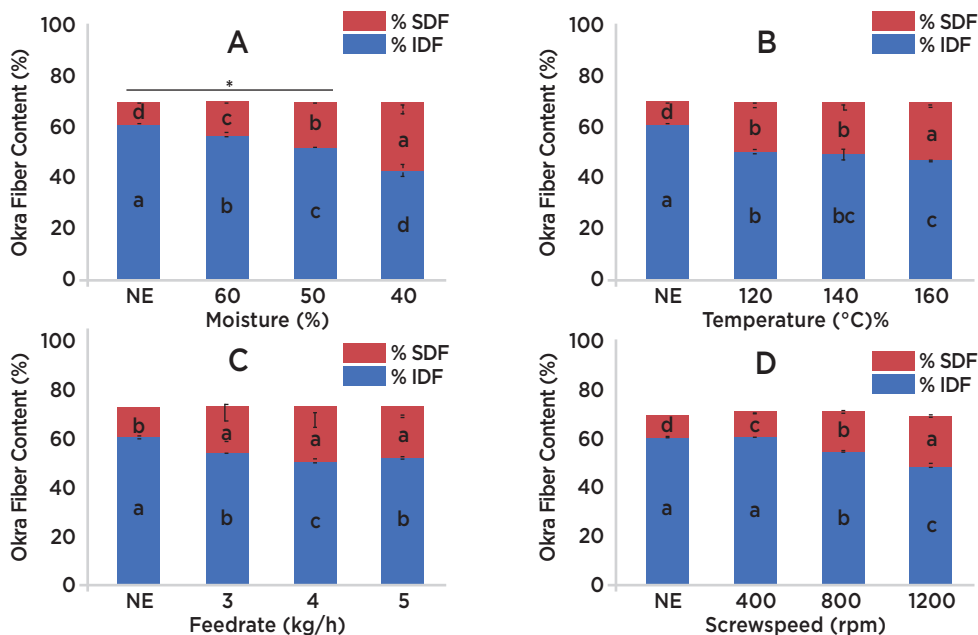


Figure 1. Flow chart for the extrusion process.



Figure 2. Insoluble and soluble fiber of okra extrudates under different extrusion parameters.



processing—into more useful and nutritious ingredients. These by-products, commonly seen as waste, are rich in dietary fiber but mostly in a form that is hard to digest. By using a machine that mixes, heats and compresses these materials under various conditions, researchers aimed to increase the amount of soluble fiber, which is easier to digest and better for gut health.

Findings of the Research

In the study, soybean meal and okara were processed with different moisture levels,

temperatures, screw speeds and feed rates.

The best results came from using lower moisture and faster screw speeds. With these conditions, the amount of soluble fiber increased by up to 42% in soybean meal and 30% in okara. These settings also changed the materials' color due to natural browning reactions from the heat. While the levels of phytic acid (a nutrient-blocking compound) didn't change much in the soybean meal, they increased slightly in okara. Trypsin inhibitors, which can reduce protein digestion, went down in okara but increased with the soybean meal, possibly due to how the materials were processed before extrusion. Some small shifts in isoflavones, which are plant-based health compounds, were also noted.

Benefits for North Dakota Soybean Farmers and the Industry

This study shows that soybean by-products can be made healthier and more valuable with extrusion. These improved materials can be used in new food products, healthier animal feeds, and even in emerging industries such as 3D-printed foods and probiotic supplements. For the soybean industry in North Dakota, these findings offer new ways to use every part of the crop more efficiently and profitably.

Green Extraction of Soybean Oil via Enzyme-Assisted Aqueous Processing Supported by Ball Milling

Principal Investigator: Minwei Xu, Ph.D., North Dakota State University (NDSU) Plant Sciences

Funded Project
\$7,996

Why the Research is Important to North Dakota Soybean Farmers

This study developed and optimized a green, aqueous enzymatic extraction process for soybean oil to increase the oil's yield while preserving protein-rich by-products. The method provides a safer, chemical-free alternative to conventional extraction, helping North Dakota farmers capture greater value per bushel and access new markets that care about environment-friendly products. Supporting sustainability positions North Dakota producers as leaders in green agriculture and aligns with the global demand for responsibly sourced foods.

The research's objectives are as follows: developing and optimizing a green, aqueous enzymatic extraction process using enzyme combinations and ball milling to improve the soybean oil's yield; identifying major oil loss pathways during extraction and evaluating the quality of the extracted oil; and characterizing the protein hydrolysate by-products generated during extraction.

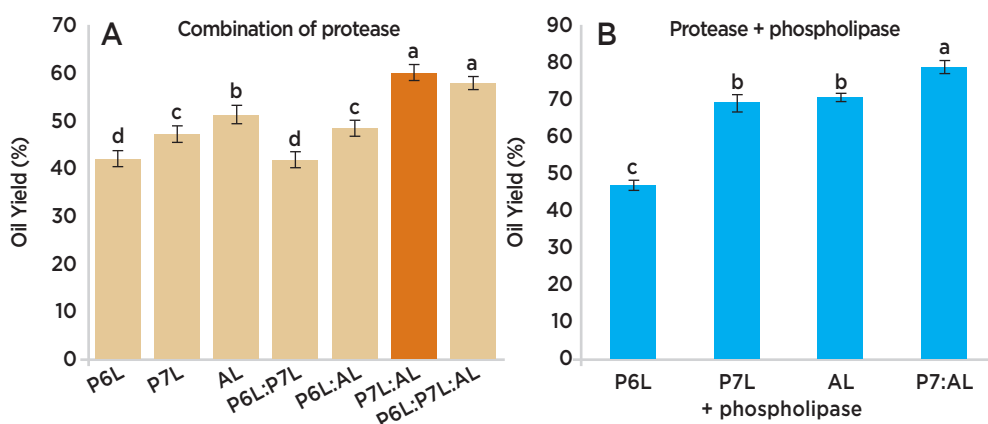
Research Conducted

For this research, scientists tested natural enzymes to break down the soybeans in water and used ball milling (similar to a heavy-duty blender) to release more oil. Different enzyme combinations, amounts and mixing times were evaluated to find the most effective process. These enzymes helped dissolve parts of the soybean that normally trap the oil. After treatment, the researchers separated and measured the oil's yield and quality, examining the remaining by-products which contained valuable proteins.

Findings of the Research

Using the right mix of enzymes released more oil: up to 91.43%. Ball milling made the process even better by breaking the soybean parts into smaller pieces. The oil

Figure 1. (a) Effect of combination protease and (b) the addition of phospholipase on oil yield.



was healthy and stable, needing only minor cleanup before use. The leftover soybean material had useful proteins that could be turned into health products or animal feed. The method avoids the use of harsh solvents such as hexane, relying instead on ethanol, which is less toxic and easier to manage safely.

Using the right mix of natural enzymes, this process was able to extract up to 91.43% of the oil from soybeans. Ball milling, which works like a powerful grinder, made the process even more effective by breaking the soybeans into smaller pieces. The produced oil is clean, healthy and stable, needing very little

extra processing before use. The material left after oil extraction is rich in valuable proteins, which can be used for health products or animal feed, giving farmers additional revenue opportunities. This method is also safer and more environment friendly, avoiding harsh chemicals such as hexane and using ethanol, which is less toxic and easier to manage.

Benefits for North Dakota Soybean Farmers and the Industry

This safer and eco-friendly process for soybean oil extraction boosts the oil's yield and creates valuable by-products, helping North Dakota farmers lead in sustainable agriculture.

Figure 2. (a) Effect of carbohydrates and ball milling on oil yield (b) and photos of final oil.





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