ND SOYBEAN COUNCIL

2023 Research Report

Cultivating Solutions

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2023 Research Committee Report

Research Provides the Foundation for the Future

At its core, research is all about the quest for answers. Science-based, unbiased research provides a path forward to solve problems while identifying opportunities.

Research has always been one of the foundational priorities for the North Dakota Soybean Council (NDSC). Research is front and center for the organization because we recognize the importance of continuous growth and improvement. The NDSC was established to support the state's soybean farmers. Forward-thinking farmer-leaders recognized that, in order to grow the soybean industry in North Dakota, investing in research was paramount.

Farmers in this state are faced with unique growing conditions that present numerous challenges for growers, including early frost; late seeding; weed, insect, and disease pressure; etc. Over the years, checkoff-supported research has led to the development of publicly available soybean varieties that are bred for the demanding conditions which North Dakota farmers face. Research projects have addressed a wide range of production challenges to help farmers manage diseases, combat weeds and eliminate insects to maximize the soybeans' yield potential.

Not that long ago, soybean production was focused on a handful of counties in the southeastern part of the state. Today, we've had soybeans grown in almost every county in North Dakota. That remarkable accomplishment is a testament to the foresight of past farmer-leaders and a tribute to the quality of research that's been conducted to support the state's soybean farmers. The NDSC remains committed to carrying on the legacy of research.

Each year, the North Dakota Soybean Council Research Committee meets with university researchers, industry representatives, Extension partners and crop consultants to identify pressing production issues, to set research priorities and to select projects with the greatest potential for influence. The goal of the NDSC's research program is not only to get answers, but it is also important to bring the latest research results into the hands of farmers who can apply that knowledge to their operations.

The focus on production research continued in 2023 as the NDSC funded numerous projects in order to help farmers from all corners of North Dakota to maximize soybean yield and to increase farmer profitability. This publication also illustrates the substantial support for new value-added opportunities for soybean products.

Soybean processing in North Dakota is undergoing a rapid transformation. For many years, exports were the primary market for the state's soybeans. Now, with in-state processing, our checkoff supported research projects reflect the potential to create new avenues for soybean usage. Those new uses can help build demand for North Dakota soybeans and support farmer profitability.

This is an exciting time for North Dakota soybean farmers and the entire soybean industry. Research investments are intended to provide answers for tough soybean management issues while, at the same time, exploring the possibility of new uses for soy products. Addressing the existing problems and exploring new opportunities are what research does best.

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On The Cover

Hans Kandel, Ph. D., retired from North Dakota State University (NDSU) as an extension broadleaf crop agronomist in July 2023. Kandel is a well-known expert in the region, having served as a University of Minnesota regional Extension agronomist in northwest Minnesota for 12 years before joining NDSU. Throughout his career, Hans worked with North Dakota soybean farmers by sharing ways to improve their productivity. He spearheaded research on numerous soybean related topics and shared those findings during a time of tremendous growth for North Dakota's soybean production. The North Dakota Soybean Council sincerely appreciates Hans' years of service and dedication to the soybean growers of North Dakota. His contribution was critical for the success of the state's soybean industry.

Determination of 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., NDSU Williston Research Extension Center (WREC)*
Co-Investigators: *Tyler Tjelde and James Staricka, Ph. D., NDSU WREC*

Funded Project $26,200

Why this Research is Important to North Dakota Soybean Farmers

In North Dakota, the majority of irrigated farms are using the "condition of a crop by observation" as a means of deciding when to apply water. These practices are common because there is a lack of information about the timing and amount of irrigation needed for crops with the state's semiarid conditions. This research's information about the appropriate amount and timing of irrigation will help western North Dakota soybean producers to apply the judicial amount of irrigation at the proper time. The ultimate benefits will be enhanced yield, quality and water productivity.

The project's overall goal is to determine the optimum amount and timing of irrigation for enhanced soybean yield, quality and water productivity.

Research Conducted

Soybean variety ND 17009GT was seeded on May 27, 2022. The seeding rate was 195,000 seeds per acre with row spacing of 30 inches. There were 12 irrigation treatments: I = Full irrigation, Wv = Deficit irrigation during the vegetative [(VE – V(n)] stage, Wf = Deficit irrigation during the flowering [R1-R2] stage, Wp= Deficit irrigation during the pod development [R3-R4] stage, Ws = Deficit irrigation during the seed filling [R5-R6] stage, Wm = Deficit irrigation during the maturity [R7-R8] stage, Wvf = Deficit irrigation during the vegetative + flowering stages, Wvp = Deficit irrigation during the vegetative + pod development stages, Wvs = Deficit irrigation during the vegetative + seed filling stages, Wvm = Deficit irrigation during the vegetative + maturity stages, Wsm = Deficit irrigation during the seed filling + maturity stages and R = Rainfed.

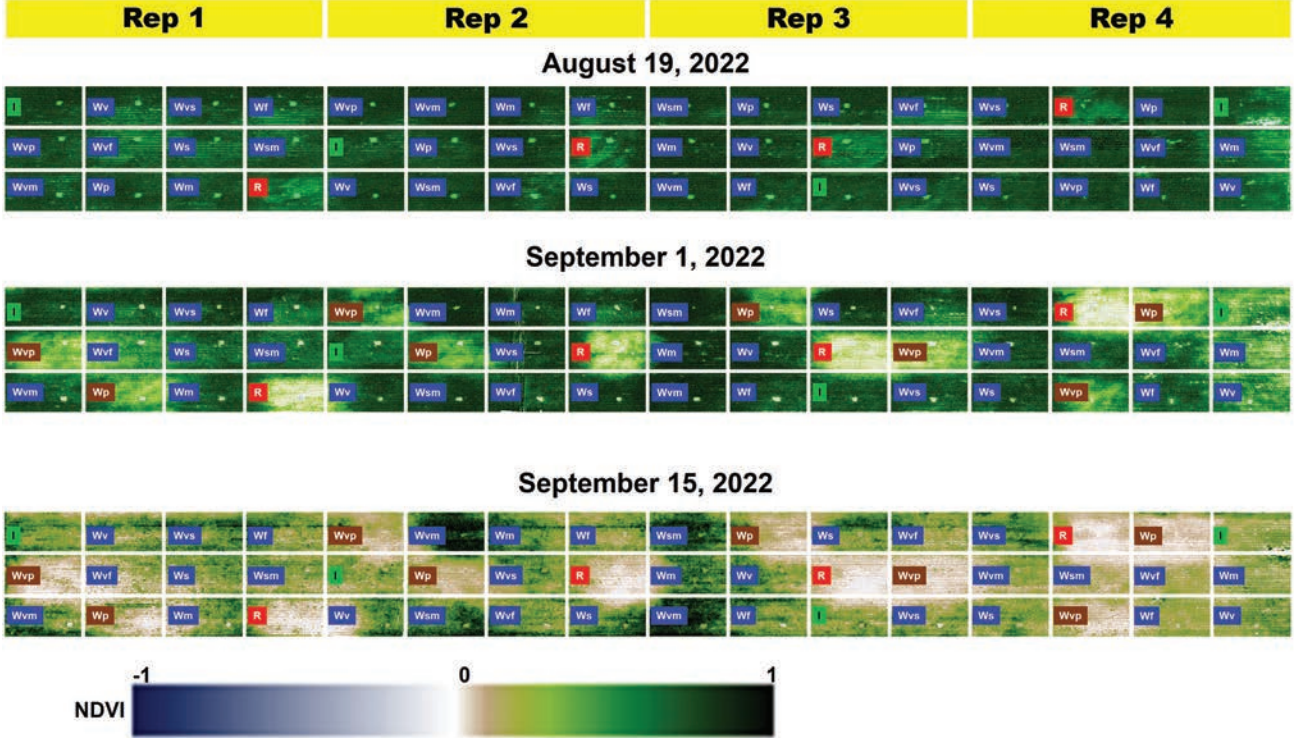
Findings of the Research

The Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Red Edge (NDRE) data from the aerial images showed that the senescence occurred at a higher pace in plots with treatment R, Wp and Wvp compared to the others. The grain number per plant was lower for R (45) and Wvf (48) compared to others that had 63 to 77 grains per plant. The soybean grains under the Wp and Wvp treatments had the highest amount of protein (42.2%), followed by treatment R (40.3%). Other treatments had 37.9% to 39.8% of grain protein. The Wsm treatment produced the highest grain yield, which was statistically on par with treatments Wm, Wvm, Ws, Wvs, I and Wv. A marked decline in soybean yield occurred under treatments wf, Wvf, Wp, Wvp and R (Figure 1).

Benefits to North Dakota Soybean Farmers

This study's findings indicate a potential for conserving irrigation water while maintaining soybean grain yield, provided that the escaping irrigation does not occur during the flowering and pod development stages. The insights obtained from this research regarding appropriate irrigation amounts and timing will assist soybean producers in western North Dakota to apply the precise amount of water at the right moment. The ultimate advantages will include improved yield, quality and water productivity. To confirm and validate these results, we plan to replicate this study in fiscal year 2023-24.

Figure 1. Soybean NDVI with different irrigation treatments and dates.



Resistance of Soybean Cultivars and Breeding Lines to Soybean Cyst Nematode

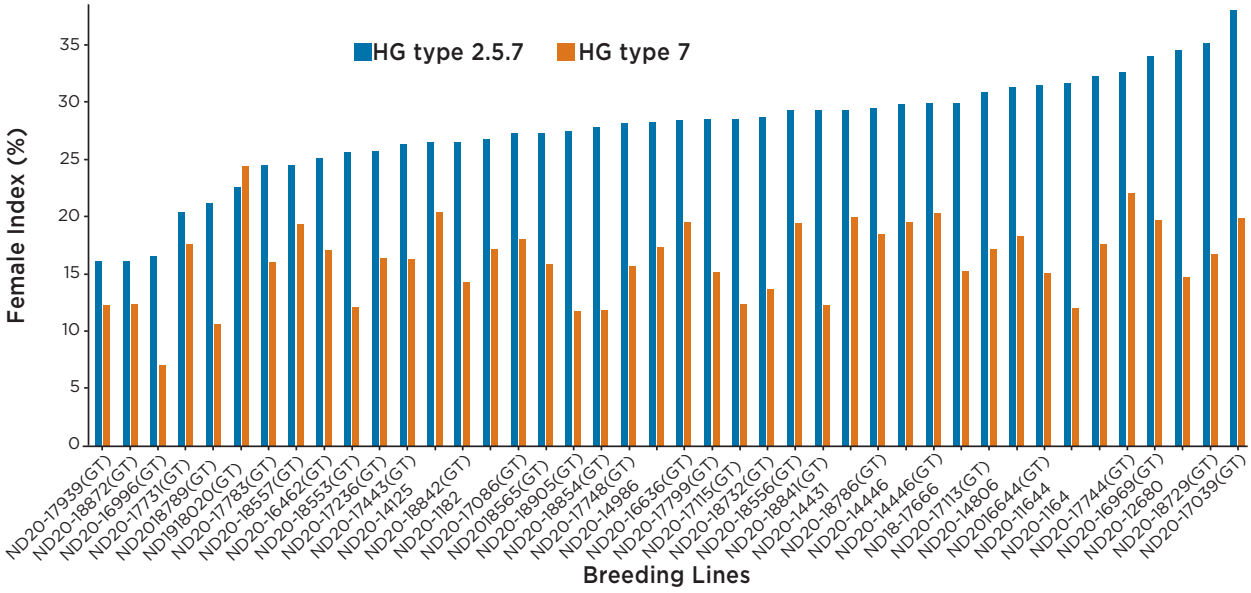
Principal Investigator: *Guiping Yan, Ph. D., NDSU Department of Plant Pathology*
Co-Investigators: *Carrie Miranda, Ph. D., NDSU Department of Plant Sciences, and Sam Markell, Ph. D., NDSU Department of Plant Pathology*

Funded Project $61,643

Why this Research is Important to North Dakota Soybean Farmers

Soybean cyst nematode (SCN) is a major yield-limiting factor of soybeans. Utilizing host resistance is one of the best methods to manage SCN, but continuous use of the same resistance sources resulted in the emergence of more virulent SCN populations that were capable of breaking resistance. New resistance sources need to be explored. Most of the SCN-resistant cultivars rely on PI 88788-type resistance, specifically the resistance genes at the *Rhg1* locus. The genes' copy number determines the level of resistance. Therefore, screening soybeans and analyzing the variation at *Rhg1* are important for identifying resistance.

Figure 2. Resistance responses of breeding lines from the NDSU soybean breeding program with female index < 40% to both HG types, 2.5.7 and 7, isolated from soybean fields in North Dakota.



Research Conducted

This research evaluated soybean cultivars and breeding lines for resistance responses to two common SCN populations and validated molecular markers for detecting the resistance genes at *Rhg1*. In total, 158 cultivars and breeding lines were screened for two SCN populations, *heterodera glycines* (HG) type 2.5.7 (more virulent) and HG type 7/0 (less virulent). Each plant was inoculated with approximately 2,000 eggs and grown in a growth chamber (Figure 1). After harvest, white females (cysts) were extracted; the female index (FI) was calculated; and resistance reactions were categorized. The copy numbers at *Rhg1* among 100 breeding lines were determined using a SYBR Green-based qPCR assay.

Figure 1. Guiping Yan, Ph. D. checks soybean plants in a controlled growth chamber that was maintained at 27 °C to ensure that the SCN resistance testing was performed under optimal conditions.

Findings of the Research

Two commercial cultivars were found to be resistant to both HG types: HG type 2.5.7, which can reproduce on the PI 88788 line, and HG type 0 or 7, which cannot reproduce on the PI 88788 line. Among the 100 breeding lines, 32 were moderately resistant to HG type 2.5.7 (FI < 30%), while one line was resistant (FI < 10%) and 41 were moderately resistant to HG type 7 (Figure 2). Forty-one lines had 10-11 copies; 1 line had 6 copies; and the remaining lines had 1-3 copies of the *Rhg1* repeat. Lines with a copy number ≥ 6 were either resistant or moderately resistant to HG type 7 while the lines with a copy number ≤ 3 were moderately susceptible or susceptible. There was a strong negative correlation (r = -0.86) between the female index values (HG type 7) and the copy numbers.

Benefits to North Dakota Soybean Farmers

SCN is a devastating disease in soybeans. Among the 100 breeding lines tested for SCN, 32 exhibited resistance or moderate resistance to both HG types, from which the breeder can choose to develop new SCN-resistant cultivars. Additionally, two commercial cultivars demonstrated resistance to both SCN populations, offering North Dakota farmers valuable choices to select resistant cultivars for infested fields. Furthermore, the copy number assessment assay will facilitate rapid detection of the resistance gene, rhg1, and will confirm the level of SCN resistance.

Develop a New Recombinase Polymerase Amplification Assay for Rapid Detection of the Root-Lesion Nematode *Pratylenchus dakotaensis* from Soil

Principal Investigator: *Guiping Yan, Ph. D., NDSU Department of Plant Pathology*

Funded Project $9,565

Why this Research is Important to North Dakota Soybean Farmers

Root-lesion nematodes are destructive plant-parasitic nematodes that pose a significant threat to various crops, including soybeans. Effective management of the nematodes is crucial, necessitating a rapid and sensitive method for detecting them in infested fields. Traditional morphological identification is time consuming, and even polymerase chain reaction (PCR)-based molecular diagnosis makes on-site field detection impractical. Recombinase polymerase amplification (RPA) is a novel, isothermal nucleic acid amplification technique, representing a competent alternative to PCR for developing fast, portable nucleic acid detection assays.

Research Conducted

This research aimed to develop an RPA assay to detect *Pratylenchus dakotaensis*, a newly discovered and named root-lesion nematode species in North Dakota soybean fields (Figure 1). Species-specific primers and probes (SPP) targeting the internal transcribed spacer region were designed and evaluated for specificity with DNA sequence analysis and lab experiments. The assay's sensitivity was determined by using serially diluted DNA from individual nematodes and DNA from artificially infested sterile soil. The RPA assay was tested with 19 field soil samples infested with *Pratylenchus* SPP. The RPA assay's validity was confirmed by comparing the result with the nematode numbers in the field samples using traditional microscopy.

Figure 1. A soybean field where *Pratylenchus dakotaensis* samples were collected.

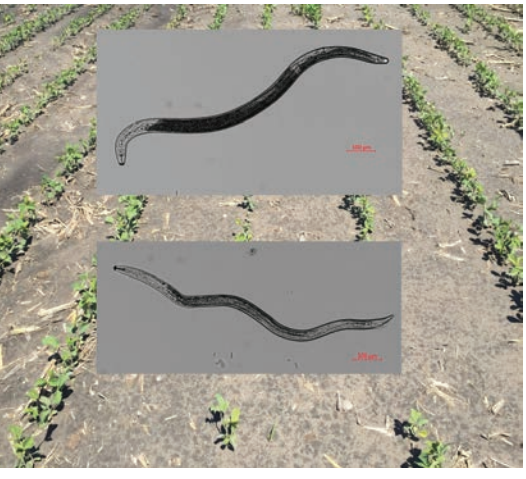
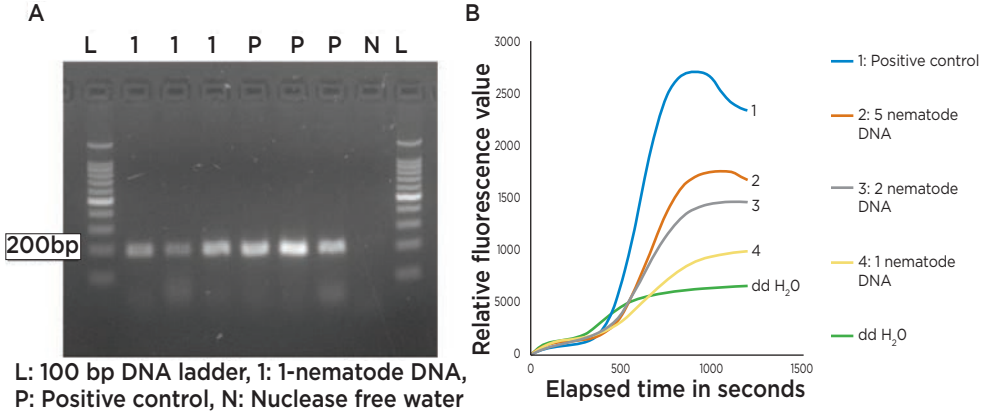


Figure 2. RPA-amplified single nematode DNA of *P. dakotaensis*. A: RPA detection using the Basic kit with the ICF4/ICR3 primers, showing a specific band (approx. 200 bp). B: RPA detection using the Exo kit with the primers and probe (ICP1), showing the fluorescence signals from all nematode samples amplified above the water (negative) control.



L: 100 bp DNA ladder, 1: 1-nematode DNA, P: Positive control, N: Nuclease free water

Findings of the Research

RPA assays were developed to detect *Pratylenchus dakotaensis* from nematode individuals and DNA extracts from field soils. RPA with Basic and Exo kits detected *Pratylenchus dakotaensis* from DNA extracted from a single nematode (Figure 2). The RPA-Exo kit detected the nematode at 39.5 0C in 20 minutes and was more sensitive than the Basic kit. The assay detected up to an equivalent of 1/32 of a single nematode DNA extracted from the artificially infested soil. Specificity tests showed that only *Pratylenchus dakotaensis* DNA (none of the other control nematode species tested) were amplified above the threshold level. When the assay was tested with 19 field soil samples collected in North Dakota, it showed a similar trend for the amplification values of the RPA-Exo and nematode counts with the traditional microscopic method. The RPA exclusively amplified soil DNA extracts from *Pratylenchus dakotaensis*-infested field samples but not DNA from field soils infested with other *Pratylenchus* SPP.

Benefits to North Dakota Soybean Farmers

A new RPA assay was developed for the rapid detection of *Pratylenchus dakotaensis* in infested field soils, and this technique has great potential for on-site field application.

Figure 3. Guiping Yan, Ph. D., visits with farmers at the Big Iron Farm Show.

Optimizing Fungicide Spray Volume for Improved White Mold Management in Soybeans

Principal Investigator: *Michael Wunsch, Ph. D., NDSU Carrington Research Extension Center*

Funded Project $66,200

Why this Research is Important to North Dakota Soybean Farmers

The use of fungicide spray volumes greater than 10 gallons per acre (gal/ac) is widely recommended for white mold management in soybeans, but the economic return for increasing spray volume is not well understood. Quantifying the influence of the spray volume on fungicide efficacy allows profit-maximizing decision making. This study's objectives were as follows:

1. Identify the minimum fungicide spray volume needed to maximize the white mold's control and the soybean's yield and quality.
2. Evaluate whether the effect of the fungicide's spray volume for white mold management differs for a single fungicide application versus two sequential applications.
3. Quantify the influence of the soybean's architecture (bushy versus upright) on the optimum fungicide spray volume for white mold management.

Research Conducted

Field trials were conducted in Carrington and Oakes on four soybean varieties of 0.6 to 0.9 maturity (Carrington) and three varieties of 1.0 to 1.2 maturity (Oakes). Row spacing was 14 inches. Endura (5.5 ounces per acre; oz/ac) was applied at the R2 stage or twice (R2 + 9 or 11 days later) at 5.0, 7.5, 10.0, 12.5 and 15.0 gal/ac. Applications were made with a tractor-mounted, PTO-driven sprayer equipped with a pulse-width modulation system (Capstan Ag Systems, Topeka, Kansas). TeeJet XR11006 nozzles at 35 pounds per square inch (PSI; medium droplets) were used when the canopy closure averaged 80%-90%; XR11008 nozzles at 30 psi (coarse droplets) were used when the canopy closure was > 90%. The pulse width was manually set on the basis of the measured spray output and was modified as needed to maintain a constant driving speed of 9.5, 10.0, 10.5 or 11.2 miles per hour (mph) across the spray volume treatments. Testing was conducted with six (Oakes) or nine (Carrington) experimental replicates.

> ***"Quantifying the influence of the spray volume on fungicide efficacy allows profit-maximizing decision making."***

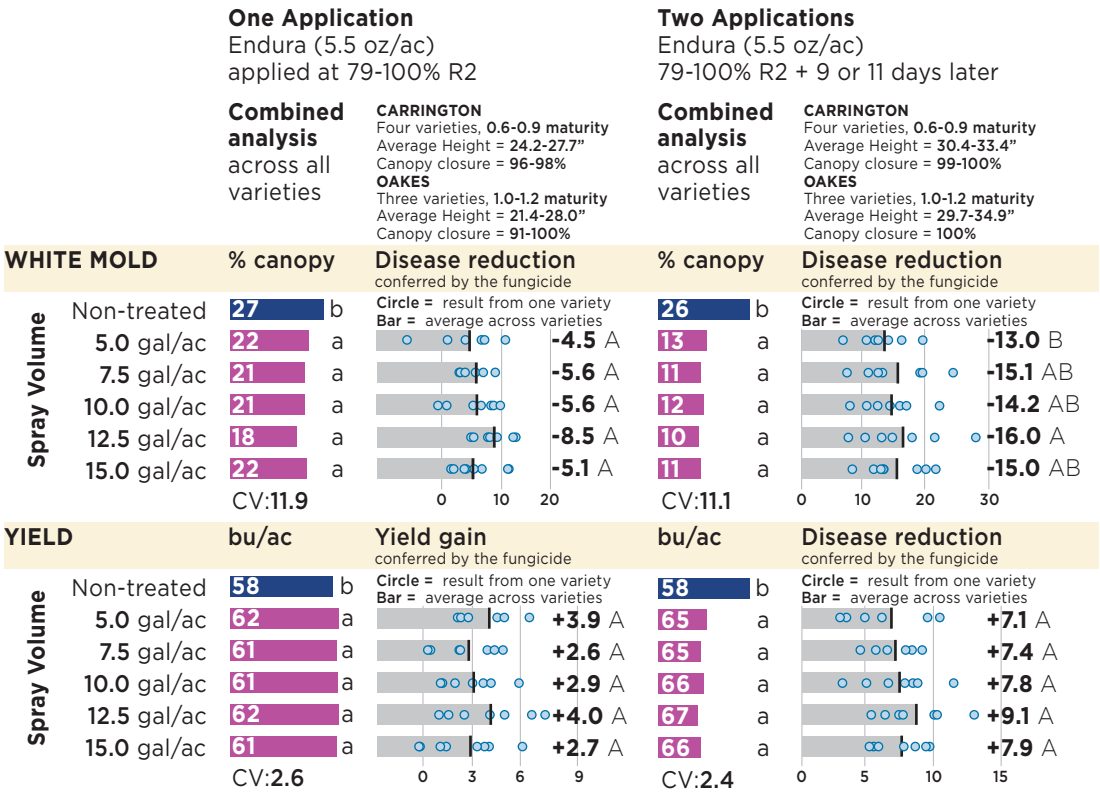
Findings of the Research

Increasing the fungicide spray volume from 5.0 gal/ac to 15.0 gal/ac had very little effect on the white mold management (Figure 1). The response to the fungicide's spray volume was similar across the upright varieties with delayed canopy closure, bushy varieties with early canopy closure, tall varieties and short varieties. When a single fungicide application was made, increasing the fungicide's spray volume from 5.0 gal/ac to 15.0 gal/ac had no influence on the white mold's management or the crop's yield. When two sequential fungicide applications were made 9 days or 11 days apart, a weak trend of slightly improved disease control and increased yield was observed as the spray volume increased from 5.0 gal/ac to 15.0 gal/ac; however, the differences were small and highly variable across varieties, and statistical separation was not observed across the spray volume treatments.

Benefits to North Dakota Soybean Farmers

The results suggest that there may be little benefit to increasing the fungicide's spray volume above 10 gal/ac for white mold management in soybeans and that it might be possible to reduce the spray volumes below 10 gal/ac without a significant reduction in the fungicide's efficacy. These results are surprising, and follow-up testing is in progress to assess the replicability of these findings.

Figure 1. Influence of fungicide spray volume on white mold management and soybean yield, Carrington, and Oakes, North Dakota (2022).



Optimizing Fungicide Application Frequency and Application Interval Relative to Soybean Maturity for Improved White Mold Management in Soybeans

Principal Investigator: *Michael Wunsch, Ph. D., NDSU Carrington Research Extension Center*

Funded Project
$35,000

Why this Research is Important to North Dakota Soybean Farmers

A single fungicide application targeting white mold is often insufficient with irrigated soybean production. This project sought to answer the following research questions about determining when a second fungicide application to target white mold is likely to be needed:

1. When is the second application targeting white mold likely to be needed?
2. When is a second fungicide application profitable?
3. Can a low-cost, generic fungicide can be utilized?

Research Conducted

Field trials were conducted with irrigation in Carrington and Oakes in 2020-22. Three to four varieties were tested at each location every year, with testing focused primarily on 0.6- to 1.1-maturity soybean varieties. Row spacing was 14, 21 or 22.5 inches. Endura, 5.5 ounces per acre (oz/ac), or Topsin, 40 fluid ounces per acre (fl oz/ac), was applied at the early to full R2 growth stage (66%-100% of plants at R2) either as a single application or prior to Endura (5.5 oz/ac) applied 7, 10, 12 or 14 days later. Applications were made using 15 gallons per acre with a handheld boom equipped with TeeJet AIXR11015 nozzles. The application pressure was 70 psi (medium droplets) when the canopy was open (< 80% closure), 60 psi (medium droplets) when the canopy closure averaged 80%-90%, and 40 psi or 50 psi (coarse droplets) when the canopy averaged > 90% closure.

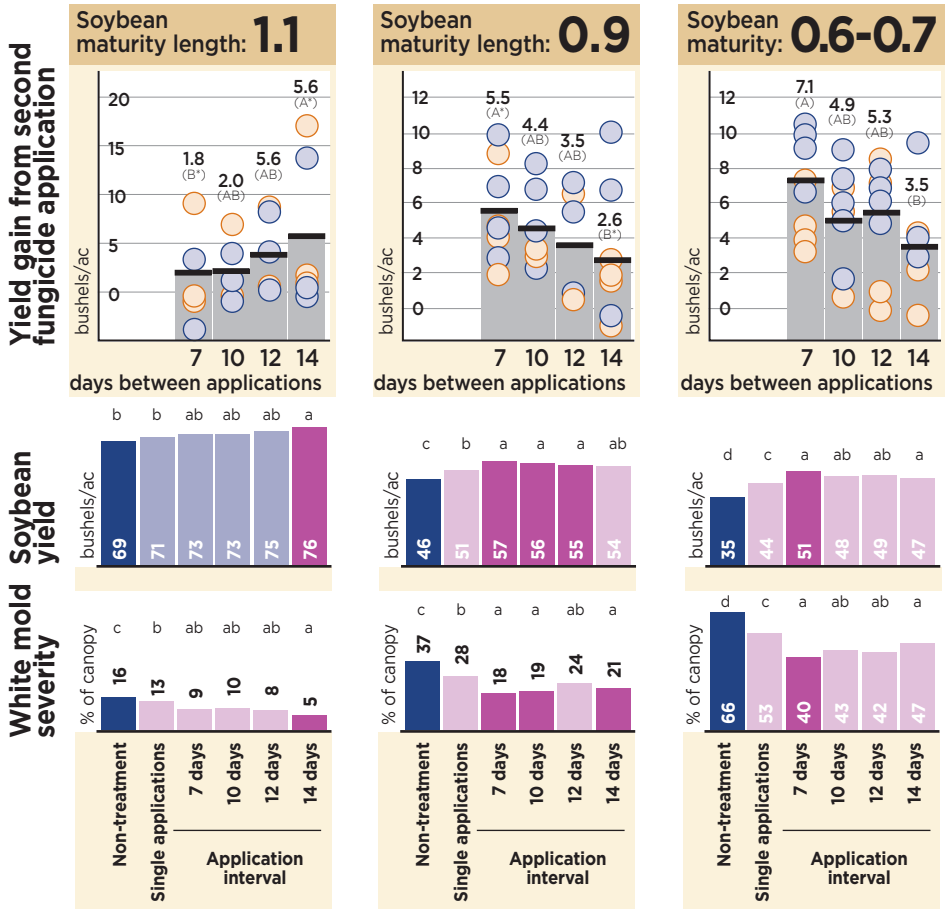
Findings of the Research

The optimal interval between sequential fungicide applications increased with soybean maturity (Figure 1). In 0.6- and 0.7-maturity soybeans, a 7-day interval between applications optimized the white mold's management. With 0.9-maturity soybeans, a 7- to 10-day interval was optimal. In 1.1-maturity soybeans, a 12- to 14-day interval was optimal.

On average, a second fungicide application was profitable when the end-of-season white-mold incidence for non-treated plots reached 41%-42% in 0.5- to 0.7-maturity varieties, 23%-25% in 0.9-maturity varieties and 17%-19% in 1.1-maturity varieties. Under low white mold pressure (< 15% incidence in non-treated soybeans at maturity), Topsin (40 fl oz/ac) and Endura (5.5 oz/ac) exhibited equivalent efficacy, and a single application of Topsin was profit-maximizing. With high white mold pressure, a second fungicide application was profit-maximizing.

Endura (5.5 oz/ac) applied twice provided slightly better white mold management than Topsin (40 fl oz/ac) followed by Endura (5.5 oz/ac), but it was not more profitable.

Figure 1. Influence of the fungicide's application frequency and the interval between sequential applications on white mold management in soybeans; Carrington, and Oakes, North Dakota (2020-22).



Benefits to North Dakota Soybean Farmers

In 0.5- to 0.7-maturity soybeans, two fungicide applications should be made 7 days apart if there is a risk of severe white mold (> 40% incidence). In 0.9-maturity soybeans, two fungicide applications should be made 7 to 10 days apart if there is a risk of elevated white mold (> 22% incidence). In 1.1-maturity soybeans, two fungicide applications should be made 12 to 14 days apart if there is a risk of moderate to high white mold (> 16% incidence). Topsin and generics (40 fl oz/ac) are an acceptable alternative to Endura (5.5 oz/ac) either as a single application or as the first application in a two-application sequence targeting white mold. When the conditions favor white mold, previous research indicates that the first fungicide application should be made at the early to full R2 growth stage unless the canopy closes earlier.

Soil Health and Agriculture Research Extension (SHARE) Farm Research

Principal Investigator: *Abbey Wick, Ph. D., NDSU School of Natural Resource Sciences*
Co-Investigators: *Marisol Berti; Greg Endres; Naeem Kalwar; Caley Gasch, Ph. D.; and Aaron Daigh, Ph. D.*

Funded Project $19,829

Why this Research is Important to North Dakota Soybean Farmers

This project's objective was to help farmers reduce the inherent risk of adopting new on-farm management practices by showing, firsthand, the challenges and expected changes that farmers may face when implementing these practices on their nearby farms. Through science-based, result-driven recommendations, some uncertainty is reduced, and a farm's productivity goals can be set with reasonable certainty.

Research Conducted

The Soil Health and Agriculture Research Extension (SHARE) Farm project in Logan Center, North Dakota, was established in 2019 and was monitored through four cropping seasons (pinto bean-corn-soybean-barley). The goals for this field-scale, long-term project were to quantify the influence of no-till and cover cropping on crop productivity, soil properties and agronomic factors. This project's long-term, on-farm approach had high value when assessing how a combination of soil health practices can be used to achieve on-farm goals while also setting reasonable benchmarks about what to expect when adopting these practices.

Findings of the Research

Through the four cropping years at the SHARE Farm, several important points can be made regarding soil health-practice adoption in the Logan Center, North Dakota, area:

Figure 1. Soil sampling at the Logan Center SHARE Farm.

Figure 2. Four years of crop productivity and soil health data were collected from the SHARE Farm project in Logan Center, North Dakota.

1. The productivity of cover crops is highly dependent on the crop type; planting method; and, most importantly, weather conditions.
2. No-till systems in this region have non-statistically significant yield differences compared to conventionally tilled systems during the first four years of no-till adoption.
3. The soil temperature is lower and has less daily fluctuation in no-till compared to tilled systems during the growing season, helping to reduce heat-induced plant stress.

Benefits to North Dakota Soybean Farmers

An inherent reduction in crop productivity during the first years of transitioning to no-till is commonly noted among agriculturalists, and there is evidence elsewhere supporting this. However, research at the SHARE Farm showed an average soybean yield of 43.5 bushels per acre with no difference between tillage systems, and similar results may be expected in other fields with similar soil, climatic and management conditions. Although there was no difference with the crop yield between tilled and no-till systems at this location, the direct financial benefit of not having the expense of several tillage passes prior to planting may well offset the costs of more intensive management. The next stage in this project is to further quantify the economic effect of soil health-practice adoption in order to help promote positive financial outcomes for North Dakota farmers.

Table 1. Crop yield, plant population and surface residue following the planting of each crop in a 4-year rotation with conventionally tilled (CT) and no-tillage (NT) management systems.

	Yield			Population			Surface Residue		
Crop	**CT**	**NT**	**P-value**	**CT**	**NT**	**P-value**	**CT**	**NT**	**P-value**
	tons ac^{-1}			**plants ac^{-1}**			**%**		
Pinto Bean	1.5	1.4	NS	57,239	75,827	**			
	bu ac^{-1}								
Corn	158	145	NS	34,848	18,392	**			
Soybeans	41	46	NS	108,667	84,367	NS	56	96	***
Barley	90	86	NS	590,707	742,133	NS	11	79	**

*, **, *** Significantly different at 0.05, 0.01, and 0.001 probability levels respectively
NS Nonsignificant

Visual Rating for Iron-Deficiency Chlorosis

Principal Investigator: *Carrie Miranda, Ph. D., NDSU Department of Plant Sciences*

Funded Project
$86,275

Why this Research is Important to North Dakota Soybean Farmers

Iron-deficiency chlorosis (IDC) is common in North Dakota and reduces soybean yield. The best way to mitigate the yield losses associated with IDC is to select a tolerant cultivar. Growers need data that compare varieties from different private companies in the same environments when using the same experimental method. Private companies enter their lines for IDC testing through the North Dakota State University (NDSU) website. These varieties are evaluated for visual ratings of IDC at multiple field locations.

Research Conducted

This project's objective is to screen private company varieties that are entered into the IDC testing application for visual ratings of IDC at multiple field locations which have a past history of IDC symptoms. A second objective is to provide visual IDC screening of approximately 100 advanced NDSU breeding lines.

In July 2022, there were 242 genetically modified organism (GMO) and 19 conventional, private-company varieties tested in fields with a previous history of IDC. One location was in Leonard, and the other site was at Colfax. Three IDC scores were taken: 1 month after planting, 2 weeks later and 2 weeks after the second measurement. Scores were taken on July 5th, July 14th and July 28th. The scores were averaged and statistically analyzed by using an analysis of variance (ANOVA) with R statistical software.

Figure 1. IDC on the 1st trifoliolate leaves near Fargo.

In 2022, there were 70 NDSU experimental lines and checks entered into IDC field testing. Four lines had adequate IDC tolerance.

Findings of the Research

The results of the IDC testing can also be found online at bit.ly/NDSUSoyVarietyTrialResults22.

Benefits to North Dakota Soybean Farmers

Data from this research will provide an independent confirmation for the IDC tolerance of soybean varieties developed by private companies and will enable growers to compare the IDC tolerance of varieties from different companies. To assist with IDC assessments for varieties from many different companies, soybean growers need information that utilizes side-by-side comparisons using the same, proven testing method.

Figure 2. IDC rating scale used by NDSU scientists to score the soybean's IDC severity. The ratings were based on a 1 to 5 scale, with 1 indicating no chlorosis and 5 being the most severe chlorosis.

> ***"Private companies enter their lines for IDC testing through the North Dakota State University (NDSU) website."***

Breeding of Improved Non-GMO Cultivars and Germplasm

Principal Investigator: *Carrie Miranda, Ph. D., NDSU Department of Plant Sciences*

Funded Project
$162,516

Why this Research is Important to North Dakota Soybean Farmers

The foundation of the North Dakota State University (NDSU) breeding program is conventional or non-GMO (genetically modified organism) varieties. There is growing demand for "food-grade" conventional soybeans or yellow hila, yellow seed coat soybeans that do not contain herbicide-resistance traits. These seeds are useful for producing soy foods or for export to Asian markets. Improving the conventional germplasm is an ongoing process to not only improve yields, but also to incorporate new resistance genes for disease and abiotic stress.

The objectives of this research were to provide North Dakota soybean growers with non-GMO cultivars which are genetically superior to the cultivars that are currently grown, with an emphasis on food-grade soybeans.

Findings of the Research

One tofu line and three natto lines were tested by a private company for potential release. Due to their exceptional performance, three conventional lines were in the final year of evaluation in the NDSU breeding program. These lines will be used to create new lines with herbicide tolerance and high yield.

> ***"There is growing demand for "food-grade" conventional soybeans or yellow hila, yellow seed coat soybeans that do not contain herbicide-resistance traits."***

Figure 1. NDSU assistant soybean breeder Gustavo Kreutz, Ph. D.

Figure 2. NDSU soybean breeding team plants soybeans, spring 2023.

Breeding of Glyphosate-Tolerant Soybean Cultivars

Principal Investigator: *Carrie Miranda, Ph. D., NDSU Department of Plant Sciences*

Funded Project
$232,812

Why this Research is Important to North Dakota Soybean Farmers

The project is designed to continue the process of developing glyphosate-tolerant (GT) soybean cultivars at North Dakota State University (NDSU). NDSU GT seeds offer farmers low seed input costs and provide a mechanism for weed control.

Research Conducted

Glyphosate-tolerant experimental lines in the NDSU breeding program are being tested in a range of maturity that varies from MG 00.6 to 1.3 and are properly adapted throughout the entirety of North Dakota. New experimental lines are developed each year. This project's objective is to develop glyphosate-tolerant experimental lines with the goal of releasing cultivars with varying maturities.

Findings of the Research

In 2022, two experimental lines, ND19-18020(GT) and ND18-20092(GT SCN), were identified for potential release. They have entered the final year of yield testing. Both varieties have soybean cyst nematode resistance; however, one line has stronger resistance. One line also has excellent iron deficiency chlorosis tolerance. The lines will be evaluated for a final year and will then be evaluated for release.

> ***"NDSU GT seeds offer farmers low seed input costs and provide a mechanism for weed control."***

Figure 1. Seeding GT soybean lines at the NDSU Agronomy Seed Farm in Casselton, North Dakota.

Table 1. Glyphosate-tolerant, fourth-year yield-testing entries

Name	Plant maturity date	2022 Yield bu/ac	IDC score (1-5 scale)	Notes
ND19-18020(GT)	Sept 20th	56.3	4	2.5.7 Peking SCN resistance
ND19-20092(GT)	Sept 14th	42.6	1.5	1PI 88788 SCN resistance

Enhancing Profitability of Soybean Production and Soil Health Through Livestock Integration

Principal Investigator: *Miranda Meehan, Ph. D., NDSU Department of Animal Sciences*
Co-Investigators: *Joshua Wianecki; Lindsay Malone; Kevin Sedivec; Zachary Carlson; Erin Gaugler; Michael Ostlie, Ph. D.; and Colin Tobin*

Funded Project $47,637

Why this Research is Important to North Dakota Soybean Farmers

Livestock integration may be a missing factor to achieve the full potential of cover crops. Livestock use can build organic matter and can improve the soil's nutrient cycling while creating a return in the form of a forage crop. Winter rye is often incorporated with soybean production systems as a cover crop. Managing winter rye with grazing can extend the grazing season while benefiting soils, crops and economics.

Research Conducted

In the fall of 2022, four winter rye and grazing management strategies were established at the Central Grasslands Research Extension Center (CGREC) and the Carrington Research Extension Center (CREC): dual (fall + spring) grazing, spring grazing, no grazing and no rye. Cattle grazed during each applicable treatment in the fall and/or spring seasons. Soil samples were collected to determine the soil's nutrients, including total nitrogen, phosphorous, potassium, total carbon, organic matter and bulk density. Winter rye forage yield, animal performance, ground cover and soybean production were evaluated.

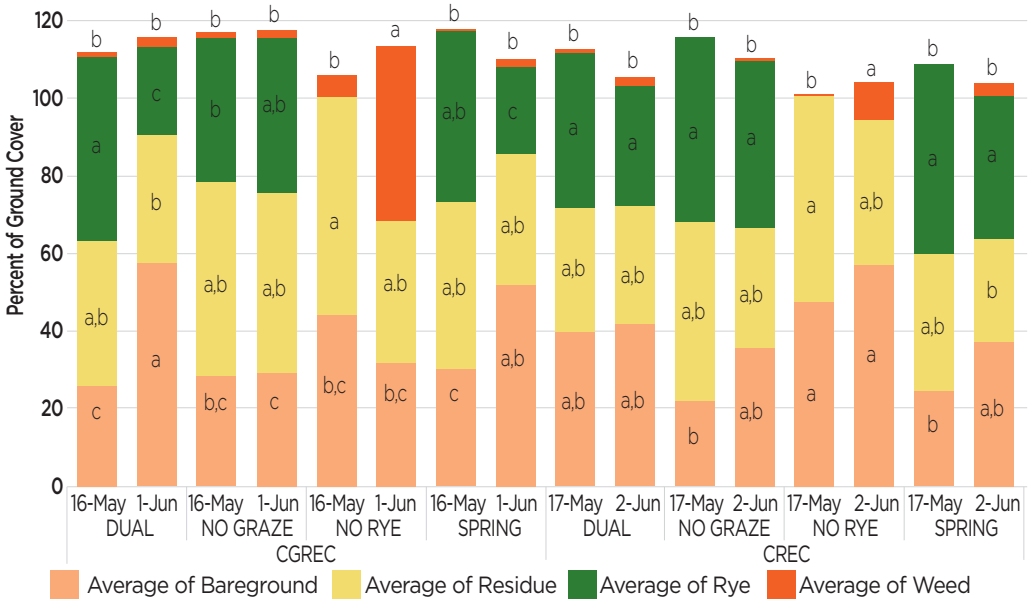
Figure 2. Spring grazing cattle at the Central Grasslands Research Extension Center (CGREC).

Findings of the Research

In the first year of the ongoing trial, a lack of fall moisture slowed the establishment of the winter rye, shortening the fall grazing period. The fall grazing period averaged 4 days at 1 head per acre across both locations. Dual grazing cattle lost an average of 4.5 pounds per day (lbs/day) across locations. The weather also delayed growth and the grazing period in the spring. The spring grazing period averaged 14 days at 1.9 head per acre across both locations. Spring livestock production was variable, with an average gain of 0.5 lbs/day at CGREC and -1.4 lbs/day at CREC.

Winter rye suppressed weeds, resulting in significantly lower weed pressure for all treatments compared to no rye. Fall grazing did not reduce rye yield or cover in the spring when comparing dual grazing to the other rye treatments. Soil nitrate was significantly higher for the CREC no rye compared to the no-grazed rye while the grazing treatments did not differ from either the no-graze or no-rye treatments. No differences were observed for the other soil chemical properties. Bulk density was unaffected by grazing, indicating that the trampling from livestock was not severe enough to affect soil structure. Soil properties can be slow to change. Continuation into 2023-2024 will aid with further evaluating the influence of livestock integration.

Figure 1. Absolute ground cover at the Central Grasslands Research Extension Center (CGREC) and the Carrington Research Extension Center (CREC), 2023. Ground cover was classified pre- and post-grazing, and the ground cover included living rye, residue, bare ground and weeds.



Soybean Cyst Nematode Sampling Program 2022

Principal Investigator: *Sam Markell, Ph. D., NDSU Department of Plant Pathology*
Co-Investigator: *Guiping Yan, Ph. D., NDSU Department of Plant Pathology*
Collaborators: *NDSU County Extension Agents*

Funded Project $62,580

Why this Research is Important to North Dakota Soybean Farmers

Soybean cyst nematode (SCN) is the most economically important biological threat to soybean production in the United States, and the nematode continues to expand in North Dakota. Soil sampling is the most reliable way to detect the presence of SCN and is the most effective way to determine how well the management tools are working in the soybean fields. This project supports a sampling program for soybean growers which increases our understanding about the SCN's prevalence in North Dakota.

Research Conducted

Pre-labeled soil-sampling bags are distributed to soybean growers and their advisers through NDSU Extension in late summer and early fall. The North Dakota Soybean Council covers the laboratory fees for the samples submitted to Agvise (partner laboratory). Growers receive their data directly through the mail, and NDSU Extension receives egg level and geographic data to construct maps.

Findings of the Research

In 2022, there were 397 total SCN samples, of which 201 were found to have at least 50 eggs plus second stage juvenile nematodes per 100 cubic centimeters (cc) of soil. Three new findings had the highest reported egg levels within an approximate 20- to 50-mile radius, including locations in southeastern Walsh, northeastern Stutsman and northeastern Kidder Counties. In contrast, robust sampling throughout Benson County was conducted, and all samples were reported as negative (0), suggesting that, even if SCN is suspected or known, it may not be an immediate threat in any given area. Since 2013, many samples (4,806) have been mapped, which has increased our understanding of the SCN threat to soybean growers in North Dakota.

Figure 3. Sam Markell., Ph. D., provides research updates during NDSU's Agronomy Seed Farm Field Day.

Benefits/ Recommendations for North Dakota Soybean Farmers and the Industry

For growers who have not detected SCN before, we recommend that they concentrate on areas in the field where SCN is most likely to first be introduced, such as field entrances. For growers who know that they have SCN, we recommend that they sample the soil to determine how well the current management strategies are working.

Acknowledgments

We thank the growers, Extension agents, and others who participated in this program; Michaela Halvorson for map construction; Agvise for sample processing; and the North Dakota Soybean Council funding.

Figure 1. Number of SCN samples and their egg levels (eggs + J2/100 cc soil) received from 2013 to 2022.

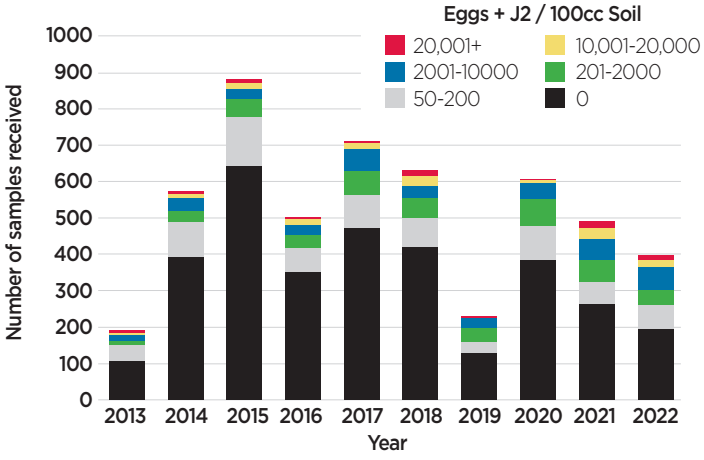
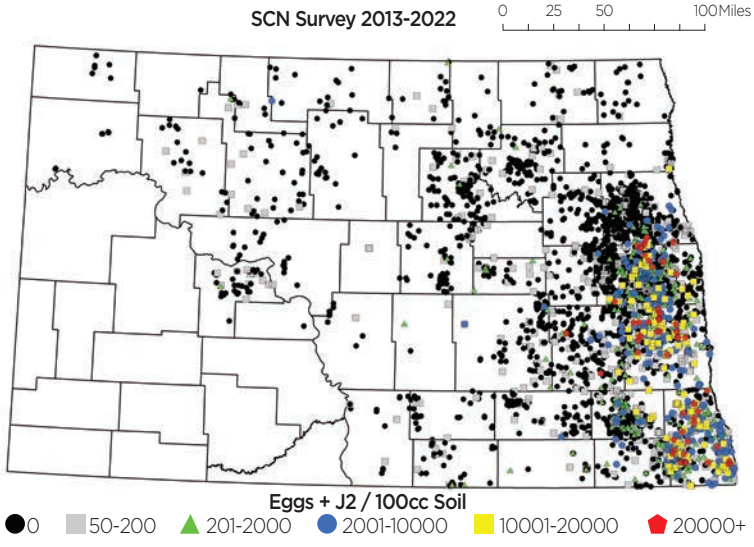


Figure 2. Cumulative distribution of SCN in North Dakota from 2013 to 2022 (4,806 mapped samples).



Soybean Yield Interference of Palmer Amaranth and Waterhemp in North Dakota

Principal Investigators: *Quincy Law, Ph. D., and Joseph Ikley, Ph. D., NDSU Department of Plant Sciences*

Funded Project
$31,003

Why this Research is Important to North Dakota Soybean Farmers

Palmer amaranth and waterhemp are two especially problematic weeds that negatively affect soybean production. This project measured soybean yield and calculated the yield loss associated with Palmer amaranth and waterhemp's presence and density. This research is important to North Dakota farmers because both weed species continue to spread across the state and can cause economic harm directly due to yield loss and indirectly through the increased cost of control.

Research Conducted

Separate Palmer amaranth and waterhemp research trials were conducted to determine the yield loss associated with these two weeds. After soybean planting, waterhemp was allowed to emerge naturally, and 24 days later, Palmer amaranth was transplanted into plots at specific densities based on how the experiment was designed (from weed-free to extremely dense). All other weeds were manually removed throughout the season. At the end of the growing season, data about weed biomass and soybean yield were collected. The soybean's yield loss was described as a function of weed density by using a yield loss equation.

A rectangular hyperbola model was used, and the mean and standard error bars for each Palmer amaranth density are presented. Soybeans were planted on 6 June; Palmer amaranth was transplanted on 30 June; and soybeans were harvested on 18 October in 2022.

Findings of the Research

In year 1 of this experiment, Palmer amaranth was estimated to cause up to a 57% soybean yield loss when Palmer amaranth was transplanted 24 days after soybean planting. The palmer amaranth's density reduced the number of soybean pods per plant but not the number of seeds per pod. Further, as the Palmer amaranth's density increased, so did the Palmer amaranth's biomass. The soybean yield was apparently reduced as waterhemp biomass increased.

Figure 3. Quincy Law, Ph. D., collects field data at one of the research sites.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

This research demonstrates the importance of controlling Palmer amaranth and waterhemp as well as mitigating their spread. Even though soybeans were planted 24 days prior to Palmer amaranth transplanting, significant yield losses were observed. As such, pre-emergence and postemergence control strategies should be utilized for Palmer amaranth and waterhemp. This research will be repeated in 2023.

Figure 1. The soybean yield's (adjusted to 13% moisture) loss as influenced by Palmer amaranth density (expressed as plants per m row).

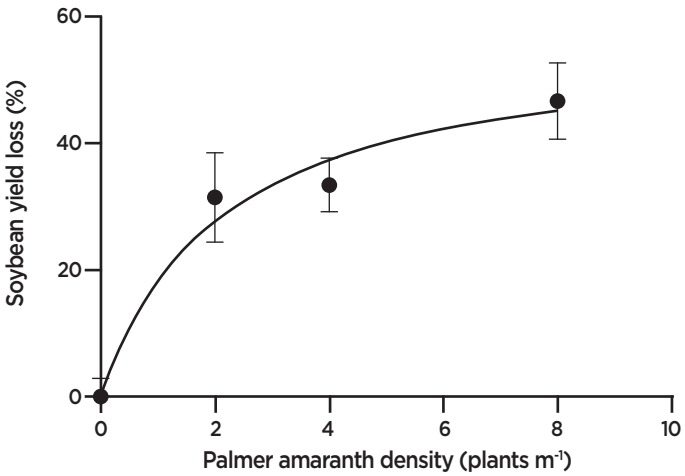
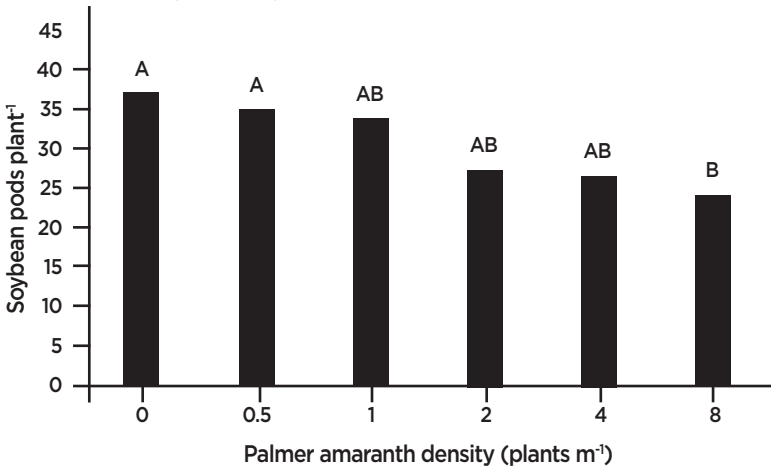


Figure 2. Soybean pods plant-1 as influenced by Palmer amaranth density (expressed as plants m-1). Means with the same letter are not significantly different according to Tukey's honest significant-difference test (α = 0.05).



Soybean Gall Midge Survey in North Dakota

Principal Investigator: *Janet Knodel, Ph. D., NDSU Extension entomologist*
Co-Investigators: *Veronica Calles Torrez, Ph.D.; and Patrick Beauzay*

Funded Project

Why this Research is Important to North Dakota Soybean Farmers

The soybean gall midge was discovered in 2018 by entomologists in Iowa, Nebraska and South Dakota who observed dead or dying soybean plants associated with an infestation of midge larvae at the stems' bases (Figure 1). These midges were identified as a new species in 2019. The soybean gall midge is now established in five states: Nebraska, Minnesota, South Dakota, Iowa and Missouri. The midge's distribution continues to expand from a total of 67 counties in 2018 to 140 counties in 2022. The soybean gall midge causes economic yield losses for soybeans in some areas with insect high populations, especially east-central Nebraska. We surveyed for this invasive insect pest in order to determine if it is present and established in North Dakota.

Research Conducted

We surveyed a total of 436 soybean fields in 45 of the 53 counties in North Dakota (Figure 2). The most intense survey was conducted in the southeastern part of the state because the known infestations of the soybean gall midge in Minnesota and South Dakota are close to the North Dakota border.

Findings of the Research

The results of our 2022 soybean gall midge survey were negative for most soybean fields surveyed in North Dakota, except for one soybean field in Sargent County near Gwinner. DNA analysis confirmed the insect's identity as soybean gall midge. This identification is the first soybean gall midge detection in North Dakota. Survey work for soybean gall midge is crucial so that soybean producers are aware of the pest's current distribution and abundance in North Dakota and so that effective pest-management strategies can be developed.

NDSU Extension outreach materials, including a second educational banner about the key insect pests for soybeans and a Soybean Insect Diagnostic Series, are being developed. These materials will be used to educate North Dakota soybean farmers, crop consultants, IPM scouts and the soybean industry.

Figure 1. A soybean stem from Sargent County, North Dakota, that is infested with soybean gall midge larvae (B. Schulzetenberg, Centrol Crop Consulting).

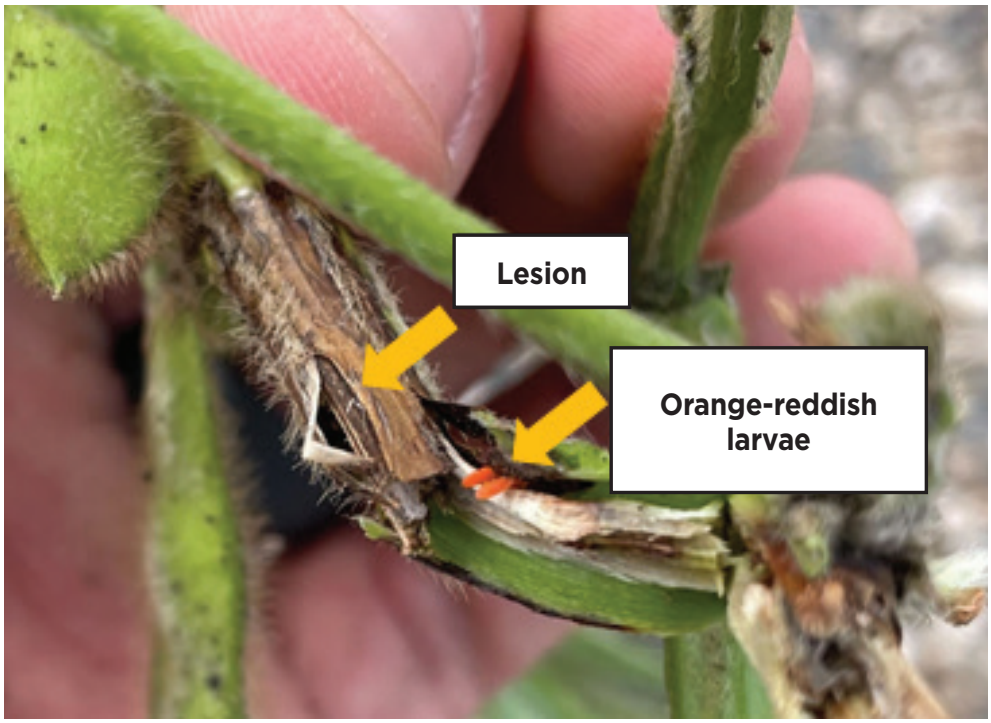


Figure 2. Survey of soybean gall midge in soybean fields, 2022.

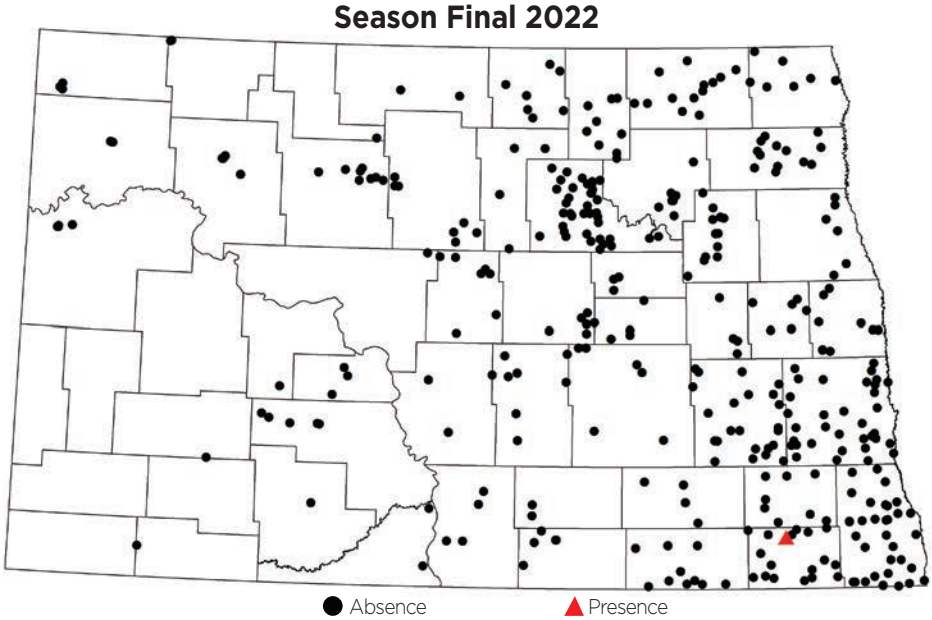


Figure 3. Janet Knodel, Ph. D., is a professor and an extension entomologist at NDSU.

Impact of Crop Sequence and Tillage on the Crop Yield and Quality, Soil Nutrients, pH, Texture and Microbial Population

Principal Investigator: *Mohammed Khan, Ph. D., NDSU Extension Assistant Director, Agriculture and Natural Resources*

Funded Project
$45,557

Why this Research is Important to North Dakota Soybean Farmers

Since the 1870s, we have grown crops, starting with wheat, in the Red River Valley by using conventional forms of tillage. The advent of glyphosate-tolerant crops made it possible for producers, especially in the western part of the state, to grow these crops using conservation practices and reduced water use. Conservation tillage (where greater than or equal to 30% of the crop residue remains) can provide benefits such as soil conservation, improved organic matter content for the soil, and reduced labor and energy use. Some producers, particularly in western North Dakota, have started growing soybeans, corn, sugarbeets and wheat using strip tillage and/or no-till. It is useful to provide research-based information about the advantages and challenges of using no-till and reduced tillage relative to conventional tillage for sugarbeets, soybeans, corn and wheat that are grown in different sequences in the Red River Valley.

Figure 1. Mohammed Khan, Ph. D., provides a research update during a field day in July.

Research Conducted

This research evaluated the influence of tillage type (conventional, no-till and strip till) on the yield, quality and diseases for soybeans, corn, sugarbeets and wheat used in four different sequences at North Dakota State University's (NDSU's) Prosper research site. In 2022, the site had to be replanted because of wind and subsequent standing water damage. The site was replanted on July 2; evaluated for pests, diseases, and soil microbial communities; and then harvested in October. Soil samples were collected for analysis. Erosion pads were included with each plot to measure the soil erosion, and soil temperature probes were also installed to determine the soil temperatures for different treatments.

Findings of the Research

There was no significant effect of the tillage method on yield, moisture content and test weight. The mean values for the respective tillage methods are given in Table 1.

Table 1. Soybean, Table of Means, Crop sequence 1 (Corn/Soybean/Wheat/Sugarbeet) x Tillage

Tillage	Yield (bu/ac)	Moisture (%)	Test weight
CT	27.5	12.4	59.8
NT	20.0	13.1	56.5
ST	19.7	13.7	59.5

Even though the soybean yields were numerically lower with no-till and trip till, they did not differ significantly from the soybean yield with conventional tillage. This finding can be due to yield variation between replicates with the same tillage method. We also observed that corn residue under no-till and strip till affected the emergence and uniformity of the soybean stand compared to conventional tillage. The soybean, corn and sugarbeet crops in the rotation were not affected by any major pest or disease during the growing season.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

Our research indicated that soybeans can be successfully grown with different tillage types in the Red River Valley. Where possible, care should be taken to reduce the corn residue, especially with strip tillage, and moving residue with coulters in to till to facilitate planting to establish a good plant population. Ongoing research is being done to determine the influence of tillage and crop sequences on the soil characteristics and microbial populations.

Pigweed Awareness Coalition: Increasing the Awareness About the Risk of Palmer Amaranth and Waterhemp in North Dakota

Principal Investigator: *Joseph Ikley, Ph. D., NDSU Extension Weed Scientist*

Funded Project
$30,000

Why this Research is Important to North Dakota Soybean Farmers

Waterhemp is currently one of the most challenging weeds for soybean production in North Dakota. At the onset of this campaign, there was documentation of populations with resistance to Group 2, 9 and 14 herbicides in seven North Dakota counties. Most populations found in North Dakota have resistance to Groups 2 and 9.

Palmer amaranth has been detected in 19 North Dakota counties. Many populations have been tested for herbicide resistance. Some populations had no detectable herbicide resistance while others were resistant to 5 sites of action (2, 4, 5, 9 and 27). Most populations have confirmed resistance to Groups 2 and 9. This weed continues to pose a risk to soybean production in the state, and continued awareness about the proper identification, biology and control will help with the early detection of new populations in order prevent Palmer amaranth from establishing a foothold in North Dakota.

Figure 1. 3D-printed Palmer amaranth used at trade shows to inform audiences about the risks that Palmer amaranth and waterhemp pose to crop production in North Dakota.

Figure 3. Jospeh Ikley, Ph. D., and Zach Bateson, Ph. D., scout field for weeds.

This project was designed to provide new Extension programming for Palmer amaranth and waterhemp across North Dakota during the winters of 2022 and 2023. We recorded new videos about the biology, identification and management of Palmer amaranth to be used throughout the winter meetings. Relevant publications were created, revised and/or printed. New information was presented at winter meetings throughout North Dakota, including new audiences such as the Stockman's Association. The goal was to ensure that all attendees were informed about the risks that Palmer amaranth and waterhemp pose to crop production in North Dakota.

Findings of the Research

Annual greenhouse evaluations of the waterhemp populations revealed one additional county with resistance to Group 14 herbicides. Additionally, dicamba-resistant waterhemp was confirmed in the greenhouse during late winter 2023. After their discovery, these results were discussed at Extension events.

Figure 2. Pigweed awareness messages delivered by North Dakota Soybean Council during KMOT trade show in Minot.

North Central Soybean Research Program (NCSRP)

Funded Project $225,000

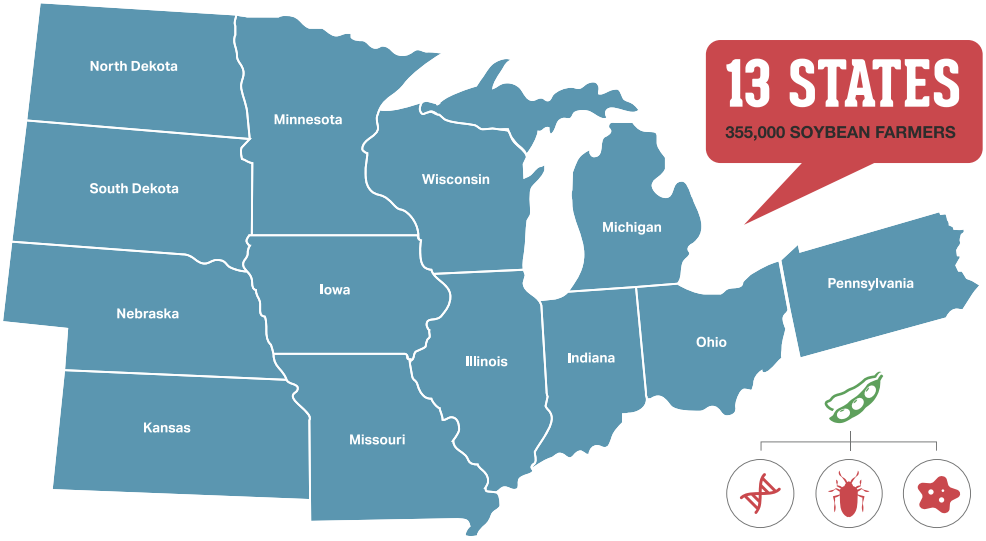
The North Central Soybean Research Program (NCSRP) is a multi-state research program that is recognized as a leader in collaborative research and outreach efforts to support soybean farmers and to drive the soybean industry forward. The NCSRP combines soybean check-off funds from its 13 state checkoff boards–North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Michigan, Ohio and Pennsylvania–to sponsor basic and applied research, extension, outreach and communications. To successfully deliver this program, farmer leaders, state staff and funded researchers work together to prioritize, monitor and communicate the basic and applied research efforts on behalf of 400,00 soybean farmers in the region, representing more than 85% of the nation's soybean production. The NCSRP's focus is to increase soybean profitability and to enhance and protect yield, while maintaining and improving soybean quality and composition, through genetic improvement, agronomics, and biotic and abiotic stress mitigation for soybean maturity groups 00-IV.

Figure 1. Pennsylvania Soybean Board hosted NCRSP board meeting in August, 2023.

Since 1992, the NCSRP has established broader collaboration and built partnerships to deliver research results to farmers as well as to provide farmers with a solid return for the check-off investments. The NCSRP Board funds research projects that address the goals to increase the soybean growers' productivity and profitability while improving environmental stewardship. The NCSRP also funds both applied and basic research, along with the communication of research results to support Midwestern soybean producers.

The NCSRP funded the following projects in 2023:

- An integrated approach to enhance durability of SCN resistance for long-term, strategic SCN management (Phase III)
- Using data-driven knowledge for profitable soybean management systems
- Field phenotyping using machine learning tools integrated with genetic mapping to address heat and drought induced flower abortion in soybean
- Improving flood and drought tolerance for soybeans in North Central region
- SOYGEN3: Building capacity to increase soybean genetic gain in future environments for seed yield and composition through combining genomics-assisted breeding with environmental characterization
- Mapping soybean protein and oil quality in farmer fields
- Multi-dimensional approaches for improved productivity, sustainability, and management of major soybean diseases in the North Central US
- The SCN Coalition: Economics and Advancing Management
- Site-specific weed management with precision application technology
- Research and extension on emerging soybean pests in the North Central region
- SoyRenSeq: a novel approach for disease resistance gene discovery and application for soybean improvement



Details and summaries for the listed projects can be found online at bit.ly/CurrentNCSRPprojects.

For more information about the NCSRP, visit NCSRP.com and soybeanresearchinfo.com.

NCSRP
NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

Optimal Respray Intervals for Glufosinate; 2,4-D; and Dicamba on Glyphosate-Resistant Waterhemp and Palmer Amaranth

Principal Investigator: *Joseph Ikley, Ph. D., NDSU Extension Weed Scientist*

Funded Project $26,861

Why this Research is Important to North Dakota Soybean Farmers

There are a number of factors that can cause a herbicide application to fail to control weeds. Optimal timing and which herbicide to use in the sequential treatment are frequent questions during the summer spray season. This research was conducted to determine the answers to those questions concerning waterhemp and Palmer amaranth, two important weeds that are detrimental to soybean production.

Research Conducted

This research was conducted to determine the optimal timing to respray a failed initial application of 2,4-D; dicamba; or glufosinate in soybeans. This research was conducted on waterhemp in a non-crop setting and on Palmer amaranth in the greenhouse. The initial treatment was applied when the pigweeds were 3 inches in height; then, respray applications were made 7, 14 and 21 days after the initial application. The utilized herbicides were grouped according to which active ingredients can be used with herbicide-resistant soybeans (i.e., 2,4-D and glufosinate for Enlist E3 soybeans; and dicamba and glufosinate for Xtendflex soybeans).

Findings of the Research

In the E3 soybean system, treatments for waterhemp were generally more consistent when 2,4-D was applied first. The final weed control ranged from 84% to 98% when 2,4-D was followed by another application of 2,4-D or glufosinate. There were no timing differences for the follow-up application. When glufosinate was applied first, the worst treatment was a sequential application of 2,4-D seven days later (63% control) or glufosinate 21 days later (66%). All other combinations provided 83% to 94% control.

Waterhemp control in the Xtendflex trial was generally poor due to high density (approximately 10x more plants per square meter than the E3 trial). When dicamba was the first herbicide applied, glufosinate applied 7 days later was the worst sequential treatment. All other combinations of dicamba or glufosinate resulted in similar control. When glufosinate was applied first, glufosinate applied 14 days later resulted in the greatest control, with dicamba 14 days later providing a similar level of control. All other combinations following the first glufosinate application resulted in poor waterhemp control.

For Palmer amaranth trials in the greenhouse, the first application of glufosinate provided complete control. Following a failed application of 2,4-D, the only difference was that 2,4-D twenty-one days later provided better control than glufosinate 21 days later. All other treatment combinations provided similar control. Following a failed application of dicamba, glufosinate applied 7 days later was worse than every other treatment combination.

Trials are currently being repeated during the 2023 growing season.

Benefits/Recommendations to North Dakota Soybean Farmers and the Industry

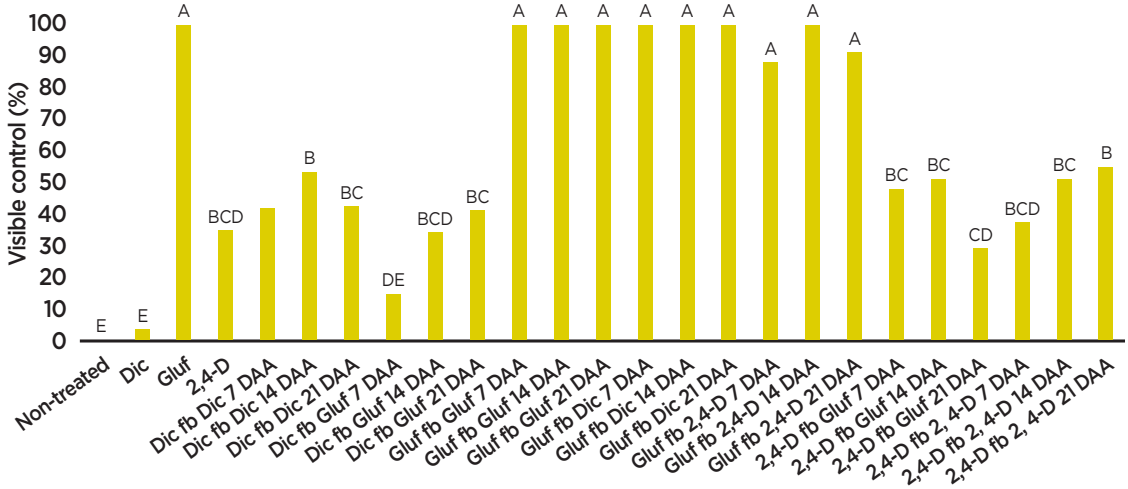
This research found treatment differences for respray timing and herbicide in case of a failed postemergence application. Although there is some variability with the data across pigweed species and herbicide treatments, in general, a respray 14 days following a failed application was always among the best treatments. Fields should be scouted within 7 days of the original application to determine the success and to allow for time to line up another application targeting 14 days following the first application. It is important to note that no single treatment provided complete control of waterhemp and Palmer amaranth, so a more comprehensive, integrated management strategy is needed rather than only relying on the use of postemergence herbicides.

Table 1. Visible control ratings, density, and biomass for the Enlist soybean trial

Treatment	Final Waterhemp Control (%)	Final Waterhemp Density (plants m^{-2})	Final Waterhemp Biomass (g m^{-2})
Enlist One fb Enlist One 7 DAT	84 AB	11 B	15 B
Enlist One fb Enlist One 14 DAT	98 A	0 B	0 B
Enlist One fb Enlist One 21 DAT	93 A	2 B	1 B
Enlist One fb Liberty 7 DAT	89 A	1 B	19 B
Enlist One fb Liberty 14 DAT	98 A	0 B	0 B
Enlist One fb Liberty 21 DAT	96 A	2 B	7 B
Liberty fb Enlist One 7 DAT	63 C	42 B	88 B
Liberty fb Enlist One 14 DAT	83 AB	14 B	47 B
Liberty fb Enlist One 21 DAT	91 A	2 B	5 B
Liberty fb Liberty 7 DAT	92 A	1 B	3 B
Liberty fb Liberty 14 DAT	94 A	6 B	8 B
Liberty fb Liberty 21 DAT	66 BC	35 B	86 B
Nontreated	0 D	78 A	1,007 A

Enlist One rate was 32 fl oz./ac. Liberty rate was 32 fl oz./ac. 8.5 lb per 100 gallons of AMS was used for all treatments. DAT; days after treatment. fb: followed by. Different letters within same column represent statistical separation at P<0.05

Figure 1. Control of Palmer amaranth in the greenhouse 42 days after initial application (DAA).



Abbreviations: Dic: dicambia; Gluf: glufosinate. Dicambia was applied as Engenia at 3.2 fl oz./ac (0.125 lb ae/ac). Glufosinate was applied as Liberty at 9.75 fl oz./ac. 2.4-D was applied as Enlist One at 6 fl oz./ac (0.18 lb ae/ac).

A Tool for Cheap and Rapid Tracking of Soybean-Inoculant Populations in Field Soil

Principal Investigator: *Barney Geddes, Ph. D., NDSU Department of Biological Sciences*

Funded Project
$14,959

Why this Research is Important to North Dakota Soybean Farmers

Unnecessary inoculation wastes farmers' money and cuts into their bottom line. However, choosing not to inoculate also carries significant risk. If optimal nodulation does not occur, soybean crops may not get enough nitrogen, resulting in yield losses. No practical approach currently exists for farmers to predict the requirement for inoculation prior to planting. This project continues the efforts to develop a cheap and reliable tool to track rhizobia in the soils, informing inoculant decisions for farmers either indirectly through accelerating agronomy or directly through the use of a service.

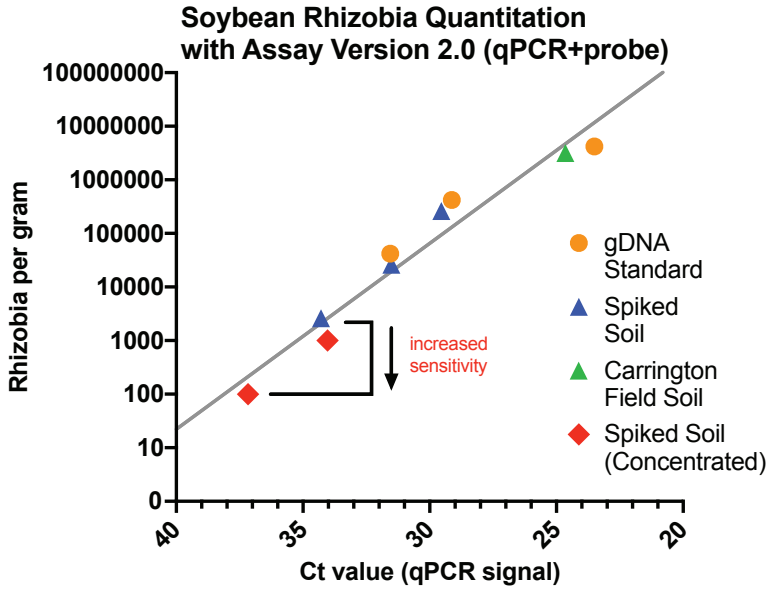
In research during this funding year, we had three key objectives:

- explore improving the sensitivity of the assay;
- evaluate the robustness of the assay with different soil types and sampling procedures;
- apply the assay to farmer's fields in North Dakota.

Findings of the Research

We showed that we could improve the sensitivity of the assay which we previously developed by incorporating fluorescent probe technology. We found that, with the sandier soils in western North Dakota, there was an underestimation of the number of rhizobia present, indicating an area for improvement in future years. We discovered that the assay proved to be robust with diverse sampling procedures, including the ones used to collect field soil for chemical analysis and the conditions that might be expected with samples sent by farmers for a chemical analysis of the soil. Finally, we analyzed rhizobium populations in 23 different field samples from eastern and western North Dakota with varying years post-soybean production. Overall, we saw high levels of rhizobia for one to three years after a soybean crop, followed by declines in year four or five. Examples with non-detectable amounts of rhizobia were observed as soon as two years after the previous crop.

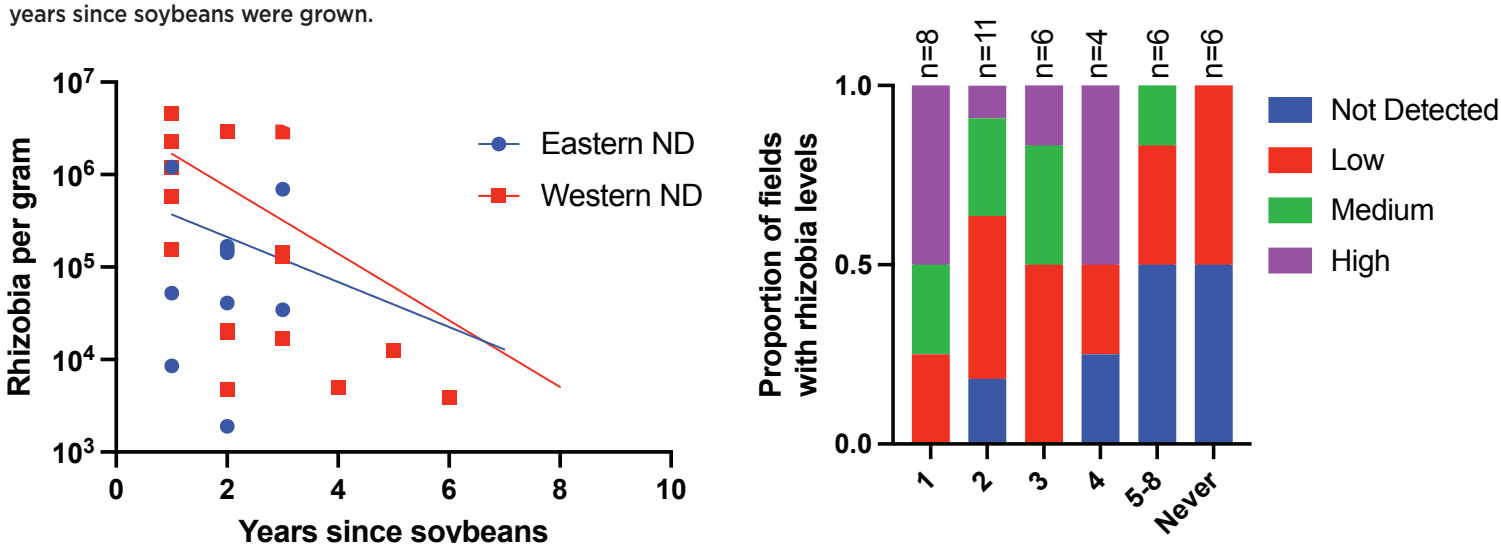
Figure 2. Assay Version 2.0 results using the qPCR platform with concentrated (undiluted) DNA samples.



Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

Our results are generally in line with current recommendations for farmers to inoculate soybeans if there has not been a previous soybean crop for five years. We did not observe substantial differences between eastern and western North Dakota in terms of the rhizobium population. There were examples where rhizobium populations were not detectable as soon as two years after the previous crop. This finding illustrates the tool's potential value to indicate if farmers should inoculate sooner than the recommended five years in special circumstances. Our data show that the test could be provided as an "add-on" for farmers' routine chemical analysis of the soil.

Figure 1. A (left) shows pooled data from 2022 and 2023 where detectable rhizobia were identified in fields compared to the number of years since soybeans were grown.



Soybean Tolerance to Preplant-Applied Dicamba

Principal Investigator: *Greg Endres, NDSU Carrington Research Extension Center*

Funded Project
$7,145

Why this Research is Important to North Dakota Soybean Farmers

There are a limited number of preplant burndown herbicides available for soybeans that are effective on herbicide-resistant broadleaf weeds, that provide initial soil residual and that are low cost. Low rates of dicamba fit this description, but waiting periods between dicamba application and soybean planting generally restrict the herbicide's use due to the potential for crop injury. Study objectives are to evaluate the soybean plant's growth and the seed yield response based on the timing of planting after applying the preplant, low-dose soil rate of dicamba with or without water activation.

Research Conducted

The two-year field trials were conducted at three NDSU research sites: Carrington (irrigated), and Minot and Prosper (dryland). The four targeted treatments were untreated; treated (Clarity or generic dicamba preplant applied 4 fluid ounces per acre in mid-May; non-Xtend tolerant soybeans planted fewer than 14 days after dicamba application, and before rain or irrigation; and 14 days or more after dicamba application, and rain or irrigation of at least 1 inch.

Field data included the soybean plants' development (emergence, flower and maturity) dates, plant density, and canopy; injury ratings 1 to 2 weeks, 3 to 4 weeks, and 6 to 8 weeks after plant emergence; crop height 3 to 4 weeks and 6 to 8 weeks after emergence; and seed yield.

Figure 2. Example of a soybean plant stand reduction: Carrington, 2021.

Findings of the Research

Averaged across five site-years, the soybean plants' injury with the first planting date (2-7 days and less than 0.10" rain after dicamba application) ranged from 43% to 87%. Plant injury with the second planting date (16-20 days and 0.6"-3.0" water following dicamba application) was 4% to 53%. Averaged across four site-years, the plant density with dicamba treatments vs. untreated checks was reduced 0% to 68% with the first planting date and 0% to 27% with the second planting date. Averaged across two site-years, the soybeans' seed yield with the dicamba-treated soil was statistically similar to the untreated checks but tended to decline with the dicamba-treated soil.

In summary, non-Xtend tolerant soybean plant injury and reduction, generally, were not acceptable with the prior low-dose preplant application of dicamba with limited waiting period for planting, especially with limited water before planting. Also, the potential for the loss of seed yield exists.

Benefits/Recommendations to North Dakota Soybean Farmers and the Industry

This North Dakota study provides data to guide farmers and crop advisers about non-Xtend tolerant soybean tolerance when the crop is planted at short intervals following preplant-applied dicamba at low rates.

Figure 1. Greg Endres, cropping systems specialist at Carrington REC.

Figure 3. Soybean plant injury during growth in dicamba-treated soil.

Winter Rye Cover-Crop Establishment Options and Soybean Response to Prior-Year Phosphorus Application

Principal Investigator: *Greg Endres, NDSU Carrington Research Extension Center (REC)*

Funded Project
$9,000

Why this Research is Important to North Dakota Soybean Farmers

The interest with and utilization of cover crops continue to grow in North Dakota due to the benefits, including reducing soil erosion, managing soil moisture, suppressing weeds, and increasing the long-term soil productivity. Farmers need North Dakota State University (NDSU) recommendations from in-state field research to develop proper seeding rates for rye based on the fall establishment dates when using rye as a cover crop prior to soybean production.

One of the phosphorous (P) fertilizer use options is a preplant P application for corn at rates to allow adequate plant nutrition for soybeans the following year. Previously, this research was not conducted in North Dakota. NDSU Extension's current suggestion regarding this strategy is based on other land-grant university information.

To develop recommendations, this research conducted two field trials:

Study 1: Winter rye fall seeding dates and rates: The study objective is to determine an appropriate rye seeding rate and an established stand that affect soybean production, including ground cover, soil moisture and weed suppression with rye.

Study 2: Response to prior-year application of phosphorus (P) fertilizer: The study objective is to examine the soybean's yield response with low-P testing soil to preplant, broadcast-applied P fertilizer the prior year for corn plus soybeans versus an annual application for corn followed by soybeans.

Research Conducted

Study 1: This research was conducted for 4 years at the Carrington REC. Treatments: Winter rye was seeded mid-September and early October at 25 pounds per acre (lb/a), 50 lb/a and 75 lb/a (six treatments). Rye was terminated with glyphosate near the soybean planting time, and the trial data were generated during soybean production.

Study 2: This research was conducted in 2021-22 at Carrington and in 2022 at the North Central RECs in Minot. Phosphorous soil analysis: Carrington = low (4 parts per million [ppm]) and Minot = medium (8 ppm). Treatments: 1) untreated check, 2) P fertilizer applied for corn in 2021 followed by P application in 2022 for soybeans and 3) P preplant applied in 2021 for corn plus soybeans. Phosphorous fertilizer was applied as 0-46-0 (triple superphosphate) based on NDSU Extension recommendations for low-testing soils with corn and soybean production.

Figure 2. P fertilizer application-timing trial at Carrington, 2022.

Findings of the Research

Study 1: The greatest rye plant density was achieved with mid-September seeding at 75 lb/a (4-year average = 598,300 plants/acre). Also, ground cover and foxtail suppression were the greatest with the same combination. The soybean's plant density and seed yield were similar among the rye treatments.

Study 2: *Carrington:* Averaged across 2 years on low-P testing soils, the soybean yield was similar among fertilizer treatments: annual P application = 36.2 bushels per acre (bu/A) and prior-year P application only = 37.5 bu/A.

Minot: The soybean yield was similar among treatments.

Figure 1. Terminated rye in soybeans.

Table 1. Seeding date and rate influence on the winter rye's stand and ground cover, Carrington, 2019-22 (4-year average)

Rye planting treatment		Rye 1		
Date	Rate	Plant density		Ground cover
	lbs/ac	plants/ac	plants/ft²	%
First: Oct 2, 2018 Sept 26, 2019 Sept 17, 2020 Sept 22, 2021	25	172,370	4	21
	50	364,780	8	21
	75	598,270	14	27
Second: Oct 31, 2018 Nov 1, 2019 Oct 8, 2020 Oct 8, 2021	25	137,790	3	9
	50	372,950	9	17
	75	569,390	13	18

Rye plant density measured and ground cover visually evaluated in May prior to planting soybean.

Timing of Pre-Plant Herbicide Programs for Weed Control with No-Till Soybeans in Southwest North Dakota

Principal Investigator: *Caleb Dalley, NDSU Hettinger Research and Extension Center*

Funded Project
$5,000

Why this Research is Important to North Dakota Soybean Farmers

Growing soybeans in southwest North Dakota has unique challenges for weed control due to the commonly used no-till cropping systems and weeds, such as kochia, that are difficult to control in soybeans. A better understanding of the weeds' response to herbicides with this climate and these production practices is needed.

The objective of this research was to compare weed control strategies when using pre-emergence and post-emergence herbicides in soybeans.

Research Conducted

On May 6 and May 16, five different herbicide treatments were applied to research plots prior to planting soybeans on May 27. The same treatments were applied immediately after planting soybeans. Treatments included 1) flumioxazin, 2) flumioxazin plus pyroxasulfone, 3) sulfentrazone plus metolachlor,4) sulfentrazone plus pyroxasulfone and 5) sulfentrazone plus metribuzin; glyphosate, ammonium sulfate (AMS) and a high surfactant methylated seed oil concentrate (HSMSOC) adjuvant were applied with these treatments. The treatments were compared with split applications of glyphosate. Treatments were also compared with glyphosate plus dicamba applied at planting or at the soybeans' V1 stage, with an untreated control where no herbicide was applied and with a weed-free control. Glyphosate was also applied across all treatments when soybeans reached the reproductive 1 (R1) growth stage, which is flowering.

Findings of the Research

The timing for preplant or at-planting herbicide applications did not significantly affect weed control or soybean yield. Flumioxazin alone provided poor control (48%) of kochia (Table 1). Adding pyroxasulfone to the flumioxazin increased kochia control slightly (59%), but the control remained poor. Sulfentrazone plus metolachlor also provided poor control (62%) of kochia. This finding was somewhat surprising because the treatment typically provides good-to-excellent control of kochia. Sulfentrazone plus pyroxasulfone increased kochia control to 76%. The best control of kochia resulted from an application of sulfentrazone plus metribuzin, with 82% control of kochia. Xtendimax applied at planting provided poor control (64%) of kochia; however, delaying the application until the V1 stage controlled kochia at 83%. A split application of glyphosate at planting and at the V1 stage provided fair control of kochia (78%).

Figure 1. Experimental site at the Hettinger Research Extension Center.

All treatments increased the soybean yield compared to when no herbicide was applied. However, soybean yield for this trial was low due to the lack of rainfall in July and August, with just 0.7 inches of rain between July 10 and August 31, which limited the production potential. There were also no real yield differences when comparing herbicide treatments.

Table 1. Effect of herbicide treatments for weed control and soybean yield at Hettinger, North Dakota, in 2022.

Herbicide treatment*	Kochia	Common mallow	Annual grass	Soybean yield
	control (%)			bu/ac
1) Untreadted	0	0	0	0
2) Flumioxazin	48	70	54	21
3) Flumioxazin + pyroxasulfone	59	84	88	23
4) Sulfentrazone + metolachor	62	72	70	22
5) Sulfentrazone + pyroxasulfone	76	83	87	23
6) Sulfentrazone + metribuzin	82	86	86	26
7) Xtendimax PRE	64	63	0	22
8) Xtendimax POST	83	80	93	21
9) Glyphosate 2X	78	97	94	25
10) Weed free	100	100	100	22
LSD (0.05)	10	10	9	5

*Treatments 2-8 were tank-mixed with glyphosate along with an appropriate adjuvant when required. Treatments 2-6 are an average of three application timings that were applied either at planting or 1 or 2 weeks before planting. Treatment 7 was applied at planting. Treatment 8 was applied when soybean were at the V1 growth stage. Treatment 9 was applied both at planting and at the V1 growth stage.

Field Validation of Mineral Nitrogen Cycling from Mixed-Crop Residues in Long-Term No-Till Systems

Principal Investigator: *Larry Cihacek, Ph.D.; and Rashad Alghamdi, Ph.D.; NDSU School of Natural Resource Sciences*

Funded Project $4,517

Why this Research is Important to North Dakota Soybean Farmers

Soybeans are widely grown with many crop rotations in North Dakota, and finding a means to mitigate nitrogen (N) immobilization that could lower fertilizer rates where heavy residue accumulations occur in long term no-till soil can reduce the overall fertilizer costs for the producer's operation.

Research Conducted

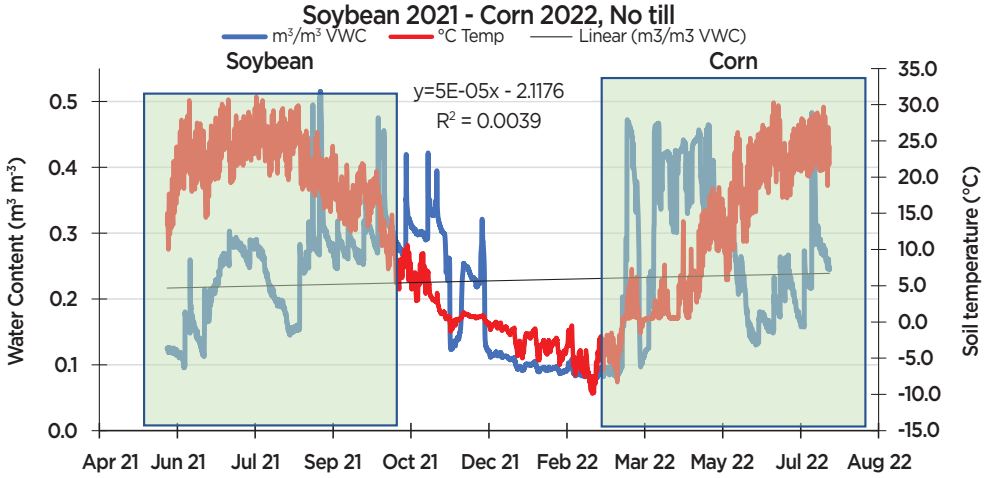
We have been conducting a field validation of mineral N cycling by utilizing 96 microplots with annual applications of soybeans, spring wheat or corn residues in a sequence that mimicks a no-till corn-soybean-spring wheat rotation. Of these plots, 64 are instrumented with temperature and moisture sensors that are placed 5 centimeters (2 inches) below the surface to evaluate the field's temperature and moisture changes across the growing season. These moisture and temperature changes affect the rate of N mineralization and may influence crop-available N at different points across the growing season. We are including 30% radish residue (a low carbon to nitrogen, N-mineralizing residue), by weight, to attempt to mitigate the observed N immobilization in no-till systems.

Findings of the Research

This study has shown that the crop residue's texture appears to influence moisture "conservation" when remaining on the soil surface under no-till conditions, and spring wheat residues promoted the highest levels of moisture content when compared to other residues. This finding may be due to the spring wheat residue providing a more uniform surface cover due to its finer texture and its ability to "flatten" over time when compared to corn or soybeans. In an accompanying laboratory study, combining radishes (30% of weight mass) with other residues appears to offset N immobilization in mixed residue systems if combined with soybean or spring wheat residue. Repeated radish applications over years seem to have a cumulative effect on reducing N immobilization and, over time, may contribute to net N mineralization. This indicates that the repeated use of cover crops may have a cumulative effect if the cover crops are consistently utilized in a crop rotation. Radishes (30% of weight mass) with other residues appears to offset N immobilization in mixed residue systems if combined with soybean or spring wheat residue.

Figure 1. A microplot arrangement on a Fargo silty clay soil on the NDSU campus evaluated the seasonal soil moisture and temperature conditions that influence the soil's microbial activity and the rate of residue breakdown.

Figure 2. Temperature and moisture changes across two growing seasons for the soybean residue that was placed on the soil surface (no-till) in 2021, followed by the corn residue that was placed on the soil surface in 2022. The horizontal trend line is for the soil moisture's trend across the two seasons.



Reversing Herbicide Resistance in Waterhemp and Palmer Amaranth

Principal Investigator: *Michael J. Christoffers, Ph.D.; NDSU Department of Plant Sciences*

Funded Project
$6,683

Why this Research is Important to North Dakota Soybean Farmers

Herbicide-resistant waterhemp and Palmer amaranth represent serious concerns for North Dakota soybean growers. The emerging genetic biocontrol technologies to supplement herbicidal weed control or to reverse herbicide resistance need to be explored. Conducting research about genetic biocontrol strategies requires safety considerations in order to ensure that plants carrying genetic changes are not allowed to reproduce and to escape containment. Plants grown in a tissue culture as undifferentiated cells do not have the capacity to propagate outside the laboratory, yet they still maintain most of the physiological processes that are targeted by herbicides.

Research Conducted

To advance potential, genetic biocontrol technologies for weed control, we previously developed a tissue culture system where callus tissue (clumps of undifferentiated cells) is grown from seedling hypotocols, followed by establishing cell suspension cultures in liquid media. We then used the waterhemp cultures to generate protoplasts (cells without cell walls) in order to facilitate genetic transformation. However, these protoplasts did not express the introduced genes. Further investigation identified significant oxidative stress among the protoplasts, and it was likely that this stress was inhibiting transgene expression. The current research project explored methods to reduce oxidative stress during the waterhemp's protoplast production.

Generating the waterhemp protoplasts was done by using two cell wall digesting enzymes, and we sourced each enzyme from at least two different suppliers in order to detect any differences for the production of oxidative stress during protoplast generation. Oxidative stress was significantly higher, by a factor of 1.5-fold, when utilizing enzymes from one source compared to the other. This finding confirmed that the enzyme supplier is important for the production of waterhemp protoplasts. Further studies using smaller enzyme concentrations did not lower the oxidative stress.

Findings of the Research

To begin similar tissue culture research with Palmer amaranth, we successfully established 6 callus tissue cultures for the weed. These calluses will be used to establish cell suspension cultures in liquid media. Another 12 cultures of Palmer amaranth were also generated, but these produced undesired roots in addition to undifferentiated cells.

Figure 1. Peter Beerbower, graduate research assistant, analyzes waterhemp protoplasts using a flow cytometer.

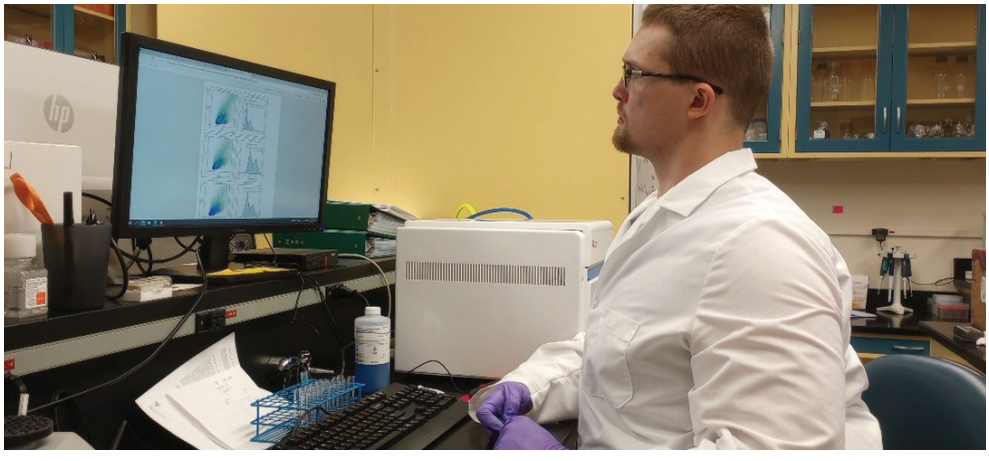


Figure 2. Palmer amaranth callus culture established from a seedling hypocotyl.

Benefits for North Dakota Soybean Farmers

This study improved the current protocols for genetic research about waterhemp by lowering the oxidative stress during protoplast generation. Palmer amaranth cultures were also established, and these cultures will be valuable with future genetic research about this important weed. Both results will facilitate studies that investigate the emerging genetic biocontrol methods to control herbicide-resistant weeds.

> ***"Conducting research about genetic biocontrol strategies requires safety considerations in order to ensure that plants carrying genetic changes are not allowed to reproduce and to escape containment."***

The Effects of Replacing Dried Distillers Grains Plus Solubles with Heat-Treated Soybean Meal in Forage-Based Diets for Growing Calves

Principal Investigator: *Zachary Carlson, Ph.D., NDSU Department of Animal Sciences*
Co-Investigators: *Lauren Hulsman Hanna, Ph.D.; Colin Tobin, Ph.D.; Kendall Swanson, Ph.D.; Grady Gullickson; Madeliene Nichols; Yssi Entzie; Lydia Hansen; and Sarah Underdahl; NDSU Department of Animal Sciences*

Funded Project $35,050

Why this Research is Important to North Dakota Soybean Farmers
Dried distiller's grains plus solubles (DDGS) have been an available protein source for beef cattle producers since the Renewable Fuel Standard in 2007. Lately, renewed interest about sustainable renewable fuels has created the idea that soybean meal may become an abundant protein source with costs being competitive when compared to DDGS. Incorporating soybean meal and heat-treated soybean meal into diets could help livestock producers to navigate the fast-changing world of sustainability and to remain profitable.

Research Conducted
Seventy Angus-based steers were utilized for an 85-day growing study to evaluate the partial replacement of 16% DDGS with heat-treated soybean meal (SBM) by substituting 0%, 4%, 8% and 12% of the DDGS (dry matter basis) with AminoPlus® (Ag Processing, Inc., Omaha, Nebraska). Steers were provided ad libitum access to feed and water in a monoslope barn with dry lot access. Individual daily intake was measured by using an automated feeding system. The objective was to evaluate the increasing concentration of amino acids and metabolizable protein by feeding heat-treated soybean meal in forage-based diets for growing cattle.

Findings of the Research
Partial replacement of DDGS with heat-treated soybean-meal supplementation does not affect the growing cattle's performance when included at 16% of the diet. Substituting DDGS with heat-treated SBM could be an option for producers after considering the availability and cost. Producers who utilize heat-treated SBM are advised to incorporate low inclusion rates in order to maximize the return on investment through the cattle's growth performance.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry
Soybean meal is a great protein source for beef cattle but is, often, not utilized due to a higher cost relative to other protein feedstuffs. Heat treating the SBM could improve the utilization of traditional soybean meal in forage-based diets when growing beef cattle and could improve the efficiency of growing cattle. With SBM production increasing in North Dakota, locality adds to the convenience and availability of SBM as an additional feedstuff.

> ***"Partial replacement of DDGS with heat-treated soybean-meal supplementation does not affect the growing cattle's performance when included at 16% of the diet."***

Figure 1. Angus-based steers utilized for an 85-day growing study at the NDSU Beef Cattle Research Complex in Fargo, North Dakota.

Liming Impacts of Soybeans and Different Western North Dakota No-Till Soils

Principal Investigator: *Chris Augustin, Ph.D., NDSU Dickinson Research Extension Center*

Funded Project $26,780

Why this Research is Important to North Dakota Soybean Farmers

Many fields in western North Dakota have decreasing yields due to acidic soil. Historically, North Dakota has not dealt with soil acidity issues. However, decades of ammonia-based nitrogen fertilizers paired with slightly acidic soil parent materials and poorly buffered soils have lowered the soil pH below 5.5 on thousands of farmable acres. These areas of strong acidity are adversely affected and reduce crop yields due to reduced nutrient availability, soil microbial activity, stunted roots from aluminum (Al) toxicity and reduced herbicide efficacy. These areas can be improved by liming. The calcium carbonate in lime neutralizes acidity. Lime recommendations are common in other states. However, there is little North Dakota information to guide soybean producers regarding acidic-soil management. This project looked at the influences of lime to develop lime recommendations for North Dakota farmers.

Research Conducted

Twenty-five acidic sites across North Dakota were selected and studied in 2021 and 2022. The soils were sampled and then limed in April or May of each year. Year one treatments included 0, 4, 8 and 16 tons of calcium carbonate per acre. Year two treatments were 0, 0.5, 1, 2 and 4 tons of calcium carbonate per acre. The fall soil samples were collected in October or November. All soils were sent to the lab for analysis shortly after the sample collection.

Findings of the Research

Even though all lime application rates were statistically significant, it appears that the greatest benefit was from the 2 and 4 tons of lime per acre treatment because they are the steepest areas of the regression. Sugarbeet waste lime (SBWL) may serve as a phosphorus fertilizer because lime increased the Olsen phosphorus tests. SBWL applications increased soil salinity, but all salinity tests were below yield-reducing levels. Calcium and magnesium are in beet lime, so the increase for the soil-tested calcium and magnesium was anticipated. Beet lime applications reduced soil extractable aluminum.

This finding suggested that surface applications of SBWL can reduce aluminum and manganese toxicity.

SBWL treatments did not affect the soil's organic matter, nitrate, potassium magnesium, zinc, sodium and cation-exchange capacity. As lime applications increased, so did the amount of calcium carbonate.

The lowest pH was observed at the 0-to-3-inch depth (pH of 5.21). This data suggests that the 0-to-3-inch soil test will better identify soil acidity issues. The 0-to-6-inch depth soil test results are diluted due to the deeper collected material.

Benefits for North Dakota Soybean Farmers

This information will guide soybean producers to fix acidic soil and to increase their bottom line. Corrected soil acidity will boost the activity of nitrogen fixing rhizobia and will lead to higher yields and better quality. Weed management will improve with the increased herbicide efficacy.

Figure 1. Lime recommendations for areas west of the Missouri River.

Buffer pH 0-3 inch depth	5.5	6.0	6.5	Formula	r^2	n
	tons calcium carbonate/ac					
5.7	Non-sufficient sample size					
5.8	Non-sufficient sample size					1
5.9	5.8	6.2	6.5	$y=0.0699x^2-0.1694x+4.6487$	0.43	12
6.0	7.4	8.0	8.7	$y=0.1404x^2-0.3177x+4.8745$	0.91	7
6.1	4.3	3.8	3.2	$y=0.1526x^2-0.7944x+4.5$	0.51	20
6.2	5.3	5.4	5.4	$y=0.0008x^2-0.1218x+4.9175$	0.36	30
6.3	5.4	5.4	5.4	$y=0.003x^2-0.1218x+4.9175$	0.36	30
6.4	6.0	6.1	6.1	$y=0.0053x^2-0.2002x+5.0732$	0.05	19
6.5	6.0	6.1	6.1	$y=0.0059x^2-0.1909x+5.1288$	0.60	41
6.6	6.1	6.1	6.2	$y=0.0066x^2-0.205x+5.1387$	0.72	26
6.7	6.1	6.2	6.2	$y=0.0071x^2-0.2079x+5.1761$	0.68	20
6.8	6.7	6.8	6.9	$y=0.0148x^2-0.3473x+5.2365$	0.62	19
6.9	6.9	7.0	7.0	$y=0.0125x^2-0.3011x+5.5956$	0.79	19
7.0	5.7	5.6	5.3	$y=0.0162x^2-0.3458x+5.7094$	0.82	14
7.1	7.0	7.1	7.2	$y=0.0183x^2-0.4107x+5.3137$	0.94	5
7.5	Non-sufficient sample size					5

Figure 2. Lime recommendations for areas east of the Missouri River.

Buffer pH 0-3 inch depth	5.5	6.0	6.5	Formula	r^2	n
	tons calcium carbonate/ac					
5.9	5.5	5.5	5.5		0.68	3
6.0	6.6	6.8	7.0		0.95	5
6.1	5.8	5.7	5.6	$y=0.0699x^2-0.1694x+4.6487$	0.79	8
6.2	Non-sufficient sample size					1
6.3	6.3	6.4	6.5	$y=0.1526x^2-0.7944x+4.5$	0.56	6
6.4	5.9	6.0	6.0	$y=0.0008x^2-0.1218x+4.9175$	0.36	34
6.5	6.3	6.4	6.5	$y=0.003x^2-0.1218x+4.9175$	0.57	26
6.6	6.9	7.0	7.2	$y=0.0053x^2-0.2002x+5.0732$	0.65	20
6.7	7.3	7.4	7.6	$y=0.0059x^2-0.1909x+5.1288$	0.60	19
6.8	6.8	6.9	6.9	$y=0.0066x^2-0.205x+5.1387$	0.65	13
6.9	2.4	1.1	-0.3	$y=0.0071x^2-0.2079x+5.1761$	0.79	7
7.0	Non-sufficient sample size					2
7.1	Non-sufficient sample size					0

*"Y" is tons of lime (CCE)/ac "X" is desitered soil pH at 0-3 inch depth

Free Herbicide Resistant

Weed Surveys

Available for Farmers

ND SOYBEAN COUNCIL

NORTH DAKOTA CORN COUNCIL

To participate, get a sample collection kit at your NDSU Extension Office

THIS SPRING

Collect and send weed leaves

To combat herbicide resistant weeds, the **North Dakota Soybean Council** and the **North Dakota Corn Utilization Council** invites farmers and agronomists to participate in the North Dakota Herbicide Resistant Weed Survey by collecting and shipping pigweed and kochia leaves from multiple regions of North Dakota to the National Agricultural Genotyping Center (NAGC).

The survey's goal is to combat herbicide resistant weeds by better understanding the genetics and distribution of resistant pigweeds and kochia to Group 2, 9 and 14 herbicides.

SCN Sampling Program Q&A

Q: How does the SCN sampling program work?
A: The NDSC covers the cost of up to 2,000 SCN samples for growers in N.D. NDSU will label, code and distribute sample bags. Growers bag and mail sample bags to the lab.

Q: When will the sampling program begin?
A: Sample bags will be at County Extension offices in mid-late August.

Q: How do I receive sample bags?
A: Each ND grower can get up to three bags at their County Extension office

Q: When is the best time to sample?
A: The number of eggs and cysts in the soil increases throughout the growing season, making SCN detection most likely if you sample at the end of the season; from just before harvest to just before freeze-up is generally recommended.

Q: What do the results tell me?
A: Results indicate how much (if any) SCN is in your soil. If you don't find SCN, excellent! If you find SCN at any level, you want to manage it immediately. If you are already managing SCN, and your levels are still high, it may be time to evaluate additional management options.

Contact Sam Markell at NDSU with questions: samuel.markell@ndsu.edu • (701) 231-8362

SOYBEAN RESEARCH &
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Are you ready to accept the challenge to be a better-than-average soybean farmer?

"That was a question posed during a soybean meeting I attended. The speaker said farmers who can improve their productivity by at least five percent over average are farmers who will succeed.

While there may be many ways to improve our production plan, one of the first that came to my mind is one we already invest in: the Soybean Research & Information Network (SRIN).

Research is one the primary buckets funded through state and national soybean checkoff dollars. As a checkoff organization representative, I often get asked how our checkoff money is spent and whether it generates return on investment. Unequivocally, I know SRIN is worth every dime."

SRIN is a website that was created to share with farmers the results from research housed in the National Soybean Checkoff Research Database for every state. SRIN representatives read through the research reports and boil down the information for farmers to understand and easily implement on their operations. The site highlights state soybean research programs, profiles key soybean researchers, hosts a YouTube channel of educational videos and farmer perspectives on production challenges, as well as shares diagnostic tools, agronomic tips and pest control recommendations by state and region. Content is constantly added to keep the site fresh and relevant and is supplemented by a timely social media presence and monthly e-newsletter.

Mike Schlosser, farmer from Edgeley, North Dakota

Sign up NOW for the SRIN monthly newsletter!

Funded by the soybean checkoff

SOYBEANRESEARCHINFO.COM

Improving DGLA Production in Soybeans for Pharmaceutical Applications

Principle Investigator: *Shaobin Zhong, Ph. D., NDSU Department of Plant Pathology*

Funded Project
$39,550

Why this Research is Important to North Dakota Soybean Farmers

Dihomo-γ-linolenic acid (DGLA) has been demonstrated to be potentially useful for cancer therapy and anti-aging treatment in humans, but sources of DGLA are very limited and cannot be found in the major vegetable oil producing crops. DGLA can be converted from linoleic acids (LA) through a metabolic process that is catalyzed by two enzymes (D6D [Δ6 desaturase] and D6E [Δ6 elongase]). Although soybean oil is rich in LA, no DGLA is produced by the soybean crop because soybeans lack the two enzymes for DGLA biosynthesis. By introducing the genes for expressing D6D and D6E into soybean plants, we developed transgenic soybean plants that produce GLA and DGLA in soybean oil. By developing new soybean varieties that produce DGLA-enriched soybean oil, the value of soybean products can be increased, and the markets for soybeans will be expanded because DGLA-enriched oil has a huge potential for use in cancer therapy and for consumption by humans to reduce cancer- and aging-related risks.

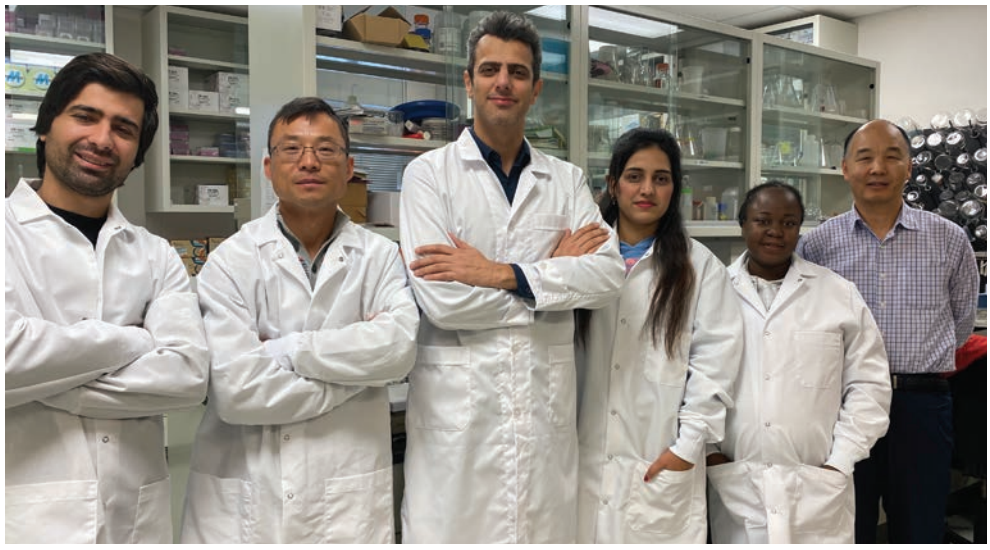


Figure 1. Research Team: From left to right: Alireza Poursafar (Ph.D. student), Yueqiang Leng (research specialist), Shahed Safar (Ph.D. student), Amna Riasat (Ph.D. student), Olawumi Amusan (Ph.D. student) and Shaobin Zhong (PI).

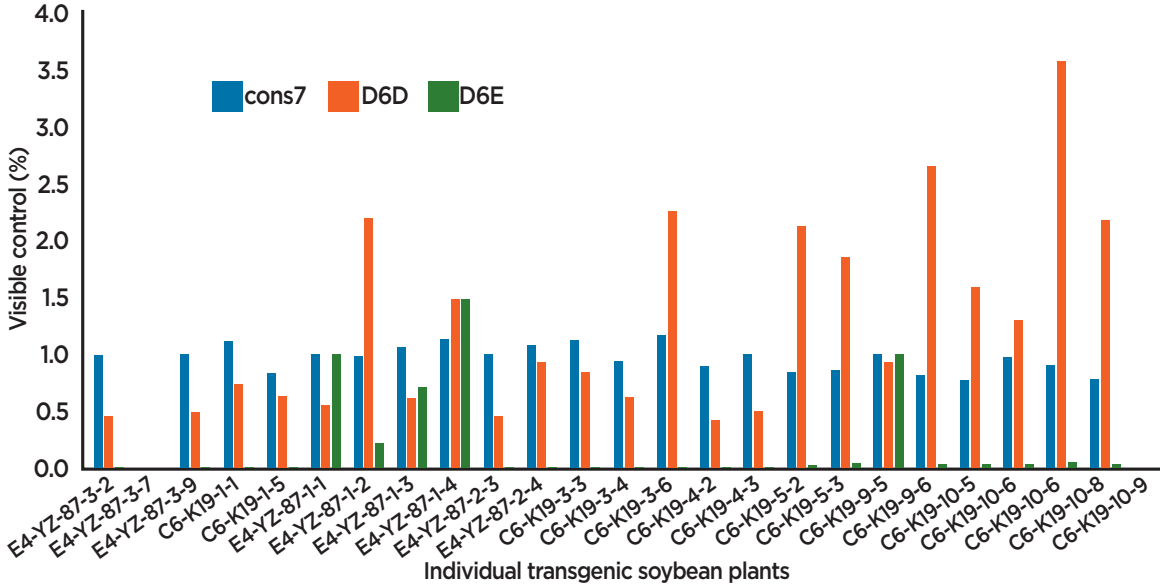
Research Conducted

The research developed transgenic soybean varieties that can produce DGLA-enriched soybean oil for pharmaceutical uses. We cloned genes expressing the two enzymes required for the production of DGLA in soybean plants, developed three gene constructs and introduced them into soybeans through genetic transformation. We obtained transgenic plants from two soybean varieties (William 82 and Thorne). Some of the transgenic soybean plants produced DGLA in soybean oil. We are attempting to improve DGLA production in transgenic soybean plants by using different gene constructs.

Findings of the Research

The two genes required for DGLA biosynthesis were introduced into soybeans by genetic transformation. Transgenic soybean plants with different gene constructs varied in DGLA production. No DGLA was detected in some transgenic soybean samples, but some samples produced up to 33.3% GLA and 10.25% DGLA in the soybean oil. More transgenic samples are being evaluated for DGLA content, and the ones with higher DGLA productivity will be selected for special soybean variety development.

Figure 1. Expression of two genes (D6D and D6E) encoding Δ-6-desaturase and Δ-6-elongase, respectively, required for DGLA biosynthesis in transgenic soybean plants.



> ***"By developing new soybean varieties that produce DGLA-enriched soybean oil, the value of soybean products can be increased."***

Soy-Based, Biodegradable Agriculture Mulching Materials

Principal Investigator: *Dean Webster, Ph. D., and Olena Shafranska, NDSU Department of Coatings and Polymeric Materials*

Funded Project
$12,885

Why this Research is Important to North Dakota Soybean Farmers

Plastic mulch film (PMF) is a high-volume agricultural material which is widely used in the production of vegetables, berries, hemp and other specialty crops. PMF is effective for suppressing weed growth, controlling soil temperature and moisture, and protecting the crop from contamination. Convenient PMFs are made from polyethylene (PE), with co-extruded layers of different types of PE, nylon and poly (ethylene-vinyl alcohol). PMFs pose a major environmental influence because, after the harvest, a large fraction of the used plastic material is left on the ground, which causes soil contamination. Biodegradable plastic mulch (BPM) is a sustainable alternative to PMF and offers a lower environmental effect.

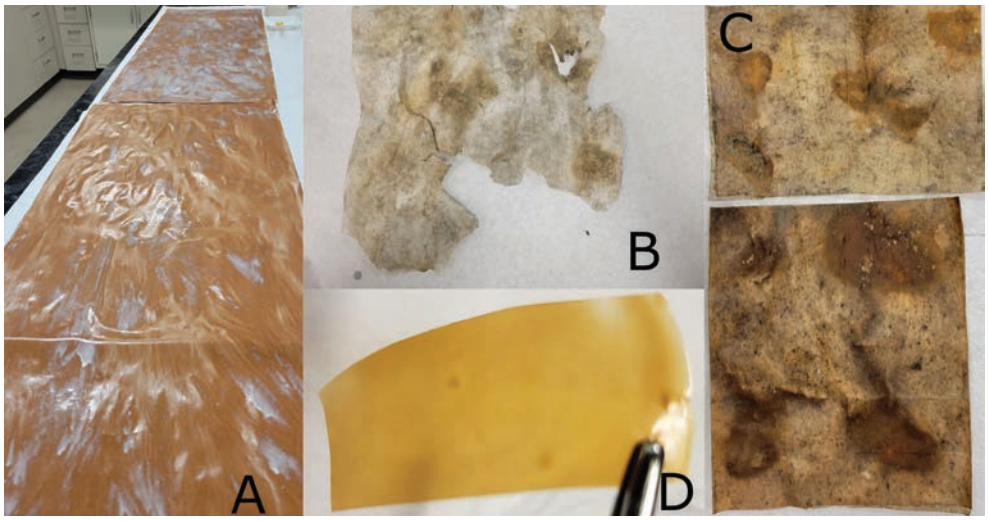
The BPMs currently available on the market are made from starch blended with polylactic acid (PLA) or other polyesters. BPMs can be tilled into the soil where they are expected to biodegrade. However, PLA shows very little degradation in the typical environment and is only compostable in an industrial environment where the temperature is 140 °F and higher.

In this project, we developed a new soy-based composite material that will be used as a biodegradable mulching material. We explored soybean oil-based polymers that can work as the matrix polymer for a cellulose-filled composite or as a coating for paper mulch.

Research Conducted

A soy-based, aqueous latex coating formulation was developed using modified soybean oil, acrylic acid and vinyl acetate. The content of soybean oil in the latex formulation and in the polymer was 19.2% and 57.1%, respectively. The bio-based polymer obtained from soy latex was studied for film-forming and physical properties while the latex was tested for stability. The formulation containing a soy-based polymer emulsion was developed and applied as a coating to different papers, such as landscaping weed barrier paper (WBP) and brown kraft paper (BKP). WBP is a commercial product that is used as a biodegradable mulching material. It has limited application due to its high decomposition rate. Soy polymer-coated and uncoated paper samples were tested for decomposition and a weight decrease in the field from June 4, 2022, until October 9, 2022 (Figure 1).

Figure 1. A: Brown kraft paper (BKP) coated with soy latex, B: uncoated BKP sample after 8 weeks in the field, C: coated with soy-polymer BKP samples after 8 weeks in the field and D: sample of a fry soy-polymer film used for an aerobic biodegradation test in the laboratory.



Findings of the Research

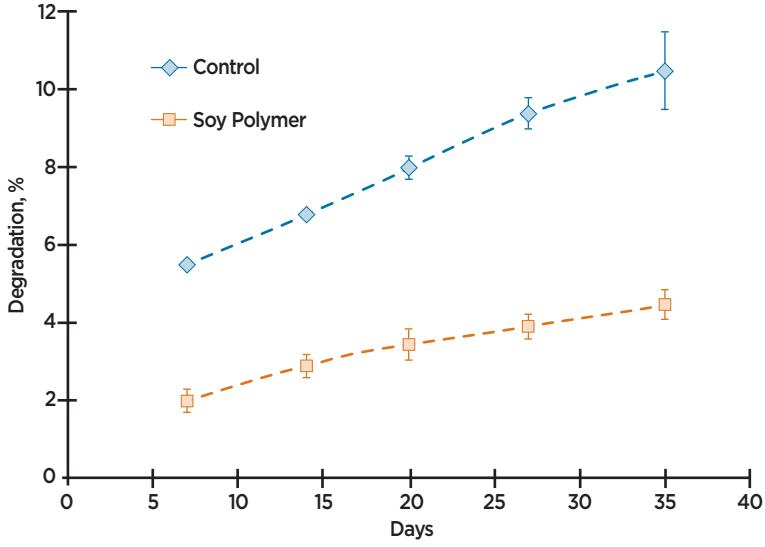
The uncoated WBP and BKP showed much higher decomposition rates than their soy-coated counterparts and were completely degraded after 14 weeks. The soy polymer-coated WBP and BKP only had some visible degradation after 10 weeks but were intact until the end of the test.

The dry soy polymer film which was used to coat the paper was tested for aerobic biodegradability in the laboratory following the standard test method, ASTM D5988. The results presented in Figure 2 confirmed the biodegradability of soy polymer; however, the degradation rate was 2.3 times slower than the degradation rate for the corn starch used as a reference.

Benefits for North Dakota Soybean Farmers

The concept of using a polymer from modified soybean oil for biodegradable mulching material was successfully demonstrated, and the new polymer showed promising results with reducing the degradation rate of the cellulose-based material while still being biodegradable. The new bio-based polymer emulsion can have wide applications for biodegradable mulching material as well as other materials for landscaping and agricultural use.

Figure 2. Aerobic degradation of soy polymer and starch (control) in the soil at 21 ± 1 °C.



Soy-Based Biodegradable Pressure-Sensitive Adhesives

Principle Investigator: *Andriy Voronov, Ph. D., NDSU Department of Coatings and Polymeric Materials*

Funded Project
$40,762

Why this Research is Important to North Dakota Soybean Farmers

Pressure-sensitive adhesives (PSAs) are tacky materials that, at ambient conditions, can be easily attached to many surfaces with a light manually applied pressure. Many industries, such as packaging, medical, electrical and automotive, have an increased demand for this type of material. Most raw resources used to obtain end-products are petroleum-based, non-sustainable and may cause allergic reactions after contact with food or human skin. Natural raw materials, such as soybean oil and protein, are spectacular in terms of sustainability and are nontoxic for human health.

Soybeans have up to 20% of the oil in their content, which is used for food industry and biofuel production. Another potential application is processing the oil into polymeric materials for various applications, such as packaging, films, adhesives, coatings and more.

Research Conducted

Our objective was to replace conventional petroleum-derived raw materials with soy-based alternatives in PSAs while keeping the end-products' targeted properties at a high level. It is usually desirable to create a bond between two dissimilar materials, so we tested soy-based PSAs on glass, steel and polymer substrate. We evaluated tack, or how sticky the soy-based PSAs are, and the strength of bonding the PSAs create.

With the current research, we employed an environment-friendly, aqueous-based process to obtain polymers for making soy-based polymeric PSAs. Currently, up to 40% of the targeted product consists of soy-based ingredients.

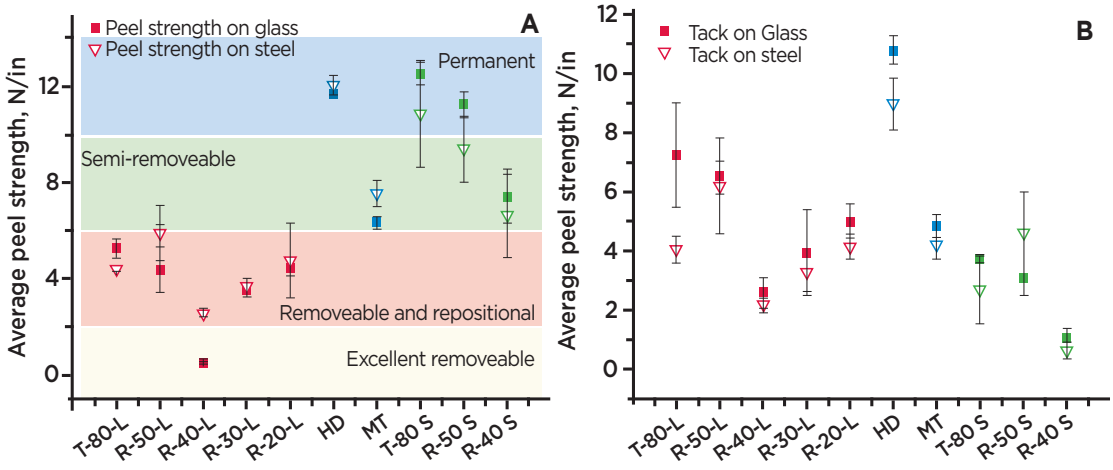
Findings of the Research

The results showed that PSAs obtained at room temperature with up to 40% of the petroleum-based ingredients replaced with soy-based counterparts had properties and performances similar to or better in comparison with the commercial products.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

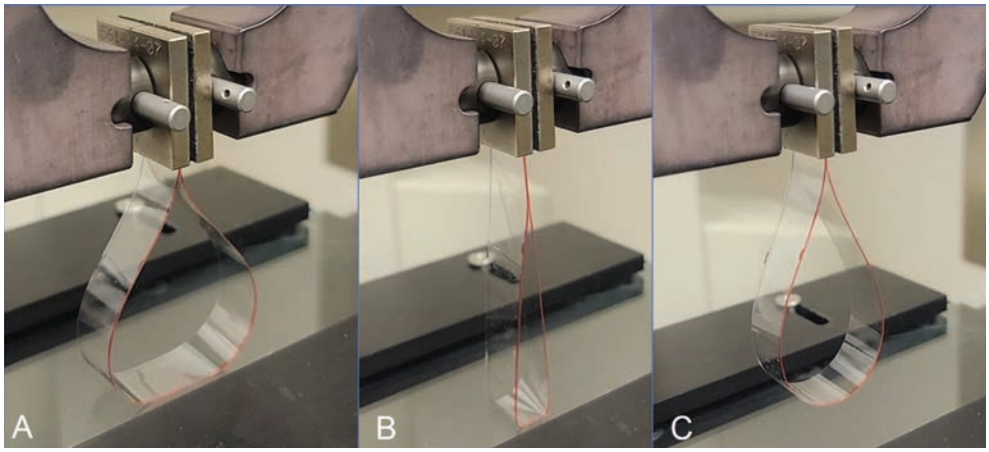
For the North Dakota soybean industry, this technology may become a prospective solution to apply with crops for high value and high profit PSAs.

Figure 2. Peel strength and loop tack results for soy-based PSAs (L: Latex adhesives, S: adhesives applied from solution, and HD and MT: commercial tapes) on glass and steel substrates.



> ***Many industries, such as packaging, medical, electrical and automotive, have an increased demand for this type of material.***

Figure 1. Viscoelastic behavior of a soy-based PSA during loop tack testing (no PSA residues left on the substrate after the experiment, C).



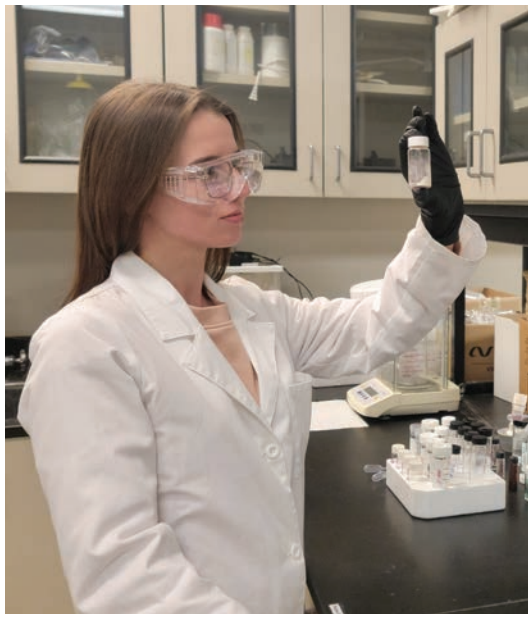


Figure 3. Graduate student of Andriy Voronov, Ph. D., conducts research in the lab.

Enhancing Lubrication Characteristics of Soybean-Based Oils as a Multifunctional Bio-Based Lubricant

Principal Investigator: *Sougata Roy, Ph. D., University of North Dakota*
Co-Investigators: *Clement Tang, Ph. D., UND; Brajendra K. Sharma, USDA Agricultural Research Service; and Majher Sarker, Ph. D., USDA Agricultural Research Service*

Funded Project $46,500

Why this Research is Important to North Dakota Soybean Farmers

This research project addresses the importance of developing bio-based lubricants, focusing on soybean oil as a next-generation bio-lubricant. With increasing global concerns about the environmental influence and depletion of mineral oil, there is a growing need for alternative lubricants. Vegetable oils, including soybean oil, have gained popularity as potential base oils. This study aimed to develop a soybean-based oil as a next-generation, multifunctional bio-lubricant and as a significant substitute for mineral-based lubricants.

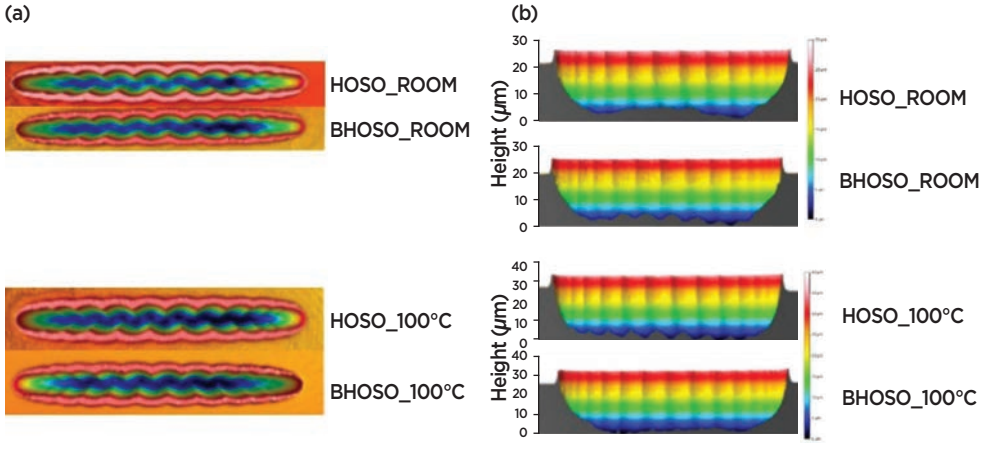
Research Conducted

The research involved conducting tests on regular soybean oil (RSOY), high-oleic soybean oil (HOSOY) and modified high-oleic soybean oil (BHOSOY). BHOSOY was produced by introducing isopropyl groups onto the double bonds of unsaturated fatty acids.

Findings of the Research

The research revealed that BHOSOY exhibited improved oxidative stability (resistance to oxidation), a lower pour point (temperature of solidification), and a lower cloud point (temperature of cloudiness or haze appearance) compared to HOSOY and RSOY. In friction and wear tests, BHOSOY demonstrated a higher coefficient of friction due to its increased viscosity but showed more stable friction behavior in all conditions. Moreover, BHOSOY exhibited 10.6% greater wear resistance than HOSOY, indicating less material loss or damage under similar friction and wear conditions. Scanning Electron Microscopy based analysis showed that BHOSOY had no cracks or metal flakes in the flat samples tested at room temperature while the other oil samples did. At high temperatures, BHOSOY exhibited significantly lower amounts of metal flakes compared to the other oils. The wear observed with the flat samples resulted from rubbing or abrasion between the contacting surfaces. In the ball samples, adhesion wear occurred, with iron transferring from the flat samples to the ball samples, as confirmed by Energy Dispersive X-Ray Spectrometry and mapping analysis. BHOSOY demonstrated the lowest wear width for both ball and flat samples.

Figure 2. White light interferometry images of wear tracks: (a) top view and (b) cross-sectional view.



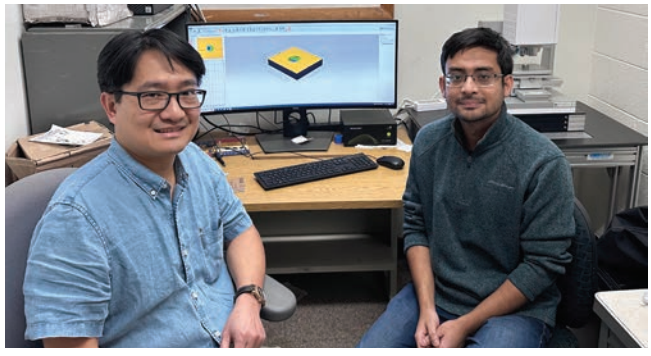
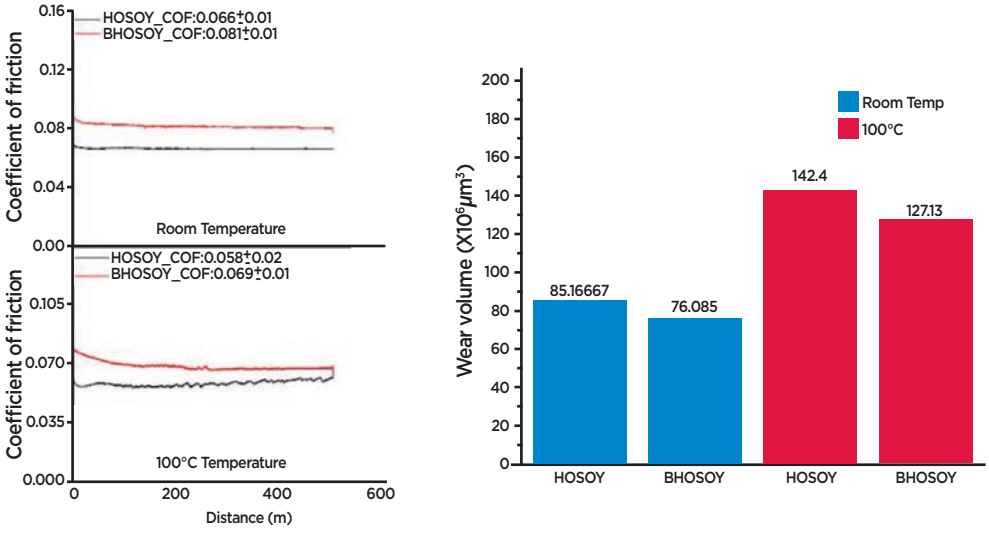


Figure 3. Research team at UND.

Figure 1. Coefficient of friction results: (a) room temperature, (b) high temperature and (c) wear volume loss.



Benefits to North Dakota Soybean Farmers

By tapping into the market for soybean-based lubricants, farmers can increase profitability and stimulate economic growth. The utilization of soybean oil for lubricant production can create new opportunities, potentially leading to a surge in soybean market prices.

Development of Catalysts for Increasing Soybean Oil Content in Renewable Coatings

Principle Investigators: *Alexander Rene Parent, Ph. D., NDSU Department of Chemistry and Biochemistry Materials*

Funded Project
$29,160

Why this Research is Important to North Dakota Soybean Farmers

Recent interest in more renewable and less toxic coatings has led to renewed interest in drying oils as binders, leading to the commercialization of several soybean oil-based coatings. Unfortunately, these coatings typically only contain a small fraction of renewable soybean oil-derived binders, with the bulk still derived from petroleum.

Research Conducted

In this project, we analyzed the rate of soybean oil autoxidation with several known driers by utilizing infrared spectroscopy (IR) while using a mathematical technique known as global analysis. This method allowed us to not only determine how quickly the soybean oil is drying, but also to measure the individual chemical steps occurring while the oil is drying. This knowledge about the individual steps should allow us to design better driers which are tailored to the specific properties of soybean oil. The results from the soybean oil drying were compared to linseed (flaxseed) oil, which has been much more extensively studied.

Findings of the Research

Through this work, we determined that the mechanism of soybean oil drying follows the same overall mechanism as linseed oil. Despite following the same mechanism, soybean oil showed significantly enhanced drying at higher drier concentrations relative to the linseed oil. This finding was likely due to the higher degree of saturation in the fatty acids of the soybean oil relative to the linseed oil. Based on the findings of this research, we began synthesizing additional driers that are expected to have superior drying properties when used with soybean oil.

Benefits to North Dakota Soybean Farmers

This research provides strong initial evidence that soybean oil can be used in high concentrations with coating formulations if driers tailored to the oil's unique properties are developed. Currently, most commercial producers perceive soybean oil as a "drop-in" replacement for small quantities of petroleum-based ingredients in the coating formulations. Further basic research in this area is likely to change this perception, encouraging research about the development of coating formulations where the bulk of the binder is derived from soybean oil.

"Based on the findings of this research, we began synthesizing additional driers that are expected to have superior drying properties when used with soybean oil."

Figure 1. IR timecourse of soybean oil during autoxidation.

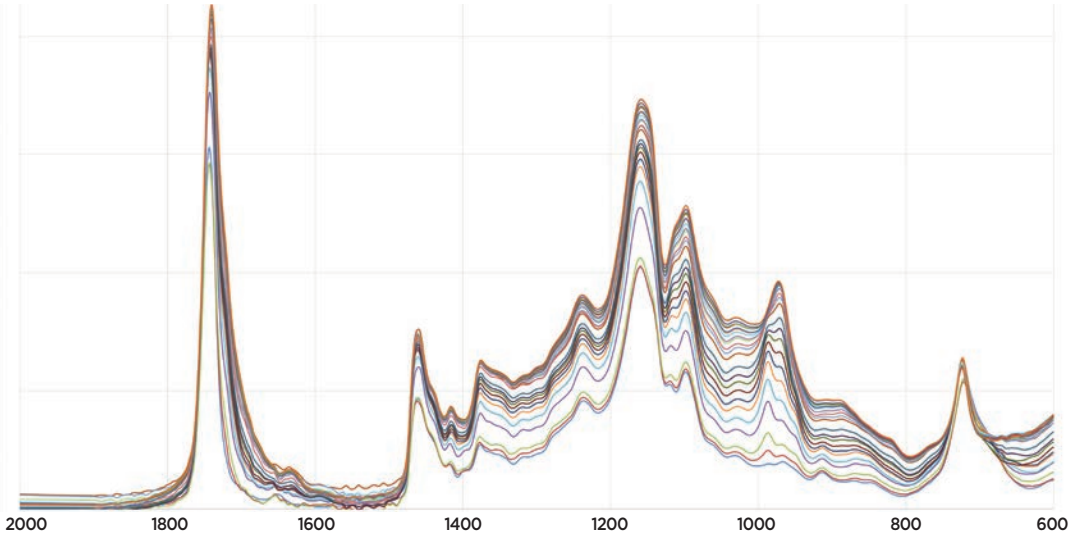
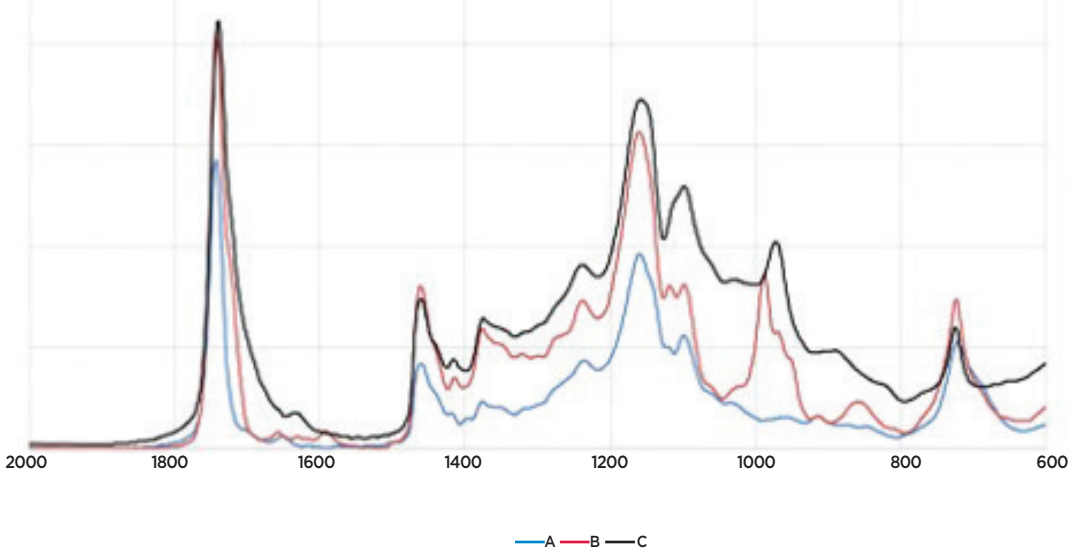


Figure 2. Species Associated Spectra Identified during Soybean Oil Autoxidation



Novel Soy-Protein Coating Materials for Corrosion Protection: Phase 2

Principal Investigator: *Ravi Kiran Yellavajjala, Ph. D., NDSU Department of Civil, Construction and Environmental Engineering*

Funded Project
$20,000

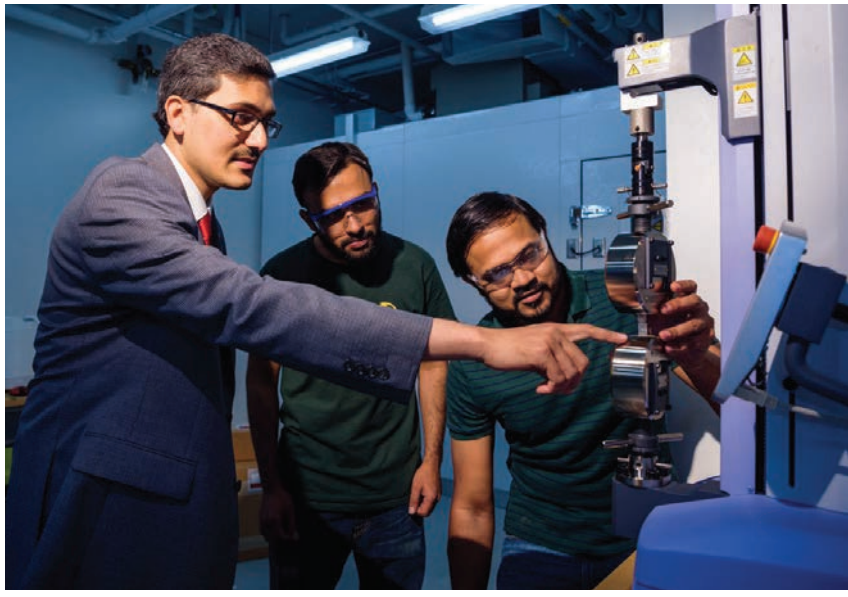
Why this Research is Important to North Dakota Soybean Farmers

The global market size for corrosion inhibitors was around $7.2 billion in 2018 and is expected to reach $9.6 billion by 2026, with maximum investment growth coming from the construction industry. The novel coating material developed with this research has the potential to take advantage of this growth in order to financially benefit the North Dakota soybean farming community.

Research Conducted

The study's goal is to improve the corrosion protection performance for a soy-protein coating developed in phase 1 of the project by introducing abrasives. During this phase, modified soy-protein (MSP) coatings were formulated by adding optimum fractions of oxides, such as silicon dioxide (SiO2), aluminum oxide (Al2O3) and zinc oxide (ZnO). These oxides were chosen by considering the consistency, the coating's workability after adding the abrasives and the dispersibility of the abrasives in the base coating. Five modified soy-protein coatings were developed and were designated by MSP percentage by weight, SiO2 percentage by weight, Al2O3 percentage by weight and ZnO. The five modified soy-protein coatings were characterized via physical, chemical, mechanical and electrochemical analyses. The physical test results obtained from the viscosity test and the coating thickness demonstrated adequate consistency (6.2 centipose rating) and a reproducible coating thickness of 200-300 micrometers. Chemical characterization performed using the Fourier Transform Infrared Spectroscopy (FTIR) curves obtained before and after the thermal exposure confirmed chemical compatibility and invalidated spurious chemical interactions among the abrasives in the formulated coatings. Mechanical characterization involving pull-out tests showed the bond strength of modified soy-protein coated rebars with concrete for MSP-10-10-10 at 7 days and 28 days of testing to be 11.03 megapascals (MPa) and 14.70 MPa, respectively. Electrochemical tests showed a substantial reduction for the corrosion current densities (MSP-10-10-10 reduced by 29%) compared to the control's unmodified coating, depicting improved passivity of the coating material.

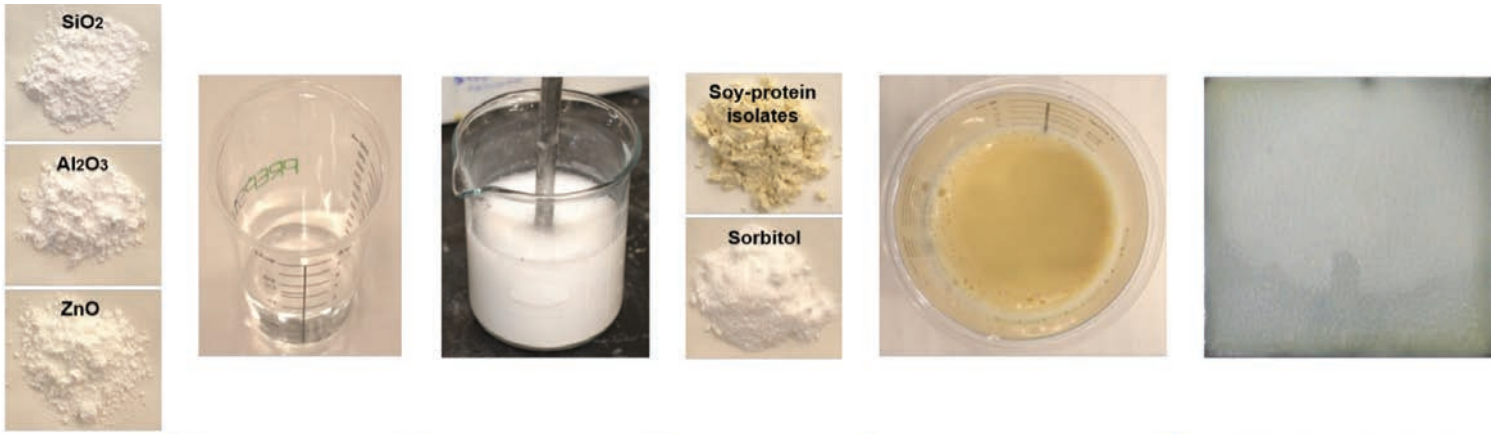
Figure 2. Ravi Kiran Yellavajjala, Ph. D., and his graduate students.



Findings of the Research

The long-term anti-corrosion performance evaluated using the macrocell corrosion test showed significant improvement in terms of a reduced corrosion rate (50% and 78% in the case of MSP-10-5-5 and MSP-10-10-10, respectively) coupled with a stabilized corrosion potential. MSP-10-5-5 and MSP-10-10-10 showed superior abrasion resistance, optimum consistency, a strong bond with concrete and high corrosion protection among the modified soy-protein coatings.

Figure 1. Preparation of modified soy-protein coatings via the infusion of abrasives.



Development of Soymeal-Based Baling Twine with High Digestibility

Principle Investigators: *Long Jiang, Ph. D., NDSU Department of Mechanical Engineering, and Zachary Carlson, Ph. D., NDSU Department of Animal Science*

Funded Project $47,962

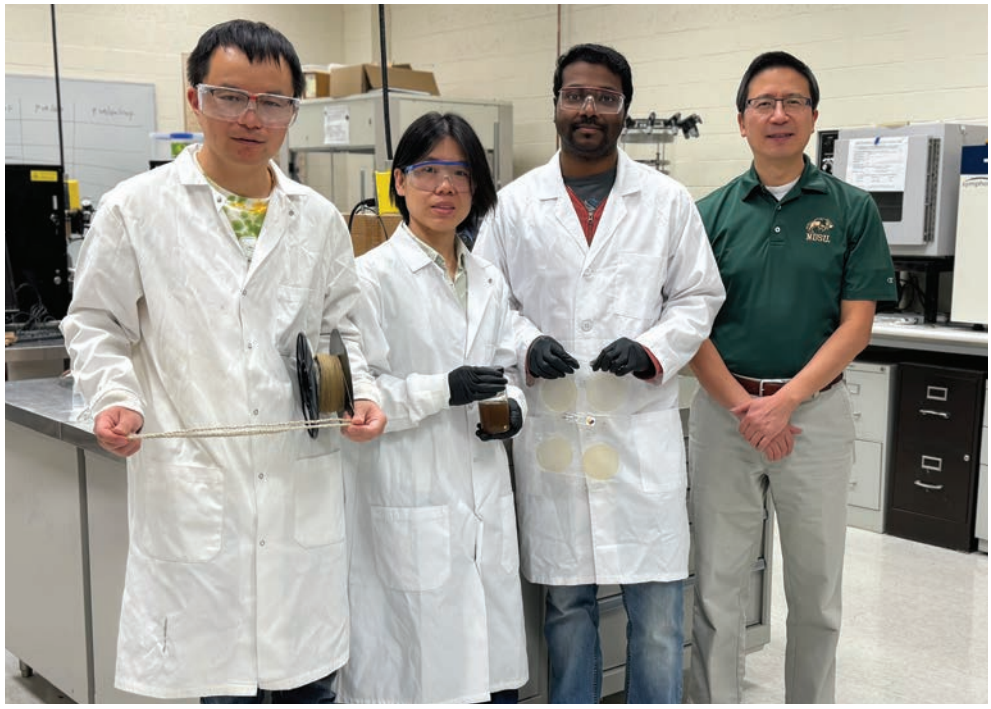
Why this Research is Important to North Dakota Soybean Farmers

Bailing twine and wraps are mostly made of polypropylene (PP), an indigestible plastic. Polypropylene can cause health issues or even death for the animals when ingested. In addition, PP is made from petroleum and lacks biodegradability, thus posing significant environmental concerns. Therefore, a biobased, biodegradable and more digestible bailing twine is highly desired. In this project, our goal is to develop a new twine material based on soymeal (SM) and polylactic acid (PLA), a biodegradable plastic made from corn starch.

Research Conducted

SM and PLA at different ratios were compounded and extruded into ribbon- and filament-shaped products. The products' mechanical testing, thermal stability, microstructure and digestibility were investigated. Soybean oil (SO) or epoxidized soybean oil (ESO) as well as a small amount of crosslinker and initiator were added to the SM/PLA base formulation at different contents in order to improve the products' flexibility, toughness and strength. The filaments made of the optimal formulation were twisted into twine, and the mechanical properties were evaluated. The properties were compared with the PP twine produced using the same method.

Figure 2. Long Jiang, Ph. D., far right, with his research team.



Findings of the Research

SM and PLA can be blended and extruded into nice ribbon and filament products at different SM to PLA ratios. The higher the ratio, the lower the surface quality and mechanical properties, but the higher the digestibility of the products. The 3:7 ratio was suitable for achieving a balanced property matrix. Incorporating the additives (i.e., plasticizer, crosslinker and initiator) can significantly improve the twine's desirable properties. SM/PLA filaments were successfully twisted into a twine product which had superior properties compared to the PP twine made using the same method. While pure PLA and PP showed zero digestibility, about 20% of the SM/PLA twine (the highest rate) were digested at the end of a digestion test with the cattle's rumen.

Figure 1. Digital photo of the bailing twine developed in this research.

Benefits to North Dakota Soybean Farmers

A new application for soymeal has been developed, presenting an exciting opportunity for soybean farmers and diverse industries.

Further Development of Soy Protein-Based Soft Gels for Sensors and Soft Robotics

Principal Investigators: *Long Jiang, Ph. D., and Qian Ma, NDSU Department of Mechanical Engineering*

Funded Project
$30,334

Why this Research is Important to North Dakota Soybean Farmers

Conductive hydrogels, as a typical flexible, soft material with a structural resemblance to biological tissues and excellent electronic properties, have flourished as promising candidates for applications in the fields of artificial intelligence (AI), soft robotics and wearable devices. Many of these advanced applications require demanding gel properties, including high stretchability, a self-healing ability, adhesiveness, multi-environmental tolerance, good and durable sensitivity, and comfortability on human bodies. It remains a challenge to provide all these properties at the same time in a single gel product. This project's goal is to develop a multifunctional, high-performance, ionic conductive hydrogel using soy protein isolate (SPI) as the main ingredient.

Research Conducted

Hydrogels containing mainly SPI and polyvinyl alcohol (PVA) were developed. A series of other functional agents was also added to the gel formulations to impart different gel functionalities and to tailor the gel's properties. The ingredients' contents varied. The gel properties of different formulations, including mechanical, self-healing, adhesion, anti-freezing and conductivity, under different temperatures were systematically tested.

Findings of the Research

Multiple chemical and physical interactions could be established among the gel's ingredients, which allow the gel's properties to be tailored significantly by varying its formulation. One of the best formulations produced a gel that shows simultaneous high stretchability (806%), good tensile strength (22.7 kilopascal), high self-healing efficiency (92.31% after healing for 2 min at room temperature), favorable adhesiveness to different substrates, high ionic conductivity (1.52 siemens per meter) at room temperature and an outstanding anti-freezing property (flexible and conductive at -70 °C). These desirable properties make the gel a promising material for advanced, flexible electronic applications.

Benefits to North Dakota Soybean Farmers

An advanced, new use for SPI was developed with this project. This novel application targets cutting-edge and high-value industries such as robotics, health, biomedical sciences, AI and more.

Figure 2. The twisting and stretching test of the ionic conductive organohydrogel.

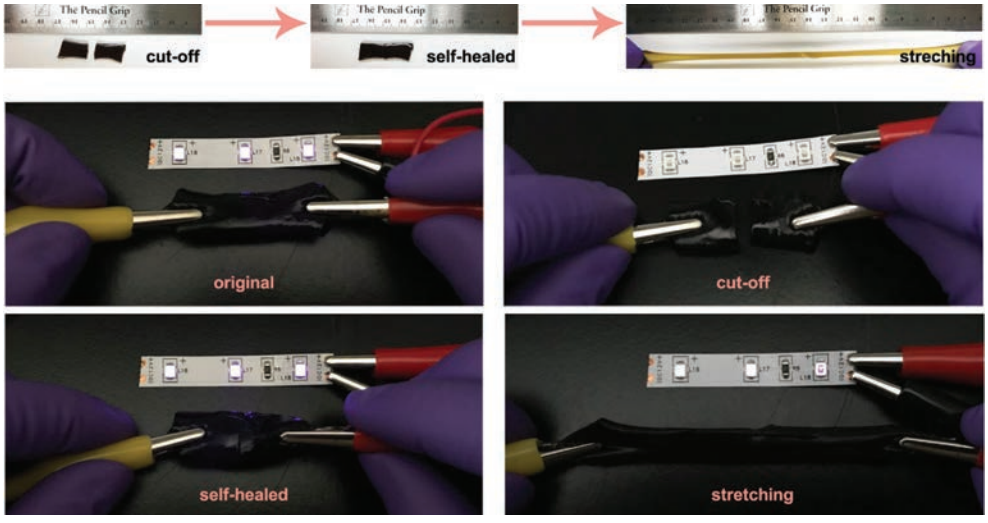
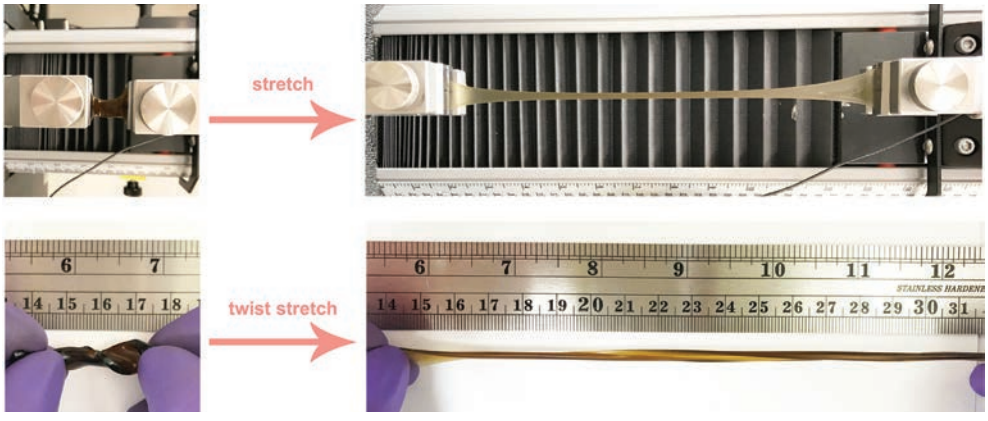


Figure 1. Photographs of the ionic conductive organohydrogel with stretching.



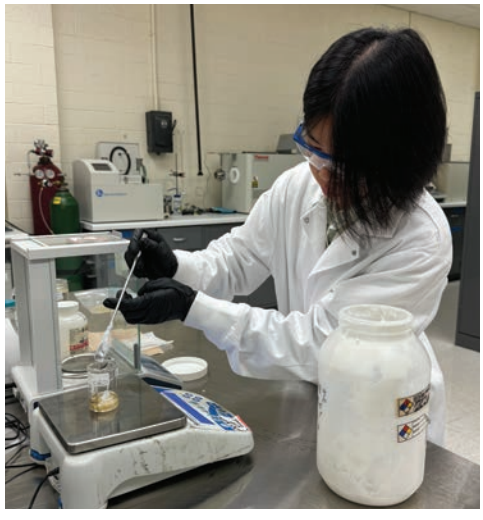


Figure 3. Graduate students of Long Jiang, Ph. D., conduct research in the lab.

Development of Bioprocessing for Biological Ammonia Production

Principal Investigators: *Ademola Hammed, Ph. D., NDSU Department of Agricultural and Biosystems Engineering*

Funded Project
$58,169

Why this Research is Important to North Dakota Soybean Farmers

Ammonia is a well-known chemical because of its wide range of industrial applications, including water purification, as a refrigerant, and with the production of fertilizer and other chemicals. The main industrial route for ammonia production is the Haber-Bosch process. But this technique is energy intensive, thus, there is a need for innovative approaches to produce ammonia.

Biological ammonia production processes are an emerging area that has the potential to alleviate CO2 emission. Several studies have reported the production of ammonia by biological means. North Dakota crops and bioproducts are abundant in protein and could be a viable source for sustainable biofuel and biochemicals production, especially ammonia. The present study was conducted to develop a bioprocessing approach for biological ammonia production.

Research Conducted

In this research, we developed a processing method to produce ammonia from soybeans. Overall, the processing method involves three stages: extraction, enzymatic breaking and fermentation. The soybean protein was first extracted, broken down into smaller units and then fermented to ammonia. The second step was carried out to reduce the extracted protein's size by utilizing enzymes. Several enzymes were tested, and the amount of produced ammonia varied with the type of enzyme used. The smaller units of protein gave quick ammonia production within 72 hours of fermentation unlike the larger sized protein that showed equal ammonia production at 168 hours.

Findings of the Research

This research work has developed a fermentation process that operates at near room temperature using natural microbes. When optimized and scaled up, it has a huge potential to decarbonize ammonia production.

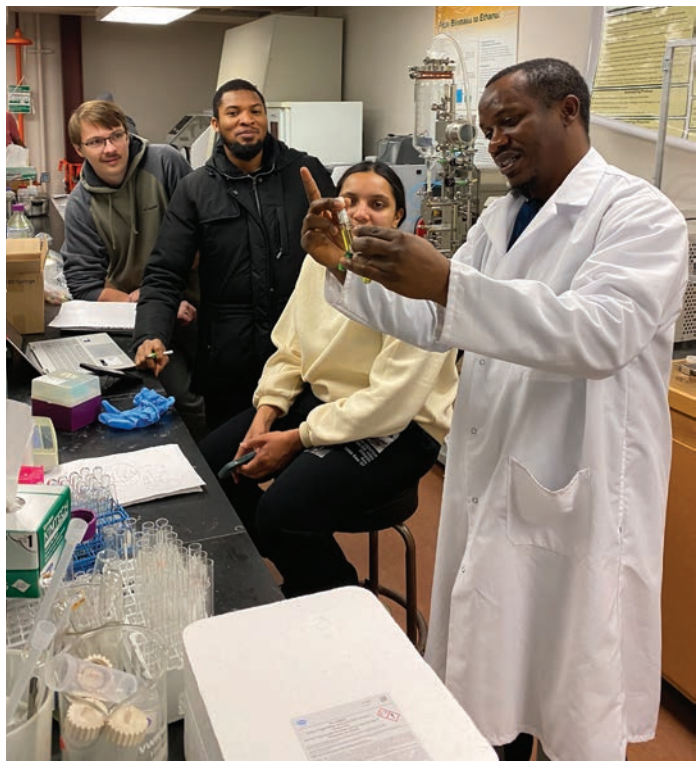


Figure 3. Ademola Hammed, Ph. D., and his team in the lab.

Figure 1. Ammonia production from different protein-containing substrates. CSA: casamino acid, PEP: peptone and SYB: whole soybean flour.

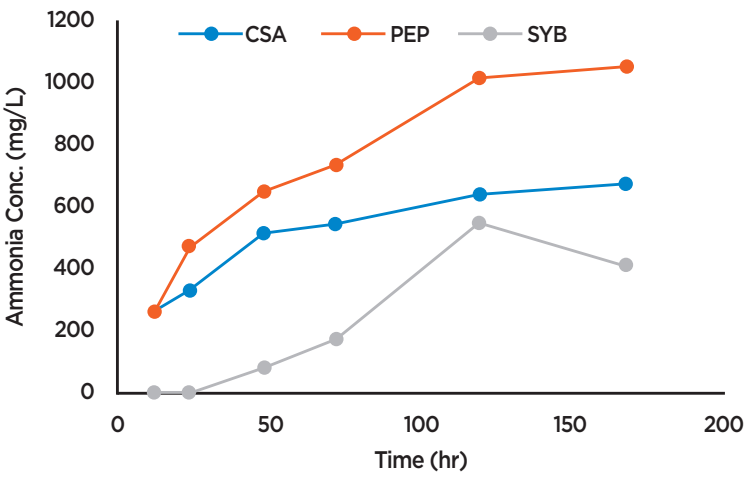
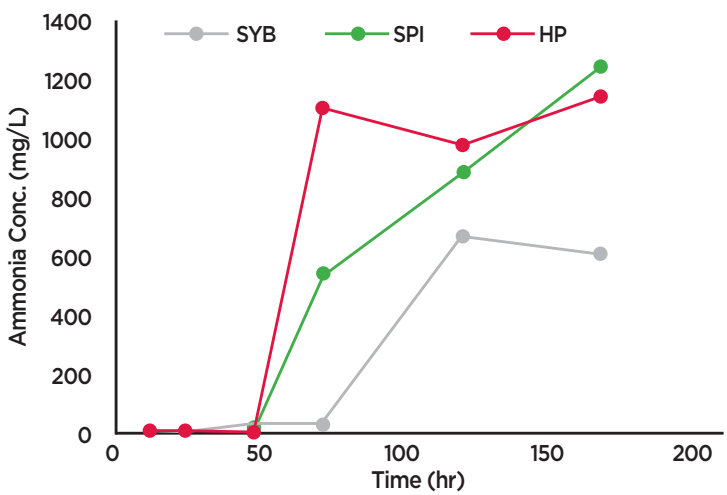


Figure 2. Ammonia yield from soybean protein isolate (SPI) and its hydrolysate (HP).



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