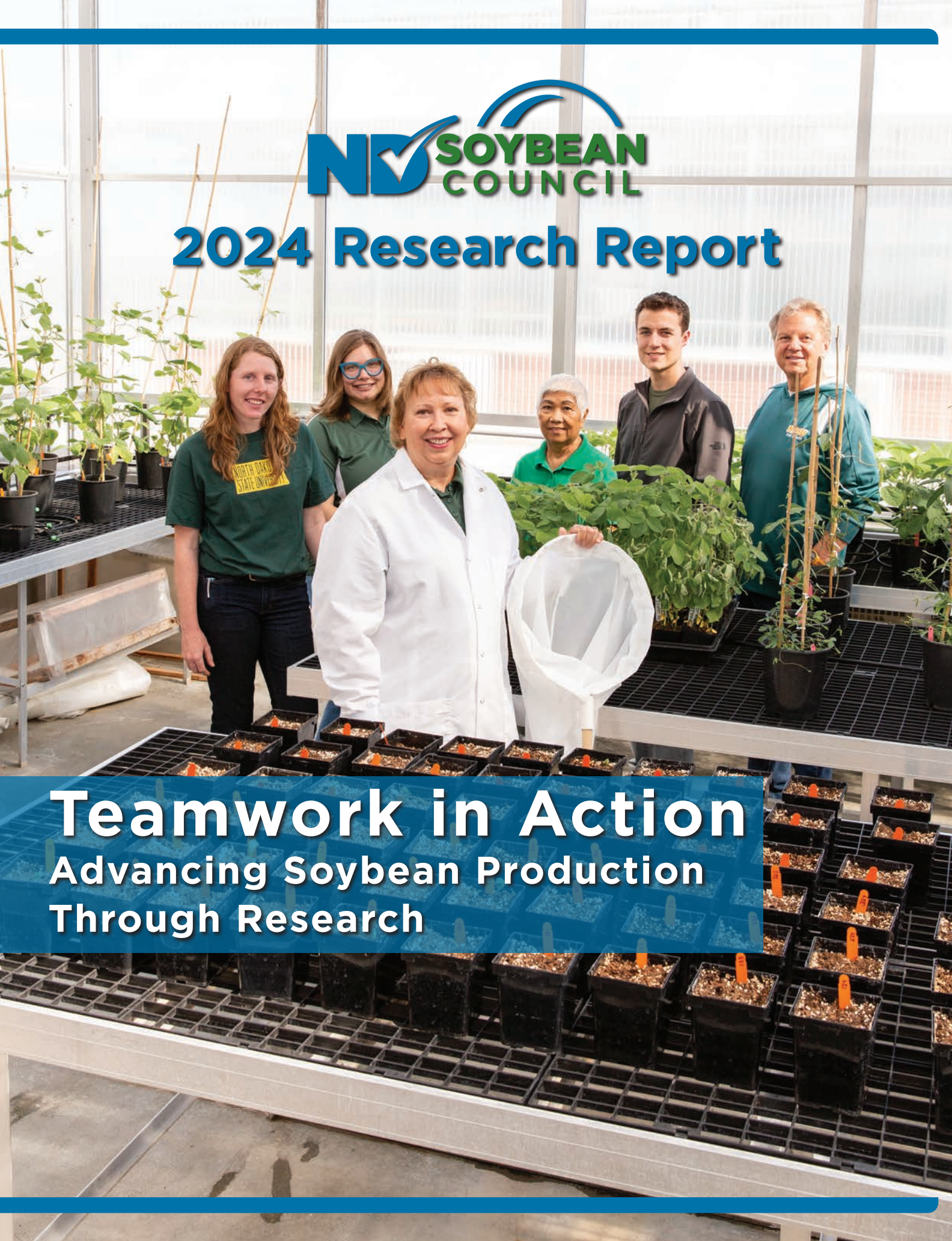
ND SOYBEAN COUNCIL

2024 Research Report



Teamwork in Action

Advancing Soybean Production Through Research

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2024 Research Committee Report

Checkoff Funds Invested in Research Played a Critical Role in Advancing Soybean Production in North Dakota.

Soybean checkoff funds have played a pivotal role in advancing North Dakota's soybean production, with a remarkable 60-fold increase since the 1980s. Once considered a minor crop, soybeans are now essential across nearly every county, driving opportunity for farmers and contributing to the state's economic success. Recent expansions in processing capacity have enhanced these opportunities. Until 2023, North Dakota had no dedicated soybean crush facilities, but today, two plants in Spiritwood and Casselton are operational, with a third under development in Grand Forks. These facilities create essential market access, adding value to soybeans by offering diverse marketing options and local processing for increased profitability.

In 2023, soybeans held the top spot as North Dakota's highest production-value crop, estimated at around $2.7 billion. This achievement highlights soybeans' critical role in the state's agricultural economy, yet the industry faces ongoing challenges. Short growing seasons, adverse weather, herbicide resistance, pest pressures like soybean cyst nematode, and soil acidification issues, particularly in western regions, all require tailored solutions. NDSC directly addresses these issues through strategic research investments, funding 30-40 research and extension projects each year. These projects support pest control, crop breeding, soil health, and cover crop management, all with the goal of increasing yield and profitability potential for farmers.

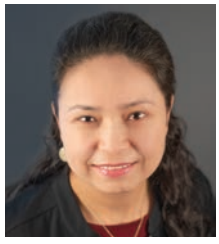
Collaboration remains central to NDSC's mission. We work alongside regional and national programs such as the North Central Soybean Research Program (NCSRP) and the US Soybean Research Collaborative (USSERC) to amplify research impact and tackle production challenges on a broader scale. This year, we've also partnered with Airable Lab, an innovative R&D center founded by the Ohio Soybean Council, to accelerate soy-based product development, fostering new uses for soybeans and bringing additional market opportunities to North Dakota farmers.

Our mission at NDSC is to make impactful, strategic investments in research that support soybean farmers now and ensure a profitable, resilient future. Within this report, you'll find summaries of NDSC-funded research projects for 2024, offering insights to help you optimize your management practices, adapt to evolving conditions, and continue improving your productivity and profitability.

We invite you to reach out with questions or share ideas on how our research initiatives can better serve the needs of North Dakota's soybean industry. Your input is valuable to our work and keeps us focused on what matters most to our growers.

We extend our gratitude to the researchers, extension specialists, and support staff whose dedication and expertise drive advancements in soybean production. Your hard work and innovation are essential to our industry's success and to the profitability of North Dakota's soybean farmers. Thank you for all you do.

Dallas Loff, dloff@ndsoybean.org
NDSC Research Committee Chair



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NDSC Director of Agronomy & Research

On The Cover

Janet Knodel, Ph. D., and her research team at North Dakota State University (NDSU) have been at the forefront of advancing integrated pest management (IPM) strategies, which are vital for North Dakota soybean farmers. Her work addresses critical pest challenges, including soybean aphids, grasshoppers, and other damaging insects, by developing science-based strategies that protect crops while minimizing environmental impact. Through rigorous field research and farmer outreach, Knodel has equipped producers with the tools and knowledge to make informed pest control decisions, boosting yields, profitability, and long-term sustainability. Her efforts are instrumental in ensuring that North Dakota soybean farmers can successfully navigate pest pressures and thrive in an ever-changing agricultural landscape.

Determining the Optimum Irrigation Amount and Timing for Enhanced Soybean Yield, Quality, Water Productivity and Soil Health in 2024

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

Funded Project $26,200

Why this Research is Important to North Dakota Soybean Farmers

The research will determine the optimum amount and timing to irrigate soybeans under semiarid conditions. The insights obtained from this research will assist soybean producers in western North Dakota to apply the precise amount of water at the right time.

Research Conducted

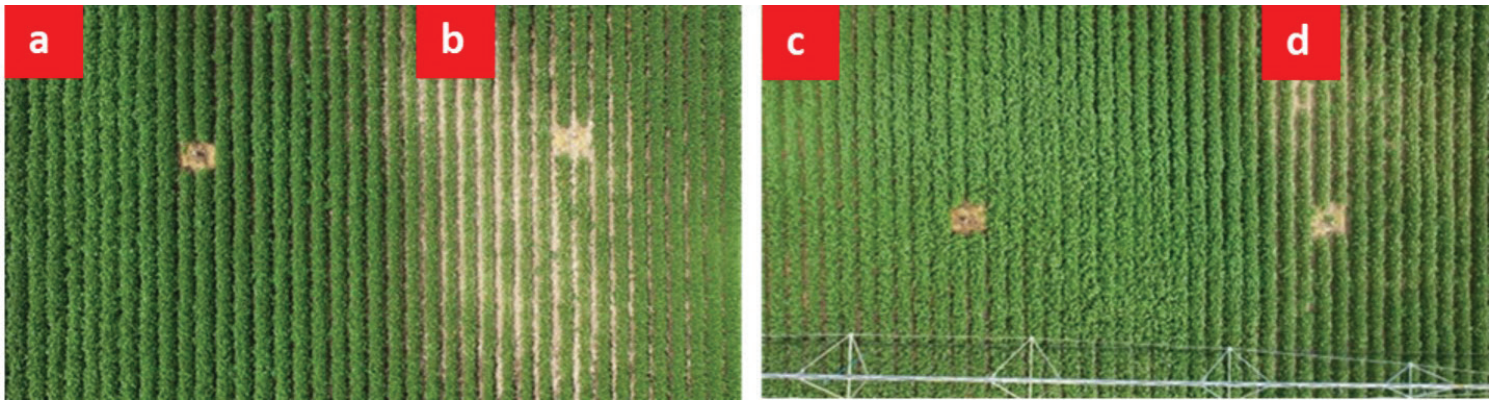
A glyphosate-tolerant soybean variety, ND 17009GT, was seeded at the Nesson Valley Irrigation Site in Ray, North Dakota (Longitude: -103.1061564, Latitude: 48.1634933) on May 24, 2023. The seeding rate was 195,000 pure live seed per acre (PLS/ac), with a row-to-row distance of 30 inches and a gross plot size of 59 feet x 50 feet. There were 12 irrigation treatments: 1) full irrigation, 2) deficit irrigation during the vegetative stage [(VE – V(n)], 3) deficit irrigation during the flowering stage [R1-R2], 4) deficit irrigation during the pod-development stage [R3-R4], 5) deficit irrigation during the seed-filling stage [R5-R6], 6) deficit irrigation during the maturity stage [R7-R8], 7) deficit irrigation during the vegetative + flowering stages, 8) deficit irrigation during the vegetative + pod development stages, 9) deficit irrigation during the vegetative + seed-filling stages, 10) deficit irrigation during the vegetative + maturity stages, 11) deficit irrigation during the seed-filling + maturity stages and 12) rainfed (R).

Figure 2. Guatam Pradhan, Ph. D. provides research update during NDSU field day.

Findings of the Research

The aerial imagery captured on July 25, 2023, highlighted discernible differences for soybean growth across various treatments. Notably, optimal growth was observed under full irrigation (Figure 1a), with a slight decrease noted under deficit irrigation during the flowering stage (Figure 1c). Growth was significantly impeded under deficit irrigation during the vegetative stage (Figure 1d), and soybeans subjected to rainfed conditions (Figure 1b) exhibited a detrimental growth effect. The ability to observe the influence of these growth patterns and treatment effects on grain yield and quality was, unfortunately, disrupted by a hailstorm that occurred on the evening of August 1, 2023; the hail completely destroyed the entire crop.

Figure 1. Representative aerial images that depict soybean growth under different irrigation regimes. (Aerial imagery captured on July 25, 2023, by Gautam Pradhan.)



Resistance of Soybean Varieties to *Pratylenchus dakotaensis*, a New Root-Lesion Nematode Species that is Infecting Soybeans

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

Funded Project
$19,540

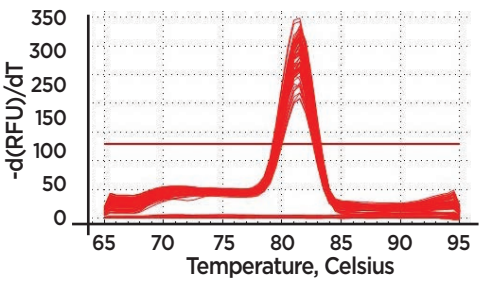
Why this Research is Important to North Dakota Soybean Farmers

Root-lesion nematodes are among the important nematode pests that affect soybean production. A new root-lesion nematode, *Pratylenchus dakotaensis*, that was reported in North Dakota soybean fields showed significant reproduction in greenhouse bioassays and resided more in the roots than in the soil. Using resistant varieties and detecting nematodes early are key management strategies. Similarly, it is important to increase the nematode population in a controlled environment to know its effect on yields. Therefore, this research focuses on identifying the resistance levels for soybean varieties, developing a molecular assay to detect it directly from the roots, and establishing a system to increase its population in the lab and the greenhouse.

Research Conducted

Resistance levels for 10 soybean varieties used in the region were assessed for *P. dakotaensis* through repeated greenhouse experiments with naturally infested soil (Figure 1). A rapid quantitative polymerase chain reaction (qPCR) assay was developed to detect and to quantify this new species directly from infected soybean roots. The assay's specificity and detection limit were also determined. A standard curve was generated. The assay was validated through correlation analysis between the numbers of nematodes artificially inoculated and the estimates made by using the qPCR assay. A system for culturing and increasing this nematode was developed using corn explants in Gamborg's GB-5 medium.

Figure 1. ***Pratylenchus dakotaensis'*** **melting curve profile. A single melting peak was observed at 81.5˚C, and no amplification was observed for the negative controls, indicating that the qPCR assay is specific.**



Findings of the Research

Among the 10 screened varieties, nine were moderately susceptible; one was susceptible; and none were resistant or moderately resistant in the combined analysis (Figure 2). The resistance rating results were mostly similar in both experiments. A DNA-based molecular assay was developed to directly detect and quantify this new species in infected soybean roots, and the test is sensitive and specific (Figure 3). There was a strong, positive correlation between the number of nematodes inoculated into the roots and detected by the developed qPCR assay. Furthermore, this new nematode species' population can be increased in the lab using corn explants and GB5 medium, whereas Barnes can be used in the greenhouse to increase its pure population.

Benefits for North Dakota Soybean Farmers and the Industry

These findings will help growers to choose soybean varieties rationally to avoid susceptible or moderately susceptiblevarieties having higher nematode reproduction. This research also provides a crucial tool for early and rapid detection and quantification of this new nematode species from soybean roots in ND. Further research shold focus on identifying resistant soybeans and new sources of resistance. Efficient nematode detection is essential for effective management of nematode disease.

Figure 2. Classification for the resistance responses of 10 soybean varieties to the new root-lesion nematode species (*Pratylenchus dakotaensis*) based on the two trials' combined data.

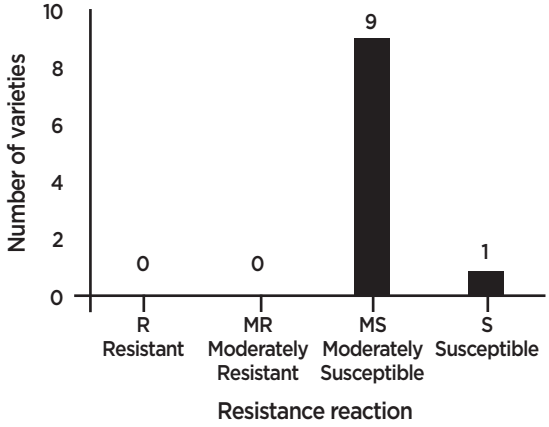


Figure 3. Soybean plants in the large cone-type container greenhouse trial for resistance responses to *Pratylenchus dakotaensis*.

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

Principal Investigator: *Jason Harmon, Ph.D., North Dakota State University (NDSU) School of Natural Resource Sciences*

Funded Project
$15,028

Why the Research is Important to North Dakota Soybean Farmers

Soybeans are a major crop in North Dakota. Soy can be an important food source for pollinators, such as honeybees. As a self-pollinating crop, soybeans do not require a pollinator visit to successfully produce seeds. Thus, we do not always think that soybeans and pollinators should have much to do with each other. Recent research suggests that this might be a missed opportunity because, sometimes, pollinators increase soybean productivity, and flowering soybeans can provide food for pollinators. Therefore, this research is designed to explore these relationships in North Dakota.

Research Conducted

We surveyed bees in and around soybean fields at the Carrington Research Extension Center (REC) near Carrington and the Central Grasslands REC near Streeter. We used two complementary sampling techniques. To actively sample pollinators, we freely searched for bees for 30 minutes at a time by walking through the soybean fields. The found bees were captured and identified, and we recorded their behavior. We also used rows of blue vane traps to determine what other bees were in and around the soybeans. Both methods were utilized together multiple times when the soybean plants were flowering.

Findings of the Research

Our active sampling showed honeybees and bumblebees, and many of them were visiting the soybean flowers. This activity was likely to feed on nectar and/or pollen from open flowers. This finding is a positive sign that bees may benefit from visiting soybeans. The bees seen in our active surveying were a fraction of the bees seen in the passive traps and the neighboring rangelands, and we are working to determine how many of those bees may have also been visiting soybean flowers. Knowing that pollinators are visiting the soybean flowers is a necessary first step for there to be any potential benefits that soybeans may receive from pollinator visits.

Figure 2. Passive (trap) sampling from a) Carrington and b) Streeter. Each graph shows the total number of bees that were caught at each location on a given date (solid line) and the percentage of soybean plants that were flowering at the time of the sampling.

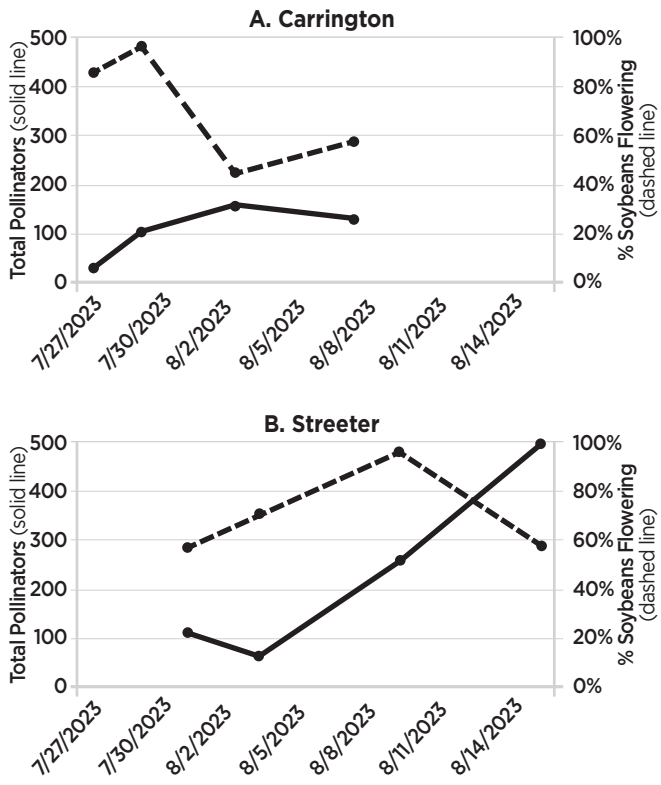
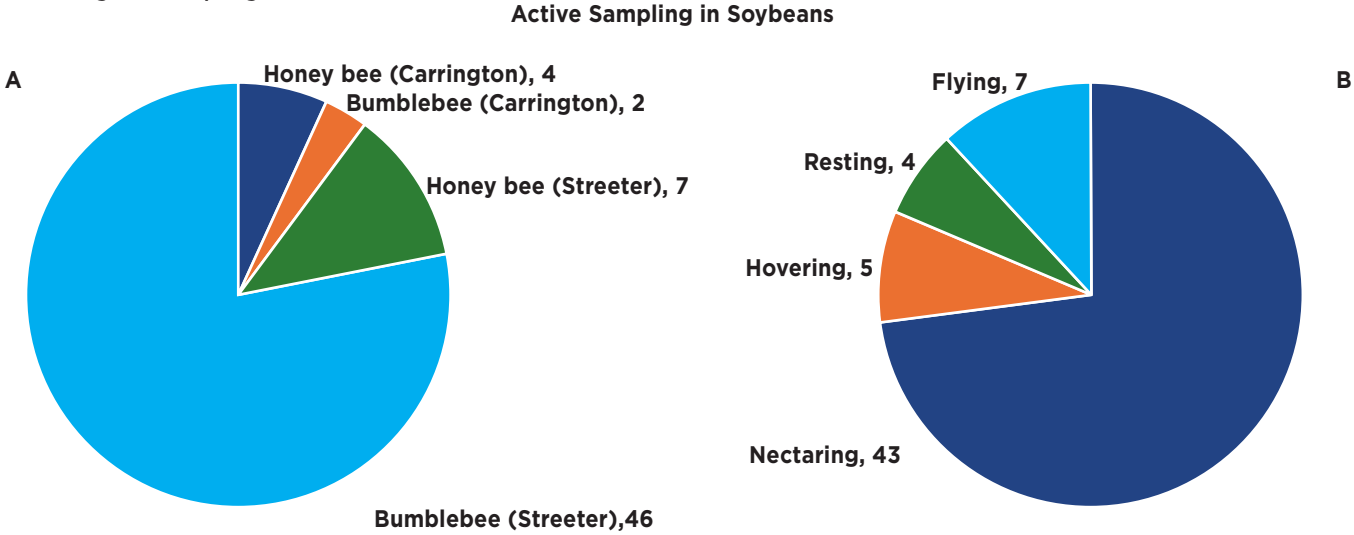


Figure 1. Active sampling from Carrington and Streeter broken down by a) site and taxonomy, or b) the behavior of the bee when observed during the sampling.



Sampling Program to Screen for Herbicide Resistance in North Dakota Weeds

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

Funded Project
$45,000

Why the Research is Important to North Dakota Soybean Farmers

Herbicides have been essential to weed control for more than 70 years. However, the rise of herbicide-resistant pigweed and kochia populations has made herbicide selection more complicated. An important step for managing herbicide-resistant (HR) weeds is identifying where they exist. Genetic tests provide an indirect, but rapid, method to detect known resistance mechanisms. This collaborative project is one of the first statewide sampling programs that distributes collection kits for genetic testing.

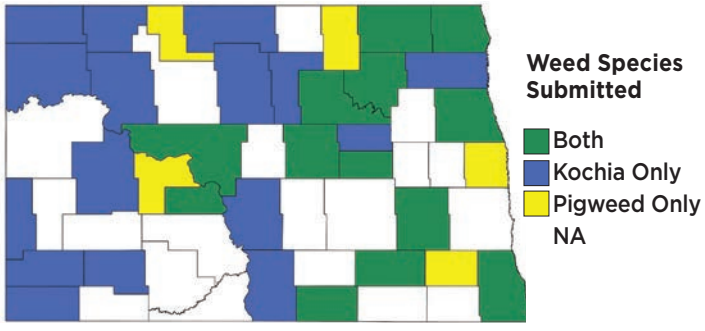
The goals are as follows:

1) provide near real-time explanations for herbicide failures,
2) create statewide maps to show where HR populations exist and,
3) survey for the newly described Group 14 herbicide resistance in kochia.

Research Conducted

We distributed 1,000 collection kits with the help of NDSU Extension and multiple stakeholders across North Dakota. Each kit allowed North Dakota submitters to send four pigweed and/or kochia leaf samples to test for genetic markers associated with resistance to Group 2, 9 and 14 herbicides. The NAGC provided a personalized report containing genetic results for kochia and pigweeds with an approximate 7-day turnaround time during the 2024 field season. After screening the samples, the NAGC created a county-level map that showed the distribution of HR genetics in North Dakota weed populations. The sample submitters' information and exact sample locations were removed from the map.

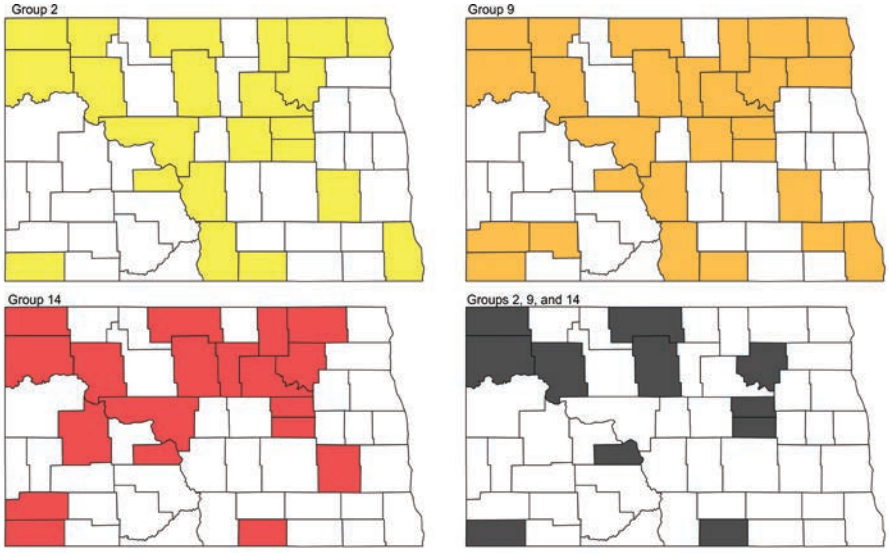
Figure 1. County origins for the kochia and pigweed samples that were submitted to the NAGC for genetic testing during the Fall 2023 and Spring 2024 survey period.



Findings of the Research

Since the release of collection kits in August 2023, we have received 200 leaf samples from 34 counties (Fig. 1).

Figure 2. Counties with weeds containing genotypes associated with resistance to Group 2, 9, and 14 herbicides. Black counties have weeds with stacked resistance to all three groups.



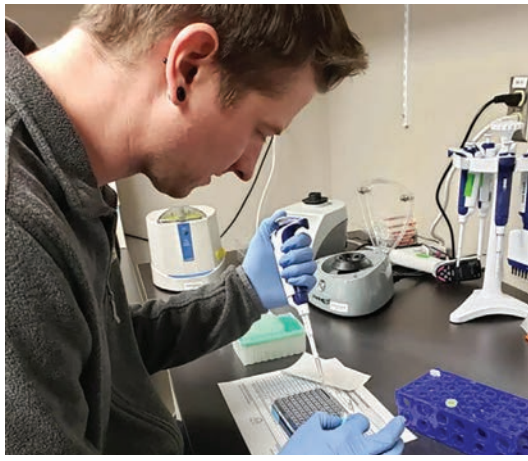


Figure 3. Zack Bateson, Ph. D. tested weeds for herbicide resistance.

Most submissions were kochia samples, which represented 67% (134 of 200) of the total samples collected. From the samples, we performed 574 genetic tests, and 44% (253 of 574) of the tests revealed HR variants (Fig. 2). Most cases of HR variants for pigweeds and kochia had elevated 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) copy numbers (108 samples), which confers resistance to glyphosate (Group 9). We also found near equal cases of the Group 2 and Group 14 resistant variants (72 and 73 samples, respectively). The newly described Group 14 resistance marker was found in half (66 of 134) of all the kochia samples tested by the NAGC. We found that 11% (22 of 200) of the samples had genetic markers associated with stacked resistance to all three herbicide groups.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

There were widespread herbicide-resistant variants across North Dakota. Through NDSU Extension, most farmers are aware of extensive Group 2 and Group 9 resistance in waterhemp and kochia across the state. However, the patchy distribution and annual changes with the weed populations or introductions can shift the prevalence of resistance individuals within the fields. Genetic testing helps to assess these changes in real time as well as to determine whether stacked resistances are present at the local and regional levels.

Evaluation of Soybean Varieties and Breeding Lines for Resistance to Soybean Cyst Nematode and Their Copy Number Variation at *Rhg1* Locus

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

Funded Project $62,609

Why the Research is Important to North Dakota Soybean Farmers

Soybean cyst nematode (SCN) causes a significant yield loss in soybeans. Effective SCN management relies on resistant soybean varieties. However, overusing limited resistance sources has led to the emergence of more virulent SCN populations. Evaluating the breeding lines and commercial varieties for SCN resistance helps when selecting resistant soybeans. Most SCN-resistant varieties have PI 88788-type resistance, particularly involving genes at the *Rhg1* locus. Copy number variations (CNVs) at *Rhg1* determine the level of resistance to SCN. Therefore, screening the soybean lines and varieties as well as analyzing the CNVs are important.

Research Conducted

This research aimed to evaluate soybean varieties and breeding lines for resistance responses to two common SCN populations in North Dakota and to assess CNVs at the *Rhg1* locus. A total of 152 soybean breeding lines and commercial varieties were tested against Heterodera glycines (HG) type 2.5.7 (higher ability to reproduce on PI 88788) and HG type 0/7 (less to no ability to reproduce on PI 88788). Each line was inoculated with 2,000 SCN eggs and grown under controlled growth chamber conditions (Figure 1). After 32 days, white females were extracted and counted. The female index was calculated, and the resistance response was classified. CNVs at the *Rhg1* locus were detected using an optimized and validated quantitative polymerase chain reaction (qPCR) assay.

Findings of the Research

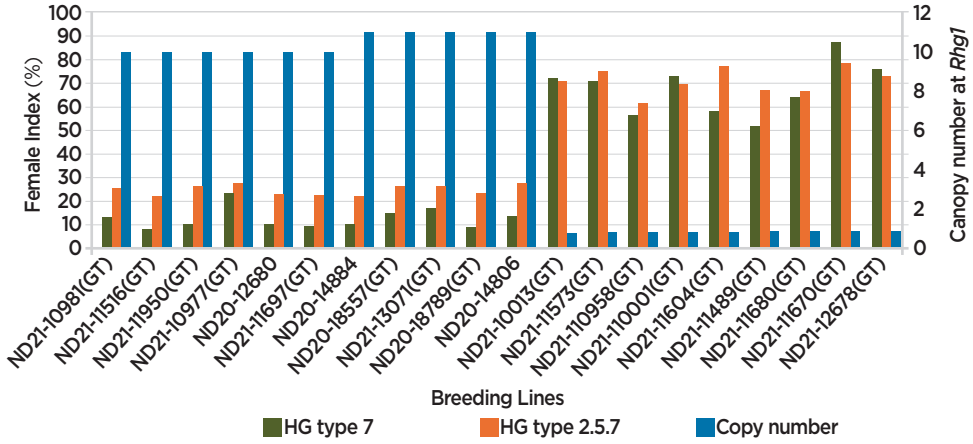
Among 35 commercial soybean varieties, nine were resistant to HG type 0/7 while six varieties were resistant to HG type 2.5.7. Five varieties showed resistance to both HG types. Among the 117 breeding lines tested, six were resistant to HG type 7 while none of the lines was resistant to HG type 2.5.7. Twenty-five breeding lines were moderately resistant or resistant to both HG types. *Rhg1* copy numbers ranged from 1 to 11, with higher copies generally linked to greater resistance (Figure 2). There was a strong negative correlation between the female indexes and the copy numbers for both populations.

Figure 1. Soybean plants were tested for SCN resistance in a controlled growth chamber that was maintained at 27°C, ensuring optimal testing conditions.

Benefits for North Dakota Soybean Farmers and the Industry

We identified soybean varieties and breeding lines with resistance to SCN. Five of the tested commercial varieties were resistant to both HG types, offering valuable options for farmers to select resistant varieties in order to reduce yield losses. Additionally, 25 breeding lines were resistant or moderately resistant to both HG types, providing a pool to develop new SCN-resistant varieties. Determining the *Rhg1* copy number helps with the rapid selection of soybean lines that have increased SCN resistance.

Figure 2. Relationship between female indexes (%) and the copy numbers at the *Rhg1* locus for 20 selected breeding lines, including 11 lines that were resistant or moderately resistant (bold) to both SCN populations and 9 lines that were susceptible or moderately susceptible to both populations.



Soybeans Interseeded with Cover Crops in Western North Dakota

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

Funded Project $28,370

Why the Research is Important to North Dakota Soybean Farmers

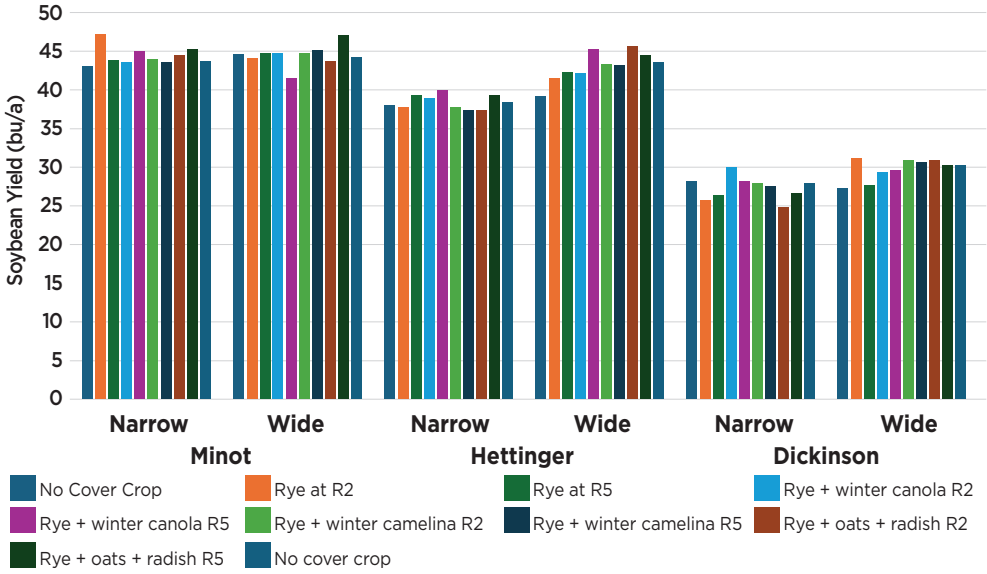
Soil erosion is a major problem in western North Dakota after the soybean harvest due to the low residue and stubble left in the soil. Keeping the soil covered is key to improving soil health by preventing soil losses from wind and runoff erosion. There is a lack of information regarding soybean yield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

Research Conducted

Cover crop trials were conducted in narrow and wide soybean row spacing. Cover crops were broadcast into standing soybeans at the reproductive stage. Five cover-crop treatments were investigated: no cover crops, winter rye, winter rye and winter canola, winter rye and winter camelina, and winter rye with oats and radishes. Soybean yield, test weight, oil and protein were recorded. The cover crops' soil cover and biomass, along with the soil moisture, were evaluated 30 days after soybean harvest. The return on investment (ROI) was calculated as ROI = gross income (yield × commodity price) - treatment cost. A cover-crop cost-sharing program was considered to calculate the ROI.

Leandro Bortolon, Ph.D.

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



Findings of the Research

According to our results, interseeding cover crops into standing soybeans in western North Dakota does not affect soybean yield (Figure 1). The establishment of cover crops is highly dependent on soil moisture and precipitation patterns. Cover crop biomass increased the soil cover even with low amounts of biomass observed across locations. Soil moisture was not affected by cover crops across all locations. The ROI using a cost-sharing program can offset the farmers' cost of using cover crops with soybeans (Table 1).

Table 1. Return on investment by using cover crops in western North Dakota.

Location/system	No Cover Crop	Rye	Rye + Winter Canola	Rye + Winter Camelina	Rye + Oats + Radish
	ROI ($/a) with no cost sharing				
Minot Narrow	444	419	407	422	444
Minot Wide	443	418	406	421	443
Hettingger Narrow	384	359	347	362	384
Hettinger Wide	431	406	394	409	431
Dickinson Narrow	272	247	235	250	272
Dickinson Wide	298	272	261	276	298
	ROI ($/a) with cost sharing				
Minot Narrow	444	449	437	452	444
Minot Wide	443	448	436	451	443
Hettinger Narrow	383	389	377	392	384
Hettinger Wide	431	436	424	439	431
Dickinson Narrow	272	277	265	280	272
Dickinson Wide	298	303	291	306	298

Management of White Mold in Soybeans with Peroxide-Based Products

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

Funded Project $34,510

Why the Research is Important to North Dakota Soybean Farmers

Among soybean producers with white mold problems, there is growing interest about peroxide-based fungicides as a tool for managing white mold in soybeans after the disease develops, but data about their efficacy are limited. This research was conducted to achieve the following objectives:

1) Quantify the efficacy and profitability of peroxide-based fungicides, applied alone or with a traditional fungicide at the first sign of disease, for white mold management in soybeans.

2) Quantify the influence of spray volume and the product's application rate on the efficacy and profitability of peroxide-based fungicides for white-mold management in soybeans.

3) Assess the efficacy and profitability of peroxide-based products applied in conjunction with a standard preventative fungicide application at the R2 growth stage versus as a stand-alone management tool for white mold.

4) Assess the efficacy of applying a peroxide-based fungicide via chemigation at the first sign of disease for white-mold management.

Research Conducted

Testing was conducted on irrigated soybeans in Carrington and Oakes with OxiDate 5.0 (27% hydrogen peroxide, 5% peroxyacetic acid) and SaniDate 12.0 (18.5% hydrogen peroxide, 12% peroxyacetic acid).

> ***"Peroxide-based fungicides are less effective against white mold in soybeans than timely, preventative applications of conventional fungicides."***

The influence of the application rate and spray volume on the efficacy of OxiDate 5.0 was tested in Carrington and Oakes using a tractor-mounted sprayer. In Carrington,

Figure 1. Influence of application rate, spray volume and tank-mix partners on the efficacy of Oxidate 5.0 applied to soybeans that received an application of Endura (5.5 oz/ac) at the early R2 growth stage or that received no prior fungicide. Within-column means followed by different letters are significantly different ($P < 0.05$).

			Carrington, ND (2023)			Oakes, ND (2023)		
	Application at R3 and R4	Spray Volume	White mold % of canopy average across 14" and 28" rows	Yield bu/a average across 14" and 28" rows	Yield gain confered by fungicide program	White mold % of canopy average across 14" and 28" rows	Yield bu/a average across 14" and 28" rows	Yield Gain confered by fungicide program
No fungicide applied at early R2	Non-treated		71 a*	29 a*	|=avg. ●= result/1 row spacing	33 a*	66 a	|=avg. ●= result/1 row spacing
	OxiDate @ 0.5% v/v	20 gal/a	67 a	30 a	+1.7 b*	28 a	68 a	+1.7 b**
	OxiDate @ 1% v/v	20 gal/a	67 a	30 a	+1.6 b	33 a	68 a	+1.5 b
	OxiDate @ 1% v/v + Topsin 20 fl oz/a	20 gal/a	61 a	35 a	+6.2 a	22 a	74 a	+7.8 a
	OxiDate @ 0.5% v/v	10 gal/a	67 a	33 a	+3.8 ab	Not evaluated		
	OxiDate @ 1% v/v	10 gal/a	64 a	33 a	+3.7 ab*	Not evaluated		
	OxiDate @ 2% v/v	10 gal/a	68 a	30 a	+1.5 b	Not evaluated		
	OxiDate @ 1% v/v + Masterlock 6.4 fl oz	10 gal/a	68 a	30 a	+1.4 b	Not evaluated		
		CV:	12.8	19.3		32.1	4.6	
Endura applied at early R2	Non-treated		58 a**	38 a*		29 a*	67 a*	
	OxiDate @ 0.5% v/v	20 gal/a	59 a	37 a	-0.6 ab*	32 a	67 a	+0.3 a*
	OxiDate @ 1% v/v	20 gal/a	53 a	39 a	+1.6 ab	20 a	69 a	+2.4 a
	OxiDate @ 1% v/v + Topsin 20 fl oz/a	20 gal/a	52 a	41 a	+3.3 a	22 a	69 a	+2.3 a
	OxiDate @ 0.5% v/v	10 gal/a	58 a	37 a	-1.0 ab	Not evaluated		
	OxiDate @ 1% v/v	10 gal/a	58 a	39 a	+1.2 ab	Not evaluated		
	OxiDate @ 2% v/v	10 gal/a	54 a	38 a	+0.4 ab	Not evaluated		
	OxiDate @ 1% v/v + Masterlock 6.4 fl oz	10 gal/a	60 a	36 a	-1.6 b	Not evaluated		
		CV:	17.1	18.2		42.6	5.7	

applications were made at 5.0 mph at the R3 (before white mold was observed) and R4 (after significant white-mold development) growth stages, and in Oakes, applications were made at 8.0 mph at the R4 (before white mold was observed) growth stage; the pulse width was modified to maintain a constant driving speed across different spray volumes. The effect of tank-mixing OxiDate 5.0 (1% volume by volume (v/v) in 15 gallons per acre) with T-methyl, Endura or ProPulse applied preventatively at the R2 or R3 stages as well as the effect of applying OxiDate at the R3 (before white mold was observed) or R4 (after significant white-mold development) stages following preventative applications of conventional fungicides at R2 or R2 and R3 were tested in Carrington with handheld applications. All applications of OxiDate were made to a closed canopy, and nozzles that emitted coarse droplets were utilized. The efficacy of chemigation with SaniDate 12.0 (0.02% v/v in 0.19-inch water) was tested in Carrington at the early R3 (before white mold was observed) and full R4 (after significant white-mold development) stages. The chemigation treatments and water control were delivered in a randomized pattern with rotating micro-sprinklers established on overlapping PVC pipe systems.

Findings of the Research

Foliar sprays of OxiDate 5.0 and chemigation with SaniDate 12.0 at the R3 and/or R4 growth stages were associated with moderate improvements with white-mold management when applied to soybeans that did not receive preventative applications of conventional fungicides, but the differences were weak and not statistically significant. Little or no response to OxiDate 5.0 or SaniDate 12.0 was observed in applications made to soybeans that received preventative applications of conventional fungicides at the R2 or R2 and R3 stages or when OxiDate was tank-mixed with conventional fungicides. The results were similar for soybeans seeded to narrow (14-inch) and wide (28-inch) rows.

The results suggest that peroxide-based fungicides are less effective against white mold in soybeans than timely, preventative applications of conventional fungicides, and the peroxide-based products cannot be relied upon to rescue a crop after white mold has developed.

Figure 2. Plant pathologist Michael Wunsch, Ph. D. holding a soybean plant exhibiting wilt symptoms caused by white mold.

Figure 3. Michael Wunsch, Ph. D. provides his research results to farmers during NDSU Carrington REC Field Day.

Potential for Combatting Iron Deficiency Chlorosis with the Soybean Microbiome

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

Funded Project $22,425

Why the Research is Important to North Dakota Soybean Farmers

Iron Deficiency Chlorosis (IDC) is a significant problem in North Dakota. IDC negatively affects soybean production. IDC causes the soybean plants' leaves to turn yellow due to a lack of chlorophyll, which is essential for plant health and growth. This change happens because, although North Dakota soils have enough iron, the nutrient is often in a plant-unavailable form that soybeans cannot absorb. High soil pH and salinity exacerbate this issue. Finding an environmentally and economically sustainable solution for IDC is crucial to improve soybean yields and to ensure the profitability of soybean farming in the region.

Research Conducted

The research aimed to explore the potential of the soybean microbiome (the community of microbes around soybean roots) to alleviate IDC. We did this by investigating three key areas that, together, build a pipeline for harnessing the microbiome to reduce IDC.

Microbe Culturing: We isolated and cultured microbes from soybean roots which were harvested from fields with varying IDC levels.

Siderophore Screening: We tested the microbes for their ability to produce siderophores, compounds that can solubilize iron and make it available to plants.

Greenhouse Assay: We optimized a greenhouse assay to evaluate how the microbial inoculants affected soybean growth under iron-deficient conditions.

Findings of the Research

Microbial Isolation: Sixty-four unique microbial isolates were obtained from soybeans grown at both high-IDC and no-IDC sites.

Siderophore Production: Eight of the microbes showed the potential for producing siderophores.

Greenhouse Results: The greenhouse tests showed that it is practical to screen for IDC reduction effects by the microbiome. We found that applying certain microbial inoculants significantly reduced the IDC symptoms in soybeans, similar to the effects of using the iron fertilizer Soygreen (Figure 1).

Benefits for North Dakota Soybean Farmers and the Industry

The research paves the way for developing microbial inoculants to reduce IDC in soybeans, potentially offering a cost-effective and sustainable solution. For North Dakota soybean farmers, this means

Reduced Costs: Microbial inoculants could be a cheaper option compared to iron fertilizers.

Ease of Application: These inoculants can be applied along with rhizobium inoculants, simplifying the process for farmers.

Sustainable Solution: Utilizing the natural soil microbiome is an environment-friendly approach to manage IDC.

Barney Geddes, Ph.D.

Figure 1. Images of IDC symptoms induced in the greenhouse with the newly optimized assay.

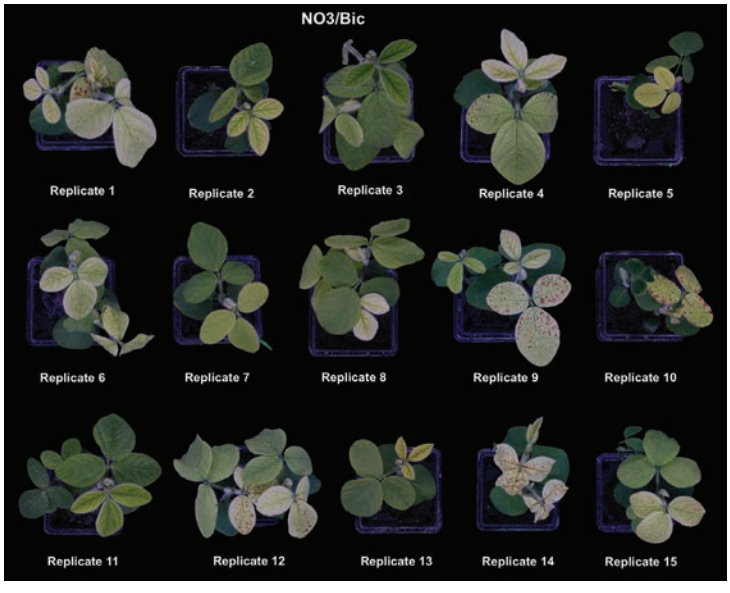
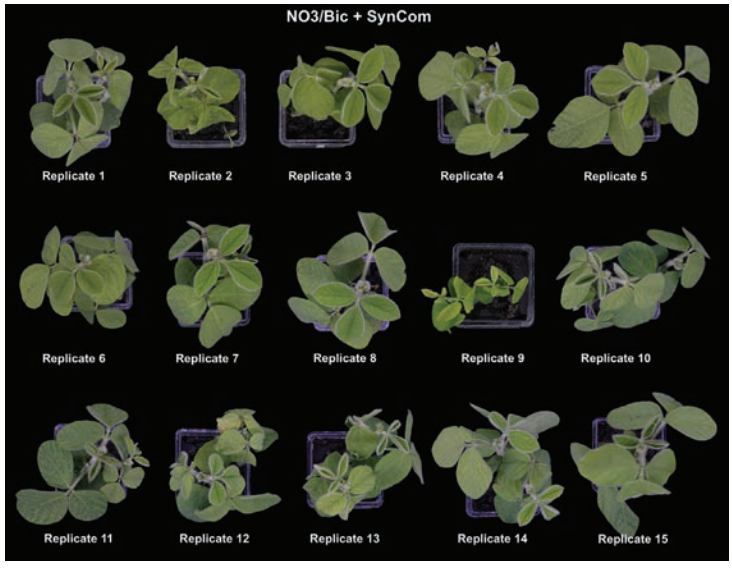


Figure 2. Images of microbe-treated soybeans that were grown in the same IDC symptom producing conditions.



Breeding of Improved Non-GMO Cultivars and Germplasm

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

Funded Project $167,224

Why the Research is Important to North Dakota Soybean Farmers

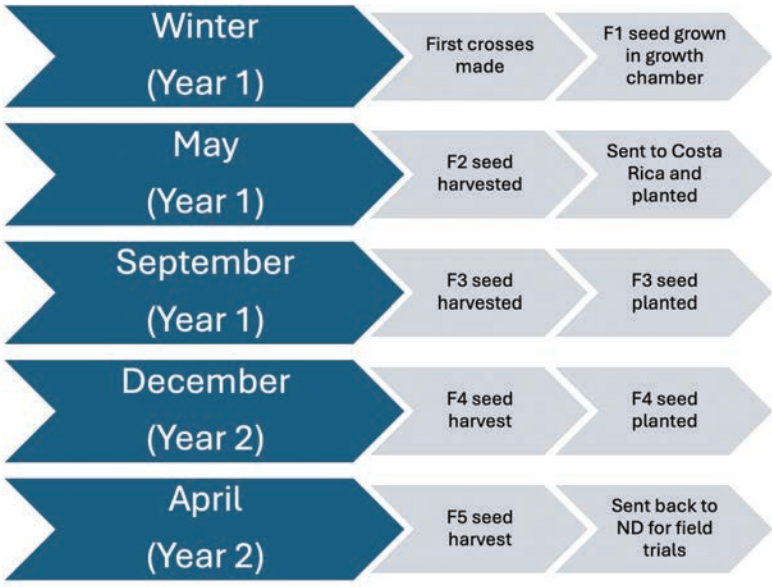
This project provides soybean farmers with improved non-GMO cultivars that have been developed by NDSU. The NDSU soybean breeding program has a long history of creating very competitive varieties, especially for conventional or non-GMO varieties. Currently, the project has improved non-GMO experimental lines that are close to being released as named cultivars or as specialty-release food-grade varieties. In addition, the non-GMO breeding effort is very important as a source of high-yielding parents for use in the development of glyphosate-resistant cultivars or other premium projects, such as high oleic. Another focus of this program is to evaluate the performance of private companies' soybean cyst nematode (SCN) resistant varieties because growers need information that enables them to select the best resistant varieties. Finally, this program also focuses on continued breeding efforts to stack SCN and sudden death syndrome (SDS) in NDSU germplasm. Because SDS has been observed in several North Dakota counties, genetic resistance is necessary to protect yields.

The project's objectives are to 1) provide North Dakota soybean growers with non-GMO cultivars which are genetically superior to the cultivars that are currently grown, 2) enable private companies and growers to compare the yield of SCN-resistant cultivars and experimental lines at three North Dakota sites that are infested with SCN, and 3) create germplasm with SCN and SDS stacked resistance.

Research Conducted

The development of non-GMO soybean germplasm is an ongoing duty. The soybean breeding program is transitioning to have all germplasm as conventional and to incorporate a herbicide trait introgression pipeline. This will allow the focus to only be on germplasm development in one project instead of spreading resources thin. Improvements have been made using growth-chamber resources to expediate breeding in order to make new varieties more quickly. SCN field testing for private companies continues, and results are published on the NDSU website. SCN and SDS resistant lines are currently being developed.

Figure 1. The NDSU soybean breeding program is utilizing an accelerated breeding pipeline to expedite the first half of the creation process for new potential varieties. Traditionally, this half of the pipeline would take 4 years to complete, but with new technology, it has been reduced to 2 years.



Findings of the Research

We found that is possible to speed up breeding by two years when using growth chambers to create new crosses. The first lines from this trial (which were created in 2022) were being tested in North Dakota in 2024. SCN testing will continue for private companies with the assistance of NDSU Extension Pathologist Dr. Wade Webster. The SCN and SDS stacked breeding lines began first-year yield testing in the summer of 2024.

Benefits for North Dakota Soybean Farmers and the Industry

Speeding up the creation of soybean germplasm will allow high-yielding and disease-resistant varieties to be available much sooner than was previously possible. The goal is to use these soybean backgrounds to add newly acquired herbicide traits to high-yielding varieties at a faster speed.

Figure 2. The NDSU soybean breeding team is pollinating soybean flowers to create new potential varieties.

Visual Rating for Iron-Deficiency Chlorosis

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

Funded Project $91,359

Why the Research is Important to North Dakota Soybean Farmers

The data in this report will provide an independent confirmation for the iron deficiency chlorosis (IDC) tolerance of commercial products and will enable growers to compare varieties from many companies. Comparing soybean varieties from different companies requires that all companies' varieties are evaluated and averaged across the same fields; otherwise, a fair comparison is not possible. This research will enable growers to increase their yield for their IDC prone fields by allowing them to select varieties with the fewest IDC symptoms.

Research Conducted

Private companies submit the newest varieties to the NDSU breeding program for IDC testing. A total of 214 varieties were tested in 2023, and 181 varieties were tested in 2024. In 2023, these lines were grown in three IDC affected fields, and in 2024, that testing increased to four locations (Figure 1). Lines are grown and scored according to NDSU's soybean IDC rating. Scores are collected, analyzed and published online every August. They are also published in the printed A-843 report each December.

Figure 2. IDC scoring for private company lines requires precise planting.

Figure 1. Field trial that shows IDC symptoms in one of our yield trials at the NDSU Agronomy Seed Farm.

Findings of the Research

IDC symptoms were more severe in 2022 and 2023 than in previous years. Therefore, we are increasing the number of locations to assess the IDC tolerance for NDSU lines across different levels of severity. We are also adding locations in case of data loss due to herbicide drift, no symptoms available, hail, etc. Many growers rely on IDC ratings to select soybean varieties, and we want to ensure high-quality data.

Benefits for North Dakota Soybean Farmers and the Industry

The IDC trial provided useful and necessary data to North Dakota farmers, assisting with the growers' decision process when selecting the most appropriate soybean variety for their fields. This project also offers the opportunity to test NDSU's experimental lines, which allows the breeding program to make thoughtful line selections based on IDC resistance, which is an important trait in eastern North Dakota. These trials will continue in 2025 and onward.

To view the IDC ratings for 2024, visit vt.ag.ndsu.edu/list/soy

> ***"The IDC trial provided useful and necessary data to North Dakota farmers, assisting with the growers' decision-making process when selecting the most appropriate soybean variety for their fields."***

Breeding of Glyphosate-Tolerant Soybean Cultivars (2024)

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

Funded Project $202,488

Why the Research is Important to North Dakota Soybean Farmers

Currently, four glyphosate-tolerant (GT) varieties that were developed by NDSU are available to soybean growers. Continual yield and trait improvement is occurring within the program, which includes introducing new materials from other successful breeding programs and continually adding new disease resistances. Effort is also made to add new herbicide-resistant traits to the program. The research and breeding outcomes will allow North Dakota soybean farmers to reduce their input costs by purchasing high-yielding, very competitive, GT cultivars developed at NDSU.

The objective is to continue the process of developing glyphosate-tolerant experimental lines with a goal of releasing cultivars with varying maturities that are adapted to North Dakota's growing conditions. In addition, other herbicide-resistance traits are being explored to incorporate with the NDSU breeding lines.

Research Conducted

New crosses are continually being created to have new, superior potential soybean lines for testing. This includes GT lines combined with Peking soybean cyst nematode (SCN) resistance and iron deficiency chlorosis tolerance. Hundreds of GT lines are tested for yield throughout the state in order to determine the most successful and high-yielding lines. The breeding program successfully acquired the use of the BASF Liberty trait in 2024.

Figure 1. Soybean breeder Carrie Miranda and assistant breeder Gustavo Kreutz in glyphosate-tolerant plots at the NDSU Agronomy Seed Farm in Casselton.

Figure 2. Breeding for Glyphosate-Tolerant Soybean Cultivars.

Findings of the Research

One GT line that also has SCN resistance is being considered for variety release. New crossing strategies will be used to expedite the introgression of the Liberty trait in the NDSU germplasm. The glyphosate tolerant project will be reduced in favor of adding new herbicide traits.

Benefits for North Dakota Soybean Farmers and the Industry

This project has served North Dakota farmers well and has released very successful lines, such as ND17009GT, which, at one point, was grown on 2.4% of all the state's soybean acres. With the demand for newer herbicide traits due to evolving herbicide resistance, especially resistance to glyphosate, it is appropriate to introgress new herbicide traits.

With the acquisition of the BASF Liberty trait and the creation of new populations utilizing high-yield lines from other maturity groups, plus the focus on breeding for Peking-style SCN resistance and IDC tolerance, there is optimism that the NDSU soybean breeding program will produce new varieties that will be competitive throughout the state.

> ***"This project has served North Dakota farmers well and has released very successful lines, such as ND17009GT. There is optimism that the NDSU soybean breeding program will produce new varieties that will be competitive throughout the state."***

Increasing Soybean Yield Under Drought Through Enhanced Symbiotic Nitrogen Fixation

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

Funded Project $37,452

Why the Research is Important to North Dakota Soybean Farmers

Western North Dakota is characterized by low-water or drought-like conditions, with soybean yields suffering as a result. While there may be multiple mechanisms to enhance drought tolerance for soybeans, many options have a negative effect on agronomic performance and yield during well-watered conditions compared to drought susceptible varieties. Having a greater ability to sustain symbiotic nitrogen fixation (SNF) under drought conditions significantly improves soybean yield. The ability to sustain SNF in soybeans has a genetic basis. This trait has been observed in U.S. germplasm collections and is used with some breeding programs.

This project's long-term goal is to incorporate sustained SNF into NDSU varieties to improve the yield with drought conditions. To take the first steps towards this result, we will investigate the ability to sustain SNF under drought with the existing, advanced NDSU germplasm. In addition, we will begin incorporating a well characterized germplasm that has been shown to have an elite ability to sustain SNF under drought into the NDSU breeding program.

Figure 1. A side-by-side comparison of an uninoculated and inoculated positive control from Arkansas R01-416F that is capable of sustained nitrogen fixation with drought stress. Credit: Cole Williams.

Figure 2. A 2023 field study in Williston, North Dakota. Pictured is graduate student Manogna Adapa.

Objective 1: Screen for the ability to sustain SNF under drought in NDSU's advanced breeding lines.

Objective 2: Initiate breeding populations using a known germplasm with a high drought SNF.

Research Conducted

To study the sustained nitrogen fixation trait in the NDSU soybean materials, we sampled lines that were tested for yield at the NDSU Williston Research Extension Center's Nesson Valley location; the lines were grown in dryland and irrigated conditions. Root and shoot biomasses were analyzed to detect nitrogen in the plant that came from rhizobium fixation. Breeding efforts have also begun to add the known SNF trait from Arkansas soybean lines into North Dakota lines.

Findings of the Research

We have identified several lines within the NDSU breeding program that share characteristics with the Arkansas lines exhibiting sustained symbiotic nitrogen fixation, potentially indicating drought tolerance. In future years, we will continue the testing. The breeding lines which are combined with the Arkansas drought resistant lines will be ready for field testing in 2025.

Benefits for North Dakota Soybean Farmers and the Industry

Creating drought-resistant soybean varieties will benefit western North Dakota farmers because drought-tolerant varieties will maintain higher yields with low-water conditions. The first field tests of NDSU's drought-tolerant lines will begin in 2025.

> ***"This research identified a few lines within the NDSU breeding program that seem to have drought resistance similar to the Arkansas lines that contain the sustained SNF trait."***

Resistance to Important Soybean Diseases

Principal Investigator: *Richard Webster, Ph.D., North Dakota State University (NDSU) Department of Plant Pathology*

Funded Project $48,950

Why the Research is Important to North Dakota Soybean Farmers

With soybean production increasing across the entire state of North Dakota, the development of soybean diseases is inevitable. Two of the most yield limiting soybean diseases across the United States are sudden death syndrome (SDS) and Phytophthora root and stem rot.

Sudden death syndrome is caused by the fungal pathogen *Fusarium virguliforme* SDS has, historically, been a major disease in states such as Minnesota and Iowa. Phytophthora root and stem rot is caused by Phytophthora sojae. Having been present for many years, Phytophthora root and stem rot is still a major threat to North Dakota soybean production. In order to manage both of these diseases, the use of genetic resistance is incredibly important to avoid the potentially devastating yield losses.

The objectives of this research were as follows: 1) screen NDSU breeding lines for resistance, and identify lines with high levels of resistance to Phytophthora root rot; 2) screen adapted soybean germplasm for resistance to sudden death syndrome, and identify sources of resistance that the soybean breeder can use to develop resistant varieties for this area; and 3) process plant samples with suspected SDS symptoms to verify the disease's presence in North Dakota fields.

Research Conducted

From July 2022 to December 2023, our team evaluated soybean varieties for resistance to Phytophthora root and stem rot and to SDS. A key element of this study was a field evaluation of two soybean varieties, Bison and Benson, both believed to be resistant to SDS.

Simultaneously, we conducted SDS greenhouse experiments using the same soybean varieties. These controlled conditions allowed for observation about how the varieties reacted to the *F. virguliforme*.

Findings of the Research

Plants in greenhouse experiments did exhibit some SDS symptoms, but inconsistency with the SDS severity posed a challenge for the results' validity. Adding to the complexities, a puzzling discovery was made in 2023. Molecular research revealed that the fungus initially thought to be causing SDS in North Dakota was actually a different species entirely. This created new questions regarding the actual presence of *F. virguliforme* in North Dakota since its first suspected appearance in 2018. Field evaluation of two soybean varieties resistant to SDS was not successful because the plots accidentally received herbicide damage and did not develop SDS symptoms by September. The study was terminated early.

Another significant part of the research involved screening 96 soybean lines for their resistance to Phytophthora root and stem rot, focusing on the two most prevalent types in North Dakota. Nearly half of the lines showed resistance to both types; about a quarter of the lines were resistant to one type; and the remaining lines were susceptible to both types. Several lines demonstrated what is known as partial resistance, surviving the disease to varying degrees but not being completely immune.

Figure 1. Survival of F2 soybean breeding lines when evaluated with *P. sojae* race 4 under greenhouse conditions.

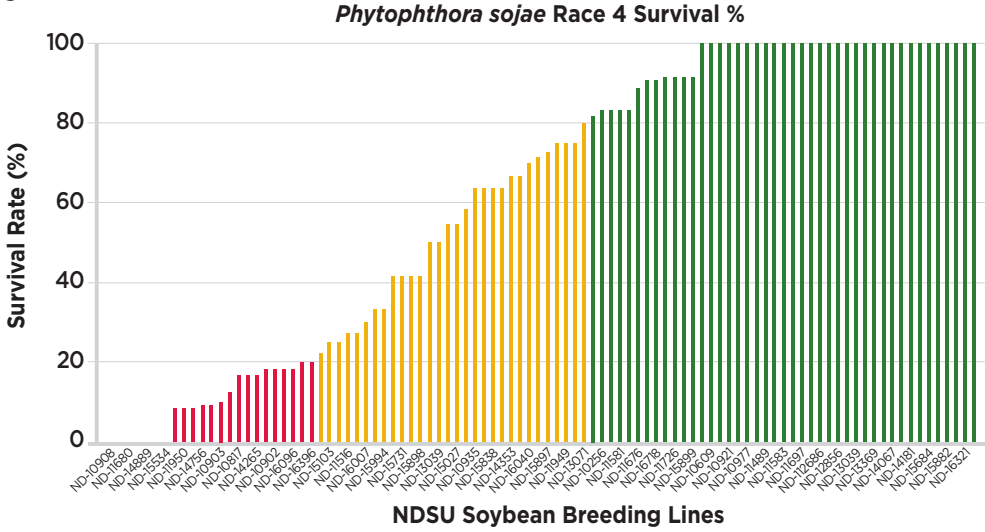
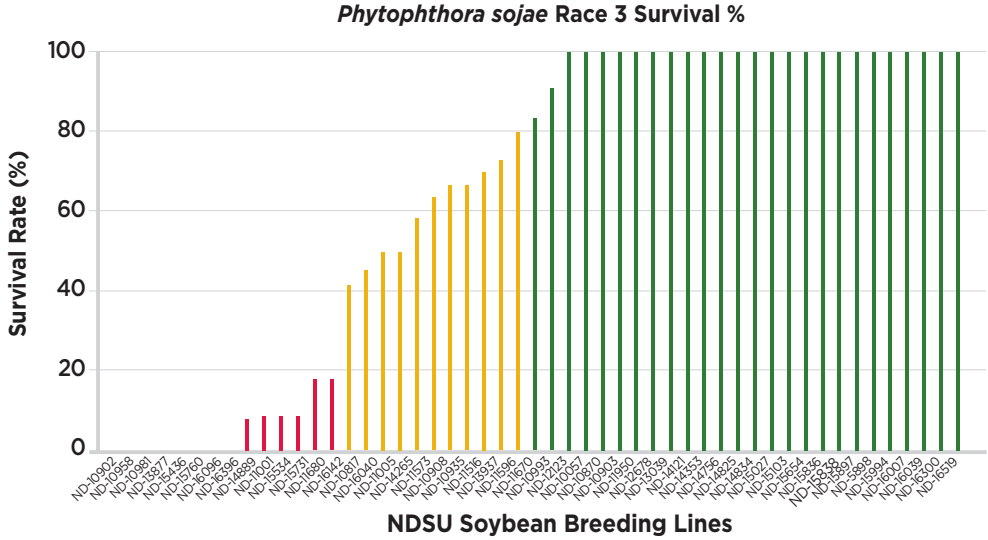


Figure 2. Survival of F2 soybean breeding lines when evaluated with *P. sojae* race 3 under greenhouse conditions.



Soybean Cyst Nematode Sampling Program 2023

Principal Investigators: *Sam Markell, Ph. D.; Guiping Yan, Ph.D.; Febina Mathew, Ph.D.; and Wade Webster, Ph.D.*

Funded Project $36,100

Why the Research is Important to North Dakota Soybean Farmers

The plant parasite Soybean Cyst Nematode (SCN) was first confirmed in North Dakota in 2003 (Richland County) and has been spreading since its introduction. Soil sampling is the most reliable way to detect the presence of SCN and the most effective way to determine how well management tools are working in the soybean fields. This project provides soybean growers with a mechanism to submit samples for analysis at no cost and increases our understanding about the SCN prevalence in North Dakota.

Research Conducted

Pre-labeled, soil-sampling bags are distributed to soybean growers and their advisers through NDSU Extension in the late summer and early fall. The North Dakota Soybean Council (NDSC) 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. (No additional information about the submitters or the fields is obtained.)

Findings of the Research

In 2023, there were 588 total SCN samples, of which 343 were found to have at least 50 eggs + J2/100 cc soil (a positive rate of 58.3%, the highest recorded since the onset of the program). Sufficient data were received to map 539 samples. Since 2013, there have been 5,666 samples received, and 5,561 have been mapped. SCN is now thought to be present in two dozen counties.

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

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

SCN is spreading and causing economic loss for our soybean farmers, and soil testing is the first step with active management and protecting yield. For growers who have not detected SCN before, we recommend that they sample field areas where SCN is most likely to first be introduced, such as field entrances. For growers who know they have SCN, we recommend that they soil sample to determine how well the current management strategies are working.

Acknowledgements

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

Figure 1. Number of SCN samples and their egg levels (eggs + J2/100 cc soil) received from 2013 to 2023.

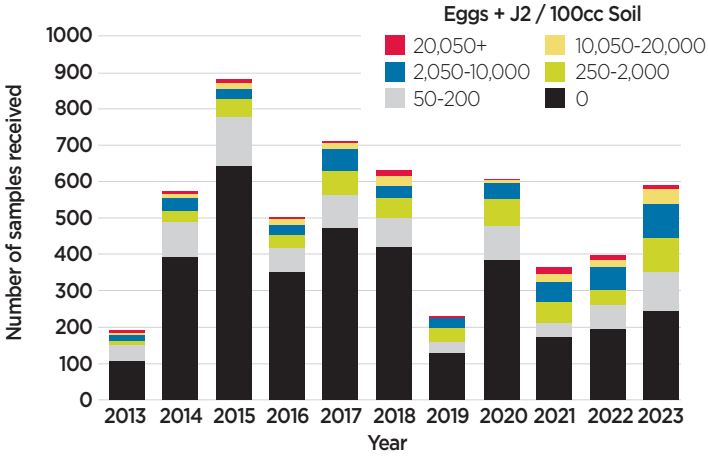
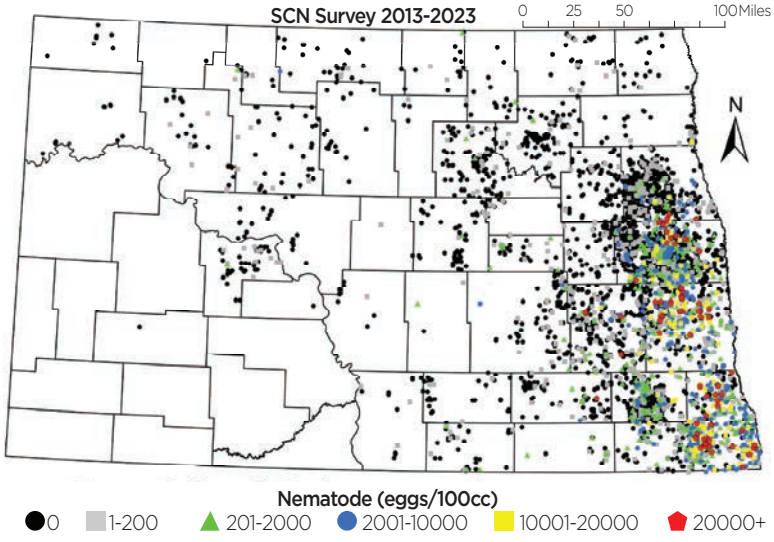


Figure 2. Cumulative distribution of SCN in North Dakota from 2013 to 2023 (5,561 mapped samples).



Evaluation of Phosphorus Needs for North Dakota Soybeans

Principal Investigators: *Lindsay Malone, Ph.D., and David Franzen, Ph.D., North Dakota State University (NDSU) School of Natural Resource Science*

Funded Project
$43,501

Why the Research is Important to North Dakota Soybean Farmers

North Dakota soybeans have increased from 1 million to nearly 6 million acres in the last two decades. The new production regions are largely in northcentral and northwestern North Dakota. The recommendations for phosphorus (P) fertilizer application have been developed from data collected in eastern North Dakota. There is a need to reevaluate the phosphorus fertilizer recommendations for soybean production in North Dakota. The current recommendations are focused on P application for fields with low (3-7 parts per million (ppm)) or very-low (0 ppm-3 ppm) soil test phosphorus (STP), but recent research in Minnesota suggests that P application on fields with medium STP (8 ppm-11 ppm) can provide increased seed yield. (D. Franzen, 2019).

Research Conducted

Eight P-trial locations (low-P fields) were utilized across North Dakota in 2023 (Figure 1). Five P-rate treatments (0, 23, 46, 69 and 92 pounds per acre (lb/ac) were replicated 4 times at each location. In the spring, the sites were screened to establish experiments in one very low Olsen P field (P < 5 g kg-1) and one low Olsen P field (P <8 g kg-1). The sites were also screened for soil acidity (pH > 5.6).

The experimental sites were maintained by farmers or Extension specialists, with management factors such as variety, seeding rate, row spacing, maturity group and tillage practice determined individually in order to improve the relevance of production to the region. The experimental design was a randomized, complete block with 5 treatments and 4 replications. Spring soil samples were taken at each site prior to P application. Composite samples across the entire study area were taken at 0 to 6 inches and 6 to 24 inches. At most sites, 3-5 cores were taken in each plot at 0 to 6 inches for Olsen STP. Fall soil samples were taken at harvest in each plot at 0 to 6 inches for routine tests (P, pH, organic matter and potassium). All soil samples were dried, ground and sent to Agvise Laboratories, Inc. in Northwood, North Dakota, for analysis. Data collection included the soybean's seed yield and the soil's test data.

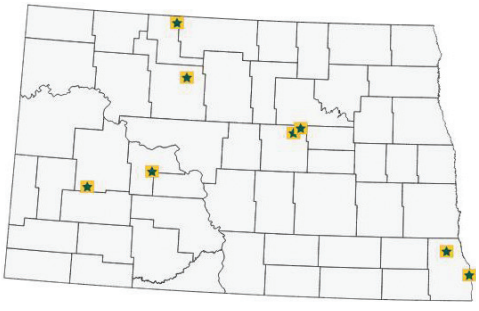


Figure 1. Map of the 2023 P-trial sites throughout North Dakota.

Findings of the Research

P fertilizer increased the yield for 2 of the 8 trials: Minot and Mohall. With these trials, the lowest P rate (23 lb/ac) was sufficient to improve yield over the no-fertilizer control (Figure 3). There was approximately a 6-bushel-per-acre yield increase at each site: 16% relative yield in Minot and 25% in Mohall. Other factors, such as rainfall, may have been yield limiting at other sites, or the soybeans in those fields were able to scavenge enough P despite the low test values for the soil.

Lindsay Malone, Ph.D.

Figure 2. Applied phosphorus rate (triple super phosphate) and relative yield across all North Dakota experimental sites. * indicates significance at the 0.05 level (Minot and Mohall only); all other sites did not respond to P addition.

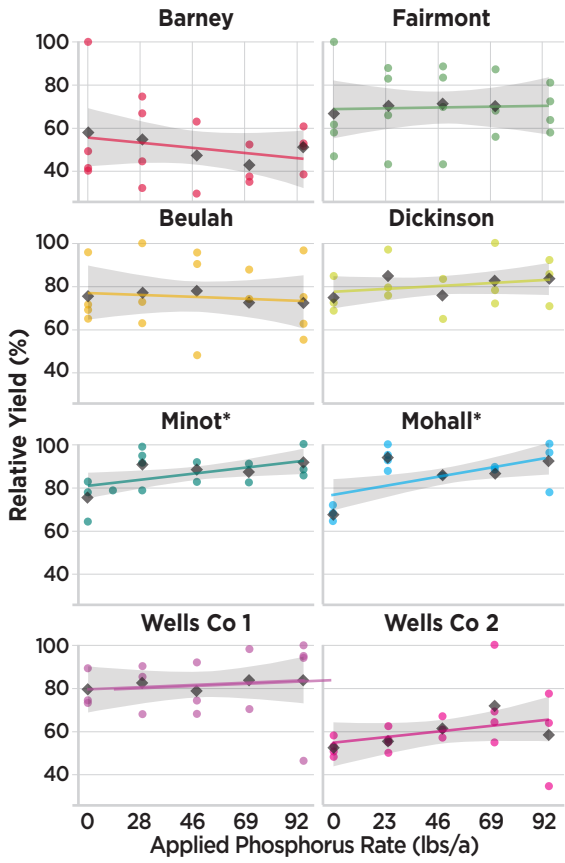
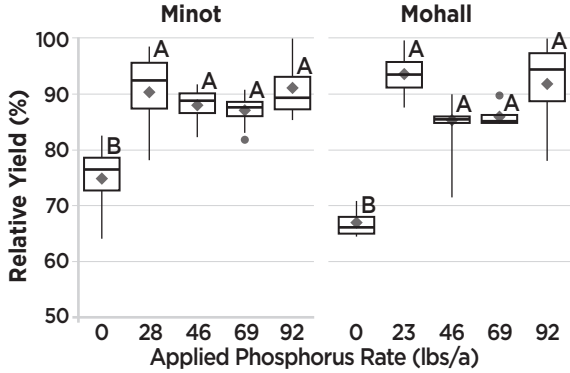


Figure 3. Boxplots for the applied phosphorus rate (TSP) and relative yield of the two responsive trials in North Dakota: Minot and Mohall. Treatments with the same letter did not result in a significantly different relative yield (α = 0.05).



Understanding How *Fusarium* Affects Soybeans in North Dakota and the Development of Disease-Management Strategies

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

Funded Project $66,233

Why the Research is Important to North Dakota Soybean Farmers

Seedling diseases, caused by *Fusarium*, can be a significant problem for soybean production in the United States. In North Dakota, soybean farmers have limited options to manage *Fusarium* diseases. Currently, growers rely on a few seed treatments and varieties that have a tolerance to the sudden death syndrome (SDS) fungus. The distribution of *Fusarium* in North Dakota is poorly understood. We hypothesize that heavy rains across North Dakota as well as farmers adopting no-till or reduced tillage practices can result in crop residues that are infested with *Fusarium*. Furthermore, SDS and *Fusarium* diseases may appear in fields where soybean cyst nematode (SCN) is present.

Research Conducted

In this study, we 1.) characterized the distribution of *Fusarium* species by surveying 100 commercial fields across 30 counties in North Dakota, 2.) evaluated the pathogenicity of *Fusarium* species on NDSU's breeding lines and assessed their cross-pathogenicity with barley, 3.) examined the association between SCN and *Fusarium* on a susceptible soybean variety in the greenhouse, and 4.) assessed the effect of seed treatments against *Fusarium* under field conditions.

Findings of the Research

To date, we isolated nine species of *Fusarium* in soil samples collected from 100 fields. Among these, *F. clavum, F. scirpi* and *F. vanettenii* were not previously reported on soybeans in the U.S. As for pathogenicity, *F. graminearum* isolates from soybeans exhibited a wide range of virulence on a rotational crop such as wheat. In addition, our preliminary results suggested that SCN does not increase the severity of the root rot caused by *F. graminearum*. From a disease management perspective, the results from the seed treatment trial showed greater yield with products such as ILEVO, Saltro and CeraMax (11% to 17% yield increase) compared to the non-treated control.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

Overall, our study emphasizes the importance of investigating *Fusarium* in North Dakota. *Fusarium*, alongside other seedling organisms, is known to cause a yield loss in soybean production regions throughout the U.S. The data gathered from our seed treatment trials will be used to develop disease management programs that target *Fusarium* for farmers. Furthermore, we will continue collaborating with the NDSU soybean breeding program to screen and to breed for varieties with resistance to Fusarium, which can then be adopted by farmers in the future. Lastly, our study about the Fusarium-SCN experiment highlights the importance of screening cultivars for resistance to both pathogens, ultimately leading to more effective disease control.

Figure 1. Distribution of seedling pathogens from the 2023 survey by counties in North Dakota (n=75 fields).

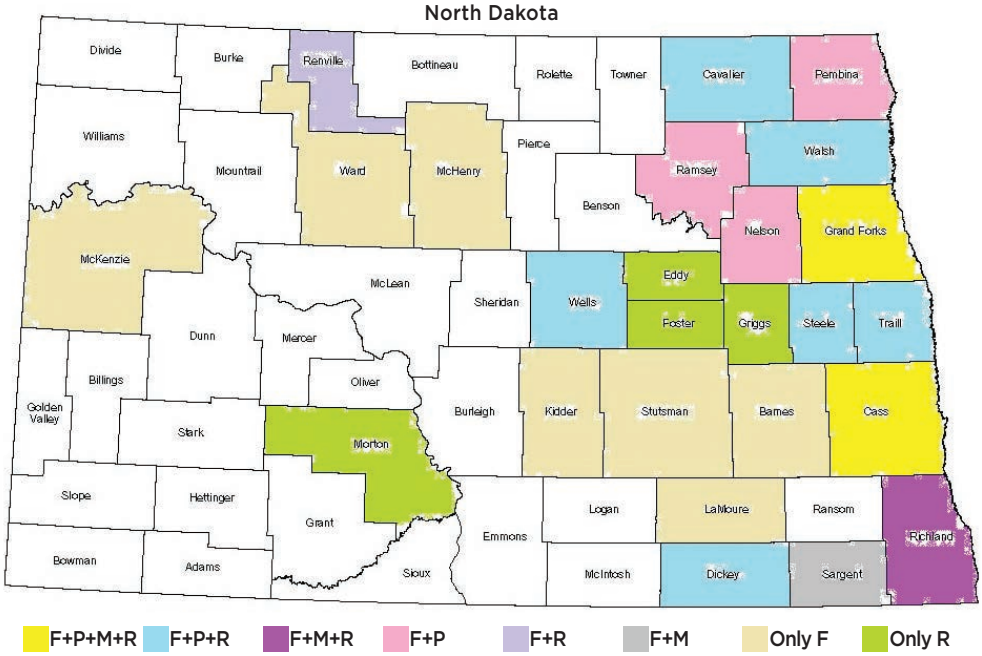


Figure 2. *Fusarium* root rot of soybeans (Picture by Nitha Rafi.)

> ***"The results from the seed treatment trial showed greater yield with products such as ILEVO, Saltro and CeraMax compared to the non-treated control."***

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

Principal Investigator: *Mohamed Khan, Ph.D., North Dakota State University (NDSU) Extension Assistant Director, NDSU College of Agriculture, Food Systems and Natural Resources*

Funded Project $50,557

Why the Research is Important to North Dakota Soybean Farmers

We have grown crops, starting with wheat, in the Red River Valley since the 1870s by utilizing conventional forms of tillage. The advent of glyphosate-tolerant crops made it possible for producers in western states to grow these crops using conservation to reduce and to conserve water. Conservation tillage (where ≥ 30% crop residue remains) can provide benefits such as soil conservation, improved soil organic-matter content, and reduced labor and energy use. Some producers have started growing soybeans, corn, sugarbeets and wheat using strip tillage and/or no-till. Providing 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 grown in rotation is useful.

The overall objective is to provide practical information for using different tillage methods to grow soybeans and other rotational crops in a sustainable and economical manner. The specific objectives are as follows: 1) determine the yield and quality of major crops grown in different crop sequences; 2) determine the tillage type's effect on the crop's yield and quality; 3) evaluate the influence of tillage and crop sequence on the disease severity caused by major pathogens of the crops in the sequence; 4) assess the influence of tillage on soil nutrients (nitrogen, potassium, phosphorous, and carbon), pH, texture, and microbial population over time.

Findings of the Research

Soybean yield and moisture remained consistent across tillage types, whereas there was a significant effect for tillage and crop position with sugarbeets and corn. The microbiome study revealed no significant differences for the observed taxa across crops or tillage methods, but the number of observed taxa tended to decrease with an increasing depth. Soil-erosivity data illustrated that wheat had significantly less soil erosion compared to corn and soybeans, likely due to the wheat's quick emergence and early ground coverage. No-till treatments had significantly less soil erosion than conventional and strip tillage. Insect-collection analysis showed the highest number of insects in weeks 1 and 3, with corn and wheat hosting the most insects. Earthworms, indicative of healthy soil, were uniformly distributed across crop types and tillage methods, although the counts were generally low.

The crops were not affected by major diseases, probably because of dry conditions. There were no differences with the microbial population across crops or sequences, but the number of taxa decreased with depth. Soil pH, organic matter and soil carbon were not affected significantly by the tillage type. The soil pH was lower at lower depths. High yields were obtained for soybeans (42 to 45 bushels/acre), corn (185 to 209 bushels/ac) and wheat (52 to 64 bushels/acre) across all tillage types.

Benefits/Recommendation for North Dakota Soybean Farmers and the Industry

Recent data from the 2023 field experiment supported the previous research, indicating that corn, soybeans, sugarbeets and wheat can be successfully grown with different tillage types in the Red River Valley. Care should be taken to reduce corn residue, especially with strip tillage and when moving residue with coulters for no-till crops, to facilitate planting and to achieve a good plant population.

The conventional and strip-till methods resulted in similar yields for soybeans, corn and wheat; the no-till crop had a lower yield for some years when the plant populations were affected by too much residue.

Figure 2. NT: No-tillage plots

Figure 1. Mohamed Khan, Ph. D., provides a research update during a field day.

Figure 3. Prosper site (2023) after harvesting the wheat.

Soybean Yield Interference for Palmer Amaranth and Waterhemp in North Dakota

Principal Investigators: *Quincy Law, Ph.D., Iowa State University Department of Horticulture, and Joseph Ikley, Ph.D., North Dakota State University (NDSU) Department of Plant Sciences*

Funded Project $43,406

Why the 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 the 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 the two weeds. Approximately 1 and 4 weeks after soybean planting, the emerged waterhemp and Palmer amaranth plants were 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 the 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.

Findings of the Research

In year 2 of this experiment, early transplanted Palmer amaranth and waterhemp reduced the yield compared to the weed-free check (Figures 1 and 2). This research emphasized the influence of the waterhemp and Palmer amaranth emergence's timing on soybean yield, with a 24% and 67% yield loss associated with early transplanted waterhemp and Palmer amaranth, respectively.

In 2023, soybeans were competitive with waterhemp and Palmer amaranth transplanted 4 weeks after planting. However, delayed planting, difficult pigweed establishment and/or white mold may have contributed to the lack of treatment separation.

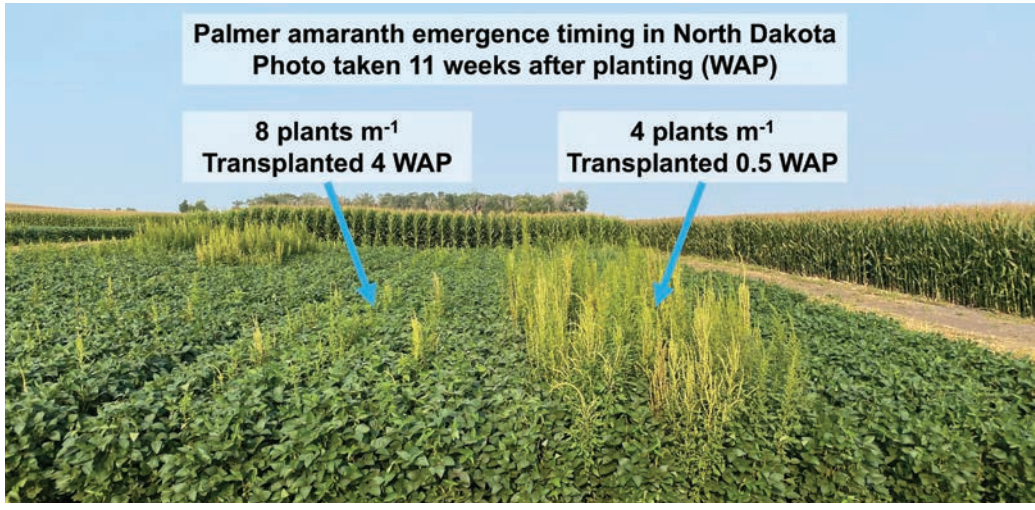


Figure 3. Influence of the transplant's timing on the Palmer amaranth's size.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

Our recommendation is to not wait on weed control. Yield loss for year 2 was the highest with early transplanted weeds. While soybeans were much more competitive with pigweeds that emerged later in the season, we observed significant yield loss in year 1 with the late-emerging Palmer amaranth. As such, preemergence and postemergence control strategies should be utilized for Palmer amaranth and waterhemp in North Dakota.

Figure 1. Soybean yield (adjusted to 13% moisture) as influenced by the waterhemp's density (expressed as plants per m row). Bars with the same letters are not significantly different according to Tukey's HSD (*α* = 0.05). Soybeans were planted on May 22; waterhemp was transplanted on May 26 (early) and June 22; and soybeans were harvested on October 2 in 2023.

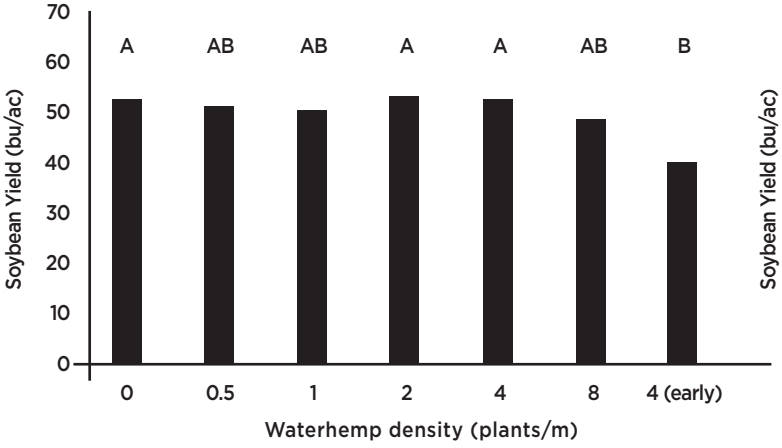
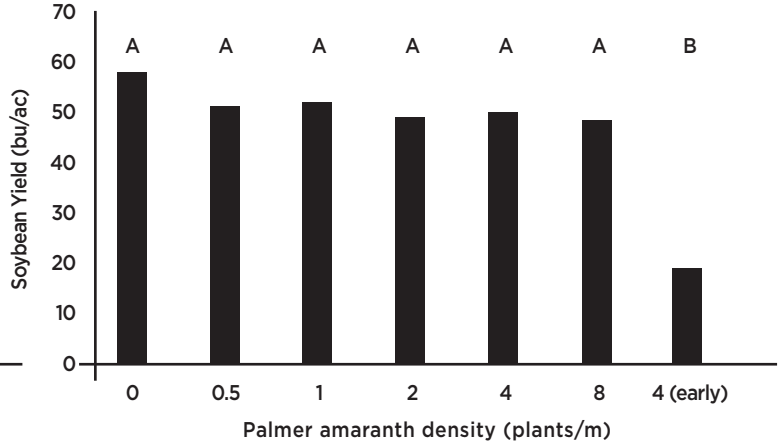


Figure 2. Soybean yield (adjusted to 13% moisture) as influenced by the Palmer amaranth's density (expressed as plants per m row). Bars with the same letters are not significantly different according to Tukey's HSD (α = 0.05). Soybeans were planted on June 12; Palmer amaranth was transplanted on June 16 (early) and July 12; and soybeans were harvested on October 25 in 2023.



North Central Soybean Research Program (NCSRP)

Funded Project
$250,000

The North Central Soybean Research Program (NCSRP) is a regional group of 13 states that support and communicate multi-state, collaborative soybean checkoff research. The program is a leader for the research and outreach efforts to support midwestern and U.S. farmers and to drive the soybean industry forward.

Farmer leaders representing each of the 13 states comprise the NCSRP's board. Each member state also provides technical staff and consultants to assist the farmer board with program prioritization, progress monitoring, portfolio and budget management, and the communication of research results. The NCSRP is supported by combined checkoff funds from each state board, including North Dakota, to fund, monitor and communicate the extensive basic and applied production research projects. The NCSRP board teams up with staff from Qualified State Soybean Boards (QSSB), university researchers and Extension programs to work on behalf of approximately 355,000 soybean farmers in the North Central region.

The NCSRP program's priorities and focus areas include increasing soybean profitability, enhancing and protecting yield, and maintaining and improving soybean quality. The board strives to support projects that complement or extend research funded by the QSSBs, the United Soybean Board (USB) and other regions, and the board diligently considers research that can affect farmers across the region. Backing studies conducted in multiple states can influence the results because weather, diseases, pests and weeds don't remain in state boundaries. The effect of this research goes far beyond the North Central region.

Over the years, the NCSRP has funded research that led to major advancements in the soybean industry. The most recent breakthrough was the discovery of new genetic ways to fight soybean cyst nematodes. Other progress with the NCSRP funding includes improved farm management through decision tools; enhanced knowledge about seedling diseases; improved genetic gain through breeding enhancements; and help identifying new pests in the region, such as the soybean gall midge.

The projects funded for Fiscal Year 2024 included:

- An Integrated Approach to Enhance the Durability of Soybean Cyst Nematode (SCN) Resistance for Long-Term Strategic SCN Management (Phase III)
- Using Data-Driven Knowledge for Profitable Soybean Management Systems
- Mapping Soybean Protein and Oil Quality in Farmers' Fields
- Multi-Dimensional Approaches for Improved Productivity, Sustainability and Management of Major Soybean Diseases in the North Central U.S.: Year 3
- Research and Extension on Emerging Soybean Pests in the North Central Region
- Site-Specific Weed Management with Precision Application Technology
- SOYGEN3: Building Capacity to Increase the Soybean's Genetic Gain for Yield and Composition by Combining Genomic-Assisted Breeding with the Characterization of Future Environments
- SoyRenSeq: A Novel Approach for Disease-Resistance Gene Discovery and Application for Soybean Improvement
- The SCN Coalition: Building on the Influence of a Public-Private Partnership.

Details and summaries for these projects, as well as more information about the NCSRP, can be found at NCSRP.com and soybeanresearchinfo.com.

The NCSRP board, along with state staff and researchers, meets several times annually. The 2024 summer meeting took place in Madison, Wisconsin, where the group visited the Crave Brothers' dairy farm and paused for a photo. The tour also included a stop at a University of Wisconsin agricultural research farm for updates on ongoing research projects.

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

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

Funded Project $28,133

Why the 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, and the optimal timing and the herbicide to use for the sequential treatment are frequent questions during the summer's spray season. This research was conducted to determine those questions' answers about waterhemp and Palmer amaranth, two important weeds that are detrimental to soybean production. The results should help to improve the overall efficacy and to reduce the seed production for these weeds in cases where re-treatments are necessary.

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 study utilized waterhemp in a non-crop setting and Palmer amaranth in the greenhouse. The initial treatment was applied when 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 for herbicide-resistant soybeans (i.e., 2,4-D and glufosinate in E3 soybeans; and dicamba and glufosinate in Xtendflex soybeans).

Findings of the Research

For the E3 soybean system in 2022, 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 7 days later (63% control) or glufosinate 21 days later (66%). All other combinations provided 83% to 94% control. In 2023, all treatment combinations were similar and provided between 91% and 99% control of waterhemp (Table 1).

Waterhemp control with the Xtendflex trial was generally less than the E3 trial. When dicamba was the first herbicide applied in 2022, 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. In 2023, the treatments with the greatest control were dicamba followed by dicamba at 7 and 14 days after treatment (DAT); dicamba followed by glufosinate at 7, 14, and 21 DAT; and glufosinate followed by glufosinate at 14 DAT and 21 DAT. Of note, glufosinate followed by dicamba only provided 78% to 81% control across all respray timings.

For the Palmer amaranth trial with Enlist soybeans, three treatments provided less control than the other treatments: 2,4-D followed by glufosinate at 7 DAT; glufosinate followed by 2,4-D at 7 DAT; and glufosinate followed by glufosinate at 7 DAT. The 7-DAT treatment timing does not appear to be the best respray timing for Palmer amaranth in this system because all respray timings at 14 DAT and 21 DAT provided better control.

The Palmer amaranth in Xtendflex data has a similar trend to the Enlist trial, where dicamba followed by glufosinate at 7 DAT, and glufosinate followed by either dicamba or glufosinate at 7 DAT provided some of the least control among all treatments. For Palmer amaranth, the only respray sequence at 7 DAT that provided equivalent control to the best treatments was the growth regulator followed by the growth regulator in both trials. The Palmer amaranth trials were only conducted in the field during 2023.

Table 1. Waterhemp control, density, and biomass in the Enlist trial at Fargo, ND in 2023.

Treatment	Final Waterhemp Control (%)	Final Waterhemp Density (plants m^{-2})	Final Waterhemp Biomass (g m^{-2})
Enlist One fb Enlist One 7 DAT	95 AB	0 B	0 B
Enlist One fb Enlist One 14 DAT	99 A	0 B	0 B
Enlist One fb Enlist One 21 DAT	95 A	0 B	0 B
Enlist One fb Liberty 7 DAT	98 A	0 B	0 B
Enlist One fb Liberty 14 DAT	96 A	0 B	0 B
Enlist One fb Liberty 21 DAT	99 A	0 B	0 B
Liberty fb Enlist One 7 DAT	95 AB	1 B	2 B
Liberty fb Enlist One 14 DAT	94 AB	1 B	2 B
Liberty fb Enlist One 21 DAT	91 B	0 B	0 B
Liberty fb Liberty 7 DAT	91 A	1 B	1 B
Liberty fb Liberty 14 DAT	95 AB	0 B	0 B
Liberty fb Liberty 21 DAT	95 AB	1 B	2 B
Nontreated	0 C	23 A	154 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 initial treatment. fb: followed by. Different letters within same column represent statistical separation at P<0.05

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

This research found treatment differences for respray timing and herbicide with a failed postemergence application. Although there is some variability for 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 original application to determine the success and to allow for time to line up another application 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 relying on the use of postemergence herbicides.

Figure 1. Joe Ikley, Ph. D., provides a research update at the Agronomy Seed Farm.

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

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

Funded Project $17,734

Why this Research is Important to North Dakota Soybean Farmers

Soybean crops in North Dakota rely on symbiosis with the rhizobia bacteria, *Bradyrhizobium japonicum*, for their nitrogen needs, reducing the necessity for nitrogen fertilizers. This symbiosis occurs through nodulation, where rhizobia form nodules on soybean roots, fixing atmospheric nitrogen for the plants. Current practices suggest that inoculants need not be reapplied after the first one or two years if soybeans are grown again in the same field, based on experiences in eastern North Dakota. As soybean cultivation expands to western North Dakota with more challenging soil and climate conditions, these recommendations may not hold. This research aims to explore inoculation recommendation based on a newly developed molecular tool (NDSoy2.0) and the response to a variety of inoculant options.

Objectives

1. Establish guidelines for inoculant recommendations based on rhizobia levels in the soil.
2. Investigate the necessity of more frequent inoculation in eastern and western North Dakota.
3. Compare the efficacy of different inoculant options (liquid, peat, granular and double inoculation) with varying rhizobia levels in the soil.

Research Conducted

Fields with varying histories of soybean cultivation were selected at the Williston, Hettinger, and Carrington Research Extension Centers (RECs). Soil samples from these fields were analyzed using a quantitative polymerase chain reaction (qPCR) assay to quantify *Bradyrhizobium* populations. Inoculant plot trials were conducted with treatments that included uninoculated, liquid, granular, peat and double inoculation. Nodulation was assessed, and yield and seed quality parameters were measured post-harvest.

Findings of the Research

- Low Rhizobia Plots: Plots without a previous soybean history showed no detectable *Bradyrhizobia* populations, indicating the necessity of inoculation.
- High Rhizobia Plots: Varied populations suggested different inoculation needs based on rhizobia levels.
- Significant increases in nodulation were observed for the low rhizobia plots, especially with liquid inoculant.
- No significant yield differences were detected across treatments, possibly due to sufficient residual soil nitrogen.

Benefits for Soybean Farmers

The study confirmed that the molecular tool can effectively guide inoculant decisions based on the soil's rhizobia levels. The liquid inoculant showed superior performance for nodulation compared to granular or peat products. The findings supported the current recommendations that farmers should not expect a response from inoculation if soybean rhizobia have been established in the field for approximately 5 years after previous inoculation.

Figure 3. Barney Geddes, Ph. D. examines soybean nodules.

Figure 1. Nodulation data from plot trials with varying levels of rhizobia and soybean planting history.

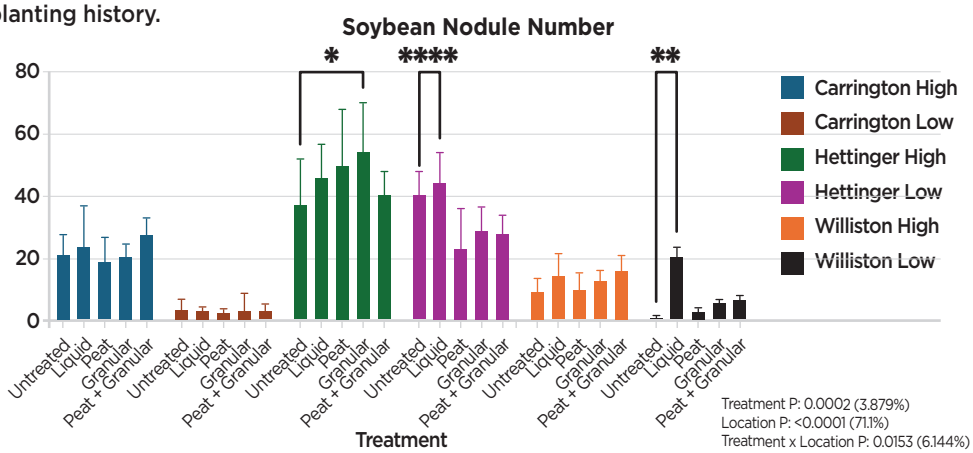
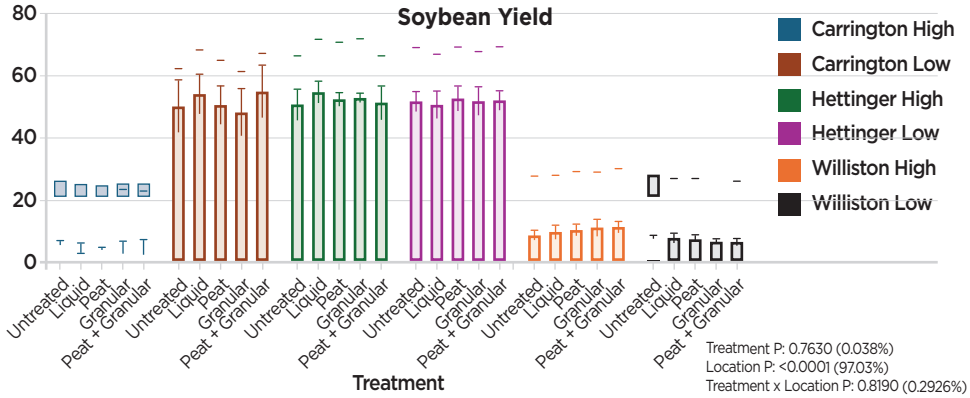


Figure 2. Yield data from plot trials with varying levels of rhizobia and soybean planting history.



Reversing Herbicide Resistance in Waterhemp and Palmer Amaranth

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

Funded Project $15,477

Why the Research is Important to North Dakota Soybean Farmers

Herbicide-resistant waterhemp and Palmer amaranth represent serious concerns for North Dakota soybean growers. Conducting research on emerging genetic biocontrol strategies requires safety considerations to ensure that any plants with the 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

We previously used waterhemp cell suspension cultures to generate protoplasts (cells without cell walls) in order to facilitate genetic transformation. However, these protoplasts did not express introduced genes and did not recover and divide. Further investigation identified significant oxidative stress among the protoplasts, and the current research project explored methods to reduce oxidative stress and to stimulate the waterhemp protoplast's cell division.

Findings of the Research

Ascorbic acid, at low concentrations, was found to have the potential to lower oxidative stress. This benefit was reduced at higher concentrations, however, perhaps due to acidity or other negative effects. Cell wall digesting enzymes from four different commercial sources were also compared, and contrary to our previous research, significant differences for the waterhemp protoplast's oxidative stress among the enzyme sources was not observed.

Inhibition of phenylalanine ammonia lyase (PAL) was also tested to reduce oxidative stress and to stimulate cell division for waterhemp protoplasts. Incorporating the PAL inhibitor 2-aminoindane-2-phosphonic acid (AIP) into culture media successfully produced cell division among waterhemp protoplasts, albeit at a low rate. After 10 days of culture with AIP, 5.5% to 6.0% of the protoplasts were dividing. Additional pretreatment of cell suspension cultures with AIP for 10 days before protoplast isolation produced similar rates of division, although the cells appeared to be fuller and healthier than without the AIP pretreatment.

While obtaining cell division for the waterhemp protoplasts was a significant advancement, growth only continued for a few divisions. More research needs to be done to achieve continued division and growth for the waterhemp protoplasts. In addition, two cell-suspension cultures were produced from Palmer amaranth and will be used to create protoplasts for research in a manner similar to waterhemp.

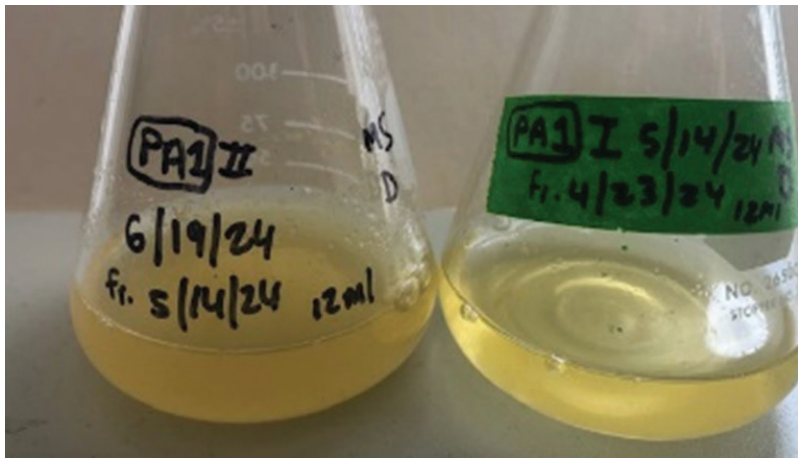
> ***"Conducting research on emerging genetic biocontrol strategies requires safety considerations to ensure that any plants with the genetic changes are not allowed to reproduce and escape containment."***

Benefits for North Dakota Soybean Farmers

This research improved the current protocols for genetic research with waterhemp by obtaining the cell division of protoplasts. Palmer amaranth cultures were also established, and these cultures will be valuable for future genetic research with this important weed. Both results will facilitate research that investigates the emerging genetic biocontrol methods to limit herbicide-resistant weeds.

Figure 1. Waterhemp protoplasts (cells without cell walls) undergoing cellular division.

Figure 2. Palmer amaranth cell suspension cultures.



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
$7,101

Why the Research is Important to North Dakota Soybean Farmers

Study 1: Rye fall seeding dates and rates: Farmers who use rye as a cover crop preceding soybeans require recommendations for fall seeding dates and rates to meet goals, including soil management and other benefits. Rye cover crop planting dates can range from August to November, and planting rates may range from 20 to 90 pounds per acre (lb/ac). The study's objective is to determine the appropriate rye seeding rate and the established stand preceding soybean production, including ground cover, soil moisture and weed suppression with rye.

Study 2: Response to prior-year application of phosphorus P fertilizer: Preplant (P) fertilizer application before the year of soybean production, typically on corn with one total application rate for corn and subsequent soybean production, is a common strategy in the eastern Corn Belt states. Advantages include reducing fertilizer input costs with one less trip across the field and, possibly, more flexibility with the available fertilizer supply and prices. The study's objective is to examine soybean yield response on 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. This research will help verify the use of this strategy as a productive fertilizer program.

Research Conducted

Study 1: Research was conducted for 4 years at the Carrington Research Extension Center (REC). Treatments: Winter rye was seeded during the last half of September and approximately one month later at 25, 50 and 75 lb/acre (six treatments). Rye was terminated with glyphosate near the soybean planting time, and trial data were generated before and during soybean production.

Study 2: Research was conducted in 2021-2023 at the Carrington REC and in 2022 at the North Central (Minot) REC. P soil analysis: Carrington = 2-7 parts per million (ppm; very low-low) and 7.7-8 pH, and Minot = 8 ppm (medium) and 6.5 pH. Treatments: 1) untreated check, 2) preplant-applied P fertilizer applied to corn followed by P application the next year for soybeans and 3) P applied to corn plus soybeans during the year of corn production. The P fertilizer (triple superphosphate) rate was based on NDSU Extension's recommendations for low-testing soils during corn and soybean production.

Findings of the Research

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

Study 2: Carrington: Averaged across 3 years on low-P testing soils, the soybean yield increased with P application compared to the untreated check and was similar among the P application strategies.

Minot: The soybean yield was similar among treatments.

Figure 3. Greg Endres, cropping system specialist (retired).

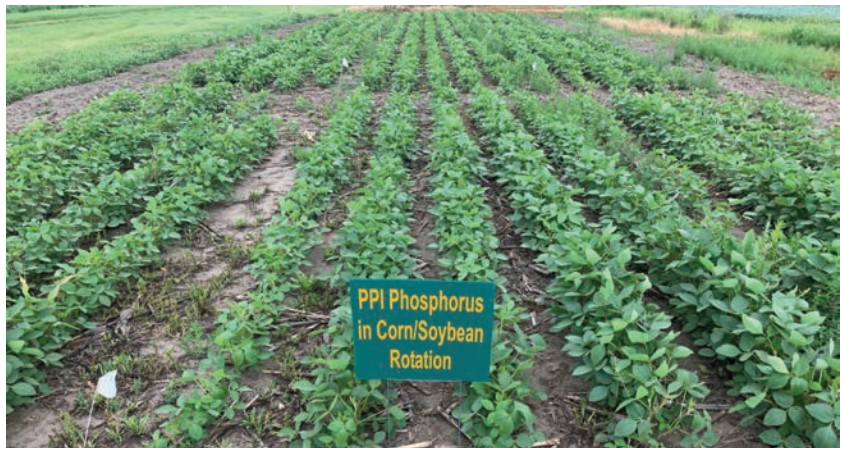
Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

Study 1: The early fall seeding date at 75 lb/acre provided the greatest cover crop ground cover and weed suppression while maintaining favorable soybean performance.

Study 2: With this study's conditions, applying P fertilizer during the year before soybean production is an acceptable alternative strategy versus in-season P application for the crop.

Figure 1. Soy rye: Terminated rye within soybeans.

Figure 2. Psoy: Trial with phosphorus fertilizer treatments.



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

Principal Investigator: *Caleb Dalley, North Dakota State University (NDSU) Hettinger Research and Extension Center*

Funded Project
$7,500

Why the Research is Important to North Dakota Soybean Farmers

Weed control is one of the most important problems when producing high yielding soybean crops. In southwest North Dakota, where soybeans are a relatively new crop, weed control is increasingly challenging due to the no-till cropping systems and problematic weeds, such as kochia. A better understanding of the weeds' response to herbicides in this climate and with these production practices is needed. The objective of this research is to compare weed control strategies using preemergence and postemergence herbicides for soybeans.

Research Conducted

On May 10 and May 19, five different herbicide treatments were applied to research plots prior to planting soybeans on May 26. The same treatments were applied immediately after planting the 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.

These treatments were compared with split applications of glyphosate (at planting and on June 19 at the soybeans' vegetative 1 (V1) growth stage). Treatments were also compared to glyphosate plus dicamba applied at planting or at the V1 soybean stage (also June 19), with an untreated control where no herbicide was applied and with a weed free control. Glyphosate (1.5 pounds acid equivalent/acre) was applied across all treatments when soybeans reached the R1 growth stage (flowering) to manage weeds which were not controlled by earlier treatments.

Findings of the Research

The timing of preplant or at-planting herbicide applications, generally, did not affect weed control or soybean yield. Valor (flumiozazin) alone provided poor control (68%) of kochia (Table 1). The addition of Zidua (pyroxasulfone) to Valor increased kochia control to 85%. BroadAxe (sulfentrazone plus metolachlor) provided good control (83%) of kochia. Authority Supreme (sulfentrazone plus pyroxasulfone) controlled kochia at 89%. Similarly, Authority MTZ (sulfentrazone plus metribuzin) resulted in 87% control of kochia. Xtendimax (dicamba), whether applied at planting or at the V1 soybean growth stage, provided excellent control (95%) of kochia. A split application of Roundup PowerMax 3 (glyphosate) at planting and at V1 also provided good control of kochia (89%). Weed control with these same treatments was much less in 2022. In 2023, there was more than adequate rainfall to activate and to incorporate the preemergence herbicide treatments compared for this trial. In 2022, rainfall was limited, which reduced the control of kochia and other weeds.

All herbicide treatments increased soybean yield compared to when no herbicide was applied. Of the herbicide treatments, Valor alone resulted in the lowest soybean yield due to poor weed control compared with other treatments. The highest yield (34 bushels per acre) was for the weed-free control and with multiple glyphosate applications, or with Xtendimax applied at the V1 soybean growth stage (33 bushels per acre). The preemergence herbicides compared in this trial all provided similar soybean yield, ranging from 26 to 30 bushels per acre.

Figure 1. Soybeans treated with glyphosate at the time of planting and again at the V1 soybean growth stage (1st trifoliate leaf) for weed control.

Applying preemergence herbicides will be an important tool to control weeds for soybeans in southwest North Dakota. In most cases, a postemergence application of glyphosate or dicamba will still be required for weed control. It will reduce weed competition during the soybeans' early growth stages and will help decrease the reliance on single herbicide modes of action, which have been shown to increase the risk of creating herbicide-resistant weed populations.

Table 1. Effect of herbicide treatments on weed control and soybean yield at Hettinger, North Dakota, in 2023.

Herbicide treatment*	Rate	Kochia	Wild buckwheat	Green foxtail	Soybean yield
	(oz./a)	control (%)			bu/ac
1) Untreadted		0	0	0	0
2) Valor	3	68	99	28	26
3) Valor + Zidua SC	3+5	85	100	89	30
4) BroadAxe	32	83	98	82	27
5) Authority Supreme	9.8	89	97	82	29
6) Authority MTZ	18	87	99	56	27
7) Xtendimax PRE	22	95	99	56	27
8) Xtendimax POST	22	95	99	72	30
9) Roundup PowerMax 3 (2X)	20	89	98	94	34
10) Weed free		100	100	99	34
LSD (0.05)		7	4	8	6

*Treatments 2-8 were tank mixed with glyphosate along with (an) appropriate adjuvant(s). Treatments 2-6 were an average of three application timings that were applied either at planting or at 1 or 2 weeks before planting. Treatment 7 was applied at planting. Treatment 8 was applied when soybeans 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 Investigators: *Larry Cihacek, Ph.D., and Rashad Alghamdi, Ph.D., North Dakota State University (NDSU) School of Natural Resource Sciences*

Funded Project $9,790

Why the Research is Important to North Dakota Soybean Farmers

In North Dakota, no-till agriculture has become a common practice, with more than a third of the cropland acreage being managed as no-till land; an additional one-third of the crops are managed with other conservation and residue management practices. The post-harvest residue remaining on the soil's surface is high in carbon (C) content and low in nitrogen (N) content due to offtake of the N as protein in grain crops. Soybean growers raise other crops that benefit from a legume crop in their rotation due to the N fixation and plant diversity that assist with weed, insect and disease control. However, with the relatively short season and the cool climate of the northern Great Plains, we have noted consistent N immobilization in our laboratory experiments. This study was established to evaluate the effect of the seasonal soil moisture and temperature conditions on soil microbial activity as well as the rate of residue breakdown.

Research Conducted

We have been conducting field validations of mineral N cycling 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 placed 5 centimeters (cm; 2 inches) below the surface to evaluate field temperature and moisture changes across the growing season. These changes in moisture and temperature affect the rate of N mineralization and may influence crop-available N at different points across the growing season. The temperature and moisture changes affect the soil's microbial activity during residue decomposition and may also affect the N immobilization that we have observed in other studies.

Findings of the Research

The crop residue's texture appears to influence moisture "conservation" when remaining on the soil surface, as happens with no-till conditions. Spring wheat residues promoted the highest levels of moisture content when compared to other residues. This result may be due to the spring wheat residue providing a more uniform surface cover due to its finer texture and ability to "flatten" over time when compared to corn or soybean. Many studies that estimate N mineralization from crop residues in laboratory environments are conducted at temperatures of 30° to 35°Celsius (C). In our study, the seasonal soil temperatures generally average 25°C or less. This is significant because earlier studies may have overestimated N mineralization from residues that may need to be replaced by additional fertilizer in no-till systems.

"The crop residue's texture appears to influence moisture "conservation" when remaining on the soil surface, as happens with no-till conditions."

Figure 1. Rashad Alghamdi, Ph. D., and Larry Cihacek, Ph. D., performs winter maintenance and battery checks for the instrumentation.

Optimizing Fungicide Spray Volume for Improved White-Mold Management in Soybeans

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

Funded Project $66,200

Why this Research is Important to North Dakota Soybean Farmers

Fungicide spray volumes greater than 10 gallons per acre (gal/ac) are widely recommended for white-mold management in soybeans, but data about the spray volume's influence are lacking. This research was designed to 1) identify the minimum fungicide spray volume needed to maximize white mold control as well as soybean yield and quality, 2) evaluate whether the influence of fungicide spray volume with white-mold management differs for a single fungicide application versus two sequential applications and 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 studies were conducted in Carrington and Oakes, North Dakota, in 2022 and 2023 with overhead irrigation for soybeans seeded at 165,000 viable seeds per acre in rows that were 14 inches apart. Testing was conducted on three to four varieties per location per year. Varieties with different height and bushiness were selected; approximately half of the varieties had 'Enlist', and approximately half of the varieties had 'Extend' herbicide traits. A single application versus two sequential applications of Endura fungicide (5.5 ounces per acre) were tested, with applications made with a tractor-mounted, PTO-driven sprayer equipped with a pulse-width modulation system (Capstan Ag; Topeka, Kansas). The pulse width was modified, as needed, to maintain the same nozzles, application pressure and driving speed

Figure 1. Influence of fungicide spray volume on white-mold management and soybean yield: Carrington and Oakes (2022 and 2023). Endura (5.5 oz/ac) was applied once at the early or full R2 growth stage. Within-column means followed by different letters are significantly different (P < 0.05; Tukey multiple comparison procedure).

	Carrington 2022 Four varieties (0.6-0.9 maturity)	**Carrington** 2023 Four varieties (0.6-0.7 maturity)	**Oakes** 2022 Three varieties (1.0-1.2 maturity)	**Optimal spray conditions** Combined analysis across **3 studies**	**Oakes** 2023 Three varieties (1.0-1.2 maturity)	**Marginal spray conditions** Results from **1 study**
	Single fungicide application			Applications **below 10 gal/a** made when:		Applications **below 10 gal/a** made when:
	July 25, **early R2** Time, **Delta T**:	July 12, **early R2** Time, **Delta T**:	July 21, **full R2** Time, **Delta T**:	Delta T > 4.0 **or** Delta T > 3.0; canopy with no dew	July 6, **early R2** Time, **Delta T**:	Delta T < 3.0 canopy with dew
5 gal/a	3:50 pm **5.3**	4:38 pm **3.7**	9:40 am **5.6**		7:53 am **2.2**	
7.5 gal/a	3:18 pm **5.2**	4:15 pm **3.8**	9:17 am **4.8**		7:36 am **1.8**	
10 gal/a	2:32 pm **5.2**	3:55 pm **3.8**	8:53 am **4.0**		7:20 Am **1.3**	Applications **above 10 gal/a** made when:
12.5 gal/a	2:10 pm **5.1**	3:25 pm **3.9**	8:20 am **3.1**		6:48 am **0.7**	
15 gal/a	1:45 pm **5.0**	3:00 pm **3.9**	7:55 am **2.5**		6:17 am **0.3**	Delta T < 1.0; canopy with dew
White mold (% of canopy)						
Non-treated	**34** b*	**57** b*	**17** a*	**36** b*	**54** c*	**54** c*
5.0 gal/ac	**27** a	**43** a	**15** a	**28** a	**53** c	**53** c
7.5 gal/ac	**28** ab	**41** a	**11** a	**27** a	**51** bc	**51** bc
10.0 gal/ac	**27** a	**44** a	**13** a	**28** a	**42** a	**42** a
12.5 gal/ac	**24** a	**44** a	**10** a	**26** a	**48** b	**48** b
15.0 gal/ac	**28** a	**45** a	**13** a	**29** a	**48** b	**48** b
F, P>F:	6.17, 0.0027	7.37, 0.0011	2.73, 0.0829	6.70, 0.0056	19.90, <0.0001	19.90, <0.0001
CV:	9.1	9.1	19.9	8.1	4.2	4.2
Yield (bu/a)						
Non-treated	**51** b*	**42** b*	**68** a*	**54** b*	No yield data due to harvest problems	
5.0 gal/ac	**55** a	**49** a	**71** a	**59** a		
7.5 gal/ac	**53** ab	**51** a	**70** a	**58** a		
10.0 gal/ac	**54** a	**49** a	**70** a	**58** a		
12.5 gal/ac	**56** a	**51** a	**70** a	**59** a		
15.0 gal/ac	**54** ab	**49** a	**70** a	**58** a		
F, P>F:	5.25, 0.0055	7.41, 0.0011	1.34, 0.3249	6.48, 0.0062		
CV:	2.9	4.9	2.3	2.3		

across the treatments which differed in spray volume. Fungicide spray volumes of 5.0, 7.5, 10.0, 12.5 and 15.0 gal/ac were tested, with the pulse width manually calibrated in the field immediately before application based on measured spray output.

Findings of the Research

The response to fungicide spray volume was consistent across soybean varieties with different plant architectures, but varied across application dates and study locations. Responses to the spray volume were observed when fungicides were applied early in the morning to a canopy that was wet with dew when the relative humidity was high, the temperatures were cool, and the Delta T values were low. Delta T is a measure of the spray droplets' evaporative potential; droplets tend to drift off-target with low Delta T values and can evaporate before hitting the surface at high Delta T values.

Applying spray volumes greater than 10.0 gal/ac did not improve white mold management or soybean yield in any study. There was a penalty for applying a spray volume below 10.0 gal/ac when the canopy was wet with dew, the relative humidity was high and the Delta T was low (Figures 1 and 2). When the 10.0, 12.5 and 15.0 gal/ac treatments were applied early in the morning to a canopy that was wet with dew and had a low Delta T (between 0.3 and 1.3), the spray-volume treatment applied with the best spray conditions performed best (Figure 1; Oakes, 2023).

The results suggest that fungicide applications should not be made when the Delta T values are below 1.0 and that spray volumes below 10.0 gal/ac are most likely to carry a penalty when applying fungicides to a canopy that is wet with dew early in the morning.

"The results suggest that fungicide applications should not be made when the Delta T values are below 1.0 and that spray volumes below 10.0 gal/ac are most likely to carry a penalty when applying fungicides to a canopy that is wet with dew early in the morning."

The North Dakota Soybean Council offers a variety of short videos showcasing checkoff-funded soybean production research. Visit our YouTube channel at YouTube.com/NDSoybeanCouncil to watch these videos and subscribe to stay updated with our latest content. You can also view the videos directly at bit.ly/NDSCresearchvideos

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

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

Funded Project $43,900

Why the Research is Important to North Dakota Soybean Farmers

Phytophthora root and stem rot, caused by the Phytophthora species, is one of the most devastating diseases for soybeans in the state of North Dakota. Being most prevalent during years with excessive moisture, this disease can lead to crop loss throughout the entire growing season. Resistance is the most effective management strategy, with the ability to eliminate the development of Phytophthora root and stem rot if using genes that are resistant to *Phytophthora sojae* (Rps) in the soybean varieties. However, there are multiple Rps genes available commercially, and not all Rps genes are effective against every Phytophthora population across the state. The research aims to investigate the distribution of *Phytophthora sojae* across the state, to examine a new Phytophthora species that has previously been reported to be pathogenic on soybeans and then to screen these populations for the effectiveness of Rps genes.

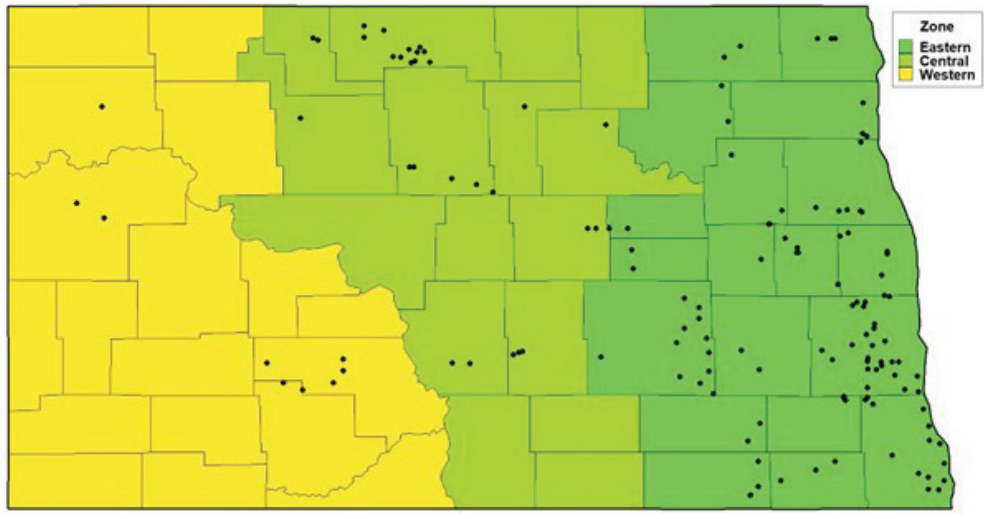
Research Conducted

During the 2023-2024 season, 147 soil samples were collected from across North Dakota with the help of stakeholders, county Extension agents and industry representatives. These samples represented a wide coverage across the state for all soybean growing regions. The soil samples were processed by sieving the soil to break up clumps. The soil was placed into cups and flooded to trigger Phytophthora to "wake up" and to produce viable spores. Then, small leaf discs of a susceptible soybean were floated at the top of the flooded soil to allow infection into the leaf. The leaves were then transferred to selective growth media for pathogen development outside the leaf. The isolates were then transferred to new plates to identify their species using microscopy. Probable samples were then utilized to extract DNA for molecular identification using internal transcribed spacer (ITS) sequencing.

Findings of the Research

From this research during the 2023-24 season, one interesting finding was the general, widespread presence of Pythium species across the collected soil samples. The vast majority of the isolated species have been identified as Pythium by either morphological or molecular methods. So far, only 10 isolates appear to be Phytophthora. A possible reason for so few Phytophthora isolates could be the dry conditions present during the 2023 field season, which made it difficult to identify field areas with high Phytophthora pressure. However, these results may illustrate that many suspected Phytophthora incidences may be more complicated than we had believed, and they may involve the presence of Pythium species at a higher level than previously suspected. The results need to be confirmed in future years to determine if this is true for North Dakota's soybean production fields.

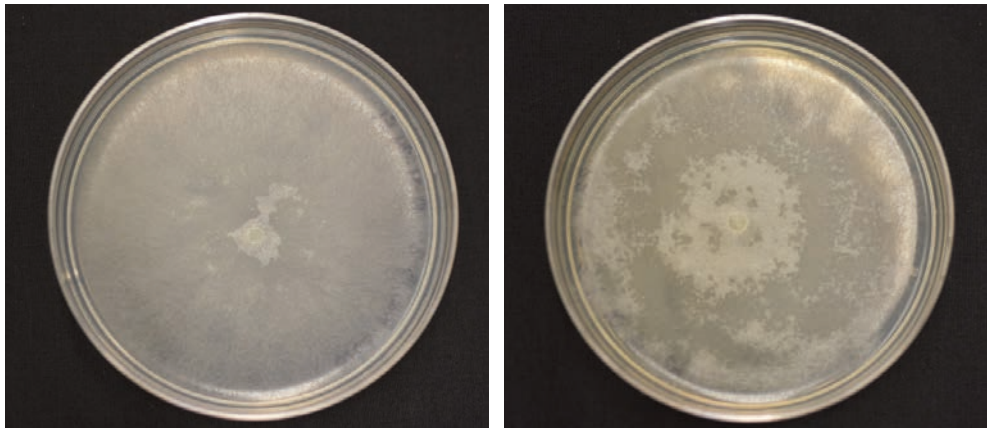
Figure 1. Map of North Dakota with the locations for soil samples collected to evaluate *Phytophthora sojae* populations.



Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

This study's results allow farmers to better understand the pathogen's presence within their fields. In this research, the Pythium species appear to be more prevalent than previously estimated. This finding affects management strategies because there is no genetic resistance similar to Phytophthora Rps genes available commercially, and farmers may need to rely more on seed treatments to properly control seedling disease and stand-loss issues with these different pathogens. More work is needed to better understand the distribution and status of Phytophthora populations across the state.

Figure 2. Oomycete growth from susceptible soybean leaf discs.



Validation of *Sclerotinia sclerotiorum* Apothecial Prediction Models for North Dakota and the Evaluation of Soybean Resistance to White Mold

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

Funded Project $36,450

Why the Research is Important to North Dakota Soybean Farmers

This research addresses white mold, a significant and unpredictable challenge for North Dakota soybean farmers. The disease thrives under specific environmental conditions, making its occurrence inconsistent and difficult to manage. By improving the accuracy of predictive tools like Sporecaster, tailored to North Dakota's diverse growing regions, farmers can make better decisions about fungicide applications, potentially saving costs by avoiding unnecessary treatments. Additionally, the study focused on identifying soybean germplasm with diverse genetic resistance, which is essential for developing new, more resilient varieties to combat this persistent disease.

Research Conducted

In 2023, our team collaborated with NDSU county Extension agents to scout soybean fields across North Dakota with a history of white mold. During the flowering stage, fields were monitored for apothecia, the small mushrooms that signal the presence of white mold.

To evaluate soybean resistance, 49 plant introduction (PI) lines from maturity groups 000-1 were tested under controlled greenhouse conditions. Using a highly aggressive isolate of *Sclerotinia sclerotiorum*, we inoculated plants at the V4 growth stage with the cut-petiole technique. Alongside these PI lines, four soybean genotypes with known resistance levels were included as standard checks. Resistance was measured by monitoring lesion development over three intervals, generating Area Under the Disease Progress Curve (AUDPC) values to assess and rank the level of resistance.

Findings of the Research

We scouted 16 soybean fields across North Dakota to test Sporecaster's predictions for fungicide applications. Results showed that adjusting the Sporecaster action threshold from the default 40% to 30% for non-irrigated fields significantly improved its accuracy. This adjustment allows farmers to better time fungicide applications, improving control and reducing unnecessary treatments.

In greenhouse trials, the screening of 49 PI lines revealed significant variation in resistance ($P < 0.01$). Several lines exhibited strong resistance to white mold, while others were highly susceptible. Notably, the susceptible lines (PI 458535 and PI 548601) provide valuable tools for future genetic studies of disease resistance mechanisms. These findings contribute critical resources for breeding efforts focused on developing soybean varieties better adapted to North Dakota's growing conditions.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

This research equips farmers with improved tools and knowledge for managing white mold. The refined Sporecaster model, with its lower action threshold for non-irrigated fields, enhances the accuracy of fungicide application decisions, reducing unnecessary inputs and lowering costs. Meanwhile, the identification of resistant PI lines from Maturity Groups 000-1 provides essential building blocks for breeding new soybean varieties with improved white mold resistance.

Figure 3. Wade Webster, Ph. D., provided research update during the Agronomy Seed Farm Field Day.

Figure 1. Evaluation of early maturity soybean germplasm lines for resistance to *Sclerotinia sclerotiorum* under greenhouse conditions. The gold bars represent four soybean check lines with known levels of resistance Soybean lines that share letters do not differ as determined by Fisher's LSD (a = 0.05).

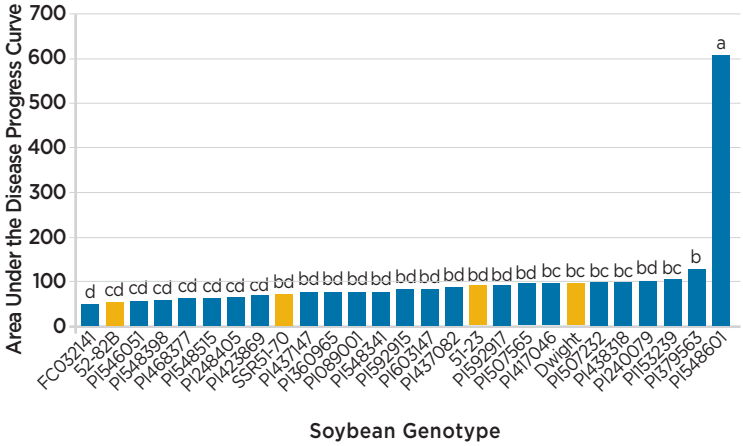
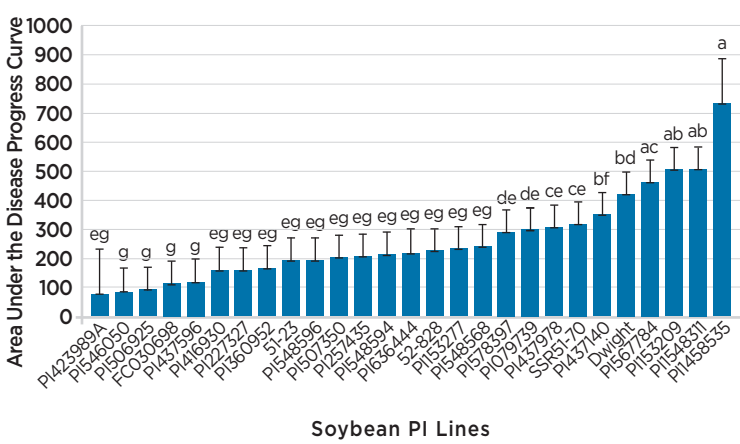


Figure 2. Evaluation of early maturity soybean germplasm lines for resistance to *Sclerotinia sclerotiorum* under greenhouse conditions. Soybean lines that share letters do not differ as determined by Fisher's LSD (a = 0.05).



Enhancing the Profitability of Soybean Production and Soil Health with Livestock Integration

Principal Investigators: *Miranda Meehan, Ph.D., Joshua Wianecki, and Zachary Carlson, Ph.D., North Dakota State University (NDSU) Department of Animal Sciences; Lindsay Malone, Ph.D., and Kevin Sedivec, Ph.D., NDSU School of Natural Resource Sciences*

Funded Project $48,382

Why the Research is Important to North Dakota Soybean Farmers

Integrated crop livestock systems (ICLS) may provide additional income and soil health benefits for producers utilizing winter cover crops. The effect of ICLS on row crop production has been demonstrated to be influenced by both crop and livestock management strategies with previous research showing how both crop rotation and the seasonality of grazing can sway the production benefits of ICLS. This project aims to determine the effects of ICLS and cover crop management on soil health, crop production and livestock performance within North Dakota.

Research Conducted

Two locations were selected to integrate livestock grazing into winter cover crop management. The management strategies included dual-season (fall and spring) grazing, spring grazing, no grazing and no cover crop. The soil's health was evaluated through nutrient analysis and physical health indicators, including bulk density and aggregate stability. Soybean production was evaluated with the soybeans' yield. Livestock performance was determined by the average daily gain during the grazing period.

Findings of the Research

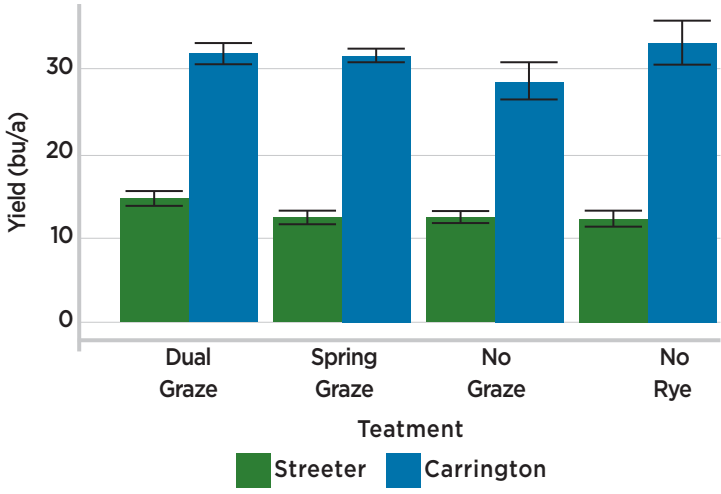
Grazing livestock caused no negative effects for crop production or soil health. Soil nutrients and aggregate stability did not differ among strategies. Only the spring graze treatment saw statistically higher bulk density; however, all bulk densities were below the levels that may harm root growth. Despite soybeans within the no-cover-crop plots attaining a larger size during staging, the soybean yield (Figure 1) did not differ, likely due to the soil's moisture and nutrients being retained within the cover-crop residues during the late season. The grazing duration and animal performance were variable, being highly dependent on precipitation and temperature during the cover crop's growing season.

Figure 2. Remaining winter rye residue in a spring grazed paddock immediately following the removal of the grazing cattle at Streeter in Spring 2024.

Benefits/Recommendations for North Dakota Soybean Farmers and the Industry

Livestock integration did not negatively affect the soil's health prior to soybean planting. Both cover-crop practices and livestock integration were shown to positively affect the soil's physical health over extended periods of time, which may not have been captured within this study. Planting date, temperature and precipitation all heavily influenced rye stands and the grazing's duration. Rye provided up to 0.84 animal use months per acre during early spring, which can reduce pressure on other grazing systems and can increase the flexibility for producers who are interested in both crop and livestock production.

Figure 1. Soybean yield in 2023



Miranda Meehan, Ph. D.

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 Richard (Wade) Webster at NDSU with questions: richard.webster@ndsu.edu • (701) 231-7057

Utilizing Soybean Hulls as a Supplemental Slow-Release Nitrogen Source for Crop Production

Principle Investigator: *Szilvia Yuja, North Dakota State University (NDSU) Carrington Research Extension Center*

Funded Project $12,560

Why the Research is Important to North Dakota Soybean Farmers

Two new soybean crushing plants were being built in North Dakota in 2022 and 2023, with a third facility planned in Grand Forks. With this recent expansion of soybean crushing capacity in the state, we anticipate that large quantities of soybean crushing by-products, such as soybean meal and soybean hulls, will become available at a reasonable price.

Due to their nutrient values, both soybean meal and soybean hulls have been used as soil amendments in home gardens, but their field-scale use has been prohibitively expensive due to the demand from the livestock industry. With large amounts of by-product soon to be generated in North Dakota due to soybean crushing, it is likely that substantial quantities would, occasionally, become available for a greatly reduced price. With such a scenario, farmers may wonder whether soybean hulls could be used as a source of fertilizer. This research is designed to evaluate the potential of utilizing soybean hulls as a supplemental slow-release nitrogen source for crop production by measuring the yield effect and the soil's residual nitrogen after harvest.

Research Conducted

We conducted a study to test at the three sites utility of soybean hulls as a source of nitrogen (N) fertilizer at the NDSU Carrington Research Extension Center; the research utilized three sites: a dryland site that is managed with conventional tillage; a dryland, long-term no-till site; and an irrigated site with conventional tillage. Spring wheat was used for this evaluation. The following treatments were applied:

- Check, no nitrogen
- 40 lbs N applied as urea
- 40 lbs N from soybean hulls
- Optimum N rate with a mix of 40 lbs N from soybean hulls + urea
- Optimum N rate with urea only

The optimum nitrogen rate was set at 90 pounds of nitrogen per acre for all three sites, which was within the recommended range for all of them. To determine the soybean hulls' nitrogen content, a sample was submitted for chemical analysis (Table 1).

Table 1. Nutrient analysis for a sample of pelleted soybean hulls.

N	P	K	S	Carbon	C/N ratio
2.3	0.13	1.4	0.12	44.4	19.3

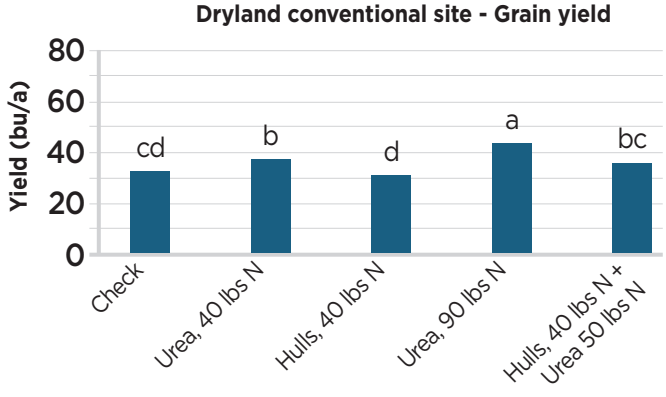
> *"There was no yield- or grain-protein response to the application of soybean hulls at any of the sites."*

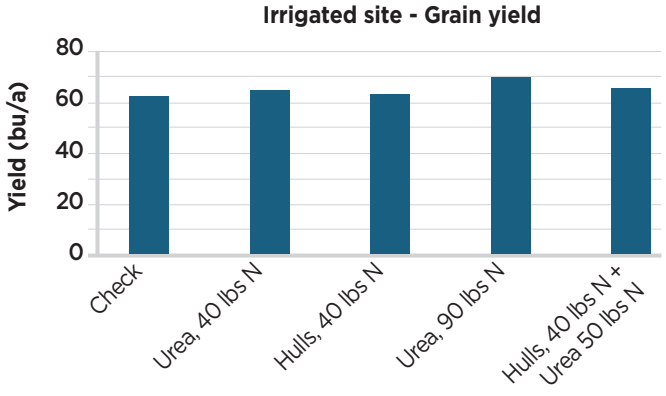
Findings of the Research

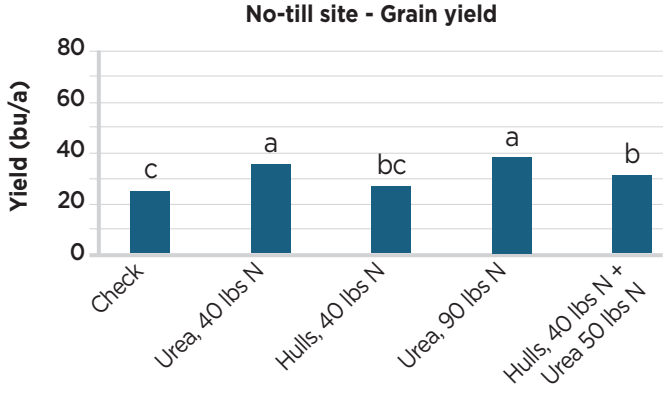
Only two of the three sites showed a crop nitrogen response: the conventional dryland and the no-till dryland. There was no yield- or grain-protein response to the application of soybean hulls at any of the sites (Figures 1, 2 and 3). Even though the applied hulls contained the equivalent of 40 pounds of nitrogen per acre, the nitrogen was not available to the plants during that year. The carbon-to-nitrogen ratio was likely too high for the hulls to release enough nutrients to have a positive influence. There was no negative effect with soybean hulls either, indicating that the soybean hulls did not tie up a substantial amount of nutrients. In the next season, we will plant spring wheat on two of the sites to see if there is any residual effect from the breakdown of the soybean hulls.

If soybean hulls are applied to the soil, they contribute organic matter, but based on this trial's results, the hulls are unlikely to benefit the crop during the application year.

Figures 1, 2, and 3. Grain yield by treatment from the conventional dryland, the conventional irrigated and the no-till dryland sites. Means labeled with different letters are significantly different from each other at the α = 0.1 level.







DGLA-Enriched Soybean Oil Production and Its Function for Anti-Aging Treatment

Principle Investigator: *Shaobin Zhong, Ph.D., North Dakota State University (NDSU) Department of Plant Pathology*

Funded Project
$15,000

Why the Research is Important to North Dakota Soybean Farmers

Dihomo-gamma-linolenic acid (DGLA) has been demonstrated to be potentially useful for cancer therapy and anti-aging treatment in humans. However, DGLA sources are very limited and cannot be found in the major vegetable oil producing crops because they lack the two enzymes (D6D [Δ6 desaturase] and D6E [Δ6 elongase]) to catalyze the conversion of linoleic acids (LA) into DGLA. By introducing the genes to express D6D and D6E into soybean plants, we developed transgenic soybean plants that produce GLA and DGLA in soybean oil. The function of GLA- and DGLA-enriched soybean oil for anti-aging treatments remains to be tested. By developing new soybean varieties that produce DGLA-enriched soybean oil, the soybean product's value can be increased, and the soybean markets will expand because DGLA-enriched oil has a huge potential for use in cancer therapy and for human consumption in order to reduce cancer- and aging-related risks.

Research Conducted

We increased the seeds from homozygous individuals (T1) derived from the four gene constructs (pBAtC: BCA-D6D-KTi-D6E, pBAtC: BCA-D6D-BCA-D6E, pBAtC: BCA-D6D-FAD2-D6E and pBAtC: BCA-D6D-Gmubi3-D6E) and analyzed the contents of fatty acids, including GLA and DGLA, in 20 soybean samples. We extracted GLA- and DGLA-containing soybean oil from three transgenic soybean lines that were homozygous for the transgene. These oil samples were used for experiments on mice. We applied DGLA ethyl ester (DGLA-EE) to old mice and evaluated its effect on liver fibrosis and inflammation. We also tested DGLA-/GLA-enriched soybean oil in a mouse model with chemotherapy-induced premature aging to examine its anti-aging function.

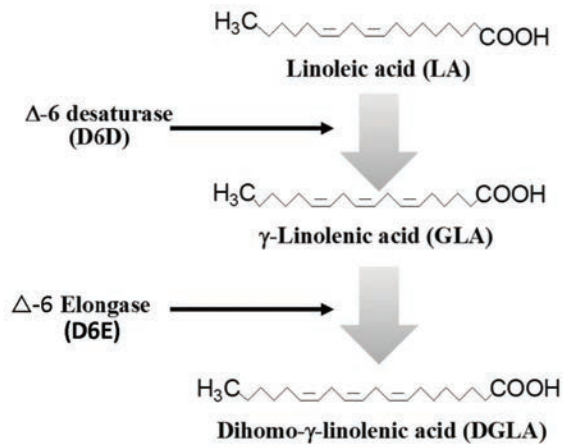


Figure 1. DGLA biosynthesis pathway. Two enzymes, delta-6 desaturase and delta-6 elongase, are required to convert linoleic acid (LA) into DGLA.

Findings of the Research

We generated different transgenic soybean lines using four gene constructs from two soybean varieties (Willimans and Thorne). We found that transgenic soybean plants with different gene constructs varied in DGLA production, depending on the promoters used. Some transgenic soybean lines produced little or no DGLA while other lines produced up to 33% GLA and 10% DGLA in the soybean oil. When old mice were given DGLA ethyl ester (DGLA-EE), markers for liver fibrosis and inflammation were reduced relative to vehicle-treated control mice. This result further confirmed the potential effectiveness of DGLA as a therapeutic that targets aging. DGLA-enriched soybean oil was also evaluated in mice that were pre-treated with a chemotherapeutic drug (doxorubicin, aka Adriamycin, abbreviated DOXO), but few phenotypic changes were observed in the treated animals, regardless of the DGLA status. Senescent cells increased following DGLA-enriched soybean oil in DOXO-treated mice, indicating that, with this model, DGLA-enriched soybean oil has the opposite effect of DGLA-EE on senescence.

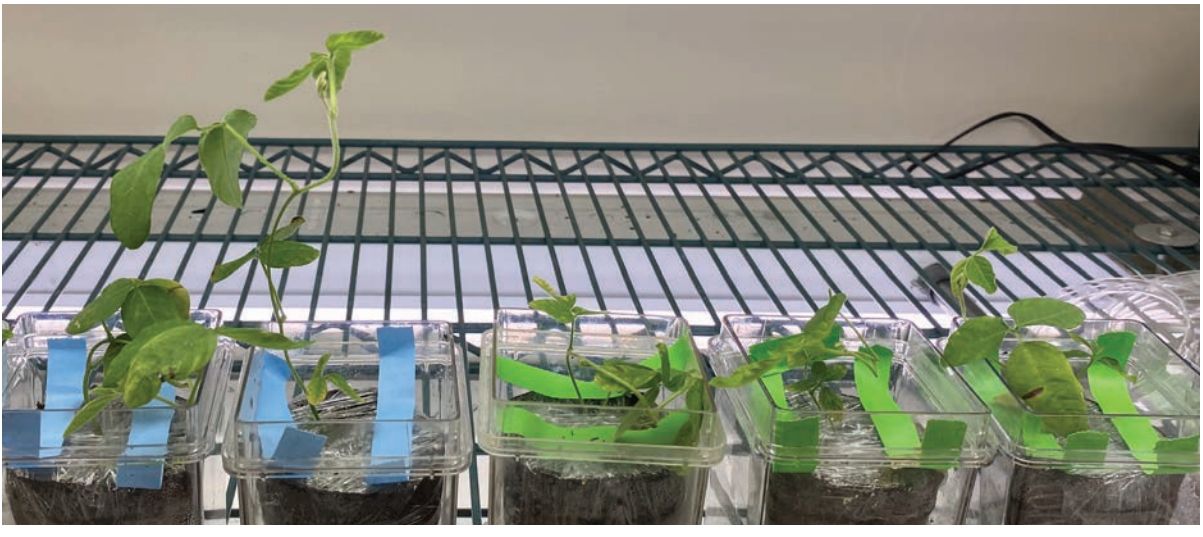


Figure 2. Transgenic soybean plants that contain the gene constructs for DGLA production.

Benefits/ Recommendations for North Dakota Soybean Farmers and the Industry

With few sources of free DGLA currently available, DGLA-enriched soybean oil could act as a supply for this compound. It may require further refinement from the triglyceride to the free fatty acid before any therapeutic benefits would be produced.

Development of Smart, Self-Healing, Injectable Gels for Local Cancer Therapy Using a Soy Protein Isolate

Principal Investigators: *Long Jiang, Ph. D., and Raj Hazra, Ph. D., North Dakota State University (NDSU) Department of Mechanical Engineering*

Funded Project $35,000

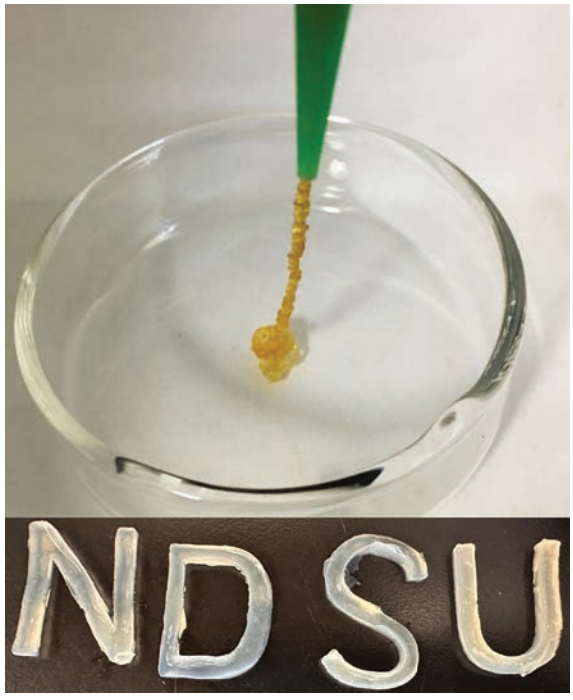
Why the Research is Important to North Dakota Soybean Farmers

Hydrogels (think of your favorite jelly snack), with their unique properties of high water content and biocompatibility, are used extensively with biomedical applications because they closely mimic the natural tissue environment. They serve as scaffolds for tissue engineering, providing a supportive framework for cell growth and regeneration, which is crucial with wound healing and organ transplantation. In drug-delivery systems, hydrogels offer controlled and sustained release of therapeutics, improving the treatments' efficacy and reducing the side effects. For this research, we aim to develop a cell-friendly hydrogel system that can support cell growth.

Findings of the Research

In this project, we develop hydrogels using soy protein as the main feedstock. The hydrogels are injectable (Figure 1), meaning that, in the future, they can be injected into a human body near a tumor site and start to release drugs to treat the tumor. The gels are designed to be smart. When there is no tumor around, the drug release from the gels is much slower, significantly reducing the side effects of cancer treatments (think of chemotherapy). This is because a tumor creates a lower pH environment around it, which can trigger the gels to release their drugs. We have shown that soy-based hydrogels are safe for normal human cells and are stable in a simulated environment that mimics the human body. We have tested two cancer-treatment drugs with the gels. Both medications are released from the gels at higher rates when the pH is low. Breast-cancer cells are subsequently killed by the released drugs (Figure 2). So far, all the experiments have been conducted in a simulated body-fluid environment. We plan to continue this study so that animal trials and, eventually, human trials can be performed.

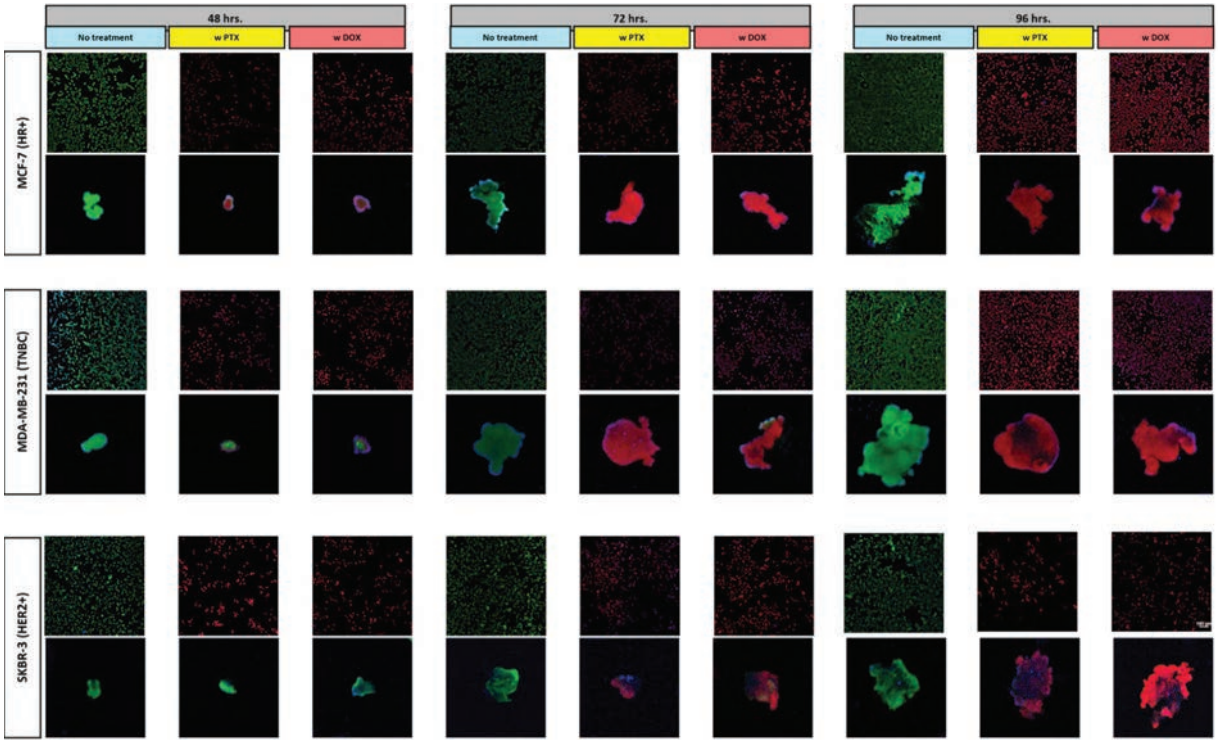
Figure 1. Soy-protein-based hydrogels can be injected and molded into different shapes.



Benefits for North Dakota Soybean Farmers and the Industry

The materials and technology utilized for the biomedical industry are expensive and in high demand. Using soy protein to create hydrogels that can be utilized for targeted drug release with cancer treatments is a new, high-value application for the crop. The hydrogels also have the potential for other biomedical applications, including tissue engineering and wound healing. These high-value applications can potentially increase the revenues for North Dakota soybean farmers and the industry.

Figure 2. Drug-loaded hydrogels kill two types of breast-cancer cells. The green color indicates living cells while the red color is for dead cells.



Flame-Retardant, Mildew-Resistant Soy Adhesive for Foamed Wood Siding and Other Wood Products

Principle Investigators: *Long Jiang. Ph.D., and Qian Ma, North Dakota State University (NDSU) Department of Mechanical Engineering*

Funded Project
$36,871

Why the Research is Important to North Dakota Soybean Farmers

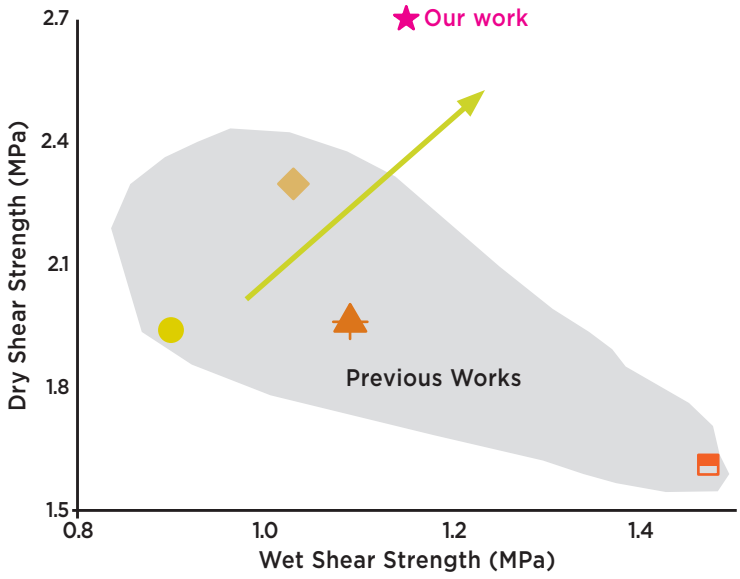
Finding large-scale, new uses for North Dakota soybeans is important to farmers because it can diversify the market and can reduce dependency on specific sectors (e.g., animal feed and oil). New options also increase the demand for soybeans, potentially leading to higher crop prices and increased profitability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

Research Conducted

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

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

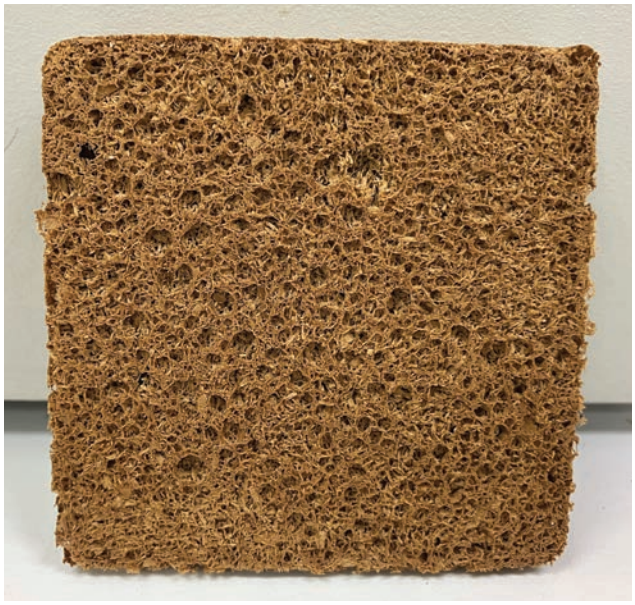
Figure 1. Comparison of dry and wet shear strength for the adhesives in this project and other studies.



Findings of the Research

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

Figure 2. Cross section of foamed wood particle board that was made using this project's adhesive.



Benefits for North Dakota Soybean Farmers and the Industry

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

> ***"The soy-based adhesive from this project is expected to take advantage of the wood adhesive market trend and, therefore, has a high market potential."***

Soy Protein Isolate-Based Electrolyte Gels for Anti-Freezing, Flexible Zinc-Ion Batteries

Principal Investigators: *Long Jiang, Ph.D., and Raj Hazra, Ph.D., North Dakota State University (NDSU) Department of Mechanical Engineering*

Funded Project
$31,000

Why the Research is Important to North Dakota Soybean Farmers

Flexible batteries with high energy storage and stretching/bending capabilities have recently attracted significant research interest to support the development of flexible electronics, such as wearable sensors for health monitoring and flexible displays. Compared to lithium-ion batteries (LIBs), zinc-ion batteries (ZIBs) have a lower cost and are safer to use while still having a good energy density. Hydrogels are very promising for flexible ZIBs among various flexible electrolytes due to their high ionic conductivity, good flexibility and intimate contact with the battery electrodes. The current generation of hydrogel electrolytes shows the drawbacks of poor low-temperature performance and a flexibility loss due to water in the hydrogels. The polymers used to make the hydrogels are also derived from petroleum. This project aims to develop robust, flexible, ionic conductive and freeze-resistant electrolyte gels based on a soy protein isolate (SPI).

Findings of the Research

By experimenting with different gel formulations and electrode fabrication processes, we created a soy-based hydrogel with high stretchability and flexibility, even at low temperatures (-78˚Celsius, Figure 1). Using this hydrogel as a separator, the assembled batteries showed good electrical performance and robustness. Mechanical stresses and deformations showed no notable effects with battery performance. The battery only exhibited a slight decrease in voltage when the temperature decreased from room temperature to -50˚Celsius (Figure 2). This soy-protein bio-based hydrogel is suitable for flexible, anti-freezing batteries that are in high demand for wearable and flexible electronics as well as other portable devices that are used in harsh conditions.

Benefits for North Dakota Soybean Farmers and the Industry

Using soy-based materials for this unique battery opens a new application route and potentially promotes soy-protein production and utilization. The global market for flexible batteries was estimated to be $294.2 million (USD) in 2020 and is projected to reach $2.4 billion by 2026, increasing at a compound annual growth rate of 40.8%. This project verifies that soy protein can be a potential cost-effective feedstock for a product in the fast-growing and high-value electronic market.

Figure 2. The battery's performance remains normal when the battery is folded or is at a low temperature.

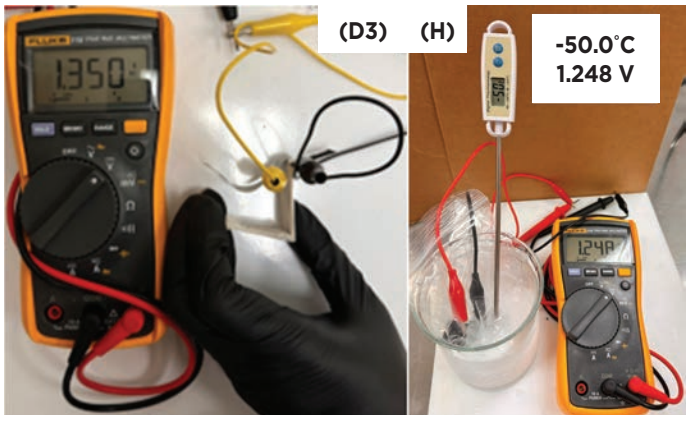
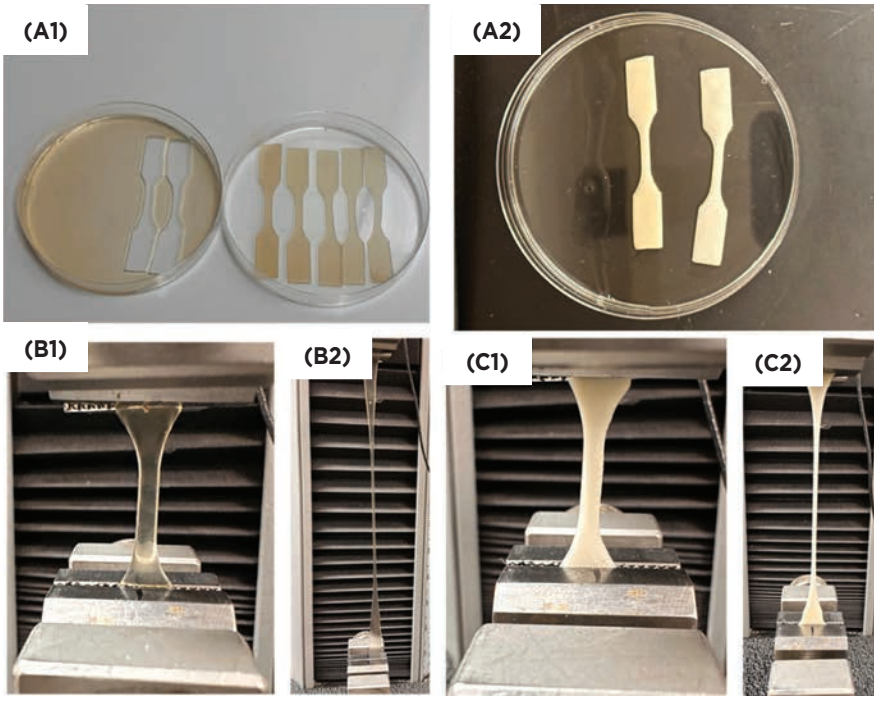
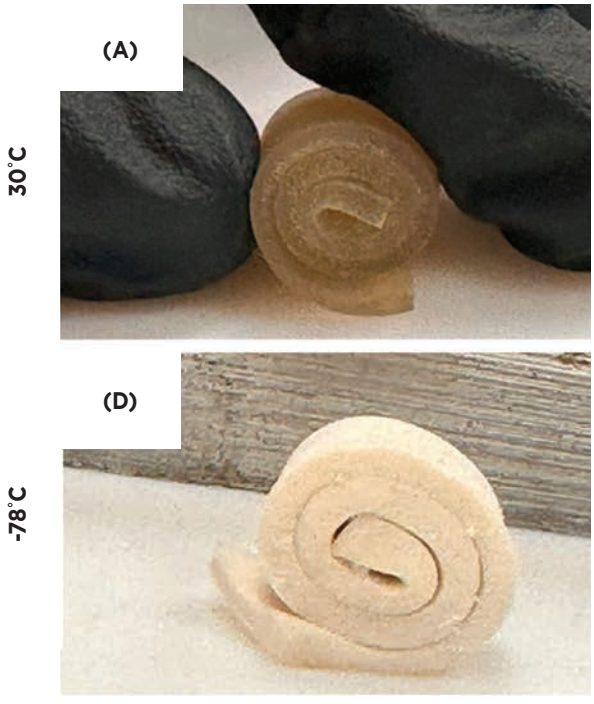


Figure 1. Photographs of the ionic conductive organohydrogel with stretching.





Bioconversion and Bioaugmentation of Soybean Meal for Sustainable Biofertilizer Production

Principal Investigators: *Ademola Hammed, Ph.D., Niloy Chandra Sarker, Ph.D., and Ewumbua Monono, Ph.D., NDSU Department of Agricultural and Biosystems Engineering*

Funded Project $65,150

Why the Research is Important to North Dakota Soybean Farmers

The expanding global population has increased the demand for sustainable biofertilizer sources, driving the exploration of alternative methods for the traditional agricultural practices. Microbial fermentation has emerged as a promising alternative due to its potential for high yields and low environmental influence. This study utilizes lignocellulosic biomass from soybean meal, hulls and other plant biomass as the primary feedstock (carbon source) for fermentation to increase the protein value. The microbial protein and *K. oxytoca M5A1*–soybean root-noodle microbes that can fix atmospheric nitrogen using inherent Nitrogenase–are also utilized for biofertilizer production. Using other biomass materials, such as switchgrass, as substrates reduces the cost of raw materials while the nitrogen-fixing capability of bacteria eliminates the need for nitrogen sources, thereby lowering the fermentation costs during microbial protein synthesis.

Research Conducted

This research involved the production of protein using lignocellulosic biomass, such as switchgrass and soybean meal residue, as the carbon source and the nitrogen-fixing ability of *K. oxytoca M5A1.* as the nitrogen source. The biomass was pretreated with aqueous ammonia and dried. The pretreated biomass was then converted to fermentable sugar at 50°Celsius for 72 hours. We quantified glucose and organic acids, monitored microbial growth and measured protein production. Additionally, the nitrogen-fixing capability of *K. oxytoca M5A1* was assessed to evaluate its efficiency for converting atmospheric nitrogen to a usable form.

Findings of the Research

The study discovered that *K. oxytoca M5A1* can use switchgrass hydrolysate as its carbon source and exhibits fast initial growth, meaning that the bacterium is capable of converting the hydrolysate into biomass effectively. During the beginning stages, the strain showed a high rate of glucose consumption; all glucose was used after only 16 hours, which suggests that *K. oxytoca M5A1* can rapidly metabolize the available sugars. Protein production took place over two phases, with higher quantities being produced when switchgrass hydrolysate was used instead of sucrose (control). This finding demonstrates hydrolysate's superior nutritional benefits for microbial protein synthesis. Furthermore, *K. oxytoca M5A1* effectively fixed nitrogen in both switchgrass hydrolysate and sucrose, highlighting its potential to reduce the need for external nitrogen sources and to enhance sustainability with microbial protein production.

Benefits for North Dakota Soybean Farmers and the Industry

The use of switchgrass and *K. oxytoca M5A1* for microbial protein production provides a sustainable and cost-effective alternative to traditional methods. Microbial fermentation can be supported with products realized after processing soybeans, such as hulls, alongside other plant remains. As a result, soybean by-products become more valuable and create additional income for farmers.

Figure 1. Growth profile of *K. oxytoca M5A1* in switchgrass hydrolysate, showing rapid initial growth that is followed by slower growth.

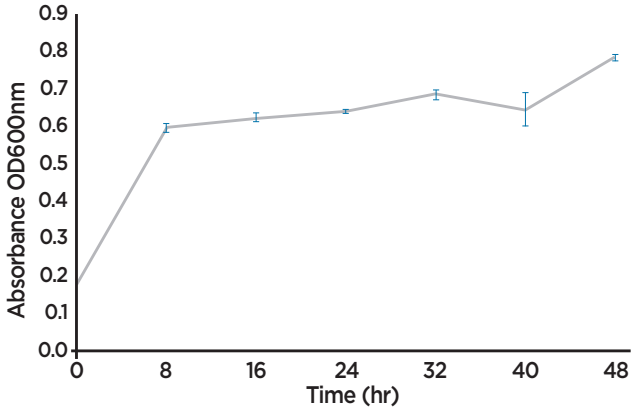


Figure 2. Glucose utilization during fermentation, with significant depletion within the first 16 hours.

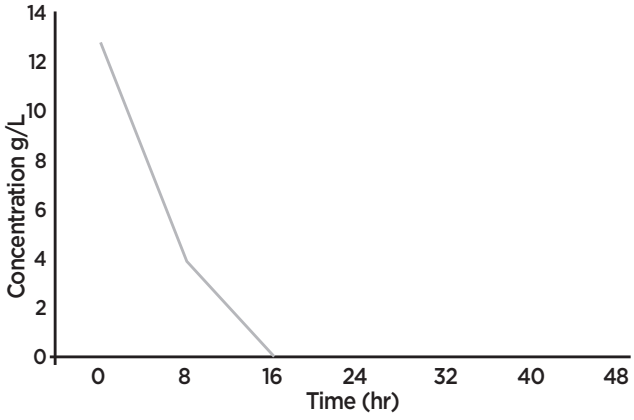
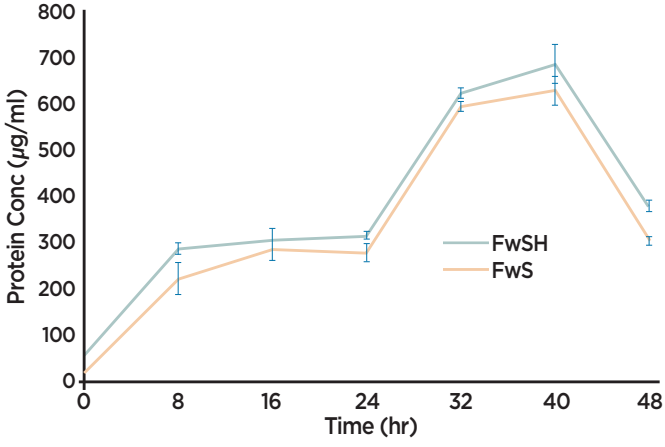


Figure 3. Microbial protein concentration of *K. oxytoca M5A1* in switchgrass hydrolysate and sucrose, highlighting the higher protein production for the hydrolysate.



Design and Commercialization of High-Value Functional Products from Soybean Meal

Principal Investigator: *Surojit Gupta, Ph.D., University of North Dakota (UND) Mechanical Engineering*

Funded Project $8,346

Why the Research is Important to North Dakota Soybean Farmers

The soybean crushing process yields two primary products: soybean meal (SBM) and soybean oil. While the oil serves various purposes, including human consumption and biodiesel production, SBM is primarily used as animal feed. Traditionally, soybean meal contributed about two-thirds of the total value from soybean crush products, with oil contributing the remaining third. However, recent price increases in soybean oil have made it the more valuable product. Developing high-performance functional materials with higher profit potential could offer new ways to enhance the value of soybean meal.

Research Objectives

1. Develop innovative pathways for producing SBM-based feedstocks.

2. Establish transformative methods for manufacturing novel, sustainable composites using SBM.

3. Conduct experimental studies to analyze the properties of these composites.

4. Create a commercialization strategy for materials developed in Phase II.

Research Conducted

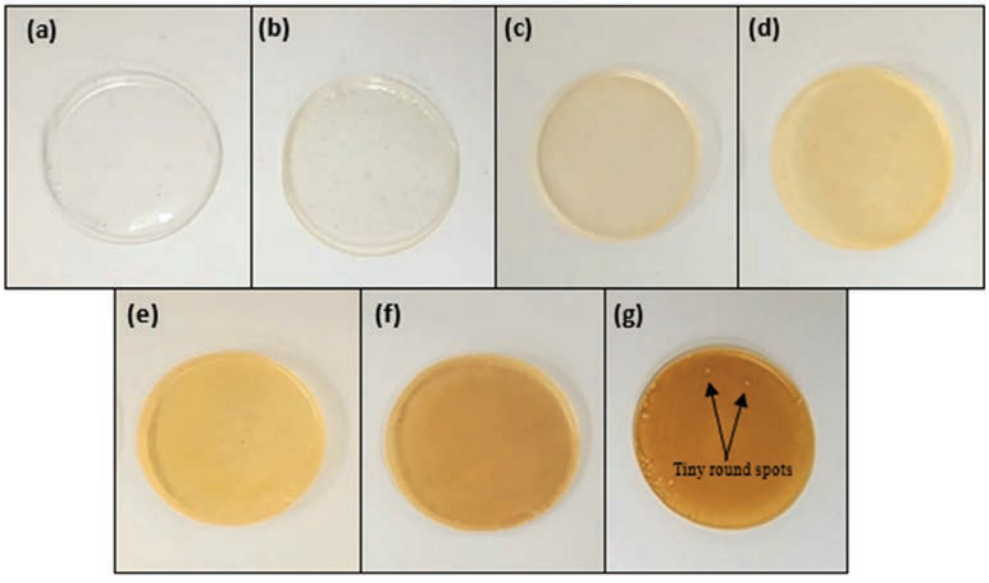
This study involved designing scaffolds by combining various fractions of polylactic acid (PLA) with soybean meal (SBM).

Findings of the Research

This research demonstrates, for the first time, that soybean meal (SBM) materials can achieve higher strength than various concrete grades (see Figure 1). Ultimate compressive strength (UCS) measures the maximum stress a material can endure under compression before failure. With SBM, it is possible to create composites with compressive strengths exceeding 55 megapascals, equivalent to high-strength concrete.

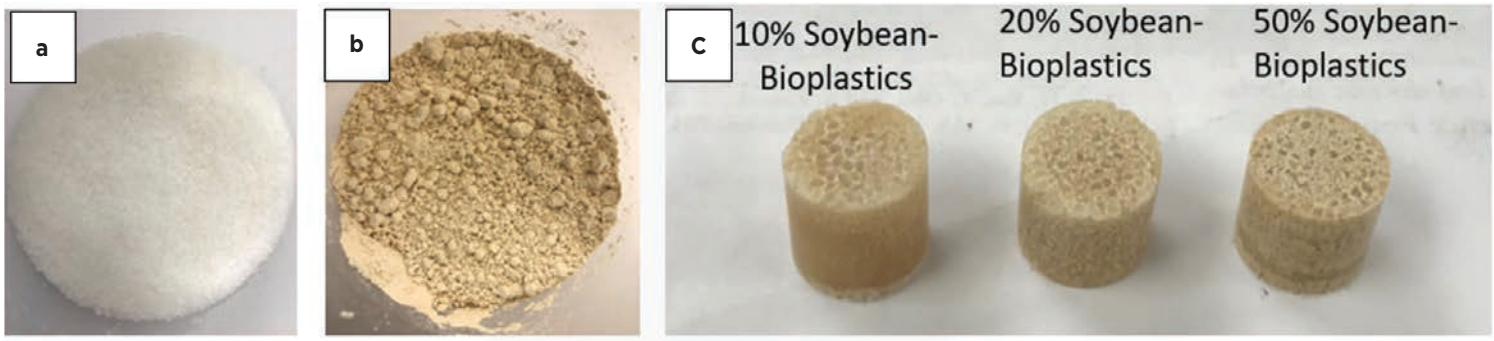
The bioplastics developed in this study offer significant mechanical strength, making them suitable for applications in packaging, structural uses, and more.

Figure 2. Digital pictures of solvent cast samples: a) pure PLA, b) 2% SBM–98% PLA, c) 5% SBM–95% PLA, d) 10% SBM–90% PLA, e) 20% SBM–80% PLA, f) 30% SBM–70% PLA and g) 40% SBM–60% PLA.



> *"The bioplastics developed in this study offer significant mechanical strength, making them suitable for applications in packaging, structural uses, and more."*

Figure 1. Digital pictures of a) bioplastic powder poly-lactic acid (PLA), b) milled and sieved SM, and c) composites of SM with bioplastics (picture courtesy of Dr. Zhang). All the composites showed plastic behavior. This work illustrates that we can add 40% SBM as an additive in the PLA matrix.



Impacts of the Soybean Meal's Supplementation Frequency on the Growth Performance of Beef Cattle in an Extensive Winter Grazing System for Backgrounding Cattle

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

Funded Project $35,050

Why the Research is Important to North Dakota Soybean Farmers

Extensive winter grazing systems, such as bale grazing, have started to gain popularity as a way for producers to decrease the input cost and the livestock's environmental effect. Infrequent supplementation in a bale-grazing system can reduce labor, fuel inputs and fertilizer without affecting growth performance. There is limited research about soybean meal as a supplement for backgrounding diets. Information from this research will contribute to the potential utilization of soybean meal as a supplement for backgrounding diets and extensive winter grazing systems.

Research Conducted

Year one of a 2-year, 44-day extensive bale grazing study evaluated the differences for the growth performance between dried distillers' grains plus solubles (DDGS) and soybean meal (SBM) in terms of supplementation frequency (daily or three times weekly), soil health, forage production and forage quality. Seventy-two Angus-based, backgrounding-aged (6.5 to 8 months) beef cattle were utilized in the study that occurred at a field south of the North Dakota State University Beef Cattle Research Complex. Body weights and blood were collected on days 0, 28 and 44. Soil and forage biomass samples were collected from 3 bale locations that were 0 feet, 5 feet, 10 feet and 15 feet from the bale center in each paddock. Cattle had ad libitum access to hay, water and trace mineral salt while being supplemented, daily or three times weekly, with either DDGS or SBM at 0.75% of their body weight.

Figure 2. Cattle eating supplemented soybean meal.

Findings of the Research

There was no difference (P = 0.32) for average daily gain (ADG), ending body weight (EBW) or estimated dry matter intake (DMI) with different supplementation frequencies. There was also no difference (P = 0.21) for ADG or EBW with different protein sources. Likewise, there were no protein source × supplementation frequency interactions (P = 0.49) for ADG, EBW or estimated DMI. There was a tendency (P = 0.092) in protein source for estimated DMI.

Benefits for North Dakota Soybean Farmers and the Industry

Replacing dried distillers' grains plus solubles with soybean meal and the supplementation frequency had no effect on the growth performance of bale grazed backgrounding cattle, suggesting that producers can reduce the supplementation frequency and can base diet decisions on transportation, cost and the availability of feedstuffs. The data also suggested that producers can implement an extensive winter bale-grazing system for their background cattle without negatively affecting cattle growth.

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

28% Protein Soy-Based Cattle Cube Processing Efficiency and Finished Product Quality

Principal Investigator: *Shane Mueller, North Dakota State University (NDSU) Northern Crops Institute*

Funded Project $23,318

Why the Research is Important to North Dakota Soybean Farmers

During drought conditions or winter grazing, beef cattle are commonly fed supplemental protein to help with digestion and utilization of the dormant forages being grazed. Cattle cubes, or cake, are a common method for accomplishing this. Commercially, cubes are available in two protein ranges: mid protein, 18% to 24% crude protein, and high protein, mostly 30% crude protein and higher. Dried distillers' grains with solubles (DDGS) cubes are commonly used for the high protein in this region.

This project was designed to evaluate the effectiveness of producing a soy-based range-cattle cube to compete in the higher protein cube market. The specific objectives for the feed mill were to understand how to process the soy-based cube and the energy demands, and to determine product quality. The end goal was to provide guidance about how to produce a soy-based range cube, including equipment setup and handling.

Research Conducted

Four formulas were used for this project. The base formula (formula 1) was pure dried distillers' grains with solubles (DDGS); formula 2 was 52.5% soybean meal (SM) and 47.5% soyhulls (SH); formula 3 was 47% soybean meal, 26.5% soyhulls, and 26.5% wheat middlings (WM); formula 4 was 40% soybean meal and 60% wheat middlings. The original plan was to run all four formulas on our 5/8" step die. Formulas 3 and 4 were not able to run on the 5/8" die. Formulas 3 and 4 were made on a 1/2" die with different specifications. Due to using two different dies, we can compare formulas 1 and 2, and then, separately, 3 and 4. Two tons of each formula were run on our California Pellet Mill brand pellet mill. The start and end times were recorded; an AMEC data logger was used to track power use; and samples were taken throughout the runs to obtain the rest of the data. The price per ton was calculated by utilizing the current market prices when each ingredient was used.

Findings of the Research

This project's results showed promise that a soy-based cube can be a viable option. When comparing formula 1 with formula 2, the production rate, pellet durability index (PDI) and energy use all showed favor to formula 2. Neither formula ran as fast as anticipated. These two formulas were expected to run slower but still close to 2 tons per hour. Results between formulas 3 and 4 were similar, with formula 4 having a slight advantage over formula 3 in kilowatt hours per ton (kwh/ton) and the pellet durability index (PDI). Our most important result was that formula 2 can be produced and that, from an energy and PDI standpoint, formula 2 can compete with the quality of a DDGS.

Table 1. Results from the feed-mill processing for all four trials.

Parameter	(1) DDGS 5/8"	(2) SBM/ SH 5/8"	(3) SBM/ SH/WM 1/2"	(4) SBM/ WM 1/2"
Time for 2 Short Ton	3:05	2:36	1:09	1:09
Tons/HR	.65	.82	1.73	1.73
kWh Used	61.184	56.27	21.419	18.361
kWh/Ton	30.59	28.135	10.71	9.18
Cold Mash Temp	2.3°C	2.1°C	-5.2°C	-4.7°C
Conditioned Temp	43°C	62°C	60.3°C	61°C
Calculated Moisture Addition	2.56%	3.73%	4.07%	4.08%
OHAUS Cold Moisture	11.42%	11.2% Dry 14.08% w/ water added	11.78%	11.86%
OHAUS Conditioned Moisture	13.34%	15.92%	15.14%	14.32%
OHAUS Cooled Moisture	11.08%	13.84%	N/A	N/A
Tumble Box PDI	79.9% and 79.85%	86.89% and 82.84%	84.7% and 84.7%	92.1% and 93.7%
Diet Cost Per Ton	$210.00	$262.35	$318.29	$244.60

Figure 1. A visual comparison of the soybean meal and soyhull cube contrasted with the DDGS cube: the DDGS cube is slightly longer. The DDGS pellet did not hold up as well as the soy cube during the PDI test.

Figure 2. The tumble box was run for 10 minutes, with a 500-gram sample of each formula, to determine the pellet durability index.

Figure 3. Surface area and pellet diameter comparisons of the two dies used.

Anaerobic Digestion of Defatted Soybean Meal for Biogas and Biofertilizer Production

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

Funded Project $35,124

Why the Research is Important to North Dakota Soybean Farmers

This research offers North Dakota soybean farmers a sustainable way to convert defatted soybean meal (DSM), a by-product of soybean oil production, into a valuable resource. By providing an alternative use for excess soybean meal, this project helps to reduce the environmental effect and to improve farm profitability through waste management and renewable energy production.

Research Conducted

The research involved a series of lab scale anaerobic-digestion (500 milliters) experiments to optimize methane production using DSM as a feedstock. The team experimented with various particle sizes, temperature settings, alkali pretreatments and DSM-to-inoculum mixing ratios. The researchers also explored the effects of co-digesting DSM with manure to enhance biogas output. Data on biogas production, methane yield, the DSM's chemical components and the nutrient contents of the slurry residues were collected and analyzed.

Findings of the Research

Breaking the DSM down to a particle size of 0.48-0.70 millimeters, setting the operation temperature at 35°Celsius and mixing the DSM with the inoculum at a 1:2 ratio resulted in the greatest methane yield. Additionally, incorporating manure with the DSM feedstock significantly increased biogas production. The residual material from this process, known as digestate slurry, has potential as a high-quality biofertilizer, which is beneficial for soil health and crop growth.

The DSM-based biogas production process offers an efficient solution to manage soybean by-product waste and supports the creation of renewable energy.

North Dakota soybean farmers are encouraged to consider adopting this biogas production technique and integrating it into their farming operations to reap its dual benefits: reducing environmental effects and increasing profitability. This approach not only meets environmental needs, but also strengthens local agriculture, creating a mutually beneficial situation for farmers and the surrounding environment.

> *"The soybean meal-based biogas production process offers an efficient solution to manage soybean by-product waste and supports the creation of renewable energy."*

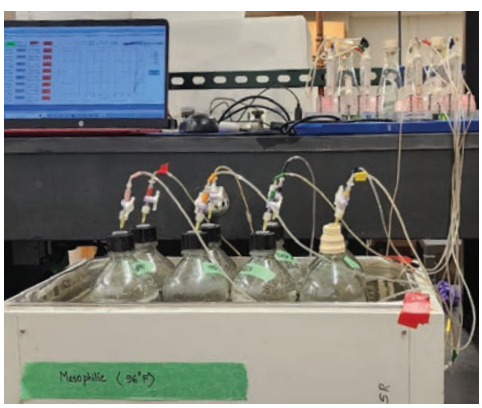


Figure 3. Anaerobic digestion lab-scale setup.

Figure 1. Cumulative biogas production of three particle sizes at mesophilic for feedstock to inoculum 1 to 2

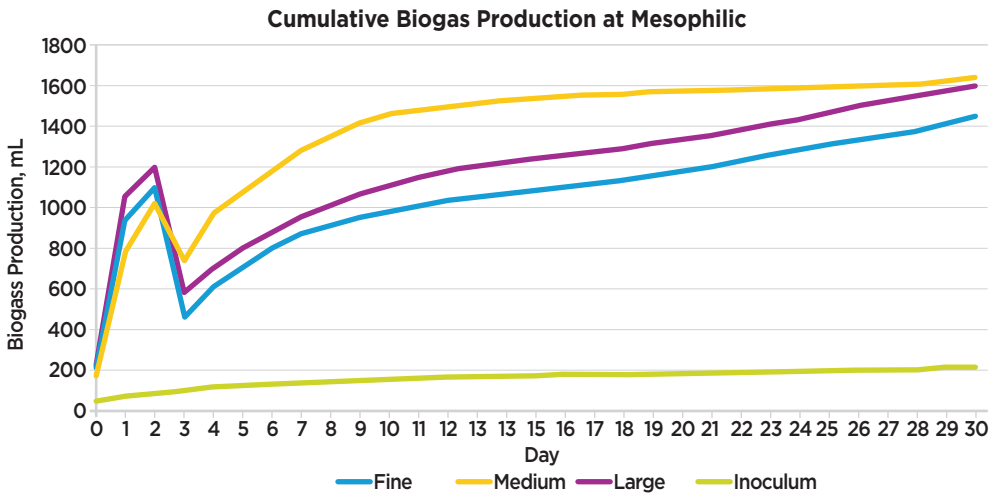
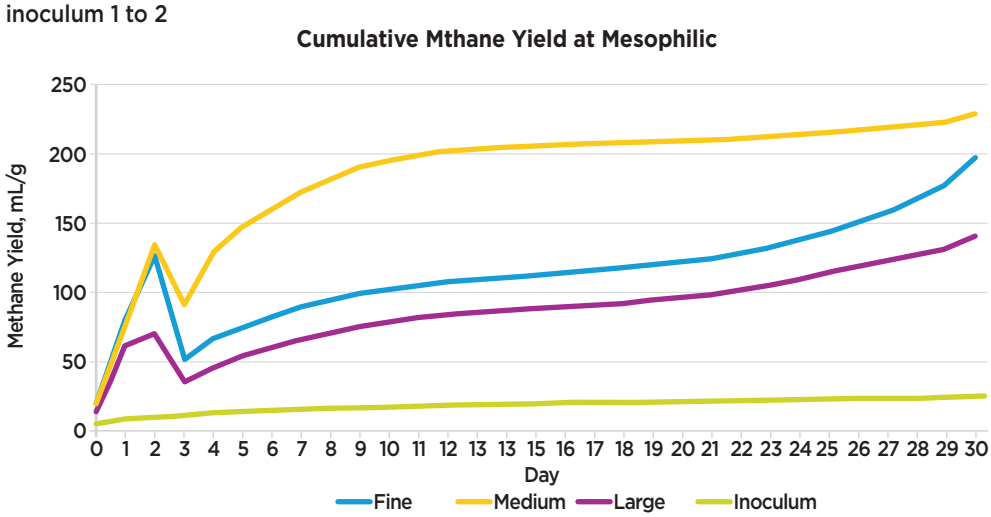


Figure 2. Cumulative methane yield of three particle sizes at mesophilic for feedstock to inoculum 1 to 2



Composite Materials from Soy Meal and Soy Hulls Both Modified with Soy-Based Polymers

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

Funded Project $45,342

Why the Research is Important to North Dakota Soybean Farmers

Due to availability and cost, physico-chemical properties and intrinsic biodegradability, soybean meal (SBM) is considered as a prospective material for manufacturing sustainable thermosets and thermoplastics. At the same time, based on high carbohydrates (natural fibers) presence, soybean hulls (SH) are a promising feedstock to make biobased polymer composites.

This study aims to increase the use of SBM and SH for high-value, high-profit ecological friendly thermoplastics, thermosets and polymer composites.

Research Conducted

In some previous studies, soy protein (SP) was applied as a filler to blend with other petroleum-based conventional thermoplastics. While the resulting materials demonstrated enhanced processability, barrier properties and toughness, such blends lack strength, which may be improved if the composites consist of higher natural carbohydrate fiber concentrations, in particular, when SP or SBM is blended with SH.

This project investigated the feasibility of simultaneously using SBM and SH in polymer composites, thermosets and thermoplastics. SBM and SH are mainly comprised of two constituents: soy protein and carbohydrates. Both components possess decent physico-chemical properties but are highly sensitive to humidity and lack mechanical performance, so they needed to be modified.

The project's main goal was to convert SBM and SH into materials that are processable in one step by using a standard film-extrusion technology. For this purpose, we developed a procedure for modifying SBM and SH with soy-based plasticizing and hydrophobizing polymers to yield composite thermosets and thermoplastics with properties and a performance that are comparable to the petroleum-based counterparts.

Findings of the Research

The suitability of simultaneously using various SBM and SH ratios for making thermoplastics, thermosets and composite polymeric materials has been demonstrated. Polymeric materials obtained from various ratios of SBM and SH modified by soy-based polymers possess prospective properties and performance that show how SBM and SH act synergistically.

Benefits for North Dakota Soybean Farmers and the Industry

For the North Dakota soybean industry, this technology may become a solution for applying the SBM and SH obtained during the soybean crushing process to high-value and high-profit thermoplastics, thermosets and composite polymeric materials.

Figure 2. Cross-linked, soy-derived polymer films made with SH, SM, and both SH and SM (A); and SM- and SH-derived polymer film's flexibility (B).

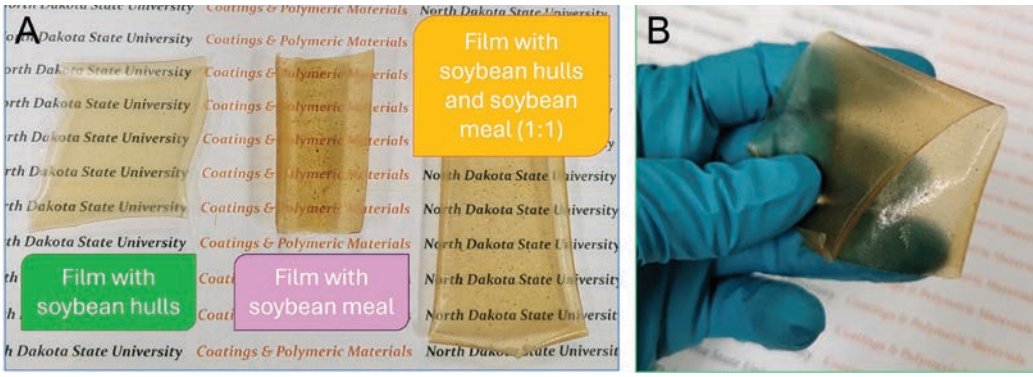
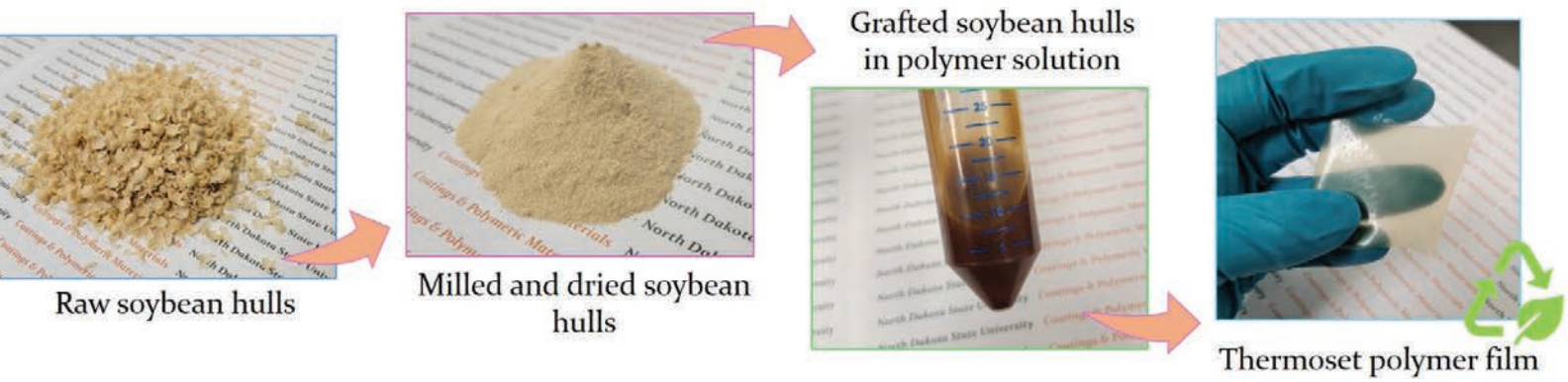


Figure 1. Composite preparation: pretreatment of SH, further modification of SH and formation of cross-linked, soy-derived polymer film.



Soybean Extracts as Green Corrosion Inhibiting Additives for Fluoropolymer Coatings

Principal Investigator: *Eugene B. Caldona, Ph. D., North Dakota State University (NDSU) Department of Coatings and Polymeric Materials*

Funded Project $37,135

Research Conducted

This project explores innovative applications for soybean derivatives, expanding their market beyond traditional food products by developing cost-effective, environment-friendly fluoropolymer coatings that contain soybean extract (SE) additives. Although fluoropolymers such as poly (vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) are valued for their hydrophobicity and chemical resistance, their applications are limited by their poor surface adhesion. This study uses SE as an additive to enhance the adhesion and corrosion protection of PVDF-HFP coatings on mild steel (Figures 1 and 2a-b).

Findings of the Research

The isoflavones in SE, rich in heteroatoms and pi-electrons, significantly improved the interaction between the coating and the metal surface. Even with minimal SE, the coatings demonstrated excellent corrosion resistance in a 3.5 weight percentage (wt%) sodium chloride solution. The utilized methods included microscopy, spectroscopy, wettability assessments, mechanical evaluations, thermal stability analyses, cyclic corrosion tests and simulation studies. Findings revealed that the coating's adhesion on metal was enhanced at higher SE concentrations, without compromising the thermal stability and hydrophobicity of PVDF-HFP. The coating with 0.5 wt.% SE (PHSE0.5) showed the best performance, indicating an optimal SE dispersion (Figure 2c). This SE loading provided strong adhesion without forming hydrophilic pathways that could facilitate water diffusion. This study highlighted SE additives as a sustainable, economical solution for improving the performance of fluoropolymer coatings.

Benefits for North Dakota Soybean Farmers and the Industry

For North Dakota soybean farmers, this research opens new industrial markets, supporting economic sustainability and growth. By promoting the use of SE additives for coatings, further optimizing the extraction processes, and collaborating with industrial partners, farmers can capitalize on increased profitability and market opportunities.

Figure 1. Schematic overview of integrating soybean extract into fluoropolymers to improve adhesion and corrosion protection.

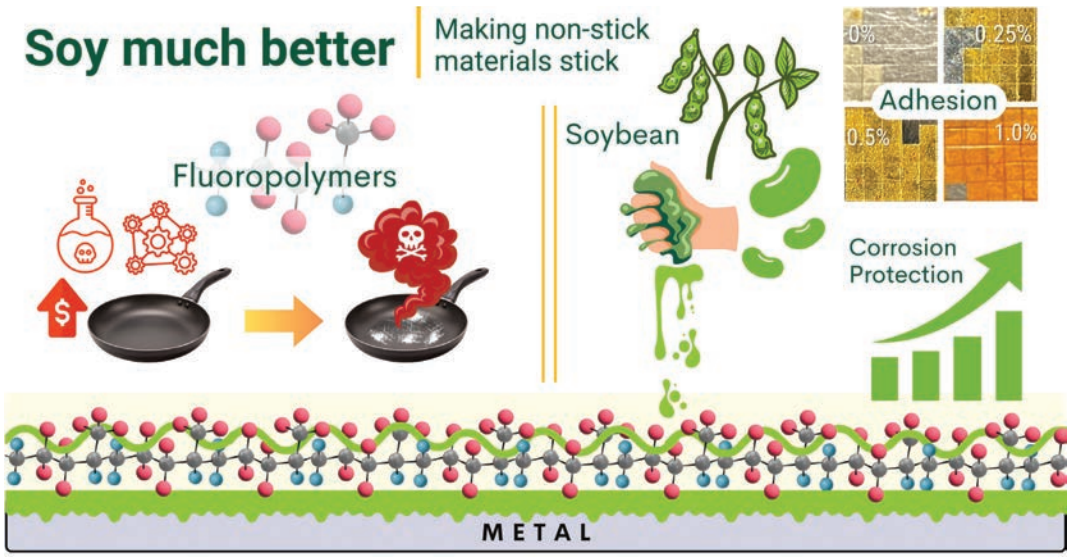
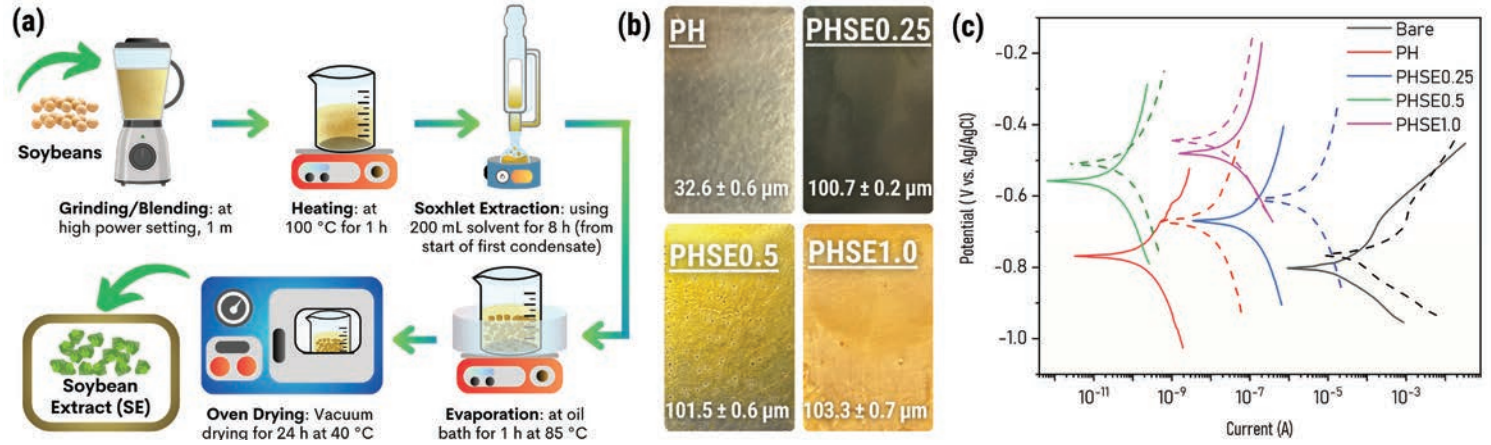


Figure 2. (a) Experimental scheme for obtaining SE through extraction. (b) Optical image and thickness of the coated samples. (c) Tafel curves of the uncoated and coated samples after 1 (solid lines) and 7 d (dashed lines) of immersion in 3.5 wt% aqueous NaCl solution.



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