# Bringing FINDINGS to FARMERS


## 2021 Research Report

North Dakota
Soybean Council
*Our World Is Growing.*

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# 2021 Research Committee Report

On the following pages, we are proud to share details about research projects that were funded by the North Dakota Soybean Council (NDSC). Each study showcased in this report has been and continues to be evaluated by North Dakota farmers, our professional staff and independent consultants. New and continuing research for Fiscal Year 2021 totaled $1,436,481, which represented 33% of the NDSC's budget.

Soybean research is one of the top priorities for the North Dakota Soybean Council. This report spells out where farmers' research dollars are going and connects projects to the challenges facing North Dakota soybean producers on the farm and in the marketplace.

While these challenges may be immediate and short term or may be yet to be realized, farmers' support for this research remains focused on addressing barriers and strengthening our state's soybean producers to weather any storms on the horizon.

When we survey farmers, increasing yields, pest management, soybean quality, and new uses for and protection of our natural resources are the goals which you have outlined for us. We are proud that NDSC farmer-leaders continue to invest and to support disciplinary production and new-use research, teaching and outreach. Researchers involved with the projects funded by the NDSC continue to address issues and opportunities as well as bringing value to North Dakota soybean farmers.

We welcome your input moving forward in order to identify and to address the production obstacles that you face. On behalf of the NDSC and the NDSC's Research Committee, we thank you for your continued support of this important work.

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## North Dakota Soybean Council Research Committee

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## On The Cover

Dr. Carrie Miranda joined North Dakota State University (NDSU) has as assistant professor and project leader for the soybean breeding program in September 2020. The goals of her soybean breeding program at NDSU are to produce high-yield varieties while discovering new genetic mechanisms for useful traits to ensure North Dakota farmers have access to superior soybean varieties.

Dr. Miranda is originally from Cleveland, Ohio, where she completed her bachelor's degree in biology at Cleveland State University. She completed her master's degree in molecular biology at San Diego State University, and completed her Ph.D. at the University of Missouri. Following graduation, she worked as a pea breeder for Puris Foods in Oskaloosa, Iowa, before returning to the University of Missouri as a U.S. Department of Agriculture-Agricultural Research Service postdoctoral fellow focused on using bioinformatic tools to identify and validate candidate genes.

# Liming the Impacts of Soybean Yield and Quality Executive Report

***Principal Investigator:*** *Dr. Chris Augustin, North Dakota State University (NDSU)*
*Dickinson Research Extension Center Director*
***Co-Investigators:*** *Brian Jenks, NDSU; Gary Willoughby, NDSU; and Tiffany Walter, NDSU*

Funded Project
$8,800

### Research Conducted

Sugarbeet waste lime is a byproduct of the sugar refining process. The calcium carbonate (lime) can neutralize soil acid and improve soil health. Lime was applied at 0, 1.5, 2.9 and 5.8 tons/acre in 2018. The research plot was tilled after application. Peas (2018 growing season) and wheat (2019 growing season) were raised prior to the study. In 2020, soybeans were grown.

### Why the Research is Important to North Dakota Soybean Farmers

Soil pH greatly influences many soil factors that affect the growth and yields for all crops. Soil factors include nutrient availability, biological activity and soil extractable aluminum. Nutrients are most available when the soil pH is approximately 5.5 to 7.5. The soil bacteria's activity decreases when the soil pH is less than 5.5. Soil bacteria greatly help a soybean crop to fulfill its nitrogen needs. Soil-extractable aluminum levels greater than 25 parts per million can reduce the plant root's development. If nutrients are not available, biological activity is reduced, or if the extractable aluminum is too high, yields will likely suffer.


**Dr. Chris Augustin, Dickinson REC Director, welcomes farmers to the 2021 Field Day in Dickinson, ND.**

### Findings

All lime treatments statistically improved the soil pH and soil extractable aluminum (Table 1) at the 0- to 6-inch depth. However, soybean yield and grain quality were not affected by the lime treatments. This work was done during a drought, which likely prevented an influence from the lime treatments.

### Benefits/Recommendations

Soil pH is very important for soil health and crop production. Soybean yield and quality were not influenced by the lime applications. However, 2.9 tons of lime/acre was the most-effective lime application to improve soil pH and extractable aluminum.

**Table 1. Lime impacts on soil pH and extractable aluminium.**

| | Lime Treatment (tons/ac) | | | |
|---|---|---|---|---|
| **Soil parameters** (0-6 inch soil depth) | **0.0** | **1.5** | **2.9** | **5.8** |
| **Soil pH*** | **4.4** | **4.9** | **5.7** | **6.3** |
| **Soil extractable aluminum** (parts per million)** | **63** | **25** | **3** | **2** |

* Ideal soil pH is 6.0 to 7.5
**Aluminium toxicity occurs when soil extractable aluminum is greater than 25 parts per million

> "Nutrients are most available when the soil pH is approximately 5.5 to 7.5. The soil bacteria's activity decreases when the soil pH is less than 5.5."

# Enhancement for a High-Throughput Genetic Test to Identify Herbicide-Resistance Traits in Palmer Amaranth

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

Funded Project
$36,000

### Research Conducted

The National Agricultural Genotyping Center (NAGC) has expanded its genetic panel for Palmer amaranth and waterhemp surveillance in North Dakota. Specifically, the NAGC validated two genetic tests to detect markers that are linked to glyphosate and PPO-inhibitor resistances in submitted pigweed samples. Together with the NAGC's pigweed species ID test, this genetic panel can identify important pigweed traits found in North Dakota fields.

### Why the Research is Important to North Dakota Soybean Farmers

Late-season pigweeds that escape herbicide applications are threats to present and future soybean production. Unfortunately, herbicide-resistant (HR) populations of Palmer amaranth and waterhemp are increasing across the soybean belt. In North Dakota, Palmer amaranth has begun expanding its distribution, and there are increasing reports of waterhemp escaping herbicides. Both pigweed species are known to carry resistance to multiple herbicide groups in other states, but little is known about North Dakota's populations. Genetic tests provide a first look into the HR potential of pigweeds and help pre-select seed stock for greenhouse herbicide trials that are limited by both space and time

**Dr. Bateson counts Palmer amaranth seeds under the microscope.**

### Findings

The two HR tests were successfully validated on leaf tissue and seed samples, and are available to all soybean farmers across the U.S from the NAGC. Confirming pigweed species is important prior to HR tests because the PPO-inhibitor (PPO-210) and glyphosate (EPSPS copies) resistance markers have only been found in Palmer amaranth and waterhemp. Research to find genetic markers for HR in other pigweed species (Powell amaranth) is currently underway.

A blind study showed 90% agreement between the HR test (EPSPS copies) and glyphosate outcomes for greenhouse trials. Additionally, the PPO-210 genotype that carries resistance in Palmer amaranth was found in plants collected in North Dakota. Thus, these two HR tests have illustrated the presence of these markers in North Dakota pigweeds and will be used for an upcoming statewide survey.

**NAGC scientists pictured from left to right: Missy Berry (research analyst), Megan O'Neil (laboratory manager), Zack Bateson (research scientist), and Lindsey Fransen (laboratory technician).**

### Benefits/Recommendations

Palmer amaranth infestations are relatively low in North Dakota due, in part, to the plant's recent arrival. Slowing its spread requires diligence to monitor and to find effective methods in order to manage newly discovered populations. The NAGC's genetic panel can quickly confirm the pigweed species and can identify which herbicides to avoid if broad-scale chemical treatment is necessary. These tests will help to limit the overuse of ineffective herbicides as well as to inform farmers about the HR potential of local weed populations throughout the growing season.

# Alternative Soybean Production Management Options in Acidic Soils

***Principal Investigator:*** *Ryan Buetow, Cropping Systems Specialist, NDSU Dickinson Research Extension Center*

Funded Project
$11,525

## Research Conducted

Many fields in western North Dakota have issues with pH values below 5.5. When the pH drops below 5.5, nutrient availability is reduced. The activity of bacteria in the soil is affected causing aluminum toxicity and lower yields. The best management practice for these situations with a no-till crop is a surface application of lime. However, it takes a large amount of product to change the soil chemistry to adequate levels. It can take time to adjust the pH levels after a surface application. Producers are searching for less costly short-term options, especially for rented land.

Work done in Oklahoma and Montana has shown that phosphorous which is applied with the seed for wheat and durum can help growth in acidic environments. A comparison of lime and phosphorous treatments, applied with the seed in acidic soil, was conducted to observe the effect on soybeans' growth and yield.

Research objectives are as follows:

- Evaluate growth and yield differences among treatments
- Increase the knowledge base of soybean practices in southwest North Dakota

Due to drought conditions during the planting and vegetative growth stages, there was considerable stand loss and poor growth. Thanks to some late-season moisture during the flowering period, we were still able to observe some differences among treatments, but it was difficult to decipher the influence from drought or treatments. A report on this trial was published in the 2020 Western Dakota Crops Day research report and was mentioned at the DIRT workshop. Due to the site's poor condition during the drought, there wasn't much outreach conducted with this site.

**Ryan Buetow at the timing trial research on acrid soils.**

## Findings

As seen in Table 1, in-furrow lime had a significant effect on soybean yield. Lime showed a significant yield bump at 75 pounds per acre in-furrow with no difference between 75 pounds and 100 pounds. This yield increase aligns with a difference in the amount of aluminum found in the tissue samples for these treatments. While we can see some differences, the crop's yield was largely influenced by dry

> "The best management practice for these situations with a no-till crop is a surface application of lime."

It is important to remember that these small rates of in-furrow lime are not enough to have a major effect on soil pH levels.

In-furrow phosphorus treatments reduced stand and yield, as expected, and did not improve plant growth. I plan to continue conducting experiments on soil acidity. While liming these fields would be the preferred practice, many farmers say that it is very difficult to pay for a lime application, especially when the producer doesn't own the land.

**Table 1. Yield and Al levels across lime treatments.**

| Lime applied in-furrow | Yield | Aluminum from tissue samples |
|---|---|---|
| lbs./ac of product | bu/ac | % |
| **0** | **13.9** | **45.6** |
| **50** | **13.9** | **40.9** |
| **75** | **15.7** | **31.8** |
| **100** | **15.8** | **31.4** |
| **4,000** (surface applied) | **14.5** | **51.2** |

# Development of Soybean Oil Oleogels for Edible Applications

***Principal Investigator:*** *Dr. Bingcan Chen, Assistant Professor, NDSU Department of Plant Sciences*

Funded Project
$34,120

### Research Conducted

We compared the physical, chemical and rheological properties of oleogels (solidified oil) by using three different types of soybean oil: commercially refined soybean oil; solvent-extracted soybean oil; and expeller-pressed, high-oleic soybean oil.

We used a single food-grade gelling agent, monoglycerides, beta-sitosterol, or sunflower wax, or combinations of the two in order to produce soybean-oil oleogels with different properties. We tested the oleogels' physical and flow properties, comparing the properties of cookies made with the fabricated soybean oleogels and the commercial shortenings.

### Why the Research is Important to North Dakota Soybean Farmers

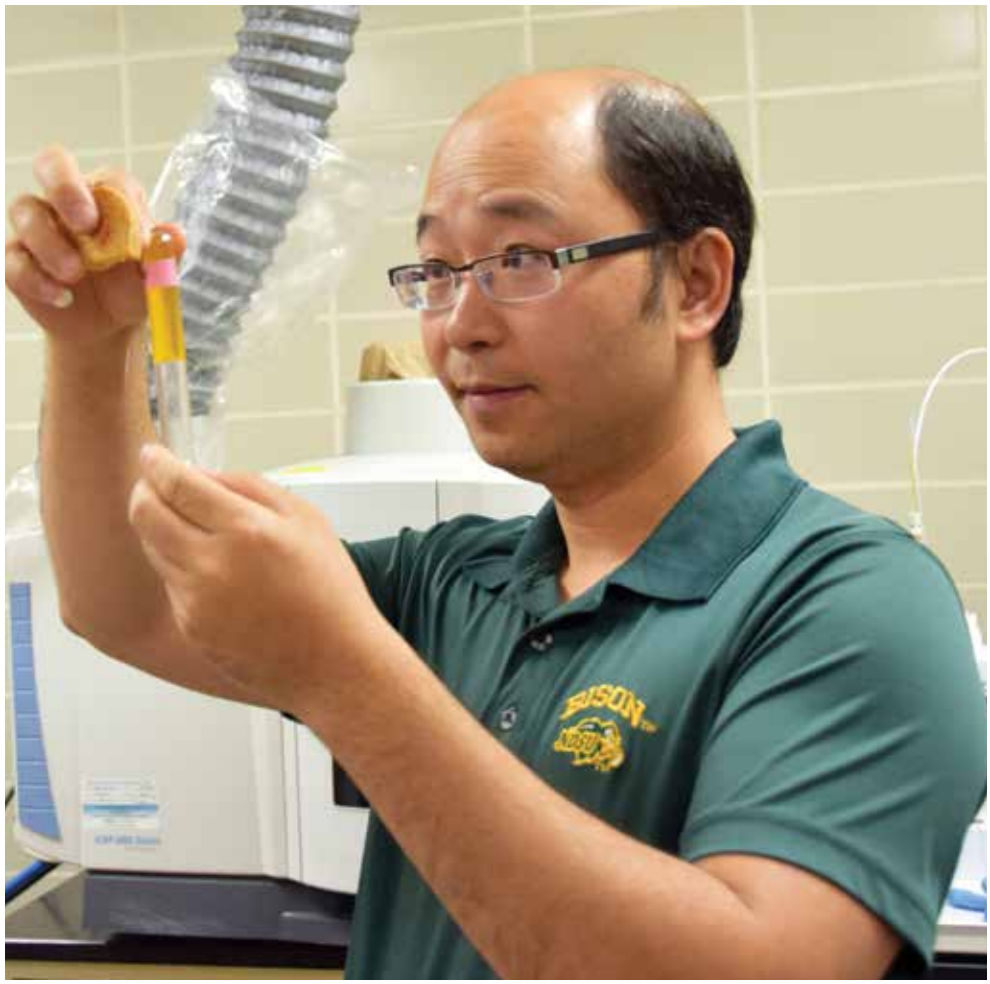
Partially hydrogenated soybean oil cannot be used in the food industry. There is an urgent need to develop novel food-processing techniques to increase the value of soybean oil. Expanding the utilization of soybean oil, particularly high-oleic soybean oil, will benefit consumers.

### Findings

The type of soybean oil determines the soybean oleogels' properties and the amount of gelators. Expeller-pressed, high-oleic soybean oil requires the lowest amount of gelator to form the gel network. It is practical to fully replace commercial shortenings with high-oleic soybean oil's oleogel when preparing cookies. The cookies made by using high-oleic soybean oil had better quality. The innovative soybean-oil oleogels can be applied by the bakery industry as a novel, functional food ingredient.

### Benefits/Recommendations

The huge market potential to replace saturated fats and partially hydrogenated soybean oil in foods by using soybean-oil oleogel will result in an increased demand and price stability for North Dakota soybeans. High oleic-acid soybean oil with less unsaturation may be an ideal candidate to produce oleogels for the bakery industry.



**Dr. Bingcan Chen evaluating the quality of soybean oil.**

> "Partially hydrogenated soybean oil cannot be used in the food industry. There is an urgent need to develop novel food-processing techniques to increase the value of soybean oil."

# Nitrogen Dynamics of Soybeans and Soybean Residues with Long-Term No-Till Production Systems

***Principal Investigators:*** *Dr. Larry Cihacek and Dr. Rashad Alghamdi, NDSU Soil Science Department*

Funded Project
$3,184

### Research Conducted

In 2017, approximately 7,050,000 acres of soybeans were harvested in North Dakota, making the state the 5th largest soybean producer in the nation. In the region, most soybeans are grown in a rotation with spring wheat or corn, and soybeans are expected to provide part of the nitrogen (N) needs for the following crops. No-till conditions often result in heavy residue accumulation while a cooler climate and short growing season slow down decomposition, inhibiting N availability and mineralization from crop residues, and N immobilization may be occurring in these systems. In nature, the carbon-to-nitrogen ratios of post-harvest crop residues differ by species. When crops are rotated in a field, the system's carbon-to-nitrogen ratios may be altered, resulting in soil N mineralization or immobilization values which vary from what is observed for each individual crop.

To better understand crop fertilizer N needs, N mineralization or immobilization was studied for crop rotation and season effects. A series of laboratory soil incubations was conducted by adding corn (C), soybean (S), spring wheat (SW) and radish (R) crop residues in order to simulate common cropping systems with a 2-year, 3-year and 3-year with cover-crop rotation. Cropping systems and rotations included C-C-C, R-R-R, C-S-C, S-C-S, SW-S-SW, S-SW-S, SW-S-C, S-C-SW, C-SW-S, SW/R-S/R-C, S/R-C-SW/R, C-SW/R-S/R and S/R-C-SW/R. Soils were incubated for 12 weeks, the length of an average North Dakota growing season; frozen for 3 weeks to simulate winter freezing; and then thawed. Samples were leached and nitrate determined every 2 weeks. After thawing, the next crop for the sequence was applied, and the process was repeated. Nitrate mineralization or immobilization was determined by using bare soil as a control and baseline to determine the trend.

> "We found that crops were only mineralizing N when the radish cover crop was included in the sequence; all other crop sequences showed immobilization."

### Findings

We found that crops were only mineralizing N when the radish cover crop was included in the sequence; all other crop sequences showed immobilization. High carbon-to-nitrogen ratio crop residues (C:N>40) did not show N mineralization patterns during the study period. Nitrogen mineralization of soybean plant residues at senescence or at harvest generally showed N immobilization for most plant parts. This study illustrated a need for field-validation research to verify these findings and to help North Dakota farmers utilize the N fertilizer credit recommendations for fields under long-term no-till management.

# Development of Magnetic Nanobiocatalyst for the Economic Biorefinery of Soybean Products

***Principal Investigator:*** *Dr. Ademola (Demmy) Hammed, NDSU Department of Agricultural and Biosystems Engineering*

Funded Project
$30,340

### Why the Research is Important to North Dakota Soybean Producers

Soybeans are high in protein and starch that consist of peptides and glucose as their building blocks. Although smaller units, such as glucose and peptides, are fermentable to value-added biochemicals such as ethanol, ammonia and lactic acid, the protein and starch need to be broken down first. One of the most viable ways to break down protein and starch is using enzymes. However, the high cost of enzymes is an economic challenge for the industry. Enzymatic processing can be economical if the enzymes are recovered and reused. The development of economic technology to convert soybeans to fermentable units will create new uses and demand for soybeans which will, in turn, increase farmers' income.

### Research Conducted

The major aim of this research was to produce attached enzymes on magnetic

*—continued on bottom of page 8*

# Establishment of Waterhemp Tissue Culture Lines for Herbicide-Resistance Research

***Principal Investigator:*** *Dr. Michael J. Christoffers, NDSU Department of Plant Sciences*

Funded Project
$7,372

### Research Conducted

Cell-suspension cultures, which are living cells suspended in a liquid nutrient solution, are often used in laboratory research. We tested six different solutions for their ability to generate waterhemp protoplasts (cells without cell walls). One solution successfully generated protoplasts, the majority of which were confirmed to be alive and viable. Subsequent cell-wall regeneration and cell division, however, were not observed with our test conditions.

### Why the Research is Important to North Dakota Soybean Growers

Herbicide-resistant waterhemp represents an important problem for North Dakota soybean production, and new tools are needed to study emerging methods for controlling this weed. When growing herbicide-resistant weeds for research, it is important to minimize the risk of seeds escaping and spreading into fields. This is especially important when researching new genetic methods of weed control, where weed genes may be altered. The cells that comprise cell-suspension cultures need to be maintained in a laboratory and cannot grow or produce new plants in the field. This makes waterhemp suspension cultures very valuable herbicide-resistance research tools. The ability to remove cell walls from these cultured cells, generating protoplasts, adds to the cultures' value because of their increased ability to take up genetic material for experimentation compared to intact cells; this possibility is due to the lack of a cell-wall barrier in the protoplasts.

**Waterhemp cell suspension cultures in shaker.**

### Final Findings

We found that, while most tested solutions did not generate protoplasts from waterhemp cells, a solution containing the 'macerozyme R-10' enzyme successfully produced viable waterhemp protoplasts. However, for our tested conditions, waterhemp protoplasts were not observed to subsequently regenerate cell walls or to start dividing. This area will be examined with future research.

### Benefits/Recommendations

Waterhemp plant material, in the form of cell-suspension cultures, is now available for further studies to investigate herbicide resistance. Researchers also have a protocol to generate protoplasts from these cell-suspension cultures, facilitating genetic research to investigate new ways for waterhemp control without the risk of weeds escaping into North Dakota fields.

*—continued from page 7*

nanoparticles and/or to create polymer support for processing soybean products, including dehulled, fat flake, defatted flake and soy meal. Similar to what happens in our body during food digestion, soybean starch was broken down into simple glucose by two enzymes, amylase (AMY) and amyloglucosidase (AMG), while soybean protein was broken down into peptide and amino acid by the enzyme pepsin. Two additional modes, stepwise (one after the other) and simultaneous, were investigated. The enzymes were then attached to a flexible polymer which was connected to magnetic nanoparticles in order to make non-magnetic and magnetic nanobiocatalysts.

### Findings

Soybean samples were broken down differently, and simultaneous AMG and AMY addition yielded more glucose for all samples except the defatted flakes. Processing was optimum at 3 hours for all samples. Attaching flexible support to the enzyme provided a joint enzyme action, making the attached enzymes perform higher when compared to the unattached enzymes. However, the AMY-AMG magnetic unit performed lower than the free enzyme. Similarly, the samples were broken down into protein by the digesting enzyme called pepsin. The results showed that pepsin-free enzymes have higher amino-acid content for all samples, except the dehulled sample, than the attached pepsin.

### Benefits/Recommendations

The non-magnetic nanobiocatalysts of AMG and AMY are viable for soybean processing to produce fermentable units to ethanol and organic ammonia. Future research will focus on the nanobiocatalysts' recoverability and the production of organic ammonia and ethanol using soybean hydrolysates as the sole substrate during fermentation.

# Late-Season Planted Cover-Crop Tolerance to Soybean Herbicides

***Principal Investigator:*** *Greg Endres, North Dakota State University (NDSU) Carrington Research Extension Center*

Funded Project
$14,700

### Why the Research is Important to North Dakota Soybean Growers

This project's goal is to build an NDSU database on late-season planted cover-crop tolerance to early season applied soybean herbicides that have soil residues. This database will assist farmers and crop advisers as plans are made to add cover crops into the cropping system.

### Research Conducted

The study was conducted at Carrington and Fargo during 2018-20 and included nine soybean herbicides and eight cover crops. Soil and post-emergence herbicides were applied to soybeans at the labeled rates and timings. The crop was mowed during August (seed-fill stages), and cover crops were direct planted into the soybean stubble, generally in late August to early September. Visual evaluation of injury (biomass and/or stand reduction) began in late September, three to four months after herbicide application.


**Greg Endres discusses his research with farmers during Carrington REC Field Day.**

### Findings

All herbicides, except Liberty 280, injured the cover crops. Barley, winter rye and field pea had the greatest tolerance to the herbicides. Radishes, turnips and rapeseed/canola had the least tolerance to the herbicides. Some herbicides potentially have a high risk of injury for cover crops: Spartan=radishes; Valor=radishes, turnips, and rapeseed/canola; Pursuit=flax, radishes, and turnips; and Flexstar=radishes.

**Research shows that many cover crops are susceptible to herbicide damage.**

### Benefits/Recommendations

Research reports for individual trials were written and published in "North Dakota Weed Control Research" (www.ag.ndsu.edu/weeds/nd-weed-control-research). After the field study was completed, a table was published in "2021 North Dakota Weed Control Guide." This reference can be utilized by farmers and crops advisers when they are selecting cover crops for fall establishment following soybeans. This database will aid in the successful establishment of fall cover crops, which will reduce soil erosion, help manage soil moisture, increase the soil's long-term productivity and provide other benefits.

# Winter Rye Cover-Crop Management Techniques for Soybeans

***Principal Investigator:*** *Greg Endres, North Dakota State University (NDSU) Carrington Research Extension Center (CREC)*

Funded Project
$5,850

### Why the Research is Important to North Dakota Soybean Farmers

This project's goal is to continue building NDSU databases about soybean yield with two trials examining winter rye as a cover crop prior to soybean production.

Rye as a cover crop: Will winter (cereal) rye as a cover crop affect soybean yield in an arid environment while providing soil benefits compared to conventional soybean production?

Fall seeding dates and rates for rye: What is the best rye seeding rate and established stand based on fall seeding dates and the following season factors that affect soybean production, including ground cover, soil moisture and weed suppression with rye?

### Research Conducted

Trial 1 commenced in 2018 at the tri-county research site with the following treatments: 1) soybeans grown without rye as a cover crop, 2) rye terminated with glyphosate 1 month before soybean planting and 3) rye terminated with glyphosate at soybean planting.

Trial 2 was conducted at the CREC starting in the fall of 2018. The research evaluated rye plant stands with selected seeding rates and fall dates as well as the effect on the following season's ground cover, soil moisture, weed suppression and soybean yield.

**Table 1. Rye plant density and ground cover, and weed control with winter rye cover-crop seeding dates and rates: Carrington, 2020.**

| Rye seeding treatment | | Rye | | Weed control | | | |
|---|---|---|---|---|---|---|---|
| Date | Rate | Plant density (8-May)[1] | Ground cover | Foxtail[2] | | Kochia | |
| | | | Visual 28-May | 28-May | 22-Jun | 28-May | 26-Jun |
| | lbs/ac | plt/ac | % | % | | | |
| 26-Sep | 25 | 338,650 | 49 | 52 | 66 | 55 | 56 |
| | 50 | 796,822 | 58 | 56 | 62 | 79 | 66 |
| | 75 | 1,149,701 | 63 | 71 | 70 | 83 | 70 |
| 1-Nov | 25 | 162,210 | 10 | 10 | 64 | 0 | 40 |
| | 50 | 401,257 | 19 | 10 | 65 | 0 | 57 |
| | 75 | 591,925 | 27 | 16 | 64 | 0 | 28 |
| CV (%) | | 19.5 | 12.2 | 40.3 | 14.9 | 42.3 | 28.2 |
| LSD (0.10) | | 140,784 | NS | NS | NS | NS | 19 |

[1]*Early seeded rye = tillering growth stage; late-seeded rye = 1- to 3-leaf stage.*

[2]*Green (majority of population) and yellow.*

### Findings

Trial 1: For successful soybean production, rye needs to be terminated 2 to 4 weeks before soybean planting in order to preserve soil moisture in an arid environment.

Trial 2: Early fall rye seeding and rates of 50 or 75 pounds per acre generally provided improved ground cover and weed suppression while maintaining soybean productivity.

### Benefits/Recommendations

Trial 1: The timing of rye termination with glyphosate needs to be carefully considered in order to balance the benefits of the cover crop while preserving soil moisture for the soybean crop.

Trial 2: Fall planting dates and rates need to be considered based on the farmer's goals for the cover crop as he/she considers soil cover and moisture, weed control and soybean performance.

**Table 2. Soil moisture, weed control and soybean response to a preplanted winter rye cover crop: Wishek, 2020.**

| Trt no. | Topsoil moisture (%)[a] | | | Green foxtail control (1-Jul) | Soybean | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Plant | | | Seed | | | | |
| | | | | | Stand (1-Jul; V3 stage) | Canopy (27-Jul) | Physiological maturity | Yield | Test Weight | Count | Oil | Protein |
| | #### | 1-Jul | 27-Jul | % | plt/ac | % | day of year[b] | bu/ac | ib/bu | no./lb. | % | |
| 1 | 18.3 | 24.2 | 22.3 | 89 | 179,290 | 86 | 260 | 45.0 | 58.0 | 3,324 | 20.2 | 35.5 |
| 2 | 20.7 | 21.6 | 20.0 | 67 | 237,620 | 84 | 259 | 40.0 | 57.9 | 3,363 | 20.0 | 35.8 |
| 3 | 16.2 | 20.5 | 22.3 | 70 | 170,750 | 81 | 261 | 29.4 | 58.0 | 2,534 | 20.0 | 35.5 |
| Mean | 18.4 | 22.1 | 21.5 | 75 | 195,890 | 84 | 260 | 37.2 | 58.0 | 3,420 | 20.1 | 35.6 |
| CV% | 11.7 | 14.1 | 8.4 | 1.7 | 21.8 | 8.1 | 0.3 | 12.5 | 0.3 | 5.7 | 1.1 | 1.1 |
| LSD (0.10) | 3.0 | NS | NS | 2 | NS | NS | 1 | 7.0 | NS | NS | NS | NS |

[a]*Extech digital soil moisture meter (model MO750) at 4-inch soil depth.*

[b]*260=September 16.*

# Managing Salinity with Cover Crops: A Whole-System Response

***Principal Investigators:*** *Dr. Caley Gasch, Dr. Jason Harmon, Dr. Sam Banerjee, Dr. Tom DeSutte, and Dr. Abbey Wick, NDSU*

Funded Project
$33,870

### Research Conducted

In the 2019 growing season, we interseeded cereal rye at 80 pounds per acre (lb/ac) into strips in soybean fields and monitored the soil's water content (0-6") in the rye strips and the adjacent control strips that traversed saline and non-saline portions of the fields. We also grew cereal rye at different seeding rates (40, 80, 120 and 240 lb/ac) in replicated pots in the greenhouse with an unlimited water supply for 5 weeks.

### Why the Research is Important to North Dakota Soybean Producers

Soil-salinity management is only possible by managing water. Soil-water removal by plants (transpiration) is an effective way to dry the soil while encouraging salts to remain deep in the soil's profile. We wanted to quantify the cereal rye's water use so that we could better understand the potential of this cover-crop species to assist with salt and water management and to make appropriate seeding-rate recommendations.

### Benefits/Recommendations

The soil's water content in the field was consistent throughout the 2019 season and did not differ between the cereal rye and the control strips. The soil water was a little higher in saline soils, which produced less cereal rye biomass than non-saline soils (Figure 1). Cereal rye grows well in soils up to salinity levels of 6 dS/m (saturated paste extract). In the greenhouse, cereal-rye biomass production and cumulative transpiration increased as the seeding rate increased to 120 lb/ac (Figure 2). We did not measure spring water use, but the fall's cereal rye transpiration is similar to winter's small grains (25" of water per year).

If water use is the goal of growing cereal rye, we recommend using the highest seeding rate within your comfort level. We found that a seeding rate (drilled) from 120-240 lb/ac would provide the most water use.

**Dr. Caley Gasch**

**Figure 1: The soil's water content (0-6") in two fields (near Jamestown) of soybeans with cereal rye (80 lb/ac, dots) or without (squares) in 2019. The left charts are for non-saline points, and the right charts are for saline points. The vertical line indicates cereal rye interseeding, and the numbers are the average biomass production of cereal rye until the fall freeze.**

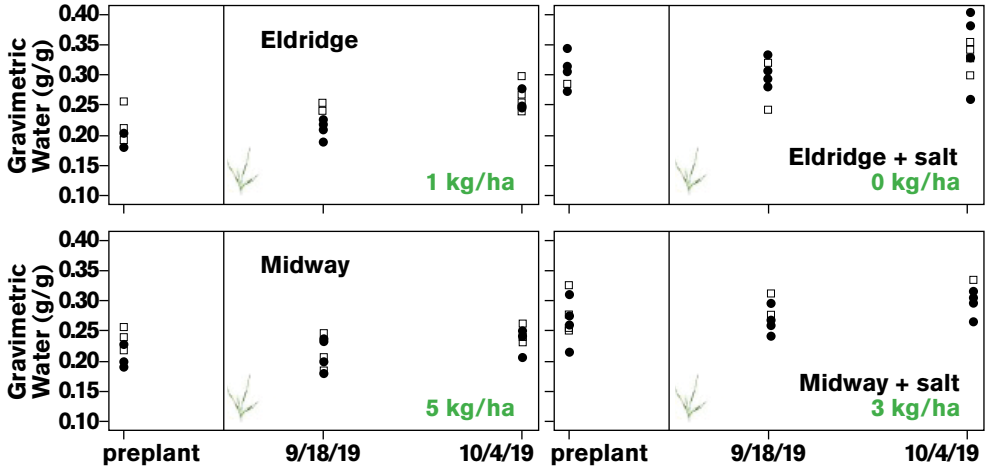
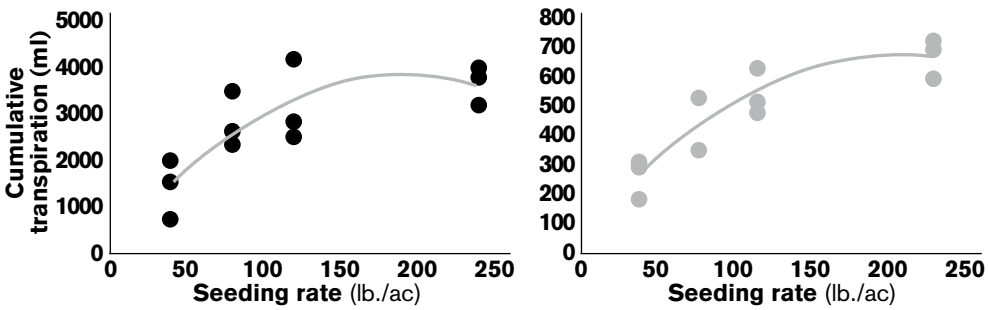



**Figure 2: Cumulative water use (left) and rye biomass (right) across four seeding rates, grown in a greenhouse with an unlimited water supply for 5 weeks. Data were collected by graduate student Alec Deschene.**




> "Soil-water removal by plants (transpiration) is an effective way to dry the soil while encouraging salts to remain deep in the soil's profile."

# Control Measures for Iron Deficiency Chlorosis in Soybeans

***Principal Investigator:*** *Dr. R. Jay Goos, NDSU Department of Soil Science*

Funded Project
$2,644

### Research Conducted

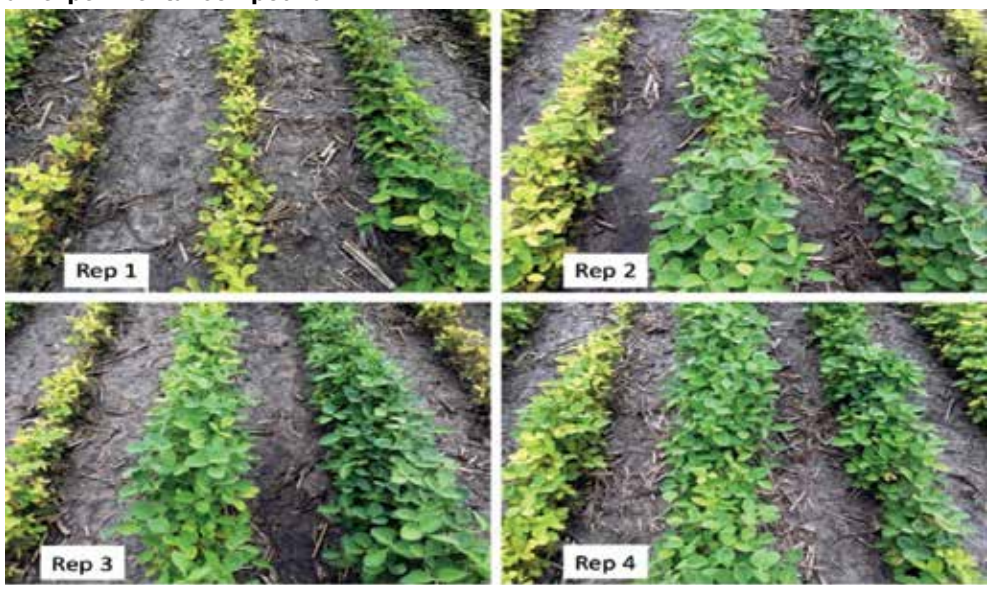
Traditional control measures for iron deficiency chlorosis (IDC) are "stackable." For example, the effects of planting a resistant variety, an in-furrow application of FeEDDHA and planting in wider rows, all "stack" and add to the reduction of IDC. A variety's resistance to IDC is determined by the genes involved with iron uptake as well as the genes that are involved with iron translocation or other processes. Therefore, one could say that these genetic traits also "stack" to define a variety's IDC resistance.

The research used this concept to identify potential control measures for IDC on a physiological level. What happens when you "stack" a known control measure for IDC, FeEDDHA fertilizer, with other compounds that might reduce IDC? For example, IDC is, by definition, a lack of chlorophyll in the plant. What happens if you combine FeEDDHA with a compound that stimulates the plant's chlorophyll production?

### Findings/Recommendations

This research screened seed treatments and foliar sprays to be used with FeEDDHA in order to reduce IDC. Two examples are given here. In a greenhouse experiment, soil was treated with three rates of Fe as FeEDDHA (Soygreen), and the seed was treated with four rates of an experimental compound. The chlorophyll levels of the 1st and 2nd trifoliolate leaflets were measured. As anticipated (Figure 1), the two treatments "stacked" with each other because both the soil treatment with FeEDDHA and the seed treatment greatly increased the chlorophyll level of this susceptible variety, giving normal chlorophyll levels (>30) when both treatments were used.

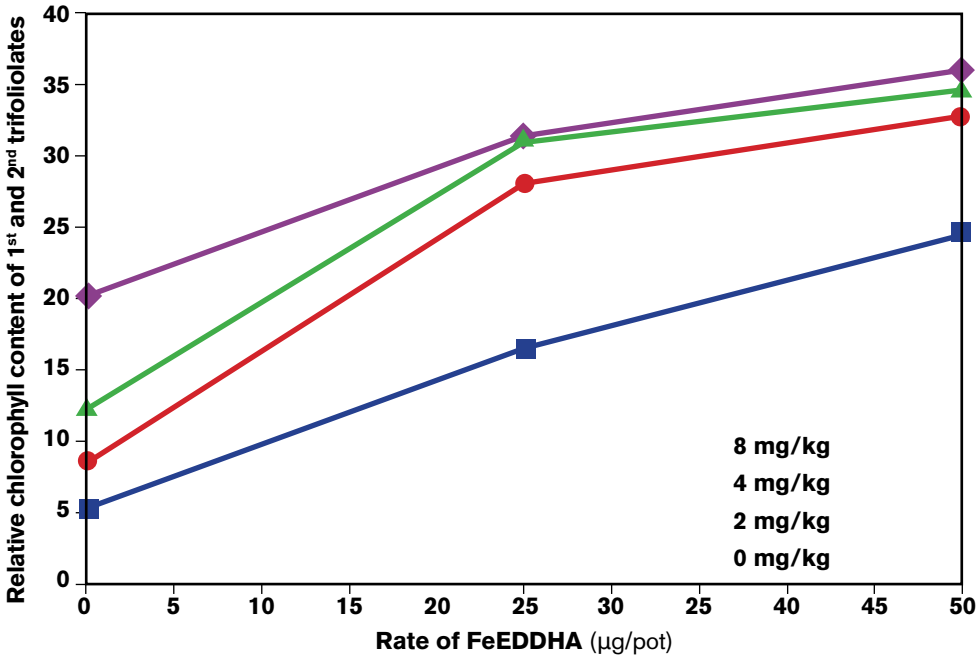
**Figure 2. Effect of a foliar spray on the severity of IDC in soybeans for a field study. From left to right: Control, sprayed with FeEDDHA, and sprayed with FeEDDHA and an experimental compound.**




In a field study, chlorotic soybeans were sprayed with FeEDDHA, with and without an experimental compound. The results are shown in Figure 2. In each replicate, from left to right: No spray, sprayed with FeEDDHA and sprayed with FeEDDHA plus an experimental compound. Again, the two compounds appeared to work together to reduce IDC. Further research is needed.

The experimental compounds are not identified in this report because the possibility of North Dakota State University patenting these treatments is being considered.

**Figure 1. Effect for the rate of Fe as FeEDDHA and the rate of seed treatment with an experimental compound on the relative chlorophyll content for the first and second trifoliolate leaflets (greenhouse study).**




> "The two compounds appeared to work together to reduce IDC."

# Seeding Date and Cultivar Influence on Soybean Performance in Northeastern North Dakota

***Principal Investigator:*** *Bryan Hanson, NDSU Langdon Research Extension Center*

Funded Project
$6,000

### Why the Research is Important to North Dakota Soybean Producers

In recent years, northeast North Dakota has seen a dramatic increase for soybean acreage, especially in counties along the Canadian border where the state's coolest temperatures and shortest growing seasons occur. Choosing the right combination for the seeding date and cultivar maturity group (MG) is an important decision that producers make to obtain optimum soybean production. This study's objective was to provide research-based data to assist farmers with determining the relationship between seeding date and MG for the state's northeast region.

### Research Conducted

Research was conducted at Langdon, North Dakota, with five seeding dates and three MGs at each seeding date. The seeding dates were in approximate 10-day intervals, ranging from May 21 to June 19. Maturity groups consisted of 00.5, 00.9 and 0.1 Roundup Ready cultivars. The target plant population was 180,000 plants per acre, seeded in 6-inch rows.

### Findings/Recommendations

Agronomic trait data trends indicated that the number of days to mature decreased with later seeding dates while later MGs took more days to mature. The percentage of grain protein increased and oil content decreased with subsequent seeding dates; differences among the varieties were less than 0.5% for the two latest seeding dates.

**Bryan Hanson at the soybean seeding date study at the Langdon REC.**

Cultivar yields were similar for the May 21 seeding date. On subsequent seeding dates, the 00.5 cultivar always had the highest yield, followed by the 00.9 and 0.1 cultivars. Yield averages for the three cultivars at the five seeding dates were 62.7, 56.7, 43.6, 38.6 and 30.6 bushels per acre, respectively.

The dramatic yield drop for the June 5, 12 and 19 seeding dates probably resulted from the September 8 frost/freeze and the dry soil conditions in late August and September.

Combined data from 2018 and 2020 resulted in a yield reduction of 30, 36 and 43% from the earliest to latest seeding dates for the MG 00.5, 00.9 and 0.1 cultivars. In 2018, the cultivars seeded on June 25 did not mature prior to the first killing freeze on September 29.

The further that the seeding date is delayed into June, the greater the chance of a successful crop with the earliest maturity group. Seeding success during the last 10 days of June would be problematic with even the earliest maturity group and would be dependent on weather conditions as well as the timing for the first fall freeze in any given year.

> "Seeding success during the last 10 days of June would be problematic with even the earliest maturity group and would be dependent on weather conditions as well as the timing for the first fall freeze in any given year."

# Utility of a Barley Crop for Iron Deficiency Chlorosis and Waterhemp Management

***Principal Investigator:*** *Dr. Joseph T. Ikley, NDSU Extension Weed Scientist*

Funded Project
$20,000

### Research Conducted

This research evaluated the ability of a companion crop to alleviate symptoms of iron deficiency chlorosis (IDC) and to suppress/control Powell amaranth and glyphosate-resistant waterhemp. We also compared soybean canopy development and yield in plots that either did or did not have an oat companion crop. This research was conducted using a Roundup Ready Xtend (AG06X8) soybean variety, and the companion crop was terminated using glyphosate + dicamba applied at the crop's 6-, 12-, 18- and 24-inch height. IDC severity, pigweed control and yield were evaluated throughout the year. A companion-crop-free and weed-free plot was included for comparison.

### Why the Research is Important to North Dakota Soybean Producers

Iron deficiency chlorosis and glyphosate-resistant waterhemp are both problematic for North Dakota soybean farmers. Planting a small-grain companion crop has proven to be beneficial in some environments, such as wet years, to manage IDC. Small grains can also be a competitive crop for late-emerging summer annual weeds, including waterhemp. As herbicide-resistant waterhemp continues to spread in North Dakota, we need to evaluate programs with integrated weed-management tactics.

### Findings

The oat companion crop did not provide suppression of waterhemp until the oats were over 12 inches tall. This also coincided with yield loss due to the companion crop and weed competition. Even though a companion crop may provide some relief from IDC symptoms, we did not see a benefit for pigweed management with this system. Delaying postemergence applications until the companion crop was 6 inches tall also resulted in less than 90% control of glyphosate-resistant waterhemp with dicamba. We also found that delaying waterhemp control until the soybean's reproductive phases resulted in a 43% reduction for the soybean yield. If uncontrolled all season long, waterhemp reduced soybean yield by 96% compared to a weed-free check.

**Dr. Ikley discusses waterhemp control at a Research Extension Center field day.**

> "Even though a companion crop may provide some relief from IDC symptoms, we did not see a benefit for pigweed management with this system."

### Benefits/Recommendations

Based on results from 2020, a small-grain companion crop will not suppress pigweed species in soybeans until yield loss occurs. These companion crops can still help with IDC in some environmental situations, but we did not see the benefit for pigweed management. In a companion study, we did find that group 15 herbicides did not cause major oat stunting, so this system could still work when paired with certain preemergence herbicides for waterhemp management.

# UV/Thermally Curable, Soy Protein-Based Resin as a Versatile Platform for Chemical Delivery

***Principal Investigator:*** *Dr. Long Jiang, NDSU Mechanical Engineering*

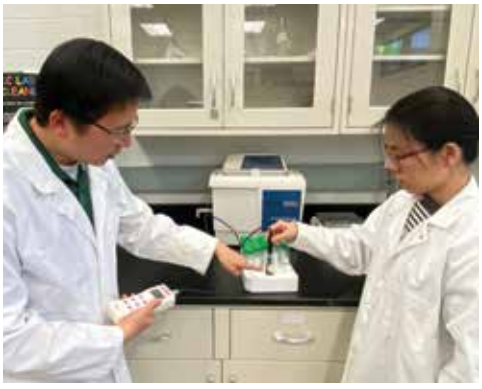
Funded Project
$33,132

### Research Conducted

We developed two soy protein resin systems for chemical delivery with controlled-release capability for agricultural and horticultural uses. Both systems were derived from soy protein-based resin with one fabricated through ultraviolet (UV) curing and the other through thermal curing. The systems contained other ingredients to improve their water resistance, structural stability and release control capability. We studied the systems' chemical reactions during UV and thermal curing. Microstructures, mechanical properties, water absorption, waster swelling and water resistance for the two delivery systems were tested using different methods. Aspirin and ammonium sulfate were utilized as a model chemical/fertilizer to study the two systems' release behavior.

### Why the Research is Important to North Dakota Soybean Producers

Soy protein isolate (SPI), a byproduct from soybean oil production, has an abundant supply. Utilizing SPI as a raw material to produce controlled-release fertilizers or pesticides provides an important new use for soybean. SPI itself is biodegradable and can provide nutrients to the soil after its degradation. The new fertilizers/pesticides can potentially find large-scale use in the agricultural and horticultural industries and can open a new market for soybeans.



**Testing chemical release from soy protein based controlled release fertilizer.**

### Findings

Both UV and thermally cured systems exhibited a controlled release, with the system formulations and processing conditions showing strong effects on their release behaviors. The UV system showed more sustained release, by far, than the thermal system, which makes the UV system more suitable for longer growth-cycle crops. More systematic studies are desired to determine the optimum formulations and processing conditions in order to meet the specific release needs for different crops.

### Benefits/Recommendations

Soy protein-based controlled-release systems provide sustained releases of fertilizer or pesticides to improve the chemicals' efficiency and to reduce the environmental effects. The release systems also provide additional nutrients to the soil when the protein decomposes. Utilizing soy protein to produce the release systems increases the market demand for soybeans.

**Figure 1. Compressive stress-strain curves for the BC/MSPI composite hydrogels.**

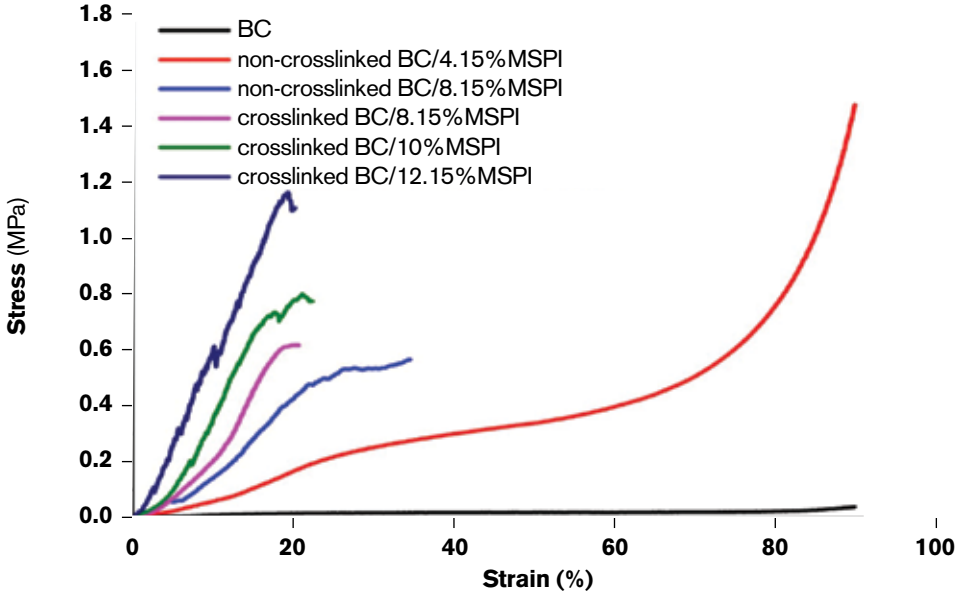
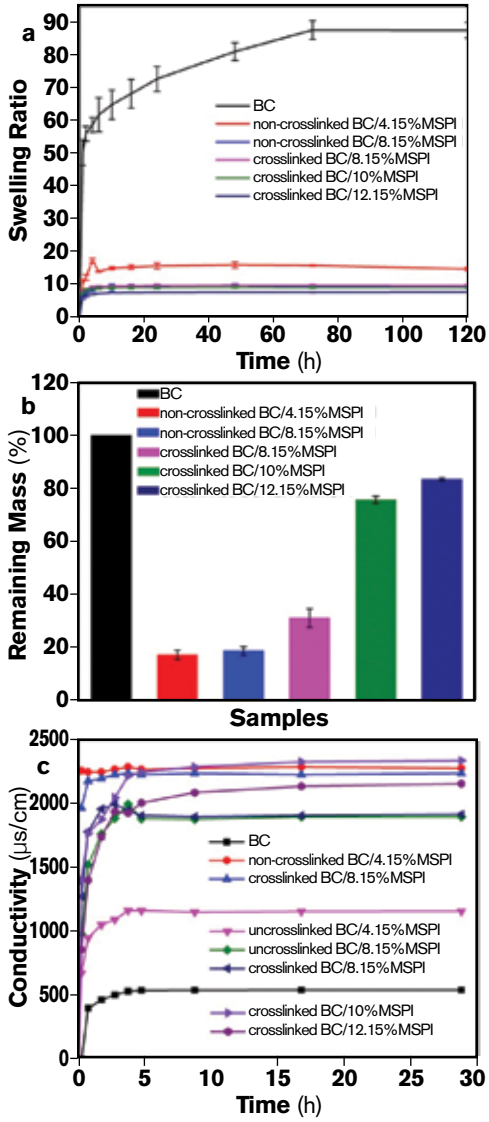



**Figure 2. (a) Swelling ratio, (b) water solubility, and (c) fertilizer release monitoring with conductivity measurements as a function of time at 25°C for (NH4)2SO4 fertilizer of the BC/MSPI composite hydrogels.**



# Pyrethroid-Resistant Soybean Aphids and Soybean Gall Midge Survey

***Principal Investigators:*** *Dr. Janet J. Knodel, NDSU Professor and Extension Entomologist; Dr. Veronica Calles-Torrez, Post-Doctoral Scientist; and Patrick Beauzay, IPM State Coordinator and Research Specialist*

***Cooperator:*** *Brian Otteson, Director, NDSU Agronomy Seed Farm, Casselton, North Dakota*

***Grower Cooperators:*** *Jared Hagert and Dale Flesberg*

Funded Project
$31,670

**Why the Research is Important to North Dakota Soybean Producers**

The soybean aphid is a major insect pest for North Dakota soybeans. This research's goal was to develop the best pest management (BPM) practices for insecticide-resistant soybean aphids. Grower complaints about pyrethroid insecticides not controlling soybean aphids were common and widespread in eastern North Dakota during 2017. Laboratory bioassays confirmed that about 70% of the tested soybean aphid populations were resistant to pyrethroid insecticides. Soybean aphids are very mobile, and pyrethroid-resistant soybean aphids could migrate from other resistant areas, such as south-central Minnesota, where the resistance first occurred in 2015. Because the populations of soybean aphids can vary by year and location, screening for pyrethroid-resistant soybean aphids is key to determine their presence or absence, and their resistance status in North Dakota.

**Research Conducted**

In 2020, soybean aphid populations were low and present at non-economic levels, so no insecticide testing for new modes of action could be conducted against these pyrethroid-resistant soybean aphids. This research is important for soybean growers so that they can wisely select which insecticide and mode of action to use against pyrethroid-resistant soybean aphids. Insecticide-resistant soybean aphids will continue to complicate the growers' pest management of soybean aphids.

Our last objective was to survey for the invasive soybean gall midge, a new insect pest for soybeans. The soybean gall midge is now established in five states, Iowa, Minnesota, Missouri, Nebraska and South Dakota, and has increased its distribution from a total of 67 counties in 2018 to 114 counties in 2020. Because its populations and severity are increasing for our neighboring states of Minnesota and South Dakota, growers need to know if soybean gall midge is present in North Dakota. A total of 605 soybean fields were inspected for soybean gall midge in 47 of North Dakota's 53 counties (89% of the counties). The results of our 2020 soybean gall midge survey were negative for all soybean fields examined in North Dakota. This news is good for North Dakota soybean growers.

**Figure 1. Soybean gall midge larvae inside the lower stem of soybeans (Veronica Calles-Torrez, NDSU).**

**Figure 2. Dark discolorations from soybean gall midge feeding injury at the base of soybean stems (Veronica Calles-Torrez, NDSU).**

**Dr. Knodel at Agronomy Seed Farm tour discusses soybean Gall Midge.**

Future survey work for soybean gall midge will be crucial for soybean production in North Dakota.

> "This research is important for soybean growers so that they can wisely select which insecticide and mode of action to use against pyrethroid-resistant soybean aphids."

# Soybean Cyst Nematode Sampling Program: 2020

***Principal Investigator:*** *Dr. Sam Markell, North Dakota State University (NDSU) Professor/Plant Pathologist*
***Co-Investigator:*** *Dr. Guiping Yan, NDSU Assistant Professor/Nematologist*
***Collaborators:*** *Dr. Berlin Nelson, NDSU Department of Plant Pathology, and the NDSU County Extension Agents*

Funded Project
$61,580

### Research Conducted

This project is designed to encourage growers to sample the soil for Soybean Cyst Nematode (SCN), the most damaging soybean pest in the United States. Growers submit soil samples to the partner laboratory in pre-labeled bags; the North Dakota Soybean Council (NDSC) covers the laboratory fees; and growers receive data directly through the mail. NDSU Extension receives egg-level and geographic data to construct distribution maps. No additional information about submitters is obtained.

### Why the Research is Important to North Dakota Soybean Producers

This program provides an incentive and mechanism to sample for SCN by covering the laboratory fees. SCN causes damage before above-ground symptoms appear, making detection with soil sampling critical. Growers can use this sampling program to help determine if their management tools, including resistance, rotation, seed treatments or other methods, are working.

### Findings

In 2020, there were 603 SCN samples received. Nematode eggs were detected in approximately one-third of the samples. Distribution maps from 2013 to 2020 (Figure 1) and 2020 only demonstrated that SCN is most common and in the highest levels in the southeastern North Dakota (Figure 2).

### Benefits/Recommendations

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

### Acknowledgements

We express our thanks to the many growers, Extension agents, crop consultants and others who participated in this program; to Michaela Halvorson for map construction; to Agvise for sample processing; and, finally, to the North Dakota Soybean Council for support.

**Dr. Markell discusses SCN management and detection.**

**Figure 1. Distribution of soybean cyst nematode (eggs/100 cc soil) in North Dakota soil received though the NDSC/NDSU Extension sampling program, 2013-2020.**

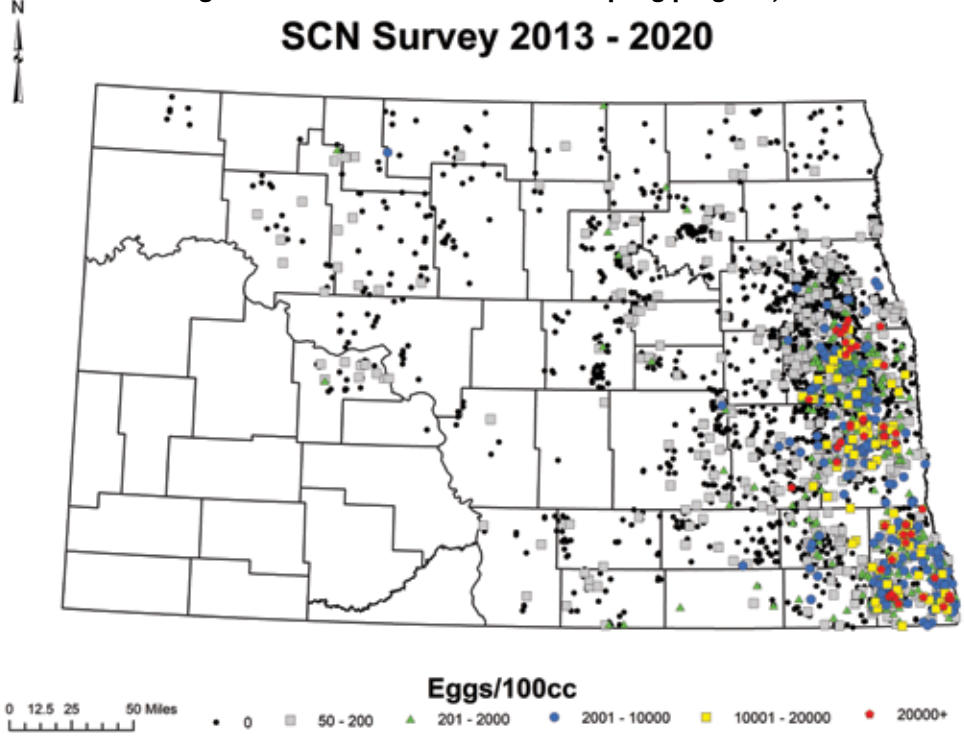
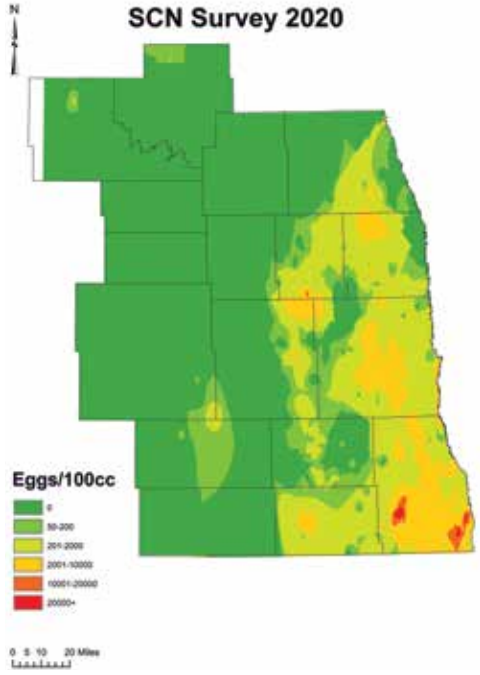



**Figure 2. The 2020 only distribution and egg level of soybean cyst nematode (eggs/100 cc soil) in southeast and east-central North Dakota soil received though the NDSC/NDSU Extension sampling program. Note of caution: SCN is very spotty in regions and fields, and heat maps (while visually appealing) do not have the resolution to reflect the SCN presence or level for any specific fields.**



# Breeding of Glyphosate-Resistant Soybean Cultivars

***Principal Investigators:*** *Dr. Carrie Miranda, NDSU Department of Plant Sciences*
***Cooperating Scientists:*** *Dr. Berlin Nelson; Dr. Guiping Yan, NDSU Department of Plant Pathology*

Funded Project
$148,413

**Why the Research is Important to North Dakota Soybean Producers**

This project has enabled North Dakota State University (NDSU) to continue the process of developing glyphosate-resistant soybean cultivars. There are glyphosate-resistant experimental lines in the NDSU breeding program that are being tested for a range of maturity that varies from a 1.0 to a 00.4 maturity and are properly adapted throughout the entirety of North Dakota. New experimental lines are developed each year, including in 2020.

This project has significantly reduced seed costs for soybean growers. Cultivars with glyphosate resistance that are developed at NDSU are not patented. The cost savings for growers who purchase NDSU's glyphosate-resistant cultivars developed will occur the second and subsequent years after the seed's initial purchase. The seed for the new experimental lines has been increased in Chile each winter in order to speed the development and release.


**Dr. Miranda shows the glyphosate-resistant lines of soybeans.**

**Results/Findings**

This project was successful with the first glyphosate-tolerant variety (ND17009GT) released in 2017, and two new varieties were successfully released in 2020. 21ND08GT73 is a maturity group (MG) 0.8 and the first later-maturing GT line released by the NDSU program. This line allows more North Dakota growers to access the cost-effective NDSU GT lines. 21ND008GT20 is a MG 00.8 variety and is considered an improvement on ND17009GT due to the increased iron deficiency chlorosis (IDC) tolerance.

A successful breeding pipeline continually has promising materials moving through it. In addition to the two variety releases, there was also one prerelease of a MG 0 line that has superior yield compared to all NDSU released varieties. There is also a MG 00.6 experimental line that is being increased to prepare for prerelease, and after another year of collecting yield data in 2021, there should be confidence and sufficient seed for its release.

A year or two beyond these releases are younger lines that show not only yield and maturity promise, but also have soybean cyst nematode (SCN) resistance that was validated by Guiping Yan. Phytophthora resistance for all these lines and other in advanced yield trials was validated by Berlin Nelson.

> “21ND008GT20 is a MG 00.8 variety and is considered an improvement on ND17009GT due to the increased iron deficiency chlorosis (IDC) tolerance.”

# Breeding of Improved Non-GMO Cultivars and Germplasm

***Principal Investigator:*** *Dr. Carrie Miranda, NDSU Department of Plant Sciences*
***Cooperating Scientist:*** *Dr. Berlin Nelson, NDSU Department of Plant Pathology*

Funded Project
$257,567

### Why the Research is Important to North Dakota Soybean Producers

This project provides soybean farmers with improved non-GMO cultivars that have been developed by North Dakota State University (NDSU). Also, growers need information that enables them to select the best private-company variety for their farm and to identify which varieties are best on soybean cyst nematode (SCN) infested soil and iron-deficiency chlorosis (IDC) prone soils.

### Research Conducted

This project provides yield results for variety testing on SCN-infested soils and soils that exhibit IDC symptoms. The NDSU soybean breeding program has a long history of providing very competitive varieties. There are many improved non-GMO experimental lines that are close to being released as named cultivars. The non-GMO breeding effort is very important as a source of high-yielding parents for use when developing glyphosate-resistant cultivars.

In addition, food-grade/yellow hila soybean varieties are produced with the non-GMO project. By partnering with soyfood companies, specialty soy lines, such as tofu and natto, are created and identified. Then, the lines are tested for market specifications by the companies.

### Results/indings

In 2020/2021, the non-GMO breeding project continued to flourish by identifying superior lines in the project that can be utilized both for food-grade soybean varieties and for parents in the glyphosate-tolerant project. These lines are superior due to a combination of yield and other favorable traits, such as hilum color, seed size, protein or sugar content, and disease resistance. The lines will also serve as parents for new crosses that are created, ensuring that superior genetics continue to influence NDSU's soybean program.

In addition, NDSU has continued to test commercial varieties in SCN-infected fields to ensure that there is a nonbiased and equal comparison of private companies' varieties to assist farmers with decision making about what varieties to purchase, especially if the growers have infected soils. Data were analyzed and reported in the NDSU bulletin titled "North Dakota Soybean Performance" and were posted online.

**Dr. Miranda and crew harvest and compile yield data.**

Finally, developing IDC- and phytophthora-tolerant lines continues to be a priority for the NDSU breeding program. This upcoming year, in addition to IDC field testing and phytophthora screening of the NDSU experimental lines, molecular markers will be used to test for IDC and phytophthora resistance in the nursery lines in order to ensure that resistance isn't lost during generation advancement.

> "These lines are superior due to a combination of yield and other favorable traits, such as hilum color, seed size, protein or sugar content, and disease resistance."

# Visual Ratings for Iron-Deficiency Chlorosis

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

Funded Project
$76,214

**Why the Research is Important to North Dakota Soybean Producers**

Iron-deficiency chlorosis (IDC) is common in North Dakota and reduces yield. The best way to reduce the yield losses associated with IDC is to select a tolerant cultivar. Growers need data that compare the varieties from various companies at the same locations. This research permitted more than 250 different GMO company varieties and non-GMO varieties to be evaluated for IDC tolerance. An additional 104 North Dakota State University (NDSU) breeding lines were evaluated. All private-company varieties that were entered into the Langdon Research Extension Center (REC), Carrington REC, Minot REC and Fargo Main Station yield trials were evaluated for visual IDC ratings at multiple field locations. These data provided independent confirmation of the IDC tolerance for the company products and enabled growers to compare varieties from different companies. This project afforded an unbiased comparison of yield data for the same environment so that growers could select tolerant cultivars in order to increase yield on fields that have a history of IDC.

**Dr. Carrie Miranda, far right, with her NDSU breeding program team.**

**Research Conducted**

In 2020, there were 206 GMO company varieties, and 33 Liberty Link and non-GMO company varieties were planted at 3 locations: Leonard, Colfax, and Erie, North Dakota. Two locations successfully showed IDC symptoms, and the scores were recorded. The data were analyzed and reported in the NDSU bulletin titled "North Dakota Soybean Performance" that was posted online.

> "This project afforded an unbiased comparison of yield data for the same environment so that growers could select tolerant cultivars in order to increase yield on fields that have a history of IDC."

**Results/Findings**

This work's goal was to give growers additional data so that they can make the best decisions when choosing varieties, especially for IDC-affected soils. Support for this project was also high among private companies, as nearly 250 varieties were entered in 2020. Due to the usefulness of the data collected, this project will continue in 2021. During 2020, fields infected with IDC were selected for the 2021 season.

# Resistance to Important Diseases

***Principal Investigator:*** *Dr. Berlin Nelson, Jr., NDSU Plant Pathology*
***Cooperators:*** *Dr. Carrie Miranda, NDSU Soybean Breeder, and Dr. Sam Markell, NDSU Extension Pathologist*

Funded Project
$58,850

**Why the Research is Important to North Dakota Soybean Producers**

A major focus of this research was to identify new soybean diseases or changes in pathogens that could threaten soybean production in North Dakota. In addition, we conducted research about ways to improve disease management. In cooperation with Dr. Miranda, we screened 148 advanced breeding lines for resistance to races of Phytophthora sojae, the cause of Phytophthora root rot. Most of the screening was for Race 4 resistance, and over 66% of the lines tested were resistant to Race 4. One of the breeding lines resistant to race 4 was released by Dr. Miranda in 2021 as ND21008GT20, a glyphosate-tolerant soybean.

In August of 2020, we continued efforts to determine if sudden death syndrome (SDS), a new disease for North Dakota, had spread in Richland County, where we first found it in 2018. SDS is caused by the soil-borne fungus Fusarium virguliforme. We surveyed an area of approximately 400 square miles. We identified 12 soybean fields with classic SDS symptoms. In addition, Extension agents in Cavalier County found a field close to the Canadian border with SDS symptoms and sent plant roots in for examination. With molecular techniques, the presence of the pathogen was verified for all these fields.

**Results/indings**

The results from this research point out that SDS is a potential future problem for North Dakota soybean growers. The disease is now well established, and because it is a soil-borne pathogen, it will readily spread from field to field. It will be important for growers, crop scouts and others managing soybean fields to identify this disease when it first appears. An important management tool that will be needed in the future is SDS-resistant soybean varieties. Currently, in our maturity groups, there are no commercial cultivars with known resistance to SDS.

A large effort is underway to develop methods to identify resistance to SDS and to identify sources of resistance that can be use in the NDSU soybean breeding program. There are sources of SDS resistance in the soybean germplasm, but there are few sources of resistance in adapted germplasm for maturity groups (MG) 0 and 00. Both greenhouse and field experiments have been conducted over the past year to improve our screening methods and to find high levels of resistance in maturity group 0. Thus far, we have found moderate levels of SDS resistance, but not high levels, in MG 0. More studies are in progress to identify additional sources of resistance.

**Greenhouse testing for resistance in soybeans to sudden death syndrome (SDS). Plants showing strong chlorosis had classic SDS symptoms while more resistant varieties still had green leaves (March 30, 2021).**

# Evaluation of Soybean Hulls as Roughage Sources in Feedlot Rations

***Principal Investigator:*** *Dr. Bryan Neville, Animal Scientist, NDSU Carrington Research Extension Center*

Funded Project
$11,455

**Why the Research is Important to North Dakota Soybean Producers**

The research's overall objective was to evaluate the fiber value provided by soybean hulls for feedlot diets. Specific objectives included evaluating the performance of changing the ruminal fermentation and pH with increasing concentrations of soybean hull, and evaluating changes in ruminal and duodenal fiber kinetics of high-grain rations that contain soybean hulls.

**Results/Findings**

Intake was negatively affected by increasing soyhull inclusion and decreased by 2.1 kilograms/day when corn silage was completely replaced with soyhulls. Intake and total tract digestibility of neutral detergent fiber (NDF) were not affected by the rate of soyhull inclusion or added straw. Further, the duodenal flow of NDF was not affected by the rate of soyhull inclusion but tended to decrease with added straw in the diet.

**Dr. Neville inspects the drylot cattle in the soybean hull study.**

In the current research, replacing corn silage with soyhulls did not affect ruminal pH; however, adding wheat straw to the diet increased ruminal pH compared to the same diets without straw. The fact that replacing greater amounts of corn silage with soyhulls did not influence ruminal pH is interesting. Based on the lower expected effective fiber content of soyhulls, we had anticipated that ruminal pH would have decreased with increasing the soyhull replacement of corn silage. The response of the ruminal fluid pH to adding 3% wheat straw to the diet was more traditional, and likely represented increases in rumination and the addition of buffers from salvia to the rumen.

**Dr. Neville demonstrates the volume increase of soybean hulls in the stomach of beef cattle.**

These data were presented at the Western Section American Society of Animal Science Meetings in 2021. A manuscript detailing this project's results is being drafted and will be submitted to a peer-reviewed journal.

The decreased intake observed in this study would likely reduce feedlot cattle performance, underscoring the need for additional research prior to recommending the use of soyhulls as a roughage source for feedlot cattle. Data evaluating soyhulls as a roughage source in high-concentrate diets are lacking, and more research about the effects of soyhull inclusion on feedlot cattle's performance would be needed to fully understand the results of utilizing this feed resource.

# Use of Soybean Hulls in Rations for Drylot Beef Cows

***Principal Investigator:*** *Dr. Bryan Neville, Animal Scientist, NDSU Carrington Research Extension Center*

Funded Project
$6,732

**Why the Research is Important to North Dakota Soybean Producers**

The purpose of this project was to evaluate feeding options, including soybean hulls, for the management of drylot cow/calf pairs. Our specific objectives included evaluating the performance of beef cows fed either soybean hull-based rations or corn/corn silage-based rations under drylot management throughout an entire production cycle, evaluating milk production and quality during lactation and the performance of beef calves resulting from cows fed either soybean hull- or corn/corn silage-based rations under drylot management, and providing a demonstration of feeding soybean hull-based rations to beef cows under drylot management.

**Results/indings**

At the project's initiation, cows were sorted into pens and placed on the respective treatments. Rations were developed for lactation, mid-gestation and late gestation. Soybean hulls were included at a rate of 26-27%, replacing the portions of corn silage, straw and modified wet distillers grains (MDGS) in the diet.

During this study, there were no differences with cow performance due to the dietary treatment. Concentrations of non-esterified fatty acids (NEFA) and glucose were not affected by the treatment. Colostrum protein content tended to be greater in the control cows compared with the soybean-hull cows. Calf birthweights, weaning weight and carcass ultrasound measurements were largely unaffected by the inclusion of soybean hulls in the diet. Similarities between treatments were expected because the diets were formulated to contain similar net energy (NEm) that was fed between treatments throughout the study.

The lack of differences for the dam performance could likely be caused by meeting the energy and protein demands throughout gestation with the use of soybean hulls. This was not unexpected because nutrient composition between the control and the soybean-hull diets was similar. Jointly, the present and previous data appear to indicate that soybean hulls can be used effectively in beef cow diets at rates up to 27% of the dietary dry matter. More research is necessary to measure dam performance with various soybean-hull inclusion rates in order to define the use of soybean hulls for drylot beef-cow diets.

# North Central Soybean Research Program (NCSRP)

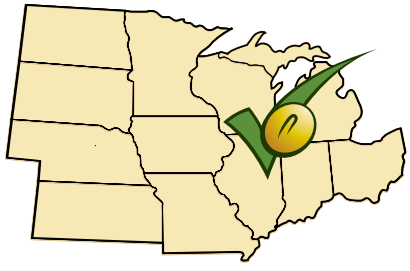
Funded Project
$150,000

The North Central Soybean Research Program (NCSRP) is a multi-state collaborative research and outreach group that supports soybean farmers and drives the soybean industry forward. The NCSRP's focus is soybean-production research and extension outreach. The NCSRP's emphasis on enhancing and protecting soybean yield through genetics and agronomic practices contributes to soybean farmers' success today and tomorrow.

The NCSRP funded 11 projects in 2020:

- Discovering and finally understanding the functions of genes that underlie major agricultural traits in soybeans
- Boots on the ground: Validation of a benchmarking process through an integrated on-farm partnership
- Multi-pronged strategies to provide efficient, sustainable and durable control for Sclerotinia stem rot

NCSRP NORTH CENTRAL SOYBEAN RESEARCH PROGRAM



- An integrated approach to enhance the durability of Soybean Cyst Nematode (SCN) resistance for long-term, strategic SCN management (Phase II)
- Developing an integrated management and communication plan for soybean sudden death syndrome
- Soybean gall midge: Surveying the North Central Region, adult monitoring and host-plant resistance
- Expanding the SCN Coalition
- Non-transgenic generation of herbicide resistance in soybean using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) base editing
- Manipulating a major gene that governs seed reserves as a means to maintain the yield and oil while increasing the protein
- Soybean entomology research and extension in the North Central Region
- Increasing the soybeans' genetic gain for yield by developing tools, know-how and community among the North Central Region's public breeders

The 2020 NCSRP research project summaries can be found online at NCSRP.com and SoybeanResearchInfo.com

# Determining Rye Safety to Soybeans with the Soil's Moisture Status

***Principal Investigator:*** *Dr. Michael Ostlie, NDSU Carrington Research Extension Center*

Funded Project
$13,556

**Why the Research is Important to North Dakota Soybean Producers**

The current recommendation is for rye cover-crop termination at least 10 days before soybean planting. One objective for this and other similar studies at our location was to determine whether this recommendation should be updated.

**Results/Findings**

The good news is that there was no significant yield difference between plots where rye was terminated at or before soybean planting for any of the trial years. On the other hand, in all three years of the trial, there was a large reduction for the soybean yield when the rye was allowed to reach maturity within the soybeans, to the point of complete crop failure in 2018. There was even substantial yield loss in 2020 when the early season soil moisture was abundant. Furthermore, for all three years, letting rye grow for two weeks after soybean planting resulted in a statistically significant yield reduction. Letting the rye grow for only one week also showed a decrease in yield for each year when compared to terminating at or before planting, but this difference was not statistically significant.

**Dr. Mike Ostlie discusses his research with producers during Carrington REC Field Days.**

One reason that delayed termination works is that our rye water use is, ultimately, small compared to soybeans. The reason for concern with this system is that peak rye water use occurred around anthesis, which often coincides with the time that the soybeans would normally be germinating. Timely rains during this project meant that soybean yields were largely protected when "planting green." However, in prior years, there were severe yield penalties when planting green. This trial's dataset was instrumental to identify water-use patterns for each crop within this system as we continue to develop the best recommendations for managing the winter rye to soybean relay system.

> "This trial's dataset was instrumental to identify water-use patterns for each crop within this system as we continue to develop the best recommendations for managing the winter rye to soybean relay system."

# Determining a Suitable Planting Date and Soil Temperature for Enhanced Growth and Yield of Soybeans Under No-Till, Semi-Arid Conditions

***Principal Investigator:*** *Dr. Gautam Pradhan, NDSU Williston Research Extension Center (REC)*

Funded Project
$11,416

### Research Conducted

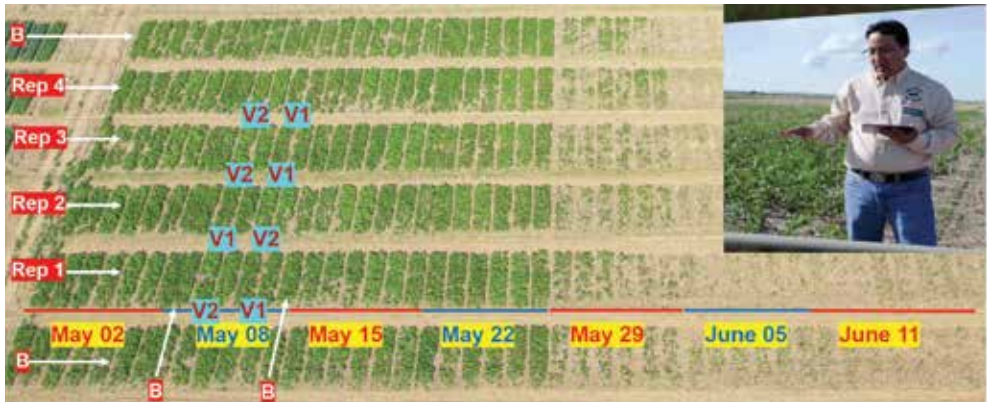
Two glyphosate-tolerant varieties ('ND17009GT' and 'ND18008GT'), either treated with the fungicide Obvious at 6.4 oz/100 lb seed or untreated, were planted at seven different dates (the 2nd, 8th, 15th, 22nd and 29th of May and the 5th and 11th in June 2020) under no-till dryland conditions.

### Why the Research is Important to North Dakota Soybean Producers

Soybean acreage has been steadily increasing in North Dakota, including the western part of the state which has an exceptionally drier climate (precipitation <15 inches/year) than the eastern side (precipitation: >20 inches/year). There is a lack of soybean production management guidelines suitable for western North Dakota's no-till dryland producers. Determining suitable planting dates and soil temperature is crucial to avoid abiotic and biotic stress as well as to have a sustainable higher soybean yield and farm income with no-till dryland conditions.

### Findings

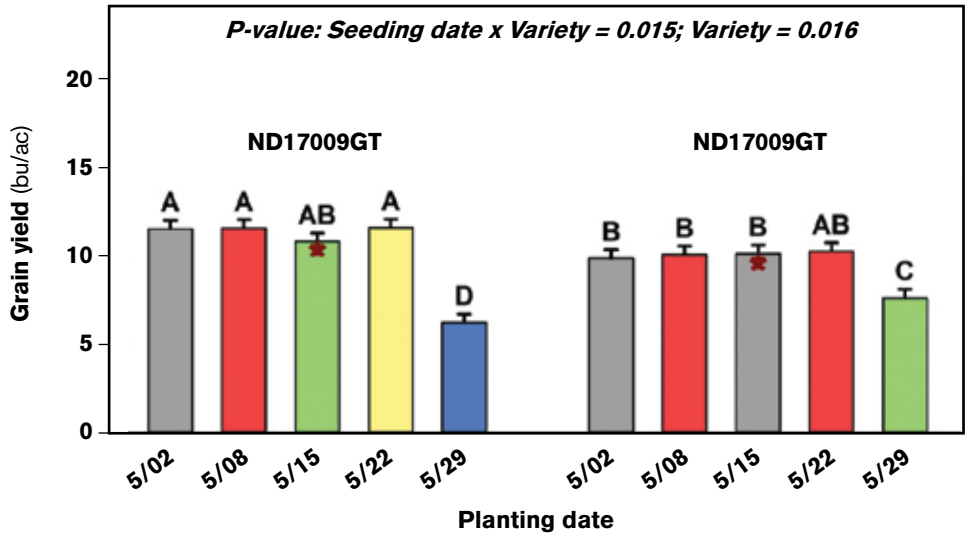
In 2020, there was extreme drought. We received annual precipitation of 7 inches, which was half of the precipitation compared to the average for the last 63 years. Also, the first fall killing freeze occurred on September 8, 2022, a month earlier than in 2019, which killed all the soybeans which were planted in June.




**Soybean under different planting dates. B = Border, V1=ND17009GT, V2=ND18008GT. For clarity, varieties were indicated for May 08 planting only. Two adjacent lots belonging to a variety in each replication were seeded with either treated or untreated seeds. Aerial image: 07/23/2020. Inset photo: Dr. Gautam Pradham explaining about the experiment to NDSC and NDSGA personnel on 07/21/2020.**

The effect of planting date, variety and seed treatment was not observed on grain number and test weight. Planting soybeans on or later than May 29th significantly decreased the plant height, above ground biomass, thousand grain weight and grain yield. When soybeans were planted on or before May 22nd, ND17009GT and ND18008GT yielded about 11.4 bushels per acre (bu/ac) and 10.1 bu/ac, respectively. When the planting was delayed until May 29th, the yield of ND17009GT decreased by 45%, and the yield for ND18008GT decreased by 24% (Figure 1). The ND17009GT variety, when averaged across other treatments, had higher biomass, grain weight and yield than ND18008GT.

**Figure 1. Differential responses of soybean varieties to planting dates for grain yield. * represents an average yield of a variety.**




### Benefits/Recommendations

The results from this year showed that, with the no-till dryland conditions in western North Dakota, a season-long drought may result in a massive decline for the soybean yield (average trial yield: 10 bu/ac in 2020 and 30 bu/ac in 2019), irrespective of the planting date. The study also illustrated that, under drought conditions, if planting is delayed until May 29th, the soybean yield may become as low as 6 to 7 bu/ac. If the combined effect of an early fall killing freeze and a drought occur, planting in June may result in zero economic yields.

# Assessment of Nitrogen (N) Fixation and the Soybean's Yield Response to the Application of Distillers Co-Products

***Principal Investigators:*** *Dr. Jasper M. Teboh, Szilvia Yuja, Dr. Mike Ostlie and Blaine G. Schatz, NDSU*

Funded Project
$12,780

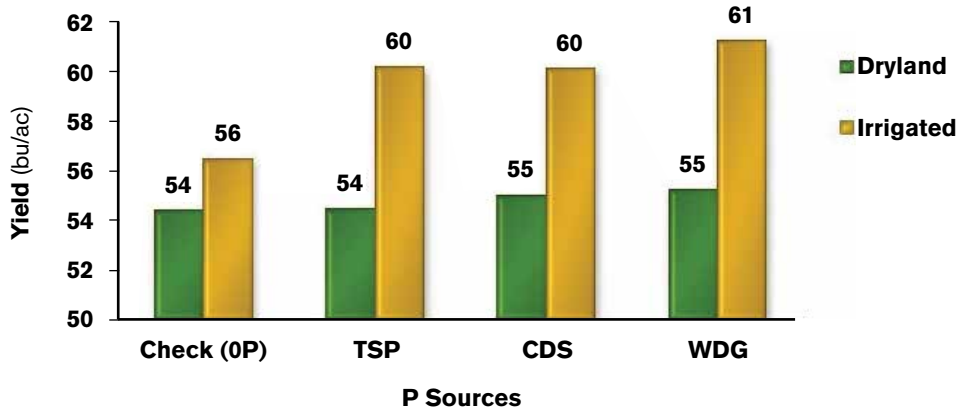
### Why the Research is Important to North Dakota Soybean Producers

Wet distillers grains (WDG) and condensed distillers solubles (CDS) are coproducts of ethanol production that can supply plant nutrients. Due to their high phosphorus (P) and nitrogen (N) content, applying WDG and CDS to the soil as P sources can contribute high amounts of N, which can affect N fixation. The study's objectives were to assess the effect of distillers grains on soybean yields and quality, and nitrogen fixation (ureide-N content in the leaves).

### Research Conducted

Dryland and irrigated soybean studies were treated with WDG, CDS and triple super phosphate (TSP) to supply 40 lbs P, plus there was a control (no added P). Soil test P was 16 lbs, and N was 10 lbs/ac for the dryland soybeans. The irrigated soil test P was 16 lbs, and N was 34 lbs/ac. At 40 lbs P, CDS and WDG contributed 30 and 66 lbs N, respectively (Table 1). The TSP and control treatments received 30 lbs N as urea. Treatments were incorporated on half of each plot (5 x 25 ft2) before seeding. At the 5th trifoliolate, leaves were sampled, and the axes ground and analyzed for ureide-N. The ureide-N concentration is an indicator of N derived from N fixation in soybean nodules.

**Figure 1. Yield response of dryland and irrigated soybean to distillers grains as sources of phosphorus**




### Findings

Phosphorus application did not affect the yield and seed quality. Yields were greater for dryland soybeans than for the irrigated crop (Figure 1), probably because irrigated soybeans were at the R5 stage during an early September frost when the dryland crop was at maturity (R8). Leaf ureide-N was not different between treatments, despite 66 lbs N from WDG, probably due to the slow release of N from WDG. Phosphorus removal was not different between the sources.

### Recommendations for North Dakota as Well as Soybean Farmers and the Industry

Farmers should feel confident about the fertilizer value of distillers grains. It sometimes produces similar or greater yields than conventional fertilizer and has produced no known negative effects on crops following its application. As a fertilizer source, distillers grains should be analyzed in order to determine the right amount to apply in order to supply the desired rate of P or N. Also, farmers also need to consider the cost of acquisition and application versus conventional fertilizers.

**Table 1. Amount of CDS and WDG applied to corn at 40 lbs. P, and the corresponding N, K, S and Zn supplied.**

| CDS Rate | Nutrients supplied with CDS | | | | |
|---|---|---|---|---|---|
| | P | N | $K_2O$ | S | Zn |
| gal/ac | lbs./ac | | | | |
| 190 | 40 | 33 | 29 | 6.9 | 0.08 |
| **WDG Rate** | **Nutrients supplied with WDG** | | | | |
| | P | N | $K_2O$ | S | Zn |
| T/ac | lbs./ac | | | | |
| 1.8 | 40 | 66 | 28.4 | 9.0 | 0.005 |

Dr. Jasper Teboh

# Soybean Oil-Based Additives for Low-Friction Rubber Compounds

***Principal Investigator:*** *Dr. Dean C. Webster and Olena Shafranska. NDSU Department of Coatings and Polymeric Materials*

Funded Project
$31,661

**Research Conducted**

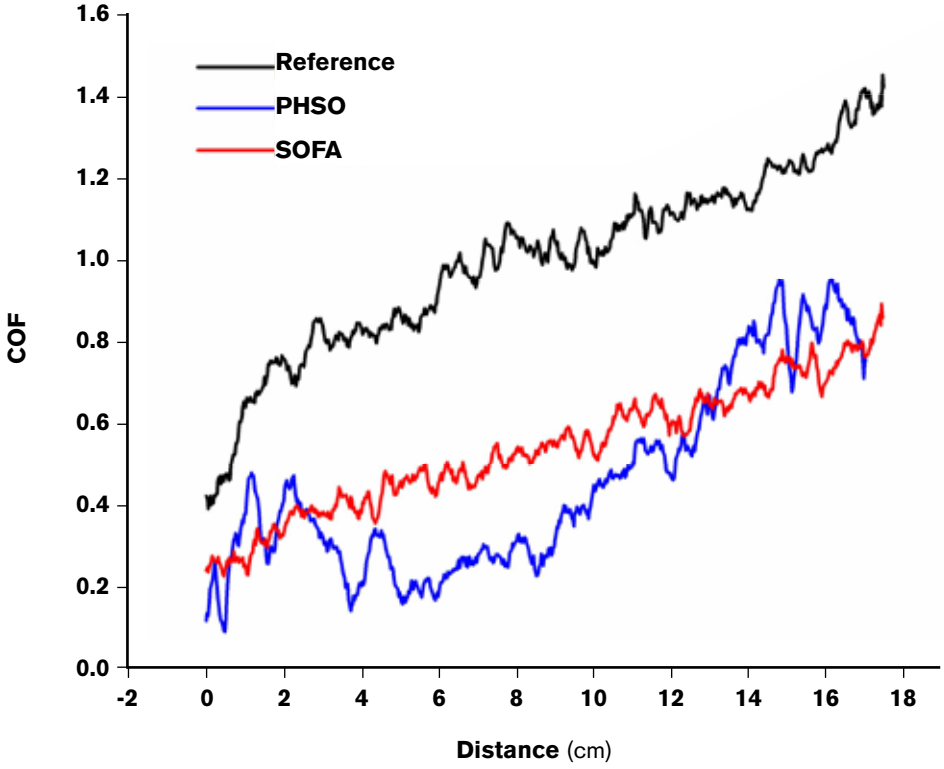
This project's objective was to evaluate the potential of modified soybean oils (SBO) as additives for polystyrene-butadiene (SBR) rubber compounds to reduce the coefficient of surface friction for the rubber. SBR rubber is widely used to manufacture conveyor belts and rubber belts for various agriculture harvesting equipment. SBR rubber has good mechanical strength and durability, but has a high coefficient of friction (COF), which leads to overheating and damaging of the rubber belt.

Chemically modified soybean oils were studied as additives to SBR rubber compounds. The compounds were vulcanized and tested for surface friction after different time periods. Two modified SBOs were selected as additives that reduce surface friction. One additive was partially hydrogenated soybean oil (PHSO), which is an inexpensive commercial product that has wide application in the food, cosmetic and household-product industries.

**Dr. Webster provides science and STEM teachers an overview of new coatings and polymeric products.**

The second additive, named SOFA, was synthesized by chemical modification of SBO with polystyrene and a fluoroacrylate. Both modified SBOs demonstrated a reduction for the surface friction of rubber compared to the reference rubber (Figure 1).

**Figure 1. Differential responses of soybean varieties to planting dates for grain yield. * represents an average yield of a variety.**




The SBR compounds were formulated with carbon black, petroleum-based aromatic oil and different amounts of the modified soy-based additives. For some compounds, the petroleum-based oil was completely replaced with soy-based additives. The compounds were vulcanized and tested for mechanical properties.

**Findings**

The results demonstrated that PHSO improves the mechanical properties of rubber, such as tensile strength and hardness. SOFA slightly reduced the tensile strength of rubber but provided a stable reduction for the surface friction. Both PHSO and SOFA can be used as additives for SBR compounds with enhanced mechanical and improved surface properties.

**Why the Research is Important to North Dakota Soybean Producers**

This project identified a new use for soybean oil in industrial applications: modifying the surface-friction properties of the rubber compounds.

# Soil Health and Agriculture Research Extension (SHARE) Farm Research Projects in Mooreton, North Dakota, and Logan Center, North Dakota

***Principal Investigators:*** *Dr. Abbey Wick, Dr. Caley Gasch, Dr. Aaron Daigh, Dr. Marisol Berti, Dr. Frank Casey, Greg Endres, Dr. Mike Ostlie and Naeem Kalwar, NDSU*

Funded Project
$26,358

**Research Conducted**

Through two years of study at Logan Center and eight years at the Mooreton Soil Health and Agriculture Research Extension (SHARE) Farms, research efforts have

- Demonstrated and evaluated field-scale, whole-system strategies on saline and non-saline soils
- Evaluated the economics of soil-health improving strategies
- Evaluated soil-health testing and how it applies to our region
- Studied the differences with conventional and no-till practices
- Studied the effect of tillage practices on crop yield, soil quality, soil moisture and soil temperature
- Transferred science-based knowledge to North Dakota farmers

**Soybean harvest at the SHARE Farm.**

**Why the Research is Important to North Dakota Soybean Producers**

Research being conducted at the SHARE Farms provides regional, science-based information to farmers so that they can reduce risk when adopting new soil health-building practices. Although the SHARE Farms are regional, there are basic concepts and management practices that can be adopted by farmers across the state. The SHARE Farms also let farmers see the practices firsthand.

**In-field data collection.**

**Findings**

Several conclusions can be drawn from the SHARE Farm projects:

- Tile-drainage can help manage soil salinity when used with other soil health-building practices, such as reduced tillage, salt-tolerant crop selection and cover crops.
- Soil temperature is, on average, lower and has less daily fluctuation with no-tilled as compared to conventionally tilled systems.
- No-till systems help to increase the soil's water content under most conditions.
- No-till systems (no-till plus cover crops) have slightly lower or non-significant yield differences compared to conventional tillage.

**Benefits/Recommendations**

Following harvest this fall, final sampling at the Mooreton site will be done, so stay tuned for final results and recommendations from that location. For updates about the SHARE Farm project and other soil-health news, visit the NDSU Soil Health webpage (NDSU.edu/soilhealth), or follow Abbey Wick on Twitter (@NDSUsoilhealth).

# Optimizing Fungicide Application Methods for the Management of Sclerotinia in Soybeans

***Principal Investigator:*** *Dr. Michael Wunsch, Plant Pathologist, NDSU Carrington Research Extension Center*

Funded Project
$62,140

### Research Conducted

In recent years, there has been significant discussion about optimizing the spray-droplet size for herbicides. Does the spray-droplet size matter when applying fungicides? Surprisingly, there is very little information about the effect of droplet size on disease management in field crops.

From 2017 to 2020, the plant pathology research program in Carrington, collaborating with agronomists at the North Dakota State University (NDSU) Robert Titus Research Farm in Oakes, quantified the effect of a fungicide's spray-droplet size on the management of white mold in soybeans. Fungicide applications were made with a tractor-mounted research-and-development sprayer that was equipped with a pulse-width modulation system from Capstan AG. Fungicides were applied with a 15 gal/ac spray volume at 4.0 mph, 6.0 mph, 6.7 mph, 8.9 mph or 10.5 mph, depending on the study. The pulse width was modified as needed to maintain a constant spray volume and constant driving speed across nozzles differing in output. Testing was conducted on multiple soybean varieties, differing in canopy architecture, with a single application of the Endura fungicide (5.5 oz/ac or 8.0 oz/ac) applied at the R2 growth stage.

### Why the Research is Important to North Dakota Soybean Producers

North Dakota producers have struggled to consistently achieve satisfactory control of white mold in soybeans by utilizing fungicides.

### Findings

For applications made with extended-range TeeJet flat-fan nozzles (Figure 1), fine-to-medium droplets optimized white-mold management when the canopy was very open (average < 75% canopy closure when fungicides were applied). Medium droplets were optimal when the canopy was open (average 80%-89% closure), and coarse droplets were optimal when the canopy was at or near closure.

**Figure 1.** IMPACT OF SPRAY DROPLET SIZE: TEEJET NOZZLES

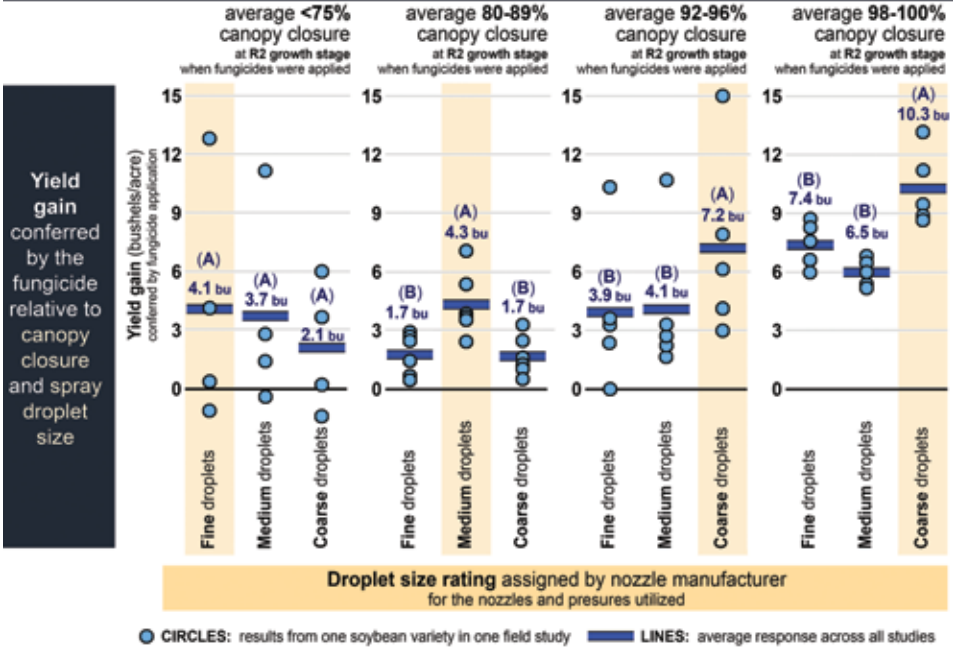
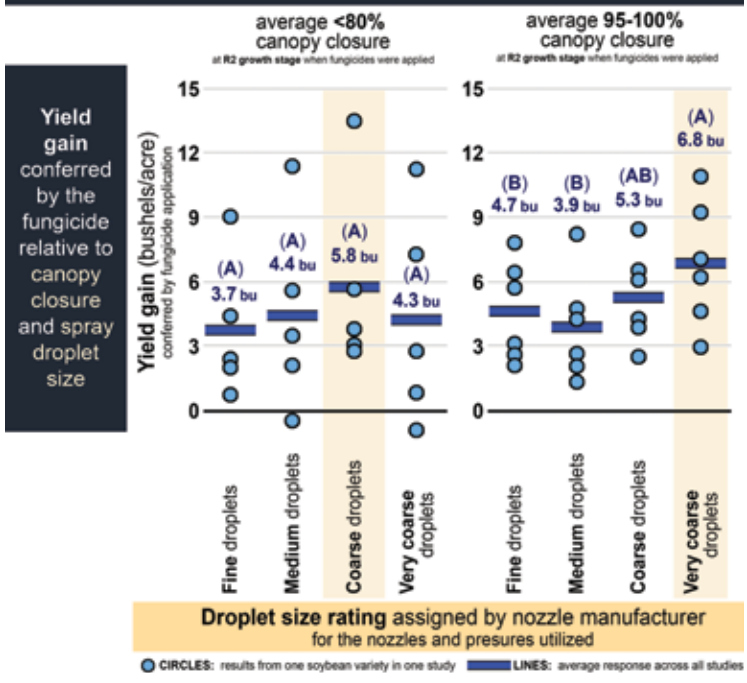



**Figure 2.** IMPACT OF SPRAY DROPLET SIZE: WILGER NOZZLES




With Wilger Combo-Jet flat-fan nozzles (Figure 2), coarse droplets were optimal when the canopy was open, and very coarse droplets were optimal when the canopy was at or near closure.

### Benefits/Recommendations

The yield response to fungicide applications which target white mold in soybeans can be nearly doubled when the droplet size is calibrated relative to the nozzle manufacturer and the soybean canopy's closure. The droplet-size spectrum considered, fine, medium, coarse, etc., differs by nozzle manufacturer. For white-mold management in soybeans, droplets considered to be "medium" by TeeJet performed similarly to droplets considered to be "coarse" by Wilger, and droplets considered to be "coarse" by TeeJet performed similarly to droplets considered to be "very coarse" by Wilger. For both manufacturers, the droplet size that optimizes white-mold management increases as the soybean canopy's closure increases. Smaller droplets optimize fungicide coverage but lack the velocity to penetrate a soybean canopy that is at or near closure.

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

***Principal Investigator:*** *Dr. Michael Wunsch, Plant Pathologist, NDSU Carrington Research Extension Center*

Funded Project
$30,355

### Research Conducted

When cool, wet weather persists or when soybeans are grown with irrigation, two fungicide applications are often needed for satisfactory white-mold management in soybeans. The standard recommendation of making sequential applications 10 to 14 days apart is not based on empirical data and differs from the standard practice in other regions of the world. This study sought to identify the optimal interval between sequential fungicide applications targeting white mold in soybeans and whether the optimal interval is influenced by soybean maturity or fungicide chemistry.

Field trials were conducted in Carrington and Oakes to evaluate the effect of applying a fungicide, Topsin (20 fl oz/ac) or Endura (5.5 oz/ac), once versus twice at 7, 10 or 14 days apart. Testing was conducted with overhead irrigation on soybean varieties with 0.1, 0.5 and 0.9 maturity. Applications were made with a handheld boom, with the first application made at the R2 growth stage.

### Why the Research is Important to North Dakota Soybean Producers

North Dakota producers have struggled to consistently achieve satisfactory white-mold management in soybeans by utilizing fungicides.

### Findings

Susceptibility to white mold increased with soybean maturity, and a significant disease pressure was only observed for the 0.9-maturity variety at the Carrington study location. For this variety in Carrington, white-mold control and soybean yield were optimized when sequential applications were made 10 days apart (Table 1). Follow-up research is needed to confirm this result. Consistent trends were observed across the time when fungicides were applied, 7, 10 or 14 days apart, but the differences were not statistically significant.

**Dr. Wunsch discusses optimal spray droplet size depending on crop canopy.**

Topsin applied at 20 fl oz/ac was consistently less effective than Endura. The label for Topsin was recently changed, permitting a single application to soybeans at 40 fl oz/ac, and future testing will evaluate the application of 40 fl oz/ac Topsin followed by Endura. In dry beans, the efficacy of Topsin improved with an increased application rate, and applying Topsin at 40 fl oz/ac followed by Endura improved white-mold management relative to two sequential applications of Endura.

### Benefits/Recommendations

The return to fungicides targeting white mold increases with soybean maturity, with two fungicide applications most likely to be profitable for longer-maturity varieties. Making sequential applications 10 days apart optimized white-mold management in this study. Follow-up research is needed to confirm this finding, but this interval is consistent with the standard practice in Brazil, where fungicide applications targeting white mold in soybeans are typically made 10 days apart.

| | **Sclerotinia incidence** (percent of plants) | | | | **Sclerotinia incidence** (percent of plants) | | | |
|---|---|---|---|---|---|---|---|---|
| | **OAKES, ND (2020)** | | | | **CARRINGTON, ND (2020)** | | | |
| Soybean variety: | **GH0145X** | **GH0543X** | **14R09N** | Combined analysis | **GH0145X** | **GH0543X** | **14R09N** | Combined analysis |
| Soybean maturity: | **0.1** | **0.5** | **0.9** | | **0.1** | **0.5** | **0.9** | |
| **Non-treated control** | **0.4** a* | **4** c* | **2** cde* | **2** d* | **0.5** a* | **2** a* | **18** bcd* | **7** de* |
| **Topsin** 20 fl oz/ac **(R2 growth stage)** | **0.7** a | **4** c | **4** e | **3** d | **0.5** a | **2** a | **25** d | **9** e |
| **Topsin** 20 fl oz/ac **(R2 + 7 days)** | **0.9** a | **3** bc | **3** de | **2** d | **0.2** a | **3** a | **22** cd | **8** de |
| **Topsin** 20 fl oz/ac **(R2 + 10 days)** | **0.5** a | **2** bc | **3** de | **2** d | **0.0** a | **2** a | **11** ab | **5** bcd |
| **Topsin** 20 fl oz/ac **(R2 + 14 days)** | **0.4** a | **2** abc | **3** b-e | **2** abc | **0.5** a | **2** a | **18** bcd | **7** de |
| **Endura** 5.5 oz/ac **(R2 growth stage)** | **0.2** a | **2** bc | **2** a-e | **1** bcd | **0.1** a | **1** a | **12** abc | **5** a-d |
| **Endura** 5.5 oz/ac **(R2 + 7 days)** | **0.1** a | **1** ab | **0** a | **0** ab | **0.0** a | **1** a | **9** ab | **3** abc |
| **Endura** 5.5 oz/ac **(R2 + 10 days)** | **0.0** a | **0** a | **1** abc | **0** a | **0.0** a | **1** a | **6** a | **2** a |
| **Endura** 5.5 oz/ac **(R2 + 14 days)** | **0.0** a | **1** a | **1** ab | **0** a | **0.0** a | **1** a | **7** a | **2** ab |
| **Topsin** 20 fl oz/ac **(R2 growth stage) + Endura** 5.5 oz/ac **(7 days later)** | **0.2** a | **1** ab | **1** a-d | **1** abc | **0.2** a | **3** a | **14** abc | **6** cde |
| *F*: | 2.07 | 6.81 | 6.76 | 13.57 | 2.13 | 2.31 | 8.58 | 11.33 |
| *P>F*: | 0.0461 | <.0001 | <.0001 | <.0001 | 0.0404 | 0.0260 | <0.0001 | <0.0001 |
| CV: | 147.2 | 55.1 | 45.6 | 57.4 | 185.6 | 67.2 | 43.5 | 37.1 |
| | **Yield** (bushels/acre) | | | | **Yield** (bushels/acre) | | | |
| | **OAKES, ND (2020)** | | | | **CARRINGTON, ND (2020)** | | | |
| Soybean variety: | **GH0145X** | **GH0543X** | **14R09N** | Combined analysis | **GH0145X** | **GH0543X** | **14R09N** | Combined analysis |
| Soybean maturity: | **0.1** | **0.5** | **0.9** | | **0.1** | **0.5** | **0.9** | |
| **Non-treated control** | **72** a* | **77** a* | **76** a* | **75** a* | **52** a* | **58** a* | **53** ab* | **54** ab* |
| **Topsin** 20 fl oz/ac **(R2 growth stage)** | **72** a | **79** a | **76** a | **76** a | **54** a | **58** a | **50** b | **54** b |
| **Topsin** 20 fl oz/ac **(R2 + 7 days)** | **74** a | **79** a | **76** a | **76** a | **53** a | **57** a | **53** ab | **54** ab |
| **Topsin** 20 fl oz/ac **(R2 + 10 days)** | **72** a | **79** a | **76** a | **76** a | **53** a | **59** a | **55** ab | **56** ab |
| **Topsin** 20 fl oz/ac **(R2 + 14 days)** | **74** a | **80** a | **77** a | **77** a | **53** a | **58** a | **50** b | **54** b |
| **Endura** 5.5 oz/ac **(R2 growth stage)** | **75** a | **77** a | **79** a | **77** a | **52** a | **57** a | **54** ab | **55** ab |
| **Endura** 5.5 oz/ac **(R2 + 7 days)** | **73** a | **77** a | **79** a | **76** a | **54** a | **58** a | **56** ab | **56** ab |
| **Endura** 5.5 oz/ac **(R2 + 10 days)** | **73** a | **78** a | **78** a | **76** a | **55** a | **60** a | **57** a | **58** a |
| **Endura** 5.5 oz/ac **(R2 + 14 days)** | **73** a | **79** a | **77** a | **76** a | **57** a | **60** a | **56** ab | **57** a |
| **Topsin** 20 fl oz/ac **(R2 growth stage) + Endura** 5.5 oz/ac **(7 days later)** | **72** a | **79** a | **77** a | **76** a | **54** a | **57** a | **52** ab | **54** ab |
| *F*: | 1.14 | 0.96 | 1.06 | 1.09 | 1.52 | 0.61 | 3.49 | 3.23 |
| *P>F*: | 0.3491 | 0.4781 | 0.4018 | 0.369 | 0.1601 | 0.7852 | 0.0015 | 0.0011 |
| CV: | 3.9 | 3.5 | 3.8 | 3.7 | 6.4 | 6.4 | 6.8 | 6.5 |

* Within-column means followed by different, non-overlapping ranges of letters are significantly different (P<0.05; Tukey multiple comparison procedure).

# Resistance of Soybean Cultivars to a New Root-Lesion Nematode Species in North Dakota

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

Funded Project
$7,740

### Research Conducted

Ten soybean cultivars used in North Dakota were evaluated for resistance to a new root-lesion nematode (RLN) species that was recently discovered in a North Dakota soybean field. The experiment was conducted under greenhouse conditions (Fig. 1A) and repeated to confirm the research findings. A quantitative real-time PCR (qPCR) assay was developed to detect and to quantify this new species in DNA extracts of field soil. Primers were tested for specificity, and detection sensitivity was determined. A standard curve was generated. The qPCR assay was validated by comparing the numbers of nematodes in 15 field-soil samples obtained by traditional microscopic counting and qPCR through correlation analysis.

### Why the Research is Important to North Dakota Soybean Producers

Root-lesion nematodes are one of the most important groups of plant-parasitic nematodes.

**Figure 1. A: Soybean plants grown in a growth chamber maintained at 22 °C for resistance evaluation to the new root-lesion nematode species (Pratylenchus dakotaensis) identified in North Dakota. B: Classification of the resistance responses from 10 soybean cultivars to this new species based on the two trials.**

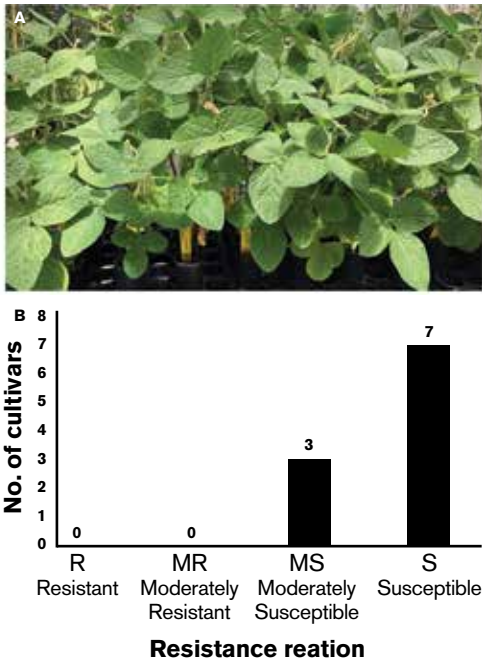
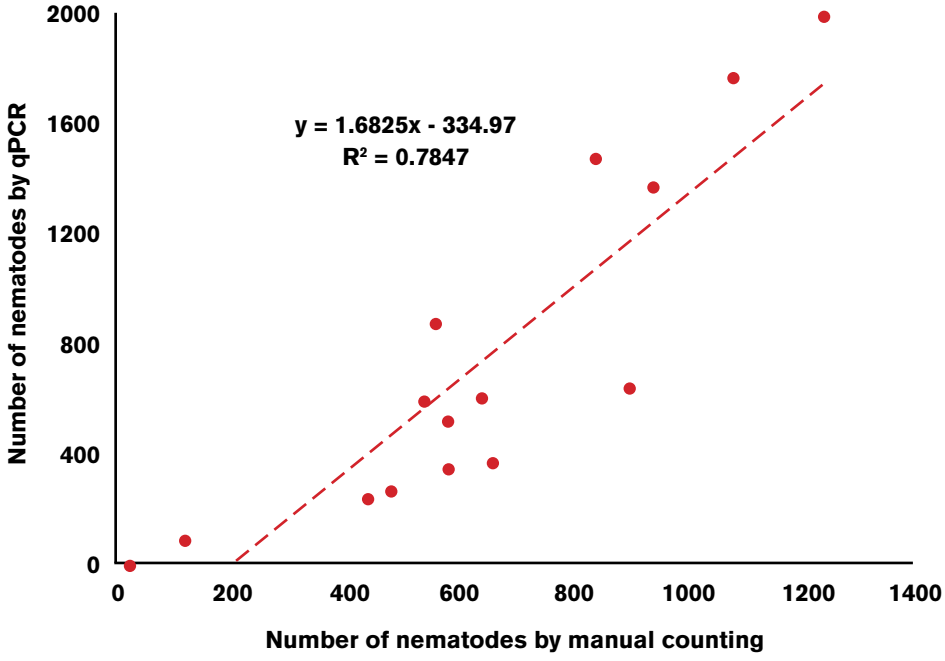



**Figure 2. Relationship between the number of Pratylenchus dakotaensis determined by qPCR and the traditional microscopic counting method from the 15 naturally infested field-soil samples.**




During our previous soil surveys in North Dakota, a new RLN species was identified. In 2021, this species was named Pratylenchus dakotaensis, paying homage to the state in which it was discovered. RLNs have a wide host range, including soybeans. One of the most economical and effective ways to control RLNs is the use of cultivar resistance. This research aims to provide valuable information about the resistance levels of soybean cultivars in North Dakota to manage the new species and to provide an efficient DNA-based, qPCR assay for improving nematode detection to facilitate management strategies.

### Findings

Resistance rating results were consistent between the two trials. Although none of the cultivars tested were resistant or moderately resistant, three cultivars were moderately susceptible, and the remaining seven were susceptible (Fig. 1B). A new qPCR assay was developed to detect and to quantify this new species in DNA extracts from field soils. The assay was highly specific and sensitive, and had a high correlation between the number of nematodes in the field-soil samples determined through manual counting and qPCR (Fig. 2). This report is the first one about detecting and quantifying this species directly from field-soil DNA.

### Benefits/Recommendations

Such research findings provide insight about the virulence of the new RLN species on commercial soybean cultivars. Moderately susceptible cultivars may perform better than the susceptible cultivars. However, further research is necessary to find better-performing resistant cultivars. The developed qPCR assay provides a rapid and efficient method for P. dakotaensis quantification in soil DNA and can serve as a valuable diagnostic tool to create informed decisions for growers.

# Identifying Effective Cover Crops for the Management of Soybean Cyst Nematode

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

Funded Project
$30,280

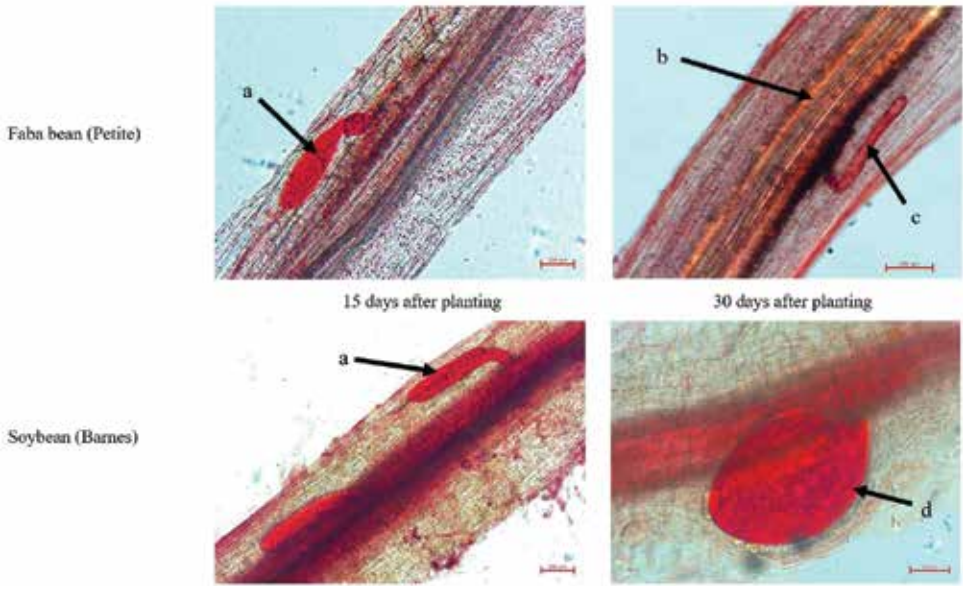
### Research Conducted

Ten cover-crop species and cultivars were evaluated for their effect on the hatching of soybean cyst nematode (SCN) eggs and the penetration of plant roots by juveniles, along with a rotational corn crop; a susceptible soybean; and an unplanted, infested soil (fallow). All the entries were planted in two sets in cone-tainers, each with 100 cm3 of infested soil that was collected from a North Dakota soybean field. Crops were harvested 15 and 30 days after planting (DAP). The plant roots were stained with food-coloring dye to visualize the nematodes inside the roots for penetration. Soil from each cone-tainer was processed to extract and to quantify the SCN juveniles and eggs for hatching.

### Why the Research is Important to North Dakota Soybean Producers

Many cover crops were evaluated for their hosting and population reduction on SCN, the major yield-limiting biotic factor of soybeans. Cover crops showed the potential for use as an alternative means to manage SCN, but their effect on SCN biology for population reduction is not well known. This research provides a better understanding about the effects of cover crops on the SCN biology to identify effective cover crops.

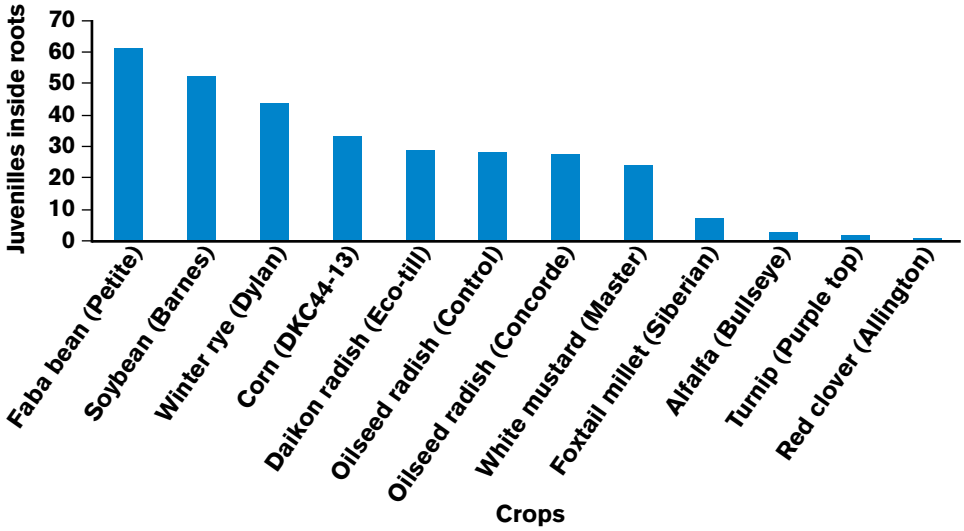
**Figure 2. Plant roots of faba beans and soybeans stained with red food-coloring dye, showing different life stages of SCN development 15 and 30 days after planting. a = swollen juveniles, b = vascular bundle, c = a degenerating juvenile and d = a fully developed white female inside the root.**




### Findings

Faba beans had a significantly higher number of juveniles the in soil and inside the roots than other cover crops and fallow 15 DAP, suggesting greater SCN hatching. Significantly, more SCN juveniles penetrated the faba-bean roots 15 DAP, but subsequently, those juveniles were significantly reduced 30 DAP. Red clover, alfalfa and foxtail millet had very low juvenile root penetration, indicating that they may starve the hatched juveniles in the absence of suitable hosts which, ultimately, results in the juveniles' death. The significant effect of brassica crops (daikon radish, oilseed radish and white mustard) on SCN hatching and penetration was not observed, suggesting a role for their bio-fumigation property on SCN population reduction.

**Figure 1. Percentage of hatched juveniles present inside the roots of cover-crop plants, along with the controls (soybeans and corn), 15 days after planting.**




### Benefits/Recommendations

All cover crops, except turnips, reduced the SCN population in infested soil. These crops can be used as cover crops or rotational crops in infested fields in order to manage SCN. Faba beans greatly enhanced the hatching of SCN eggs and the penetration of roots by juveniles without supporting reproduction, suggesting a great potential to serve as a trap crop for SCN management. The research findings will be useful for farmers to select effective cover crops for reducing SCN damage in order to improve soybean production in North Dakota's infested fields.

# Developing Multi-Enzyme, Metal-Organic Framework Nanocrystals for Rapid Soybean Biomass Conversion

***Principal Investigator:*** *Dr. Zhongyu Yang, NDSU Department of Chemistry and Biochemistry*

Funded Project
$29,650

### Research Conducted

The central goal of this project was to find a way to better use one of the most important agriculture products in North Dakota: soybeans. We focused on obtaining valuable sugar and food proteins from the soybean residuals after soybean oil production. To do so, we developed nanocrystals with three enzymes that degrade the key component of soybean-oil residues, cellulose, hosted on them. We demonstrated the effectiveness of our approach with native cellulose materials and began heading toward large-scale production of our strategy.

### Why the Research is Important to North Dakota Soybean Producers

Soybeans are one of the most abundant products in North Dakota. The major use of soybeans is extracting oil. After the oil extraction, the residual soybean is mainly utilized as animal foods, which are generally considered to be low value. However, these residuals contain important sugar and food proteins that are hidden in the intense cellulose network. If these valuable parts can be taken from the cellulose network, the soybeans' value can be maximized, leading to increased income for local farmers/soybean industries.

### Findings

It was possible to keep all the key enzymes on several nanocrystals with different properties, such as size, shape, thermal stability and magnetic properties, and proven that each enzyme is active on the nanocrystals. We were also successful with proving the long-term stability for the resultant nanocrystals. It is difficult to recycle and reuse the nanocrystals after a few reaction rounds, which was this project's bottleneck. However, we fully believe that, with a combination of several strategies, it is possible to overcome this problem.

### Benefits/Recommendations

We demonstrated the possibility of degrading cellulose from soybean residuals. This finding suggested that, for the soybean industry, the residuals after soybean-oil extraction should be collected, cleaned and subjected to more application options. Perhaps, a portion of the residuals can still be used as animal feed, yet the majority should be degraded with cellulose-degrading enzymes, as shown in our work, and subjected to sugar and food-protein extraction. There is still a long way to go toward this goal. However, if successful, this research will lead to a significant increase for our local income as well as the attracting food and energy companies to North Dakota, resulting in an improvement for the local economy and employment.

# Genetic Engineering of Soybeans to Produce DGLA-Enriched Oil

***Principal Investigator:*** *Dr. Shaobin Zhong, NDSU Department of Plant Pathology*

Funded Project
$48,610

### Research Conducted

Dihomo-gamma-linolenic acid (DGLA) is a 20-carbon, polyunsaturated fatty acid which plays an important role in human health, especially for halting cancer growth. However, major vegetable oils lack DGLA because the main oil-producing crops, such as soybeans, corn, canola and other crops, do not have the two genes encoding the enzymes [(delta-6-desaturase (D6D) and delta-6-elongase (D6E)] for DGLA biosynthesis. Our research goal is to develop transgenic soybean lines that express D6D and D6E to convert linoleic acid (LA) to DGLA and to produce DGLA-enriched oil for cancer-therapy use.

We made a new gene construct with genes to express D6D and D6E, and transgenic soybean plants were generated from two soybean cultivars, William 82 and Thorne, with Agrobacterium-mediated transformation. The transgenic soybean samples' fatty acids were analyzed, and gamma-linolenic acid (GLA) and DGLA were detected in the transgenic soybean seeds. We will continue to improve the DGLA productivity in soybean plants.

### Why the Research is Important to North Dakota Soybean Producers

Soybean oil accounts for over 40% of the intake of linoleic acid (LA) and alpha-Linolenic acid (ALA) in the United States because of its widespread use, but the crop fails to produce DGLA because it lacks the enzymes for DGLA biosynthesis. The research developed new soybean varieties that produce DGLA-enriched soybean oil, which has a huge potential for use in cancer therapies and for people's consumption to reduce cancer-related risks. The research enhanced the value of a soybean product and expanded the soybean markets.

### Findings

Transgenic soybean plants with the two genes required for DGLA biosynthesis have been developed. Some transgenic soybean plants produced up to 33.3% GLA and up to 10.25% DGLA in the soybean oil.

### Benefits/Recommendations

By growing new soybean varieties that produce DGLA-enriched soybean oil, farmers will have a better economic return due to the extended and enhanced value of soybean oil in the healthcare and pharmaceutical industries, especially with cancer therapy.

# Liquid Soy Protein-Based Coating for Protecting Against a Chloride-Ion Attack

***Principal Investigator:*** *Dr. Ravi Kiran Yellavajjala, NDSU Civil, Construction and Environmental Engineering*

Funded Project
$30,430

**Research Conducted**

Corrosion is a major form of deterioration that affects the service life and functionality of reinforced concrete structures, such as bridge decks and reinforced concrete pavements (RCPs). In this study, a new, low-cost and non-toxic protective coating material was synthesized from soy protein isolate (a protein-rich component of soybeans) to mitigate corrosion on RCP and bridge decks. The corrosion-protection performance of the soy-derived coating material was evaluated through laboratory experiments. This soy-derived coating material can be applied on concrete rebars in the field. It can also be applied on cracked reinforced concrete surfaces in order to restrict further corrosion.

**Why the Research is Important to North Dakota Soybean Producers**

The global market for corrosion-protection products (corrosion inhibitors) was estimated to be $7.2 billion in 2018, and it is projected to reach $9.2 billion in 2026. The soy-derived coating developed in this study has the potential to take advantage of this growth, financially benefiting the North Dakota soybean farming community. Even if only 1% of the soybean products, by weight, are used to make the envisaged coating material, this will generate new demand for at least 1 million metric tons of soybeans, which roughly translates to $300-350 million of additional revenue for North Dakota's soybean farming community.

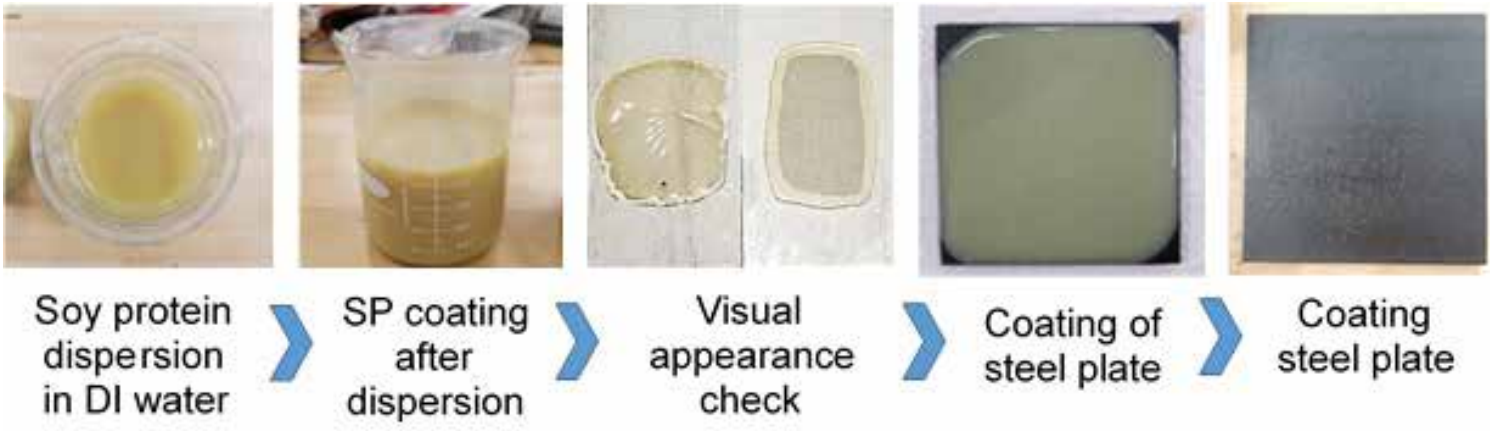
> "Applying soy-protein coatings can reduce corrosion in the reinforcing bars by up to 90% when compared to the reinforcing bars with no coating."

**Findings**

The results obtained from the laboratory investigations showed that soy-derived coatings are effective to protect the reinforcing bars from corrosion. The corrosion-protection performance of the soy-derived coatings was validated through short-term and long-term laboratory tests. Applying soy-protein coatings can reduce corrosion in the reinforcing bars by up to 90% when compared to the reinforcing bars with no coating. The soy-derived coating materials had adequate adhesion for application on the steel surface. The soy-derived coatings also had adequate strength and could be conveniently handled and transported to the field.

**Benefits/Recommendations**

The soy-protein coatings developed in this study can significantly expand the utilization of soybean products in a new industry (corrosion protection) and, hence, can increase the profitability of soybean production. Moreover, this work will also attract the industry's attention to develop more value-added products from soybeans.




**Basic steps for the synthesis and application of soy protein-based coatings.**

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