Research

The Key to Success

2019 Research Report

North Dakota Soybean Council
Our World Is Growing.

Table of Contents

2019 Research Committee Report

The North Dakota Soybean Council (NDSC) remains committed to funding research that enhances yield by managing diseases, nematodes, insects and weeds. Other areas of research are soil and tillage management, and crop management systems which include cover crop research and soil fertility. The NDSC supports the soybean breeding program at North Dakota State University that is releasing new conventional and glyphosate-tolerant varieties. The board also supports research that increases the demand for soybeans through new uses, such as road-dust retardant, polymers, livestock nutrition and human nutrition. New and continuing research for FY 2019 totaled $1,557,962, which represented 29 percent of the NDSC's budget.

The Research Committee is comprised of motivated, caring farmers and scientists who are committed to funding research in order to better understand and manage plant stressors that reduce soybean yield and farmers' profitability. The dedicated committee works hard gathering input from the state's soybean farmers to set priorities based on producers' needs; sorts through numerous research proposals and listens to presentations; and then the research committee presents their recommendations to the full NDSC board about funding projects which provide the greatest benefit to farmers.

Thanks to the farmers' checkoff investments, North Dakota has become one of the nation's top soybean producing states. This publication contains research information that individuals can utilize on their farms. The research results can help farmers be profitable and sustainable under the many challenging conditions they encounter while producing soybean crops.

We invite you to visit the Soybean Research and Information Network at www.soybeanresearchinfo.com. This website showcases all soybean checkoff-funded research and extension work across the country, focusing on basic and applied soybean research that addresses production agronomics and cropping systems, including breeding and disease, insect, weed and abiotic stress management.

As always, we welcome farmers' input about the production and marketing challenges that can be addressed through research.

Dan Spiekermeier
NDSC Research Committee Chair
dspiekermeier@ndsoybean.org

Kendall Nichols
NDSC Director of Research
knichols@ndsoybean.org

Dan Spiekermeier inspects soybean roots for nodules.

On The Cover

Front cover: Dr. Ted Helms has been NDSU's Soybean Breeder since 1986. Thanks to Dr. Helms' breeding programs, numerous soybean varieties have been developed for North Dakota soil conditions. On June 30, 2020, Dr. Helms will be retiring from NDSU. The North Dakota Soybean Council sincerely thanks him for his outstanding contributions to North Dakota's soybean industry.

Back cover: Dr. Ted Helms and crew work long hours planting experimental lines of soybean for variety development in Spring 2019.

—Photos courtesy of Betsy Armour

North Dakota Soybean Council Research Committee

Dan Spiekermeier, Sheldon, Chair

Chris Brossart, Wolford

Mike Schlosser, Edgeley

Brian Jodock, Northwood

Rick Albrecht, Wimbledon

Brent Kohls, Mayville

David Teigen, Rugby

Joe Ericson, Wimbledon, ND Soybean Growers Association Representative

Bill Connor, Industry Representative, FMC Agricultural Solutions

Dr. Emmett Lampert, Wimbledon, Research Consultant

Dr. Seth Naeve, Research Consultant, University of Minnesota, St. Paul, Minnesota

Staff – Kendall Nichols, Director of Research

Soy-Based Asphalt Rejuvenants

Principal Investigator: *James Bahr, NDSU Department for Research and Creative Activities*

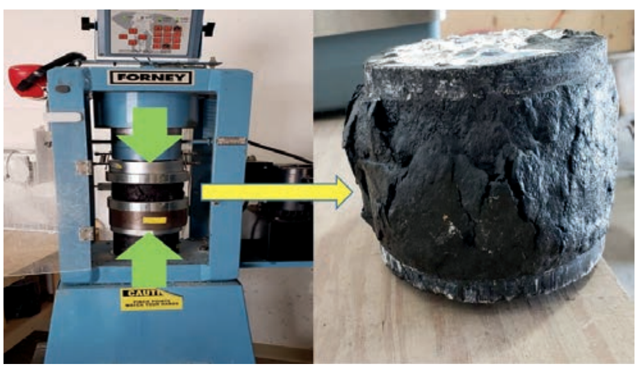
Funded Project
$57,684

Research Conducted

In 2017, we applied a soy-based, road-dust control agent, developed at North Dakota State University (NDSU), to a gravel road that also contained reclaimed asphalt pavement (RAP) millings. After a few weeks, the loose gravel surface transformed into a firm, asphalt-like surface (see photo), indicating that the soy material could rejuvenate RAP. In FY19, we performed a systematic study of the soy/RAP rejuvenation with the goal of determining the optimal soy/RAP mix ratio that could create a suitable construction material.

Soy-based road dust control applied to a gravel road containing RAP (left), The same gravel road 6 weeks later transformed into an "asphalt-like" surface (right).

In the lab, we extracted the aged asphalt binder from RAP millings and treated it with increasing levels of our soy material. The treated samples were analyzed with various methods in order to determine the change in viscosity, stiffness, glass transition temperature and strength, relative to an untreated control. Finally, the soy-treated binders were recombined with gravel, formed into cylinders and compression tested (see photo).



Compression test specimen made from soy treated RAP

Trays of rejuvenated RAP millings in the laboratory

Creating new uses for soybeans is important for North Dakota soybean farmers because it helps to expand the market for soybeans in the United States and reduces the reliance on vulnerable foreign markets. Our soy-based, dust-control material has great potential for road-dust control and RAP rejuvenation, both of which are large U.S. markets. If our soy material replaced just 10 percent of road treatments for dust control and treated 5 percent of the yearly RAP generated in the U.S., we could estimate an annual combined soybean usage of approximately 50 million bushels.

> "Creating new uses for soybeans is important for North Dakota soybean farmers because it helps to expand the market for soybeans in the United States and reduces the reliance on vulnerable foreign markets."

Findings

The results from the NDSU Asphalt Testing Lab indicate that 10 percent of our soy product added to aged asphalt binder is the optimal amount. At this concentration, the rejuvenated binder has increased flexibility, improved low-temperature performance, reduced viscosity and increased strength when re-combined with the aggregate. Although this research required the binder to be separated from the aggregate, in reality, the soy product would be added directly to the RAP millings. Going forward, we can accurately treat larger quantities of RAP for future road testing.

Expanding markets for soybeans is more important than ever, and our product has the potential to do just that with a clear benefit to the North Dakota farming industry. North Dakota farmers could help make this situation a reality by purchasing soy-based products for their own operations and encouraging local counties to do the same.

Maximizing Soil Warming and Health Under Different Tillage Practices in a Corn-Soybean Rotation

Principal Investigators: *Dr. Aaron Daigh and Dr. Abbey Wick, NDSU Department of Soil Sciences; and Jodi DeJong-Hughes, UMN Center for Agriculture, Food and Natural Resources*

Funded Project $62,635

Research Conducted

We evaluated chisel plow, shallow vertical till, strip till (shank) and strip till (coulter) systems in a 4-year study for soil warming/drying, crop stands and yields, and soil health.

Four on-farm sites with corn-soybean rotations were used. Full-sized equipment was utilized on soils which represented over 67 million acres in the region.

This on-farm research helps farmers be more informed with their residue management so that they can be more efficient and profitable while making their soils healthier and less prone to erosion. To date, the study's findings have been disseminated in YouTube videos with more than 10,000 views; over 70 field days, presentations, and other university events; the Upper Midwest Tillage Guide; and more than 60 publications, news articles, and other media sources.

Dr. Daigh discusses his research with Agweek TV.

Findings

Crop residue cover among tillage systems ranged from 25 to 83 percent. Tillage did not affect plant populations within sites, but strip till (shanks) had lower corn yields at one farm in 2015. Both strip tills had higher soybean yields at one farm in 2018. Otherwise, yields did not differ among tillage practices. Strip till was estimated to have the lowest costs among the systems, with $10-22 less per acre than the chisel plow.

Dr. Daigh and Dr. Wick review research findings.

Soil temperatures were the highest and moisture lowest in the strip-till berms and chisel-plowed strips as compared to the vertical till and the undisturbed areas between the strip-till berms. These differences were largest in the sandy soils but were rarely observed in the clay soils. The vertical till tended to warm and dry approximately midway between that observed for chisel plow and areas with no tillage.

For soil health, among 19 soil properties, only one (fungal/bacteria ratio) slightly differed among tillage systems for one farm after 4 years. However, soil microbial communities showed distinct biweekly and bimonthly cyclical patterns that were not affected by the tillage system.

Our results suggest that reduced tillage does not necessarily translate to yield reductions but is typically more economical. We recommend that economics and desired erosion control among tillage systems, rather than yield alone, be used to guide tillage preferences. This research also suggests that quantifiable changes to soil health may take more than 4 years to be observable in the region. Lastly, the weekly-to-monthly cycle for soil microbial communities need to be considered if they are used as a measure of soil health.

Preceding and Interseeding Cover Crops into Standing Soybeans to Reduce the Soybean Cyst Nematode Population

Principal Investigator: *Dr. Marisol Berti, NDSU Department of Plant Sciences*
Co-Investigator: *Dr. Guiping Yan, NDSU Department of Plant Pathology*
Research Specialist: *Alan Peterson, NDSU Department of Plant Sciences*

Funded Project $7,335

Research Conducted

The experiment was conducted in Prosper and Casselton in 2018 in order to determine the effect of preceding and interseeding cover crops into soybean cyst nematode (SCN)-susceptible and SCN-resistant soybeans on soil with high SCN populations. The winter camelina cultivar, Joelle; brown mustard Mighty Mustard™ cultivar, Kodiak; and crambe cultivar, Westhope, were planted before soybeans or interseeded at the V6 stage. A check plot for each variety without a cover crop was included.

SCN (Heterodera glycines) is the most important pest in soybeans, causing over a billion dollars in losses in the U.S. every year. Many farmers do not know that they have SCN in their fields, and 15-30 percent of soybean yield can be lost without any evident aboveground symptoms in the soybeans. One of the main control practices for SCN is the use of resistant varieties; however, the resistance is breaking, and most soybean varieties in North Dakota have the same source of resistance. Cover crops that precede soybean planting or that are interseeded into standing soybeans are becoming more common in North Dakota's corn-soybean systems, and because many are non-host crops, they are a potential options to manage SCN.

Findings

Cover crops, either preceded or interseeded, did not significantly decrease the SCN population at both locations. SCN populations increased in the susceptible variety for almost all treatments while they decreased in the resistant variety. However, camelina interseeded at the V6 soybean stage was able to reduce the SCN population by 32 percent at Prosper across both varieties. The uneven distribution of the SCN population in the soil made it very difficult to detect significant differences and to replicate the positive results observed in greenhouse studies with camelina and mustard. The soybean yield for the susceptible variety averaged across all treatments was significantly lower than the resistant variety's yield.

In spite of not finding significant results, we believe that non-host cover crops interseeded into soybeans have the potential to be an additional tool to manage the SCN population; however, more research is needed.

We recommend that farmers continue using the current management recommendations, such as rotation with non-host crops and SCN resistant varieties, in fields with SCN. At this point, we cannot recommend interseeding camelina, mustard or crambe as a tool to reduce SCN.

> "Non-host cover crops interseeded into soybeans have the potential to be an additional tool to manage the SCN population."

Mustard cv. Kodiak interseeded at V6 into standing soybean in Prosper, ND.

Research specialist Alan Peterson and MS graduate student Swarup Podder taking samples of interseeded cover crop in Prosper, ND.

Nitrogen Relationships in Soybeans in Southwest North Dakota

Principal Investigators: *Ryan Buetow and Glenn Martin, NDSU Dickinson Research Education Center; and John Rickertsen, NDSU Hettinger Research Education Center*

Funded Project
$14,944

Research Conducted

The research objectives were to evaluate yield and growth differences among five nitrogen (N) fertilizer management strategies applied to two soybean cultivars with different maturities grown at two plant populations as well as to increase the knowledge base of soybean practices in southwest North Dakota.

The research was conducted at two locations in 2017 and 2018; however, only data from the Hettinger location were recorded due to herbicide damage at Dickinson in 2017. In 2018, the Dickinson site had issues with too high of nutrient levels, and we also dealt with early frost in the region. The Dickinson site was a little further behind the Hettinger site in maturity at first frost, and there was frost damage that caused issues with pod filling. Due to this issue, only data from Hettinger were included for 2018. Information from this trial was disseminated at Western Dakota Crops Day in Hettinger and was discussed with stakeholders throughout the season.

2017 and 2018 Results

There were differences between some of the treatment interactions that need to be further investigated before making any conclusions. In 2017, no significant yield differences were found between the populations. Populations with 80,000 plants/acre averaged 23.3 bushels per acre while 160,000 plants per acre averaged 24.2 bushels per acre. In 2018, the crop with 160,000 plants per acre yielded significantly higher at 27.1 bushels per acre compared to 25.4 bushels per acre for the crop with 80,000 plants per acre. Depending on seed input costs and soybean price, this may not necessarily result in higher profits.

Drought conditions in 2017 reduced yield capacity for the soybeans. Under drought conditions, a plant population with half of the recommended seeding rate yielded just as much as the full rate. While it may be possible that, with higher rainfall, a larger yield is possible, more work should be conducted before changing recommendations. Under drought conditions with a reduced yield potential, it could be possible to reduce seed input costs without losing bushels, and depending on the economic environment, it may still be profitable to decrease plant population.

The trial was continued in 2019 with locations planted in Dickinson, Hettinger and Mandan.

“There were differences between some of the treatment interactions that need to be further investigated before making any conclusions.”

Ryan Buetow annotates research results.

Establishing Waterhemp Tissue Culture Lines for Herbicide-Resistance Research

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

Funded Project $5,476

Research Conducted

Callus tissue cultures are clumps of cells which are grown under laboratory conditions. Callus cultures can be used for biological research, such as the study of herbicide resistance. Four waterhemp seed samples were used to study and to determine conditions for laboratory germination and establishing callus cultures from seedling stems. Cultures were successfully produced from all four waterhemp seed samples. Genetic testing was used to determine that one waterhemp seed sample also contained Powell amaranth, and this sample was not used for later experiments.

Waterhemp in North Dakota

The remaining three waterhemp samples were used to establish additional callus cultures for growth rate comparisons. Callus growth rates were highly variable, and no significant differences among cultures established from the different waterhemp seed samples were observed.

Most current herbicide-resistant weed research is limited to the study of resistant weeds that have already developed. New genetic technologies, such as gene editing, have the potential to allow researchers to produce new resistant weeds in the laboratory, even before these variants are discovered in the field. Related technologies that use gene editing, such as gene drives, also hold promise for improving the control of herbicide-resistant weeds. Plants grown in a tissue culture can remain as callus, without the capacity to propagate outside the laboratory, while still allowing researchers to investigate how new genetic technologies can be utilized to study and to combat herbicide resistance.

Findings

This project established conditions for successfully generating waterhemp callus tissue cultures. Several cultures for use in future research investigating herbicide resistance and emerging genetic technologies for weed control were also produced. The successful generation of calli from all tested samples indicates that establishing callus cultures is likely not limited to certain waterhemp seed sources.

Waterhemp plant material in the form of callus tissue cultures is now available for further study investigating herbicide resistance. The conditions for establishing additional waterhemp callus cultures in the future have also been established. These cultures will allow researchers to study new weed variants without the risk of escape into North Dakota fields.

Evaluation of Soybean Tolerance to Salinity, Alkalinity and the Combined Saline-Alkalinity

Principal Investigator: *Dr. Qi Zhang, NDSU Department of Plant Sciences*

Funded Project $5,820

High soil salinity is a common problem of soybean production in North Dakota, resulting in reduced growth/yield or even death under the severe condition. Previous research on screening salt-tolerant plants was mainly conducted using chloride salts. In North Dakota, the predominant forms of salinity are sulfate salts, while chloride-salinity is only seen in the eastern Grand Forks. Information on soybean responses to sulfate-salinity is scarce. Iron-deficiency chlorosis (IDC) is commonly seen in the high pH soil (pH > 7) (i.e. alkalinity) in North Dakota. Research on soybean tolerance to IDC has been well documented. Salinity and alkalinity often coexist in nature. Limited information is available on soybean responses to the combined salinity-alkalinity stress.

We conducted this project in a hydroponic system to develop screening methods for soybean tolerance to sulfate-salinity, alkalinity, and saline-alkalinity and identify genotypes with high tolerance to the aforementioned stresses.

Findings

Chloride-salinity was more detrimental to soybean plants than sulfate-salinity. Chloride-salinity caused severe damage at 4 dS m^{-1} and plant death at 8 dS m^{-1} after three weeks of saline exposure. Plants survived 16 dS m^{-1} under sulfate-salinity, although growth was inhibited at 8 dS m^{-1}. Alkalinity (pH = 7.3 – 9.4) reduced soybean growth. Tissue biomass was reduced at pH of 7.3, while, leaf chlorosis was seen at pH of 8.8 – 9.4. The combined stress caused a higher growth reduction compared to salinity and alkalinity alone. All stresses caused increased Na but decreased K and Ca uptake in shoot. Alkalinity and saline-alkalinity also affected Fe, Mn, and Zn absorption.

Fifty genotypes, including 9 glyphosate-resistant and 41 non-resistant one, were evaluated for the

Defoliated Soybean Response to Priaxor Fungicide

Principal Investigators: *Lindy L. Berg, NDSU Extension; Greg Endres and Kelly Bjerke, NDSU Carrington Research Extension Center; and Lesley Lubenow, NDSU Langdon Research Center*

Funded Project $2,000

Research Conducted

A greenhouse study was conducted at the NDSU Carrington Research Extension Center from January 2019 to June 2019. This study's objective was to determine the plant and seed yield response to Priaxor fungicide application after simulated hail injury at the R2 and R5 soybean growth stages.

The study design was a randomized, complete block design with a split-split plot arrangement that had three replications. On January 14, soybean cultivar AG009X8, inoculated with rhizobia bacteria, was planted in 10-inch diameter pots with Miracle-Gro Moisture Control potting soil.

Replications included

- Untreated checks: no defoliation and no fungicide.
- 33 percent leaf removal: we counted all leaves and removed 33 percent of the leaves, starting at the top and going to the bottom of the plant.
- 66 percent leaf removal: we counted all leaves and removed 66 percent of the leaves, starting at the top and going to the bottom of the plant.
- Main stem cut-off: cut the main stem at the position that would remove half of the trifoliate notes on the main stem; 100 percent of the leaves below the cut were removed.
- Main stem bent over: the main stem was bent over at a 135-degree angle at the same point as the cut-off treatment. One hundred percent of the leaves were removed below the break, and 25 percent of the leaves were removed from the stem's bent-over portion.

Greg Endres of Carrington Research Extension Center speaks to farmers about his latest research.

Priaxor was foliar applied 3 days post injury, at a rate of 4 ounces per acre, with a handheld boom backpack sprayer.

Canopy coverage was recorded using the Canopeo phone app, and greenness was measured using a Minolta SPAD-502 chlorophyll meter. Physiological maturity (R8 stage) was recorded, and the seed was hand threshed on June 6.

The data were analyzed using SAS software.

Findings

The foliar fungicide applied at R2 or R5 stages did not increase the seed yield for defoliated or non-defoliated soybean plants. Also, plant maturity was not affected by the fungicide. Across fungicide treatments (untreated check and Priaxor) and growth stages, plant maturity and yield were similar between the untreated check and 33 percent defoliation. Seed yield declined 19 to 32 percent with the 66 percent defoliation, cut stem or bent stem treatments compared to the untreated check. Also, plant maturity was delayed for 5 to 11 days with the 66 percent defoliation, cut stem or bent stem treatments compared to the untreated check.

---

tolerance to sulfate-salinity (8 dS m^{-1}, a salinity level caused moderate plant growth reduction), alkalinity (pH = ~ 9.0), and the combined saline-alkalinity. Genetic differences were detected mostly in salinity tolerance, but not in alkalinity. Genotypes with high tolerance to salinity and/or alkalinity did not all performed well under the combined stress.

Soybean breeders can use our protocols to screen for high tolerance to salinity, alkalinity, and saline-alkalinity and incorporate the plant materials identified in this research into different breeding purposes. Our research also expands growers' knowledge on the effects of salinity (salt type and concentration), alkalinity, and their interaction on soybean growth.

North Dakota soybeans.

Determining Rye Safety for Soybeans With Soil Moisture Status

Principal Investigators: *Mike Ostlie; Szilvia Yuja; Jasper Teboh; Greg Endres; Ezra Aberle; and Steve Zwinger, NDSU Carrington Research Extension Center; and Dr. Paulo Flores, NDSU Department of Agricultural and Biosystems Engineering*

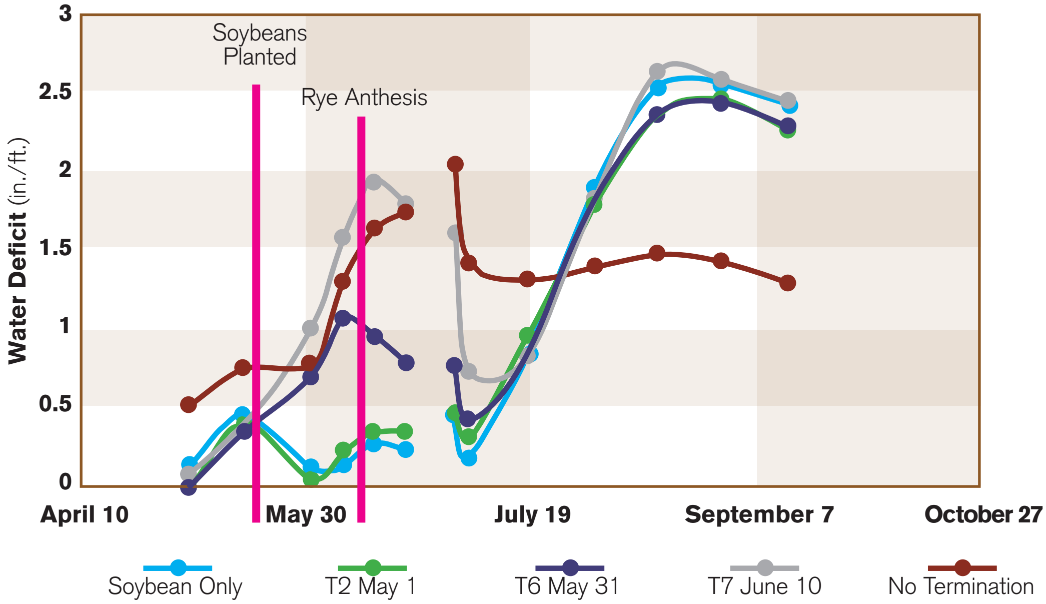
Funded Project
$14,550

Research Conducted

The project's goal was to compare soil moisture differences based on how long rye remained in a rye/soybean relay. After rye green-up, rye glyphosate termination occurred weekly for 7 weeks (different plots). Soil moisture was recorded weekly for each plot through rye anthesis and every 2 weeks thereafter. Soybeans were planted at the rye boot stage.

This research was the focus of several workshops during the summer of 2018, including the Advanced Crop Advisor's Workshop and the CREC Fall Row Crop Tour, and data were prepared for the Carrington Research Education Center's annual report and Wild World of Weeds Workshop.

Winter rye is growing in popularity as a cover crop prior to soybeans. However, past research has documented instances of rye growth reducing soybean yields under dry conditions. During wet seasons, the soybeans can be planted into standing rye that is terminated shortly after soybean planting with little change in soybean yield. Other years, rye needs to be terminated several weeks prior to soybean planting in order to prevent a soybean yield reduction. This project aims to develop a set of guidelines for rye termination timing so that producers can predict when their soybean crop may be at risk from the rye.



Findings

Water use patterns were fairly consistent with the expectations. Peak rye water use occurred around anthesis while the soybeans' water use peaked in mid-August (Figure 1). Rye that was terminated at or before soybean planting had similar soil moisture as the soybean-only plots. Rye continued to use water for approximately 7 days after termination. Even though there was a spike in rye water use when the rye was terminated 1 week after soybean planting, the soil moisture status improved enough that soybean yield was not affected. Only further delaying the termination removed enough water to reduce soybean yields. Terminating rye at anthesis reduced soybean yields by approximately 10 bushels per acre. In 2018, a 1.5" water deficit in the top 2 feet of soil triggered yield reductions for the soybeans.

We are continuing to evaluate how the water deficit will affect soybean yields over multiple years. Based on this and past research, the safest approach is to terminate rye 2 weeks prior to planting, which is also consistent with insurance guidelines. We are currently working to build a prediction tool that can be used to determine the soybean yield risk from rye to assist with termination timing

Visual Ratings for Iron Deficiency Chlorosis

Principal Investigator: *Dr. Ted Helms, NDSU Department of Plant Sciences*

Funded Project
$81,762

Research Conducted

All private company varieties that have been entered into the Langdon Research and Extension Center (REC), Carrington REC, Minot REC, Williston REC and Fargo Main Station's yield trials were evaluated for visual iron deficiency chlorosis (IDC) symptoms at multiple field locations with a past history of IDC symptoms. Also, advanced North Dakota State University (NDSU) breeding lines were evaluated. Comparing soybean varieties from different companies requires that all varieties be evaluated with side-by-side comparisons in the same field; otherwise, a fair comparison is not possible.

In 2018, four locations on farmer-cooperator fields with a past history of IDC symptoms were identified and were later planted with hill plots. Three of the four sites had to be abandoned due to either too many IDC symptoms or too much rainfall. We found another IDC site and planted that site in mid-June. There were 235 Roundup Ready® and Xtend® varieties as well as 60 Liberty Link and non-GMO company varieties tested. Also, the NDSU soybean breeder evaluated 120 advanced NDSU breeding lines for visual IDC symptoms. Those locations included Leonard, and Hunter, North Dakota.

This is the largest dataset with the most comparisons of many different company varieties, Roundup Ready, Xtend, Liberty Link and non-GMO, for North Dakota and western Minnesota.

Fall-Seeded Cover Crop Tolerance to Soybean Herbicides

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

Funded Project
$14,700

Research Conducted
Soybeans were planted May 24, 2018, in Fargo, followed by the application of soil-applied herbicides Raptor, Sencor, Spartan, Valor and Zidua on May 25 as well as POST herbicides Engenia, Flexstar and Raptor on June 30 at the labeled rates for soybeans. Cover crops, including turnips, lentil, radishes, flax, field pea, winter rye and barley, were planted perpendicular to herbicide strips on August 22 and were evaluated for plant tolerance on September 12 and 26.

Soybeans were planted in Carrington on May 16, 2018, followed by the application of soil-applied herbicides Pursuit, Sencor, Spartan, Valor and Zidua on May 28 as well as POST herbicides Engenia and Flexstar on June 7. Soybeans (R5 growth stage) were terminated by mowing on August 8. Cover crops, including turnips, radishes, flax, field pea, winter rye and barley, were planted perpendicular to herbicide strips on September 24, and barley, rye and field pea were evaluated for plant tolerance on November 2.

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

Findings
Cover crop injury (biomass and/or stand) was present among all crops in the Fargo plots except the field pea during evaluation on September 12.

Cover crop growth in September 2018 at Fargo trial.

Plant injury occurred with Raptor, Sencor, Spartan and Raptor (PRE and POST applied). Injury at 24 to 52 percent was noted on lentil, radishes and turnips with sulfentrazone, and 21 to 54 percent injury was seen with flax, radishes and turnips with PRE Raptor. During the September 26 evaluation, lentil, radishes and turnips had 40 to 57 percent injury with Spartan. Flax, radishes and turnips had 60 to 79 percent injury with PRE Raptor.

At Carrington, barley injury was 2 to 3 percent with Pursuit, Valor and Zidua on November 2.

Research reports for the two trials were written and published in the 2018 North Dakota Weed Control Research which is available at www.ag.ndsu.edu/weeds/nd-weed-control-research. After the field study is tentatively completed in 2019, a table will be published in the 2020 North Dakota Weed Control Guide as a reference for farmers and crops advisers to select cover crops for fall establishment following soybeans. This database will assist with the successful establishment of fall cover crops, which will reduce soil erosion, help manage soil moisture, increase the soil's long-term productivity, and give other benefits.

These data enable growers to increase the yield on IDC-prone fields because the varieties with the least amount of yellow IDC symptoms will yield the best for the fields with that problem.

Findings
Data were analyzed and reported in the NDSU bulletin titled North Dakota Soybean Performance. The data were also posted online.

There are genetic differences among cultivars for tolerance to IDC. The variety choice is the most important factor to increase yield on fields where IDC is present. Even a small amount of yellowing in the soybean leaves can reduce the final yield by 20 percent. For fields with IDC, visual yellowing is closely correlated with yield.

The benefit for North Dakota soybean farmers is that they can increase the yield for their fields that have a past history of IDC by selecting varieties with good IDC visual ratings. The recommendation is to choose varieties with the desired herbicide-resistant traits, maturity, yield and IDC tolerance.

Dr. Helms providing IDC ratings to farmers.

Soybean Response to Selected Plant Nutrition Inputs and Rye as a Cover/Companion Crop

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

Funded Project
$8,000

The goal of this project is to continue building North Dakota State University (NDSU) databases about soybean yield impact with three trials which examine specific plant nutrition and establishment factors.

Plant Nutrition

Double-inoculated soybean seed: With recent soybean production history, is there a yield response when using two rhizobia inoculant formulations (granular plus liquid as a 'double inoculant') vs. a single formulation or no inoculant?

Special fertilizer inputs: Is there a yield response to soil- or foliar-applied sulfur (S)?

Plant Establishment

Rye as a cover crop: Will winter (cereal) rye as a cover crop affect soybean yield while providing the soil with benefits when compared to conventional soybean production?

Research Conducted

Trial 1: Conducted at the NDSU Carrington Research Extension Center and Tri-county research site near Wishek during 2015-18 (6 site-years) with granular, liquid and a combination of rhizobia-inoculant formulations applied to soybean seeds on ground with a prior soybean production history.

Trial 2: Conducted at the Tri-county research site during 2016-18 using preplant, soil-applied S as MES15 (Mosaic) or foliar-applied as MAX-IN S (Winfield).

> "The goal of this project is to continue building NDSU databases about soybean yield impact..."

Soybean grown with winter rye cover crop near Wishek, North Dakota.

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

Findings

Trial 1: Seed yield was statistically similar among the treatments.

Trial 2: No seed yield response with soil- or foliar-applied S compared to the untreated check during each year of the trial. The trial continues in 2019.

Trial 3: Research continues in 2019 and requires multiple years of data before reaching conclusions.

Recommendations

Trial 1: With a previous history of soybeans (1 to 3 years separating the soybean crops), single or double inoculation of soybean seeds with rhizobia will not increase the seed yield.

Trial 2: This research's current results indicate a lack of soybean yield response with S.

Trial 3: Using winter rye before soybean production provides numerous potential benefits, including reduced soil erosion, weed suppression and long-term improvement of soil productivity. Timing the rye termination with glyphosate needs to be carefully considered in order to balance the cover crop's benefits while preserving soil moisture for the soybean crop.

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

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

Funded Project
$7,173

Research Conducted

Twenty soybean cultivars that are commercially available in North Dakota were evaluated for resistance to a new species of root-lesion nematode (RLN) identified in the state. The experiment was conducted under greenhouse conditions and was repeated twice to confirm the research findings. Because RLN can occupy either the soil or roots, this nematode's habitat preference was evaluated by comparing the number of nematodes present in the roots and in the soil.

RLNs are one of the destructive groups of plant-parasitic nematodes worldwide. This soil-borne pathogen is widely distributed in the U.S. and has a wide host range which includes soybeans. One of the most effective control practices for such plant-parasitic nematodes is using resistant cultivars. The results of this research help to identify the resistance or susceptibility of the soybean cultivars used in North Dakota in order to suppress this new RLN species.

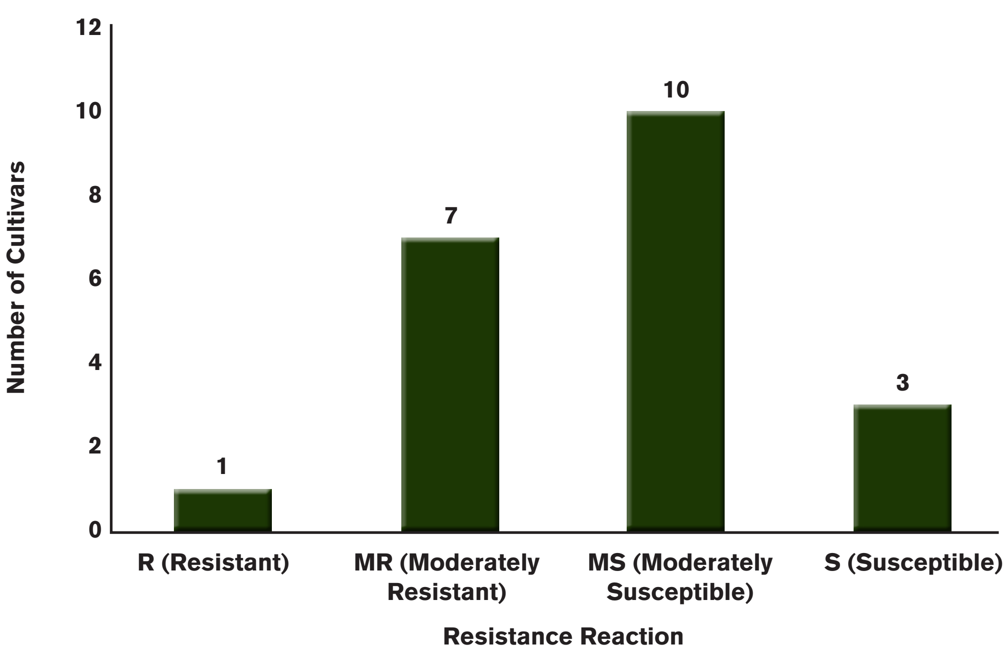
Soybean plants grown in a growth chamber and maintained at 22 °C (71.6° F) for evaluating resistance to the new root-lesion nematode species identified in North Dakota.

Findings

Two soybean cultivars (NS 1911NR2 and NS 60083NXR2) were susceptible to the new RLN species across all three repetitions of the experiment. The S12-R3, NS 0081NR2 and NS 1291NLL cultivars as well as the positive control, Barnes, were moderately susceptible, whereas the S06-Q9 and NS 61493NXR2 cultivars were moderately resistant across all three experiments.

Although a cultivar that was resistant for all the experiments was not identified in this study, the 3408RR2YN and NS 0651NR2 cultivars were resistant for one repetition and moderately resistant for the remaining repetitions. The resistance-rating variation between the experiments could be attributed to different inoculum concentrations and the time of year when the experiments were conducted. Our results also demonstrated that more than 50 percent of the nematodes can be present in the roots compared with the soil habitat, indicating the importance of extracting nematodes from both the soil and the roots for quantification purposes.

These research findings provide insight about the virulence of this new species, identified in North Dakota, against commercial soybean cultivars. The identified, susceptible cultivars can be used with future studies to culture this new species and to increase the population for determining its effect and economic threshold on soybeans. The resistant/moderately resistant cultivars which were identified should be better options than the susceptible/moderately susceptible cultivars for nematode management. However, further research is necessary to assess these cultivars' performance against the new RLN species in field conditions.



> "These research findings provide insight about the virulence of this new species, identified in North Dakota, against commercial soybean cultivars."

Soybean Soil Fertility in North-Central and Northwest North Dakota

Principal Investigators: *Dr. Dave Franzen, NDSU Department of Soil Science; and Chris Augustine, NDSU North Central Research Extension Center*

Funded Project $7,366

Research Conducted

There are few soybean soil fertility studies from north-central and northwest North Dakota. The research objectives were as follows:

1. Determine major nutrient requirements for soybeans in north-central and northwest North Dakota.
2. Determine the soybean response to sugarbeet waste lime for pH improvement in the acidic soils of north-central North Dakota.
3. Determine the starter fertilizer response of soybeans in north-central and northwest North Dakota.
4. Determine the foliar fertilizer response of soybeans in north-central and northwest North Dakota.

Chris Augustine operates the soybean seeder he modified for the fertility project.

Over 3 years, there were 6 different locations. The northern sites had a soil pH less than 7; the south sites had a pH greater than 7. Each site was designed as a randomized complete block. There were 12 treatments with 4 replications.

1. Check (no fertilizer)
2. Bradyrhizobium inoculated at planting
3. 100 pounds acre of 11-52-0 broadcast (preplant)
4. 3 gallons per acre 10-34-0 (in-furrow at planting)
5. 3 gallons per acre 6-24-6 (in-furrow at planting)
6. 50 pounds of nitrogen (N) per acre as urea (preplant broadcast)
7. Sugarbeet waste lime at 2 tons per acre (South on acidic soils: preplant broadcast)
7. Iron ortho-ortho-EDDHA seed applied (North, high pH-in-furrow at planting)
8. Sugarbeet waste lime at 4 tons per acre (South preplant broadcast)
9. Naked ortho-ortho-EDDHA seed applied (Levesol-North)
10. Foliar 9-18-9 at V5
11. Foliar 9-18-9 with S at V5
12. Foliar 9-18-9 at R2
13. Foliar 9-19-9 with S at R2

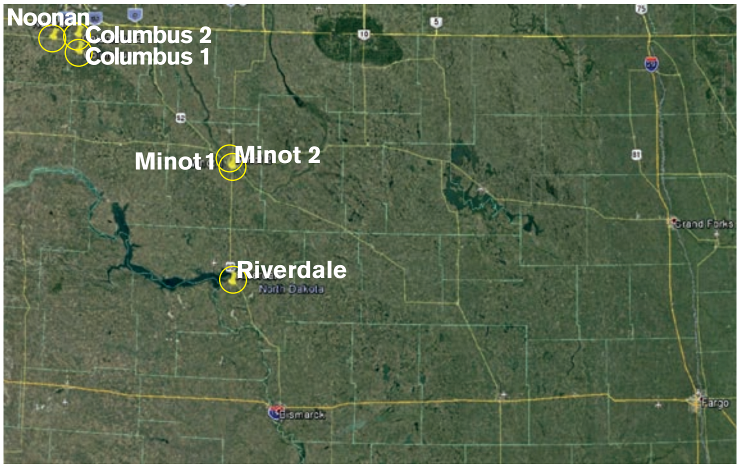
Findings

There were no significant differences among treatments consistent through the years. There was a tendency for seed inoculation to increase yield but not at all sites. There was also a trend for foliar treatments to reduce yields. The lowest phosphorous (P) sites were 7 parts per million (ppm), with no response to P treatment. Soil pH was as low as 5.8, and no response to lime was recorded. With a high pH, there was no response to Soygreen™. Iron Deficiency Chlorosis does not seem to be an issue in this region, even in wetter years. There was no response to N.

There were minimal increases for protein and oil with fertilizer treatments, and the differences were inconsistent between years.

This research indicated that soybeans would be most profitably grown with minimal fertilizer inputs along with monitoring soil to test the P and pH in order to ensure that the values do not slip into very low ranges. A low P range should be considered as 6 ppm or less. Low soil pH should be considered at values of 5.5 or less.

Dr. Franzen speaks at the Carrington Research Extension Center on soil fertility for corn and the upcoming soybean fertility revisions.



Locations of experiments for soybean soil fertility in north central and northwest North Dakota (in yellow).

Managing Salinity With Cover Crops: A Whole-System Response (Year 2)

Principal Investigators: *Dr. Caley Gasch; Dr. Tom DeSutter; and Dr. Abbey Wick, NDSU Department of Soil Science; and Dr. Jason Harmon, NDSU School of Natural Resource Sciences*

Funded Project
$54,625

Research Conducted

For 2 years, this study has been monitoring soil properties, plant growth and insects in four fields that have salt patches. The fields are managed for a corn-soybean rotation, and they are located near Jamestown, Aneta and Northwood. Across each field, we broadcast cereal rye at 40 pounds per acre before leaf drop and then terminate it the following spring before, or at, planting. We are curious to see if the cover crop will alleviate some of the negative effects of salinity on the soybeans or if it poses too many risks for soybean production.

Salinity affects about 13 percent of North Dakota's land area, and almost every farmer works in fields that have salt patches. We hope to 1) identify if cover crops offer a practical management strategy to improve soybean production on salty land and 2) to provide education and guidance for managing saline soils.

Dr. Gasch examining soil structure under a soybean crop. Soil that crumbles easily is a good indicator of soil health. Cereal rye cover crops in a soybean rotation help build good soil structure.

Findings

This work is ongoing, but our findings, so far, indicate that the cereal rye, at the applied rate, does not negatively affect soybean growth (in terms of water use, fertility, or diseases and pests). However, we haven't seen any drastic changes, or improvements, in the soil during the study's first two years. We'll be watching for the development of soil structure under the cover crop, a nice indicator of improved soil health. Unfortunately, the negative effects of the salts seem to overwhelm any benefit from the cover crop when they are applied at the 40 pound per acre rate.

Dr. Gasch uses a hand-held probe to measure salinity in a soybean field. Salinity negatively impacts crop growth and salt patches will grow in size if left unmanaged. Soil testing can help determine the severity and extent of salt patches, and NDSU resources can help you develop a management plan for saline soils.

We have not observed rapid changes in soil properties, including salinity levels, during the study's two years. We will continue to monitor these fields for another year or two, and we will detect any soil structural benefits which are provided by the cereal rye. Based on these results, we recommend considering a higher rate for the rye application, especially in areas where corn and soybeans won't grow. Other plant species that are more salt tolerant, such as wheat, barley or alfalfa, and have low input are also options to consider for salty patches. We are confident that by increasing plant activity in saline soils (using salt-tolerant species), we can improve the productivity for those problem areas in the long run.

"Salinity affects about 13 percent of North Dakota's land area, and almost every farmer works in fields that have salt patches."

Development of a High-Throughput Genetic Test to Identify Palmer Amaranth and Related Pigweed Species

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

Funded Project
$33,358

Project Scope

Palmer amaranth has invaded the fields of North Dakota. Recognized as one of the most yield-robbing pigweeds in agriculture, the North Dakota Department of Agriculture quickly added Palmer amaranth to the noxious weed list. Since its initial discovery in 2018, this weed has become a popular topic at North Dakota conferences and expos with a large emphasis on how to properly identify Palmer amaranth and to distinguish it from other pigweeds, specifically Waterhemp.

The early detection of Palmer amaranth can mean the difference between effective control for an early infestation and a permanent increase for annual herbicide use to reduce an established population. Unfortunately, visual identification at the vulnerable and early stages is challenging for even the most experienced weed scientists. Additionally, nature is not always textbook, making it difficult to fully document the overwhelming variation among individual Palmer amaranth weeds, which can arise from field or regional differences in soil types, nutrient loads and water availability. As a result, the photographs which are used to help differentiate pigweed species can sometimes fall short, potentially causing confusion and inadequate control recommendations. Thus, the best way to confirm a suspected pigweed as Palmer amaranth is to supplement the initial visual diagnosis with a DNA test.

Palmer amaranth infested field in Nebraska.

Due to these difficulties with the proper identification and time-dependence of herbicide control, the National Agricultural Genotyping Center (NAGC) partnered with weed scientists at North Dakota State University in order to make a rapid DNA test available to soybean growers. Through this public-private partnership, the test was developed on pigweed species found in North Dakota. Specifically, the DNA test can detect Palmer amaranth, Waterhemp, Powell amaranth, Redroot pigweed, Smooth pigweed and other pigweeds. Importantly, the one-step test can directly differentiate both Palmer amaranth and Waterhemp from each other as well as from other pigweed species.

The next goal is to integrate this test into a surveillance program in order to limit the spread of Palmer amaranth. The DNA test developed by the NAGC is available to everyone and can test dried and fresh plant tissue, including a single leaf from a pulled plant or a newly emerged weed that was picked from the field. Detailed sampling and shipping procedures can be found at https://www.genotypingcenter.com or by calling the NAGC at 701-239-1451.

The NAGC is now accepting samples from seed agencies and North Dakota seed companies to genetically identify pigweed seeds found during purity tests for Palmer amaranth contamination.

Dr. Tom Peters with Palmer amaranth in NE.

> "The early detection of Palmer amaranth can mean the difference between effective control for an early infestation and a permanent increase for the annual herbicide use to curtail an established population."

High-Throughput Methods to Screen Soybean Varieties for Resistance to Iron Deficiency Chlorosis

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

Funded Project
$15,240

Research Conducted

Iron deficiency chlorosis (IDC) remains a widespread and destructive disorder for North Dakota soybeans. Planting a resistant variety is the most important control measure. Other control measures, such as an in-furrow iron fertilizer, must be added to a resistant variety. Unfortunately, selecting a resistant variety is not as easy as it sounds. A variety's commercial lifespan is typically 3 or 4 years, and the information about the varieties' IDC resistance which is given to farmers by many seed companies is often not accurate. North Dakota State University (NDSU) performs field testing for IDC resistance, but only a small fraction of the marketplace gets tested. This project's objective was to develop a rapid (approximately 4-week) greenhouse screening procedure that would identify the top-end of IDC resistance.

The procedure developed involves growing individual plants in conical pots that are about 6 inches long ("Conetainers"), in a 1:1 soil-to-sand mixture, that is sub-irrigated to keep the soil quite wet as in the field. The soil is from a field location that consistently produces IDC in soybeans. Chlorosis is intensified by adjusting the concentration of nitrate in the sub-irrigation solution and by the rate of phosphorus applied to the soil.

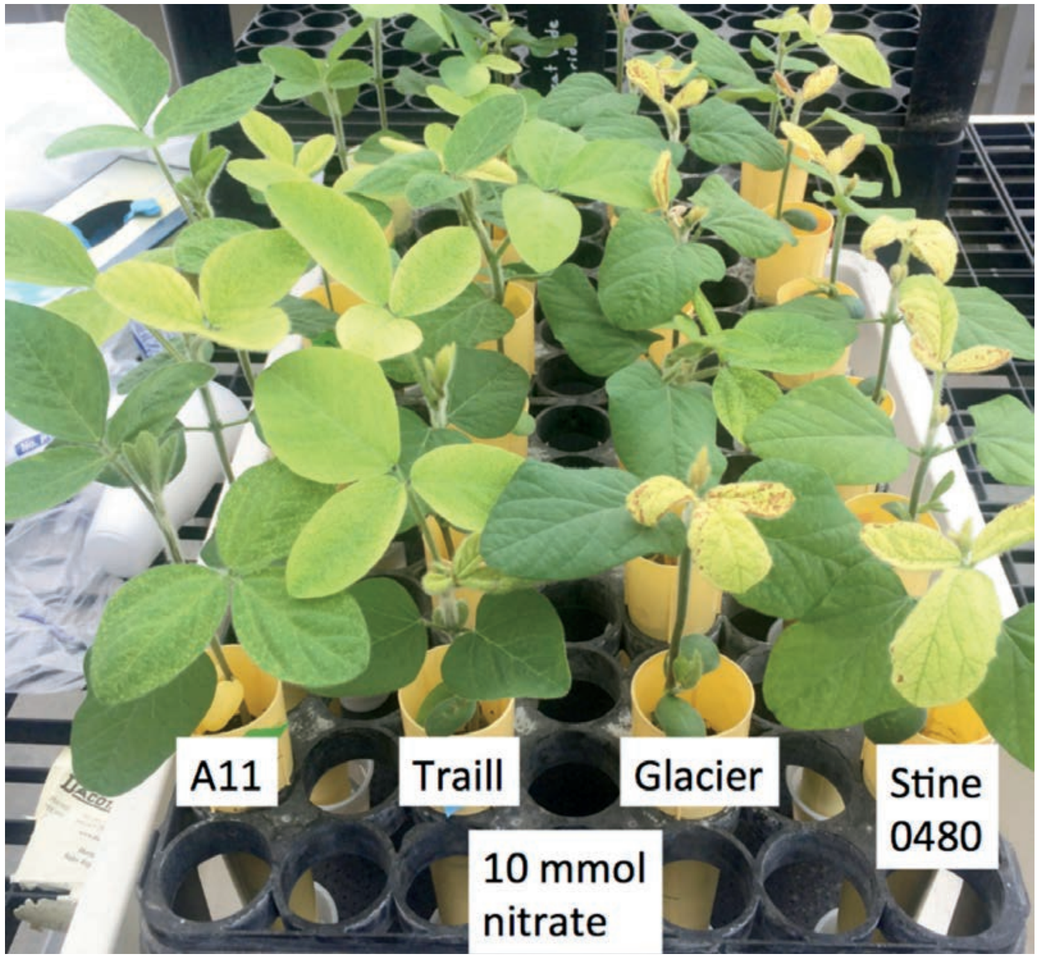


Figure 1. Four soybean varieties that differ widely in their resistance to IDC, in a greenhouse test.

Dr. Goos comparing the chlorophyll content of a chlorosis-susceptible soybean (left) with a chlorosis-resistant variety (right)

Findings

The final protocol involved a nitrate sub-irrigation solution of 10 millimolar sodium nitrate and 100 milligrams of phosphorus per 2 kilograms of soil-sand mixture. It was not necessary to include bicarbonate in the sub-irrigation solution.

An example of the results are shown in Figure 1. From left to right, there is Iowa State germplasm A11, a very resistant line; Traill, which has acceptable IDC resistance; and Glacier and Stine 0480, which do not have acceptable levels of IDC resistance.

The method developed is not difficult to perform and should help seed companies, dealerships or even individual farmers to identify varieties with higher levels of IDC resistance.

> "This project's objective was to develop a rapid greenhouse screening procedure that would identify the top-end of IDC resistance."

Water Stress Development and Mitigation in West Central North Dakota

Principal Investigators: *Dr. R. Jay Goos, NDSU Department of Soil Science; Jeremy Wirtz, Graduate Student, NDSU School of Natural Resource Sciences; and Eric Eriksmoen, NDSU North Central Research Extension Center*

Funded Project $33,785

Research Conducted

A soybean crop can use about 16 inches of water during a growing season. Yield loss due to drought stress is an annual concern in western North Dakota, especially in years with below normal precipitation.

Farmers in western North Dakota are already using advanced methods of soil and water conservation, such as no-till, but is there anything else that can be done to stretch limited water supplies? This research's first objective was to evaluate seed-applied growth regulators that slow water use. Perhaps saving water early might reduce water stress during grain fill.

Farmers are also expressing increased interest in cover crops. Cover crops are used to protect the soil and to increase soil health. However, cover crops also take up water, a precious commodity in a semi-arid climate.

The study's second objective was to measure the water used by a rye cover crop and to see if that led to reduced soybean yield.

Findings

A greenhouse and two field studies were utilized to evaluate the seed-applied growth regulators that slow water use by soybeans. In the field study, 4 parts per million of uniconazole improved the plants' water status at one site in early August. The treatment did not increase yield.

The effect of the rye cover crop on water depletion is shown in Figure 1. The two seeding rates were 25 and 50 pounds per acre, and the rye was terminated about 2 weeks before planting, around seeding time. The termination time was more important than the seeding rate, and up to 1.5 inches of water were used by the rye. However, rainfall was timely, and the yields were not decreased by the rye cover crop.

In this study's two years, final yields of 12-35 bushels per acre were obtained. Can we explain these yield differences based on water stress? In Figure 2, the lowest yield of 12 bushels per acre was observed at Cole Harbor. The crop essentially "burned up" and ended the year in severe water stress without relief. The second-lowest yield, 16 bushels per acre, was observed at Minot. At this site, the crop did not enter severe water stress but was in a state of water stress for the entire grain-fill period. At the other three locations, the plants were not under water stress in early August and did not enter severe water stress. At these three sites, the yields were acceptable for western North Dakota (29-35 bushels per acre).

Figure 2. Effect of water stress during seed fill on soybean yields in western North Dakota, 2017-2018.

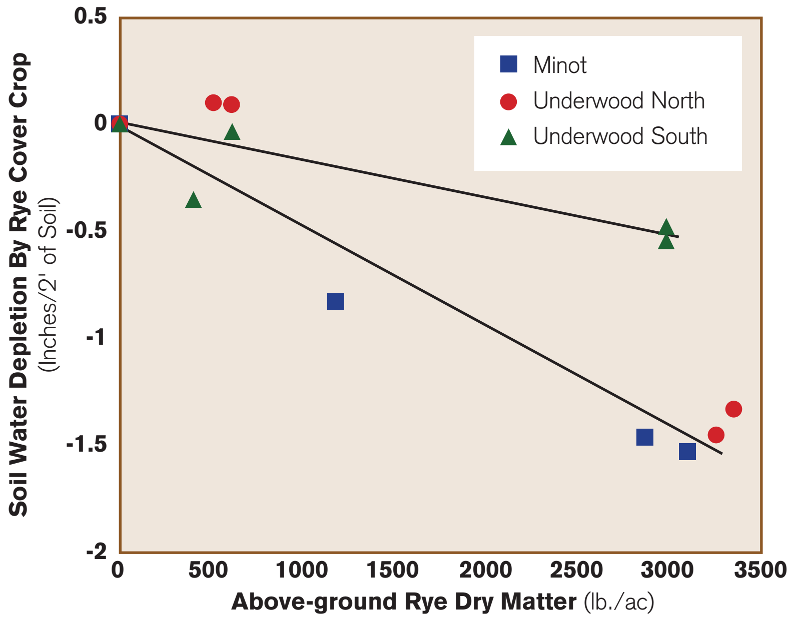
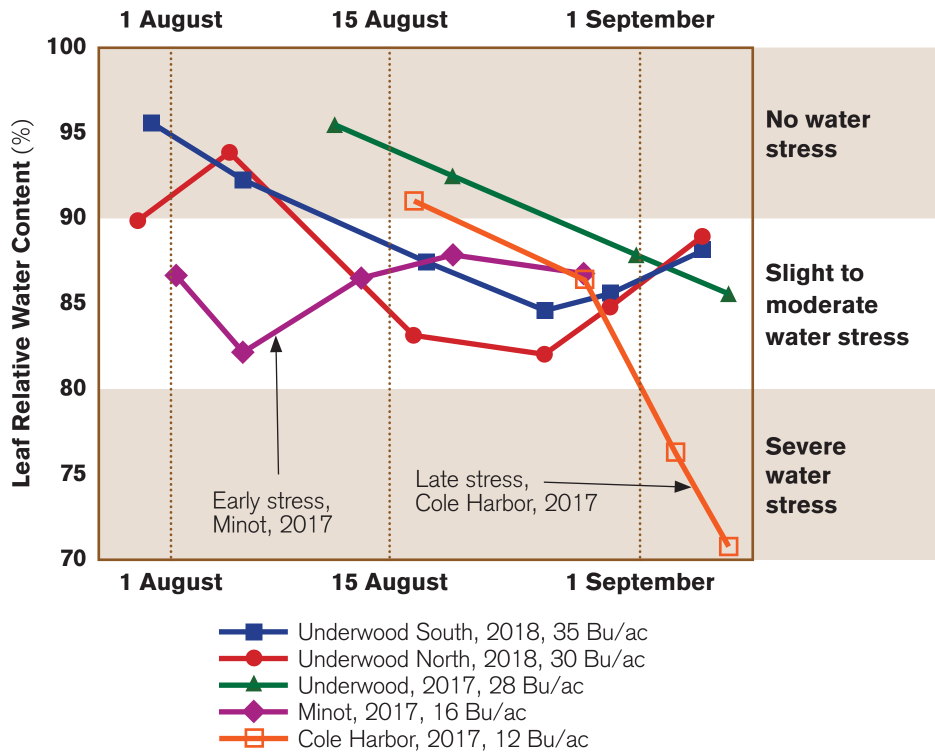


Figure 1. Water use by a rye cover crop at three locations in western North Dakota, 2018.



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

Planting season.

Research Conducted

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

Research was conducted at Langdon with 5 seeding dates and 3 MGs for each seeding date. The seeding dates were in approximate 10-day intervals, ranging from May 15 to June 25. 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. The June 25 seeding date failed to produce a harvestable crop because of a killing frost on September 29.

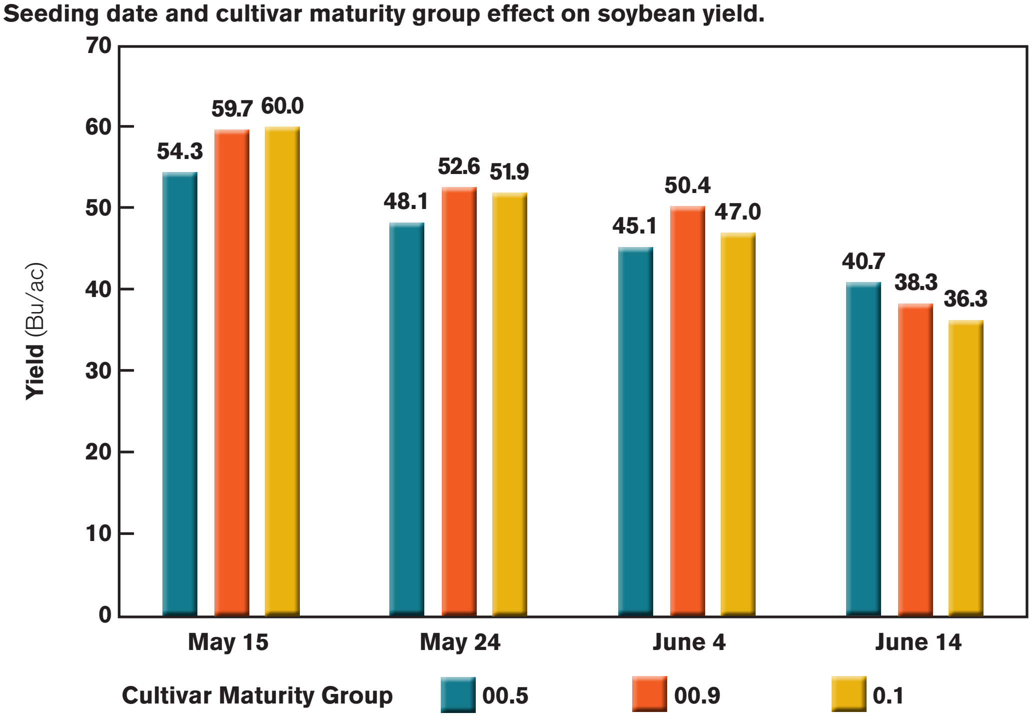
Findings

Agronomic-trait data trends (not shown) indicated that the number of days to maturity decreased with later seeding dates while later MGs took more days to mature. Plant and pod height decreased with later seeding dates. No differences were observed for grain protein among the seeding dates, but oil content decreased at later seeding dates.

Yields were greatest at the earliest seeding date and decreased for each of the subsequent dates. Yield decreases between the May 15 and June 14 seeding dates for the 00.5, 00.9 and 0.1 cultivars were 13.6, 21.4 and 23.7 bushels per acre, respectively. The yield response to seeding date varied by MG. Maturity group cultivars 00.9 and 0.1 had significantly higher yields at the May 15 and May 24 seeding date, but at the June 14 seeding date, the MG 00.5 cultivar had the highest yield. The 00.9 MG had the greatest yield on the June 4 seeding date.

The further that the seeding date is delayed into June, the greater the chance of a harvestable crop with the earliest MG. However, the chances of a harvestable crop which is seeded the last ten days of June would be problematic with even the earliest MG and would be dependent on the weather conditions as well as the timing of the first fall freeze in any given year.

Seeding date and cultivar maturity group effect on soybean yield.



LSD 5% Compare cultivars at same seeding date – 4.0 Bu/ac
Compare a cultivar at different seeding dates – 3.5 Bu/ac

> "Choosing the right combination of seeding date and cultivar maturity group is an important decision that producers make to achieve optimum soybean production."

Breeding of Glyphosate-Resistant Soybean Cultivars

Principal Investigator: *Dr. Ted Helms, NDSU Department of Plant Sciences*
Co-Investigator: *Dr. Berlin Nelson, NDSU Department of Plant Pathology*

Funded Project
$162,120

Research Conducted

Glyphosate-resistant experimental lines have been developed by the North Dakota State University (NDSU) Soybean Breeding Project. Crosses were initiated during the summer of 2010, and new crosses were started in every subsequent year. As part of the continuing process to develop new lines, 1,310 new experimental glyphosate-resistant lines were evaluated for yield in replicated plots during 2018. Seed for one advanced experimental line, ND15-22873GT, was increased in Chile during the 2018-2019 winter season. ND15-22873GT has a 0.7 relative maturity, is tolerant to iron deficiency chlorosis and has a yield which is similar to the commercial check varieties. Each year, there is the potential to release high-yielding, new glyphosate-resistant cultivars that were developed by NDSU.

Growers would like to purchase glyphosate-resistant soybean varieties and be able to save their own seed for planting the next year. This action would reduce input costs and could be especially beneficial for fields that have limited yield potential. These varieties need to be high-yielding, lodging-resistant, tolerant to iron deficiency chlorosis (IDC), and have good disease and pest resistance. Soybean varieties are protected by a patent on the glyphosate-resistant gene (construct) and are often protected by a second patent on the variety. Monsanto has provided a website to explain these issues (http://www.soybeans.com/patent.aspx).

Dr. Helms and crew plant experimental lines in May 2019.

This research's purpose is to provide superior glyphosate-resistant varieties that have been developed by NDSU. At this time, two glyphosate-resistant soybean varieties which were developed by NDSU are available to growers.

Findings

ND17009GT is a 00.9 maturity, and ND18008GT is a 00.8 maturity variety; both of them are glyphosate resistant. ND15-22873GT is an experimental line that was pre-released with a 0.7 maturity and is glyphosate resistant. ND15-22873GT has been approved for pre-release, and seed is being increased during the 2019 growing season. The decision to release ND15-22873GT will be made in January 2020.

The benefit to the North Dakota soybean industry is a reduced cost of soybean seed for varieties that are glyphosate resistant. Farmers can save their own ND17009GT seed but cannot save their own ND18008GT seed. When soybean growers can save their own seed for glyphosate-resistant soybean varieties, it reduces the input costs. Farmers can then plant this seed without paying a technology fee.

Dr. Helms checks planting depths.

“Growers would like to purchase glyphosate-resistant soybean varieties and be able to save their own seed for planting the next year.”

Breeding Improved Non-GMO Cultivars and Germplasm

Principal Investigator: *Dr. Ted Helms, NDSU Department of Plant Sciences*
Co-Investigator: *Dr. Berlin Nelson, Jr., NDSU Department of Plant Pathology*

Funded Project $225,697

Research Conducted

In 2018, yield data were collected for 40 private company Xtend and Roundup Ready 2 (RR2) varieties at two sites that had iron deficiency chlorosis (IDC) symptoms. Due to excessive rainfall and too much IDC, these yield trials were not reported in 2018. Four sites that were infested with SCN were used to test 27 Xtend and RR2 company varieties as well as 10 Liberty Link and non-GMO types.

In 2018, there were 1,584 new non-GMO experimental lines tested for yield in replicated plots. Seed of one advanced line, ND12-15647, was increased. ND12-15647 was later released as 'ND Rolette'. Protein and oil data for the variety-fee test sites were collected and analyzed.

Soybean growers would like yield data for fields that have a past history of IDC. Growers would like to be able to identify varieties with a high yield on soybean cyst nematode (SCN)-infested soil. These data will help farmers to choose the best variety for different fields. Growers benefit when they have the option of planting non-GMO varieties because it gives them an alternative instead of purchasing expensive seed for the GMO types each year.

Dr. Helms breeding cultivars.

Findings

Among the 27 Xtend and RR2 varieties that were evaluated for yield on SCN-infested soil sites, the yield varied from a low of 48.7 bushels per acre to a high of 69.3 bushels per acre. These data were published in the North Dakota Soybean Performance Bulletin (A-843) and online.

A new, non-GMO variety that was named 'ND Rolette' was released in January 2019. 'ND Rolette' has a relative maturity of 00.9 with exceptionally high yield for its maturity, very good IDC tolerance, resistance to lodging, and resistance to races 3 and 4 of phytophthora root rot.

In 2018, grain samples for protein and oil analyses were collected for all company varieties entered in the LaMoure, Grandin, Arthur, Hankinson, Milnor, and Walcott, North Dakota testing sites. These samples were analyzed, and the data were reported in the North Dakota Soybean Performance Bulletin (A-843).

The NDSU breeding program provides growers with the option to grow non-GMO varieties. Growers can use the published data from the SCN-infested soil-variety trials and from the yield evaluation of the IDC variety trials to aid with the selection of varieties that would be especially suited to specific fields. This will help farmers to increase the profit for those fields.

> "Soybean growers would like yield data for fields that have a past history of IDC. Growers would like to identify varieties with a high yield on SCN-infested soil."

Soybean harvest for Dr. Helms.

Understanding Stem Diseases in North Dakota: An Assessment and Educational Effort

Principal Investigator: *Dr. Sam Markell, NDSU Department of Plant Pathology*
Co-Investigators: *Dr. Dean Malvick, UMN Department of Plant Pathology*

Funded Project $66,862

Research Conducted

In 2017 and 2018, over 400 soybean fields in 31 counties were evaluated for the prevalence of stem diseases. Fields were surveyed during early maturity, and stems were evaluated for charcoal rot, pod and stem blight, phomopsis seed decay, northern stem canker, white mold, anthracnose, phytophthora stem rot and other diseases. Results of this study give North Dakota soybean growers and researchers data on which diseases are most common, which diseases may be causing yield loss, and where improvements in disease management can be made.

Why is the Research Important to North Dakota Soybean Farmers?

Multiple stem diseases can cause yield loss on soybeans. In some cases, cost effective management tools (such as rotation recommendations or selection of a resistant variety) are available. However, without a better understanding of the prevalence of these diseases, and tools that facilitate easy identification of these diseases, growers are more likely to experience yield loss.

Final findings of the Research?

In 2017 and 2018, 4,020 and 4,100 stems were evaluated for soybean diseases in 31 counties (Table 1). The most commonly identified diseases were those caused by Diaporthe/Phomopsis species, which are primarily residue borne pathogens and favored by short crop rotations. Charcoal rot was concentrated in the southeastern soybean growing counties, particularly in Cass, Traill and Barnes, where surveyors also noted large areas of fields dying prematurely. White mold and Phytophthora stem rot were less common, but both diseases need adequate rainfall (2017 and 2018 were relatively dry). Anthracnose was common, but rarely causes yield loss as is not considered a cause for concern. Brown stem rot was visually identified in both years, but molecular diagnostic confirmation is currently underway.

Benefits/Recommendations to the North Dakota Soybean Farmers and Industry:

This survey provides robust data on the prevalence of stem diseases occurring in North Dakota, and gives soybean growers (and others) information on what diseases they may expect, and subsequently manage (if possible). We recommend that soybean growers scout their fields and identify the diseases that are occurring. Improved tools to help growers identify diseases have recently been developed, such as the Soybean Disease Diagnostic Series (PP1867), are available. Importantly, this survey was conducted in two relatively dry growing seasons (2017 and 2018), in wetter growing seasons, we would expect more white mold and late season Phytophthora stem rot.

> "This survey provides data on the prevalence of stem diseases occurring in North Dakota, and gives soybean producers information on what diseases they can expect, and subsequently manage."

Table 1. Number of soybean fields with identified stem diseases in 31 North Dakota counties in 2017 and 2018.

County	Number of Fields	Pod and Stem Blight/Phomopsis Seed Decay	Charcoal Rot	Phytophthora Stem and Root Rot	Northern Stem Canker	White Mold	Anthraacnose
Barnes	20	20	8	1	13	4	11
Benson	20	11	1	0	14	0	8
Bottineau	4	2	0	0	3	0	0
Cass	23	22	16	0	9	3	6
Cavalier	11	2	1	0	11	0	8
Dickey	14	12	0	0	7	5	6
Eddy	6	5	0	0	5	0	1
Emmons	2	0	0	0	0	0	0
Foster	13	5	2	1	6	1	6
Grand Forks	20	7	8	0	7	0	4
Griggs	4	4	0	0	1	1	2
LaMoure	20	13	2	0	9	5	1
Logan	20	12	1	0	10	0	2
McHenry	4	2	0	0	0	0	0
McIntosh	6	2	0	1	2	0	0
McLean	4	1	0	0	0	0	0
Nelson	10	3	3	0	9	0	3
Pembina	20	10	1	0	5	1	0
Pierce	3	2	0	0	0	0	1
Ramsey	20	5	0	0	9	0	3
Ransom	9	6	0	0	1	7	1
Renville	4	2	0	0	0	0	1
Richland	20	15	7	3	7	4	4
Sargent	12	8	6	0	5	3	9
Steele	20	19	9	0	12	2	10
Stutsman	14	12	1	0	13	3	6
Towner	20	3	0	1	11	0	0
Traill	21	15	12	0	7	0	15
Walsh	20	12	1	0	12	1	10
Ward	20	2	0	0	5	0	0
Wells	2	2	0	0	0	0	0
Total	**406**	**236**	**79**	**7**	**193**	**40**	**118**

Identification of Pyrethroid-Resistant Soybean Aphids and the Use of Drones for Insect Scouting

Principal Investigators: *Dr. Janet J. Knodel, NDSU Department of Entomology; Patrick Beauzay, NDSU Extension Plant Pathology; and John Nowatzki, NDSU Department of Agricultural and Biosystems Engineering*

Co-Investigators: *Dr. Robert Koch, UMN Department of Entomology*

Grower Cooperators: *Jared Hager;, Dale Flesberg; and Brian Otteson, NDSU Agronomy Seed Farm*

Funded Project
$40,000

Research Conducted

Soybean aphids are a major economic insect pest of soybeans in North Dakota. The main goal of this research was to develop the best pest management (BPM) practices for insecticide-resistant soybean aphids.

Soybean aphids that are resistant to pyrethroids (bifenthrin and lambda-cyhalothrin) were detected in eastern North Dakota in 2017. Laboratory bioassays confirmed that about 70 percent of the tested soybean aphid populations were resistant to pyrethroid insecticides in 2017. In 2018, soybean aphid populations were extremely low throughout the state. Soybean aphids were only found at one field site near Emerado for conducting the bioassays. These soybean aphids were highly susceptible to both pyrethroid insecticides because all aphids were dead at the 4-hour mortality assessment. In contrast, soybean aphid populations from Emerado which were tested in 2017 were found to be resistant to only bifenthrin. This finding suggests that pyrethroid-resistant soybean aphids are mobile and may have migrated from other resistant areas in 2017.

Because populations of pyrethroid-resistant soybean aphids can vary by year and location, screening more North Dakota populations determine their presence or absence as well as their resistance status.

Dr. Knodel discusses research findings.

These findings are essential for growers so they can wisely decide which BPM practices to use for pyrethroid-resistant soybean aphids.

Since insecticide-resistant soybean aphids will continue to complicate insect management for growers. Additional research is critical, since insecticide-resistant soybean aphids will continue to complicate insect management for growers.

In 2018, Extension education was delivered to over 1,500 soybean growers. A grower evaluation survey showed that 91 percent of the growers who attended education sessions plan on using integrated pest management (IPM) strategies to manage soybean aphids. Growers who used IPM strategies to manage pyrethroid-resistant soybean aphids saved an estimated collective annual cost of $12 million and reduced insecticide input by about 700,000 pounds.

Our last objective was to evaluate the feasibility of using drones to scout for soybean aphids. Drone scouting could improve the field scouting efficiency and aid in detecting economic populations of soybean aphids quicker. Unfortunately, the drone with the autonomous probe needed for this objective was not available from the company due to some unexpected problems.

Insecticide bioassay setup in the laboratory to test soybean aphids for insecticide resistance (Patrick Beauzay, NDSU).

Soybean Cyst Nematode Sampling Program: 2018

Principal Investigator: *Dr. Sam Markell, NDSU Department of Plant Pathology*
Co-Investigators: *Dr. Guiping Yan, NDSU Department of Plant Pathology*
Collaborators: *Dr. Berlin Nelson, NDSU Department of Plant Pathology*

Funded Project
$59,580

Research Conducted

Soybean cyst nematode (SCN) is estimated to cause over $1 billion in yield losses annually for U.S. soybeans growers. Since first reported in Richland County in 2003, the nematode has continued to spread throughout North Dakota. Unless proactively managed, North Dakota growers' economic losses are expected to increase as the nematode establishes in new fields and counties.

Management tools are available, but early detection of SCN is critical to prevent yield loss. Detecting SCN visually is very difficult, and a 15 to 30 percent yield loss is common before the appearance of any above-ground symptoms. The most reliable way to detect SCN is to actively soil-sample areas where the nematode is most likely to be introduced into a field before the symptoms are present.

To facilitate SCN sampling by growers, the North Dakota Soybean Council and NDSU Extension developed a free sampling program in 2013.

Findings

In the fall of 2018, 558 samples were received. All SCN soil-sample data from 2013 to 2018 were combined and mapped (Figure 1). SCN was most frequently identified in southeastern North Dakota, but positive tests were observed in the eastern half of the state.

> "This program is designed to proactively detect SCN before above-ground symptoms are present and before extensive yield loss occurs."

To better visualize SCN in southeastern North Dakota, a "heat map" was created (Figure 2). While these are visually appealing, the map should be viewed with a high level of caution because SCN is very patchy. It is very likely that fields in areas with high egg counts will actually not have SCN and that some fields in areas without SCN eggs will be positive.

This program is designed to proactively detect SCN before above-ground symptoms are present and before extensive yield loss occurs. The economic benefits for early detection and active management of SCN are a reduction in the potential yield loss for many years; these benefits occur not only in the field where the SCN was first detected, but also in other fields that are managed on that farm. With thousands of samples submitted since 2013, this program, along with the use of management tools, has very likely saved North Dakota soybean growers many millions of dollars.

Figure 1. SCN Survey 2013 – 2018

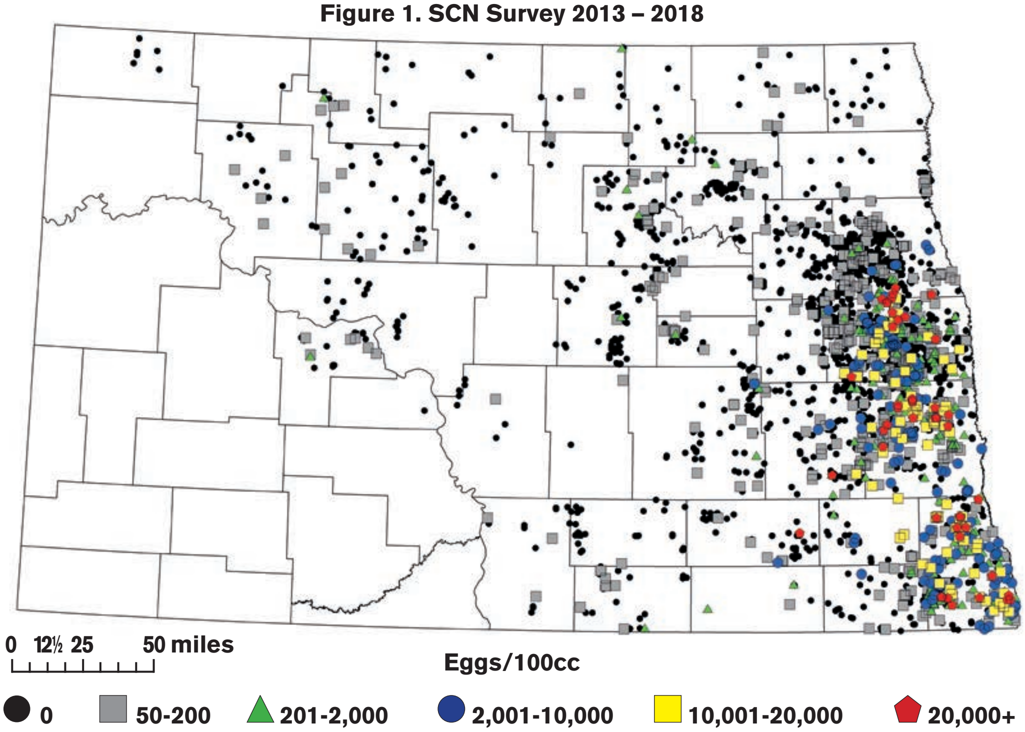
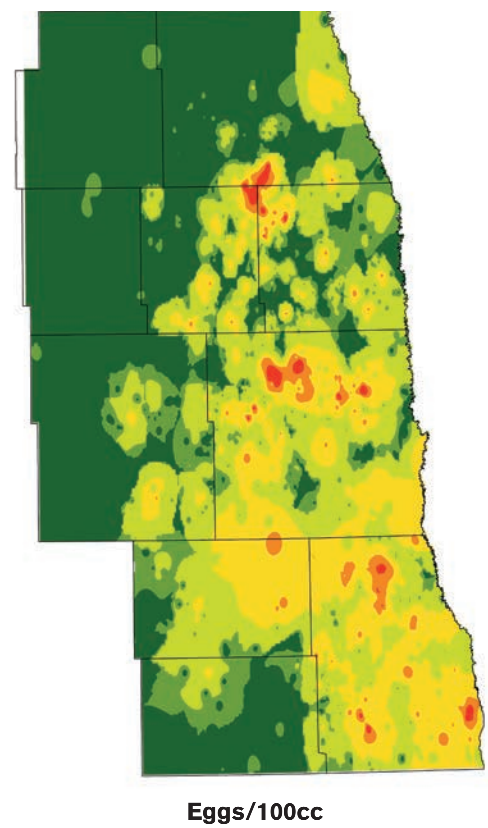


Figure 2. SCN Survey 2013 – 2018



Controlling Soybean Diseases

Principal Investigator: *Dr. Berlin Nelson Jr., NDSU Department of Plant Pathology*
Co-Investigators: *Dr. Ted Helms, NDSU Department of Plant Sciences, and Dr. Sam Markell, NDSU Department of Plant Pathology*

Funded Project
$53,400

Research Conducted

This research's primary objectives were to screen North Dakota State University (NDSU) soybean breeding lines for resistance to major diseases and to monitor soybean fields for new pathogens that can cause serious yield losses. In cooperation with Dr. Helms, the soybean breeder, we screened 60 advanced breeding lines for resistance to Phytophthora sojae race 4 or race 3. Over 80 percent of the NDSU lines were resistant to this pathogen. One breeding line which is resistant to race 4 was released in 2019 by NDSU and Dr. Helms as 'ND Rolette,' a high-yielding conventional soybean cultivar with a 00.9 maturity. Phytophthora root rot is a major disease in the Red River Valley, and resistance is the primary way to prevent serious losses.

Figure 2. Large patches of dead and dying soybean plants in a field with charcoal rot, August 2018.

Findings

In August 2018, we surveyed 153 soybean fields in 10 counties (Barnes, Cass, Dicky, Griggs, LaMoure, Richland, Ransom, Sargent, Steele and Traill) for evidence of sudden death syndrome (SDS) which is caused by Fusarium virguliforme. This disease had not previously been reported in North Dakota, but it is a serious disease for other soybean-producing states, including Minnesota and South Dakota. We were searching for specific foliar symptoms that are associated with SDS. In several Richland County fields, we discovered classic foliar symptoms of SDS. The plants were collected, and fungi were isolated from the roots. These fungi caused disease in greenhouse experiments and were identified by DNA analysis as F. virguliforme. SDS is, therefore, a new soil-borne disease of North Dakota soybeans.

Figure 1. Foliar symptoms of sudden death syndrome in soybeans, August 2018.

In addition to finding SDS, we also found, for the first time, a soybean field with major damage from charcoal rot in 2018. This soil-borne disease is caused by the fungus Macrophomina phaseolina. The field was in an area in Cass County where there were drought conditions during July and August. This 210-acre field had approximately 60 percent of the plants dead or dying by the beginning of September.

The information we gain from studying the SDS and charcoal rot diseases will be used to prepare information for growers, crop scouts and others in North Dakota's soybean industry so that these diseases can be identified, disease development can be understood and management options can be explained. Both diseases have the potential to cause extensive yield loss for soybeans. A major effort of our future research will be to find resistance to these diseases and to incorporate resistance into breeding material for North Dakota.

Effect of Soil Salinity on Fusarium and Rhizoctonia Root Rots of Soybeans

Principal Investigator: *Dr. Berlin Nelson Jr., NDSU Department of Plant Pathology*

Funded Project
$34,000

Research Conducted

This project's purpose is to determine if the severity of Fusarium and Rhizoctonia roots rots increases under low-to-moderate levels of soil salinity.

Soil salinity is a serious problem in some areas of soybean production. A series of experiments under greenhouse conditions were conducted using the root rot fungi Fusarium solani, F. tricinctum and Rhizoctonia solani in order to determine if low levels of soil salinity might increase the soybean plants' root rot damage. Because we know that salinity has a great effect on soybean growth, the most likely interaction between soil salinity and root rots would be at low salinity levels where the plants would grow under field conditions. Our experiments tested the soil-salinity levels of electrical connectivity (EC), a measurement of soil salinity, at EC 1 and EC 2 compared to EC 0 at several different inoculum levels for these root rot fungi.

The fungi were grown on sterilized wheat seeds. Then, the infested seeds were mixed into the soil. The plants were grown for 3 weeks. Then, the root rot lesions, plant height, root weight and total plant weight were measured. The soil salinity was adjusted to EC 1 and EC 2 using sodium sulfate and magnesium sulfate. Salinity levels were maintained by carefully adjusting the water loss from the soil.

> **Because we know that salinity has a great effect on soybean growth, the most likely interaction between soil salinity and root rot would be at low salinity levels where the plants would grow under field conditions.**

Findings

The experiments' results indicated that there was no major evidence that soil salinity would, in general, increase root rot for soybeans in the seedling stage. Indeed, the evidence indicated that soil salinity between EC 1 and EC 2 had a major negative effect on soybean growth in these experiments; the effects of the root rot pathogens were either less important to plant growth under soil salinity, or the activity of the root rot fungi was generally suppressed by soil salinity. There were few indications of significant interactions between the root rot fungi and soil salinity, but these interactions appeared to be less important than the overall effect of soil salinity on the soybean growth. It is important to point out that the EC 1 and EC 2 levels in these experiments were very uniform throughout the soil, whereas under field conditions, such uniform salinity would be less likely; plants in the field would be growing in soil with more variation for the EC levels. These experiments are further evidence about the major effects of soil salinity on the growth of soybeans as well as the need to manage this soil condition.

Figure 1. Root systems of three plants all inoculated with the same amount of Fusarium but growing at different soil salinity levels. The plant on the right growing at EC 2 has a 43 percent reduction in root mass compared to the plant growing in the soil with no salinity (EC 0). The plant at EC 1 also has a reduced root mass.

Multiple Applications of Dicamba on Non-Dicamba Tolerant Soybeans: Effect on Seed Yield and Quality as Well as the Effectiveness of a UAS to Assess Dicamba Damage

Principal Investigators: *Mike Ostlie, NDSU Carrington Research Education Center; Dr. Paulo Flores, NDSU Department of Agricultural and Biosystems Engineering; and Dr. Kirk Howatt, NDSU Department of Plant Sciences*

Funded Project $27,111

Research Conducted

A herbicide drift study was conducted to test microrates of dicamba on conventional soybean performance. Spectral data were collected to test methods for visualizing dicamba injury in a field. The images were analyzed with four different vegetation indices. These data were prepared for presentations at the Wild World of Weeds Workshop and the Western Society of Weed Science. These data were also published in the Carrington Research Education Center Annual Report and on Twitter (@agronomizeNDSU).

Table 1

Treatment	Rate fl. oz./ac	Injury 20 DAT	Injury 40 DAT	PM Days	Plant Hit cm	Yield Bu/ac	Protein	Oil
Check		0.0	0.0	106.8	59.5	24.3	37.2	17.3
Dicamba	0.014	6.3	2.5	106.8	57.5	23.6	37.3	17.3
Dicamba	0.14	28.8	26.3	106.8	44.0	22.9	37.9	17.1
Dicamba	1.4	58.8	68.8	129.0	32.0	9.7	39.4	16.1
Glyphosate + Dicamba	0.025 + 0.014	16.3	11.3	106.8	51.5	22.0	37.3	17.1
Glyphosate + Dicamba	0.025 + 0.14	30.0	27.5	107.0	42.5	20.7	37.9	17.1
Glyphosate + Dicamba	0.025 + 1.4	68.8	73.8	129.0	30.0	7.2	36.8	16.4
LSD (0.05)		4.1	5.0	0.6	7.0	4.5	0.8	0.4

Soybeans are inherently very sensitive to dicamba. This project was created to track the effect of injury to yield, to determine if symptoms can be measured with an aerial image and to identify any changes with subsequent seed viability.

While dicamba symptoms readily affected fields in 2017 and 2018, it is less clear how much the yields were affected as a result of the injury. In many cases, injury appeared with little-to-no observed yield loss, but this finding was not true in other instances. Local data are important to demonstrate realistic yield and quality expectations once visual symptoms are observed.

Findings

Only the highest rate of dicamba, with and without glyphosate, reduced yield (Table 1). That same rate also caused an extreme delay in plant maturity, where the plants only matured due to frost. Even with up to 25 percent injury to the plants, the yield was not reduced, similar to previous years' work.

Vegetation indices were analyzed with a comparison to visual injury and yield 20 days after herbicide application. The relationship between visual symptoms and analyzed imagery was strong. Among the indices used, the normalized difference vegetation index (NDVI), normalized difference red edge (NDRE) and green normalized difference vegetation index (GNDVI) all generated nearly identical relationships to yield and injury. The Excess Green (ExGr) index had a consistently lower correlation; however, the relationships were still good.

Dicamba symptoms do not dictate a decline in soybean yields. One of the keys is whether the growing points remained healthy. The affected plants were still shorter than unaffected plants, but all plants continued to grow. The highest dicamba dose caused severe stunting and no new growth until late in the season. There was no loss of germination due to any dose of dicamba tested.

Aerial images appear to be suitable for measuring dicamba injury. The Excess Green index, which was calculated from a color image with a Phantom 4 Pro, could be used to quantify the area which is affected by dicamba injury.

Upper left: check plot, upper right: low dicamba dose, lower left: middle dicamba dose, lower right: high dicamba dose

Mike Ostlie speaks to farmers during Carrington Research Extension Center's Agronomy Field Day.

Determining the Optimal 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*
Co-Investigators: *Dr. Jerald Bergman and Dr. James Staricka, NDSU Williston Research Extension Center*

Funded Project $11,883

Research Conducted

A glyphosate-resistant soybean variety was seeded at the Williston Research Extension Center on May 3, 10, 16 and 25, as well as on June and 3, 9, and 15, 2018, using a 7-row, no-till plot planter. Soil moisture and temperature data, at a 4-inch depth, were continuously recorded from April 26, 2018, to October 30, 2018. Canopy temperature and normalized difference vegetation index (NDVI) were measured weekly with a FLIR® E60 Thermal Imaging camera and a modified NDVI Sony camera. The crop was harvested using a plot combine, and biomass was collected 4 days before harvest.

Soybean acreage has been steadily increasing in North Dakota, including the western part of the state which has an exceptionally drier climate than the eastern part. There is a lack of a soybean-production management guidelines which are suitable the for no-till, dryland soybean producers of western North Dakota. Determining the suitable seeding date and soil temperature is crucial to avoid abiotic and biotic stress as well as to have a sustainable higher soybean yield and increased farm income with the no-till, dryland condition.

Findings

There was a significant effect for the seeding date on all the analyzed traits except the normalized difference vegetation index (NDVI) and canopy temperature (CT). On August 22, 2018, the average NDVI was 0.63, and the average CT was 32.4 degrees Celsius. Soybean seeded on and after June 9 had the highest plant stand compared to the other seeding dates (Fig. 1A). Soybeans seeded on May 16 were 3 to 5 inches taller, and they had more above-ground biomass, test weight and grain protein than the other seeding dates (Table 1). Soybeans seeded on May 16 also produced the maximum grain yield of 17.8 bushels per acre, which was an average of 3.3 to 6.8 bushels more grain than other planting dates (Fig 1B). The soybean grain weight was higher when seeded after June 3, and the grain oil content was higher when seeded earlier.

The growth, grain protein, test weight and yield results showed that mid-May is suitable for seeding soybeans under the no-till, dryland conditions of western North Dakota. The experiment will be repeated next year in order to validate the findings.

Figure 1. Soybean plant stand and grain yield under different seeding dates

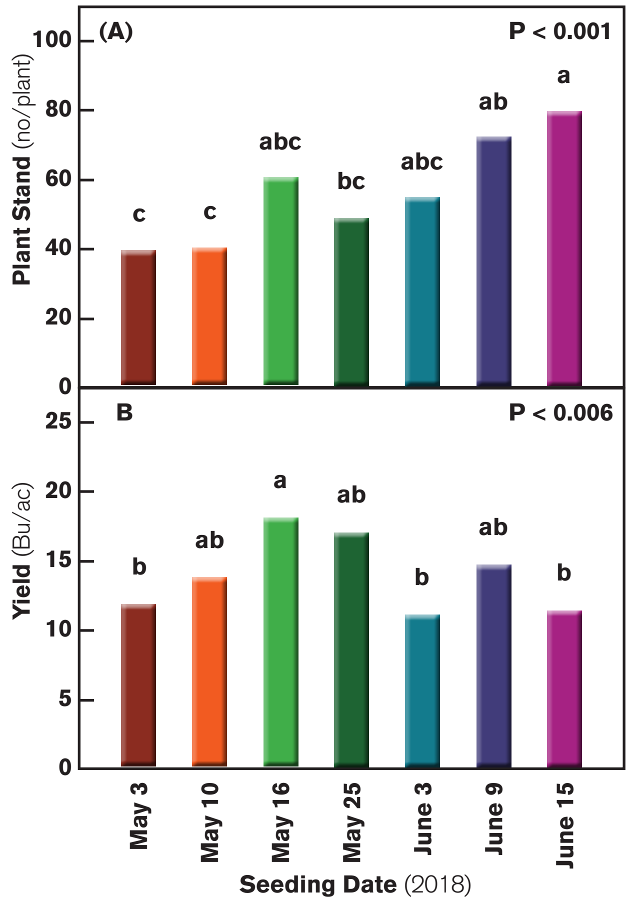


Table 1. Soybean growth, yield components and grain quality under different seeding dates

Seeding Date (2018)	Plant Height (in.)	Above Ground Biomass (lb./ac)	1000 Grain Weight (g)	Test Weight (lb./Bu)	Grain Protein (%)	Grain Oil (%)
May 3	15.5 B C	3737.3 B A	113.4 E	56.8 B	32.5 B A	17.2 B A
May 10	15.1 B C	2827.7 B A C	114.6 E D	57.2 B A	34.8 B	17.3 A
May 16	19.1 A	4014.7 A	115.7 E D C	58.3 A	36.3 A	16.7 B C D
May 25	17.0 B A	3041.1 B A C	116.9 B D C	57.3 B A	35.7 B A	16.8 B C
June 3	16.1 B C	3067.7 B A C	117.7 B A C	57.4 B A	35.7 B A	16.4 C D
June 9	15.3 B C	2680.9 B C	118.7 B A	57.4 B A	35.8 B A	16.3 D
June 15	13.7 C	2214.1 C	120.3 A	56.7 B	36.1 B A	15.7 E
P-value	0.0003	0.0034	<.0001	0.0038	0.0176	<.0001

Effect of Plant Population and Row Spacing on Physiology, Water Use Efficiency and Yield for No-Till, Dryland Soybeans

Principal Investigators: *Dr. Gautam Pradhan, NDSU Williston Research Extension Center*
Co-Investigators: *Dr. Jerald Bergman and Dr. James Staricka, NDSU Williston Research Extension Center*

Funded Project
$15,953

Research Conducted

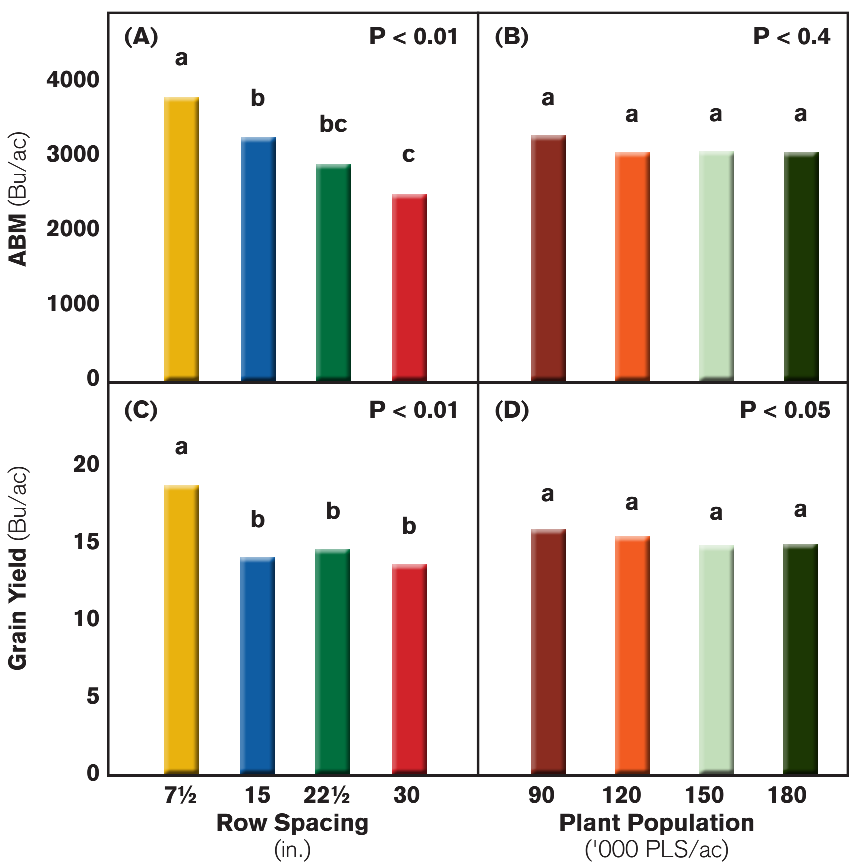
A Roundup Ready 2 Yield (RR2Y) soybean variety with a maturity group of 0.3 was planted at the Williston Research Extension Center on May 30, 2018, to determine a suitable planting geometry for the no-till, dryland conditions of western North Dakota. Row spacings of 7.5, 15, 22.5 and 30 inches were maintained as the main plots, and plant populations (seeding rates) of 90,000; 120,000; 150,000; and 180,000 seeds per acre were considered as sub-plots.

Soybean acreage has been steadily increasing in North Dakota, including the western part of the state, which has a substantially drier climate than the eastern portion. There is a lack of information about the suitable planting geometry for this part of the state. Determining a suitable plant population and row spacing is crucial to have a sustainable, higher soybean yield and improved farm income with no-till, dryland conditions.

Findings

There was no effect of plant population and row spacing on the normalized difference vegetation index, canopy temperature, available soil moisture, plant height, test weight, grain protein, grain oil and grain weight. When averaged across the row spacing, there was no effect of plant population on above-ground biomass (ABM) and grain yield (Fig. 1B, 1D); however, when averaged across the plant population, a row spacing of 7.5 inches produced 525 to 1,250 more pounds of biomass per acre (Fig. 1A) and 4 to 5 more bushels of grain per acre (Fig. 1C) than the wider row spacings. There was evidence for the interaction effect of plant population times row spacing on grain yield, but because the 90,000 plant population produced higher or equal bushels of grain at different row spacings, and the 7.5-inch row spacing produced higher or equal bushels of grain at different plant populations, the interaction effect was not further elaborated.

This experiment confirmed our findings from 2016 and 2017 that a row spacing of 7.5 inches and 90,000 population-per-acre seeding rate are a suitable planting geometry for no-till, dryland soybean production in western North Dakota. The study recommends planting soybeans at a lower seeding rate and in narrow rows, reducing expensive seed costs, enhancing yield and increasing the farm income for North Dakota soybean producers.



Research and Extension Efforts at the Soil Health and Agriculture Research Extension (SHARE) Farm

Principal Investigators: *Dr. Abbey Wick and Dr. Frank Casey, NDSU Department of Soil Science; Dr. David Ripplinge, NDSU Department of Agribusiness and Applied Economics; and Dr. Caley Gasch, NDSU Department of Soil Science*

Funded Project
$51,250

The Soil Health and Agriculture Research Extension (SHARE) Farm is the primary site for the NDSU Soil Health program where field-scale, long-term, farmer-driven research is being conducted. Accompanying the research program is an equally complex Extension program. The goal of the SHARE Farm is to bring whole-systems evaluation to soil health building practices.

Several different management system aspects have been evaluated at the SHARE Farm. Research ideas come directly from farmer input and include the evaluation of soil salinity management approaches, conservation tillage practices, using cover crops in a rotation and soil health indicators. This information has been incorporated into economic calculator tools; the first tool salinity tool is available online: www.ag.ndsu.edu/bioeconomics/Library/tools/salinity-economics-tool.

Salinity management practices, such as tile drainage, have shown a primary benefit of keeping the water table at the installation depth below the soil surface. After 5 years, the field's tiled portion is starting to show minimal levels of salt leaching from the soil surface. Tiling should not be the only strategy used to manage salts; selecting salt-tolerant crops, crops with high transpiration rates or planting cover crops that remove excess soil moisture late in the growing season/fall are options.

"Tiling should not be the only strategy used to manage salts; selecting salt-tolerant crops, crops with high transpiration rates or planting cover crops that remove excess soil moisture late in the growing season/ fall are options."

When converting to a reduced till/cover crop system, crop yields have not been consistently different between treatments (conventional management versus no-till+cover crop) from year to year in the first three years of evaluation (2016-2018). Moisture and temperature results from the conservation tillage study are in Daigh's report.

If testing for soil health and looking for guidance, keep these tips in mind. (1) Fertility testing services provided by a commercial soil-health testing service, as a bundle, are redundant, inaccurate for our soils, and unnecessary; (2) scoring functions that commercial soil-health testing labs provide to rank, or score, a field for soil health (such as a 72 percent soil-health score) are not accurate for our region and should be ignored; and (3) soil aggregation is a good soil-health indicator, especially for high-clay Red River Valley soils.

recommend watching for the development of soil structure (aggregates) as soils are transitioned into conservation practices because it tends to be more reliable than microbial indicators over time. If using microbial indicators to assess the soil's health, be sure to sample under similar conditions from year to year (soil moisture and temperature) in order to minimize the variability with these indicators.

More information is available online: ndsu.edu/soilhealth.

Soybean farmers from across the U.S. visit the SHARE farm in August, 2018.

Determining Thresholds for the Profitable Use of Fungicides to Control White Mold in Soybeans

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

Funded Project $16,062

Research Conducted

A single fungicide application is not always sufficient to protect soybean yield when the risk of white mold is high during soybean bloom, but determining when a second fungicide application is needed can be difficult.

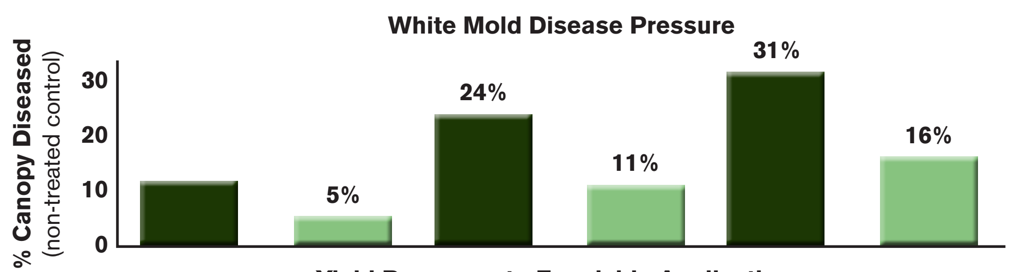
This project evaluated the effect of soybean maturity length and white mold infection timing on disease severity and returns to fungicide applications. Replicated field trials were conducted under overhead irrigation in Carrington, and Oakes, North Dakota. In Carrington, 38 soybean varieties from 00.5 to 1.0 maturity were evaluated with and without fungicides (zero, one and two fungicide applications targeting white mold); in Oakes, 25 varieties from 00.1 to 1.3 maturity were evaluated. An additional study was established in Carrington; intensive supplemental irrigation conducive to white mold was delivered during the R2 and R3 growth stages, versus the late R3 to early R6 growth stages, and compared to a non-irrigated treatment.

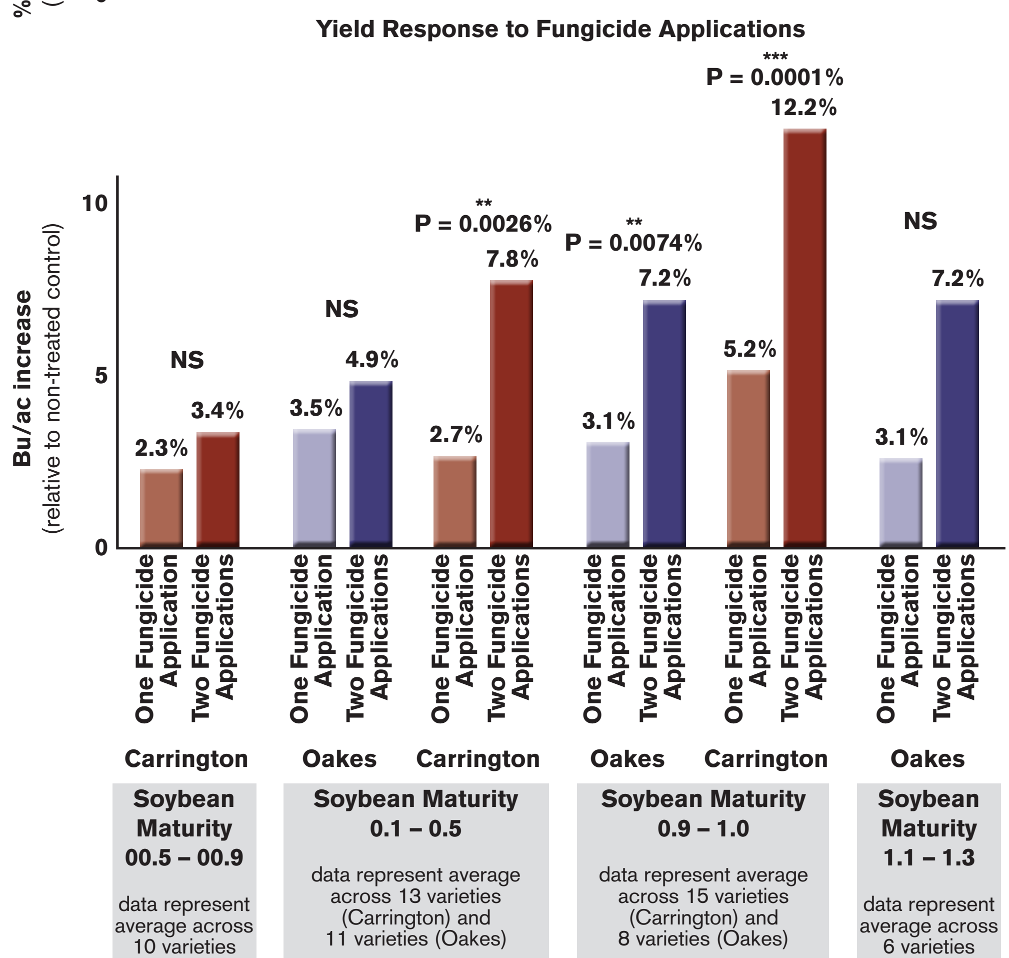
Findings

Although differences among varieties of similar maturity were observed, susceptibility to white mold was strongly correlated to soybean maturity. In Carrington, end-of-season white mold severity averaged 5 percent across 00.5- to 00.8-maturity varieties and 39 percent across 0.9- to 1.0-maturity varieties. In Oakes, end-of-season white mold severity averaged 5 percent across 0.1- to 0.3-maturity varieties and 16 percent across 1.1- to 1.3-maturity varieties. With longer maturity soybean varieties, a single fungicide application was often insufficient, and yields were sharply improved by making a second fungicide application.

White mold was most severe when conditions favored disease during the R2 and R3 growth stages (full bloom and initial pod development). Across four soybean varieties from 0.6 to 0.9 maturity, end-of-season white mold severity averaged 31 percent when intensive irrigation favoring white mold was delivered for a 3-week period during the R2 and R3 growth stages, and the severity averaged 13 percent when intensive irrigation was delivered for a 3-week period from the late R3 to early R6 growth stage. Fungicide applications conferred strong yield gains when conditions were favorable for white mold during the R2 and R3 stages, but not when conditions were favorable for white mold from the late R3 to early R6 stages.

The results suggest that soybean maturity and the growth stage can be used to help guide fungicide decision making. A single fungicide application at the R2 stage may be sufficient for white mold management in most short-maturity varieties (00 through approximately 0.3 or 0.5), and a second application may be needed with many longer-maturity varieties when the white mold risk is high during the R2 and R3 stages.





Identify and Develop Glyphosate-Resistant Weed Maps in Soybean Fields

Principal Investigator: *John Nowatzki, NDSU Department of Agricultural and Biosystems Engineering*

Funded Project
$1,748

Research Conducted

This project's primary goal was to develop a method to identify and to map weed species and herbicide-resistant weeds in crop fields by utilizing Unmanned Aerial System (UAS) technology.

A field-scale study was conducted on a soybean crop field at the North Dakota State University (NDSU) Agronomy Seed Farm located in Carrington, North Dakota. The Roundup Ready NuTech Soybean (Glycine max) was planted on May 22, 2017, at 403,845 seeds/ha. The field experiment was conducted by growing two common species of weeds (Kochia and Waterhemp) in the greenhouse from seeds which were collected from parent plants that were known to be either susceptible or resistant to the glyphosate herbicide. These plants were then transplanted to an experiment field in order to create a mixed crop with three species of susceptible and resistant weeds in the field. Field data were also collected from a research field in Mayville. The Mayville field was naturally infested with glyphosate-resistant and susceptible lambsquarter as well as ragweed. The fields' weeds were manually identified and tagged with their species and geographic coordinates through field scouting. Two quad-copter unmanned aerial vehicles (UAVs), a Phantom3 and DJI S1000 (SZ, DJI Technology Co., Ltd.; Shenzhen, China), were used to fly the cameras over the experimental fields to collect high-resolution multispectral and thermal images, respectively. Multispectral images were used to classify the weed species. Thermal images were captured 4 days after glyphosate application and were used to identify the herbicide-resistant status weed plants. Weeds in the field were also identified and tagged with their species and geographic coordinates through field scouting. Later on, the resistance data were added to this file after the weeds were evaluated for resistance. When the weeds were approximately 7.6 cm tall, glyphosate [N-(phosphonomethyl) glycine] with a 1.7 percent concentration was applied to the fields at a uniform rate.

> "The field's weeds were manually identified and tagged with their species and geographic coordinates through field scouting."

Findings

The thermal images indicated that the susceptible weed canopies were significantly warmer than the resistant weed canopies 4 days after glyphosate application. The high accuracy for all three weed species at the two different locations showed that the plant's canopy temperature can be a reliable, discriminative feature to identify glyphosate-resistant weeds early after spraying.

John Nowatski conducts a drone demonstration for farmers to create weed maps.

Optimizing Fungicide Applications for the Management of Sclerotinia in Soybeans

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

Funded Project
$41,152

Research Conducted

Obtaining consistent control of Sclerotinia (white mold) in soybeans with fungicides is complicated by the difficulty of achieving satisfactory fungicide deposition to the lower canopy where most white-mold infections begin.

White mold primarily infects soybeans through dead blossoms, and soybeans are most susceptible to white mold at the R2, R3 and R4 growth stages when the soybeans are in full bloom with dead blossoms abundant in the canopy's interior. When conditions favor white mold as soybeans enter bloom, applying fungicides at the R2 growth stage optimizes white-mold control. Achieving satisfactory fungicide deposition to the lower soybean canopy at the R2 growth stage can be difficult; in North Dakota, soybeans are often at or near canopy closure and are 24 to 27 inches tall in the R2 growth stage.

Fungicide deposition to the lower canopy is typically optimized with larger spray droplets that have the velocity to penetrate the canopy but still confer acceptable coverage. In order to evaluate the effect of the spray droplet's size on white-mold control, the fungicide Endura (boscalid; BASF Corp.) was applied at 5.5 oz/ac with Spraying Systems TeeJet extended-range (XR) flat-fan nozzles at 30 or 50 psi to emit fine-to-coarse droplets. The spray volume was 15 gallons/acre, and applications were made with a tractor-mounted boom which was equipped with a pulse-width modulation system to permit a constant driving speed across all treatments. With the testing conducted in soybeans grown under overhead irrigation in Carrington and Oakes, medium spray droplets optimized white-mold control when the soybean canopy was open (average canopy closure < 90 percent) when fungicides were applied, and coarse spray droplets optimized white-mold control when the soybean canopy was at or near closure (average canopy closure > 90 percent) when fungicides were applied (Figure 1). In 2019, these studies are being expanded to evaluate nozzles from two manufacturers.

To evaluate the potential use of drop nozzles for delivering fungicides to the lower canopy, the 360 Undercover drop nozzle (360 Yield Center; Morton, IL) was tested with a tractor-mounted boom in soybeans which were seeded in 21-inch rows.

Findings

The gain in white-mold control associated with applying fungicides through drop nozzles was greatest when applications were made to a soybean canopy that was at or near closure (90-100 percent canopy closure), and the use of drop nozzles facilitated strong, consistent disease control with a broad range of fungicides, including low-cost applications of the off-patent fungicide Topsin (thiophanate-methyl; Figure 2).

Figure 1. Response to spray droplet size with the fungicide Endura applied at 5.5 oz/ac during the R2 growth stage to soybeans seeded in 21-inch rows; Carrington, North Dakota (2018). Within-column means followed by different letters are significantly different (P < 0.05).

	Carrington, ND	Carrington, ND	Carrington, ND	Carrington, ND	Oakes, ND
Variety (Maturity Rating):	ProSeed 'XT60-40' (0.4)	Peterson '18X06N' (0.6)	Dairyland 'DSR-0904' (0.9)	Peterson '17X09N' (0.9)	Pioneer 'P11A95X' (1.1)
Fungicide Application Date / growth stage:	July 13 / 100% R2	July 16 / 80% R2, 20% R3	July 13 / 100% R2	July 13 / 100% R2	July 13 / 80% R2, 20% R3
Canopy Closure at Fungicide Application:	75-90%	80-95%	90-95%	90-95%	97-100%
White Mold Severity Index (% of Canopy Diseased)					
Disease Assessment	October 28 (R9)	October 6-7 (R9)	October 21-22 (R9)	October 18-20 (R9)	October 2-5 (R9)
Non-Treated Control	6 b	14 b	17 b	36 a	39 b
Fine Droplets XR8003, 50 psi	4 ab	7 a	16 ab	34 a	32 ab
Medium-Fine Droplets XR8004, 40 psi	5 b	6 a	16 ab	34 a	28 ab
Medium Droplets XR8006, 40 psi	2 a	5 a	11 ab	31 a	30 ab
Medium-Coarse Droplets XR8008, 35 psi	4 ab	7 a	10 ab	31 a	29 ab
Coarse Droplets XR8010, 30 psi	4 ab	7 a	9 a	26 a	25 a
	CV: 21.8	CV: 52.1	CV: 39.5	CV: 28.1	CV: 21.6
Soybean Yield (13% Moisture)	bu/A	bu/A	bu/A	bu/A	bu/A
Non-Treated Control	64 a	64 a	58 a	51 a	53 b
Fine Droplets XR8003, 50 psi	67 a	66 a	58 a	54 a	59 ab
Medium-Fine Droplets XR8004, 40 psi	64 a	65 a	57 a	53 a	63 ab
Medium Droplets XR8006, 40 psi	68 a	71 a	60 a	54 a	62 ab
Medium-Coarse Droplets XR8008, 35 psi	66 a	67 a	61 a	58 a	61 ab
Coarse Droplets XR8010, 30 psi	66 a	67 a	61 a	59 a	66 a
	CV: 4.9	CV: 8.9	CV: 8.1	CV: 10.9	CV: 10.5

Figure 2. Response to fungicides applied once or twice with boom-mounted nozzles (XR8006 flat-fan nozzles, 40 psi; medium droplets) or drop nozzles (XR11001 flat-fan nozzles on side ports and TX-VK3 hollow-cone nozzles on lower rear port, 40 psi; fine and very fine droplets). Within-column means followed by different letters are significantly different (P < 0.05).

		Carrington, ND (2018) Peterson Farms, '17X09N' (0.9 maturity)		Oakes, ND (2018) Pioneer 'P11A95X' (1.1 maturity)	
		White Mold (% of canopy)	**Yield** Bu/ac	**White Mold** (% of canopy)	**Yield** Bu/ac
Boom-Mounted Nozzles One Fungicide Application R2 Growth Stage XR8006 flat-fan nozzles, 40 psi, medium droplet size	Non-Treated Control	29 a	59 a	29 b	54 a
	Omega 16 fl. oz./ac	23 a	61 a	16 ab	58 a
	Topsin 20 fl. oz./ac	29 a	63 a	28 ab	60 a
	Endura 8 fl. oz./ac	19 a	62 a	11 a	63 a
	Proline 5 fl. oz./ac	33 a	56 a	20 ab	63 a
		CV: 36.7	CV: 11.0	CV: 17.7	CV: 15.6
Boom-Mounted Nozzles Two Fungicide Application R2 + R3 Growth Stage, 11 days apart XR8006 flat-fan nozzles, 40 psi, medium droplet size	Non-Treated Control	32 c	56 ab	37 b	53 a
	Omega 16 fl. oz./ac	17 ab	64 ab	19 ab	61 a
	Topsin 20 fl. oz./ac	28 bc	54 b	26 ab	56 a
	Endura 8 fl. oz./ac	13 a	66 a	18 ab	62 a
	Proline 5 fl. oz./ac	32 c	53 b	14 a	65 a
		CV: 33.2	CV: 10.7	CV: 44.9	CV: 11.2
'Undercover 360' Drop Nozzles One Fungicide Application R2 Growth Stage XR11001 flat-fan nozzles (side ports) TX-VK3 hollow-cone nozzle (rear ports) 40 psi, fine, very fine droplet size	Non-Treated Control	26 b	59 ab	33 b	56 a
	Omega 16 fl. oz./ac	22 b	61 ab	18 ab	58 ab
	Topsin 20 fl. oz./ac	26 b	57 ab	11 a	66 ab
	Endura 8 fl. oz./ac	10 a	69 a	9 a	66 ab
	Proline 5 fl. oz./ac	23 b	56 b	10 a	69 a
		CV: 14.2	CV: 11.8	CV: 53.0	CV: 9.9
'Undercover 360' Drop Nozzles Two Fungicide Application R2 + R3 Growth Stage, 11 days apart XR11001 flat-fan nozzles (side ports) TX-VK3 hollow-cone nozzle (rear ports) 40 psi, fine, very fine droplet size	Non-Treated Control	33 b	55 b	37 b	52 b
	Omega 16 fl. oz./ac	11 a	71 a	13 a	63 a
	Topsin 20 fl. oz./ac	9 a	68 a	12 a	64 a
	Endura 8 fl. oz./ac	7 a	68 a	13 a	67 a
	Proline 5 fl. oz./ac	15 a	63 ab	6 a	64 a
		CV: 61.7	CV: 10.5	CV: 54.6	CV: 7.9

Fabrication and Utilization of Soybean Oleogel as a Shortening Replacer in Cookies

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

Funded Project
$29,510

Research Conducted

- We transformed the commercial liquid soybean oil into a semi-solid and self-stand product, named oleogel, which is similar to shortenings.
- We used a single food-grade gelling agent (beta-sitosterol and monoacylglycerol), or the combinations of the two to produce soybean-oil oleogels with different properties.
- We tested the oleogels' physical and flow properties.
- We compared the properties of cookies made with soybean oleogels and commercial shortenings.

Why the Research is Important to North Dakota Soybean Farmers

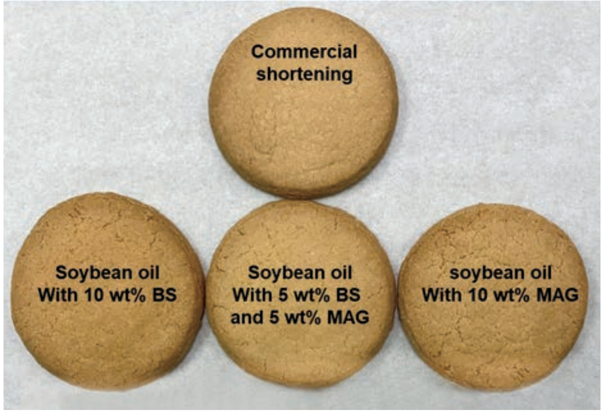
- Partially hydrogenated soybean oil cannot be used in the food industry.
- It is urgent to develop a novel technique so that soybean oil will not lose this traditional market.

Findings

- We successfully used the soybean oleogel to fully replace commercial shortenings and to prepare cookies.
- Our research results showed that soybean oil oleogels are able to replace commercial shortenings when making food products.
- The innovative soybean oil oleogels may become a novel, functional food ingredient that makes North Dakota soybeans more marketable and promotes additional value for the soybean crop.

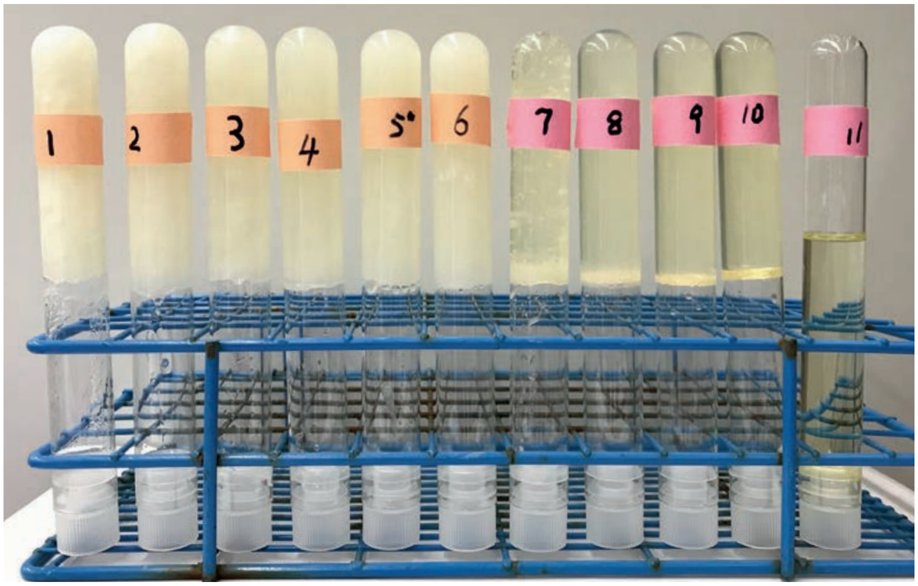
Benefits/Recommendations to North Dakota Soybean Farmers and the Industry

- The huge market potential to replace the saturated fats and partially hydrogenated soybean oils in foods by using solidified soybean oil oleogel will result in an increased demand and price stability for North Dakota soybeans farmers.
- It is highly recommended to promote this technology to the food industry and the baking industry by using soybean oil oleogels instead of tropical oil shortenings.

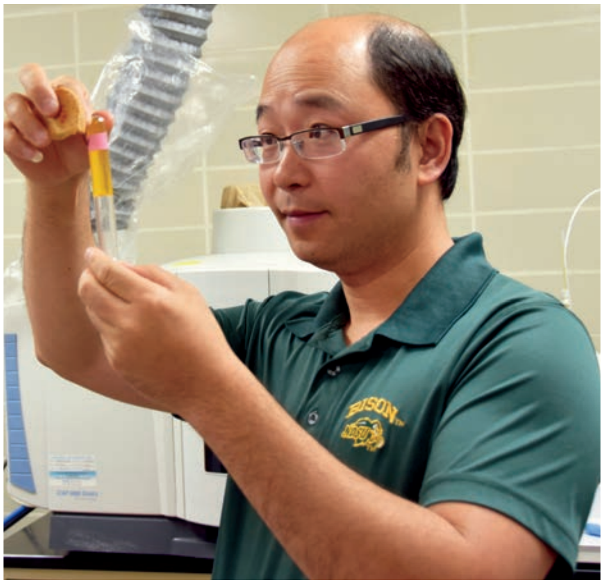


Appearance of cookies made with commercial shortenings and soybean oil oleogels with 10 percent beta-sitosterol (BG), 10 percent monoglycerides (MAG), or 5 percent BG+5 percent MAG

> "It's highly recommended to promote this technology to the food industry and the baking industry by using soybean oil oleogels instead of tropical oil shortenings."



Photograph of soybean oil oleogel samples prepared using monoglycerides (MAG) with either beta-sitosterol (BG) or gamma-oryzanol (GO) at a fixed concentration of 10 percent.



Dr. Bingcan Chen in his laboratory.

Screening Cover Crops for Managing Soybean Cyst Nematode and Other Nematodes in Infested Soils

Principal Investigator: *Dr. Guiping Yan, NDSU Department of Plant Pathology*
Co-Investigators: *Dr. Marisol Berti, NDSU Department of Plant Sciences; and Dr. Samuel Markell, NDSU Department of Plant Pathology*

Funded Project
$31,480

Research Conducted

Twenty-six entries including 22 cover crops and species, corn and wheat as rotational crops, and two susceptible soybean cultivars were evaluated for host range in a growth chamber by inoculating each plant with 2,000 eggs of two soybean cyst nematode (SCN) populations from two soybean fields in ND (Figure 1). Ten cover crops were further evaluated in microplot experiments. Crops were planted in pots each containing 5 kg of infested field soil (Figure 2). After 75 days of growth, soil samples were collected from each pot. SCN eggs and other plant-parasitic nematodes were extracted and counted for evaluation of each crop for population reduction.

Why the Research is Important to North Dakota Soybean Farmers

SCN is one of the major yield-reducing pests of soybean in ND. Host resistance and crop rotation are common practices to manage SCN, but limited sources of resistance to this nematode put pressure on virulence change in populations to overcome resistance. Thus, integrated management strategy is necessary for sustainable management of SCN. Cover crops may reduce plant-parasitic nematode populations and provide an alternative means to manage SCN.

Findings

Twenty-one entries (alfalfa, balansa clover, berseem clover, winter camelina, faba beans (Petite and CNS), flax, forage oat, forage pea, Japanese millet, brown mustard, white mustard, daikon radish, oilseed radishes (Image, Concorde, and Control), pennycress, sunn hemp, white proso millet, corn, and wheat did not support any SCN reproduction, suggesting non-hosts. Chickling vetch and crambe showed low reproduction as poor-hosts, while lupine showed some reproduction, suggesting a suitable host. SCN reproduced less in all tested crops compared to the two susceptible soybean cultivars. All the tested crops significantly reduced SCN populations compared with the susceptible soybean Barnes, but not with the non-planted control (fallow). White mustard, oilseed radish (Concorde, Control), and faba bean (Petite) were more effective than others in population reduction. None of the crops significantly reduced populations of other nematodes in infested soil.

Benefits/Recommendations to North Dakota Soybean Farmers and Industry

Nineteen cover crops and species are identified as non-hosts for SCN. These crops have the potential to be used as cover crops or rotational crops in infested fields to reduce SCN numbers. The experiments will be repeated in 2019 to confirm their population reduction levels. The research findings are useful to navigate the selection and use of cover crops for farmers to reduce SCN damage to increase soybean yield in infested fields.

Figure 1. Cover crops grown in cone-tainers each containing 100 cm³ of sterilized sandy soil inoculated with each SCN population and kept in a growth chamber at 27°C for host range evaluation.

Figure 2. Cover crops grown in large plastic pots with SCN-infested soil in the microplot under natural conditions for evaluating population reduction of SCN and other nematodes.

Modification of Insoluble Dietary Fiber in Soybean Residue Okara to Value-Added Soluble Dietary Fiber by Enzyme-assisted Microfluidization

Principal Investigator: *Dr. Jiajia Rao, NDSU Department of Plant Sciences*

Funded Project
$7,003

Research Conducted

The influence of physical pretreatments (milling, autoclave, ultrasound), enzyme type (Viscozyme, Celluclast and Shearzyme), reaction time (12, 24 and 36h), reaction pH (pH 4, 4.5, 5, 5.5 and 6) on the physical and functional properties of okara has been examined. All experiment conditions and parameters have been optimized to achieve desirable functionality of okara including water holding, oil holding and swelling capacity.

North Dakota food grade non-GMO soybeans.

Why the Research is Important to North Dakota Soybean Farmers

The impact of this research is hard to value monetarily to the ND soybean farmers, since there is no commercial production of okara soluble dietary fiber in market yet. But based on the current market price (US$ 400/ton) for soybean fiber directly extracted from soybeans, the economic impact would be huge for the soy product manufactures. Fresh okara consists of 10-12 g insoluble dietary fiber/100g okara and 80 g moisture/100 g okara. The success of proposed technique could potentially produce one million tons of soluble dietary fiber annually as functional food ingredients and an increased extra venue of $400/ton in 1 million tons could amount $400,000,000. The additional value of okara promoted by this technique will create new market for soybean product manufactures. This in return will increase the demand of ND soybeans and benefit ND soybean farmers to expand marketing and stabilize soybean price.

Findings

Our data strongly suggested that autoclave + enzyme treatment significantly improved the physical properties of okara insoluble dietary fiber. The results showed that autoclave (121°C for 20 min) plus enzyme (ration 1:1, pH 5.5 for 12 h) treated okara had more disintegrated and irregular surface structure. Enzyme + autoclave treatment showed greatest functionalities for the okara of all the three particle size due to majority of insoluble fiber converted to soluble fiber. In addition, compared to the control (non-treatment) group, autoclave treatment alone significantly increased the water holding capacity.

> "Based on the current market price for soybean fiber directly extracted from soybeans, the economic impact would be huge for the soy product manufacturers."

Benefits/Recommendations to North Dakota Soybean Farmers and Industry

Dietary fiber has been reported as a functional food component to reduce risk of heart disease, diabetes and obesity. However, insoluble fiber is the dominate fraction of raw okara dietary fiber which greatly impeded its utilization as food ingredient. Our study suggested that autoclave and enzyme treatment significantly converted insoluble fiber in okara to soluble fiber and improved its functionality as a food ingredient which could increase the value of soybean as well as the byproduct of okara.

Phosphorus Fertilizer Management Decisions for Soybean Based on Time of Planting

Principal Investigator: *Dr. Jasper Teboh, NDSU Carrington Research Extension Center*

Co-Investigators: *Szilvia Yuja, Dr. Dave Franzen, and Blaine Schatz, NDSU Carrington Research Extension Center*

Funded Project $15,820

Research Conducted

Three trials were conducted at Carrington Research Extension Center (CREC) and Oakes to evaluate the effect of phosphorus (P) fertilization of soybeans planted at three different dates, and to determine from these results if it was economical to fertilize soybeans with P. Description of the three planting dates used were early (May 14), normal (May 24), and late (June 5) at CREC, and early (May 11), normal (May 24), and late (June 8) at Oakes. These dates fall within the range of average early, normal, or late planting in North Dakota.

Why the Research is Important to North Dakota Soybean Farmers

Phosphorus fertilization adds to the cost of production of soybeans. What is sometimes not realized is that yield gains from P fertilization are dependent on low available soil P; and even when P is sometimes low, application of P does not result in yield any significant yield gains due to improved availability from mineralization. In addition, the notion that soybean yield response to P is very likely for early planted soybeans has needs further verification, since the crop may require P to minimize adverse stressed on the crop due to late planting, and there has not been any extensive research in North Dakota that verifies that yields are better from P addition for early planted beans than later planting.

Phosphorus did not improve yields at all three sites. Planting dates significantly affected yields at Carrington under dryland but not under irrigation.

Table 1. Yield and seed quality response to P rates and planting dates of soybeans under dryland and irrigated conditions in Carrington (CREC, 2018)

	Sites							
	CREC Dryland				CREC Irrigated			
P Rate (P) (lbs./ac)	**Yield** (Bu/ac)	**Protein** (%)	**Oil** (%)	**TWT** (lbs./ac)	**Yield** (lbs./ac)	**Protein** (%)	**Oil** (%)	**TWT** (lbs./ac)
0	39.6	36.58	18.74	56.8	52.6	34.74	18.89	56.63
20	39.4	36.49	18.83	56.8	53.5	34.76	18.90	56.59
40	41.0	36.28	18.82	56.9	53.8	34.78	18.87	56.32
Date	**Yield** (Bu/ac)	**Protein** (%)	**Oil** (%)	**TWT** (lbs./ac)	**Yield** (lbs./ac)	**Protein** (%)	**Oil** (%)	**TWT** (lbs./ac)
Early	46.3	35.43	57.2a	57.2a	55	34.67b	19.32a	56.26b
Normal	37.0b	36.54b	56.2b	56.2b	53.8	34.55b	19.02b	55.91c
Late	36.8b	37.53a	57.1a	51.1a	51.1	35.06a	18.33c	57.02a
Effects	**Analysis of Variance (P-values)**							
Rate	0.4693	0.0783	0.5875	0.5875	0.8227	0.9585	0.7815	0.1234
Date	.0002	0.0242	<0.0001	<0.0001	0.5028	0.0263	<0.0001	<0.0001
P x Date	0.7617	0.6555	0.5115	0.5115	0.8926	0.5826	0.2467	0.9381

TWT = Test Weight, KWT = Kernel wright

Means followed by similar letters are not statistically different at 90% confidence level

Findings

Phosphorus was applied and incorporated before planting. Phosphorus did not improve yields at all three sites. Planting dates significantly affected yields at Carrington under dryland but not under irrigation (Table 1). At Oakes, yields were also not impacted by planting dates (Table 2). It is probable that, adequate moisture and temperature, and long season of growth were important for the two irrigated trials, thereby minimizing the negative impact of late planting. Based on the soil test levels at CREC irrigated site (3 ppm), CREC dryland (10 ppm), and Oakes irrigated site (19 ppm), yield response was expected at the irrigated site, probable at the dryland site, and not expected at Oakes. If farmers are applying P with the aim of increasing soybean yields, response will likely be inconsistent.

Assessment of Potassium and Phosphorus Mining in Soybean Fields in North Dakota

Principal Investigators: *Dr. Jasper Teboh, Ezra Aberle, Szilvia Yuja, and Blaine Schatz, NDSU Carrington Research Extension Center; Eric Eriksmoen, NDSU North Central Research Extension Center; Dr. Gautam Pradhan and Jim Staricka, NDSU Williston Research Extension Center; ; and John Rickertsen, NDSU Hettinger Research Education Center*

Funded Project
$12,992

Research Conducted

This trial estimated the removal of potassium (K) from soil by soybeans following harvest at Hettinger, Minot, and Williston. At Carrington, (CREC) K and phosphorous (P) removed by soybeans estimated from a trial that either received 50 lbs K or did not, across plots that had received the same N treatments applied in over three years on conventional till (CT), and no-till (NT). Soil samples from the top six inches of each plot before planting, mid-season, and at harvest, were divided into two groups, one group refrigerated and the other air-dried. The samples were analyzed by wet analysis at AgSource Laboratories, Ellsworth (IA).

Why the Research is Important to ND soybean farmers

There are some concerns about K and P mining (removal without supplementation) in soybean fields, and as a result, yields of subsequent crops could be impacted if production continues without K fertilization. Also, reliability soil tests for K, and predictability of yield response when soil samples are stored by refrigeration or air-dried. This is important because only when a good soil available nutrient estimate is made from analysis that K fertilizer recommendations can be effective.

Findings

Application of 50 lbs K at CREC did not improve yields, protein or oil concentration. Aboveground biomass was significantly increased by K application under NT but not under CT. Test weight was significantly greater under NT. Yields were low due to drought conditions in 2018. At CREC yield average was 34 bu/ac, and a bushel removed 1.2 lbs K and 0.54 lbs P on average, which is relatively low compared to 0.65 lbs P/bu for a 69-bushel crop in a previous trial at CREC. Available soil K was greater at mid-season than before planting and after harvest (Figure 1), and was not necessarily less following harvest at the other sites. Soil analysis of refrigerated samples showed higher K values than air-dried samples. Available soil P after harvest was not less than before planting. More research is needed to assess the need for P fertilization of soybeans to improve yields. Potassium fertilization is likely to enhance yield for soils that the North Dakota state recommendations have clearly defined. Response depends strongly on type of clay.

Figure 1. Change in soil K before planting, at reproductive stage, and post harvest of soybeans

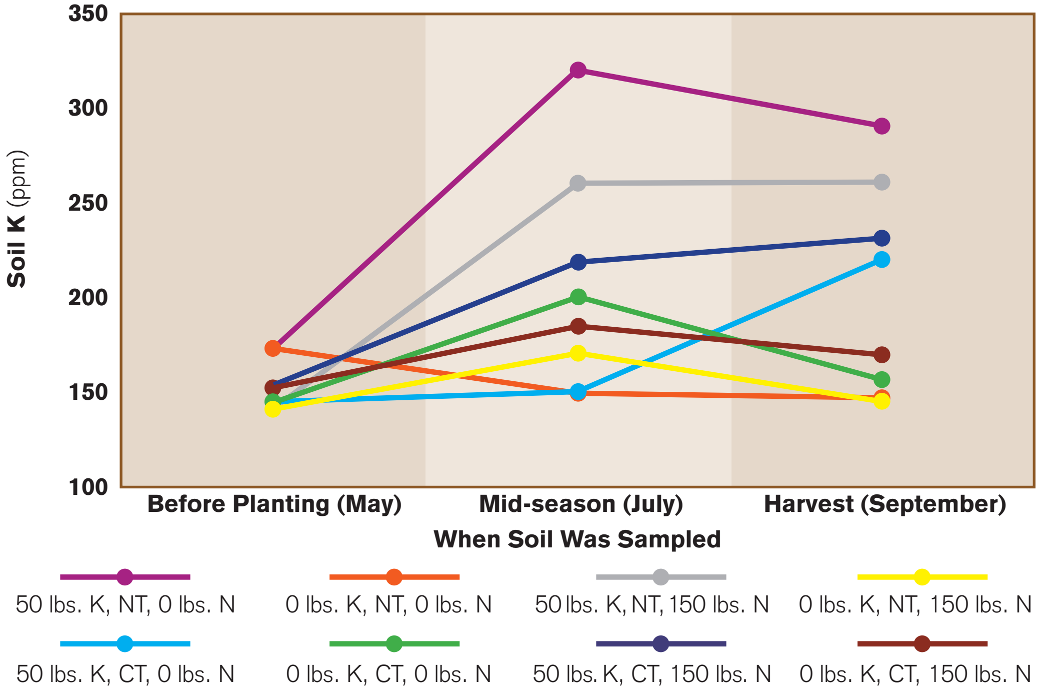
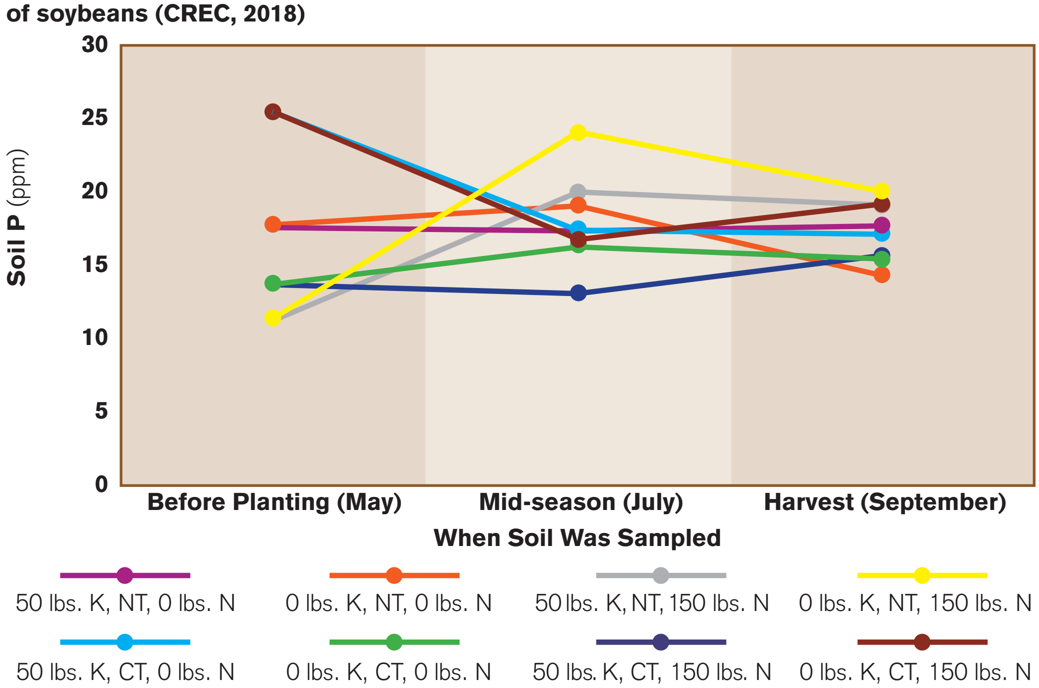


Figure 2. Change in soil P before planting, at reproductive stage, and post harvest of soybeans (CREC, 2018)



Evaluating Soybean Cultivars and Germplasm for Resistance to Soybean Cyst Nematode

Principal Investigator: *Dr. Guiping Yan, NDSU Department of Plant Pathology*
Co-Investigators: *Dr. Ted Helms, NDSU Department Plant Sciences, and Dr. Sam Markell, NDSU Department of Plant Pathology*

Funded Project
$51,270

Research Conducted

One hundred fifty-one soybean lines (germplasm of maturity group 00 to 1, commercial cultivars, and breeding lines) each in four replicates were screened for soybean cyst nematode (SCN) HG type 2.5.7, and one hundred sixty-two germplasm, commercial cultivars and breeding lines each in four replicates were screened for SCN HG type 0 isolated from soybean fields in North Dakota. Each plant was inoculated with 2,000 SCN eggs and grown in a growth chamber for 35 days (Figure 1). The female index was calculated for each soybean line by comparing the number of white females (cysts) formed with that on the susceptible soybean Barnes, then categorized for resistance reactions.

Why the Research is Important to North Dakota Soybean Farmers

SCN (Heterodera glycines) is a major yield-limiting factor of soybean. In 2015 and 2016, a more virulent form (HG type 2.5.7) that reproduced well on PI 88788 was detected in soybean fields in ND. The new forms have higher levels of virulence and are able to overcome the resistance that is used for control. The shift in SCN populations has led to a decrease in resistance in soybean cultivars derived from PI 88788 elsewhere. Hence, it is imperative to screen soybean cultivars and lines for identifying resistance against the new virulent type.

Findings

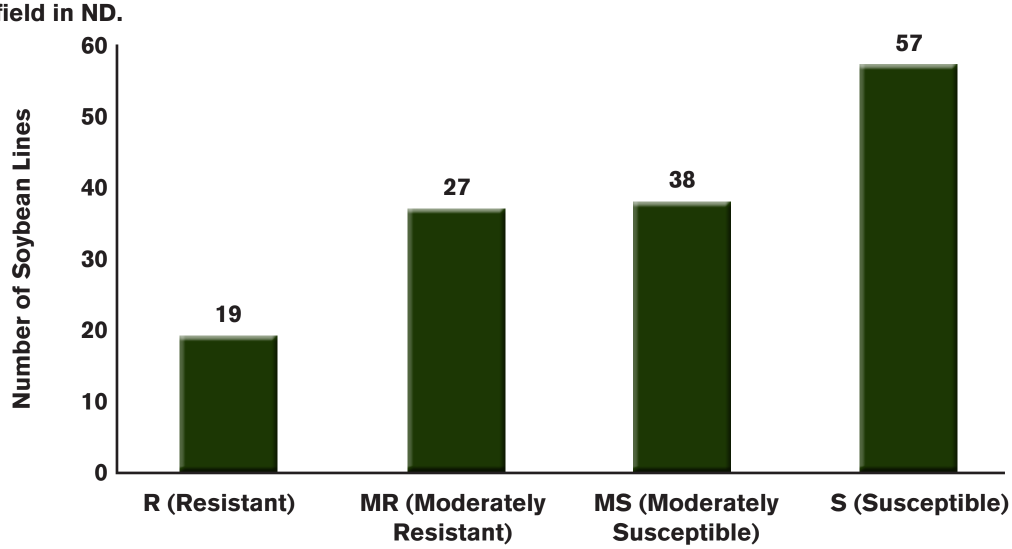
Out of 151 germplasm, commercial cultivars, and breeding lines tested for HG type 2.5.7, 19 lines were resistant, 27 were moderately resistant, 38 were moderately susceptible, and 57 were susceptible (Figure 2). For HG type 0, out of 162 lines, 24 were resistant, 61 were moderately resistant, 50 were moderately susceptible, and 27 were susceptible. Therefore, out of all the entries tested, 37% were resistant or moderately resistant to HG type 2.5.7, and 52% were resistant or moderately resistant to HG type 0. More importantly, seven of them showed resistance to both HG type 2.5.7 and 0, and two germplasm lines did not support any reproduction of HG type 2.5.7.

Benefits/Recommendations to North Dakota Soybean Farmers and Industry

A number of resistant germplasm and lines were identified in this research. The important soybean lines will be re-tested to confirm their resistance reaction. The research findings are useful to navigate the use of resistance sources for farmers and the resistance sources that should be introduced to the soybean breeding programs to develop new cultivars with resistance to the common and new SCN virulent populations.

Figure 1. A consistent temperature of 27 °C was maintained in the growth chamber, ensuring soybean cyst nematode resistance tests were performed under the optimum condition.

Figure 2. Classification of resistance responses of soybeans (germplasm, breeding lines, and cultivars) to soybean cyst nematode HG type 2.5.7 detected in a soybean field in ND.



North Dakota
Soybean Council
Our World Is Growing.

4852 Rocking Horse Circle South, Fargo, ND 58104 | ndsoybean.org