Soybean Research: Building a Strong Industry.
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Dear Valued Soybean Producers:

Every year, the North Dakota Soybean Council (NDSC) invests your checkoff dollars in soybean research to find solutions to the challenges that soybean farmers face regularly. Research is one of the most important efforts NDSC supports. The results of that research are paying dividends. Sooybeans, which were initially just grown in the Red River Valley, are now grown across the state of North Dakota, including areas where soy production was thought to be impossible. From 1980-2014, North Dakota has seen a 579% increase with the production of soybeans. In 2015, the planted area for soybeans is estimated at 5.80 million acres for North Dakota, which ranks number four in the nation for planted acres.

NDSC oversees a soybean research program based on farmer priorities to ensure that the research remains focused on the challenges you face today. Our Research Committee’s mission is to strategically invest research dollars to secure a more profitable future for North Dakota soy producers. Farmers and researchers who are familiar with pertinent soybean issues serve on NDSC’s Research Committee. This committee identifies farmer priorities, sets NDSC’s research objectives and solicits studies to meet these priorities.

By supporting public research, NDSC is doing its part to maintain and increase producer profitability. Each year, NDSC funds research that contributes to a steady increase in soybean yields, greater variety availability, improved pest management options and much more. New and continuing research for the fiscal year (FY) beginning July 1, 2014, and ending June 30, 2015, totaled $1,887,280. Along with 12 other upper Midwest states, NDSC’s checkoff leverages about $200,000 in soybean research through the North Central Soybean Research Program. In FY 2015, research funding represented approximately 34 percent of NDSC’s budget.

If not for support from you and your checkoff funds, it is unlikely that North Dakota would have grown to become one of the nation’s top soybean-producing states. This publication contains current research information that you can utilize on your farms. We welcome your input about the production challenges you are experiencing that could be addressed through research.

Sincerely,

Rick Albrecht
Kendall Nichols
NDSC Research Committee Chair
NDSC Director of Research Programs
knichols@ndsoybean.org

North Dakota Soybean Council Research Committee
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Derik Pulvermacher, Crosby
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David Teigen, Rugby
Brett Bowman, Adrian
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Craig Olson, Colfax – ND Soybean Growers Association President
Dr. Emmett Lampert, Wimbledon
Dr. Seth Naeve, Research Consultant
University of Minnesota, St. Paul, Minnesota
Staff – Kendall Nichols, Director of Research

The Research Committee of the North Dakota Soybean Council (NDSC) gained a better understanding of NDSU’s soybean-breeding program by visiting glyphosate-resistant soybean plots located near Rancagua, Chile in early January 2015.

Back row (from left to right): Tyler Speich, Milnor; Rick Albrecht, NDSC Research Committee Chairman, Wimbledon; and Joe Ericson, Wimbledon. Bottom row (from left to right): Brent Kohls, Mayville; Kendall Nichols, NDSC director of research; and Charles Linderman, Carrington.
Soybean Productivity with Iron Chelate on Raised Seedbeds

**Principal Investigator: Dr. Hans Kandel, Plant Sciences, NDSU**

During the 1990s through the early part of the 2013 and 2014 seasons, excess water significantly impacted crop production in North Dakota. We investigated if iron chelate applied to the seed and available to the developing plant may reduce IDC severity. When soybean plants develop the first or second trifoliolate leaves, iron-deficiency chlorosis (IDC) may appear in some production fields. Chlorosis is caused by the plant not being able to take up enough iron (Fe), even if there is sufficient Fe in the soil. We investigated if iron chelate that was applied close to the developing plant may reduce IDC severity.

The objective of this research was to determine if there is a yield advantage for using three production practices: controlled tile drainage, raised beds and iron chelate (FeEDDHA) seed application. The research was conducted near Fargo and Casselton in 2013 and 2014. Water-level control structures were used to control the water table at the Fargo site. Raised beds, 12 inches tall and 30 inches apart, were made in the fall; the control was planting soybeans without a raised bed (flat). Two iron-chelate (ortho-ortho-FeEDDHA) seed-application rates (0 lbs A, the control, and 3 lbs A) were used on five varieties. Soybean stand counts, IDC and plant-vigor scores, and SPAD meter (measures chlorophyll content or greenness) readings were taken.

**Results**

Across two years, no significant differences for yield and height were found between the open tile and closed tile. However, the plots planted on open-tile areas had less IDC and were more vigorous. Soybeans on flat ground with tile yielded 36.8 bushels per acre, which was significantly more than the yield of 34.0 bushels per acre for soybeans grown on flat land without tile.

Across all six environments, soybeans grown on raised beds had significantly higher stand counts, vigor scores and height, resulting in a 6.4 percent yield advantage. The main visual difference was observed early in the season when the flat land had saturated conditions, whereas the raised beds kept the root system out of the saturated zone.

Across all six environments, applying the Fe-chelate resulted in 10 percent fewer plants compared with the no-iron seed-treatment application. This result was not expected but it confirmed that soybean seed is sensitive to various fertilizer products.

There was less chlorosis with the Fe-chelate applied to the seed. However, the difference was not meaningful, and no yield difference was observed compared with the no-iron seed treatment. Protein and oil content, test weight and the July plant greenness were not significantly different between the iron and no-iron treatments.

**Summary**

- On average (2013-2014), tile drainage without raised beds resulted in an 8 percent yield increase.
- Raised beds had more vigorous and taller plants, resulting in the 6.4 percent yield advantage.
- Fe-chelate applied as a seed treatment decreased the plant stand and marginally decreased IDC, but, across all environments, did not result in a yield advantage.
- In this experiment, taller soybean plants tended to have higher yields.

---

**Table 1. Soybean response to tile drainage, raised beds, and Fe-chelate seed treatment at Fargo and Casselton, 2013 and 2014.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Stand</th>
<th>IDC</th>
<th>Vigor</th>
<th>Height</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plants per acre</td>
<td>1 to 5</td>
<td>1 to 9</td>
<td>inch</td>
<td>Bu/a</td>
</tr>
<tr>
<td>No tile (closed)³</td>
<td>121 950a⁴</td>
<td>2.6a</td>
<td>4.6b</td>
<td>21.1a</td>
<td>36.4a</td>
</tr>
<tr>
<td>Tile (open)</td>
<td>117 376b</td>
<td>2.3b</td>
<td>5.2a</td>
<td>21.2a</td>
<td>36.8a</td>
</tr>
<tr>
<td>Flat⁵</td>
<td>105 655a⁴</td>
<td>2.34a</td>
<td>4.4b</td>
<td>22.0b</td>
<td>40.4b</td>
</tr>
<tr>
<td>Raised beds</td>
<td>134 032b</td>
<td>2.30a</td>
<td>5.9a</td>
<td>22.8a</td>
<td>43.0a</td>
</tr>
<tr>
<td>No Iron²</td>
<td>125 804a⁴</td>
<td>2.45a</td>
<td>5.2a</td>
<td>22.4a</td>
<td>41.4a</td>
</tr>
<tr>
<td>Iron</td>
<td>113 883b</td>
<td>2.20b</td>
<td>5.1a</td>
<td>22.4a</td>
<td>42.0a</td>
</tr>
</tbody>
</table>

¹ IDC scores are based on a scale of 1-5 (1 = no IDC; 5 = severe IDC).
² Vigor scores are based on a scale of 1-9 (1 = very poor; 9 = excellent).
³ Numbers followed by the same letter within each column, for each treatment pair, are non-significantly different (P<0.05).
⁴ Averaged across flat and raised beds for NW22 2013 and 2014.
Impact of the Previous Crop on Soybean and Canola Yield

Principal Investigator: Brian Jenks, NDSU North Central Research Extension Center; Co-Principal Investigators: Dr. Nancy Ehlke, Department of Agronomy and Plant Genetics, University of Minnesota; Dr. Mike Ostlie, NDSU Carrington Research Extension Center; Dr. Jasper Teboh, NDSU Carrington Research Extension Center; Bryan Hanson, NDSU Langdon Research Extension Center; Eric Eriksmoen, NDSU North Central Research Extension Center

Research Objectives:
1. To determine if soybean yield is greater following canola than following wheat.
2. To determine if canola yield is greater following soybean than following wheat.

These objectives will be accomplished by using a 3-year crop sequence to evaluate soybean and canola production when the crops are grown back-to-back. Canola, soybean and wheat crops were grown in 2014 as shown in Table 1. Soybean and canola were planted in 2015 to evaluate the previous crop’s impact. Thus, the important data from this study will come in 2015. All four locations were able to establish the study and are on track. This study will be repeated by planting wheat in 2014, followed by soybean or canola in 2015 (Table 2). This study was also established at all four locations in 2014.

Some research and farmer experiences indicate that soybeans grow just as well on canola ground as on wheat ground. This study is designed to test that theory in the northern plains where soybean and canola are commonly grown. If the hypothesis is true, then the main benefit would be potentially higher soybean yields following a profitable canola crop. Our research has gone as planned in 2014 and in 2015 with no unusual challenges.

Table 1. Planned crop sequence to evaluate effect of previous crop on soybean and canola yield

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheat</td>
<td>Wheat</td>
<td>Soybean</td>
</tr>
<tr>
<td>2</td>
<td>Wheat</td>
<td>Canola</td>
<td>Soybean</td>
</tr>
<tr>
<td>3</td>
<td>Wheat</td>
<td>Wheat</td>
<td>Canola</td>
</tr>
<tr>
<td>4</td>
<td>Wheat</td>
<td>Soybean</td>
<td>Canola</td>
</tr>
</tbody>
</table>

Table 2. Repeat of planned crop sequence in Table 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wheat</td>
<td>Wheat</td>
<td>Soybean</td>
</tr>
<tr>
<td>2</td>
<td>Wheat</td>
<td>Canola</td>
<td>Soybean</td>
</tr>
<tr>
<td>3</td>
<td>Wheat</td>
<td>Wheat</td>
<td>Canola</td>
</tr>
<tr>
<td>4</td>
<td>Wheat</td>
<td>Soybean</td>
<td>Canola</td>
</tr>
</tbody>
</table>

Visual Ratings for Iron-Deficiency Chlorosis

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

Iron is less available to the soybean plant on high-pH soils. The symptoms of iron-deficiency chlorosis (IDC) include leaves that are yellow in June and sometimes through July. Soybean growers with a field that has a past history of IDC need information to aid them with side-by-side comparisons of different companies’ varieties. There are genetic differences for IDC tolerance among cultivars. Even a small amount of yellowing in the soybean leaves can reduce the final yield by 20 percent. We measure the IDC tolerance by the amount of yellowing in the leaves. For fields with IDC, visual yellowing has been shown to be closely correlated with yield. These data provide unbiased information that enables growers to choose the best variety for their IDC-prone fields.

The objective was to screen 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 yield trials for visual ratings of IDC at multiple field locations that have a past history of IDC symptoms.

A second objective was to provide visual IDC screening for approximately 100 advanced NDSU breeding lines. Comparing soybeans from different companies required that all varieties be evaluated with side-by-side assessments in the same field. Otherwise, a fair comparison was not possible.

In 2014, four locations in farmer-cooperator fields with a past history of IDC symptoms were identified and later planted with hill-plots. There were 280 Roundup Ready company varieties tested as well as 60 Liberty Link and non-GMO company varieties tested. Also, the NDSU soybean breeder evaluated 100 advanced NDSU breeding lines for visual IDC symptoms. Those locations included Leonard, Prosper, Hunter and Galesburg. A total of 7,040 hill-plots were rated for IDC. The data were analyzed and reported in the NDSU bulletin titled North Dakota Soybean Performance and were posted online.

This data set is the largest one with the most comparisons for many different company varieties, including Roundup Ready, Liberty Link and non-GMO, for North Dakota and western Minnesota. Because the 2014 data are averaged across three locations that each had four replications, the data are quite reliable when helping a grower to select the best varieties for his/her IDC-prone fields. These data enable growers to increase the yield for the IDC-prone fields because varieties with the least amount of yellow IDC symptoms yield the best for fields with that problem.
Determining the optimum soybean seeding date requires growers to consider the variety maturity ratings that are appropriate for their production region and the calendar date when planting occurs. Recently, planting dates in North Dakota have been delayed due to excessively wet spring conditions towards the end or beyond the seeding window for optimum crop performance. Yield reductions for the late seeding of full-season, frost-sensitive crops, such as soybeans, are related to shortening the growing season, often due to frost damage before maturity.

Selecting the proper maturity for a soybean variety to seed at later dates improves crop-yield performance, quality and profit.

A soybean field experiment was conducted in Carrington (northern), Prosper (central), and Lisbon (southern), ND, during the 2014 growing season to determine the variety-maturity and seeding-date effects on crop performance. The experimental factors were variety, maturity (00.9, 0.7 and 1.4) and seeding date with three and six levels, respectively. Seeding dates at each location began in mid/late May, extended into early July and were spaced approximately 10 days apart (Table 1). The soybean traits that were determined include flowering, plant height and lodging, maturity, seed weight, seed yield and seed-oil content.

At the northern, Carrington location, results indicated no yield benefit from growing the 1.4 maturity P91Y41 variety and high yield reductions with this variety when planted on June 23 and later dates (Table 2). High yield reductions for the early and mid-maturity varieties, AG00932 and P90Y70, respectively, occurred after the June 23 date. The highest yield was for the 0.7 maturity variety that was seeded on May 23 at 44.7 bu/ac. Good yields (30 to 50 bu/ac) for the 00.9 and 0.7 maturity varieties were achieved at the first four seeding dates: May 23, June 4, June 13 and June 23.

At the central, Prosper location, there was a 6.5 bu/ac yield benefit for the 1.4 maturity variety (70 bu/ac yield) compared to the 00.9 maturity variety when sown on May 28 (Table 3). Growers could expect very good yield performance (> 50 bu/ac) for the 00.9, 0.7 and 1.4 maturity varieties with the May 28, June 4 and June 13 seeding dates as well as good performance (30 to 50 bu/ac) for the 00.9 and 0.7 maturity varieties when seeded on June 23. Growers should note that seeding the 1.4 maturity variety later than June 13 (Date 3) and the 00.9 and 0.7 varieties later than June 23 resulted in severe yield reductions.

At the southern, Lisbon location, there was a yield benefit for the 1.4 maturity variety (51.4 bu/ ac) compared to the 00.9 and 0.7 maturity varieties with the May 22 and June 3 seeding dates along with similar variety yields for the June 10 seeding, but not at the later seeding dates where the earlier-maturing varieties yielded greater (Table 4). The yield decline for the 1.4 maturity variety was not as pronounced with the southern June 23 seeding as for the northern (Carrington) and central (Prosper) locations. The 00.9 and 0.7 maturity varieties produced 31 bu/ ac yields with a July 2 seeding date and 26 bu/ac yields when seeding on July 9 at Lisbon. At the Carrington and Prosper locations, seeding on D5 (July 2/July 3) and D6 (July 9/July 10) was not recommended for these varieties.

Table 1. Soybean seeding dates at Carrington, Lisbon and Prosper locations during the 2014 growing season

<table>
<thead>
<tr>
<th>Seeding date</th>
<th>Carrington</th>
<th>Lisbon</th>
<th>Prosper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date 1 (D1)</td>
<td>May 23</td>
<td>May 22</td>
<td>May 28</td>
</tr>
<tr>
<td>Date 2 (D2)</td>
<td>June 4</td>
<td>June 3</td>
<td>June 4</td>
</tr>
<tr>
<td>Date 3 (D3)</td>
<td>June 13</td>
<td>June 10</td>
<td>June 13</td>
</tr>
<tr>
<td>Date 4 (D4)</td>
<td>June 23</td>
<td>June 23</td>
<td>June 23</td>
</tr>
<tr>
<td>Date 5 (D5)</td>
<td>July 3</td>
<td>July 9</td>
<td>July 9</td>
</tr>
</tbody>
</table>

**Table 2. Mean seed yield (bu/ac) for three soybean varieties at six seeding dates at Carrington, ND in 2014**

<table>
<thead>
<tr>
<th>Seeding date</th>
<th>AG00932 (0.9 mr*)</th>
<th>P90Y70 (0.7 mr)</th>
<th>P91Y41 (1.4 mr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 May 23</td>
<td>36.2</td>
<td>44.7</td>
<td>41.6</td>
</tr>
<tr>
<td>D2 June 4</td>
<td>37.5</td>
<td>36.3</td>
<td>35.6</td>
</tr>
<tr>
<td>D3 June 13</td>
<td>35.8</td>
<td>32.1</td>
<td>30.4</td>
</tr>
<tr>
<td>D4 June 23</td>
<td>30.0</td>
<td>30.0</td>
<td>17.0</td>
</tr>
<tr>
<td>D5 July 3</td>
<td>10.8</td>
<td>10.0</td>
<td>1.2</td>
</tr>
<tr>
<td>D6 July 10</td>
<td>9.5</td>
<td>5.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

LSD (0.05) = 3.6  * = maturity rating

**Table 3. Mean seed yield (bu/ac) for three soybean varieties at six seeding dates at Prosper, ND in 2014**

<table>
<thead>
<tr>
<th>Seeding date</th>
<th>AG00932 (0.9 mr*)</th>
<th>P90Y70 (0.7 mr)</th>
<th>P91Y41 (1.4 mr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 28</td>
<td>63.8</td>
<td>67.0</td>
<td>70.3</td>
</tr>
<tr>
<td>June 4</td>
<td>58.3</td>
<td>62.2</td>
<td>54.2</td>
</tr>
<tr>
<td>June 13</td>
<td>50.9</td>
<td>53.7</td>
<td>52.6</td>
</tr>
<tr>
<td>June 23</td>
<td>39.6</td>
<td>45.3</td>
<td>26.4</td>
</tr>
<tr>
<td>July 2</td>
<td>21.1</td>
<td>25.7</td>
<td>7.4</td>
</tr>
<tr>
<td>July 9</td>
<td>12.3</td>
<td>12.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

LSD (0.05) = 6.3  * = maturity rating

**Table 4. Mean seed yield (bu/ac) for three soybean varieties at six seeding dates at Lisbon, ND in 2014**

<table>
<thead>
<tr>
<th>Seeding date</th>
<th>AG00932 (0.9 mr*)</th>
<th>P90Y70 (0.7 mr)</th>
<th>P91Y41 (1.4 mr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1 May 22</td>
<td>41.3</td>
<td>44.2</td>
<td>51.4</td>
</tr>
<tr>
<td>D2 June 3</td>
<td>40.7</td>
<td>42.4</td>
<td>47.8</td>
</tr>
<tr>
<td>D3 June 10</td>
<td>42.4</td>
<td>48.3</td>
<td>46.0</td>
</tr>
<tr>
<td>D4 June 23</td>
<td>39.7</td>
<td>42.9</td>
<td>35.5</td>
</tr>
<tr>
<td>D5 July 2</td>
<td>31.3</td>
<td>31.8</td>
<td>22.0</td>
</tr>
<tr>
<td>D6 July 9</td>
<td>25.5</td>
<td>27.4</td>
<td>8.8</td>
</tr>
</tbody>
</table>

LSD (0.05) = 4.3  * = maturity rating
Field Demonstration of Different Insecticide Strategies for Managing Soybean Aphids

Principal Investigators: Dr. Janet Knodel, Extension Entomologist, NDSU; Patrick Beauzay, NDSU

Soybean aphid, which is native to Asia, was first detected in North Dakota in 2001, and today, poses a serious threat to soybean production. Soybean producers and other agriculture professionals need to scout fields for seasonal aphid populations and need to apply foliar insecticides when economic populations warrant treatment to prevent yield losses.

The goal of this research was to determine which management strategy provided the best control of soybean aphids: an insecticide applied as a foliar insecticide, an insecticide applied as a seed treatment or a Rag1 aphid-resistant soybean. In addition, three different foliar-applied insecticides and spray timings were tested to determine the optimal insecticide and timing. The tested insecticides were Warrior II (pyrethroid), Lorsban 4E (organophosphate) and Leverage 360 (pyrethroid + neonicotinoid). Application timings included the established economic threshold (E.T.) of 250 aphids per plant, only 100 aphids per plant and application at the R1 (beginning bloom) growth stage regardless of aphid populations. Sixteen treatments were tested at three different field sites (Casselton, Harwood and Emerado) in 2014.

All foliar-applied insecticides prevented soybean aphids from exceeding the E.T. levels, regardless of spray timing, and consequently, there were no yield differences among the foliar treatments. The exception was Lorsban 4E that was applied early at R1 at the Emerado site, where aphids rebounded and resulted in a significant yield loss. The use of Cruiser Maxx soybean-insecticide seed treatment alone did not prevent aphids from exceeding the economic threshold at Harwood and Emerado. There were no advantages for aphid control or increased yield when using the insecticide seed treatment + Warrior II at the ET compared to just spraying Warrior II at the ET for all three locations. The Rag1 variety had very low aphid numbers at all three locations, regardless of whether an insecticide seed treatment was used. There were no yield differences among the Rag1 treatments at Casselton and Harwood. The Rag1 variety did not reach maturity at Emerado.

The results from this year’s study lead us to the following conclusions:

- Application timing is more important than insecticide product to control soybean aphids.
- Growers should wait until the E.T. is reached before applying a foliar insecticide because there is no significant yield gain from spraying before the E.T. is reached.
- Residual foliar insecticide activity may not last through the entire aphid season, so growers may have to re-spray at an additional cost.
- Soybean aphid numbers may not increase to the E.T. level due to climatic conditions and/or beneficial insects keeping aphids in check naturally. (Growers might not have to spray at all.) There is no demonstrated yield advantage for spraying early.
- The use of an insecticide seed treatment is not recommended because it will not keep soybean aphids from reaching the E.T. (Growers will still have to spray if the E.T. is reached.) There is no demonstrated yield advantage for using an insecticide seed treatment versus no insecticide seed treatment when aphids are sprayed at the E.T.
- Rag1 aphid-resistant soybeans provide excellent control of soybean aphids; however, the current Rag1 aphid-resistant soybean varieties do not always reach maturity in northern North Dakota.
Installing subsurface tile drainage for poorly drained, high-clay soils is a common practice to remove excess water. With high-clay soils, tile drainage also provides an opportunity for farmers to follow conservation-tillage practices to avoid soil compaction. The tile’s drain spacing and installation depth need to be optimized in order to maximize the yield benefit and to reduce the loss of nutrients through the tile.

This long-term, on-farm project has been evaluating the feasibility of adopting no-tillage and strip-tillage practices for a tile-drained condition and optimizing the tile depth and spacing with Fargo clay soils. This project is located at Ron Holiday’s farm in Mapleton, ND. The tile was installed in June 2013. Under tile drainage, soybean production and soil properties were evaluated to compare (1) conservation-tillage practices (no- and strip-till) with a chisel plough and (2) different tile depths, 3-ft and 4-ft, with spacings of 30-ft, 40-ft and 50-ft.

During the 2014 growing season, the average soybean yield for the tile-drained plots with and without a control structure was 29.4 Bushels/ac, whereas a check plot that only used surface drainage had an average yield of 32.3 Bushels/ac (Figure 1a). After harvest, residual soil nitrate-nitrogen was 43 lb N/ac for tiled soil and 54.4 lb N/ac for a surface-drained (check) plot. The higher yield for the check plots might lead to higher biological nitrogen fixation and higher residual nitrogen. Annual yield variability might be expected for drain tile. Yield among tillage practices was not compared because tillage was applied after the 2014 growing season.

Contrasting different tile-depth and spacing combinations revealed that 30-ft wide and 4-ft deep tile spacing had the highest yield of 30.5 Bushels/ac, whereas the lowest yield, 23.2 Bushels/ac, was only found with surface-drained (check) plots. Tile spacing that was 40-ft wide and 3-ft deep had a yield of 27.8 Bushels/ac, but the 40-ft wide and 4-ft deep tile had a yield of 24.1 Bushels/ac (Figure 1b). These results illustrated that the decision about tile depth and spacing is critical for soybean production. This long-term project will be continued for the 2015 growing season.
Virulent Types of Soybean Cyst Nematode in North Dakota

Principal Investigator: Dr. Berlin Nelson, Plant Pathology, NDSU

Most North Dakota soybean growers are now familiar with soybean cyst nematode (SCN; caused by Heterodera glycines), the most important soybean disease in the United States. Since the discovery of SCN in North Dakota in 2003, the nematode has spread over a considerable portion of eastern North Dakota and is now reported in about 19 counties from the border with South Dakota to the Canadian border. Because SCN is a soil-borne pathogen, it is readily transported from field to field on any type of equipment that carries soil. This pathogen can cause substantial yield losses if the nematode population is high and if the environmental conditions are favorable for the nematode's reproduction on the soybean's roots.

The primary management of this pathogen is using resistant soybean cultivars and using crop rotation to keep nematode numbers low in the soil. It is almost impossible to eliminate nematodes from a field once it is infested. SCN must be managed.

There are good sources of resistance to SCN; however, most U.S. soybean cultivars use one primary source of resistance from a Plant Introduction called PI88788. The experience of growers in other states that have a long history of soybean production where resistant cultivars have been the primary control method. There are other options that a grower can use but they are not as common with commercial cultivars as the PI88788 source is.

The objective of this two-year project was to determine if new virulent types (called HG types) of SCN were beginning to appear in North Dakota's infested fields. During the last examination of SCN for virulence about eight years ago, we only found HG 0, the least-virulent SCN type (previously known as race 3). HG 0 will not attack the common resistance source, PI88788. Because growers have been using resistant cultivars for a number of years, the selection pressure on the pathogen has increased, and new virulent types could be appearing in fields. During 2013 and 2014, we collected soil from 61 soybean fields and extracted the nematode. In the greenhouse, we have a system where we infect plants with the nematode and determine which HG type is common in the field (Figure 1).

Once all the testing is completed, a report will be provided to advise growers of any changes in the SCN population about which they need to be aware.

Figure 1. Testing for SCN HG types in the greenhouse under controlled conditions. The plants are growing in containers that are filled with sand infested with the nematode. The temperature is maintained at 27 C by placing the containers in plastic pots that are immersed in a water bath that is maintained at that temperature. Plants are evaluated after 30 days of growth.
Impact of Selected Establishment Factors on Soybean Production

Principal Investigator: Greg Endres, NDSU Carrington Research Extension Center; Cooperating Scientists: Dr. Mike Ostlie, Carrington Research Extension Center, and Dr. Hans Kandel, Plant Sciences, NDSU

During some years, such as 2012, farmers plant soybeans earlier than recommended. In 2013 and 2014, soybeans were typically planted during the last half of May through the first half of June. Are there consistently improved yields with early planting, and what are the yield losses with June planting dates when compared to planting soybeans in mid-May? If planting early or late, what maturity-group variety should be grown? Also, NDSU recommends broadcast phosphorus (P) as the best choice for yield response, but this advice is based on midwest research that currently has limited North Dakota data.

This study included two trials that examined the planting date as the main factor in combination with two other factors that may, economically, increase soybean seed yield and quality:

1. Early versus late-maturing cultivars.
2. Soil placement options of starter P contained in a complete fertilizer blend

**Trial 1: Planting date by maturity group by starter fertilizer placement**

The trial was conducted at the CREC in 2014. Soybeans planted on May 5 yielded 47.2 bu/acre compared to 44.5 bu/acre with a May 23 planting date. Averaged across 5 site-years (2011-14), early planted soybeans (April 24 to May 5) had a 4.9 bu/acre (12%) advantage compared to the normal planting period (May 15-23). Also, in 2014, the 0.8 maturity-group variety had a yield advantage of 5.1 bu/acre, compared to the 0.2 maturity-group variety, when averaged across planting dates. While risks exist for planting soybeans early, an increased yield potential exists without additional expenses.

Broadcast and pre-plant incorporated P fertilizer (liquid 6-24-6) applied, at the NDSU recommended rate based on soil analysis and the yield goal, to a loam soil that tested low for P was compared to P application in a 0x2-inch band while planting. The broadcast application tended to increase the seed yield compared to the banded application. Six site-years of NDSU research (CREC, 2005-14) indicated a 1 percent yield increase with broadcast versus banded P. The modest yield increase for broadcast versus banded P fertilizer will have to be considered by farmers as they review the plant’s nutrition strategies for soybean production.

**Trial 2: Planting date x maturity group**

The three locations for examining the two factors were the CREC off-station research sites at Dazey and Wishek as well as an NDSU Red River Valley location (Prosper). Maturity groups for all three sites included 0.2 and 0.8 using the same cultivars. The planting dates were 1) Wishek (McIntosh County): May 13 and 22, 2) Dazey (Barnes County): May 16 and 28, and 3) Prosper (Cass County): May 29 and June 9. The yield averaged across sites was similar among planting dates. Also, at each location, the yield was generally similar for the interaction of the planting dates and maturity groups.

2014 CREC trial with plants at physiological maturity.

Differences in maturity groups for the early planted plots in the 2014 CREC trial.
Optimizing the Use of Row Spacing, Partial Host Resistance and Fungicides to Manage Sclerotinia in Soybeans

Principal Investigator: Dr. Michael Wunsch, NDSU Carrington Research Extension Center; Cooperators: Leonard Besemann, NDSU Carrington Research Extension Center; Tyler Tjelde, NDSU Williston Research Extension Center; Pravin Gautam; Amada Arens, NDSU Langdon Research Extension Center

Sclerotinia stem rot (white mold) is a recurrent disease of irrigated soybeans and an important disease for dryland soybeans in North Dakota, causing losses in seed yield and quality when conditions are cool and moist during bloom and pod-fill. The objectives of this study were to optimize the use of row spacing, fungicides and partially resistant varieties to improve Sclerotinia management in soybeans.

The optimal fungicide-application timing was tested with Endura (boscalid; BASF Corp.) applied at 8 oz/ac. For seven field experiments conducted across North Dakota in 2014, Sclerotinia disease control and soybean yields were optimized when Endura was applied at the early R2 growth stage in soybeans planted in rows that were 7 to 15 inches apart and at the full R2 stage for soybeans planted in rows that were 22 to 30 inches apart. The early R2 growth stage was defined as 80 to 90 percent of plants with a blossom at one of the top two nodes; the full R2 growth stage was defined as 100 percent of plants with a blossom at one of the two nodes. Two to three days generally separated the early and full R2 growth stage. For soybeans seeded in wide rows, applying fungicides at the full R2 stage was optimal even when the canopy did not close until later. Results may be different if the soybean canopy closes earlier or if a different fungicide is utilized, and additional testing is being done in 2015.

Irrigated field trials were established in Carrington, Hofflund (30 miles east of Williston) and Oakes to evaluate the use of partially resistant varieties and row spacing as tools to manage Sclerotinia. In Carrington, 14 soybean varieties were evaluated in rows that were 7, 14, 21 and 28 inches apart in 2013 and 2014. In Oakes, six varieties were evaluated in rows that were 14 and 28 inches apart in 2014; in Hofflund, six varieties were evaluated in rows that were 15 and 30 inches apart.

Wide-row spacing (28 to 30 inches) consistently minimized Sclerotinia disease development but did not always optimize soybean yields. Surprisingly, under heavy disease pressure, soybeans planted in 7-inch rows developed less white mold and produced higher yields than soybeans planted in 14-inch or 21-inch rows. Additional research is underway to confirm these findings.

Partially resistant varieties were a very effective management tool for Sclerotinia. For five field experiments conducted across North Dakota in 2013 and 2014, the yields for partially resistant varieties were, on average, 15 to 20 bu/ac higher than susceptible varieties under high Sclerotinia disease pressure. However, selecting varieties with partial resistance to Sclerotinia may require careful research because the Sclerotinia resistance ratings provided by breeders did not always accurately predict the varieties’ field performance in the field trials.

Apothecia which produces Sclerotinia sclerotiorum spores.
Water-Use Shift for Soybeans

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

The historic expansion of soybean acres across North Dakota continues, displacing shorter-season crops such as wheat and barley. Soybeans, a full-season crop, require more water than wheat or barley. The North Dakota Agricultural Weather Network’s (NDAWN) soybean water use model estimates that a soybean crop, if given all the water it wishes to take, could use up to 18 inches of water in central North Dakota, whereas average growing season rainfall is 10-11 inches. Good management can maximize off-season storage of water that was captured from rain and snow but yield losses due to drought stress are inevitable when precipitation is below normal.

Antitranspirants are compounds that induce plants to use less water. The concept of a “water-use shift” induces a crop to use less water during the vegetative growth stages so that there is more water available during the reproductive growth stages. The objective of this research was to screen materials for their ability to reduce the soybeans’ water use.

Soybean plants were grown in the greenhouse for 21 days and then sprayed with different concentrations of potential antitranspirants. The water use was then measured for the next six days simply by weighing the pots every morning and watering to bring the pots back to their original weight. Seven greenhouse runs were performed, and 17 materials were eventually tested. A typical greenhouse run is shown in Figure 1.

Of the 17 materials tested, nine reduced the plants’ water use. The results are summarized in Figure 2. Spraying abscisic acid, the hormone that plants produce to slow their water use, on the plants dramatically reduced the water use, but the effect diminished with time. Two growth regulators that were known to be antitranspirants, Cerrone (ethephon) and paclobutrazol, reduced the water use, and the effect strengthened as the experiment progressed.

Four fungicide products, also marketed for their “plant-health” benefits (Headline SC, Priaxr, Quadris and Stratego YLD), slowed the water use by about 10 percent during the study. If such a reduction in water use lasted for several weeks or if multiple applications were made, that would probably save enough water for a modest yield increase. This might partially explain some “plant-health” benefit for such products.

This study demonstrated that spraying antitranspirants on soybeans can reduce water use. The next step is to determine if the “water-use shift” is a potential tool to lessen yield losses from drought stress, especially on the western frontier of soybean production in North Dakota where the drought risk is the greatest.

The author thanks Kirk Howatt, Sam Markell and Andrew Friskop for their assistance in conducting this experiment.
At planting time, soybean producers make important decisions to maximize seed yield and economic return by optimizing the planting date and plant population. With the expanded soybean acres in the northern growing regions of Manitoba and North Dakota, current information about the soybean response to delayed planting and stand loss is limited. Farmers in these short-growing season regions face the risk of both late-spring and early fall frost. When a grower is evaluating a poor soybean stand due to factors such as poor seeding, unfavorable seedbed conditions, soil crusting or excess moisture, it can be difficult to decide if replanting is the best action to take. Soybean plants also have the ability to compensate for reduced plant stands through the addition of branches, pods and seed; therefore, it is possible that the best course of action is to make the best of the field’s existing soybean stand.

The objectives of this study were to:

1) Identify the impact of reduced soybean stands on soybean yields.

2) Monitor the compensation level of soybean plant growth based on planting date and plant density.

3) Compare the optimum soybean populations for ideal- and late-seeding windows.

Six target plant populations, 80,000; 110,000; 140,000; 170,000; 200,000 and 230,000 plants/acre, were seeded on an ideal (May 26) and late (June 9) calendar date in 2014. The lowest plant population was intended to mimic a 50 percent stand loss. The “late” planting date was intended to mimic a soybean crop that was replanted. The results of this Manitoba study can be compared to the results of North Dakota State University’s Carrington Research Extension Center in Carrington, ND, and to results from the second year of this study which will be repeated at Carman, Manitoba and Carrington, in 2015.

Results from the 2014 field season indicated that farmers might be better off keeping a field with a poor soybean stand if the crop was planted during the growing area’s ideal planting window rather than reseeding the field to reach the target stand. As expected, soybean yields at Carman were higher for the ideal (May 26) planting date, and soybean yields for both planting dates increased with a larger plant population (Table 1). Unexpectedly, similar average yields were achieved for the target plant population of 110,000 plants/acre that was seeded at an ideal planting date (May 26th) as with the target populations, ranging from 170,000 to 230,000 plants/acre, seeded at a late planting date. Comparable yields were achieved at the ideal-seeding date window with a lower range of plant population as those in the late-seeding window with higher plant populations in 2014. With the exception of stands in the 80,000 plants/acre range, reseeding poor soybean stands that were planted during the ideal planting window would not be recommended based on results for the first year of this study.

<table>
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<tr>
<th>Target Plant Population (plants/ac)</th>
<th>Average Soybean Yield (bu/ac) Ideal</th>
<th>Average Soybean Yield (bu/ac) Late</th>
<th>Average Number of Main Stem Branches Ideal</th>
<th>Average Number of Main Stem Branches Late</th>
<th>Average Lowest Pod Height (cm) Ideal</th>
<th>Average Lowest Pod Height (cm) Late</th>
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<td>230,000</td>
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<td>12 cd</td>
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<td>10.7 ab</td>
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Means with the same letters are not statistically different across both planting dates (P = 0.05).

Picture caption: Soybeans nearing maturity on September 12, 2014, at the Ian N. Morrison Research Station in Carman, Manitoba. The soybeans on the right were planted at the ideal planting date (May 26th), and the soybeans on the left were planted at the late planting date (June 9th) in the first rep of the experiment.
Sclerotinia stem rot (white mold) is a recurrent disease of irrigated soybeans and a sporadic but important disease of dryland soybeans in North Dakota, causing losses for seed yield and quality when conditions are cool and moist during bloom and pod-fill. The commercial availability of Contans, a commercial formulation of the biological control agent Coniothyrium minitans, has provided an additional tool for managing Sclerotinia. Contans provides possibilities to control Sclerotinia at its source through the degradation of the fungal resting structures in the soil (sclerotia) that give rise to the spores of the Sclerotinia fungus, but very little information is available about the efficacy of Contans in northern climates at the 1- to 2-lb/ac application rate that the manufacturer recommends for soybeans.

Spring and fall applications of Contans were tested in a 45-acre soybean production field under pivot irrigation. Contans was applied to moist soils at 1 and 2 lbs/ac on October 10, 2013, and May 21, 2014 and lightly incorporated with a shallow cultivation within eight hours of application. Contans operates by degrading the resting structures of the Sclerotinia fungus in the soil, reducing the production of apothecia (small, spore-producing, mushroom-like structures) below the crop canopy. Because the spores produced by the mushroom-like structures can be carried by the wind, large plot sizes (225 ft x 225 ft; 1.16 acres) were utilized to reduce the interference caused by wind-blown spores and to permit the successful differentiation of treatment effects. A 40 ft x 50 ft sub-plot in the center of each 1.16-acre treatment plot was evaluated for apothecia, disease and yield. To permit the evaluation of the comparative efficacy of Contans versus foliar fungicides, a 10-ft strip within this sub-plot was treated with 5.5 oz/ac of Endura (boscalid; BASF Corp.) shortly before canopy closure at the R2 growth stage.

When Contans was applied at 2 lbs/ac in the fall, a 40 percent reduction in apothecia was observed, but the observed reduction in apothecia production was not statistically significant. No other Contans treatment reduced apothecia numbers by more than 10 percent.

Applying Contans to the soil in the spring and fall was less effective than a foliar fungicide (Endura; 5.5 oz/ac) applied at the R2 growth stage. A single application of Endura reduced Sclerotinia incidence by 56 percent and increased soybean yield by 10 bu/ac, and the most effective Contans treatment (2 lbs/ac applied in the fall) reduced the Sclerotinia incidence by 20 percent and increased soybean yield by 1 bu/ac. No other Contans treatments reduced Sclerotinia incidence by more than 14 percent or increased yield by more than 0.5 bu/ac.

The results suggest that, under high disease pressure, a properly timed application of a foliar fungicide may provide a stronger economic return than a fall or spring application of Contans; Contans retails at approximately $20/lb, and 5.5 oz of Endura retails for about $20. This experiment is being repeated in 2015.
Control of Soybean Diseases

Principal Investigator: Dr. Berlin Nelson, Plant Pathology, NDSU;
Cooperating Scientist: Dr. Ted Helms, Plant Sciences, NDSU

Soybean growers are well aware that diseases can impact yields, increase production costs and affect crop-rotation decisions. There are major soybean diseases in North Dakota that can cause serious problems with soybean production. The primary diseases are caused by seedling pathogens and root-infecting pathogens. Foliar diseases have not generally been a serious problem. This project has an emphasis on working with the soybean breeder to test modern cultivars for disease resistance and to develop public cultivars with resistance to major diseases. In addition, we look for and try to determine if there are new pathogen strains that might increase the disease problems, and we investigate the role of certain pathogens to cause crop diseases so that we can better understand how to manage these diseases.

We have a large emphasis on soybean cyst nematode (SCN) because this disease is a major threat. In the summer of 2014 and in cooperation with Dr. Helms, the soybean breeder, four field sites were established in Richland and Cass Counties in order to test commercial cultivars for SCN resistance in field conditions. To determine the levels of SCN reproduction on the cultivars’ roots, soil samples were taken from each site in the spring and the fall. This is an indication of the cultivars’ resistance levels. Those same cultivars were also tested for resistance under controlled greenhouse conditions. Those data were published in the North Dakota Soybean Variety Trial Results for 2014 and Selection Guide, NDSU Extension publication A843-14. In May 2015, another four SCN testing sites were established, and the same procedures will be followed to test cultivars for SCN resistance. Efforts continue to incorporate resistance to SCN and Phytophthora sojae (the cause of Phytophthora root rot) into public germplasm and cultivars. We screen breeding lines for SCN resistance and have identified lines with resistance. We are making progress toward developing a public cultivar that is resistant to SCN. We have also screened breeding lines for resistance to P. sojae and identified those with resistance. Dr. Helms tries to incorporate resistance to P. sojae in any cultivar or germplasm released by NDSU.

We have also been surveying for new races of P. sojae but have not found any races that were not previously known. Races 3 and 4 are still the most common. Another disease that we are investigating is a root problem caused by Fusarium tricinctum; this disease may be involved in the late-season death of soybeans along with other fungal pathogens. Experiments that were conducted in 2014 to study that pathogen’s role in adult plant death were not successful because most plants died in the seedling stage (Figure 1). Fusarium root rots are important in our area and we are continuously studying their role in the fields’ disease damage.

Figure 1. Effect of Fusarium tricinctum on soybean plants. The pot in the lower left has no Fusarium, and seedlings are growing normally while, in the other three pots which are infested with F. tricinctum, the plants are stunted and growing poorly, or seedlings did not emerge. Eventually, most of the seedlings infected with Fusarium died.
Effect of Soil Salinity on Soybeans’ Disease Resistance

Principal Investigators: Dr. Berlin Nelson, Plant Pathology, NDSU; Dr. Abbey Wick, Soil Science, NDSU

Soil salinity is a serious problem in North Dakota and can affect the soybeans’ growth and yield. It is a difficult problem for growers to manage. Unfortunately, there has been limited research on the effect of salinity on soybean diseases. An in-depth examination about the effect of saline conditions on the soybean cultivars’ resistance to major diseases in North Dakota is warranted.

Phytophthora root rot and soybean cyst nematode are two major diseases that affect soybean production in North Dakota. Both diseases are primarily controlled by using resistant cultivars. Many commercial cultivars that are grown in this area have resistance to one or both diseases. If salinity reduces the effectiveness of host resistance, then the primary method of disease management is useless in saline fields. The objective of this two-year study was to determine if soil salinity affects the soybean cultivars’ resistance to Phytophthora root rot and soybean cyst nematode.

The emphasis was on low levels of salinity where the plants still grow but are stressed by salinity. The information from this research will help growers understand the saline soils’ impact on production and the importance of managing saline soils to benefit disease control.

The first year of the project involved working with resistance to Phytophthora sojae, the cause of Phytophthora root rot, under saline soil conditions. We first tested the methodology of creating saline soil conditions and then inoculating plants under those conditions. With the help of Dr. Jay Goos, from the NDSU Department of Soil Science who advised us about the saline soil, we developed a procedure to conduct the research. The tested saline-soil treatments were EC levels of 0, 0.5, 1.0, 1.5, 2.0 and 2.5 dS m-1, saturated paste using sodium sulfate and magnesium sulfate. The salts were dissolved in water and then added to a soil-sand mix to obtain a uniform salinity level for the soil. Nutrients were added so that plants would grow normally. Plants of the Barnes and LaMoure cultivars were grown in various EC levels. Barnes was resistant to race 4 while LaMoure was susceptible. LaMoure was included in the experiment as a positive check for disease development. The experiments were conducted in the greenhouse. After inoculation with race 4 of the pathogen, the number of surviving plants was recorded.

The results for the four experiments indicated that, at the low salinity levels of EC 0.5 to 2, the resistant cultivar, Barnes, maintained resistance to P. sojae (Figure 1) while the susceptible cultivar, LaMoure, showed susceptibility throughout the salinity treatments. Barnes averaged over 98 percent survival from EC 0.5 to 2 while LaMoure plants averaged 15 percent or less survival. At an EC of 2.5, there was a dramatic reduction in the emergence and growth of seedlings such that there were few plants of either cultivar to inoculate. Because of the method we used to create the salinity levels, the amounts used with these experiments are most likely of greater uniformity throughout the soil mix compared to the salinity that naturally occurs in a field soil. Thus, we believe the substantial damage to plant growth at a salinity level of EC 2.5 for these experiments may be considerably greater than one might expect in a field soil that registers an EC of 2.5. Future research will evaluate the soybean’s resistance to soybean cyst nematode under the same salinity levels.

Figure 1. Barnes soybean plants six days after inoculation with Phytophthora sojae and growing in soil at salinity levels from EC 0 on the far left to EC 2.5 on the far right. Notice that there are few dead plants because Barnes has maintained resistance even as salinity levels increase. Also notice that, as salinity increases, there is less plant growth and fewer plants.
Soybean Response to Nitrogen Inputs with Tile-Drained Conditions

Principal Investigators: Ryan Buetow, NDSU Area Extension Specialist/Cropping Systems (Dickinson REC); Dr. Hans Kandel, Plant Sciences, NDSU

Soybeans have the ability to form a symbiotic relationship with nitrogen-fixing bacteria. However, it may be possible to increase yield by adding synthetic nitrogen (N) fertilizer. Applying N fertilizer may reduce the amount of N that is fixed by the symbiotic relationship. Iron-deficiency chlorosis (IDC) is a major production issue in eastern North Dakota. There are many factors that contribute to the expression of IDC. Some causes for IDC are high soil pH, a high level of carbonates, salts, cold temperatures and excess water in the soil profile. IDC expression is also more pronounced by excess nitrates in the soil. Tile drainage reduces excess water from the profile, and over time, may reduce the concentration of soluble salts. The objectives of this research were to evaluate the yield and growth differences for six N management strategies applied to four soybean cultivars grown on tile vs. non-tiled conditions. We also evaluated the effect of tile and N application on the expression of IDC. Research was conducted in 2013 and 2014 at a NDSU research site north of Fargo.

In 2013, tile-drained plots near Fargo yielded 2 bushels more per acre (5.9 percent). The soybean yield was 33.9 bushels per acre with non-tiled versus 35.9 bushels per acre under tiled conditions. In 2014, the yield was 53.1 bushels per acre on non-tiled versus 54.3 bushels per acre on tiled ground. Although the statistical analysis showed that the yield differences for both years were not significant, the increased yield trend was consistent with previous research near Fargo.

Tile decreased IDC severity, and the plants were less yellow compared with the non-tiled treatment. Applying N negatively affected IDC as expected (Table 1) but the plants outgrew the IDC stress. Across environments, grain yields were higher with the application of N than with the control which had the lowest IDC score (Table 2). In 2013, there were no significant yield differences among N treatments; and in 2014, the yields were significantly increased from the control in four of the five N treatments. Across environments, N application increased the yield (42.8 bushels per acre for the control vs. 44.8 bushels per acre average for the N treatments). Protein and oil content, as well as total seeds per plant, pods per plant and seeds per pod, were not significantly different among N treatments. Greenness readings were taken and varieties were significantly different in greenness during the season; however, no consistent trends could be found for the plants’ greenness due to fertilizer treatments.

Using 2015 prices, the financial returns for soybeans grown with fertilizer N application were not different from no N application. The economics of N fertilization for soybeans depend on the price of the fertilizer N and soybeans, which both fluctuate. Selecting IDC-tolerant, high-yielding varieties is an important management strategy to optimize soybean yield.

In summary, N application in this experiment made the plants more chlorotic and increased the yield but did not result in financial benefits.

---

**Table 1. IDC scores for N application treatments at Fargo, 2013-2014**

<table>
<thead>
<tr>
<th>N applied</th>
<th>2013</th>
<th>2014</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs/acre</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>2.2c</td>
<td>2.0c</td>
<td>2.1d</td>
</tr>
<tr>
<td>25-25 (as urea) split</td>
<td>2.7b</td>
<td>2.4b</td>
<td>2.6b</td>
</tr>
<tr>
<td>50 (as urea)</td>
<td>3.0a</td>
<td>2.5b</td>
<td>2.8a</td>
</tr>
<tr>
<td>50 (as ESN)</td>
<td>2.5bc</td>
<td>2.1c</td>
<td>2.3c</td>
</tr>
<tr>
<td>50 (as urea) at R2 3</td>
<td>2.2c</td>
<td>2.0c</td>
<td>2.1d</td>
</tr>
<tr>
<td>75 (as urea)</td>
<td>2.9ab</td>
<td>2.8a</td>
<td>2.9a</td>
</tr>
</tbody>
</table>

1 Based on the visual scale from Goos and Johnson (2008), with 5 being the most chlorotic.
2 Within columns, means followed by the same letter are not significantly different at (P≤0.05).
3 Treatment applied at R2, all other treatments applied at emergence.

**Table 2. Harvested yield among N applications at Fargo, 2013-2014**

<table>
<thead>
<tr>
<th>N applied</th>
<th>2013</th>
<th>2014</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs/acre</td>
<td>-------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>0</td>
<td>34.1a</td>
<td>51.5b</td>
<td>42.8b</td>
</tr>
<tr>
<td>25-25 (as urea) split</td>
<td>35.5a</td>
<td>55.2a</td>
<td>45.3a</td>
</tr>
<tr>
<td>50 (as urea)</td>
<td>36.0a</td>
<td>54.0a</td>
<td>45.0a</td>
</tr>
<tr>
<td>50 (as ESN)</td>
<td>34.6a</td>
<td>54.0a</td>
<td>44.3a</td>
</tr>
<tr>
<td>50 (as urea) at R2 3</td>
<td>35.1a</td>
<td>53.3a</td>
<td>44.2a</td>
</tr>
<tr>
<td>75 (as urea)</td>
<td>35.9a</td>
<td>54.5a</td>
<td>45.2a</td>
</tr>
</tbody>
</table>

1 Within columns, means followed by the same letter are not significantly different at (P≤0.10).
2 Treatment applied at R2, all other treatments applied at emergence.
Maximizing Soil Warming and Health for Different Tillage Practices in a Corn-Soybean Rotation

Principal Investigators: Dr. Aaron Daigh, Soil Science, NDSU; Jodi Defong-Hughes, University of Minnesota Extension; Dr. Abbey Wick, Soil Science, NDSU

There are many advantages of reducing soil tillage to build soil health. However, less tillage creates concerns about yield reductions due to cool and wet soils in the poorly drained landscape that dominates much of North Dakota and the Red River Valley. This study’s objectives are as follows:

1. Monitor soil warming, water contents; thermal properties under chisel plow, vertical tillage, strip till with shank, and strip till with coulters, and no tillage on various soil series with subsurface drainage or natural drainage.
2. Evaluate soil health and crop emergence and yields.
3. Transfer information to producers through field days, videos, etc.

This multi-state effort is being conducted in North Dakota and Minnesota and is year one of a four-year field study. Four, on-farm locations, have a corn-soybean rotation and rotate each year. At each location, the five tillage practices are used with full-sized equipment in plots that are 40 or 66 feet wide by 1,800 feet long (Figure 1) in a replicated design. The evaluated soil series are Fargo silty clay; Lakepark clay loam; Barnes-Buse loam; Delamere fine sandy loam and Wyndmere fine sandy loam. These soil series cover more than 67 million acres of prime farmland in the Northern Great Plains region.

During March through June the strip till, with either a shank or a coulter, provided a comparable or slightly better alternative to the chisel plow for springtime soil warming and drying. Additionally, they conserved mild quantities of water in the areas between the tillage strips; this water would be beneficial in years with little snowmelt or spring rains prior to seedling growth. The vertical tillage also conserved mild quantities of water but allowed the soil to dry much more than the no-tillage system while also providing a mild temperature increase.

The locations with subsurface drainage did not enhance soil warming and drying when compared to areas that did not require that drainage. However, the subsurface drainage likely prevented even cooler and wetter conditions. As expected, the soil’s clay and water contents had a major impact on soil warming and the differences among the tillage practices were greatest under soils what were innately warmer.

Soil samples have been collected to determine soil health and are currently being analyzed in the laboratory. Crop-residue cover, crop populations and yields are also being evaluated during the summer and fall months.

To introduce the study to North Dakota producers, two videos were produced (Figure 2). Through a cooperative effort by NDSU and University of Minnesota (UMN) Extension, information obtained during this first year’s spring months will be presented at NDSU’s fall Soil Health Field Day, as well as at the UMN’s Tillage, Technology and Residue Field Day.

Fig. 1. Installation of strip tillage on fine sandy loam soils (top). Three tillage plots are shown in top image; from left to right: vertical tillage, strip tillage with coulter, chisel plow. Bottom left: strip till will coulter implement. Bottom right: vertical tillage implement.

Fig. 2. Extension videos posted on the NDSU Soil Health website describing the project and the tillage equipment used.
Employing Fall and Spring Herbicide Treatments to Combat Glyphosate-Resistant Kochia in Central North Dakota’s Soybeans

Principal Investigators: Dr. Mike Ostlie, Brian Jenks; Greg Endres, NDSU Carrington Research Extension Center

In the fall of 2014, a study was initiated to evaluate the effectiveness of fall-applied herbicides when compared to spring-applied herbicide programs. The main objective was to identify if there were any fall applications that provide kochia control that is similar to a typical spring application. The study was conducted near Minot and Carrington. Fall applications were made in early October 2014 while spring applications were made in early May 2015. Soybeans were planted no-till in the trial area. It should be noted that kochia had already emerged on May 1, so the weed-control ratings for the fall treatments are considered post-emergence, whereas the fall treatments would be pre-emergence control of kochia. Herbicide effectiveness was measured after soybean planting and will continue throughout the 2015 growing season.

Several products were evaluated for a fall or spring application. At Carrington in 2014-15, no product provided equal control in the fall and the spring (Table 1). Although the fall application of Spartan at 8 oz/a equaled the spring application of Spartan applied at 5 oz/a. Even though that wouldn’t be an equivalent comparison by rate, it at least shows that there were effective fall treatments in Carrington this year. In Minot, Spartan performed similar as a fall or spring treatment. Both sites in 2014-2015 were in contrast to the previous year in Carrington where Spartan, Fierce and Valor were statistically similar for either fall or spring treatments.

Several other products were utilized as a spring-only. These products were used in combination to provide residual kochia control throughout the season and to help with the burn-down of existing plants (Table 2). In Carrington and Minot, several product combinations were highly effective for killing and maintaining kochia control. The Minot study was placed in a location with glyphosate-resistant kochia, resulting in fairly low control with glyphosate alone (Table 1).

Fall herbicide applications for kochia control can be effective if the environmental conditions are right. No-till producers may be more inclined to consider this application method to ensure the early season control of kochia. In 2014 and 2015, the kochia was growing long before the soybeans were planted. By the time typical soybean burn-down occurred, many kochia plants would have been too large for effective management if they were glyphosate resistant. With tight application windows in the spring between the corn and soybean planting, fall herbicide applications would be one way to lessen the spring workload while also ensuring product activation and ensuring that the product will be applied prior to kochia emergence. A well-timed, spring herbicide application is often the most effective option, as evidenced by this study.

### Table 1. Summary of products that were used as fall and spring treatments

<table>
<thead>
<tr>
<th>Product</th>
<th>Fall Rate oz/a</th>
<th>Fall from Fall App (%)</th>
<th>Control from Fall App (%)</th>
<th>Control from Spring App (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority MTZ</td>
<td>18</td>
<td>14</td>
<td>72.5</td>
<td>89.8</td>
</tr>
<tr>
<td>Spartan</td>
<td>5</td>
<td>5</td>
<td>62.6</td>
<td>86</td>
</tr>
<tr>
<td>Spartan</td>
<td>8</td>
<td>8</td>
<td>87.3</td>
<td>86</td>
</tr>
<tr>
<td>Fierce</td>
<td>3</td>
<td>3</td>
<td>51.3</td>
<td>91</td>
</tr>
<tr>
<td>Valor</td>
<td>3</td>
<td>3</td>
<td>40</td>
<td>75</td>
</tr>
<tr>
<td>metribuzin 0.5 lb/a</td>
<td>0.5 lb/a</td>
<td>56.3</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>Broadaxe</td>
<td>25</td>
<td>25</td>
<td>45</td>
<td>73.8</td>
</tr>
</tbody>
</table>

| Minot 2014-2015 | |
|----------------|------------------|------------------|------------------|
| Fierce | 3 | 3 | 51.3 | 91 |
| Valor | 3 | - | 40 | - |
| metribuzin 0.5 lb/a | - | 40 | - |
| Spartan | 5 | 4 | 70 | 76 |
| glyphosate | - | 22 | - | 48 |

### Table 2. Effectiveness of spring pre-emergent treatment combinations for controlling kochia in soybeans

#### Carrington treatments

<table>
<thead>
<tr>
<th>Product</th>
<th>Rates (oz/a)</th>
<th>Control (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verdict + Zidua</td>
<td>7.5 + 3</td>
<td>87.3</td>
</tr>
<tr>
<td>metribuzin + Sharpen</td>
<td>0.5 lb/a + 1.5</td>
<td>96.8</td>
</tr>
<tr>
<td>Fierce + metribuzin</td>
<td>3 + 0.5 lb/a</td>
<td>98</td>
</tr>
<tr>
<td>Authority MTZ + Sharpen</td>
<td>14 + 1.5</td>
<td>96</td>
</tr>
</tbody>
</table>

#### Minot treatments

| Spartan Charge | 5 | 86 |
| Gramoxone + metribuzin | 3.2 + 0.5 lb/a | 93 |
| Spartan + Sharpen | 4 + 1 | 78 |
| Fierce + metribuzin | 3 + 0.5 lb/a | 95 |
| Verdict + metribuzin | 5 + 0.5 lb/a | 76 |
| Verdict + Zidua | 5 + 2.5 | 77 |

1. All spring products were applied with MSO
2. All spring products were applied with AMS+MSO
Timing Winter Rye Removal for Weed Control in Soybeans

Principal Investigators: Dr. Mike Ostlie and Steve Zwinger, NDSU Carrington Research Extension Center

North Dakota’s soybean production is currently threatened by numerous factors, including glyphosate-resistant weeds, root and foliar diseases, soil erosion and creeping salinity. Winter rye is growing in popularity due to a number of different niches that it can fill in a crop rotation. One of the main benefits that rye provides as a cover crop is weed control through a combination of allelopathy and heavy competition. The strengths of rye can also be used to supplement soybeans’ weaknesses. Rye can be used to break disease cycles, provide weed suppression, provide winter cover, utilize excess spring moisture, or be used for fall or spring grazing, all while still utilizing the growing season for a cash crop.

In 2014, a study was conducted at the Carrington Research Extension Center to evaluate weed control and soybean yields with different scenarios for removing rye. The treatments consisted of a no-rye check; plots with rye tilled into the soil or sprayed prior to planting soybeans; treatments where rye was mowed, harvested for forage, or sprayed at anthesis; and a treatment where rye was left for the duration of the soybeans’ growing season. The rye was planted on September 26, 2013. Soybeans were planted on June 3, 2014, into rye that was just entering the “boot” stage. A supplemental glyphosate application was made to all soybeans (except in treatments 6 and 7) on June 16.

The weed suppression from rye was largely in the form of reduced kochia growth and vigor but not necessarily reduced plant numbers. Soybean growth and development did not appear to be influenced by the presence of rye, nor the removal strategies (other than mechanical damage) through the June 16 rye removal treatments, when rye was at anthesis and the soybeans were developing their first true leaves. The weed suppression of the Hancock rye disappeared once the rye began to lose leaves and the canopy opened. At that point, the stunted kochia within the canopy began more vigorous growth. By the middle of August, this rye variety on its own, lost most of its effectiveness on kochia. The other treatments, aided by the application of glyphosate, continued to maintain a high level of suppression even though the rye had been removed quite some time earlier. Preliminary data suggests that different rye varieties provide numerous levels of weed control (data not shown).

In the treatments where rye remained past anthesis, soybean yields were heavily influenced (~75 percent reduction compared to other treatments). The highest soybean yield was achieved with the pre-plant burndown of the rye (Table 1). This likely resulted in lower early season competition with the soybeans. The no-rye check plot had a fairly low yield. Much of that was attributed to a lack of weed control early in the season because all other plots retained an average of ~50 percent kochia suppression.

Overall, the rye and soybeans grew well together. The rye recovered remarkably well from the soybean-planting operation and the soybeans grew through the rye canopy with ease for the first month or so (through rye anthesis). Ultimately, whether for winter ground cover, weed control or forage, rye could benefit the soybean-production system in most scenarios. The decision about a specific method and time of removal could be left to the individual producer to fit within the existing equipment and resources.

Table I. Weed control and yield of soybeans based on different winter rye removal strategies

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Time of Removal</th>
<th>Kochia Control (%)</th>
<th>Yield</th>
<th>Rye</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>May 2B</td>
<td>July 15</td>
<td>August 1B</td>
</tr>
<tr>
<td>1. No rye</td>
<td></td>
<td>0</td>
<td>–</td>
<td>62.5</td>
</tr>
<tr>
<td>2. Rye tilled</td>
<td>May 27</td>
<td>46.3</td>
<td>–</td>
<td>66.3</td>
</tr>
<tr>
<td>3. Rye sprayed – prior to soybean planting1</td>
<td>May 27</td>
<td>50.0</td>
<td>–</td>
<td>76.3</td>
</tr>
<tr>
<td>4. Rye mowed</td>
<td>June 162</td>
<td>53.7</td>
<td>–</td>
<td>77.5</td>
</tr>
<tr>
<td>5. Rye forage harvested</td>
<td>June 16</td>
<td>60.0</td>
<td>–</td>
<td>77.5</td>
</tr>
<tr>
<td>6. Rye left standing</td>
<td>na</td>
<td>55</td>
<td>38.8</td>
<td>16.3</td>
</tr>
<tr>
<td>7. Rye harvested for grain</td>
<td>August 6</td>
<td>53.8</td>
<td>45</td>
<td>16.3</td>
</tr>
<tr>
<td>8. Rye sprayed – anthesis</td>
<td>June 16</td>
<td>46.3</td>
<td>–</td>
<td>88.8</td>
</tr>
</tbody>
</table>

LSD (0.05): NS 9.1 12.9 0.3 8.4

Note: soybeans planted June 3, soybeans harvested October 8, rye planted September 26, 2013
1 Spray application was glyphosate
2 Soybeans first true leaves, rye at anthesis
Breeding of Glyphosate-Resistant Soybean Cultivars

Principal Investigator: Dr. Ted Helms, Plant Sciences NDSU;
Cooperating Scientist: Dr. Berlin Nelson, Plant Pathology, NDSU

Growers would like to purchase a glyphosate-resistant soybean variety and be able to save their own seed for planting the next year. 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). The purpose of this research is to provide superior glyphosate-resistant varieties that have been developed by North Dakota State University (NDSU).

Creating glyphosate-resistant experimental lines was initiated at NDSU with a new breeding program. Developing a different soybean variety requires seven years. As the first step in the breeding process, crosses were initiated in the summer of 2010. Now, experimental lines that resulted from 2010 crossings are in the final stages of yield evaluation and seed increase. As part of the continuing process to create new lines, 3,323 plant-rows were planted in the spring of 2014. During the 2014 growing season, 1,327 new glyphosate-resistant, experimental lines were tested for yield, lodging resistance and maturity. In 2014, 212 experimental lines were tested for the second year; and 29 of these were advanced for the third year of yield evaluations during the 2015 growing season. A total of 5,792 plots were devoted to this project in 2014.

Two glyphosate-resistant experimental lines were increased during the 2014-2015 winter season in Chile, South America, with the goal of releasing at least one of those lines in January 2017. There are a total of 29 different, advanced, experimental glyphosate-resistant lines that have the potential to be released in January 2017. The researchers anticipate that only one or two of the varieties will be released. It will require another year of seed increase before commercial quantities of seed are available for farmers to plant in the 2018 growing season.

The benefit to the North Dakota soybean industry would be to reduce the cost of soybean seed of NDSU varieties that are glyphosate-resistant. Growers could save their own seed of glyphosate-resistant soybean varieties that were developed at NDSU. The farmers could then plant this saved seed of NDSU varieties without paying a technology fee. Presently, farmers must purchase expensive new seed each year. Farmers cannot save seed of private company Roundup Ready One® varieties unless they obtain permission from the seed company that developed the variety.

Developing a different soybean variety requires seven years.

Glycose-resistant experimental line in Chile.

Dr. Ted Helms, NDSU soybean breeder, provides North Dakota Soybean Council board members with an overview of NDSU’s glyphosate-resistant breeding program near Rancagua, Chile in January 2015. “Having a winter nursery is standard practice for soybean breeders and helps reduce the number of years the breeding process takes from 10 years to 7 years,” says Dr. Helms. “This allows farmers to take advantage of the better, high yielding, improved, pest-resistant soybean varieties more quickly.”
SHARE Farm: Quantification of Salt Removal from Leaching and Tile Drainage

Principal Investigators: Dr. Abbey Wick, Soil Science NDSU; Dr. Frank Casey, Natural Resource Sciences, NDSU; Dr. David Ripplinger, Agribusiness and Applied Economics, NDSU

Background/Need for Research
The SHARE Farm is a location where salinity-management and soil health-building strategies can be tested based on farmer input and then distributed to farmers using Extension programming. Tile drainage is one approach farmers are currently using to manage salinity and to deal with the high groundwater table in order to improve crop production. Farmers often ask, “How quickly do the salts flush once tile drain is installed?” and “When will it pay?” With tile drainage being installed on 80 acres at the SHARE Farm in late summer 2014, it was a good year to start evaluating the effectiveness of tile drainage. Testing observations in the greenhouse is a start for large-scale projects at the SHARE Farm. Information is then distributed to farmers using Extension activities such as videos, field days, workshops and café talks.

In 2014, we removed large, intact soil cores (dimensions: 8” x 4’) from high- and low-salinity areas at the SHARE Farm. The samples were taken back to the main campus where we could artificially wet and dry the cores. We put instruments in each core to monitor the water flow and analyze the salts that were flushed. This allowed us to evaluate the effectiveness of tile drainage on salt removal in clay soils. Evaluation of permanent soil sampling and well locations within the field, along with salinity mapping, was continued in 2014-2015 to accompany tile drainage research.

Results
Initial results from the experiment indicated that, during wet periods, such as the spring time, only about 0.08 percent of salt required for remediation was removed. This low level of salt removal could be a result of the dominant shrink-swell clay soils found in the Red River Valley. When the clay is dry, large cracks open up and rainwater moves rapidly through the soil profile. The clay then swells, the cracks close, and water movement is reduced. When the water stops moving, so do the salts dissolved in the water, and remediation of the saline soils slows. This information is currently being incorporated into an economic model.

For Extension programming under the SHARE Farm Project, we held a large field day on August 21, 2014. We used small-group discussions to make the experience more personal for farmers and brought in various specialists to update farmers on the projects funded by the corn and soybean councils. We also held a series of winter café talks in Milnor, Wahpeton, Hillsboro and Thompson. The talks were well attended.

Take-Home Message
Tile drainage can help prevent the accumulation of salts in the root zone, primarily by intercepting the water table. However, leaching salts above the tile drain is variable, and it may take many years to fully remediate clay soils in the Red River Valley. Developing the economic model and Extension activities will continue in 2016, reaching farmers with information and continuing to obtain feedback.

Figure 1. Pie chart of salt removed from high-salinity cores in relation to the total removal required for remediation.

Cation removal in high salinity cores from a one time leaching event

Dr. Abbey Wick
Impacts of Tillage System, Fertility and Crop Rotation on Rhizobium Populations and N Dynamics

Principal Investigator: Ezra Aberle, NDSU Carrington Research Extension Center; Cooperating Scientists: Dr. Ann-Marie Fortuna, Soil Science, NDSU; Heather Dose, Soil Science, NDSU

Soybean acreage has nearly doubled in recent years. Nitrogen is biologically fixed by symbiotic Rhizobia species that infect soybean roots and induce nodulation. Biological nitrogen fixation (BNF) can account for 25 to 75 percent of the N in soybean plants and can affect grain quality (Zapata et al., 1987). Bradyrhizobium japonicum is used extensively as an inoculant to promote BNF in soybean (Glycine max) in the north-central Midwest. Strains of B. japonicum with high capacities to fix biological N (effectiveness) are applied to seeds at planting. Their persistence in the soil for more than one growing season is dependent upon the competitiveness and the fitness of the naturalized rhizobium (previously inoculated and often less effective) as well as the management practices (Thies et al., 1991).

Tillage often reduces rhizobium levels in the soil while no-till methods tend to support rhizobium populations, due to the buildup of residues that aid in the persistence of rhizobium, when they are not living in their plant host. Rotations without a host plant can also reduce rhizobium populations. This could be of benefit if naturalized rhizobium is less effective. Our research estimated the numbers of B. japonicum as well as its activity, infectiveness, effectiveness and survivability in a typical north-central Great Plains soil under differing crops, tillage and fertility regimes that included fertilizer and manure inputs.

Soil samples were collected at 0-6 and 6-12 inches prior to planting (May), during the V2-4 (June) and V6-8 (July) growth stages, and after harvest in October. Rhizobium populations in the soil and the nodules were measured at the V2-4 and V6-8 stages. Nitrogen fixation in soybean was estimated by measuring the ureide-N concentrations in the plant tissue.

In our study, no-till and points in the rotations without a legume crop decreased the number of rhizobium in the soil. The no-till method also reduced the amount of biological N that was fixed by rhizobium (Figure 1). In the no-till systems, nutrients can be stratified and partially immobilized. Soybean-oil content was also lower in the no-till systems. Unlike previous years, there was no significant difference in yield due to the tillage system; therefore, there were no differences in the economics.

Figure 1. The amount of plant nitrogen obtained from biological nitrogen fixation under conventional and no-till management at the soybean’s V2-4 and V6-8 growth stages.

In our study, no-till and points in the rotations without a legume crop decreased the number of rhizobium in the soil. The no-till method also reduced the amount of biological N that was fixed by rhizobium (Figure 1). In the no-till systems, nutrients can be stratified and partially immobilized. Soybean-oil content was also lower in the no-till systems. Unlike previous years, there was no significant difference in yield due to the tillage system; therefore, there were no differences in the economics. This could be attributed to the uniformly good yields, 52.7-54.4 bu/acre, that were achieved. Applying N fertilizers at other entry points for the rotation influenced the rhizobium’s number and effectiveness. Manure applications increased the number of persistent rhizobium, likely due to the buildup of organic materials that could be used by rhizobium prior to infecting the host plant. This research indicated that tillage had the greatest effect on the rhizobium populations and N dynamics. No-till systems may contain additional N that is rendered available to the plant, which would reduce the need for rhizobium to biologically fix the N.
From the Ground Up: How Salinity Gradients Damage Soybeans, Contribute to Arthropod Pest Infestations and Impact Soil-Nitrogen Reserves

Principal Investigators: Dr. Abbey Wick, Soil Science, NDSU; Dr. Tom DeSutter, Soil Science, NDSU; Jason Harmon, Entomology, NDSU; Dr. Diedre Prischmann-Voldseth, Entomology, NDSU

Funded Project $73,299

Need for Research
North Dakota producers are experiencing reduced yields as a result of soil salinity, with 5-30 percent of the fields being affected, depending on where the fields are located. Soybeans are especially sensitive to salinity, where current research shows yields are reduced at an EC1:1 of 4 mmhos/cm. (The EC values are labeled “soluble salts” on the soil test results.) This range between 2 and 4 is where active management for salinity is key. To improve management in North Dakota, we need to know more about the soybean response locally.

When water carrying dissolved salts moves towards the surface, the water evaporates while the salts remain. Any changes to a soybean plant, such as reduced surface shading or lower water use by stunted plants, can impact the water dynamics and, thus, salinity. This is why a salt affected area can become worse after multiple years of failed crops.

To further complicate issues, there is some indication that salt-stressed soybeans may become “hotspots” for pests. Again, this is not well understood, but knowing more could improve management.

In the greenhouse at NDSU, we evaluated the effects of salinity on soybean plants and then looked at the performance of an arthropod pest (two-spotted spider mite and soybean aphid) on the salt-stressed plants. We followed the greenhouse experiment with a field experiment to evaluate “real world” yield response.

Results
In the greenhouse, across the salinity gradient (0.4 to 4.2 mmhos/cm), soybean leaf biomass decreased by 63 percent, and leaf area decreased by 58 percent; meaning less surface shading and more potential evaporation from the surface to bring salts to the surface. Roots were also affected as salinity increased. Root length decreased by 44 percent, and root mass decreased by 48 percent. [Nodulation was non-existent at an EC1:1 of 4.2 mmhos/cm.]

Smaller numbers of roots mean less water use and a greater potential for salt accumulation. Field studies showed soybean yield declined at an EC of 1.1 mmhos/cm with 50 percent yield reduction at 2.2 mmhos/cm. This is a dramatic change from previous values. [Figure 1 shows previous values identified in existing research (upper) and new values identified in this study (lower). Red indicates yields reductions of greater than 50 percent.]

As soybeans were increasingly stressed by salt levels, the spider mite and aphid performance increased. Adult, female spider mites responded by laying more eggs on plants as the salt levels increased (Figure 2). Mite populations also exploded on soybean plants after one week of infestation with 50 individuals to over 500; there were more mites on the plants grown in higher salinity levels.

**Figure 1. Visual of soybean yield response to increasing levels of salinity.**

<table>
<thead>
<tr>
<th>Soluble Soil Salts</th>
<th>0 to 1.86 mmhos/cm</th>
<th>1.86 to 2.96 mmhos/cm</th>
<th>2.96 + mmhos/cm</th>
</tr>
</thead>
</table>

**Figure 2. Spider-mite egg counts on salt-stressed plants.**

Take-Home Message
Soybeans respond negatively to very low levels of salinity: lower leaf area, biomass, rooting and yield. This response can amplify salinity problems because of the reduced surface shading and lower water use by roots. In addition, spider mites and aphids respond positively to the salt-stressed plants, leading to the potential “hotspots” in salt-affected areas. Active management during the initial signs of a salinity problem is important for the continued use of soybeans in a rotation.
Breeding of Improved Non-GMO Cultivars and Germplasm

Principal Investigator: Dr. Ted Helms, Plant Sciences, NDSU; Cooperating Scientist: Dr. Berlin Nelson, Plant Pathology, NDSU

As glyphosate-resistant weeds, such as kochia and water hemp, become more common, farmers may benefit from growing non-GMO varieties and applying herbicides with different modes of action than glyphosate. This scheme would avoid using expensive herbicides on GMO varieties with the associated high cost of seed. Also, the NDSU breeding program provides farmers with the option of growing non-GMO varieties in the event that seed prices for GMO varieties are too expensive. A grower has the option of purchasing non-GMO varieties that have been developed by North Dakota State University without paying a “technology fee” and can then save the seed.

This research had four broad objectives, to:
1) Provide North Dakota soybean growers with cultivars which are genetically superior to the currently grown cultivars.
2) Collect grain samples from the Variety Fee Tests, and to report the protein and oil data in the NDSU Soybean Performance bulletin.
3) Increase the yield for IDC-prone soils and to increase the profit with those problem soils.
4) Enable private companies and growers to compare the yield of Soybean Cyst Nematode (SCN)-resistant cultivars on sites that are infested with SCNs.

A total of 13,459 nursery rows and 10,605 yield trial plots, dedicated to this research grant, were planted in 2014. “ND Henson,” an early maturity variety with high yield, was released in January 2015. Grain samples for protein and oil analyses were collected for all company varieties entered at the LaMoure, Northwood, Grandin, Arthur, Walcott and Milnor testing sites. These samples were analyzed, and the data were reported in the North Dakota Soybean Performance Bulletin (A-843).

In 2014, yield data were collected for 40 private-company Roundup Ready varieties at four North Dakota sites that had IDC symptoms. Averaged across the Hunter, Leonard, Prosper and Galesburg locations, the yield range varied from a low of 5.4 bu/A for a susceptible company variety to a high of 23.5 bu/A for an IDC-tolerant company variety. Four sites that were infested with SCNs were planted with 40 Roundup Ready company varieties to test for SCN resistance. These data were published in the North Dakota Soybean Performance Bulletin (A-843) and also online.

Growers benefit when there are non-GMO varieties that offer a choice between buying new seed each year and being able to save seed for non-GMO varieties to plant the following year. Past success by NDSU to develop non-GMO varieties for the oilseed market includes “ND Henson,” “Ashtabula” and “Sheyenne.” Also, tofu and natto specialty-type varieties, such as “ProSoy,” “ND1406HP” and “ND1100S,” have been developed. NDSU’s non-GMO varieties provide growers with an alternative for using glyphosate and permit different herbicides to be rotated in soybean fields across years. Growers benefit when varieties from different companies are compared at the same field sites because this enables farmers to increase the yield for fields that have soil or pest problems.

www.ndsoybean.org
Evaluating Soybean-Planting Rates and Late-Planting Dates

Principal Investigators: Dr. Mike Ostlie and Greg Endres, NDSU Carrington Research Extension Center

In 2014, a soybean study was established to quantify any negative effects associated with delayed planting and cases of stand loss. Three planting dates, with roughly two weeks between each date, were chosen: May 23, June 5 and June 23. For each planting date, five target populations were used, beginning at 200,000 plants/A and decreasing by 30,000 until 80,000 plants/A was reached. Plots were seeded in 14" rows. Every two days during the growing season, the plots were monitored for flower initiation, canopy closure and physiological maturity.

Due to conditions at the time of planting, the first planting date reached the targeted populations regularly (Figure 1). For the second two planting dates, the actual population was often well below the targeted population. Just one example of how much the growing season changed in early June.

Monitoring the soybeans’ growth and development produced some very clear trends. Even though there were two weeks between each planting date, there was only a 6-10 day delay for most growth milestones between the dates. Essentially, the days from first flower until physiological maturity were always roughly the same (68-71 days) regardless of planting date and rate; only the days until flowering changed. The number of days until canopy closure was affected more by the planting population than by the planting date (as expected). The last planting date never reached physiological maturity in Carrington because a killing frost was received on October 3.

When it came to plant yield, the planting date was the greatest determining factor. The lowest plant population at the first planting date was similar to the yield realized with the highest plant population for the next planting date (Figure 2). Yields for populations between 140,000 and 200,000 plants/a were surprisingly stagnant. Unfortunately, the third planting date was not harvested, but it could be assumed that the yield followed a similar trend as the second planting date, with a smaller yield difference than that between the first two dates.

Some big differences noted between the first planting date and the other two dates could largely be explained by the stark weather shift that occurred in early June. During the Memorial Day weekend, there was a period of hot weather that caused rapid emergence of many crops over that span (3 to 5 days for soybean emergence). Crops planted after that hot period were subjected to temperatures that were below normal for summer.

Please note that these data are not meant to promote reduced populations in soybeans. These data are meant to provide evidence for or against replanting a crop that had a population reduction due to environmental effects.
The goal of this project was to study the efficacy of seed-treatment chemistries to control root disease as well as to examine their impact on yield for multiple planting dates and environments in North Dakota. To improve our understanding about the pathogens that cause root-rot diseases and the seed-treatment options, we can go for early in the growing season and as the season advances. With the help of North Dakota Soybean Council (NDSC) funding, three experiments were conducted at three North Dakota locations (Langdon, Carrington and Minot) in 2014.

Generally, farmers are told to plant earlier because the soybeans’ yield potential increases. However, cool and wet soils are frequently encountered at these planting dates and will slow seedling growth, making the seeds more vulnerable to the seed and root rots that are caused by plants pathogenic fungi, eventually resulting in a reduced stand. These pathogens’ sensitivity to the fungicides used in seed-treatment products is evaluated in this study. Most fungicide seed treatments are only active for 2 to 3 weeks. Thus, when germination and emergence are slowed with cool soil temperatures, the seedlings are vulnerable to infection by pathogens. This is the main reason for choosing two different planting dates and the generated data help to explain why one seed treatment benefits the yield at one location and not necessarily at another.

Obviously, the choice of a fungicide seed treatment depends on knowledge about what disease problems are prevalent in a particular field. Not much research has been done about the prevalence of soil-borne pathogens that can infect soybean seeds and seedlings. For the current research, fungicides with straight and a combination of seed-treatment products were selected to manage these seedling rots. The soybean seed (Variety: S007-Y4 for Minot and Langdon; Variety: S04-D3 for Carrington) was treated with straight and combination products; in all, 15 chemical treatments and a non-treated control were planted at three North Dakota locations. Products that contain metalaxyl or mefenoxam as active ingredients are effective against Pythium and Phytophthora. Other active ingredients, e.g., azoxystrobin, trifloxystrobin, ipconazole, captan, carboxin, fludioxonil, thiram, sedaxane and thiophanate methyl are effective against Fusarium and Rhizoctonia. The obtained results were correlated with the disease incidence to plant stand and yield. Due to the lack of significant disease pressure none of the chemicals tested showed positive effect as expected on either plant stand or on yield. Even though we had cold (<55 F), wet conditions for a few planting days in all three environments/locations for the 2014 field trials, the benefit of a seed treatment on the soybean-stand establishment was not evident. We did not see significant yield differences among the different seed-treatment fungicides used as expected. However, we did detect evidence that one seed treatment (Mefenoxam+Fludioxonil+Sedaxane+thiamethoxam) had an effect on yield (over 2 bushels/ac increase) for all three locations, but the difference was not statistically significant. This seed-treatment chemical was made from a combination of three fungicides and an insecticide (Thiamethoxam). At pre-planting, it is difficult to determine what risk there may be for soybean root rot in any season and not all seed-treatment fungicides are equally effective against all fungal pathogens. However, our preliminary data indicated that Pythium and Rhizoctonia were the major pathogens at all three locations that we tested. The current research information can be used to treat soybean seed, depending on the prevalent pathogens that are specific to a North Dakota location.
Controlling Volunteer Roundup Ready (RR) Canola Control with Pre-Emergent Herbicides

Principal Investigators: Dr. Rich Zollinger, Plant Sciences, NDSU; Devin Wirth, Plant Sciences, NDSU; Jason Adams, Plant Sciences, NDSU

Many crops are grown in North Dakota, including soybean and canola in northern and western North Dakota. Canola produces small, smooth, round, hard seeds. Many of these canola seeds can be thrashed on the ground during the harvesting process and can spill from the trucks hauling the seed from the fields. Roundup Ready canola followed by Roundup Ready soybean is a popular crop rotation in the state. Volunteer Roundup Ready canola seed can germinate the next year when soybean is planted and can become a serious weed problem for Roundup Ready soybeans.

Preferential use of glyphosate controls most grass and broadleaf weeds in soybean, but does not have any activity on Roundup Ready canola volunteer plants. Studies were conducted to evaluate the activity of several pre-emergent herbicides that are used with corn and soybeans to remove volunteer Roundup Ready canola. Pre-emergence herbicides were applied following the seeding but prior to volunteer canola emergence.

Sharpen only at 2 fl oz/A or greater controlled the volunteer canola, but at 1 fl oz/A, the chemical only provided 70 percent control. Authority Elite/BroadAxe at labeled rates gave 75 to 85% percent control, and SureStart II at 1.5 to 2 pt/A only gave 70 percent control. Herbicides that were ineffective for canola control were Zidua, Valor, Fierce, Boundary and metribuzin applied at 0.25 to 0.5 lb/A. These observations were somewhat different than similar studies conducted in 2013 because metribuzin either applied alone or in combination gave good-to-excellent canola control. In addition, SureStart, Boundary and Zidua at rates greater than 4 fl oz/A, along with Fierce, also gave complete control of canola. The difference for canola control in 2013 and 2014 is attributed to good, activating rainfall in 2013 and deficient rainfall in 2014. This information will help soybean growers obtain adequate and season-long control of volunteer Roundup Ready canola that may emerge in their soybean fields.

Studies were conducted to evaluate the activity of several pre-emergent herbicides that are used with corn and soybeans to remove volunteer Roundup Ready canola.

Dr. Rich Zollinger
Increasing Awareness of Soybean Cyst Nematode in North Dakota

Principal Investigator: Dr. Samuel Markell, Plant Pathology, NDSU

Why Is This Project Important?
Soybean cyst nematode (SCN) is an invasive pest that was first identified in North Dakota in 2003. The pathogen can cause approximately 15-30% yield loss without above ground symptoms. When SCN egg levels become high the disease is very difficult to manage and yield loss can be devastating. However, management strategies for SCN are available and if growers are proactive, egg levels can be kept low and yield loss can be minimized. This research and Extension project was created to increase SCN awareness among growers in an effort to prevent unnecessary yield loss.

What Was Done?
SCN sample bags were distributed to growers, free of charge, at NDSU County Extension offices and field days in August and September. Growers could sample for SCN, mail the bag to the laboratory and receive their data in the mail. The NDSU plant pathology department was given geographical points and SCN egg level data to create a map of SCN distribution in the state.

Three SCN field days were held in Arthur (September 18th), Wyndmere (September 22nd) and Galesburg (September 23rd). Demonstrations included SCN resistant varieties, SCN nematicide seed treatments, SCN root-digging and an SCN soil-sampling demonstration.

What Were The Results?
By January 1, 580 SCN sample bags were sent in for analysis by growers, of which 179 were positive (Figure 1). Of the 179 positives samples, 95 were considered low level (200 eggs/100cc or below, as indicated by gray squares). Low levels should be viewed with some caution, false positives are known to occur. The highest concentration of positive samples and highest recorded egg levels were detected in Richland, Cass and Southern Traill Counties. Data from the 2013 and 2014 SCN sampling programs were combined and analyzed and we determined that SCN has been confirmed in seven additional counties since 2012.

Attendance at the SCN field days was approximately 120 people. Areas surrounding field day locations were the most heavily sampled in the state, suggesting that those attending the field days had a greater understanding and appreciation for the damage that SCN can do to soybean fields.

How Does This Benefit the North Dakota Soybean Farmers And Industry?
Awareness and detection are the first steps to effectively manage SCN.

Acknowledgements
We thank the people and organizations that contributed to this project, including: Arthur Companies; Peterson Farms Seed; Syngenta Crop Protection; Bayer Crop Science; each county crop improvement association from Cass, Richland and Traill counties; the growers who allowed us to utilize their land; and the Extension agents who distributed SCN bags, hosted field days and helped with map creation.

Figure 1. Distribution of SCN (eggs/100cc) in North Dakota from samples submitted by growers.

Figure 2. Distribution of SCN (eggs/100cc) in Southeast North Dakota from sample submitted by growers.

Figure 3. Counties with Soybean Cyst Nematode and year of first detection.
Impact of Tillage Systems and Previous Crop on Root Rot and Soybean Performance

Allie Arp, NCSRP Communications Liaison

Now more than ever there is a focus on furthering soybean research in efficient and non-duplicative ways and increasing return on investment.

North Dakota State University (NDSU) is contributing to two North Central Soybean Research Program (NCSRP) projects in a big way. The NCSRP is a group of farmer leaders representing twelve states in the North Central region committed to improving soybeans through university research. NCSRP programs complement state, national and commercial efforts to improve and protect soybean yield and quality and discover and transfer new traits and technologies for farmers' benefit. Projects funded by NCSRP cover a variety of topics including enhancing soybean yield, agronomics and quality through genetics; cover crops; improving disease resistance and overall management for soybean production.

“North Dakota soybean farmers see NCSRP as a wise investment of their checkoff dollars to address regional soybean issues,” said Ed Anderson, Ph.D., NCSRP executive director. “NDSU researchers lead and participate in research and extension projects and programs that help North Dakota and other upper Midwestern soybean growers to be more profitable and productive.”

One study being led from NDSU is “Iron deficient chlorosis: Getting to the root of the problem.” This project is led by Phil McClean with contributions from Ted Helms, both of NDSU. They are also collaborating with Robert Stupar and Jim Orf of the University of Minnesota.

This project is looking at soybean genetics to determine how to improve resistance to Iron deficiency chlorosis (IDC) without decreasing yields. The group will be testing several genes to determine the most effective combination. While conditions for IDC are not present every year, researchers have identified molecular markers for soybean breeders to use in determining if the genes are present and effective.

“”This project is looking at soybean genetics to determine how to improve resistance to Iron deficiency chlorosis.” “
The second study involving NDSU is “Soybean aphid management, resistance and outreach in the North Central region.” Dr. Deirdre Prischmann, Dr. Jason Harmon and Dr. Janet Knodel of NDSU join 27 researchers from 12 states, including 11 NCSRP member-states, on a project led by Kelley Tilmon of South Dakota State University to conduct one of the most collaborative studies across the region.

“As the NCSRP farmer board seeks to drive the greatest Return-on-investment of their checkoff dollars, they cite the multi-state aphid project as a good example of a diverse and collaborative program that has brought great basic and practical knowledge to researchers and farmers alike,” said Anderson.

This project focuses on one of the most detrimental pests to soybean yields, the soybean aphid. Investigators continue to look at control techniques including management, breeding for resistance, studying genomes and biological control along with a detailed plan for outreach about the results. Regional screening revealed 15 soybean aphid populations that were resistant to usual treatments. An automated aphid counting system for cell phones was researched and current economic thresholds were challenged as part of this study. NDSU researchers were part of the program team that was focused primarily on integrated pest management considering resistant varieties, seed treatments, agronomic factors and the economic return on different soybean aphid management strategies. Results are being communicated to help farmers make profitable and sustainable management decisions.