On-Farm Cropping Trials
Northwest and West Central Minnesota

2011 Minnesota Wheat Research Review
This is the fourth year the Research Review and On-Farm Cropping Trials have been combined into one booklet. Up until then, these reports have been published separately.

On-Farm Cropping Trials
The mission of the NWROC is to contribute, within the framework of the Minnesota Agricultural Experiment Station (MAES) and the College of Food, Agricultural, and Natural Resource Sciences to the acquisition, interpretation and dissemination of research results to the people of Minnesota, with application to the knowledge base of the United States and World. Within this framework, major emphasis is placed on research and education that is relevant to the needs of northwest Minnesota, and which includes projects initiated by Center scientists, other MAES scientists and state or federal agencies.

Contributors to the On-Farm Trials include: Russ Severson, Extension Educator, Extension Regional Office, U of M Crookston, rseverso@umn.edu; Doug Holen, Extension Educator, Extension Regional Office, Fergus Falls, holeno09@umn.edu; Phillip Glogoza, Extension Educator, Extension Regional Office, Moorhead, glogo001@umn.edu; Ben Arlt, Extension Educator, Mahnomen and Norman Counties, Mahnomen, arltx013@umn.edu; Jochum Wiersma, Small Grain Specialist, Crookston, wiers002@umn.edu; Ian MacRae, Extension Entomologist, Crookston, macra002@umn.edu; Howard Person, Extension Educator, Pennington and Marshall Counties, Thief River Falls, perso005@umn.edu; Jim Orf, Dept Agronomy & Plant Genetics, St. Paul, orfxx001@umn.edu; Jeff Coulter, Extension Agronomist, Dept of Agronomy, St. Paul, coult077@umn.edu; Paul R. Peterson, Extension Agronomist-Forages, St. Paul, peter072@umn.edu; Albert Sims, Soil Scientist, Crookston, simsx008@umn.edu; Jim Stordahl, Extension Educator, Polk County, stordahl@umn.edu; Dan Kaiser, Extension Soil Scientist, St. Paul, dekaiser@umn.edu; Senyu Chen, Southern Research and Outreach Center, chenx099@umn.edu; Randy Nelson, Extension Educator, Clay County, MN, nels1657@umn.edu;

This project was made possible thanks to the hard work of many people. This includes farmers, County and Regional Extension Educators, and specialists who conducted these trials, and their names are listed. Previous On-Farm Cropping Trials booklets can be found at http://www.nwroc.umn.edu/Cropping_Issues/index.htm.

2011 Wheat Research Review
Researchers submit progress reports on projects funded partially or in full by the committee’s recommendation. Research progress is communicated to the public. Crop scientists participate in a research reporting session held each year that is open to the public. The Council feels this committee has been an efficient vehicle for not only prioritizing wheat checkoff funds, but also in improving the dissemination of results. Better practices to plant better wheat is our goal. To that end, we encourage your input on this committee, and your feedback on the wheat research projects that are funded by the Minnesota Wheat Checkoff.

Members of the 2011 - 2012 Small Grains Research & Communications Committee include Brian Borge; Mark Fillbrandt, Bigg Dogg Agg; David Garrett, AgriMaxLLC; Doug Holen, U of M Regional Extension Service; Carter Hontvet; Peter Hvidsten; Carol Ishimaru, U of M Dept of Plant Pathology; Brian Jensen, MN Wheat Council; Scott Lee; Richard Magnusson; Dean Maruska, Bayer CropScience; Wayne Olson; Larry J. Smith, University of Minnesota; Brian Sorensen, Dakota Specialty Milling; David Torgerson, MN Wheat; Jochum Wiersma, U of M Small Grains Specialist; Dave Willis, Agassiz Crop Management; Marv Zutz, Minnesota Barley.

Information about the committee and previously funded research can be found online at www.smallgrains.org. Click on the Research tab.

On the Cover: University of Minnesota wheat and barley breeding material is subject to mist irrigation throughout critical growing stages to induce disease related stresses. The cover photo shows the mist irrigation system operating in the St. Paul disease nursery. These mist irrigated nurseries provide a consistent environment, on an annual basis, which allows the breeders to throw out the susceptible genetics and keep the most resistant lines that will someday become new varieties. Dr. Ruth Dill- Macky, U of M Plant Pathologist is the lead scientist running and maintaining the mist nurseries in St. Paul. Without the Small Grains Disease Initiative funding, from the State of Minnesota, these nurseries would not have been possible. The nurseries are a critical component of the process for developing varieties with improved scab resistance.
Table of Contents - On-Farm Cropping Trials For NW & WC MN

2011 Corn MESZ Rate Trials - NW-MN.................................................................5
Corn Response to Micronutrients Across Minnesota.........................................................6
Soybean Variety Trial - Norman County.................................................................8
2011 Corn Zn Rate Trials - NW MN.................................................................10
Corn Response to Sulfur in Northern Minnesota.......................................................11
Effects of QLF TS Terra Fed® and Organic Renewal™ on Organically Grown Corn - Clay County.......14
Effect of Tire Ruts on Crop Growth and Yield - Yellow Medicine.................................15
County Soybean Variety Plots - Kittson, Roseau / LOW County.................................16
MicroEssentials - SZ® as a Fertilizer Source for Soybean........................................18
Soybean Response to Micronutrients Across Minnesota.............................................20
County Soybean Variety Plots - Marshall, Polk, Red Lake / Pennington County.............22
# Table of Contents - Research Reporting Report

- **Wheat Yield, Quality and Plant Health Parameters from Starter Applications of MicroEssentials and ESN in Northwest Minnesota**  
  Nancy Jo Ehlke, Department of Agronomy and Plant Genetics, U of M  
  page 26

- **Accelerated Breeding Resistance to Fusarium Head Blight**  
  Karl D. Glover, Plant Science Department, SDSU  
  page 30

- **Determining Wheat Response to Tile Drainage In the Red River Valley**  
  Hans Kandel and Joel Ransom, Department of Plant Sciences, NDSU  
  page 33

- **Transfer of Leaf and Stem Rust Resistance Genes to Hard Red Winter Wheat Genetic Backgrounds**  
  Francois Marais, Department of Plant Sciences, NDSU  
  page 38

- **Coordinated Effort to Isolate a Fusarium Head Blight Resistance Gene**  
  Gary J. Muehlbauer, Department of Agronomy and Plant Genetics, U of M  
  page 40

- **Developing an Interactive Web-based Variety Selection Tool for Wheat**  
  Joel Ransom, Department of Plant Sciences, NDSU  
  page 42

- **A Coordinated Research Plan to Address Bacterial Leaf Streak**  
  Ruth Dill-Macky, Department of Plant Pathology, U of M  
  page 43

- **Effect of Location and Genotype on Arabinoxylan Production in HRS Wheat from Minnesota**  
  Senay Simsek, Department of Plant Sciences, NDSU  
  page 47

- **Strategies for Maintaining Grain Protein in Diverse Spring Wheat Varieties**  
  Joel Ransom, Department of Plant Sciences, NDSU  
  page 50

- **Processed Wheat Bran as a Food that Decreases Food Intake**  
  Daniel Gallaher, Department of Food Science and Nutrition, U of M  
  page 51

- **Protein and Yield Response to Nitrogen Fertilizer and Variation of Plant Tissue Analysis in Wheat**  
  Daniel Kaiser, Department of Soils, Water and Climate, U of M  
  page 54

- **Minnesota Small Grain Pest Survey Scouting**  
  Doug Holen, U of M Extension Regional Office, Fergus Falls  
  page 65

- **Evaluation of Winter Wheat Germplasm for Resistance to Stem, Leaf and Stripe Rust**  
  Maricelis Acevedo, Department of Plant Pathology, NDSU  
  page 69

- **Positioning NDSU Spring Wheat Breeding Program to Better Serve MN Wheat Growers**  
  Mohamed Mergoum, Dept. of Plant Sciences, NDSU  
  page 71

- **Refining Nitrogen Recommendation Zones for Hard Red Spring Wheat in Minnesota**  
  Jochum Wiersma, Northwest Research & Outreach Center, U of M  
  page 75

- **Expanding Wheat Breeding and Genetics**  
  James A. Anderson, Dept. of Agronomy and Plant Genetics, University of Minnesota  
  page 77

- **2011 Red River Valley Variety Trial Results and Selection Guide - Barley**  
  page 79

- **2011 Red River Valley Variety Trials Results and Selection Guide - Spring Wheat**  
  page 82

- **2011 Spring Wheat and Barley Variety Performance in Minnesota**  
  (Preliminary Report)  
  page 91
On-Farm Cropping Trials

2010 Corn MESZ Rate Trials - NW MN

Cooperators: J&J Agronomy LLC (John & Jeff Halland)
Nearest Towns: Gary, MN
Planting Date: May 12, 2011 (7-inch twin rows spaced 30 inches apart)
Harvest Date: September 29, 2011 (35,000 plants/acre)
Experimental Design: Randomized Complete Block with 4 replications

Purpose of Study:
Many fertilizer suppliers in NW and WC Minnesota have switched to selling Micro-essentials MESZ which contains 10% nitrogen, 40% phosphorus, 10% sulfur and 1% zinc in each granule of fertilizer which replaces the MAP or DAP previously sold to supply starter fertilizer nitrogen and phosphorus for crop production. Additional information is needed for this new product in the market related to the crop response in corn.

Results:
The two MESZ rate trials were established in a corn growers’ production field near Gary, MN in Norman County with two rates of MESZ (75 lb/a and 150 lb/a) supplemented with additional N as Urea to equal 120 lb/a nitrogen compared to a control plot with 120N, 50P₂O₅, 50K₂O, 11S and 0 Zn with the three treatments replicated four times. The plots were then treated as part of the growers field for the remainder of the growing season. 10 linear feet of the center two twin-rows of the plot were hand harvested and shelled to determine corn grain yields. Ear-leaf samples were collected on August 17, 2011 and analyzed for nutrient content at AGVISE Laboratory.

There were no significant differences among the control, the 75 or 150 lb/a MESZ treatments with respect to yield, test weight, oil %, protein %, or starch % for the grain analyzed from either location. There were no significant differences to the mineral analysis of the ear-leaf samples to the variables total-N, P, K, S, Ca, Mg, Zn, Fe, Mn, Cu or B, either.

The soil test data for the north and south plots were 4 ppm Olson P, 140 ppm K, 5.5% organic matter with a pH of 8.1. The north plots had a zinc level of 0.33 ppm and an S level of 4 lb/ac, while the south plots had a zinc level of 0.42 ppm and sulfur was 70 lb/ac.

The 2011 growing season was not as favorable early on for corn growth and development due to excessive moisture and cooler conditions. Dryer and above normal heat later in the season was beneficial for the crop for growth and development. These conditions may have contributed to the lack of a response.

<table>
<thead>
<tr>
<th>South plot</th>
<th>North plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESZ</td>
<td>Yield 15.5%</td>
</tr>
<tr>
<td>lb/a</td>
<td>bu/a</td>
</tr>
<tr>
<td>Control</td>
<td>148.3</td>
</tr>
<tr>
<td>75</td>
<td>143.0</td>
</tr>
<tr>
<td>170</td>
<td>133.2</td>
</tr>
<tr>
<td>LSD₀.₀₅ = NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

For Additional Information:
Russ Severson, Ben Arlt, Jim Stordahl & Dan Kaiser
Research assistance provided by the NW Research and Outreach Center, Crookston
**Corn Response to Micronutrients Across Minnesota**

**Fertilizer:**
- Treatments
  1) Control (Chk) - no fertilizer
  2) Without Zinc (-Zn)
  3) Without Manganese (-Mn)
  4) Without Copper (-Cu)
  5) Without Boron (-B)
  6) All - 10 lb/ac Zn + 10 lb/ac Mn + 10 lb/ac Cu + 5 lb/ac B

Nitrogen, Phosphorus, and Potassium kept at non-limiting levels. Fertilizer was broadcast and incorporated before planting except for Delavan which was managed with no-tillage.

**Weed Management:** Glyphosate

**Experimental Design:** Randomized complete block design with 4 replications

**Objective:** The purpose of this study was to determine if there is a potential yield response in corn to selected micro-nutrients applied broadcast before planting.

**Results:**
This study used a simple drop out design to study the effects of micronutrients by comparing plots with 4 micronutrients with plots where one of the particular nutrients are not applied. To test treatment effects, an analysis of variance procedure was used to determine whether any of the treatments were significantly different. When the analysis indicated significance, all treatments with a particular nutrient were averaged and compared to averages of treatments without. Initial soil test results are given in Table 1. Soil samples were taken at 0-6” soil depth from all locations. However, at the time of this report the samples from three of the locations are still being analyzed. Soil types varied by location. The soil at Oklee was a Northwood muck, Rochester was a Marshan silt loam, Staples was a Verndale sandy loam, and Westport was an Estherville loam. The Oklee site was selected because of the high amounts of organic matter (data not shown). This was to better evaluate response to copper since these types of soils typically are more responsive to copper (Cu) in small grains. Corn is somewhat sensitive to Cu deficiency according to many reports. However, most mineral soils contain plenty of copper to satisfy the needs of most crops. Typically zinc (Zn) is the most deficient micronutrient reported in corn.

Reports of lowered micronutrient uptake in glyphosate tolerant crops have spurred interest in Manganese (Mn), especially in soybean. However, no documented cases of Mn deficiency in corn have been reported outside of areas of the country that have

<table>
<thead>
<tr>
<th>Location</th>
<th>County</th>
<th>P</th>
<th>K</th>
<th>Zn</th>
<th>Mn</th>
<th>B</th>
<th>OM</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oklee</td>
<td>Red Lake</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Rochester</td>
<td>Olmsted</td>
<td>66</td>
<td>185</td>
<td>1.9</td>
<td>53.7</td>
<td>0.4</td>
<td>3.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Staples</td>
<td>Wadena</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Westport</td>
<td>Pope</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

P, Bray-P1 phosphorus; K, ammonium acetate potassium; Zn, DTPA zinc; Mn, DTPA manganese; B, hot water extracted boron; OM, organic matter loss on ignition; pH, 1:1 soil: water; na, data not available

For Additional Information:
Daniel Kaiser (dekaiser@umn.edu) 612-624-3482

Project Funding Provided by:
Agrumi
Corn Response to Micronutrients Across Minnesota (continued)

Year 1 Summary
- Corn is not known to respond to any micronutrient other than zinc in Minnesota.
- Grain Yield was increased by one or more micronutrients at one location.
- At Staples, either Zn or Cu increased yields. Soil test data to confirm initial levels of either was not available at the time of this summary to indicate if either or both was deficient.
- Corn grain harvest moisture was not affected by micronutrient application at any location.

Soils historically low in Mn. The final micronutrient, Boron (B) was included since soil tests ran on sandy soils typically will show lower boron levels. However, corn is not as sensitive to B deficiency as crops such as alfalfa. Therefore, the current fertilizer suggestions for corn do not include any B applications to corn. Two of the locations included sandy soils or soils that have high leaching potentials (Staples and Westport). Borate is the form of B in the soil and is highly leachable. Typically soils low in B are sandy soils low in organic matter. Another major issue with B application is B toxicity which can be a significant problem in crops due to the over application of the nutrient.

Yield data is given in Table 2 (reported yields are adjusted to 15.5% moisture). Grain yields were high at all locations except for the peat/muck soil site at Oklee. This site was wet early in the year and had a hard frost before the corn reached physiological maturity. Consequently yield potentials were limited at this site and calculated grain moisture were very high (Table 3). There were no significant yield increases at Oklee, Rochester, or Westport. The only site that soil test data were available was the Rochester location which tested high in Zn and Mn was adequate according to data from states which have Mn guidelines for crops (from the Tri State fertilizer recommendations MI, OH, IN). Soils typically responsive to Mn in those areas are high in organic matter and also have high pH. The Oklee site would fit this description, but still yields were not affected. The only site where there was a significant yield increase was Staples. At this location plots receiving Zn and Cu both appeared to have yields 7 bu/ac higher than those without. Even though we cannot tell whether both did have an effect, it is likely that Zn increased yields due to the soil type at this location and the fact that Zn is the micro-nutrient most likely to be deficient. Soil test values from this location can help to confirm this result.

Grain moisture data is given in Table 3. Nutrient deficiencies can delay maturity thereby significantly influencing grain moisture levels at harvest. In this study there was no significant increase or decrease in grain moisture at harvest for any of the micronutrient treatments. At Oklee the grain harvest moisture were extremely high. This may have been due to extreme shrinkage of the kernel following the hard freeze and the plot not being fully mature. Harvest moistures were much lower at all other locations.

---

Table 2. Corn Yield (@15.5%) summary by treatment for each location.

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Chk</th>
<th>-Zn</th>
<th>-Mn</th>
<th>-Cu</th>
<th>-B</th>
<th>All</th>
<th>P&gt;F +</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>----</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Oklee</td>
<td></td>
<td>105</td>
<td>117</td>
<td>109</td>
<td>116</td>
<td>113</td>
<td>109</td>
<td>0.26</td>
</tr>
<tr>
<td>Rochester</td>
<td></td>
<td>243</td>
<td>238</td>
<td>241</td>
<td>227</td>
<td>237</td>
<td>233</td>
<td>0.30</td>
</tr>
<tr>
<td>Staples</td>
<td></td>
<td>189c</td>
<td>191bc</td>
<td>197ab</td>
<td>191bc</td>
<td>202a</td>
<td>199ab</td>
<td>0.03</td>
</tr>
<tr>
<td>Westport</td>
<td></td>
<td>196</td>
<td>193</td>
<td>194</td>
<td>199</td>
<td>194</td>
<td>189</td>
<td>0.69</td>
</tr>
</tbody>
</table>

+ Treatments are significantly different when \( P < 0.05 \)

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Table 3. Corn grain moisture summary by treatment for each location.

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Chk</th>
<th>-Zn</th>
<th>-Mn</th>
<th>-Cu</th>
<th>-B</th>
<th>All</th>
<th>P&gt;F +</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>----</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Oklee</td>
<td></td>
<td>41.6</td>
<td>38.5</td>
<td>40.2</td>
<td>38.9</td>
<td>40.0</td>
<td>41.7</td>
<td>0.14</td>
</tr>
<tr>
<td>Rochester</td>
<td></td>
<td>15.7</td>
<td>15.6</td>
<td>16.2</td>
<td>15.7</td>
<td>15.6</td>
<td>15.6</td>
<td>0.71</td>
</tr>
<tr>
<td>Staples</td>
<td></td>
<td>13.3</td>
<td>13.1</td>
<td>13.1</td>
<td>13.0</td>
<td>13.0</td>
<td>13.1</td>
<td>0.46</td>
</tr>
<tr>
<td>Westport</td>
<td></td>
<td>14.2</td>
<td>14.6</td>
<td>15.1</td>
<td>15.0</td>
<td>14.6</td>
<td>15.4</td>
<td>0.14</td>
</tr>
</tbody>
</table>

+ Treatments are significantly different when \( P < 0.05 \)

---

For Additional Information:
Daniel Kaiser (dekaiser@umn.edu)
612-624-3482
On-Farm Cropping Trials

Soybean Variety Trial - Norman County

Cooperators: Wayne & John Brandt, Ada, MN
Location of Plot: 3 mi. North on Hwy # 9 from Hwy 200 in Ada, MN and 2 3/4 mi. east on Co. Rd 23.
Green Meadow Twp. Planted: T145N-R45W, NW 1/4 Sec. 31 June 11, 2011
Chemicals: Power Max 22 oz./A + 6 oz./A Select on July 18, 2011
Planting help: Craig Larson, Ray Bisek, Dan Ness, Ken Pazdernik, Mark Olson, John Brandt (Farmer) Data for Protein, Oil and Moisture run at NW Research and Outreach Center, Crookston, MN
Data Analyzed by Dr. Phil Glogoza
Plot Manager: Pazdernik Agronomy Services, Ken Pazdernik, 218-206-4499 or email pazdernik@loretel.net

Purpose of Study:
To expand the soybean research effort in NW Minnesota involving growers and county soybean associations in research and communications and provide more localized soybean yield data for producers to use in making choices of future soybean varieties to plant on their farms.

Table 2. Late RM Varieties evaluated for Norman County. 2011.

<table>
<thead>
<tr>
<th>Company</th>
<th>Variety</th>
<th>RM</th>
<th>Yield*</th>
<th>Protein</th>
<th>Oil</th>
<th>Moisture</th>
<th>Plant Ht.**</th>
<th>Maturity***</th>
</tr>
</thead>
<tbody>
<tr>
<td>NK Brand</td>
<td>S06-H5 Brand</td>
<td>0.6</td>
<td>45.3</td>
<td>34.4</td>
<td>17.5</td>
<td>9.1</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>Proseed</td>
<td>P2 11-60</td>
<td>0.6</td>
<td>42.4</td>
<td>32.9</td>
<td>17.1</td>
<td>9.1</td>
<td>25</td>
<td>8</td>
</tr>
<tr>
<td>Gold Country Seed</td>
<td>O840</td>
<td>0.8</td>
<td>41.4</td>
<td>33.0</td>
<td>16.9</td>
<td>9.3</td>
<td>26</td>
<td>9</td>
</tr>
<tr>
<td>Legend Seed</td>
<td>06R21</td>
<td>0.6</td>
<td>40.7</td>
<td>32.9</td>
<td>16.9</td>
<td>9.5</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>Mustang Seeds</td>
<td>O8331</td>
<td>0.8</td>
<td>40.5</td>
<td>33.5</td>
<td>16.8</td>
<td>9.5</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>Dairyland Seed</td>
<td>0603RR2Y</td>
<td>0.6</td>
<td>39.4</td>
<td>33.8</td>
<td>16.8</td>
<td>9.7</td>
<td>27</td>
<td>8</td>
</tr>
<tr>
<td>REA Hybrids</td>
<td>67G61</td>
<td>0.7</td>
<td>37.4</td>
<td>33.5</td>
<td>16.3</td>
<td>10.1</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>NK Brand</td>
<td>S08-A2 Brand</td>
<td>0.8</td>
<td>37.3</td>
<td>32.4</td>
<td>17.3</td>
<td>9.7</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>Renk Seed</td>
<td>RS061 R2</td>
<td>0.6</td>
<td>37.0</td>
<td>32.6</td>
<td>17.1</td>
<td>10.0</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>Producers Hybrids</td>
<td>0609 R2</td>
<td>0.6</td>
<td>35.9</td>
<td>33.4</td>
<td>17.4</td>
<td>13.6</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Thunder Seed</td>
<td>3106 R2Y</td>
<td>0.6</td>
<td>35.8</td>
<td>32.7</td>
<td>17.3</td>
<td>14.2</td>
<td>26</td>
<td>8</td>
</tr>
</tbody>
</table>

LSD (0.05) = 4.2 0.6 1.3 --- ---

* Yield (bu/a) adjusted to 13.5 % Moisture
** Plant height measured on 8-18-2011 from first rep. by Ken Pazdernik
*** Maturity rating on 9-14-2011, Rating 1 is ripe to 9 is green, by Ken Pazdernik
## Soybean Variety Trial - Norman County (continued)

### On-Farm Cropping Trials

#### Table 1. Early RM Varieties evaluated for Norman County. 2011

<table>
<thead>
<tr>
<th>Company</th>
<th>Variety</th>
<th>RM</th>
<th>Yield*</th>
<th>Protein</th>
<th>Oil</th>
<th>Moisture</th>
<th>Plant Ht.**</th>
<th>Maturity***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legend Seed</td>
<td>009R20</td>
<td>0.9</td>
<td>46.0</td>
<td>32.8</td>
<td>18.3</td>
<td>8.5</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>NK Brand</td>
<td>S02-B4 Brand</td>
<td>0.2</td>
<td>45.2</td>
<td>32.8</td>
<td>18.5</td>
<td>8.5</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td>Gold Country Seed</td>
<td>O241</td>
<td>0.2</td>
<td>45.1</td>
<td>33.6</td>
<td>17.8</td>
<td>8.8</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>Wensman Seed</td>
<td>3030</td>
<td>0.3</td>
<td>44.8</td>
<td>33.7</td>
<td>17.8</td>
<td>9.2</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>REA Hybrids</td>
<td>65G22</td>
<td>0.5</td>
<td>44.0</td>
<td>33.2</td>
<td>16.9</td>
<td>9.4</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>Legend Seed</td>
<td>02R21</td>
<td>0.2</td>
<td>43.9</td>
<td>33.3</td>
<td>17.8</td>
<td>9.1</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>Proseed</td>
<td>P2 10-40</td>
<td>0.4</td>
<td>43.6</td>
<td>33.6</td>
<td>17.7</td>
<td>9.0</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>Wensman Seed</td>
<td>L30084</td>
<td>0.9</td>
<td>43.3</td>
<td>33.0</td>
<td>17.9</td>
<td>8.9</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Wensman Seed</td>
<td>R3009</td>
<td>0.9</td>
<td>42.7</td>
<td>33.0</td>
<td>18.2</td>
<td>8.6</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Mustang Seeds</td>
<td>O4401</td>
<td>0.4</td>
<td>41.7</td>
<td>33.3</td>
<td>18.0</td>
<td>9.1</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Hyland Seed</td>
<td>HS04RY03</td>
<td>0.4</td>
<td>40.6</td>
<td>33.3</td>
<td>17.9</td>
<td>9.1</td>
<td>21</td>
<td>6</td>
</tr>
<tr>
<td>Hyland Seed</td>
<td>HS009RY01</td>
<td>0.9</td>
<td>40.2</td>
<td>33.1</td>
<td>17.6</td>
<td>9.7</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Thunder Seed</td>
<td>3103 R2Y</td>
<td>0.3</td>
<td>40.0</td>
<td>33.6</td>
<td>17.4</td>
<td>10.8</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Thunder Seed</td>
<td>3105 R2Y</td>
<td>0.5</td>
<td>39.6</td>
<td>34.0</td>
<td>17.3</td>
<td>9.0</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>Proseed</td>
<td>P2 11-50</td>
<td>0.5</td>
<td>39.5</td>
<td>33.0</td>
<td>16.8</td>
<td>9.2</td>
<td>26</td>
<td>6</td>
</tr>
<tr>
<td>Fielders Choice</td>
<td>O092</td>
<td>0.1</td>
<td>39.2</td>
<td>33.0</td>
<td>17.5</td>
<td>9.5</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>Fielders Choice</td>
<td>O400</td>
<td>0.4</td>
<td>39.2</td>
<td>32.9</td>
<td>18.4</td>
<td>9.1</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Hyland Seed</td>
<td>HS01RY02</td>
<td>0.1</td>
<td>38.6</td>
<td>33.0</td>
<td>18.1</td>
<td>9.4</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>Renk Seed</td>
<td>RS 021 R2</td>
<td>0.2</td>
<td>38.4</td>
<td>33.5</td>
<td>18.5</td>
<td>9.8</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>REA Hybrids</td>
<td>65G51</td>
<td>0.5</td>
<td>38.3</td>
<td>32.8</td>
<td>17.3</td>
<td>12.7</td>
<td>26</td>
<td>7</td>
</tr>
<tr>
<td>Stine Seed</td>
<td>01RA06</td>
<td>0.1</td>
<td>37.7</td>
<td>33.6</td>
<td>17.3</td>
<td>11.2</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Seeds 2000</td>
<td>2051 RR2y</td>
<td>0.5</td>
<td>37.5</td>
<td>32.9</td>
<td>17.1</td>
<td>9.2</td>
<td>30</td>
<td>6</td>
</tr>
</tbody>
</table>

LSD (0.05) = 3.5 0.5 0.3 0.6 --- ---

* Yield (bu/a) adjusted to 13.5 % Moisture
** Plant height measured on 8 -18-2011 from first rep. by Ken Pazdernik.
*** Maturity rating on 9-14-2011, Rating 1 is ripe to 9 is green, by Ken Pazdernik.

For Additional Information: Ken Pazdernik and Ben Arlt
2011 Corn Zn Rate Trials - NW MN

Cooperators: J&J Agronomy LLC (John & Jeff Halland)
Nearest Towns: Gary, MN
Planting Date: May 12, 2011 (7-inch twin rows spaced 30 inches apart)
Harvest Date: September 29, 2011 (35,000 plants/acre)
Experimental Design: Randomized Complete Block with 4 replications

Purpose of Study:
U of M calibration and correlation data on zinc is very limited in northern Minnesota. Additional information is needed on the response of the newer corn genetics to zinc fertility. There are several fields in the northern region testing less than 0.5 ppm Zn.

Results:
The two zinc rate trials were established in a corn growers' production field near Gary in Norman County with fertilizer zinc rates of 0, 2.5, 5, 10, 15 & 20 pounds of zinc per acre with the treatments replicated four times. The zinc source was 36% zinc sulfate which was broadcast and incorporated prior to planting. N, P, & K were added to the site at sufficient rates. The plots were treated as part of the growers field for the remainder of the growing season. Ten linear feet of the center two twin-rows of the plot were hand harvested and shelled to determine corn grain yields. Zinc fertilizer response is suspected with a soil test of 0.5 ppm zinc or less. The two research sites soil test zinc were north plot 0.33 ppm Zn and south plot 0.42 ppm Zn, respectively.

Neither plot responded to zinc this year for grain yield and test weight even though the soil test was below 0.5 ppm Zn. The 2011 growing season was not as favorable early on for corn growth and development due to excessive moisture and cooler conditions. Dryer and above normal heat later in the season was beneficial for crop growth and development and may have contributed to a lack of response. Ear-leaf samples from August 17, 2011 showed a significant increase in zinc uptake at both the north and south sites as one would expect with the rates applied.

<table>
<thead>
<tr>
<th>South plot (0.42 ppm ZN)</th>
<th>North plot (0.33 ppm ZN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZN Rate</td>
<td>Yield 15.5%</td>
</tr>
<tr>
<td>lb/a</td>
<td>bu/a</td>
</tr>
<tr>
<td>0</td>
<td>148.3</td>
</tr>
<tr>
<td>2.5</td>
<td>148.0</td>
</tr>
<tr>
<td>5</td>
<td>137.7</td>
</tr>
<tr>
<td>10</td>
<td>146.8</td>
</tr>
<tr>
<td>15</td>
<td>143.6</td>
</tr>
<tr>
<td>20</td>
<td>160.0</td>
</tr>
<tr>
<td>LSD (0.05)=</td>
<td>NS</td>
</tr>
</tbody>
</table>

For Additional Information:
Russ Severson, Ben Arlt, Jim Stordahl & Dan Kaiser

Project Funding Provided by: Minnesota Corn Research and Promotion Council

Research assistance provided by the NW Research and Outreach Center, Crookston
On-Farm Cropping Trials

Corn Response to Sulfur in Northern Minnesota

Treatments:
Study 1: Combination of spring applied sulfur source and rate
- Sources: 1) Ammonium Sulfate (21-0-0-24s)
  2) Sulf-N® 26 (26-0-0-14s)
- Rates: 0, 5, 10, 20, and 30 lbs S/ac
Study 2: Nitrogen rates with and without sulfur
- Sulfur rates: 0 and 25 lbs S per acre as spring applied ammonium sulfate
- Nitrogen rates: 0, 50, 100, 150, 200, 250 lbs N as spring applied urea

Previous Crops:
Study 1: Soybeans; Study 2: Corn

Objective:
Study 1: To compare the effects of sulfur source and rate on corn grain yield and moisture
Study 2: To evaluate corn grain yield and harvest moisture response to nitrogen when sulfur is and is not applied.

Results:
The initial soil test values for each study are listed in Table 1. Both studies evaluated the use of sulfur for corn. For study 1 two fertilizer sources were applied at 4 rates at the Mahnomen location and 5 rates at Westport. The two sources compared were dry granular ammonium sulfate and Sulf-N®. The Sulf-N sources is a fused ammonium sulfate nitrate product that is water soluble. Space was limited at Westport so only the Sulf-n treatment was included at that location. Nitrogen was added to equal out the amount applied by all treatments. Study two focused on the interaction between nitrogen and sulfur on the yield of corn. Two locations were studied, one in SE Minnesota on low organic matter soils (3.0% or less in the top 6” depth) that have responded to sulfur in the past and on a continuous corn field in NW Minnesota. Research has found some yield benefit from applying sulfur in continuous corn regardless of soil organic matter level. The NW Minnesota fields were added to compare data from the NW area with those in southern MN that have responded to sulfur to determine if sulfur suggestions for corn can be universal across the state. The Mahnomen site included an eroded knoll similar to soil conditions in southern Minnesota on which sulfur responses have been seen. In study two, both locations were managed with continuous corn and all N and S fertilizer was spring applied and incorporated prior to planting.

Table 2 includes the summary statistics for the main treatment effects for study 1. At the Mahnomen location both sulfur source and rate significantly differed. The interaction between the two was not significantly different but the probability level was close to the accepted level. A significant interaction would indicate that the effect of sulfur rate varied by sulfur source.

Table 1. Initial soil test data for 0-6” samples collected from Study 1 sites (Mahnomen and Westport) and Study 2 sites (Elbow Lake and Saint Charles).

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Series</th>
<th>County</th>
<th>P</th>
<th>K</th>
<th>S</th>
<th>OM</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahnomen</td>
<td>Barnes-Langhei</td>
<td>Mahnomen</td>
<td>15</td>
<td>115</td>
<td>3</td>
<td>3.1</td>
<td>7.9</td>
</tr>
<tr>
<td>Westport</td>
<td>Estherville</td>
<td>Pope</td>
<td>53</td>
<td>138</td>
<td>3</td>
<td>6.6</td>
<td>6.2</td>
</tr>
<tr>
<td>Elbow Lake</td>
<td>Towner</td>
<td>Grant</td>
<td>18</td>
<td>135</td>
<td>57</td>
<td>4.8</td>
<td>7.6</td>
</tr>
<tr>
<td>Saint Charles</td>
<td>Seaton</td>
<td>Winona</td>
<td>14</td>
<td>80</td>
<td>4</td>
<td>2.8</td>
<td>6.8</td>
</tr>
</tbody>
</table>

P, Bray-P1 phosphorus; K ammonium acetate potassium; S, mono-calcium phosphate extractable sulfur; OM, organic matter loss on ignition; pH, 1:1 soil:water

For Additional Information: Daniel Kaiser (dekaiser@umn.edu) 612-624-3482
Project Funding Provided by: Pioneer Hybrid International
Yield (adjusted to 15.5% moisture) data from this study is given in Figure 1. Sulfur applied as AMS increased yields by nearly 30 bu/acre with the 10 lb S rate at the Mahnomen site. For the Sulf-N treatment there was little yield increase until the highest sulfur rate. The 5 lb. sulfur rate did increase yields but not as much as the 10 lb. rate, which agrees with southern MN data on optimal application rate. Application of 20 lb. of S did not result in a further yield increase. There was no difference in yields at the Westport site. Yields were high at this location and it appeared that no sulfur was needed. Similar to sites in southern Minnesota, the low organic matter level at the Mahnomen site likely contributed to the sulfur response and indicates similar S guidelines may be used. Grain moisture was not significantly impacted by sulfur application at either location, therefore the data is not shown.

**Table 2.** Summary statistics for main treatment effects of sulfur source and rate and their interaction for Study 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Site</th>
<th>Statistics +</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--------------</td>
</tr>
<tr>
<td>Yield</td>
<td>Mahnomen</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Westport</td>
<td>--</td>
</tr>
<tr>
<td>Moisture</td>
<td>Mahnomen</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Westport</td>
<td>--</td>
</tr>
</tbody>
</table>

+ Main effects and interactions are significant when $P < 0.05$.  

**Table 3.** Summary statistics for main treatment effects of sulfur application and nitrogen rate and their interaction for Study 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Site</th>
<th>Statistics +</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>--------------</td>
</tr>
<tr>
<td>Yield</td>
<td>Elbow Lake</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>Saint Charles</td>
<td>0.99</td>
</tr>
<tr>
<td>Moisture</td>
<td>Elbow Lake</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>Saint Charles</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

+ Main effects and interactions when $P < 0.05$.  

**Table 4.** Corn grain harvest moisture summary by sulfur and nitrogen rate for Study 2.

<table>
<thead>
<tr>
<th>Site</th>
<th>N Rate</th>
<th>S rate</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow Lake</td>
<td></td>
<td>0</td>
<td>10.7</td>
<td>12.9</td>
<td>11.9</td>
<td>13.0</td>
<td>12.5</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>11.6</td>
<td>12.3</td>
<td>13.2</td>
<td>12.6</td>
<td>13.0</td>
<td>12.9</td>
</tr>
<tr>
<td>Saint Charles</td>
<td></td>
<td>0</td>
<td>20.0</td>
<td>18.4</td>
<td>19.3</td>
<td>20.6</td>
<td>20.4</td>
<td>21.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>20.1</td>
<td>17.8</td>
<td>18.3</td>
<td>18.6</td>
<td>19.2</td>
<td>20.0</td>
</tr>
</tbody>
</table>
For Study 2, grain yield did not respond to sulfur at either of the locations (Table 3). Other sulfur locations showed similar results in 2011, likely as a result of warmer, early season conditions potentially leading to greater mineralization of S and less S needed from fertilizer. The Elbow Lake site had the highest sulfur soil test of either location (Table 1) which is likely due to precipitated gypsum in the soil profile. Yield (Table 3 and Figure 2) was significantly affected by nitrogen rate at both locations. At the Elbow Lake location, yield responded linearly to the highest N rate. High amounts of early season rainfall resulted in the 250 lb. rate not maximizing yield due to N loss. Conversely, at the St. Charles location yield was maximized by 130 lb. of N which is lower than that recommended for continuous corn in SE Minnesota. At both locations there was no evidence that the application of sulfur changed the optimum amount of N that needed to be applied.

Grain moisture was significantly affected by N rate at both locations, while S affected moisture only at St. Charles. As the amount of N increased, grain harvest moisture increased. However, at the St. Charles site the application of sulfur generally resulted in 1% lower grain moisture at harvest. Even though there was no yield response, the savings from dryer grain at harvest could potentially cover the cost of the sulfur application, depending on the amount needed to decrease moisture. This is a result that has been seen at other locations and is likely due to a hastening of maturity.

For Additional Information:
Daniel Kaiser (dekaiser@umn.edu) 612-624-3482
On-Farm Cropping Trials

Effects of QLF TS Terra Fed© and Organic Renewal™ on Organically Grown Corn - Clay County

Cooperator: Lynn Brakke Organic Farms
Nearest Town: Comstock, MN
Soil Type: Bearden loam
Tillage: Spring: One pass with a field cultivator
Previous Crop: Soybean
Planting Date: 5/18/11
Variety: Bison 1
Row Width: 22 inch
Fertilizer: QLF TS Terra Fed© and Organic Renewal™ was applied to the soil on each side of the middle row of three row plots (30 feet long) at 10 gal/ac using a CO₂ pressurized plot sprayer. No spray solution was applied to the untreated check. After application the soil on each side of the middle row in all plots, including the untreated check, was cultivated using a hand held garden hoe.

Planting Population: 32,000 plants/ac
Harvest Date: 10/3/11
Experimental Design: Latin Square with four replicates.

Purpose of Study:
Evaluate the effects of soil applied QLF TS Terra Fed© and Organic Renewal™ on corn yield and quality in an organic production system.

Results:
Twenty feet of row was harvested from the middle row of each three row plot and used to determine yield and quality.

There were no significant difference observed between treatments for yield, protein and oil.

Table 1. Yield and seed quality from organically grown corn treated with QLF TS Terra Fed© or Organic Renewal™. Comstock, MN, 2011.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Spray date</th>
<th>Growth stage</th>
<th>Yield (bu/ac)</th>
<th>Protein (%)</th>
<th>Oil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated check</td>
<td>---</td>
<td>---</td>
<td>121.4</td>
<td>7.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Organic Renewal™ 3.2 fl oz/ac</td>
<td>7/12</td>
<td>V10</td>
<td>129.3</td>
<td>7.2</td>
<td>4.9</td>
</tr>
<tr>
<td>QLF TS Terra Fed© 5 gal/ac</td>
<td>7/12</td>
<td>V10</td>
<td>123.9</td>
<td>6.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Organic Renewal™ 6.4 fl oz/ac</td>
<td>7/12</td>
<td>V10</td>
<td>121.2</td>
<td>7.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

LSD₀·₀₅ = NS NS NS

For Additional Information:
Randy Nelson and Phil Glogoza

Page 14
Effect of Tire Ruts on Crop Growth and Yield - Yellow Medicine

Cooperator: Crop consultant, Frenchie Bellicot and the producers near Clarkfield, MN.
Nearest Town: Clarkfield, MN
Soil Type: Varies
Tillage: Either chisel plow or disk ripped with a spring field cultivation
Previous Crop: Corn and soybean rotation on all fields
Field Info: All producers used their own weed, pest, and fertility regimes

Purpose of Study:
The fall of 2009 received abnormally high levels of precipitation and a majority of the fields received ruts from the combine during harvest. Seven field were chosen to look at the long-term affect of tire ruts on the stand, height, yield of corn and soybeans.

Results:
In 2010, at seven locations, 1/1000th of an acre was flagged in a rutted area of the field and 2 to 3 rows over in a non-rutted area. Plant height and corn growth stage was lower (8.5") for the rutted areas versus the areas that did not receive ruts (table 1). The early and final stands were not affected by the soil disruption (table 1 and 2). Corn yield (table 2) was lower by an average of 27.3 bu/ac, a 17% yield decrease.

In 2011, the same seven locations were flagged to look at the soil ruts affect on soybean growth and yield. On July 20th, the plant height was shorter by 5.3" in the rutted areas of the fields (table 3). Again, as with corn stand, soybean population was not statistically affected by rutting (table 3). Soybean vegetative growth was behind by a staging of 1.9 and the reproductive growth was behind by 1 stage in the rutted areas (table 3).

Due to the soybean grain moisture dropping at a rapid rate, 4 of the seven fields were harvested before we could hand harvest the grain. Table 4 lists the yield average for three of the seven fields. Grain moisture was not affected due to rutting, however, the yield decreased an average of 16% (4 bu/ac) due to the rutting affects from two previous years.

This study will be continued in 2012, at the seven fields, to determine if the rutting will have an affect on corn yield three years after the initial rutting event.

For Additional Information: Jodi DeJong-Hughes and Jeff Coulter
Project Funding Provided by: U of M Extension

### Table 1. Corn height, population and growth stage in 2010.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant Height (inches)</th>
<th>Early Corn Pop (plants/ac)</th>
<th>Corn Growth (V Stage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Ruts</td>
<td>31.0</td>
<td>29,900</td>
<td>10.4</td>
</tr>
<tr>
<td>Ruts</td>
<td>22.5</td>
<td>28,900</td>
<td>9.1</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>6.5</td>
<td>NS</td>
<td>0.7</td>
</tr>
</tbody>
</table>

### Table 2. Corn final population, grain moisture and yield in 2010.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Final Pop (plants/ac)</th>
<th>Grain Moisture (%)</th>
<th>Corn Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Ruts</td>
<td>29,100</td>
<td>14.9</td>
<td>158.6</td>
</tr>
<tr>
<td>Ruts</td>
<td>29,100</td>
<td>15.1</td>
<td>131.3</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS</td>
<td>NS</td>
<td>11.1</td>
</tr>
</tbody>
</table>

### Table 3. Soybean height, stand and growth stage for 7 fields in 2011.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant Height (inches)</th>
<th>Plant Pop (plants/ac)</th>
<th>V Stage</th>
<th>R Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No ruts</td>
<td>14.9</td>
<td>148,300</td>
<td>8.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Ruts</td>
<td>9.6</td>
<td>138,500</td>
<td>6.1</td>
<td>1.1</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>2.3</td>
<td>NS</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

### Table 4. Soybean grain moisture and yield for 3 fields in 2011.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain Moisture (%)</th>
<th>Soybean Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Ruts</td>
<td>8.1</td>
<td>26.1</td>
</tr>
<tr>
<td>Ruts</td>
<td>8.0</td>
<td>22.1</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>NS</td>
<td>2.1</td>
</tr>
</tbody>
</table>
On-Farm Cropping Trials

County Soybean Variety Plots — Kittson - Roseau/LOW County

Cooperator: Paul Johnson (Hallock) & Drew Parsley (Warroad)
Planting Date: 5/16/11 (Hallock) 5/18/11 (Warroad)
Harvest Date: 9/27/11 (Hallock) 9/26/11 (Warroad)
Experimental Design: RCB 3 replications

Purpose of Study:
To expand the soybean research effort in NW Minnesota involving growers and county soybean associations in research and communications and provide more localized soybean yield data for producers to use in making choices of future soybean varieties to plant on their farms. Additionally these plots provide more environments to evaluate the same varieties to give more confidence in variety selection and stability. These plots will also build collaborative efforts between local soybean associations, Northern Soybean Growers Team, MN Wheat Council and U of M in providing research and education for the region.

<table>
<thead>
<tr>
<th>Late RM Brand</th>
<th>Variety</th>
<th>RM</th>
<th>Hallock</th>
<th>Warroad</th>
<th>Site avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Yield 13% (bu/A)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prairie Brand</td>
<td>PB-0240R2</td>
<td>0.2</td>
<td>63.5</td>
<td>59.5</td>
<td>61.5</td>
</tr>
<tr>
<td>REA Hybrids</td>
<td>61G21</td>
<td>0.1</td>
<td>62.6</td>
<td>60.4</td>
<td>61.5</td>
</tr>
<tr>
<td>Channel</td>
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<td>0.2</td>
<td>64.2</td>
<td>57.1</td>
<td>60.7</td>
</tr>
<tr>
<td>REA Hybrids</td>
<td>62G22</td>
<td>0.2</td>
<td>62.6</td>
<td>57.7</td>
<td>60.2</td>
</tr>
<tr>
<td>Peterson Farms Seed</td>
<td>11R01</td>
<td>0.1</td>
<td>64.7</td>
<td>53.1</td>
<td>58.9</td>
</tr>
<tr>
<td>Proseed</td>
<td>P2 10-20</td>
<td>0.2</td>
<td>59.4</td>
<td>57.8</td>
<td>58.6</td>
</tr>
<tr>
<td>Asgrow</td>
<td>AG0231</td>
<td>0.2</td>
<td>63.4</td>
<td>51.8</td>
<td>57.6</td>
</tr>
<tr>
<td>Legend Seeds</td>
<td>LS 02R21</td>
<td>0.2</td>
<td>60.8</td>
<td>53.7</td>
<td>57.3</td>
</tr>
<tr>
<td>Pioneer Hi-Bred</td>
<td>90Y21</td>
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<td>59.2</td>
<td>55.0</td>
<td>57.1</td>
</tr>
<tr>
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<td>58.3</td>
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<td>56.5</td>
</tr>
<tr>
<td>Nutech Seed</td>
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<td>0.2</td>
<td>54.4</td>
<td>57.9</td>
<td>56.1</td>
</tr>
<tr>
<td>Wilbur-Ellis</td>
<td>Integra 97014R</td>
<td>0.0</td>
<td>54.5</td>
<td>56.4</td>
<td>55.4</td>
</tr>
<tr>
<td>Dyna-Gro</td>
<td>35RY01</td>
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<td>59.8</td>
<td>50.5</td>
<td>55.2</td>
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<tr>
<td>Thunder Seed</td>
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</tr>
<tr>
<td>Hyland Seeds</td>
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<td>60.1</td>
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<td>52.0</td>
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<td>Hefty Seed</td>
<td>H00Y12 (RR2)</td>
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<td>51.5</td>
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<td>Northstar Genetics</td>
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<td>53.3</td>
<td>46.2</td>
<td>49.8</td>
</tr>
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$LSD_{0.05} = 6.6$ 10.5 —
### On-Farm Cropping Trials

#### County Soybean Variety Plots — Kittson - Roseau/LOW County (continued)

<table>
<thead>
<tr>
<th>Brand</th>
<th>Variety</th>
<th>RM</th>
<th>Hallock Yield 13% (bu/A)</th>
<th>Warroad Yield 13% (bu/A)</th>
<th>Site avg. Yield 13% (bu/A)</th>
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<tr>
<td>Legend Seeds</td>
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<td>64.9</td>
<td>63.2</td>
<td>64.0</td>
</tr>
<tr>
<td>Croplan</td>
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<td>0.09</td>
<td>64.6</td>
<td>59.5</td>
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</tr>
<tr>
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<td>PB-00950R2</td>
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<td>61.7</td>
<td>57.5</td>
<td>59.6</td>
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<td>59.0</td>
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<tr>
<td>Wensman Seed</td>
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<td>61.4</td>
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<tr>
<td>Dyna-Gro</td>
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</tr>
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</tr>
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<td>53.7</td>
</tr>
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</tr>
<tr>
<td>Thunder Seed</td>
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<td>0.05</td>
<td>55.6</td>
<td>50.5</td>
<td>53.1</td>
</tr>
<tr>
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<td>58.4</td>
<td>47.6</td>
<td>53.0</td>
</tr>
<tr>
<td>Proseed</td>
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<td>0.05</td>
<td>55.2</td>
<td>49.7</td>
<td>52.5</td>
</tr>
<tr>
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<td>0.09</td>
<td>55.7</td>
<td>48.7</td>
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</tr>
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<td>Legend Seeds</td>
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<tr>
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<td>0.05</td>
<td>55.4</td>
<td>46.9</td>
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<tr>
<td>Thunder Seed</td>
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<td>55.3</td>
<td>46.3</td>
<td>50.8</td>
</tr>
<tr>
<td>Hefty Seed</td>
<td>H007Y12 (RR2)</td>
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<td>missing</td>
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<td>50.6</td>
</tr>
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<td>51.6</td>
<td>43.3</td>
<td>47.4</td>
</tr>
<tr>
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<td>0.05</td>
<td>44.6</td>
<td>33.4</td>
<td>39.0</td>
</tr>
</tbody>
</table>

\[ \text{LSD}_{0.05} = 7.6 \quad 9.1 \quad — \]
Objective:
The purpose of this study was to determine the efficacy of using MicroEssentials-SZ, a multi nutrient fertilizer manufactured by Mosaic, on the yield of soybean and to determine which nutrient or nutrients may be responsible for increased yield.

Results:
This research studied the effect of MicroEssentials-SZ on the yield of soybeans. Treatments were designed to compare the impact of individual nutrients applied with the fertilizer. The product is a multi-nutrient blend of nitrogen (N), phosphorus (P), sulfur (S), and zinc (Zn) that has an analysis of 12-40-0-10-1 (% N-P₂O₅-K₂O-S-Zn). The material is manufactured using dry mono-ammonium phosphate (MAP), ammonium sulfate, elemental sulfur, and zinc oxide. In this study we compared treatments using N only as ammonium nitrate, N and P as MAP, and N, P and S as MAP, ammonium sulfate, and elemental sulfur. All treatments were intended to supply the nutrients in the same amount as the MEZ which was applied at 200 lb. of product per acre (24 lb N, 80 lb P₂O₅, 20 lb S, and 2 lb Zn per acre). Treatment differences were assessed using analysis of variance procedures. When the analysis indicated one or more treatments significantly differed treatment means were compared for response to N, P, K, S, and Zn by averaging treatments with and treatments without each individual nutrient and comparing their means’.

Initial soil test results are given in Table 1. Soil P levels were High to Very High at all locations, K ranged from Medium to Very High, and in general Zinc was higher than levels in which deficiencies are likely to occur in other crops. The only locations where a deficiency of an element was likely was K at the Warroad site which was in the medium classification for soybeans. The Very High levels of soil test P indicate that a response to P from the MEZ product is highly unlikely. There is no established critical value for Zn on soybeans in the state of Minnesota.

Results from soybean trifoliate samples collected at full bloom are given in Table 2 and 3 for the Hallock and

Table 1. Initial soil test data for 0-6” samples collected before treatment application for soybean MicroEssentials - SZ studies.

<table>
<thead>
<tr>
<th>Location</th>
<th>County</th>
<th>Soil Test</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<td></td>
<td>29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27</td>
</tr>
</tbody>
</table>

P,Bray-P1 phosphorus; K ammonium acetate potassium; Zn, DTPA zinc; OM, organic matter loss on ignition; pH, 1:1 soil:water
Warroad locations (samples were collected from all sites but data are not available). Table 2 summarizes trifoliate P levels by treatment. Application of P at Warroad increased trifoliate P concentration. For the cases of S and Zn there was no difference in treatment so the data were averaged across treatments for both locations (Table 3).

All treatments tested sufficient for P and Zn (P: 0.26 to 0.50%; S, no critical level available; Zn, 20 to 50 ppm). Soybean yields (adjusted to 13% moisture) were significantly affected by one or more treatments at the Warroad location (Table 4). Treatment means comparisons indicate that N increased yield by an average of 6 bu/ac at the Warroad site. A comparison could not be made between the trifoliate N concentration and yield response since the data has not been run at this time. However, the effect of P on trifoliate concentration was not translated into higher yield. In no cases did the MEZ treatment increase yields further than any other treatment other than the control (chk). The only other site that showed a small increasing yield trend was at Waseca where yields were slightly higher with P. However this increase, if significant, would be only 1 bu/ac which would not be economical based on the rates applied.

The lack of yield response to the MEZ treatment alone is not surprising since the only difference between that and any other treatment applied is the inclusion of zinc. Soybeans are not known to be highly responsive to zinc as compared to other crops such as corn or edible beans. In addition the sulfur in MEZ did not increase yields. Similar to Zn, soybeans are not known to be highly responsive to sulfur. When applying fertilizer sources such as MEZ or MAP for soybeans, the main consideration should be price per lb. P2O5 or N since these nutrients may significantly affect yields. While soybeans may not respond to S or Zn there could be a benefit from the carry over of these nutrients to following years’ crops.
On-Farm Cropping Trials

Soybean Response to Micronutrients Across Minnesota

Fertilizer: Treatments
1) Control (Chk) - no fertilizer
2) Without Zinc (-Zn)
3) Without Manganese (-Mn)
4) Without Molybdenum (-Mo)
5) Without Boron (-B)
6) All - 10 lb/ac Zn + 10 lb/ac Mn + 0.5 lb/ac Mo + 5 lb/ac B
Phosphorus and Potassium kept at non-limiting levels
Fertilizer was broadcast and incorporated before planting except for Delavan which was managed with no-tillage.

Weed Management: Glyphosate

Experimental Design: Randomized complete block design with 4 replications

Objective:
The purpose of this study was to determine if there is a potential yield response in soybean to selected micronutrients applied broadcast before planting.

Results:
This study used a simple drop out design to study the effects of micronutrients by comparing plots with 4 micronutrients with plots where one of the particular nutrients are not applied. To test treatment effects, an analysis of variance procedure was used to determine whether any of the treatments were significantly different. When the analysis indicated significance, all treatments with a particular nutrient were averaged and compared to averages of treatments without. Initial soil test results are given in Table 1. Soil P levels were High to Very High at all locations, P ranged from Medium to Very High, and in general Zinc (Zn) was higher than levels in which deficiencies are likely to occur. Soil tests were also run for manganese (Mn) and boron (B). There currently are no critical values for soybeans grown in Minnesota for either nutrient since neither has been shown to be deficient. Soybeans are responsive to Mn, however, yield responses are typically seen in areas of the country with soils that have been historically deficient in Mn. Research in Michigan has shown soybean yield increases due to Mn and recommendations exist in that state when soil test levels are less than 24 ppm. The only location with a soil test near that level was the Rock Dell location. Other locations that can exhibit lowered Mn availability are those with high soil pH, but in this case there was no relationship between pH and Mn.

Table 1. Initial soil test data for 0-6” samples collected before treatment application for soybean micronutrients studies.

<table>
<thead>
<tr>
<th>Location</th>
<th>County</th>
<th>P</th>
<th>K</th>
<th>Zn</th>
<th>Mn</th>
<th>B</th>
<th>OM</th>
<th>pH</th>
</tr>
</thead>
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<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
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</tr>
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<td>Polk</td>
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<td>35.5</td>
<td>1.0</td>
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<td>7.5</td>
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</tr>
<tr>
<td>Rochester</td>
<td>Olmsted</td>
<td>66</td>
<td>185</td>
<td>1.9</td>
<td>53.7</td>
<td>0.4</td>
<td>3.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Rock Dell</td>
<td>Olmsted</td>
<td>51</td>
<td>130</td>
<td>3.9</td>
<td>24.3</td>
<td>0.8</td>
<td>3.2</td>
<td>6.8</td>
</tr>
<tr>
<td>Warroad</td>
<td>Lake of the Woods</td>
<td>29</td>
<td>96</td>
<td>1.0</td>
<td>28.1</td>
<td>0.5</td>
<td>2.8</td>
<td>7.6</td>
</tr>
</tbody>
</table>

P, Bray-P1 phosphorus; K, ammonium acetate potassium; Zn, DTPA zinc; Mn, DTPA manganese; B, hot water extracted boron; OM, organic matter loss on ignition; pH, 1:1 soil:water; na, data not available

For Additional Information:
Daniel Kaiser (dekaiser@umn.edu) 612-624-3482

Project Funding Provided by:
Minnesota Soybean Research & Promotion Council
The upper most, fully developed trifoliate was sampled at R2 (full bloom) to assess plant nutrient status at selected sites (Fosston, Hallock, and Rochester were sampled, however, the data from Rochester is not currently available). Twenty samples were collected and composited from each plot and analyzed for zinc, manganese, and boron. Leaf molybdenum concentration was not determined.

Zinc was the only nutrient where the concentration differed between treatments at any site (Table 3). At Fosston leaf zinc content differed between treatments. Table 3 lists the least significant differences between treatments, however, comparisons between treatments with and without specific nutrients indicated that leaf zinc content was greater with the application of molybdenum. However, most concentrations were at or near the sufficient range of 20 to 50 ppm.

Table 4 compares the average tissue concentration for zinc, manganese, and boron across treatments at each location (sufficient ranges: Mn, 21 to 100 ppm; B, 21 to 55 ppm). At both the Hallock and Fosston sites the average tissue concentration fell in the sufficient range for all nutrients. This indicates that it was unlikely that a deficiency was present and yield would be limited. The yield data (reported at 13% moisture) in Table 5 confirms this result.

There was no significant effect of the micronutrients studied on yield at any of the locations. Glyphosate application at many of the southern locations was during periods of high temps which did induce some glyphosate flash symptoms in many fields in 2011. In the fields studied there was no advantage to Mn which has been reported to be limiting when glyphosate flash occurs. Yields in the southern sites were lower which may limit potential response to micronutrients. While there may have been some variability between treatment yields it was likely due to within plot variability.

### Year 1 Summary
- There was no yield advantage for applying Zn, Mn, Mo, or B to soybeans at these locations.
- The potential effect of the climatic conditions at individual locations may have limited potential for determining treatment differences.
- Soil tests did not aid in the determination of where micronutrient deficiencies may occur.
- Plant tissue tests at selected sites agreed with yield data that micronutrients levels were sufficient enough to maintain soybean yields.

### Table 3. Soybean trifoliate zinc concentration from samples taken at R2 (full bloom).

<table>
<thead>
<tr>
<th>Site</th>
<th>Chk -Zn</th>
<th>-Mn</th>
<th>-Mo</th>
<th>-B</th>
<th>All</th>
<th>P&gt;F +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fosston</td>
<td>21abc</td>
<td>20abc</td>
<td>19c</td>
<td>19c</td>
<td>236a</td>
<td>22ab 0.04</td>
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<tr>
<td>Hallock</td>
<td>27</td>
<td>26</td>
<td>29</td>
<td>27</td>
<td>28</td>
<td>26    0.51</td>
</tr>
</tbody>
</table>

+ Treatments are significantly different when P<0.05.

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Nutrient and Sufficiency level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zn</td>
<td>Mn</td>
</tr>
<tr>
<td>Fosston</td>
<td>21</td>
<td>92</td>
</tr>
<tr>
<td>Hallock</td>
<td>27</td>
<td>51</td>
</tr>
</tbody>
</table>

+ SL, sufficiency level: L, Low; S, Sufficient; H, High

### Table 4. Soybean trifoliate nutrient concentration from samples taken at R2 (full bloom) averaged across treatments.

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Nutrient and Sufficiency level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zn</td>
<td>Mn</td>
</tr>
<tr>
<td>Fosston</td>
<td>21</td>
<td>92</td>
</tr>
<tr>
<td>Hallock</td>
<td>27</td>
<td>51</td>
</tr>
</tbody>
</table>

+ SL, sufficiency level: L, Low; S, Sufficient; H, High

### Table 5. Soybean yield summary by treatment for each location

<table>
<thead>
<tr>
<th>Site</th>
<th>Treatment</th>
<th>Chk -Zn</th>
<th>-Mn</th>
<th>-Mo</th>
<th>-B</th>
<th>All</th>
<th>P&gt;F +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delavan</td>
<td>41</td>
<td>40</td>
<td>42</td>
<td>41</td>
<td>43</td>
<td>42</td>
<td>0.86</td>
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<tr>
<td>Fosston</td>
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<td>62</td>
<td>66</td>
<td>62</td>
<td>66</td>
<td>65</td>
<td>0.50</td>
</tr>
<tr>
<td>Hallock</td>
<td>57</td>
<td>55</td>
<td>56</td>
<td>59</td>
<td>59</td>
<td>59</td>
<td>0.36</td>
</tr>
<tr>
<td>Montgomery</td>
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<td>39</td>
<td>39</td>
<td>39</td>
<td>40</td>
<td>36</td>
<td>0.65</td>
</tr>
<tr>
<td>Rochester</td>
<td>38</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>38</td>
<td>38</td>
<td>0.54</td>
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<tr>
<td>Rock Dell</td>
<td>35</td>
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<td>34</td>
<td>32</td>
<td>31</td>
<td>29</td>
<td>0.25</td>
</tr>
</tbody>
</table>

+ Treatments are significantly different when P<0.05.
### On-Farm Cropping Trials

**County Soybean Variety Plots — Marshall, Polk, Red Lake/Pennington County**

_cooperator:_ Cecil Deschene (Argyle), Roger Hinrichs (Red Lake Falls), Kyle Vig (Fosston)

**Planting Date:**
- Argyle: 5/27/11
- Red Lake Falls: 5/19/11
- Fosston: 5/20/11

**Harvest Date:**
- Argyle: 9/30/11
- Red Lake Falls: 9/28/11
- Fosston: 9/29/11

**Experimental Design:** RCB 3 replications

**Purpose of Study:**
To expand the soybean research effort in NW Minnesota involving growers and county soybean associations in research and communications and provide more localized soybean yield data for producers to use in making choices of future soybean varieties to plant on their farms. Additionally these plots provide more environments to evaluate the same varieties to give more confidence in variety selection and stability. These plots will also build collaborative efforts between local soybean associations, Northern Soybean Growers Team, MN Wheat Council and U of M in providing research and education for the region.

<table>
<thead>
<tr>
<th>Early RM</th>
<th>Variety</th>
<th>RM</th>
<th>Fosston</th>
<th>Argyle</th>
<th>Red Lake Falls</th>
<th>Site avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyna-Gro</td>
<td>30RY09</td>
<td>0.9</td>
<td>75.8</td>
<td>58.9</td>
<td>67.4</td>
<td></td>
</tr>
<tr>
<td>Legend Seeds</td>
<td>LS 009R20</td>
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<td>73.2</td>
<td>63.0</td>
<td>65.2</td>
<td>67.2</td>
</tr>
<tr>
<td>Seeds 2000</td>
<td>0091 RR2Y</td>
<td>0.9</td>
<td>75.2</td>
<td>55.9</td>
<td>69.9</td>
<td>67.0</td>
</tr>
<tr>
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<td>W 30091R2</td>
<td>0.9</td>
<td>69.6</td>
<td>63.8</td>
<td>66.7</td>
<td></td>
</tr>
<tr>
<td>Croplan</td>
<td>R2T0091</td>
<td>0.9</td>
<td>74.8</td>
<td>61.9</td>
<td>62.0</td>
<td>66.2</td>
</tr>
<tr>
<td>Asgrow</td>
<td>AG00932</td>
<td>0.9</td>
<td>73.3</td>
<td>61.9</td>
<td>61.7</td>
<td>65.6</td>
</tr>
<tr>
<td>Croplan</td>
<td>R2T0085</td>
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<td>73.7</td>
<td>55.3</td>
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<tr>
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<td>PB-00950R2</td>
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<td>71.6</td>
<td>54.4</td>
<td>67.6</td>
<td>64.5</td>
</tr>
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<td>69.3</td>
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</tr>
<tr>
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<td>NS 0096R2</td>
<td>0.9</td>
<td>68.4</td>
<td>57.3</td>
<td>64.0</td>
<td>63.3</td>
</tr>
<tr>
<td>Thunder</td>
<td>31009 RR</td>
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<td>71.8</td>
<td>53.7</td>
<td>64.3</td>
<td>63.3</td>
</tr>
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<td>Proseed</td>
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<tr>
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<tr>
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<td>0090</td>
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<tr>
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<td>60.7</td>
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<td>58.3</td>
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</table>

LSD <sub>0.05</sub> = 5.3 7.6 5.9

*Table continued on page 23*
## On-Farm Cropping Trials

### County Soybean Variety Plots — Marshall, Polk, Red Lake/Pennington County (continued)

<table>
<thead>
<tr>
<th>Late RM Brand</th>
<th>Variety</th>
<th>RM</th>
<th>Fosston Yield</th>
<th>Argyle Yield</th>
<th>Red Lake Falls Yield</th>
<th>site avg. Yield 13% (bu/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stine Seeds</td>
<td>05RC68</td>
<td>0.5</td>
<td>77.0</td>
<td></td>
<td></td>
<td>77.0</td>
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<tr>
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<tr>
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</tr>
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<tr>
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<td>57.5</td>
<td></td>
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<td>59.9</td>
<td>68.5</td>
<td>66.6</td>
</tr>
<tr>
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<td>63.0</td>
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<td>66.5</td>
</tr>
<tr>
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<td>66.4</td>
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<td></td>
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<td>65.0</td>
</tr>
<tr>
<td>Pioneer</td>
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<td>63.0</td>
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</tr>
<tr>
<td>REA Hybrids</td>
<td>62G22</td>
<td>0.6</td>
<td>71.9</td>
<td>60.4</td>
<td>60.3</td>
<td>64.2</td>
</tr>
<tr>
<td>Proseed</td>
<td>P2 11-50</td>
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<td>67.5</td>
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</tr>
<tr>
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<td>Legend Seeds</td>
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<td>63.7</td>
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<td>0.0</td>
<td>66.7</td>
<td>60.5</td>
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<td>63.6</td>
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<td>69.0</td>
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<td>63.0</td>
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</tbody>
</table>

*Table continued on page 24*
### On-Farm Cropping Trials

#### County Soybean Variety Plots — Marshall, Polk, Red Lake/Pennington County (continued)

Table continued from page 23

<table>
<thead>
<tr>
<th>Late RM Brand</th>
<th>Variety</th>
<th>RM</th>
<th>Fosston</th>
<th>Argyle</th>
<th>Red Lake Falls</th>
<th>site avg.</th>
</tr>
</thead>
<tbody>
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<td>61.7</td>
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<tr>
<td>Hefty Seed</td>
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<tr>
<td>REA Hybrids</td>
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<td>71.1</td>
<td>54.6</td>
<td>56.4</td>
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<td>56.1</td>
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<td>60.3</td>
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<tr>
<td>Nutech</td>
<td>6052</td>
<td>0.4</td>
<td>67.9</td>
<td>54.5</td>
<td>57.5</td>
<td>60.0</td>
</tr>
<tr>
<td>Hefty Seed</td>
<td>H00Y12</td>
<td>0.0</td>
<td>66.1</td>
<td>53.5</td>
<td>59.8</td>
<td></td>
</tr>
<tr>
<td>Thunder</td>
<td>3103 R2Y</td>
<td>0.3</td>
<td>65.9</td>
<td>55.8</td>
<td>57.2</td>
<td>59.7</td>
</tr>
<tr>
<td>Integra</td>
<td>20100</td>
<td>0.1</td>
<td>65.2</td>
<td>53.6</td>
<td>59.4</td>
<td></td>
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<tr>
<td>Stine Seeds</td>
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<td></td>
<td>59.2</td>
<td>59.2</td>
<td></td>
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<tr>
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<td>6030</td>
<td>0.3</td>
<td>61.0</td>
<td>60.4</td>
<td>56.0</td>
<td>59.1</td>
</tr>
<tr>
<td>Proseed</td>
<td>P2 10-20</td>
<td>0.2</td>
<td>65.4</td>
<td>52.2</td>
<td>59.0</td>
<td>58.9</td>
</tr>
<tr>
<td>Peterson Farms</td>
<td>11R03</td>
<td>0.3</td>
<td>62.5</td>
<td>55.2</td>
<td>57.4</td>
<td>58.4</td>
</tr>
<tr>
<td>Nutech</td>
<td>6025</td>
<td>0.2</td>
<td>63.4</td>
<td>48.9</td>
<td>61.9</td>
<td>58.1</td>
</tr>
<tr>
<td>Dairyland</td>
<td>DSR-0603/R2Y</td>
<td>0.6</td>
<td>63.1</td>
<td>52.3</td>
<td>57.7</td>
<td></td>
</tr>
<tr>
<td>Proseed</td>
<td>P2 11-30</td>
<td>0.3</td>
<td>66.3</td>
<td>49.6</td>
<td>55.9</td>
<td>57.3</td>
</tr>
<tr>
<td>Thunder</td>
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<td>67.7</td>
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<td>50.6</td>
<td>56.9</td>
</tr>
<tr>
<td>Northstar</td>
<td>NS 0216R2</td>
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<td>61.8</td>
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<td>48.2</td>
<td>55.2</td>
</tr>
<tr>
<td>Stine Seeds</td>
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<td></td>
<td>53.1</td>
<td>53.1</td>
<td></td>
</tr>
<tr>
<td>Dairyland</td>
<td>DSR-0502/R2Y</td>
<td>0.5</td>
<td>51.4</td>
<td>51.4</td>
<td>61.4</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{LSD}_{0.05} = 6.1 \quad 9.0 \quad 6.6 \quad —
\]
Research Questions

New formulations of phosphate fertilizers have been reported to increase phosphorous uptake (up to 30%) by plant roots (Source: MicroEssentials - The Mosaic Company). An increase in phosphate uptake by wheat roots is theorized to improve plant growth and development which may lead to increased wheat yields, improved quality, and ultimately profitability. In addition, coated nitrogen products are available for use in wheat and other crops. In these field trials a coated nitrogen (ESN) product from Agrium was applied at planting. ESN can be applied broadcast or in-furrow at nitrogen rates up to three times the current safe rate of urea. A benefit of this polymer coated urea is the time released formulation that, in theory, will supply nitrogen to the crop throughout the entire growing season. Further, this formulation has the potential to reduce nitrogen loss through volatilization, denitrification, and leaching.

Producers are interested in obtaining unbiased data on the use of MicroEssentials and ESN in spring wheat and perennial ryegrass seed production systems under northern Minnesota’s environmental conditions. The objective of this research is to compare MicroEssentials alone and with ESN compared to a standard phosphorus fertilizer starter program in spring wheat under seeded to perennial ryegrass. In addition to phosphorus, the MicroEssentials products contain sulfur and zinc which have been reported to be involved in protein synthesis and may increase protein levels in wheat. A coated urea product may offer the potential to improve wheat yield and quality (protein), especially if the product is not released into the soil solution until later in the growing season.

Results

Results from the large plot trial are reported in Table 2. The three treatment average wheat yield was 66.5 bu/a, test weight 63.3 #/bu and protein 12.4%. The average wheat yield in Roseau county over the last five years is 43 bu/A. The 2011 growing season produced wheat yields well above the five year average. However, dry conditions in July and August had a negative impact on wheat growth and development at this location. Wheat plants showed visible signs of drought stress due to the lack of precipitation in July and August. No significant treatment differences were detected based on a statistical confidence level of 10%.

Small plot trial results are presented in Table 3. The twelve treatment average wheat yield was 87.2 bu, test weight 61.38#/bu and protein level of 13.74%. Wheat yields from the small plot location was well above the Roseau county five year average wheat yields of 43 bu/A. The wheat plants at the small plot location didn’t show visible symptoms of late-season drought which was observed at the large plot location.

Statistical differences in wheat yields from the small plot trials were detected at the 10% confidence level (Table 3). The highest wheat yields were obtained with a starter fertilizer applied at planting compared to phosphorus and potassium applied broadcast or no starter. No statistical differences at the 10% level of confidence were detected from any of the MicroEssentials products compared to the standard phosphorus source (MAP). Further, at this location and year, no treatment differences in wheat yields or protein levels from ESN applied with Microessentials were detected at the 10% confidence level.

The lowest wheat yield in the trial (81.1 bu/A) was from urea nitrogen applied broadcast without starter phosphate or potassium. The addition of 30# of ESN down the tube with the balance of the nitrogen (urea) applied broadcast gave an average wheat yield of 84.5 bu/A. In the absence of additional phosphorus or potassium, 30# of ESN applied as a starter tended to give higher wheat yields and proteins.

A foliar nitrogen treatment (28% UAN) applied at wheat anthesis was included in this trial as a method to improve protein levels in wheat. Ten gallons of 28% UAN was mixed with 10 gallons of water and this mixture was applied with a hand boom sprayer delivering a spray volume of 20 GPA. In 2011, the liquid nitrogen applied at wheat anthesis caused significant wheat leaf burn which was resulted in an average wheat yield of 84.5 bu/A. This wheat leaf burn...
was quantified by a visual color rating. This color rating of the wheat plants was a 1 to 9 scale with 1 a dark green color and 9 brown or tan (necrotic) color to the wheat plant. The foliar nitrogen treatment gave an average color rating of 4. The next highest color rating was a 3 from the no treatment. All other treatments gave color score generally in the range of 1 to 2.

**Application/Use**

The rationale for this research is to compare Micro-Essentials alone and with ESN compared to a standard phosphorus fertilizer starter program in spring wheat. In addition to phosphorus, the MicroEssentials products contain sulfur and zinc which have been reported to be involved in protein synthesis and may increase protein levels in wheat. A coated urea product may offer the potential to improve wheat yield and quality (protein), especially if the product is not released into the soil solution until later in the plant developmental stages of the spring wheat. The combination of this coated urea and MicroEssentials offer the potential to improve both wheat yields and seed quality.

**Materials and Methods**

Soil test results for both sites are listed in Table 1. Background fertility levels are important information when making fertility recommendations. The soil test levels for phosphate and potassium at these two sites were in the medium category. According to research conducted by North Dakota State University and published in the North Dakota Fertilizer Manual, a response to additional phosphorus and potassium can be expected 40 to 60% of the time when background fertility levels are in the medium range.

In 2011, the on-farm trial was conducted in Lake of the Woods County. The farmer cooperator for the on-farm research trial was Mr. Steven Helmstetter of rural Roosevelt, MN. The farmer cooperators equipment was used for all field operations from field preparation, planting, spraying and harvest. This site was planted on April 27th and harvested on August 11th. Individual plot size was 85 feet wide by 500 feet long. This site had three treatments and three replications for a total of 9 strips in the field. Flags marked each strip to help with field observation and harvest. The three at planting treatments were: 1) MAP + potassium (7-30-20); 2) MES10 (9-30-20-7s) and 3) MES10 + ESN (39-30-20-7s). Urea nitrogen was applied for a 70 bushel yield goal. The amount of nitrogen was adjusted such that each treatment had the same amount of nitrogen.

The small plot replicated trials were conducted at the Magnusson Research Farm. Plots were planted on May 19th and harvested on August 24th. The experimental design was a randomized complete block with 4 replications. Wheat and perennial ryegrass were seeded with and without a starter fertilizer. The starter fertilizer was applied down the tube with the wheat and ryegrass seed. Management of these small plots is similar to area wheat production fields. Plots were harvested for yield with a small plot combine. Sub-samples from each plot will determine wheat seed quality assessments.

The small plot fertility trials had twelve fertility treatments including a control (no starter fertilizer) treatment for a total of 12 treatments replicated four times for a total of 48 individual plots, (Table 3). Three MicroEssentials products are included in these trials: MES10 (12-40-0-10S), MES15 (13-33-0-15S) and MESZN (12-40-0-10S-1ZN). The standard rate of P2O5 and K2O will be 30 units. The standard MAP fertilizer was compared to; MES 10, MES15 and MESZN, a 2X rate of MES10 and K2O all applied in-furrow; a single broadcast soil incorporated MES10 treatment; MES10 plus ESN at 30 and 60 units applied in-furrow; 30# ESN only and MES10 + a foliar nitrogen treatment applied at wheat anthesis. The amount of nitrogen was adjusted so each treatment had the same amount of total applied nitrogen by the end of the growing season.

A crop protection regime followed a similar pattern in both the large and small plot location. Herbicides were applied at early tillering stage which included a half rate of a fungicide. A second fungicide treatment with an insecticide was applied at Feekes 9 and a third fungicide treatment was applied at Feekes 10.5 for scab protection.

Data collected included: background soil fertility, plant emergence, stand counts, vigor ratings, crop color rating, flag leaf tissue test, plant dry weights, crop yield, and crop quality parameters (test weight, protein), biomass production for wheat and perennial ryegrass.
Economic Benefit to a Typical 500 Acre Wheat Enterprise

If small or large plot research demonstrates a wheat yield or quality advantage compared to the standard phosphate or nitrogen fertilizer products, northern Minnesota wheat producers would be able to put more dollars on the “bottom line”. In 2011, statistical differences in wheat yield or quality were not observed between the premium phosphate and coated urea products compared to the standard fertilizer products. However, the environmental conditions in 2011 were not conducive to fertilizer loss due to in-seasons rainfall patterns. This research will be repeated in 2012.

Related Research

This is our research group’s first request for funding. Producers are interested in obtaining unbiased data on the use of MicroEssentials and ESN in spring wheat and perennial ryegrass seed production systems under northern Minnesota’s environmental conditions. This research is part of a larger research program investigating fertility requirements for grass seed cropping systems that integrate spring wheat into the production system.

Spring and winter wheat variety trials are planted, maintained and harvested by field staff at the U of MN Magnusson Research Farm in collaboration with the University of Minnesota wheat breeding project. In Roseau in 2010, the spring wheat variety trial under normal and intensive management systems had 45 entries for a total of 270 plots, the winter wheat variety trial had 22 entries for a total of 66 plots, and 108 advanced breeding lines were evaluated for a total of 216 plots. The variety trials are managed by Donn Vellekson, Research Plot Coordinator. Herbicide screening, growth regulators, fungicide, and fertility trials are conducted to help meet the needs of producers in the region.

Fertility rate and timing trials are conducted annually in grass seed cropping systems at the CFANS Magnusson Research Farm. These research trials are a subset of numerous agronomic trials involving large plot, on-farm research and small plot trials investigating the fertility requirements of northwestern Minnesota cropping systems. Our current research activities include two small plot fertility trials involving 16 and 22 fertility treatments replicated four times on fall and spring planted perennial ryegrass respectively for a total of 152 plots plus 3 on-farm locations with treatments replicated 3 or 4 times for a total of 84 plots.

Recommended Future Research

Wheat yields and protein levels from the large and small plot trials in Roseau and Lake of the Woods counties in 2011 were generally better than that of 2010. One major difference in the growing seasons of 2010 compared to 2011 is the moisture received in May. The precipitation data in Table 4 lists long term averages during the growing season (April-September). The precipitation data from 2011 indicate April was the only month that had precipitation levels significantly above the long term average. However, in 2010 the month of May and September had over twice the normal precipitation. The elevated levels of precipitation in May of 2010 probably caused a loss of available nitrogen to the wheat plant and were a factor in the low protein wheat in 2010.

In future fertility research, we will continue to evaluate ESN as a nitrogen source and MicroEssentials as a starter fertilizer in wheat. If 2011 had a similar precipitation pattern as 2010 would the ESN formulation of nitrogen been more available (less loss from excessive moisture) to the wheat plant? If so, would nitrogen formulation have a positive response in wheat yield and protein? In addition, the foliar nitrogen in 2011 caused significant wheat leaf burn which translated into wheat yield reductions. Future research with foliar treatments will be conducted in both small and large plots. Additional sources of foliar nitrogen and timings of application will be evaluated to determine wheat response (yield and protein) to various foliar applied nitrogen sources.

Publications

An article which summarized the projects first year’s results was submitted to the Wheat Growers for consideration to be published in the late-fall 2011 edition of the Prairie Grains Magazine. In addition, a presentation on the first year’s results will be given at the Prairie Grains Conference, December 7 & 8, 2011 at the Alerus Center in Grand Forks, ND.
Table 1: Background soil test values for small and large plot fertility trials in 2011.

<table>
<thead>
<tr>
<th></th>
<th>Soil pH</th>
<th>Phosphorus (Olsen) ppm</th>
<th>Potassium ppm</th>
<th>Nitrogen (0-6&quot;) ppm</th>
<th>Nitrogen (6-24&quot;) ppm</th>
<th>Sulfur ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small plot</td>
<td>8.0</td>
<td>7</td>
<td>132</td>
<td>25</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>Large plot</td>
<td>7.8</td>
<td>6</td>
<td>106</td>
<td>32</td>
<td>22</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2: Large plot wheat yield, test weight and protein in ‘Barlow’ spring wheat from various MAP and MES10 treatments in 2011. Cooperator: Steve Helmstetter Roosevelt, MN.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (bu/A)</th>
<th>Test Weight (#/bu)</th>
<th>Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MES10</td>
<td>66.4</td>
<td>63.2</td>
<td>12.5</td>
</tr>
<tr>
<td>MAP</td>
<td>68.6</td>
<td>62.7</td>
<td>12.6</td>
</tr>
<tr>
<td>MES10+ESN</td>
<td>64.5</td>
<td>64.0</td>
<td>12.2</td>
</tr>
<tr>
<td>LSD (0.10)</td>
<td>4.6</td>
<td>1.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Table 3: Small plot wheat yield, test weight, moisture, protein and visual color ratings in ‘Sampson’ spring wheat from various in furrow fertilizer treatments in 2011. Cooperator: U of Minnesota Magnusson Research Farm Roseau, MN.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>In-furrow analysis</th>
<th>Yield* Bu/A</th>
<th>Test weight %</th>
<th>Moisture %</th>
<th>Protein*</th>
<th>Color** scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>MES10</td>
<td>9+30+30+7s</td>
<td>86.7</td>
<td>61.6</td>
<td>13.3</td>
<td>13.6</td>
<td>1.8</td>
</tr>
<tr>
<td>MES10+30# ESN</td>
<td>39+30+30+7s</td>
<td>89.3</td>
<td>61.1</td>
<td>13.5</td>
<td>13.6</td>
<td>1.3</td>
</tr>
<tr>
<td>MES10 (2x)</td>
<td>18+60+60+14s</td>
<td>89.2</td>
<td>61.5</td>
<td>13.9</td>
<td>13.7</td>
<td>1.8</td>
</tr>
<tr>
<td>MES15</td>
<td>9+30+30+14</td>
<td>88.1</td>
<td>61.1</td>
<td>13.7</td>
<td>13.5</td>
<td>2.3</td>
</tr>
<tr>
<td>MESZ</td>
<td>9+30+30+7s+1zn</td>
<td>89.0</td>
<td>61.7</td>
<td>13.5</td>
<td>13.5</td>
<td>1.3</td>
</tr>
<tr>
<td>MAP</td>
<td>7+30+30</td>
<td>88.6</td>
<td>61.3</td>
<td>13.9</td>
<td>13.8</td>
<td>1.5</td>
</tr>
<tr>
<td>No Starter</td>
<td>None</td>
<td>81.8</td>
<td>61.6</td>
<td>13.6</td>
<td>13.6</td>
<td>3</td>
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<tr>
<td>MES10 Surface applied</td>
<td>None</td>
<td>86.1</td>
<td>61.5</td>
<td>13.4</td>
<td>13.6</td>
<td>1.8</td>
</tr>
<tr>
<td>MES10+30#ESN</td>
<td>39+30+30+7s</td>
<td>89.5</td>
<td>61.1</td>
<td>13.6</td>
<td>13.9</td>
<td>1.3</td>
</tr>
<tr>
<td>MES10+60#ESN</td>
<td>69+30+30+7s</td>
<td>89.3</td>
<td>60.5</td>
<td>14.3</td>
<td>14.2</td>
<td>2</td>
</tr>
<tr>
<td>30#ESN</td>
<td>30+0+0</td>
<td>84.5</td>
<td>61.6</td>
<td>13.3</td>
<td>13.9</td>
<td>1.5</td>
</tr>
<tr>
<td>MES10+28%UAN at anthesis</td>
<td>9+30+30+7s</td>
<td>84.5</td>
<td>61.5</td>
<td>13.6</td>
<td>14.0</td>
<td>4</td>
</tr>
<tr>
<td>LSD (0.10)</td>
<td>4.5</td>
<td>0.7</td>
<td>0.7</td>
<td>0.3</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

* Corrected to 12% moisture  
** Visual rating 1 to 9 scale 1 green and 9 brown

Table 4: Precipitation totals from April through September at Roseau, MN in 2010 and 2011.

<table>
<thead>
<tr>
<th>Year</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Annual Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1.20</td>
<td>6.01</td>
<td>3.03</td>
<td>3.64</td>
<td>2.42</td>
<td>6.02</td>
<td>29.62</td>
</tr>
<tr>
<td>2011*</td>
<td>3.14</td>
<td>2.63</td>
<td>3.87</td>
<td>2.38</td>
<td>1.63</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>Mean**</td>
<td>1.43</td>
<td>2.44</td>
<td>3.50</td>
<td>3.23</td>
<td>2.91</td>
<td>2.43</td>
<td>21.22</td>
</tr>
</tbody>
</table>

*Precipitation data collected from Magnusson Research Farm and MN Climatology Working Group  
** Precipitation data at Roseau, MN from 1891-2010. Source: Minnesota Climatology Working Group, St. Paul, MN.
Accelerated Breeding for Resistance to Fusarium Head Blight
Karl D. Glover, Plant Science Dept., SDSU

Research Question

Complete resistance to Fusarium Head Blight (FHB) is unknown, yet genetic variability for resistance is well documented. Steady progress toward increasing resistance levels has been demonstrated by breeding programs through the implementation of largely repeatable FHB screening procedures. Breeding programs must sustain efforts to simultaneously select resistant materials with desirable agronomic characteristics. The objective of this program is to use traditional plant breeding and selection techniques to develop hard spring wheat germplasm and cultivars that possess agronomic characteristics worthy of release in addition to acceptable levels of FHB resistance.

Results

Entries retained in the advanced yield trial (AYT) are thought to be at least moderately resistant to FHB. Those that do not perform adequately are generally discarded after the first year of AYT observation. 2011 AYT results are presented in the appendix. Thirty-five experimental breeding lines were tested during the 2011 growing season. Eighteen experimental lines had FHB disease index values that were less than the test average. Among them, 13 were found to have tombstone ratings that were less than average. Eight of these 13 entries also produced more grain than average and the test weight of seven were heavier than average. The final group of seven most desirable experimental lines includes SD3997, SD4112, SD4253, SD4308, SD4313, SD4330, and SD4343 (Table 1). In addition to its desirable level of FHB resistance, SD3997 has become known in the program as a line with both good yield potential and grain protein content. It is anticipated that SD3997 will be released as a new cultivar in fall 2011. The remaining lines will likely be tested further in the 2012 AYT. Both SD4178 and SD4215 are in the initial stages of seed increase for potential future release.

Application/Use

With the progression of time, increases in FHB resistance levels should help to prevent devastating losses to growers caused by severe FHB outbreaks.

Materials and Methods

Breeding efforts to increase resistance began within this program after the 1993 FHB epidemic in the spring wheat production region. Both mist-irrigated greenhouse and field screening nurseries were established and disease evaluation methods were developed. Breeding materials are evaluated for FHB resistance using three generations per year: two in the greenhouse and one in the field. We have the capacity to screen 4,500 individual hills in the greenhouse. We also have 4 acres in the field under mist-irrigation. Both the field and greenhouse nurseries are inoculated with grain spawn (corn that is infested with the causal fungus) and spore suspensions. Mist-irrigation is used to provide a favorable environment for infection. Approximately 25 percent of the experimental populations possess Fhb1 as a source of resistance. Most of what remains are crosses with various “field resistant” advanced breeding lines. Experimental materials are advanced through the program in the following fashion:

- **Year 1**
  - Field: Space planted F₂ populations
  - Fall greenhouse: F₂:3 hills
  - Spring greenhouse: F₂:4 hills
- **Year 2**
  - Field: F₄:5 progeny rows
  - Off-season Nursery: F₅:6 progeny rows
- **Year 3**
  - Field: F₅:7 Yield Trials
  - F₅:6 Yield Trials
  - (1 replication, 2 locations)
- **Year 4**
  - Field: F₅:8 Yield Trials
  - (2 replications, 5 locations)
- **Year 5**
  - Field: Advanced Yield Trials
  - (3 reps, 8 locations)

F₂ populations are planted in the field and individual plants are selected. These are advanced to the fall greenhouse where seed from each plant is sown as individual F₂:3 hills and evaluated for FHB resistance. Four plants from each of the top 25% of the hills are advanced to the spring greenhouse. They are sown as individual F₃:4 hills and evaluated for FHB resistance. Those with FHB resistance nearly equal to or better than ‘Brick’ are advanced to the mist-irrigated field nursery as F₄:5 progeny rows. They are evaluated again for resistance and general agronomic performance. Plants are selected within the superior rows and sent to New Zealand as F₅:6 progeny rows for seed increase. A portion of seed from each selected plant is also grown in the fall greenhouse to
confirm its resistance. If the FHB resistance of an F$_{5:6}$ line is confirmed, then the respective progeny row is harvested in New Zealand. In the following South Dakota field season, the selected lines are tested in a two replication, multi-location yield trial. Those that have agronomic performance and yield similar to current cultivars are included in more advanced, multi-location, replicated yield trials the following year. In year 5, lines advanced through this portion of the program are included in the AYT along with entries from the traditional portion of the program. Performance data with respect to FHB resistance and agronomic potential from the 2011 AYT are presented in Table 1 of the appendix.

### Economic Benefit to a Typical 500 Acre Wheat Enterprise

The presence of FHB inoculum within fields and favorable weather conditions are just two factors that heavily influence whether this disease will become problematic. Immediate economic benefits are therefore difficult to assess. When conditions become favorable for disease presence, however, cultivars with elevated FHB resistance levels can help to reduce potentially serious losses for growers.

### Publication


### Table 1

South Dakota State University advanced yield trial spring wheat entries ranked according to FHB disease index values (lowest to highest – collected at Brookings) presented along with agronomic data obtained from three replication tests conducted at seven test environments in 2011.

<table>
<thead>
<tr>
<th>ENTRY</th>
<th>FHB DIS INDEX</th>
<th>TOMBERSTONE (%)</th>
<th>GRAIN YIELD (BU/AC)</th>
<th>TEST WEIGHT (LB/BU)</th>
<th>GRAIN PROTEIN (%)</th>
<th>HEAD DATE (D &gt; 6/1)</th>
<th>PLANT HEIGHT (INCHES)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD4343</td>
<td>24.43</td>
<td>6.00</td>
<td>34.36</td>
<td>55.14</td>
<td>16.01</td>
<td>27.82</td>
<td>41.31</td>
</tr>
<tr>
<td>SD4280</td>
<td>27.56</td>
<td>10.00</td>
<td>28.67</td>
<td>53.86</td>
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**Determining Wheat Response to the Tile Drainage in the Red River Valley**

Hans Kandel & Joel Ransom, Department of Plant Sciences, NDSU

**Table 1.** Winter wheat at NW 22, 2009-2010, Fargo North Dakota.

<table>
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<th>Yield (bu/a)</th>
<th>Protein (%)</th>
<th>Test Weight (lb/bu)</th>
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+P = 25 lb P/a at seeding, +K is 10 lb K/a at seeding. All fertilizer plots received equal to 10 lb N/a at seeding. Only letters in the same column in each sub-section should be compared. If the letter behind the number is similar the numbers are not significantly different at the p<0.05 level.

**Research Questions**

From the 1990s through 2011, excess water has impacted crop production significantly in eastern North Dakota and Northwest Minnesota. Interest in subsurface drainage has increased, not only due to the wet climatic cycle, but also to help reduce the financial risk associated with high input costs to farmers. Subsurface drainage tends to result in more stable production at a higher yield level. Subsurface drainage has been a common practice in many parts of the Upper Midwest, however, adoption of subsurface drainage in the RRV has been relatively new.

This research is investigating the yield response of winter and spring wheat grown under subsurface (tile) drained and non-subsurface (no tile) drained conditions. In addition to measuring yield, crop plants have been evaluated for diseases and other growth characteristics. We also have been monitoring the water table between subsurface drained and non-subsurface drained experimental units.

**Results**

**Winter wheat**

The experiment was conducted at the NDSU research location ‘NW22’ near Fargo, North Dakota.

Eight units of about 0.7 acres were tiled in the summer of 2008. Each unit has a separate water table control structure. With the control structure open the water is drained and with the control structure closed a non-subsurface drained condition is created. Small research plots were seeded in the fall of 2010 perpendicular to the direction of the drain tile. The winter wheat was seeded into canola stubble.

The first planting was Sept x, 2010 and Oct x, 2010 for the second. Harvesting took place on July x 2011. The treatments were the varieties Jerry and Hawken (with and without fertilizer applied at seeding). Winter conditions were conducive to winter wheat survival. On average wheat yields on tiled ground were significantly higher than without subsurface drainage. On average test weight was higher on tiled ground.

**Spring wheat**

The early summer of 2011 was relatively cool and wet. However it turned hot during the flowering and grain fill, resulting in relatively low yield and test weight. As yields were lower the protein levels in 2011 were higher than in 2010. There was no significant difference in the yield between no tile and tiled conditions (Table 2), however the yield in the tiled area was 7.4% higher than the no tiled area. Yield of
Howard and Faller were numerically higher under tiled conditions in both 2010 and 2011. In 2010 there were significant differences among the varieties for yield with Faller out-yielding Traverse and Howard under both tile and no tile conditions and Sabin when grown under tile.

However, in 2011 there were no differences in yield among the varieties.

**Table 2.** 2010-11 spring wheat response to no tile vs tile, seed treatment and fungicide application at NW 22, Fargo, North Dakota.

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<th>2011 Yield (bu/a)</th>
<th>Protein (%)</th>
<th>Test weight (lb/bu)</th>
<th>1000 Kernel Weight (gram)</th>
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Only letters in the same column in each sub-section should be compared. If the letter behind the number is similar the numbers are not significantly different at the p<0.05 level.
There was no significant increase in wheat yield when seed treatments were applied in 2010 but there was a significant yield increase in 2011. The use of a fungicide applied at heading resulted in a yield increase in 2010 but not in 2011. Table 3 provides the yield, protein, test and thousand kernel weight of Traverse, Howard, Faller, Sabin and Samson spring wheat varieties with combinations of seed treatment and fungicide application at heading. Fungicide application increased the yield.

Table 3. 2011 Yield, protein content, and thousand kernel weight of individual varieties with and without seed treatment and fungicide application, NW 22, Fargo North Dakota.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Seed Treatment</th>
<th>Fungicide Heading</th>
<th>Yield (bu/a)</th>
<th>Protein (%)</th>
<th>1000 Kernel weight (gram)</th>
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</thead>
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<tr>
<td>Traverse</td>
<td>No</td>
<td>No</td>
<td>38.5</td>
<td>16.4</td>
<td>24.3</td>
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<tr>
<td>Traverse</td>
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<td>Yes</td>
<td>37.6</td>
<td>16.7</td>
<td>22.4</td>
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<tr>
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<td>No</td>
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<td>15.8</td>
<td>24.6</td>
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<td>Yes</td>
<td>39.1</td>
<td>16.5</td>
<td>24.4</td>
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<tr>
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<tr>
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<td>17.2</td>
<td>24.7</td>
</tr>
<tr>
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<td>16.9</td>
<td>25.5</td>
</tr>
<tr>
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<td>Yes</td>
<td>38.3</td>
<td>16.9</td>
<td>25.1</td>
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<tr>
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<tr>
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<td>18.2</td>
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<tr>
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<tr>
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<td>Yes</td>
<td>37.0</td>
<td>18.2</td>
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<tr>
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<td>No</td>
<td>33.2</td>
<td>16.8</td>
<td>23.0</td>
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<tr>
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<td>34.9</td>
<td>17.1</td>
<td>22.0</td>
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<tr>
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Application/Use

There was on average a 5% increase in wheat yield due to the fungicide application at heading. However, response of varieties is related to their genetic potential to resist diseases. Those with less genetic protection against diseases will benefit more from a fungicide application.

Materials and Methods

The spring wheat plots were seeded on May 4, 2011. Half of the seed received a seed treatment of Raxil MD, 5 fl oz/cwt treated with a laboratory seed treater. The plots were seeded with a small no till plot planter. The herbicide Wolverine as use on June 9 at a rate of 1.7 pt/a. A fungicide application took place on June 18 on half the plots with Prosaro 421 SC at 6.5 fl oz (+ NIS 1.5 pt/100 gal) per acre applied at 30 psi using XR TEEJET 8001 VS nozzles at early flowering (July 3 and 5 depending on the variety). Wheat was harvested with a research plot combine on August 10.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Winter wheat

The winter wheat yields were about 10 bushel more with subsurface drainage. On a 500 acre farm this would be a 5000 bushel increase in production.

Spring wheat

The yield increase due to seed treatments was 1.4 bushel per acre, at $ 9.00 per bushel this would be a gross income increase of $12.60 per acre and with a seed treatment product cost of approximately $2.15 for a total increase of $5,225 for a 500 acre farm (wheat price and seed treatment cost on November 4, 2011, there might be a small charge for treating the seed).

Related Research


Recommended Future Research

There is a need to get long term yield data on tiled vs non-tiled fields. It is also anticipated that managing the water table (opening and closing subsurface control structures) during the season will provide an additional management tool. No regional research has looked at this aspect of wheat production. Nitrogen management may be different between tiled and non-tiled fields. Figure 1 shows the water table in inches below the surface. The water table in the subsurface drained units was generally lower than in the units without subsurface drainage.

Figure 1. Water table below the surface and rainfall in inches during the 2011 season at NW 22, Fargo, ND.
Left winter wheat and right spring wheat on July 22, 2011 at NW 22. Fargo, North Dakota.

Two of the sub-surface drainage control structures at the NW 22 research site. Spring wheat and winter wheat are in a crop rotation with soybean.
Transfer of Leaf and Stem Rust Resistance Genes to Hard Red Winter Wheat Genetic Backgrounds
Francois Marais, Department of Plant Sciences, NDSU

Research Questions

The new hard red winter wheat breeding program at NDSU is lacking with respect to breeding parents that have resistance to prevailing cereal rust diseases. This project aims to acquire and transfer 20 effective leaf rust resistance (Lr) and five effective stem rust resistance (Sr) genes into well-adapted winter wheat genetic backgrounds.

Results

Twenty Lr genes were acquired, including Lr19-149-299.478, 42, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 61, 62, 63, 66 and Lrbi (temporary designation). Five Sr genes that are effective both against UG99 variants and North American pathotypes were obtained, namely Sr2 and improved recombinants of Sr22, 26, 39 and 50. Five of the translocations with leaf rust resistance genes also carry stripe rust resistance (Yr) genes (Lr53/Yr35, Lr54/Yr37, Lr56/Yr38, Lr57/Yr40 and Lr62/Yr42). For four of the Lr translocations (Lr19, Lr56, Lr59 and Lr62), shortened forms carrying reduced amounts of alien chromatin were identified. These are being characterized (genomic in situ hybridization) in order to select the most useful for transfer to winter wheat. The respective source materials were crossed (84 crosses) with winter wheat (cultivars Jerry and Norstar) and the F1 is being screened to identify resistant plants for continued crossing with winter wheat. A growth chamber was obtained and a seedling evaluation protocol was implemented. The respective genetic backgrounds in which the resistance genes occur were tested and appropriate pathotypes for screening of the segregates were identified.

Application/Use

The current material will be backcrossed to winter-hardy winter wheats. Segregating populations that are derived from the second and third backcrosses will then be selected for agrotype, winter-hardiness and rust resistance and the best retained for continued line development and field evaluation. Winter-hardy plants/inbred lines with acceptable plant type and carrying diverse, useful genes will be selected for crosses with a wide spectrum of elite winter wheat germplasm.

Materials and Methods

1st set of crosses:
Genetic stocks (primarily in spring wheat) with the respective resistances were obtained from the Cereal Research Centre in Winnipeg, Canada; Dr Ian Dundas (Australia); Stellenbosch University (South Africa); Kansas State University; University of California-Riverside and CIMMYT, Mexico. For genes occurring in segregating stocks, seedling resistance tests (McIntosh RA, Wellings CR and Park RF, 1995. Wheat rusts - an atlas of resistance genes, CSIRO Publications, East Melbourne, Australia) were done to identify carrier plants. Winter wheat parents Jerry and Norstar were vernalized and used for pollination.

2nd set of crosses:
For F1 combinations derived from segregating plants, leaf rust seedling tests were done to identify carriers. Winter wheat varieties Jerry, Decade and Norstar are being used for making the first backcrosses.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The research material that is being developed will be integrated into the germplasm pool of the new winter wheat breeding program. In addition to the transfer of rust resistance genes, projects to develop and use improved sources of fusarium head blight, tan spot and septoria resistance are also being conducted. Once fully operational, the new breeding program will aim to integrate the various sources of new germplasm in order to develop new winter wheat varieties with improved agrotype, winter-hardiness, adaptation, yield, processing quality and pyramided disease resistance. Producers will benefit from the use of varieties with multiple disease resistance both through no/reduced need for spraying and increased yields attributable to the resistance.
Related Research

Winter wheat breeding material and a supporting pre-breeding program (for continued parental development) is being established at NDSU. A primary concern is the low levels of resistance to leaf, stem and stripe rust; Fusarium head blight, tan spot and Stagonosporum nodorum blotch that occur in the available germplasm.

In addition to the transfer of rust resistance, hybridization programs aiming to transfer specific FHB, tan spot and septoria resistance genes from spring wheat were therefore also initiated. The genes being transferred include (a) Fhb1, Fhb2, Fhb5a ex Sumai 3; (b) an FHB QTL on 3AL of Frontana; (c) FHB genes on 5AS and 5AL of PI277012 (ex Dr S Xu) and (d) the tan spot and septoria resistance genes tsn1, snn2, QTs.fcu-1BS and QTs.fcu-3BL (ex Dr S Xu).

A third winter X spring wheat crossing block aims to introduce further genes for rust and leaf spot disease resistance, wheat sawfly, sprouting tolerance, yield and quality. The ultimate aim is to utilize superior, resistant material from each of the above crossing schemes in crosses with the best selections from the pedigree breeding program. At the same time, the material will be used to establish a pre-breeding program that will continue to develop improved parental material through gene pyramiding. The establishment of such a base population for recurrent mass selection using the various materials that are being developed is the subject of a current MS research project.

A current PhD study (MS Ibrahim) utilizes in situ hybridization to confirm the inferred compositions of promising recombinant forms of some of the alien translocations being used in the study, these are Lr19, Lr56, Lr59, Lr62 and Lrbi. A total of 13 recombinants are being studied in order to identify those with the least alien chromatin.

Recommended Future Research

In the next two years the following is being planned:
Following the completion of the second round of crosses, the material derived with respect to each gene will have one or more of the following general pedigrees:

Resistance source/Norstar//Jerry
Resistance source/Norstar//Decade

Recommended Future Research

Resistant F1 plants will be selected within each cross and selfed to derive F2 for field planting (fallow field) in the fall of 2012. The F2 will be selected for winter survival, rust resistance and plant type. The better selections will (a) be used in crosses with pedigree program parents, (b) back-crossed to a winter-hardy wheat or (c) be used for the development of inbred lines.

The best lines will furthermore be included in a pre-breeding program so as to obtain genotypes with pyramided resistance that can serve as future breeding parents.

Publications

None
Coordinated Effort to Isolate a Fusarium Head Blight Resistance Gene

Gary J Muehlbauer, Department of Plant Sciences, U of M

Research Questions

Fusarium head blight (FHB) is a major disease problem for Minnesota wheat growers. A major resistance gene located on chromosome 3BS referred to as Fhb1, exhibits partial resistance to FHB. Fhb1 has been incorporated into breeding programs and resulted in new varieties with improved resistance. However, the new varieties are still susceptible during a severe FHB epidemic. Unfortunately, the Fhb1 gene that underlies resistance has not been isolated. We plan to use a combination of genetic and physical mapping, gene expression analysis and mutant characterization to isolate the gene. This is a collaborative project with Drs. Jim Anderson (U of MN), Mike Pumphrey (Wash. St. U.), Bikram Gill (K-State U.) and Eduard Akhunov (K-State U.).

Materials and Methods

We are using genetic stocks developed by Dr. Jim Anderson (University of Minnesota) that contain either the Fhb1 resistant or susceptible allele. We established three experiments: (1) F. graminearum inoculated spikelets and the inoculated spikelets were sampled; (2) F. graminearum inoculated spikelets and the rachis was sampled; and (3) deoxynivalenol treated spikelets and the treated spikelets were sampled. RNA from the experiments has (experiment #1) or will (experiment #2 and #3) will be sequenced using next generation sequencing technologies. In collaboration with Drs. Akhunov and Gill, analysis is ongoing using the data obtained from experiment #1.

Results

We examined gene expression in spikelets infected with Fusarium graminearum from plants carrying either the Fhb1 resistant allele or the Fhb1 susceptible allele. We used next-generation sequencing of RNA to obtain 250 million sequencing reads from each genotype. We identified 425 genes that exhibited differential expression between the two genotypes. In addition, we identified 20 genes that exhibited expression in the resistant genotype and lack of expression in the susceptible genotype that are candidates for the Fhb1 gene. Validation and further examination of these genes is beginning. We sent the sequencing data to Drs. Eduard Akhunov and Bikram Gill. Dr. Akhunov is helping us further examine the data and Dr. Gill is using the results to help isolate the Fhb1 gene.

Application/Use

Having the Fhb1 gene will result in the perfect marker for marker-assisted selection for FHB resistance in breeding programs and be an ideal candidate for genetic engineering. This will ultimately benefit the growers through improved FHB resistant varieties.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Fusarium head blight is a major disease problem in the wheat growing regions of Minnesota. Yield and quality losses due to this disease can be devastating. Prophylactic fungicide treatments can cost $15/acre. In addition, in severe FHB disease years the crop is not worth harvesting. Therefore, the economic benefits to this research are large.

Related Research

We have developed transgenic wheat carrying a barley UDP-glucosyltransferase gene. These transgenic plants exhibit a high level of FHB resistance. In our two FHB screens of these lines, we identified transgenic lines that exhibited as low as 5% disease severity. For comparison, Sumai3 (a FHB resistant genotype used in breeding programs around the world) exhibited ~10% disease severity, and Bob-white the nontransgenic control exhibited ~50% disease severity. These results demonstrate that we have developed transgenic wheat with higher FHB resistance than the best genotypes used in breeding programs. We have initiated crosses with the transgenic plants with Rollag, a recent variety developed by Dr. Jim Anderson (University of Minnesota).
Recommended Future Research

There are three areas of future research that I think are important.

1. Continue to identify and test putative genes for FHB resistance. My laboratory has an active gene discovery project that is focused on identifying genes with the potential to confer FHB resistance. When we identify genes that may confer FHB resistance we develop and test transgenic wheat for resistance to Fusarium head blight.

2. Isolate the Fhb1 resistance gene. Fhb1 exhibits a high level of FHB resistance. My laboratory in collaboration with Drs. Jim Anderson, Mike Pumphrey, Eduard Akhunov and Bikram Gill have developed a coordinated approach to isolate the Fhb1 resistance gene.

3. Develop a regional approach to testing germplasm collections for wheat improvement. A regional approach to developing and testing germplasm collections for traits that are of interest to the growers should be a top priority. These collections should be composed of germplasm that contains either induced or natural variation that captures the majority of the variation worldwide. The utility of these populations is that they can be repeatedly phenotyped for new traits as they become important.

Appendix

Abstracts related to the project:


Oral presentations:
“Genomics approaches to Triticeae improvement” at Oregon State University, Corvalis, OR
“Wheat Genomics” at the Wheat Production Forum, Moorhead, MN

Publications

Eight abstracts were published and two oral presentations were given on topics related to this project.
Developing an Interactive Web-based Variety Selection Tool for Wheat

Joel Ransom, Department of Plant Sciences, NDSU

Research Questions

Can a web-based variety selection tool assist growers in obtaining and summarizing variety trial information more efficiently than from current sources so that they can be more effective in selecting appropriate varieties.

Results

The basic framework for the selection tool has been developed which includes the format for adding variety trial data and the interface for obtaining summarizing these data. The interface allows the user to select a location by zip code and request an area around this location from which variety trial results will be provided. The tables generated by this query will produce a mean for varieties included in all locations polled and will calculate an appropriate LSD. There is still substantial work to be done to make the tool usable to the public and to populate the database.

Application/Use

This web-based tool will allow growers or crop consultants/extension educators to obtain variety trial information that is scalable and not restricted by political borders such as a state line; allow the user to create his/her own area of inference; and allow for meaningful means comparisons by applying the rigor of statistical analysis. The web-based database, for now, encompasses the spring wheat variety trials of Minnesota and North Dakota.

Materials and Methods

A computer programmer has been hired and the PIs have been working with him on a regular basis to allow for the development of this web-based tool along the lines envisioned by this project. In the near future, a series of meetings is planned with growers to ensure that the tool is relevant and usable.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

Selecting an appropriate variety can have significant economic impact on a grower’s operation. A conservative estimate is that selecting the “best” variety for a farm will add two bu/acre to the yield. This will translate into a yield increase of 1,000 bushels on a 500 acre farm with a dollar value, depending on the market, of about $7,000.

Related Research

The PIs are not aware of any other research currently being done on this topic. There are several other web-based tools in other crops and regions of the USA that are being reviewed as this project’s tool is being developed.

Recommended Future Research

Complete the current phase of research, test it and advertise it widely. The development of an app that would run this tool from a smart phone should also be considered.

Publications

A Coordinated Research Plan to Address Bacterial Leaf Streak
Ruth Dill-Macky, Department of Plant Pathology, U of M

Research Questions

1) Develop techniques for producing inoculum & inoculating plants in the greenhouse and field.
2) Establish if BLS is of economic importance.
3) Examine the structure of the pathogen population.
4) Develop a cooperative regional BLS screening nursery.

Results

1) In greenhouse inoculation trials, UMN determined leaf infiltration at flag leaf stage with an inoculum concentration of 10⁷ CFU/ml produced the most consistent and measurable results. Dew chamber incubation post inoculation was not necessary for lesion development and was therefore not implemented. Lesion area measurements using digital imaging software provided the most concise and consistent data. UMN continued examination of field based inoculation methods for screening of BLS. The quality of the data from the 2011 field experiments provided valuable insights on the methods needed for the establishment of reliable and repeatable field-based assessments of BLS in the future. The use of carborundum, a fine abrasive, in the inoculum increased disease severity observed and appeared to have a greater impact than timing of the inoculation. Needle inoculation produced some of the highest disease levels observed. Although this method is more laborious than other tested, such a strategy could be useful in epidemiological studies of BLS. The disease was also successfully established in both irrigated and dryland sites which indicates that screening is possible in the absence of irrigation.

2) UMN examined the impact of BLS on yield in a field experiment in St Paul, disease severities of ca. 30% resulted in yield losses approaching 40%. This trend held true across all varieties tested. Significant impacts on individual head weight or seed number were not observed. SDSU tested the impact on grain yield, test weight and grain protein in the field at two locations (Brookings and Watertown, SD). Paired treatments were utilized where inoculated plots of each genotype were compared to non-inoculated control plots.

3) UMN observed all 2009 and 2010 isolates (representing strains from both wheat and barley) and other X. translucens pathovars (poae, cerealis, phleipratensis and secalis) to be pathogenic in RB07 and Blade in greenhouse screenings. Virulence of isolates varied widely. RB07 was more susceptible than Blade overall, but there were several isolates which were more virulent on Blade than RB07. These results indicate that strain-genotype interaction and variation in isolate virulence should be considered in breeding efforts. Additionally, as all X. translucens pathovars from wheat and barley were shown to be virulent on wheat, it is necessary to confirm the identity of X. translucens isolates present in Minnesota to ensure that materials are screened for all pathovars present in the region.

At NDSU, pathogenicity studies revealed significant differences among wheat cultivars (df = 11, F-value = 116.1), and among bacterial strains (df = 28, F-value = 31.36). In addition, interactions between wheat cultivars and bacterial strains (df = 308, F-value = 15.19) were highly significant (P < 0.0001). The 29 strains varied greatly for aggressiveness on the 12 wheat cultivars. Among them, four strains (26, 27, 28, 29) were more aggressive on wheat cultivars than the other strains tested. Wheat cultivars Mochis, Pavon, PI 345476, PI 326301, PI 338387, and PI 351315 exhibited differential responses to several strains of X. translucens pv. undulosa and could be good candidates for further study.

4) UMN undertook a screening of advanced breeding lines (2011 AY1) in the greenhouse and at three field locations in MN. Variation in host susceptibility was observed across lines. Several of the most resistant and most susceptible lines from the greenhouse screening were similarly rated as either resistant or susceptible in the field. Lines with intermediate reactions showed more fluctuation in performance both in the greenhouse and in the field. In addition to screening of advanced lines, several populations selected by Dr. Jim Anderson, which were thought to be segregating for BLS, were screened in the 2011 BLS field nurseries and the data provided to Dr. Anderson.

In screening conducted at NDSU, nearly 31.9% of the accessions were resistant to BLS. The mean disease scores of resistant and susceptible checks were 1 and 4, respectively. Among the BLS-resistant
accessions, 43 accessions had disease scores between 0 and 1, while 138 accessions had disease scores between 1.1 and 2. Significant differences were observed for the proportion of resistant accessions when classified by geographic origin. The percent of BLS resistant accessions from Africa was significantly higher than for those originating from Asia. Some countries bordering the Mediterranean also showed a high percentage of BLS resistant accessions. The resistant accessions identified in this experiment may provide sources of resistance to BLS.

At SDSU, several experimental lines were found with various degrees of resistance. Line SD4205 was among the most apparently resistant and was used, along with more susceptible genotypes, to initiate a QTL mapping study.

**Materials and Methods**

1) UMN tested greenhouse inoculation methods at different growth stages. Spray, leaf infiltration and needle inoculation were performed at seedling, tillering and flag leaf stages with and without a subsequent dew chamber incubation. Leaves were harvested 14 days after inoculation (dpi) and photographed for digital analysis. Lesion length measurements were taken manually and lesion areas were calculated using the digital analysis program ‘Fiji’.

A field experiment was conducted in St. Paul to examine several variables that influence BLS development including; inoculation technique (needle and spray), timing of inoculation (anthesis and heading), the use of an abrasive (carborundum) to aid penetration of the inoculum. Four wheat varieties; Blade, Knudson, RB07 and ND495 were examined and the experiment included four replications. Spray inoculations were conducted using a CO2-powered backpack sprayer with inoculum applied either at anthesis or at both anthesis and heading. Inoculations were conducted both with and without carborundum in the inoculum. A total of five inoculation treatments were examined. A non-inoculated control was included in the experiment. A mist-irrigation system was utilized to facilitate infection and disease development. Disease development in control plots suggested that background level of BLS was quite low. Inoculum consisted of X. translucens strains that were grown on solid Wilbrinks agar for three days. One plate was washed into 3 L of 0.85% saline in the field just prior to inoculation producing approximately $10^7$ cfu/ml. Carborundum was used at a rate of 10g/L of inoculum. Two rating systems were examined: a whole row score (0-9 scale; one value per plot), and a leaf score (percent scale; 20 leaves/plot). Plots that were spray inoculated were assessed 14-20 days after inoculation while the needle inoculated plots were assessed 23 days after inoculation.

2) A field experiment examining the impact of BLS on wheat yield was conducted in St. Paul. Three
varieties (Blade, Knudson and RB07) were examined. To generate various levels of disease the same inoculation methods described in Part 1 (see above) were used with the exception that needle inoculations were replaced by an inoculation using a gas-powered backpack sprayer ad carborundum amended inoculum. Mist irrigation, inoculum production and rating of disease were preformed as described in Part 1. Fifty individual heads were harvested from each plot, threshed and cleaned. Seed number and weight per head were recorded. The remainder of each plot was harvested in bulk and plot weights were recorded.

NDSU conducted field experiments from 2009-2011 to examine the effects of foliar sprays and seed treatments on inoculated plots of Alsen and Freyr in an irrigated nursery. Plots were rated using a 1-9 scale and 1 ft² areas were harvested for each plot to determine yield loss.

3) UMN collected isolates from around MN and currently has a collection of 92 Xanthomonas translucens isolates. These have all been confirmed via media testing and 16S sequencing. All 2009 and 2010 isolates (33 total) plus four other Xt pathovars (poeae, cerealis, phleipratensis and secalis) were examined in greenhouse pathogenicity tests using RB07 and Blade. All greenhouse testing was performed using leaf infiltration at the flag leaf stage with an inoculum concentration of 10⁷ CFU/ml. Leaves were harvested 14 dpi and were photographed for digital analysis. Lesion length measurements were obtained manually and lesion areas were calculated using Fiji, a digital imaging program.

NDSU collected leaf samples infected with Xanthomonas translucens pv. undulosa from Casselton, Carrington, Lisbon, Langdon, and Prosper in ND. These samples were mainly collected from breeding lines, winter wheat, spring wheat, and durum wheat cultivars. Sample size varied according to the prevalence and distribution of the disease and ranged from 23 to 63 within each location. Bacteria were isolated from 2 to 4 mm leaf segments that were placed in 100 µl of sterile distilled water. One wire-loop of the resulting bacterial suspension was streaked on Wilbrink’s medium and incubated at 28ºC for 5 days. A single yellow colony was re-streaked on peptone sucrose agar (PSA) plates and incubated at 28ºC for 3 days. In this manner a total of 226 isolates of X. translucens pv. undulosa were isolated and stored in 15% glycerol at -80ºC.

At NDSU 29 strains from five locations in North Dakota were examined for their disease reaction on twelve wheat cultivars. These strains were previously confirmed by pathogenicity, biochemical and physiological tests, and 16S rDNA sequence analysis. Two experiments were performed for each strain in a separate growth chamber. The twelve wheat cultivars used were selected based on their response to BLS in previous studies. The wheat cultivars included were Alsen, Dam, Fil, Magnum, Mochis, ND495, Pavon, PI 266860, PI 345476, PI 326301, PI 338387, and PI 351315. The spring wheat breeding line ND495 was used as susceptible check. For each wheat cultivar, 18 plants (three plants/cone, three replications, and two experiments) were infiltrated on the flag leaf with a strain of X. translucens pv. undulosa. Disease reactions were assessed 7-10 dpi using a 0 to 6 scale.

4) Entries in a Minnesota advanced breeding nursery (AY1 2010) were screened in the St. Paul greenhouse with a Minnesota Xt isolate collected in 2010 (JA1-10A) via leaf infiltration. Disease development was assessed using lesion area measurement. Variation in host susceptibility was observed across lines. Several of the lines that performed as most resistant and most susceptible agreed with field ratings. Intermediate susceptible varieties showed much more variability in performance both in the greenhouse and in the field. AY1 and wheat breeding population were screened at three Minnesota locations (St. Paul, Crookston and Lamberton). Entries were planted in one-foot long ‘dash’ plots, with six replications planted for each entry (4 inoculated and 2 non-inoculated). Plots were inoculated using a Solo backpack sprayer with carborundum. Two inoculations (anthesis and heading) were applied at each location. Inoculation production was done as described in Part 1 (see above). Disease severity was rated using a whole plot score (0-4 scale, one rating /plot) at 14 to 20 dpi.

At NDSU a total of 566 spring wheat accessions from diverse origin were arbitrarily selected and evaluated for resistance to BLS. Wheat accessions were arranged in a randomized complete block design (RCBD) with three replications. The strain BLS-CS42 from Casselton, ND was used in this study. The inoculum density was adjusted to ca. 10⁷ CFU ml⁻¹ and 10 to 15 µl of inoculum was infiltrated into a fully expanded flag leaf. Disease reactions were assessed 7 to 9 dpi using a 0 to 6 rating scale (Milus and Chalkly, 1994). Disease scores of 0 to 2 (less than 10% water-soaking within the infiltrated areas) were considered resistant (R) whereas disease scores of > 2 to 6 (greater than 10% water-soaking) were regarded susceptible (S).

In the process of determining when best to inoculate spring wheat in the field, germplasm tested in the
Advanced Yield Trial of the SDSU breeding program was inoculated with a bacterial cell suspension in the 2009 growing season. It was also hoped that some materials with contrasting levels of BLS resistance would be identified. Population development largely took place in 2010 and by spring 2011, F\textsubscript{1} plants from within approximately 60 unique populations were selected and screened for BLS resistance in the greenhouse. In 2011 the F\textsubscript{2} head-rows derived from F\textsubscript{1} plants were screened in the field. Resistance data were collected from all individuals screened in the F\textsubscript{1} and F\textsubscript{2} generations (approx. 530 individuals). During winter 2011-2012 molecular marker genotypes will be collected on each individual. Assuming that BLS resistance is conferred by a single major-effect QTL inherited in a dominant fashion, then all individuals will be available to harvest as either a heterozygous or homozygous susceptible row at the New Zealand winter nursery. It will be ideal if all marker genotypes can be collected and analyzed by early 2012, but if not, samples will be collected from all 532 rows in order to perpetuate each line. In the event that it cannot be done in early 2012, this plan will allow eventual selections to be made based on putative BLS resistance QTL genotypes.

**Economic Benefit to a Typical 500 Acre Wheat Enterprise**

We have demonstrated that Bacterial Leaf Streak is of economic importance to the wheat industry. Data has been generated that growers can use to select wheat varieties which are less susceptible to BLS. Techniques have been established that allow us to screen breeding materials and therefore provided the tools to make progress in disease resistance introgression.

**Related Research**

In addition to MNWRPC funding, UMN currently has support from the Minnesota Small Grains Initiative (SGI) and the Rapid Agricultural Response Fund (RARF) that has allowed for additional research on BLS.

Under the SGI grant, MLST (multilocus sequence typing) is being implemented to determine the pathovar identity of MN \textit{X. translucens} isolates. SGI funding also supports research on seed screening assays, evaluation of commercially available cultivars, parent germplasm and advanced breeding lines, extending field research plots to include barley as well as wheat.

RARF funding supports the screening of segregating populations for resistance to BLS, screening core collections of wheat and barley germplasm, examination of the relative role of seed borne inoculum on disease development and production of an extension bulletin that describes BLS etiology and management.

Funding from all three grants combined with inter and intra departmental collaborations has allowed UMN to make significant progress in developing effective and reproducible screening methods BLS, refining methods to work with and correctly identify the pathogen, and allowing for initial detection of potential sources of resistance to BLS in both wheat and barley.

The SDSU works outlined in this project was supported in part by the South Dakota Wheat Commission. The matching funding supporting the graduate student research in the SD portion of this project.

**Recommended Future Research**

Although much progress has been made toward the objectives of this proposal, a proposal for FY12 will be submitted to continue this research. Further research both in the field and the greenhouse is needed to confirm the data generated over FY11. Additionally, although techniques have been developed to work with BLS further work is needed to refine and standardize these methods. We anticipate that research in FY12 can provide valuable information on the response of commercially available wheat cultivars to BLS and as well as identify sources of BLS-resistance in germplasm.

**Publications**


Results and progress were presented at several grower meetings in spring and summer of 2011.
Effect of Location and Genotype on Arabinoxylan Production in HRS Wheat from Minnesota

Senay Simsek, Department of Plant Sciences, NDSU

Research Question

Many factors have effect on the biochemical composition of wheat grain and thus largely determine its end-use quality. These influencing factors can be grouped according to whether they originate from the genetic makeup of the plant (i.e., genotype or cultivar) or from the environment (all external conditions under which the plant grows). Cultivar and environment each influence wheat composition to varying degrees.

Arabinoxylans are carbohydrates naturally found in wheat flour. They have significant impact on farinograph and baking water absorption of flours.

1) Determine the influence of genotype and environment on the WE-AX and WU-AX in Hard Red Spring wheat from Minnesota.
2) Identify how the impacts of genotype and environment affect the end-use quality of the wheat (especially water absorption) due to the variations to the structure and distribution of the arabinoxylan in wheat.

Results

We are currently in the process of compiling and analyzing the data from the GC to determine the statistical significance in relation to the varieties and growing locations studied. As is typical for wheat we found that the total arabinoxylan content was higher for the whole wheat samples. The average arabinoxylan content for all whole wheat samples was 7.2% where the average arabinoxylan content for all flour samples was 1.8%. The average A/X ratio for all whole wheat samples was 0.72, which was lower than the average A/X ratio (0.85) of the flour samples. The next step for this project will be to analyze the samples for total starch content to round out the chemical composition analysis. Finally, we will be compiling and analyzing all data for all tests conducted to determine the statistical significance.

Application/Use

Varieties that will be used in this study are provided by Dr. Anderson’s breeding program and traditional spring wheat quality tests are performed by USDA staff located in Fargo, ND. There is very limited research has been done on effect of cultivar and location on production of arabinoxylan content in wheat from Minnesota even though these minor constituents have significant impact on water absorption capacity of flour. Our research will complement UMN breeding program to see whether location and/or cultivar is affecting arabinoxylan production and how they are correlated to water absorptions.

Materials and Methods

HRS wheat variety trial samples were provided by Dr. James Anderson. The samples included flour from the AY1 lines from 2009 and 2010, as well as, whole wheat samples from the AY1 lines from 2010. The 2009 AY1 samples were grown in Lamberton, Morris and Stephen Minnesota; and the 2010 AY1 samples were grown in Crookston, Roseau and Stephen Minnesota. In total 45 wheat varieties from three locations and two years will be analyzed. The samples were milled in the case of flour on a Buhler laboratory mill and ground in the case of whole wheat on a UDY mill. The samples were then analysed for moisture, ash and protein content using AACC Approved Methods; 44-15, 8-01 and 46-30 (AACC 2000). The samples have been analyzed for monosaccharide content, using gas chromatography (GC) using the alditol acetate method of derivitization (Blakeney et al 1983). After which, the total arabinoxylan content and the arabinose to xylose (A/X) ratio was calculated by multiplying the sum of arabinose an xylose by 0.88 and dividing the arabinose by xylose contents (Dornez et al 2008).

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The proposed project will help the UMN HRS wheat breeding program to identify and develop wheat varieties that have target arabinoxylan content. Since AX production is under genetic control, the potential exists for new varieties with targeted AX content that have better end-use functionality.

Related Research

In the past, MNWRPC funded Dr. Simsek’s project...
on refrigerated dough. Arabinofuranosylarabinoxylans have significant impact on refrigerated dough quality. Refrigerated dough products use wheat flour as their primary ingredient, so the quality and chemical composition of the flour determine the quality of the final product. Although arabinofuranosylarabinoxylans make up a minor component of wheat, they have significant effects on the quality of the end products. Variation in arabinofuranosylarabinoxylan and xylanase activity due to genetic or environmental factors can impact their functionality within wheat flour. Specifically, arabinofuranosylarabinoxylan content and xylanase activity can affect the quality of refrigerated dough made from wheat flour.

Six varieties of hard red spring wheat, grown in three locations in Minnesota, USA were evaluated to determine the genetic and environmental effects on arabinofuranosylarabinoxylan, xylanase activity and refrigerated dough quality. Total arabinofuranosylarabinoxylan percentages in the flours ranged from 0.97 to 1.54 and the arabinose to xylose ratios ranged from 0.67-0.82 in the flour. Xylanase activity of the flour was measured and ranged from 0.20-0.84 mU/g. An important factor in the suitability for refrigerated dough is the syrping during storage. The extent of dough syrping was measured over a period of ten days. There was a large amount of variability in dough syrping among the varieties and locations. The average dough syrping on day ten ranged from 2.05 to 14.83 percent. Despite the significant interaction effect of genotype and environment, two varieties, Glenn and Oklee, had lower dough syrup formation with greater stability across growing locations and storage days than other varieties.

Overall, the ability to segregate wheat lines to improve refrigerated dough quality in wheat breeding programs and the food industry depends on information on genotypic and environmental effect on dough syrping. The chemical composition of the flour showed variability across growing locations as well as between varieties. The chemical composition, including: starch, protein, arabinofuranosylarabinoxylan and xylanase can affect the DDS. These results indicate that refrigerated dough quality is affected by complex interaction of many flour biochemical components rather than a single component. Therefore, further research is necessary to determine association of multiple flour biochemical components, which include protein, starch, and enzymes in addition to arabinofuranosylarabinoxylan and xylanase, with variation of dough syrping among growing location and varieties, and difference of varieties in stability over growing locations.

**Recommended Future Research**

At this point, we would like to request extension to complete the proposed project. The next step for this project will be to analyze the samples for total starch content to round out the chemical composition analysis. Finally, we will be compiling and analyzing all data for all tests conducted to determine the statistical significance.

**Publications**

In preparation

**Appendix**

See opposite page.
List of the genotypes that have been used in this study.

<table>
<thead>
<tr>
<th>No.</th>
<th>Genotype</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ada</td>
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</tr>
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<td>Barlow</td>
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<td>4</td>
<td>Bigg Red</td>
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<td>Blade</td>
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<td>Brick</td>
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<td>SDSU</td>
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<td>Brogan</td>
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<td>41</td>
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<tr>
<td>42</td>
<td>Vantage</td>
<td>Westbred</td>
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Strategies for Maintaining Grain Protein in Diverse Spring Wheat Varieties

Joel Ransom, Department of Plant Sciences, NDSU

Research Questions

Can in-season plant or soil measurements predict the need for additional nitrogen before grain filling in order to maintain protein levels at desirable levels in a diverse group of genotypes and are there methods of applying N, in-season, that can cost-effectively be employed to increase grain protein?

Results

The 2011 growing season was not ideal for crop development so yields were low and protein was high, even in the low-N plots. Preliminary results from Prosper showed that there was a significant impact of N treatment and variety on yield and protein. As was previously mentioned, protein content was high, even in Faller. There was a linear relationship between and stalk nitrogen content at the 4/5 leaf stage and grain protein. None of the other measurement were predictive of protein content. In the second study, treatments consisted of a factorial combination of variety (Faller, Glenn and RB07) and nitrogen treatment (120 lbs; 90 lbs N; 90 lbs N with 30 lbs applied post anthesis as UAN; 90 lbs N with 30 lbs applied post anthesis as urea solution; 90 lbs N with 30 lbs applied at boot stage as UAN; 90 lbs N with 30 lbs applied at boot stage as dry Urea; 90 lbs N with 30 lbs applied at Roundup stage as UAN; 90 lbs N with 30 lbs applied post anthesis with urea solution and urease inhibitor). At Crookston, the highest yield was achieved with Faller followed by Glenn and then RB07. Yield did not differ substantially between N treatments. However, protein was significantly different between treatments. The lowest protein content occured when on 90 lbs of N was applied and when the supplemental N was applied at the boot stage. At Hettinger, all post N treatments increased grain protein, except the N applied at the roundup stage. Similar trends were noted at Prosper. There were N treatment by variety interactions for protein in some of the locations. Additional data is need before definite recommendations can be made, however, as this growing season was far from typical.

Application/Use

Additional research is needed before this research can be extended. In season applications of N do hold promise as a way of increasing protein content (this year about 0.5% was typical) which should be useful in years when yield is high and protein content is predicted to be low.

Materials and Methods

This project was conducted at three locations in eastern ND and northwestern MN. The research has two components. The first is to determine if there are in-season measurements that can predict protein status at harvest in diverse genotypes. Measurements made were: Greenseeker readings, tissue and soil NO₃- levels, and chlorimeter readings at key growth stages. These data were compared to grain protein at harvest and yield of four cultivars (Faller, Barlow, Glenn and RB07), grown at three different levels of N fertilization. The second component of this study is to verify the effectiveness of various in-season practices on increasing protein content in new varieties with diverse grain protein characteristics. The study is a factorial experiment, where three cultivars receive a range of in-season N treatments as described above. These treatments will be compared to treatments where all of the fertilizer N is applied at planting. Data to be analyzed will be yield, protein, and market value at different prices per bushel and discount/premiums for protein.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

The results of this work has the potential of increasing the value of a bushel of wheat produced by $0.50 to $1 in a year when protein premiums are significant. If a farmer has an average yield of 50 bu, this would mean that he/she could increase the value of the crop by $12,500 to $25,000 from a 500 acre field.

Recommended Future Research

There is one additional study that is ongoing in ND looking at the impact of late season N on the milling and baking quality of the grain.
Processed Wheat Bran as a Food that Decreases Food Intake

Daniel D. Gallaher, Department of Food Science and Nutrition, U of M

Background

Wheat bran is a rich source of phenolic compounds that, if absorbed, are thought to have highly beneficial health effects. Unfortunately, these phenolic compounds are normally bound in such a way that they remain almost entirely unavailable for absorption. As part of a recently completed USDA grant, we have conducted a study in obese, diabetic rats in which we fed wheat bran that was chemically treated and subjected to high pressure homogenization to release the phenolic compounds, thereby making the phenolic compounds present in the wheat bran available for intestinal absorption. The wheat bran processed in this way is food grade and completely safe to eat.

The diabetic, obese rats fed the processed wheat bran were found to have lower plasma insulin levels and improved insulin sensitivity, indicating that they were less diabetic as a result of consuming the processed wheat bran, compared to normal (unprocessed) wheat bran. Rats consuming the processed wheat bran tended to weigh less and tended to consume less diet that rats consuming normal wheat bran. Most importantly, the rats consuming the processed wheat bran diet clearly had less body fat, indicating that the processed wheat bran was in some way reducing the accumulation of body fat.

Control of eating is clearly a very complex phenomenon. However, a number of hormones have been identified that play important roles in both the desire to begin eating and the signal to stop eating. These are referred to as satiety-related hormones. We hypothesized that consumption of the processed wheat bran may have changed the concentration of these satiety-related hormones in such a way as to decrease food intake in our animals compared to rats eating normal, unprocessed wheat bran.

Procedures

In our experiment, obese, diabetic rats (Zucker Diabetic Fatty, ZDF) were fed one of the following diets for three weeks:

- Control (no wheat bran) – lean – normal rats
- Control (no wheat bran) – obese – ZDF rats
- Wheat Bran – obese – ZDF rats
- Optimized Wheat Bran (processed) – obese – ZDF rats
- Soluble Fraction of Optimized Wheat Bran – obese – ZDF rats
- Insoluble Fraction of Optimized Wheat Bran – obese – ZDF rats
- Low viscosity hydroxypropyl methylcellulose (a viscous dietary fiber) – obese – ZDF rats

The diets were fed for three weeks. Blood was drawn from the rats in both the fasted state and at two hours after a meal. Body weight, food intake, and body fat have already been measured in these animals.

The specific hormones to be measured are amylin, ghrelin, PYY, and insulin. All the assays for hormones will be radioimmunoassays, and will be purchased as commercial kits.

Results

Satiety-related hormones are peptide hormones released from the gastrointestinal tract or the pancreas that influence food intake. They often act on nervous fibers, either centrally (e.g. the hypothalamus in the brain) or peripherally (e.g. the vagus nerve).

Ghrelin is produced in the stomach and the small intestine. As ghrelin concentrations in the plasma increase, hunger increases. Ghrelin is the only satiety-related hormone that increases food intake. Normally, after a meal, plasma ghrelin decreases. As seen in Figure 1, this was found in the normal rats. However, in the Diabetic Zucker Fatty (ZDF) rats, ghrelin tended to increase after a meal, indicating they are responding to a meal in a very different way. However, in the fasted state, the rats fed the soluble fraction of the processed wheat bran had the lowest plasma ghrelin concentration, suggesting that rats consuming the soluble fraction of wheat bran were less hungry.

Amylin is produced in the pancreas in the same cells that produce insulin, and are co-secreted with insulin. High plasma concentrations of amylin are thought to increase satiety and decrease food intake. However, recent evidence suggests that amylin concentrations may also reflect the total amount of body fat. This appears to be true, as all the ZDF rats, which are much fatter than the lean rats, had a much higher concentration of plasma amylin (Figure 2). The ZDF animals that had less body fat – the Optimized, Soluble, Insoluble, and LV-HPMC groups – also had less plasma amylin in the fasted state. This appears to confirm that the processed wheat bran is lowering body fat.

PYY is produced in the lower part of the small intes-
tine and the colon, and high concentrations in the plasma have been found to lower food intake. That is, high PYY concentrations are thought to increase satiety. As shown in Figure 3, all ZDF rats had higher concentrations of PYY than did the lean animals. Plasma PYY concentrations were more variable within a diet group than the other hormones; consequently, no statistically significant differences were found among the ZDF groups. However, there was a tendency for the processed wheat bran-fed groups to be increased after a meal compared to the wheat bran group. This would suggest a tendency for the processed wheat bran to be more satiating after a meal.

To integrate the information obtained in this study and develop a clearer story of what is affecting food intake, we conducted a multiple regression analysis of all the plasma parameters measure against food intake (Table 1). The combined measures of insulin concentration in the fed state, fasting plasma glucose, and PYY concentrations in the fed state explained about half the variation in food intake among the animals. That is, differences in these three measures are half the explanation as to why different animals eat different amount of food. These same three measures were either lower or strongly tended to be lower in the processed wheat bran groups.

**Summary**

The Zucker Diabetic Fatty (ZDF) rat is a model for the human condition referred to as metabolic disease. Metabolic disease is a risk factor for diabetes and cardiovascular disease. Rats fed processed wheat bran had reductions in the factors that define metabolic disease, such as high cholesterol, high fasting glucose, insulin resistance, and excess body fat. These rats also ate less diet. Although the hormone results were complex and the interpretation challenging, overall, the changes in the satiety-related hormones were in the direction that would suggest that the processed wheat bran increased satiety and therefore may explain, in part, the decrease in food intake.

**Table 1.** Multiple regression analysis of food intake & plasma parameters among ZDF rats.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Partial $R^2$</th>
<th>Model $R^2$</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin in Fed State</td>
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<td>&lt;0.0001</td>
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<tr>
<td>Fasting glucose</td>
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<tr>
<td>PYY in fed state</td>
<td>0.0932</td>
<td>0.4921</td>
<td>0.0032</td>
</tr>
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</table>

Bars represent the means ± SEM, n=12. Bars within a feeding state (fasted vs. fed) with different letters are significantly different (p<0.05).
Figure 2. Plasma concentrations of amylin in the fasted and meal-fed states.

Bars represent the means ± SEM, n=12. Bars within a feeding state (fasted vs. fed) with different letters are significantly different (p<0.05).

- Concentrations increased in obese groups
- Concentrations correlate with degree of adiposity

Figure 3. Plasma concentrations of PYY in the fasted and meal-fed states

Bars represent the means ± SEM, n=12. Bars within a feeding state (fasted vs. fed) with different letters are significantly different (p<0.05).

- Concentrations tended to increase after a meal
- Tendency for processed wheat bran to increase concentrations after meal
Protein and Yield Response to Nitrogen Fertilizer and Variation of Plant Tissue Analysis in Wheat

Daniel Kaiser, Department of Soils, Water and Climate, U of M

Research Question

The current N management guidelines recommend applying nitrogen based on the yield goal of wheat minus any N credits from a previous crop or from soil nitrate (Rehm, 2002). This recommendation has served wheat growers for many years and is constant no matter where you are in the Red River Valley. For southern Minnesota table values are recommended for wheat because soil nitrate does not play as big of a role in recommendations. The idea of single sets of recommendations for large areas of the state are coming into question as farmers have adopted more precision agriculture technologies and have the ability to apply variable rates of crop inputs across fields and can collect yield data from individual field areas. In order to provide the information to make these recommendations data must be collected from multiple locations, especially if researchers want to better provide farmers with data that may provide differences between specific regions even within the larger regions within the state.

Plant tissue analysis has become more increasingly offered to wheat and other crop growers as a way to assess the nutrient status within the plant at a particular time that may ultimately be related back to yield. Crop uptake generally follows a consistent pattern; however, nutrients vary in when they are taken up and where they may go in the plant. Therefore, if environmental conditions exist that may limit uptake certain elements may be deficient in some areas of the plant. For example, elements such as sulfur or zinc are taken up into the plant and are not remobilized into other plant tissues if the supply in the soil becomes low. Therefore, plant tissue analysis can be problematic and may not accurately reflect yield at the end of the season if the cause of the temporary deficiency is corrected. Also, varieties may differ in their growth patterns ultimately affecting crop uptake of nutrients and the concentrations in plant tissues. Therefore, particular normal values may be only normal for particular varieties in specific locations rather than a one size fits all number for a tissue concentration. No recent work has been published that shows variety to variety variation across locations. Therefore work should be undertaken to provide farmers with an idea of what their tissue analysis really means.

The objectives of this study are to:
1) Study protein and yield response using nitrogen rate trials in Northern and Southern Minnesota
2) Evaluate economic optimum nitrogen rates for spring wheat
3) Evaluate the variability in plant tissue collected from the fully extended flag leaves
4) Compare variability in nutrient composition of plant tissue for spring wheat between varieties and locations in well fertilized trials.

Results

Nitrogen Rate Studies – A summary of the locations studies are included in Table 1 and 2. Three locations were studies in northwestern Minnesota, one near Hallock, one near Hendrum, and one near Foxhome. Soil P and K levels were adequate for wheat (Table 1) and the two foot soil test N levels ranged from 48 to 168 lbs. of N per acre. The highest soil test N levels are much greater than the rate that would be recommended so no N rate response would be expected at that site. A summary of grain yield data (adjusted to 13.5% moisture) is given in table 3. Grain yields were significantly impacted by nitrogen application at the Foxhome and Hallock locations, but yield variability influenced the results at Hendrum as there was no statistical evidence of a yield increase even though yields trended higher with increasing N application rates. At Foxhome, yields decreased with increasing N rates. This was likely a result of the high initial 2' soil nitrate levels. No lodging was apparent at the location but yields were significantly decreased in a linear fashion (decrease in grain yields was consistent for each lb. of N applied across all N rates). At the Hallock location yields were increased in a linear fashion up to 106 lbs. of N per acre at which no further yield increase was seen. Nitrogen use was about 1.2 lbs. of N per bushel needed to maximize yields. Previous work in northwest Minnesota has indicated about 1.5 lbs. of N is needed per bushel in order to maximize yields (Kaiser, unpublished data).
Grain protein was influenced by one or more nitrogen treatments at all locations. Linear models were fit to the data at both Foxhome and Hallock which indicate that the increase in protein was relatively constant per lb of N applied. At Foxhome, protein increased up to 170 lbs. of N applied per acre while yields decreased. This indicates that while fertilizer N did not benefit yield it did benefit protein and that the residual N left in the soil itself was not enough at this location to maximize protein. Grain protein was not maximized by the highest N rate at the Hallock location. This is consistent with past data in that grain protein in this area has been shown to steadily increase with increasing nitrogen fertilizer rates but the highest rates in the studies were not enough. In previous work the highest N rates were 180 lbs. For the new study the rate was increased for the very reason of seeing of protein could be maximized around some of the Hallock field trials but in this case it still was not. It is unclear why this response differs at this location but it was evident that protein was lower for the lowest N rates than the other location even though previous crop was similar and there was not a large difference in the residual N in the soil. At Hendrum the data analysis found that some treatments differed in protein, but the values were variable and no trend can be observed. This could be due to excess water at this location.

### Plant sampling study

Plant sampling has increasingly been used in order to determine hidden nutrient deficiency symptoms in crops. In this study we sampled 15 varieties from the on-farm variety plots to compared the nutrient levels in flag leaf tissue. The variety trials were selected because they are managed with fertility as a non-limiting factor. For all sites a single sampling date was selected even though some varieties did vary in their maturity level at sampling. A single composite soil samples was collected from each location at the time of sampling. Soil data is given in Tables 7 and 8. A number of tests were ran for both macro- and micro-nutrients. In most cases P and K levels were adequate for crop growth. Soil test levels at Morris, Oklee, and Stephen were the lowest for P. However, fertilizer should have been applied to take care of any nutrient deficiencies. Soil test K was the lowest at Morris however there should have been adequate K based
on current recommendations. There are no suggested optimum soil test levels for calcium, magnesium, sulfate sulfur, zinc, iron, manganese, and boron. Zinc deficiencies are either rarely if ever seen or the soil test is a poor indicator of crop response in the case of sulfur. In the case of copper a soil test between 2.5 and 5.0 ppm is considered marginal on organic soils. In this case we were not dealing with any organic soils so the same range would not hold and in fact all of the soil test values came in at or below this level. We do not expect a significant chance of a positive yield increase due to copper fertilization at any of the sites studied.

At this time we are still in the process of analyzing some of the plant sampling data. Two of the locations, Fergus Falls and Humboldt, were sampled but the data is still being analyzed at the lab so they are not included in the full data analysis. In addition, this report only summarizes the data for nitrogen (N), phosphorus (P), potassium (K), sulfur (S), zinc (Zn), and copper (Cu).

Table 9 summarizes the significance of each individual main treatment effect, site and line, and their interaction for the nutrients studied. Part of the purpose of this study was to determine if 1) varieties significantly differed in their tissue concentration and 2) if the differences were similar across sites. We would expect site averages to differ due to differences in environmental conditions, soil types, fertilizer rates, or management practices. For all nutrients the effect of site was significant. The effect of line was only significant for P, K, S, and Cu. There may have been some differences between lines for N and Zn leaf concentration but this likely only occurred at some of the locations. Significant main treatment interactions for most nutrients may indicate that the lines do not always vary the same way at all locations or that the effect of line may only be significant at some of the locations. There was only a significant interaction for the macronutrients studies in this report (N, P, K, and S).

Actual values for the flag leaf tissue concentrations are given in Tables 10 through 15. Since there was a large number of lines involved a simple means separation procedure like LSD (least significant difference) could not be used to determine which lines or sites may have significantly differed. Since we would assume there is some difference between sites, as was noted earlier, we were only interested in the overall effect of line. One of the analyses we used to determine whether lines differed similarly across locations was a simple rank correlation procedure. At this time this has not been fully completed. The significant interactions would possibly indicate that there is no pattern across locations. This would indicate that the difference between varieties is somewhat random or greatly affected by factors associated with a particular location. If the varieties did not differ in their ranking across locations then it would indicate that a single number for a critical value may not be adequate as varieties may inherently have one single critical value. When completed we should have a better understanding of this as well as more nutrients to look at for the analysis.

**Application/Use**

The nitrogen rate data when combined with previous work shows that in many cases N rates applied based on historical yield goals likely will not limit yields when yield potential is high but will limit protein. Economic data shows that limiting protein can have a significant impact on economics within a field, especially with a variety that does not have a high genetic protein potential. In order to maximize profit more N likely needs to be applied. However, using the current recommendations if the yield goal can be accurately predicted within a given year the current recommendation of 2.5 x yield goal minus N credits may be used. The biggest challenge to wheat growers is accurately predicting yield goals. In addition, there are justifiable concerns for yield loss due to lodging from the over-application of N. The risk of over- or under application of N needs to be weighed before making the decision on how much to apply, which could hinge on what variety is planted within a field.

The plan analysis data can be important in that it can tell us how much variability in tissue concentration we can expect based on sites and varieties. Since we do not have specific fertilizer rates we cannot fully determine optimum concentrations. Yields can be used in order to determine if there is a link between yield and concentration. Since we are dealing with varieties there is some yield differences inherent between varieties which can make it difficult to determine if the difference in achieved yield is related to the tissue concentration or is just inherent in the particular variety.
Materials and Methods

**Nitrogen rate studies:** Small plot trials will be conducted at two to three locations in conjunction with the on-farm variety trials. Small plot studies replicated four times will include eight nitrogen rates starting at 0 and ranging in 30 lb increments up to 210 lbs of N per acre. All nitrogen will be applied as broadcast urea incorporated prior to planting. Additional P, K, and S will be applied in order to make sure these nutrients will not limit yield or protein response. For trials in Northern Minnesota a single variety will be planted across locations. Yield will be determined after harvesting the entire plot with a small plot combine and protein will be determined with a NIR. Soil samples will be taken from 0-6” and 6-12” depths for P, K, pH and nitrate. Yield data will be analyzed to determine the amount of nitrogen required to maximize agronomic yield as well as determine economic optimum nitrogen rates.

**Plant tissue survey:** Selected wheat varieties will be sampled at selected variety trial locations. In 2011 this included 5 locations in Northwest Minnesota and 3 locations in central or western Minnesota outside of the Red River Valley. The preferred sampling will be conducted at Feekes 9.0 (prior to boot) in which about 20 flag leaves will be sampled out of each plot. However, differences in maturities between varieties may give us a range in maturities at the time of sampling. This sampling is different from the recommended sampling of the whole plant (Overdahl, 1987) but represents a common analysis being used by farmers. Samples will be dried and sent in a single batch and analyzed for ICP for nutrient concentration. The variety trials will be ideal since yields are collected and potentially could be related back to nutrient content and conditions should be maintained with nutrients not being yield limiting.

**Economic Benefit to a Typical 500 Acre Wheat Enterprise**

Data in Figure 4 summarizes the net return per lb of N based on a range of discount levels (0, 0.05, 0.10, 0.15, and $0.20 per fifth of a percent protein) multiplied out to a 500 acre operation. The net return per lb of N is high for the lowest N rates which indicate that return is highest for the lower N rates. What is interesting is the overall effect of the discounts on net return per lb of N. In most cases net return decreases except for the highest discount level ($0.20 per fifth). In this case the penalty for lack of N on protein is so severe that the net return increases to a certain point then starts to decrease. When the net return per lb is at 0 then the MRTN values is reached. Where the lines cross the X axis should be the same as the calculated MRTN values from Table 6. In Figure 3 the total N values also includes the total amount of N in the 2’ soil N test. Average soil test N levels were near 50 lbs across locations. In this event the amount of N in the soil typically can give the highest return if accounted for when fertilizer is applied. The lowest loss per lb of N was $0.50 per acre which was the price associated with the cost of the nitrogen for the calculation.

**Related Research**

This study is a continuation of nitrogen rate work funded previously by the Minnesota Fertilizer Research and Education Council which ended in 2010. The overall goal is to incorporate data from the current study with previous work to develop a N rate response database for spring wheat.

**Recommended Future Research**

The current research does show the large potential economic benefit to N application for a high yielding moderate protein producing spring wheat variety. However, future research on varieties with varying protein potentials is key in order to determine if the MRTN approach can be adequately used for spring wheat. For example, the question could be raise if a variety with a higher protein potential may need as much N since it may be easier to achieve 14% protein. Further research would be helpful to determine if MRTN values should be not only adjusted based on the ratio of the price on nitrogen to the value of wheat but also to the protein potential for a variety.
Table 1. Trial location and planting information for spring wheat N rate studies.

<table>
<thead>
<tr>
<th>Location</th>
<th>County</th>
<th>Soil Type</th>
<th>Soil Texture</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foxhome</td>
<td>Grant</td>
<td>Formdale</td>
<td>Clay Loam</td>
<td>Knudson</td>
</tr>
<tr>
<td>Hallock</td>
<td>Kittson</td>
<td>Northcote</td>
<td>Clay</td>
<td>Knudson</td>
</tr>
<tr>
<td>Hendrum</td>
<td>Norman</td>
<td>Fargo</td>
<td>Silty Clay</td>
<td>Knudson</td>
</tr>
</tbody>
</table>

Table 2. Spring soil test averages across replications for Spring wheat N trials.

<table>
<thead>
<tr>
<th>Location</th>
<th>Soil Test (0-6&quot;)†</th>
<th>P ppm</th>
<th>K ppm</th>
<th>SOM %</th>
<th>pH</th>
<th>Nitrate N‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foxhome</td>
<td>41</td>
<td>250</td>
<td>4.8</td>
<td>7.2</td>
<td>164</td>
<td></td>
</tr>
<tr>
<td>Hallock</td>
<td>49</td>
<td>463</td>
<td>7.5</td>
<td>7.1</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Hendrum</td>
<td>30</td>
<td>391</td>
<td>5.0</td>
<td>7.9</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>

† P, Bray phosphorus; K, ammonium acetate potassium; SOM, soil organic matter; pH, soil pH.
‡ 0 to 2 foot soil nitrate level.

Table 3. 2011 Yield averages for nitrogen rate treatments for the spring wheat N rate study.

<table>
<thead>
<tr>
<th>Location</th>
<th>Nitrogen Applied (lbs N/acre)</th>
<th>0</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>150</th>
<th>180</th>
<th>210</th>
<th>avg.</th>
<th>Sig.</th>
<th>Model</th>
<th>MaxN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistics‡</td>
<td>-P&gt;F--</td>
<td>-lbN/ac-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foxhome</td>
<td>48</td>
<td>47</td>
<td>44</td>
<td>40</td>
<td>48</td>
<td>39</td>
<td>35</td>
<td>33</td>
<td>42</td>
<td>0.04</td>
<td>Lin</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hallock</td>
<td>64</td>
<td>70</td>
<td>80</td>
<td>84</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>90</td>
<td>81</td>
<td>&lt;0.01</td>
<td>LP</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>Hendrum</td>
<td>46</td>
<td>51</td>
<td>55</td>
<td>58</td>
<td>60</td>
<td>60</td>
<td>62</td>
<td>59</td>
<td>56</td>
<td>0.26</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

† Sig., significant for main treatment effects (nitrogen rate) according to ANOVA; Model, regression model that best fits the data (lin, linear; Quad, quadratic; QP, quadratic plateau; LP, linear plateau; NM, no model); MaxN, N rate where response was maximized (a rate of 180 indicates no maximum was achieved with N rates applied).

Table 4. Summary of estimated nitrogen needs based on maximum yields at each location and economic optimum N rates.

<table>
<thead>
<tr>
<th>Location</th>
<th>Estimated N Need†</th>
<th>EONR‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield</td>
<td>2.5x</td>
</tr>
<tr>
<td></td>
<td>bu/ac</td>
<td>------</td>
</tr>
<tr>
<td>Foxhome</td>
<td>48.0</td>
<td>120</td>
</tr>
<tr>
<td>Hallock</td>
<td>87.8</td>
<td>220</td>
</tr>
<tr>
<td>Hendrum</td>
<td>56.0</td>
<td>140</td>
</tr>
</tbody>
</table>

† Yield, maximum agronomic yield; 2.5x, nitrogen rate at 2.5 x AONR; STN, average 2’ soil nitrate; calculated, calculated N rate (YGx2.5-Ncredits.).
‡ Economic optimum nitrogen rate at specific fertilizer:wheat price ratios based on yield response data.
§ Maximum agronomic nitrogen rate based on yield response.
Table 5. 2011 grain protein averages for nitrogen rate treatments from the spring wheat N study.

<table>
<thead>
<tr>
<th>Location</th>
<th>Nitrogen Applied (lbs N/acre)</th>
<th>Sig. -P&gt;F-</th>
<th>Statistics† Model</th>
<th>MaxN lbN/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 30 60 90 120 150 180 210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foxhome</td>
<td>14.0 14.4 14.6 14.9 15.1 15.4 15.6 15.6 14.9 &lt;0.01 LP 171</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hallock</td>
<td>11.7 12.5 12.5 12.8 13.6 13.8 14.4 14.5 13.2 &lt;0.01 Lin 210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hendrum</td>
<td>14.8 14.2 14.2 14.2 14.5 14.5 14.4 14.6 14.4 &lt;0.01 NM --</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Sig., significant for main treatment effects (nitrogen rate) according to ANOVA; Model, regression model that best fits the data (lin, linear; Quad, quadratic; QP, quadratic plateau; LP, linear plateau; NM, no model); MaxN, N rate where response was maximized (a rate of 180 indicates no maximum was achieved with N rates applied).

Table 6. Summary of maximum return to N (MRTN) data for yield data summarized for Knudson wheat grown over four years in the Red River Valley.

<table>
<thead>
<tr>
<th>Discount $/fifth</th>
<th>EONR (0.10)†</th>
<th>EONR (0.15)†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
<td>MRTN</td>
</tr>
<tr>
<td></td>
<td>lbs total N/ac</td>
<td></td>
</tr>
<tr>
<td>0.00</td>
<td>125</td>
<td>136</td>
</tr>
<tr>
<td>0.05</td>
<td>142</td>
<td>153</td>
</tr>
<tr>
<td>0.10</td>
<td>167</td>
<td>177</td>
</tr>
<tr>
<td>0.15</td>
<td>178</td>
<td>187</td>
</tr>
<tr>
<td>0.20</td>
<td>184</td>
<td>191</td>
</tr>
</tbody>
</table>

† MRTN, Maximum return to N for specified nitrogen price ($/lb):crop price ($/bu); EONR, Economic optimum nitrogen rate.

Table 7. Summary of extractable macronutrients and soil organic matter

<table>
<thead>
<tr>
<th>Location</th>
<th>Nitrate-N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>SO₄²⁻S</th>
<th>O.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ppm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fergus Falls</td>
<td>14</td>
<td>19</td>
<td>197</td>
<td>2808</td>
<td>539</td>
<td>1</td>
<td>4.7</td>
</tr>
<tr>
<td>Humboldt</td>
<td>33</td>
<td>12</td>
<td>490</td>
<td>4971</td>
<td>1566</td>
<td>9</td>
<td>6.1</td>
</tr>
<tr>
<td>Lamberton</td>
<td>4</td>
<td>11</td>
<td>154</td>
<td>3000</td>
<td>686</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>Morris</td>
<td>2</td>
<td>4</td>
<td>117</td>
<td>3017</td>
<td>628</td>
<td>4</td>
<td>4.4</td>
</tr>
<tr>
<td>Oklee</td>
<td>23</td>
<td>6</td>
<td>159</td>
<td>5018</td>
<td>616</td>
<td>2</td>
<td>5.5</td>
</tr>
<tr>
<td>Stephen</td>
<td>50</td>
<td>6</td>
<td>445</td>
<td>5148</td>
<td>1056</td>
<td>2</td>
<td>5.4</td>
</tr>
<tr>
<td>Strathcona</td>
<td>31</td>
<td>73</td>
<td>180</td>
<td>3419</td>
<td>488</td>
<td>30</td>
<td>4.9</td>
</tr>
<tr>
<td>Waseca</td>
<td>1</td>
<td>17</td>
<td>203</td>
<td>3880</td>
<td>605</td>
<td>3</td>
<td>6.3</td>
</tr>
</tbody>
</table>
Table 8. Summary of extractable micronutrients and soil pH.

<table>
<thead>
<tr>
<th>Location</th>
<th>Zn</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>B</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fergus Falls</td>
<td>1.5</td>
<td>91.4</td>
<td>1.3</td>
<td>56.6</td>
<td>0.6</td>
<td>6.5</td>
</tr>
<tr>
<td>Humboldt</td>
<td>1.1</td>
<td>37.5</td>
<td>2.8</td>
<td>14.2</td>
<td>1.2</td>
<td>7.0</td>
</tr>
<tr>
<td>Lamberton</td>
<td>1.0</td>
<td>100.6</td>
<td>1.5</td>
<td>36.2</td>
<td>0.9</td>
<td>6.4</td>
</tr>
<tr>
<td>Morris</td>
<td>0.9</td>
<td>41.0</td>
<td>1.3</td>
<td>71.3</td>
<td>0.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Oklee</td>
<td>0.7</td>
<td>11.6</td>
<td>0.6</td>
<td>10.6</td>
<td>0.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Stephen</td>
<td>1.3</td>
<td>16.1</td>
<td>1.8</td>
<td>8.9</td>
<td>1.2</td>
<td>7.7</td>
</tr>
<tr>
<td>Strathcona</td>
<td>1.6</td>
<td>23.6</td>
<td>0.4</td>
<td>3.9</td>
<td>0.6</td>
<td>7.9</td>
</tr>
<tr>
<td>Waseca</td>
<td>2.1</td>
<td>111.4</td>
<td>1.7</td>
<td>50.0</td>
<td>1.1</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Table 9. Summary of statistical analysis for main treatment effects and their interaction.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Main Effect Significance†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site</td>
</tr>
<tr>
<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Potassium</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Sulfur</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.05</td>
</tr>
<tr>
<td>Copper</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

† Effects are considered significant at P<0.05.

Table 10. Flag leaf nitrogen concentration for each sampled location and variety.

<table>
<thead>
<tr>
<th>Line</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lamberton</td>
</tr>
<tr>
<td>-------</td>
<td>------------</td>
</tr>
<tr>
<td>Albany</td>
<td>4.1</td>
</tr>
<tr>
<td>Brick</td>
<td>3.6</td>
</tr>
<tr>
<td>Briggs</td>
<td>4.3</td>
</tr>
<tr>
<td>Faller</td>
<td>4.0</td>
</tr>
<tr>
<td>Glenn</td>
<td>3.8</td>
</tr>
<tr>
<td>Jenna</td>
<td>4.1</td>
</tr>
<tr>
<td>Knudson</td>
<td>4.0</td>
</tr>
<tr>
<td>Marshall</td>
<td>4.0</td>
</tr>
<tr>
<td>RB07</td>
<td>3.6</td>
</tr>
<tr>
<td>Sabin</td>
<td>3.8</td>
</tr>
<tr>
<td>Samson</td>
<td>3.7</td>
</tr>
<tr>
<td>Select</td>
<td>3.7</td>
</tr>
<tr>
<td>Tom</td>
<td>4.1</td>
</tr>
<tr>
<td>Vantage</td>
<td>3.4</td>
</tr>
<tr>
<td>WB-Mayville</td>
<td>4.2</td>
</tr>
<tr>
<td>Average</td>
<td>3.9</td>
</tr>
</tbody>
</table>
### Table 11. Flag leaf phosphorus concentration for each sampled location and variety.

<table>
<thead>
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### Table 12. Flag leaf potassium concentration for each sampled location and variety.

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Table 13. Flag leaf sulfur concentration for each sampled location and variety.

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Table 14. Flag leaf zinc concentration for each sampled location and variety.

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Table 15. Flag leaf copper concentration for each sampled location and variety.

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Figure 1. Economic summary using a 0.10 price ratio (price per lb. N: price per bu wheat) assuming no protein discounts. Wheat price was assumed to be $5.00 per bu. and N costs were $0.50 per lb.
**Figure 2.** Economic summary using a 0.10 price ratio (price per lb. N: price per bu wheat) assuming $0.10 discount per fifth. Wheat price was assumed to be $5.00 per bu. and N costs were $0.50 per lb.

**Figure 3.** Economic summary using a 0.10 price ratio (price per lb. N: price per bu wheat) assuming $0.20 discount per fifth. Wheat price was assumed to be $5.00 per bu. and N costs were $0.50 per lb.

**Figure 4.** Summary of net return to each additional pound of N multiplied across a 500 acre wheat operation for different grain protein discount levels.

The X axis represents total N applied which includes the amount in the 2’ soil test taken in the spring. Average 2’ soil test N was around 50 lbs of N per acre.
Minnesota Small Grain Pest Survey Scouting

Doug Holen, U of M Extension Regional Office - Fergus Falls

Research Questions

The objective of this project was to allow for timely small grain pest identification across the state of MN, resulting in early producer notification through Extension media in combination with NDSU’s already established pest survey program. This need was identified with the two year absence of a state small grain plant pathologist and MDAs decision to discontinue their statewide crop pest survey.

Results

Statewide sampling began the first week of June and continued throughout the small grain growing season and ended on August 11th. During that time, the Minnesota scouts surveyed for insect pests, including wheat stem maggot and multiple cereal grain aphids species. Aphids were found across the sampling region and were at threshold levels in some isolated areas. Small grain viruses (i.e., barley yellow dwarf, wheat streak mosaic virus) and bacterial leaf stripe were also common from the report data. Common fungal pathogens found included leaf rust, loose smut, septoria, fusarium head blight and tan spot. Season final data is illustrated in Appendix 12 and 13. These maps provide a regional representation of what was detected, where and when. Reports were released weekly.

This approach allowed for the first detection of many pests and was combined with location and plant stage. Incidence and severity were reported for each pest. Many other factors such as lodging, hail, planting dates, and pesticide applications were recorded to support the data.

Application/Use

This pest survey was developed and implemented for the early and correct identification of small grain insect and pathology pests across the state of Minnesota and to combine and report those findings with the ongoing project at North Dakota State University. The idea was to create a regional approach to surveying and reporting pest data to producers, researchers, consultants, and agricultural industry. The outcomes included early identification of tan spot across the entire sampling area allowing for quick management decisions. Small grain aphids were also found quickly and reported as to allow for timely notifications and treatments.

The data collected was reported weekly in print with the NDSU Pest Survey Report but was also disseminated to other researchers. The overall findings were represented to consultants and seed industry personnel, as well as discussed at summer plot tours. Sites included Kilkenny, Mora, Benson, Fergus Falls, Perley, Strathcona, Hallock and the Northwest Research and Outreach field day.

This detection and reporting system notified producers of the presence or absence of pests and the incidence and severity of the problem. With that data, producers could make educated, timely, and effective decisions leading to an economically feasible integrated pest management approach. The data collected represented pests found, but equally important was the time they were identified, as well as those not found.

Materials and Methods

Two pest scouts were hired to collect the needed data. Scout 1 (Coreen Berdahl) worked under the supervision of Jochum Wiersma with a home base of Crookston, representing production areas of Northwestern Minnesota. Scout 2 (Derrick Nelson) worked under the supervision of Doug Holen out of Fergus Falls with geographic responsibilities of west central, central, and southern Minnesota. This project had oversight from faculty of the U of MN St. Paul campus as well as training for job responsibilities and data reporting with NDSU. Three travel courses were mapped from each home base and traveled weekly to assure maximum geographic representation. Random fields were found and sampled with data collection taking place on site with the use of notebook computer systems. Samples were collected for verification if questions persisted with findings. All data components were downloaded and forwarded to Phil Glogoza who formatted the data set and then passed it through to NDSU for reporting in their system. Generated data sets were then also forwarded to supervisors. Supervisors were in constant communications with the scouts allowing for current knowledge on findings. About 40 fields per week were sampled.
between the two scouts. Some fields were revisits if a pest population warranted monitoring, otherwise new sites were sought.

**Economic Benefit to a Typical 500 Acre Wheat Enterprise**

The economic benefit was the timing and correct identification of small grain pests. With that information, producers knew what pest was present, when it was detected, at what levels, and plant growth stage it was found. Decisions could then be made as to whether or not treatment was necessary, and which products and rates were needed if thresholds were found. Equally important were decisions that pesticide applications were not economically justified due to pest populations and/or plant growth stage. As history has shown, millions of dollars have been lost due to pests such as leaf rust and fusarium head blight, as well as millions spent on pesticides in hope of controlling these and many other small grain pests. An average producer will apply fungicide one to two times per season and insecticide if needed. These efforts allowed for the timely notification of pest populations and allowing for the proper expenditure of money for pest management when and where needed.

**Related Research Effort**

At this time there is no related effort in Minnesota. The Minnesota Department of Agriculture had previously performed something similar across the state and for all crops. That program no longer exists. The absence of an outstate plant pathologist within the U of MN Extension system also highlighted the need for such a project. For two seasons, the project supervisors have responded to statewide pathology questions and programming. This approach saved many faculty hours by reducing the need for travel to investigate client reports while establishing and process for timely collection and representation of area-wide survey data.

NDSU has had the pest survey system in place for many years and our goal from the beginning planning stages was to incorporate our data into their program for a stronger and regionally larger report.

**Recommended Future Research**

It is our belief that this surveying effort should continue and can be improved upon with quicker data turnaround time to the agricultural community.

The benefits of this program include: identify the presence of regional pests in a timely fashion, save countless hours of small grain researchers time and resources in travel and communications, improve knowledge of localized pest conditions, increase visibility and perception of overall effort in small grains, establish a cooperative effort with NDSU, generate data for use by local coops, consultants, researchers, and producers.

Suggestions to improve the surveying system: Daily log of data collected and dissemination; cooperate with NDSU for training and reporting; better equip the scouts to make the best use of their time; use rental vehicles; develop cards with information on where to access the data that the scouts can hand out to clientele when approached; and, better planning of travel paths for more direct routes to the most possible fields.

It is this researcher’s objective to submit a very similar proposal with the mentioned improvements. This was a very valuable pilot year.
Evaluation of Winter Wheat Germplasm for Resistance to Stem, Leaf and Stripe Rust

Maricelis Acevedo, Department of Plant Pathology, NDSU

Research Questions

Evaluate current winter wheat varieties, cultivars and elite breeding lines for stem, leaf and stripe rust resistance.

Screen winter wheat landraces from the USDA-ARS National Small Grain Core Collection to potentially identify new sources of resistance.

Results

We were able to establish a reliable protocol for evaluation of stripe rust resistance under growth chamber conditions. A total of 120 advance lines that Dr. Marais is using to develop the NDSU winter wheat breeding program were evaluated in a replicated experiment. Approximately, 6% of the materials tested were highly resistant to stripe rust at seedling stage. Additional tests are currently ongoing to confirm the resistance reaction.

Leaf rust resistance screening of the winter wheat elite breeding lines and advanced germplasm against local races demonstrated that approximately 47% (57/121) of the entries were resistant to both races tested. Of the over 900 winter wheat landraces evaluated 18% and 30% were resistant to the THBL and MCDL races respectively. In addition, preliminary assessment of resistance, under greenhouse conditions, to a field bulk collection with virulence on Lr21 showed that 21% (25/119) of the entries tested have high to moderately resistance to the new races.

In conclusion, the research done during the past year has allowed the confirmation or identification of sources of resistance to leaf and stripe rust pathogen relevant to our region. The combination and incorporation of these sources of resistance into winter wheat breeding programs for the Northern Plains will provide an economic and environmentally sound strategy to manage wheat rust. Incorporation of rust resistance into winter wheat breeding lines is an essential tool to make winter wheat a competitive crop for our region. Future research will concentrate on validating the preliminary data obtained during the past year, complement it with additional tests and screening of the most promising materials for resistance against the stem rust pathogen race TTKSK (Ug99).

Application/Use

Cereal rusts are a major threat to wheat production worldwide. Every year yield losses are observed in the U.S. due to one or more of the wheat rust pathogens.

Use of fungicides is an effective measure to manage rust diseases but cost millions of dollars to U.S. wheat growers annually. Use of resistant varieties is the most economically sound and environmentally friendly rust disease management strategy. Limited information is available about the resistance or susceptibility of winter wheat materials adapted to our region. Information obtained from the evaluation of winter wheat varieties, cultivars and breeding lines against races of leaf, stripe and stem rust can be used to determine our risk of epidemics and yield loss. Information on elite breeding lines will help the decision-making process for the selection of the new generation of parental lines that will be utilized in the winter wheat breeding program. Evaluation of landraces from the USDA National Small Grain Collection (NSGC) will give us the opportunity to potentially identify novel sources of resistance that can be incorporated into breeding programs.

Materials and Methods

The objective of the proposed project was to evaluate current winter wheat varieties, cultivars and elite breeding lines for stem, leaf and stripe rust resistance. In addition, we propose to screen 800 winter wheat landraces from the winter wheat core collection of the USDA-NSGC representative of geographic regions of the world where winter wheat has been traditionally grown. Rust reaction in winter wheat cultivars, breeding lines and landrace accessions were evaluated at seedling stage under greenhouse experiments in replicated trials. Plants were inoculated 8-10 days after planting and evaluated for leaf rust resistance 12-14 days after inoculation. For the stripe rust resistance evaluation with a local isolate collected from the field was utilized. For leaf rust evaluation two predominant local races THBL and MCDL, available in our program were utilized.
Economic Benefit to a Typical 500 Acre Wheat Enterprise

Assuming a standard 20-30% potential yield loss to rust diseases, the potential economic impact of the three rust diseases to North Dakota winter wheat can be very significant. Use of resistant varieties can reduce yield loss caused by rust to a minimum without extra cost for fungicide application to growers.

Recommended Future Research

For the stripe rust resistance evaluation local isolates collected from the field and isolates representing the new races established in the Southern Plains will be utilized. For leaf rust and stem rust evaluation predominant local races available in our program will be utilized. To obtain reliable field data replicated field experiments will be artificially inoculated. Inoculum will be composed of predominant local races previously identified in ND wheat fields from natural infections. Data obtained from the variety trials will rely on natural disease pressure. Promising genotypes with stem rust resistance to local races will be included in the International Rust Nurseries in Kenya to be evaluated for “Ug99 lineage” resistance.
Positioning NDSU Spring Wheat Breeding Program to Better Serve MN Wheat Growers

Mohamed Mergoum, Department of Plant Sciences, NDSU

Introduction

Spring wheat cultivars released by the university (public) wheat breeding programs at the three state (MN, ND and SD) have historically played a major role in the wheat production in the region. In general, this is still true except for few cultivars released by private companies. Among these wheat breeding programs, NDSU is well known for its high quality germplasm and cultivars. While our intentions are still to maintain that hallmark germplasm/cultivars development, recently more emphasis was oriented to develop high yielding cultivars to meet our growers demand, particularly those in the Western MN and Eastern ND regions. By combining NDSU resources and the support from the Minnesota Wheat Research and Promotion Council (MNWRPC), our efforts have bared fruits in 2007 when spring wheat Faller was released by NDSU. Faller was truly, the first variety that combined high yield potential with relatively good quality attributes, challenging all other high yielding cultivars released by other breeding programs in the spring wheat region. Just two years after its release, Faller became the leading cultivar in MN since 2009. More than 21, 30 and 28% of MN total wheat acreages were grown to Faller in 2009, 2010, and 2011. In 2011, RB07 developed and released by the U of MN (public breeding) was second to Faller by 22.2%. Under high input and good environmental conditions -such as in 2009 and 2010- most high yielding cultivars, including Faller grown in the region showed relatively, lower protein levels. This has caused many discounts for wheat with protein levels lower than 14%. While these low levels of protein can be explained by crop management such as low N available to plants given the high yield levels attained (case of Faller), the genetic character of quality is critical. In all cases, demand for new adapted cultivars to the MN environments which combine high productivity and acceptable levels of “marketable” quality traits such as grain protein is needed.

Objectives

The goal of this project is to support the on-going breeding program to develop superior spring wheat cultivars targeted to MN, particularly the Western wheat growing environments. These specific objectives are to focus on developing cultivars/germplasm that should possess the following traits:

- High yield potential.
- Good quality characteristics which allow premiums for wheat growers and sustainable competition on the international market. These traits include protein content, milling and baking characteristics.
- High levels of resistances to dominant leaf diseases such as leaf and stem rusts, a continuous threat to wheat; leaf spotting diseases; and bacterial leaf diseases that can be devastating in some years.
- Good resistance to Fusarium head blight (Scab), still a major disease for wheat in MN and the region.

Research Activities / Preliminary Results

Most data collected in summer 2011 field research activities are still in process. Therefore, this report does not include those data. In 2011, several research activities have been conducted by the NDSU spring wheat breeding program in order to achieve our goal. Although these activities have a multidisciplinary character, the wheat breeding program did coordinate them to make sure that the objectives are being addressed efficiently and timely. Among these research activities we can list the following:

1. Crosses and populations development:
   In 2011, about 150 crosses were made to incorporate into our adapted germplasm traits of economic values for wheat growers and industry in the Western MN and Eastern ND. These crosses were made among the most adapted cultivars and elite genotypes to MN environments in the Fall and Spring in greenhouse cycles. These crosses were planted in the greenhouse to generate $F_2$ populations to be planted in the field in summer of 2012. Similarly, $F_2$ segregating populations generated from previous $F_2$ were planted in field in summer 2011. Most of our new adapted parents have diseases (leaf diseases, FHB...etc), yield potential and quality. However, new races may emerge anytime due to the selection pressure on these pathogen caused by cultivating resistant cultivars on a large scale. The key is to identify new sources of resistance and combine –pyramid- these genes and other genes governing important
economic traits in one genotype. In 2011, depending of crosses, 100 to 300 spikes were selected from the most promising F₂ population to be advanced for further generations and selections. Similarly, five to 10 spikes from each selected F₁ lines (generated from previous F₂ populations) were threshed and shipped to New Zealand or Arizona as head-rows for generation advancement and selection for some agronomic traits (lodging, height, maturity, shattering, and other plant type). Similar procedures were followed to advance and select germplasm from other segregating generations such as F₄ and F₅ until homozygosity is reached.

2. Diseases evaluation/screening:
Screening for pests in general, is a routine operation in our breeding program and all germplasm planted in the field. The first screening starts at F₂ and following generations until the release of a cultivar. The screening is conducted for all pests that are prevalent in the field. Among these, leaf diseases (rusts, and leaf spotting diseases), scab, bacteria and insects (in some years) are the main biotic stresses that are facing our breeding program. Therefore, all breeding material planted in the field is subjected to the screening for these pests. However, in addition to these screening at the breeding nurseries, advanced material is subjected to more scrutinized screening for these major diseases (rusts and scab) in specific diseases nurseries. In 2011, these additional nurseries for rusts and scab were installed in many locations including Fargo, Prosper, Carrington, and Langdon, ND. Furthermore, screening of elite material is also done in the greenhouse as well as by our colleagues in the U of MN and SDSU. In 2011, the most striking event was the appearance of the new leaf rust race in parts of ND and MN that has overcome the Lr21 gene. This is a major gene that has been used for decades to protect our and other breeding programs germplasm in the region. Among the cultivars that have this gene is Faller, and Prosper. Fortunately, many other cultivars and germplasm carry other genes that protect against the new race. This race is not yet widespread in the region. In 2011, we have screened (preliminary) under filed condition our elite material to this new race. Also, we are currently testing our elite material under greenhouse condition with the collaboration of Plant Pathology (Dr. M. Acevedo). Similarly, about 3000 lines were screened for scab under field condition in collaboration with Dr. S. Zhong (Plant Pathology Department).

3. Early evaluation of segregating generations and preliminary yield trials:
In summer 2011, the breeding program evaluated about 2,000, 500, and 200 of F₅, F₆, and F₇ families for disease resistances and agronomic traits. Preliminary yield trials (PYT) which include mainly F₅ were conducted in non-replicated plots under natural conditions in the field. Selected material from these nurseries is being evaluated for some quality traits in the laboratory with Dr S. Simsek. These lines would be advanced either using single-seed-descent for some populations intended for genetic studies or they will be advanced in the winter nurseries.

4. Screening and evaluation of advanced and elites lines:
   a. MN Testing sites
A yield trial including advanced lines and checks (75 entries) was installed for the first time at two locations in Western MN. The two locations are Wolverton (Southwest MN) and Alvarado (Northwest MN). These two locations are relatively contrasting sites of the Red River Valley where spring wheat is still a major crop. The performance of wheat lines in these two locations was very different (Figure 1 and 2). Yields level at Alvarado were relatively high compared to those obtained at Wolverton. The overall average yield at Alvarado was 56.5 bu/ac while at Wolverton it was 28.4 bu/ac. This shows the contrasting environmental conditions at these two locations. At Wolverton, wheat was substantially damaged by the excess of water due to rain. At Alvarado, yields were relatively high due to better conditions compared to Wolverton. However, in both locations, high yielding lines with equal or exceeding the best checks were identified. These promising lines will be subjected for further tests. However, quality data is being generated for these lines for final selection. In addition, these lines are being tested for leaf disease, particularly for the new leaf rust race.

Test weight flowed –somehow- the grain yield trend in both locations. While test weight in general, was very high at Alvarado, a high yield ding location (Figure 2) with a mean of 63.6 lb/bu, it was relatively lower at Wolverton (lower yield site, Figure 1) with an average mean of 60.8 lb/bu. The test weight ranged between 64.9 and 60.9 lb/bu at Alvarado; and between 63.1 and 60.8 lb/bu registered at Wolverton. Test weight of Faller, Glenn, Barlow and Prosper were respectively 63.5, 64.7, 63.4, and 63.3 at Alvarado and 59.6, 62.4, 60.8, and 79.7 at Wolverton. Other parameters such as quality performance in particular are being studied.
**ND Testing:**
In addition to the yield trial conducted in MN sites with 75 entries, other yield trials including Intermediary (IYT) and Preliminary (PYT) were conducted in many sites in the Eastern parts of ND. These yield trials were conducted in Casselton, Prosper, and Langdon in Eastern ND (Red river valley). At Casselton and Prosper, these yield trials were damaged by flood. Usually, the data generated from these yield trials include agronomic and quality data, pests’ reactions, and other data on traits such as bacterial reactions. These genotypes were also evaluated in replicated hill plot nurseries grown in the Scab nurseries. Data is being processed and selected lines –based on field observations were included in New Zealand or Arizona winter nurseries to accelerate generation advancement and seed increase. The winter nurseries are also used to select for maturity, height, lodging resistance and shattering.

**Quality Evaluation:**
Samples from all yield trials are being prepared to be sent to our quality laboratory (Dr S. Simsek) to perform quality testing. For lines included in the IYTs, grain characteristics as well as milling and dough will be performed. For lines that are included in AYT, and EYT, additional test on baking performance will be added to the quality package tests. This data will be added to the other agronomic performance for further selection and decision making for further testing, seed increase, or eventual cultivar release.

5. Markers Assisted Selection (MAS):
Screening the spring wheat germplasm developed by this project, using known molecular markers, was conducted in collaboration with the Genotyping Center at the USDA-ARS at Fargo (Dr Chao Lab.). Currently, DNA samples from about 1500 lines included in the yield trials are being prepared. These samples will be sent to the USDA-ARS Fargo genotyping Center (Dr S. Chao) to determine the presence/absence of selected molecular marker in these lines. Particularly, molecular markers for FHB resistance located on chromosome 3BS (Sumai3) and 3AS (*Triticum dicoccoides*), leaf diseases, grain protein content,… etc will be utilized in this screening. The use of these markers may be very useful in indicating the absence/presence of the genes of interest. This may allow us to start combining/pyramiding different genes and different traits.

6. Tri-States(ND-MN-SD) common trials and potential releases:
A “Tri-state Cooperative Trial” (TCT) which include elite material from the three public (ND, MN, and SD) spring wheat breeding programs was established for the first time in 2011. This trial was established to substitute for the Uniform Regional Spring Wheat Nursery that was historically conducted in the spring wheat region. TCT included 25 genotypes (20 lines and 5 checks) from the three breeding programs and was conducted in several locations in each state. In ND, It was conducted in five locations. Unfortunately, TCT and all other trials were severely damaged by flood at Prosper and Casselton and by hail in Carrington. Data from two locations only will be available.

**Major Achievements**

2011 was a milestone year in term of collaboration between NDSU and the U of MN spring wheat breeding program. For the first time in recent history, NDSU and the U of MN have joined their efforts to release jointly the NDSU developed hard red spring wheat cultivar “Prosper”. It is a conventional to semi-dwarf variety with an early to medium-early maturity. Prosper has a very high yield that equals or betters Faller. It is moderately resistant/moderately susceptible to scab and is resistant to stem rust. Based on preliminary reports from 2010 and 2011, Prosper appears to be susceptible to a new leaf rust race that is emerging in our region. Prosper’s average protein content and test weight are similar to Faller and it has a high flour extraction. In addition, it has good milling and baking qualities similar to Faller. Prosper is released to complement and eventually replace Faller.
Figure 1: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Wolverton, MN during 2011. *NB: Bars for the checks Faller, Glenn, Barlow and Prosper represent yield in bu/ac.*

Figure 2: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Alvarado, MN during 2011. *NB: Bars for the checks Faller, Glenn, Barlow and Prosper represent yield in bu/ac.*
Refining Nitrogen Recommendation Zones for Hard Red Spring Wheat in Minnesota
Jochum Wiersma, Northwest Research & Outreach Center

Research Questions

An underlying assumption of any recommendation is that the area for which the recommendation is made is relatively uniform. The outcomes experienced by individual growers at any location within the target area should be close to the expected outcome predicted by the recommendation.

Minnesota’s current HRSW N recommendations divide the state in two zones or target areas; an eastern zone where the soil nitrate test is not appropriate and a western zone where the soil nitrate test is used. Variability in the original 69 site-year data set, used to develop the current N recommendation, as well as anecdotal evidence of growers suggests considerable variation in optimum N rates across the western zone. Therefore, it is warranted to explore this variation in more detail, a prerequisite to more nuanced N management recommendations in the future. Since HRSW grain protein responds linearly over a wider range of available N, we selected grain protein as the response variable by which to measure this variation rather than grain yield.

Results

Initial results indicate that the survey created enough participation to create a robust, balanced dataset. The response rate was 8.5% and 6.1% for the number of sample bags mailed in 2010 and 2011, respectively. The initial analysis of the unadjusted grain protein content pointed to a geospatial pattern within the western N management zone in 2010. The initial host spot analysis of the unadjusted grain protein content did not reveal any spatial pattern within the western N management in 2011. The 2011 data revealed a bimodal rather than a normal distribution as was the case in 2010. This suggests that there is an underlying effect that obscures any spatial pattern in 2011. Hence, additional analyses of the data are warranted before the 2011 is dismissed as a total loss.

Materials and Methods

In collaboration with the Minnesota Wheat Research & Promotion Council a mail survey was conducted.
during the 2010 and 2011 HRSW harvests. Each survey kit contained 5 sample bags/surveys and 2 pre-paid return envelopes (Photo 1). Producers were asked to return a grain sample, one bag representing one field, as well as information about the field from where the sample originated. A total of 4242 and 5096 survey kits were mailed to producers in June of 2010 and 2011, respectively. Reminder cards were mailed 3 and 6 weeks later. Regional media was used to create awareness and encourage participation.

Producers were asked to record the geographic location of the sampled field and share information about the variety, planting date, and amount and source of N applied. With few exceptions, producers recorded field locations using civil township names and section numbers. Where appropriate the ¼ section and ½ quarter section were also documented.

Grain protein was determined on the received samples using NIR. Civil Townships were converted to Public Land Survey (PLS) Township and Range and an attribute field was added to the sampled field data set that accounted for the county, township and range, section, quarter section, and quarter-quarter section geographic location. This data set was joined in ArcView 9.2 to the PLS quarter-quarter section data set obtained from the Minnesota DNR Data Deli.

Grain protein from the mapped fields was subjected to two geostatistical procedures. First, a Getis-Ord Gi* Hotspot analysis completed on the data (Map 2) then the same data were subjected to several interpolation methods. The lowest residual mean square (a measure of error) was obtained with the spherical model type of ordinary Kriging (Map 3).

Related Research


Recommended Future Research

The principal investigators are evaluating whether to repeat the survey for a third year.

Publications

Expanded Wheat Breeding and Genetics

James A. Anderson, Department of Agronomy and Plant Genetics, U of M

Research Questions

The objectives of this proposal are to i) develop improved varieties and germplasm combining high grain yield, disease resistance, and end-use quality; and ii) provide performance data on wheat varieties adapted to the state of Minnesota.

Results

During the 2010/2011 crossing cycle, 352 crosses were made. The Variety Trial, which contained 32 released varieties, 9 University of Minnesota experimental lines, and 4 experimental lines from other programs was grown at Crookston, Fergus Falls, Hallock, Lamberton, Morris, Oklee, Roseau, St. Paul, Stephen, Strathcona, and Waseca. During the 2011 growing season, 160 advanced experimental lines were evaluated in advanced yield trials at 10 locations. A total of 533 preliminary yield trial lines were tested in unreplicated plots at Crookston, Morris, and St. Paul. Fusarium-inoculated, misted nurseries were established at Crookston, and St. Paul. Inoculated leaf rust nurseries were conducted at Crookston and St. Paul and a stem rust nursery was also conducted at St. Paul. The disease nurseries involve collaboration with agronomists and pathologists at Crookston and with personnel from the Plant Pathology Department and the USDA-ARS. Data from the yield and scab nurseries are summarized and published in Prairie Grains and the U of M Extension Service’s Minnesota Varietal Trials Results.

The breeding program expanded the number of yield plots grown in 2011 vs. 2010. A total of 6,628 yield plots were planted in 2011 compared with 5,683 in 2010. This increase was due to 1) increasing the number of 1st year yield trial lines from 437 to 533; and 2) increasing the number of locations where 2nd year yield trial lines were evaluated from 5 to 10.

One advanced experimental line, MN03196, underwent a seed increase via Minnesota Crop Improvement Association in 2011. MN03196 has good straw strength, high test weight, competitive grain yield in the northern regions of the state, and grain protein content intermediate between RB07 and Faller (Table 1). MN03196’s good leaf rust resistance is due to genes other than $Lr21$. Varieties that contain gene $Lr21$, especially Faller and Prosper, are susceptible to leaf rust races that have increased since 2010. MN03196 is a candidate for 2012 release.

Table 1. Comparison of MN03196 with higher yielding varieties, RB07, and Rollag. Genotypes are in order by yield.

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* 20 environments from 2009-2011.
Two other experimental lines were approved for winter increase in 2011/2012: MN06028 (MN97695-4/Ada) is short, and has very strong straw, high protein, and excellent end-use quality. Yield is above average and scab resistance is average. MN07098-6 (SD3696/Ulen sel) has been a consistent high yielder with good adaptation across the entire state and good scab resistance. MN07098-6 has higher grain protein than the varieties with higher yield. End-use quality and pre-harvest sprouting reaction of MN07098-6 is below average.

**Application/Use**

Experimental lines that show improvement over currently available varieties are recommended for release. Improved germplasm is shared with other breeding programs in the region. Scientific information related to efficiency of breeding for particular criteria is presented at local, regional, national, and international meetings and published.

**Materials and Methods**

All yield nurseries are grown in small, replicated plots (typically 40-50 sq. ft. harvested area per plot). Fusarium-inoculated nurseries at Crookston and St. Paul consist of single 4 to 6 ft. rows, with 1 to 3 replications. Fusarium-infected corn seed or spray-applied macroconidia are used as inoculum. The plot areas are misted periodically to maintain a high humidity environment for at least three weeks after anthesis.

**Economic Benefit to a Typical 500 Acre Wheat Enterprise**

Choice of variety is one of the most important decisions growers make each year. The development of high-yielding varieties that are resistant to the prevalent diseases and have good end-use quality are necessary to increase grower profit and protect against constantly changing pathogens and pests. As an example, a new variety that yields 4% higher will produce 3 extra bushels in a field that averages 75 bu/A.

**Related Research**

These funds provide general support for our breeding/genetics program. Additional monetary support for breeding-related research in 2011 came from the Minnesota Small Grains Initiative and Rapid Agricultural Response fund via the Minnesota Agricultural Experiment Station, the U.S. Wheat and Barley Scab Initiative via USDA-ARS, and National Research Initiative Competitive Grant no. 2011-68002-30029 (Triticeae-CAP) from the USDA National Institute of Food and Agriculture.

**Publications**


## 2011 North Dakota Barley Variety Trial Results for 2011 and Selection Guide

Compiled by Joel Ransom, Tim Friesen, Rich Horsley, Mike McMullen and Paul Schwarz (NDSU main station); Blaine Schatz (Carrington Research Extension Center); Glenn Martin (Dickinson Research Extension Center); Eric Eriksmoen (Hettinger Research Extension Center); Bryan Hanson (Langdon Research Extension Center); Mark Halvorson (North Central Research Extension Center-Minot) and Gordon Bradbury (Williston Research Extension Center).

### TABLE 1. 2011 North Dakota barley variety descriptions.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Use 1</th>
<th>Origin 2</th>
<th>Year Released</th>
<th>Awn Type 3</th>
<th>Rachilla Hair Length 4</th>
<th>Aleurone Color</th>
<th>Height</th>
<th>Straw Strength</th>
<th>Relative Maturity</th>
<th>Stem Rust</th>
<th>Spot Blotch</th>
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<td>S</td>
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<td>S</td>
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1 M = malting; MT = Being tested in plant scale tests for malting and brewing quality; F = feed; SP = special uses (hulless). 2 BARI = Busch Agricultural Resources Inc.; Can = Canada; MN = U of Minnesota; MT = Montana State U; ND = North Dakota State University. 3 R = rough; S = smooth; H = hulless. 4 S = short; L = long. 5 R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; NA = not available. 6 Moderately Resistant to Fusarium head blight. 7 Lower DON accumulations than other varieties tested. 8 Recommended as a malting barley in western USA. Presentation of data for the entries tested does not imply approval or endorsement by the authors or agencies conducting the test. NDSU approves the reproduction of any table in this publication only if no portion is deleted, if appropriate footnotes are given and if the order of the data is not rearranged.
## TABLE 2. Yield and test weight of barley varieties at three locations in eastern North Dakota, 2009-2011.

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<th>Langdon</th>
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## TABLE 3. Plump and protein of barley varieties at three locations in eastern North Dakota, 2011.

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<th>Variety</th>
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<th>Langdon</th>
<th>Average Eastern N.D.</th>
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### TABLE 4. Yield and test weight of barley varieties at four locations in western North Dakota, 2009-2011.

<table>
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<th>Hettinger</th>
<th>Minot</th>
<th>Williston</th>
<th>Average Western N.D.</th>
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<td>(bu/a)---</td>
<td>(lb/bu)</td>
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### TABLE 5. Plump and protein of barley varieties at four locations in western North Dakota, 2011.

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<tr>
<th>Variety</th>
<th>Dickinson</th>
<th>Hettinger</th>
<th>Minot</th>
<th>Williston</th>
<th>Average Western N.D.</th>
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2011 North Dakota Hard Red Spring Wheat
Variety Trial Results for 2011 and Selection Guide

Compiled and Edited by Joel K. Ransom, Mohamed Mergoum, and Senay Simsek, NDSU

Hard red spring (HRS) wheat was harvested from 5.5 million acres in 2011, down from 2010 due to large areas of the state that were not planted. Planting was delayed in many areas of the state due to wet spring conditions. The late planting coupled with hot weather in July had a detrimental impact on spring wheat yields. The estimated yield of 31.5 bu/acre was down sharply from the near record level of 44.0 bu/acre in 2010.

Glenn was the most popular HRS wheat variety in 2011, occupying 18.1 percent of the planted acreage, followed by Faller (11.4 percent), Barlow (8.5 percent), RB07 (7.0 percent), Brennan and Kelby (5.4 percent), Briggs (4 percent), Vantage (3.5 percent) and Freyr (3.3 percent). Brennan, Freyr and Kelby were released by AgriPro, Briggs by South Dakota State University, Vantage by WestBred and RB07 by the University of Minnesota. All other varieties are NDSU releases.

In 2010 new races of the wheat leaf rust pathogen, *Puccinia triticina* with virulence on resistance gene Lr21 were identified in three locations in North Dakota and Minnesota. These new races are a threat for wheat production in the Northern Great Plains since more than 50% of the hard red spring wheat acreage in ND and MN are planted with cultivars that relied on Lr21 for effective leaf rust resistance. In 2011 virulence on Lr21 was observed in rust nurseries in Fargo, Carrington and Langdon, ND. Many cultivars that were resistant to moderately resistant prior to 2010 are moderately susceptible to susceptible to these new races. At the time of this publication the frequency of these races in our region was unknown.

Successful wheat production depends on numerous factors, including selecting the right variety for a particular area. The information included in this publication is meant to aid in selecting that variety or group of varieties. Characteristics to consider in selecting a variety may include yield potential, protein content when grown with proper fertility, straw strength, plant height, reaction to problematic pests (diseases, insects, etc.) and maturity. Every growing season differs; therefore, when selecting a variety, we recommend using data that summarize several years and locations. Choose the variety that, on average, performs the best at multiple locations near your farm during several years.

Selecting varieties with good milling and baking quality also is important to maintain market recognition and avoid discounts. Hard red spring wheat from the northern Great Plains is known around the world for its excellent end-use quality. Millers and bakers consider many factors in determining the quality and value of wheat they purchase. Several key parameters are: high test weight (for optimum milling yield and flour color), high falling number (greater than 300 seconds indicates minimal sprout damage), high protein content (the majority of HRS export markets want at least 14 percent protein) and excellent protein quality (for superior bread-making quality as indicated by traditional strong gluten proteins, high baking absorption and large bread loaf volume).

Gluten strength, and milling and baking quality ratings, are provided for individual varieties in Tables 2 and 3, based on the results from the NDSU field plot variety trials. These ratings are applied to varieties grown for multiple years at seven NDSU Research Extension Centers across the state to provide producers and end users with end-use performance data. The wheat protein data often are higher than obtained in actual production fields but can be used to compare differences among varieties.

The agronomic data presented in this publication are from replicated research plots using experimental designs that enable the use of statistical analysis. These analyses enable the reader to determine, at a predetermined level of confidence, if the differences observed among varieties are reliable or if they might be due to error inherent in the experimental process. The LSD (Least Significant Difference) numbers beneath the columns in tables are derived from these statistical analyses and apply only to the numbers in the column in which they appear. If the difference between two varieties exceeds the LSD value, it means that with 95 percent confidence (LSD probability 0.05), the higher-yielding variety has a significant yield advantage. When the difference between two varieties is less than the LSD value; there is no significant difference between those two varieties under those growing conditions. NS is used to indicate no significant difference for that trait among any of the varieties at the 95 percent level of confidence. The CV stands for coefficient of varia-
tion and is expressed as a percentage. The CV is a measure of variability in the trial. Large CVs mean a large amount of variation that could not be attributed to differences in the varieties. Presentation of data for the entries tested does not imply approval or endorsement by the authors or agencies conducting the test. NDSU approves the reproduction of any table in the publication only if no portion is deleted, appropriate footnotes are given and the order of the data is not rearranged. Additional data from county sites are available from each Research Extension Center at www.ag.ndsu.edu/varietytials/spring-wheat.

Contributing Authors: Joel Ransom, Mohamed Mergoum, Senay Simsek, Maricelis Acevedo, Eric Eriksmoen (Hettinger Research Extension Center), Tim Friesen (North Central Research Extension Center, Minot), Bryan Hanson (Langdon Research Extension Center), Maricia McMullen, Glenn Martin (Dickinson Research Extension Center), Gordon Bradbury (Williston Research Extension Center), Blaine Schatz (Carrington Research Extension Center), Shaobin Zhong

NDSU Main Station

Table 1. North Dakota hard red spring wheat variety descriptions, agronomic traits, 2011.

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1 Refers to agent or developer: MN = University of Minnesota; MT = Montana State University; ND = North Dakota State University; SD = South Dakota State University; Can. = varieties developed in Canada. Bold varieties are those recently released so data is limited and rating values may change. NA indicates insufficient information is available to make an accurate assessment. 2 Straw Strength = 1-9 scale with 1 the strongest and 9 the weakest. These values are based on recent data and may change as more data become available. 3 Days to Head = the number of days from planting to head emergence from the boot averaged over several locations in 2010 and 2011. 4 R = resistant; MR = moderately resistant; M = intermediate; MS = moderately susceptible; S = susceptible; VS = very susceptible. 5 Leaf spot refers to the leaf fungal diseases such as tan spot and septoria. It does not include bacterial leaf streak. 6 Solid stemmed or semisolid stem, imparting resistance to sawfly. 7 Hard white wheat. 8 CL = refers to a Clearfield variety, with tolerance to Beyond™ family of herbicide. 9 These lines were resistant to moderately resistant to races prevalent prior to 2011. Resistance may have been defeated by new races of the pathogen that at an unknown prevalence in natural population.
TABLE 2. Analytical milling and baking data from field plot variety trials at Carrington, Casselton, Dickinson, Hettinger, Dickinson, Hettinger, Langdon, Minot and Williston, 2009 and 2010 (unless otherwise noted).

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<th>Variety</th>
<th>2011 N.D. Planted (% area)</th>
<th>Test Weight (lb/bu)</th>
<th>Protein 12% MB (%)</th>
<th>Vitreous Kernels (%)</th>
<th>Falling Number (seconds)</th>
<th>Farinograph Classification (1-8)</th>
<th>Farinograph Stability (minutes)</th>
<th>Farinograph Absorption (%)</th>
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Analyses conducted at the NDSU Hard Red Spring Wheat Quality Laboratory in Fargo, N.D. For footnotes, see bottom of Table 3.
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Analyses conducted at the NDSU Hard Red Spring Wheat Quality Laboratory in Fargo, N.D.

1 Scale 1-8, where 1 = weak and 8 = very strong dough-mixing properties. Farinograph properties affected by growing conditions, so compare varieties.

2 Mill and Bake Quality Rating scale 1 to 5, with 1 being low and 5 being superior.

3 Varieties were not tested at all locations.

4 Glenn is the current Wheat Quality Council check variety for comparing new experimental lines and newly released varieties.
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¹ Hard white spring wheat variety
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1 Hard white spring wheat variety
2011 Wheat, Barley and Oat Variety Performance in Minnesota
Preliminary Report

Preface
Jochem Wiersma

The 2011 growing season will likely be remembered as somewhat disappointing. The cause of this disappointment was the sharp declines in yield from what many had enjoyed in the last five plus years. The declines in yields can largely be attributed to delayed planting and a hot and humid July. The planting delays stemmed from back-to-back wet years and near record snowfall. The snow cover allowed for near perfect winter survival of both winter wheat and winter barley, but delayed spring planting progress. By April 10th, no small grains had been planted anywhere in the State. Continued cold and wet weather in the second half of April and first week of May pushed field work further back and well behind the 2010 pace and the 5-year average.

Field work did not start in earnest until the second week of May. By May 15th, 54% of the oat acreage, 39% of the spring wheat, 22% of the barley acreage had been planted. A week later this had increased to 83%, 80%, and 76% for oat, wheat, and barley, respectively. The remaining acres were seeded in the last week of May and first week of June. Initial growing conditions were favorable for small grains as cool conditions prevailed for much of May and June. The cool conditions allowed for ample tillering. Not surprisingly, jointing was well behind the 2010 pace and 5-year average. On June 12th, only 14% of the barley, 19% of the wheat, and 32% of the oat had reached the jointing stage. In comparison, those percentages were 85%, 77%, and 77% the year prior.

USDA’s June yield prognosis had Minnesota’s spring wheat yield pegged at 52 bushels per acre, 4 bushels less than 2010 but 3 bushels more than in 2009. Yield predictions for barley and oats were 59 bu and 61 bu, respectively.

While June was near ideal for small grains, July was the opposite. High heat and humidity sped up development and by July 25th crop growth and development was approaching the 5-year average with more than a third of the wheat crop already turning ripe. Severe weather and heavy downpours initially delayed harvest but by the middle of August harvest was in full swing. By the end of the month harvest was ¾ complete and on par with the 5-year average.

The USDA has the state’s average yields pegged at 62, 54, and 42 bushels per acre for barley, oat and spring wheat, respectively; well below the June estimates and some 20% below the 2010 state averages. The overall quality of the crop was good although test weights suffered in the southern two thirds of the state as a result of the heat and humidity during grain fill. The Regional HRSW Crop Quality Report points towards not only a decrease in test weight but smaller kernels as well. The overall grade, however, is dark northern spring (DNS) compared to northern spring (NS) in 2010 as the percentage vitreous kernel increased from 58 to 76%. Field symptoms of Fusarium head blight were found by scouts throughout Minnesota. FHB incidence and severity were higher than they have been since 2005, the last year FHB was a significant problem. Fortunately, DON contamination in grain that has been delivered to elevators is not exceeding the 2 ppm threshold and is often below 1 ppm. The absence of any discounts for lower grain protein contents in spring wheat is a nice reprieve from the last three years in which producers were faced with record discounts for protein contents below 14%. Unfortunately, the premiums for high grain proteins evaporated too and thus the lower than expected yields are not offset by any premiums for the higher protein grain that was harvested.

Spring wheat acreage declined by some 50,000 acres to 1.55 million acres while winter wheat acreage declined to 30,000 acres. Oat acreage declined sharply to just 110,000 acres. Barley acreage declined another 10,000 to just 60,000 acres. Record corn and soybean prices are having a definite impact on small grain acreage and the late spring likely aggravated the acreage trends.
Introduction

Successful small grain production begins with selection of the best varieties for a particular farm or field. For that reason, varieties are compared in trial plots on the Minnesota Agricultural Experiment Station (MAES) sites at St. Paul, Rosemount, Waseca, Lamberton, Morris, and Crookston. In addition to the six MAES locations, trials are also planted with a number of farmer cooperators. These plots are handled such that the factors affecting yield and performance are as close to uniform for all entries at each location as possible.

The MAES 2011 Wheat, Barley and Oat Variety Performance in the Minnesota Preliminary Report is presented under authority granted by the Hatch Act of 1887 to the Minnesota Agricultural Experiment Station to conduct performance trials on farm crops and interpret data to the public.

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Variety Classifications

Varieties are listed in the tables alphabetically. No other distinction or classification is used to group varieties. Seed of tested varieties can be eligible for certification, and use of certified seed is encouraged. However, certification does not imply a recommendation. Registered and certified seed is available from seed dealers or from growers listed in the ‘MN Crop Improvement Association 2011 Directory’, available through the Minnesota Crop Improvement Association office in St. Paul or online at http://www.mncia.org.

Interpretation of the Data

The presented data are the preliminary variety trial information for single (2011) and multiple year (2009-2011) comparisons in Minnesota. The yields are reported as a percentage of the location mean, with the overall mean (bu/A) listed below. Two-year and especially one-year data are less reliable and should be interpreted with caution. Similarly, averages across multiple environments, whether they are different years and/or locations, provide a more reliable estimate of mean performance and are more predictive of what you may expect from the variety the next growing season. The least significant difference or LSD is a statistical method to determine whether the observed yield difference between any two varieties is due to true, genetic differences between the varieties or to interactions with other variables such as a difference in soil fertility or experimental error. If the difference in yield between two varieties equals or exceeds the LSD value, the higher yielding one was indeed superior in yield. If the difference is less, the yield difference may have been due to chance rather than genetic differences, and we are unable to differentiate the two varieties. The 10% unit indicates that, with 90% confidence, the observed difference is indeed a true difference in performance. Lowering this confidence level will allow more varieties to appear different from each other, but also increases the chances that false conclusions are drawn.

The Authors and Contributors

This report is written, compiled, and edited by Dr. Jochum Wiersma, Small Grains Specialist. The contributing authors/principal investigators are: Dr. James Anderson, Wheat Breeder, Department of Agronomy & Plant Genetics, St. Paul; Dr. Kevin Smith, Barley Breeder, Department of Agronomy & Plant Genetics, St. Paul; Dr. Ruth Dill-Macky, Plant Pathologist, Department of Plant Pathology, St. Paul; Dr. Brian Steffenson, Plant Pathologist, Department of Plant Pathology, St. Paul; Dr. Martin Carson, USDA-ARS, Cereal Disease Laboratory, St. Paul; Dr. James Kolmer, USDA-ARS, Cereal Disease Laboratory, St. Paul; Dr. Yue Jin, USDA-ARS, Cereal Disease Laboratory, St. Paul; Mr. Gerald Ochocki, USDA-ARS, Cereal Disease Laboratory, St. Paul; Dr. John Wiersma, Agronomist, Northwest Research & Outreach Station, Crookston.
In addition, Dr. Fred Kolb, University of Illinois contributed BYDV data for oats.

Matt Bickel, Robert Bouvette, James Cameron, Roger Caspers, Dave Graftstrom, Mark Hanson, Tom Hoverstad, Gary Linkert, George Nelson, Steve Quiring, Susan Reynolds, Edward Schiefelbein, Catherine Springer, Galen Thompson, and Donn Vellekson supervised fieldwork at the various sites.

Special thanks are also due to all cooperating producers.

**SPRING WHEAT**

James Anderson, Jochum Wiersma, Gary Linkert, Susan Reynolds, Catherine Springer, John Wiersma, George Nelson, Ruth Dill-Macky, James Kolmer, and Yue Jin

The results of the state yield trials are summarized in Tables 1 through 6. The average yield across the southern testing locations (St. Paul, Waseca, Lamberton and Morris) was 44 bu/A in 2011. This compares to an average of 65 bu/A in 2009 and a three-year average of 57 bu/A. The northern locations, which include the on-farm locations, averaged 69 bu/A in 2010 compared to 81 bu/A last year and 78 bu/A for the three-year average.

Tables 2, 3, and 4 present the relative grain yield of tested varieties in 1, 2, and 3-year comparisons. Albany, the 2009 release from Limagrain Cereal Seeds, was again the top yielding cultivar in both the northern and southern testing locations in 2011. Faller continued to impress in the northern locations and had a solid showing in Lamberton and Morris. Samson and Prosper were also in the top bracket for yield in the northern locations, while Select, Knudson rounded out the top three across the southern locations. In the 2-year and 3-year comparisons, Albany had the high mark for grain yield with Faller and its sister line Prosper rounding out the top three across the state and across the northern location, closely followed by Samson and Jenna. Faller and Jenna rounded out the top three varieties in the southern locations in both the 2 and 3 years comparisons. Based on three years of trial comparisons Albany, Faller, Prosper, Jenna, Samson, and Knudson remain competitive varieties for yield across the northern part of the state while Select and Sabin do well in addition to the aforementioned varieties in the southern half of the State. Higher yielding cultivars tend to be lower in grain protein. In cooler, more-productive growing seasons, this may mean that grain protein ends up below 14.0%. N fertility management is paramount to maximize grain yield and grain protein.

The varietal characteristics are presented in Tables 1, 5, and 6. Table 6 summarizes all the disease reactions for individual varieties. Varieties that are rated 4 or better are considered the best hedge against a particular diseases. Varieties that are rated 7 or higher are likely to suffer significant economic losses under even moderate disease pressure. This past season once more demonstrated that vigilance against FHB remains paramount. A new race of leaf rust that is able to overcome resistance gene Lr21 was again found in 2011 and the varieties Faller and Prosper were particularly susceptible. Only Briggs maintained a 1 rating for leaf rust. Carefully consider a variety’s rating for leaf rust, and plan to use a fungicide if a variety is rated 5 or higher for either leaf or stem rust and disease levels warrant treatment. The foliar disease rating represents the total complex of leaf diseases other than the rusts, and includes the Septoria complex and tan spot. Although varieties may differ for their response to each of those diseases, the rating does not differentiate among them. Therefore, the rating should be used as a general indication and only for varietal selection in areas where these diseases historically have been a problem or if the previous crop is wheat or barley. Control of leaf diseases with fungicides may be warranted, even for those varieties with an above average rating.

Bacterial Leaf Streak can not be controlled with fungicides. Variety selection of more resistant varieties is the only recommended practice at this time if you have a history of problems with this disease. Blade, Breaker, and Cromwell provide the best resistance against this disease while Albany, Brogan, Pivot, RB07, Select and Vantage have a rating of 6 against this disease and are the most consistently affected by the disease.
Leading varieties in Minnesota, based on acres planted in 2011 are Faller and RB07 with 29 and 22% respectively. Edge, SY-Soren, and WB Mayville were new entries in the trials, while testing of Freyr, Hat Trick, Howard, and Kuntz was discontinued.

Variety selection for 2011 continues to be a balance between yield potential, disease responses, and grain quality. Brick, Glenn, and Rollag provide the best resistance against FHB, with Rollag having a higher yield potential and better agronomics than either Glenn and Brick. Albany, Barlow, Blade, Breaker, Cromwell, Faller, Prosper, Sabin, Select, and Tom are all varieties with a 4 for FHB. When combining this group of varieties some of the top yielders include- like Albany, Faller, and Prosper - and cultivars with a higher grain protein content such as Rollag, Barlow, and Glenn.

BARLEY

Kevin Smith, John Wiersma, Ruth Dill-Macky, Jochum Wiersma, Brian Steffenson, and Ed Schiefelbein

Yield averages for barley in Minnesota were 51 bu/A which was down from 62 bu/A last year resulting in a production of 3 million bushels. Growing conditions were generally wet in the early part of the growing season for the five test locations for barley variety trials in Minnesota. The highest yields were in St. Paul and the lowest in Morris (Table 7). Fusarium head blight (FHB) was essentially absent.

The yield data in Table 7 were collected from advanced yield trials that contain the important varieties for the region planted in five locations in the state. Yield data is presented as percent of the mean of the varieties listed in the table. The mean of the varieties is presented in bu/A. Rasmusson was the highest yielding variety followed by Lacey and Quest based on 2011 state averages (Table 7). Lacey, Rasmusson, Tradition, and Stellar-ND are the most lodging resistant of the group (Table 8). The two-rowed varieties Pinnacle and Rawson had the plumpest grain while Celebration was a little thinner than the other varieties.

Table 9 describes the reaction of the currently grown varieties to the five major diseases in the region. Disease reaction is based on at least three years of data and scored from 1 – 9 where 1 is most resistant and 9 is most susceptible. Conlon and Celebration have the best net blotch resistance while Quest and Conlon have the best FHB resistance among the varieties presented.

OATS

Roger Caspers, Ruth Dill-Macky, Martin Carson, and Jochum Wiersma

Harvested oat acreage in 2011 declined to a forecasted 120,000 acres across the state. Yield estimates also dropped to 58 bu/acre, down 7 bu/acre from 2010. Although adequate moisture was available throughout the growing season, high temperatures during pollination may have had adverse effects on seed development at some testing sites. This is evidenced by a drop in the overall 3-year state average of 106 bu/acre to 89 bu/acre in 2011. Test weight mirrored this with the 3-year average of 41.9 lbs/bu dropping almost a full pound per bushel to 41.0 lbs/bu.

Rockford (ND) and Souris (ND) continue to lead the state-wide test, with the gap closing slightly from results in 2010. Souris was the highest yielding variety in 2011, with Rockford again yielding highest in the 3-year test. As an earlier maturing variety, Saber (IL) also yielded over the state average and had the highest groat percentage in both 1-year and 3-year state testing. Note that Streaker (SD) is a hulless variety and no groat percentage is given.

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1 Abbreviations: MN = Minnesota Agricultural Expt. Station; NDSU = North Dakota State University Research foundation; SDSU = South Dakota Agricultural Expt. Station.; Limagrain = Limagrain Cereal Seeds.  
2 2011 data.  
3 1-9 scale in which 1 is the strongest straw and 9 is the weakest.  
Based on 2008-2011 data. The rating of newer entries may change by as much as one rating point as more data is collected.

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¹ Morris 2010 was a fungicide-treated trial.
² Waseca 2011 was abandoned due to excessive field variability. 2-year data are 2009-2010 average.

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\(^1\) The 2009 Roseau site was not planted due to excessive wetness.
\(^2\) The 2011 Perley site was abandoned due to excessive wetness. 2-year data are 2009-2010 average.
\(^3\) The 2009 Hallock and Strathcona sites were abandoned to due excessive field variability.

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1 The 2009 Roseau site was not planted due to excessive wetness.
2 The 2011 Perley site was abandoned due to excessive wetness. 2-year data are 2009-2010 average.
3 The 2009 Hallock and Strathcona sites were abandoned to due excessive field variability.

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Mean (bu/A) | 62.2 | 70.0 | 70.8 | 69.3 | 75.7 | 78.1 | 44.3 | 57.6 | 57.2 |

LSD (0.10) | 5.9 | 4.0 | 3.2 | 6.7 | 4.5 | 3.6 | 11.6 | 7.5 | 6.1 |
TABLE 5. Grain quality characteristics of Hard Red Spring Wheat varieties in Minnesota in single year (2011) and multiple year comparisons (2010-2011).

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1 12% moisture basis.
2 2006-2010 crop years.
3 1-9 scale in which 1 is the best and 9 is worst. Values of 1-3 should be considered as resistant.

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\(^1\) 1-9 scale where 1=most resistant, 9=most susceptible. \(^2\) Faller and Prosper are susceptible to leaf rust races that have increased in 2010. In 2011 leaf rust infections throughout Minnesota were low, however Faller and Prosper were among the most susceptible cultivars. \(^3\) Stem rust levels have been very low in production fields in recent years, even on susceptible varieties. \(^4\) Bacterial leaf streak symptoms are highly variable from one environment to the next. The rating of newer entries may change by as much as one rating point as more data is collected. \(^5\) Combined rating of tan spot and Septoria spp. \(^6\) This variety is more susceptible to powdery mildew.
**TABLE 7.** Relative grain yield (percent of the mean of the trial) of barley varieties at several locations in Minnesota in single year (2011) and multiple year comparisons (2009-2011).

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1 Only two years of data, 2009 and 2010.  2 Only two years of data, 2010 and 2011.  3 Only one year of data, 2011.  4 Only two years of data available at Morris.

**TABLE 8.** Agronomic characteristics of barley varieties in Minnesota in multiple year comparisons (2005 - 2011).

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**TABLE 9.** Disease reactions¹ of barley varieties in Minnesota in multiple year comparisons.

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¹ 1-9 scale where 1=most resistant, 9=most susceptible.  ² Reaction to the dominant strain of the stem rust pathogen.

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1 1=Erect, 5=Flat.


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1 R=resistant, MR=moderately resistant, MS=moderately susceptible and S=susceptible. 2 Artificially inoculated; R=resistant, MR=moderately resistant, MS=moderately susceptible and S=susceptible. 3 Barley Yellow Dwarf Virus score from Urbana, Illinois with 1=no symptoms, 9=dead.