**Research Questions**

Yield of HRSW is affected by many agronomic practices starting with choice of the cultivar, the planting date, and seeding rate. Previous research has shown that optimum seeding rates differ for individual cultivars (Wiersma, 2004). This research project explores the relationship between a set of genetic traits, including Rht-B1 and Rht-D1 genes for semi-dwarf stature and the Ppd-D1 gene for photoperiod sensitivity of individual HRSW cultivars at different planting dates and seeding rates. Can we predict the likely response of newly released cultivars to plant populations based on the presence or absence of key genes? Using statistical techniques it is possible to develop regression models that supersede individual cultivars and looks to explain how a group of genetically similar cultivars respond to seeding rate and planting date changes.

**Results**

In 2015 locations had variable responses to seeding rate averaged over cultivar for grain yield (Table 2). Kimball and Lamberton had the largest increase in grain yield as seeding rates increased while Hallock, Crookston, and Prosper all had smaller yield differences between seeding rates. A delay in planting date lowered grain yield at all three locations (Table 3). The additional sensor data that was added to this research in 2015 had mixed results. Greenseeker data was not correlated with yield across cultivars. The greenseeker was predictive of yield within seeding rates for a specific cultivar, for Kelby especially (Table 4). There were very good correlations between the greenseeker and a phone based free app called Canopeo early in the season before the sensors saturated, and the two can be used interchangeably. Lodging was a confounding factor at several locations in 2015. Lodging increased linearly with seeding rate for many lodging prone cultivars (Table 6).

**Application and Use**

The environmental conditions in 2015 favored lodging if the agronomic practices such as seeding rate, cultivar, or nitrogen fertility were favorable. Some cultivars used in this research had no increase in yield as seeding rate increased due to severe lodging, which increased with higher seeding rates (Table 7). When choosing a seeding rate and considering to go higher, it is important to check straw strength of the cultivar, as some cultivars will not stand even with the recommended seeding rate in certain environments. Generally, overseeding has more negatives than positives and should be avoided unless specific outcomes are planned for and expected. The planting date aspect of the trials was evidence that planting on time will result in far greater yield than late planting.

**Materials and Methods**

Six field locations were established in 2015. Crookston and Lamberton, MN and Prosper, ND were a randomized complete block design (RCBD) with planting date as the whole-plot, cultivar as the split, and seeding rate as the split-split. Hallock, Perley, and Kimball, MN were identical without planting date. Planting dates were separated by three to five weeks. There were twelve cultivars and five seeding rates from 0.6 to 2.2 million pure live seeds/acre. The data collected were stand counts, spike counts, height, lodging, and grain yield components. Greenseeker and Canopeo were used for sensor data.

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

As an example, the seeding rate for maximum net income with yields from Kimball, MN, 2015, is 1.4 million seeds/acre while 2.2 million seeds/acre is the lowest (Table 5). If a farmer were to plant 500 acres with the math from Table 5, planting at 1.4 million seeds per acre would net $32,135 more than the most uneconomical seeding rate of 2.2 million seeds per acre. Additionally, any economic benefit to a farmer from not harvesting lodged wheat can be in part solved with seeding rate for certain cultivars.

**Recommended Future Research**

This research is being used towards a PhD graduate degree for Grant Mehring at North Dakota State University with Dr. Jochum Wiersma and Dr. Joel Ransom as co-advisors to the research. The is a lot more to understand about this research to answer the initial research question posed several years ago. With additional statistical analysis and interpretation that is ongoing during Fall-Winter-Spring of 2015 and 2016 more detailed conclusions will come out of this research and be published in the appropriate media. As it is to date, there is enough data to end field work until the analysis has been finished. At that point there may be an indication of a need for further research on the subject of seeding rates for diverse HRSW cultivars.
Publications


Mehring, G.H., J.J. Wiersma, and J.K. Ransom. 2015. Tillering Response in HrsW Cultivars As Influenced By Planting Date, Plant Population, and Genetic Background. Poster presented at American Society of Agronomy annual meeting, Minneapolis, MN.

<table>
<thead>
<tr>
<th>Group</th>
<th>Cultivar</th>
<th>Ppd-D1</th>
<th>Rht-B1</th>
<th>Rht-D1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Albany</td>
<td>b</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Faller</td>
<td>b</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>2</td>
<td>Knudson</td>
<td>a</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Samson</td>
<td>a</td>
<td>b</td>
<td>a</td>
</tr>
<tr>
<td>3</td>
<td>Briggs</td>
<td>b</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Vantage</td>
<td>b</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>4</td>
<td>Sabin</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>Oklee</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>5</td>
<td>Kelby</td>
<td>a</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>Kuntz</td>
<td>a</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>6</td>
<td>Marshall</td>
<td>b</td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>Rollag</td>
<td>b</td>
<td>a</td>
<td>b</td>
</tr>
</tbody>
</table>

Table 1. The HRSW cultivars included in research and presence of Ppd-D1, Rht-D1, and Rht-B1 genes.

<table>
<thead>
<tr>
<th>Seeding Rate</th>
<th>Hallock PD 1</th>
<th>Hallock PD 2</th>
<th>Perley PD 1</th>
<th>Perley PD 2</th>
<th>Prosper PD 1</th>
<th>Prosper PD 2</th>
<th>Kimball PD 1</th>
<th>Kimball PD 2</th>
<th>Lamberton PD 1</th>
<th>Lamberton PD 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Million seeds/ac</td>
<td>83.2</td>
<td>91.9</td>
<td>76.7</td>
<td>103.3</td>
<td>70.4</td>
<td>51.4</td>
<td>82.2</td>
<td>76.3</td>
<td>64.1</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td>84.6</td>
<td>95.0</td>
<td>79.9</td>
<td>107.9</td>
<td>71.2</td>
<td>53.6</td>
<td>90.1</td>
<td>81.3</td>
<td>67.3</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>84.3</td>
<td>94.8</td>
<td>81.0</td>
<td>104.5</td>
<td>70.0</td>
<td>54.9</td>
<td>92.3</td>
<td>86.2</td>
<td>68.8</td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>81.9</td>
<td>96.3</td>
<td>81.9</td>
<td>104.2</td>
<td>69.6</td>
<td>54.5</td>
<td>91.8</td>
<td>87.3</td>
<td>68.0</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>84.0</td>
<td>94.2</td>
<td>80.2</td>
<td>102.5</td>
<td>66.3</td>
<td>55.1</td>
<td>82.2</td>
<td>87.0</td>
<td>69.9</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>83.6</td>
<td>94.4</td>
<td>80.0</td>
<td>104.5</td>
<td>69.5</td>
<td>53.9</td>
<td>87.7</td>
<td>83.6</td>
<td>67.6</td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>81.9</td>
<td>91.9</td>
<td>76.7</td>
<td>102.5</td>
<td>66.3</td>
<td>51.4</td>
<td>82.2</td>
<td>76.3</td>
<td>64.1</td>
<td></td>
</tr>
<tr>
<td>Max</td>
<td>84.6</td>
<td>96.3</td>
<td>81</td>
<td>107.9</td>
<td>71.2</td>
<td>55.1</td>
<td>92.3</td>
<td>87.3</td>
<td>69.9</td>
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</tr>
<tr>
<td>Range</td>
<td>2.7</td>
<td>4.4</td>
<td>4.3</td>
<td>5.4</td>
<td>4.9</td>
<td>3.7</td>
<td>10.1</td>
<td>11</td>
<td>5.8</td>
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<tr>
<td>LSD (0.5)</td>
<td>NS</td>
<td>2.5</td>
<td>2.5</td>
<td>3.2</td>
<td>2.2</td>
<td>2.2</td>
<td>4.9</td>
<td>3.7</td>
<td>3.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Effect of seeding rate on yield at 6 study locations, with 2 planting dates at 3 locations, 2015.
Table 3. Effect of planting date by seeding rate interaction averaged over HRSW cultivar on yield at Lamberton and Crookston, MN, and Prosper, ND, 2015.

<table>
<thead>
<tr>
<th>Planting Date</th>
<th>Lamberton, MN 2015</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600,000</td>
<td>1,000,000</td>
<td>1,400,000</td>
<td>1,800,000</td>
<td>2,200,000</td>
<td>LSD</td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>76.3</td>
<td>81.3</td>
<td>86.2</td>
<td>87.3</td>
<td>87.0</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>64.1</td>
<td>67.3</td>
<td>68.8</td>
<td>68.0</td>
<td>69.9</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Crookston, MN 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>91.8</td>
<td>95.0</td>
<td>94.8</td>
<td>96.3</td>
<td>94.2</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>76.7</td>
<td>79.9</td>
<td>81.0</td>
<td>91.8</td>
<td>80.2</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Prosper, MN 2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>70.4</td>
<td>71.1</td>
<td>70.0</td>
<td>69.6</td>
<td>66.3</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Late</td>
<td>51.4</td>
<td>53.6</td>
<td>54.9</td>
<td>54.5</td>
<td>55.0</td>
<td>2.2</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Costs and benefits associated with seeding rate with yields from Kimball, MN, 2015.

<table>
<thead>
<tr>
<th>Seeding Rate</th>
<th>Seeding Rate</th>
<th>Seed cost$</th>
<th>Yield</th>
<th>Gross Income$</th>
<th>Net Income$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds/ac</td>
<td>-Bushels/ac-</td>
<td>--$/ac--</td>
<td>-Bushels/ac-</td>
<td>----$/ac----</td>
<td>----$/ac----</td>
</tr>
<tr>
<td>600,000</td>
<td>0.9</td>
<td>10.80</td>
<td>82.2</td>
<td>415.10</td>
<td>404.31</td>
</tr>
<tr>
<td>1,000,000</td>
<td>1.5</td>
<td>18.00</td>
<td>90.1</td>
<td>454.90</td>
<td>436.90</td>
</tr>
<tr>
<td>1,400,000</td>
<td>2.1</td>
<td>25.20</td>
<td>92.3</td>
<td>466.00</td>
<td>440.80</td>
</tr>
<tr>
<td>1,800,000</td>
<td>2.6</td>
<td>31.20</td>
<td>91.8</td>
<td>463.44</td>
<td>432.24</td>
</tr>
<tr>
<td>2,200,000</td>
<td>3.2</td>
<td>38.40</td>
<td>82.2</td>
<td>414.93</td>
<td>376.53</td>
</tr>
</tbody>
</table>

1 Certified seed cost of $12.00 per bushel of HRSW.  
2 December wheat price of $5.05.

Table 5. Correlations between NDVI at different timings and yield for different cultivars sown at differing densities, at three locations in ND/MN. Bolded values are significant at the 5% level.

<table>
<thead>
<tr>
<th>Seeding Rate</th>
<th>Seeding Rate</th>
<th>Seed cost$</th>
<th>Yield</th>
<th>Gross Income$</th>
<th>Net Income$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds/ac</td>
<td>-Bushels/ac-</td>
<td>--$/ac--</td>
<td>-Bushels/ac-</td>
<td>----$/ac----</td>
<td>----$/ac----</td>
</tr>
<tr>
<td>600,000</td>
<td>0.9</td>
<td>10.80</td>
<td>82.2</td>
<td>415.10</td>
<td>404.31</td>
</tr>
<tr>
<td>1,000,000</td>
<td>1.5</td>
<td>18.00</td>
<td>90.1</td>
<td>454.90</td>
<td>436.90</td>
</tr>
<tr>
<td>1,400,000</td>
<td>2.1</td>
<td>25.20</td>
<td>92.3</td>
<td>466.00</td>
<td>440.80</td>
</tr>
<tr>
<td>1,800,000</td>
<td>2.6</td>
<td>31.20</td>
<td>91.8</td>
<td>463.44</td>
<td>432.24</td>
</tr>
<tr>
<td>2,200,000</td>
<td>3.2</td>
<td>38.40</td>
<td>82.2</td>
<td>414.93</td>
<td>376.53</td>
</tr>
</tbody>
</table>

1 Certified seed cost of $12.00 per bushel of HRSW.  
2 December wheat price of $5.05.

Table 5. Correlations between NDVI at different timings and yield for different cultivars sown at differing densities, at three locations in ND/MN. Bolded values are significant at the 5% level.
Table 6. Effect of the interaction between seeding rate and cultivar on lodging at Kimball, MN, 2015.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Seeding Rate (seeds acre&lt;sup&gt;1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600,000</td>
</tr>
<tr>
<td></td>
<td>1- 9&lt;sup&gt;z&lt;/sup&gt;</td>
</tr>
<tr>
<td>Albay</td>
<td>1.3</td>
</tr>
<tr>
<td>Briggs</td>
<td>1.3</td>
</tr>
<tr>
<td>Faller</td>
<td>3.0</td>
</tr>
<tr>
<td>Kelby</td>
<td>2.3</td>
</tr>
<tr>
<td>Knudson</td>
<td>1.7</td>
</tr>
<tr>
<td>Kuntz</td>
<td>1.3</td>
</tr>
<tr>
<td>Marshall</td>
<td>1.0</td>
</tr>
<tr>
<td>Oklee</td>
<td>2.3</td>
</tr>
<tr>
<td>Rollag</td>
<td>1.0</td>
</tr>
<tr>
<td>Sabin</td>
<td>2.7</td>
</tr>
<tr>
<td>Samson</td>
<td>1.0</td>
</tr>
<tr>
<td>Vantage</td>
<td>1.0</td>
</tr>
<tr>
<td>Mean</td>
<td>1.7</td>
</tr>
<tr>
<td>LSD 0.05&lt;sup&gt;x&lt;/sup&gt;</td>
<td>2.2</td>
</tr>
</tbody>
</table>

<sup>2</sup>Lodging is based on a visual 1-9 scale with 1 being erect and 9 being flat on the ground.

<sup>x</sup>Can be used to compare within any column or row, but not between a column and row.

Figure 1. The relationship between canopy closure and NDVI at the 5 leaf stage was consistently very high at eight weeks after planting, Prosper, ND, 2015.