Minnesota Wheat Research and Promotion Council
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Project Title: Positioning NDSU Spring Wheat Breeding Program to Better Serve MN Wheat Growers

Introduction:

Over decades, the public wheat breeding programs at the Universities in the spring wheat region (MN, ND, MT, and SD) have historically played a major role in the wheat production by releasing very competitive wheat cultivars. This has been true for most commonly grown cultivars, except for few cultivars released by non-public breeding programs. Among these wheat breeding programs, NDSU is well recognized for its well adapted and high quality germplasm and cultivars. While our goal is to maintain that hallmark germplasm/cultivars, more emphasis was made recently, in developing high yielding cultivars to meet our growers demand, particularly in the high inputs regions of 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 has been a major cultivar in the region. It has been the leading cultivar in MN since 2010 to 2012 and the second leading cultivar in ND from 2009. Faller was truly, the first variety that combines 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 in 2009. At a time 30% of MN total wheat acreages were grown to Faller. In 2013, Faller was still grown on 17.27%, second only to the other NDSU cultivar 'Prosper' released jointly with the University of MN in 2011. Prosper was released to enhance the wheat production and improve incomes of wheat growers in MN and ND as did Faller. Indeed, just like Faller, Prosper, after just two years of its release, become the leading cultivar in MN with 17.3% followed by Faller. Combined together, the MN wheat acreage grown to both Faller and Prosper surpassed 34.5% in 2013. Demand for new adapted cultivars to the MN environments which combine high productivity and good and "marketable" quality traits such as grain protein are needed and continues to be a major challenge the wheat breeding programs. The MNWRPC is well aware of this important research and breeding components and appreciate the impact of new adapted cultivars on the MN wheat growers and the wheat industry. Therefore, the MNWRPC funded this project for 3 years from 2011 to 2013. Continuing support by the MNWPRC to our program will allow us to continue our efforts to release adapted cultivars to the MN wheat growers.

Objectives:

The overall objective of this on-going project is to support the breeding program to develop superior spring wheat cultivars targeted to MN, and particularly the Western wheat growing environments. Thee 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 (FHB), still a major disease for wheat in MN and the region.

Research activities and procedures:

Using the funds provided by this project, an additional two locations of testing of elite HRSW material generated by NDSU spring breeding program were added in the Western MN where wheat is dominant. These two locations were Alvarado and Wolverton, MN. Agronomic data as well as diseases and quality performance were collected in the summers of 2011- 2013 on these advanced yield trials conducted at the two MN locations and three other ND testing locations in the Red River Valley (Casselton, Prosper, and Langdon, ND). These data were critical for selecting elite adapted lines for release or further testing. In the three years spanning this project, 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 of the project are being addressed efficiently and timely. Among these research activities we can list the following:

1. **Crosses and populations development:**

About 200 crosses were made each year to incorporate traits of economic values for wheat growers and industry in the Western MN and Eastern ND into our adapted germplasm. These crosses involved parental lines among the most grown cultivars and elite genotypes adapted to MN environments were conducted in the Fall and Spring in greenhouse cycles. Parents with diseases (leaf diseases, FHB…etc) resistances, yield potential and quality were included in the crossing bloc. However, new races may emerge anytime due to the selection pressure on these pathogens 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. Seed from these crosses were planted in the greenhouse to generate F_2 populations that were planted in the field the following summer. Similarly, F_2 segregating populations generated from previous F_1 from previous Fall greenhouse cycle were planted in field in the same summer. About 100 to 300 spikes were selected from the most promising F_2 populations and advanced for next generations. Subsequently, five to 10 spikes from each selected F_3 lines (generated from previous F_2 populations) were threshed and shipped to New Zealand or Arizona and planted as head-rows for generation advancement and selection for agronomic traits (lodging, height, maturity, shattering, and other plant type). Similar procedures were followed to advance and select germplasm from previous segregating generations including F_4 and F_5 to reach homozygosity.

2. **Diseases evaluation/screening:**

All geramplasm planted in the field were subjected to screening for prevalent diseases in the field. The first screening starts at F_2 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), FHB, bacteria and insects (in some years) are the main biotic stresses that are our breeding program is facing. 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 pathogens (rusts and FHB) in specific diseases nurseries. These additional nurseries for rusts and FHB 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 by our colleagues in the U of MN and SDSU. Recently, more efforts were focused on the new leaf rust race that has overcome the *Lr21* gene. This major gene has been used widely for decades to protect our germaplsm against leaf rust in the region. Among the cultivars that have this gene are Faller and Prosper. Fortunately, many other cultivars and germaplsm carry other genes that protect against this new race. In general, we screen the germaplsm included in the yield trials for the new race under filed condition. In addition, elite material is tested under greenhouse condition with the collaboration of Plant Pathology (Dr. M. Acevedo). Similarly, about 3000 lines were screened for FHB under field condition in collaboration with Plant Pathology Department (Dr S. Zhong

3. **Early generations and preliminary and intermediate yield trials evaluation/testing:**

Each year, the breeding program evaluates more than 200 F_2 populations and more than 13,000 of F_3 and F_4 generations that were designed for the Eastern ND and Western MN. Similarly, about 1500, and 500 F_5 and F_6/F_7 lines were evaluated for disease resistances and agronomic traits in the preliminary yield trials (PYT) and intermediate trials (IYT), respectively. PYTs were conducted in non-replicated plots while IYTs have two replicates in randomized bloc design. Agronomic and disease notes were taken from the field and seed of these entries were evaluated for some quality traits in the laboratory (Dr S. Simsek). These lines were be advanced either to IYT (from PYT) or advanced yield trials (AYT) following cycle.

4. **Screening and evaluation of advanced and elites lines:**

a. MN Testing sites

As a result of this project, an advanced yield trial including lines and checks (75 entries) selected from previous yield trials was installed at two extra locations in Western MN in the last 3 years. The two locations were Wolverton (Southwest MN) and Alvarado (Northwest MN). These two locations are relatively contrasting sites of the Red River Valley where spring wheat is a major crop. AYT and EYT were conducted in randomized bloc design with 4 replicates.

ND Testing:

In addition to the yield trial conducted in MN sites, the same yield trial was tested in several locations across ND with three locations in the Red River Valley: Casselton, Prosper and Langdon. The other yield trials including PYT, IYT, and AYTs were conducted in many sites in the Eastern parts of ND. Number of replicates and experimental design of these trials are similar to those conducted in MN.

5. **Quality Evaluation:**

Each year, samples from plot for the elite yield trials installed at MN and ND and all other yield trials were sent to our quality laboratory for quality tests. Data on grain characteristics, milling, and dough attributes were generated for genotypes included in the IYTs while additional test on baking performance were generated for AYT and EYT. These data generated each year, are combined with the agronomic performance had allowed us to make decision whether we need further testing, seed increase, or discard lines. Some lines that were candidates for release were also included in these trials and data helped us making decision for their release. This was the case of Faller (in the past), Prosper, and recently released cultivar Elgin-ND.

6. **Markers Assisted Selection (MAS):**

MAS based on using known molecular markers for some quality and disease resistance traits,

was conducted in collaboration with the Genotyping Center at the USDA-ARS at Fargo (Dr. Chao Lab.). Each year, DNA samples from about 1500 lines included in the yield trials were sent to the USDA_ARS Fargo genotyping Center to determine the presence/absence of selected molecular marker in these lines. Particularly, molecular markers for FHB resistance located on chromosome 3BS (Sumai3) and, leaf diseases, grain protein content,…etc, were utilized in the screening. The use of these markers was helpful in indicating the absence/presence of the genes of interest. This has also helped us in planning our crosses to start combining and pyramiding different genes for some traits including FHB, and rusts.

7. Regional//Tri-States Nurseries:

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 replace 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. The five NDSU lines included pre-released lines, particularly ND 808 (Prosper), ND 811 (Velva), and ND 818 (Elgin-ND).

In 2011, TCT was conducted in 5 locations in ND. Unfortunately, TCT in the eastern part of ND were severely damaged by flood at Prosper and Casselton and by hail in Carrington. Therefore, no data from these locations were used to make inference on variety release.

In 2012, TCT also included 25 genotypes (20 lines and 5 checks) from the three breeding programs. Because the 2001 ND eastern sites were lost to flood and hail, we decided to include in the 2012 TCT trials the same lines as in 2011. In 2013, the 'old' and traditional "Uniform Regional HRSW Nursery" was launched again. This trial is coordinated by the USDA-ARS. Therefore the data is published on the USDA-ARS website.

Main Results:

a. MN Testing sites

The data on yield and other major agronomic and quality traits collected across both MN locations coupled with other ND locations during the three years were vital in making decision for releasing cultivars or advancing elite germplasm for further testing. Among the most important agronomic traits, grain yield is mostly considered the choice trait by growers for cultivar selection in the region. Quality, particularly protein is also considered when choosing cultivars by growers. In this report, for the above reasons, we focus mainly on grain yield. Hence, the yield data for the MN sites are represented in Figures 1and 2 for 2011; 3 and 4 for 2012; and 5 and 6 for 2013. In 2011, the performance of wheat elite lines in these two locations was very different (Figures 1 and 2). Yields levels 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 were subjected for further tests. However, quality data for generated for these lines were critical for final selection. In addition, these lines are being tested for leaf disease, particularly for the new leaf rust race.

In 2012, yields levels at both locations were relatively high compared to those obtained in 2011

(figures 3 and 4). The overall average yield at Alvarado was 70.9 bu/ac compared to 63.5 bu/ac registered at Wolverton. This shows that conditions at Alvarado were relatively better than at Wolverton. Similarly, yield levels ranged from 85.6 to 60.1 bu/ac and 73.8 to 52.5 bu/ac at Alvarado and Woleverton, respectively (Figures 1 and 2). Over all, at both locations, we had several lines that yielded similar or better than the best check (Prosper at Alvarado, and Velva at Wolverton). These promising lines were subjected to further tests including quality and diseases reaction, particularly for the new leaf rust race, before they were considered for potential release.

In 2013, yields levels achieved at Wolverton and particularly at Alvarado were high. This reflects the record yield achieved overall in the State of MN. The average yield trial was 88.3 and 57.3 at Alvarado and Wolverton, respectively. Faller was the highest yielding cultivar in both locations reaching the maximum yield levels of 100.1 and 79.6 bu/ac, followed by Prosper with 99.6 and 77.8 bu/ac at Alvarado and Woleverton, respectively (Figures 5 and 6). In the same trials, 27and 15 lines had yields between 91 1nd 100 bu/ac at Alvarado and more than 71 bu/ac at Wolverton. The yields of the recently released cultivar "Elgin-ND" across Alvarado and Wolverton were 96 and 74.5 bu/ac, respectively (Figures 5 and 6).

b. ND Testing sites

As indicated for the MN sites and for the same reasons, only data on grain yield are reported in this report. The data for 2011 and 2012 are represented in Figures 7and 8, respectively. For 2013 however, data is being processed and analyzed and therefore were not ready to be included in the present report.

In 2011, at Casselton and Prosper, the yield trials were severely damaged by flood resulting low yield levels compared to Langdon (Figure 7). Yield varied from 10.3 to 25.6 bu/ac and 14.8 to 17.7 bu/ac with trial mean of 19.1 and 16.5 bu/ac at Casselton and Prosper, respectively. Therefore, grain yield data from these two locations were not considered seriously for selection to advance lines to 2012 testing. At Langdon, however, Yields varied from 65.4 to 78.3 bu/ac with an average trial of 52.5 bu/ac. The maximum yield trial was achieved by Faller. However, several lines with yield not significantly different from Faller were identified. Among the high performing genotypes, Prosper, the joint release from NDSU and the U of MN, had very similar yield than Faller, showing its great potential to be major cultivar in the region.

In 2012, grain yield averages (Figure 8) of elite lines and checks ranged from 48.9 to 71.7 bu/ac; 42.8 to 64.7 bu/ac; and 48.1 to 74.8 bu/ac with an overall mean of 59.4, 54.8 and 58.9 bu/ac, at Casselton, Prosper and Langdon respectively (Figure 8). Faller was the highest yielding at Prosper and Langdon. However, several other lines had yield similar to Faller. Other checks including Prosper, Barlow, and Elgin-ND had respectively yield of 62.5, 58.9, and 66.9 bu/ac; 60.4, 61.6, and 61.6 bu/ac; and 64.3, 54.8, and 56.0 bu/ac, at Casselton, Prosper and Langdon respectively.

Major achievements:

From 2011 to 2013, Elite yield trials conducted at two locations in MN and several sites in ND including 3 sites in the Eastern regios generated valuable agronomic data (Figures 1-8). Samples from these trials were analyzed for quality performance at the NDSU quality lab. Similarly, DNA samples from these genotypes were sent to the USDA-ARS lab and diagnosed for several molecular markers. During this period, the breeding and regional trials were also conducted in the region and allowed us to generate more agronomic and quality data for elite germplasm. Using all these data, elite germplasm was

identified and breeding material from early testing yield trials were screened and advanced for further testing.

The funding from the MNWRPC, that started even prior to 2011, has contributed significantly to achieve several milestones in our breeding program. Among these, we can cite the following:

- **Release of Faller:** In 2007, Faller was released by NDSU. Faller was mainly targeted to the Eastern ND and Western MN because of it very high yield potential and good disease package. Faller was truly, the first variety that combines 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 in 2009. At a time 30% of MN total wheat acreages were grown to Faller. In 2013, Faller was still grown on 17.27%. Faller is also very popular in ND and performs every well compared to the other leading cultivars including Glenn and Barlow (Table 1). Faller was the second leading cultivar in ND (up to 17.2% of ND 6 million acres) from 2009 t0 2011.

- **Release of Prosper:** For the first time in recent history, NDSU and the U of MN have jointly released the NDSU developed hard red spring wheat cultivar **Prospe**r. It is a semi-dwarf variety with an early to medium-early maturity and has exceptionally high yield that equals or betters Faller. It is moderately resistant/moderately susceptible to FHB and resistant to stem rust. Prosper was released to enhance the wheat production and improve incomes of wheat growers in MN and ND as did Faller. Indeed, just like Faller, Prosper, after just two years of its release, become the leading cultivar in MN with 17.3% followed by Faller. Combined together, the MN wheat acreage grown to both Faller and Prosper surpassed 34.5% in 2013. Similarly to Faller, Prosper performs well in ND (Table 1) and is becoming very well established cultivar in ND with more than 8.8% of ND 5.7 million acres in 2013.

- **Release of Elgin-ND**: This is the most recent release of NDSU HRSW breeding program. Elgin-ND was released in 2013. Elgin-ND, in general showed much higher yield than all other cultivars except Faller and Prosper. While Elgin-ND' yield over many years is close to Faller yield, protein level of Elgin-ND is much higher than both cultivars. The yields of Elgin-ND across Alvarado and Wolverton in 2012 were respectively, 69.8 and 66 bu/ac compared to 74.9 and 64.1 bu/ac for Faller (Figure 3 and 4). In the same trial Prosper yields were 82.6 and 66.2 bu/ac, respectively. In 2013, Elgin-ND yields were also high (96 and 74.5 bu/ac) compared to Faller (100.1 and 79.6 bu/ac) and Prosper (99.6 and 77.8 bu/ac) at Alvarado and Woleverton, respectively (Figures 5 and 6). In ND (Table 1), Elgin-ND performed very well, very close to both Faller and Prosper during the 2010-11 period (Table 1).

Overall, the impact of our breeding program through the release of adapted and modern HRSW cultivars is substantial. NDSU released cultivars since 2007, including Faller and Prosper have played a major role in the wheat production in MN, the wheat industry in the US, and wheat export market internationally. Hundreds of millions of dollars have been generated by these cultivars for the wheat business as a whole and for MN wheat growers, in particular***. Our goal is to continue such impact in the future by releasing more adapted and highly performing cultivars. However, to achieve this***

goal, the continuation of the MNWRPC support to our program is vital.

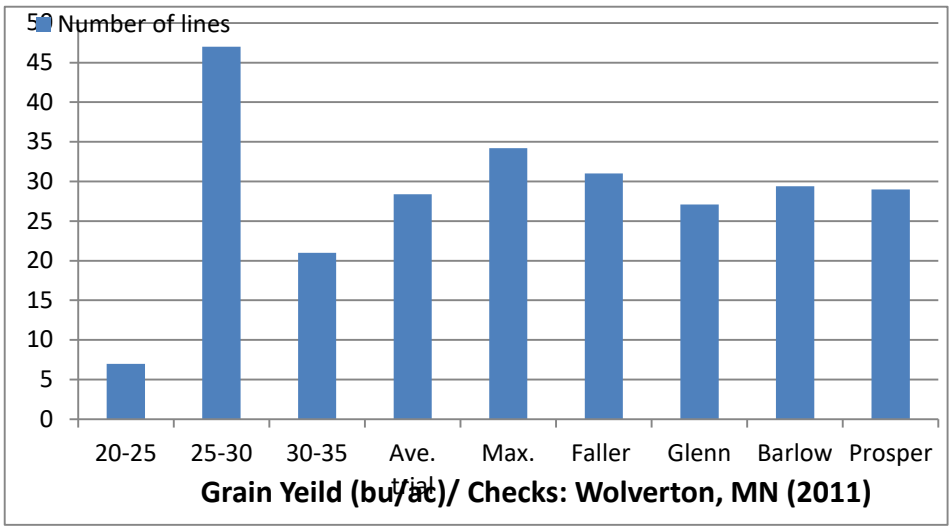

Figure1: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Wolverton, MN during 2011. ***NB: Bars for the checks Faller, Glenn, Barlow and Prosper represent yield in bu/ac.***

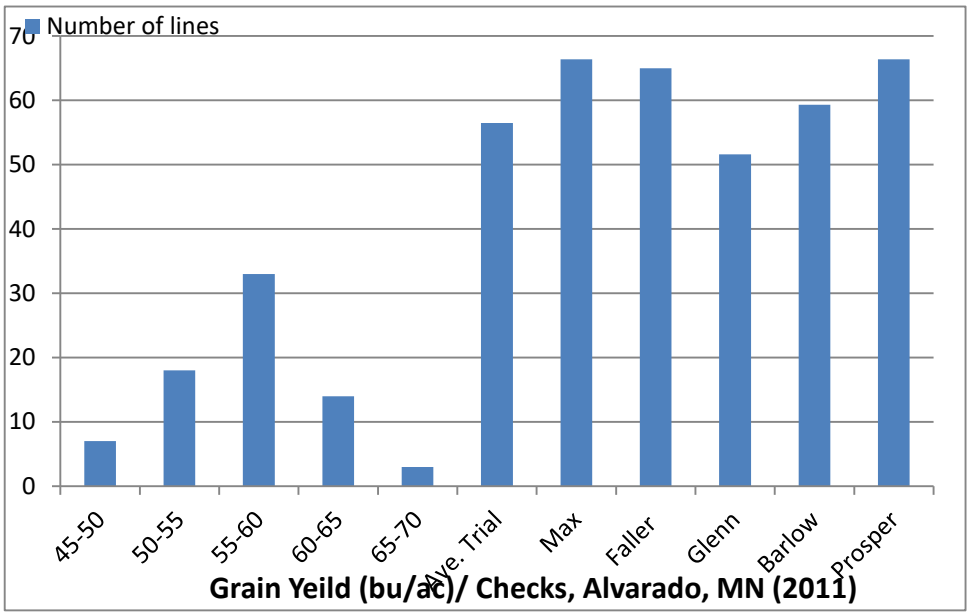

Figure 2: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Alvarado, MN during 2011. ***NB: Bars for the checks Faller, Glenn, Barlow and Prosper represent yield in bu/ac.***

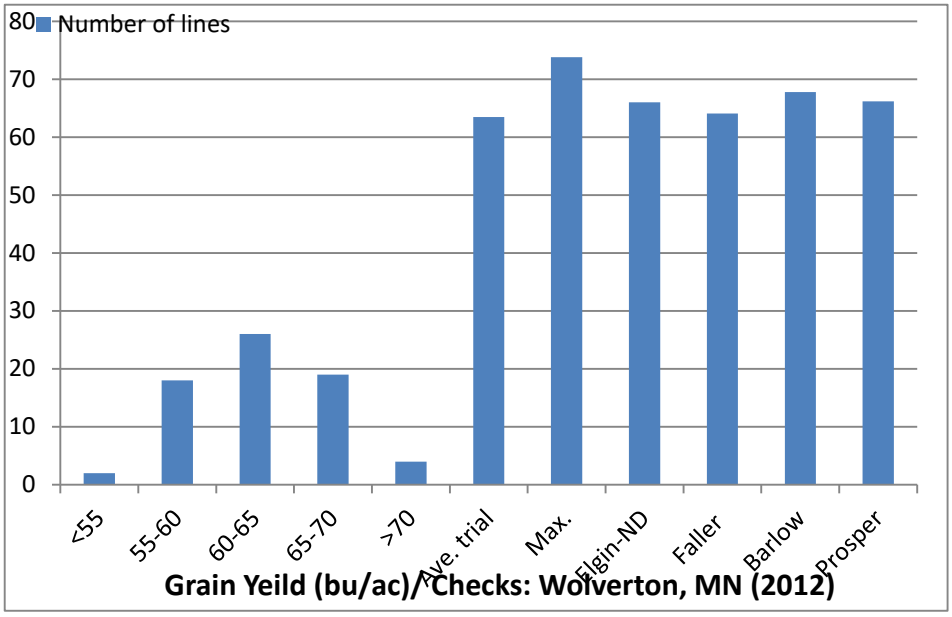

Figure 3: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Wolverton, MN during 2012. ***NB: Bars for the checks Velva, Elgin-ND, Faller, Glenn, Barlow and Prosper represent yield in bu/ac.***

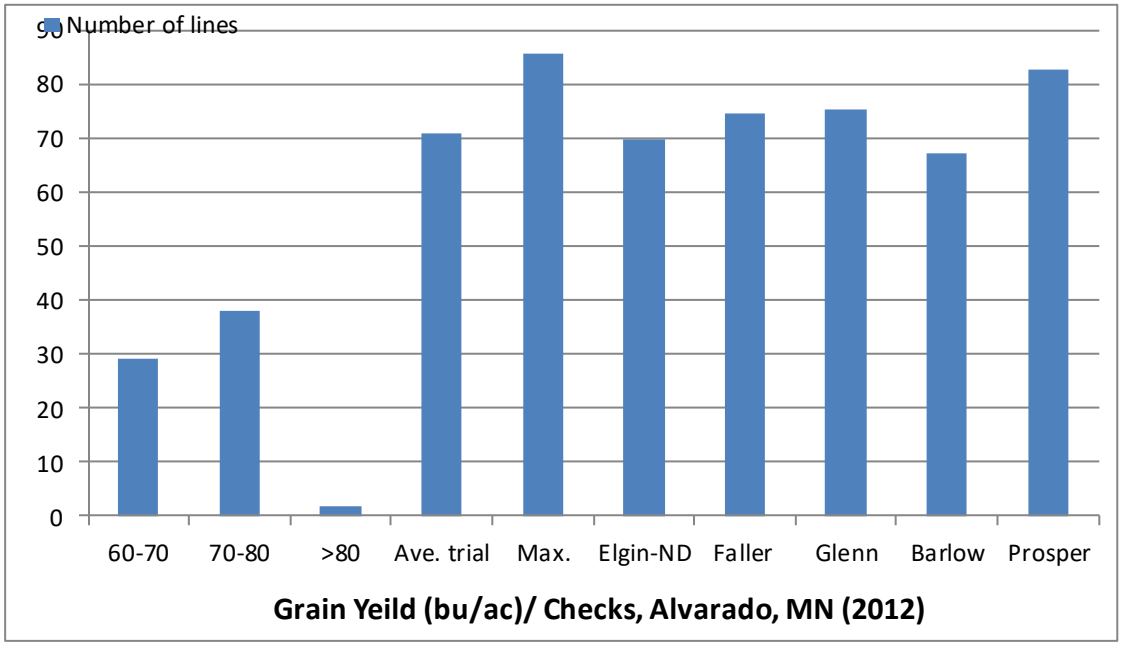

Figure 4: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Alvarado, MN during 2012. ***NB: Bars for the checks Velva, Elgin-ND, Faller, Glenn, Barlow and Prosper represent yield in bu/ac.***

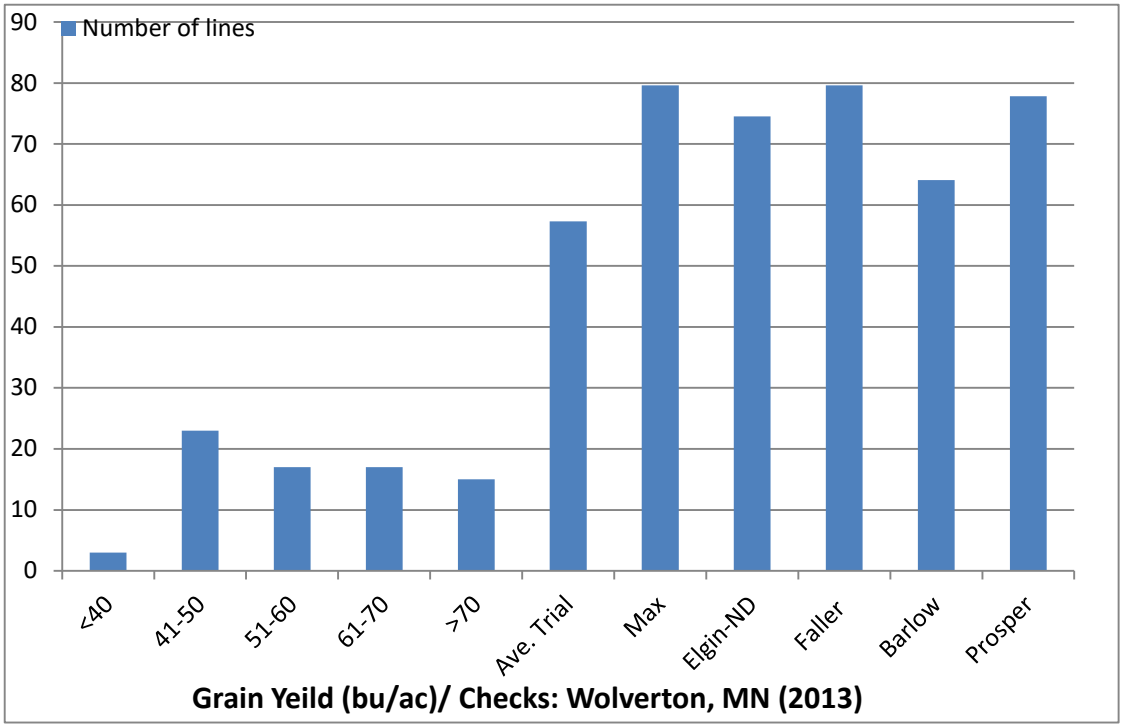

Figure 5: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Wolverton, MN during 2013. ***NB: Bars for the checks Ave. trial, Max, Elgin-ND, Faller, Barlow, and Prosper represent yield in bu/ac.***

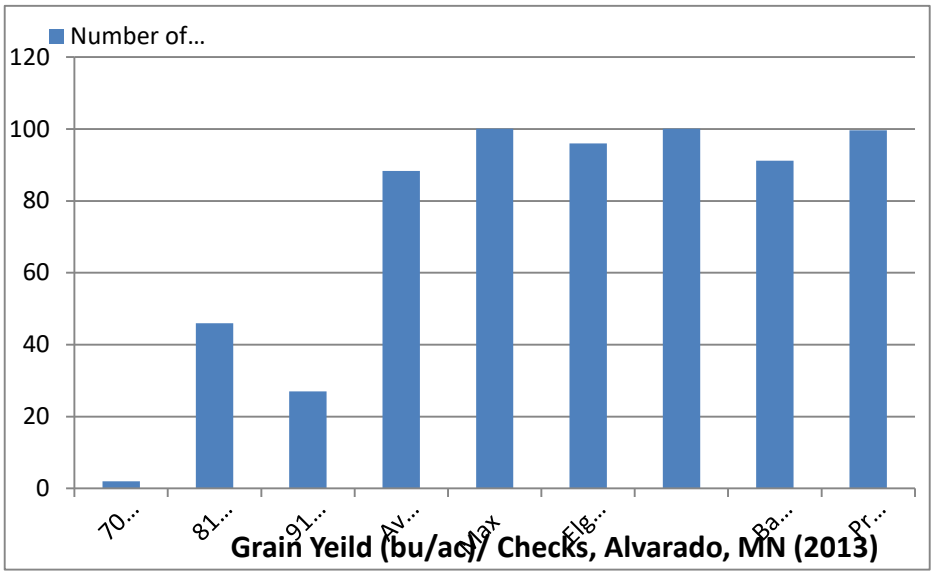

Figure 6: Frequency distribution of hard red spring lines in relationship with yield levels achieved at Alvarado, MN during 2013. ***NB: Bars for the checks Velva, Elgin-ND, Faller, Glenn, Barlow and Prosper represent yield in bu/ac.***

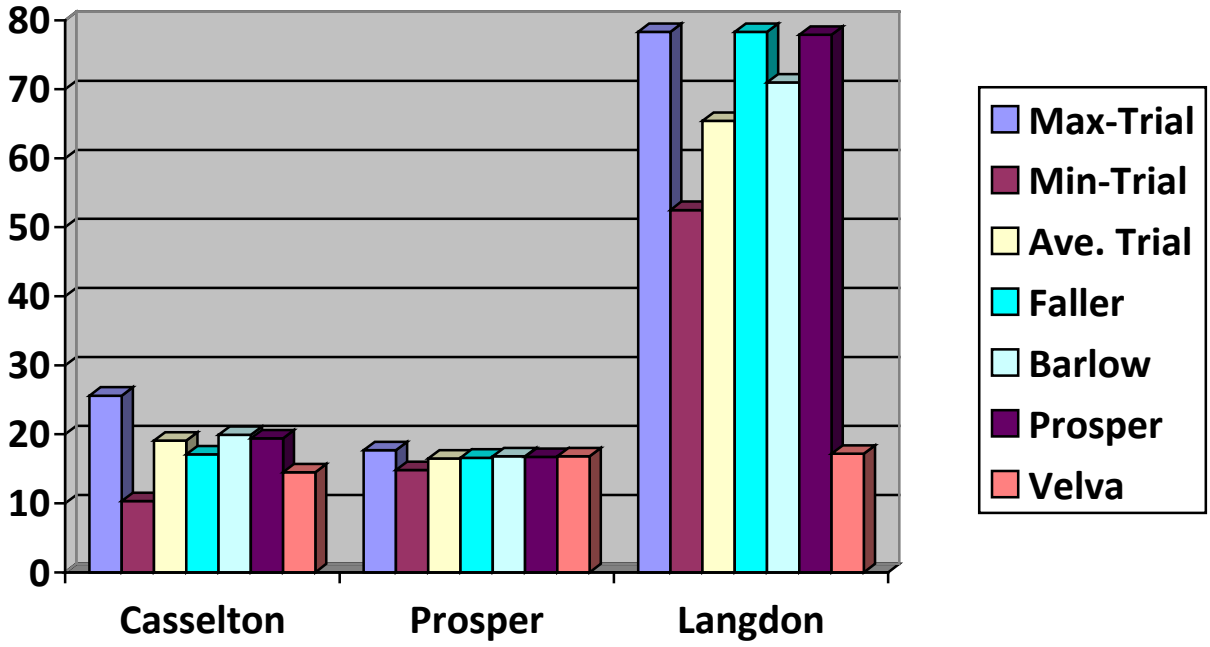

Figure 7: Yield variation (Max, Min, and average yields of the trial) of hard red spring lines and checks at Casselton, Prosper and Langdon, ND in 2011.

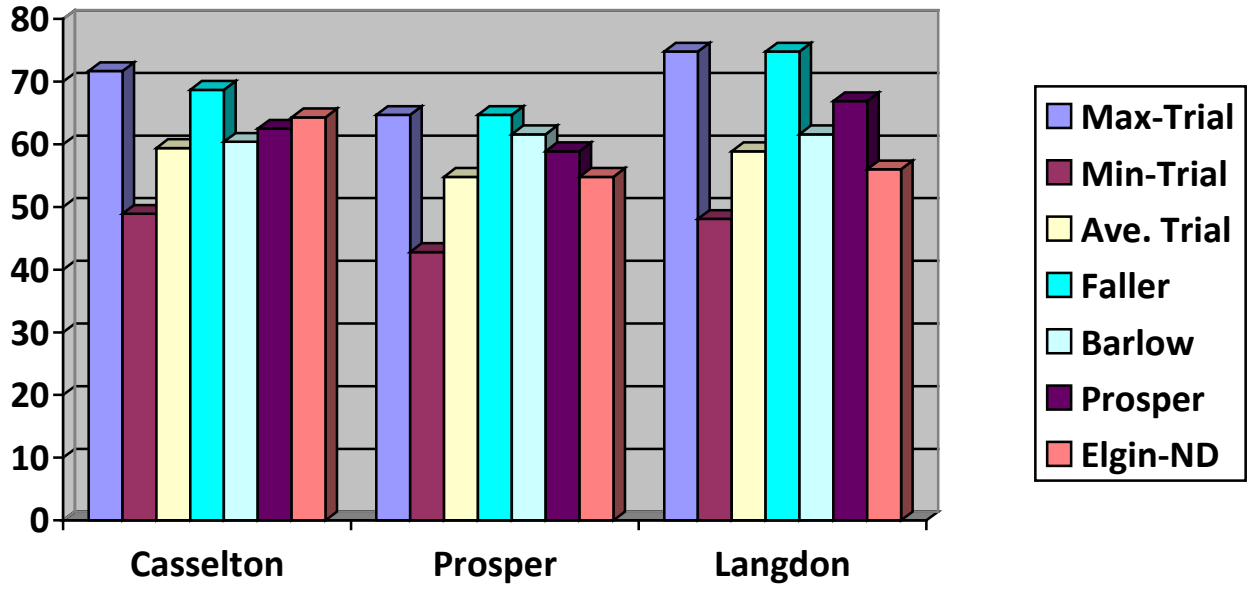

Figure 8: Yield variation (Max, Min, and average yields of the trial) of hard red spring

lines and checks at Casselton, Prosper and Langdon, ND in 2012.

Table 1: Agronomic/Quality performance of Recently released NDSU HRSW cultivars (Elgin-ND, Prosper, Velva,…) and checks in the Eastern ND –including Red River Valley- during the 2010-11 period.

Variety	Days Heading	Plant Height	Lodging	Scabby Kernels	Leaf Diseases	Test Weight	Grain Yield	Grain Protein
	day	inch	1-9	%	%	Lb/bu	Bu/ac	%
Advance	53.4	29.7		1.0	13.8	60.2	48.8	15.2
Alsen	55.7	31.2	0.4	0.3	25.8	60.2	49.4	15.4
Barlow	54.1	32.7	1.5	1.4	11.6	60.3	55.5	15.3
Brennan	55.0	27.2	3.7	0.8	21.7	58.7	51.1	16.0
Brick	52.1	33.1	1.8	0.2	29.1	61.0	55.9	14.9
Briggs	53.6	32.0	2.3	0.7	11.7	59.8	55.5	15.0
Dapps	54.0	34.9	1.1	0.3	16.7	58.8	47.1	15.8
Elgin-ND	**56.2**	**33.9**	**1.8**	**0.6**	**12.6**	**58.9**	**59.4**	**15.3**
Faller	57.2	32.4	0.8	0.2	14.2	59.4	62.0	14.3
Forefront	51.0	32.8		0.4	18.8	60.6	49.1	15.6
Glenn	53.6	33.6	0.0	0.0	17.0	62.0	50.9	14.9
Howard	56.3	32.5	2.2	1.2	14.2	60.1	55.0	14.9
Jenna	58.5	29.4	2.2	0.8	13.4	58.6	57.3	15.3
Kelby	54.1	27.4	2.9	0.5	17.8	58.8	50.5	15.8
Norden	56.7	30.0	0.3	0.7	28.9	60.5	54.7	15.1
Prosper	**57.7**	**32.0**	**1.5**	**0.2**	**9.6**	**59.2**	**62.0**	**14.5**
RB07	55.4	30.3	2.1	0.1	19.2	58.8	55.6	15.0
Reeder	54.3	31.0	0.8	1.8	10.7	58.4	50.1	15.0
Rollag	55.5	29.3	0.8	0.4	14.2	59.9	51.6	15.9
Select	52.4	32.0	1.8	0.8	32.8	60.3	55.1	14.8
Steele-ND	55.4	33.0	2.8	1.2	21.9	60.4	55.1	15.2
Vantage	60.1	29.7	0.0	2.3	8.9	60.4	50.7	16.5
Velva	**57.9**	**31.0**	**0.0**	**2.4**	**9.7**	**57.3**	**52.5**	**15.1**