

**USDA-ARS/
U.S. Wheat and Barley Scab Initiative
FY12 Final Performance Report
July 16, 2013**

Cover Page

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Fiscal Year:	FY12
USDA-ARS Agreement ID:	59-0206-9-066
USDA-ARS Agreement Title:	Breeding Adapted Spring Wheat for Scab Resistance.
FY12 USDA-ARS Award Amount:	\$ 194,166*

USWBSI Individual Project(s)

USWBSI Research Category**	Project Title	ARS Award Amount
VDHR-SPR	Development of Adapted Hard Red Spring Wheat Cultivars and Germplasm Resistant to Scab Disease.	\$ 129,562
VDHR-SPR	Genetic Characterization of Fusarium Head Blight Resistance in Two Elite Spring Wheat Cultivars.	\$ 47,547
VDHR-SPR	Development of White and Specialty Spring Wheat Germplasm and Cultivars Resistant to Scab Disease.	\$ 17,057
	Total ARS Award Amount	\$ 194,166

Principal Investigator

Date

* Partial funding for this research is under ARS agreement # 59-0206-9-062

** MGMT – FHB Management

FSTU – Food Safety, Toxicology, & Utilization of Mycotoxin-contaminated Grain

GDER – Gene Discovery & Engineering Resistance

PBG – Pathogen Biology & Genetics

BAR-CP – Barley Coordinated Project

DUR-CP – Durum Coordinated Project

HWW-CP – Hard Winter Wheat Coordinated Project

VDHR – Variety Development & Uniform Nurseries – Sub categories are below:

SPR – Spring Wheat Region

NWW – Northern Soft Winter Wheat Region

SWW – Southern Soft Red Winter Wheat Region

Project 1: *Development of Adapted Hard Red Spring Wheat Cultivars and Germplasm Resistant to Scab Disease.*

1. What major problem or issue is being resolved relevant to Fusarium head blight (scab) and how are you resolving it?

Particularly in ND and the Northern Central Plains of the US, Fusarium head blight (FHB) or scab disease remains the major threat for wheat production and its uses. North Dakota (ND) in particular where the hard red spring wheat (HRSW) is leading crop in the State and US, this disease can cause significant economic losses. The disease is complex and causes significant reduction in grain yield and impacts negatively the wheat quality. In the past two decades, FHB disease had tremendous implications on wheat on ND HRSW producers; end-users; and export market. The NDSU HRSW wheat breeding program is addressing this problem by the development of elite and adapted genotypes/ lines/cultivars and breeding populations that incorporate diverse genetic resistance with desired agronomic and quality traits. The strategy used is based on incorporating genes of resistance into elite germplasm and pyramiding several types of genetic resistance to the disease from diverse sources using classical breeding methods and appropriate novel technologies such as selected molecular markers. Based on our accomplishments and impact (Listed in this and previous reports), we strongly believe that genetic resistance provides a strategic long-term, economically, and environmentally sound solution to this problem. In 2011-2012 growing cycle, our efforts have continued to develop elite HRSW germplasm and cultivars that are adapted to ND in particular, and spring wheat region, in general. Significant accomplishments have been achieved and are listed in this report.

2. List the most important accomplishment and its impact (i.e. how is it being used) to minimize the threat of Fusarium head blight or to reduce mycotoxins. Complete both sections (repeat sections for each major accomplishment):

Accomplishment:

Significant progress in breeding HRSW against FHB disease have accomplished in the NDSU HRSW breeding program during 2012-2013 growing cycles. These are illustrated in the release and pre-release of many HRSW cultivars and elite germplasm that are hallmark of wheat production in the spring wheat region in particular, and in for the USA and the wheat breeding program worldwide. The cultivars we released are grown on large scale in ND and the Northern plains (ND, MN, SD, and MT) generating hundreds of millions of dollars of benefits for the growers, the industry and export market. These cultivars are the following:

New released (potential releases) cultivars/germplasm:

- ❖ **2013 release: 'Elgin-ND' (ND818):** Elgin-ND is a HRSW cultivar with wide adaptation allowing it to compete very well with most dominant cultivars in ND and neighboring state including MN, SD and MT. In addition, Elgin-ND quality attributes

- are much improved compared to Faller, the dominant cultivars in Eastern ND and Western MN, the FHB prone zone. Elgin-ND has very high protein content, very close to Glenn, the current quality check cultivar. Overall, Elgin-ND has good milling (flour extraction similar to Glenn) and baking qualities similar to Barlow and Howard. Elgin-ND possesses an excellent diseases resistances package. It is moderate resistant/moderate susceptible to FHB. It is resistant to leaf and stem rusts prevalent races and medium susceptible/resistant to the new emerging leaf rust race Lr21.
- ❖ **‘Velva’** (Released in 2012): is a medium susceptible to FHB compared to the susceptible checks. Velva was not selected from introduced FHB germplasm sources of resistances such as Chinese Sumai3. It was selected from a cross involving cultivars which may carry some indigenous FHB resistance. It has general adaptation but better fit to Central and Western ND environments. It has excelled performance, particularly where Reeder is grown. Overall, Velva has high grain yield, higher than most cultivars adapted to Central and Western region. It is a Semi-dwarf line with medium late maturity, similar to Reeder and Faller; and medium to strong straw strength similar to Reeder. Protein of Velva is good, similar to Reeder with average milling properties. Similarly, Velva has Good baking properties similar or slightly better than Reeder. Test weight is also average similar to Reeder. Velva has an excellent leaf diseases package better than Reeder. It is resistant or medium resistant to leaf and stem rusts; resistant to septorias; and resistant to races 2 and 3 of tan spot, but Velva is susceptible to bacterial leaf streak.
 - ❖ **‘Prosper’** (released in 2011): Prosper was selected from a cross involving ND2710 which is a derivative from Sumai3. Hence it has medium resistance to FHB is based on *fhb1* from Sumai3 similar to Faller released in 2007. Prosper has very high grain yield better or at least equal to Faller. It performs relatively well in The Eastern of ND and Western MN environments. It has medium straw strength. Prosper is a conventional to semi-dwarf height variety, with an early to medium early maturity. Prosper average protein content and test weight, similar to Faller, and high flour extraction. Overall, it has good milling and baking qualities similar to Faller. Prosper possesses an excellent diseases resistances package. It is resistant to Leaf and stem rusts. Given that Prosper was targeted to high rainfall areas of ND and Western MN, it was also jointly released by North Dakota State University and the Minnesota Agricultural Experiment Station. In 2012, Prosper was grown on 2% of ND wheat acreages. This indicates that Prosper will be widely grown in the future.
 - ❖ In 2012, ND 803 Spring Wheat Germplasm Combining Scab and Leaf Diseases with High Agronomic and Quality Traits was registered as germplasm for FHB source of resistance and many other valuable traits, in the Journal of Plant Registration.

Pre-release (potential releases) Lines:

In 2013 two HRSW lines were pre-released. These are ND 816 and ND 817.

- ❖ **ND 816** was selected from a cross involving an NDSU cultivar release (2005) ‘Glenn’ and NDSU experimental line ND2831. ND816 has therefore, a medium resistance to FHB. ND816 has very good resistance to other foliar diseases including stem and leaf rusts. Particularly, its reaction to the new emerging leaf rust race (Lr21) is medium. Overall, Compared to Barlow, Glenn and Faller, the top leading cultivars in ND in 2012, ND816 yield performance is similar to Barlow but superior to Glenn. Its Protein is similar to Glenn and Barlow but higher than Faller. Test weight of ND 816 is similar to Barlow, higher than Faller and lower than Glenn. Its milling and baking properties are in general good. It is a medium early line with medium straw strength and conventional height.
- ❖ **ND817** is line that showed promising results in term of agronomic and quality performance. It has good resistance to scab as well.

Previous released cultivars:

- * The 2009 release cultivar ‘**Barlow**’. Barlow is also a derivative cultivar of Sumai3. Hence it has medium resistance to FHB is based on *fhb1* from Sumai3. The level of resistance of Barlow is close to Alsen and Faller, very popular HRSW cultivars in the spring region. However, Barlow has high yield than Alsen and Glenn, the number one cultivar in the spring region, very good leaf disease package compared to Glenn, and excellent quality attributes. Barlow has wide adaptation. It performs very well in all ND environments, including the Western dry land regions of ND. In 2011, Barlow was the third leading cultivar –after Glenn and Faller, both NDSU cultivars released by this program- in ND with 8.5% of about 6.4 million wheat acres in ND. Barlow was also grown in neighboring states of MN, SD and MT.
- * The **2007** release ‘**Faller**’ was the second leading cultivar in wheat acreages after Glenn in ND since 2009 with 11.4% in 2011. Faller was grown on 17 and 15% of ND wheat acreages in 2009 and 2010, respectively. Faller is also the leading cultivar in MN since 2009. Faller occupied 21 and 30% of MN wheat acreages in 2009 and 2010, respectively. Faller is a derivative cultivar of Sumai3. Hence it has medium resistance to FHB, similar to Alsen. Faller is a very high yielding cultivar with very good leaf disease package compared to Glenn and medium protein content. Faller is recommended for high rainfall and FHB prone spring wheat regions. It is the first NDSU cultivar with such high yield potential. Faller was also grown in other neighboring states of SD and MT.
- * ‘**Glenn**’ released in **2005** is has been the **LEADING** HRSW cultivar in the spring wheat region replacing since 2008. In 2011, Glenn was covering about 1.2 million acres in ND only (18.1% of total ND wheat). Glenn replaced Alsen that dominated the wheat production for 5 years since 2003. Glenn with parentages involving both Sumai-3 and Steele-ND has higher FHB resistance level (better than Alsen variety). In addition Glenn has excellent quality attributes allowing it to be the quality standard by the Wheat Quality Council and the industry in the USA. Based on the US-Wheat Associates survey (OVA), Glenn is now the most preferred cultivar by the wheat importers worldwide. Glenn is

expected to dominate the wheat production for some years. In 2009, Glenn was grown on 25% (about 1.7 million acres) of ND wheat acreages. Glenn was also grown in neighboring states of MN, SD and MT.

- * Many other NDSU releases such as the 2004 HRSW release ‘**Steele-ND**’ and ‘Howard’ released in 2006, both have good FHB resistance level different from Alsen (Sumai3) are grown on substantial acreages in the spring wheat region.

Previous released germplasm, RIL population:

- * In 2009, we have released the RILs population ND735/Steele-ND with resistance to leaf spotting diseases and scab.
- * Previously, several lines were released as germplasm. These include **ND 756, ND 2710, ND 744, and ND 751** (See Crop Sciences).

Impact:

Our NDSU wheat cultivars released to the spring wheat growers and industry in the USA and by the wheat export market sector generate **Hundreds of millions of dollars** every year. Following are some facts that detail this situation:

- * In average, about 50-60% (3.3-4 million acres) of ND spring wheat acreages are grown to NDSU wheat cultivars. This demonstrates the good performance and adaptation of our cultivars to meet wheat growers and end-users. Among these common grown NDSU cultivars, **Glenn, Faller, Barlow, Alsen, Steele-ND, and Howard. All of them have good level of resistance to FHB** and excellent agronomic/quality traits contribute. In 2012, these and other NDSU cultivars have occupied more than 57% of 5.5 million acres (>3.1 million acres) of wheat grown in ND in 2012. Barlow, Glenn and Faller, all NDSU cultivars were the top and leading cultivars in ND in 2012 with 17.2, 14.4, and 13.1%, respectively of total ND wheat acres. These figures show that **the impact** on wheat business (growers, industry and export market) of the FHB resistant HRSW cultivars developed by this program using partly, the USWBSI initiative funds **is phenomenal**.
- * In addition, the NDSU HRSW cultivars are also grown and leading in some neighboring states (MN, SD, and MT) where spring wheat is a major crop and FHB is a threat. Since 2009, Faller was the leading wheat cultivar in MN with about 30% of wheat acreages. Other cultivars such as Glenn, Steele-ND, and Howard are also popular in MN, SD, and MT as well. This is an important impact that should be factored in as well.
- * Releasing superior and very high quality HRSW cultivars with improved **FHB resistance** has allowed the spring wheat crop to survive in Western MN and Eastern ND. It has also allowed the wheat growers to be competitive in the wheat market at the national and international levels.

- * The HRSW germplasm and cultivars with FHB resistance that we have released are well known and extensively used in the breeding program nationally and worldwide. Our HRSW breeding program continues to be the ‘**Center of excellence**’ for wheat germplasm with high quality and **good sources of FHB** resistance.

Project 2: *Genetic Characterization of Fusarium Head Blight Resistance in Two Elite Spring Wheat Cultivars.*

1. What major problem or issue is being resolved relevant to Fusarium head blight (scab) and how are you resolving it?

Decades of breeding of HRSW for FHB resistance at NDSU, U of MN, and SDSU and other breeding programs in the spring region, many cultivars with FHB resistance have been released and are being grown on a large scale, particularly, NDSU cultivars, replacing the most susceptible cultivars. Most of these cultivars trace their resistances to the Chinese sources, particularly Sumai3. This is true for cultivars such as Alsen and supposedly Glenn, both NDSU releases that have dominated the spring wheat area since 2002. However, recently we have collected some data showing that Glenn does not show the presence of the closest markers to the main FHB resistance gene *Fhb1* from Sumai 3. These results have been confirmed by many labs including U of MN (USDA-ARS, Fargo,...etc). All these results show that haplotyping Glenn is consistent with our data that Glenn may not have *Fhb1* markers as we previously believed based on Glenn pedigree. This has raised a major question among us, breeders involved in this project. *Does Glenn have a new combination of FHB resistant genes from its diverse pedigree tracing to Chinese, US, and wild type wheat origin? or have breeders at NDSU who developed this cultivar have broken the linkage between the *Fhb1* and the new flanking markers?* To confirm either case, more research is needed to elucidate this assumption. Similarly, among the most popular grown cultivar developed by NDSU, **Parshall** was grown on significant acreages in the spring wheat region for many years because it has showed consistently good tolerance to FHB. Parshall parentage do not trace to any exotic origin such as Chinese germplasm. We believe Parshall has an indigenous source of resistance that may of great interest to the wheat breeders. To address both topics indicated above and to clarify the genetics of FHB resistance of both Glenn and Parshall, several Recombinant Inbred Lines (RILs) populations involving these two sources or resistances and susceptible parents from MN (MN00261-4), SD (SD3870), and ND (Reeder) were developed. In this study we will use a couple RIL populations with Glenn and Parshall to map the FHB resistance and use other RIL populations for validating our results.

2. List the most important accomplishment and its impact (i.e. how is it being used) to minimize the threat of Fusarium head blight or to reduce mycotoxins. Complete both sections (repeat sections for each major accomplishment):

Accomplishment:

Mr. Ahmed El Doliefy, our graduate student has been hired to work on this project since

2010. In 2012-13, he has continued his research activities related to this project by evaluations for FHB reaction of the RILs and their parents along with the checks under ND field and greenhouse conditions. Data entry and mapping work of the FHB resistance in Glenn and Parshall is being conducted. Drs J. Anderson and K. Glover were responsible for field evaluations in MN and SD, respectively. Data collected by both Drs Anderson and Glover is being entered along with data collected from ND trials. Dr. S. Chao, in the USDA-ARS lab in Fargo, has provided Ahmed the SNPs data she will make available her facilities and expertise to help Ahmed in the mapping phase, particularly to saturate the genomic regions of interest that determined by the Diversity Array Technology (DArT, Australia) and SNPs data analysis. In 2012, greenhouse evaluations were continued and DNA samples preparation for SNPs analysis were achieved. Also, DON, and FDK work was continued in 2012-13. Following are the achievements in 2012.

Field evaluations:

In 2012, the final evaluation of RILs populations, their parents, and appropriate susceptible and most resistant FHB checks were conducted under field and greenhouse conditions. The experiments were planted in the FHB field nurseries located in the three states, ND, MN, and SD in summer of 2012. Data on some agronomic traits including heading height and FHB diseases notes including incidence and severity visually estimated were recorded for each plot approximately 21 days after anthesis. Plots were harvested and seed were sampled for determination of TDK and DON levels.

Lab. Work and DNA extraction:

In 2012, DNA was been extracted (by Ahmed) from the RILS of all populations, their parents, and checks. This DNA was sent to Dr. Chao Lab. for SNPs analysis. SNPs data has been received and is currently being analyzed to map FHB resistance QTLs/genes. In 2011, DNA was also sent to DArT analysis. The data generated by both DArT and SNPs in 2011 and 2012, respectively will be used by Mr. Ahmed El Doliefy with the help of Dr Chao to (1) generate a basic map and identify important QTL regions, (2) augment the identified QTL regions with microsatellite markers (SSR) that show polymorphism between parents; and (3) subsequently, generate linkage maps. This work will start as soon as all phenotypic data that was generated from 2010 to 2012 field FHB nurseries. At the moment Ahmed is in the process of generating the chromosomes maps based on SNPs and DArT data. He is also working on determining TDK on seed from greenhouse experiments conducted in 2012-13. Ahmed also, prepared samples from 2013 greenhouse experiment for DON testing. Data entry and compiling has also been a major activity of Ahmed during the 2102-13 period.

Impact:

As previously stated, this research has a substantial potential impact on the breeding for FHB resistance, particularly, if Glenn resistance to FHB is not based on the Fhb1 gene. This would be breakthrough for all wheat breeding programs dealing with FHB as a major threat for wheat. Similarly, new genes for resistance to FHB in wheat are warranted as the arsenal of genes available to breeders is very limited. Parshall can be a good source of novel FHB

resistance genes that could be mined by breeders. In both cases, the direct impact on wheat production at the state and regional (northern Great Plains), and national levels is tremendous. In the past years, NDSU HRSW cultivars with FHB resistance have been dominating the spring wheat growing region in the US. Recently released NDSU cultivars Barlow, Faller, Glenn, Steele-ND and Howard are major HRSW cultivars in the US spring wheat region. However, new and novel FHB resistant genes are needed to enhance the resistance of the most common and available cultivars.

Project 3: *Development of White and Specialty Spring Wheat Germplasm and Cultivars Resistant to Scab Disease.*

1. What major problem or issue is being resolved relevant to Fusarium head blight (scab) and how are you resolving it?

Fusarium head blight (FHB), also known as scab, is a major threat to wheat production in many parts of the world, particularly in the Northern Central plains of the USA. It causes significant losses in wheat grain yield and its quality due to the accumulation of fungal mycotoxins, such as deoxynivalenol (DON). In the US spring wheat region, the losses due to FHB have been estimated to billions of dollars afflicted to wheat growers, industry, and export market. Hard white and specialty spring wheat (HWSW) genotypes resistant to FHB are needed by regional producers to remain competitive in domestic and international markets. A successful wheat breeding approach has been to combine different sources of host FHB resistance, including Types I and II resistances, into a single genotype. This has been done successfully in the hard red spring wheat (HRSW) breeding program and should be implemented in our HWSW breeding program as well.

The NDSU HWSW breeding program has been addressing this problem by initiating/reinforcing the development of elite and adapted genotypes/ lines/cultivars and breeding populations that incorporate genetic resistance with desired agronomic and quality traits. The strategy used is based on importing/incorporating/pyramiding several types of genetic resistance to FHB, particularly from our adapted HRSW sources. These include Glenn, Alsen, Faller, Prosper, Steele-ND, and some elite lines. These genes are being incorporated into adapted HWSW lines using classical breeding methods and appropriate novel technologies such as selected molecular markers. Based on our experience, we strongly believe that genetic resistance is/will provides a strategic long-term, economically, and environmentally sound solution to the problem. In 2012-2013 cycles, we continued to test our HWSW germplasm to FHB under both artificial and natural infection conditions. However, given the situation of hard white wheat and its limited acreages in the region, it was decided that the funding of this project will be terminated in 2013-14. Therefore, focus was made on only screening existing populations involving parents with FHB resistance but not generating new ones. We have also included some HWSW lines from advanced generations in our trials. Our goal is to develop elite HWSW germplasm that are adapted to ND in particular, and spring wheat region, in general.

Past funds from the USWBSI have allowed us to evaluate the function of types I resistance genes. A graduate student, Mr. Dalitso Yabwalo was then hired in 2008 to conduct this research. Reciprocal backcross monosomic lines developed by hybridizing FHB resistant spring wheat 'Frontana' to a set of 'Chris' spring wheat monosomics, which are susceptible to FHB were used in Mr. Dalitso Yabwalo study. This work has been completed in 2010 and the results were published in Plant Breeding journal in 2011.

- List the most important accomplishment and its impact (i.e. how is it being used) to minimize the threat of Fusarium head blight or to reduce mycotoxins. Complete both sections (repeat sections for each major accomplishment):**

Accomplishment:

Using USWBSI funds have allowed NDSU HWSW breeding program to develop several elite spring wheat lines including NDSW0714 and NDSW0715 which contained one and two QTL for FHB resistance, respectively. Also, using other grants funded by the USWBSI funding, many HRSW cultivars have been developed in the last decades with excellent agronomic and quality performance and good levels of FHB resistance. These include Glenn, Faller, Steele-ND, Howard, Barlow, Prosper, and recently released cultivars such as Elgin-ND and other in the pipeline of our HRSW breeding program. These genotypes have been used extensively in generating more than hundreds of crosses and segregating populations in past years. This material from these germplasm was selected for FHB and is being advanced in the HWSW breeding pipeline.

Breeding for developing HWSW germplasm with FHB resistance started practically in 2009. Past UWSBSI funding, although may affect breeding, was rather for specific projects. This current project is in its fourth year. About 100 crosses involving HWSW and HRSW parents to generate HWSW germplasm with FHB resistance was done in past years. In 2012 however, due to significant cuts to this grant by the USWBSI, emphasis was made to rather evaluate part of the existing germplasm rather than generating new crosses and populations. Therefore, about 90, 1200, 300, 100, 25, 20, and 10 F₂ population, F₃ families, F₄, PYT, IYT, AYT, and EYT lines respectively were screened in 2012 filed nurseries including FHB scab. The screening of the above white/specialty wheat genotypes under scab nursery conditions (artificial inoculation and mist irrigation) was continued at three locations in ND in 2012. Based on data from previous years, many genotypes were selected and identified. Field data was supplemented by the molecular markers information from the USDA-ARS Fargo Genotyping Center to make final selection of resistant genotypes that combine different sources of resistance. This material is being advanced for tests in 2013 nurseries.

In the past, a graduate student, Mr Dalitso Yabwalo was funded by the USWBSI has finished his study on the evaluation of the monosomics lines to determine the function of both type I resistance. These results were published in the Plant Breeding Journal (Yabwalo, D.N., M. Mergoum, and W.A. Berzonsky. 2011. Further characterization of the scab resistance of 'Frontana' spring wheat and the relationships between resistance mechanisms. Plant Breeding 130: 521-525.). The results demonstrate that 3A is a major genomic region for FHB resistance; therefore, mapping and cloning efforts should focus on this chromosome. The results also indicated the involvement of chromosomes 6A and 4D in reducing FHB spread although to a lesser extent than 3A.

Impact:

The impact from developing HWSW cultivars adapted to ND in particular and the spring region in general could be significant given that this class of wheat can expand to larger

acreages in the spring wheat region. The use of white wheat for producing ‘whole wheat’ flour is certainly more appealing for end-users than other red wheat. This type of wheat is also very desirable for the export market such as producing noodle in Asia. Therefore the impact of developing HWSW with FHB resistance may be substantial. Substantial revenues could be generated by growing such as cultivars as is in the case of our HRSW developed by NDSU HRSW breeding program. The results of this project will allow us to identify white and specialty wheat germplasm with good FHB resistance.

Previous funding of a graduate student by the USWBSI has generated good results that may have significant impact on our breeding program and the other breeding programs dedicated to pyramid FHB resistance genes. The results from Yabwalo et al., 2011 study indicated the importance of the type I FHB resistance from Frontana and its benefits in pyramiding genes for FHB, which is was demonstrated by a decrease in the level of disease severity over time. The study also provides information to breeders on how pyramiding genes can be useful in developing host plant resistance to FHB, and ultimately resulted in the release of a spring wheat germplasm line which combines two different genes for resistance to FHB. These results can be used also to demonstrate if molecular markers can be effectively employed to pyramid different genes, despite these genes expressing a similar Type II phenotypic resistance to FHB.

Include below a list of all germplasm or cultivars released with full or partial support of the USWBSI. List the release notice or publication. Briefly describe the level of FHB resistance.

New released (potential releases) cultivars/germplasm:

- ❖ **2013 release: ‘Elgin-ND’ (ND818)**: Elgin-ND is a HRSW cultivar with wide adaptation allowing it to compete very well with most dominant cultivars in ND and neighboring state including MN, SD and MT. In addition, Elgin-ND quality attributes are much improved compared to Faller, the dominant cultivars in Eastern ND and Western MN, the FHB prone zone. Elgin-ND has very high protein content, very close to Glenn, the current quality check cultivar. Overall, Elgin-ND has good milling (flour extraction similar to Glenn) and baking qualities similar to Barlow and Howard. Elgin-ND possesses an excellent diseases resistances package. It is moderate resistant/moderate susceptible to FHB. It is resistant to leaf and stem rusts prevalent races and medium susceptible/resistant to the new emerging leaf rust race Lr21.
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medium late maturity, similar to Reeder and Faller; and medium to strong straw strength similar to Reeder. Protein of Velva is good, similar to Reeder with average milling properties. Similarly, Velva has Good baking properties similar or slightly better than Reeder. Test weight is also average similar to Reeder. Velva has an excellent leaf diseases package better than Reeder. It is resistant or medium resistant to leaf and stem rusts; resistant to septorias; and resistant to races 2 and 3 of tan spot, but Velva is susceptible to bacterial leaf streak.

- ❖ **‘Prosper’** (released in 2011): Prosper was selected from a cross involving ND2710 which is a derivative from Sumai3. Hence it has medium resistance to FHB is based on *fhb1* from Sumai3 similar to Faller released in 2007. Prosper has very high grain yield better or at least equal to Faller. It performs relatively well in The Eastern of ND and Western MN environments. It has medium straw strength. Prosper is a conventional to semi-dwarf height variety, with an early to medium early maturity. Prosper average protein content and test weight, similar to Faller, and high flour extraction. Overall, it has good milling and baking qualities similar to Faller. Prosper possesses an excellent diseases resistances package. It is resistant to Leaf and stem rusts. Given that Prosper was targeted to high rainfall areas of ND and Western MN, it was also jointly released by North Dakota State University and the Minnesota Agricultural Experiment Station. In 2012, Prosper was grown on 2% of ND wheat acreages. This indicates that Prosper will be widely grown in the future.
- ❖ In 2012, ND 803 Spring Wheat Germplasm Combining Scab and Leaf Diseases with High Agronomic and Quality Traits was registered as germaplsm for FHB source of resistance and many other valuable traits, in the Journal of Plant Registration.

Pre-release (potential releases) Lines:

- In 2013 two HRSW lines were pre-released. These are ND 816 and ND 817.
- ❖ **ND 816** was selected from a cross involving an NDSU cultivar release (2005) ‘Glenn’ and NDSU experimental line ND2831. ND816 has therefore, a medium resistance to FHB. ND816 has very good resistance to other foliar diseases including stem and leaf rusts. Particularly, its reaction to the new emerging leaf rust race (Lr21) is medium. Overall, Compared to Barlow, Glenn and Faller, the top leading cultivars in ND in 2012, ND816 yield performance is similar to Barlow but superior to Glenn. Its Protein is similar to Glenn and Barlow but higher than Faller. Test weight of ND 816 is similar to Barlow, higher than Faller and lower than Glenn. Its milling and baking properties are in general good. It is a medium early line with medium straw strength and conventional height.
 - ❖ **ND817** is line that showed promising results in term of agronomic and quality performance. It has good resistance to scab as well.

Previous released cultivars:

- * The 2009 release cultivar '**Barlow**'. Barlow is also a derivative cultivar of Sumai3. Hence it has medium resistance to FHB is based on *fhb1* from Sumai3. The level of resistance of Barlow is close to Alsen and Faller, very popular HRSW cultivars in the spring region. However, Barlow has high yield than Alsen and Glenn, the number one cultivar in the spring region, very good leaf disease package compared to Glenn, and excellent quality attributes. Barlow has wide adaptation. It performs very well in all ND environments, including the Western dry land regions of ND. In 2011, Barlow was the third leading cultivar –after Glenn and Faller, both NDSU cultivars released by this program- in ND with 8.5% of about 6.4 million wheat acres in ND. Barlow was also grown in neighboring states of MN, SD and MT.
- * The **2007** release '**Faller**' was the second leading cultivar in wheat acreages after Glenn in ND since 2009 with 11.4% in 2011. Faller was grown on 17 and 15% of ND wheat acreages in 2009 and 2010, respectively. Faller is also the leading cultivar in MN since 2009. Faller occupied 21 and 30% of MN wheat acreages in 2009 and 2010, respectively. Faller is a derivative cultivar of Sumai3. Hence it has medium resistance to FHB, similar to Alsen. Faller is a very high yielding cultivar with very good leaf disease package compared to Glenn and medium protein content. Faller is recommended for high rainfall and FHB prone spring wheat regions. It is the first NDSU cultivar with such high yield potential. Faller was also grown in other neighboring states of SD and MT.
- * '**Glenn**' released in **2005** is has been the **LEADING** HRSW cultivar in the spring wheat region replacing since 2008. In 2011, Glenn was covering about 1.2 million acres in ND only (18.1% of total ND wheat). Glenn replaced Alsen that dominated the wheat production for 5 years since 2003. Glenn with parentages involving both Sumai-3 and Steele-ND has higher FHB resistance level (better than Alsen variety). In addition Glenn has excellent quality attributes allowing it to be the quality standard by the Wheat Quality Council and the industry in the USA. Based on the US-Wheat Associates survey (OVA), Glenn is now the most preferred cultivar by the wheat importers worldwide. Glenn is expected to dominate the wheat production for some years. In 2009, Glenn was grown on 25% (about 1.7 million acres) of ND wheat acreages. Glenn was also grown in neighboring states of MN, SD and MT.
- * Many other NDSU releases such as the 2004 HRSW release '**Steele-ND**' and 'Howard' released in 2006, both have good FHB resistance level different from Alsen (Sumai3) are grown on substantial acreages in the spring wheat region.

Previous released germplasm, RIL population:

- * In 2009, we have released the RILs population ND735/Steele-ND with resistance to leaf spotting diseases and scab.
- * Previously, several lines were released as germplasm. These include **ND 756, ND 2710, ND 744, and ND 751** (See Crop Sciences).

Publications of cultivars and germplasm:

Mergoum Mohamed, Richard C. Frohberg, Robert W. Stack, Senay Simsek, Tika B. Adhikari, Jack W. Rasmussen, Mohammed S. Alamri, Pawn K. Singh, and Timothy L. Friesen. **2012**. ‘Prosper’: A High-Yielding Hard Red Spring Wheat Cultivar Adapted to the North Central Plains of the USA. **Journal of plant Registration 7:75-80**.

Mergoum Mohamed, Richard C. Frohberg, Robert W. Stack, Senay Simsek, Tika B. Adhikari, Jack W. Rasmussen, Mohammed S. Alamri, and Timothy L. Friesen. **2012**. ND 803 Spring Wheat Germplasm Combining Scab and Leaf Diseases with High Agronomic and Quality Traits. **Journal of plant Registration 7:113-118**.

Mohamed Mergoum, Senay Simsek, Shaobin Zhong, Maricelis Acevedo, Timothy L. Friesen, Pawan K. Singh, Tika B. Adhikari, Jack W. Rasmussen, Mohammed S. Alamri, and Richard C. Frohberg. **2013**. ‘Velva’ Spring Wheat: An Adapted cultivar to North Central Plains of the USA with High Agronomic and Quality Performance. **Journal of plant Registration (Submitted)**

Include below a list of the publications, presentations, peer-reviewed articles, and non-peer reviewed articles written about your work that resulted from all of the projects included in the grant. Please reference each item using an accepted journal format. If you need more space, continue the list on the next page.

Mergoum Mohamed, Richard C. Frohberg, Robert W. Stack, Senay Simsek, Tika B. Adhikari, Jack W. Rasmussen, Mohammed S. Alamri, Pawn K. Singh, and Timothy L. Friesen. **2012**. ‘Prosper’: A High-Yielding Hard Red Spring Wheat Cultivar Adapted to the North Central Plains of the USA. **Journal of plant Registration 7:75-80**.

Mergoum Mohamed, Richard C. Frohberg, Robert W. Stack, Senay Simsek, Tika B. Adhikari, Jack W. Rasmussen, Mohammed S. Alamri, and Timothy L. Friesen. **2012**. ND 803 Spring Wheat Germplasm Combining Scab and Leaf Diseases with High Agronomic and Quality Traits. **Journal of plant Registration 7:113-118**.

Mohamed Mergoum, Senay Simsek, Shaobin Zhong, Maricelis Acevedo, Timothy L. Friesen, Pawan K. Singh, Tika B. Adhikari, Jack W. Rasmussen, Mohammed S. Alamri, and Richard C. Frohberg. **2013**. ‘Velva’ Spring Wheat: An Adapted cultivar to North Central Plains of the USA with High Agronomic and Quality Performance. **Journal of plant Registration (Submitted)**

Proceedings/Abstracts

Mohamed Mergoum, Richard Frohberg, Robert Stack, Truman Olson, Senay Simsek, Mohammed Alamri and Shaobin Zhong. **2012**. THREE DECADES OF BREEDING WHEAT (TRITICUM AESTIVUM L.) FOR FUSARIUM HEAD BLIGHT RESISTANCE: SUCCESSES AND CHALLENGES. 4th International Symposium on Fusarium Head Blight (4thIFS), August 23 to 26th, 2012, Nanjing, People's Republic of China.

Ahmed ElFatih EIDoliefy, James A. Anderson, Karl D. Glover, Shiaoan Chao, Mohammed S. Alamri, and **Mohamed Mergoum**. **2013**. Molecular Mapping of Fusarium Head Blight Resistance in Two Adapted Spring Wheat Cultivars. *In* ASA-CSSA-SSSA-CSSS Abstracts 2013 [CD-ROM], Tampa, FL, USA.