USDA-ARS/
U.S. Wheat and Barley Scab Initiative
FY10 Final Performance Report
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Cover Page

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Fiscal Year:	FY10
USDA-ARS Agreement ID:	59-0206-9-080
USDA-ARS Agreement Title:	Development of Scab Resistant Soft Red Winter Wheat Varieties and Scab Resistance QTL Mapping.
FY10 USDA-ARS Award Amount:	$ 115,644

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-NWW	Development of Scab Resistant Soft Red Winter Wheat Varieties.	$ 76,098
VDHR-NWW	Development and Distribution of Male Sterile Facilitated Recurrent Selection Populations.	$ 1,951
VDHR-NWW	Mapping QTL in Biparental Populations.	$ 8,794
VDHR-NWW	Coordinated Evaluation of FHB Resistance of Advanced Soft Winter Lines and Cultivars.	$ 17,469
VDHR-NWW	Improved Breeding for FHB Resistance by Advanced Genetic and Phenotypic Characterization of Soft Winter Wheat.	$ 2,927
VDHR-NWW	Coordinated Evaluation and Utilization of Marker Assisted Selection.	$ 8,405
	Total ARS Award Amount	**$ 115,644**

Frederic L. Kolb 7/15/2011

Principal Investigator Date

* 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 Scab Resistant Soft Red Winter Wheat Varieties.*

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

   The major issue is that producers need varieties with high levels of scab resistance. We are working on the development of high-yielding, well-adapted, scab resistant lines. As more lines with good scab resistance are identified we are using these parents in crosses, so that in many crosses both parents, or two parents out of three in a three-way cross, are scab resistant. We also believe that it is important to combine several types of resistance rather than rely solely on Type II resistance. We are addressing this by using the ISK index (0.3 x % incidence + 0.3 x % severity + 0.4 x % shriveled kernels) to select breeding lines with high levels of scab resistance. Development of varieties with low deoxynivalenol (DON) levels is also crucial; therefore, all breeding lines are evaluated each year for DON level.

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 (1): Eighty varieties from the Illinois State Variety Trial were evaluated for FHB resistance in a FHB evaluation nursery, and data were made available to producers. We developed a new index that incorporates the severity, incidence and FDK % into a single number. We have adjusted this rating to the same disease level for each season (50% ISK index). This allows us to provide data to producers on the FHB resistance of varieties evaluated in different seasons.
   Impact(1): In order to use FHB resistance as a criterion in variety selection producers must have as much information as possible on FHB resistance. The FHB resistance data provide very useful information to Illinois seedsmen and producers and allows them to use FHB resistance as a criterion in variety selection. Producers and seedsmen have a three year summary of data of FHB resistance and DON level that can be used in decisions about what varieties to produce. The information on FHB resistance is available online at http://vt.cropsci.illinois.edu/wheat.html.

   Accomplishment (2): In 2010, about 420 breeding lines from the University of Illinois wheat breeding program were evaluated in the misted, inoculated scab evaluation field nursery. Scab resistant lines were evaluated for many additional traits including grain yield, milling and baking quality, standability, and resistance to other diseases.
   Impact (2): Sustained annual selection for FHB resistance in the inoculated, misted field nursery has significant long-term impact by assuring that new varieties will be FHB resistant. Constant selection for FHB resistance in the breeding program is essential in order to identify breeding lines with FHB resistance and also to discard FHB susceptible lines early so that resources are not wasted evaluating FHB susceptible lines. The constant selection pressure applied using evaluation in misted, inoculated nurseries is essential in reducing DON.

   Accomplishment (3): In 2010, 2288 wheat samples were sent to the lab at the University of Minnesota for deoxynivalenol (DON) analysis.

Impact (3): DON evaluation is an essential component of FHB resistance evaluation because new varieties must have not just lower FHB field symptoms but also reduced DON content.

This is information that is primarily useful to the wheat breeder, but information on low DON producing varieties can also be used by the producer in variety selection.

Accomplishment (4): In 2010-11we produced about 220 single crosses and about 175 three-way and four-way crosses were made involving FHB resistance sources. Marker assisted selection (MAS) was used for F_1 enrichment for the 3BS FHB resistance locus in 39 three-way populations (MAS done in cooperation with Gina Brown-Guedira, USDA-ARS). About 56 F_3 and F_4 bulks were grown in the inoculated and mist-irrigated FHB nursery and heads were selected under heavy FHB disease pressure.

Impact (4): The crosses of scab resistant parents by adapted high yielding parents will provide populations that can be used for development of scab resistant varieties. These crosses are the source of variability that will be used for future development of scab resistant soft red winter wheat varieties.

Accomplishment (5): Several soft red winter wheat breeding lines with a high level of FHB resistance (better than Ernie) with high yield potential were increased for potential release for licensing and potential commercial production.

Impact (5): Lines that enter commercial production provide seedsmen and producers with additional FHB resistant varieties. The availability of improved varieties with FHB resistance provides additional choices for seedsmen and producers and contributes to an overall reduction in DON and decreased susceptibility to FHB. For the seed industry in this part of the Midwest, release of breeding lines for licensing results in breeding lines being grown on larger acreages than release as a named variety. Thus, licensing results in greater impact than release as a public variety because there is no marketing for a public variety.

Project 2: *Development and Distribution of Male Sterile Facilitated Recurrent Selection Populations.*

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

The cooperative male sterile facilitated recurrent selection populations were developed as a way to generate FHB resistant breeding lines and facilitate the combination of FHB resistant genes from different sources. Recurrent selection has the objective of increasing the frequency of desirable alleles for one or more traits while maintaining a high level of variability in the population. Intermating among selected parents each generation allows recombination to occur thus combining genes from different sources. Male sterility provides a mechanism to easily allow recombination among FHB resistance sources. The dominant male-sterile gene was utilized to create recurrent selection populations segregating for FHB resistance because the progenies of the male-sterile plants always segregate 1:1 for sterility and a generation of selfing is not required to obtain true-breeding fertile genotypes. Our objective was to create four populations with FHB resistance adapted to different regions of the eastern U.S. Seed from the sterile heads were planted, and their sterile offspring were

tagged for harvest to repeat the process. These populations were developed over several seasons at the Ohio Agricultural Research and Development Center in Wooster, Ohio. Breeding programs in the eastern U.S. contributed FHB resistant lines to serve as pollinators. Sterile plants were selected; those highly susceptible to FHB were discarded.

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:

In 2009, male-sterile populations were grown in the field at Wooster, OH. From this, four populations were developed in 2009-2010:

1. The early maturity selections from the male-sterile population were planted with pollinator parents for a southern-mid-Atlantic soft red wheat population.
2. Two-thirds of the seed from the mid-maturity selections from the male-sterile population were planted with pollinator parents for an early Midwest soft red wheat population.
3. One-third of the seed from mid-maturity selections from the male-sterile population and some from the late selections were planted with pollinator parents for a late Midwest soft red wheat population.
4. Late maturity selections from the male-sterile population were planted with pollinator parents for a late soft winter wheat population, including white winter wheat genotypes.

In summer 2010, sterile heads were identified and tagged at four different maturity dates. Sterile heads that were very susceptible to *Fusarium graminearium* were removed on June 14 (early Midwest and mid-Atl.) and June 17 (late Midwest and white). After being harvested and threshed, *Fusarium* damaged kernels were removed by aspiration, removing approximately 50% of the kernels.

A bulk from each population was distributed to cooperating breeding programs in fall 2010. Cooperating breeding programs have been provided information on procedures to assist them in utilizing the populations in their individual breeding programs, continuing cycles of mating and selection for FHB resistance within their target environments.

Impact:

Breeding programs in the eastern soft wheat region have male-sterile facilitated recurrent selections populations that can be used with local FHB resistant breeding lines as pollinators to further develop recurrent selection populations as a source of potential FHB resistant breeding lines with resistance from different sources.

Project 3: *Mapping QTL in Biparental Populations.*

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

Many breeding lines in our program (and other soft winter wheat programs) exhibit FHB resistance that cannot be traced to a Chinese source or other known FHB resistance source. We are using this resistance ("native resistance") extensively in our breeding program and in many cases we are combining the native resistance with other resistance sources. The purpose of this experiment is to determine if the QTL controlling the resistance in IL97-1828 are the same as known FHB resistance QTL and to identify molecular markers associated with new QTL.

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:

The 283 recombinant inbred lines (RILs) and checks were phenotyped for the second year at Urbana, IL during the 2010 season, and the population was phenotyped at Wooster, Ohio (OARDC) in cooperation with Clay Sneller. DNA was sent for DArT analysis and reproducible DArT markers were obtained for 253 of the RILs. A small number of SSRs were also mapped in the population. QTL for resistance to FHB were identified on seven linkage groups that mapped to six different chromosomes (1A, 1B, 1D, 2B, 3B, and 4A), but no QTL was detected in all three environments. QTL explained between 2.9% and 8.7 % of the phenotypic variance. None of the QTL appear to be novel, and our results indicates that several regions contributing small effects are important for FHB resistance in IL97-1828.

Impact:

The association of markers with QTL for FHB resistance in this native resistance source will enhance our capability to select for FHB resistance in breeding materials involving this source. Although the information generated by this research will not be of direct use to wheat producers or consumers, information from this project combined with knowledge gained from other research should enhance the selection efficiency for FHB resistance which will benefit producers and consumers in the long-term through the development of improved FHB resistant varieties.

Project 4: *Coordinated Evaluation of FHB Resistance of Advanced Soft Winter Lines and Cultivars.*

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

Objectives: 1) Phenotype advanced breeding lines that are candidates for release: 2) place FHB and other agronomic, disease resistance, and quality data in database: 3) report on purification and seed increase of the best lines.

Coordinated evaluation of breeding lines among the programs in the NWW provides all breeding programs in the CP with FHB resistance data from multiple locations in a single season. This coordinated evaluation of breeding material plays an important role in the identification of breeding lines with high levels of FHB resistance. Our objective is to

cooperatively obtain information on breeding lines from various programs within the CP and the SWW CP to allow the breeders involved to make better decisions about which breeding lines to advance and release.

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:

About 265 breeding lines in cooperative nurseries including the Uniform Northern Winter Wheat Scab Nursery, the Uniform Preliminary Northern Winter Wheat Scab Nursery, the Uniform Southern Scab Nursery, the Uniform Eastern Soft Winter Wheat Nursery, and the Adv. and Prelim. Five-State Nurseries were evaluated for FHB resistance in a misted, inoculated FHB field nursery. Lines from the Univ. of Illinois program were submitted for all of the cooperative nurseries except the Uniform Southern Scab Nursery, thus, breeding lines with FHB resistance were made available to other breeding programs for use as germplasm. Three University of Illinois breeding lines (out of four entries) were among the most FHB resistant lines in the 2010 NUWWN and four University of Illinois breeding lines (out of six entries) were among the most FHB resistant lines in the 2010 PNUWWN.

Impact:

The data provided were useful to many different breeding programs in making decisions about which breeding lines merit further evaluation as varieties and which breeding lines will be useful as germplasm. Exchange of FHB resistant breeding lines among programs is essential and will contribute to the development of FHB resistant varieties. Obtaining FHB resistance data for entries in the cooperative nurseries from many environments allow wheat breeders to make better selection decisions about what lines to advance for further evaluation. Breeding lines from the University of Illinois breeding program were made available to other breeding programs for use as parents if the breeders wish to use them.

Project 5: *Improved Breeding for FHB Resistance by Advanced Genetic and Phenotypic Characterization of Soft Winter Wheat.*

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

The objective of this project is to develop populations, knowledge of the genetics of FHB resistance, and breeding methodologies for rapid improvement of FHB resistance in soft winter wheat (SWW). Genetics studies in SWW suggest that there are several unique sources of FHB resistance that are controlled by several QTL with moderate to small effects, thus complicating traditional MAS approaches. Consequently, recurrent selection is likely to be an effective breeding tool to accumulate favorable alleles. We propose to develop knowledge of the types of resistance, the genetics of this resistance, and efficient breeding methodologies for improving FHB resistance in SWW. Specifically, we will determine the genetic structure of FHB resistance in SWW, develop models to implement genomic selection (GS) for multiple FHB traits, and characterize RKI and RTA in SWW.

Our approach will be to phenotype and genotype a set of 70 elite SWW lines that have good FHB resistance and 1034 families derived from those elite lines. The population will be phenotyped for multiple FHB traits (INC, SEV, IND, FDK, DON) in field trials. The data will be used in an association analysis (AA) to determine the genetics of resistance in SWW to estimate the effect of QTL on multiple mechanisms of FHB resistance and the frequency of favorable alleles in the SWW. The data will also be used to develop a GS model that predicts the breeding value of individuals using estimated gene effects from the entire genome. The model can be used in subsequent selection cycles to choose superior parents with little or no phenotyping. Collectively, AA and GS will allow us to 1) select parents that are fixed for the same major genes, 2) design crosses that facilitate combining different genes and multiple mechanisms of FHB resistance, and 3) allow selection of superior individuals without phenotyping thereby reducing time per breeding cycle.

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:

1. Ten elite lines were selected from the University of Illinois breeding program with strong FHB resistance derived primarily from native SWW sources.
2. About 137 inbred lines with varying levels of FHB resistance from multiple crosses involving the elite lines from above and parents with less FHB resistance were selected. There are 934 lines total from all of the programs involved.
3. The 70 elite lines (10 x 7 program) and 137 lines from the University of Illinois program were planted for phenotypic evaluation in the 2010-11 season (with plans to repeat these evaluations in 2011-2012). Incidence, severity, index, FDK, and DON data will be collected from the misted and spray inoculated FHB nursery. The set of 70 elite lines will be used to estimate environmental effects and to standardize data from the families tested at different locations.

Impact:

The data will be used in an Association Analysis to determine the genetics of multiple mechanisms of FHB resistance in soft winter wheat. The large population size will enable us to estimate effects of genes with moderate to large effect. The family structure of the population will allow us to use both population and family-based association analysis techniques. The association analysis will 1) be used to evaluate the importance of previously identified QTL in soft red winter wheat, 2) identify new QTL with pronounced effects over genetic backgrounds, 3) estimate correlation of QTL effects for multiple mechanisms of FHB resistance, 4) identify adapted germplasm with these QTL, and 5) design crosses to combine mechanisms of resistance.

Project 6: *Coordinated Evaluation and Utilization of Marker Assisted Selection.*

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

   The objectives of this project are to 1) evaluate the effectiveness of use of FHB-resistance QTL in the NWW breeding programs through marker assisted selection (MAS); 2) quantify the effects of these QTL in reducing FHB and DON; and 3) measure their impact on other key traits such as yield and milling and baking quality.

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:
   Approximately 700-1000 partially inbred lines (RIL) from crosses with an array of parents homozygous for the resistance alleles at Fhb1 and other QTL were planted in breeding nurseries in KY, MO, IN, IL, MI, OH and NY. These lines were genotyped at Fhb1 and other resistance QTL at the USDA-ARS *Eastern Regional Small Grains* Genotyping Lab, Raleigh, NC. This material is being phenotyped for FHB traits, and in some cases yield and other agronomic traits in the individual Co-PI's scab and yield nurseries. Based on genotypic and phenotypic data, a number of pairs of sister lines, homozygous for resistance and susceptibility alleles at each QTL were identified in each breeding program. Seed of these lines was distributed to Co-PIs for planting in the fall 2010 and FHB phenotyping, yield testing and milling and baking quality analysis. Lines for inclusion in the study were identified and planted in fall 2010 and FHB phenotyping, yield testing and milling and baking quality analysis will occur in the 2010-2011 season and be repeated in the 2011-2012 season. Phenotyping will include standard FHB traits such as incidence, severity, FDK and DON.

   Impact:
   Outputs will include information on the effect of genetic background on QTL expression, sharing of lines to use as parents, and possible identification of lines worthy of joint germplasm and/or cultivar release. This project will result in immediate sharing of germplasm lines with QTL-derived resistance, often paired with native resistance. The extensive phenotyping and testing of these lines should expedite the release of those lines with variety release potential. Beyond individual institution releases, it is possible that the regional evaluation of these lines will identify some candidates for joint release as improved FHB-resistant, low DON varieties. Finally, this project will provide crucial information on the variability of QTL effects across genetic backgrounds. This will inform breeders in the soft winter wheat region on the probability of success of deploying these QTL in high yielding resistant, low DON varieties and thus make the breeding process more efficient.

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.

No breeding lines were released in 2010.

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.

Abstracts:

Brucker, E.A., N.H. Karplus, C.A. Bradley, and **F.L. Kolb. 2010.** Evaluation of host plant resistance and fungicide treatment for suppression of Fusarium head blight. Proceedings of the 2010 National Fusarium Head Blight Forum, Milwaukee, WI, Dec. 7-9, 2010. p. 75.

Brucker, E.A., J.N. Mundell, D.A. Van Sanford, and **F.L Kolb. 2010**. Comparison of two methods for estimating *Fusarium* damaged kernels in soft red winter wheat. Proceedings of the 2010 National Fusarium Head Blight Forum, Milwaukee, WI, Dec. 7-9, 2010. p. 131.

Karplus, N.H., E.A. Brucker and **F.L. Kolb. 2010**. Identifying QTL for Fusarium head blight resistance in a RIL population derived from a three-way cross involving three resistant parents. Proceedings of the 2010 National Fusarium Head Blight Forum, Milwaukee, WI, Dec. 7-9, 2010. p. 147.

Thompson, C.J., E.A. Brucker, and **F.L. Kolb. 2010**. Comparison of two Fusarium head blight inoculation methods in wheat. Proceedings of the 2010 National Fusarium Head Blight Forum, Milwaukee, WI, Dec. 7-9, 2010. p. 170.

Thompson, C.J., E.A. Brucker, and **F.L. Kolb. 2010.** Identification of quantitative trait loci for Fusarium head blight resistance in a winter wheat population. Proceedings of the 2010 National Fusarium Head Blight Forum, Milwaukee, WI, Dec. 7-9, 2010. p. 171.

Shoots, J., M. Guttieri, **F.L. Kolb**, J. Lewis, A. McKendry, H. Ohm, C. Sneller, M.E. Sorrells, E. Souza, D. Van Sanford, J. Costa, C. Griffey, S. Harrison, J. Johnson, and P. Murphy. 2010. Development and Distribution of Male-Sterile Facilitated Recurrent Selection Populations. Proceedings of the 2010 National Fusarium Head Blight Forum, Milwaukee, WI, Dec. 7-9, 2010. p. 165-66.

Presentation:

Kolb, F. L. 2010. Management of Head Scab with Genetic Resistance and Fungicides. Illinois Wheat Association Forum. August 25, 2010.