USDA-ARS/
U.S. Wheat and Barley Scab Initiative
FY10 Final Performance Report
July 15, 2011

Cover Page

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Fiscal Year:	FY10
USDA-ARS Agreement ID:	59-0206-9-077
USDA-ARS Agreement Title:	Fusarium Head Blight Research in Winter Wheat.
FY10 USDA-ARS Award Amount:	$ 119,799

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-NWW	Mapping QTL in Biparental Populations.	$ 34,293
VDHR-NWW	Accelerating the Development of Scab Resistant Soft Red Winter Wheat.	$ 64,298
VDHR-NWW	Development and Distribution of Male Sterile Facilitated Recurrent Selection Populations.	$ 1,951
VDHR-NWW	Coordinated Evaluation of FHB Resistance of Advanced Soft Winter Lines and Cultivars.	$ 8,525
VDHR-NWW	Improved Breeding for FHB Resistance by Advanced Genetic and Phenotypic Characterization of Soft Winter Wheat.	$ 2927
VDHR-NWW	Coordinated Evaluation and Utilization of Marker Assisted Selection.	$ 7,805
	Total ARS Award Amount	**$ 119,799**

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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: *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?**

   Fusarium head blight (FHB) resistance in the soft red winter wheat variety Truman developed and released at the University of Missouri is broad-based, having excellent levels of types I and II resistance as well as good kernel quality retention and low DON under heavy disease pressure. Haplotype data suggests that the resistance in Truman differs from the resistance in Sumai 3 and its derivatives as well as the resistance in Ernie. The overall objectives of this mapping project are to identify QTL associated with each of the 4 types of FHB resistance in Truman in a recombinant inbred line population consisting of 239 RILs developed from the cross Truman/MO 94-317. Collaborative phenotyping effort at Missouri, Kentucky, and Purdue, was initiated to provide data from multiple environments upon which to base the genotyping effort.

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:

   Data for FHB incidence, severity, FDK and DON were received from Purdue and Kentucky and were completed at Missouri. Two replications of data for each location were received. At Missouri, preliminary genotyping was conducted on 179 RILs using 460 DArTs and 64 polymorphic SSRs. QTL were identified on chromosomes 1BL (type II at MU; FDK at KY and spread at PU), 2ALc (FHBI at MU; incidence at MU and PU; DON at MU and FDK at KY), 2BSc (incidence at PU; type II at MU), 3BSc (FHBI at MU; Type II at MU; FDK at MU, PU, KY; DON at MU, PU, KY and incidence at PU), and 6AL (DON at KY). R^2 values typically are in the 10-20% range. An additional 83 SSRs have now been mapped and 1615 SNPs are available to refine QTL locations for these traits.

   Impact:

   The source of FHB resistance in Truman is a highly penetrant source of resistance for all 4 FHB resistance traits (greenhouse spread, field incidence, severity, FDK and DON). Dr. Gina Brown-Guedira is closely involved in the progress of the genotyping effort and once useful markers are identified they will be made available to her genotyping lab for use in marker-assisted-selection, F2 enrichment, and or backcrossing efforts, thereby enabling either Dr. Brown-Guedira or other breeders to pyramid genes for all four types of resistance in regional variety development efforts. Publication of these results in peer-reviewed journal(s) when complete will benefit the scientific community as a whole.

Project 2: *Accelerating the Development of Scab Resistant Soft Red Winter Wheat.*

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

   Fusarium head blight, in wheat continues to be an important problem in the north-central region of the United States. This ongoing project has focused largely on the exploiting the broadly based, effective, genetically different, native sources of resistance identified in Missouri wheat germplasm; an approach that has been shown to accelerate the development and release of FHB resistant cultivars for the soft red winter wheat region. In 2010 our major objectives were: (1) the continued identification and verification of useful sources of FHB resistance in the Missouri wheat breeding program; (2) the incorporation of new sources of resistance (both native and exotic), as they are verified, into elite Missouri soft red winter wheat breeding lines; and (3) genetic characterization through haplotyping of Missouri resistant breeding germplasm.

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):

   In 2009 we identified a completely new, broad-based, native source of resistance in our breeding materials that is equal to Truman but in a much more desirable agronomic background. This family of lines was developed from a cross of Coker material with one of our own, breeding lines, MO 92-599. In 2010, the resistance in this group has been verified in 2010 Northern and Preliminary Scab Nurseries where they topped the nurseries. Resistance in one of these lines, MO 080104, has been further verified by those who screened the Eastern Soft Red Winter Wheat Nursery where it was entered for yield and adaptation. In terms of agronomic performance, MO 080104 finished 2nd in the nursery (statistically, not different from the first entry) and has since been named a new check for the Eastern Nursery. Once markers are complete for Truman, they will be run on this line but based on the pedigree, we don't expect this source of resistance is the same as that in Truman. We have made appropriate crosses with this lined to develop a doubled haploid mapping population to identify QTL associated with the resistance. It is under increase for release as it provides excellent yield and test weight, is moderately early maturing, has short stature and has resistance to stripe rust, WSBMV, and has tolerance to acid soils. It is photoperiod insensitive and is adapted across the entire soft red winter wheat region.

   Impact (1):

   MO 080104 has the potential to be widely grown across the entire soft red winter wheat region and because of its desirable agronomic package coupled with Truman level of resistance will, when grown, immediately lessen the risk of FHB in all areas in which it is grown.

Accomplishment (2):

Field resistance levels in all of our advanced lines (approximately 300) ranged from 2.1% to 42% with no lines (except susceptible checks) exceeding this value. In our most advanced yield trial, we now have 80% of our lines with a field index (incidence x severity) that is less than 20% disease, which is comparable to Ernie. 24% of these lines have an FHBI that is less than 10% or equal to Truman. Lines primarily combine native resistance from the Missouri program with sources of resistance from Illinois (particularly IL 95-4162 and IL 94-1653), from Purdue and from exotic sources containing Sumai 3. We are now building on the MO 080104 family of lines because of the superior agronomic performance of this line and its high level of resistance.

Impact (2):

The release of FHB-resistant cultivars is the primary goal of the USWBSI. Our program has had considerable success focusing on native resistance through screening and recombination in adapted backgrounds. The germplasm pipeline noted above will certainly lead to future releases from the program that, where grown, will lessen the overall threat from FHB in Missouri and the surrounding states. Superior sources, whether released or used as improved germplasm will also be shared with breeders in other states through the uniform scab nursery system. By making this germplasm widely available, alleles discovered in our program should enhance the scab resistance in cultivars throughout the soft red winter wheat region.

Project 3: *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?

It is thought that combining genetically different sources of FHB resistance into individual cultivars may increase the level of resistance, maintain resistance over broad geographical areas, and/or enhance resistance levels under heavy epidemics in any one geographical area. The use of native sources of resistance that are in broadly adapted genetic backgrounds, should accelerate the development of FHB resistant lines that also possess the agronomic traits necessary for immediate adoption within areas where FHB is a serious problem. Because wheat is self-pollinated, combining several sources of resistance into individual cultivars is labor intensive, requiring hand emasculation and pollinations. The use of genetic male sterility should enable these genetic combinations to be produced more easily resulting in highly useful, cross-composites of several different sources of resistance. These populations can be easily recombined with locally adapted sources, thereby shifting adaptation to the target environment of the local breeding program. Subsequently these populations can be used for selection for FHB, grain yield and relevant agronomic traits and those populations may also be shared among breeders in the target region.

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:

During the 2010/11 crop season, early, mid-season and full-season populations segregating for genetic male sterility acquired from The Ohio State University were grown in Missouri. Each was surrounded with a composite of 7 elite Missouri lines that spanned the maturity of each male sterile population. Male sterile heads were identified, tagged, sprayed with FHB and resistant heads were harvested. Within each population, seed from resistant heads checked for FDK, bulked and replanted in the 2011/2012 season for a further round of recurrent selection. Following the 2012 season, markers will be applied to individual selections to identify gene combinations.

Impact:

This project is necessarily long term but has tremendous potential for impact by providing a mechanism to accumulate genes for FHB resistance from diverse sources in locally adapted backgrounds. These populations are simultaneously regional and local, providing both the opportunity for individual breeding programs to select genotypes with favorable local adaptation and the region-wide opportunity to recomposite and recombine local selections into an improved regional pool. As a result of this project breeding programs in the eastern regions will have several pools of germplasm from which to extract breeding lines. The breeding lines extracted from these populations have the potential to have unique combinations of FHB resistance genes.

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?**

Resistance in newly developed germplasm produced in all breeding programs where FHB resistance is an objective requires verification. The nursery systems including the Northern and Southern FHB nurseries as well as other cooperative performance nurseries including the Eastern Soft Red Winter Wheat Nursery and 5-State Advanced and Preliminary Nurseries provide an excellent opportunity to screen the most advanced soft red winter wheat varieties for FHB resistance. Coordinated evaluation of these nurseries accelerates the process of verification by providing breeders with a number of location years of data each year. This multi-location evaluation would be cost prohibitive in most breeding programs and thus, the cooperative nursery systems provide an opportunity to exchange this information among the breeding community and communicate new sources of resistance to all interested breeders. Evaluation of the Official Variety Trials, immediately transfers FHB resistance information to the growers and permits more informed decisions regarding variety selection.

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 2010/11, we provided information on incidence, severity, the FHB index, FDK and greenhouse severity on the Northern, Preliminary, the Uniform Eastern Soft Red Winter Wheat Nursery (18% of lines with field index of less than 10%), the 5-State advanced (14% with FHBI less than 10% with best lines from Missouri and Ohio) and preliminary (32% with FHBI less than 10% with best lines from MO, IL, and PU) Nurseries, and the Official Variety Trial for Missouri. Of note for growers, 10% of 80 lines have an FHBI of less than 10% while 30% have an FHBI of less than 20%. Although we don't conclusively know where lines (other than the public lines) come from based on our best guess of where these proprietary brands were developed, most were developed with USWBSI funding. Truman and MO 080104 remained the top lines for FHB resistance, however, our data suggests that the number of resistant lines being entered into the MO OVT has increased over earlier evaluations of this nursery. Once FDK and DON are determined, these will be added to the list and posted on the web with the OVT data to enable growers to choose more FHB resistant lines.

Impact:

Results of this project suggest improvement in most programs for FHB resistance in upcoming germplasm. These tests help validate sources of resistance from other breeding programs as well as from the Missouri program, thereby providing information on stability of resistance of newly developed germplasm evaluated in the Northern, Preliminary and Southern Scab Nursery. It also presents the opportunity for sharing of this elite germplasm through the Wheat Breeder's Code of Ethics, thereby enhancing resistance in all breeding programs within the initiative. Although long term, coordinated screening should significantly lessen the risk of FHB where released varieties combining different sources of resistance are grown. Evaluation of the Official Variety Trials will immediately provide growers with FHB resistance levels on all commercial cultivars, thereby enabling more informed grower choices of varieties to plant on their respective farms. Again, where growers select resistant material, the threat of FHB will be significantly lessened.

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?

There is moderate to strong resistance to FHB in Eastern US SWW. The FHB resistance includes Type I & II resistance as well as potentially resistance to kernel infection (RKI) and toxin accumulation (RTA). It is likely that a combination of all types of resistance is needed to reliably produce grain with low deoxynivalenol (DON). Genetics studies in SWW suggest that resistance is controlled by a few QTL with moderate effect and many QTL of small effect. Traditional mapping and MAS approaches may not be effective given the potentially large number of unique resistance sources and that most variation is likely controlled by genes with small effect. The evolving picture of FHB resistance in SWW currently suggests that 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 and populations for improving FHB resistance in SWW. Our specific goals are:

1. Elucidate the genetic structure of multiple mechanisms of FHB resistance in SWW
2. Develop models to implement genomic selection (GS) for multiple FHB traits.
3. Document RKI and RTA in SWW

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:

We grew and evaluated a replicated panel of soft red winter wheat lines representing 7 FHB elite lines from each program and 100 additional sets of lines from pedigrees involving the 7 elite Missouri lines. Data for this year's nursery are not yet analyzed but preliminary data suggests good levels of resistance in many lines. Data has been collected for incidence, severity, FDK and seed will be sent for DON analysis.

Impact:

This analysis, once complete, will help identify QTL across entire populations that may be useful in marker-assisted selection using these sources of resistance. Once completed, markers will be made available to the genotyping lab and will be published through peer reviewed journals. Where pyramiding different sources of resistance into individual lines marked reduces the impact of FHB, this project should lead to a reduction in the impact of FHB on the wheat community.

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 effectiveness of MAS for FHB resistance alleles at several QTL derived from Asian wheat lines has been demonstrated convincingly in spring wheat, where native resistance sources are scarce. However, in SWW, relatively few varieties have been released that are derived from Sumai 3 or other Asian resistance sources. In part, this stems from the difficulty in combining the QTL based resistance with superior agronomic performance and acceptable milling and baking quality. Further, there is an abundance of native resistance in SWW that has been deployed in a number of resistant varieties. Nonetheless, we hypothesize that the highest levels of resistance will come through combining native SWW resistance with that conferred by exotic QTL. The approaches used to address this problem are as follows:

1. PIs will identify lines in their programs that have been genotyped as homozygous for the resistance alleles at the QTL noted earlier. Lines *thought* to be homozygous for the resistance alleles (but not yet genotyped) will be genotyped, either in house or through the regional USDA genotyping laboratory in Raleigh, NC.
2. These lines will be increased outside the nurseries for distribution to cooperators in fall 2010.
3. Lines will be allocated to regional nurseries according to likely adaptation (eg northern corn belt; southern corn belt) phenotyped in regional scab nurseries and grown in replicated yield trials in 2010-11 and 2011-12 and evaluated for milling and baking quality at the USDA regional quality lab in Wooster, OH. Phenotyping will include standard FHB traits such as incidence, severity, FDK and DON and will likely include evaluation in at least one cooperator's greenhouse.
4. Promising lines can be used as parents by all of the breeders in the CP, and lines that show regional adaptation may be candidates for joint 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):

<u>Accomplishment:</u>

In 2010, we genotyped approximately 80 $F_{4:8}$ lines combining *FHB1* with putative alleles in a Truman derived sib (980725) that has better agronomic potential than Truman (i.e. earlier, higher in grain yield). Additionally, 7 Hungarian sources of resistance, was genotyped and found to contain all of the Sumai 3 alleles but in a better background. Although 980725 is a full sib of Truman and probably carries some of the Truman alleles, it is not as resistant as Truman. Five $F_{4:8}$ lines homozygous for *FHB1* and five $F_{4:8}$ lines null for *FHB1* were included in a marker assisted nursery to be distributed to breeders for yield evaluations in 2011. Additionally, replicated yield trials containing 75 genotyped lines from this group some homozygous for *FHB1* while others were either heterozygous for *FHB1* or null for this allele were evaluated in our FHB nursery and concurrently grown for yield trials to establish

the impact on yield of *FHB1*. FHBI for lines homozygous for *FHB1* in the MO 980725 background, ranged from 6.4% to 22.6%, with 4 of the 5 lines ranging from 6.4% to 10% FHBI. Interesting 2 lines heterozygous for FHB1 had scores of 4.9% and 5.6% respectively. None was as resistant as Truman (FHBI = 3.1%) and 2 lines that were null for *FHB1* had FHBI values of 4.1, 7.6, and 10.3% respectively. Yield data on the complete set of lines has not yet been analyzed but will be compared with presence/absence of *FHB1* to determine the impact, this exotic allele may have on performance. Additionally, once Truman markers are completed (fall 2011), MO 980725 will be scored for those markers to determine which, if any, these lines contain. It was genotyped in 2010 and carries no alleles from Sumai 3.

Impact:

These data suggest that pyramiding *FHB1* into a moderately susceptible background may increase resistance levels in the line. Where yield is not impacted, the use of markers associated with resistance from Sumai 3 may provide a way to accelerate the development of scab resistant lines with suitable agronomics for growers to use commercially, thereby lessening the risk of FHB to the wheat economy.

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.

None during this period.

MO 080104, although not yet released, is in increase for release in Missouri. It has Truman level of resistance in a much better agronomic package including high yield, test weight, early maturity, short stature, photoperiod insensitivity, broad adaptation, and resistance to other relevant diseases. We anticipate releasing this line in 2011, however, because of the need to get the variety grown over the area of its adaptation (which is much of the soft red winter wheat region) we may seek proprietary release of the line to a company with the infrastructure to market and make the variety broadly available throughout the region.

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.

Abate, Z.A., and A.L. McKendry. 2010. Diallel analyses of Fusarium head blight resistance in genetically diverse winter wheat germplasm. Euphytica 175:409-421.

Liu, S. M.D. Hall, C.A. Griffey, A.L. McKendry, J. Chen, G. Brown-Guedira, D. Van Sanford, and D.G. Schmale. 2010. Mapping field resistance to Fusarium head blight and its association with dwarfing genes in the soft red winter wheat cultivar Massey. Theor. Appl. Genetics. Under review.

Rottinghaus, G.E., B.K. Tacke, T.J. Evans, M.S. Mostrom, L.E. Sweets, and A.L. McKendry. Fusarium mycotoxin concentrations in the straw, chaff and grain of soft winter wheats expressing a range of resistance to Fusarium head blight. Presented at the International Symposium on Algal and Fungal Toxins for Industry. Merida, Yucatan. July 1, 2010.

Islam, Md. S., G. Brown-Guedira, M.J. Gerau, and A. L. McKendry. 2010 Preliminary QTL Analysis for Fusarium Head Blight Resistance in the Soft Red Winter Wheat, 'Truman'. In: S. Canty, A. Clark, A. Anderson-Scully, D. Ellis and D. Van Sanford (eds). Proceedings of the National Fusarium Head Blight Forum: 2010 Dec 7-9; Milwaukee, WI. 145.

Shoots, J., Guttieri, M., Kolb, F., Lewis, J., A.L. McKendry, H. Ohm, C. Sneller, M.E. Sorrells, E. Souza, D. Van Sanford, J. Costa, C. Griffey, S. Harrison, J. Johnson, and P. Murphy. Development and Distribution of Male-Sterile Facilitated Recurrent Selection Populations. 2010. In: S. Canty, A. Clark, A. Anderson-Scully, D. Ellis and D. Van Sanford (eds). Proceedings of the National Fusarium Head Blight Forum: 2010 Dec 7-9; Milwaukee, WI. 145.