USDA-ARS/
U.S. Wheat and Barley Scab Initiative
FY16 Final Performance Report
Due date: July 28, 2017

Cover Page

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Fiscal Year:	2016
USDA-ARS Agreement ID:	59-0206-4-025
USDA-ARS Agreement Title:	Fusarium Head Blight Research in Winter Wheat.
FY16 USDA-ARS Award Amount:	$ 94,150
Recipient Organization:	The Curators of the University of Missouri 310 Jesse Hall Columbia, MO 65211
DUNS Number:	153890272
EIN:	43-6003859
Recipient Identifying Number or Account Number:	39837
Project/Grant Reporting Period:	5/27/16 - 5/26/17
Reporting Period End Date:	05/26/17

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-NWW	Accelerating the Development of Scab Resistant Soft Red Winter Wheat.	$ 84,733
VDHR-NWW	Male Sterile Facilitated Recurrent Selection for FHB Resistance.	$ 680
VDHR-NWW	Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials.	$ 8,737
	FY16 Total ARS Award Amount	**$ 94,150**

Anne L McKendry — July 26, 2017

Principal Investigator — Date

* MGMT – FHB Management
FST – Food Safety & Toxicology
GDER – Gene Discovery & Engineering Resistance
PBG – Pathogen Biology & Genetics
EC-HQ – Executive Committee-Headquarters
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: *Accelerating the Development of Scab Resistant Soft Red Winter Wheat.*

1. **What are the major goals and objectives of the project?**

   The focus on 'native' resistance in the Missouri program has accelerated the development Fusarium head blight (FHB) resistant varieties. The specific goals of this project are to develop and release to the soft red winter wheat community, varieties of wheat that have enhanced levels of FHB resistance and to accelerate this process by building on sources of FHB resistance that are native to US soft red winter wheat. The ultimate goal is to combine these sources of resistance with other more exotic resistance to both increase resistance levels in our varieties and make them more durable under heavy disease pressure. This project had 3 primary objectives: (1) the continued design of crosses that combine FHB-resistant parents with native and/or exotic sources of resistance; (2) systematic screening of advanced breeding lines for all 4 types of FHB resistance and verification of resistance levels in lines with putative resistance identified in previous years of screening; (3) Greenhouse and field increases and preliminary agronomic evaluation of 300 doubled haploid lines acquired from Dr. Van Sanford, that contain FHB QTL including those on 3BS (Fhb1), 2DL, 5A that had been introgressed into adapted soft red winter wheat backgrounds. Backgrounds include lines from Kentucky, Syngenta and Virginia. A fourth objective, *phenotyping a mapping population (Bess/MO 94-317) to validate SNP markers in Truman*, was originally included in this project but was substituted for the doubled haploid objective when these lines became available. The mapping population was phenotyped with other funds, completing this objective.

2. **What was accomplished under these goals?** *Address items 1-4) below for each goal or objective.*

   Objective 1 "*the continued design of crosses that combine FHB-resistant parents with native and/or exotic sources of resistance"*

   1) Major activities: A crossing block was conducted and approximately 400 single, 3-way or 4-way crosses were made with FHB resistant parents that had been previously screened in greenhouse and field inoculated nurseries. All crosses were designed to enhance FHB resistance in the resulting populations by selecting parents with FHB resistance levels that had an FHB index less than 15%, coupled with low DON and Fusarium damaged kernels. To accelerate the development of FHB resistant cultivars, parental choice was also informed by good yield and test weight, soft red winter wheat quality, resistance to stripe rust, leaf rust, soilborne mosaic virus resistance, maturity and height. We have used this approach for many years and outcomes from advanced yield testing that are listed below reflect results of this approach.

   2) specific objectives: See 'Objective 1:' above.

3) Significant results**:** Each cross contained at least one source of resistance in the parents while approximately 85% contained two or more sources of resistance. All contained at least one native source of resistance while about 30% combined native sources with other sources including those from China, S. Korea, Brazil, Argentina, Romania, Hungary and CIMMYT.

4) Key outcomes or other achievements

- Screening the most advanced yield trial (AYT1) suggests that our approaches are working well. In FY16 we evaluated 64 entries, 56 experimental lines and 8 check varieties. In that test, Truman was the most resistant check with an FHBI of 3.8%. Ernie, a more moderate check had an FHBI of 15.7% while the susceptible check had an FHBI of 42.2%. The mean FHBI of the 56 experimental lines was 7.9% with 55 lines being lower than Ernie and 11 lines being ≤ Truman. One line had an FHBI (18.5%) greater than the 15% cutoff.
- One line (MO 151062) was advanced towards licensing in 2017 which combined resistances in a Syngenta line with those from a line from Brazil (Brazil 8). FHBI rating for 2017 was 11.7%.
- In 2016, we released two MR lines noted later in this report. Both lines are expected to be widely adopted as seed quantities are increased. Initial sales will be in the fall of 2017.

Objective 2: *systematic screening of advanced breeding lines for all 4 types of FHB resistance and verification of resistance levels in lines with putative resistance identified in previous years of screening;*

1) Major activities: In the Missouri program, lines in head row (generally 20,000 to 30,000 annually) are selected based on agronomic traits. Where there is natural infection of FHB, susceptible lines are eliminated from the breeding stream prior to initial yield testing. The first inoculated FHB screen occurs after preliminary yield trials on lines that have been selected for grain yield, test weight, height, maturity, and prevalent diseases in the year of testing. In FY16, we evaluated 407 new lines in our inoculated FHB nursery for incidence, severity, FHBI, Fusarium damaged kernels (FDK), and DON content. For screening in the field environment, lines were sprayed in an over-head mist irrigated, inoculated nursery at heading (by heading date of each individual line) with inoculum concentrated to 70,000 spores per mL of a macroconidial suspension of *Fusarium graminearum*, previously tested for agressivity on Missouri resistant breeding lines. During the winter of 2016/2017, all lines evaluated in the field, were also evaluated in the greenhouse for severity using point-inoculation.

2) specific objectives: See ‘Objective 2:’ above.

3) Significant Results: To date, all data have been collected except for DON data from the nursery. It is anticipated that samples will be sent to the University of Minnesota for

DON testing by August 1st, 2017. FDK data have been completed and are being tabulated and analyzed.

- Mean data for 6 nurseries containing entries being screened for the first time suggest that we had good FHB data in FY16. Resistant check varieties Truman, (FHBI 6.3%), Ernie (FHBI 13.7%), and the susceptible check MO 94-317 (FHBI 51.6%) all had data that was within the expected range for each variety.
- 407 lines were evaluated for the first time in an inoculated nursery and in the greenhouse. The mean FHBI was 16.1 with 109 varieties having an FHBI that was ≤ Truman and 55 more lines with an FHBI that was > Truman but ≤ Ernie. These 164 lines will be advanced for more advanced agronomic testing and for verification of their FHB response, pending their 2017 performance for other agronomic data.

4) Key outcomes or other achievements

- 10 lines will be entered into the cooperative Northern and Preliminary Northern scab nurseries for further evaluation of their FHB reaction across multiple locations.
- By entry into these nurseries we will be disseminating the best of these lines to other interested breeders who will be free to cross with this material if they wish.

Objective 3: *Greenhouse and field increases and preliminary agronomic evaluation of 300 doubled haploid lines acquired from Dr. Van Sanford, that contain FHB QTL including those on 3BS (Fhb1), 2DL, 5A that had been introgressed into adapted soft red winter wheat backgrounds. Backgrounds include lines from Kentucky, Syngenta and Virginia.*

1) Major Activities: Greenhouse and field increases and preliminary agronomic evaluation of 300 doubled haploid lines acquired from Dr. Van Sanford, that contain FHB QTL including those on 3BS (Fhb1), 2DL, 5A that had been introgressed into adapted soft red winter wheat backgrounds. Backgrounds include lines from Kentucky, Syngenta and Virginia.

2) specific objectives: See 'Objective 3:' above.

3) Significant Results:
   - A preliminary increase of the lines (3 plants/line) was done in the greenhouse.
   - Headrows of the lines in the field environment suggested that parental lines used in doubled haploid production differed for reduced height genes leading to several lines that were double dwarfs.
   - Lines were variable for agronomic traits including height, disease resistance (primarily BYDV), and yield potential.
   - Some double dwarf lines produced very little seed in the greenhouse increase.

4) Key outcomes or other achievements
   - Lines will be screened for FHB in inoculated nurseries in both the greenhouse and field in the 2017/2018 crop season to evaluate resistance in this set of lines.

- Concurrently, selected lines will be grown in a single plot in the 2017/2018 crop year to evaluate yield and other agronomic traits.

3. What opportunities for training and professional development has the project provided?

Four of our undergraduate students in the Breeding, Biology and Biotechnical Undergraduate Emphasis Area within the Division of Plant Science are completing their Capstone Internship in Plant Breeding (for credit) in my program during the 2017 crop season. They were partially supported as undergraduate students by the FY16 grant. These students will either go on to graduate school in Plant Breeding or go to work in Ag-related industry once they graduate.

One MS student, working on research unrelated to FHB and funded by other sources, learned to produce inoculum, inoculate (in both the greenhouse and field environments) and rate genotypes for FHB resistance in both the greenhouse and field nurseries associated with the FY16 project.

4. How have the results been disseminated to communities of interest?

Results have not yet been disseminated to communities of interest, however all advanced lines screened in our breeding program will be candidates for inclusion in the Uniform Northern and Preliminary Northern Scab Nurseries. Ten of the best FHB lines identified by this research will be included in the Northern and Preliminary Northern Scab Nurseries, thereby providing other interested breeders to screen the lines and to use them in their crossing programs should they wish to. The best lines agronomically will be entered into the 5-State Nurseries and the Uniform Eastern Nursery, where again, they are available upon request for interested breeders to include them in their crossing programs.

Project 2: *Male Sterile Facilitated Recurrent Selection for FHB Resistance.*

1. **What are the major goals and objectives of the project?**
   Each breeding program, including that in Missouri, has planted the male sterile facilitated recurrent selection (MSFRS) populations for several generations to facilitate the accumulation of native sources of resistance into local germplasm while maintaining the diversity within populations to enable selection for high levels of Fusarium head blight (FHB) resistance in locally adapted backgrounds with unique combinations of FHB resistance alleles.

2. **What was accomplished under these goals?** *Address items 1-4) below for each goal or objective.*

   Specific objective: *The specific objective for FY16 was to derive lines from a bulk population that had undergone 6 cycles of recurrent selection with Missouri FHB sources.*

   1) Major activities: The major objective of this project is to accumulate FHB resistance genes from a variety of native sources in an effort to enhance the resistance levels in soft red winter wheat. Each season we selected 7 or 8 of our best FHB resistant lines that were consistent with the maturity of the population. In FY16, we grew a bulk population (2 4-row, 200-strips) for line derivation. The population was inoculated twice in 2017 and at harvest, 500 heads were selected for agronomic potential and low FHB systems. Heads were individually threshed and will be grown as head rows in the FHB inoculated nursery in the 2017/2018 season. The remnant population was harvested for distribution to interested breeders.

   2) specific objectives: See 'Specific objective:' above.

   3) Significant results:
      - The population was inoculated twice in 2017 and at harvest, 500 heads were selected for agronomic potential and low FHB systems.
      - The population was not rated because it was segregating, however, in general, resistance levels appeared high.
      - Heads were individually threshed and will be grown as head rows in the FHB inoculated nursery in the 2017/2018 season. The remnant population was harvested for distribution to interested breeders.

   4) Key outcomes or other achievements
      - The remnant population was harvested for distribution to interested breeders. This information has been disseminated to northern breeders.
      - Data for the best lines will be shared and they will be entered into the Preliminary Northern Scab Nursery once verified and sufficient see is available.

3. What opportunities for training and professional development has the project provided?

Four of our undergraduate students in the Breeding, Biology and Biotechnical Undergraduate Emphasis Area within the Division of Plant Science are completing their Capstone Internship in Plant Breeding (for credit) in my program during the 2017 crop season. They were partially supported as undergraduate students by the FY16 grant. These students learned how genetic male sterility can be used in a breeding program.

One MS student, working on research unrelated to FHB and funded by other sources, learned to produce inoculum, inoculate (in both the greenhouse and field environments) and rate genotypes for FHB resistance in both the greenhouse and field nurseries associated with the FY16 project. He also had first-hand experience with the use of genetic male sterility in breeding.

4. How have the results been disseminated to communities of interest?

The remnant population following 6 cycles of crossing with Missouri FHB resistant varieties was harvested and is available for distribution to interested breeders. This information has been shared with northern breeders via email.

Project 3: *Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials.*

1. **What are the major goals and objectives of the project?**
   Strong Fusarium head blight (FHB) resistance must be combined with high-yield to impact the Eastern US wheat industry. Regional uniform testing has stood the test of time as one of the best ways to evaluate and distribute new germplasm and to identify other agronomically desirable traits such as yield and test weight required for profitable wheat production within the target environments of individual breeding programs. The goal of the Missouri breeding program was to collaborate across the northern and southern FHB regions in screening the Uniform Northern, Preliminary Northern, and Southern FHB nurseries for incidence, severity, Fusarium damaged kernels and DON content of harvested grain. In addition, the Missouri breeding program screens the 5-State Nurseries (both advanced and preliminary), the Uniform Eastern Soft Red Winter Wheat Nursery, and the Official Variety Trial conducted by MU extension for these four types of resistance.

2. **What was accomplished under these goals?** *Address items 1-4) below for each goal or objective.*

   Specific objective: *to provide greenhouse and field data for FHB resistance to breeders, and others entering lines into cooperative nurseries. Data will be collected for incidence, severity, the Fusarium head blight index (FHBI = incidence * severity), Fusarium damaged kernels (FDK), ISK (= 0.03 INC + 0.03 SEV = 0.04 FDK), and DON.*

   1) Major activities: In FY16 we screened collaborative nurseries including: the Uniform Northern and Preliminary Northern FHB Nursery, the Southern FHB Nursery, the Advanced and Preliminary 5-State Performance Nurseries, the Uniform Eastern Soft Red Winter Wheat Nursery, and the Missouri Official Variety Trial of commercial varieties. To date, data from all nurseries are complete for incidence, severity, FHBI, FDK and ISK and samples have been sent to Minnesota for DON analyses

   2) specific objectives: See 'Specific objective:' above.

   3) Significant results:
      - MU data for FHBI for the Northern Scab Nursery ranged from 1.23 to 21.6% and averaged 7.23% while FDK values ranged from 5.0 to 22.5% and averaged 10.4%. ISK, which integrates across incidence, severity and FDK, with heavier weighting to FDK (the intrinsic value of wheat to the grower) ranged from 16.8 to 38.0 and averaged 26.8. These values suggest significant improvement in FHB resistance across the Northern region.
      - The Preliminary Northern Scab Nursery had a similar FHBI range (2.6-23.2%) with a mean of 9.8% while FDK of lines ranged from 5.0 – 25% and ISK ranged from 19.2-45.8 with means of 13.6% and 30.2, respectively. This again suggests progress in this less advanced nursery over results from FY15.
      - The Southern Scab Nursery showed significant improvement with FHBI ranging from 4.4-20.0 (mean of 9.4%), FDK ranging from 8.0 – 30% (mean of 11.8%) and

ISK ranging from 23.2 – 45.6 (mean of 29.8). These data suggest breeders in the south are making considerable progress in improving FHB resistance in their material.

- MU data from the 112 varieties in the 2017 OVT has not yet shown as much improvement. FHBI ranged from 3.8-73.9% (mean of 26.5%), FDK ranging from 5.0-50.0% (mean of 12.2%) and ISK ranging from 22.5-60.2 (mean of 41.5) which are approximately equal to values for the past 2 years. DON data are not yet available although samples have been sent for analyses.
- Cooperative breeding nurseries including the 5-State Nurseries and the Eastern Nursery were evaluated and where the best of these entries go into the marketplace they should improve resistance available to growers. Data from the Uniform Eastern Soft Red Winter Wheat (FHBI mean 10.5%; FDK mean 12.5%, ISK mean 30%); 5-State Advanced (FHBI mean 9.9%, FDK mean 10.4%, ISK mean 29.6) and 5-State Preliminary Nurseries (FHBI mean, 10.1%; FDK mean 9.1% and ISK mean 29.2) suggest that FHB resistance in these advanced agronomic lines is approaching that of the FHB nurseries themselves and should, once the best of these are released, elevate the FHB resistance levels available to growers through the OVT.

4) Key outcomes or other achievements

The average value for FHBI from the northern nursery (7.23%) was half that of FY15 (15.3%) suggesting good progress for FHB resistance in this advanced nursery. Similar results were achieved with the Preliminary Northern Nursery. Data from the official variety trial continue to mirror those of the past two years, however data from the feeder nurseries (5-State and Eastern Nurseries) show good improvement in advanced lines that once released or licensed should elevate the FHB resistance in lines available to growers.

3. What opportunities for training and professional development has the project provided?

Four of our undergraduate students in the Breeding, Biology and Biotechnical Undergraduate Emphasis Area within the Division of Plant Science are completing their Capstone Internship in Plant Breeding (for credit) in my program during the 2017 crop season. They were partially supported as undergraduate students by the FY16 grant. These students were exposed to all aspects of this project and thus learned about the value of cooperative nurseries to breeders and had hands-on experience evaluating these nurseries for FHB.

One MS student, working on research unrelated to FHB and funded by other sources, learned to produce inoculum, inoculate (in both the greenhouse and field environments) and rate genotypes for FHB resistance in both the greenhouse and field nurseries associated with the FY16 project. He also had first-hand experience with the importance of cooperative nurseries to breeders of both FHB and agronomic performance.

4. How have the results been disseminated to communities of interest?

Results of all cooperative nurseries have been or will be delivered to the coordinators of those nurseries through their respective reporting structure and subsequently provided to all breeders entering lines. OVT results to date have been delivered to coordinators of the Missouri OVT and will be made available to growers through field days or through publications resulting from this nursery. DON data will be provided once available.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY16 award period. The term "support" below includes any level of benefit to the student, ranging from full stipend plus tuition to the situation where the student's stipend was paid from other funds, but who learned how to rate scab in a misted nursery paid for by the USWBSI, and anything in between.

1. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their MS degree during the FY16 award period?**
   Yes – David Chappell graduated with his MS in Plant Breeding Genetics and Genomics in December 2016 and currently is employed by Monsanto in the area of plant pathology. His work was not related to FHB and he was funded through other sources but learned our protocols for FHB through this project.

   If yes, how many? One

2. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their Ph.D. degree during the FY16 award period?**

   If yes, how many? Nothing to report

3. **Have any post docs who worked for you during the FY16 award period and were supported by funding from your USWBSI grant taken faculty positions with universities?**

   If yes, how many? Nothing to report

4. **Have any post docs who worked for you during the FY16 award period and were supported by funding from your USWBSI grant gone on to take positions with private ag-related companies or federal agencies?**

   If yes, how many? Nothing to report.

Release of Germplasm/Cultivars

Instructions: In the table below, list all germplasm and/or cultivars released with full or partial support through the USWBSI during the FY16 award period. All columns must be completed for each listed germplasm/cultivar. Use the key below the table for Grain Class abbreviations. *Leave blank if you have nothing to report or if your grant did NOT include any VDHR-related projects.*

Name of Germplasm/Cultivar	**Grain Class**	**FHB Resistance** (S, MS, MR, R, where R represents your most resistant check)	**FHB Rating** (0-9)	**Year Released**
MO 121058 (Proprietary License)	SRW	MR	16.3% FHBI (mean of 7 tests in 2017)	2016
MO 120187 (Proprietary License – inside Missouri and secondarily licensed outside of Missouri)	SRW	MR	14.0 % FHBI (Mean of 7 tests in 2017)	2016

Add rows if needed.

NOTE: List the associated release notice or publication under the appropriate sub-section in the 'Publications' section of the FPR.

Abbreviations for Grain Classes

Barley - BAR
Durum - DUR
Hard Red Winter - HRW
Hard White Winter - HWW
Hard Red Spring - HRS
Soft Red Winter - SRW
Soft White Winter - SWW

Publications, Conference Papers, and Presentations

Instructions: Refer to the FY16-FPR_Instructions for detailed instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY16 grant. Only include citations for publications submitted or presentations given during your award period (5/27/16 - 5/26/17). If you did not have any publications or presentations, state 'Nothing to Report' directly above the Journal publications section.

Journal publications.

Petersen, S., J.H. Lyerly, **A.L. McKendry**, M.S. Islam, G. Brown-Guedira, C. Cowger, Y. Dong, and J.P. Murphy. 2017. Validation of Fusarium Head Blight Resistance in US Winter Wheat. [In press] Crop Sci. doi:10.2135/cropsci2015.07.0415.
Status: Published
Acknowledgement of Federal Support: YES

Huang, M., A. Cabrera, A. Hoffstetter, C. Griffey, D. Van Sanford, J. Costa, **A. McKendry**, S. Cao, and C. Sneller. 2016, Genomic Selection for Wheat Traits and Trait Stability. Theor. Appl. Genet. 129:1697-1710
Status: Published
Acknowledgement of Federal Support: YES

Books or other non-periodical, one-time publications.

McKendry, Anne L. 2016. UM16C_10_29_13 Invention Disclosure MO 120187 Soft Red Winter Wheat (Held in the Office of Technology Management and Industry Relations University of Missouri-Columbia). Support from USWBSI acknowledged.
Status: Published
Acknowledgement of Federal Support: YES

McKendry, Anne L. 2016. UM16C_10_29_13 Invention Disclosure MO 121058 Soft Red Winter Wheat (Held in the Office of Technology Management and Industry Relations University of Missouri-Columbia) Support from USWBSI acknowledged.
Status: Published
Acknowledgement of Federal Support: YES

Other publications, conference papers and presentations.

None to report during this period