USDA-ARS
U.S. Wheat and Barley Scab Initiative
FY19 Performance Report
Due date: July 24, 2020

Cover Page

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Fiscal Year:	2019
USDA-ARS Agreement ID:	59-0206-8-204
USDA-ARS Agreement Title:	Fusarium Head Blight Research in Soft Red Winter Wheat
FY19 USDA-ARS Award Amount:	$ 102,133
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:	00063970
Project/Grant Reporting Period:	5/27/19 - 5/26/20
Reporting Period End Date:	5/26/2020

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-NWW	Accelerating the Development of Scab Resistant Soft Red Winter Wheat	$ 91,470
VDHR-NWW	Male Sterile Facilitated Recurrent Selection for FHB Resistance	$ 1,163
VDHR-NWW	Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials	$ 9,500
	FY19 Total ARS Award Amount	**$ 102,133**

August 23, 2020

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 research project?

The FHB resistance in most of the Missouri lines builds on the resistances in the Truman family, Ernie, and/or the MO 030291 family of lines (including MO 080104). Our basic hypothesis is that by using these native resistances as a base for improving FHB resistance in our breeding program we should be able to get resistant cultivars into the market place more rapidly. Our best native resistances appear to be broad based with low severity and incidence, good kernel quality retention under disease pressure, and low toxin (DON) levels in the harvested grain. Since the release of Truman in 2005, we have designed crosses among lines that carry our own native sources of FHB resistance and lines carrying exotic or genetically diverse sources of resistance from other soft red winter wheat breeding programs as well as sources from Asia, South America, Eastern Europe, and CIMMYT. In 2012, MO 080104 was licensed and since that time, we have licensed 6 other proprietary lines, that range in resistance from levels approximately equal to Truman (2 lines), Bess (1 line) and Ernie (3 lines). These lines include a grazing variety that combines resistance in Truman with that of a South Korean variety (Seu Seun 6). Within the FY19 timeline, the objectives of my FHB breeding project will therefore continue to be to: (1) combine genetically different introduced sources of resistance with U.S. native resistance. Choice of parental material was informed by yield, test weight, maturity, height, FHB resistance and resistance to other relevant diseases; (2) add further genetic diversity to our program through hybridization of our advanced lines with the best of 300 doubled haploid lines acquired from Dr. Van Sanford of the University of Kentucky, that contain important FHB resistance QTL in adapted soft red winter wheat backgrounds; (3) systematically screen all advanced lines for FHB resistance by evaluating incidence, severity, FDK, and DON in greenhouse and field inoculated, and misted, FHB nurseries; (4) a final objective of this project, although <u>not funded</u> <u>in this project</u> was to screen 600 plots (2 replications of a 300 entry panel) of hard red winter wheat in collaboration with Dr. Stephen Baenziger of the University of Nebraska. The Missouri breeding project should continue to produce high yielding FHB resistant lines that will lessen the risk the risk of Fusarium head blight to the wheat economy of the soft red winter wheat region. It will also produce germplasm and/or cultivars that will be shared with interested breeders across the region through cooperative FHB nurseries.

2. What was accomplished under these goals or objectives? *(For each major goal/objective, address items a-b) below.)*

<u>Objective 1</u>: The continued design of crosses that combine FHB-resistant parents with native and/or exotic sources of resistance.

a) <u>What were the major activities</u>?
A crossing block has been an ongoing component of this project for 20 years. Our goal has been to make approximately 350-450 single, 3-way or 4-way crosses with FHB resistant parents that have been previously screened in greenhouse and field inoculated

nurseries in Missouri and other states within the USWBSI. All crosses are 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 low Fusarium damaged kernels. To accelerate the development of FHB resistant cultivars, parental choice are 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. To broaden diversity in the program, five 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 and screened in two seasons in Missouri were included in the crossing block. Backgrounds include lines from Kentucky, Syngenta and Virginia. We have used this crossing approach for many years and outcomes from advanced yield testing indicate our approach has enhanced the overall levels of FHB resistance across our program and resulted in releases from the program since 2012.

b) What were the significant results?

Over the years, as better sources of resistance were available, the number of parents with FHB resistance and the levels of that resistance have increased. Our approach has been to use single crosses only when one or both parents contain native resistance. As the level of adaptation in parents from outside of our program decreases, the complexity of the cross increases. Where exotic material is used, a minimum of a 4-way cross is used with a minimum of three parents that are well adapted and contain native sources of resistance. Over this project, all crosses have contained at least one source of native resistance. Of these, 95% of crosses contain 2 sources of native resistance that differed based on pedigree for the genetic source. Where exotic material was included in the cross (25% of crosses), 3 or 4-way crosses were made with one exotic source combined with 2 or 3 native US sources. Achievements are described in objective 2.

c) List key outcomes or other achievements:

Beyond actually making the crosses, outcomes and achievements are necessarily long term. As the number of FHB resistant parents has increased, our crossing schemes have evolved as described above. The outcomes and achievements are described below under objective 2.

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.

a) What were the 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 (single plot testing) on lines that have been selected for grain yield, test weight, height, maturity, and prevalent diseases in the year of testing. In the fall of 2019 83 new lines were selected for

continued testing based on the traits listed above. These 83 lines were also evaluated for the first time in the 2020 field FHB nursery along with 84 advanced lines being validated from the 2019 FHB nursery. 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 2019/2020, all lines evaluated in the field, were also evaluated in the greenhouse for severity using point-inoculation. Inoculation was at first anthesis in a single basal floret of a central spikelet. Spore concentration was 50,000 spores per mL with subsequent protocols developed and used over the past 20 years at Missouri.

b) What were the significant results?

Data taken included incidence, severity, and FHBI, and greenhouse severity. Checks included resistant checks Truman (R), Bess (MR), Ernie (MR), and MO 080104 (MR), and susceptible checks Coker 9835, and MO 94-317. Field data reflected the very high FHB in the 2020 nursery due to both inoculated and natural infection. Greenhouse data suggested that these lines continue to have good FHB resistance.

- Advanced yield trial lines were validated in the greenhouse (GH) and field. GH data were very good with severity data ranging from 7.6% to 31.2%.
- Field data reflected the higher than normal FHB in the nursery. Advanced lines averaged 39% FHBI. One line MO 182405 (FHBI – 4.5%) was better than Truman (8.9% FHBI); 7 lines were better than MO 080104 (FHB 15.3); 15 lines were better than Bess (FHB 18%) and 36 lines were better than Ernie (29.1%). Susceptible checks (Coker 9835, FHBI 92.8%; and MO 94-317; FHBI 83.8%) for the 2020 field nursery were highly infected suggesting that MO advanced lines would be highly functional in high disease environments.
- 84 lines were field tested for the first time in 2020 averaging 37.3% infection. Nine lines were either better than or equal to Truman, with the most resistant line (MO 190137) averaging 1.7% FHBI; 20 lines were equal to or better than MO 080104; 41 lines were equal to or better than Bess; and 67 lines were better than or equal to Ernie.
- Because of restrictions on hiring as a result of COVID-19, FDK and DON data are being collected but are not yet available.

c) List key outcomes or other achievements:

Because of my September 1st, 2019 retirement lines were not entered in the 2020 Northern or Preliminary Northern Nurseries as is normal. However, lines have been preserved in cold storage and will be available when my position is refilled.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Yes – there were several significant impacts COVID-19 on hiring and data collection in the 2019/2020 crop season.

With the MU COVID-19 shut-down in March 2019, all research ceased, buildings and greenhouses were closed and faculty, staff, and students were prohibited from being on campus. This resulted in the premature conclusion of both our greenhouse screening program and our crossing block. Consequently, we were able to screen all cooperative nurseries and our preliminary yield nursery lines but we were not able to complete the greenhouse screening of our advanced lines.

As things became clearer regarding viral transmission and the use of masks and social distancing to mitigate transmission we were permitted to request essential status for some of our workers. We returned to work with one technician and two of our normal 4 students in May for the field season. We had our normal FHB nursery with overhead mist irrigation but we were not able to hire our normal compliment of student workers, nor were the 2 we had able to work 40 hour work weeks. Consequently, although we completed most of the field nursery and harvested necessary nurseries, we have yet to complete FDK and DON data collection because of the loss of student help. We will complete these in the next month or two and will provide that data to nursery coordinators once available. As a consequence, we were not able to expend all of the salary and wage monies that were budgeted.

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

For FY19, 2 undergraduate students completed their undergraduate internships in my breeding program, learning crossing techniques for combining adapted and unadapted sources of resistance. They learned how to produce FHB inoculum for FHB screening; how to inoculate in both the greenhouse and field environments; and how to rate FHB in both environments; finally – each student participated in all aspects of the wheat breeding program.

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

Normally, our advanced lines are disseminated to other interested breeders through the Northern and Preliminary Northern FHB nurseries as well as the 6-State Nurseries and Eastern nurseries. However, with my retirement in September 2019, lines were not disseminated. When my replacement is hired, this dissemination will be resumed.

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

1. What are the major goals and objectives of the research 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 or objectives? *(For each major goal/objective, address items a-b) below.)*

Specific objective: To identify lines with superior levels of FHB resistance from populations produced through male sterile facilitated recurrent selection.

a) What were the major activities?

To re-evaluate in the field, FHB resistance in the 25 best lines that were selected from a larger population (65 lines evaluated in 2019) resulting from 6 cycles of dominant male sterile facilitated recurrent selection.

b) What were the significant results?

Data taken included incidence, severity, and FHBI, and greenhouse severity. Checks included in this test included resistant checks Truman (R), Bess (MR), Ernie (MR), and MO 080104 (MR), and susceptible checks Coker 9835, and MO 94-317. Field data reflected the very high FHB in the 2020 nursery due to both inoculated and natural infection.

- The mean FHBI of these 25 lines was 46.6% and reflected the higher than normal amount of FHB in the nursery due to natural infection along with inoculation.
- No lines had an FHBI that was equal to or better than our most resistant checks Truman, FHBI – 9.7; MO 080104, FHBI 11.8% Bess, FHBI 14.3%
- Twelve lines had an FHBI that was equal to or better than Ernie (FHBI – 22.4%).
- No lines exceeded the susceptible check variety MO 94-317 (FHBI – 83.8%)

c) List key outcomes or other achievements.

Lines did carry resistance, however did not show the high levels observed in 2019 probably due to the high level of FHB in the nursery. With my retirement in September 2019, lines will not be re-screened until my replacement is identified. Until then lines will be maintained in cold storage. Where resistance levels are verified, lines will be included in our FHB crossing block.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Yes – there were several significant impacts COVID-19 on hiring and data collection in the 2019/2020 crop season.

With the MU COVID-19 shut-down in March 2019, all research ceased, buildings and greenhouses were closed and faculty, staff, and students were prohibited from being on campus. This resulted in the premature conclusion of both our greenhouse screening program and our crossing block. Consequently, we were able to screen all cooperative nurseries and our preliminary yield nursery lines but we were not able to complete the greenhouse screening of our advanced lines.

As things became clearer regarding viral transmission and the use of masks and social distancing to mitigate transmission we were permitted to request essential status for some of our workers. We returned to work with one technician and two of our normal 4 students in May for the field season. We had our normal FHB nursery with overhead mist irrigation but we were not able to hire our normal compliment of student workers, nor were the 2 we had able to work 40 hour work weeks. Consequently, although we completed most of the field nursery and harvested necessary nurseries, we have yet to complete FDK and DON data collection because of the loss of student help. We will complete these in the next month or two and will provide that data to nursery coordinators once available. As a consequence, we were not able to expend all of the salary and wage monies that were budgeted.

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

For FY19, 2 undergraduate students completed their undergraduate internships in my breeding program, learning crossing techniques for combining adapted and unadapted sources of resistance. They learned how to produce FHB inoculum for FHB screening; how to inoculate in both the greenhouse and field environments; and how to rate FHB in both environments; finally – each student participated in all aspects of the wheat breeding program.

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

Further evaluation is necessary to determine the value of these lines and therefore they have not been disseminated. Following my retirement in September of 2019, re-evaluation will not be complete until my replacement is identified.

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

1. What are the major goals and objectives of the research 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 or objectives? *(For each major goal/objective, address items a-b) below.)*

1) <u>Objective</u>: 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.

a) <u>What were the major activities</u>?

With my retirement in September 2019 we screened collaborative nurseries including: the Uniform Northern and Preliminary Northern FHB Nursery, the Southern FHB Nursery. We also screened the Uniform Eastern Soft Red Winter Wheat Nursery, but not the Missouri Official Variety Trial of commercial varieties. For the first time, data were presented on a 0-9 scale. All lines were harvested and data for FDK and ISK were taken although with problems associated with COVID-19 listed below have been completed.

b) <u>What were the significant results</u>?

- For this final year of our participation in this nursery, we report data for FHBI in percentages rather than on a 1-9 scale as I feel the percentage scale is more accurate and represents the nuances of minor genes better than the 0-9 scale. MU data for FHBI for the Northern Scab Nursery (50 entries) averaged 27.4% and ranged from 5.0 to 67.3% infection. 8 lines were better than the resistant check Truman (10.0%). Relative to our nursery checks, 15 lines were better than or equal to 3 additional nursery moderately resistant checks (Bess, 10.9; MO 080104, 11.8%; and Ernie,

(16.1%). No lines were more susceptible that our susceptible check MO 94-317 (72.7% FHBI).

- MU data for the Preliminary Northern Scab Nursery (37 entries) ranged from 10.5% to 73.4% FHBI. The test average was 45.8%. No lines were significantly better than Truman (10.5% FHBI). Only 3 lines were equal to or better than Ernie (16.1% FHBI). FDK averaged 10% while DON averaged 1.4ppm.
- The Southern Scab Nursery (48 entries) ranged from 13.0-98.7% (mean of 49.4%), which was higher than the mean in 2019. Four entries were about equal to the resistant checks while 3 additional entries had an FHBI that was less than 30%. There was significantly more disease in the 2020 nursery which may have led to higher FHBI overall.
- Due to university closures due to OCVID-19 FDK and DON have yet to be completed. Once data for these two traits have been completed, it will be forwarded to the appropriate nursery coordinators.
- 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. Analysis of these data is currently ongoing.

c) List key outcomes or other achievements.

This is an important component of our FHB research as validation is best if conducted by other programs. Data from the preliminary and northern nurseries was higher than expected due to heavy nursery infection but continue to indicate progress in breeding for FHB resistance among many northern and southern programs. Where lines are also agronomically good, the release of these lines to the public will lessen the impact of FHB on soft red winter wheat but more work is required to make these lines broadly available to growers and to develop lines that contain both good FHB resistance and yield.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Yes – there were several significant impacts COVID-19 on hiring and data collection in the 2019/2020 crop season.

With the MU COVID-19 shut-down in March 2019, all research ceased, buildings and greenhouses were closed and faculty, staff, and students were prohibited from being on campus. This resulted in the premature conclusion of both our greenhouse screening program and our crossing block. Consequently, we were able to screen all cooperative nurseries and our preliminary yield nursery lines but we were not able to complete the greenhouse screening of our advanced lines.

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

For FY19, 2 undergraduate students completed their undergraduate internships in my breeding program, learning crossing techniques for combining adapted and unadapted sources of resistance. They learned how to produce FHB inoculum for FHB screening; how to inoculate in both the greenhouse and field environments; and how to rate FHB in both environments; finally – each student participated in all aspects of the wheat breeding program.

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

Results for all nurseries will be sent to nursery coordinators.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY19 award period (5/27/19 - 5/26/20). 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 FY19 award period?**

   Due to my retirement, I didn't have any students in the last year.

   If yes, how many?

2. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their Ph.D. degree during the FY19 award period?**

   Due to my retirement, I didn't have any students in the last year.

   If yes, how many?

3. **Have any post docs who worked for you during the FY19 award period and were supported by funding from your USWBSI grant taken faculty positions with universities?**

   No

   If yes, how many?

4. **Have any post docs who worked for you during the FY19 award period and were supported by funding from your USWBSI grant gone on to take positions with private ag-related companies or federal agencies?**

   No

   If yes, how many?

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 FY19 award period. All columns must be completed for each listed germplasm/cultivar. Use the key below the table for Grain Class abbreviations.

NOTE: 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**
None during this period				

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 FY19-FPR_Instructions for detailed more instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY19 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period (5/27/19 - 5/26/20**) should be included. If you did not publish/submit or present anything, state 'Nothing to Report' directly above the Journal publications section.

NOTE: Directly below each citation, you **must** indicate the Status (i.e. published, submitted, etc.) and whether acknowledgement of Federal support was indicated in the publication/ presentation. See example below for a poster presentation with an abstract:

> De Wolf, E., D. Shah, P. Paul, L. Madden, S. Crawford, D. Hane, S. Canty, R. Dill-Macky, D. Van Sanford, K. Imhoff and D. Miller. 2019. "Impact of Prediction Tools for Fusarium Head Blight in the US, 2009-2019." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum*, Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY. p. 12.
> Status: Abstract Published and Poster Presented
> Acknowledgement of Federal Support: YES (Abstract and Poster)

Journal publications.

None during this period.

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

None during this period.

Other publications, conference papers and presentations.

None during this period.