USDA-ARS/
U.S. Wheat and Barley Scab Initiative
FY19 Final Performance Progress Report
Due date: July 29, 2021

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 - 5/26/21
Reporting Period End Date:	5/26/2021

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**

July 29, 2021

Principal Investigator Date

* MGMT – FHB Management
FST – Food Safety & Toxicology
R – Research
S – Service (DON Testing Lab)
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 focus on 'native' resistance in the Missouri breeding program has accelerated the development of Fusarium head blight (FHB) resistant varieties. The specific goals of this project were 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. Major objectives of this project were:
   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, resistance to relevant diseases, as well as FHB resistance level – particularly low FDK and DON. Pedigree information and marker data (where available) will also inform parental choice.
   2) To 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, that contained important FHB resistance QTL introgressed into soft red winter wheat backgrounds including lines from Kentucky, Syngenta and Virginia.
   3) To systematically screen all advanced lines for FHB resistance by evaluating incidence, severity, FHBI, FDK, and DON in greenhouse or field inoculated, and misted, FHB nurseries.

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

   a) What were the major activities?

   Objectives 1 and 2:

   A crossing block has been an ongoing component of this project for more than 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 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 low Fusarium damaged kernels (FDK). 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. To further broaden diversity in the program, Objective 2 was included in this objective. Five doubled haploid lines acquired from Dr. Van Sanford were included in the crossing block. Each lined contained 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. 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.

Objective 3:
In the Missouri program, lines in head row (generally 20,000 to 30,000 annually) were selected based on agronomic traits. Where there was natural infection of FHB, susceptible lines were eliminated from the breeding stream prior to initial yield testing. The first inoculated FHB screen occurred after preliminary yield trials (single plot testing) on lines that were selected for grain yield, test weight, height, maturity, and prevalent diseases in the year of testing. In the fall of 2019 77 new lines were selected for continued testing based on the traits listed above. These 77 lines were also evaluated for the first time in the 2020 field FHB nursery along with 63 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, however, COVID restrictions (described below) prevented us from completing the greenhouse objective until the fall/winter of 2020/2021. A one-year no cost extension was awarded to complete this work.

b) What were the significant results?

Objectives 1 and 2:
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 decreased, the complexity of the cross increased. Where exotic material was used, a minimum of a 4-way cross was used with a minimum of three parents that were well adapted and contained native sources of resistance. Over this project, all crosses have contained at least one source of native resistance. Of these, 95% of crosses contained 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.

Objective 3:
Data taken included greenhouse severity and field incidence, severity, and FHBI. Checks included resistant checks Truman (R), Bess (MR), Ernie (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. Significant results included the following:

Checks for field data over two replications ranged from a low of 7.9% (Truman; R) through intermediate levels for MO 080104 and Bess (15.6 and 18.8%, respectively) to 22.5% for Ernie (MR). The susceptible check MO 94-317 (73.3% FHBI) reflected the high level of FHB in the nursery.

Advanced lines averaged 44% FHBI. Three lines MO 181074, MO 170771 and 180750 were better than or equal to Truman (7.9% FHBI); 10 additional lines were better than Ernie (FHB 22.5%); while 9 additional lines had an FHBI less than 30%. Susceptible checks for the 2020 field nursery were highly infected and suggested that these 22 MO advanced lines would be highly functional in high disease environments.

77 lines from the Preliminary Yield Nursery were field tested for the first time in 2020 and performed better than the advanced lines, averaging 21.9% infection. FHBI data for these lines ranged from 6.4% to 50.3%. Six lines were either better than or equal to Truman, with the most resistant line (MO 190137) averaging 1.7% FHBI; 14 additional lines were equal to or better than MO 080104 while another 21 lines were equal to or better than Bess. Of the
77 lines tested, a total of 67 lines were better than or equal to Ernie.

Because of restrictions on hiring as a result of COVID-19, we were not able to complete FDK and DON data for this advanced breeding material.

c) List key outcomes or other achievements.

Objectives 1 and 2:

Beyond actually making the crosses, outcomes and achievements are necessarily long term. As the number of FHB resistant parents increased, our crossing schemes evolved as described above. With my retirement, F1 crosses and lines derived from them have been stored in cold storage until the next breeder is hired. All generations of the breeding program will be available to whoever comes after me. Other outcomes and achievements are described below under objective 2.

Objective 3:

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 and/or restrictions, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.**
   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 2020, 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 2020 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-week. Consequently, although we completed most of the field nursery and harvested necessary nurseries to preserve the seed we were unable to complete FDK and DON data collection because of the loss of student help. We were not able to expend all of the salary budgeted for this project. A one-year no cost extension was awarded to finish collecting data on advanced lines within the program. I retired in September of 2019 and Kaitlyn Bissonnette served as the PI for this extension, however, I volunteered my time and essentially led the project.

4. **What opportunities for training and professional development has the project provided?**
   In FY19, three undergraduate students in Plant Science were trained in the following areas: (1) the production of FHB inoculum for FHB screening; (2) how to inoculate in both the greenhouse and field environments; (3) how to rate FHB in both environments; (4) data entry and analysis; (5) all aspects of the wheat breeding program.

   Because of COVID, hours were limited as were the number of students we could hire, so I didn't feel our training was a good as it typically has been.

5. **How have the results been disseminated to communities of interest?**
   Over the years of this project, breeding lines have been disseminated to communities of interest through the Northern and Preliminary Northern Uniform FHB Nurseries as well as through the 6-State Nurseries and the Uniform Eastern Soft Red Winter Wheat Nurseries.

   Results have not been distributed to communities of interest because of my retirement. Advanced and preliminary yield lines will be preserved. They will be greenhouse increased

and purified in 2021. USWBSI funding is helping with this preservation. Following increase, seed will be made available to interested breeders for crossing.

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, planted 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 these three items 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?
   In the 2019 field season, 65 lines derived and purified from our population were evaluated for four components of FHB resistance. In the 2020 field nursery we re-evaluated the best 25 of these lines and compared data to our normal resistant and susceptible check varieties. Data collected included incidence, severity, and FHBI. Checks included resistant checks Truman (R), Bess (MR), Ernie (MR), and MO 080104 (MR), and susceptible checks Coker 9835, and MO 94-317.

   b) What were the significant results?
   Field data reflected the very high FHB in the 2020 nursery due to both inoculated and natural infection. The mean of the resistant checks was 24.6% FHBI while the mean of the entries was 52.3% FHBI. Seven of the male sterile derived lines had an FHBI that was equal to or better than the mean of the resistant checks.

   c) List key outcomes or other achievements.
   Three of these male sterile derived lines were equal to Truman and will be preserved, increased and purified with our breeding material and shared with others within the Northern Coordinated Project. It is not clear if they simply contain the resistance genes of Truman (a recurring male parent over cycles of intermating) or if they contain a combination of resistance genes from other male parents. We'd need to know the answer to this question to determine if using a dominant male sterile gene and resistance genes from a group of male parents is an efficient way to combine FHB resistance alleles from various lines into a single adapted background. Marker analysis may provide the answer to this question.

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

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 2020, 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. 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 or the male sterile 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 for the field season in May 2020. 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 to preserve the seed we were unable to complete FDK and DON data collection because of the loss of student help. We, therefore, were not able to use all of the salary that I had budgeted. A one-year no cost extension was awarded to finish collecting data on advanced lines within the program. I retired in September of 2019 and Kaitlyn Bissonnette served as the PI for this extension, however, I volunteered my time and essentially led the project.

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

In FY19, three undergraduate students in Plant Science were trained in the following areas: (1) the production of FHB inoculum for FHB screening; (2) how to inoculate in both the greenhouse and field environments; (3) how to rate FHB in both environments; (4) data entry and analysis; (5) all aspects of the wheat breeding program. Because of COVID, hours were limited as were the number of students we could hire, so I didn't feel our training was a good as it typically has been.

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

Results have not been distributed to communities of interest because of my retirement. Lines will be preserved along with the best advanced lines. They will be greenhouse increased and purified in the 2021 greenhouse. USWBSI funding is helping with this preservation. Following increase, they will be made available to interested breeders for crossing.

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, FHBI, Fusarium damaged kernels (FDK), and DON content of harvested grain. In addition, the Missouri breeding program screened the 6-State Nurseries (both advanced and preliminary), the Uniform Eastern Soft Red Winter Wheat Nursery, and the Official Variety Trial conducted by MU extension.

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

   a) **What were the major activities?**
   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, however, we did not the Missouri Official Variety Trial of commercial varieties as the director of that program also retired in September 2019 and without that leadership in 2019/20 I chose not to screen the varieties. Also because of my retirement, I did not enter Missouri lines in the cooperative nurseries but we did screen the nurseries. All lines were harvested and data for FDK were completed however, DON was not completed because of COVID restrictions described below.

   b) **What were the significant results?**
   For this final year of our participation in this nursery, I 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 averaged 25.4% and ranged from 3.0 to 67.3% infection. Twelve lines were better than the resistant check Truman (10.0%) while 14 additional lines were equal to or better than Ernie. One line in the test (NE-15-624) was more susceptible than our internal susceptible check MO 94-317 (64.3% FHBI). FDK were determined for this test and averaged 60% damaged kernels, however 14 lines were better than or equal to Truman which had an FDK value of 10%. The test average seemed high and reflected the high level of disease in the nursery in 2020. Although the high value for FDK didn't appear consistent with the test average of 25.4% FHBI it may reflect the independence of these two FHB resistance variables.

MU data for the Preliminary Northern Scab Nursery ranged from 2.9% to 67.3% FHBI. The test average was 33.8%. Two lines were significantly better than Truman (10.5% FHBI) and an additional 11 lines were equal to or better than Ernie. Again, FDK values were high, averaging 66% but despite the high mean value, 11 lines were equal to or better Truman.

The Southern Scab Nursery ranged from 10.4 – 98.7% FHBI with a mean of 49.6% again, reflecting the high level of FHB (both natural and inoculated) in the 2020 field nursery. Twelve lines were better than or equal to the resistant check Bess (33.7%) while 1entry (15VDH-FHB-MAS22-14 (FHBI; 10.4%) had an FHBI that was less than our internal resistant check Truman (12.5%). FDK again reflected the level of disease in the nursery ranging from 15-100% and averaging 73%. Two lines had FDK values that were better than or equal to the nursery check Bess (25%).

Due to university closures due to OCVID-19 DON was not determined.

Cooperative breeding nurseries including the 6-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.

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 Northern and Preliminary Northern Scab Nurseries and the Southern Scab Nursery were higher than expected due to heavy nursery infection in 2020. Both Northern Scab Nurseries continue to have better overall resistance than the Southern Scab Nursery but progress over the years is apparent in all three nurseries. 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 and/or restrictions, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

There were several significant impacts COVID-20 on hiring and data collection in the 2019/2020 crop season.

With the MU COVID-19 shut-down in March 2020, 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 but, prior to March we were able to screen all cooperative nurseries. 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 for the field season in May 2020. 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-week. Consequently, although we completed most of the data collection and harvested necessary nurseries to preserve the seed we were limited in what we were able to accomplish because of the loss of student labor. We managed to collect FKD but didn't have enough harvested seed for DON analysis. Because we didn't expend budgeted salary dollars, a one-year no cost extension was awarded to finish collecting data on advanced lines within the program. I retired in September of 2019 and Kaitlyn Bissonnette served as the PI for this extension, however, I volunteered my time and essentially led the project.

4. **What opportunities for training and professional development has the project provided?**
   In FY19, three undergraduate students in Plant Science were trained in the following areas: (1) the production of FHB inoculum for FHB screening; (2) how to inoculate in both the greenhouse and field environments; (3) how to rate FHB in both environments; (4) data entry and analysis; (5) all aspects of the wheat breeding program. Because of COVID, hours were limited as were the number of students we could hire, so I didn't feel our training was a good as it typically has been.

5. **How have the results been disseminated to communities of interest?**
   Data were distributed for cooperative nurseries through the normal nursery coordinators.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the **FY19 award period (5/27/19 - 5/26/21)**. 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.

I have had no graduate students or post-docs in 2018 or 2019 because of my anticipated retirement in September 2019

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?**
   ☐Yes ☒No
   If yes, how many? Click to enter number here.

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?**
   ☐Yes ☒No
   If yes, how many? Click to enter number here.

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?**
   ☐Yes ☒No
   If yes, how many? Click to enter number here.

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?**
   ☐Yes ☒No
   If yes, how many? Click to enter number here.

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 (5/27/19 - 5/26/21)**. 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**	**FHB Rating** (0-9)	**Year Released**
None during this period	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year

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

Publications, Conference Papers, and Presentations

Instructions: Refer to the 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 - 5/26/21**) 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:

Z.J. Winn, R. Acharya, J. Lyerly, G. Brown-Guedira, C. Cowger, C. Griffey, J. Fitzgerald, R.E. Mason and J.P. Murphy. 2020. "Mapping of Fusarium Head Blight Resistance in NC13-20076 Soft Red Winter Wheat." In: S. Canty, A. Hoffstetter, and R. Dill-Macky (Eds.), *Proceedings of the 2020 National Fusarium Head Blight Forum (*p. 12.), Virtual; December 7-11. Online: https://scabusa.org/pdfs/NFHBF20_Proceedings.pdf.
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