**USDA-ARS**
**U.S. Wheat and Barley Scab Initiative**
**FY17 Final Performance Report – NCE for FY18**
**Due date:** July 12, 2019

## Cover Page

| | |
|---|---|
| **Principle Investigator (PI):** | Anne McKendry |
| **Institution:** | The Curators of the University of Missouri |
| **E-mail:** | mckendrya@missouri.edu |
| **Phone:** | 573-882-7708 |
| **Fiscal Year:** | 2017 (NCE for FY18) |
| **USDA-ARS Agreement ID:** | 59-0206-4-025 |
| **USDA-ARS Agreement Title:** | Fusarium Head Blight Research in Winter Wheat. |
| **FY17 USDA-ARS Award Amount:** | $ 93,968 |
| **Recipient Organization:** | The Curators of the University of Missouri<br>310 Jesse Hall<br>Columbia, MO 65211 |
| **DUNS Number:** | 153890272 |
| **EIN:** | 43-6003859 |
| **Recipient Identifying Number or Account Number:** | 39837 |
| **Project/Grant Reporting Period:** | 5/27/18 - 5/26/19 |
| **Reporting Period End Date:** | 05/26/19 |

## USWBSI Individual Project(s)

| USWBSI Research Category* | Project Title | ARS Award Amount |
|---|---|---|
| VDHR-NWW | Accelerating the Development of Scab Resistant Soft Red Winter Wheat. | $ 84,569 |
| VDHR-NWW | Male Sterile Facilitated Recurrent Selection for FHB Resistance. | $ 678 |
| VDHR-NWW | Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials. | $ 8,721 |
| | **FY17 Total ARS Award Amount** | $ 93,968 |

Anne L McKendry

7/9/19

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 breeding program has accelerated the development of 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 resistances to both increase resistance levels in our varieties and make them more durable under heavy disease pressure. The main thrust of our effort is to combine Missouri sources that differ by pedigree with resistant sources from other northern breeding programs. We then further combine these native resistances with sources from CIMMYT, Brazil, Japan, China and Europe (primarily Romania). This project in FY17 had 3 specific 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) field and greenhouse screening 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. What was accomplished under these goals?** .

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

2) <u>Major activities</u>: A crossing block has been an ongoing component of this project for 20 years. Over the past 5 years of this project, 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 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 over the past 5 years of this project indicate our approach has enhanced the overall levels of FHB resistance across our program.

3) <u>Significant results</u>: 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% 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.

4) 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.

**1) 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

**2)** 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 2017, 25,800 head rows were evaluated and 2500 were entered into 2018 preliminary yield testing where agronomic traits including yield, and test weight were evaluated. 200 new lines were selected for continued testing based on the traits listed above. These 200 new lines were also evaluated for the first time in the 2018 FHB nursery along with 100 advanced lines being validated from the 2017 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 2017/2018, 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.

**3)** Significant results: Data taken included incidence, severity, FHBI, FDK and greenhouse severity. Checks included Truman, Ernie, MO 080104 and MO 94-317 which is our susceptible check. Greenhouse data suggested that these lines continue to have good FHB resistance.

- Advanced yield trial lines (100 lines) were validated in the greenhouse (GH) and field. GH data were very good with severity data ranging from 5.6% to 29.3%.
- 46 advanced lines were better than Ernie (20% severity) and 31 lines were better than Truman (8.6% severity).

- For the 200 lines screened for the first time, 78 lines were better than Truman (8.1% severity) while 189 lines were better than Ernie (18.5% severity).
- DON data for the 300 total lines listed above ranged from 0.05ppm to 2.1 ppm. Data for the resistant checks ranged from 0.09 ppm (Truman) to 1.90 ppm (Ernie) and 1.23ppm (MO 080104). Selected lines will be re-screened in 2019 to ensure accuracy of the data.

**4)** Key outcomes or other achievements: -

Ten lines were entered into the 2018 Northern (5 lines) and Preliminary Northern (5 lines) FHB nurseries. All 5 Missouri line and the Truman check were among the 11 lines identified as the best lines in the Northern Winter Wheat Scab Nursery. 4 lines were low for all 7 traits (including FDK and DON), as was the resistant check Truman which is also a Missouri line. The 5$^{th}$ line (MO 160140) was low for low for all traits evaluated except incidence and its derivative ISK where it was average. In the Preliminary Northern Winter Wheat Scab Nursery, 4 of the Missouri lines were low for all 7 traits as was the resistant check Truman. The other line (MO 160959) was low for 5 traits but average for incidence and DON. To have 8 of the 10 lines entered to have low scores for all traits measured in the northern region and to be among the best of the 55 Northern lines and 47 Preliminary Northern lines tested across the region is a key achievement and validation of the approach we have used to enhance FHB resistance in winter wheat through the use of native plant resistance.

**1) Objective 3**: To add the 3BS (Fhb1), 2DL, 5A QTL to our program from additional soft red winter wheat backgrounds.

**2)** Major activities: To add further genetic diversity to our program we acquired 300 doubled haploid lines from Dr. Van Sanford, that contained FHB QTL including those on 3BS (Fhb1), 2DL, and 5A that had been introgressed into adapted soft red winter wheat backgrounds which differed from the genetic backgrounds currently in my program. Backgrounds included lines from Kentucky, Syngenta and Virginia. In 2017, we increased seed of all 300 lines in the greenhouse and also grew a single 3-ft head row in the field. Field grown lines were evaluated for agronomic traits (including: height, maturity, resistance to prevalent diseases other than FHB, etc.) but were not inoculated so that good quality seed could be generated. In 2018, we grew a small test of 90 of the best of the 300 lines that appeared to be adapted to Missouri and inoculated all 300 lines in the field nursery.

**3)** Significant results: Of the 300 lines evaluated, there was segregation for height genes. Several were double dwarfs while others were tall. Upon harvest, we noted that the seed was shriveled in many of the lines. 90 lines selected in 2017 were grown in a yield trial in 2018 against Missouri check varieties to determine yield and test weight. All 300 lines were evaluated for greenhouse FHB severity which ranged from 1.18 – 51.3% disease and in the field nursery for incidence, severity, FDK. FDK from the field data averaged 23%. 254 lines had a greenhouse severity less than or equal to Ernie (20%) while 100 lines had a severity

less than or equal to Truman (8%). Although yield trials didn't indicate that any lines performed better than our check varieties, five diverse lines were identified for crossing.

**4)** Key outcomes or other achievements: - Five lines with good FHB resistance were entered into our 2018/2019 crossing nursery.

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

In 2017/2018, 4 undergraduate students completed their undergraduate internships in my breeding program, learning crossing techniques for combining adapted and unadapted sources of resistance. They learned sterile technique and how to produce FHB inoculum for FHB screening; how to inoculate in both the greenhouse and field environments; how to rate FHB in both environments; data entry and analysis. In addition, they learned about the use of dominant genetic male sterility as a pollination control system in wheat and had hands on training in project 2 of this grant. Finally – each student participated in all aspects of the wheat breeding program. Each of these students received academic credit for their capstone undergraduate internship through their participation in this project.

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

- Advanced lines were disseminated to other interested breeders through the Northern and Preliminary Northern FHB nurseries as well as the 6-State Nurseries.
- One line currently in the Eastern Soft Red Winter Wheat Nursery [MO 151062 (B980582/Brazil8)] which has very good FHB resistance coupled with yield, test weight and a good agronomic package is being advanced in Missouri for consideration for licensing. Based on Eastern data from 2019, a decision will be made as to whether this line will also be released more broadly across the eastern soft red winter wheat region.

**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?**

**1)** **Objectives** To evaluate FHB resistance in 500 derived lines from selections made in a population resulting from 6 cycles of dominant male sterile facilitated recurrent selection.

**2)** 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 grown as head rows in the FHB inoculated nursery in 2018. In FY17 and through the no-cost extension in FY18 head rows were inoculated and rated for FHB response. Sixty-five selections were made based on FHB response following inoculation that had good agronomic type and had FHB levels lower than or equal to Truman will be validated in the 2019 FHB nursery.

**3)** Significant results: Head rows with FHB ratings less than or equal to Truman (8% FHBI) were selected and hand harvested. Sixty-five rows were selected. Each will be re-evaluated in FY18 to validate FHB ratings.

**4)** Key outcomes or other achievements: Results of this study suggest that recurrent selection using a dominant male sterile gene could result in lines with enhanced FHB resistance. Lines will be validated in 2019 and pure-lined. Once data are confirmed and lines are sufficiently pure, lines will be shared through the FHB nursery system with breeders interested in using this material in their crossing programs.

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

As indicated above, 4 undergraduate students completed their undergraduate internships in my breeding program. Through this project, they learned about the use of male sterility (particularly dominant male sterility) by participating in all aspects of the field work associated with this project. They also learned about the use of male sterility by participating in the use of these lines in greenhouse crossing.

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

Results have not yet been disseminated as this is a long term project. I anticipate that populations from which lines were derived or the lines themselves as seed levels permit will be disseminated to interested breeders.

**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?**

**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.

**2)** <u>Major activities:</u> In 2017/2018 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. For the first time, data were presented on a 0-9 scale. All lines were harvested and data for FDK and ISK were taken. Samples were then be sent to Minnesota for DON analyses.

**3)** <u>Significant results</u>:

- MU data for FHBI for the Northern Scab Nursery (55 entries) averaged 2.5 and ranged from 0.7 to 6.7 on a 0-9 scale reflecting FHBI in 10% increments. The test average was 2.5. No lines were better than Truman (0.7) at the Missouri location but 26 lines were equal to or better than Ernie (2.5). FDK averaged 15% and DON data for the nursery averaged 1.8ppm.
- The Preliminary Northern Scab Nursery (47 entries) ranged from 1.1 to 7.1 on the 0-9 scale. The test average was 2.8. Again, no lines were significantly better than Truman (1.2) but 30 lines were equal to or better than Ernie (3.0). FDK averaged 10% while DON averaged 1.4ppm.
- The Southern Scab Nursery (49 entries) ranged from 1.3-7.5 (mean of 3.1), with 12 entries better than or equal to Bess and 17 better than or equal to Ernie, the two resistant check varieties in this nursery. These data from MU suggest continued improvement for FHB resistance in this region.

- 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.
- MU data from the 2018 OVT suggest more work is necessary to improve FHB in commercial lines available in Missouri. Two-year data (2017 and 2018) for 43 entries in the Missouri OVT ranged from 13.4% to 67.6% disease and averaged 40.3% FHBI. Only 5 lines had less than 25% disease, 3 of which are licensed varieties from Missouri.

**4)** 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 indicate good progress in breeding for FHB resistance with more lines each year performing at a level equal to Truman and better than the resistant check Ernie. 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. What opportunities for training and professional development has the project provided?**

As above, 4 undergraduate interns took part in the data collection for all nurseries.

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

Data for the Northern, Preliminary Northern, and Southern Nurseries were submitted to nursery coordinators. Results from the 2017 and 2018 OVT were presented at a wheat growers meeting in August 2018. The history of the initiative was discussed and the need for growers to take these data into consideration along with yield data, particularly those data combined over years. The presentation was very well received.

# Training of Next Generation Scientists

**Instructions:** Please answer the following questions as it pertains to the FY17-NCE 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 FY17-NCE period?**

   **If yes, how many?** None during this period

2. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their Ph.D. degree during the FY17-NCE period?**

   **If yes, how many?** None during this period

3. **Have any post docs who worked for you during the FY17-NCE period and were supported by funding from your USWBSI grant taken faculty positions with universities?**

   **If yes, how many?** None during this period.

4. **Have any post docs who worked for you during the FY17-NCE 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?**

None during this period.

5. **Undergraduate Training**: As noted in this document, 4 undergraduate students were supported by funding during this period. They learned sterile technique and how to produce FHB inoculum for FHB screening; how to inoculate in both the greenhouse and field environments; how to rate FHB in both environments; data entry and analysis. In addition, they learned about the use of dominant genetic male sterility as a pollination control system in wheat and had hands on training in project 2 of this grant. Finally – each student participated in all aspects of the wheat breeding program. Each of these students received academic credit for their capstone undergraduate internship through their participation in this project.

# 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 FY17-NCE 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 FY17-FPR_Instructions for detailed instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY17-NCE grant period. Only include citations for publications submitted or presentations given during your award period (5/27/18 - 5/26/19). If you did not have any publications or presentations, state 'Nothing to Report' directly above the Journal publications section.

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

Conley, E.J., and J.A. Anderson. 2017. Accuracy of Genome-Wide Prediction for Fusarium Head Blight Associated Traits in a Spring Wheat Breeding Program. In: Proceedings of the XXIV International Plant & Animal Genome Conference, San Diego, CA.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES (poster), NO (abstract)

**Journal publications.**

Huang, M., N. Mheni, G. Brown-Guedira, A. McKendry, C. Griffey, D. Van Sanford, J. Costa, and C. Sneller. 2018. Genetic Analysis of Heading Date in Winter and Spring Wheat. Euphytica https://doi.org/10.1007/s10681-018-2199-y
Status: Published
Acknowledgement of Federal Support YES (support from AFRI but not USWBSI)

Huang, M., B. Ward, C. Griffey, D. Van Sanford, A. McKendry, G. Brown-Guedira, P. Tyagi, and C. Sneller. 2018. The accuracy of Genomic Prediction Between Environments and Populations for Soft Wheat Traits. Crop Sci. 58:2274-2288.
Status: Published
Acknowledgement of Federal Support: YES (support from AFRI but not USWBSI)

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

None during this period

**Other publications, conference papers and presentations**.

None during this period