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

Cover Page

Principle Investigator (PI):	Jim Anderson
Institution:	University of Minnesota
E-mail:	ander319@umn.edu
Phone:	612-625-9763
Fiscal Year:	2019
USDA-ARS Agreement ID:	59-0206-8-202
USDA-ARS Agreement Title:	Breeding and Genomic Selection for Fusarium Head Blight Resistance in Spring Wheat
FY19 USDA-ARS Award Amount:	$ 206,509
Recipient Organization:	Regents of the University of Minnesota Suite 450 Sponsored FIN RPT-P100100001 Minneapolis, MN 55455-2003
DUNS Number:	555917996
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Recipient Identifying Number or Account Number:	CON000000075555
Project/Grant Reporting Period:	5/13/19 - 5/12/20
Reporting Period End Date:	5/12/2020

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-SPR	Breeding Fusarium Head Blight Resistant Spring Wheat	$ 136,108
VDHR-SPR	Optimization of Training Population Content and Size for Genomic Selection for FHB	$ 55,187
VDHR-SPR	Introgression to Wheat and Candidate Gene Discovery for Resistance Gene Fhb7	$ 15,214
	FY19 Total ARS Award Amount	**$ 206,509**

James A. Anderson   August 18, 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

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Project 1: *Breeding Fusarium Head Blight Resistant Spring Wheat*

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

1) Develop Fusarium head blight resistant wheat germplasm and varieties adapted for commercial production in Minnesota and the surrounding region.
2) Characterize the level of FHB resistance of all wheat varieties grown in the region.
3) Utilize genomic selection to improve the efficiency of identifying FHB susceptible lines.

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

a) What were the major activities?

Objectives 1-2: Scab nurseries were established at two field sites, Crookston and St. Paul, in 2019. A total of 1,617 genotypes were evaluated in 1 to 3 replications for a total of 5,190 across the two locations. We evaluated the FHB reaction of external germplasm from the 2019 Uniform Regional Scab Nursery (27 lines) and 2019 Regional Performance Nursery (39 lines). We completed Visual Scabby Kernel (VSK) assessment of all materials from both nurseries and received DON data from select materials, predominantly the most advanced nurseries.

Objective 3: The genomic selection aspect of this project integrates with my other USWBSI-funded project *Optimization and Establishment of Genomic Selection for FHB Resistance in Wheat.* As part of our breeding efforts we genotyped 2,763 F_5 lines using GBS. This information, combined with the predictions from genomic selection from a training population of a subset of 544 lines that were also phenotyped to include VSK and test weight, and observations from our winter nursery in New Zealand, including seed size measurements were used to select a set of 360 lines for entry into preliminary yield trials in spring 2020. Marker-assisted selection was used to characterize parental lines (all done in-house) and Preliminary yield trial candidates (in cooperation with the USDA Fargo Genotyping Lab). We routinely use DNA markers to screen for genes that provide resistance to Fusarium head blight, leaf rust, Ug99 stem rust resistance, tan spot and high molecular weight glutenins that are necessary for good baking quality. The Genotyping Center screened 2,720 pre-yield trial lines and 153 parents of F_5 materials with 8 gene-specific DNA markers, generating 22,984 marker data points. In addition, since Fall 2019 we screened 631 individual F_1 plants from topcrosses and backcrosses and 63 parents from Fall 2019 and Spring 2020 crossing blocks for as many as 48 markers in-house, generating a total of 5,605 datapoints.

b) What were the significant results?

- Both the Crookston and St. Paul FHB screening nursery were excellent, providing highly discriminatory data. From the 2019 FHB nursery data and results from previous years, the FHB resistance of 36 spring wheat cultivars was assessed and reported.

- We used genomic selection at the F_5 stage for FHB to help select lines to advance to preliminary yield trials.
- 'MN-Torgy' was released in 2020. It is moderately resistant (4 on 1-9 scale) to FHB.

c) List key outcomes or other achievements.

High yielding wheat varieties with high grain protein content, good straw strength and good scab resistance are in demand by wheat growers because they greatly influence the profitability of wheat production in Minnesota. Recent releases include 'Linkert' (2013), 'Bolles' (2015), 'Shelly' (2016), 'Lang-MN' (2017), 'MN-Washburn' (2019), and 'MN-Torgy' (2020). University of Minnesota developed spring wheat varieties accounted for an estimated 36.7% of Minnesota's 1.45 million spring wheat acres in 2019, including 'Linkert' which was the no. 1 variety for the 4th consecutive year. More than 750,000 acres of MN-developed spring wheat varieties also were grown in North Dakota in 2019, including 'Bolles' which was the 3rd leading variety in ND. Germplasm from our breeding program also is being used as parents by private and public breeding programs in the region. Our goal is to continue to release high yielding, disease resistant varieties with good end-use quality. In addition, we coordinate the testing of ~40 public and private released hard spring wheat varieties per year in statewide trials to assess their performance in yield nurseries, end-use quality assessments, and reactions to important diseases. This information is critical to growers to make informed choices among varieties.

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. Delay in receiving DON data, but this did not affect any of our 2020 planting decisions, but could affect the transition from 2020 to 2021 decisions.

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

All members of my project, regardless of what species they work on (wheat, intermediate wheatgrass, or field pennycress) help with inoculation and scoring of our FHB nurseries. This provides them with knowledge of the importance of this disease and our screening methodologies.

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

Wheat cultivar performance, including FHB reaction, of 36 spring wheat cultivars was assessed and reported to growers via print media, web-accessible publications, winter meetings, and field day presentations. We routinely enter five lines in the regional FHB nursery and a variety candidate performance nursery. The data of these nurseries is publicly available and other participants in the nursery have access to cross with this germplasm.

Project 2: *Optimization of Training Population Content and Size for Genomic Selection for FHB*

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

Our goals were to 1. determine if a small set of lines (200 lines) selected by genomic relationship would be as effective as a larger set of lines (300 lines) selected by pedigree information; 2. determine if the addition of parents to the training set improves prediction abilities

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

a) What were the major activities?

The 2019 F_5 cohort comprised of 2,763 lines selected from the F_4 head rows in 2018. Euclidean distances were calculated from the 3,046 SNP markers and used to generate three clusters that represented the groups present in the population. After the clustering process, a principal component analysis was then performed with the markers and the two principal components were used to visualize the cluster partitioning. Since the cluster analysis is based on Euclidean distances, the lines that fall within a cluster were expected to be more genetically like each other compared to lines in a different cluster. A subset of lines proportional to the size of the cluster were selected from each of the three clusters (total of 200 lines) to serve as the training population to predict the performance of other lines within that cluster. Additionally, 300 lines selected by pedigree information and 44 parental lines were included to make a training population of 544 lines. These lines were tested in two misted inoculated FHB nurseries in St Paul and Crookston MN.

For the first objective we conducted a five-fold cross validation with three scenarios
1) within the 200 lines selected by genomic relationship
2) within the 300 lines selected by pedigree relationship
3) within the entire F_5 training population (500 lines)

For the second objective, we carried out a five-fold cross validation in the above scenarios in two cases
1) F_5 without parents
2) F_5 with parents

For the 2020 F_5 cohort, 2,628 lines selected from F_4 head rows advanced to this stage. The same process as above was carried out to select the training set. In total, 500 F_5 lines and 65 parents are being evaluated in two field nurseries.

b) What were the significant results?

For the first objective, prediction ability was highest within 200 lines selected by genomic relationship with values ranging from 0.01 to 0.10 while the accuracies for the other scenarios were not significantly different from zero.

For the second objective, we found that the addition of parents to the training set improved prediction accuracies in all the three cases. However, accuracies remained highest when the 200 lines selected by genomic relationship was used as the training population with values ranging from 0.05 to 0.45.

c) List key outcomes or other achievements.

While our accuracies in 2019 were lower than observed in 2018 (accuracies ranging from 0.17 – 0.60), we still found that the use of a small population optimized by their genetic relationship provided better prediction than a larger set selected by pedigree. We were also able to justify the inclusion of parental lines in the training set as our results suggests that it improves prediction accuracies.

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.

No

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

All members of my project, regardless of the species they work on (wheat, intermediate wheatgrass, or field pennycress) help with inoculation and scoring of our FHB nurseries. This provides them with knowledge of the importance of this disease and our screening methodologies. Specifically, Prabin Bajgain (postdoc) and Emmanuel Adeyemo (graduate student) carried out the phenotypic evaluations, GBS genotyping, and genomic selection work for this project. Other graduate students, postdocs, on our project and others in our Department have also learned about our experiences with genomic selection.

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

We have discussed this research with many colleagues, including those on the cutting edge of genomic selection research. Emmanuel Adeyemo (graduate student) presented a departmental seminar at the University of Minnesota in October 2019, and posters at the 1st International Wheat Congress in Saskatoon, Saskatchewan in July 2019 and at the 2019 USWBI meeting in St Louis, MO. A manuscript was also published in *Agronomy* in April 2020

Project 3: *Introgression to Wheat and Candidate Gene Discovery for Resistance Gene Fhb7*

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

1) Map the FHB resistance on chromosome 7E and develop introgression lines for wheat FHB resistance breeding.
2) Introgress the 7E FHB resistance into the Wheaton and Rollag spring wheat genetic backgrounds, compare expression, and assess synergy with the *Fhb1* gene.

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

a) What were the major activities?
My lab had no activity on this project during the last year. Dvorak's lab has continued to backcross *Fhb7* into UMN cultivars 'Rollag', 'Wheaton', and 'MN-Washburn.'

b) What were the significant results?
The Dvorak lab has reached BC2 generation in backcrossing *Fhb7* to the three cultivars.

c) List key outcomes or other achievements.
I plan to grow out BC3F2 progenies provided by Dr. Dvorak in spring 2021 and field 2021 for FHB evaluation.

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.

No.

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

None in the Anderson lab.

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

No results have been disseminated.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY19 award period (5/13/19 - 5/12/20). 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?**
   No

   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?**
   Yes

   If yes, how many? 2 (1 has taken a USDA-ARS permanent Cat. 1 scientist position)

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**
MN-Torgy	HRS	MR	4	2020

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 (5/13/19 - 5/12/20**) 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.

Journal publications.

Adeyemo, E.; Bajgain, P.; Conley, E.; Sallam, A.H.; Anderson, J.A. Optimizing Training Population Size and Content to Improve Prediction Accuracy of FHB-Related Traits in Wheat. *Agronomy* 2020, 10, 543.
Status: Published
Acknowledgement of Federal Support: YES

ElFatih, A., A. ElDoliefy, A. Kumar, J.A. Anderson, K.D. Glover, S. Mamidi, E.M. Elias, R. Seetan, M.S. Alamri, S.F. Kianian, S. Sapkota, A. Green, and M. Mergoum. 2020. Genetic dissection of Fusarium head blight resistance in spring wheat cv. 'Glenn'. Euphytica 216:71.https://doi.org/10.1007/s10681-020-02610-0.
Status: Published
Acknowledgement of Federal Support: YES

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

Other publications, conference papers and presentations.

Adeyemo, E., P. Bajgain A. Sallam, and J. Anderson. 2019. Optimizing Training Population Size to Improve Prediction Accuracy of Disease Traits in Wheat. Poster presented at: International Wheat Congress; July 2019; Saskatoon, Canada. https://2019iwc.ca/posters-program/
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES (Poster)

Adeyemo, E., P. Bajgain R. Bernardo, and J. Anderson. 2019. Genomic Selection in Wheat; Harnessing Relationships to Reduce Training Population Size. Seminar presented at the Applied Plant Sciences Seminar, University of Minnesota; October 2019; St Paul, MN.
Status: Abstract Published and Presented
Acknowledgement of Federal Support: YES (Presentation)

Adeyemo, E., P. Bajgain R. Bernardo, and J. Anderson. 2019. Harnessing Relationships to Improve Genomic Prediction Accuracy of Fusarium Head Blight Traits in Wheat. 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. 83.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES (Poster)

Hay, W.T, S.P. McCormick, M.P. Hojila-Evangelista, M.J. Bowman, R. O. Dunn, J.M. Teresi, M.A. Berhow, J.A. Anderson, and M.M. Vaughan. 2019. Wheat Cultivars Lose Nutritional Quality at Elevated CO2 Altering *Fusarium graminearum* Growth and Mycotoxin Production. 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. 96.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES (Poster)