USDA-ARS
U.S. Wheat and Barley Scab Initiative
FY18 Performance Report
Due date: July 12, 2019

Cover Page

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Fiscal Year:	2018
USDA-ARS Agreement ID:	59-0206-6-003
USDA-ARS Agreement Title:	Development of Scab Resistant Wheat Varieties for Michigan.
FY18 USDA-ARS Award Amount:	$ 101,000
Recipient Organization:	Michigan State University Contract & Grant Administration Hannah Administration Building, Room 2 East Lansing, MI 48824-1046
DUNS Number:	193247145
EIN:	38-6005984
Recipient Identifying Number or Account Number:	s
Project/Grant Reporting Period:	4/24/18 - 4/23/19
Reporting Period End Date:	04/23/19

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-NWW	Development of Scab Resistant Wheat Varieties for Michigan and the Great Lakes Region.	$ 80,527
VDHR-NWW	Male Sterile Facilitated Recurrent Selection for FHB Resistance.	$ 1,163
VDHR-NWW	Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials.	$ 1,938
VDHR-NWW	Use of Genomic Selection to Improve FHB Resistance and Yield in Northern SWW.	$ 17,372
	FY18 Total ARS Award Amount	$ 101,000

7/12/19

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: *Development of Scab Resistant Wheat Varieties for Michigan and the Great Lakes Region.*

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

The mission of the Michigan State University Wheat Breeding and Genetics program is to develop high-yielding, high-quality soft red and soft white winter wheat varieties with high levels of resistance to FHB. Breeding populations are developed with parents having high yield potential and Fhb resistance. Speed breeding is implemented in the greenhouse to quickly advances early generations. Genomic selection is used to identify inbred lines with high yield potential and resistance to FHB. Novel sources of Fhb resistance are being identified in exotic germplasm to support the development of resistant varieties.

Major project goals:

A. *Develop and apply selection to 500 breeding populations segregating for FHB resistance using a combination of phenotypic and genomic selection strategies.*
B. Evaluate resistance levels of breeding yield trial entries and training population in a misted FHB nursery.
C. Enrich populations for Fhb1
D. Disseminate resistant germplasm.
E. Communicate levels of FHB resistance and susceptibility in Michigan wheat varieties.

2. What was accomplished under these goals?

1) Major Activities

A. Development of breeding populations and early generation selection. Phenotypic selection was applied in 550 F_5 populations. Populations were planted in 35' four row plots at 6" spacing at the Saginaw Valley Research Center. A total of 1,919 single plants were tagged, harvested and planted in headrows. DNA was isolated and normalized from each genotype. Sequence based genotyping was performed to generate ~3,000 SNPs per genotype. For each genotype, genomic-estimated breeding values (GEBVs) were estimated for grain yield and DON mycotoxin. The GEBVs were subsequently used to advance inbred lines to yield testing.

Bulk F_5 and F_4 populations developed in 2016 and 2017 were planted at Mason, MI The 2016 populations were selected phenotypically in the field at the F_2 and advanced to the F_5 in the greenhouse using the minibulk system. The 2017 populations were advanced using the minibulk system and planted in the field at the F_4. A total of 347 populations developed in 2016 and 454 populations developed in 2017 were planted in 35' four row plots at 6" spacing. In total, 800 segregating populations were planted in fall 2018.

The minibulk system was used to advance a total of 442 population from crosses made in fall 2017 and spring 2018. Currently, the populations are F_3 plants. The F_4 populations will be planted at Mason, MI in 35' four row plots at 6" spacing in fall 2018.

A total of 581 crosses were made in fall 2018 and spring 2019 to develop segregating breeding populations. Approximately 500 crosses contain at least one FHB-resistant parent and 160 crosses (32% of all crosses) involve at least one parent with *Fhb1* including 17 topcrosses where each parent carries *Fhb1*. Crosses are being advanced in using the minibulk system and the F_4 seed will be planted in bulk in fall, 2020. Marker assisted selection will be done in derived lines to select inbred lines carrying *Fhb1*.

Heavy natural FHB infection was present at the main breeding nursery at Mason, MI. This allowed for excellent selective pressure in a headrow nursery of 8,000 unique inbred lines. A total of 1500 rows were selected, harvested and processed. A subset of 400 lines were planted in preliminary yield trials at either Richville or Mason, MI.

B. Evaluation of resistance levels of breeding yield trial entries and training population in a misted FHB nursery. In 2018 FHB evaluation, major emphasis on generating high quality data with high replication rather than generate less reliable data on more lines. A total of 413 unique wheat genotypes were evaluated for FHB resistance in a misted and inoculated nursery. Each line was planted in at least three replicates. Nurseries tested included the MSU GS Training Population (TP), MSU Advanced Yield Trial (AYT), Michigan State Commercial Wheat Performance Trial (OVT), P+NUWWN, Uniform White and Uniform Red Nurseries.

The 2018 FHB nursery was highly successful. Infection conditions were ideal and very high levels of disease develop uniformly across the nursery. FHB incidence ranged from 60% to 100% across the nursery. High quality data were collected on incidence, severity, FHB index and 0 to 9 rating. DON sampling was done for all nursery entries across the TP, AYT, OVT and P+NUWWN.

Data from the TP and AYT were used to train GS prediction models to select for FHB resistance. Visual FHB ratings were published in the initial OVT report and DON data were published when received in March, 2019. P+NUWWN data were reported to collaborators.

C. Enrichment of populations for Fhb1. A total of 160 crosses (32% of all crosses) involve at least one parent with *Fhb1* including 17 topcrosses where all three parents carry *Fhb1*. Crosses are being advanced in using the minibulk system and the F_4 seed will be planted in bulk in fall, 2020. Marker assisted selection will be done in derived lines to select inbred lines fixed for *Fhb1*.

D. Dissemination of resistant germplasm. For regional FHB resistance evaluation seven entries were submitted to the Uniform FHB nurseries comprised of FHB resistant

germplasm and lines tested in regional nurseries. Four out of seven lines demonstrated low FHB Index scores and low DON.

E. Communication of FHB resistance in Michigan wheat varieties. Wheat growers and agribusiness were educated on FHB-resistant varieties in presentations at field days and winter meetings. Four talks were given to agribusiness and growers that included messages regarding the benefits of planting resistant varieties, especially the decreased FHB risk from the combination of a moderately resistant variety treated with a fungicide. Educational materials including a list of moderately resistant varieties, how resistance is determined visually and DON levels, and traits to look for in selecting varieties to mitigate the risk of FHB.

2) Specific Objectives

A. Development of breeding populations and early generation selection. Two cycles of crossing were carried out to develop 500 new breeding populations. Two inbreeding generations were carried out in the greenhouse for over 800 breeding populations developed in 2016 and 2017. F_5 seed of the 2016 and F_4 seed of the 2017 populations were planted in fall 2018 for selections in summer 2019.

B. Evaluation of resistance levels of breeding yield trial entries and training population in a misted FHB nursery. A total of 100 advanced breeding lines being tested in replicated trials and a training population of 160 lines were evaluated for FHB resistance in a misted and inoculated nursery. Together, these 260 lines comprise the MSU genomic selection training population. Data were collected on visual severity, incidence and FHB index as well as DON mycotoxin. Cross validation of DON predictions ranged from 0.51 to 0.56. Predictions were made in 2000 inbred lines and GEBVs were used to advance new inbred lines into yield testing.

C. Enrichment of populations for Fhb1. A major focus was placed on *Fhb1* crosses and 160 successful crosses were made with parents carrying *Fhb1*, representing 32% of all crosses.

D. Dissemination of resistant germplasm. FHB resistant germplasm was shared with collaborators through the Uniform Norther FHB nurseries.

E. Communication of FHB resistance in Michigan wheat varieties. At field days and winter workshops, growers were informed of the value of planting moderately resistant varieties to mitigate FHB risk. Growers and agribusiness are reminded 1) FHB resistance does not compromise yield and 2) FHB resistant varieties are available in both soft red and white winter wheat market classes.

3) Significant Results

A. Development of breeding populations *and early generation selection.*

- One soft red winter wheat variety was released. ‘MI14R1140’ is a new soft red winter wheat variety developed by Michigan State University Wheat Breeding and

Genetics. This variety is ideal for production in Michigan with high yield potential and excellent milling and baking quality. MI14R1140 demonstrated higher grain yield than 80% of all soft winter wheat varieties tested across Michigan in 2018 and stable yield potential across the Eastern US. MI4R1140 has a strong foliar disease package with resistance to stripe rust, leaf rust, stem rust and powdery mildew. Flowering date is similar to commercial wheat varieties grown in Michigan. High flour yield will add value to the Michigan milling and baking industry.

- One soft white winter wheat variety was released. 'MI14W1039' is a new soft white winter wheat variety developed by Michigan State University Wheat Breeding and Genetics. This variety is ideal for production in Michigan with high yield potential and excellent milling and baking quality. MI14W1039 demonstrates high grain yield across Michigan and the Great Lakes region. Fusarium head blight resistance in MI14W1039 is an improvement over the majority of soft white winter wheat varieties available to Michigan wheat growers. The very early flowering of MI14W1039 flowers very early providing growers the opportunity to split variety maturities while creating a unique market space for the variety.
- The advanced line MI16R1172 was advanced into regional and commercial yield testing. This line has very high levels of FHB resistance in combination with excellent yield potential.

4) Key Outcomes or Other Achievements

Genomic selection and the minibulk system have trimmed four years from the winter wheat breeding cycle. GS is being implemented each year to apply selection in 2000 inbred lines. A training population of 250 lines is being used to annually update prediction models for grain yield and DON. The minibulk system has been optimized and is being used to rapidly develop inbred lines in the greenhouse. The cost per line from the minibulk system is estimated at $1/100^{th}$ the cost of a doubled haploid at only $0.04. By using speed breeding protocols, inbred lines can be developed within one year of a cross. Together, GS and the minibulk system have reduced the breeding cycle for winter wheat to six years from crossing to identifying commercially viable lines.

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

One graduate student, Jonathan Turkus, gained experience in evaluating FHB in an inoculated and misted nursery. Jon's efforts supported breeding population advancement in the greenhouse, selection in segregating populations, data collection on breeding lines and cooperative nursery entries.

Two undergraduate students, Marcy Stephens and Stephanie Schavey supported advancement of breeding populations, maintenance of the FHB nursery, collected images of each row in the nursery and collected images of grain samples from the nursery.

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

Results from the 2018 project have been communicated to all industry stakeholders. Results were communicated in three talks given to the Michigan Agri-Business Association, Michigan Millers Association, Michigan Crop Improvement Association and wheat field days hosted by The Michigan Wheat Program.

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

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

Recurrent selection is a breeding procedure with the objective of increasing the frequency of desirable alleles for one or more traits while maintaining a high level of variability in the population. The goal for this project is to develop several adapted breeding populations with genes for FHB resistance derived from multiples sources. From segregating populations, inbred lines will be derived that will be evaluated for grain yield. Methods employed will rapidly incorporate FHB resistance into wheat genotypes with adaptation to soft winter wheat growing environments.

2. What was accomplished under these goals?

1) Major Activities. Inbred lines were extracted from segregating populations in summer, 2015, and were planted in 2016 preliminary yield trials. One line, MI15R0416 was tested in the replicated advanced yield trial in five locations across Michigan.

2) Specific Objectives. The primary objective in this goal was to identify Fhb-resistant lines extracted from segregating populations that have superior agronomic performance and high yield.

3) Significant Results. One inbred line derived from segregating populations, MI15R0416 was tested in five locations in two replicates across Michigan. Grain yield at 73.1 bu/ac was below the trial mean of 76.5 bu/ac and will not be moved forward in the breeding program. The line was also evaluated in three replications in the misted and inoculated FHB nursery. FHB severity, incidence and index were well above the nursery means at 58.9%, 38.8% and 22.8%, respectively.

4) Key outcomes or other achievements
Nothing to report

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

Nothing to report

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

Nothing to report

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

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

A. Phenotype advanced breeding lines that are candidates for release
B. Place FHB and other agronomic, disease resistance, and quality data in a database
C. Report on purification and seed increase of the best lines.

2. What was accomplished under these goals?

1) Major Activities

A misted and inoculated Fhb nursery was planted to assess levels of resistance in elite breeding lines and varieties available to growers. Five isolates from across Michigan were used to develop the corn grain spawn. Inoculum was applied at three intervals approximately four, three and two weeks before flowering starting at approximately the Feekes 5 growth stage. Data were collected on flowering date for each row in the nursery. Disease ratings then took place at approximately 21 days after flowering. Ratings were taken over the course of three days on June 18,19 and 20, 2018.

The 2018 FHB nursery was highly successful. Infection conditions were ideal and very high levels of disease develop uniformly across the nursery. FHB incidence ranged from 60% to 100% across the nursery. High quality data were collected on incidence, severity, FHB index and 0 to 9 rating.

A total of 110 entries from the Michigan State Wheat Performance trial were evaluated for FHB incidence, severity and index. Other nurseries evaluated included the MSU GS Training Population (TP), MSU Advanced Yield Trial (AYT), Michigan State Commercial Wheat Performance Trial (OVT), P+NUWWN, Uniform White and Uniform Red Nurseries. Samples were collected for DON analysis and results are being reported in the 2018 wheat performance trial results.

2) Specific Objectives

The objective of this work is to determine the level of Fhb resistance in wheat varieties available to wheat farmers and provide wheat breeders with information on levels of resistance in breeding germplasm.

3) Significant Results

Across all nurseries evaluated in the misted and inoculated FHB nursery, the average severity, incidence and FHB index were 40.9%, 42.2%, and 19.3%. Both soft red and soft white winter wheat varieties with resistance to FHB have been identified.

The Uniform FHB nurseries are a valuable source of resistant germplasm. At least ten new lines from this nursery are used in crosses each year.

4) Key Outcomes or Other Achievements

Data on FHB resistance will assist in management decisions and variety selection by Michigan wheat growers.

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

Nothing to report.

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

Results of this work have been communicated to cooperating breeding programs to help identify resistant lines as sources of resistance for introgression into the crossing program.

FHB resistance in the Michigan State Wheat Performance Trial will are reported in Michigan Farm news and online at https://varietytrials.msu.edu/wheat

Project 4: *Use of Genomic Selection to Improve FHB Resistance and Yield in Northern SWW.*

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

The major goal of this project is to quickly incorporate Fhb resistance into elite soft winter wheat breeding lines. Genomic selection enables prediction of Fhb resistance based on marker genotype. Selection candidates can be genotyped and levels of Fhb resistance estimated based on a genome wide SNP marker profile. Selected lines predicted to have high levels of resistance can be inter-mated to develop new populations with progressively higher levels of resistance. The time frame of a selection cycle using genomic selection is on the order of months compared to years of selection using phenotypic selection alone.

2. What was accomplished under these goals?

1) Major Activities

Approximately 4,000 lines were SNP genotypes for the development of GS prediction models. Between OSU and MSU breeding programs, DNA was isolated, normalized and sequence based genotyping libraries were prepared for 40 96-well plates of samples. Sequencing was done at the MSU Genomics Core. At MSU, SNP marker information was used to train prediction models for grain yield and DON. A total of ~3,000 SNPs per genotype were generated on lines for predictions. Cross validation accuracies for grain yield and DON mycotoxin averaged 0.45 and 0.56, respectively. From 1,919 inbred lines representing 551 populations, a total of 392 individuals were targeted for selection based on low DON, high yield or a combination of both traits. GEBVs were made available for visual selection.

2) Specific Objectives

Genomic selection is being implemented to 1) increase selection accuracy for both grain yield and DON and 2) shorten the breeding cycle by substituting a GEBV for one year of phenotypic data.

3) Significant Results

Very high cross validation accuracies were found for both grain yield and DON mycotoxin. Results are very promising and suggest substantial genetic gain is possible for both traits in the coming years.

4) Key outcomes or other achievements

Workflows to tissue sample, isolate and normalize DNA and prepare sequence based genotyping libraries have been optimized to easily develop GEBVs for grain yield and DON each year on ~2,000 inbred lines.

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

Nothing to report.

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

Nothing to report.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY18 award period. The term "support" below includes any level of benefit to the student, ranging from full stipend plus tuition to the situation where the student's stipend was paid from other funds, but who learned how to rate scab in a misted nursery paid for by the USWBSI, and anything in between.

1. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their MS degree during the FY18 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 FY18 award period?**
   Yes, Linda Brown.

   If yes, how many? One student graduate with a PhD in Plant Breeding and Genetics. Linda is currently working as a plant breeder for Kemin, Des Moines, IA.

3. **Have any post docs who worked for you during the FY18 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 FY18 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 FY18 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**
MI14R1140	SRWW	MR	4	2018
MI14W1039	SWWW	MR	4	2018
Check MI14W0190 (Fhb1)	SWWW	R	1	

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 FY18-FPR_Instructions for detailed instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY18 grant. Only include citations for publications submitted or presentations given during your award period (4/24/18 - 4/23/19). 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 presentation with an abstract:

> Conley, E.J., and J.A. Anderson. 2018. 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.

Nothing to report

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

Pennington D., **E.L. Olson**, J. Turkus, S. Martin. 2018 Michigan State University Wheat Performance Trials.
Status: Published
Acknowledgement of Federal Support: YES (publication)

Other publications, conference papers and presentations.

Olson E.L. June, 2018. *Wheat Breeding Program Update and Wheat Crop Conditions*. Michigan Millers Association Annual Meeting, Michigan Millers Association, Traverse City, MI.
Status: Presented
Acknowledgement of Federal Support: YES (presentation)

Olson E.L. March, 2019. *Wheat Breeding and Genetics at Michigan State University*. Michigan Crop Improvement Association Membership Meeting. Okemos, MI.
Status: Presented
Acknowledgement of Federal Support: YES (presentation)

Olson E.L. March, 2019. *Soft Winter Wheat Varieties for Michigan 2018 and 2019 Releases*. Michigan Wheat Program Annual Winter Meeting. Richville, MI.
Status: Presented
Acknowledgement of Federal Support: YES (presentation)

Olson E.L. January, 2019. *Michigan Wheat Breeding and Genetics Program Update*. Michigan Agri-Business Association Meeting, Lansing, MI.
Status: Presented
Acknowledgement of Federal Support: YES (presentation)