USDA-ARS
U.S. Wheat and Barley Scab Initiative
FY20 Annual Performance Progress Report
Due date: July 29, 2021

Cover Page

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Fiscal Year:	2020
USDA-ARS Agreement ID:	59-0206-0-114
USDA-ARS Agreement Title:	Development of Scab Resistant Wheat Varieties for Michigan and the Great Lakes Region
FY20 USDA-ARS Award Amount:	$ 118,437
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:	RC111134
Project/Grant Reporting Period:	5/2/20 - 5/1/21
Reporting Period End Date:	5/1/2021

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	$ 116,499
VDHR-NWW	Coordinated Phenotypes of Soft Wheat Germplasm for the Midwest	$ 1,938
	FY20 Total ARS Award Amount	**$ 118,437**

Eric L. Olson

August 3, 2021

Principal Investigator Date

* MGMT – FHB Management
FST – Food Safety & Toxicology
R- Research
S – Service (DON Testing Labs)
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 research 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 advance early generations while implementing selection for FHB resistance. 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:

1) *Develop and apply selection to 500 breeding populations segregating for FHB resistance using a combination of phenotypic and genomic selection strategies.*
2) *Evaluate resistance levels of early generation selection candidates and entries in replicated breeding yield trials, regional germplasm and commercial wheat varieties in a misted FHB nursery.*
3) *Enrich populations for the Fhb1 gene using marker assisted selection.*
4) *Disseminate resistant germplasm through regional testing networks.*
5) *Communicate levels of FHB resistance and susceptibility in Michigan wheat varieties and regional breeding germplasm.*

2. What was accomplished under these goals or objectives?

a) What were the major activities?

1) Development of breeding populations and early generation selection.

Using the minibulk system, 441 populations developed in the 2018 crossing cycle were advanced from the F_1 to the F_4 generation over period of 12 months. Populations were planted in 35' four row plots at 6" spacing at the wheat research farm in Mason, MI. A total of ~2,828 single plants were selected based on early maturity and agronomic type. Tissue was collected from flag leaves of selected plants. DNA was isolated, normalized and sequence based genotyping was done to generate ~4,300 SNPs per selected plant. SNPs were used to develop genome-estimated breeding values (GEBVs) for grain yield over three years, 2018, 2019 and 2020 using data from two testing environments, Mason and Richville MI. DON myotoxin levels and pre-harvest sprouting. A total of 680 F_4-derived lines were selected and planted in 10' four row plots at 3" spacing for seed increase and visual selection based on GEBVs, agronomic type, height and resistance to foliar

pathogens. In 2021 the 680 selection candidates were evaluated in the misted and inoculated FHB nursery and FHB resistance was used to inform selections. Approximately 3lb. of seed was harvested from 298 selected lines that will planted in yield trials in two replicates at three locations.

The 680 selection candidates in 10' plots were also genotyped for dwarfing genes, and *Fhb1* at the RSGGL in Raleigh, NC. DNA stocks isolated at MSU were shipped for genotyping in Raleigh. Marker data was used to apply another layer of selection in single replicate observation plots. A total of 93 lines (14% of total) entering replicated yield testing carry *Fhb1*.

Bulk F_4 populations developed in 2018 were planted at Mason, MI in Septemnbter, 2020. A total of 442 F_4 populations were planted in 35' four row plots at 6" spacing with ~280 plants per plot. A total of 1,700 single plant selections were made in May, 2021. Tissue was collected in the field with DNA isolated and normalized for genotyping that will take place in August, 2021.

The minibulk system is being used to advance a total of 487 populations from crosses made in fall 2019 and spring 2020. Currently, the populations are F_3 plants in the greenhouse. The F_4 seed will be planted at Mason, MI in 35' four row plots at 6" spacing in fall 2021 to undergo selection in spring 2022.

A total of 462 unique crosses were made in fall 2020 and spring 2021 to develop segregating breeding populations. All crosses have at least one FHB-resistant parent and 220 crosses involve at least one parent with *Fhb1*. Crosses are being advanced using the minibulk system and the F_4 seed will be planted in the field in bulk plots in fall, 2022. Marker assisted selection will be done in derived lines to select inbred lines carrying *Fhb1*.

2) *Evaluation of resistance levels of breeding yield trial entries and training population in a misted FHB nursery.*
In 2020 FHB evaluation, major emphasis was placed on generating high quality data with high replication rather than generate less reliable data on more lines. Overall, 759 genotypes were evaluated in a misted and inoculated nursery. A total of 259 wheat genotypes in regional and commercial yield trials were evaluated for FHB resistance. 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 as well as the 6-state preliminary and advanced nurseries. A set of 500 breeding program selection candidates were evaluated in two replicates. P+NUWWN data were reported to collaborators.

The 2020 FHB nursery was highly successful despite high temperature stress and dry conditions. Infection conditions were ideal and very high levels of disease developed uniformly across the nursery. FHB incidence ranged from 30% to 100% across the nursery. High quality data were collected on incidence, severity, FHB index and 0 to 9 rating.

DON values were high ranging from 1.0 ppm in the most resistant MSU breeding germplasm to 11.6 ppm in the most susceptible line. DON data was generated for total of 356 breeding lines and 120 commercial wheat variety trial entries.

Data from the breeding trial entries 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 May, 2020.

3) *Enrichment of populations for Fhb1.* A total of 220 crosses involve at least one parent with *Fhb1*.
Marker assisted selection identified 93 genotypes in the single plot observation nursery with *Fhb1*. A total of 41 entries (16%) in first year yield trials carry *Fhb1* and seven of which have been advanced to regional and commercial yield testing.

4) *Dissemination of resistant germplasm.*
For regional FHB resistance evaluation nine entries were submitted to the Uniform FHB nurseries comprised of FHB resistant germplasm and lines tested in regional nurseries.

5) *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.

Table 1. Genomic selection prediction accuracies and standard deviations for grain yield, DON and FHB severity

Trait	Accuracy	SD
3 years, 2 locs	0.32	0.06
2018	0.32	0.32
2019	0.30	0.21
2020	0.38	0.07
Mason	0.38	0.12
SVREC	0.40	0.12
Mason20	0.39	0.09
SVREC20	0.46	0.13
Mason19	0.29	0.15
SVREC19	0.29	0.16
Mason18	0.33	0.17
SVREC18	0.33	0.19
DON	0.67	0.05
FHB Severity	0.54	0.07

b) What were the significant results?

1. Development of breeding populations and early generation selection.

2020 saw the another successful implementation the breeding program structure combining speed breeding and genomic selection. Program staff were able to carry out the challenging logistics of genotyping thousands of plants and making selections in time for planting in the fall. Genotypic data were available for all 700 selection candidates in the field. The project PI had a depth of information on predicted grain yield, visual FHB resistance and DON mycotoxin levels as well as dwarfing genes and *Fhb1* status to guide selections in the field.

2. Evaluation of resistance levels of breeding yield trial entries and training population in a misted FHB nursery.

Disease pressure in 2020 was high giving us excellent visually scored disease data. Program staff are becoming highly skilled at isolating new FHB strains each year and preparing hundreds of pound of grain spawn. Training population data collected in the FHB nursery is of high value and is facilitating genomic selection for FHB resistance.

3. Enrichment of populations for Fhb1

Among selection candidates derived from segregating populations, 85 carry the *Fhb1* gene. These lines will be planted in yield trials at four locations 2020-21. I am grateful to the RSGGL for genotyping these lines and the USWBSI and USDA-ARS for providing them the resources to carry out their mission. Assistant breeder, Amanda Noble, has been successful at enriching breeding populations for *Fhb1* with a third of all new breeding populations carrying the gene.

c) List key outcomes or other achievements.

Two soft red winter wheat varieties were released in 2020.

'MI16R0906' 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. MI16R0906 was the third highest yielding soft winter wheat line tested in 2020 commercial yield trials in Michigan. MI16R0906 demonstrates yield stability across the soft wheat region in Illinois, Ohio and Wisconsin. Flowering date and height are similar to commercial soft red wheat varieties grown in Michigan. MI16R0906 has milling and baking quality that meet the needs of the soft wheat industry.

'MI17R0357' 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. MI17R0357 was highest highest yielding soft winter wheat line tested in 2020 commercial yield trials in Michigan. MI17R0357 demonstrates very high yield potential with specific adaptation to Michigan. Flowering date is earlier than average. Height is shorter than average. MI17R0357 has milling and baking quality that meet the needs of the soft wheat industry.

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.

DON data for 2020 was delayed due to the milling requirement. This delay affected genomic predictions for FHB resistance in new inbred lines. It will also delay the release of two soft red winter wheat varieties that have no data available for DON. It may be possible to substitute a predicted breeding value for DON in these lines.

Program mechanics were still able to operate during the pandemic. The project PI was without child care for long stretches. The excessive stress of childcare and running a

breeding program involving supervision of five full time professionals and seven undergraduates took a toll on personal productivity for the project PI.

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

Two graduate students received training in breeding for FHB resistance, Melissa Winchester and Tommy Reck. Both students have become proficient in growing grain spawn and ascospore cultures. They have carried out germplasm screening in both the field and greenhouse. The work done by Mel will lead to culling of susceptible genotypes during speed breeding of breeding populations. Tommy's work will deliver new large effect resistance QTL from *Aegilops tauschii.*

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

Melissa Winchester presented a poster on her work at the 2020 USWBSI forum. Data from FHB nurseries has been shared with collaborators. Growers and industry are continuously updated on our progress on breeding for FHB resistance.

Project 2: *Coordinated Phenotypes of Soft Wheat Germplasm for the Midwest*

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

   A. Phenotype advanced breeding lines that are candidates for release

   B. Place FHB and other agronomic, disease resistance, and quality data in database

   C. Report on purification and seed increase of the best lines.

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?

   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 four days from June 14 through June 17 , 2020 based on flowering date.

   The 2020 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 115 entries from the Michigan State Wheat Performance trial were evaluated for FHB incidence, severity and index. Other nurseries evaluated included the MSU Early Generation Selection Candidates, 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 will be reported when samples are processed.

   b) What were the significant results?

   - Data from the MSU GS training population enabled high prediction accuracies for visual severity and DON at 0.54 and 0.67, respectively.

c) List key outcomes or other achievements.

- Data from the MSU GS training population was used to predict DON and visual FHB traits among ~2,400 inbred lines. GEBVs were used to select 700 soft red and white winter wheats for planning in observation and increase plots.
- Data from the MSU nursery was used to inform breeding decisions in collaborator's germplasm
- Accurate data was provided for advancing MSU breeding lines based on FHB resistance.

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.

Nothing to report

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

Nothing to report

5. 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 FY20 award period (5/2/20 - 5/1/21). 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.

1. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their MS degree during the FY20 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 FY20 award period?**
   ☐Yes ☒No
   If yes, how many? Click to enter number here.

3. **Have any post docs who worked for you during the FY20 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 FY20 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 FY20 award period (5/2/20 - 5/1/21). 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
MI17R0357	SRW - Soft Red Winter	MR - Moderately Resistant	27.4ppm DON	2020
MI16R0906	SRW - Soft Red Winter	MS - Moderately Susceptible	33.6 ppm DON	2020
MI14W0190 – Fhb1 moderately resistant check	SWW - Soft White Winter	MR - Moderately Resistant	28.3 ppm DON	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	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 PR_Instructions for detailed more instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY20 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period (5/2/20 - 5/1/21**) 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.

Strauss N. M., A.T. Wiersma, P. DeMacon, E. Klarquis, A Carter., K.A Garland Campbell., **E.L. Olson**. 2020. Registration of the Wheat D-Genome Nested Association Mapping Population. Journal of Plant Registrations. DOI: 10.1002/plr2.20078
Status: Published
Acknowledgement of Federal Support: Yes

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

Ng P. K. W., **E.L. Olson**. 2020. MSU wheat quality testing of advanced lines: Report on milling and baking test results for selected Michigan-grown soft wheats harvested in 2020.
Status: Published
Acknowledgement of Federal Support: Yes

Pennington D., **E. L. Olson**, S. Martin. A. Noble 2020. 2020 Michigan State University Wheat Performance Trials.
Status: Published
Acknowledgement of Federal Support: Yes

Other publications, conference papers and presentations.

Winchester, Melissa, Olson, E., Nobel, A., and Reck, T. 2020. "Selective Breeding under Rapid Generation Advancement to Increase Resistance in Winter Wheat to Fusarium Head Blight in Michigan." In: S. Canty, A. Hoffstetter, and R. Dill-Macky (Eds.), *Proceedings of the 2020 National Fusarium Head Blight Forum* (p. 106.), 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)