USDA-ARS | U.S. Wheat and Barley Scab Initiative

FY21 FINAL Performance Progress Report

Due date: July 26, 2022

Cover Page

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
Principle Investigator (PI):	Eric Olson
Institution:	Michigan State University
Institution UEI:	R28EKN92ZTZ9
Fiscal Year:	2021
FY21 USDA-ARS Award Amount:	$90,345
Recipient Organization:	Michigan State University Department of Plant, Soil and Microbial Sciences 1066 Bouge St., RM 382 PSSB, East Lansing, MI 48824
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Period of Performance:	5/2/21 - 5/1/23
Reporting Period End Date:	5/1/2022

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	$88,407
VDHR-NWW	Coordinated Phenotypes of Soft Wheat Germplasm for the Midwest	$1,938
	FY21 Total ARS Award Amount	$90,345

I am submitting this report as an: ☒Final Report

I certify to the best of my knowledge and belief that this report is correct and complete for performance of activities for the purposes set forth in the award documents.

Eric L. Olson — 7/26/2023

Principal Investigator Signature | Date Report Submitted

‡ BAR-CP – Barley Coordinated Project
DUR-CP – Durum Coordinated Project
EC-HQ – Executive Committee-Headquarters
FST-R – Food Safety & Toxicology (Research)
FST-S – Food Safety & Toxicology (Service)
GDER – Gene Discovery & Engineering Resistance
HWW-CP – Hard Winter Wheat Coordinated Project
MGMT – FHB Management
MGMT-IM – FHB Management – Integrated Management Coordinated Project
PBG – Pathogen Biology & Genetics
TSCI – Transformational Science
VDHR – Variety Development & Uniform Nurseries
NWW –Northern Soft Winter Wheat Region
SPR – Spring Wheat Region
SWW – Southern Soft Red Winter Wheat Region

Project 1: Development of Scab Resistant Wheat Varieties for Michigan and the Great Lakes Region

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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.

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? *(For each major goal/objective, address these three items below.)*

a) What were the major activities?

1. Development of breeding populations and early generation selection.

MSU22 crossing cycle. A total of 583 unique crosses were made in fall 2021 and spring 2022 to develop segregating breeding populations. All crosses have at least one FHB-resistant parent and 216 crosses involve at least one parent with *Fhb1*. Leaf rust susceptible individuals have been culled from the F_2 and subsequently the F_3 as populations are advanced in the greenhouse using the minibulk system. The F_4 seed will be planted in the field in bulk plots in fall, 2023. Marker assisted selection will be used to select $F_{4:5}$ lines carrying *Fhb1*.

MSU21 generation advance. The minibulk system is being used to advance a total of 487 populations from crosses made in fall 2020 and spring 2021. Leaf rust susceptible individuals have been culled during inbreeding. Populations of 300 F_4 individuals will be space-planted at 8” in 50’ plots at Mason, MI in fall 2022 to undergo selection in spring 2022.

MSU20 F_4 line derivation. In September, 2021, 560 bulk F_4 populations from the 2020 crossing cycle were planted at Mason, MI. Each population was comprised of 300 F_4 individuals space-planted at 8” in 50’ plots. A set of 3,000 single plant selections were made in May, 2022. Tissue was collected in the field with DNA isolated and normalized for genotyping that will take place in August, 2022.

MSU19 advance to replicated yield testing. A set of 500 $F_{4:5}$ lines derived from MSU19 populations were evaluated in an observation nursery in 2022. Plots were six rows and five feet wide by five feet long. F_4 lines were selected in 2020 based on GEBVs for grain yield, DON mycotoxin levels and resistance to pre-harvest sprouting. Lines at this stage are evaluated in two replications in the misted and inoculated FHB nursery and in the greenhouse for leaf rust resistance. Approximately 3lb. of seed was harvested from 311 selected lines.

This number will be reduced to 250 using 2022 GEBVs and disease resistance data. Selected lines will be planted in yield trials in two replicates at three locations. For three years this nursery has been planted using family structure. In 2022-23, this nursery will be randomized and planted using an augmented design in order to select on grain yield.

The 500 $F_{4:5}$ lines were genotyped for *Rht* dwarfing genes, and *Fhb1* at the RSGGL in Raleigh, NC. DNA was isolated and normalized at MSU, then shipped for genotyping in Raleigh. Marker data was used for selection in single replicate observation plots. Among $F_{4:5}$ lines, 17% carry *Fhb1*. Perfect correspondence was found between heterozygous Rht marker genotypes and segregation for height within lines enabling high confidence culling.

Replicated Yield Testing. A set of 250 lines from the 2018 crossing program were evaluated in two replicates in three locations. A set of 35 lines from the 2017 crossing program were evaluated at 17 locations across IL, IN, KY, MO, OH and MI. A set of five soft white wheat lines were evaluated in the Michigan commercial yield trial.

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

In 2021, 1,263 unique wheat genotypes were evaluated in replication in a misted and inoculated nursery. All regional and cooperative and commercial yield trials were evaluated for FHB resistance. Lines were evaluated in two to three replicates. Nurseries tested included the F4 observation nursery (2 reps), Year 1-3 yield trials, MSU Preliminary Yield Trial, 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. Nurseries exchanged with regional breeding programs were also included in the FHB nursery.

The 2021 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 1 to 5 scale.

The 2020 DON values were high ranging from 4.1 ppm in the most resistant MSU breeding germplasm to 61.9 ppm in the most susceptible line. DON data was generated for a total of 1,043 unique genotypes across all trials.

Data from the breeding trial entries were used to train GS prediction models to select for FHB resistance. Correlation between genomic predictions and actual DON values in 2021

was 0.65. Visual FHB ratings were published in the initial OVT report and DON data were published when received in June, 2022.

Enrichment of populations for Fhb1. In the 2022 crossing cycle, 216 crosses involve at least one parent with *Fhb1*. The *Fhb1* crossing strategies implemented have maintained the gene at high frequency across all generations of the program. Marker assisted selection identified 84 $F_{4:5}$ lines in the single plot observation nursery with *Fhb1*, a frequency of 0.17. In Y1 and Y2 trials, the *Fhb1* gene is present at a frequency of 0.15 and 0.20.

1. ***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.

2. ***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.

b) What were the significant results?

1. Development of breeding populations and early generation selection

2021 saw the another successful implementation the breeding program structure combining speed breeding and genomic selection. Program staff carried out the challenging logistics of genotyping thousands of plants and making selections in time for planting in the fall. The project PI had four years of 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 2022 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. Genomic model training data collected in the FHB nursery is of high value and has facilitated genomic selection for FHB resistance. A large SNP marker and DON data set was generated that will be made publicly available on T3 and other platforms that can be accessed by the USWBSI community.

3. Enrichment of populations for Fhb1

Among selection candidates derived from segregating populations, 84 carry the Fhb1 gene. These lines will be planted in yield trials at three locations 2022-23. 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 at nearly 20% across all generations in the program.

c) List key outcomes or other achievements.

The combination of accelerated generation advance with genomic selection prior to yield testing has shortened the timeline for variety release to seven years. In 2022, lines derived from the 2017 crossing program were tested across the northern soft wheat region. Over a five year timeframe, two years were spent in the greenhouse, one year as an observation plot and two years in replicated yield testing. Variety release is anticipated one to two years from now pending sustained performance. After two years of testing stage, several lines have demonstrated yield stability across years and a wide geography.

With the resources provided through the USWBSI, we have an opportunities to evaluate new strategies to collection visual FHB data. In 2022, FHB symptoms were assessed in the field and greenhouse with thermal and hyperspectral imaging in order to automate the rating process and improve the accuracy of disease ratings. Data have been collected and image analysis approaches are currently being optimized.

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

Assistant breeder, Amanda Noble continues to excel at management of staff and breeding nurseries. Amelia Orr, a post baccalaureate researcher gained technical proficiency in rating FHB and processing FHB samples. Amelia has refined her skill at producing FHB conidia in the lab and conducted numerous inoculations in the greenhouse. Samantha Mitchell was an undergraduate researcher working with the group who has now transferred into a graduate student role in the program focused on FHB resistance. One PhD student, Jhon Concepcion, has been trained to work with the FHB system in the greenhouse and field. Jhon has led the development of image analysis tools to rate FHB in the greenhouse and field using thermal and hyperspectral imaging. The entire team of MSU wheat FHB researchers took part in preparing the corn inoculum used in the 2022 nursery.

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

Data from FHB nurseries has been shared with collaborators. Growers and industry are continuously updated on our progress on breeding for FHB resistance at field days and industry events. Results of 2022 work will be shared at the USWBSI annual forum.

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

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

1) Phenotype advanced breeding lines that are candidates for release
2) place FHB and other agronomic, disease resistance, and quality data in a database
3) 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 20 through June 22, 2022 based on flowering date.

The 2022 FHB nursery was highly successful. Infection conditions were ideal and very high levels of disease develop uniformly across the nursery. FHB incidence ranged from 30% to 100% across the nursery. High quality data were collected on incidence, severity and FHB index.

A total of 126 entries from the Michigan State Wheat Performance trial were evaluated for FHB incidence, severity and index. Other nurseries evaluated included the 500 MSU Early Generation Selection Candidates, MSU Preliminary and Advanced Yield Trial, Michigan State Commercial Wheat Performance Trial (OVT), P+NUWWN, Uniform White and Uniform Red Nurseries.

b) What were the significant results?

High levels of FHB resistance was identified among entries evaluated in the 2022 Coordinated FHB Phenotyping.

c) List key outcomes or other achievements.

Data was reported to collaborators to facilitate selections and build data sets supporting variety release.

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

Assistant breeder, Amanda Noble continues to excel at management of staff and breeding nurseries. Amelia Orr, a post baccalaureate researcher gained technical proficiency in rating FHB and processing FHB samples. Amelia has refined her skill at producing FHB conidia in the lab and conducted numerous inoculations in the greenhouse. Samantha Mitchell was an undergraduate researcher working with the group who has now transferred into a graduate student role in the program focused on FHB resistance. One PhD student, Jhon Concepcion, has been trained to work with the FHB system in the greenhouse and field. Jhon has led the development of image analysis tools to rate FHB in the greenhouse and field using thermal and hyperspectral imaging. The entire team of MSU wheat FHB researchers took part in preparing the corn inoculum used in the 2022 nursery.

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

Data from the 2022 FHB nursery has been provided to collaborators.

Publications, Conference Papers, and Presentations

Please include a listing of all your publications/presentations about your FHB work that were a result of funding from your FY21 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period** should be included.

Did you publish/submit or present anything during this award period?

☒ Yes, I've included the citation reference in listing(s) below.

☐ No, I have nothing to report.

Journal publications as a result of FY21 grant award

List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Include any peer-reviewed publication in the periodically published proceedings of a scientific society, a conference, or the like.

Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published [include DOI#]; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

Books or other non-periodical, one-time publications as a result of FY21 grant award

Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like.

Identify for each one-time publication: Author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (book, thesis or dissertation, other); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

1. Pennington D., **E. L. Olson**, S. Martin, A. Noble, A. Orr. 2021. 2021 Michigan State University Wheat Performance Trials. Report. https://varietytrials.msu.edu/wheat/
   acknowledgement of federal support: Yes

Other publications, conference papers and presentations as a result of FY21 grant award

Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication.