Project FY22-NW-006: Development of FHB 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 advance inbred lines with high yield potential and resistance to FHB into replicated yield testing.

Major project goals:

1. *Develop and apply selection to 600 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.)*

What were the major activities?

1. Development of breeding populations and early generation selection.

MSU24 crossing cycle. A total of 436 unique crosses were made in fall 2023 and spring 2024 to develop segregating breeding populations. All crosses included at least one FHB-resistant parent and 262 included *Fhb1* from at least one parent and 69 populations included *Fhb1* from more than one parent. Leaf rust susceptible individuals were culled from the F_2 and F_3 generations 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, 2024. Marker assisted selection will be used to identify $F_{4:5}$ lines carrying *Fhb1*.

MSU23 generation advance. The minibulk system is being used to advance a total of 433 populations from crosses made in fall 2022 and spring 2023. Leaf rust susceptible individuals have been culled during inbreeding. Populations of 300 F_4 individuals will be space-planted at 8" spacing in 50' x 6 row plots at Mason, MI in fall 2023 to undergo selection in spring 2024.

MSU22 F_4 line derivation. In September, 2023, 449 bulk F_4 populations from the 2022 crossing cycle were planted at Mason, MI. Each population was comprised of 300 F_4 individuals space-planted at 8" spacing in 50' x 6 row plots. A set of 2,280 single plant

selections were made in the first week of June, 2024. Tissue was collected in the field with DNA isolated and normalized for genotyping that will take place in July, 2023. GEBVs for FHB severity, DON and grain yield from 12 year x locations will be used to advance 500 lines into the 2025 observation nursery and FHB screening.

MSU21 advance to replicated yield testing. A set of 2,300 $F_{4:5}$ lines derived from MSU21 populations were evaluated in a single plot observation nursery in 2023. Plots were two rows spaced at 7.5" and 10' in length. F_4-derived lines were selected as single plants in 2023. GEBVs could not be developed due to changes in sample processing for sequencing at the MSU genomics core. New lab protocols for sequencing library quantification had to be established and new lab equipment was purchased to accommodate the changes. Sequencing did not take place until May, 2024. Approximately 3lb. of seed was harvested from 351 selected lines advanced based on canopy leaf retention in response to disease at Mason as well as GEBVs for DON and grain yield. Selected lines will be planted in yield trials in two replicates at two locations in 2025.

Replicated Yield Testing. A set of 250 lines derived from the 2020 crossing program were evaluated in two replicates at three locations in MI. A set of 44 experimental lines and 4 checks were evaluated at 28 locations across IL, IN, KY, MO, OH, MI and Canada.

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

In 2023, 719 unique wheat genotypes were evaluated in replication in a misted and inoculated nursery. This number is 500 fewer than 2022 because 2023 sequencing and genotyping could not be completed to advance lines to the 2024 observation nursery. Rather, all 2,300 lines were planted in a single plot at a single location. All regional, cooperative and commercial yield trials were evaluated for FHB resistance in sthree replicates. Nurseries tested included the F4 observation nursery (2 reps), Year 1-3 yield trials, MSU Preliminary Yield Trial, MSU Advanced Yield Trial, Michigan State Commercial Wheat Performance Trial (OVT), P+NUWWN and Eastern Uniform Soft Red Winter Wheat Nurseries. Nurseries exchanged with regional breeding programs were also included in the FHB nursery.

Two research projects took place in the 2023 FHB nursery. The samples were imaged using a hyperspectral camera as part of a phenomics project to predict DON levels in intact (unground) grain samples. A second project was aimed at predicting visual FHB symptoms using thermal imaging.

The 2023 FHB nursery was hindered by high temperature stress and dry conditions, particularly at flowering. Data were collected on incidence, severity, FHB index. A total of 1,200 DON samples were collected and processed. Reps were bulked to minimize the number of samples for analysis.

The 2023 DON values were high ranging from 0.01 ppm to 26.9 ppm in the most susceptible line and an average of 6.6 ppm. DON data was generated for a total of 1,137 unique genotypes across all trials. Data was shared with collaborators and used in research projects.

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.

3. Enrichment of populations for Fhb1.
Among 2023 crosses, 262 included *Fhb1* from at least one parent and 69 populations included *Fhb1* from more than one parent. Genotyping of advanced lines in the Big6 cooperative nursery confirmed the presence or absence of *Fhb1*.

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. Five 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 were distributed 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.

What were the significant results?

The 2023 genomic selection step in the program could not be completed on time due to changes in how sequencing libraries are handled at the MSU genomics core. New equipment and new protocols were needed to complete genotyping finally in May, 2024. The FY2024 funding cuts have further hindered the use of GS at MSU. Five years of predicted grain yield, visual FHB resistance and DON mycotoxin levels were used to guide selections in the field.

Program staff have become 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.

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 eight years. The MSU wheat breeding program has successfully integrated speed breeding and genomic selection into the wheat variety development process. Continued use of these breeding strategies will accelerate the increase in FHB resistance in wheat varieties available to farmers across the Great Lakes region.

With the resources provided through the USWBSI, we have the opportunity to evaluate new strategies to collection visual FHB data. In 2023, 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.

Research led by graduate student, Jonathan Concepcion has led to high accuracy prediction of DON concentration in Fusarium infected grain using hyperspectral imaging. Predictions are made on whole kernels and require no milling. Results from this work have the potential to be transformative for FHB phenotyping. A single gene was identified to control reflectance levels across the entire hyperspectral phenome of DON infected kernels.

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 technical staff member has gained technical proficiency in rating FHB and leads the generation of corn grain spawn inoculum that we rely on for success in establishing disease in the field. Amelia has also inoculated and rated thousands of individual heads in the greenhouse.

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 2023 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 2023 and ongoing work are shared at the USWBSI annual National FHB Forum.

5. What do you plan to do during the next reporting period to accomplish the goals and objectives?

All crossing, FHB phenotyping, yield testing activities and collaborations will continue through the next reporting period.