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

FY22 Performance Progress Report

Due date: July 26, 2023

Cover Page

USDA-ARS Agreement ID:	59-0206-2-112
USDA-ARS Agreement Title:	Fusarium Head Blight (FHB) Resistant Wheat Cultivars for the Gulf Coast Region
Principle Investigator (PI):	Stephen Harrison / Noah DeWitt
Institution:	Louisiana State University Agricultural Center
Institution UEI:	UF3LV6W2W6K9
Fiscal Year:	2022
FY22 USDA-ARS Award Amount:	$98,201
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Period of Performance:	May 1, 2022 – April 30, 2026
Reporting Period End Date:	April 30, 2023

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-SWW	Development of FHB Resistant Wheat Cultivars Adapted to the Gulf Coast region.	$79,938
VDHR-SWW	A Double Haploid Initiative to Speed Development of FHB Resistant Soft Winter Wheat.	$18,263
	FY22 Total ARS Award Amount	$98,201

I am submitting this report as an: ☒ Annual 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.

Stephen A Harrison

7/24/202 .

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 FHB Resistant Wheat Cultivars Adapted to the Southeast region.

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

Fusarium head blight (FHB) is a major disease of wheat in the Southeast United States. Unlike stripe rust or powdery mildew, for which varietal resistance can be selected for with low-replication visual evaluations and information on major resistance genes, developing FHB resistant varieties requires substantial resources. The LSU Wheat Breeding program dedicates more resources towards breeding for fusarium resistance than for any trait outside of yield. As part of our cooperation with in-state extension agents and pathologists, and across states through SunGrains and regional nurseries, the LSU Wheat Breeding program delivers information about FHB resistance that supports wheat breeding and cultivation efforts in the broader Southern soft red winter wheat region. This proposal addresses all three VDHR research priorities and has the overall goal of encouraging growers to plant high-yielding, FHB resistant varieties that lead to reduced DON content in the grain trade. The objectives are as follows:

Objective 1 – Screen available varieties and breeding lines to document the number of released varieties from public and private programs with improved FHB resistance.

Objective 2 – Increase efficiency of coordinated research activities to develop and release FHB resistant varieties.

Objective 3 – Implement modern breeding technologies to enhance the rate of genetic gain for FHB resistance.

Noah DeWitt has joined the LSU wheat breeding program as an assistant professor in wheat breeding and quantitative genetics, and has participated in all aspects of the project.

2. What was accomplished under these goals or objectives?

GOAL 1 – – Document FHB resistance in varieties and breeding lines

a) What were the major activities?

In cooperation with regional nursery coordinators and state-level cooperators, a set of wheat nurseries were organized for the 2022-2023 field season representing public and private varieties tested in the Louisiana state variety trial, and SunGrains and commercial breeding lines from programs across the Southern United States. This core nursery was planted in three inoculated, misted nurseries at LSU AgCenter research stations in Baton Rouge, Alexandria (in partnership with collaborator Boyd Padgett), and Winnsboro (in partnership with collaborator Paul P. “Trey” Price). An additional set consisting primarily of LSU breeding lines and populations was planted at the Baton Rouge and Winnsboro locations. Nurseries consisted of replicated, paired headrows, totaling approximately 4,000 total rows across all three locations. Lines were rated for heading date and for FHB severity on a 0-9 ordinal scale. Whole paired headrows were hand harvested from all three locations, threshed at a slow wind speed, and sieved to remove chaff. Sub-sampled grain from all headrows was rated for percent Fusarium Damaged Kernels (FDK). Approximately 2,000 whole samples were milled and shipped to Yanhong Dong at the USDA DON Lab in St. Paul in early July for deoxynivalenol (DON) screening. Entry means for FHB severity, FDK, and DON will be included in the annual Wheat Research Summary of variety trial performance results published each year.

b) What were the significant results?

Despite a late spring freeze presenting some difficulties for visual rating of FHB and FDK, inoculation produced substantial FHB pressure in the misted nurseries, and excellent data on FHB reaction was collected for the statewide variety trials and all regional nurseries at all three locations. Seed from all misted nurseries was rated for FDK and submitted for DON determination. The data on FHB, FDK, and DON will be included in the annual Wheat Research Summary published for growers, consultants, and seedsmen. FDK and DON of varieties in the misted nurseries from statewide variety trials ranged from 2.2 ppm to 23.7 ppm and 5% to 58% in 2022, and FDK ranged from 11% to 56% in 2023 in the state variety trial averaged over two north Louisiana misted nurseries. All three misted nurseries were effective in identifying resistance to FHB, FDK and DON accumulation. The annual Wheat Research Summary (variety trials data) published in August includes FHB severity, FDK incidence and DON concentration on all variety trial entries. An FHB Index value is calculated as a weighted function of FHB, FDK and DON. The data is included in tables for each location along with a summary table of FHB reaction type and FHB index across environments. The FHB index is used to classify varieties and develop the list of resistant and moderately resistant varieties published on the USWBSI website. FHB data from two nurseries was included in USDA regional and SunGrains nursery reports to assist collaborating breeders in developing FHB resistant varieties.

c) List key outcomes or other achievements.

This work remains important for informing growers, seedsman, and breeders on the FHB resistance of varieties and breeding program lines. Excellent data was collected from misted nurseries at three locations this year. Results from breeding line screening for FHB severity, FDK, and DON will inform decision on line advancement and parental selection in the LSU and cooperating wheat breeding programs. Results will be posted publicly for variety trial and regional nursery entries. The variety trial publication highlights FHB data and classifies lines into FHB resistance categories to encourage growers to plant resistant varieties.

GOAL 2 – Participate in coordinated regional efforts to improve FHB resistance and release FHB resistant varieties

a) What were the major activities?

Over 400 new wheat crosses were made in 2023 with >90% having FHB resistant parents. Information on markers for major FHB QTL *Fhb1* and *Fhb1B Jamestown* was used to help select parents and crossing targets. Seed from these populations will be shared with regional collaborators through the SunGrains cooperative. In an effort to select for FHB resistance within-family, F_2 segregating populations were planted in inoculated, misted nurseries. Single heads were selected based on FHB severity and will be advanced as F_3 bulks.

Participation continued in the regional Uniform Southern Scab nursery effort, which was evaluated at three misted nursery locations for FHB severity, FDK, and DON. Phenotypes from these trials feed into training populations used to generate shared genomic predictions for FHB resistance. Predictions for FHB resistance and imputed major FHB QTL generated by this regional effort were used to guide decisions on advancement of lines from the first-year observation nursery to multi-location testing.

b) What were the significant results?

The overall level of resistance in both the LSU wheat breeding program and regional cooperators' programs has been improved through multi-year efforts to use FHB predictions and QTL information to guide crossing decisions and early-generation line advancement. The presence of LSU genotypes in these regional nurseries and data collected at the three Louisiana misted nursery locations is an important component of these prediction efforts. Results from the nurseries directly guide decisions on advancement of lines from coordinated regional trials to later trials and on variety release. Through the SunGrains "Sunshow" demonstration plot effort, information on FHB QTL was used to influence seedsmen decision regarding line release and to help communicate information on varietal resistance to growers.

c) List key outcomes or other achievements.

LA16020-LDH22, a double haploid, was released in August 2021 as AGS 3022, only six years after the initial cross. Crossing and line advancement decisions that resulted in this variety were guided by predictions and regional trailing. It has excellent yield, disease reaction, and FHB resistance and has been adopted for production by growers. It had the highest yield, 0% stripe rust, and the lowest FDK and DON (misted nursery) ratings of ten entries in the early-maturing variety trial across north Louisiana. Further FHB resistant breeding lines were increased by Georgia Seed Development Commission as variety release candidates. Six crosses containing a desirable pyramid of effective FHB QTL in a high-yielding background have been submitted to develop DHs. The three entries in the southern regional scab nursery with the lowest DON concentration were LSU breeding lines.

GOAL 3 – Test and implement modern breeding strategies to increase the rate of genetic gain for FHB resistance

a) What were the major activities?

Activities for this goal focused on reducing generation time from cross to cross and improving prediction accuracy for FHB resistance traits. In 2022 and 2023, a SunGrains F1 nursery was grown in Ft. Collins, CO to save a year in the breeding cycle. The LSU Wheat breeding program is investigating the use of a custom-built growth chamber to pursue rapid generation advancement (RGA) in the F_1 and F_2 generations. Seed of selected DHs from each VDHR-SWW program were shared with all other cooperators for selection and variety development to obtain maximum benefit from the expenditure of resources.

Genomic predictions were used to select bulk families, advance breeding lines, make crosses, and allocate DH resources. Phenotypic data, marker assisted selection, imputed QTL presence, and POPVAR were used to select parents that combine multiple QTL and have a good probability of producing elite populations and varieties. Discussions on using genomic predictions of FHB resistance to select lines for crossing from genotyped lines entered into first-year observation nurseries have suggested that this may be limited by the ability of current training populations to predict within-family. Graduate student Julio Sellani has initiated work to test the relative efficacy of genomic predictions for FHB resistance traits for within versus between family selection and guide training population design. This work was initiated this year by entry of the approximately 600 line observation nursery into misted nursery, followed by phenotyping for FHB severity, FDK, and DON.

b) What were the significant results?

Genomic selection protocols included imputation of major QTL for FHB resistance and calculation of genomic-estimated breeding values (GEBVs) for yield, FHB resistance (FHB severity, FDK, and DON), and other important traits. The ability to accurately determine presence of major FHB QTL from GBS markers significantly increases the utility of genomic selection and reduces the resource limitations constraining running markers on large numbers of breeding lines. Crosses with parents containing multiple FHB QTL and high predictions for FHB resistance traits and yield were submitted for development of DH lines. Genomic selection predictions, marker data, and regional yield trial data were used to place promising lines from first year regional testing into the crossing block, reducing breeding cycle generation time. Predictions of FHB resistance traits were heavily weighted in advancement decisions of lines from first year observation plots into replicated yield trials; genomic selection models, marker QTL information and field data were used to advance ~85 breeding lines to replicated yield testing each year. F_1 seed from 2022 crosses grown in Colorado were evaluated as F_2 bulks in 2023, eliminating a year from the breeding program cycle.

c) List key outcomes or other achievements.

The SunGrains nurseries decrease the breeding cycle by providing extensive phenotypic data, genomic predictions, and imputed QTL presence used to make informed release decisions and to rapidly recycle genotypes back as parents. Most crosses made in 2023 were made between parents with characterized FHB QTL and with FHB resistance as a major priority. Approximately 5000 yield plots were evaluated over three locations. Advancement of lines was based on field phenotypes, GEBVs, and imputed presence of important FHB QTL. The SunGrains multi-state genomic selection program evaluated about 4,000 lines and entries in five regional nurseries.

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

Three graduate students were trained in setting up mist systems, inoculating nurseries, and rating field symptoms for FHB. Graduate student Julio Sellani was trained in post-harvested processing of FHB samples and visual ratings of FDK. Graduate student Julio Sellani received additional training in data analysis, including instruction on trial analysis, genome-wide association studies, and generating genomic predictions.

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

An in-person field day held in April of 2021 and 2022 at the Macon Ridge Research Station that highlighted variety resistance, FHB screening, the breeding program, and fungicide control of FHB. The September 2020 issue of Louisiana Crops featured a grower-oriented article on FHB resistance breeding and fungicide management. The Research Summary detailing results of the statewide variety trials highlighted varietal resistance and classified varieties according to FHB reaction. https://www.lsuagcenter.com/~/media/system/8/c/9/9/8c9920cfdc7db214a60be8e169fa61d7/volume%2010%20issue%208%20september%202020%20updatepdf.pdf. Results of the statewide wheat performance trial are published each year and include FHB, FDK and DON data from the current season.

Project 2: A Double Haploid Initiative to Speed Development of FHB Resistant Soft Winter Wheat.

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

   Double haploids (DHs) funded through this project have facilitated increases in frequency of major FHB resistance QTL and improvements in overall FHB resistance in Southeast US soft red winter wheat germplasm. DHs greatly reduce breeding program cycle time, and in concert with genotyping, allow for rapid targeting and development of populations out of which FHB resistant breeding lines and varieties have been developed. The objective of this project is to utilize DH technology to decrease the breeding cycle and release FHB resistant varieties more quickly and efficiently, while sharing selected DHs with all VDHR-SWW breeders to increase efficiency of the coordinated project breeding programs. This will ensure DH lines undergo robust, multilocation evaluation and provide appropriate information needed to justify release and licensing to companies for marketing to growers.

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

   Objective 1:

   a) **What were the major activities?**

   DHs evaluated each cycle are a combination of lines derived from LSU crosses and DHs shared by other VDHR-SWW programs. DHs selected from this group are advanced from the headrow stage to a two-location observation nursery and then subsequent multi-location yield trials using the predictions generated by project 1. DHs selected and harvested in spring 2022 as first year headrows were shared with other VDHR-SWW breeders to allow them the opportunity for selection and advancement.

   The end of the North Carolina State University double haploid program and price increases from Heartland Plant Innovations (Manhattan, KS) has reduced the number of new DH lines annually. The LSU wheat breeding program and other VDHR-SWW programs have begun working with lab members at the USDA-ARS Eastern Regional Small Grains Genotyping lab in Raleigh, NC, as they develop a new protocol for DH development in anticipation of a federally funded DH lab in Raleigh. The expectation is that annual DH line production will increase following the hiring of an SY-level position and the construction of a new USDA building in Raleigh in the next couple of years.

   Six crosses were submitted for DH production in 2022, and five in 2023. Two of the 2023 crosses were submitted to the ERSGGL in Raleigh for protocol testing, and three will be submitted to HPI. Most crosses have Fhb1 parents on one or both sides of the pedigree, include four recently released and highly productive Fhb resistant varieties, and combine multiple other Fhb QTL with QTL for Hessian Fly resistance, soil borne mosaic virus resistance, stripe rust resistance, leaf rust resistance and other genes important to the success of varieties in the southeastern US.

Selected DHs from each VDHR-SWW institution were shared with all other cooperators for selection and variety development to obtain maximum benefit from the expenditure of resources. In 2023, 58 DH headrows were harvested from crosses submitted in 2021, and previously generated DHs were evaluated at every stage of testing from headrows to regional yield trials.

b) What were the significant results?

The DH line LA16020-LDH22 was released as variety AGS 3022 in 2021, only six years after the initial cross. It has excellent yield and very good FHB resistance; AGS 3022 ranked second for yield across south Louisiana in 2022 and had below average FDK and DON. AGS 3022 had 7.4 ppm DON in the Winnsboro misted nursery compared to 35.7 ppm for the FHB susceptible variety, AGS 2055. New DHs evaluated each year are shared across participating VDHR-SWW program with the understating that each program has the ability to select, advance, and release DHs from other programs, so long as the originating program does not plan to release that DH.

c) List key outcomes or other achievements.

The use of off-season nurseries and DHs has substantially decreased the release time of the variety development cycle. Development of LA16020-LDH22 (AGS 3022) was accomplished in only six years from cross to release. Availability of this line provides producers in the Southeast United States with a greater choice of FHB resistant varieties in the seed market, key to reducing DON presence within the national wheat supply chain. Continued sharing of selected DHs across the entire VDHR-SWW should increase impact of investment and result in releases of additional FHB resistant varieties, and allows individual cooperators to evaluate a large number of DH lines per year despite price increases and production difficulties. This effort also maximizes the per-program impact of DH spending by greatly increasing the amount of screening performed on each DH line before selection.

Annual funding for DH production has substantially impacted the LSU Wheat breeding program. In 2022, there were 45 LSU DHs in advanced yield trials derived from crosses made between 2015 and 2018. In the first year SunPre regional yield for 2022 30% of the entries came from DHs and the DHs entered the trial almost four years sooner than non-DHs. Increasing the portion of the program derived from fast-cycling DHs will result in quicker release of FHB resistant varieties and greater genetic gain due to overall shortening of the cycle time. AGS 3022 is a productive, FHB resistant variety well adapted to the Southeast United States and Gulf Coast region, and it is anticipated that further varieties will be produced from advanced DH lines currently in the breeding program pipeline.

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

Graduate students were trained on the concept of double haploids and their relevance to breeding program design.

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

Seed from all DH lines advanced and harvested by VDHR-SWW breeding programs will be shared to every member. Three to five grams of seed per DH line will be shared to allow each breeder to grow DH lines in headrows, including their respective FHB nurseries. This is a valuable collaborative effort that helps to maximize the return on investment by enabling more breeders to evaluate each selected DH line, which is beneficial given that a DH line may perform better in a given region than elsewhere.

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 FY22 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 May 1, 2022 – April 30, 2023?

☒ Yes, I've included the citation reference in listing(s) below.
☐ No, I have nothing to report.

Journal publications as a result of FY22 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).

Winn., Zachary, Jeanette Lyerly, Brian Ward, Gina Brown-Geudira, Richard Boyles, Mohamed Mergoum, Jerry Johnson, Stephen Harrison, Ali Babar, Richard Mason, Russell Sutton, and Paul Murphy. 2022. Profiling of Fusarium head blight resistance QTL haplotypes through molecular markers, genotyping-by-sequencing, and machine learning. https://doi.org/10.1007/s00122-022-04178-w
Acknowledged federal support: yes

Arlyn J. Ackerman, Ryan Holmes, Ezekiel Gaskins, Kathleen E. Jordan, Dawn S. Hicks, Joshua Fitzgerald, Carl A. Griffey, Richard Esten Mason, Stephen A. Harrison, Joseph Paul Murphy, Christina Cowger, and Richard E. Boyles. Evaluation of Methods for Measuring Fusarium-Damaged Kernels Wheat. Agronomy 2022, 12, 532. https://doi.org/10.3390/agronomy12020532
Acknowledged federal support: yes

Books or other non-periodical, one-time publications as a result of FY22 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.

Nothing to Report.

Other publications, conference papers and presentations as a result of FY22 award

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

Stephen A. Harrison, et al. 2022 Small Grain Performance Trials. LAES Research Summary No. 225. https://www.lsuagcenter.com/articles/page1659450013218

Fusarium Head Blight of Wheat (Scab) in Louisiana. 2022. Steve Harrison, Trey Price, and Boyd Padgett, LSU AgCenter scientists; Kelly Arceneaux, Allyson Harding, Katie Fontenot, Reddy Biradar, Myra Purvis, Dustin Ezell, Fred Collins, and Laura Lee, LSU AgCenter research associates. Louisiana Agriculture Magazine. https://www.lsuagcenter.com/articles/page1628783805876