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

FY21 FINAL Performance Progress Report

Due date: July 26, 2023

Cover Page

USDA-ARS Agreement ID:	59-0206-0-137
USDA-ARS Agreement Title:	Development of FHB Resistant Wheat Genotypes Adapted to the Gulf Coast and use of DHs to Expedite Variety Development
Principle Investigator (PI):	Steve Harrison
Institution:	Louisiana State University Agricultural Center
Institution UEI:	UF3LV6W2W6K9
Fiscal Year:	2021
FY21 USDA-ARS Award Amount:	$98,776
PI Mailing Address:	Louisiana State University Agricultural Center, School of Plant, Environmental, & Soils Sciences 104 MB Sturgis Hall, Baton Rouge, LA 70803-2110
PI E-mail:	SHarrison@agcenter.lsu.edu
PI Phone:	225-578-2110
Period of Performance:	6/1/21 - 5/31/23
Reporting Period End Date:	5/31/2023

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-SWW	Development of FHB Resistant Wheat Varieties for the Gulf Coast	$82,364
VDHR-SWW	Double Haploids to Expedite Development of FHB Resistant Soft Winter Wheat Varieties	$16,412
	FY21 Total ARS Award Amount	$98,776

I am submitting this report as a: ☒ 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.

Stephen A Harrison
Principal Investigator Signature

Jully 23, 2023
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 Varieties for the Gulf Coast

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1. **What are the major goals and objectives of the research project?**
   Fusarium Head Blight (FHB) is an important disease of wheat along the Gulf Coast and has significantly contributed to reduced acreage. Losses to FHB occur because of heavy rainfall during anthesis, more corn acres, and a lack of adapted varieties with FHB resistance. Development of FHB resistant wheat varieties with high yield, regional adaptation, and broad disease resistance is the major goal of the LSU wheat breeding program. This proposal addresses all three VDHR research priorities and stives to encourage growers to plant high-yielding, FHB resistant varieties that lead to reduced DON content in the grain trade.

   Our proposal will accelerate development of FHB resistant wheat varieties adapted to this unique environment and provide resources to help growers deal effectively with FHB, which should lead to reduced DON content in the grain trade. Objective 1 is to screen available varieties and breeding lines to document the number of released varieties from public and private programs with improved FHB resistance. Objective 2 is to increase efficiency of coordinated research activities to develop and release FHB resistant varieties. Objective 3 is to implement modern breeding technologies to enhance rate of gain in development of FHB resistant varieties. Obj 4) Utilize shared DHs, a shared off-season nursery, and shared regional yield trials with open germplasm access to increase progress for all programs.

2. **What was accomplished under these goals or objectives?**

   a) **What were the major activities?**
   Obj 1,3) Misted inoculated nurseries totaling 4,000 rows were grown in replicated, paired headrows at Alexandria, Baton Rouge and Winnsboro each year. The statewide variety trial was screened at three locations and regional nursery yield trials were screened at two locations. LSU preliminary yield trial entries and segregating populations were screened at one location. All rows were rated for FHB severity (0-9), hand harvested, and threshed with low wind speed to retain damaged kernels. FDK was determined on carefully cleaned samples, which were then ground to produce 30 grams of flour per sample. Approximately 2,000 samples were shipped to the USDA DON under direction of Yanhong Dong in St. Paul in early July. FHB, FDK, and DON were included in the annual Wheat Research Summary of variety trial performance results published each year and varieties were classified for FHB reaction type.

   Obj 2) Over 1,500 new wheat crosses were made during the three years of this project with >90% having FHB resistant parents. Segregating populations were screened and plants with reduced FHB severity and good agronomics were advanced to headrows. About 5400 yield plots were evaluated each year and head selections made from >1200 segregating plots at two locations each year. Obj 3, 4) Molecular markers for FHB QTL were run on 570 advanced breeding lines each year that were entered in the genomic

selection prelim project (WPGS) each year. First year DHs were evaluated in short rows and selected rows were harvested, entered in preliminary yield trials, and seed was shared among VDHR-SWW breeders. Obj 4) An off-season nursery of F1 plants from FHB crosses was grown in Idaho or Colorado each summer to speed up the breeding cycle of SunGrains programs.

Obj 2) Increase efficiency…: SunGrains and regional replicated yield trials and LSU advanced breeding lines were evaluated at two Louisiana locations in yield plots and misted nursery plots. Seed of DHs selected as headrows by each of eight VDHR-SWW participating program were shared with all cooperating universities for evaluation, selection, and advancement. The 1,500+ new LSU crosses combined parents containing desired QTL for FHB, high yield, and other essential traits. Head selections were made from segregating plots grown at two locations and in a misted nursery and advanced to headrows in the F3:4 stage.

A summer SunGrains F1 nursery was grown in Aberdeen, ID in 2021 and Denver, CO in 2022 to save a year in the breeding cycle. 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. 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. Genomic selection was used in advancement decisions and to select parents.

b) What were the significant results?

Obj 1) Excellent data on FHB reaction was collected for the statewide variety trials and all regional yield nurseries in three misted nurseries. Seed from two or three misted nurseries was rated for FDK and submitted for DON determination. FDK and DON of varieties in the misted nurseries from statewide variety trials ranged from 2% to 63% and 2.2 ppm to 35.7 ppm in 2021 and from 5% to 53% and 2.2 ppm to 23.7 ppm in 2022. respectively, 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. FHB Index value is calculated as a weighted function of FHB, FDK and DON. The data on FHB, FDK, and DON was included in the annual Wheat Research Summary published for growers, consultants, and seedsmen in August each year. 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 was used to classify varieties and develop the list of resistant and moderately resistant varieties published on the USWBSI web site. FHB data from two nurseries was included in USDA regional and SunGrains nursery reports to assist collaborating breeders in developing FHB resistant varieties.

Obj 2) The majority of crosses made contained FHB resistance in both parents. The Wheat Genomic Selection Prelim (WPGS) included 570 breeding lines in first year yield trials at two locations.

Obj 3) Genomic selection models, marker QTL information and field data were used to advance ~85 breeding lines from WPGS to replicated yield testing each year.

Obj 4) Crosses with parents containing multiple FHB QTL/genes with high yield were submitted for development of DH lines. Genomic selection predictions (PopVar), marker data, and regional yield trial data were used to place promising lines from first year regional testing into the crossing plot, saving a couple of years in the breeding cycle. The genomic selection (GS) protocol included imputation of major QTL for FHB resistance and calculation of GEBVs for yield, FHB resistance 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. GS data was heavily weighted in advancement decisions of lines from the genomic selection prelim that will be in replicated yield trials. Shared DHs were evaluated in headrows and yield plots.

c) List key outcomes or other achievements.

Obj 1,3) Excellent data was obtained from the misted nurseries. FHB, FDK, and DON data was posted for variety trial and regional nursery entries. The variety trial publication highlighted FHB data and FHB resistance category to encourage growers to plant resistant varieties. Obj 2) Breeding lines are increased by Georgia Seed Development Commission and LA16020-LDH22, a double haploid, was released in August 2021, only six years after the initial cross. 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. Obj 4). First year DH lines selected as headrows in Winnsboro were harvested and shared with all VDHR-SWW breeders to allow them the opportunity to select FHB resistant DHs that perform better in their respective environments than in the Gulf Coast.

The SunGrains nurseries decrease the breeding cycle time and increase genetic gain by providing extensive phenotypic and genomic data, and imputed QTL presence used to make informed release decisions and to rapidly recycle genotypes back as parents. Most crosses made in 2022 were made between parents with characterized FHB QTL and with FHB resistance as a major priority. ~5100 yield plots were evaluated over three locations. The LSU Genomic Selection Prelim grown in two locations included 570 advanced breeding lines that were also screened in a misted nursery and subjected to the SunGrains genomic selection protocol and QTL imputation. Advancement was based on field phenotype, genomic estimated breeding value, and imputed presence of important FHB QTK. The SunGrains multi-state genomic selection program evaluated about 4,000 lines and entries in five regional nurseries.

FHB, FDK, and DON ratings from all regional nurseries were distributed to breeders and published in nursery reports in July to aid breeders in development and release of FHB resistant varieties. 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.

3. **What opportunities for training and professional development has the project provided?**
   Three graduate students were involved in setting up mist systems, inoculating nurseries, and rating field symptoms for FHB. One graduate student is in charge of the misted nurseries and rated all harvested samples for FDK and has a FHB related research project.

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

Project 2: Double Haploids to Expedite Development of FHB Resistant Soft Winter Wheat Varieties

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

Objectives are to: (1) Utilize doubled haploid (DH) technology to decrease the breeding cycle and release FHB resistant varieties more quickly and efficiently. Develop new DHs that combine yield, adaptation, and FHB resistance. 2) Implement a topcross enrichment DH program to pyramid effective FHB QTL and increase frequency of those pyramids in DHs derived from those populations. Prior to selection of crosses for DH production, enrich crosses for FHB QTL and other important QTL using established markers and the USDA ARS Eastern Regional Small Grains Genotyping Lab. 3) Share selected DHs with all VDHR-SWW breeders to increase efficiency of the coordinated project breeding programs to develop and release FHB resistant varieties from DHs. 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.

Double Haploids were created from three, six, and four crosses in 2021, 2022, and 2023. Most 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. 58 DH headrows were harvested in 2023 and DHs are evaluated at every stage of testing from headrows to regional yield trials.

Crosses submitted for DH development in 2022.

CROSS		Pedigree / Genes
LA22109	**Ped**	GA15VDH---07ADH33F/LA16020LDH-22
	Genes	RHT2, FHB1, F1BJT, LR18, YR17, YR4BL, SBM1, //RHT2, Fhb1BJT, Fhb4AN, YR17, LR9, 1RS.1AL, SBM1
LA22121	**Ped**	GA161240LDH-113 -20LE6/LA16020LDH-22
	Genes	,Rht-D1b, Sbm1, Fhb1, FHB1AN, Yr17., Sr24/Lr24?, Sr_6D, Yr_4BL,Pm1a,//RHT2, Fhb1JT, Fhb4AN, YR17, LR9, 1RS.1AL, SBM1
LA22274	**Ped**	LA16020LDH-22/LA15005GBB-4-1-3
	Genes	RHT2, Fhb1BJT, Fhb4AN, YR17, LR9, 1RS.1AL, SBM1//FHB1, FHB1BJT, H13, SR36, SBM1,
LA22438	**Ped**	LANC11558-33/AR15V25-19-2174N
	Genes	RHT2, F1BJT, F1AN, YR4BL, H13H, SBM1//,Rht-D1b,Sbm1,Fhb1_het,FHB5AN_het,FHB1BJT,Yr17.,Lr18,Yr_4BL_het,H13_het
LA22440	**Ped**	LANC11558-33/GA151313-LDH-192 -20E48
	Genes	RHT2, F1BJT, F1AN, YR4BL, H13H, SBM1//,Rht-D1b, Sbm1, FHB1BJT, FHB1AN, Yr17.Lr9?, Lr18, H13
LA22491	**Ped**	NC14704-37/GA161240LDH-113 -20LE6
	Genes	??? //,Rht-D1b, Sbm1, Fhb1, FHB1AN, Yr17., Sr24/Lr24?, Sr_6D, Yr_4BL,Pm1a,

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?

Obj 1, 3) 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 to the Genomic Selection Prelim tested at two locations. Advanced yield trials and regional trials include LSU DHs each year. Obj 2) Topcrosses made by the Virginia Tech program were screened at the Eastern Wheat Genotyping Lab and selected plants submitted for DH development. Obj 3) 414 DHs selected and harvested in 2023 as first year headrows were shared with other VDHR-SWW breeders to allow them the opportunity for selection and advancement.

b) What were the significant results?

Obj 1) The DH LA16020-LDH22 was released as a variety in 2021, only six years after the initial cross. It has excellent yield and very good FHB resistance. Obj 2) The new DHs evaluated each year come from all of the participating VDHR-SWW program. Obj 3) New DHs are shared with all VDHR-SWW breeding programs with the understating that each program has the ability to select, advance, and release DHs from other programs as long as the originating program does not plan to release that DH.

AGS 3022 (LA16020-LDH22) is a DH derived variety released just five years after the cross was made. It was the second-highest yielding variety 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.

c) List key outcomes or other achievements.

Obj 1) Release of LA16020-LDH22 (AGS 3022) provides Gulf Coast producers with a greater choice of FHB resistant varieties in the seed market and is key to reducing DON presence within the national wheat supply chain. Obj 3). Sharing selected DHs across the entire VDHR-SWW is a new initiative that should increased impact of investment and result in release of additional FHB resistant varieties.

The use of off-season nurseries and DHs have substantially decreased the length of the variety development cycle. For example, AGS 3022 (LA16020) was released in six years through the DH channel of the breeding program. Sharing of DHs improves the efficiency of all VDHR-SWW programs and maximizes return form investment.

There were 45 LSU DHs in advanced yield trials in 2022 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. This will result in quicker release of FHB resistant varieties and greater genetic gain due to shortening of the cycle time. AGS 3022 is a productive, FHB resistant variety well adapted to the Gulf Coast region.

3. What opportunities for training and professional development has the project provided?
Two graduate students were involved in setting up mist systems, inoculating nurseries, and rating field symptoms for FHB. Graduate students rated FDK in the lab, collected DNA and assisted in running molecular markers for FHB QTL.

4. How have the results been disseminated to communities of interest?
Seed from all DH lines that were advanced and harvested by each VDHR-SWW breeding program 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 a chance to look at many more DH lines, which is beneficial given that a DH line may perform better in a given region that elsewhere.

A Wheat Field Day was held in person and also presented virtually in April 2022 and 2023 to highlight FHB research. The LSU wheat breeding program maintains two wheat websites for data and state trials and one for the SunGrains breeding collaborative group. Completed variety trial reports are posted on the LSU AgCenter variety trial website. Data on FHB severity, FDK, and DON for the regional nurseries are published in the official reports. A Fusarium article targeted to growers, with data on variety reaction and fungicide efficacy, was published (https://lsuagcenter.com/articles/page1628783805876) in the August 2021 issue of Louisiana Crops and on the USWBSI website.

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 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, Z.J., Lyerly, J., Ward, B. et al. Profiling of Fusarium head blight resistance QTL haplotypes through molecular markers, genotyping-by-sequencing, and machine learning. Theor Appl Genet 135, 3177–3194 (2022). https://doi.org/10.1007/s00122-022-04178-w. Acknowledgment of 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. Acknowledgment of support: Yes

Schoen, A., Wallace, S., Holbert, M. F., Brown-Guidera, G., Harrison, S., Murphy, P., Sanantonio, N., Van Sanford, D., Boyles,R., Mergoum, M., Rawat, N., & Tiwari, V. 2023. Reducing the generation time in winter wheat cultivars using speed breeding. Crop Science 1-12. https://doi.org/10.1002/csc2.20989. Acknowledgment of support: Yes

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

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

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

Stephen Harrison, Arceneaux, Kelly J., Price, III, Paul P, Padgett, Guy B. Development of Wheat and Oat Varieties with Improved Yield and Disease Resistance. June 2021. Louisiana Agriculture Magazine.

Stephen A. Harrison, et al. 2021 Small Grain Performance Trials. LAES Research Summary No. 224. https://www.lsuagcenter.com/~/media/system/0/6/f/c/06fc2422553fc3de11f617f33887a9e0/2021_smallgrainsperformancetrialspdf.pdf

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