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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Phone:	843-519-0488
Fiscal Year:	2020
USDA-ARS Agreement ID:	59-0206-0-150
USDA-ARS Agreement Title:	Collaborative Research to Improve evaluation of Advanced Wheat Germplasm for FHB Resistance in the Atlantic Coastal Plain
FY20 USDA-ARS Award Amount:	$ 109,830
Recipient Organization:	Clemson University Grants and Contracts Administration 230 Kappa Street, Suite 200 Clemson, SC 29634-5355
DUNS Number:	04-262-9816
EIN:	57-6000254
Recipient Identifying Number or Account Number:	207-2013983
Project/Grant Reporting Period:	5/15/20 - 5/14/21
Reporting Period End Date:	5/14/2021

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-SWW	Developing and Evaluating Wheat Lines for FHB Resistance in Atlantic Coastal Plain	$ 96,027
VDHR-SWW	Double Haploids to Expedite Development of FHB Resistant Soft Winter Wheat Varieties	$ 13,803
	FY20 Total ARS Award Amount	**$ 109,830**

Rich Boyles
Principal Investigator

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Date: 2021.07.29 15:03:36 -04'00'
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: *Developing and Evaluating Wheat Lines for FHB Resistance in Atlantic Coastal Plain*

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

The ***goal of this project*** is to increase the capacity and rigor required to (1) collect robust and accurate FHB resistance field data on commercially available and recently released wheat cultivars and (2) develop advanced breeding lines with further enhanced and more durable *Fusarium* head blight (FHB) resistance. This work aims to accelerate variety development and screening efforts by incorporating advanced genomics and phenomics methods that recently became available (and understood) for applied use in breeding programs.

Objective 1. Continue intercrossing moderately FHB resistant elite lines to stack FHB QTL. *Rationale* — Because scab resistance is quantitative, stacked QTL (4+) are needed for durable FHB resistance.

Objective 2. Expand the SC scab nursery to include SunGrains DH populations and Clemson $F_{4:6}$ breeding lines. *Rationale* — An increased pool of FHB resistance within the Clemson breeding program and broader community is needed.

Objective 3. Support advanced phenomics methods and genomic selection pipelines to increase predictability of FHB resistance across collaborative breeding programs. *Rationale* — FDK is most highly correlated with DON but is labor-intensive and subjective. FDK will be measured using high-throughput analysis to accurately evaluate FHB resistance and provide a larger training population for genomic prediction of FDK for future breeding populations.

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?

Objective 1. Continue intercrossing moderately FHB resistant lines to stack FHB QTL. Wheat crosses using elite MR scab lines were made January-February 2021 to develop doubled haploids and segregating populations for phenotypic and marker-assisted selection of resistant progeny. Marker data for known scab QTL and genomic estimated breeding values (GEBVs) on SunGrains 2020 breeding lines were examined to select best available parents for crossing. Among parent lines included in the nursery, FHB QTL present in the nursery were Fhb1, Jamestown 1B, Neuse 1A, Neuse 4A, Neuse 6A, Wuhan 2DL, Bess 2B, Bess 3B, and Ning 5A.

Objective 2. Expand the SC scab nursery to include SunGrains DH populations and Clemson $F_{4:6}$ breeding lines. In addition to the USSN, USSRWWN, GAWN, and SunGrains trials, DH lines generated by NCSU/SunGrains and Clemson observation lines

($F_{4:6}$) were effectively screened. *Fusarium graminearum* isolates were graciously provided by Dr. Christina Cowger and were cultured and combined into a single inoculum slurry. The slurry was mixed with autoclaved corn kernels to generate 200 lbs of scabby corn, which was spread evenly across headrows within the one acre Florence misted nursery in two applications: 03/19/21 and 04/02/21. The Florence 2021 FHB nursery was double the size of the 2020 nursery, which accommodated the additional DH and observation lines.

Objective 3. Support advanced phenomics methods and genomic selection pipelines to increase predictability of FHB resistance across collaborative breeding programs.
More than 1,200 FHB samples representing three locations and two years were analyzed using six phenotypic methods: DON, FDK Vibe QM3, FDK Visual, FDK Manual, FDK NIR, and FHB Field Rating. The phenotypic platforms were compared against each other based on standard deviation, variance, variance to mean ratio, coefficient of variation, mean square error, least significant difference, F-value, and p-value. Pairwise correlations among traits were also compared. The different phenotypes were also separately used for genome-wide association mapping to disover QTL for FHB resistance and compare statistical power and resolution across the different phenotypic platforms.

b) What were the significant results?

Objective 1. Continue intercrossing moderately FHB resistant lines to stack FHB QTL.
A total of 809 crosses were made in the 2021 Clemson greenhouse crossing nursery, with 729 being successful. This is a 30% increase in crossing number. F_1 seed of select crosses (n=388) based on marker data for FHB and other QTL of imporatance were transplanted in the greenhouse for advancement.

Objective 2. Expand the SC scab nursery.
Thirty-three of 160 doubled haploids evaluated in the FHB nursery were advanced and increased for yield testing in 2021-2022. Out of 3,040 $F_{4:6}$ breeding lines, 455 lines were advanced for yield testing in 2021-2022. As a result, 89% (488/550) of the Clemson wheat preliminary lines entering into yield testing will have been screened for FHB resistance in an inoculated scab nursery. DH lines advanced will be shared with VDHR-SWW breeders.

Objective 3. Increase assessment and predictability of FHB resistance.
DON has served as the gold standard for determining FHB resistance in germplasm. The phenotypic correlations between DON and the other FDK traits were as follows: *r*=0.52 FDK Visual, *r*=0.48 FDK Manual, *r*=0.39 FDK NIR, and *r*=0.83 for FDK Vibe QM3. Based on 1,200 FHB samples across multiple site-years, the FDK results using the Vibe QM3 grain analyzer was significantly more correlated with DON than any other FDK platform.

c) List key outcomes or other achievements.

Objective 1. Continue intercrossing moderately FHB resistant lines to stack FHB QTL.

The Clemson wheat breeding program has now saturated the breeding pipeline with elite genetic material that contain nearly all known FHB resistance QTL. This pipeline represents a near- and long-term investment in wheat cultivar development that will supply the industry with superior cultivars that have exceptional FHB resistance.

Objective 2. Expand the SC scab nursery.

With the high majority (~90%) of lines entering into the wheat preliminary yield stage having been carefully evaluated for FHB resistance in a misted, inoculated nursery, the level of FHB resistance advancing in the Clemson wheat breeding program will increase significantly.

Objective 3. Increase assessment and predictability of FHB resistance.

With a much more objective screening method for FDK established using the Vibe QM3, breeders in the VDHR-SWW CP will have an increased ability to correctly asses FHB resistance, especially in earlier stage germplasm. Increased objectivity will also be used to identify new genetic resistance mechanisms for further improvement.

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.

The pandemic did not result in a loss of VDHR-SWW CP activities with the exception of losing our F1 summer nursery location in Aberdeen, ID. Adjustments were made to offset this by increasing F1 crosses in the greenhouse in 2021. In addition, it did slow down the throughput of processing FHB samples due to a lack of summer workers hired. Currently, the pandemic is not affecting any research objectives.

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

Mr. AJ Ackerman, a PhD candidate not funded by the VDHR-SWW, led the process of culturing inoculum and scaling up scabby corn for field deployment, which has provided hands-on pathology experience. In addition to AJ, an undergraduate student worker, Mrs. Dawn Hicks, has coordinated FDK calibrationa and analysis with the Vibe QM3 and Perten DA7250 NIR analyzer. A high school student, Mr. Ezekiel Gaskins, from the SC Governor's School also worked on this project as part of his mandatory summer research internship project. Two research technicians have been able to learn tractable skills as a result from participating in this project. Both technicians and students have

been trained to plant, manage, and harvest the wheat FHB nursery as well as operate seed processing machinery and seed imaging software.

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

Data and associated results were presented to the VDHR-SWW research group at the annual planning meeting held on 17 March 2021. Trial results from the 2020 FHB nursery were circulated to the SRWW community once the data were finalized and proofed in August 2020. PhD student AJ Ackerman is in the final writing stages to publish the FDK study with the Vibe QM3 instrument. Target journal will be Agronomy so it reaches an international audience. SC OVT FHB data are being uploaded to the ScabSmart website.

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?**

   Objective 1. Implement a topcross, F2 enrichment approach to increase probability of DH lines containing FHB QTL of interest.

   Objective 2. Develop wheat doubled haploids with pedigrees that include adapted, FHB resistant 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?**

   Objective 1. Implement a topcross, F2 enrichment approach to increase probability of DH lines containing FHB QTL of interest. Topcrosses were made by Dr. Carl Griffey at Virginia Tech in spring 2020. Seedlings from three-way crosses resulting from these topcrosses were vernalized in the cold room. Leaf tissue was collected from each seedling for genotyping by Dr. Gina Brown-Guedira at the USDA Eastern Regional Small Grains Genotyping Lab. Each breeder and member of the VDHR-SWW CP was provided the marker results from all genotyped seedlings, and breeders made 4-6 plant selections that would be advanced for DH development.

   Objective 2. Develop wheat doubled haploids with pedigrees that include adapted, FHB resistant lines. Seedlings were grown in the greenhouse by the NC State program led by Dr. Paul Murphy and pollinated with maize to generate haploid embryos. Embryos were rescued and resulting explants were treated with colchicine for chromosome doubling. Explant seedlings were transplanted in the greenhouse for seed growouts. Seed of individual DH lines were then harvested and distributed to the respective breeder who originally selected them. All DH lines were planted and evaluated as headrows in the misted FHB nursery. Sufficient seed quantity was produced to allow sharing 3 grams of each line to all cooperating VDHR-SWW members.

   b) **What were the significant results?**

   Objective 1. Implement a topcross, F2 enrichment approach to increase probability of DH lines containing FHB QTL of interest.

   For Clemson, there were a total of 122 DH lines from nine different plant selections (two pedigrees). This was lower than on a typical year because of an unusually hot summer that decreased pant vigor and productivity in the greenhouse.

Objective 2. Develop wheat doubled haploids with pedigrees that include adapted, FHB resistant lines.

There were 33 of the 122 DH lines that were harvested in spring 2021 for advancement to yield testing. Sufficient seed quantity was produced to allow sharing 3 grams of each line to all cooperating VDHR-SWW members.

c) List key outcomes or other achievements.

Objective 1. Implement a topcross, F2 enrichment approach to increase probability of DH lines containing FHB QTL of interest.

The F2 enrichment using marker-assisted selection eliminated many undesirable DH lines by selecting specifically for individual genotypes that were segregating or fixed for all desirable alleles at QTL of interest. This dramatically improves the return on investment and increases the likelihood of identifying a DH line worthy of advanced testing as well as cultivar release.

Objective 2. Develop wheat doubled haploids with pedigrees that include adapted, FHB resistant lines.

The high percentage of DH lines advanced to the yield stage demonstrate the effectiveness of this DH program. The time from cross made to first year (stage 1) yield testing will be less than two years, which is greatly reduced from the 5-6 year timeline that it takes using conventional breeding and generational advancement.

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.

Yes, because of the reduced capabilities of the USDA Eastern Regional Small Grains Genotyping Lab that was caused by the government shutdown and preventation of research personnel to enter facilities, the topcross MAS and F2 enrichment initiative was also shut down during the 2020 calendar year. This was also interrupted with the retirement of Dr. Carl Griffey and transition of the VA Tech wheat breeding program.

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?

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.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY20 award period (5/15/20 - 5/14/21). 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 (5/15/20 - 5/14/21). 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
Nothing to report.	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
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 (5/15/20 - 5/14/21**) 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.

Mergoum, M., Johnson, J. W., Buck, J. W., Sutton, S., Lopez, B., Bland, D., ... & Cambron, S. E. (2021). A new soft red winter wheat cultivar,'GA 07353-14E19', adapted to Georgia and the US Southeast environments. *Journal of Plant Registrations*, *15*(2), 337-344.
Status: Published
Acknowledgment of Federal Support: Yes

Ibrahim, A. M., Sutton, R., Johnson, J. W., Mergoum, M., Simoneaux, B., Harrison, S. A., ... & Fountain, M. O. (2021). Registration of 'GA06343-13E2 (TX-EL2)'soft red winter wheat. *Journal of Plant Registrations*, *15*(1), 107-112.
Status: Published
Acknowledgment of Federal Support: Yes

Mergoum, M., Johnson, J. W., Buck, J. W., Sutton, S., Lopez, B., Bland, D., ... & Boyles, R. (2021). Soft red winter wheat 'GA 051207-14E53': Adapted cultivar to Georgia and the US Southeast region. *Journal of Plant Registrations*, *15*(1), 132-139.
Status: Published
Acknowledgment of Federal Support: Yes

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

Nothing to report.

Other publications, conference papers and presentations.

Boyles R. Harnessing diversity and leveraging genomics for cereal crop improvement. School of Integrative Plant Science Plant Breeding and Genetics Seminar, Cornell University, Ithaca, NY. May 4, 2021
Status: Presented
Acknowledgment of Federal Support: Yes

Boyles, R. Update on FDK phenotyping. VDHR-SWW Annual Meeting (held virtually). March, 17, 2021
Status: Presented
Acknowledgment of Federal Support: Yes