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:	59-0206-0-143
USDA-ARS Agreement Title:	Scab Research Projects and Development of Scab Resistant Soft Red Winter Wheat Varieties at the University of Illinois
Principle Investigator (PI):	Jessica Rutkoski
Institution:	University of Illinois
Institution UEI:	Y8CWNJRCNN91
Fiscal Year:	2021
FY21 USDA-ARS Award Amount:	$199,791
PI Mailing Address:	University of Illinois, Department of Crop Sciences 1102 S. Goodwin Ave., Urbana, IL 60801
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Period of Performance:	6/8/21 - 6/7/23
Reporting Period End Date:	6/7/2023

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-NWW	Development of Scab Resistant Soft Red Winter Wheat Varieties	$114,671
VDHR-NWW	Fast, Efficient Phenotyping Methods for FHB Resistance using Imagery and Imputation	$67,157
VDHR-NWW	Coordinated Phenotypes of Soft Wheat Germplasm for the Midwest	$17,963
	FY21 Total ARS Award Amount	$199,791

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.

Principal Investigator Signature — July 19, 2023 — Date Report Submitted

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ǂ 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 Soft Red Winter Wheat Varieties

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

The major goals and objectives of this project are to 1) increase and document the number wheat varieties with FHB resistance and high grain yield, and 2) implement new and underutilized breeding techniques to enhance short and long-term improvement of FHB resistance and grain yield.

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?

To address our two main goals, we executed a breeding strategy aimed at improving both FHB resistance and yield, and we evaluated the Illinois official variety trial for FHB resistance in our inoculated and misted scab nursery.

During June and July, 2021 we completed the 2020-2021 field season where we obtained useful data on 493 breeding lines, and 83 varieties for yield and scab resistance. We also evaluated an additional 1957 new lines for agronomic performance. In fall of 2021 we sucessfully planted a new set of breeding trials for yield and scab resistance evaluation for the 2021-2022 field season. During the 2021-2022 field season expression of scab symptoms in our scab nursery was excellent. On 486 breeding lines and 93 varieties in the state variety trial, we accurately rated FDK and sent all samples to the University of Minnesota for evaluation of Deoxynivalenol. We also evaluated an additional 1337 new lines for agronomic performance. In fall of 2022 we successfully established the next set of trials and nurseries for the 2022-2023 season.

To generate new breeding materials, we generated 200 cross combinations per year between 30-40 selected parents with high yield and at least moderate resistance to scab. Each year we also generated between 800 and 1500 new F3-derived breeding lines from new crosses. We obtained genotypic data on all new breeding lines from the USDA small grains genotyping lab in Raleigh, North Carolina. Each year, we used this data to estimate Genomic Best Linear Unbiased Predictions (BLUPs) for scab resistance and agronomic traits to make selection decisions.

Notably, beginning August 2021, we successfully implemented new fully randomized and partially-replicated experimental designs and an accelerated line development protocol. This has improved our selection accuracy and has reducing our breeding cycle time.

b) What were the significant results?

Thirty eight out of 39 of our most advanced breeding lines have higher levels of scab resistance than Pioneer 25R74, and of these 32 have higher levels of scab resistance than our moderately resistant check IL07-19334.

The results on FHB resistance among released varieties have been published on the Illinois Official Variety Trial website: http://vt.cropsci.illinois.edu/wheat.html

c) List key outcomes or other achievements.

During the project period, we licensed 6 lines: IL19-14856, IL19-5466, US17-IL-108-039, IL18-17905, IL18-1453, IL17-23874, to private seed companies for further testing and increasing. All of the lines are at least moderately resistant to scab.

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

This project has given graduate students and undergraduates the opportunity to gain experience evaluating and identifying symptoms of FHB resistance. Undergraduate students have learned about the technical processes of plant breeding and have gained exposure to agriculture and agricultural research. Several of our undergraduate students have used their work experience with our research group to help them get jobs or admission to graduate school.

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

Results of the breeding program, in the form of germplasm, has been shared with private seed companies for licensing.

Results of FHB resistance evaluation on varieties in the Illinois State Variety trial have been published on the variety testing website: http://vt.cropsci.illinois.edu/wheat.html

Project 2: Fast, Efficient Phenotyping Methods for FHB Resistance using Imagery and Imputation

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1. **What are the major goals and objectives of the research project?**
   This research project aims to improve the efficiency and accuracy of FHB resistance evaluation using imagery and statistical techniques.

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?
   We collected images of FHB infected plots and on grain samples, we analyzed aerial image data collected on plots during 2020, we trained a deep-learning model to evaluate Fusarium Damaged Kernels (FDK), and we evaluated the genomic prediction accuracy of models that used FDK estimated using deep learning with that of models that used FDK estimated using human ratings. Our previous work showed that FDK is more important than incidence or severity for training genomic prediction models; thus, we shifted our research towards using imagery for FDK phenotyping.

   b) What were the significant results?
   We determined that including FDK estimated using deep learning as a secondary trait in a genomic prediction model improved accuracy for Deoxynivalenol by more than 150% relative to a single-trait model. However, using human-rated FDK phenotypes improved genomic prediction model accuracy by more than 300%.

   c) List key outcomes or other achievements.
   A deep learning model capable of evaluating FDK has been trained, and this research has been published in the Plant Phenome Journal.

3. **What opportunities for training and professional development has the project provided?**
   One postdoctoral researcher funded by this project, Rupesh Gaire, learned how to use multi-trait genomic selection models. Dr. Gaire is now working as a Senior Researcher at Bayer. A second postdoctoral researcher funded by this project, Arlyn Ackerman, learned how to use multi-trait genomic selection models and learned how to utilize predicted FDK phenotypes to help train genomic selection models. Dr. Ackerman is now working for the Breeding Insight project at Cornell University.

4. **How have the results been disseminated to communities of interest?**
   Our work showing that FDK can improve genomic prediction accuracy for Deoxynivalenol was published in The Plant Genome Journal on January 19, 2022. Our work on using artificial intelligence to evaluate FDK was published in the Plant Phenome Journal on January 26, 2023. Computer code for multi-trait genomic selection has been made available on github https://github.com/jrutUIUC.

Project 3: 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?**
   This research project aims to 1) gather robust, multi-location data on scab resistance among advanced breeding lines that are candidates for variety release, 2) make data available in a centralized database, and 3) provide FHB resistance data on candidate varieties to seedsmen to help promote the release of more FHB-resistant varieties.

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

   d) What were the major activities?
   Cooperative nurseries were evaluated for FHB resistance our inoculated and misted nursery. On each plot we evaluated Days to Heading, Incidence, Severity, Fusarium Damaged Kernels, and Deoxynivalenol. Deoxynivalenol analysis was provided by the University of Minnesota. The cooperative nurseries that we evaluated for scab resistance include the Northern Uniform Scab Nursery, Preliminary Northern Uniform Scab Nursery, Uniform Eastern, Southern Uniform Scab Nursery, Advanced 5-State, and Preliminary 5-State.

   e) What were the significant results?
   Each year, we obtained a high level of disease pressure in the FHB nursery and data reliability were high. Also, through this project, we shared 7-10 new elite breeding lines per year with other breeding programs that they can use for testing and potentially for crossing.

   f) List key outcomes or other achievements.
   Data collected on cooperative nurseries were made available to cooperators in each nursery to facilitate selection of FHB resistant breeding lines. This data is being used to facilitate variety release decisions.

3. **What opportunities for training and professional development has the project provided?**
   Undergraduate students have gained experience evaluating FHB resistance.

4. **How have the results been disseminated to communities of interest?**
   Data have been made publicly available on the T3 database, and data have been shared with collaborators over email.

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).

Gaire, Dr. R., Arruda, Dr. M., Mohammadi, Dr. M., Brown-Guedira, Dr. G., Kolb, Dr. F., Rutkoski, Dr. J., 2022. Multi-trait Genomic Selection Can Increase Selection Accuracy for Deoxynivalenol Accumulation due to Fusarium Head Blight in Wheat. *The Plant Genome 15*(1), p.e20188. https://doi.org/10.1002/tpg2.20188
Acknowledged of federal support - yes.

Wu, J., Ackerman, A., Gaire, R., Chowdhary, G. and Rutkoski, J., 2023. A neural network for phenotyping Fusarium-damaged kernels (FDKs) in wheat and its impact on genomic selection accuracy. *The Plant Phenome Journal*, *6*(1), p.e20065. https://doi.org/10.1002/ppj2.20065
Acknowledged of federal 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.

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).

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.

Presentations:

Advancements in Wheat Variety Development. American Seed Trade Association (ASTA) CSS and Seed Expo, Chicago, IL. December 5-8, 2022.

Multi-trait Genomic Selection and it's Potential to Streamline Scab Resistance Phenotyping. National Fusarium Head Blight Forum. Virtual. December 6-7, 2021.

Genomic Selection to Improve the Profitability of Wheat Production. American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America International Annual Meeting, Salt Lake City, Utah, November 7-10, 2021.

Adopting a Genomic Selection Enabled Breeding Strategy: My Experience in Wheat. The National Association of Plant Breeders 2021 Annual Meeting, Cornell University (Online) August 15-19, 2021.