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:	59-0206-0-134
USDA-ARS Agreement Title:	Evaulation and Implementation of Breeding Methods to Improve FHB Resistance in Barley
Principle Investigator (PI):	Kevin Smith
Institution:	University of Minnesota
Institution UEI:	KABJZBBJ4B54
Fiscal Year:	2021
FY21 USDA-ARS Award Amount:	$172,948
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Period of Performance:	5/13/21 - 5/12/23
Reporting Period End Date:	5/12/2023

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
BAR-CP	Developing Malting Barley Varieties with Enhanced FHB Resistance and Lower DON	$148,062
BAR-CP	Optimizing Parent Combinations to Improve FHB/DON Resistance in Barley	$24,886
	FY21 Total ARS Award Amount	$172,948

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 — Date Report Submitted: 7/25/2023

* 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: Developing Malting Barley Varieties with Enhanced FHB Resistance and Lower DON

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1. **What are the major goals and objectives of the research project?**
   The overall goal of this project is to develop malting barley varieties with enhanced resistance to FHB and lower concentration of the mycotoxin deoxynivalenol (DON). To accomplish this goal, we are conducting a comprehensive FHB breeding effort utilizing greenhouse for crossing and single-seed advance, inoculated disease nurseries for FHB and DON evaluation, various uses of markers to improve selection, regional yield and quality testing, and collaborative regional nurseries to evaluate elite breeding lines. This project focuses on line development and evaluation for lower FHB/DON. Our breeding efforts have concentrated on two-row barley in response to industry needs. We also initiated a winter barley program to explore more sustainable production systems and potential avoidance of FHB.

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. *Create new breeding populations by crossing parents that carry resistance to FHB and other desirable traits*.

   In the fall of 2021, we identified a set of 76 parents from our breeding program to make crosses to develop new breeding populations. Most of the 89 crosses made have at least one parent that is lower in DON concentration compared to ND Genesis or is predicted based on genomic selection modeling to have progeny that are lower in DON compared to ND Genesis.

   In the winter greenhouse of 2022, we selected 38 parents and made 43 crosses with lines that should provide better winterhardiness. Many of these sources were outside of our breeding program and we are currently assessing their FHB resistance. In most cases they were paired with a parent from our program with lower DON compared to ND-Genesis.

   In the fall of 2022, we identified a set of 35 spring and 40 winter (facultative) parents from our breeding program to make crosses to develop new breeding populations. Most of these 102 new crosses have at least one parent that is lower in DON concentration compared to ND Genesis or is predicted based on genomic selection modeling to have progeny that are lower in DON compared to ND Genesis.

   In the winter greenhouse of 2023, we selected 28 parents and made an additional 31 crosses with lines that should provide better winterhardiness. In most cases these crosses included a parent from our program with lower DON compared to ND-Genesis.

   Objective 2. *Conduct selection for FHB resistance and lower DON concentration in segregating breeding populations using genetic markers and field screening*

In the summer of 2021, we conducted FHB evaluation in misted and inoculated field nurseries at Crookston and St. Paul, MN totaling just over 2,834 plots. We evaluated FHB severity and harvested selected plots for DON. These nurseries included trials from first year yield trial entries, advanced breeding lines, a thesis project related to naked barley and DON, and varieties from our spring and winter (facultative) two-row breeding programs. This data was used to select parents and advance lines in our breeding program.

In the Fall of 2021, we genotyped 1,290 F3 breeding lines with genome-wide markers to produce predictions for agronomic performance, malting quality, FHB severity, and DON concentration. This genotypic data was used to select 344 new lines that were entered into first year yield and FHB evaluations for the 2022 growing season.

In the summer of 2022, we conducted FHB evaluation in misted and inoculated field nurseries at Crookston and St. Paul, MN totaling 1,917 plots. We evaluated FHB severity and harvested selected plots for DON. These nurseries included trials from first year yield trial entries, advanced breeding lines, and varieties from our spring and winter (facultative) two-row breeding programs. This data was used to select parents and advance lines in our breeding program.

In the Fall of 2022, we genotyped 1,309 F3 breeding lines with genome-wide markers to produce predictions for agronomic performance, malting quality, FHB severity, and DON concentration. This genotypic data was used to select 362 new lines that were entered into first year yield and FHB evaluations for the 2023 growing season.

Objective 3. *Advance lines to regional testing and industry evaluation that are candidates for new cultivar releases.*

Two first year, four second year, and one third year entry from crop year 2021 were advanced to American Malting Barley Association industry pilot testing for malting quality.

Eight first year and two second year entries from crop year 2022 were advanced to American Malting Barley Association industry pilot testing for malting quality.

b) What were the significant results?

Objective 1. *Create new breeding populations by crossing parents that carry resistance to FHB and other desirable traits*.

In 2021 and 2022, we created 265 new breeding populations. Most of the parents were from within our program and selected to have DON levels below ND-Genesis. Those few parents with equal or higher levels of DON were selected to bring in an important agronomic or malting quality trait that is deficient in our breeding population. This should substantially increase the frequency of resistance to FHB and DON in our breeding program in combination with agronomic and quality traits necessary to release new varieties.

Objective 2. *Conduct selection for FHB resistance and lower DON concentration in segregating breeding populations using genetic markers and field screening*

Our genomic selection for DON has had some mixed results over the past two years. Conducting simple cross-validation within the training populations, we obtained prediction accuracies of 0.49 and 0.45 for 2021 and 2022, respectively. These are reasonably good. However, validation based on predicting lines that are not part of the training population from different years (and locations) in the breeding program is a more realistic assessment of practical accuracy. In this case we have achieved accuracies ranging from 0.02 to 0.43 depending on which validation set we use. It is encouraging that the accuracies for the 2022 training population predicting lines from 2019 and 2021 were 0.43 and 0.40. So, it is possible that our predictions are getting better as we add more genotype and phenotype data from relevant germplasm.

Our field screening has been very successful over the past two years with both of our locations (St. Paul and Crookston) producing disease and DON levels that are useful for selection. In 2021, 269 of 413 (65%) lines from first year testing evaluated for DON had lower levels compared to ND-Genesis. In 2022, 262 of 297 (88%) lines from first year testing evaluated for DON had lower levels compared to ND-Genesis.

Objective 3. *Advance lines to regional testing and industry evaluation that are candidates for new cultivar releases*.

One of our advanced line (S2M184) was rated satisfactory for a second time in AMBA pilot testing with the 2021 crop. It has lower 20% DON compared to ND Genesis and is earlier, shorter and has better straw strength. It is now being considered for plant scale testing and we are increasing seed for possible release.

c) List key outcomes or other achievements.

Objective 1. *Create new breeding populations by crossing parents that carry resistance to FHB and other desirable traits*

These activities maintain the steady flow of breeding lines created and advanced to field trials, marker genotyping, and FHB field screening to improve resistance to FHB and reduce DON levels in grain.

Objective 2. *Conduct selection for FHB resistance and lower DON concentration in segregating breeding populations using genetic markers and field screening.*

We successfully met our target of generating new first year breeding lines for evaluation and evaluating advanced breeding lines for industry evaluation and consideration as new variety candidates.

Objective 3. *Advance lines to regional testing and industry evaluation that are candidates for new cultivar releases.*

One line that was advanced from AMBA Pilot testing to consideration for Plant Scale testing has lower DON and better agronomic performance compared to ND-Genesis. All of the advanced lines that we submit to the AMBA Quality Evaluation Program have lower DON compared to ND Genesis which is the dominant variety planted in our region.

3. **What opportunities for training and professional development has the project provided?**
We trained one MS student who studied the relationship between DON accumulation in kernels and hulls in a naked barley association mapping panel. His stipend and tuition and student labor were supported by another source, but the research was conducted in a USWBSI supported disease nursery.

4. **How have the results been disseminated to communities of interest?**
Every March we submit a research progress report to the American Malting Barley Association. This report is made available to AMBA members from the malting and brewing industries. We also submit annual reports (this report) to the USDA USWBSI. We have submitted several short reports and abstracts for inclusion in the annual FHB Forum proceedings. Every year I present the status of varieties and progress in the breeding program at field days each year in Crookston and St. Paul, MN. I presented a talk at the combined North American Barley Researchers Workshop and Barley Improvement Conference in 2022. I presented information on our winter barley program and the potential for winter barley production to reduce DON contamination at a growers meeting in 2023. I discussed similar topics on a webinar sponsored by the Practical Farmers of Iowa in 2022. I meet each year with individuals from Rahr Malting to discuss recent progress in breeding and the status of FHB resistance in varieties. I presented information about winter barley and FHB resistance at a virtual conference sponsored by Albert Lea Seeds in 2022.

Project 2: Optimizing Parent Combinations to Improve FHB/DON Resistance in Barley

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1. **What are the major goals and objectives of the research project?**
   The major goal was to directly compare the performance, in our breeding program, of those breeding lines that trace back to crosses informed by a new cross selection procedure (PopVar) to those breeding lines from cross combinations designed conventionally (Breeder).

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 simulated crosses among a subset of parents in our 2020 crossing block and predicted their performance for multiple traits including DON. We made 16 crosses informed by PopVar predictions and 15 crosses selected the Breeder conventionally. The progeny of these crosses were advanced in our regular breeding program treated the same way. We tracked the progress of these progeny tracking their origin (PopVar or Breeder). From the Breeder and PopVar strategies 40 and 15 lines, respectively, were advanced to first year yield trials in 2022. Of these lines from the Breeder and PopVar strategies 3 and 2 lines, respectively, were advanced to second year yield trials in 2023.

   b) **What were the significant results?**
   The average performance for DON in the Breeder and PopVar lines in 2022 was 10.3 ppm and 5.2 ppm, respectively. This compares to 15.6 ppm for ND-Genesis.

   c) **List key outcomes or other achievements.**
   Our initial results are somewhat mixed in terms of the number of lines advanced by each strategy and the performance. We will continue to track these lines into trials in 2023 and 2024. Additionally, we have crosses created using the same strategy that were initiated in 2021 and 2022 and we will evaluate the performance of those crosses as the data becomes available.

3. **What opportunities for training and professional development has the project provided?**
   None

4. **How have the results been disseminated to communities of interest?**
   All of our raw data is uploaded to the public database, T3 Barley, and is freely available to researchers. As this work takes at least three to four years to evaluate the effectiveness of these breeding strategies in a single breeding cycle, we will wait for additional data before presenting results.

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?

X 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).

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:

Smith, K. P 2022. Winter Barley: A New Crop for Minnesota Farmers. 2022 Oats, Barley & Forages Day, A Virtual Conference from Albert Lea Seed Feb 3, 2022.

Smith, K.P. 2022. Practical Farmers of Iowa Shared Learning Call – Winter Barley, Online, Sept 2, 2022.

Smith, K.P. 2022. Frozen Promise: Toward winter barley for the Bold North. North American Barley Researchers Workshop, Davis, CA, Sept 22-24, 2022

Smith, K.P. 2022. Shedding deoxynivalenol with naked barley. North American Barley Researchers Workshop, Davis, CA, Sept 22-24, 2022

Smith, K.P. 2022. Barley Research Update, Northwest Research and Outreach Center's (NWROC) annual Crops and Soils Day, July 20, 2022

Smith, K.P. 2021 Barley U. Field Day on the University of Minnesota Saint Paul Campus, June 28, 2022.

Smith, K.P. 2021. Hulless Barley: Naked But Not Afraid, Northwest Research and Outreach Center's (NWROC) annual Crops and Soils Day, July 21, 2021

Smith, K.P. 2021 Barley U. Field Day on the University of Minnesota Saint Paul Campus, July 1, 2021.

Minnesota Agriculture Experiment Station

Barley. Varietal Trials Results. MAES 2021
Barley. Varietal Trials Results. MAES 2022

Conference Abstracts

John Hawkins and Kevin Smith. (2021). Exploring Variation for FHB Resistance and Toxin Mitigation in Naked Barley. Proceedings of the 2021 National Fusarium Head Blight Forum; Virtual. December 6-7, 2021. Retrieved from: https://scabusa.org/forum/2021/2021NFHBForumProceedings.pdf

Kevin P. Smith, Ed Schiefelbein, Guillermo Velasquez and Yanhong Dong. (2022). Reducing DON Concentration with Naked Barley. Proceedings of the 2022 National Fusarium Head Blight Forum; December 4-6, 2022, Tampa FL. Retrieved from: https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf