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

FY22 Performance Progress Report

Due date: July 26, 2023

Cover Page

USDA-ARS Agreement ID:	59-0206-2-147
USDA-ARS Agreement Title:	Genetic Enhancement of Fusarium Head Blight (FHB) Resistance in Barley
Principle Investigator (PI):	Brian Steffenson
Institution:	University of Minnesota
Institution UEI:	KABJZBBJ4B54
Fiscal Year:	2022
FY22 USDA-ARS Award Amount:	$50,206
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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
BAR-CP	Development of a Multi-parent Population to Enhance FHB Resistance in Barley	$50,206
	FY22 Total ARS Award Amount	$50,206

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.

July 26, 2023

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 a Multi-parent Population to Enhance FHB Resistance in Barley

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

The overall long-term goal of this research is to facilitate the development of barley cultivars with resistance to FHB and the accumulation of mycotoxins, such as DON. Our proposal directly addresses the primary mission of the USWBSI "to enhance food safety and supply by reducing the impact of FHB on wheat and barley." The specific goals for this research within the four-year timeframe are to: 1) develop a Multi-parent Advanced Generation Intercrosses (MAGIC) population using the most resistant barley accessions possessing unique haplotypes at characterized FHB/DON loci; 2) phenotype the MAGIC population for reaction to FHB and DON accumulation in multiple environments; 3) genotype the MAGIC population with SNP markers and perform QTL analyses to identify and map alleles conferring resistance to FHB and DON accumulation; and 4) identify progeny with enhanced resistance and distribute them to barley breeders. Within the Barley Coordinated Project, our proposal aligns closely with Objective 3 (Evaluate and implement modern breeding technologies to further enhance short term and long-term improvement of FHB resistance in barley, and to efficiently introgress effective resistance genes into barley germplasm) under the Research Area of Variety Development and Host Resistance (VDHR), but is also an important step in advancing Objective 2 (Increase efficiency of coordinated barley breeding programs to develop and release FHB resistant varieties) within VDHR.

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?
b) What were the significant results?
c) List key outcomes or other achievements.

Objective 1 activities: Preliminary data collected for this project involved the evaluation of over 25,000 *Hordeum* accessions for FHB resistance in the field over the course of our long-term USWBSI-funded research. From this extensive field screening effort, we identified about 230 two-rowed accessions (the type now preferred by the malting and brewing industries) that exhibited a moderate to high level of resistance. To fully validate the resistance of these selections and rigorously assay DON accumulation, we evaluated the lines together in head-to-head trials in up to 10 environments (i.e. unique location-year combinations) over the past six years at Crookston and St. Paul, Minnesota. Twenty-one of the best performing accessions from this group were then selected as candidate parents. The criteria used for selecting these 21 lines was as follows in order of priority: i) lowest DON level; ii) lowest FHB severity; iii) heading date within a few days of standard barley cultivars; iv) height within about 10 cm of standard barley cultivars; v) genetic diversity as revealed through principal component analysis; and vi) improvement status (i.e. breeding lines over unadapted landraces). All 21 candidates exhibited DON levels that were >3.0 ppm lower than the moderately resistant six-rowed malting cultivar 'Quest' released by the University of Minnesota. Within this group of candidates, four are from North America, seven are from Europe, two are from Africa, and the final eight are progeny

selections derived from crosses between various FHB-resistant landrace or wild barley (*Hordeum vulgare* ssp. *spontaneum*) accessions and malting barley cultivars. One additional candidate under consideration is an advanced two-rowed malting barley from the Minnesota breeding program.

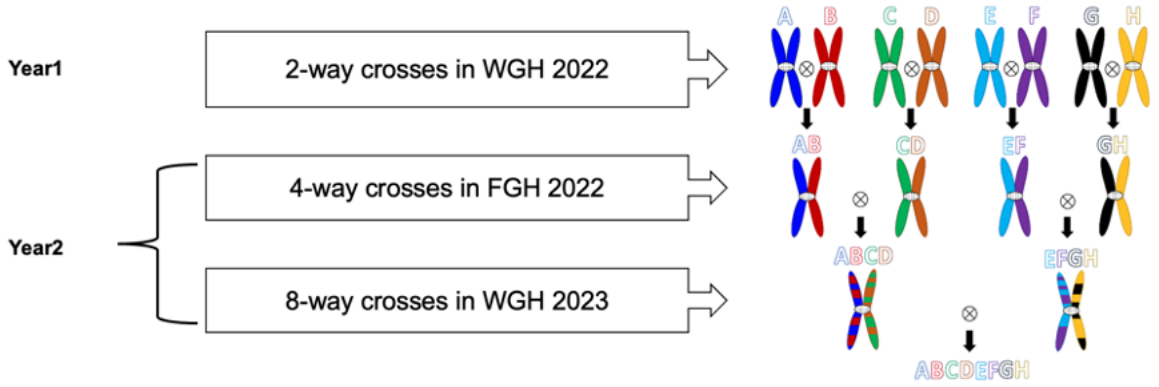
We recently completed an extensive meta-analysis of the genetics of FHB resistance and DON accumulation in barley based on 11 mapping populations and two germplasm panels (Sallam et al. 2023). Haplotypes at each identified QTL from this meta-analysis were characterized in the 21 founder candidates to aid in the selection of the final 8 parents for MAGIC population development (Page et al. 2022). The final eight parents selected for this population and their origins are given in Table 1. Two (S2M184, an advanced Minnesota breeding line and AC Minoa, a cultivar released by Agriculture and Agri-Food Canada) of the eight founder parents selected for the population are adapted cultivars and will therefore increase the chances of identifying agronomically advanced progeny with low FHB severity and DON levels.

Table 1. Final eight founder parents selected for development of MAGIC population.

Accession	Origin
S42IL_170	Backcross line from Scarlett/ISR42-8 (wild barley from Israel)
AC_MINOA	Cultivar from Agriculture and Agri-Food Canada
KTYQST_53_4	Backcross line from Quest/Kutaya (Netherlands)
PI_356118	Landrace from Ethiopia
HSR_31C	Backcross line from Rasmusson/PI466423 (wild barley from Israel)
VIR_18426	Landrace from Romania
2ND29827	Breeding line from North Dakota State University
S2M184	Breeding line from University of Minnesota

Objective 1 results: To develop the MAGIC population, F_1's were generated from inter-crosses with eight selected founder parents (i.e. A, B, C, D, E, F, G, and H) during the 2022 winter greenhouse season (Figure 1). Next, F_1's from these initial crosses (A×B; C×D; E×F; and G×H) were used in four-way inter-crosses (AB×CD and EF×GH) during the 2022 fall greenhouse season. The eight-way inter-crossing of parent pairs (ABCD×EFGH) were done during the 2023 winter greenhouse season. Due to the late spring harvest of crossed seed from the eight-way

Figure 1. The scheme and timeline for development of a MAGIC population to enhance resistance to FHB and DON accumulation in barley. Displayed is only one of seven barley chromosomes.



intercrosses, we were not able to increase F_1 seeds from the eight-way inter-cross in the spring. Instead, F_1 seeds will be selfed during the 2023 Fall greenhouse season to produce F_2 seed. Selfing to the F_3 generation will done in the 2024 Winter greenhouse season. Preliminary evaluation of the population will be done in Crookston in the summer of 2024 to discard lines that are late in their maturity.

Objective 1 key outcomes or other achievements: We successfully developed a MAGIC population by intercrossing eight founder accessions possessing unique alleles conferring the highest level of resistance to FHB and DON accumulation. We successfully obtained 1,076 F_1 seeds from the eight-way crosses. This number exceeds the 800-1000 progeny we initially stated we would obtain in our proposal; however, we anticipate that some progeny will be eliminated due to poor plant growth or very late maturity. In the end, we expect to advance about 1000 progeny for genotyping and phenotyping in 2025.

Research on objectives 2, 3 and 4 will commence once the MAGIC population is selfed to the F_5 generation.

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

This USWBSI-funded research has provided an excellent training opportunity for many scientists over the past few years. The basis for the current research project was part of the Ph.D. thesis of my graduate student Rae Page who submitted her dissertation entitled "Genetics of Fusarium head blight resistance in barley and of rust resistance in the wild wheat relative *Aegilops longissima*" in May 2023. Other participants in this research included post-doctoral research associates Ahmad Sallam, Eric Nazareno, and Oadi Matny; Researcher 2 scientist Tamas Szinyei; Researcher 3 scientist James Nesbit; and Ph.D. student Yoonjung Lee. Undergraduate students assisting on this project in various capacities include Emma Leff, Annie Russell-Pribnow, and Arno Swart. All of these individuals were trained in the methodology for working with FHB, including production and storage of inoculum; inoculation techniques; disease severity scoring; and DON analyses. Moreover, several members of my senior research team gained valuable experience in SNP genotyping, molecular map construction and QTL analysis.

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

A portion of this research project is part of Rae Page's Ph.D. thesis. She presented her research at several venues listed below, including the USWBSI Forum. She also completed her dissertation in May 2023. Another key research publication was on meta-analysis of the genetics of resistance to Fusarium head blight in barley and considerations for breeding. This was a summary of more than 18 years of genetic studies and formed the basis for the haplotype analyses that ultimately contributed to the selectio of the eight final parents of the MAGIC population.

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).

Sallam, A. H., Haas, M., Huang, Y., Tandukar, Z., Muehlbauer, M., Smith, K., and Steffenson, B. J. 2023. Meta-analysis of the genetics of resistance to Fusarium head blight in barley and considerations for breeding. Plant Breed. 142.
Status: In press, Acknowledgement of 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.

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).

Page. R. 2023. Genetics of Fusarium head blight resistance in barley and of rust resistance in the wild wheat relative *Aegilops longissima*. Ph.D. dissertation. University of Minnesota, Saint Paul. 215 pp.
Status: Published
Acknowledgement of federal support: YES

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.

R. Page, A.H. Sallam, T. Szinyei, O. Matny, J. Wodarek, B. Steffenson. 2022. Development of a multi-parent population to enhance FHB resistance in barley. 23rd North American Barley Researchers Workshop & 43rd Barley Improvement Conference. Presentation; 9/27/2022. Davis, CA, USA.
Status: Published. Acknowledgement of Federal Support: YES

Page, R., Sallam, A. H., Szinyei, T., Matny, O., Wodarek, J., and Steffenson, B. J. (2022). A MAGIC touch: Developing a population to enhance FHB resistance in barley. Proceedings of the 2022 National Fusarium Head Blight Forum; Tampa, FL. December 4-6, 2022. Retrieved from: https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf
Status: Published. Acknowledgement of Federal Support: YES