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

FY21 FINAL Performance Progress Report

Due date: July 26, 2023

Cover Page

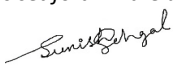
USDA-ARS Agreement ID:	59-0206-0-117
USDA-ARS Agreement Title:	Winter Wheat Breeding for Scab Resistance in South Dakota
Principle Investigator (PI):	Sunish Sehgal
Institution:	South Dakota State University
Institution UEI:	DNZNC466DGR7
Fiscal Year:	2021
FY21 USDA-ARS Award Amount:	$140,466
PI Mailing Address:	South Dakota State University, Plant Science Department 2380 Research Parkway, 1113B Seed Technology Brookings, SD 57006-1096
PI E-mail:	sunish.sehgal@sdstate.edu
PI Phone:	605-688-5709
Period of Performance:	5/6/21 - 5/5/23
Reporting Period End Date:	5/4/2023

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
HWW-CP	Developing Winter Wheat Varieties with Enhanced Resistance to FHB and low DON	$95,453
HWW-CP	Innovated Selection Plan to Improve the FHB Resistance of Hard Winter Wheat	$6,985
GDER	EMS Mutagenized Populations for Characterization of Resistance to FHB in Wheat	$38,028
	FY21 Total ARS Award Amount	$140,466

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.



7/25/2023

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: Developing Winter Wheat Varieties with Enhanced Resistance to FHB and low DON

---

1. **What are the major goals and objectives of the research project?**
   The major goal of this project was to successfully address USWBSI – HWW-CP priorities, which are to develop high-yielding and high-quality hard winter wheat varieties with improved resistance to FHB and lower DON content. The specific objectives of this proposal are (1a) Increase the efficiency of coordinated project breeding programs to develop and release FHB resistant varieties, (1b) Test and evaluate regional germplasm to include breeding lines from the public and private breeding programs in mist-irrigated field nurseries, (2) Enhance selection efficiency through technologies such as genomic selection, marker-assisted selection, doubled haploid production, leading to pyramiding of major and minor genes for FHB resistance.

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?**
   1. Evaluate Hard Winter Wheat (HWW) cultivars from the region, advanced breeding lines, and germplasm in the mist-irrigated inoculated FHB nursery. Utilization of FHB resistant genotypes as parents in crosses and advance most resistant breeding lines with the lowest disease index, FDK, and DON content.
   2. Participation in multi-location regional screening under the mist-irrigated inoculated FHB nursery (i.e. Regional HWW FHB Nursery).
   3. Marker-assisted selection to enhance FHB resistance in SD germplasm.

   b) **What were the significant results?**
   1.Data was collected on 46 Elite, 126 Advanced Yield Trial entries from the SDSU winter wheat breeding program in mist irrigated FHB nurseries. Four advanced breeding lines performed well in the state trials and ranked among the top 10 in Northern Regional Performance Nursery (NRPN).
   2.The FHB disease ratings on regional germplasm in the Northern Hard Winter Wheat FHB Public and Private Nurseries and South Dakota CPT is made available to South Dakota producers, and colleagues at other participating institutions and private industries.
   3.Crosses were made specifically for FHB resistance and marker-assisted backcrosses were advanced BC_1F_3 made to incorporate *Fhb1* into the South Dakota germplasm and combine with native FHB resistance.

   During the extension period a module for FDK evaluation using NIR based seed sorter was developed in collaboration with Qualysense. More than 6,000 single kernels were imaged and NIR spectra collected. Convolutional Neural Network (CNN) was used to develop Image based model and partial least squares (PLS) regression was used to develop NIR based model. Wheat Analyzer Module (combined module Vision + NIR) achieved maximum prediction accuracy, (average R^2 = 0.84) followed by Vision module

(average R^2=0.82) and NIR module (average R^2 =0.77). The independent validation accuracies ranged from 0.52 to 0.69.

c) List key outcomes or other achievements.

The major outcome was the release of 'SD Midland' hard red winter wheat for central and western South Dakota. SD Midland is semi-dwarf wheat (RhtD1b) and is expected to offer the producers a higher-yielding winter wheat variety with excellent milling and baking characteristics. It has an average tolerance to FHB. Further NIR based Seed Sorter module was developed to evaluate FDK.

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

Three graduate students Jinfeng Zhang, Subash Thapa, and Anshul Rana (partially supported by the project), and two undergraduate students got hands-on training/experience in day-to-day operations of the breeding program and FHB screening nursery during this period. Additionally, students assisted with collecting Fusarium damaged kernel (FDK) scores and helped in the preparation of samples for DON analysis.

Subash presented his work at the 2022 National FHB Forum.

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

FHB resistance ratings collected on released cultivars are made available to growers as a part of the annual South Dakota Crop Performance Testing Hard Winter Wheat report. Additionally, data collected from Northern Hard Winter Wheat FHB Public and Private Nurseries is shared with colleagues from both public and private breeding programs. The results from this project were shared through field days and articles in appropriate popular press sources, word of mouth, Twitter, brochures, and Extension press releases from the Agricultural Experiment Station.

Project 2: Innovated Selection Plan to Improve the FHB Resistance of Hard Winter Wheat

---

1. **What are the major goals and objectives of the research project?**
   Our goal is to develop HWW cultivars that are resistant to FHB and accumulate reduced levels of DON following infection. Specifically, we will address the following objectives and associated research activities: 1. Increase efficiency of coordinated project breeding programs to develop and release FHB resistant varieties; and Objective 2, associated activity 2. Enhance selection efficiency through technologies such as genomic selection, marker-assisted selection, doubled haploid production, and/or high throughput phenotyping leading to pyramiding of major and minor genes for FHB resistance.

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

   a) **What were the major activities?**
   200 lines from South Dakota were phenotyped both in Ohio (Dr. Clay Sneller) and South Dakota in 2020 and 2021. Data was analyzed and published.

   b) **What were the significant results?**
   Genomic prediction (GP) using data from multiple years from South Dakota evaluations showed promise. We observed a moderate PA using univariate models for DIS (0.39 and 0.35) and FDK (0.35 and 0.37) using TP19 and TP20, respectively, while slightly higher PA was observed (0.41 for DIS and 0.38 for FDK) when TP19 and TP20 (TP19 + 20) were combined to leverage the advantage of a large training population. Although GP with a multivariate approach including plant height and days to heading as covariates did not significantly improve PA for DIS and FDK over univariate models, the PA for DON increased by 20% using DIS, FDK, DTH (days to heading) as covariates using multi-trait model in 2020. Finally, we used TP19, TP20, and TP19 + 20 in forward prediction to calculate genomic-estimated breeding values (GEBVs) for DIS and FDK in preliminary breeding lines at an early stage of the breeding program. We observed moderate PA of up to 0.59 for DIS and 0.54 for FDK, demonstrating the promise in genomic prediction for FHB resistance in earlier stages using advanced lines.

   Further, we conducted a multi-locus genome-wide association study (ML-GWAS) with 9,321 high-quality single nucleotide polymorphisms (SNPs) covering all 21 wheat chromosomes. A total of six distinct MTAs were identified for the FHB disease index (DIS) on five different chromosomes including 2A, 2B, 3B, 4B, and 7A. Further, eight MTAs were identified for Fusarium damaged kernels (FDK) on six chromosomes 3B, 5A, 6B, 6D, 7A, and 7B. Out of the 14 significant MTAs, ten were found in previously reported regions for FHB resistance in different wheat classes and were validated in HWW while four MTAs represent likely novel loci for FHB resistance. The additive effect of favorable alleles of the identified MTAs was significant as the combination of these alleles resulted in lower mean DIS and FDK scores.

c) List key outcomes or other achievements.
Genomic prediction for FHB traits like DON and FDK can facilitate the rejection of highly susceptible materials at an early stage in a breeding program. Several QTLs for FHB resistance were identified in HWW breeding materials. Two manuscripts were published from these studies.

2. What opportunities for training and professional development has the project provided?
Two graduate students Jinfeng Zhang and Subash Thapa and another graduate student Harsimardeep Gill (not supported by this grant) got hands-on training in genomic data analysis and genomic prediction.

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

The results from this project were shared through field days and research articles, Twitter, brochures, and Extension press releases from the Agricultural Experiment Station.

Project 3: EMS Mutagenized Populations for Characterization of Resistance to FHB in Wheat

---

1. **What are the major goals and objectives of the research project?**
   The goals of the project are 1) to develop and evaluate EMS mutagenized M2 derived M4 lines in spring wheat cultivars for finding resistance against FHB, 2) to develop a TILLING resource for characterization of genes that could play a role in FHB resistance.

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?
   We developed EMS mutagenized populations in two wheat cultivars RB07 (MR) and Berkut (S) to identify FHB-resistant and susceptibility mutants. Further, we are developing a TILLING resource for these two wheat cultivars.

   e) What were the significant results?
   In 2021-22, we have developed M_3 population in Berkut 800 lines and RB07 population of 493 M4 lines. Leaf tissues from M_2 plants from both populations were collected to develop TILLING pools.

   f) List key outcomes or other achievements.
   Mutation populations have been developed. The seed increase will be followed by FHB screening.

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

   One graduate student (Anshul Rana) got hands-on training in mutagenesis and FHB screening.

4. **How have the results been disseminated to communities of interest?**
   The results from this project were shared through field days and poster presentations and social media.

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.

Zhang J, Gill H, Brar N, Halder J, Ali S, Liu X, Bernardo AE, St Amand PC, Bai G, Turnipseed B, Sehgal S. Genomic prediction of Fusarium head blight resistance in early stages using advanced breeding lines in hard winter wheat. The Crop Journal. 2022 Mar 25;1. DOI: https://doi.org/10.1016/j.cj.2022.03.010
Acknowledgment of federal support: Yes

Zhang J, Gill HS, Halder J, Brar NK, Ali S, Bernardo A, Amand PS, Bai G, Turnipseed B, Sehgal SK. Multi-Locus Genome-Wide Association Studies to Characterize Fusarium Head Blight (FHB) Resistance in Hard Winter Wheat. Frontiers in Plant Science. 2022 Jul 25;13:946700. DOI: https://doi.org/10.3389/fpls.2022.946700
Acknowledgment 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.

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.

Gill, H. S., Zhang, J., Brar, N., Halder, J., ... and Sehgal S. K. (2022). Genomic prediction to improve FHB resistance in winter wheat. Proceedings of the 2022 National Fusarium Head Blight Forum; Tampa, FL. December 4-6, 202. Retrieved from: https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf
Acknowledgment of Federal Support: Yes

Rana, A., Halder, J., Zhang, J., Thapa, S., Gill, H., ... and Sehgal S. K. (2022). Artificial Intelligence-based Detection and Sorting of Fusarium Damaged Kernels in Wheat and Implications for FHB Resistance Breeding. Proceedings of the 2022 National Fusarium Head Blight Forum; Tampa, FL. December 4-6, 202. Retrieved from: https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf
Acknowledgment of Federal Support: Yes