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

FY22 Performance Progress Report

Due date: July 26, 2023

Cover Page

USDA-ARS Agreement ID:	59-0206-2-153
USDA-ARS Agreement Title:	Breeding for Scab Resistance in Winter Small Grains for South Dakota
Principle Investigator (PI):	Sunish Sehgal
Institution:	South Dakota State University
Institution UEI:	DNZNC466DGR7
Fiscal Year:	2022
FY22 USDA-ARS Award Amount:	$127,699
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:	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
DUR-CP	Developing FHB Resistant Winter Durum to Increase Crop Diversity in US Great Plains	$22,079
HWW-CP	Developing Winter Wheat Varieties with Enhanced Resistance to FHB for South Dakota	$105,620
	FY22 Total ARS Award Amount	$127,699

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.

Sunish Sehgal

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 FHB Resistant Winter Durum to Increase Crop Diversity in US Great Plains

---

1. **What are the major goals and objectives of the research project?**
   The major goal of our project is to develop winter durum varieties and germplasm. The specific objectives are to 1) Evaluate winter durum germplasm and lines in preliminary observation trials for FHB resistance and advance superior lines for variety development; (2) introgress FHB resistance into elite winter durum adapted to the US Great Plains.

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?**
   In the first year of the project winter durum germplasm (18 lines) was evaluated in the field FHB nursery. More than 50 new crosses were developed among elite lines in 2022-23 and new populations were advanced to the next generation. The FHB resistance sources 10Ae564, 15En279, 15En88 (spring durum) were received from Dr. Steven Xu on 10/8/2022 and the crosses have been made with a couple (elite winter durum) lines for introgression. More than 100 durum breeding lines were evaluated in an early observation trial (EOT) and eight new winter durum lines were advanced to Preliminary yield trials (PYT) in 2023.

   b) **What were the significant results?**
   The winter durum germplasm evaluated in FHB nursery showed high incidence and the disease severity ranged from 30% to 85%. The FDK in the samples ranged from 65-100% suggesting that durum is very highly susceptible to FHB therefore development of resistant varieties is essential for the success of winter durum.
   Forty-two new breeding populations have been developed. Eight new winter durum lines have reached the Preliminary Yield Trial (PYT) stage in 2023 and are being evaluated in two locations.

   c) **List key outcomes or other achievements.**
   In the first year of the project eight new winter durum lines have reached the Preliminary Yield Trial stage.

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

   One post-doctoral research associate (Dr. Joytirmoy Halder) participated in the USWBSI 2022 FHB forum.

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

   The results from this project were shared through field days and social media.

Project 2: Developing Winter Wheat Varieties with Enhanced Resistance to FHB for South Dakota

---

1. **What are the major goals and objectives of the research project?**
   Our primary goal is to develop and release new superior winter wheat varieties with enhanced resistance to FHB and reducing fungal mycotoxins, primarily deoxynivalenol (DON) to limit the loss of grain yield and quality. The specific objectives of this proposal are 1) to develop FHB-resistant and low DON winter wheat varieties for South Dakota and surrounding regions; (2) pyramiding major and minor genes for FHB resistance by developing and implementing phenotypic and genomic selection models for SDSU winter wheat program.

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?**
   More than 120 crosses were performed to combine FHB resistance including Fhb1, Fhb6, and native sources of resistance to FHB into South Dakota breeding materials, more than 90% of the crosses (110) had successful seed set. Nearly 80 populations were advanced $F_{2:3}$ using speed breeding of mini bulks and 50 $F_{2:4}$ mini bulk from the last season are being selected in the field.

   Breeding lines and released cultivars from other public and private breeding programs were evaluated in a locally grown mist-irrigated and inoculated FHB field nursery. These nurseries include the South Dakota Crop Performance Testing nursery (CPT), Hard Winter Wheat FHB nursery (Public and Private), Northern Regional Performance Nursery (NRPN), Southern Regional Performance Nursery (SRPN), and a private FHB Nursery. Crop Performance trials (with and without fungicides at Brookings) were conducted to determine the impact FHB on different varieties and elite lines.

   Genome-wide association and evaluation of genome-wide selection models was performed along with the development of high throughput phenotyping-based machine learning models for FHB using RGB/NIR/hyperspectral imaging, for disease incidence, FDK, and DON content.

   b) **What were the significant results?**
   Data was collected on 46 Elite, 120 Advanced Yield Trial entries from the SDSU winter wheat breeding program in mist-irrigated FHB nurseries. **Six** SDSU advanced breeding lines ranked among the top 10 in Northern Regional Performance Nursery (NRPN) and **four** advanced breeding lines ranked in the top 10 in the SD State Variety Trials.

   The FHB disease ratings on regional germplasm in the Northern Hard Winter Wheat FHB Public and Private Nurseries and South Dakota CPT are made available to South Dakota producers, and colleagues at other participating institutions and private industries.

Genome-wide association studies identified six native QTLs for FHB disease index (DIS) and eight for Fusarium-damaged kernels (FDK). These QTLs will be validated and evaluated in genome-wide selection models. The genomic selection models were further evaluated in the program.

We evaluated 242 advanced breeding lines from the SDSU wheat breeding program for DON content and subjected to hyperspectral imaging. Three different conventional machine learning models (viz., PLSR, RFR, and SVR) and two deep learning models (CNN with 1D, 2D, and 3D convolutions and DNN) were evaluated on the training (70%) and test (30%) sets to determine the most efficient model based on accuracy with the coefficient of determination in prediction (R^2) and root mean squared error (RMSE) and relative root mean squared error (RRMSE). PLSR among the conventional ML models (with R^2 P=0.88 and R^2 P=0.90, respectively) and 1D-CNN among the DL-based models (with R^2 P=0.90 and R^2 P=0.96, respectively) achieved the highest prediction accuracies with both the original and augmented datasets.

c) List key outcomes or other achievements.

SD Midland, a new HRW was released in 2021. It had good stripe rust resistance with average FHB tolerance. It was rated excellent for milling and baking quality and won 'Best of Show' miller's choice award at the 2022 Wheat Quality Council meetings.

Advanced breeding line SD18B025-8 (HRW) ranked overall 3 in the state trials in 2022 and 4th in the 2022 NRPN trials demonstrating excellent yield potential. It has a good resistance package for rust and an average tolerance for FHB. SD18B025-8 was rated excellent for milling and baking quality and won the miller's choice 'Best of Show' award at 2023 Wheat Quality Council meetings. If it performs well in 2023 it is expected to be released in fall 2023.

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

Two graduate students Subash Thapa and Harsimardeep Gill 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. Two postdoctoral researchers, Dr. Joytimoy Halder and Dr. Dinesh Saini also got training in hyperspectral, NIR spectroscopy, and machine learning. Additionally, students assisted with collecting Fusarium damaged kernel (FDK) scores and helped in the preparation of samples for DON analysis.
Subash, Harsimardeep, Dinesh, and Jyotirmoy presented her work at the 2022 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

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.

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

Acknowledgment 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).

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.

Saini DK, Rana A, Maimaitijiang M, Halder J, Zhang J, Thapa S, Ali S, Glover K, Sehgal S.K.*Prediction of DON Content in Wheat Flour Using Close-Range Hyperspectral Imaging Coupled with Machine and Deep Learning Approaches* USWBSI National Fusarium Head Blight Forum, published https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf , 2022 USWBSI National FHB Forum, December 4-6, 2022
Acknowledgment of Federal Support: Yes

Thapa S, Maimaitijiang M, Kaushal S, Halder J, Rana A, Nafchi A, Ali S, Sehgal S.K. Estimating FHB Infection Level in Winter Wheat Spikes using High-Resolution Imaging and Deep Transfer Learning. USWBSI National Fusarium Head Blight Forum, published https://scabusa.org/forum/2022/2022NFHBForumProceedings.pdf , 2022 USWBSI National FHB Forum, December 4-6, 2022
Acknowledgment of Federal Support: Yes