USDA-ARS
U.S. Wheat and Barley Scab Initiative
FY17 Final Performance Report – NCE for FY18
Due date: July 12, 2019

Cover Page

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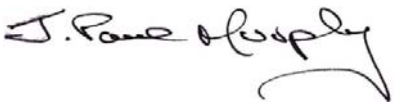
Fiscal Year:	2017 (NCE for FY18)
USDA-ARS Agreement ID:	59-0206-4-031
USDA-ARS Agreement Title:	Development of Wheat with Resistance to Scab Adapted to the Mid-Atlantic.
FY17 USDA-ARS Award Amount:	$ 101,012
Recipient Organization:	North Carolina State University Office of Contracts & Grants Box 7214 Raleigh, NC 27695-7214
DUNS Number:	04-209-2122
EIN:	56-6000756
Recipient Identifying Number or Account Number:	558515
Project/Grant Reporting Period:	6/16/18 - 6/15/19
Reporting Period End Date:	06/15/19

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-SWW	Enhancement of Fusarium Head Blight Resistance in the Southeastern U.S. Germplasm.	$ 62,882
VDHR-SWW	Developing Double Haploids to Expedite Variety Development in SRWW.	$ 9,431
VDHR-SWW	Bioinformatics Support for Genomic Selection in the Southeastern Soft Wheat Region.	$ 28,699
	FY17 Total ARS Award Amount	$ 101,012



July 10, 2019
Principal Investigator Date

* MGMT – FHB Management
FST – Food Safety & Toxicology
GDER – Gene Discovery & Engineering Resistance
PBG – Pathogen Biology & Genetics
EC-HQ – Executive Committee-Headquarters
BAR-CP – Barley Coordinated Project
DUR-CP – Durum Coordinated Project
HWW-CP – Hard Winter Wheat Coordinated Project
VDHR – Variety Development & Uniform Nurseries – Sub categories are below:
SPR – Spring Wheat Region
NWW – Northern Soft Winter Wheat Region
SWW – Southern Soft Red Winter Wheat Region

Project 1: *Enhancement of Fusarium Head Blight Resistance in the Southeastern U.S. Germplasm.*

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

1) Increase and document acreage seeded to varieties with improved FHB resistance to increase grain yield and grain quality and reduce DON in the US grain supply.

2) Increase efficiency of coordinated project breeding programs to develop and release FHB resistant varieties.

3) Implement new breeding technologies and germplasm to further enhance short term and long term improvement of FHB resistance and to efficiently introgress effective resistance genes into breeding germplasm.

2. What was accomplished under these goals?

Objective 1.

1) Major activities: Five hundred ninety three F_2 and F_3 bulks (combined) were advanced during 2018-19 utilizing mass selection. Almost all crosses contained one or more parents exhibiting moderate FHB resistance. Approximately 30,000 headrows in the F_4, F_5 and F_6 generations (combined) were selected using the pedigree method. The misted/inoculated nursery evaluated five cooperative uniform nurseries (USFHBN, GAWN, SPE, SPL, SUNWHEAT) and in-house advanced lines. Four hundred twenty three new two- and three-way crosses were made and over 95 percent of the crosses had parents with FHB resistance. Eight new crosses entered the doubled haploid program. Approximately 1,200 doubled haploid lines were produced in-house and will enter field evaluation in fall 2019. Approximately 2,400 doubled haploid lines were produced under contract for the University of Georgia, Virginia Tech, Louisiana State University, and University of Arkansas.

2) Specific objectives: evaluated 679 advanced generation, in-house lines, at up to seven locations for overall agronomic superiority, and specifically, FHB resistance. FHB resistance, or lack thereof, trumps all other traits when a line is being considered for advancement in our breeding program.

3) Significant results: All 40 NCSU entries in the SUNPRE Late Uniform Nursery had moderate resistance to FHB and 37 contained known major QTL for scab resistance, including, *Fhb1, Jamestown1B*, *Neuse1A*, *Neuse4A*, *Massey3B* plus Hessian fly, powdery mildew, leaf rust and soil borne virus resistances. The nineteen Advanced generation lines in second year of testing across the state had FHB ratings of 4 or below. Six NCSU entries in the NC Official Variety Test have moderate levels of scab resistance plus overall good agronomic performance.

4) Key outcomes or other achievements; Breeders Seed of three competitive lines with moderate FHB resistance, NC14-20985, NC15-21834 and NC15-21970 produced for possible release in 2020.

Objective 2.

1) Major Activities: Coordinated the Southern Uniform Scab Nursery. Participated in coordinated breeding activities with the six university SUNGRAINS cooperative breeding program.

2) Specific Objectives: The Southern Uniform Scab Nursery evaluated 44 advanced generation lines from five public and two private company breeding programs for resistance to FHB at up to seven locations. I called for entries and distributed seed to cooperators in September 2018. I collated and summarized data and published report on the USWBSI website. Examples of coordinated SUNGRAINS activities included growing early and later generation uniform nurseries, many of which I screened for FHB resistance in an inoculated and misted nursery.

3) Significant results: https://scabusa.org/pdfs_dbupload/suwwsn18_report.pdf . The results of the 2017-18 Southern Uniform Scab Nursery was collected, analyzed and published online at the web address above. A poster and hard copy reports were presented at the December 2018 Scab Forum. The quantification of scab resistance of entries in the SUNGRAINS nurseries impacted the advancement decisions of six university breeding programs. MAS for major FHB QTL and *H13* among $F_{5:7}$, $F_{5:8}$, $F_{5:9}$ and doubled haploid lines greatly enhanced selection efficiency.

4) Key outcomes or other achievements: The Southern Uniform Scab Nursery provides public and private sector breeders with multi-environment evaluations of FHB resistance in advanced generation breeding lines compared with the resistant check varieties.

Objective 3

1) Major activities. Utilized marker assisted selection, genomic selection and doubled haploid technology to increase breeding efficiency in NC and other SUNGRAINS programs. Investigated the genetic control of FHB resistance in NC13-20076. This moderately resistant line contains no known resistance QTL.

2) Specific objectives. In-house evaluation of 489 conventional and doubled haploid lines for major QTL such as *Fhb1*, *Ning 5A*, *Wuhan 2D* and recently identified *Bess 2B*, *Bess 3B*, *NC-Neuse 1A* and *6A*, and *Jamestown 1B* QTL. Initiated another cycle of double haploid development involving 16 SUNGRAINS crosses. Evaluated 200 random DH lines from the cross NC13-20076 x GA06493-13LE6 at three misted and inoculated locations.

3) Significant results. Presence of major QTL was utilized in selection among 489 lines in first year yield testing. Genomic selection predictions correlated with observed data to

investigate the utility of the methodology in wheat breeding in the southeast. PopVar identified optimum crosses to make and checked against what breeders themselves choose.

4) Key outcomes or other achievements. The highest correlations between observed and GS predicted performance was for FHB resistance traits (r= 0.50 (DON), 0.56 (FDK) and 0.59 (Severity). GS could be incorporated in breeding programs for FHB resistance selection. Another set of DH populations are four years ahead along the variety development conveyor belt. Three locations of good data obtained on NC13-20076 mapping population.

Pedigrees of 10 DH populations produced during 2018-19

Parent 1	Parent 2	Parent 1	Parent 2
ARLA06146E-1-4	NC13-20076	NC13-20076	NC13-21213
ARLA06146E-1-4	NC15-21787	NC13-21213	NC14-23372
GA061471-15LE38	NC13-20076	NC14-23372	NC15-21834
Hilliard	NC11331-6	NC14-23372	VA09MAS1-12-8-4
Hilliard	NC15-21787	NC15-21787	VA09MAS1-12-8-4

Pedigrees of nine DH populations to be produced during 2019-20

Parent 1	Parent 2	Parent 1	Parent 2
ARLA06146E-1-4	NC11546-14	NC11546-14	NC113210-58
ARLA06146E-1-4	VATK429-3	NC11546-14	VA16W-202
GA15-MAS23-18LE43	VATK429-3	NC13217-35	NC13210-58
Hilliard	NC13210-58	NC14-20373	NC11546-14
Hilliard	NC11564-14		

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

Primary opportunities for training involved four undergraduate students who worked part-time on the laboratory, greenhouse and field aspects of the DH effort. In addition, five undergraduate students worked in scab nurseries and on post-harvest processing of materials harvested from the scab nurseries.

Paul Murphy and Roshan Acharya (PhD Student) attended the Scab Forum in St Louis in December 2018. Roshan Acharya organized and conducted the NC Uniform Scab Nursery.

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

Results have been disseminated through poster presentations at scientific meetings, scientific journal publications, and presentations to growers and industry representatives in winter 2018 / spring 2019. In addition the Southern Scab Nursery report can be found at this website: https://scabusa.org/pdfs_dbupload/suwwsn18_report.pdf

Project 2: *Developing Double Haploids to Expedite Variety Development in SRWW.*

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

Increase efficiency of individual breeding programs to develop and release FHB resistant varieties through the use of doubled haploid technology. Use of doubled haploid technology for winter wheat reduces the time to develop a variety by approximately four years.

2. What was accomplished under these goals?

DH lines from Heartland Plant Innovations. One hundred forty nine DH lines from VA12W-68 / MDC07026-F2-19-13-4 // Hilliard were evaluated in head rows at Kinston NC. Four were selected for Advancement to the 2020 Observation test.

DH lines from other internal sources. One hundred seventy five doubled haploid lines from seven crosses were evaluated in one replicate yield trials at Kinston and Plymouth, NC. The crosses were: NC8248-14 / MD08-22-22-13-4, NC8248-20 / NC11-22289, NC09-20986 / NC8248-26, NC11-22289 / / MDC07027-12-24 / NC08-140, Jamestown / NC8248-20, NC13-20076 /GA06493-13LE6, NC14-23372 / MDC07026-F2-19-13-3, NC09-20986 / NC11-23321, Hilliard /MD07026-12-30, NC11-23321 / MD08-22-22-13-4 and NC8248-14 / VA12W-54 // MDC07026-F2-19-13-1. Seventy five of these DH lines have been advanced to the 2020 Wheat Preliminary stage with evaluation expanded to six locations in NC. Seventy four percent of lines entering the 2020 Advanced generation test are double haploids.

DH Lines from NCSU DH Production Facility. DH seed from 10 F_1 crosses were planted in head rows in fall 2018. (Table 1). Nine F_1 crosses produced in January 2019 (Table 2) are being pollinated by corn pollen to initiate the doubled haploid process at present.

Pedigrees of 10 DH populations produced during 2018-19

Parent 1	Parent 2
ARLA06146E-1-4	NC13-20076
ARLA06146E-1-4	NC15-21787
GA061471-15LE38	NC13-20076
Hilliard	NC11331-6
Hilliard	NC15-21787

Parent 1	Parent 2
NC13-20076	NC13-21213
NC13-21213	NC14-23372
NC14-23372	NC15-21834
NC14-23372	VA09MAS1-12-8-4
NC15-21787	VA09MAS1-12-8-4

Pedigrees of nine DH populations to be produced during 2019-20

Parent 1	Parent 2
ARLA06146E-1-4	NC11546-14
ARLA06146E-1-4	VATK429-3
GA15-MAS23-18LE43	VATK429-3
Hilliard	NC13210-58
Hilliard	NC11564-14

Parent 1	Parent 2
NC11546-14	NC113210-58
NC11546-14	VA16W-202
NC13217-35	NC13210-58
NC14-20373	NC11546-14

Specific Objectives: To produce DH lines segregating for superior agronomic traits, and the important disease and insect resistances required of cultivars for the southeastern US. Major emphasis is placed on stacking *Fhb1* with lesser effect QTL identified in soft red winter wheat germplasm.

Significant Results: Between 51 and 66 percent of lines in our three, two, and one-year pre-NC Official Variety Test evaluations in 2018-19 were doubled haploid lines (Table 3.). This is revealing because less than five percent of crosses made in our program undergo the doubled haploid procedure. Thus, the better quality pedigrees advancing faster through the doubled haploid approach are yielding competitively, at a higher frequency, than the conventionally bred lines.

Table 3. Percentage of breeding lines that are doubled haploids at three stages of Advanced Generation Yield Testing

Three years pre-OVT	**57**
Two years pre-OVT	**51**
One year pre-OVT	**66**

Key Outcomes and Achievements: sixty six percent of lines entering our Wheat Advanced Test Nursery (one year pre-OVT) are DH lines which have undergone extensive testing across the southeastern US including multi-year FHB resistance evaluations.

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

Primary opportunities for training involve three to four undergraduate students who worked part-time on the laboratory, greenhouse and field aspects of the DH effort.

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

Results have been disseminated to NC growers at field days where we discuss experimental cultivars. In addition over 2,000 DH lines have been shared with cooperators for evaluation, use as parents and selection for release in states other than North Carolina.

Project 3: *Bioinformatics Support for Genomic Selection in the Southeastern Soft Wheat Region.*

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

To develop new breeding technologies (Genomic Selection) to further enhance short term and long term improvement of FHB resistance. Jeanette Lyerly works closely with the Eastern Genotyping Laboratory to coordinate and examine implementation of GS for scab resistance in breeding programs in KY, VA, NC, SC, GA, LA, AR and TX.

What was accomplished under these goals?

1 Major activities: Curate phenotypic data from Uniform Southern Soft Red Winter Wheat Scab Nursery, GAWN, Sunpre-early, Sunpre-late, and SUNWHEAT cooperative nurseries. We coordinated the sequencing pipeline, data curation, updating of training populations, prediction estimation for numerous traits including FDK and DON and investigated various techniques to improve prediction accuracies for 3,165 SUNGRAINS early generation lines. Conducted filtering and imputation steps followed by generation of predictions. Examination of utility of predictions for numerous traits post-harvest. Provided PopVar output for cross predictions. Evaluation of diverse training sets and environments to optimize the GS models for the southern breeding programs and worked closely with collaborators to deliver predictions. Annual updating of training populations. Assist PI's in UK and VA Tech with GS application and R script.

Specific objectives: provided FHB resistance predictions for over 3,000 lines in the NCSU, UK, UGA, LSU and UAR breeding programs. Updated FHB training population with uniform scab nursery data. Provided genomic predictions for entries in the scab nursery and PopVar output for entries in the uniform scab nursery.

Significant results: An FHB model that was developed based on a combination of nursery phenotypic data and genotyping by sequencing has been updated. The predictions provided for the numerous uniform nurseries and hundreds of advanced generation lines is aiding investigations into the potential use of GS in breeding for superior FHB resistance. It will also allow individual project leaders to evaluate the efficacy of GS using this training population for their particular germplasm. Genomic selection predictions correlated with observed data to investigate the utility of the methodology in wheat breeding in the southeast. PopVar identified optimum crosses to make and checked against what breeders themselves choose.

Key outcomes or other achievements. The highest correlations between observed and GS predicted performance was for FHB resistance traits (r= 0.50 (DON), 0.56 (FDK) and 0.59 (Severity). GS could be incorporated in breeding programs for FHB resistance selection.

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

Jeanette Lyerly has participated in / attended the following:
Sungrains Breeders summer meeting — August 2018 in AR.
2019 Scab Forum.
Data Matters Workshop, NCSu, August 2018.
Audited CS726 – Advanced Topics in Quantitative Genetics, Fall 2018.
Easter and Southern Small Grain Workers Conference, April 2019.
Project Workflow using R workshop, NCSU, May 2019.

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

Results have been disseminated through poster presentations and talks at scientific meetings. In addition the Southern Scab Nursery report can be found at this website: https://scabusa.org/pdfs_dbupload/suwwsn18_report.pdf

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY17-NCE period. The term "support" below includes any level of benefit to the student, ranging from full stipend plus tuition to the situation where the student's stipend was paid from other funds, but who learned how to rate scab in a misted nursery paid for by the USWBSI, and anything in between.

1. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their MS degree during the FY17-NCE period?**

   No

   If yes, how many?

2. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their Ph.D. degree during the FY17-NCE period?**

   No

   If yes, how many?

3. **Have any post docs who worked for you during the FY17-NCE period and were supported by funding from your USWBSI grant taken faculty positions with universities?**
4.

   No

   If yes, how many?

5. **Have any post docs who worked for you during the FY17-NCE period and were supported by funding from your USWBSI grant gone on to take positions with private ag-related companies or federal agencies?**

   No

   If yes, how many?

Release of Germplasm/Cultivars

Instructions: In the table below, list all germplasm and/or cultivars released with full or partial support through the USWBSI during the FY17-NCE period. All columns must be completed for each listed germplasm/cultivar. Use the key below the table for Grain Class abbreviations.

NOTE: Leave blank if you have nothing to report or if your grant did NOT include any VDHR-related projects.

Name of Germplasm/Cultivar	**Grain Class**	**FHB Resistance** (S, MS, MR, R, where R represents your most resistant check)	**FHB Rating** (0-9)	**Year Released**

Add rows if needed.

NOTE: List the associated release notice or publication under the appropriate sub-section in the 'Publications' section of the FPR.

Abbreviations for Grain Classes

Barley - BAR
Durum - DUR
Hard Red Winter - HRW
Hard White Winter - HWW
Hard Red Spring - HRS
Soft Red Winter - SRW
Soft White Winter - SWW

Publications, Conference Papers, and Presentations

Instructions: Refer to the FY17-FPR_Instructions for detailed instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY17-NCE grant period. Only include citations for publications submitted or presentations given during your award period (6/16/18 - 6/15/19). If you did not have any publications or presentations, state 'Nothing to Report' directly above the Journal publications section.

NOTE: Directly below each reference/citation, you must indicate the Status (i.e. published, submitted, etc.) and whether acknowledgement of Federal support was indicated in publication/ presentation. See example below for a poster presented at the FHB Forum:

> Conley, E.J., and J.A. Anderson. 2017. Accuracy of Genome-Wide Prediction for Fusarium Head Blight Associated Traits in a Spring Wheat Breeding Program. In: Proceedings of the XXIV International Plant & Animal Genome Conference, San Diego, CA.
> Status: Abstract Published and Poster Presented
> Acknowledgement of Federal Support: YES (poster), NO (abstract)

Journal publications.

Books or other non-periodical, one-time publications.

Other publications, conference papers and presentations.

Ward, B. P., G. Brown-Guedira and J. P. Murphy. 2018. Genotyping-by-sequencing markers for detecting allelesof the Fhb1 quantitative trait locus in soft winter wheat. In: S. Canty, A. Hoffstetter, B. Weirmer and R. Dill-Macky (Eds.), Proceedings of the 2018 National Fusarium Head Blight Forum (p 141). East Lansing, MI/Lexington, KY: U.S.

Status: Abstract Published and Poster Presented

Acknowledgement of Federal Support: YES (poster), NO (abstract)

Murphy, J. P., J. H. Lyerly, R. K. Acharya, B. Ward, and G. Brown-Guedira. 2018. The 2018 Uniform Southern Soft Red Winter Wheat Scab Nursery. In: S. Canty, A. Hoffstetter, B. Weirmer and R. Dill-Macky (Eds.), Proceedings of the 2018 National Fusarium Head Blight Forum (p 126-128). East Lansing, MI/Lexington, KY: U.S.

Status: Abstract Published and Poster Presented

Acknowledgement of Federal Support: YES (poster), NO (abstract)

Acharya, R. K., J. M. Sarinelli, J. H. Lyerly, P Tyagi, G. Brown-Guedira and J.P. Murphy. 2018. Influence of Environmental Selection on Prediction Accuracy of Training Population in the Uniform Southern Soft Red Winter Wheat Scab Nursery. In: S. Canty, A. Hoffstetter, B. Weirmer and R. Dill-Macky (Eds.), Proceedings of the 2018 National Fusarium Head Blight Forum (p 97-98). East Lansing, MI/Lexington, KY: U.S.

Status: Abstract Published and Poster Presented

Acknowledgement of Federal Support: YES (poster), NO (abstract)