USDA-ARS
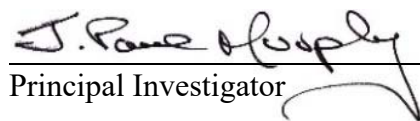## U.S. Wheat and Barley Scab Initiative
FY17 Preliminary Final Performance Report
Due date: July 31, 2018

Cover Page

Principle Investigator (PI):	J. Paul Murphy
Institution:	North Carolina State University
E-mail:	Paul_Murphy@ncsu.edu
Phone:	919-513-0000
Fiscal Year:	2017
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:	6/16/17 - 6/15/18
Reporting Period End Date:	6/15/2018

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

_____   07/20/2018
Principal Investigator   Date

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[*] 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

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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?**

   1) <u>Major activities</u>: Approximately 500 F_2 and F_3 bulks (combined) were advanced during 2017-18 utilizing mass selection. Most 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. Five hundred forty three new two- and three-way crosses were made and over 95 percent of the crosses had parents with FHB resistance. Eleven new crosses entered the doubled haploid program. Approximately 1,500 doubled haploid lines were produced in-house and will enter field evaluation in fall 2018. Approximately 2,000 doubled haploid lines were produced under contract for the University of Georgia.

   2) <u>Specific objectives:</u> evaluated 603 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 the breeding program.

   3) <u>Significant results:</u> Thirty seven of 40 NCSU entries in the SUNPRE Late Uniform Nursery contain known major QTL for scab resistance, including, *Fhb1, Jamestown1B, Neuse1A, Neuse4A, Massey3B* plus Hessian fly, powdery mildew, leaf rust and soil borne virus resistances. This is true of 76 percent of our entries in our Wheat Advanced Test. Six NCSU entries in the NC Official Variety Test have moderate levels of scab resistance plus overall good agronomic performance.

   4) <u>Key outcomes or other achievements</u>; Breeders Seed of three competitive lines with moderate FHB resistance, NC14-23372, NC15, 21787 and NC15-20369 produced for possible release in 2019.

(Form – PFPR17)

Objective 2. Major Objectives: Coordinated the Southern Uniform Scab Nursery. Utilized marker assisted selection and doubled haploid technology to increase breeding efficiency.

Specific Objectives: The nursery evaluated 42 advanced generation lines from five public and two private company breeding programs for resistance to FHB at up to seven locations. Collated and summarized data and published online. In-house evaluation of approximately 556 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 12 crosses.

Significant results: https://scabusa.org/pdfs_dbupload/suwwsn17_report.pdf. The results of the 2016-17 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 2017 Scab Forum. 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.

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.

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

Paul Murphy and Roshan Acharya (PhD Student) attended the Scab Forum in Milwaukee in December 20176. 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 two field day presentations to growers and industry representatives in spring 2018. In addition the Southern Scab Nursery report can be found at this website: https://scabusa.org/pdfs_dbupload/suwwsn17_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?

1) Major activities:

 DH lines from Heartland Plant Innovations. Two hundred six DH lines from three crosses (NC8248-14 / VA12W-54 // MD07026-F2-19-13-1, NC8248-14 / VA12W-72 // MD07026-F2-19-13-1, and NC8248-14 / MD07026-F2-19-13-1 // VA11W-279) were evaluated in head rows at Kinston NC. Twenty one were selected from the field and 17 were advanced for further testing in 2019 following evaluation for test weight. Forty two doubled haploid lines from seven crosses were evaluated in one replicate yield trials at Kinston and Plymouth, NC. The crosses were: MD08-26-H2-7-12-9 / 12V51 // VA12W-150, MD08-26-H2-7-12-9 / Jamestown // VA09W-73, MD08-26-H2-7-12-9 / USG 3555 // VA12W-150, MD08-26-H2-7-12-9 / VA11W-278 // Hilliard, MD08-26-H2-7-12-9 / VA11W-278 // VA12W-150, MD07027-12-24 / Hilliard // VA11W-278 and VA11W-95 / MD08-26-H2-7-12-9 / 12V51. Fifteen of these DH lines have been advanced to the 2019 Wheat Preliminary stage with evaluation expanded to six locations in NC. Neither of the DH entries from the cross MD07027-12-24 / Hilliard evaluated in the 2018 Wheat Preliminary test were advanced to the 2019 What Advanced Test. And finally, F_1 seed of NC11331-6 / VA11W-279 is undergoing DH production. NC11331-6 is a DH line with *Fhb1*, *H13* and *Bdv2.* VA11W-279, a high yielding line, containing the *3BL Massey QTL* and *H13.*

DH Lines from NCSU DH Production Facility. DH seed from 11 F_1 crosses made in 2017 are being harvested from the greenhouse for planting in head rows in fall 2018. (Table 1). Ten F_1 crosses produced in January 2018 (Table 2) are being pollinated by corn pollen to initiate the doubled haploid process at present.

Table 1. Pedigrees of 11 DH populations produced during 2017-18

Parent 1	Parent 2	Parent 1	Parent 2
Hilliard	NC14-23372	NC13-23443	NC13-20076
Hilliard	NC13-20076	TX-EL2	NC13-20076
NC13-20076	VA11-279	VA11W-279	NC14-23372
NC13-20076	VA12W-68	MD09W272-8-4-13-3-15	NC13-21213
NC13-21213	NC14-23372	MD09W272-8-4-13-3-15	NC14-23372
NC13-23443	NC14-23372		

Table 2. 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

2) 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.

3) Significant Results: Between 20 and 65 percent of lines in our three, two, and one-year pre-NC Official Variety Test evaluations in 2017-18 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	54
Two years pre-OVT	65
One year pre-OVT	20

4) Key Outcomes and Achievements: Twenty 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 200 DH lines have been shared with cooperators in six states for evaluation, use as parents and selection for release in states other than North Carolina.

(Form – PFPR17)

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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 support implementation of GS for scab resistance in breeding programs in VA, NC, GA, LA and AR.

2. What was accomplished under these goals?

1) <u>Major activities</u>: Curate phenotypic data from Uniform Southern Soft Red Winter Wheat Scab Nursery, GAWN, Sunpre-early, Sunpre-late, and SUNWHEAT cooperative nurseries. Organize sequencing of entries in those nurseries plus 3,000 additional early generation lines from NCSU, UGA, LSU and UAR. Conduct filtering and imputation steps followed by generation of predictions. Examination of utility of predictions for numerous traits post-harvest. Provide PopVar output for cross predictions. Evaluation of diverse training sets and environments to optimize the GS models for the southern breeding programs and work 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.

2) <u>Specific objectives</u>: provide FHB resistance predictions for approximately 3,000 lines in the NCSU, UK, UGA, LSU and UAR breeding programs. Update FHB training population with uniform scab nursery data. Provide genomic predictions for entries in the scab nursery and PopVar output for entries in the uniform scab nursery.

3) <u>Significant results</u>: 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 selection of superior FHB resistance. It will also allow individual project leaders to evaluate the efficacy of GS using this training population for their particular germplasm. I expect a training population for FHB resistance to be much more broadly adapted to numerous programs than say a training population for grain yield, due to the contrasting genetic architectures of the two traits. The correlations between the predicted and phenotypic field evaluations will be presented in the December 2018 Scab Forum.

4) <u>Key outcomes or other achievements</u>: GS for FHB resistance and numerous other traits is a reality in the Southern Soft Red Winter Wheat Coordinated Project. This is a major development.

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

Jeanette Lyerly participated in the following courses and workshops**:**
Bayesian Statistics: From Concept to Data Analysis, University of California, Santa Cruz (Coursera course) – May 2018
Preparing your code and data for reproducible publication: A hands-on workshop for researchers (workshop) – April 2018
Functional programming with purrr (workshop) — October 2017
Sungrains Breeders summer meeting — August 2017
Deep Learning for Data Scientists: Using Apache MXNet and R on AWS (webinar) — July 2017

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

Results have been disseminated through poster presentations at scientific meetings and two field day presentations to growers and industry representatives in spring 2018. In addition the Southern Scab Nursery report can be found at this website:
https://scabusa.org/pdfs_dbupload/suwwsn17_report.pdf

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY17 award 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 award period?**
   Yes
   If yes, how many?
   One, Roshan Acharya.

2. **Did any graduate students in your research program supported by funding from your USWBSI grant earn their Ph.D. degree during the FY17 award period?**
   No
   If yes, how many?

3. **Have any post docs who worked for you during the FY17 award period and were supported by funding from your USWBSI grant taken faculty positions with universities?**
   No
   If yes, how many?

4. **Have any post docs who worked for you during the FY17 award 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?

(Form – PFPR17)

Release of Germplasm/Cultivars

Instructions: In the table below, list all germplasm and/or cultivars released with <u>full or partial</u> support through the USWBSI during the <u>FY17 award period</u>. All columns must be completed for each listed germplasm/cultivar. Use the key below the table for Grain Class abbreviations. *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
NC13-21213	SRW	MS	5	2018

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 grant. Only include citations for publications submitted or presentations given during your award period (6/16/17 - 6/15/18). If you did not have any publications or presentations, state 'Nothing to Report' directly above the Journal publications section.

Journal publications.

Petersen, S., J. H. Lyerly, A. L. McKendry, M. Sariful Islam, G. Brown-Guedira, C. Cowger, Y. Dong, and J. P. Murphy. 2017. Validation of Fusarium Head Blight Resistance QTL in US Winter Wheat. Crop Sci. 57:1–12.
Status: Published.
Acknowledgement of Federal Support: Yes

Cowger, C., R. Weisz, C. Arellano, and J. P. Murphy. 2016. Profitability of Integrated Management of Fusarium Head Blight in North Carolina Winter Wheat. Phytopathology. 106: 814-823.
Status: Published.
Acknowledgement of Federal Support: Yes

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

Nothing to Report

Other publications, conference papers and presentations.

Acharya, R. K., J. M. Sarinelli, J. H. Lyerly, P. Tyagi, G. Brown-Guedira, and J.P. Murphy. 2017. Influence of environmental selection on prediction accuracy of training population in the uniform southern soft red winter wheat scab nursery. In: S. Canty, B. Wiermer and D. Van Sanford (Eds.), Proceedings of the 2017 National Fusarium Head Blight Forum (p. 77). East Lansing, MI/Lexington, KY: U.S.
Status: Poster and Abstract Published
Acknowledgement of Federal Support: Yes

Fitzgerald, J., C. Griffey, W. Brooks, N. Carpenter, D. Van Sanford, J. P. Murphy N. McMaster, and D. Schmale III. 2017. Evaluation of winter barley cultivar Nomini for quantitative resistance to Fusarium head blight. In: S. Canty, B. Wiermer and D. Van Sanford (Eds.), Proceedings of the 2017 National Fusarium Head Blight Forum (p. 84). East Lansing, MI/Lexington, KY: U.S.
Status: Poster and Abstract Published
Acknowledgement of Federal Support: Yes

Murphy, J. P., J. H. Lyerly, R. Acharya, J. M. Sarinelli, P. Tyagi and G. Brown-Guedira. 2017. The 2017 Uniform Southern Soft Red Winter Wheat Scab Nursery. In: S. Canty, B. Wiermer and D. Van Sanford (Eds.), Proceedings of the 2017 National Fusarium Head Blight Forum (p 88-91). East Lansing, MI/Lexington, KY: U.S.
Status: Poster and Abstract Published
Acknowledgement of Federal Support: Yes

Sarinelli, J. M., J. P. Murphy, R. Acharya, C. Sneller and G. Brown-Guedira. 2017. A regional approach to genomic selection for scab resistance. In: S. Canty, B. Wiermer and D. Van Sanford (Eds.), Proceedings of the 2017 National Fusarium Head Blight Forum (p 94). East Lansing, MI/Lexington, KY: U.S.
Status: Poster and Abstract Published
Acknowledgement of Federal Support: Yes