USDA-ARS
U.S. Wheat and Barley Scab Initiative
FY19 Final Performance Report
Due date: July 24, 2020

Cover Page

Principle Investigator (PI):	Mark Sorrells
Institution:	Cornell University
E-mail:	mes12@cornell.edu
Phone:	607-255-1665
Fiscal Year:	2019
USDA-ARS Agreement ID:	59-0206-8-196
USDA-ARS Agreement Title:	Development of FHB Resistant Wheat and Barley Varieties for the Northeastern U.S.
FY19 USDA-ARS Award Amount:	$ 125,194
Recipient Organization:	Cornell University 341 Pine Tree Road Ithaca NY 14850
DUNS Number:	872612445
EIN:	15-0532082
Recipient Identifying Number or Account Number:	1498554
Project/Grant Reporting Period:	5/3/19 - 5/2/20
Reporting Period End Date:	5/2/2020

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
BAR-CP	Interstate Spring 2-rowed Malting Barley Breeding for FHB Resistance and Reduced DON	$ 39,351
VDHR-NWW	Genetics and Breeding of FHB Resistant Soft White & Red Winter Wheat for the Northeastern U.S	$ 69,584
VDHR-NWW	Male Sterile Facilitated Recurrent Selection for FHB Resistance	$ 1,264
VDHR-NWW	Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials	$ 3,388
VDHR-NWW	Use of Genomic Selection to Improve FHB Resistance and Yield in Northern SWW	$ 11,607
	FY19 Total ARS Award Amount	**$ 125,194**

7/24/2020

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

FY19 Final Performance Report
PI: Sorrells, Mark
USDA-ARS Agreement #: 59-0206-8-196
Reporting Period: 5/3/19 - 5/2/20

Project 1: *Interstate Spring 2-rowed Malting Barley Breeding for FHB Resistance and Reduced DON*

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

The overall goal of this project was to develop spring 2-row malting barley varieties with FHB resistance and adaptation to the northeastern U.S.

Specifically:
1) Evaluate FHB resistance in spring malting barley varieties in a Uniform Eastern Spring Malting Barley nursery coordinated by Richard Horsley at North Dakota State University,
2) Evaluate FHB resistance in malting barley varieties in the New York State Regional Spring and Winter Malting Barley testing program,
3) Evaluate FHB resistance and agronomic traits in our NY spring 2-row elite line training population, and
4) Use genomic selection to develop spring 2-row malting barley varieties with FHB resistance and adaptation to the northeastern U.S.

2. What was accomplished under these goals or objectives? *(For each major goal/objective, address items a-b) below.)*

a) What were the major activities?

Evaluated all experimental lines, cooperative and regional trial entries for both winter and spring barley in our misted, irrigated FHB nursery. In our misted, inoculated FHB nursery we evaluated all entries from the Winter Malting Barley Trial, Eastern Spring Malting Barley (ESBN) Trial, Cornell Regional Winter and Spring Malting Barley Trials, our advanced spring malting barley breeding program, and potential new sources of resistance from the J. Innes Center.

b) What were the significant results?

We collected replicated incidence, severity and FHB damaged kernels data on 90 JIC lines, 25 ESBN lines, 36 Spring Malting Barley Regional entries, 366 advanced selections from our breeding program, 30 WMBT entries, 24 Winter Malting Barley Regional entries, and 25 lines from the Oregon State University Naked Barley Trial

c) List key outcomes or other achievements.

Over the past 6 years, we have accumulated reliable FHB data for winter and spring malting barley varieties from various breeding programs in Europe, western Canada, and western and midwestern U.S. as well as some new sources of resistance for New York. Also, we have been able to determine optimum application times for fungicides. This is

critical information because before 2013 there was no malting barley being grown in NY so it was necessary to develop the information on cultural practices and educate the farmers on how to grow it. The NY Farm Brewery Legislation created a new market for malting barley required by craft maltsters and brewers.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Yes – We were not allowed to hire summer temporary employees. This necessitated reducing the workload for both spring and winter barley FHB trials. Consequently, we were unable to score two of the spring FHB trials because of lack of labor. We were able to collect data and harvest all of our winter FHB trials.

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

Daniel Sweeney is a PhD candidate who is in charge of the spring malting barley breeding program. Together we have designed a high intensity breeding program using the latest technologies to generate high quality breeding lines that are candidates for variety release in the shortest possible time. We have released the first ever Cornell spring malting barley this spring of 2020. Karl Kunze is in charge of our winter malting barley and organic naked barley breeding programs. Travis Rooney has joined our project to characterize seed dormancy and the interaction with malting quality. All of my grad students receive training in plant breeding methods and evaluation of FHB in our misted, inoculated nursery. Also, our undergraduate summer field assistants receive training and background information on both winter and spring FHB nurseries.

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

Each year we publish the results of our state regional trials for both spring and winter malting barley including FHB and malting quality data in hard copy through mail or email and online.

Cornell Small Grains Performance Trials - 2017 Winter Malting Barley
https://plbrgen.cals.cornell.edu/sites/plbrgen.cals.cornell.edu/files/shared/WMB%20Reg17%20Table.pdf
Cornell Small Grains Performance Trials - 2017 Spring Malting Barley
https://plbrgen.cals.cornell.edu/sites/plbrgen.cals.cornell.edu/files/shared/SMB%20Reg17%20Table.pdf

We also present the results at three fields days and two workshops for extension agents.

Project 2: *Genetics and Breeding of FHB Resistant Soft White & Red Winter Wheat for the Northeastern U.S*

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

The climate in the northeastern U.S requires that farmers grow FHB resistant wheat. FHB is the single greatest problem for successful production of soft white and red winter wheat in New York. We successfully commercialized Jensen and Medina soft white winter wheat varieties. Because most of the DON is in the bran, FHB resistance in white wheat is more important than for red because white wheat bran is widely marketed to the food industry for use as an additive in high bran food products. We are also developing FHB resistant soft red winter wheat varieties for this region and we have collaborated with Ohio State University to release Otsego and Erie soft red winter wheat varieties for New York. We have approval to release a new FHB resistant soft white winter wheat variety NY99056-161.

Our objectives are to:

1) Develop FHB resistant soft red and white wheat cultivars for the northeastern U.S. in collaboration with Gary Bergstrom, Department of Plant Pathology. Evaluate our elite lines in the Cornell University FHB Advanced Line nursery.
2) Pyramid FHB resistance genes by hybridizing elite lines with native FHB resistance to new sources of FHB resistance, both Asian and other sources.
3) Evaluate FHB resistant lines in New York regional trials for release, farmer recommendations, and seed increase.
4) Participate in the coordinated sharing of information from the above activities to generate a comprehensive source of information that can be used in forward breeding strategies

2. What was accomplished under these goals or objectives? *(For each major goal/objective, address items a-b) below.)*

a) What were the major activities?

Breeding, FHB nursery evaluations, recurrent selection, genomic selection

b) What were the significant results?

Breeding – 50 new crosses made with 2B and 5A sources in the past year, 29 new general FHB crosses made from FHB nursery selections; 225 new selections were screened for FHB resistance alleles at the 3B and 5A loci; 420 screening nursery plots were grown from the previous year's selections. In our advanced trials, we have 5 new soft red FHB lines and two second-year selection. In our soft white winter wheat advanced trial we have 10 new FHB lines and 8 second-year entries. In our Master nursery, we have 150 FHB selected entries. Eight-four lines that were selected using genomic selection were evaluated in two trials. Our breeding program is the only public wheat breeding program

in the northeastern U.S. that is releasing soft white and red winter wheat varieties that have been selected for FHB resistance. The wheat varieties grown in NY are nearly all from Cornell and Pioneer and all are moderately susceptible to moderately resistant to FHB. Branded varieties are not usually tested because the companies do not want to enter their varieties in our testing program. The branded varieties are of minor importance.

c) List key outcomes or other achievements.

Over the past 9 years we have released of 7 new soft winter wheat varieties with at least moderate FHB and preharvest sprouting resistance. Two of the varieties have fhb1 from marker assisted backcrossing and four have native resistance. Except for branded varieties, all varieties marketed in NY have at least some moderate resistance to FHB. We advise farmers to not grow susceptible varieties.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Yes – We were not allowed to hire summer temporary employees. This necessitated reducing the workload for winter wheat FHB trials. Consequently, we were unable to score two of the winter wheat FHB trials because of lack of labor. We were able to collect data and harvest all of the rest of our winter FHB trials.

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

Each season we train up to 8 graduate students, 1-3 post docs and 4-5 undergraduates how to plan, set up, maintain, and score a misted, inoculated FHB nursery. They receive training on the significance of the disease, sources of inoculum, biology of fusarium, and implications of developing resistant varieties. The graduate students and post docs are also taught how to analyze the data and prepare summaries.

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

Each year I have presented results of FHB evaluation at three field days and at county agent training schools. I distribute the results of our FHB evaluations both electronically by email and on our web site (http://small grains.cals.cornell.edu) and by hard copy to other wheat breeders and to stakeholders in New York and surrounding states.

Project 3: *Male Sterile Facilitated Recurrent Selection for FHB Resistance*

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

The objective of this project was to advance male-sterile facilitated recurrent selection populations that have been developed to combine genes for FHB resistance from multiple sources in soft winter wheat backgrounds adapted to the eastern U.S. In addition, this project will develop populations of adapted breeding lines with genes for FHB resistance derived from multiple sources.

2. What was accomplished under these goals or objectives? *(For each major goal/objective, address items a-b) below.)*

a) What were the major activities?

Intermating dominant male sterile lines with multiple sources of resistance, selection of resistant plants, evaluation of selections. We developed soft winter wheat populations with multiple sources of FHB resistance and improved those populations by recurrent selection.

b) What were the significant results?

To initiate this project, the dominant male sterile population was allowed to intermate with entries in the NWWSN for two generations. The population was then intermated for a generation followed by half sib selection. Since then, the dominant male sterile population was planted as replicated half sib families in the misted, inoculated FHB nursery. Male sterile plants were tagged at anthesis and three weeks later each half sib family was scored for FHB incidence and severity. The most resistant 25% of the families were selected and within each family, male sterile plants that showed the fewest symptoms were selected and harvested. Those selected plants became the half sibs for the next generation. A bulk harvest of the selected half sibs was planted adjacent to the half sib families to serve as a pollen source for the male steriles. In addition, male fertile plants from the selected families were planted in a replicated trial to determine if there has been an increase in FHB resistance resulting from selection over the past 5 generations.

c) List key outcomes or other achievements.

Our population appears to have a high level of FHB resistance and is well adapted to northeastern growing conditions. These populations will be beneficial to regional and local breeding programs because they are an adapted population with multiple sources of FHB resistance in a soft winter wheat genetic background. This project will provide breeding programs in the eastern region with germplasm from which to extract breeding lines that have the potential to have unique combinations of FHB resistance genes.

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Yes – We were not allowed to hire summer temporary employees. This necessitated reducing the workload for winter wheat FHB trials. Consequently, we were unable to score two of the winter wheat FHB trials because of lack of labor. We were able to collect data and harvest all of the rest of our winter FHB trials.

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

Each season we train up to 8 graduate students, 1-2 post docs and 4-5 undergraduates how to plan, set up, maintain, and score a misted, inoculated FHB nursery. They receive training on the significance of the disease, sources of inoculum, biology of fusarium, and implications of developing resistant varieties. The graduate students and post docs are also taught how to analyze the data and prepare summaries. In addition, for this nursery, I teach them how to perform modified half-sib selection.

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

We have reported the results of this project to other members of the Northern Winter Wheat FHB community. Once we have completed the evaluation of the fertile selections, we will prepare a germplasm release publication.

Project 4: *Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials*

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

   Fusarium head blight resistance must be combined with high yield, disease resistance, and good milling and baking quality to impact the Eastern U.S. wheat industry. Our breeding program generates new breeding lines each year for advanced stages of development and testing. Multi-location testing is carried out each year to determine the FHB resistance of these lines, as well as their yield, quality, agronomic value, and resistance to other diseases.

   Objectives:
   1) Phenotype advanced breeding lines that are candidates for release,
   2) place FHB and other agronomic, disease resistance, and quality data in database,
   3) report on purification and seed increase of the best lines.

2. **What was accomplished under these goals or objectives?** *(For each major goal/objective, address items a-b) below.)*

   a) What were the major activities?

      Each year we have collected incidence, severity, FDK, and DON data on the NUWWSN by evaluating it in a misted inoculated FHB nursery. Each year we enter four of our own experimental lines in the NUWWSN and enter the data from our NUWWSN location in a coordinated database. Phenotyped advanced breeding lines that are candidates for release; placed FHB and other agronomic, disease resistance, and quality data in database: reported on purification and seed increase of the best lines.

   b) What were the significant results?
      Advanced lines that perform well in this nursery are entered into our state regional trials to determine if they are suitable for variety release.

   c) List key outcomes or other achievements.

      The results are included in our regional trial summaries that are distributed to extension personnel, farmers, and seed companies and published on the Internet. We also enter our data into the T3 public database.

3. **Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.**

   Yes – We were not allowed to hire summer temporary employees. This necessitated reducing the workload for winter wheat FHB trials. Consequently, we were unable to score

two of the winter wheat FHB trials because of lack of labor. We were able to collect data and harvest all of the rest of our winter FHB trials.

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

Each season we train up to 8 graduate students, 1-2 post docs and 4-5 undergraduates how to plan, set up, maintain, and score a misted, inoculated FHB nursery. They receive training on the significance of the disease, sources of inoculum, biology of fusarium, and implications of developing resistant varieties. The graduate students and post docs are also taught how to analyze the data and prepare summaries.

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

Each year I have presented results of FHB evaluation at three field days and at county agent training schools. I distribute the results of our FHB evaluations both electronically by email and on our web site (http://small grains.cals.cornell.edu) and by hard copy to other wheat breeders and to stakeholders in New York and surrounding states.

Project 5: *Use of Genomic Selection to Improve FHB Resistance and Yield in Northern SWW*

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

The primary goal was to determine if genomic selection for FHB resistance is effective. Genomic selection uses a training population of lines that is phenotyped and genotyped. A prediction model is built using the phenotypic and genotypic data from the training population. That model can then be used to predict the value of other genotyped individuals that are related to the training population.

Objectives:
1) To implement GS for FHB resistance in soft winter wheat.
2) Initiate evaluation of the effectiveness of GS for FHB resistance in soft winter wheat lines.

2. What was accomplished under these goals or objectives? *(For each major goal/objective, address items a-b) below.)*

a) What were the major activities?

Genotyped advanced lines and phenotyping them for model training, line selection and crossing. Implemented GS for FHB resistance in soft winter wheat by completing two cycles of GS. We initiated evaluation of the effectiveness of GS for FHB resistance in soft winter wheat lines.

b) What were the significant results?

The results of the fourth cycle of selection are currently being evaluated and analyzed and will be reported this winter and in a publication.

c) List key outcomes or other achievements.

Over the past four years we have phenotyped a training population of 649 lines. This includes 600 RILs consisting of 100 lines from each of six breeding programs, each phenotyped at the breeder's location and 49 checks that were phenotyped by all six breeders at all locations and years. The lines that were selected using GS are currently being evaluated to measure gain from selection

3. Was this research impacted by the COVID-19 pandemic (i.e. university shutdowns, reduced or lack of support personnel, etc.)? If yes, please explain how this research was impacted or is continuing to be impacted.

Yes – We were not allowed to hire summer temporary employees. This necessitated reducing the workload for winter wheat FHB trials. Consequently, we were unable to score two of the winter wheat FHB trials because of lack of labor. We were able to collect data and harvest all of the rest of our winter FHB trials.

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

Each season we train up to 8 graduate students, 1-2 post docs and 4-5 undergraduates how to plan, set up, maintain, and score a misted, inoculated FHB nursery. They receive training on the significance of the disease, sources of inoculum, biology of fusarium, and implications of developing resistant varieties. The graduate students and post docs are also taught how to analyze the data and prepare summaries.

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

The results of this project are currently being analyzed and will be reported this winter at the Scab Forum and in a publication.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY19 award period (5/3/19 - 5/2/20). 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 FY19 award period?**
   None

   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 FY19 award period?**
   None

   If yes, how many?

3. **Have any post docs who worked for you during the FY19 award period and were supported by funding from your USWBSI grant taken faculty positions with universities?**
   None

   If yes, how many?

4. **Have any post docs who worked for you during the FY19 award period and were supported by funding from your USWBSI grant gone on to take positions with private ag-related companies or federal agencies?**
   None

   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 FY19 award 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**
NY99056-161	SWW	MR	6	2019
SR564-4	BAR	MS	4	2019

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 FY19-FPR_Instructions for detailed more instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY19 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period (5/3/19 - 5/2/20**) should be included. If you did not publish/submit or present anything, state 'Nothing to Report' directly above the Journal publications section.

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

> De Wolf, E., D. Shah, P. Paul, L. Madden, S. Crawford, D. Hane, S. Canty, R. Dill-Macky, D. Van Sanford, K. Imhoff and D. Miller. 2019. "Impact of Prediction Tools for Fusarium Head Blight in the US, 2009-2019." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum* (p. 12), Milwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
> Status: Abstract Published and Poster Presented
> Acknowledgement of Federal Support: YES (Abstract and Poster)

Journal publications.

Cox, W., J. Hanchar, J. Cherney, and M.E. Sorrells. 2019. Economic responses of maize, soybean, and wheat in three rotations under conventional and organic cropping systems. Agronomy Journal. 9:424-437.
Status: Published
Acknowledgement of Funding Support: No

Krause, M.R., L. González-Pérez, J. Crossa, P. Pérez-Rodríguez, O. Montesinos-López, R.P. Singh,† S. Dreisigacker, J. Poland, J. Rutkoski, M.E. Sorrells, M.A. Gore, and S. Mondal. 2019. Hyperspectral reflectance-derived relationship matrices for genomic prediction of grain yield in wheat. Genes Genomes Genetics. 9:1231-1247.
Status: Published
Acknowledgement of Funding Support: No

Neyhart, J.L., D. Sweeney, M. Sorrells, C. Kapp, K.D. Kephart, J. Sherman, E.J. Stockinger, S. Fisk, P. Hayes, S. Daba, M. Mohammadi, N. Hughes, L. Lukens, P. González Barrios, L. Gutiérrez, and K.P. Smith. 2019. Registration of the S2MET Barley Mapping Population for Multi- Environment Genomewide Selection. Journal of Plant Registrations doi:10.3198/jpr2018.06.0037crmp.
Status: Published
Acknowledgement of Funding Support: No

Sun J., J.A. Poland, S. Mondal, J. Crossa, P. Juliana, R.P. Singh, J.E. Rutkoski, J-L. Jannink, L. Crespo-Herrera, G. Velu, J. Huerta-Espino, M.E. Sorrells. 2019. High-throughput phenotyping platforms enhance genomic selection for wheat grain yield across populations and cycles in early stage. Theor Appl Genet. https://doi.org/10.1007/s00122-019-03309-0.
Status: Published
Acknowledgement of Funding Support: No

Books or other non-periodical, one-time publications.
None

Other publications, conference papers and presentations.

Cornell Small Grains Breeding and Genetics Project 2019 – Northeast Grainshed Symposium, Canton, MA, Invited January 30.
Status: Oral Presentation presented
Acknowledgement of Funding Support: Yes

Cornell Small Grains Breeding and Genetics Project Ancient Grains: Emmer, Einkorn and Spelt – Cornell Cooperative Extension Workshop, Coxsackie, NY, Invited February 7.
Status: Presented
Acknowledgement of Funding Support: Yes

Cornell Small Grains Performance Trials – Hard copy mailed and pdf emailed to about 250 people. Small Grains Performance Trials – All trials https://plbrgen.cals.cornell.edu/research-extension/small-grains/cultivar-testing/
Status: Published
Acknowledgement of Funding Support: Yes

Small Grains Varieties for NY –Wheat Management Field Day, Ithaca, NY - June 4
Status: Presented
Acknowledgement of Funding Support: Yes

Small Grains Varieties for NY – In Service Cooperative Extension Agent Training, Ithaca, NY, Invited November 6.
Status: Presented
Acknowledgement of Funding Support: Yes

Born Bred and Brewed in NY - Malting barley varieties for NY, Empire Barley and Malt Summit, Liverpool, NY, Invited December 17.
Status: Presented
Acknowledgement of Funding Support: Yes