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

Cover Page

Principle Investigator (PI):	Eric Olson
Institution:	Michigan State University
E-mail:	eolson@msu.edu
Phone:	517-353-0142
Fiscal Year:	2019
USDA-ARS Agreement ID:	59-0206-6-003
USDA-ARS Agreement Title:	Development of Scab Resistant Wheat Varieties for Michigan
FY19 USDA-ARS Award Amount:	$ 101,000
Recipient Organization:	Michigan State University Contract & Grant Administration Hannah Administration Building, Room 2 East Lansing, MI 48824-1046
DUNS Number:	193247145
EIN:	38-6005984
Recipient Identifying Number or Account Number:	RC103795
Project/Grant Reporting Period:	4/24/19 - 4/23/20
Reporting Period End Date:	4/23/2020

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
VDHR-NWW	Development of Scab Resistant Wheat Varieties for Michigan and the Great Lakes Region	$ 80,527
VDHR-NWW	Male Sterile Facilitated Recurrent Selection for FHB Resistance	$ 1,163
VDHR-NWW	Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials	$ 1,938
VDHR-NWW	Use of Genomic Selection to Improve FHB Resistance and Yield in Northern SWW	$ 17,372
	FY19 Total ARS Award Amount	**$ 101,000**

8/3/2020

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 Performance Report
PI: Olson, Eric
USDA-ARS Agreement #: 59-0206-6-003
Reporting Period: 4/24/19 - 4/23/20

Project 1: *Development of Scab Resistant Wheat Varieties for Michigan and the Great Lakes Region*

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

The mission of the Michigan State University Wheat Breeding and Genetics program is to develop high-yielding, high-quality soft red and soft white winter wheat varieties with high levels of resistance to FHB. Breeding populations are developed with parents having high yield potential and Fhb resistance. Speed breeding is implemented in the greenhouse to quickly advances early generations. Genomic selection is used to identify inbred lines with high yield potential and resistance to FHB. Novel sources of Fhb resistance are being identified in exotic germplasm to support the development of resistant varieties.

Major project goals:

1. *Develop and apply selection to 500 breeding populations segregating for FHB resistance using a combination of phenotypic and genomic selection strategies.*
2. *Evaluate resistance levels of breeding yield trial entries and genomic selection training population in a misted FHB nursery.*
3. *Enrich populations for Fhb.*
4. *Disseminate resistant germplasm.*
5. *Communicate levels of FHB resistance and susceptibility in Michigan wheat varieties.*

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?

1. Development of breeding populations and early generation selection.

As a consequence of implementing the minibulk system, the 2017 populations caught up to the 2016 populations and over 1,000 populations were available. Phenotypic selection was applied in 800 F_4 and F_5 populations. Populations were planted in 35’ four row plots at 6” spacing at the wheat research farm in Mason, MI. A total of ~2,200 single plants were selected based on early maturity and agronomic type. Tissue was collected from flag leaves of selected plants. DNA was isolated, normalized and sequence based genotyping was done to generate ~1,300 SNPs per selected plant. SNPs were used to develop genome-estimated breeding values (GEBVs) for grain yield in two years, 2018 and 2019 and two environments, Mason and Richville, MI as well as DON mycotoxin levels and pre-harvest sprouting. A total of 500 lines were selected and planted along with other lines with SNP data from previous years in10’ four row plots at 3” spacing for seed increase and visual selection based on type, height and resistance to foliar plathogens. Altogether, ~600 lines were planted. The approximately 3lb. of seed harvested from selected lines will be used for yield testing in two replicates at four locations. The ~600 selection candidates were also planted in the FHB nursery in two replicates.

The selection candidates with high GEBVs were genotyped for dwarfing genes, photoperiod genes, soilborne mosaic virus resistance, *Tsn1* and *Fhb1*at the RSGGL in Raleigh, NC. DNA stocks isolated at MSU used for marker genotyping in Raleigh. Marker data was used to apply another layer of selection in single replicate observation plots.

Bulk F_4 populations developed in 2018 were planted at Mason, MI. A total of 442 populations were planted in 35’ four row plots at 6” spacing with ~280 plants per plot. Single plant selections were available to be made in May, 2020.

The minibulk system is being used to advance a total of 580 populations from crosses made in fall 2018 and spring 2019. Currently, the populations are F_3 plants in the greenhouse. The F_4 seed will be planted at Mason, MI in 35’ four row plots at 6” spacing in fall 2020 to undergo selection in spring 2021.

A total of 562 unique crosses were made in fall 2019 and spring 2020 to develop segregating breeding populations. The target number of crosses was not reached due to the lack of child care for the project PI. Assistant breeder, Amanda Noble made the majority of spring 2020 crosses and crosses were narrowed to select few parents.

Approximately 500 crosses contain at least one FHB-resistant parent and 180 crosses (32% of all crosses) involve at least one parent with *Fhb1*. Crosses are being advanced in using the minibulk system and the F_4 seed will be planted in the field in bulk plots in fall, 2020. Marker assisted selection will be done in derived lines to select inbred lines carrying *Fhb1*.

2. Evaluation of resistance levels of breeding yield trial entries and training population in a misted FHB nursery.

In 2019 FHB evaluation, major emphasis on generating high quality data with high replication rather than generate less reliable data on more lines. A total of 501 unique wheat genotypes were evaluated for FHB resistance in a misted and inoculated nursery. Each line was planted in at least three replicates. Nurseries tested included the MSU GS Training Population (TP), MSU Advanced Yield Trial (AYT), Michigan State Commercial Wheat Performance Trial (OVT), P+NUWWN, Uniform White and Uniform Red Nurseries as well as the 6-state preliminary and advanced nurseries.

The 2018-19 FHB nursery was highly successful. Infection conditions were ideal and very high levels of disease develop uniformly across the nursery. FHB incidence ranged from 60% to 100% across the nursery. High quality data were collected on incidence, severity, FHB index and 0 to 9 rating. DON sampling was done across the TP, AYT, OVT and P+NUWWN.

Data from the TP and AYT were used to train GS prediction models to select for FHB resistance. Visual FHB ratings were published in the initial OVT report and DON data were published when received in March, 2019. P+NUWWN data were reported to collaborators.

3. Enrichment of populations for Fhb1.

A total of 180 crosses (32% of all crosses) involve at least one parent with *Fhb1*. Crosses are being advanced in using the minibulk system and the F_4 seed will be planted in bulk in fall, 2020. Marker assisted selection identified 85 genotypes in the single plot observation nursery with *Fhb1*.

4. Dissemination of resistant germplasm.

For regional FHB resistance evaluation nine entries were submitted to the Uniform FHB nurseries comprised of FHB resistant germplasm and lines tested in regional nurseries.

5. Communication of FHB resistance in Michigan wheat varieties.

Wheat growers and agribusiness were educated on FHB-resistant varieties in presentations at field days and winter meetings. Four talks were given to agribusiness and growers that included messages regarding the benefits of planting resistant varieties, especially the decreased FHB risk from the combination of a moderately resistant variety treated with a fungicide. Educational materials including a list of moderately resistant varieties, how resistance is determined visually and DON levels, and traits to look for in selecting varieties to mitigate the risk of FHB.

b) What were the significant results?

1. Development of breeding populations and early generation selection

2019 saw the first successful implementation the new breeding program structure combining speed breeding and genomic selection. Program staff were able to carry out the challenging logistics of genotyping thousands of plants and making selections in time for planting in the fall. Genotypic data were available for all 600 selection candidates in the field. The project PI had a depth of information on predicted grain yield and mycotoxin levels as well as dwarfing genes and photoperiod to guide selections in the field.

2. Evaluation of resistance levels of breeding yield trial entries and training population in a misted FHB nursery

The FHB nursery in 2019 was one of the most successful nurseries ever carried out at MSU. Disease pressure was high giving us excellent visually scored disease data. Program staff are becoming highly skilled at isolating new FHB strains each year and preparing hundreds of pound of grain spawn. Training population data collected in the FHB nursery is of high value and is facilitating genomic selection for FHB resistance.

3. Enrichment of populations for Fhb1

Among selection candidates derived from segregating populations, 85 carry the *Fhb1* gene. These lines will be planted in yield trials at four locations 2020-21. I am grateful to the RSGGL for genotyping these lines and the USWBSI and USDA-ARS for providing them the resources to carry out their mission. Assistant breeder, Amanda Noble, has been successful at enriching breeding populations for *Fhb1* with a third of all new breeding populations carrying the gene.

c) List key outcomes or other achievements.

Four soft winter wheat varieties were released in 2019. One soft red winter and one soft white winter carry the *Fhb1* gene.

Soft Red Winter Wheat

'MI160898' is a new soft red winter wheat variety developed by Michigan State University Wheat Breeding and Genetics. This variety is ideal for production in Michigan with high yield potential and excellent milling and baking quality. MI16R0898 has a high two-year grain yield comparable to the commercial soft red winter wheat varieties 'DF112R', 'SY 100' and 'AgriMAXX 413'. In 2019, grain yield for MI16R0898 ranked in the top 25% of commercial wheat varieties tested in Michigan in 2019 and #4 out of 39 entries in the Uniform Eastern Soft Red Winter Wheat Nursery tested at Mason, MI. DON mycotoxin levels and visual FHB index are very low in MI16R0898 conferred by the *Fhb1* gene. MI16R0898 is has excellent resistance to Stagonospora Leaf Blotch due in part to the absence of the ToxA receptor Tsn1. Soilborne Mosaic Virus resistance in MI16R0898 is conferred by the Sbm1 gene. MI16R0898 has average flour yield and meets all soft wheat quality specifications. Flowering for MI16R0898 is two days later than DF112R and similar to SY100. MI16R0898 is three inches taller than the soft white winter wheat 'Jupiter' and similar to the soft white winter wheat 'Ambassador'.

Soft White Winter Wheat

'MI14W0190' is a new soft white winter wheat variety developed by Michigan State University Wheat Breeding and Genetics. This variety is ideal for production in Michigan with high yield potential and excellent milling and baking quality. MI14W0190 demonstrates stable grain yield across Michigan and the Great Lakes region, particularly in Huron and Sanilac counties, the largest soft white wheat producing counties in Michigan. Fusarium head blight resistance in MI14W0190 is far superior to all soft winter wheat varieties available to Michigan wheat growers due in part to the *Fhb1* resistance gene. MI14W0190 also has excellent resistance to Stripe Rust. The disease resistance package of MI14W0190 makes it an ideal variety for organic wheat production. MI14W0190 flowers one day later than 'Ambassador' and one day earlier than 'Jupiter' early providing growers the opportunity to stagger variety maturities. MI14W0190 height is similar to the soft white winter wheat 'Ambassador'.

'MI16W0133' is a new soft white winter wheat variety developed by Michigan State University Wheat Breeding and Genetics. This variety is ideal for production in Michigan with high yield potential and excellent milling and baking quality. MI16W0133 has a high two-year grain yield higher than the commercial soft white winter wheat varieties Dyna-Gro 9242W, Jupiter and Ambassador. In 2019, grain yield for MI16W0133 ranked in the top 10% of commercial wheat varieties tested in Michigan in 2019 and #2 out of 39 entries in the Uniform Eastern Soft WhiteWinter Wheat Nursery tested in Richville, MI and New Haven, IN. MI16W0133 is susceptible to FHB and will require preventative fungicide applications. MI16W0133 has excellent resistance to Stagonospora Leaf Blotch due in part to the absence of the ToxA receptor Tsn1. Soilborne Mosaic Virus resistance in MI16W0133 is conferred by the Sbm1 gene. MI16W0133 has above average flour yield and meets all soft wheat quality specifications. Flowering for MI16W0133 is one day later than 'Whitetail', similar to 'Ambassador' and two days earlier than 'Jupiter'. MI16W0133 has a very short plant architecture similar to Jupiter.

'MI16W0528'is a new soft white winter wheat variety developed by Michigan State University Wheat Breeding and Genetics. This variety is ideal for production in Michigan with high yield potential and excellent milling and baking quality. MI16W0528 has a high two-year grain yield higher than the commercial soft white winter wheat varieties Dyna-Gro 9242W, Jupiter and Ambassador. In 2019, grain yield for MI16W0528 ranked in the top 30% of commercial wheat varieties tested in Michigan in 2019 and #1 out of 39 entries in the Uniform Eastern Soft WhiteWinter Wheat Nursery tested in Richville, MI and New Haven, IN. MI16W0528 is moderately resistant to FHB evidenced by low DON levels and low visual FHB index. Soilborne Mosaic Virus resistance in MI16W0528 is conferred by the Sbm1 gene. MI16W0528 has above average flour yield and meets all soft wheat quality specifications.

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.

DON data for 2019 was not able to be processed at the University of Minnesota lab. This delay will affect genomic predictions for FHB resistance in new inbred lines. It will also delay the release of two soft red winter wheat varieties that have no data available for DON. It may be possible to substitute a predicted breeding value for DON in these lines.

Program mechanics were still able to operate during the pandemic. The project PI was without child care until July. The excessive stress of childcare and running a breeding program involving supervision of five full time professionals and seven undergraduates took a toll on personal productivity for the project PI.

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

Two graduate students received training in breeding for FHB resistance, Melissa Winchester and Tommy Reck. Both students have become proficient in growing grain spawn and ascospore cultures. They have carried out germplasm screening in both the field and greenhouse. The work done by Mel will lead to culling of susceptible genotypes during speed breeding of breeding populations. Tommy's work will deliver new large effect resistance QTL from *Aegilops tauschii.*

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

Results from the 2019 project have been communicated to all industry stakeholders. Results were communicated in three talks given to the Michigan Agri-Business Association, Michigan Millers Association, Michigan Crop Improvement Association and wheat field days hosted by The Michigan Wheat Program. When I have an audience with the wheat industry, I highlight the value of genetic resistance.

FY19 Performance Report
PI: Olson, Eric
USDA-ARS Agreement #: 59-0206-6-003
Reporting Period: 4/24/19 - 4/23/20

Project 2: *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 is to advance male-sterile facilitated recurrent selection populations to combine genes for FHB resistance from multiple sources in soft winter wheat backgrounds adapted to the eastern U.S. The goal for this project is to develop several adapted breeding populations with genes for FHB resistance derived from multiples sources. This project is a continuation of the project begun in 2009 to generate FHB male-sterile facilitated recurrent selection populations with FHB resistance in the eastern soft wheat region. As a result of this project breeding programs in the eastern U.S. have several pools of germplasm from which to extract breeding lines. The breeding lines extracted from these populations potentially have unique combinations of FHB resistance genes. Because of the male-sterility in these populations individual breeders should be able to use these populations to develop new combinations of FHB resistance genes and select lines from these populations. Several breeding programs are now extracting fertile lines from the local populations. Intermating with adapted FHB resistant male parents will be continued.

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?

   Inbred lines were derived from segregating populations and evaluated in the FHB nursery. A set of five lines were evaluated in replicated yield trials.

   b) What were the significant results?

   None of the lines had acceptable levels of resistance to FHB. Grain yield was not high enough to warrant further advanced testing.

   c) List key outcomes or other achievements.

   The MSU program will opt out of continuing objectives related to using Male Sterile Facilitated Recurrent selection for FHB resistance. Rather, genomic selection will be used to rapidly accumulate alleles for FHB resistance in forward breeding activities.

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.**

   No

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

Three graduate students gained experience in rating FHB resistance in a misted and inoculated nursery. The students were trained in the entire process of planting the nursery, growing the corn grain spawn and rating disease.

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

Project collaborators have been informed of results.

FY19 Performance Report
PI: Olson, Eric
USDA-ARS Agreement #: 59-0206-6-003
Reporting Period: 4/24/19 - 4/23/20

Project 3: *Coordinated Phenotyping of Uniform Nurseries and Official Variety Trials*

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

   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?

A misted and inoculated Fhb nursery was planted to assess levels of resistance in elite breeding lines and varieties available to growers. Five isolates from across Michigan were used to develop the corn grain spawn. Inoculum was applied at three intervals approximately four, three and two weeks before flowering starting at approximately the Feekes 5 growth stage. Data were collected on flowering date for each row in the nursery. Disease ratings then took place at approximately 21 days after flowering. Ratings were taken over the course of three days on June 28 and 29, 2019.

The 2019 FHB nursery was highly successful. Infection conditions were ideal and very high levels of disease develop uniformly across the nursery. FHB incidence ranged from 60% to 100% across the nursery. High quality data were collected on incidence, severity, FHB index and 0 to 9 rating.

A total of 1133 entries from the Michigan State Wheat Performance trial were evaluated for FHB incidence, severity and index. Other nurseries evaluated included the MSU GS Training Population (TP), MSU Advanced Yield Trial (AYT), Michigan State Commercial Wheat Performance Trial (OVT), P+NUWWN, Uniform White and Uniform Red Nurseries. Samples were collected for DON analysis and results will be reported when samples are processed.

b) What were the significant results?

- Data from the MSU GS training population enabled high prediction accuracies for visual FHB traits and DON at 0.35 and 0.55, respectively.

c) List key outcomes or other achievements.

- Data from the MSU GS training population was used to predict DON and visual FHB traits among ~2,400 inbred lines. GEBVs were used to select 600 soft red and white winter wheats for planning in observation and increase plots.
- Data from the MSU nursery was used to inform breeding decisions in collaborator's germplasm
- Accurate data was provided for advancing MSU breeding lines based on FHB resistance.

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.

No

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

One graduate student at The Ohio State University was trained in genomic selection.

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

Yes, one journal article was published in Theoretical and Applied Genetics

FY19 Performance Report
PI: Olson, Eric
USDA-ARS Agreement #: 59-0206-6-003
Reporting Period: 4/24/19 - 4/23/20

Project 4: *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?

1) Assess the phenotypes of lines from the past three cycles of GS and assess the effectiveness of rapid cycling GS

2) Assess the efficacy of using GS to enhance selection of stage 1 & 2 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?

Funding was primarily to cover the cost of genotyping lines to validate the accuracy of genomic selection. A total of 768 lines from the Ohio State University wheat breeding program were genotyped using sequence based genotyping. DNA was isolated at OSU and shipped to MSU where it was quantified and normalized for sequencing library prep. Project Co-PI, Eric Olson, prepared sequencing libraries of OSU lines. SNP calling was done my a MS student at OSU under the supervision of Clay Sneller.

Hypotheses regarding the efficiency of genomic selection were carried out at OSU by MS student, Daniel Borrenpohl.

b) What were the significant results?

The most significant result of this work is the determination that genomic selection is more cost-effective than phenotyping grain yield and FHB traits in year one yield trials.

c) List key outcomes or other achievements.

The results of this study were used to inform decisions on the implementation of GS in soft winter wheat breeding programs.

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.

No

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

Daniel Borrenpohl, a MS student at OSU, isolated DNA, called SNPs and conducted the cross validation and computation work to evaluate genomic selection strategies.

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

Results of this work have been published in Theoretical and Applied Genetics, Borrenpohl D., M. Huang**, E.L. Olson** and Clay Sneller. 2020. The value of early-stage phenotyping for wheat breeding in the age of genomic selection. Theoretical and Applied Genetics. 133: 2499-2520.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY19 award period (4/24/19 - 4/23/20). 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?**
   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 FY19 award period?**
   No

   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?**
   NA

   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?**
   NA

   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**
Soft White Winter Wheat Resistant Check MI14W0190	Soft White Winter	R	1.8ppm DON	2019
MI16W0528	Soft White Winter	MR	5.3ppm DON	2019
MI16W0133	Soft White Winter	S	10.6ppm DON	2019
Soft Red Winter Wheat Resistant Check MI14R0082	Soft Red Winter	R	0.46ppm DON	Check
MI16R0898	Soft Red Winter	MR	2.8ppm DON	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 (4/24/19 - 4/23/20**) 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.

Borrenpohl D., M. Huang**, E.L. Olson** and Clay Sneller. 2020. The value of early-stage phenotyping for wheat breeding in the age of genomic selection. Theoretical and Applied Genetics. 133: 2499-2520.
Status: Published in Theoretical and Applied Genetics
Acknowledgement of Federal Support: YES

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

Other publications, conference papers and presentations.

Reck T., A. Noble, S. Martin, M. Winchester, **E.L. Olson**. 2019. "Screening segregating breeding populations for Type I and Type II resistance of Fusarium Head Blight in the greenhouse." In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum (p. 12), M*ilwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES

Olson E.L., A. Noble, S. Martin, T. Reck. 2019. Rapid generation advancement and genomic selection accelerate genetic gain for resistance to Fusarium Head Blight. " In: S. Canty, A. Hoffstetter, H. Campbell and R. Dill-Macky (Eds.), *Proceedings of the 2019 National Fusarium Head Blight Forum (p. 12)*, *M*ilwaukee, WI; December 8-10. University of Kentucky, Lexington, KY.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES