USDA-ARS
U.S. Wheat and Barley Scab Initiative
FY20 Annual Performance Progress Report
Due date: August 31, 2021

Cover Page

Principle Investigator (PI):	Erick DeWolf
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Fiscal Year:	2020
USDA-ARS Agreement ID:	59-0206-0-155
USDA-ARS Agreement Title:	Predictive Models for Fusarium Head Blight
FY20 USDA-ARS Award Amount:	$ 71,700
Recipient Organization:	Kansas State University 10 Andrerson Hall Manhattan, KS 66506
DUNS Number:	929773554
EIN:	48-0771751
Recipient Identifying Number or Account Number:	AR9757 / GAPP006584
Project/Grant Reporting Period:	6/7/20 - 6/6/21
Reporting Period End Date:	6/6/2021

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
MGMT	Continued Deployment of Prediction Models for Fusarium Head Blight	$ 20,704
MGMT	Application of Model Ensembles and Machine Learning to the Prediction of Fusarium Head Blight	$ 35,438
MGMT	Integrated Management of Fusarium Head Blight in Kansas	$ 15,558
	FY20 Total ARS Award Amount	**$ 71,700**

Erick D. DeWolf

August 31, 2021

Principal Investigator Date

* MGMT – FHB Management
FST – Food Safety & Toxicology
R- Research
S – Service (DON Testing Labs)
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

FY20 Annual Performance Progress Report
PI: DeWolf, Erick
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Project 1: *Continued Deployment of Prediction Models for Fusarium Head Blight*

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

   Continued deployment of the FHB forecasting models; support and quality control on weather databases; coordination of the FHB Alert System with NFO; training and support for colleagues developing state level commentary; user survey at the close year.

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

   a) **What were the major activities?**

   Deployment of disease forecasting models for Fusarium head blight of wheat and barley in the US. This includes development, refinement and quality control of the web-based tools that deliver the daily estimates of disease risk in 33 states. Coordination of the state and regional level commentary by wheat and barley disease specialists in the US. Working with the USWBSI Network and Facilitation Office to deliver this commentary via the FHB Alerts.

   b) **What were the significant results?**

   Delivery of disease forecasting models for wheat and barley growers in 33 states where FHB and DON are known to be a problem. This includes both areas in the Eastern US that have a long history of problems with FHB, and recent expansions of the forecasting system to address western states where the disease emerged as a problem in the last 5-10 years.

   c) **List key outcomes or other achievements.**

   Continued the redesign and improvements of the web-based tools. Improvements this year include an enhanced user interface that is easier to navigate, increased stability of the weather database used to estimate the risk of disease.

   We developed a number of improvements in 2021 that will be deployed in the 2022 growing season. These improvements include additional graphing features that will allow users to obtain site-specific information about trends in disease risk, and the underlying weather conditions for any location (grid cell) of the disease risk map. We also redesigned the commentary display modules to help growers navigate to commentary for their state and region more efficiently.

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

The primary impact of the COVID-19 pandemic remains the disruptions to normal work flow caused by changes in work environment and reduced availability of colleagues around the country. While technology has made people are more accessible than ever, we find most people are stressed, burned out and weary of consent uncertainty brought about by the pandemic. Our research group was able to complete most tasks required by the project despite these disruptions. Some additional features of the forecast tools were delayed to avoid potential disruption to the in-season deployment of the web-based tools in 2021. These features will be part of the tools in 2022.

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

Although this project does not support formal student training, we regularly use the disease forecasting tools as a platform for demonstrating key concepts of integrated disease management in the graduate courses, and international workshops. Some noted examples include: International Fusarium Workshop, Graduate Courses on Plant Disease Epidemiology, and Multi-State Committees on Small Grain Diseases East of the Rocky Mountains (NCERA-184).

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

The disease forecasting system is a mechanism of communicating scientific results to the public. The web-based tools and FHB Alerts reach thousands of wheat and barley producers each year, directly. The information distributed by the disease forecasting system is also used to enhance extension newsletters, blog posts and social media feeds in key wheat producing states.

Project 2: *Application of Model Ensembles and Machine Learning to the Prediction of Fusarium Head Blight*

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

This project aims to develop the next generation of forecasting models deployed via the national level forecasting effort supported by the USWBSI. The most recent project was exploring the potential of groups of simple forecasting models (ensembles) to improve the overall accuracy and stability of model predictions. We also added some educational/training objectives to the project in the past cycle. These training objectives seek to translate the findings of the modeling effort into clear statements about the key aspects of FHB epidemiology.

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

a) What were the major activities?

We completed the initial evaluations of the ensemble modeling approaches this past year. Overall, the ensemble approach did improve the performance for the forecasting models (see details below). These results were published in the journal *PLOS Computational Biology* during 2021. We also made progress on the training and educational objectives of the project his past year. In support of this objective, we began using machine learning algorithms (Random Forests) to identify weather patterns (key weather variables) that consistently stimulate or suppress outbreaks of FHB and DON. These approaches are also helping us identify weather patterns that modify these relationships (variable interactions). We are using these results to develop a foundation of educational resources to share with the USWBSI community. Our hope is that it will help our colleagues develop commentaries for the FHB Alerts and web-based forecasting tools, and also help inform the next generation of scientists trained by the Initiative.

b) What were the significant results?

The ensembling approach explored in this phase of the analysis considered three ways of combing model predictions: soft voting, weighted averaging, and a model stacking approach based on penalized regression. Soft voting and weighted average approaches generally improved prediction accuracy and other aspects of model fit relative to any individual model alone, but not universally so. Model stacking based on a penalized regression algorithm; however, was superior to the other methods of ensemble modeling considered in this analysis. For example, the ROC-AUC values (a statistic summarizing overall model accuracy) of the stacked ensemble modeling

provided 24% , 14% and 12% gains over the individual models, soft vote and model averaging approaches, respectively.

By nature, FHB epidemics are rare events. The current data set contains nearly 1,000 location years or cases. Less than 30% of these cases represent FHB epidemics. When modeling rare events, developing models with datasets that balance event and non-events, in this case, FHB epidemics and non-epidemics, can improve model performance. This past year, we investigated the potential for balancing within the model development dataset to improve the performance of the FHB models. Within the logistic regression framework used for the FHB modeling, we have not found balancing to improve model performance.

We have also made progress on objectives focused on employing machine learning to identify weather patterns stimulating FHB epidemics. This analysis supports the educational objectives of the current proposal. To date, we focused on the random forests algorithm within machine learning and are currently exploring ways to make the variable selection within the set of >300 candidate predictor variables more efficient. We have identified 13 strategies for improving efficiency of the variable selection process and have tested them on example datasets. We preparing to use the best performing methods on the FHB data matrix this fall.

c) List key outcomes or other achievements.

Publication of ensemble modeling manuscript in *PLOS Computational Biology*
Developing strategies for testing the deployment of model ensembles in operational disease forecasting system.

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

Effects of the COVID-19 pandemic were minimal for this project.

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

This past year, we initiated a post-doctoral training project that focuses on developing the next generation of plant disease epidemiologists. This project includes colleagues at Penn State University, Ohio State University, and North Carolina State University. The FHB modeling dataset is one of several key data sets used in this training initiative. This project involves four post-doctoral researchers.

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

The outcomes and results of the FHB predictive model project are deployed via the national FHB forecasting project supported by the USWBSI. The models and the information provided are also used by the extension community throughout the US. Together, these resources support the fungicide decisions of thousands of wheat are barley growers in the US.

Project 3: *Integrated Management of Fusarium Head Blight in Kansas*

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

- Evaluate the effectiveness of integrated management strategies that combine varieties with best available genetic resistance with fungicide products for suppressing FHB in Kansas.
- Collaboration with the multi-state effort to combine the integrated management of FHB and DON. A powerful tool for evaluating the efficacy of management strategies and specific fungicide products new to the wheat and barley community.
- Communication of these results to wheat producers in Kansas.

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

a) What were the major activities?

Replicated research plots were established near Manhattan KS and Belleville KS, which have a history of FHB epidemics. These plots included three wheat varieties with differing levels of genetic resistance to FHB (S, MS, and MR). Plots were inoculated with spores (macroconidia and ascospores) of Fusarium graminearum and treated with fungicides according to the protocols established for the IM-CP. Disease incidence and severity (FHB index) was rated at least two times at each location. The plots were harvested at maturity, and grain evaluated for symptoms of Fusarium damaged kernels (FDK). The replicated grain samples were ground and sent for DON analysis. Disease data were entered and preliminary analysis conducted. We are currently waiting for DON results.

b) What were the significant results?

Severe FHB developed at both Manhattan and Belleville locations in 2021. Susceptible inoculated control plots had >15% FHB Index at Belleville and >30% Index at Manhattan. Preliminary results indicate that wheat varieties with moderate levels of genetic resistance had lower levels of disease, than susceptible varieties. Fungicides also suppressed disease development when applied at anthesis. Fungicides applied at heading provided less disease suppression. Plots with the lowest FHB Index and FDK were planted with varieties that were MR to FHB and received fungicide applications.

c) List key outcomes or other achievements.

We made several adjustments to our inoculation protocol in 2021. Enhancements included integration of several recent Fusarium isolates into the inoculum production,

addition of ascospores within the inoculum, and a 10X increase in the number of spores used to inoculate the plots.

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

COVID-19 continues to slow the progress on many research projects. It is very difficult to spread workload among multiple personnel because of travel restrictions and limitations on number of individuals allowed in the same research spaces. Such restrictions have made it difficult to complete some of our graduate student training goals.

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

The USWBSI does not formally support the graduate student training. None the less, we use the FHB IM projects in Kansas to train graduate students on how to inoculate, rate disease.

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

The results of the replicated trails here in Kansas are incorporated in newsletter articles and extension presentations in Kansas. These resources help keep wheat growers in Kansas up-to-date on the best available varieties and fungicides. The Kansas data also provides specific examples of how these management tools can be combined to provide improved suppression of the FHB and DON.

Training of Next Generation Scientists

Instructions: Please answer the following questions as it pertains to the FY20 award period (6/7/20 - 6/6/21). 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?**
   ☐Yes ☐No ☒ Not Applicable
   If yes, how many? Click to enter number here.

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?**
   ☐Yes ☐No ☒ Not Applicable
   If yes, how many? Click to enter number here.

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?**
   ☐Yes ☐No ☒ Not Applicable
   If yes, how many? Click to enter number here.

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?**
   ☐Yes ☐No ☒ Not Applicable
   If yes, how many? Click to enter number here.

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 FY20 award period (6/7/20 - 6/6/21). 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	FHB Rating (0-9)	Year Released
N/A	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
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Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year
Click here to enter text.	Select Grain Class	Select what represents your most resistant check	Enter as text 0-9 rating	Select Year

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

Publications, Conference Papers, and Presentations

Instructions: Refer to the PR_Instructions for detailed more instructions for listing publications/presentations about your work that resulted from all of the projects included in the FY20 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period (6/7/20 - 6/6/21**) 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:

Z.J. Winn, R. Acharya, J. Lyerly, G. Brown-Guedira, C. Cowger, C. Griffey, J. Fitzgerald, R.E. Mason and J.P. Murphy. 2020. "Mapping of Fusarium Head Blight Resistance in NC13-20076 Soft Red Winter Wheat." In: S. Canty, A. Hoffstetter, and R. Dill-Macky (Eds.), *Proceedings of the 2020 National Fusarium Head Blight Forum (*p. 12.), Virtual; December 7-11. Online: https://scabusa.org/pdfs/NFHBF20_Proceedings.pdf.
Status: Abstract Published and Poster Presented
Acknowledgement of Federal Support: YES (Abstract and Poster)

Journal publications.

Shah, D.A., De Wolf, E.D., Paul, P.A., and Madden, L.V. 2021. Accuracy in the prediction of disease epidemics when ensembling simple but highly correlated models. PLOS Computational Biology. https://doi.org/10.1371/journal.pcbi.1008831.
Status: Published
Acknowledgement of Federal Support: YES

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

Nothing to report.

Other publications, conference papers and presentations.

Marian Luis, J., Ng,, S.J., Bergstrom, G, Bissonnette, K. Bowen, K., Bradley, C., Byamukama, E., Chilvers, M., Collins, A., Cowger, C., Darby, H., DeWolf, E., Dill-Macky, R., Esker, P., Friskop, A. n Kleczewski, N., Koehler, A.,. Langston, D., Madden, L., Marshall, J., Mehl, H., Moraes, W., Nagelkirk, M., Rawat, N., Smith, D. Telenko, D., Wegulo, S., Young-Kelly, H. and Paul, P.A. 2020. Fusarium Head Blight Management Coordinated Project: Integrated Management Trials, 2018-2020. In: S. Canty, A. Hoffstetter, and R. Dill-Macky (Eds.),

Proceedings of the 2020 National Fusarium Head Blight Forum (pp.39). East Lansing, MI/Lexington, KY: U.S. Wheat & Barley Scab Initiative.
Status: Abstract Published, Poster Presented
Acknowledgement of Federal Support: YES (abstract and poster)

Marian Luis, J., Ng,, S.J., Bergstrom, G, Bissonnette, K. Bowen, K., Bradley, C., Byamukama, E., Chilvers, M., Collins, A., Cowger, C., Darby, H., DeWolf, E., Dill-Macky, R., Esker, P., Friskop, A. n Kleczewski, N., Koehler, A.,. Langston, D., Madden, L., Marshall, J., Mehl, H., Moraes, W., Nagelkirk, M., Rawat, N., Smith, D. Telenko, D., Wegulo, S., Young-Kelly, H. and Paul, P.A... 2020. Fusarium Head Blight Management Coordinated Project: Uniform Fungicide Trials, 2018-2020. In: S. Canty, A. Hoffstetter, and R. Dill-Macky (Eds.), Proceedings of the 2020 National Fusarium Head Blight Forum (pp.44). East Lansing, MI/Lexington, KY: U.S. Wheat & Barley Scab Initiative.
Status: Abstract Published, Poster Presented
Acknowledgement of Federal Support: YES (abstract and poster)