USDA-ARS | U.S. Wheat and Barley Scab Initiative

FY22 Performance Progress Report

Due date: July 26, 2023

Cover Page

USDA-ARS Agreement ID:	59-0206-2-105
USDA-ARS Agreement Title:	Forecasting Models for Wheat Fusarium Head Blight
Principle Investigator (PI):	Erick DeWolf
Institution:	Kansas State University
Institution UEI:	CFMMM5JM7HJ9
Fiscal Year:	2022
FY22 USDA-ARS Award Amount:	$34,059
PI Mailing Address:	Kansas State University, Department of Plant Pathology 4024 Throckmorton PSC, Manhattan, KS 66506
PI E-mail:	dewolf1@ksu.edu
PI Phone:	785-532-3968
Period of Performance:	May 1, 2022 – April 30, 2026
Reporting Period End Date:	April 30, 2023

USWBSI Individual Project(s)

USWBSI Research Category*	Project Title	ARS Award Amount
MGMT	Continued Deployment of Prediction Models for Fusarium Head Blight of Wheat & Barley	$10,437
MGMT	Improved Model Ensembles for Prediction of Fusarium Head Blight	$23,622
	FY22 Total ARS Award Amount	$34,059

I am submitting this report as an: ☒ Annual Report

I certify to the best of my knowledge and belief that this report is correct and complete for performance of activities for the purposes set forth in the award documents.

Erick DeWolf
Principal Investigator Signature

7/26/2023
Date Report Submitted

‡ BAR-CP – Barley Coordinated Project
DUR-CP – Durum Coordinated Project
EC-HQ – Executive Committee-Headquarters
FST-R – Food Safety & Toxicology (Research)
FST-S – Food Safety & Toxicology (Service)
GDER – Gene Discovery & Engineering Resistance
HWW-CP – Hard Winter Wheat Coordinated Project
MGMT – FHB Management
MGMT-IM – FHB Management – Integrated Management Coordinated Project
PBG – Pathogen Biology & Genetics
TSCI – Transformational Science
VDHR – Variety Development & Uniform Nurseries
NWW –Northern Soft Winter Wheat Region
SPR – Spring Wheat Region
SWW – Southern Soft Red Winter Wheat Region

Project 1: Continued Deployment of Prediction Models for Fusarium Head Blight of Wheat & Barley

---

1. **What are the major goals and objectives of the research project?**
   - Deployment of the daily estimates of disease risk in 39 states
   - Develop prototypes of a web-based user interface for delivering estimates of disease risk based on model ensembles.
   - Develop climate-based risk assessment for Fusarium head blight in the US.

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 the daily estimates of disease risk in 39 states. The disease forecasting models were successfully delivered in the targeted areas during the 2022 and early months of the 2023 growing seasons. This includes development of daily maps of disease risk and coordination of the commentary provided by disease experts. As well as, working with the USWBSI NFO to coordinate delivery of the FHB Alerts via text message and email.

   We continued to improve the user interface this season. Important changes included:

   a. Upgrades to the help documentation for use of the forecasting tools
   b. Improvements to the display of expert commentary by region and adjustments in the display commentary that displays a list of the most recent updates across the country. Users can also view all available commentary provided for a growing season at the national, or regional levels.
   c. Completed testing of tools that will enable users to select any section on the risk map to view recent weather and disease risk trends. These tools should be completed by the end 2023 growing season.

   b) Develop prototypes of a web-based user interface for delivering estimates of disease risk based on model ensembles. Our work here focused on selecting appropriate models for ensemble deployment that will be delivered via this approach. In during this phase of the project, we were working with an ensemble of simple logistic regression models that use only pre-anthesis weather information. This ensemble was identified by the model development team with additional details are provided in the report covering model development. For this project, the focus was on integrating the model ensemble into the systems used to provide daily estimates of disease risk. That included developing code to calculate the summaries of hourly weather data for each of the member models, calculating disease risk for each member and then developing approaches to display the unified summary of disease risk based on the ensemble. This required the development of a new web-based model interface for expert evaluation of the ensemble approach.

c) *Develop climate-based risk assessment for Fusarium head blight in the US.* We also have gathered the needed weather resources to complete the analysis. This project requires 30 years of hourly weather data from the continental US. We also established a database that will allow us to calculate estimates of crop growth stage and disease risk at a 20km grid throughout the spatial domain. Plans are now in place to use this database to estimate the historical disease risk given the current disease model, as well as, the new ensembles of predictive models.

b) What were the significant results?

- The delivery of disease forecasting models and expert commentary that support grower fungicide decisions across United States.
- Establishing a database of weather observations that will be used to conduct the historical risk assessment based on model results for the past 30 years.
- Developed new web-based tools to support testing of the ensemble approaches to estimating disease risk.

c) List key outcomes or other achievements.

User surveys in recent years document the value of the disease forecast model to their farms and agriculture businesses. The current survey indicates that value of the forecasting system and FHB Alerts exceeds $57 million each year.

3. 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).

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

The Fusarium Head Blight Prediction Center is the primary mechanism of communicating disease risk to farmers and the agriculture industries in the US. These web-based tools and FHB Alerts reach thousands of wheat and barley producers each year. 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: Improved Model Ensembles for Prediction of Fusarium Head Blight

---

1. **What are the major goals and objectives of the research project?**
   1. Expand the data matrix used for modeling FHB with cases representing new environments and years.
   2. Improve predictive performance of disease forecasts by combining models representing specific epidemiological processes within model ensembles.

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?**

   Expand the data matrix used for modeling FHB with cases representing new environments and years.

   During this past year, we have been working with cooperators at Ohio State University to bring carefully curate the data sets used for development of disease models. This includes careful evaluation to ensure the location information and GPS coordinates are consistent. This will become increasingly important as we transition to gridded weather data sources such as ERA5 or NASA Power, which provide site specific weather observations. The quality control procedures also identified some differences in how the t states contributing observations rate and report the levels of FHB resistance. Some of these differences are expected as wheat breeding efforts continue to improve the levels of resistance to FHB. For example, relative disease resistance of varieties considered MR historically shift to become MS as improved levels of resistance are released. In some cases, different states will list the same variety with different disease ratings within the same year requiring us to identify research reports and variety ratings to develop a consensus disease rating. This quality control and curation process has focused heavily on observations collected between 2015-2022.

   Improve predictive performance of disease forecasts by combining models representing specific epidemiological processes within model ensembles.

   This past year, the model development team identified an ensemble of simple logistic regression models that can be used to test and refine the delivery of web-based tools used for model development. Each member of the ensemble evaluates the risk of disease using a unique set of weather patterns. Some of these model include variables extending more than 30 days prior to anthesis. The goal of the ensemble is to improve accuracy and stability of the disease prediction models across environments and years. The selection and implementation of this ensemble requires coordination across model development and deployment teams. To meet this need we have been meeting monthly to evaluate progress and problem solve road blocks to implementation of the ensembles. This includes careful communication of input variables required for each member of the ensemble, evaluating the output of the each model and developing methods of displaying the unified predictions of disease risk.

We also continued our work to improve the ensembles used to predict FHB based on machine learning. In this year we examined the plausibility of random forests (RF) for the prediction of FHB epidemics. The RF approach provided an effective means of identifying candidate variables as predictors. In this analysis we The filtered input predictor set of over 300 weather based variables with the aid of three RF variable selection algorithms (Boruta, varSelRF and VSURF), using resampling techniques to quantify the variability and stability of selected variable sets. Post-selection filtering produced 58 competitive RF models with no more than 14 predictors each. Overall, this approach appears to provide important improvements model accuracy over the logistic regression based approaches that have been the base approach use to develop model FHB.

b) What were the significant results?

- The unified effort update the FHB dataset will result in the addition of 300 cases to the matrix used to develop predictive models for FHB in the United States. When completed this dataset will include over 1300 cases representing more than 15 states and observations collected between 1986 and 2022. This information is important to ensure that the FHB models remain robust in changing environments.

- The model development team identified an ensemble of simple logistic regression models that is being used to test and refine the delivery of web-based tools used for model development. This ensemble includes four models each using unique weather variables to estimate disease risk. These variables include temperature, relative humidity and barometric pressure measurements as much as 30 days prior to anthesis (Figure 1).

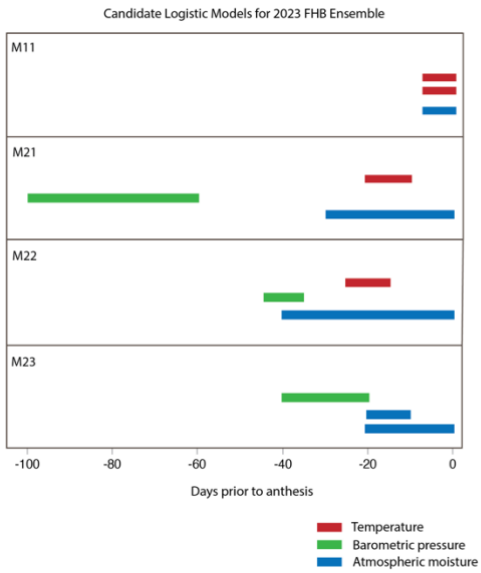

Figure 1. Weather based predictors used within an ensemble of logistic regression model predicting FHB. This year we working with cooperators in the model deployment team to test and evaluate procedures needed to deploy FHB predictions base on a model ensemble.

- The machine learning approaches to developing model ensembles for predicting FHB epidemics appear very promising. We identified approaches and models with overall superior predictive performance than the LR models and may be suitable candidates for use by the Fusarium Head Blight Prediction Center.

- The machine learning approaches have also helped us gain new insights into the relationships of environment and disease development. For example, one variable representing temperature stability in the 20 days before anthesis was the most frequently selected predictor within the machine learning approach. This represents was a departure from previous modeling results that have relied primarily on relative humidity-based variables.

c) List key outcomes or other achievements.

- Publication of ensemble modeling manuscript describing the use of machine learning to model FHB epidemics in the USA in the journal *Phytopathology*.

- The modeling work supported by the USWBSI has assembled one of the best datasets for modeling FHB in the world. The quality of this data has enabled the modeling team to explore novel modelling approaches and make potentially valuable advancements in model accuracy.

- The ensemble modeling approaches used in this research represent a departure from the common paradigm of modeling plant diseases. For decades, plant pathologists have developed groups of models then systematically search through the candidate models to identify a single model to apply as part of an operational disease forecasting system. The ensemble modeling approaches demonstrate an approach for combining multiple models that can improve performance (accuracy and stability) of disease forecasting systems.

- Our recent efforts to model FHB with machine learning have produced multiple candidate models (ensembles) with overall superior predictive performance to previously deployed logistic regression models.

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

We continued 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.

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

The disease forecasting models developed by the FHB modeling team are deployed through the FHB Prediction Center that is supported by the USWBSI. This forecasting system brings daily estimates of disease risk to wheat and barley growers in 39 states.

Publications, Conference Papers, and Presentations

Please include a listing of all your publications/presentations about your FHB work that were a result of funding from your FY22 grant award. Only citations for publications published (submitted or accepted) or presentations presented during the **award period** should be included.

Did you publish/submit or present anything during this award period May 1, 2022 – April 30, 2023?

X Yes, I've included the citation reference in listing(s) below.

☐ No, I have nothing to report.

Journal publications as a result of FY22 award

List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Include any peer-reviewed publication in the periodically published proceedings of a scientific society, a conference, or the like.

Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published [include DOI#]; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

Shah, D., De Wolf, E.D., Paul, P.A. and Madden, L.V. 2023. Into the trees: random forests for predicting Fusarium head blight of wheat in the United States. Phytopathology (in press).
Status: Journal Publication Available On-line as First Look
Acknowledgment of Federal Support: YES (publication)

Books or other non-periodical, one-time publications as a result of FY22 award

Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like.

Identify for each one-time publication: Author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (book, thesis, or dissertation, other); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

Other publications, conference papers and presentations as a result of FY22 award

Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication.