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

FY21 Performance Progress Report

Due date: July 26, 2022

Cover Page

Principle Investigator (PI):	Erick DeWolf
Institution:	Kansas State University
E-mail:	dewolf1@ksu.edu
Phone:	785-532-3968
Fiscal Year:	2021
USDA-ARS Agreement ID:	59-0206-0-155
USDA-ARS Agreement Title:	Predictive Models for Fusarium Head Blight
FY20 USDA-ARS Award Amount:	$73,263
Recipient Organization:	Kansas State University Department of Plant Pathology 4024 Throckmorton PSC, Manhattan, KS 66506
DUNS Number:	929773554
EIN:	48-0771751
Recipient Identifying Number or Account Number, if any:	AR9757 / GAPP006584
Project/Grant Period:	6/7/21 - 6/6/23
Reporting Period End Date:	6/6/2022

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	$17,121
	FY21 Total ARS Award Amount	$73,263

I am submitting this report as an: ☒ Annual Report ☐ Final 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.

Principal Investigator Signature

7/26/22

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

---

1. **What are the major goals and objectives of the research project?**
   1) Deployment of predictive models for Fusarium head blight in the US
   2) Update web-based tools used to deliver disease forecasts
   3) Survey of users of FHB Alerts and forecasting tools

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 predictive models for Fusarium head blight in the US

   This support from the USWBSI allowed a team of plant pathologists, meteorologists and geographers and information technology specialists to deliver daily estimates of disease risk for much of the continental US. These activities include: Monthly meetings to coordinate projects and review progress; Daily support and quality control procedures to ensure weather data used by the system is of the highest quality possible and timely risk maps are available to growers each day; Rapid response to problems with data flow or processing errors; and Applying disease risk models and publishing daily disease risk maps; Coordination of national efforts to develop and distribute state-level expert commentary via the web-tools and FHB Alert system.

   Update web-based tools used to deliver disease forecasts

   The funding supported the on-going efforts to add new features to the predictive web-based tools to keep these resources compatible with the latest computer software on desktop and mobile devices. During this funding term we have transitioned to an entirely new user interface, updated the risk maps to reflect cutting edge GIS theory, improved help documents and navigation within the system, and developed tools that will allow users to access site-specific estimates of weather and estimates of disease risk.

   Survey of users of FHB Alerts and forecasting tools

   This funding supports our efforts to verify model performance throughout the US this includes gathering input from University cooperators on the model accuracy in their state. We also work with the NFO to coordinate a user survey via the FHB Alert system. This survey gathers demographic information about the users, provides an means of evaluation of how the system is working for users, and gathers valuable impact information for the USWBSI.

b) What were the significant results?

- The delivery of disease forecasting models that support grower management decisions in 39 states.
- Transition to a new user interface that keeps these tools compatible with current browser and mobile device technologies
- Completion of user surveys that help us evaluate model performance and gather important impact information.

c) List key outcomes or other achievements.

- Wheat and barley growers in 39 states had access to daily estimates of disease risk and expert commentary supporting their management of FHB. This includes expansion of the system to include additional states in the western US where the disease has recently emerged as a production constraint.
- Users continue to document the value of the disease forecast model to their farm and agriculture businesses. The current survey indicates that value of the forecasting system exceeds $57 million each year.

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

- Demonstration of new forecasting tools for extension wheat disease specialists that develop commentary for FHB Alerts. Meeting of the Small Grain Pathology Multistate Committee, (NCERA-184), March 2022.

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

- The primary focus of this effort is the dissemination of the predictive models developed by the USWBSI. This effort has a national focus and reaches wheat and barley growers in 39 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?

- Incorporate additional observations of FHB epidemics into the data sets used to model FHB.
- Explore the potential for ensembles of predictive models and machine learning to improve predictive models for FHB.

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?

Incorporate additional observations of FHB epidemics into the data sets used to model FHB.

This funding supported the incorporation of observations from integrated management cooperative project (IM-CP) within the USWBSI. This includes observations from replicated field trails throughout the US. This involves coordination of the research protocols, coordinating reports from cooperators, and curating the data contributed.

Explore the potential for ensembles of predictive models and machine learning to improve predictive models for FHB.

This funding from the USWBSI supports efforts to improve the FHB forecasting models used in the US. These activities include and gathering weather observations associated with each new location added to the modeling data sets, quality control procedures to identify potential errors, experimentation and tunning of the machine learning and ensemble modeling approaches, assessment of model performance, evaluation of model errors, and verification of model performance with new observations.

b) What were the significant results?

We developed methods for combining multiple predictive models (model ensembles) that were able to improve the accuracy of FHB forecasts. These methods involve evaluating the variability among to predictions in 38 candidate disease models. We demonstrate how combining models representing this diversity within ensembles improves the accuracy predictions of disease over any individual model alone. Additional improvements in performance of the ensemble were made when added another layer of models to combine or weight the different predictive models within the ensemble.

Constructing models that predict Fusarium head blight (FHB) epidemics and which are also amenable to large-scale deployment is a challenging task. In the US, the emphasis has been on simple logistic regression models which are easy

to implement but may suffer from lower accuracies when compared to more complicated, harder-to-deploy (over large geographies) model frameworks such as functional or boosted regressions. In this project we examined the plausibility of random forests (RF) for the binary classification of FHB epidemics, as a possible mediation between model simplicity and complexity without sacrificing accuracy. Parsimony was also a goal in that a minimalist set of predictors was desirable rather than having the RF model use the available 300+ candidate variables as predictors. The input variable set of 999 observations from 27 states over 30 years was filtered with the aid of three RF variable selection algorithms (Boruta, varSelRF and VSURF), using nested resampling to quantify the variability and stability of selected variable sets. This led to 58 competitive RF models with no more than 14 predictors each, and which had overall superior predictive performance to previously reported simple logistic regression models. Further stacking (ensembling) of the RF models using penalized regressions as the meta-learner did not improve classification of epidemics and nonepidemics, presumably because of high correlations in the predicted probabilities of the individual RF models. Penalization imposed by the meta-learners was viewed as another round of filtering, this time on the RF models, leading to a smaller set which may be amenable for incorporation into regional prediction systems for FHB.

c) List key outcomes or other achievements.

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. We will begin testing these models for deployment in the 2023 growing season.

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

Presentation and discussion of the modeling results at the International Fusarium Workshop, 2022. This workshop brings Fusarium researchers from around the world

together to learn about Fusarium identification and management. Discussion of the FHB modeling effort at the workshop provides training for an international group of Fusarium 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.

Project 3: Integrated Management of Fusarium Head Blight in Kansas

---

1. **What are the major goals and objectives of the research project?**
   Carryout research that investigates the role of combining wheat varieties with differing levels of genetic resistance to FHB and best available fungicides in Kansas.

   Evaluate the efficacy of fungicides for the suppression of the FHB, FDK and DON 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?**
   Carryout research that investigates the role of combining wheat varieties with differing levels of genetic resistance to FHB and best available fungicides in Kansas.

   Replicated research plots were established at two locations in Kansas with a history of severe disease (Manhattan and Bellville). In 2021 and 2022, these plots contained 3 wheat varieties with different levels of genetic resistance to FHB. Plots were inoculated with macroconidia of Fusarium graminearum at flowering. A portion of the plots remained uninoculated in support the FHB modeling effort. Fungicide treatments were applied according the protocols established for the USWBSI IM-CP. In 2021 and 2022, these treatments compared newly labeled fungicide products with industry standards and investigated manufacturer claims regarding pre- and post-anthesis treatment efficacy. Disease was rated during the late milk and dough stages of the kernel development. Grain was harvested, evaluated for Fusarium damaged kernels, and sent for DON analysis.

   Evaluate the efficacy of fungicides for the suppression of the FHB, FDK and DON in Kansas.

   Replicated plots were planted at the K-State Plant Pathology Research Farm located near Manhattan, Kansas. These plots were organized in a replicated complete block design and used the FHB susceptible wheat variety ‘KanMark’. The plots were inoculated with corn spawn colonized with Fusarium graminearum 3 times between jointing and flag leaf emergence (30g/ sq m). The location was irrigated each night (10 min hour) to stimulate perithecia development and disease development. Fungicide treatments were applied according to the uniform fungicide cooperative project protocol. These treatments focused on comparison of fungicide efficacy alone or in combination with a second application. Disease was rated during the milk and dough stages of development. The grain was harvested, evaluated for FDK and sent to a USWBSI sponsored lab for DON analysis.

b) What were the significant results?

Carryout research that investigates the role of combining wheat varieties with differing levels of genetic resistance to FHB and best available fungicides in Kansas.

Severe disease developed in the at both locations of the 2021 integrated management project. The susceptible wheat variety had the greatest severity with more than 30% FHB Index in plots that did not receive a fungicide application. Combinations of genetic resistance and fungicides provided suppression of disease with lowest disease occurring in moderately resistant wheat varieties that received a fungicide application. When applied at anthesis, Miravis Ace provided similar levels of disease suppression as Prosaro (the long time standard for FHB management). Application during heading or 3 days post anthesis diminished efficacy of the Miravis Ace treatment.

Intense drought dominated the production environment for much of Kansas during the 2022 growing season. As a result, only low levels of FHB developed in the integrated management plots in both Manhattan and Bellville. FDK and DON analysis are underway, but we anticipate only trace levels of grain damage or mycotoxin contamination.

Evaluate the efficacy of fungicides for the suppression of the FHB, FDK and DON in Kansas.

Severe FHB developed in the 2022 uniform fungicide evaluation located near Manhattan, KS. The untreated control plots had disease incidence near 100% at this location. Most fungicide treatments suppressed disease development by 20-40%. Plots treated with the relatively new product, Spherex had lower FHB index and slightly higher yields than other fungicides tested in this trial including Prosaro, and Prosaro Pro.

c) List key outcomes or other achievements.

These studies have provided multiple years of fungicide efficacy testing and integrated management results specific to Kansas. These results, when combined with national level combined datasets, provide valuable teaching resources. These results are already supporting local extension programming in Kansas.

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

These projects provide a valuable training ground for graduate students in plant pathology at Kansas State University. During the course of this funding cycle we have trained 3 graduate students on experimental design and execution of FHB related research.

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

The results of this research were incorporated into the extension and educational programming of Dr. Andersen Onofre. The results were shared directly in presentations for wheat growers and via electronic newsletters that are read by hundreds of producers in Kansas.

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 FY21 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?

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

☐ No, I have nothing to report.

Journal publications as a result of FY21 grant 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).

1. 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. Federal Support acknowledged (Yes)
2. Zhao, H., Sassenrath, G., Zambreski, Z., Shi, L., Lollato, R., De Wolf, E., and Lin. X. 2021. Predicting winter wheat heading date: a simple model and its validation in Kansas. Journal of Applied Meteorology and Climatology : https://doi.org/10.1175/JAMC-D-21-0040.1. Federal Support acknowledged (No)

Books or other non-periodical, one-time publications as a result of FY21 grant 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).

1. Hollandbeck, G., Andersen-Onofre, K., De Wolf, E., and Todd, T. 2021. Kansas Cooperative Plant Disease Survey Report, 2021. Kansas Wheat Disease Loss Estimates. Federal Support acknowledged (No)
2. Andersen Onofre, K., De Wolf, E.D., Lollato, R. and Whitworth, J. R. 2021. Wheat variety disease and insect ratings, 2021. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Pub. No. MF991. Federal Support acknowledged (No)
3. Andersen-Onofre, K., De Wolf, E.D. 2021. Foliar fungicide efficacy ratings for wheat disease management, 2020. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Pub. No. EP130. Federal Support acknowledged (No)

Other publications, conference papers and presentations as a result of FY21 grant award

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

1. Cucak, M., Dalla Lana, F., Ojiambo, P., De Wolf, E., Paul, P. and Esker, P. 2021. Into the new era of decision support in crop protection: multifaceted disease management advisors based on machine learning and open science. Plant Health Meeting. On line.

August 2-6, 2021. Federal Support acknowledged (No)

2. 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., Negelkirk, 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. Federal Support acknowledged (Yes)
3. 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., Negelkirk, 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. Federal Support acknowledged (Yes)