Project FY24-MG-002: Improving the stability of forecasting models for Fusarium head blight

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1. **What are the major goals and objectives of the research project?**
The overall goal of this project is to create stable models for predicting Fusarium head blight (FHB). Our specific objectives are to 1) Continue expanding the FHB data matrix with observations from the IM-CP, but also estimate how many observations are needed for model stability; 2) Search for a stable FHB predictive model or ensemble of models that generalizes well to any environment (in the future or in other states); 3) Formally assess the stability of variable selection in logistic regression (LR) and random forest (RF) models proposed for FHB prediction; 4) Assess the predictive stability of LR and RF models developed to date.

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

What were the major activities?

- Objective 1: The modeling team (KSU/OSU) successfully completed integrating new observations into the data sets used for the development and evaluation of the FHB models. The total dataset used for modeling FHB was expanded with new observations from the 2024 growing season and now contains over 1,200 observations.
- The addition of this information brings important new observations about the development of FHB from 22 states. The expanded dataset includes information about many contemporary cultivars and a range of genetic resistance levels.
- The expanded dataset describes disease development in a wide range of environments and disease intensities with FHB indexes ranging from 0 to >80% (Figure 1).
- The modeling team also completed rebuilding the weather-based predictors used in modeling FHB using ERA-5 climate datasets. The ERA-5 datasets allow us to leverage ongoing investments in the atmospheric sciences to develop and curate the best available environmental data. We completed a comparison of these gridded weather products with station-based observations already contained in our datasets. For example, the ERA-5 appears to be very accurate and estimates temperature within 1.5 C and RH within 5%.
- We have added many new predictor variables to the FHB data matrix including some long-term climate indices designed by the meteorology community to describe regional trends in moisture availability and oceanic drivers of weather systems in central and eastern U.S. where FHB remains a consistent problem. We hypothesize that these environmental variables will enable us to predict an elevated risk of FHB weeks or even months prior to the flowering stages of the growth that are critical for FHB development.
- We evaluated combinations of predictive models that may perform well together as an ensemble and provide more accurate and stable predictions of FHB in the US. This involves fitting logistic regression models based on both linear representations of the environmental predictors and cubic splines that better account for non-linearities in the relationships between weather and the development of severe FHB. We then evaluate model fit over observed range of predicted probabilities (Figure 3). In this case, it is desirable for the model

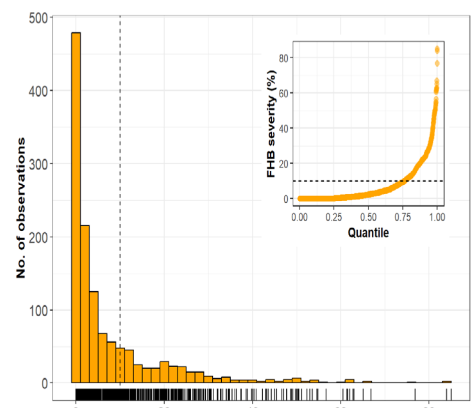

Figure.7¡.Intensity.of.FHB.index.and.FHB. severity.across.the.Ω7?866.observations.in. the.FHB.modeling.dataset¡

to have consistent relationship between predicted probability and observed proportion. The value for the C or ROC fit statistic ranges from 0.5 to 1 with values closer to 1 indicating a higher degree of overall predictive accuracy.

- We are also evaluating the potential of decision curve analysis (DCA) as a tool for model evaluation and improve how we use the models to provide FHB management information to growers. The DCA helps determine whether a predictive model for FHB will improve a growers' ability to make management decisions relative to other alternative strategies. In this case, an alternative strategy might be to always spray for FHB regardless of the weather conditions. The DCA considers the outcomes of the spray decision including benefits of correctly predicting and treating FHB, or potential harm caused by unnecessarily spraying the crop or failing to treat when a fungicide was needed (yield lost to FHB). DCA evaluates the model across a range of threshold probabilities for deciding to spray. This accounts for varying perspectives among growers and their willingness to tolerate different types of risk. For example, some growers may prefer to spray a fungicide at lower probability of FHB to ensure minimal yield loss to disease. Other growers might be willing to tolerate low levels of disease in an effort to reduce the costs associated with unnecessary fungicide applications.

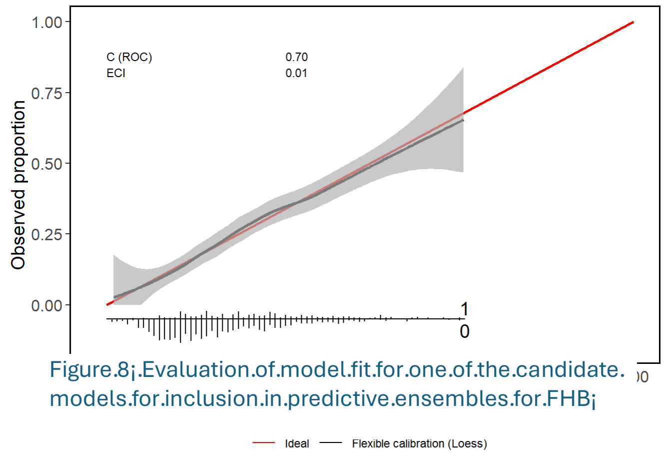

Figure.8¡.Evaluation.of.model.fit.for.one.of.the.candidate. models.for.inclusion.in.predictive.ensembles.for.FHB¡

- The DCA provides a visual representation of how forecasting model for FHB impacts the spray decisions given a probability thresholds (Figure 4). This type of analysis could help extension specialists identify and communicate scenarios where the forecasting models for FHB that are delivered by the USWBSI are likely to result in the most benefits for growers.

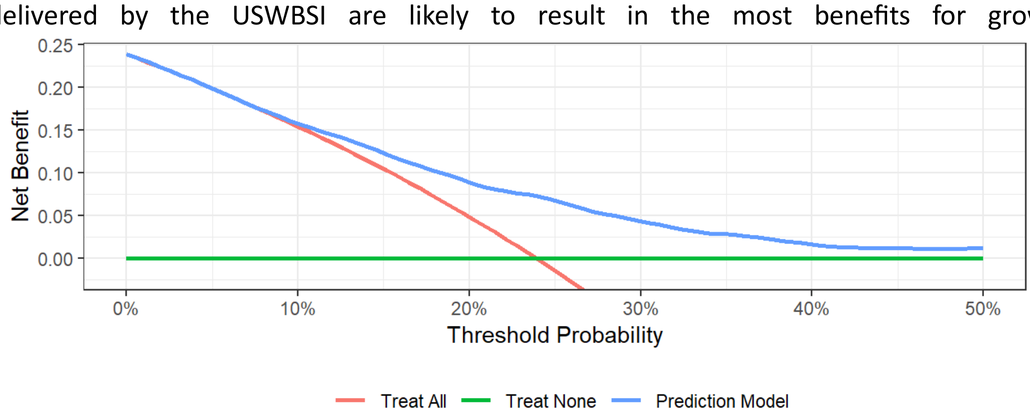

Figure.0¡..Decision.curve.analysis.that.provides.a.visual.assessment.comparing.the.different.strategies.for. fungicide.use.for.FHB.management¡..

- Objectives 3-4: We are working through the complex coding required to conduct the evaluation of model stability required for objectives evaluating model stability. Preliminary results are helping us evaluate the model complexity (number of predictor variables) that can be supported by the current dataset without overfitting the model and compromising the stability of the model predictions in new environments. These assessments are essential if we are to obtain realistic estimates of model accuracy when the models are deployed for use by wheat and barley growers in the US.

What were the significant results?

- The development of forecasting models for FHB has direct influence on the disease management decisions of wheat and barley growers in the US. The cooperative FHB forecasting project and the IM-CP enable us to greatly expand the datasets used for modeling during this past project year.
- Completed comparisons of the ERA-5 gridded weather datasets with station-based observations of weather provide evidence that the gridded weather products offer key improvements to over station-based observations of weather without compromise in quality.
- We are identifying groups of models that work well as an ensemble that can improve the predication accuracy of FHB forecasts in the US.
- We are exploring ways to improve the way we communicate the benefits of incorporating the FHB models into on-farm decision making with decision curve analysis.

List key outcomes or other achievements.

- We now using ERA-5 gridded weather products in the FHB modeling projects. This transition accelerates the disease modeling process and effectively leverages the investments made in atmospheric sciences worldwide.
- Preliminary results of the model stability analysis are already helping guide the complexity of the models we develop and will enable realistic estimates of model accuracy when the models are deployed for use by wheat and barley growers in the US.

3. **What opportunities for training and professional development has the project provided?**
This project provides professional development opportunities for the research associate conducting the analysis and integrates advancements in statistical science into agricultural research and plant pathology specifically.

4. **How have the results been disseminated to communities of interest?**
The models developed in this project are applied within the FHB Prediction Center which delivers daily estimates of disease risk for 35 states where FHB is a critical production issue.

5. **What do you plan to do during the next reporting period to accomplish the goals and objectives?**
We plan to proceed with the proposed a methods applying stabilized regression to FHB forecasting. This approach involves fitting a model to each environment. It is possible that the set of predictors is different among the environments. However, what we are looking for are models that do not vary much between environments. Stabilized regression is then a weighted average of the individual models. We give higher weights to those predictors that generalize across environments and consider these variables as more important in prediction. We will evaluate the results graphically and examine which predictors are stable, those that are unstable and those that don't have much of an influence on prediction. The method will be implemented in the `StabilizedRegression` package within the R programing environment. The recently expanded dataset developed in the last project year now provides enough environments (including multiple observations per environment) to apply the proposed method.

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1. **What are the major goals and objectives of the research project?**
   The overall goal of this project is to create better models for predicting Fusarium head blight (FHB). The objectives were to:
   1) Continue expanding the FHB data matrix with observations from the IM-CP (**Paul Lab**), but also estimate how many observations are needed for model stability (**DeWolf Lab**);
   2) Search for a stable FHB predictive model or ensemble of models that generalizes well to any environment (in the future or in other states) (**DeWolf Lab**);
   3) Formally assess the stability of variable selection in logistic regression (LR) and random forest (RF) models proposed for FHB prediction (**DeWolf Lab**);
   4) Assess the predictive stability of LR and RF models developed to date (**DeWolf Lab**).

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

   What were the major activities?
   Obj 1. In 2024 growing season, integrated management (IM) trials were conducted in several US wheat growing states that are commonly affected by FHB. FHB and DON data were collected and submitted to the Paul lab for processing and analysis. During the season, IM trials were conducted as part of the IM_CP in 18 wheat growing states, namely AL, DE, ID, IN, IL, KS, LA, MD, MI, MO, ND, NE, OH, PA, SD, TN, VA, and WI. Each trial included at least two commercial wheat cultivars representing different levels of FHB resistance classified as susceptible, moderately susceptible, or moderately resistant. FHB index, incidence and DON data were collected from nontreated, naturally infected, non-irrigated plots for each cultivar. These data were then edited and prepared for inclusion in the master dataset to support ongoing FHB risk model development and validation

   Obj 2, 3, and 4 see Dr. DeWolf's report for details.

   What were the significant results?
   Obj 1. During the 2024 season several new observations were collected from the IM_CP and added to the master dataset. Each new observation consisted of mean FHB index and corresponding DON data from a unique environment - combination of cultivar resistance class, trial location, wheat market class, cropping and tillage history and local weather conditions. These data are being mined specifically from trial-resistance-class cases that were neither treated with fungicides nor inoculated with *Fusarium graminearum* spore suspensions.

   Obj 2, 3, and 4 see Dr. DeWolf's report for details.

   List key outcomes or other achievements.
   Obj 1. New IND data and associated weather data were collected from a range of wheat growing locations that likely represent some unique FHB-weather patterns that are new to our master dataset.

   Obj 2, 3, and 4. see Dr. DeWolf's report for details.

3. **What opportunities for training and professional development has the project provided?**
   Through conversations with Dr. Denis Shah via email and zoom meetings, the project provided training to a postdoctoral researcher in data management and data mining. The postdoc gained hands-on experience in extracting and curating FHB index data, as well as cleaning and organizing disease datasets.

4. **How have the results been disseminated to communities of interest?**
   Barring meetings and conversations among members of model development team, no major dissemination efforts were completed during the reporting period.

5. **What do you plan to do during the next reporting period to accomplish the goals and objectives?**
   Continue collecting new data through the IM_CP and developing and testing models as proposed.