Project FY22-TS-006: High Fidelity/Temporal Measurement of FHB for Improved Detection and Monitoring

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1. **What are the major goals and objectives of the research project?**
    - ***a.*** *Replicate, refine, and validate previously developed machine learning models for FHB severity in imaged wheat/barley plots*
    - ***b.*** *Assess FHB severity for field plots multiple times a week using developed and tested FHB models.*
    - ***c.*** *Use high temporal FHB monitoring with environmental variables to understand FHB progression and forecast models.*

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

1. Replicate, refine, and validate previously developed machine learning models for FHB severity in imaged wheat/barley plots

    a. What were the major activities?

    To complete this objective, we needed a good way to validate that the model could at least perform as good as human raters (in field and looking at images), with the goal of the model being better than an individual rater by being a composite of multiple raters. For this objective we used 5 different raters on a subset of 100 FHB inoculated wheat plots and 100 FHB inoculated barley plots. The raters rated FHB on a 0-100% scale looking at the whole plot, using 5% increments. The same raters manually annotated the location of FHB on heads from the rover images. Each of the 5 raters annotated approximately 2,000 heads for disease. In addition, the 5 raters also annotated the disease for the same 200 heads.

    b. What were the significant results?

    These data collections in wheat were used for inter-rater variation of disease estimations as thresholds for our model performance. Raters in the field had an interclass correlation of 0.66. Raters annotating the same images had an interclass correlation of 0.79. Our pipeline run on 10,000 heads from the field resulted in a correlation of 0.91 and 0.75 compared with human field ratings and human annotations from images.

    c. List key outcomes or other achievements.

    We have had less success with barley in this objective as it is harder for raters to agree on in-field ratings compared to wheat for FHB quantification. We are very happy with our outcomes for our wheat models in comparison with in field ratings and ratings based on images as well. We have proven this method to be a high throughput and effective way to rate FHB in wheat as imaging and FHB models predictions are in line with human raters.

2. Assess FHB severity for field plots multiple times a week using developed and tested FHB models.

    a. What were the major activities?

    For this objective we successfully worked with Mineral to use the rover to image wheat/barley plots in both St. Paul and Crookston, MN. With our collaborators at the University of Minnesota a total of ~10,000 wheat/barley FHB screening plots were established at the St. Paul and Crookston, MN field sites. The rover was used to image

plots at both locations on average 2 times per week throughout the summer. All the plots inoculated with FHB for evaluation could be imaged within a single day with the use of the rover. The last imaging day was decided as the last time that FHB was visually distinguishable from plant senescence. After this day FHB disease detection would be complicated by trying to separate disease and dried tissue.

b. What were the significant results?

We were able to capture high quality images this year that were comparable to previous years. This allowed us to be able to look many heads per plot (~100), which can give us a better idea of true disease levels across the plot. We have used the time series data to see nice trends in the amount of disease. We are excited to start to look at the disease from this angle, which was previous not possible at this scale, in earnest. Also, the ability to capture multiple rows in images at one time was key as well for being able to phenotype in breeding and management style plot layouts. We successful captured multiple rover runs per week, collecting millions of images of thousands of plots 10 to 15 times throughout the season.

c. List key outcomes or other achievements.

There were two significant results from the object so far in the project. The first being that we are yearly able to capture images from thousands of plots in a single day and increased the throughput by capturing images with 4 rows in a single image. This was achieved through learning from previous years' work and making the proper adjustments. Being able to acquire images in this way is the first step to being able to work at scale. Also, as our partnership with Mineral will not be continued, we have acquired all the data collected, analysis, and models (>40TB) from this collaboration and have it at the University of Minnesota for future use and access.

3. Use high temporal FHB monitoring with environmental variables to understand FHB progression and forecast models.

a. What were the major activities?

We have spent the majority of our time doing data collection and tuning and improving our FHB detection model. The accuracy, recall, and precision of the model is important to be able to improve current forecasting models. We are at a point that we are happy with our model performance in wheat and can begin to use the FHB disease predictions from the images to test them in forecasting.

b. What were the significant results?

The significant results for this specific objective haven't been realized yet. In the near future we will be combining the FHB detection results across many timepoints with weather and development information to inform new forecast models.

c. List key outcomes or other achievements.

Currently we don't have any outcomes from this objective.

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

The project has provided numerous training activities for project personnel and members of collaborators groups. In the field, new students on the project and adjacent to the project were trained in FHB disease rating in wheat and barley. This is important for them to understand for completion of project objectives and to understand disease development. It also interests them in the pathogen and its importance to small grains. Also, students and project participants were exposed to active hands-on work with the development of machine learning models for imaged-based disease detection. Project members actively

worked in image annotation, model performance, and platform improvement. These are highly sought-after skills in high-throughput phenotyping. Members of the project have gained professional development activities by attending the 2023 National Fusarium Head Blight Forum and through regular video meetings and on campus visits with industry leaders at Mineral, and interaction with pathologists and plant breeders.

4. **How have the results been disseminated to communities of interest?**
   The results of the project have been presented to the plant community through three seminars at conferences, at the University of Minnesota, the FHB Forum, and the North American Plant Phenotyping Network Conference. These were presented by faculty and students on the project and the research and findings were well received. The project has also been disseminated to the community through a publication on bioRxiv that is currently going through the peer review process and by a poster presentation at an international conference. We have also held several field talks at the University of Minnesota about the rover, project goals, and outcomes. These have been attended by faculty, staff, post docs, and graduate students from a variety of disciplines.

5. **What do you plan to do during the next reporting period to accomplish the goals and objectives?**
   For the remainder of the project, we will continue to work through the objectives to reach completion. This will not require more data collection but will require a large and focused effort in data analysis. We will also continue to try to incorporate our temporal data into improved forecasting models.