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?

1. Replicate, refine, and validate previously developed machine learning models for FHB severity in imaged wheat/barley plots.
2. Assess FHB severity for field plots multiple times a week using developed and tested FHB models.
3. 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.)*

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

What were the major activities?
To replicate and refine existing FHB severity models, we conducted extensive validation using both field and image-based assessments. Five trained human raters evaluated FHB severity in 100 wheat and 100 barley plots using a 0–100% scale. These same raters also annotated approximately 10,000 wheat and barley heads for FHB symptoms in images captured by the rover during the 2022 field season. The annotations were used to fine-tune the 2021 machine learning model to accommodate updated imaging hardware and varying disease conditions. To ensure the model's robustness and enable cross-season validation, we also collected and annotated new image datasets in 2023, extending the training data to span three growing seasons (2021–2023). This iterative process of data collection, annotation, and model refinement was essential for model generalization and long-term success.

What were the significant results?
We quantified inter-rater variability in disease severity ratings, which revealed lower consistency in barley (average pairwise r = 0.37) than in wheat (average r = 0.77). Rater agreement declined as disease progressed, likely due to visual confounding with senescence. These findings validated the need for machine learning-based approaches and helped establish realistic performance benchmarks. Preliminary assessments of the updated model suggest that its performance is comparable to or better than the average human rater in wheat, demonstrating progress toward an automated, scalable alternative for disease quantification.

List key outcomes or other achievements.

- Built a robust benchmark dataset of human-derived FHB ratings and image annotations.
- Identified key challenges in human rating consistency, especially in barley.
- Iteratively refined a deep learning-based model now trained on images from 2021–2023.
- Established clear performance baselines for image-based models using inter-rater metrics.

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

What were the major activities?
With the support of the Mineral team, we deployed the rover to image ~10,000 wheat and barley plots inoculated for FHB at St. Paul and Crookston, MN. Imaging was performed approximately twice weekly throughout the growing season. We implemented technical adjustments to improve image quality,

including slowing rover speed from ~1.2 mph to ~0.75 mph and reconfiguring cameras from side to overhead angles to better capture 4-row plots. These improvements were based on learnings from the 2021 season and aimed to increase the number and quality of visible heads per image to enhance model input data.

What were the significant results?
We collected millions of high-resolution images across the season, enabling disease detection over time at an unprecedented scale. Improvements to camera positioning allowed for full 4-row plot coverage in single frames, better simulating breeding and management plot layouts. Importantly, we maintained the ability to image all plots in a single day, ensuring alignment with visual assessments and minimizing environmental variability between image sets.

List key outcomes or other achievements.
- Developed a rover-based workflow for high-resolution imaging of large field trials.
- Successfully acquired disease-relevant images from thousands of plots on a repeat basis.
- Improved imaging throughput and quality without sacrificing speed or coverage.
- Created a large and diverse dataset foundational to continued model training and testing.

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

What were the major activities?
We conducted repeat imaging throughout the disease development window at both field sites to capture FHB progression over time. These images are currently being analyzed using the improved detection model. Although we have not yet reached the modeling stage of disease forecasting, we are aligning image-based FHB quantification data with corresponding environmental variables (e.g., temperature, humidity, and precipitation) to establish the inputs for future disease progression modeling.

What were the significant results?
The temporally resolved image dataset represents a significant foundational resource. While formal integration with environmental data is ongoing, the groundwork is laid for evaluating disease development across genotypes and locations. This step is essential for moving beyond single-timepoint assessments to dynamic disease modeling and forecasting.

List key outcomes or other achievements.
- Established high-temporal image datasets suitable for modeling disease progression.
- Laid the foundation for coupling phenotypic and environmental data in forecasting models.
- Positioned image-based phenotyping as a key tool for advancing FHB epidemiology research.
- Reinforced the value of automated, repeatable image collection in disease monitoring.

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, a new round of students on the project have been trained in FHB disease rating for both wheat and barley. This is important for them to understand for completion of project objectives. Also, students and project participants are also getting exposure and active hands-on work with the development of machine learning models. They are actively working 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 several years of the National Fusarium Head Blight Forum and through regular video meetings and on campus visits with industry leaders at Mineral.

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

Project results have been shared with both academic and professional audiences through multiple outreach efforts. Findings were presented at several major scientific conferences: the Plant Genomics & Gene Editing Congress, the American Society of Plant Biologists (ASPB) Midwestern Section Meeting, and the National Fusarium Head Blight Forum. These presentations marked large-scale public dissemination of the project and results and were well received by plant science researchers and industry stakeholders. Locally, the team has hosted several field talks at the University of Minnesota to demonstrate the rover system, explain project goals, and share preliminary outcomes. These events engaged faculty, staff, postdoctoral researchers, and graduate students from a range of disciplines, facilitating interdisciplinary discussion and feedback. Additional dissemination activities, including manuscript preparation and broader outreach, are planned as the project advances.