Project FY24-SP-001: A scalable, low-cost phenotyping strategy for plot and single spike FHB field rating

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1. **What are the major goals and objectives of the research project?**
   1. Transition FHB imaging and detection from rover based to cell phone captured imagery.
   2. Improve image analysis pipeline to increase throughput of cell phone image acquisition.
   3. Validate cell phone imagery in a reliable diverse panel of germplasm to demonstrate the broad use of the phenotyping methods and disease assessment models across disease severities and spike morphologies.

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

Objective 1: Transition FHB imaging and detection from rover-based to cell phone captured imagery

What were the major activities?

The team transitioned from using rover-based high-throughput phenotyping to a more scalable, cell phone–based imaging method. Wheat plots were planted, maintained, and inoculated at two field sites (St. Paul and Crookston, MN) by project collaborators. Throughout the 2024 season, protocols were developed to standardize mobile image capture, accounting for speed, repeatability, and image quality. Around the peak FHB disease period, cell phone users captured images from each plot at three timepoints in St. Paul and one timepoint in Crookston, with two users capturing three images per plot at each imaging session.

What were the significant results?

Over 4,000 plot-level images were collected (2,000+ per site), covering diverse developmental stages and disease severities. The newly acquired mobile images were integrated into the existing FHB detection and quantification pipeline for analysis. Preliminary results indicate strong correlation between mobile-based image analysis outputs and both traditional field ratings and prior rover-based image results. This confirms the viability of mobile platforms as a scalable phenotyping tool.

List key outcomes or other achievements.

- Developed a repeatable and efficient field imaging protocol using widely accessible mobile technology.
- Successfully transitioned high-throughput phenotyping to a scalable, low-cost platform without compromising data quality.
- Established groundwork for broader adoption of mobile phenotyping methods in breeding and pathology programs.

Objective 2: Improve image analysis pipeline to increase throughput of cell phone image acquisition

What were the major activities?
Following image acquisition, the cell phone images were processed using the previously developed machine learning-based image analysis pipeline. The team began identifying bottlenecks and inaccuracies—particularly in wheat head detection—and initiated refinements to improve the segmentation and classification stages of the pipeline. Parallel efforts focused on improving speed and robustness of the pipeline to handle image volumes typical of mobile capture.

What were the significant results?
Initial processing of the mobile image dataset exposed some misclassifications and failures in spike detection due to variable image angles and lighting. These insights are guiding targeted improvements in the pre-processing and head detection modules. Refinements are ongoing, but early updates have already increased head detection accuracy and reduced mislabeling.

List key outcomes or other achievements.

- Identified critical areas for improvement in image segmentation under mobile acquisition conditions.
- Began refining wheat head detection to improve model precision and robustness.
- Improved pipeline scalability for processing larger image datasets, essential for multi-site use and future deployment.

Objective 3: Validate cell phone imagery in a reliable diverse panel of germplasm to demonstrate the broad use of the phenotyping methods and disease assessment models across disease severities and spike morphologies

What were the major activities?
Validation activities included imaging a diverse germplasm panel under natural FHB infection conditions and collecting visual disease ratings from five independent human raters at four timepoints. These ratings covered early, peak, and late FHB development. The image-based model's performance is being benchmarked against this multi-rater dataset to assess generalizability across spike morphologies and severity levels.

What were the significant results?
Preliminary comparisons suggest that model-based disease scores correlate well with the consensus from human ratings. Variation in ratings among human observers provides an important baseline for evaluating model consistency. Early results show that image-based phenotyping may reduce inter-rater variability, particularly in moderate to high severity conditions.

List key outcomes or other achievements.

- Generated a diverse, well-characterized dataset of visual and image-based FHB severity ratings.
- Demonstrated the model's capacity to detect FHB consistently across genotypes with varying spike morphology.
- Set the stage for downstream validation of image-based phenotyping as a robust and objective alternative to conventional scoring.

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

The project has provided extensive training and professional development opportunities for project personnel and collaborators. In the field, a new group of students has been trained to assess Fusarium Head Blight (FHB) severity—an essential skill for fulfilling the project's research objectives. Beyond field-based phenotyping, students and project participants are gaining valuable hands-on experience in the development and refinement of machine learning models using mobile-acquired image datasets. This transition to exclusively mobile image platforms—without reliance on commercial hardware from Mineral—has allowed students to work directly with scalable, accessible phenotyping tools that can be implemented broadly in breeding and research programs.

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

Project results have been actively shared with both academic and applied research communities. A key presentation was given at the National Fusarium Head Blight Forum, where the goals, approaches, and early outcomes of the project were presented to researchers and stakeholders in small grains pathology and breeding. The project also had a strong presence at the USWBSI High Throughput Phenotyping Workshop in Fargo, ND (September 26, 2024), where team members played an integral role in shaping the conversation around future directions for FHB phenotyping. The approaches and results presented were well received and are being considered for adoption by collaborating institutions.

In addition to these national-level outreach activities, the project team hosted several local field talks at the University of Minnesota. These events highlighted the mobile imaging, shared preliminary model outputs, and promoted discussion across breeding, pathology, engineering, and data science groups. As the project continues, further dissemination efforts—including peer-reviewed manuscripts, data sharing, and presentations—are planned to broaden the impact and utility of this work.

Trainees have been engaged in all aspects of the machine learning pipeline, including image annotation, model evaluation, and iterative platform improvement. These experiences have equipped them with highly marketable skills in high-throughput phenotyping, data science, and digital agriculture. Additionally, members of the project have benefited from professional development by attending the National Fusarium Head Blight Forum and through active participation in the USWBSI High-Throughput Phenotyping Workshop, helping to shape future directions in FHB phenotyping.

5. What do you plan to do during the next reporting period to accomplish the goals and objectives?

At the beginning of FY25, we will conduct a comprehensive evaluation of the imaging and model outputs from the previous year's field season. This assessment will guide any necessary adjustments to the imaging protocols or model parameters to improve FHB detection accuracy. Based on our findings, we will finalize and share a refined in-field image capture protocol with collaborating breeding programs, allowing time for feedback and integration into their own phenotyping workflows.

Field preparations and planning for imaging at UMN will begin in late May 2025 to ensure we are fully operational for timely data collection in both St. Paul and Crookston, MN. As in previous years, we will target three imaging dates per location—one prior to, one during, and one following the peak of FHB severity—to capture the temporal dynamics of disease development. In the future, we will also coordinate with collaborating breeders to ensure similar imaging timelines are followed at their field sites, as effort allows, to ensure similar and comparable data is collected and shared across sites.

Once imaging is completed, we will begin analyses to assess FHB progression over time at scale. In parallel, we will continue refining the machine learning models for FHB detection using the newly acquired data. Special attention will be given to evaluating model performance across genotypes with different spike morphologies and varying FHB severities. This step is critical to ensuring that our models are robust and generalizable for broad adoption across diverse breeding programs and germplasm sources.