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?**
   - Transition FHB imaging and detection from rover based to cell phone captured imagery.
   - Improve image analysis pipeline to increase throughput of cell phone image acquisition.
   - 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? We completed the transition from specialized rover-based imaging to cell phone-based image capture for FHB phenotyping. Mobile imaging protocols were developed and refined for breeding nursery conditions, including single-row plots, with attention to camera orientation, imaging height, positioning, lighting, and timing of image collection. Multiple years of mobile imagery have now been collected and evaluated, providing a substantial dataset for continued assessment and refinement of both image acquisition and disease detection methods. The mobile approach has also been evaluated across different users, field configurations, locations, and stages of disease development. The work demonstrated that mobile images can be analyzed using the existing FHB image analysis framework provided by the rover and produce disease estimates that are strongly associated with rover-based estimates and conventional field ratings.

What were the significant results? Mobile phone imagery successfully captured sufficient information for accurate FHB disease assessment and provided a practical alternative to rover-based imaging. Across comparisons, mobile- and rover-derived disease estimates were highly correlated ($r = 0.96$), while mobile image-based estimates were also strongly correlated with field ratings ($r = 0.82$). The mobile approach is now being used exclusively in field-image collection.

List key outcomes or other achievements. The project has successfully established cell phone imaging as the primary platform for FHB phenotyping, eliminating the need for specialized rover hardware. The resulting approach is more portable and scalable and can be deployed by multiple users across locations. Continued collection and evaluation of mobile images are being used to further improve image acquisition protocols and increase the generalizability of the resulting disease assessment models.

Objective 2. Improve image analysis pipeline to increase throughput of cell phone image acquisition.
What were the major activities? We adapted the existing FHB image analysis pipeline to accommodate mobile imagery and the field configurations used by breeding programs. This included developing methods to delineate individual plots within images, improving the ability to associate detected spikes with the appropriate genotype, and developing a mobile-specific image quality/gradability model to address false spike detections and differences resulting from the mobile imaging protocol. We have also continued to improve the efficiency and throughput of the overall analysis workflow through faster machine-learning approaches, distributed processing using the Minnesota Supercomputing Institute, and increased automation of image and output quality-control procedures. These improvements are intended to reduce the amount of manual intervention required as image datasets increase in size.

What were the significant results? The adapted pipeline successfully enabled disease assessment of single-row plots and substantially reduced problems associated with false spike detections and low-quality images. The mobile-specific gradability model achieved 89% test accuracy, while the plot delineation approach had an average error rate of approximately 3% for assignment of spikes to the appropriate plot. The resulting workflow also demonstrated consistency across different mobile users, with an overall correlation of 0.85 between users.

List key outcomes or other achievements. The image analysis pipeline has been successfully transitioned from a rover-oriented workflow to one capable of processing mobile phone imagery from breeding nursery plots. Additional improvements in computational speed, distributed processing, and automated quality control are increasing the scalability of the analysis and reducing reliance on manual processing. The continued use of images collected under different conditions is also providing an expanding resource for improving model generalization and making the pipeline more robust to variation in future image acquisition.

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 has been initiated using multiple years of mobile imagery collected across breeding populations, locations, imaging dates, and disease severities. Comparisons have been made between image-derived disease estimates and conventional field ratings, while image datasets containing variation in spike morphology, maturity, disease severity, and field conditions have been incorporated into ongoing model development. We are also beginning to expand this validation beyond the initial UMN datasets through collaboration with breeding programs at North Dakota State University and Michigan State University. These collaborations will provide additional environments and germplasm for testing the generalizability of the mobile phenotyping approach.

What were the significant results? Initial validation demonstrates that mobile image-based disease estimates can provide reliable FHB assessments across different disease progression stages and field configurations. The mobile phone based pipeline has maintained a correlation of 0.82 with conventional field ratings, consistent with results obtained during the initial transition from rover to mobile imaging. The ability to collect images repeatedly throughout disease development also provides opportunities to evaluate temporal disease metrics that are difficult to obtain through conventional field rating.

List key outcomes or other achievements. The project has established the feasibility of using mobile imagery for FHB phenotyping and has generated several years of data that can be used to improve model generalization. Broader validation across diverse germplasm, environments, and wheat and barley production systems remains an active component of the project. Expansion to additional participating breeding programs, beginning with NDSU and MSU, will provide independent datasets needed to further evaluate the robustness and broad applicability of the imaging and disease assessment models.

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

A graduate student supported by this project received extensive hands-on training and professional development throughout the reporting period. The student worked directly with the PI to develop skills in mobile-based image acquisition, image analysis, data management, and AI-based phenotyping approaches for Fusarium head blight. The student also worked closely with collaborating wheat and barley breeding programs at the University of Minnesota, gaining practical experience in field organization, field operations, experimental plot management, and disease data collection while learning directly from experienced breeders and researchers.

The student also had opportunities to interact with international scientists, including researchers at the Norwegian University of Life Sciences, providing exposure to international perspectives and approaches in FHB research and phenotyping. Professional development was further supported through participation in scientific conferences, including the FHB Forum and the NAPPN conference. At these meetings, the student presented research generated through this project, discussed their work with other researchers, and gained experience communicating research findings to both specialized and broader scientific audiences. These activities provided training in both the technical skills required for the project and the professional skills needed for a career in plant pathology, phenotyping, and agricultural research.

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

See below otherwise nothing to report.

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

During the next reporting period, activities will focus on further refining and validating the cell phone-based phenotyping system to increase its robustness, scalability, and applicability across diverse FHB field environments and germplasm. We will continue to collect and evaluate cell phone imagery from multiple environments, users, plot configurations, disease severities, and germplasm backgrounds. These data will be used to further refine the image acquisition SOP, with particular attention to factors such as image positioning, lighting, time of day, plot configuration, and image quality. The goal is to establish practical and reproducible imaging procedures that can be readily adopted by additional USWBSI research and breeding programs.

We will continue iterative improvement of the image analysis pipeline as new images become available. Images will be quality controlled and used to identify limitations in image gradability, plot delineation, spike detection, and disease assessment. The pipeline will then be modified and reevaluated against manually reviewed reference images to improve accuracy and generalization across different imaging conditions. Continued use of faster machine-learning approaches, distributed processing through the Minnesota Supercomputing Institute, and automated image and output quality-control procedures will further increase analysis throughput while reducing the amount of manual intervention required.

A major emphasis during the next reporting period will be broader validation of the cell phone-based system across diverse germplasm and environments. Collaborations with NDSU and MSU will be expanded to obtain imagery representing additional populations, field conditions, disease severities, and spike morphologies. These data will be compared with conventional field disease assessments and other available reference measurements to evaluate the consistency and reliability of the cell phone-based phenotyping approach. As additional datasets become available, they will also be incorporated into model development to improve the ability of the pipeline to generalize beyond the environments and populations used for initial development.

Together, these activities will move the project from development and initial validation toward a more broadly deployable phenotyping system. The expected outcomes for the next reporting period are an increasingly standardized cell phone imaging protocol, a more robust and efficient image analysis pipeline, expanded multi-environment and multi-program validation, and improved guidance for adoption of the approach by USWBSI wheat and barley research and breeding programs.