

1. Objectives/aims

Plant breeding programs are eager to leverage high-throughput phenotyping (HTP) to support cultivar development and research. This enthusiasm often wanes when programs are faced with the task of employing automated data collection systems such as unmanned aerial vehicles (UAVs) and imaging equipment. Many users lack the cross-disciplinary expertise to not only deploy HTP but also to extract and make meaningful use of the data, and even fewer have the necessary skills to train colleagues in the process. Breeders, researchers, and students often attempt to teach themselves, but they may quickly discover that publicly available educational materials do not provide step-by-step training and are often designed to promote commercial products rather than build capacity. Together, these factors hamper the uptake of HTP.

To address this need, we propose to host an in-person workshop focused specifically on procedures to 1) establish and operate a UAV and imaging platform, 2) process imagery and extract meaningful data, and 3) conduct statistical analyses with these data that provide benefits to crop breeding and research programs. The workshop will take place on February 19-21, 2022, at the Utah State University (USU) Kaysville Education Center, which is located 20 miles north of Salt Lake City. The timing strategically avoids most field breeding and research program activities in North America. The host institution is centrally located, near a major airport hub, and adjacent to research fields that can be readily used for demonstrating HTP image acquisition.

2. Furthering the aims of the AG2PI

The proposed workshop strives to deliver a solution to a community-wide gap in capacity building and the availability of training materials for HTP. This expertise remains concentrated in a small number of research groups with the necessary resources and reputation to recruit highly qualified postgraduates with experience in HTP and multivariate analyses. Those without these resources may turn to commercial offerings to obtain HTP data, an often costly alternative which restricts researchers to limited data products and prevents students from developing valuable skillsets. The workshop will tap two experts, Drs. Xu Wang and Jessica Rutkoski, who will empower attendees to begin implementing HTP tools at their home institutions. The workshop will be limited to 30 attendees to promote one-on-one interaction with instructors. Dr. Margaret Krause will provide assistance with hands-on activities and manage workshop logistics.

An additional aim of equal importance is the rapid dissemination of these resources to the broader community. Aerial images, data, teaching materials, and R scripts will be made publicly available to benefit those who cannot attend the workshop. To promote knowledge transfer across the country, we will offer several 'HTP Ambassador Travel Scholarships' to offset the cost of attendance for selected student recipients. Scholarship applicants must provide a personal statement which 1) demonstrates that they are currently involved in projects requiring the application of these skills and 2) indicates how they will act as an HTP Ambassador and provide training to others within their home institution/region following the workshop. Finally, we aim to create a network of researchers that can continue to share experiences with HTP, ask and answer questions, and form new research collaborations. To help promote the formation of this network, we will host a social event (covered by registration fees) on the first day of the workshop, and we will create a channel on the Slack communication platform where workshop attendees can easily stay connected and work together on troubleshooting and future HTP projects.

To evaluate project success, we will report the number of attendees trained, their host institutions/geographic regions, and crops of interest as well as the number of training material downloads. Feedback will be collected from attendees to improve the training materials prior to

making them available publicly. This feedback will also benefit the development of future HTP workshops. A follow-up survey will be circulated 1-2 years later to assess 1) how attendees have utilized the training within their own breeding or research programs, 2) if the training contributed to the development of scholarly products, and 3) how attendees have served as a resource to others within their institution/region who are interested in learning and deploying HTP methods.

3. Expected outcomes & deliverables

Following the workshop, attendees should be capable of deploying HTP and imaging platforms as well as utilizing the resulting data to aid breeding decisions and/or inform research. In greater detail, attendees should be able to assess options for UAVs, cameras, sensors, base stations, etc. to fit the needs of their programs; design field experiments and deploy ground control points for optimal imaging; utilize RTK GPS systems and base stations; create flight plans using the Mission Planner software; assemble UAVs with cameras/sensors; load flight plans within UAV controllers; follow best practices for flights, UAV maintenance, image storage, and data management; process aerial imagery using the AgiSoft Metashape software; extract plot-based phenotypic values from stitched images using the QGIS software; filter out soil background, shadows, etc.; calculate vegetation indices; understand the use of secondary/correlated traits in selection schemes; calculate phenotypic/genetic correlations and reliability using multivariate mixed models with the ASReml-R statistical software; and perform prediction and validation using the R software. Furthermore, attendees should have sufficient hands-on practice with the training materials to serve as a resource within their home institutions and share acquired knowledge with colleagues. The workshop will produce publicly available training materials for HTP deployment, image processing, and data analysis. We will use various social media platforms and AG2PI communication channels to share these resources. Finally, the workshop will build a nationwide network linking researchers working on HTP in various crops.

4. Qualifications of the project team

Dr. Jessica Rutkoski (co-PI) is an assistant professor and small grains breeder at the University of Illinois with expertise in quantitative genetics and multivariate analysis of HTP data. Dr. Xu Wang (collaborator) is an assistant professor at the University of Florida with expertise in UAVs and image processing. Dr. Margaret Krause (PI) is an assistant professor and small grains breeder at USU and has led previous hands-on HTP trainings. All team members are early-career breeders and researchers who utilize HTP within their own programs and share the same enthusiasm for spreading HTP knowledge and skills across the crop research community.

5. Proposal timeline

Dr. Wang will lead the first two days of the workshop (February 19th and 20th), covering UAVs, sensors, image processing, and data extraction, while Dr. Rutkoski will lead the final day (February 21st), providing instruction on multivariate statistical analyses with HTP data. Training materials will be made publicly available within one month of the workshop.

6. Engaging AG2P scientific communities & underrepresented groups

Attendees, including HTP Ambassadors, will be strategically selected to promote equitable access of HTP knowledge across demographics, geographic locations, and crop species of interest. We will aim to maximize the number of host institutions represented to facilitate greater knowledge transfer and capacity building nationwide.