

“Hands-On Training in High-Throughput Phenotyping” Evaluation Report

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The “Hands-On Training in High-Throughput Phenotyping” workshop, supported by an Agricultural Phenotype 2 Genome Initiative (AG2PI) seed grant (USDA-NIFA awards 2020-70412-32615 and 2021-70412-35233), was held at the Utah State University Kaysville Education Center in Kaysville, Utah on February 19th to 21st, 2022.

Personnel

The instructors were assistant professors Dr. Xu ‘Kevin’ Wang of the University of Florida, Dr. Jessica Rutkoski of the University of Illinois–Urbana Champaign, and Dr. Margaret Krause of Utah State University. The application was made available through Google Forms beginning on December 10th, 2021, and advertisements of the workshop were made through social media (Twitter, LinkedIn, Instagram), PhenomeForce, the National Wheat Improvement Committee, the WheatCAP, and the instructors’ institutions. A total of 37 applications were received. Several submissions were from international applicants, whom we were unable to invite because of the COVID-19 pandemic. A total of 23 attendees representing 13 institutions in 12 states attended the workshop (Fig. 1, see Appendix Table 1). Attendees hailed from institutions located in the Midwest, Intermountain West, and Pacific Northwest. In attendance were 16 graduate students, 1 postdoctoral research, 3 university faculty, 2 research technicians, and 1 USDA scientist (see Appendix Table 1). Sufficient funds were available through the seed grant and registration fees to award \$800 travel scholarships to all attending graduate students.

The workshop attendees currently conduct research in a range of crop-specific and non-crop specific (e.g., gene regulatory networks, crop-weed dynamics) systems. A total of 10 research systems were represented (Fig. 2), though the majority of the attendees work in the wheat breeding and research. Since the instructors’ professional networks overlap considerably with the wheat research community, advertisement of the workshop likely disproportionately reached this demographic. In addition, several of the graduate student attendees are supported by the Agriculture and Food Research Initiative Competitive Grant 2022-68013-36439 (WheatCAP) from the USDA National Institute of Food and Agriculture, which has a significant research emphasis on the use of unmanned aerial systems. Organizers of future workshops might consider investing in efforts to attract attendees representing a wider range of research systems, particularly those which have not yet benefitted considerably from high-throughput phenotyping.

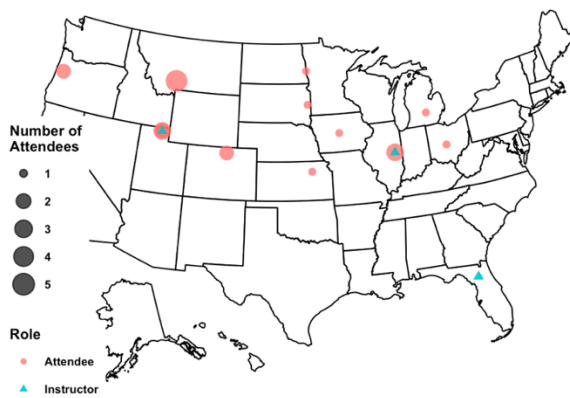


Figure 2. Institutions of the workshop's 23 attendees and 3 instructors.

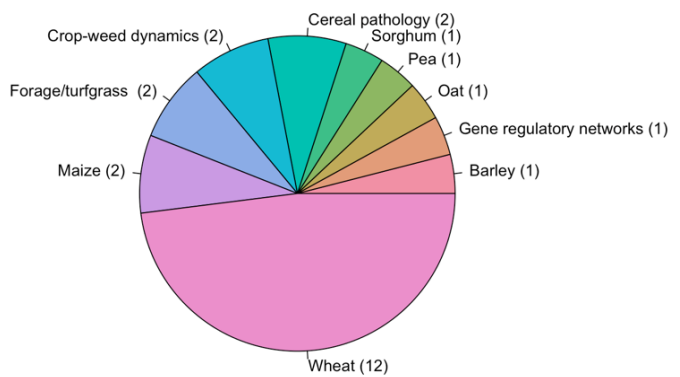


Figure 1. Research systems represented by the 23 workshop attendees.

Workshop Overview

The workshop took place over three days following an 8:00 AM–5:00 PM schedule. The topics of the first, second, and third days of the workshop were “unmanned aerial systems and sensors”, “imagery processing”, and “statistical analysis”, respectively. Dr. Wang led the first and second days, while Dr. Rutkoski led the final day of the workshop. Each day involved a combination of material presented through Powerpoint and visual aids, discussion, and hands-on practice activities.

During the first day of the workshop, Dr. Wang presented material related to unmanned aerial systems, cameras/sensors, ground control points, unmanned aerial system integration, and ground preparation. Attendees practiced designing a flight plan on their personal computers using the open-source web-based application “UAV Mission Planner”

(<https://uavmissionplanner.netlify.app/>). Following lunch, attendees went outdoors to practice surveying the GPS coordinates of ground control points using low-cost Emlid Reach RS2 RTK GNSS receivers. Using the flight plan developed during the morning session, Dr. Wang demonstrated a flight with a DJI Matrice 600 unmanned aerial vehicle equipped with a Micasense RedEdge multispectral sensor. The workshop instructors refrained from endorsing particular commercial products, but it should be noted that DJI and Micasense are currently widely used by breeders and researchers for high-throughput phenotyping.

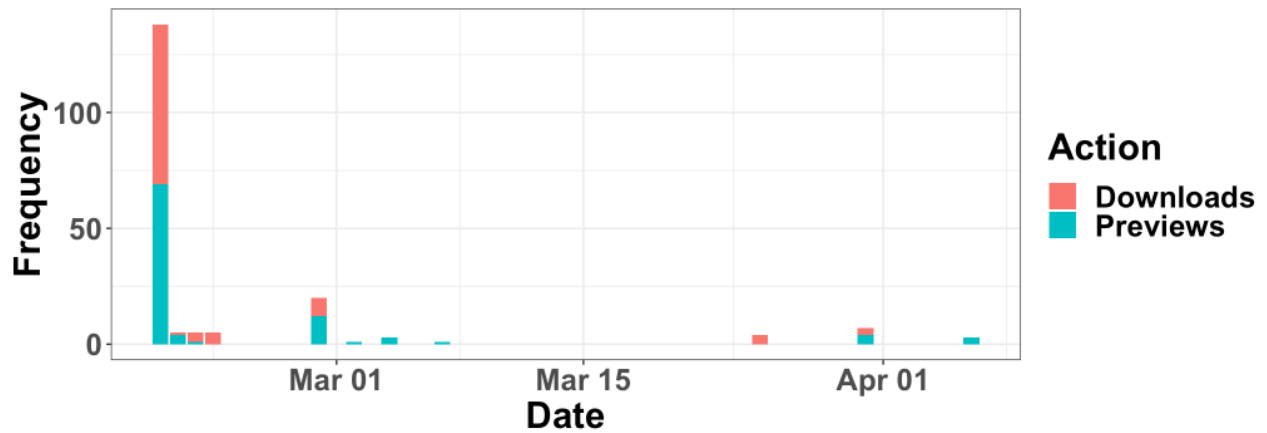
On the second day, Dr. Wang led attendees in processing of the Micasense RedEdge imagery collected the previous day. Attendees used a trial license of the software Agisoft Metashape on their personal computers to georeference the imagery using the ground control point survey data and to stitch the imagery into an orthomosaic. Dr. Wang shared a Python script to automate the construction of plot polygons, and attendees practiced extracting plot-based data using the open-source software QGIS.

Dr. Rutkoski guided attendees through several high-throughput phenotyping data analyses on the third day of the workshop. Attendees used a trial license of the statistical software ASReml-R to calculate best linear unbiased predictions, genetic variances, and reliabilities for example high-throughput phenotyping trait datasets. Attendees practiced incorporating genomic markers into prediction models and learned how to combine high-throughput phenotyping and agronomic traits in multi-trait models.

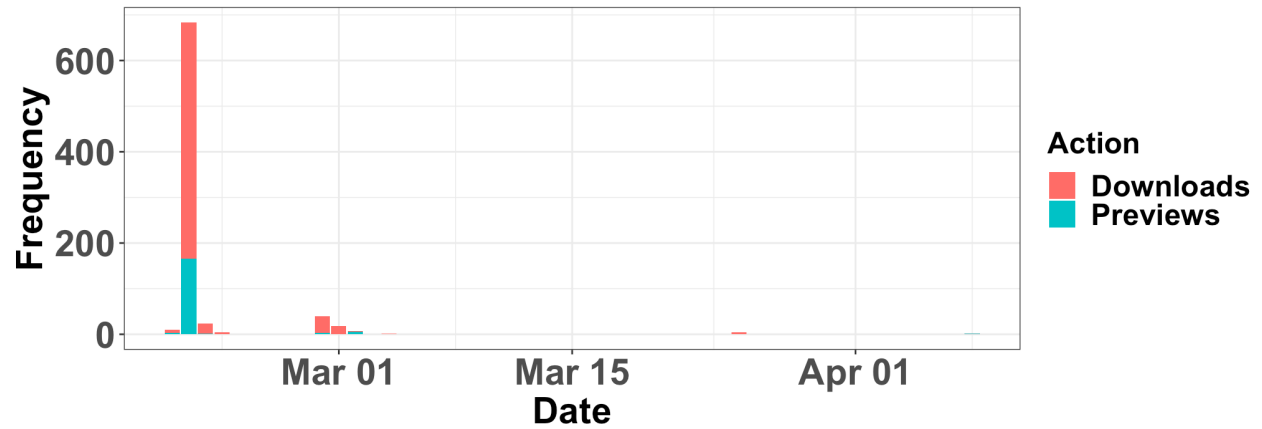
Workshop Materials

A Box folder was created to contain all workshop materials (<https://usu.box.com/s/tumbisvkvlgzpqosx0hlwdr3z897jvp>), which attendees were provided with access to. The box folder contained Powerpoint presentations, example imagery, example datasets, and R and Python scripts. Recordings of each day of the workshop were created using Kaltura Classroom and uploaded to the Box folder. Attendees could also access workshop materials and share resources through a Slack platform (handsonworksh-xxv5659.slack.com). Files from the first, second, and third days of the workshop were previewed or downloaded 192, 791, and 407 times, respectively, since February 18th, 2022 (Fig. 3). The majority of file access took place during the course of the workshop, though access data suggests that materials from all three days of the workshop have been re-accessed in recent weeks. It is difficult to accurately track how often participants are using the workshop material because they may have downloaded the resources to their computers during the workshop for later access. The example datasets and scripts have been made available publicly through Dr. Wang’s and Dr. Rutkoski’s Github repositories (<https://github.com/xwangksu>, <https://github.com/smallgrains-uiuc>).

Day 1: Unmanned Aerial Systems and Sensors



Day 2: Imagery Processing



Day 3: Statistical Analysis

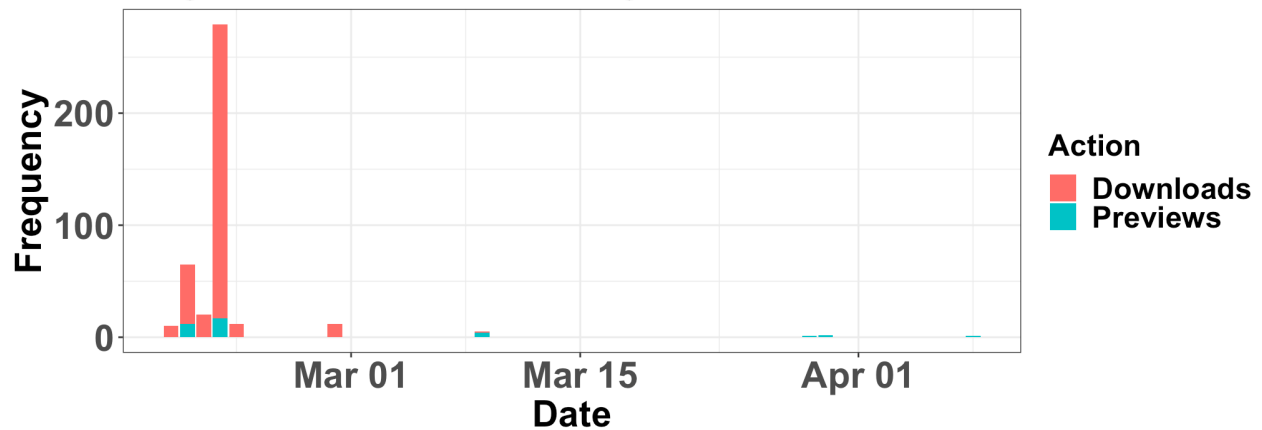


Figure 3. Number of downloads and previews of files in the Box folder since February 18th, 2022

Follow-Up Survey

A follow-up survey was circulated on Google Forms, receiving 21 responses. A CSV file containing the full responses to the survey is included with this report. When asked to rank each day of the workshop in terms of 1) their level of interest in the topics covered, 2) the amount they learned, and 3) how likely they are to refer back to the training materials in the future, attendees indicated overwhelmingly positive responses. The second day of the workshop, which covered imagery processing, received the most favorable responses to all three inquiries. Nineteen of the 21 responses indicated that they would be very likely to refer back to the imagery processing materials in the future. While the third day of the workshop, which covered statistical analyses using high-throughput phenotyping data, received a majority of positive responses, there were ~1–3 responses indicating limited interest in the subject matter. All 21 responses indicated that they would highly recommend this workshop to others.

The survey asked attendees whether there were any topics which weren't covered during the workshop that they wished would have been included. Responses included more emphasis on open-source platforms, machine learning, basic Python scripting skills, costs associated with high-throughput phenotyping, FAA remote pilot test preparation, opportunities for collaboration, and practical research applications of high-throughput phenotyping (e.g., weed identification).

Attendees were asked how they see themselves using what they've learned within the next year. Several responses indicated they would be conducting flights in the coming year and would rely on the skills learned, while others mentioned applying the imagery processing and data analysis methods to imagery sets they had already collected. One response discussed applying the skills learned to a ground-based phenotyping cart.

The survey inquired about remaining barriers to attendees' use of high-throughput phenotyping tools. Several attendees highlighted the costs associated with commercial equipment and software licenses, the time involved in deploying high-throughput phenotyping, and general lack of experience and practice. One response suggested that they are limited in the number of flights which they can reasonably process data from and expressed interest in having access to a service which can provide support in imagery processing and data extraction.

With respect to the length of time of the workshop, 81 percent felt the length of time was reasonable, while 14 percent felt it could have been shorter. Regarding the number of participants attending the workshop, 86 percent felt the number was reasonable, whereas 14 percent suggested there could have been more participants.

The attendees were asked whether they benefitted from the "in-person" format of the workshop or if they could have learned the same amount from a virtual option. The responses indicated an overwhelming preference for the in-person format. One attendee reflected the hands-on activities and one-on-one troubleshooting with instructors were very helpful, and that these elements would have been more difficult through a virtual format. Others appreciated the opportunity to interact with others, ask questions, and form connections. One response indicated that they had attended several virtual meetings but felt that the format of this workshop was best for developing skills. Another highlighted the difficulties of maintaining focus during virtual events.

The emphasis of the workshop was on providing attendees with "do-it-yourself" options. One question on the survey asked whether the attendees liked this, or if they would have preferred presentations from companies offering fee-for-service options. A few responses indicated some interest in hearing about commercial options, but overwhelmingly the attendees appreciated the focus on "do-it-yourself". Some attendees highlighted that information on fee-

for-service options is widely available through other avenues. One attendee reflected that, even if they were to hire a service for some aspects of the implementation, they felt they needed to first acquire foundational knowledge about high-throughput phenotyping methods in order to be an informed consumer.

With respect to the greater high-throughput phenotyping community in the United States, attendees were asked which training and community-building activities would be most beneficial to them. The top two responses were in-person hands-on training workshops (20 responses) and example datasets with step-by-step tutorials (19 responses). Online hands-on trainings, research conferences, online seminar series, and communication forums (e.g., Slack, Stack Overflow, etc.) each received between 7 and 11 responses. In response to the positive feedback, the organizers will consider hosting similar in-person workshops in the coming years.