

Project #: 126593

Progress Report Year: 3 of 3 (maximum of 3 year funding cycle)

Title: **Intelligent Prediction and Association Tool to Facilitate Wheat Breeding**

Cooperators *Dr. Michael Pumphrey, Dr. Kimberly Campbell, and Xianming Chen*

Executive summary *We updated one software package (GAPIT), released one new software package (LADDER), and submitted two articles partially under the support of this project in this fiscal year. The GAPIT software package updated for new functions to integrate GWAS (Genome Wide Association Study) into GS (Genomic Selection) (<http://zzlab.net/GAPIT>). GAPIT has received over 2500 citations, including the breeders at WSU and USDA-ARS. LADDER is a software for image labeling and integrating artificial intelligence to evaluate stripe rust (<https://zzlab.net/Ladder>). LADDER integrate both labeling and prediction in a single user-friendly graphic user interface with interactive deep learning to reduce the laborious human labeling for fast development of machine vision systems. LADDER provides fully automatic labeling for abundantly available initial images of wheat stripe rust to gain essential predictability. The navigation of integrating prediction with labeling benefit human adjustment to iteratively improve predictability. Development of evaluation system for wheat stripe rust was presented as a use case to demonstrate the efficiency of using interactive deep learning to develop machine vision systems. The two manuscripts on the methodology and software implementation were published.*

Introduction *Wheat plays a crucial role, contributing to 20% of human caloric intake and serving as the primary source of plant-based protein. Its significance is underscored by global wheat trade surpassing that of all other crops combined. Despite its pivotal role, wheat has historically trailed behind major crops like maize, soybean, and rice in genetic improvements. The current paradigm in wheat breeding primarily emphasizes augmenting variation to drive genetic progress. However, there exists untapped potential to make substantial gains in the other three factors of the breeder equation: selection intensity, accuracy, and interval. Recognizing this opportunity, our project aims to shift the focus towards these neglected aspects, positioning wheat breeding on the path of comprehensive and accelerated genetic enhancement.*

Approach

The project aims to streamline breeding processes through three key objectives. The first involves integrating artificial intelligence (AI) into genomic prediction for enhanced accuracy. The second focuses on creating cost-effective methods for rapid spectral-based falling number assessments using hyperspectral images, especially beneficial for farmers. Lastly, the third objective centers on a drone-based system for efficient stripe rust assessment in wheat, utilizing deep learning for automated image labeling. The overarching goal is to automate and improve breeding practices, addressing challenges in statistical method selection, falling number testing, and disease assessment, contributing to increased efficiency and accuracy in wheat breeding programs.

Results

We have significantly enhanced the MMAP cloud computing platform by seamlessly integrating multiple conventional genomic prediction methods with cutting-edge machine learning techniques. Accessible at <https://zzlab.net/MMAP>, the platform operates across various servers using JavaScript. Over the course of three years, we meticulously collected field images through drone surveys during peak stripe rust periods. Harnessing this extensive image dataset alongside annual stripe rust scores, we developed a highly efficient labeling method for artificial intelligence models, substantially augmenting our capacity to predict stripe rust. Additionally, we gathered spectral sensor data from wheat samples subjected to varying germination durations, successfully creating a cost-effective prototype, valued at \$2000, capable of distinguishing wheat with low falling numbers from those with high falling numbers. Our accomplishments are underscored by six peer-reviewed articles that acknowledge the invaluable support from the WGC. Furthermore, our contributions extend to three articles for Wheat Life and impactful presentations at the WGC annual meeting and various national/international conferences. These collective endeavors underscore our unwavering commitment to advancing wheat research and technology.

Impact

Our collaborative research positions the WSU/USDA-ARS research team as one of the world's leading institutions to conduct fundamental and applied research, publish academic articles, and update and release software packages. Our project's success not only benefits Washington but will also benefit the entire world through the dissemination of knowledge. In short term, breeders conduct their data analyses with the most advanced statistical methods and computing tools. They gain more opportunities to find the causative genes controlling traits of interest and have more confidence to eliminate lines with low genetic potentials to reduce the cost of field trials. In long term, breeders have more chances to retain the genetic lines with desirable genes and recombine them to create superior varieties.

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Project year 3 of 3-year cycle

Objective	Deliverable	Progress	Timeline	Communication
1) Enhance Genomic Prediction with Artificial Intelligence	An updated cloud computing platform MMAP implementing both conventional and artificial intelligence genomic prediction methods and conducting optimization to improve prediction accuracy.	We updated the cloud computing platform MMAP with multiple conventional genomic prediction methods and artificial intelligence methods. The platform (https://zzlab.net/MMAP) consists multiple servers using Java Script. One peer review article was published by Bioinformatics, which acknowledged the support from WGC.	December 31, 2021: Add artificial intelligence genomic prediction methods to MMAP cloud computing platform; June 30, 2022: Optimize among conventional and intelligence genomic prediction methods.	1) One article for Wheat Life; 2) One presentation at WGC annual meeting; 3) One presentation at national/international conference; and 4) one paper on academic journal
2) Develop Drone-based Stripe Rust Assessment	A drone based computer system to evaluate wheat stripe rust.	We have collected field images using drones during the peaks of stripe rust for two years. With these images and the annual stripe rust scores, we have developed an efficient methods to generate labels to artificial intelligence models to predict stripe rust.	December 31, 2022: Collect images over three years to train models to predict stripe rust scores from images; June 30, 2023: A drone based computer system to evaluate wheat stripe rust.	1) One article for Wheat Life; 2) One presentation at WGC annual meeting; 3) One presentation at national/international conference; and 4) one paper on academic journal
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