FOR ADMINISTRATIVE USE
Program Area Code Proposal Code

Minnesota Wheat Research and Promotion Council

RESEARCH PROPOSAL GRANT APPLICATION

1. NAME AND ADDRESS OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

Name: Regents of the University of Minnesota
Address: Office of Sponsored Project Administration
450 McNamara Alumni Center
200 Oak Street SE
Minneapolis, MN 55455-2070

2. TITLE OF PROPOSAL
Wheat Multi-Trait Predictions: A Quantitative, Genotype x Environment (GxE) Approach to Supporting Minnesota Wheat Breeding and Farmer Varietal Selections

3. PRINCIPAL INVESTIGATOR(S)	4. PI #1 BUSINESS ADDRESS	
Kevin Silverstein (PI) Yuan Chai (co-PI) James Anderson (co-PI)	University of Minnesota Minnesota Supercomputing Institute 550 Walter Library 117 Pleasant Street SE Minneapolis, MN 55455	
5. PROPOSED PROJECT DATES (Jan 1 – Dec 31)	**6. TOTAL PROJECT COST**	**7. PI #1 PHONE NO.**
02/01/2022 – 12/31/2023 Note: Annual Research Reports are Due November 15th	$97,499.42	651-500-6671

8. RESEARCH OBJECTIVES: (List objectives to be accomplished by research grant)

- **Minnesota spring wheat multi-trait prediction tool**
  A perennial challenge faced by wheat breeders and producers is to identify and select the best performing varieties for each location. Several critical wheat traits, including grain yield and protein content, are tightly linked to environmental conditions. GEMS Informatics Center, in collaboration with wheat breeder Dr. Jim Anderson from the Department of Agronomy and Plant Genetics, will develop a wheat multi-trait prediction tool that intelligently combines genomic information, environmental conditions, and their GxE interactions to accurately predict the performance of different wheat varieties under different environments. This tool will allow simultaneous optimization in the selection of relevant traits under different environments, including grain yield, protein content, straw strength, heading date, height, and disease resistance.

- **Increasing efficiency of regional spring wheat breeding programs**
  Limits on experimental land and funding make it impossible to test all varieties at all locations for all years in order to choose the best performing varieties. The spring wheat multi-trait prediction tool developed by this project will improve the cost-effectiveness of regional spring wheat breeding programs by enabling breeders to select for varieties with a higher likelihood of success for a number of commercially valuable traits, which in turn realizes efficiencies in breeding by way of lowering the cost of environmentally-sensitive phenotypic assessments and shortening the breeding cycle.

Attach a 2-page detailed discussion of importance of the proposal to wheat profitability; how study complements previous research in area; procedures to be used; and competency of the research group in achieving research objectives. (Please keep the proposal concise, only 2 pages will be provided reviewers).

Signature	Date1/7/22
	

Minnesota Wheat Research and Promotion Council
RESEARCH PROJECT PROPOSAL
(2-pages maximum)

Abstract

A perennial challenge faced by wheat breeders and producers is to identify and select the best performing varieties for each location. A high-yielding variety at one location during one season may not perform well at another location and/or another season, exemplifying the strong effects of Variety (Genotype) by Environment (GxE) interactions on crop performance. Limits on experimental land and funding make it impossible to test all varieties at all locations for all years so as to choose the best performing varieties. In this project, researchers at the UMN CFANS GEMS Informatics Center, in collaboration with breeder Dr. Jim Anderson from the Department of Agronomy and Plant Genetics, will develop a wheat trait prediction tool to intelligently combine genomic information, environmental conditions, and their GxE interactions to accurately predict the performance of different varieties under different environments. This project will utilize the rich genotypic and phenotypic data collected through Dr. Anderson's field trials and the comprehensive weather and soil data provided by the GEMS Informatics Center to build a spatially-explicit, MN-focused wheat trait prediction tool to accelerate wheat breeding programs and assist varietal selections for wheat breeders and farmers across the state.

Describe the background for your proposed project and the importance of this project to the profitability of wheat production in MN

To meet the increasing demand for wheat production, it is important to continually make genetic improvements in wheat crops to help farmers realize the full productivity potential in their fields. Like all agricultural crops, wheat grain yield and many other traits such as grain protein content are not determined by genetics alone, but are typically subject to strong environmental effects and GxE interactions. There is often no clearly superior variety to plant across different locations and over multiple seasons. Identifying the best performing varieties adapted for a specific location under local climate and soil conditions poses a great challenge for plant breeders and wheat farmers, especially when resources are limited for expensive phenotypic evaluation of a large number of candidate varieties across many environments. This project will address this challenge by integrating genomic information, environmental conditions and their interactions to improve crop phenotypic trait prediction. Researchers from the GEMS Informatics Center have successfully developed a Crop Multi-Trait Prediction workflow for U.S. barley crops that intelligently integrates genomic and environmental covariates to accurately predict the performances of many varieties under varying, and possibly new, environmental conditions. This project will build off that existing informatics infrastructure to develop and apply a wheat trait prediction model that takes into account both genomics information and environmental conditions to enable GxE-informed trait predictions, which will assist breeders and farmers in MN to identify and select varieties that are most likely to perform well in different local environments. Depending on data availability, the predicted performance traits will likely include grain yield, grain protein, straw strength, heading date, height, and resistance to Fusarium head blight and bacterial leaf streak. This project will help optimize both breeding efforts and farmers' varietal choices to help achieve the full productivity potential on farmers' fields and improve profitability of wheat production in MN.

Research methods

Built upon the existing GEMS Crop Multi-Trait Prediction framework, this study will develop a wheat multi-trait prediction model specifically for MN as described below:

- ***Genotype a panel of MN wheat varieties.*** A collection of approximately 103 wheat varieties and breeding lines of commercial and breeding importance for MN wheat production will be genotyped using Genotyping-By-Sequencing to derive SNP markers at the UMN Genomics Center. Given restrictions on the access and use of information for private varieties, this study will target public varieties and selected private varieties where data use rights are given for genotyping. Nonetheless, our selected panel still represents a significant share of the wheat area in Minnesota.
- ***Phenotype data from field trials.*** Dr. Jim Anderson's lab actively collects and maintains detailed field trial data for a large collection of wheat genotypes from 15 sites across Minnesota. For the purpose of this study, a subset of this field trial data will be assembled to obtain matching field phenotypic data during the period 2012-2021 with major wheat crop traits including grain yield, protein content, straw strength, heading date, height, and disease resistance.
- ***Environmental data and crop growth modeling.*** The GEMS Informatics Center will provide access to a comprehensive collection of daily weather observations and location-specific soil data for each trial location. Using

both in-season and historical weather data, the APSIM wheat crop growth model will be used to simulate plant development at each trial. The GEMS Crop Multi-Trait Prediction workflow will apply a phenologically-informed approach to intelligently select environmental covariates that are relevant at different growth stages.

- ***Phenotypic prediction model training, testing, and validation.*** The quantitative traits for a specific genotype in a given environment will be modeled using a linear mixed-effect model that includes the effects of genotype (G), environment (E), and their interaction (GxE). This model will be validated using leave-one-environment-out cross validation where all but one environment will be used in model training and one left out for testing. The goal is to identify models that maximize the predictive ability, or the correlation between predicted and observed phenotypes. New field trial data from the year 2022 will be used as an external validation to test the model's predictive accuracy.

Timeline for completion

First 6 months (02/01/2022 - 07/31/2022): field trial data cleaning and wheat variety genotyping

- Hire an undergraduate student research assistant to undertake data cleaning and pre-processing for wheat field trial data across 15 experimental sites located throughout Minnesota during the period 2012-2021
- Genotyping-By-Sequencing for a curated collection of MN wheat varieties and advanced breeding lines

Middle 12 months (08/01/2022 - 07/31/2023): data analysis, model development and preliminary results

- Adapt an APSIM crop growth model for wheat in Minnesota
- Harmonizing wheat phenotypic and genetic data with GEMS-sourced weather, soil, and crop management data
- Applying GEMS Crop Trait Prediction workflow to develop a GxE-informed wheat multi-trait prediction model

Last 5 months (08/01/2023 - 12/31/2023): final results and publication

- Complete final data analysis and generate final results and prepare scientific manuscript for journal submission
- Pilot an Application Programing Interface (API) to enable on-going access to the Wheat Multi-trait Prediction Tool

Outreach plan

We will prepare a scientific paper for journal publication so our research findings will reach a larger academic and public audience. Furthermore, the MN-focused Wheat Crop Trait Prediction model developed in this project will be accessible via an API (Application Programming Interface) informatics pipeline using the informatics infrastructure maintained by the University of Minnesota's GEMS Informatics Center.

List other current or pending funding sources for this project:

Existing data from MN wheat varietal trials were funded by multiple sources, including (1) UMN Wheat Breeding Program ($535,374), 1/19-12/21, MNWRPC; (2) Breeding and Genomic Selection for FHB Resistance in Spring Wheat ($144,876), 6/21-5/22, USWBSI (VDHR) via USDA-ARS; and (3) Breeding Disease Resistant Wheat ($135,939), 7/21-6/23, Minnesota Small Grains Initiative via MAES. The methodology and workflow for the GEMS Crop Multi-Trait Prediction model for U.S. barley crop was developed by the GEMS Informatics Center with funding from various sources, including USDA-NIFA, the MNDrive program and Office of Vice-President for Research, both at the University of Minnesota, and earned revenue generated by the GEMS Informatics Centre's subscription services.

Research group (other collaborators not listed as PIs):

Dr. Philip Pardey, Director of GEMS Informatics Center, will serve as a key personnel to provide support in overall research guidance and allocation of GEMS resources. Dr. Emily Conley, lab technician at the Department of Agronomy and Plant Genetics, will conduct the genotyping for the selected panel of wheat varieties. Dr. Tanushree Naik, research scientist at GEMS, will adopt and implement the GEMS Crop Multi-Trait Prediction model for the prediction of spring wheat multi-traits across MN.

Relationship to past projects and research conducted by you or others in the region:

Phenotyping data of the selected wheat variety panel for this study uses past field trial data from 15 sites across Minnesota funded by multiple sources. The MN wheat multi-trait prediction tool will be developed based on the methodology and workflow of the GEMS Crop Multi-Trait Prediction model developed for the U.S. barley crop.

Minnesota Wheat Research and Promotion Council

RESEARCH PROJECT PROPOSAL BUDGET

Project Title: Wheat Multi-Trait Predictions: A Quantitative, Genotype x Environment (GxE) Approach to supporting Minnesota Wheat Breeding and Farmer Varietal Selections

Principal Investigator(s) / Project Director(s) **Kevin Silverstein**	Funds Requested For Year 1 (2022)	Year 2 (2023)	Year 3 (2024)
A. Salaries and Wages	**$ 27,573.95**	**$ 20,437.13**	$
1. Co-principal Investigator(s) **Kevin Silverstein (PI)** **Year 1 - 4% effort = $4,508.67 + Year 2 - 4% effort = $5,044.93** **Yuan Chai (co-PI)** **Year 1- 10% effort = $7,529.85 + Year 2 - 10% effort = $8,425.44**	$12,038.51	$13,470.36	
2. Senior Associates **Phil Pardey** **Year 1 - 1% effort = $1959.51 + Year 2 - 1% effort = $2182.25**	$1,959.51	$2,182.25	
3. Research Associates – Post Doctorate	0.00	0.00	
4. Other Professionals **Wheat Breeding Lab Tech** **Year 1 - 7% effort = $3175.63 + Year 2 - 7% effort = $3553.34**	$3,175.63	$3,553.34	
5. Graduate Students	0.00	0.00	
6. Prebaccalaureate Students **Plant Science Under Grad** **Year 1 (02/14/22 - 05/29/22) 20 hours a week @ $15/ hour (300 hours)** **Year 1 (08/29/22 - 12/16/22) 20 hours a week @ $15/hour (320 hours)**	$9,300.00	0.00	
7. Secretarial – Clerical **Admin Support** **Year 1 - 1.657% effort = $1,202.82 + Year 2- 1.657% effort = $1,128.65**	$1,100.30	$1,231.17	
8. Technical, Shop and Other	0.00	0.00	
B. Fringe Benefits **Kevin Silverstein** **Year 1 – 33.5% = $1,510.40 + Year 2 – 33.5% = $1,690.05** **Yuan Chai** **Year 1 - 33.5% = $2,522.50 + Year 2 - 33.5% = $2,822.52** **Phil Pardey** **Year 1 – 33.5% = $656.43 + Year 2 -33.5% = $731.05** **Wheat Breeding Lab Tech** **Year 1- 33.5% = $1,063.84 + Year 2 -33.5% = $1,190.37** **Admin Support** **Year 1 – 28.7% = $315.79 + Year 2 - 28.7% = $353.35**	$6,068.96	$6,787.34	
C. Consulting and Professional Services **Tanushree Naik**	$14,545.83	$14,982.21	
D. Supplies and Services GEMS subscription: data hosting and computing ($1,652 per year) Weather, soil, crop calendar data access ($600 yr1 + $1,200 yr2) Molecular marker genotyping ($2,000 yr 1)	$4,252	$2,852	

E. Travel	0.00	0.00	
F. Sub-Contracts	0.00	0.00	
G. Repairs & Maintenance	0.00	0.00	
H. Rentals & Lease	0.00	0.00	
I. Other Expenses	0.00	0.00	
TOTAL AMOUNT OF THIS REQUEST (per year)	**$ 52,440.75**	**$45,058.68**	**$**