**FOR ADMINISTRATIVE USE Minnesota Wheat Research and Promotion Council**

**Program Area Code Proposal Code**

 **RESEARCH PROPOSAL GRANT APPLICATION**

|  |
| --- |
| **1. NAME AND ADDRESS OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE** **Name: Regents of the University of Minnesota** **Address: Sponsored Projects Administration 450 McNamara Alumni Center, 200 Oak Street SE, Minneapolis, MN 55455-2070** |
| **2. TITLE OF PROPOSAL** **A Novel High-Throughput Phenotyping Pipeline to Deliver More Productive and Stress Resilient Minnesota Wheat Varieties** |
| **3. PRINCIPAL INVESTIGATOR(S)** PI# 1 Name: Walid SadokPI# 2 Name: Daniel M. MonnensPI# 3 Name: James A. Anderson | **4. PI #1 BUSINESS ADDRESS** University of MinnesotaOffice of Sponsored Projects Administration450 McNamara Alumni Center200 Oak Street SE, Minneapolis, MN 55455-2070 |
| **5. PROPOSED PROJECT DATES** January 1, 2023 – December 31, 2023 Note: Research Reports are Due November 15th of Each Year | **6. TOTAL PROJECT COST**$52,855   | **7. PI #1 PHONE NO.**612-625-8291 |
| **8. RESEARCH OBJECTIVES:**  (List objectives to be accomplished by research grant)Our main goal is to develop a new remote-sensing technology to help wheat breeders rapidly and cheaply identify superior breeding lines that are equipped with high-performing, high-yielding canopies. This technology aims at saving time and resources by rapidly capturing canopy thermal signatures, using an unmanned aerial vehicle (UAV) equipped with infrared (thermal) and RGB cameras, ground-truthing sensors, sophisticated algorithms and high-performance computer processing. We have successfully deployed this technology during the first two years on preliminary yield trials consisting of 508 and 468 breeding lines and were able -using this technology- to identify superior breeding lines that exhibited better yields under the droughty conditions of last two summers. Our specific goals for this year are to i) finalize our image processing pipeline of the second set of 468 lines, ii) replicate the field-based experiment in a third year and possibly iii) initiate a joint data analysis effort based on the two populations of advanced breeding lines to identify a potential genetic marker associated with cooler canopy. We expect this new development to lead to a fully validated image analysis pipeline, that will routinely support the UofM wheat breeding program by enabling identification of superior breeding germplasm which in turn will enable the release of more productive and stress resilient wheat varieties to MN growers. |
| **Signature Of Principal Investigator**  | **Date****1/2/2023** | **Phone Number****612-625-8291** |
| **Signature Of Authorized Representative****Text  Description automatically generated with medium confidence** | **Title**Senior Grant & Contract Officer | **Date****1/10/2023** |
| **Address Of Authorized Representative**Riana Fletcher, Office of Sponsored Projects Administration450 McNamara Alumni Center, 200 Oak Street SE, Minneapolis, MN 55455-2070 | **Phone Number**612-625-0996 |

**Minnesota Wheat Research and Promotion Council**

**RESEARCH PROJECT PROPOSAL**

**(2-pages maximum)**

Abstract

We are developing a new technology, based on remote-sensing of canopy thermal signatures, that could make it possible for wheat breeders to rapidly and cheaply identify superior breeding lines that are equipped with high-performing, high-yielding canopies. This novel pipeline relies on unmanned aerial vehicles (UAVs) equipped with thermal and RGB cameras, ground-truthing sensors, sophisticated algorithms and high-performance computer processing. In our first two years, we deployed this technology on two preliminary yield trials totaling 976 lines. While data analysis is still ongoing due to the very large dataset, our preliminary results point to a promising potential of this technology, by enabling us to identify superior lines that ended up exhibiting better yields under the droughty conditions of last two summers. Our central goal for this proposal is to confirm these findings in a third year, finalize the data analysis of the second year and initiate a joint analysis of data from the two first years to identify potential genetic markers. The development of this new technology will directly support the U of M wheat breeding program and, as a result, help farmers benefit from more productive and stress-resilient Minnesota-adapted wheat.

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

Maintaining wheat canopy health under variable field conditions is critical to stabilizing or improving wheat yields. This is because by capturing light, nitrogen and other nutrient resources from the roots, wheat canopies are the engine that fuels reproductive growth and therefore grain yields. While a highly productive and healthy canopy is a very desirable trait for a breeder, such canopies are nearly impossible to detect with the naked eye, which is not equipped to detect certain wavelengths that varieties emit when they are under-performing or stressed. For a breeding program, this challenge has to be addressed to enable rapid screening of hundreds if not thousands of breeding lines. To tackle this problem, in the first year, we started developing a drone-based remote-sensing technology that is based on thermal imaging which is being tested to support the U of M wheat breeding program. This method differentiates between productive and underperforming canopies based on their thermal ‘signatures’.

While there are existing drone-based approaches to monitor crops, our method is unique as it relies on advanced thermal imaging technology coupled with energy balance modeling, and is informed by physiology-based ground truthing techniques. This combination ensures that differences in thermal images among genotypes actually captures differences in cultivar physiology rather than differences due to weather changes. This distinction is critical because traits that are ‘masked’ by the environment have low heritability and are more difficult to genetically improve.

In the first two years, we tested and deployed our technology on two populations of 508 and 468 advanced breeding lines that are part of the U of M wheat Preliminary Yield Trials (PYT). This breeding pipeline, renewed each year, enables wheat breeder Jim Anderson to evaluate the yield potential of his most promising lines. This year, for instance, our trial enabled us to identify a group of superior breeding lines that out-yielded the best performing check by up to 24 bu/a, a performance higher than last year’s, where the best breeding line out-yielded the best check by 16 bu/a. Furthermore, our analysis conducted on the 508 breeding lines indicate that our thermal sensing technology was effective and useful, revealing a statistically significant and negative association between canopy warming and yield. That is, breeding lines with cooler canopies out-yielded those with warmer ones, across the entire set of 508 lines, consistent with expectations based on our previous work on canopy conductance. While needing confirmation based on this year’s trial, this encouraging result shows that selecting for genotypes with cooler canopies is a promising breeding target for the U of M wheat breeding program.

Building on such favorable findings, our goal for the incoming year is to i) finalize the automated extraction of thermal images and their correction using environmental and physiological data from this summer’s trial, ii) conduct data analysis to identify promising genotypes from this 2nd trial and iii) initiate a joint data analysis effort based on the two populations of advanced breeding lines (976) to identify a potential genetic marker associated with cooler canopy.

Research methods

Field experiment:

The experimental design will be an augmented incomplete block design with 4 checks in each block (14 blocks). A total of 450 genotypes including 4 checks will be planted in (4.5 ft x 8 ft) yield plots at the U of M St Paul campus. After planting, aerial thermal images will be collected weekly with a thermal camera (Vue Pro R 640) mounted on an unmanned aerial system (UAS; Inspire 2, DJI) using a specialized gimbal. Flights will always take place on sunny days around solar noon, i.e., between 13:00 and 13:30 hours. Along with the thermal images, RGB (Red-Green-Blue) images will be collected using the drone RGB camera and gimbal (Zenmuse X5S, DJI). These RGB images are needed to align with the thermal images to differentiate soil from crop temperature and estimate the change in canopy cover over time, and to obtain an estimation of plant height. To ensure that the remote-sensing approach effectively captures canopy temperature, we will also deploy ground-truthing temperature sensors (thermocouples) to be installed physically on plants during flag leaf appearance so that we have an estimate of temperature as experienced by the plants.

Image & data analysis:

Will be performed to extract reliable temperature signatures from images after correction based on flight conditions and canopy growth dynamics and these will be studied in relation to the plant’s genetic make-up, physiological status and yield performance.

Timeline for completion

January-March 2023: Finalizing the data analytics pipeline of the second trial. April-May 2023: Equipment testing and calibration, planting. May-August 2023: Drone flying, data acquisition, harvest. September-December 2023: Image data analysis of third trial and reporting.

Outreach plan

We hope to disseminate our findings to growers at the winter Prairie Grains Conference in 2023. At the end of the project, we will also communicate updates on our research online on the U of M extension portal and also through ad hoc meetings and field days to growers and other agriculture professionals. Our results will be disseminated more broadly to the scientific community through presentations in major conferences such as the Crop Science Society of America meetings. We expect this research will generate publishable results targeting scientific journals with a large and diverse readership such as Crop Science. We have recently published our research on canopy conductance -which led to developing this phenotyping pipeline- in a well-respected plant science journal, where MWR&PC support is acknowledged (Tamang et al. 2022; <https://onlinelibrary.wiley.com/doi/full/10.1111/ppl.13752>, fully accessible to non-subscribers).

List other current or pending funding sources for this project:

Anderson and Sadok have received funding for a graduate student from USDA-NIFA. This funding will support a graduate student who will start in the fall of 2022/spring of 2023. The student is expected to participate and further support this UAV-based remote-sensing, which should enable us to deploy our technology on a larger number of trials.

Research group (other collaborators not listed as PIs):

The research group consists of co-PIs whose name is already listed.

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

This research builds directly on a successful project previously funded by the MWR&PC, which results were recently published in a peer-reviewed scientific journal (Tamang et al. 2022). The goal of that project was to identify the genetic basis of canopy conductance on wheat, an important trait that directly drives yield performance, but which can only be reliably measured under controlled environment conditions. We successfully identified the genetic basis of canopy conductance and we used genotypes having ‘lazy’ and ‘hardworking’ versions of canopy conductance genes to develop the current, field-based remote-sensing method. We were able to find that genotypes with high conductance (having the ‘hardworking’ version of the gene) actually have cooler canopies in the field, consistent with the biophysics of canopy transpiration. Thus, we were able to extend our ability to identify superior canopies without the need of relying on controlled environment research, which will make our method more readily useable in wheat breeders’ fields across the region and beyond.

 **Minnesota Wheat Research and Promotion Council**

 **RESEARCH PROJECT PROPOSAL BUDGET**

|  |
| --- |
|  **Project Title:** **A Novel High-Throughput Phenotyping Pipeline to Deliver More Productive and Stress Resilient Minnesota Wheat Varieties** |
|  **Principal Investigator(s) / Project Director(s)** Walid Sadok, Daniel M Monnens, James A Anderson   |   Funds Requested For Year 1 Year 2 Year 3 (2023) (2024) (2025) |
| A. Salaries and Wages  | $ | $ | $ |
|  1. Co-principal Investigator(s) |  |  |  |
|  2. Senior Associates |  |  |  |
|  3. Research Associates – Post Doctorate  |  |  |  |
|  4. Other Professionals  | 40,042  |  |  |
|  5. Graduate Students |  |  |  |
|  6. Prebaccalaureate Students |  |  |  |
|  7. Secretarial - Clerical |  |  |  |
|  8. Technical, Shop and Other |  |  |  |
| B. Fringe Benefits | 12,813 |  |  |
| C. Consulting and Professional Services |  |  |  |
| D. Supplies and Services   |  |  |  |
| E. Travel |  |  |  |
| F. Sub-Contracts |  |  |  |
| G. Repairs & Maintenance |  |  |  |
| H. Rentals & Lease  |   |  |  |
| I. Other Expenses |  |  |  |
| **TOTAL AMOUNT OF THIS REQUEST (per year)** | **$52,855**  | **$**  | **$**  |