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: Sponsored Projects Administration
450 McNamara Alumni Center, 200 Oak Street SE
Minneapolis, MN 55455-2070

2. TITLE OF PROPOSAL
Maximizing Canopy Conductance to Enhance Spring Wheat Yield Potential in the Upper Midwest

3. PRINCIPAL INVESTIGATOR(S)	4. PI #1 BUSINESS ADDRESS
PI# 1 Name: Walid Sadok	Department of Agronomy and Plant Genetics 411 Borlaug Hall
PI# 2 Name: Brian J Steffenson	1991 Upper Buford Circle
PI# 3 Name: James A Anderson	St. Paul, MN 55108

5. PROPOSED PROJECT DATES (calendar years)	6. TOTAL PROJECT COST	7. PI #1 PHONE NO.
January 1st, 2020 – December 31, 2020 Note: Research Reports are Due November 15th of Each Year		612-625-8291

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

There are very few reliable traits that are associated with increased wheat yield potential. We have recently identified increased canopy conductance as a promising trait that is linked to historic wheat yield increases in Minnesota and elsewhere. Because this trait is extremely challenging to measure in the field, we have developed a novel 'precise phenotyping' platform that enables the screening of hundreds of wheat plants for maximized canopy conductance. This makes it possible to screen breeding and mapping populations to identify quantitative trait loci (QTL) and associated markers (genes) that can be transferred to a wheat breeding program to release new MN wheat varieties with enhanced yield potential. In the previous years of this research, we 1) Adapted this platform to enable high throughput phenotyping of wheat mapping populations, 2) Screened (twice) the parents of the Minnesota Nested Association Mapping Population (MNAMP), a highly diverse group of wheat parents, developed by Brian Steffenson, 3) Phenotyped families from the MNAMP whose parents exhibited the greatest contrast in canopy conductance from the recurrent parent RB07, 4) Initiated an effort to confirm those QTL in a breeding population developed by wheat breeder Jim Anderson and 5) Identified several quantitative trait loci (QTL) controlling canopy conductance. In this year, our goals are to i) finalize the list of candidate QTL to be transferred into the breeding pipeline by phenotyping final time a mapping population to complete the genetic analysis and ii) initiate an effort to confirm their effects in the field. At the end of this year, we will have identified and delivered to the breeding program promising QTL and candidate genotypes for multi-location yield trials.
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 Of Principal Investigator	Date	Phone Number
[signature]	1/31/2020	612-625-8291
Signature Of Authorized Representative	**Title** Amy Bicek-Skog, Prin. Grant Admin. Sponsored Projects Administration	**Date** 1-31-2020
Amy Bicek-Skog [signature]		

Address Of Authorized Representative	Phone Number
Amy Bicek-Skog, Office of Sponsored Projects Administration, 450 McNamara Alumni Center, 200 Oak Street SE, Minneapolis, MN 55455-2070	612-625-0413

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

Project Title: Maximizing Canopy Conductance to Enhance Spring Wheat Yield Potential in the Upper Midwest

Importance of this project to the profitability of wheat producers:

Increasing grain yield and seed protein content are two major goals to Minnesota wheat growers. However, despite the recent progress in breeding and management, further improvements have been difficult to achieve because high-yielding cultivars tend to have lower grain protein. Breaking the ceiling dictated by this relationship requires the discovery of novel traits that allow for increases in both carbon and nitrogen available to the seed. Our group has published peer-reviewed evidence indicating that maximizing whole-plant canopy conductance to water released by transpiration may allow for maximizing the amount of CO_2 fixed by the crop from the atmosphere and nitrogen uptake from the soil along with other mobile nutrients. In this published work, we show that this conductance is correlated with substantial increases in wheat yields, making it an excellent target for selection in the U of M wheat breeding program (Schoppach et al. 2017; Sadok et al. 2019; Tamang et al. 2019). Until now however, there was no tool available for breeders to enable screening hundreds of lines needed for a breeding program. Thanks to a new 'precision phenotyping' platform we have developed, we seek to identify genes controlling this trait and introgress them into the U of M wheat breeding program to deliver superior, higher-yielding cultivars to Minnesota wheat growers.

Procedures:

Dr. Sadok's research has recently shown that whole-plant canopy conductance to water vapor lost by transpiration is positively correlated with yield performance in Minnesota, North Africa and South-Australia (Schoppach et al. 2017; Sadok et al. 2019; Tamang et al. 2019). Our hypothesis for this observation is that genotypes with higher canopy conductance maintain stomata – small transpiring pores on the surface of the leaf – open during longer periods of the day, even at midday when typical cultivars close their stomata. As a result, 'high-conductance' plants tend to transpire more, therefore pulling more water, nitrogen (N) and other mobile minerals from the soil into the crop. Because atmospheric carbon dioxide (CO_2) fixation has to take place through these same open stomata, high-conductance plants will fix more carbon needed for grain filling, in addition to N and other beneficial nutrients, making them particularly suitable for MN. Based on computer-based simulation modelling taking into account weather data, soil type and crop management, our work on a similar context in North Africa projected a yield increase by 15-20% in well-watered environments as a result of increasing canopy conductance to values that are within the range observed in our MN experiments (Sadok et al. 2019). Using a novel, whole-plant, high-throughput phenotyping system (see below) developed by the Sadok Lab (Tamang and Sadok 2018), we have initiated a pre-breeding research program supported by the MWR&PC focused on identifying favorable genes controlling this promising trait with the near-term goal of introgressing them in elite lines of the U of M wheat breeding program.

High-throughput screening for enhanced canopy conductance – that is, measurements done on hundreds of plants – is nearly impossible to undertake in the field because of various confounding weather variables (such as time-of-day effects, rapid variation in windspeed, passage of clouds, changes in temperature, plant microclimate) that add substantial noise to the data. While gas exchange equipment could be used to conduct measurements in the field (see goals), such equipment can only be deployed on a limited set of genotypes (1-10 lines typically), and could only be used for field-based validation, rather than for phenotyping. To address this bottleneck, the Sadok Lab developed a controlled-environment phenotyping (screening) system (the Gravimetric Phenotyping or GraPh platform) to enable 'high-fidelity' screening of whole-plant canopy conductance within large populations (Tamang and Sadok, 2018). In the first years of this research, we: 1) Adapted the GraPh platform to enable high throughput phenotyping of wheat mapping populations, 2) Screened (twice) the parents of the Minnesota Nested Association Mapping Population (MNAMP), a highly diverse group of wheat lines consisting of RB07 and 25 other exotic lines, developed by Brian Steffenson, 3) Phenotyped (three times) families from the MNAMP which parents exhibited the greatest contrast in canopy conductance from the recurrent parent RB07, 4) Identified several quantitative trait loci (QTL) controlling canopy conductance in those families and 5) Initiated an effort to confirm those QTL in a breeding population developed by wheat breeder Jim Anderson (145 recombinant inbred lines (RIL) from a cross between MN-adapted parental lines MN99394-1-2 and MN99550-5- 2). Thanks to the progress achieved, our goals for next year are two-fold: i) finalize the list of candidate QTL to be transferred into the breeding pipeline by phenotyping a third and final time the RIL population to complete the genetic analysis and ii) initiate an effort to confirm their effects in the field.

Goal 1. Finalize the phenotyping of canopy conductance to identify a 'firm' list of candidate QTL. To achieve this goal, we will phenotype one final time 3 MNAMP families, totaling approx. 300 lines. Each one of these families will consist of approx. 50 recombinant inbred lines (RIL), resulting from crosses between RB07 and contrasted parents from the pool of 25 MNAMP parents. The families will be grown under naturally fluctuating conditions in the greenhouse, in pots filled with field- harvested topsoil, with 3 replications per plant (i.e., a total of 450 pots). After growing for 4-5 weeks, the families will be transferred to the GraPh platform, which is deployed inside three adjacent, identical walk-in growth chambers at the St. Paul campus of the University of Minnesota. In this platform, canopy conductance is measured as the slope of the relationship between progressive increases in atmospheric vapor pressure deficit (VPD) and water loss by the transpiration of the entire plant. Transpiration is measured by tracking pot weight change measured by rugged balances connected continuously to data loggers. Increases in VPD generate a 'negative pressure' that forces water out of the leaves (stomata), and the slope between VPD and pot weight change will allow us to quantify with high precision the plant's conductance to water. The increase in VPD imposed in the growth chamber mimics VPD conditions that would typically take place under a sunny, cloudless summer day in the field in Minnesota. Based on the collected data, we will carry out a final joint QTL mapping to confirm a list of promising QTL already identified, some of which explained 24% of the phenotypic variability.

Goal 2. Initiate a field-based confirmation of detected QTL. Based on the list of QTL confirmed, we will select genotypes from the mapping populations harboring contrasted alleles for the large-effect QTL detected for field-based validation. In a first step, selected genotypes will be grown in the field on the St. Paul campus of the University of Minnesota in single row plots. This location was chosen since it will facilitate the screening of a relatively large number of genotypes with contrasting alleles for the identified QTL (up to 30 lines dependently on the list of confirmed QTL). The field experiment will use a low-throughput, but a highly advanced technology for measuring canopy conductance under fluctuating conditions to ensure that we capture QTL that discriminate between genotypes under field conditions. To this end, we will use a high-end ($50,000 worth) portable gas exchange system (LiCor LI-6800) that was recently acquired by the Sadok lab. In parallel, we will initiate a seed increase effort for the pre-selected genotypes in order to enable validating the QTL not only based on canopy conductance values measured in the field, but using actual yield data. This will enable, in the following years, to conduct multi-location yield trials on a subset of 6-10 contrasted genotypes to validate the positive effects of selected QTL on yield. Therefore, at the end of this year, we will have identified and delivered to the breeding program promising QTL and candidate genotypes for multi-location yield trials.

Regional linkage to other research activities:

Because improved canopy conductance has multiple benefits for the crop in terms of canopy cooling, increased nutrient uptake and stress tolerance, this project can benefit other projects addressing those aspects throughout the region. For instance, the phenotyping system would benefit the NDSU HRSW breeding program because canopy conductance is strongly related to key goals of the program such as enhancing drought and heat stress tolerance. Indeed, our system can identify genotypes displaying a 'water-saving' canopy conductance, which has led to breeding more drought-tolerant cultivars in Australia. Alternatively, in heat stress-prone environments, high canopy conductance genotypes would display higher canopy cooling, therefore protecting the plant form heat stress. Superior genotypes with maximized or water-saving canopy conductance will be shared with other wheat breeding programs in the region.

List current or potential other funding sources for this project: The PI has recently completed an international project he led with the goal of using canopy conductance traits to increase wheat productivity in North Africa. This research is currently supported in part by project on canopy conductance funded by USDA-NIFA through the Minnesota Agricultural Experiment Station. Data from this project will be also used to support another USDA-NIFA project in preparation.

Research Group:
Walid Sadok and the postdoctoral research associate will lead the phenotyping effort and the data analyses. Brian Steffenson and Jim Anderson will provide mapping populations and genetic maps and will provide expertise on the genetic analysis and QTL identification.

Relationship to past projects:
Dr. Sadok has led in the past a project in collaboration with Australian wheat genomicists and successfully identified canopy conductance traits and QTL that are associated with improving wheat productivity under drought conditions. In collaboration with other physiologists from North Africa and the U.S. he led an international modeling effort that quantified wheat yield gains resulting from canopy conductance traits.

Estimate the budget requirements:
Funding is requested for a 75% postdoc (salary: $38,250 and fringe: $9,295 at 24.3%). Funds are requested to support greenhouse and growth chamber rental costs for 4 months: $3,567. Total: $51,111.

References:
Sadok, W., et al. 2019. European Journal of Agronomy, 107: 1–9 | Tamang, B.G., et al. 2019. Planta, 250: 115–127 | Tamang, B.G., and W. Sadok. 2018. Environmental and Experimental Botany, 148: 192–202 | Schoppach, R., et al. 2017. Journal of Agronomy and Crop Science, 203(3): 219–226.