Grant Code: AP2713

Title: Developing Wheat Cultivars for Idaho

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Justification/Rationale: Idaho wheat production contributes significantly to domestic and overseas wheat markets. Nationally, Idaho ranks in the top eight states for wheat and wheat product exports. Most of wheat production in the southern part of the state is grown under irrigation, while in the northern part grown under dryland. Improved grain yield and desirable end-use quality are the two major traits required in cultivar development. Resistances to biotic and abiotic stresses have significant impacts to grain yield and end-use quality. Stripe rust has been the most important disease for both winter and spring wheat as it caused significant yield loss for growers and quality reduction for the wheat industry. The predominant spring wheat (Alturas, Louise, and Jefferson) and winter wheat (Moreland, Stephen and Brundage) cultivars are being replaced by the increasing number of new wheat varieties that have better yield, improved disease resistance, and desirable end-use quality. Fusarium head blight (FHB) has emerged to the irrigated production areas in southern Idaho, especially for spring wheat, due to increasing corn production, no-till practices, and the climate change. Most of wheat cultivars are very susceptible to FHB. When an epidemic occurs the fungus in the infected grains will produce DON and causes grains unusable for human consumption and animal feeds. Snow mold and dwarf bunt are endemic diseases that limit use of winter wheat varieties in dryland production. Other diseases and pests affecting wheat production in this region include barley yellow dwarf virus (BYDV), bacterial leaf blight, physiological leaf spots, dryland crown rot, cereal cyst nematodes, and wireworm. Drought and heat are the two major abiotic stresses. Pre-harvest sprouting and late maturity alpha amylase damage are also concerns in recent years. To facilitate marker-based breeding in the small grains, the USDA-ARS has established four regional genotyping centers in Manhattan, KS; Pullman, WA; Fargo, ND; and Raleigh, NC. The integration of the genotyping laboratories in the previous and current CAP projects provides the foundation for the breeding programs to implement marker-assisted selection (MAS) and genomic selection (GS) strategies.

Hypothesis & Objectives: The genetic recombination of desired genes can be achieved by crossing, selfing, mutation, and gene editing, and selected via molecular markers and traits expressed in favorable environments. The breeding processes can be accelerated using a proper combination of traditional breeding and new breeding technologies. The objective of this study is to develop adapted premier wheat cultivars using a combination of traditional and genomics-assisted breeding methods.

Procedures/Plan of Work:

1. **BREEDING PROCEDURES**:

1.1. Marketing and Variety Release: assist in identifying licensing partners for UI Sparrow; release IDO1706 (UI Jade) hard white winter wheat and IDO1405S soft white spring for irrigated production in SE Idaho.

1.2. Breeder Seed Production: plant breeder seeds of winter wheat in plots for IDO1706 HWW, IDO1607 HRW, IDO1708 and IDO1005 SWW; in headrows for IDO1608 HRW, IDO1806 and two additional experimental lines of hard white winter wheat; plant breeder seeds in plots for two soft white spring wheat lines IDO1702S and IDO1403S; in headrows for IDO1704S HWS, IDO1801S HRS, and IDO1805S HRS.

1.3. Elite and Breeding Line Evaluation: Yield trials are defined previously as Elite Yield Trial (EYT), Preliminary Yield Trial (PYT), and Observation Yield Trial (OYT). OYT is the first year, non-replicated trial that is planted in one or two environments depending on seed availability. PYT is the second year, replicated yield trial that is usually planted in two or three environments. EYT is the third year, replicated yield trial that is planted in four to seven locations in SE ID. Lines in the EYT will be evaluated for stripe rust by Dr. X. Chen, dwarf bunt by Dr. David Hole, FHB by us, stem rust by Drs. Yu Jin and J.M. Bonman, snow mold by Drs A. Carter and/or J. Marshall, nematodes by Dr. R. Smiley, Hessian fly by Dr. Bosque-Pérez, and Wheat Streak Mosaic Virus by Dr. M. Flower. Elite lines will also be genotyped with known functional markers by Dr. D. See in the ARS genotyping center at WSU and in our MAS lab. After harvesting, end-use quality of the selected lines in the EYT, PYT, and OYT from multiple locations will be assessed in the Idaho Wheat Quality Lab (Mrs O'Brein). Yield, agronomic, disease and insect resistance, and marker data will be used in selection of lines for crossing and further evaluation in the Western Regional Trials (WRT) and Tri-state Variety Trials (VYT) in the following years. In FY20 we have 10 lines (6 spring) in WRT and 17 lines (10 spring) in VYT, 200 lines (180 spring) in EYT, 490 lines (2500 spring) in PYT,1240 lines (800 spring) in OYT, 180 spring lines in CL plus, 315 lines in special research projects. We also plant 400 plots (all winter) for cereal extension program and 376 plots for LCS.

1.4. Headrow Evaluation: Headrows will be planted in Aberdeen and assessed for plant type and agronomic characteristics and disease resistance. After harvesting, test weight, seed color, protein, and flour hardness will be assessed and used in grouping of selected headrows into Observation Yield Trials in the following year. Headrow trials are also used for seed increase of F1 and special genetic materials. In FY20 we are expecting to assess 25,000 F5 head rows.

1.5. Early Generation Test (F2, F3, and F4): Around 800 populations (550 spring) of F2 and F3 will be advanced with modified bulk selection and 200 F4 populations (100 spring) will be advanced with head selection in non-replicated trials in irrigated and water stress environments in SE ID.

1.6. Objectives for 2019 New Crosses: Make crosses to improve yield and yield components (mainly on spring wheat) using molecular markers generated by Wheat CAP, to pyramid

dwarf bunt resistance genes and FHB resistant QTL via MAS, to improve LMA/PHS resistance and grain cadmium content and drought tolerance, along with maintaining resistance to stripe rust and end-use quality. Make additional crosses for specialty wheat, such as resistant starch and special amino acid.

2. **Molecular Marker Assisted Breeding:**

2.1. Assess herbicide resistance via MAS (KASP) in around 180 selected DHLs and RILs. The selected lines (target 20 lines) will be assessed for herbicide resistance in field quantification trials in Aberdeen and under contracted service to speed up release.

2.2. Genotyping of advanced lines in our lab and in the regional genotyping center for newly cloned FHB1, FHB3, Hessian Fly (H25 and unknown), stripe rust (Yr5, Yr15, Yr36, QTL2BS, QTL4AS), height (Rht1 and Rht2), vernalization (VRNB1), heading (PPD-D1), baking quality (GluBx7oe, GluD1, GluA3, GluB3, QTL1B-VOL), dwarf bunt (QTL7DS and QTL 6DL), stem rust (Sr2, Sr39, Sr47), LMA/PHS (QTL2BS, QTL5AS, QTL7A), yield components (SNS4A, SNS5A, SNS7A, SPN6A, SPN4A, KW7D), resistant starch.

2.3. Marker-assisted backcrossing in the crosses involved in the new germplasm introgression.

3. **Marker Development and Validation:**

3.1. Breeding durable and high level of dwarf bunt resistance using molecular marker-assisted selection (Separate proposal).

3.2. Characterizing the cause effect for low falling number hard white spring wheat (separate proposal).

3.3. QTL mapping of grain cadmium content in spring wheat (in Dan Strawn proposal).

3.4. Validation, characterization and deployment of QTL for grain yield components in wheat (USDA-ARS NIFA Wheat CAP).

3.5. Developing FHB resistant spring wheat via MAS and genomic selection (USDA-ARS USWBSI project).

4. **Collaborative Research Projects:**

4.1. Grow Brundage and UI Platinum M3 EMS materials under collaboration with Dr. Fu to identify desirable mutation lines for important traits related to Idaho wheat production system.

4.2. Assess advanced lines of winter and spring wheat for Lima Grain Cereal Seeds and Cereal Extension Program.

Duration: 2019-2025

Cooperation/Collaboration: Details were included in the proposal.

Anticipated Benefits, Expected Outcomes and Impacts and Transfer of Information: New cultivars released by this project, combining improved yield with biotic and abiotic resistances, will be grown by wheat growers and be used by end-users in Idaho, the PNW, and the US to maintain or increase their productivity and competitiveness in domestic and international markets. Information on cultivars and breeding lines will be distributed to growers through the wheat breeding project website, commodity schools, IGPA meetings and magazines, and publications in

Journal of Plant Registration and other journals. QTL and molecular markers identified will be used in the breeding programs in the US and the world and published in peer referred journals and presented at national and international meetings. Students involved in the projects will be trained and worked in public and private sectors after graduated.

Literature Review: Development of desirable wheat varieties is dependent on the extent of genetic variation, favorable selection environments, and efficient selection methods. Genetic improvement of desirable traits for premier wheat cultivars can be achieved and accelerated by using a combination of traditional and new breeding technologies.

Advances in genotyping (SNP, GBS, exome capture) are decreasing molecular marker costs and increasing genome coverage to the point that new strategies are now feasible. MAS continues its role in the selection of major genes/QTL, such as Hessian Fly, dwarf bunt, stripe rust, glutenin genes. Genomic selection (GS) is a new breeding method that use whole genome-wide markers to predict the total genetic variance contributed by major and minor QTL. Two case studies have demonstrated that the GS is a very promising breeding strategy for FHB resistance in winter wheat (Rutkoski et al., 2012; Arruda et al., 2015). It is essential to explore the GS in spring wheat lines developed in PNW region as these lines have unknown FHB resistance sources and controlled by several minor QTL (Wang et al., 2017). GS may have potential applications in selecting of grain yield and other traits that controlled by multiple genes with smaller genetic effects and genetic by environmental interactions.

Recent technology and resources developments in sequenced mutant populations and assembly methods have allowed gene cloning much easier and faster, the wheat community now is moving to an era in the major cereals (Uauy C. 2017).

FY2020

IDAHO WHEAT COMMISSION - BUDGET FORM

Principal Investigator: Jianli Chen

Allocated by	Idaho Wheat Commission	during FY 2018	$ 150,815
Allocated by	Idaho Wheat Commission	during FY 2019	$ 141,914

REQUESTED FY2020 SUPPORT:

Budget Categories	(10) Salaries (*staff, post-docs, etc.*)	(12) Temp Help	(11) Fringe	(20) Travel	(30) OE	(70) Graduate Tuition/ Fees	TOTALS
Idaho Wheat Commission	$ 19,635	$ 53,499	$ 24,207	$ 15,000	$ 47,100	$ -	$ 159,441

TOTAL BUDGET REQUEST FOR FY 2020: $ 159,441

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

Budget Categories	*(Insert PI Name)*	*(Insert CO-PI Name)*	*(Insert CO-PI Name)*	*(Insert CO-PI Name)*
(10) Salaries	$ -	$ -	$ -	$ -
(12) Temp Help	$ -	$ -	$ -	$ -
(11) Fringe Benefits	$ -	$ -	$ -	$ -
(20) Travel	$ -	$ -	$ -	$ -
(30) Other Expenses	$ -	$ -	$ -	$ -
(70) Graduate Student Tuition/F	$ -	$ -	$ -	$ -
TOTALS	$ -	$ -	$ -	$ -

Total Sub-budgets $ -

Explanatory Comments:
$19,635 is requested for Weidong Zhao's 13 pays salary and benefits to do breeding for early generation and MAS.
$53,499 is requested for six IH working from one month to 16 months in breeding actitivities.
Jose and Flora 16 pays each; Jim 13 pays; Ema and Maria 4 pays each at harvesting; Lyona 2 pays in crossing.
$24,207 is requested to cover benefits for Weidong and all IHs.
$15,000 is requested for travels to PNW, growers convention, off-station nurseries.
$47,000 is requested to cover renting fees of 35 acres field, DH production, CL Plus service, harvesting bags and stakes, etc

Fall 2018 Version

ANNUAL REPORT

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Accomplishments: We have a productive year in 2018. Breeder seeds of thirteen elite lines were harvested, three of them are expected to release (Table 1). IDO1706 is a medium tall with strong straw, brown chaff, and awned hard white winter wheat. The yield of this line was the highest with 164 Bu/A (trials mean 141 Bu/A, high yield check LCS Jet was 158 Bu/A) based on the average yield from three irrigated locations in Dr. Marshall's variety trials. IDO1706 also has very good disease resistance to dwarf bunt and stripe rust. The bread baking quality of this line is comparable to UI Silver. Another is soft white spring wheat IDO1405S. This line has very good yield, comparable end-use quality and tolerance to FHB like UI Stone. IDO1405 has least concern about the threshing ability. The third potential release is a very short hard white winter line IDO1506. Releasing this line is mainly for wheel-line irrigation growers because of its short plant height. IDO1506 has average grain yield and end-use quality, but excellent resistance to dwarf bunt and stripe rust. IDO1405S passed PNW quality council (QC) in 2017. IDO1506 and IDO1706 were submitted to PNW QC this year.

We have made good progress on hard white winter wheat development. In addition to IDO1706 and IDO1506, we have selected IDO1806 and several experimental lines that showed good performance in yield, stripe rust and dwarf bunt resistance, and improved bread-baking quality. We succeeded in pyramiding of hessian fly gene H25, stripe rust, and end-use quality in spring wheat and developed and produced seeds for several lines (IDO1603S, IDO1701S, IDO1703S, IDO1702S). We observed that H25 Hessian fly resistance gene might have yield drag in these lines. However, Hessian fly resistance gene from Jefferson and Blanca Royale have been introgressed to new elite spring wheat lines IDO1704S, IDO1801S, and IDO1805. These lines also have good resistance to stripe rust and end-use quality. IDO1805S has good resistance to FHB from Alsen.

Future direction of my program will be to develop high yielding cultivars with value-added traits using molecular marker-assisted selection. Such germplasm has been developed. FHB resistance from known resistance source 'W14' and from National Small Grain Collection and nematodes resistance from Ouyen have been introgressed to the new experimental lines. Breeding for special quality, such as low Cadmium and desirable SRC, high falling number wheat are moving forward as expected. Over 100 elite lines with two gene herbicide resistance were advanced in hard white spring wheat. With the purchase of real-time PCR, KASP assay have been established in our lab and are being used in selection of different traits.

Projections for FY2020:

1. Assist in identifying licensing partners for UI Sparrow; release IDO1706 hard white winter wheat and IDO1405S soft white spring for irrigated production in SE Idaho.
2. Plant breeder seeds of winter wheat in plots for IDO1706, IDO1607, IDO1708; in headrows for IDO1806 and two additional experimental lines of hard white winter wheat.
3. Plant breeder seeds in plots for two soft white spring wheat lines IDO1702S and IDO1403S; in headrows for IDO1704S HWS, IDO1801S HRS, and IDO1805S HRS.
4. Apply molecular markers in variety development using resources generated from Wheat CAP, Scab initiative, and other IWC supported projects.
5. Produce DH lines under service with HPI and use KASP to select multiple resistance genes to dwarf bunt.
6. Work with faculty from CALS and PS department in variety testing and research projects.
7. Work with USDA scientists and evaluate stem rust resistance in Kenya and Ethiopia nurseries; stripe rust resistance in Pullman, WA; FHB resistance in Maryland; dwarf bunt resistance in Logan, UT; end-use quality in CA.
8. Continue working with Ardent Flour Mills on screening desirable wheat varieties for ultra-low cadmium flour production and desirable SRC profile.
9. Make presentations and/or write materials related to new varieties to industry partners, such as Lima Grain Cereal Seeds, Ardent Flour Mills, Highland Specialty Grains, Thresher, Grain Craft, McKay Specialty Grain.
10. Assist on-farm strip trials and conduct field day for marketing new cultivars with extension program and IWC.
11. Organize two field days in Rockland and Arbon and attend field days organized by others
12. Present variety update to PNW growers, researchers, and industry.
13. Continue effort and present my research and variety update to national and international customers and visitors as needed.

Publications:

Dong, H., R. Wang, Y. Yuan, J. Anderson, M. Pumphrey, Zh. Zhang, and J. Chen*. 2018. Evaluation of the Potential for Genomic Selection to Improve Spring Wheat Resistance to Fusarium Head Blight in the Pacific Northwest. Frontiers in Plant Science. https://doi.org/10.3389/fpls.2018.00911.

Liu, Y., R. Wang, Y. Hu, and J. Chen*. 2018. Genome-Wide Linkage Mapping of Quantitative Trait Loci for Late-Season Physiological and Agronomic Traits in Spring Wheat under Irrigated Conditions. Agronomy, 60. doi:10.3390/agronomy8050060.

Bissonnette, K. M., Ph. Wharton, J. Chen, J. Marshall. 2018. Survey of Fusarium species associated with fusarium head blight of spring wheat (Triticum aestivum) in Southeastern Idaho. Plant Health Progress 19: 125-127. https://doi.org/10.1094/php-10-17-0066-S.

Assanga, S.O., S. Dhakal, C-T., Tan, J.C. Rudd, G. Zhang, A. Ibrahim, Q. Xue, R. Devkota, S. Haley, J. Chen, M. P. Fuentealba, S. Baker, J. Baker. S.Y. Liu. 2017. Mapping of quantitative trait loci for grain yield and its components in a US popular winter wheat using

90K SNPs. PLoS ONE. Dec. 2017. DOI 10.1371/journal.pone.0189669.
Liang, X., D. Strawn, J. Chen, J.M. Marshall. 2017. Variation in cadmium accumulation in spring wheat cultivars: uptake and redistribution to grain. Plant and Soil DOI 10.1007/s11104-017-3454-z.

Table 1. List of breeder seed production in 2018

Line	Class	Breeder seed	Major traits	PNW QC
IDO1405S	SWS	Strips	High yield, FHB tolerance, Q+, easy thresh	2017
IDO1604S	HWS	Strips	Like UI Platinum	2016
IDO1602S	HWS	Strips	Like UI Platinum	2016
IDO1603S	HRS	Plots	Excellent quality, resistance to stripe rust and Hessian fly, average yield	2017
IDO1701S	HRS	Plots	Excellent quality, resistance to stripe rust and Hessian fly, average yield	2017
IDO1703S	HRS	Plots	Excellent quality, resistance to stripe rust and H25, average yield	2017
UI Platinum	HWS	Plots, purification	High yield and excellent quality	2013
IDO1403S	SWS	Headrows	Resistance to stripe rust and high FN, low yield	2017
IDO1702S	SWS	Headrows	Resistance to stripe rust and H25, Q+, lower yield than UI Stone	2018
IDO1607	HRW	Headrows	Good quality and improved resistance to stripe rust compared to Moreland	2016
IDO1706	HWW	Headrows	Excellent yield and quality, moderately resistant to stripe rust and dwarf bunt	2018
IDO1708	SWW	Headrows	Good quality and resistance to stripe rust	2018
IDO1005	SWW	Headrows	Good quality and resistance to stripe rust	

Table 2. Seed increased for State Variety trials and breeder seed will be produced in 2019.

Line	Class	Breeder seed	Major Traits	PNW QC
IDO1704S	HWS	2019	Improved loose smut and Hessian fly resistance compared to UI Platinum	2018
IDO1801S	HRS	2019	Improved rust resistance over Jefferson, Hessian fly resistance	2018
IDO1805S	HRS	2019	Improved rust resistance over Jefferson, FHB resistance	2018
IDO1806	HWW	2019	Q+, Short hard white winter	2019
IDO1906	HWW	2020	Q+, Early, Short hard white winter	2019