Grant Code:	AP3629
TITLE:	Developing Wheat Cultivars for Idaho
PERSONNEL:	J. Chen, J. Wheeler, N. Klassen, R. Wang, W. Zhao, J. Bevan, B. Mangum, J. Prestige, F. Esparza, J. Carrillo
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JUSTIFICATION:
Idaho wheat production contributes significantly to domestic and overseas wheat markets. Nationally, Idaho ranks in the top eight states for wheat production. Most wheat production in southeastern Idaho is grown under irrigation, while in northern Idaho it is grown under dryland. Improved grain yield and 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 occurs frequently and has caused significant yield loss for growers and quality reduction for the wheat industry. Fusarium head blight (FHB) has emerged in irrigated production areas, especially for spring wheat, due to increasing corn production, no-till practices, and the climate change. Most wheat cultivars are very susceptible to FHB. When an epidemic occurs, the fungus in the infected grains will produce DON and causes grain to be unusable for human consumption and animal feeds. Dwarf bunt are endemic diseases that limit use of winter wheat varieties in high elevation dryland production areas. 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 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.

RESEARCH 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.

1. **BREEDING PROCEDURES**:
   - **1.1. Marketing and Variety Release:** assist in identifying licensing partners for UI Sparrow and UI Bronze Jade; release UI Cookie in spring of 2020.
   - **1.2. Breeder Seed Production:** plant breeder seeds for ten elite lines, including two hard white winter wheat (IDO1906 and IDO1806, good quality and stripe rust resistance), two soft white winter wheat (IDO1708 and IDO1810, good quality and stripe rust resistance), two soft white spring wheat (IDO1802S and IDO1404S, high yield and good quality),

two hard white spring wheat (IDO1804S and IDO1904S, good quality and stripe rust resistance), and two hard red spring wheat (IDO1805S, FHB resistance and good quality, and IDO1701S, Hessian Fly resistance and good quality).

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. 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) in the following years.

1.4. **Headrow Evaluation**: Headrows will be planted in Aberdeen, ID 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 OYT in the following year. Headrow trials are also used for seed increase of F1 and special genetic materials.

1.5. **Early Generation Test (F2, F3, and F4)**: We will focus on evaluation of agronomics and resistance to stripe rust and bacteria leaf blight and advance populations using modified bulk breeding method.

1.6. **Objectives for 2021 New Crosses**: Develop MAGIC population (second cycle of crossing); Introgress Hessian Fly resistance gene H26 to elite lines of winter and spring wheat; introgression of new FHB resistance gene from synthetic wheat to elite spring wheat; Introgression of LMA and low Cd into more elite line backgrounds; Top- or backcross for strong gluten and resistant starch in spring wheat; Top- or backcrossing for yield components in spring wheat.

2. **Molecular Marker Assisted Breeding:**

2.1. Use KASP marker system and gel-based marker system installed in our lab in conjunction with the service under Western Regional Genotyping lab.

2.2. Lines in the EYTs and used in the crossing parents will be genotyped.

2.3. Traits that can be assessed via molecular markers include: 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.

3. Marker Development and Validation:

3.1. Developing desirable storage protein profile for strong gluten hard white wheat (in collaboration with a USDA-ARS lab).
3.2. 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 (separate 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 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: Details were integrated in the proposal.

ANTICIPATED BENEFITS/EXPECTED OUTCOMES/INFORMATION TRANSFER:
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 refereed journals and presented at national and international meetings. Students involved in the projects will be trained and work in public and private sectors after graduation.

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, and glutenin genes. Release of UI Sparrow is an example in using

doubled haploid (DH) system and reduced five years compared to the traditional method. Another example from our program is the use of a combination of DH and molecular marker assisted selection. Two spring hard white DH lines were developed in less than 10 years during mapping of QTL associated with late maturity alpha amylase and cadmium uptake. The two DH lines can be used as parental lines in additional crossing and selected via marker assisted selection.

FY2021

IDAHO WHEAT COMMISSION - BUDGET FORM

Principal Investigator: Jianli Chen

If applicable,	**Allocated by**	**Idaho Wheat Commission**	**during FY 2019**	**$ 141,914**
If applicable,	**Allocated by**	**Idaho Wheat Commission**	**during FY 2020**	**$ 159,441**

REQUESTED FY2021 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	$ 19,989	$ 53,894	$ 29,922	$ 12,000	$ 41,500	$ -	$ 157,305

TOTAL BUDGET REQUEST FOR FY 2021: **$ 157,305**

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/Fees	$ -	$ -	$ -	$ -
TOTALS	$ -	$ -	$ -	$ -

Total Sub-budgets **$ -**

$19,989 is requested for Weidong Zhao's 13 pays salary and benefits to do breeding for early generation and MAS.
$53,894 is requested for six IH working from one month to 16 pays 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.
$29,922 is requested to cover benefits for Weidong and all IHs.
$12,000 is requested for travels to PNW, growers convention, off-station nurseries.
$41,500 is requested to cover renting fees of 35 acres field, CL Plus service, harvesting bags and stakes, etc

Fall 2019 Version

ANNUAL REPORT

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Address: Jianli Chen, University of Idaho Aberdeen Research & Extension Center, Aberdeen, ID 83210; 208-397-4162, ext. 229; jchen@uidaho.edu
Accomplishments: We had a productive year in 2019. A high yielding hard white winter cultivar 'UI Bronze Jade' was released last spring, and another high yielding and FHB tolerant soft white spring wheat cultivar 'UI Cookie' is in the process of being release. Breeder seed of six winter and six spring wheat lines were harvested. Seven of them (two hard white winter IDO1906 and IDO1806, two soft white winter IDO1708 and IDO1810, one hard white spring IDO1804S, and two soft white spring IDO1802S and IDO1404S) were submitted to the PNW quality council to be evaluated in Jan. 2020. When this council approves the quality of the lines, we can request to release through the Idaho Variety Release Committee. This council includes thirteen labs from public universities and private companies in the US. Two hard red spring wheat lines, IDO1701S (high yielding, stripe rust and Hessian fly resistance) and IDO1805S (high yielding, stripe rust and FHB resistance) passed PNW QC in Jan. 2019.
Molecular markers have been broadly used in trait development and evaluation, including genes for plant adaptation, such as height genes, photoperiod, vernalization; genes for storage proteins, flour color, resistant starch, falling number, and grain cadmium content; genes for resistances to stripe rust, dwarf bunt, FHB, Hessian fly. Using molecular markers, we introduced a strong gluten gene *GluBx7oe* to improve gluten strength in our hard-white winter wheat backgrounds; we added FHB resistance gene *Fhb1* on the top of other resistance genes and good baking quality in spring wheat backgrounds; we developed two-gene herbicide resistant spring wheat lines; we added resistant starch genes in spring wheat backgrounds. Future direction of my program will be to develop high yielding cultivars with value-added traits using a combination of traditional, double haploid system, and molecular marker-assisted selection.
Additional progress related to this project:
Finding solutions to low falling number wheat in Idaho. The most important progress in this project is that we selected two doubled haploid lines (DHLs) that have resistance to LMA and PHS. We did a seed increase and harvested a large quantity of seed last summer. One of the two lines will be advanced to State Variety Trials this spring. One graduate student, Jacob Bevan, completed PHS, LMA and FN tests in one mapping population derived from UI Platinum x SY Capstone (PC). QTL associated LMA and PHS has been analyzed. He plans to graduate in spring of 2020. A visiting scholar, Ms. Ling Qiao, conducted the first year LMA experiment using the detached spike method in another mapping population (PS) derived from UI Platinum x LCS Star. The two persons harvested 1746 LMA samples that are being tested for FN and alpha amylase content. This study suggests that development of LMA resistance can be achieved through breeding and screening a large amount of lines using detached spike LMA method. Molecular markers and protein chemistry may accelerate the breeding of LMA resistance.
Intentions for FY2020: 1) Conduct the second-year detached spike LMA experiment for UI Platinum x LCS Star population; 2) Obtain the LMA related alpha amylase; 3) Apply for the

USDA-NIFA grant and develop two manuscripts; 4) Conduct variety testing for selected lines and deploy marker-assisted selection in breeding of LMA.

QTL mapping of grain cadmium content in spring wheat. We have a team consisting of Dr. Jianli Chen, Dr. Dan Strawn and Dr. Xi Liang. Dr. Chen's program focuses on the QTL mapping of grain Cd content and on developing low Cd wheat cultivars using MAS. Dr. Strawn's program focuses on variety-soil relation and Dr. Liang's program focuses on the physiological aspects of Cd uptake. Together, we have screened low Cd wheat cultivars that AFM can use for baby food products, including the two cultivars, UI Stone and UI Sparrow, developed in our program. In 2019, we continued our QTL mapping research and planted the mapping population in one high-Cd and one low-Cd location. Upon completion of the Cd test in spring 2020, we will do a comprehensive analysis to develop manuscripts for publication and develop molecular markers for a new cultivar development. In 2019, we also harvested a large amount of seed for two low Cd hard white spring wheat lines and will test them in multiple yield trials in 2020. I gave an oral talk at 2019 CSSA international meeting in November, 2019. This project provided training for one Ph.D student. Results from this study will not only allow for new wheat production strategies to provide baby food producers with a source of low Cd wheat, but it will also help us to understand genes underlying the low Cd. We are planning to submit one manuscript in 2020.

Breeding durable and high level of dwarf bunt resistance using molecular marker-assisted selection.

In 2019, we conducted three field experiments in Logan, UT and designed more markers and fine-mapped the *QDB.ui-7DS* QTL that we published in 2016. We also identified two additional QTL *QDB.ui-6DL* and *QDB.ui-7AL* and the results were presented in a poster presentation at 2019 PAG meeting and published in TAG. Molecular markers associated with the three QTL were used and genotyped in elite lines in the breeding program. In 2020, we are going to identify the candidate genes underlying the three QTL and to use the identified markers in cultivar development.

Breeding FHB resistant spring wheat cultivars. We are in the process of 'UI Cookie' release, which has FHB tolerance like 'UI Stone'. We also developed a hard red spring wheat 'IDO1805S' that has a high level of FHB resistance. In addition, we successfully integrated *Fhb1* and *Fhb3* genes from the Chinese resistance sources 'W14', 'Ning 9016', and 'Futai 8944' into adapted backgrounds and developed eight soft white spring (F8) and four hard red (F8) experimental lines that have *Fhb1* (Singh et al., 2019, Plant Pathology Journal). These lines have been crossed with more elite lines in 2019. In 2020, we are going to introgress the unknown resistance gene from synthetic wheat to our elite backgrounds in collaboration with Dr. Steven Xu at the USDA-ARS facility at Fargo, ND. This is a USDA-ARS funded grant.

Projections for 2020:

1. Assist in identifying licensing partners for UI Sparrow and UI Bronze Jade; release UI Cookie in spring of 2020.
2. Plant breeder seeds for ten elite lines, including two hard white winter wheat (IDO1906 and IDO1806, good quality and stripe rust resistance), two soft white winter wheat (IDO1708 and IDO1810, good quality and stripe rust resistance), two soft white spring wheat (IDO1802S and IDO1404S, high yield and good quality), two hard white spring wheat (IDO1804S and IDO1904S, good quality and stripe rust resistance), and two hard

red spring wheat (IDO1805S, FHB resistance and good quality, and IDO1701S, Hessian Fly resistance and good quality).

3. Apply molecular markers in variety development using resources generated from Wheat CAP, Scab initiative, and ourselves.
4. Identify the desirable storage protein profile for strong gluten hard white cultivar development.
5. Work with faculty from CALS and PS department in variety testing and research projects.
6. 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.
7. Continue working with Ardent Flour Mills on screening desirable wheat varieties for ultra-low cadmium flour production and desirable SRC profile.
8. 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.
9. Assist on-farm strip trials and conduct field day for marketing new cultivars with extension program and IWC.
10. Organize two field days in Rockland and Arbon and attend field days organized by others
11. Present variety update to PNW growers, researchers, and industry.
12. Continue effort and present research and variety update to national and international customers and visitors as needed.

Publications:

Chen, J., J. Wheeler, N. Klassen, W. Zhao, K. O'Brien, C. Jackson, J.M. Marshall, K. Schroeder, and X.M. Chen. 2020. Registration of 'UI Bronze Jade' hard white winter wheat. Journal of Plant Registration, accepted.

Wang, R., T. Gordon, D. Hole, W. Zhao, K. Isham, J. M. Bonman, B. Goates, and **J. Chen***. 2019. Identification and Assessment of Two Major QTL for Dwarf Bunt Resistance in Winter Wheat Line 'IDO835'. Theor Appl Genet. https://doi.org/10.1007/s00122-019-03385-2. **IF: 3.9.**

Singh, L., J.A Anderson, **J. Chen**, B.S Gill, V.K Tiwari, and N. Rawat. 2019. Development and validation of a perfect KASP marker for Fusarium head blight resistance gene *Fhb1* in wheat. The Plant Pathology Journal 35 (3): 200-207. https://doi.org/10.5423/PPJ.OA.01.2019.0018.

Zheng, X., X. Wen, L. Qiao, J. Zhao, X. Zhang, X. Li, Sh. Zhang, Z. Yang, Zh. Chang, **J. Chen***, J. Zheng*. 2019. Genetic dissection of QTrl.saw-2D.2, a major QTL for total seedling root length in wheat. Planta. https://doi.org/10.1007/s00425-019-03154-x. **IF: 3.2.**

Shao, Y., M-H. Tsaia, Y. He, **J. Chen**, C. Wilson, A.H. Lin. 2019. Reduction of falling number in soft white spring wheat caused by an increased proportion of spherical B-type starch granules. Food Chemistry 284:140–148. **IF: 4.9.**

Wang, R., Y. Liu, K. Isham, W. Zhao, J. Wheeler, N. Klassen, Y. Hu, J.M., Bonman, **J. Chen***. 2018. QTL identification and KASP marker development for productive tiller and fertile spikelet numbers in two high-yielding hard white wheat cultivars. *Molecular*

Breeding 38 (135). Open access. IF: 2.1. https://doi.org/10.1007/s11032-018-0894-y.