GRANT CODE: AP7070
TITLE: Developing Wheat Cultivars for Idaho
PERSONNEL: J. Chen, J. Wheeler, G. Dhillon, A. Kaur J. Pabitra, Y. Gao, F. Esparza, J. Carrillo
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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 production. Idaho hard white wheat production ranks first in the US and is 95% spring planted. Most Southeastern Idaho wheat production is under irrigation. Hard white (HW) wheat is the newest market class in the USDA wheat classification system. HW wheat has functional qualities needed for whole wheat products and for blending flour for specific products such as tortillas. Development of hard white winter and spring wheat cultivars has been one of our priorities since 2008. Two released hard white cultivars 'UI Silver' (HWW, 2009) and 'UI Platinum' (HWS, 2014) have been widely used in state wheat production and as check cultivars in State Variety Trials. The new hard white spring wheat 'UI Gold' released in 2022 has shown excellent performance in State Variety Trials and in high yield in seed production fields. Soft white wheat is the predominate class in Idaho and Pacific Northwest (PNW). The released soft white wheat cultivars 'UI Stone' (SWS, 2013), 'UI Sparrow' (SWW, 2017), and 'UI Cookie' (SWS, 2020) have also been widely used in state wheat production and as check cultivars in variety testing.

Improved grain yield and end-use quality are the two primary traits required for new wheat cultivars. However, resistance to biotic and abiotic stresses contributes greatly to grain yield and end-use quality. Stripe rust has been the most important disease in both winter and spring wheat as it occurs frequently and causes significant yield and quality losses for Idaho growers and the wheat industry. Fusarium head blight (FHB) has emerged in irrigated production areas, especially in spring wheat, due to increasing corn production, no-till practices, and climate change. Dwarf bunt is a critical fungal disease that can constrain the adoption of organic wheat production where chemical seed treatment is not allowed. Hessian fly (HF) resistance is an essential trait for cultivars grown in Northern Idaho and Washington. Other diseases and pests affecting wheat production in Idaho include barley yellow dwarf virus, bacterial leaf blight, physiological leaf spots, dryland crown rot, cereal cyst nematode, and wireworm. Pre-harvest sprouting and late maturity alpha amylase (LMA/PHS) damage have also become production concerns in some years. Drought and heat are the main abiotic stresses. In 2021, the Idaho wheat crop suffered record drought and heat stress. To sustain Idaho's status as a consistent high-quality wheat provider, we must continually address these production concerns by applying cutting-edge breeding technologies to cultivar development.

OBJECTIVES: The genetic recombination of desired genes can be achieved by crossing, selfing, mutation, and gene editing. Selection within segregating populations can be enhanced by generating doubled haploid (DH) lines, using molecular marker-assisted and genomic selection, and by growing breeding populations in representative production environments favorable for trait expression. The breeding process can be accelerated using a proper combination of traditional breeding methods and new breeding technologies. The long-term research goal of this project is to facilitate food safety and security

by generating new wheat cultivars that have high grain yield, desirable end-use quality, and resistance to major biotic and abiotic stresses using a combination of traditional and genomics-assisted breeding methods.

METHODS/ PLAN OF WORK:

1. **Marketing and Variety Release.** We will assist in marketing of 'UI Gold', release and license a new soft white spring wheat line 'IDO1902S'. Twenty spring and winter wheat lines (include FHB resistant spring wheat) will be advanced to State Variety Trials or Western Regional Trials and planted for seed increase. 125 winter wheat elite lines have been planted in Idaho and will be evaluated under irrigation in Aberdeen and Kimberly and under dryland condition in Rockland. Forty spring wheat elite lines will be evaluated as a fall-planted spring wheat trial under irrigation in Kimberly and as a spring-planted trial under irrigation in Aberdeen. Five outreach events will be organized, including a marketing table at Cereal School in all locations, a seed dealer event in Aberdeen, field day in Aberdeen and Rockland, and a demonstration booth at Tri-State Growers' Convention.

2. **Implementing genomic prediction for grain yield and yield related traits in spring wheat.** A total of 442 spring wheat lines comprised of released cultivars and elite lines from UI, PNW, and CYMMITT will be assessed for grain yield, heading date, plant height, yield component traits (the number of spikelets per spike, thousand kernel weight, spike length, productive tillers per unit area) under irrigation in Aberdeen, ID. These lines will also be assessed by drone in ten growth stages from planting to harvesting. The phenotypic and genomic data collected will be analyzed to do genomic prediction in the coming two years. In addition, the 442 lines will be assessed for resistance to stripe rust in collaboration with Dr. Chen and resistance to FHB with Dr. See in collaboration with USDA-ARS at Pullman, WA, genotyped in the program lab for various gene specific markers, such as those for flowering genes *FTA1*, *B1*, *D1*, vernalization, photoperiod sensitivity, storage protein, FHB, HF (*H25* and *H26*), stem rust (*Sr2*, *Sr39*, *Sr47*), and LMA/PHS. The efficiency of marker assisted selection (MAS) will be compared to that predicted by genomic selection. This effort has been leveraged under support from USDA NIFA WheatCAP project.

3. **Development of winter and spring wheat cultivars and germplasm with dwarf and common bunt resistance.** This effort will be leveraged with support from USDA-NIFA AFRI grant and a separate proposal to IWC. The breeding program will also assess agronomic performance in 4-row headrow plots for the 384 diverse winter wheat lines being used in genomic selection. Around 3000 headrows from three mapping populations and germplasm were planted for seed increase.

4. **Development of winter and spring wheat cultivars or germplasm with novel Hessian fly (HF) resistance gene. Winter wheat:** 145 F3 lines derived from crosses between IDO2008 (SWW) and UI Bronze Jade (HWW) with the HF donor lines were selected based on agronomic traits and gene

specific markers and planted in 4-row plots in the fall of 2023. 174 three-way F1 or BC1F1 in the adapted backgrounds of two hard red, two soft white, and six hard white lines were planted in the greenhouse and will be screened for HF resistance using MAS. The selected F2 or BC1F2 individuals will be planted in headrows in field in the fall of 2024. We expect to select high yielding lines with novel HF resistance, drought tolerance combined with resistance to stripe rust and desirable end-use quality adapted for Idaho and PNW grain production.

Spring wheat: Novel Hessian fly genes were integrated in 502 F3 and 480 BC2F2 in several elite line backgrounds and harvested in 2023. Four thousand selected heads will be evaluated in headrow plots in irrigated condition in Aberdeen in 2024. We expect to select high yielding lines with novel HF resistance, drought tolerance combined with resistance to stripe rust, FHB, and desirable end-use quality adapted for Idaho and PNW grain production.

5. **Characterization of advanced lines for resistant starch and agronomic performance.** A total of 217 lines have previously been characterized for resistant starch using molecular markers. These lines will be sent out to test resistant starch content in service lab and be evaluated for agronomic performance under irrigation in Aberdeen, ID. Additional 300 winter wheat lines were planted for evaluation of agronomic performance and will be simultaneously screened for resistant starch using molecular markers. The selected lines will be tested for resistant starch in the following year.

6. **Enrichment of germplasm.** A total of 327 F6 winter lines derived from the crosses between ID elite lines with Kansas germplasm were planted in a non-replicated irrigated trial and will be evaluated for Agronomic performance in Aberdeen in the summer of 2024. A total of 140 line from CYMMITT were evaluated for grain yield and test weight under dryland in Logan, UT (in collaboration with USU) and two irrigation regimes in Aberdeen in 2023. These lines are being tested for bread baking quality. Based on quality, grain yield, and test weight the selected lines will be assessed for agronomic performance and resistance to stripe rust and FHB and be used in crossing with elite lines in 2024. A total of 124 winter lines from the Virginia Tech breeding program were planted to assess winter hardness and other agronomic traits to establish germplasm exchange collaboration.

7. **Other collaborative trials.** Dryland Winter Wheat State Variety Trials were planted and managed for Dr. Juliet Marshall. Four Western Regional Trials, two winter and two spring will be evaluated under irrigation in Aberdeen in collaboration with Kim Campbell at the USDA-ARS, Pullman, WA. Two additional nurseries one spring and one winter will be planted under irrigation with the target of monitoring stripe rust infection in Aberdeen in collaboration with Dr. Xianming Chen in the USDA-ARS, Pullman, WA.

DURATION: 2023-2026

COOPERATION / COMPLEMENTATION: Major breeding activities and operations have been directly supported by Idaho Wheat Commission and University of Idaho Agricultural Experimental Station. Traits and new technologies being used in cultivar development are tightly linked to the production concerns and to the national research priorities and are being supported by USDA-ARS NIFA Wheat CAP and AFRI projects.

ANTICIPATED BENEFITS/EXPECTED OUTCOMES: New cultivars released by this project, combining improved yield with biotic and abiotic resistances, will be grown by wheat farmers, and 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 field day events, the wheat breeding project website, commodity schools, demonstration tables at grower events, IGPA meetings and magazines, and publications in Journal of Plant Registration and other journals. QTL, molecular markers, and new candidate genes identified will be used in the breeding programs worldwide, published in peer refereed journals, and presented at national and international meetings. Students involved in the projects will be well prepared to work in the public and private sectors after graduation.

LITERATURE REVIEW: Development of desirable wheat varieties is dependent on the 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. Development of DH lines can reduce the development time for new cultivars and improve selection efficiency. Release of UI Sparrow, an example in using the DH system, accelerated time to release by five years compared to the conventional breeding method. Another example from our program is the use of a combination of DH and molecular MAS. Three hard white spring DH lines (CdDH-266, IDO2002S, and IDO2102S) were developed in less than 10 years through mapping of QTLs associated with late maturity alpha amylase and cadmium uptake. Advances in genotyping (SNP, GBS, exome capture, and NGS) continue to decrease the cost of molecular marker and increase genome coverage, thus enabling development of new breeding strategies. MAS has been useful for pyramiding major-effect genes in crops, but it has been less effective when breeding for minor-effect genes (Kearsey and Farquhar, 1998). Genomic selection (GS) represents a more amenable approach to improve traits with complex genetic architecture. First proposed by Meuwissen et al. (2001) for animal breeding, GS develops genomic estimated breeding values (GEBVs) for breeding lines using genome-wide markers. GS can more effectively capture small-effect loci that would otherwise be overlooked by QTL mapping approaches due to limited power to declare significant marker effects (Heffner et al., 2009). GS has been evaluated in wheat for economically important traits, such as grain yield (Hu et al., 2019; Lozada et al., 2019; Michel et al., 2019a), end-use quality (Ben-Sadoun et al., 2020; Michel et al., 2018; Hu et al., 2019); FHB resistance (Arruda et al., 2015; Arruda et al., 2016; Herter et al., 2019), snow mold resistance (Lozada et al., 2019), stripe rust resistance (Beukert et al., 2020), and winter hardness and frost tolerance (Michel et al., 2019b).

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FY2025
COMMODITY COMMISSION BUDGET
Principal Investigator: *Jianli Chen*

Allocated by Idaho Wheat Commission *(Commission/Organization)*	during FY2023	$	155,960
Allocated by Idaho Wheat Commission *(Commission/Organization)*	during FY2024	$	166,795

REQUESTED SUPPORT Budget Categories	*Awarded for FY2024*	*Requested for FY2025*
(10) Salary (*staff, post-docs, et NOTE: Faculty salary/fringe NOT allowed*	$ 21,320	$ 28,000
(12) Temporary Help/IH	$ 56,000	$ 55,440
(11) Fringe Benefits	$ 32,474	$ 34,461
(20) Travel	$ 10,000	$ 10,000
(30) Other Expenses	$ 47,000	$ 48,200
(40) Capital Outlay >$5k	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -
(70) Graduate Student Tuition/Fees	$ -	$ -
TOTALS	$ 166,794	$ 176,101

TOTAL BUDGET REQUESTED FOR FY2025:	$ 176,101

BREAKDOWN FOR MULTIPLE INDEXES:

Budget Categories	*(Insert Co-PI Name)*	*(Insert Co-PI Name)*	*(Insert Co-PI Name)*	*(Insert Co-PI Name)*
(10) Salary (*staff, post-docs, et*	$ -	$ -	$ -	$ -
(12) Temporary Help	$ -	$ -	$ -	$ -
(11) Fringe Benefits	$ -	$ -	$ -	$ -
(20) Travel	$ -	$ -	$ -	$ -
(30) Other Expenses	$ -	$ -	$ -	$ -
(40) Capital Outlay >$5k	$ -	$ -	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -	$ -	$ -
(70) Graduate Student Tuition/Fees	$ -	$ -	$ -	$ -
TOTALS	$ -	$ -	$ -	$ -
			Total Sub-budgets	$ -

ANNUAL REPORT

Grant Code: AP7070
Title: Developing Wheat Cultivars for Idaho
Personnel: J. Chen, J. Wheeler, G. Dhillon, A. P. Joshi, Y. Gao, F. Esparza, J. Carrillo
Address: Dr. Jianli Chen, University of Idaho Aberdeen Research & Extension Center, Aberdeen, ID 83210, 208-397-4162, ext.229; jchen@uidaho.edu

Abstract:
The Aberdeen Breeding and Genetics Program made a productive year in cultivar development of spring wheat in 2023. We filed PVP application for a hard white spring wheat cultivar 'UI Gold' and licensed it to two seed companies in southeastern Idaho. We also produced pre-foundation seed for a new soft white spring wheat line 'IDO1902S' and identified a potential licensee. This line will be released in Feb. 2024. In addition, the breeding program evaluated 150 new spring wheat lines from CIMMYTT in irrigated and dryland trials in collaboration with Utah State University. The selected lines will be further evaluated for baking quality and used in crossing in 2024. For both spring and winter wheat development in 2023, around 1557 lines (1287 spring and 270 winter) in 3665 plots (2471 spring and 1194 winter) were evaluated for yield, agronomic traits, disease and insect resistance, and end-use quality; around 18,645 lines (6391 spring and 12,254 winter) in 21,121 headrows (8059 spring and 13,062 winter) were evaluated for either of basic agronomic traits or stripe rust, FHB, dwarf bunt, or seed increase. We continually have five winter wheat (UI Sparrow, IDO1708, UI Silver, UI Bronze Jade, and IDO2006) tested in State Variety Trials and contributed three new HRW (A12003W-1, A12005W-8, and A15699W-5) and one SWW (A11240W-26) lines in the West Regional Trials. The novel Hessian Fly resistance gene has introgressed in adapted cultivars and elite lines in both winter and spring wheat. The breeding program has developed elite lines with high yield and excellent quality combined with resistance to stripe rust, FHB, hessian fly, dwarf bunt, and abiotic stresses. In addition, we completed in-house genotyping of ~2,000 lines for multiple traits, 90K SNP genotyping in 384 genetic materials, and sent out 2000 lines for multiple disease screening. These efforts are leveraged with two federal grants from USDA-NIFA for the coming three to five years.

Background / Objectives:
Idaho wheat production contributes significantly to domestic and overseas wheat markets. Nationally, Idaho ranks in the top eight states for wheat production. Idaho hard white production ranks first in the US. Most Southeastern Idaho wheat production is under irrigation. Hard white (HW) wheat is the newest market class in the USDA wheat classification system. HW wheat has functional qualities needed for whole wheat products and for blending flour for specific products such as tortillas. Development of hard white winter and spring wheat cultivars has been one of our priorities since 2008. Two released hard white cultivars 'UI Silver' (HWW, 2009) and 'UI Platinum' (HWS, 2014) have been widely used in the state wheat production and as check cultivars in the State Variety Trials. The new hard white spring wheat 'UI Gold' released in 2022 has shown excellent performance in the State Variety Trials and in seed production. Soft white wheat is the predominate class in Idaho and Pacific Northwest (PNW). The released soft white wheat cultivars 'UI Stone' (SWS, 2013), 'UI Sparrow' (SWW, 2017), and 'UI Cookie' (SWS, 2020) have also been widely used in the state wheat production and as check cultivars in variety

testing. Therefore, the objectives of the present study in 2023 were to continue our efforts on the development and releasing of hard and soft white wheat cultivars that have high grain yield, excellent bread-baking quality, and resistance to biotic and abiotic stresses, especially on value-added traits and with integrated technologies.

Results / Accomplishments:
The Aberdeen Breeding and Genetics Program focused on hard white and soft white spring wheat variety development in 2023. UI Gold hard white spring wheat released in 022was filed for PVP and non-exclusively licensed to two private companies. Because of long and cold spring, UI Gold performed very well this year with high grain yield and excellent bread-baking quality. This cultivar has the potential to replace cultivars Dayn and SY Teton in Southeastern Idaho in 2024 - 2025 production. We harvested pre-foundation seed for a new soft white spring wheat IDO1902S and identified a potential exclusive licensee. In addition to the cultivar releases, the breeding program has developed new elite lines with high yield and excellent quality combined with resistance to stripe rust, FHB, hessian fly, dwarf bunt, and abiotic stresses. A new doubled haploid line was submitted to State Variety Trial, three additional winter wheat lines were submitted to the regional trials. In total, around 1557 lines (1287 spring and 270 winter) in 3665 plots (2471 spring and 1194 winter) were evaluated for yield, agronomic traits, disease and insect resistance, and end-use quality; around 18,645 lines (6391 spring and 12,254 winter) in 21,121 headrows (8059 spring and 13,062 winter) were evaluated for either of basic agronomic traits or stripe rust, FHB, dwarf bunt, or seed increase.

In the early stage of variety development, we introgressed *H26* and *FHB7* in collaboration with USDA-ARS at Fargo, ND. The *H26* gene has pleiotrophic effects on several important economic traits, such as grain yield, drought tolerance, and nutrient use efficiency (note that this is confidential information pending peer-reviewed publication in 2024). *H26* was introgressed into nine adapted winter wheat backgrounds (5 HWW, 2 HRW, and 2 SWW) and six adapted spring wheat cultivars or elite lines. Novel traits from a Chinese winter cultivar were introgressed in three adapted winter wheat cultivars. Around 393 three-way winter F1 or BC1F1 were made and planted. Among 2256 spring wheat populations or headrows in F1 to F4 were evaluated for basic agronomic traits or seed increase, 982 were involved in H26 introgression, 800 involved in resistant starch, and the other involved in special traits in elite line backgrounds.

The breeding program completed in-house KASP genotyping of ~2,000 lines for multiple traits, including grain yield, herbicide resistance, and resistant starch, and genes for glutenin, *Rht*, *PPD*, and vernalization. *Fhb1* and *Fhb7, H25* and *H26*, and dwarf and common bunt resistance, genotyped 90K SNP in 384 genetic materials from the serviceThese efforts are leveraged with two federal grants from USDA-NIFA. We applied UAS (Drone) technology in a three-acre yield nursery and anticipate using the data for genomic selection in cultivar development. We have successfully established the CRISPr-*CAS 9* system and obtained edited plants for two important genes. Our long-term goals are to clone genes controlling grain yield/or yield components and genes for resistance to dwarf and common bunt.

We had a very special growing season in 2023. Historical record cold winter resulted in winter kill and lost a dryland trial in Rockland. Long, wet, and cold spring caused late planting and ununiform gemination of spring wheat.

Outreach / Applications / Adoption:
The breeding program hosted a seed dealer event and distributed rack cards and variety descriptions. We had 20 participants from seed and milling companies andgrowers. We also demonstrated potential releases and NIFA projects at two field day events in Rupert, Aberdeen, and Idaho Falls this summer. In addition, we did a vendor booth marketing UI Cookie, UI Gold, and IDO1902S at the Tr-State Growers' Convention at Coeur d'Alene, ID

What are the deliverables?
New cultivars UI Silver, UI SRG, UI Stone, UI Platinum, UI Sparrow, UI Bronze Jade, UI Cookie, and UI Gold released by this project, combining improved yield with biotic and abiotic resistances, have been grown by wheat farmers, and 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 have been distributed to growers through field day events, the wheat breeding project website, commodity schools, IGPA meetings and magazines, and publications in the Journal of Plant Registration and other journals. QTL, molecular markers, and new candidate genes identified will be used in the breeding programs worldwide, published in peer refereed journals, and presented at national and international meetings. Students involved in the projects will be trained for work in the public and private sectors after graduation.

Next Steps / Projections:
- Assist with UI Gold commercialization, release, and license IDO1902S.
- Advance new lines with value-added traits and assess them for agronomic, disease and insect resistances, and quality performance via field testing, MAS, and genomic selection.
- Organize a seed dealer event in Aberdeen, conduct two fielddays at Rockland and Aberdeen, and participants fielddays organized by others.
- Conduct a vender display booth at Cereal School locations and at Tri-State Growers' Convention.
- Plant on-farm trials to market new-developed and new-released cultivars.
- Maintain current interaction with industry collaborators and state holders.
- Provide data and related information in marketing wheat varieties released from my program.
- Show case for new NIFA funded projects at growers' fieldday and other events.
- Make three presentations at the professional meetings, including one international meeting in West Australia.
- Publish two to three refereed papers in prestigious journals.
- Attend other professional meetings: PAG, CSSA, Western Wheat Workers, Grain Grower Convention.

Publications / Presentations / Popular articles / News Releases / Variety Releases:
Refereed Publication

Chen, J*., J. Wheeler, J.M. Marshall, X. Chen, S. Windes, C. Wilson, M. Su, B. Yimer, K. Schroeder, Ch. Jackson. 2023. Release of 'UI Gold' Hard White Spring Wheat. Journal of Plant Registrations. https://doi.org/10.1002/plr2.20309. Conceptualized this study, wrote, and revised manuscript.

Joshi P, G.S. Dhillon, Y. Gao, A. Kaur, J. Wheeler, and **J. Chen***. An Optimal Model to Improve Genomic Prediction for Protein Content and Test Weight in a Diverse Spring Wheat Panel. Front Plant Sci (Under Revision, 2023). Conceptualized this study, wrote, and revised manuscript.

Oral talk (*Corresponding Author)

Joshi, P., G. Dhillon, D. Hole, T. Gordon, H. Burstmayr, M. Ehn, W. Krause, M. Krause, and **J. Chen***. 2023. Assessment of Dwarf Bunt and Common Bunt Resistance in Wheat Differential Lines. Proceeding of XXII international bunt and smut workshop. Boku, Austria. June 13 – 15, 2023. Https://short.boku.ac.at/bunt.

Dhillon, G., P. Joshi, Y. Yan, F. Xiao, W. Krause, M. Krause, and **J. Chen***. 2023. Candidate gene analysis of the 7DS QTL for dwarf bunt resistance using targeted capture sequencing. Proceeding of XXII international bunt and smut workshop. Boku, Austria. June 13 – 15, 2023. Https://short.boku.ac.at/bunt.

Krause, W., **J. Chen**, P, Joshi, D. Hole, P. Nelson, J. Clawson, T. Gordon, and M. Krause. 2023. Genomic selection for dwarf bunt resistance in wheat. Proceeding of XXII international bunt and smut workshop. Boku, Austria. June 13 – 15, 2023. Https://short.boku.ac.at/bunt.

Joshi P, G.S. Dhillon, Y. Gao, A. Kaur, J. Wheeler, and **J. Chen***. 2023. Comparative mapping of Dwarf Bunt and Common Bunt Resistance QTL in Winter Wheat Doubled Haploid Population. Oral presentation at 2023 ASA, CSSA, SSSA international annual meeting, San Louis, MO. Oct. 29 – Nov. 1, 2023.

Poster Presentation

Joshi P, G.S. Dhillon, Y. Gao, A. Kaur, J. Wheeler, and **J. Chen***. 2023. An Optimal Model to Improve Genomic Prediction for Protein Content and Test Weight in a Diverse Spring Wheat Panel. Front Plant Sci (Under Revision). Poster presentation at 2023 ASA, CSSA, SSSA international annual meeting, St. Louis, MO. Oct. 29 – Nov. 1, 2023.

Other presentations

Field day presentation at Aberdeen for seed production, variety development and basic research projects. Provided variety description flyer and marketing materials.