

**Washington Grain Commission**  
**Wheat and Barley Research Annual Progress Reports and Final Reports**

**Project #:** GR00010245  
**Progress Report Year:** 2 of 3  
**Title:** Field Breeding Hard White and Red Winter Wheat  
**Investigator/Cooperators:** AH Carter, KG Campbell, XM Chen, TD Murray

**Executive summary:** Hard wheat is a small but important market class for Washington, but fluctuations in production and concerns over trade-offs between yield and protein concentration has limited production. Identifying cultivars which can help mitigate these concerns will benefit growers in the state of Washington. This proposal aims to develop hard wheat cultivars which are tolerant to biotic and abiotic stress which occurs in Washington. Furthermore, the proposal aims to release cultivars which have both high yield and high grain protein content, and have stable yield across multiple production regions. Cultivars Sequoia, Scorpio, and Gemini have been released to meet the production constraints of hard wheat in Washington. Scorpio in particular combines the broadest adaptation in Washington, with multiple tolerances, high grain yield, and high protein concentration.

**Introduction:** Due to the price of hard red winter wheat being below that of soft white winter wheat in 2021, production of hard red winter wheat has remained somewhat steady in 2022 and 2023. In order to maintain and increase the number of acres of hard wheat in Washington, cultivars need to be developed which have the biotic and abiotic stress tolerance needed for our diverse production regions. Furthermore, agronomic characteristics for high economic return are needed, specifically combining high yield with high grain protein concentration. Additionally, high end-use quality properties are needed to maintain and increase market opportunities for hard wheat. By developing cultivars with these characteristics, and focusing on maintaining these characteristics across diverse cropping systems and climate variation, improvements in the stability of production of hard wheat in Washington can be achieved.

**Approach:** We are testing multiple populations of hard wheat across production systems, and have breeding lines in every stage of testing across the state. We focus on agronomic characteristics to improve production, meeting the unique demands of different cropping systems such as emergence from deep planting, cold tolerance, and earliness. Furthermore, we put focus on developing strong abiotic and biotic stress tolerance, by focusing on traits such as low pH tolerance, stripe rust resistance, and other important pests. Lines are tested at multiple locations across the state and selected on performance. Traits such as herbicide tolerance are being added to hard wheat in order to further improve performance and maintain high levels of productivity in various cropping systems.

**Results:** Scorpio was released in 2019 and commercial seed is available of this line. Scorpio is broadly adapted to many intermediate and high rainfall growing areas of the state, and has very good end-use quality, very good stripe rust resistance, is resistant to Hessian fly, and tolerant of low pH soils. Scorpio also continues to be one of the best performing lines in multi-year summaries from 2018-2023, indicating the ability to perform even under drought stress

conditions. This combination of traits makes it a desirable cultivar for many production areas. We continue to work with seed dealers to make this cultivar available to growers. We will continue to watch the hard red market and in discussion with seed dealers and growers, determine when new cultivars need to be released to enter the market. We released a new line in 2023 named Gemini which has had very high grain yield in the intermediate rainfall locations, and carries good emergence and low pH soil tolerance for production in a wide range of cropping systems. Continued emphasis is placed on selecting breeding lines with superior quality and disease resistance. We also work on developing hard lines with excellent emergence capabilities, and continually screen material to this end. Efforts have been initiated and are ongoing to develop hard cultivars with herbicide tolerance (Clearfield and CoAXium systems are our main targets), snow mold tolerance, and aluminum tolerance. We maintain about 10% of the hard material as hard white and apply heavy selection pressure to ensure adapted material is advanced. Some of these hard white lines have been tested under irrigation in Southern Idaho and have performed very well. There is interest to release these lines for production under irrigation in Idaho.

**Impact:** Sequoia replaced many of the Farnum acres in the state due to its excellent emergence capability and high yield potential under low rainfall and deep planting conditions. It was once again in demand starting the fall of 2021 due to the extremely dry planting conditions and emergence concerns. Although grown on limited acres, we continue to develop lines with excellent emergence for those regions which need this trait to reduce risk to planting failures under deep planting conditions when moisture is limited. Scorpio is a WSU hard red cultivar targeted to multiple rainfall zones and provides growers with a high yielding line with good disease resistance, aluminum tolerance, and Hessian fly tolerance. It has been increasing in commercial production due to its high grain yield and grain protein concentration. Gemini has been released to provide additional cultivars with high grain yield, excellent end-use quality, and good stress tolerance. Current and future hard red and white lines will continue to lead to a sustainable production of hard wheat in the PNW.

**WGC project number:** GR00010245  
**WGC project title:** Development of hard red and white winter wheat  
**Project PI(s):** AH Carter  
**Project initiation date:** July 1, 2022  
**Project year:** 2 of 3

Objective	Deliverable	Progress	Timeline	Communication
Develop hard red and white winter wheat cultivars	New cultivars released for production in WA	In 2019 we released Scorpio, which combines high yield, good protein content, stripe rust resistance, low pH soil tolerance, and Hessian fly tolerance in one line. Seed of Scorpio was increased by the seed industry and was commercially planted in 2022 with increased production in 2023. Gemini was released in 2023 for commercial production. We had over 3,100 plots and 12,000 rows of hard material under evaluation at various stages of the breeding process for 2023. In 2023, focus continues to be put on developing hard red winter lines with herbicide tolerance.	Each year we evaluate germplasm at each stage of the breeding process. Each year lines are entered into statewide testing for final release consideration. A cultivar is released, on average, every three years.	Progress is reported through field days, grower meetings, commission reports, popular press, and peer-reviewed manuscripts, Wheat Life articles, and through the annual progress reports
	Agronomic traits	Field trials and agronomic data were conducted and collected at 14 locations in 2023. This includes emergence, winter survivability, heading date, test weight, plant height, and grain yield. All trials gave good data in 2023. Our snow mold locations gave a good rating of snow mold tolerance in 2023, although one location had snow mold so severe nothing survived. Planting went well in 2023, and all locations had very good stand establishment and we are looking forward to a good year of screening the germplasm.	Evaluation is done annually at multiple locations across the state.	In 2023 we communicated results of this project through the following venues: 8 peer-reviewed publications; 2 field day abstracts; various field days and grower interactions; 2 poster presentations; 3 popular press interviews; 1 podcasts; 1 grower meeting presentations; and 4 seed dealer presentations;
	Biotic and Abiotic stress resistance	Lines were screened for snow mold, stripe rust, eyespot foot rot, nematodes, Cephalosporium stripe, SBWMV, Hessian fly, and aluminum tolerance.	Evaluation is done annually at multiple locations across the state.	

	End-use quality	All breeding lines with acceptable agronomic performance in plots were submitted to the quality lab. Those with acceptable or better milling characteristics were advanced to baking trials. Data should be back in early-2024. Lines with inferior performance will be discarded from advancement.	Each year, all head rows are evaluated for end-use quality and lines predicted to have superior quality advanced. Each yield trial is submitted for quality evaluations and those with high performance are advanced in the breeding process.	
	Herbicide resistance	Trials were conducted in Lind, Walla Walla, Prescott, Davenport, and Pullman for herbicide resistance. The hard red material had a lower priority (based on production acreage) for development when we started compared to the soft white germplasm, but we now have multiple populations and advanced lines are being tested. The Clearfield and CoAXium systems are the basis of our current efforts.	Evaluation is done annually at multiple locations across the state	Advanced hard red lines with herbicide tolerance are in final stages of testing for release consideration.
Field test adapted germplasm with novel genes introgressed for essential traits	Incorporation of novel genes into adapter germplasm for evaluation under WA environments			Progress is reported through field days, grower meetings, commission reports, popular press, and peer-reviewed manuscripts, and through the annual progress reports
	Rht genes	Populations have been developed and are under field evaluation for Rht1, 2, and 8.	Crosses made through the project #12235 will be evaluated under field conditions upon MAS.	
	Stripe rust genes	Multiple different stripe rust resistance genes have been introgressed into our germplasm which are under evaluation in Mount Vernon, Central Ferry, and Pullman. We have also started mapping populations to find markers linked to these genes.	Crosses made through the project #12235 will be evaluated under field conditions upon MAS.	
	Foot rot genes	Pch1 has been selected for and is under evaluation in field trials in Pullman.	Crosses made through the project #12235 will be evaluated under field conditions upon MAS.	
	SBWMV	Crosses are initiated and being evaluated for resistance to SBWMV, mainly first through marker analysis and then under field trials in Walla Walla.	Crosses made through the project #12235 will be evaluated under field conditions upon MAS.	
	Herbicide tolerance	Hard red lines with herbicide tolerance are being field tested in both the Clearfield and CoAXium systems. Populations are first screened in the greenhouse, then transitioned to field testing.	Crosses made through the project #12235 will be evaluated under field conditions upon MAS.	

	Hessian fly tolerance	With the identification that Scorpio was tolerant to Hessian fly, we have been able to go into our crossing block and find crosses and populations with Scorpio as a parent to begin making selection. These lines were screened at the University of Idaho as part of the Hessian fly proposal and were advanced to field testing. One additional line, WA8368, has been identified as having Hessian Fly tolerance.	Crosses made through the project #12235 will be evaluated under field conditions upon MAS. Screening will be done through project #3674	
	GPC-B1 and Bx7oe	These two genes have been incorporated into many hard breeding lines. These are being tested for agronomic performance in the field. Some lines have already been returned to the breeding program as parents for additional crosses.	Crosses made through the project #12235 will be evaluated under field conditions upon MAS.	

Do not use a font size less than 10 point. Let the template break over pages if necessary. The formatting will be retained when saved as a pdf file.