

**Washington Grain Commission
2023 Wheat and Barley Research Annual Progress Reports and Final Reports**

Project #: 3019-3200

Progress Report Year: 3 of 3

Title: Improving Spring and Winter Barley Varieties for Malt, Feed and Food

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Executive summary The Washington Grain Commission research funds were integral for the program's applied breeding efforts to meet the goals of developing and maintaining a world class barley breeding program. The program's major focus is the development of widely adapted spring and winter adjunct and craft malt barley varieties that make the American Malting Barley Association (AMBA) recommended list. To meet this goal, genetic, genomic, gene discovery and functional analysis research is utilized to fill knowledge gaps that leverage and enhance our breeding efforts. Additionally, this basic research is also applied to the development of biofortified hulless food varieties, and high yielding feed and forage barley varieties. With the last three years of WGC funding, I focused on enhancing the genetics in the program to address deficiencies in malt and nutritional quality. The quality issues present in the program have been overcome by the introduction of new genetics through hundreds of crosses with elite malt and food barley lines collected from worldwide sources. Now that we have diverse quality genetics introgressed into the program we can continually focus on using genetic and genomic analysis, quality data and agronomic performance across environments to identify adapted experimental lines as parental materials for continual gains on quality, wide adaptability, and ultimately yield across diverse environments. We were fortunate to secure funding from the WGC to establish the state-of-the-art WSU Malt Quality Lab (WMQL) which allows for the generation of malt and food barley quality data on our experimental lines as they come off the field. We continue to innovate and evolve to add new capabilities in the WMQL. Now that we have addressed the quality issues in our WSU germplasm, we have four promising experimental lines (20WAM-248, 20WAM-487, 20WAM-721, and 20WAM-783) that were entered into the WSU and University of Idaho variety testing trials and AMBA pilot testing program in 2023 and we expect to release one or more as WSU malt barley varieties based on the AMBA and variety testing results in 2024. Thus, the timely WMQL malt quality data allows for intelligent early generation selection and high-quality data for late generation determination of lines to enter the variety testing trials and the AMBA testing program.

Introduction Washington state farmers harvested ~84 thousand acres (Ka) of barley in 2023, 40% more than 2022, ranking fourth in the nation behind; 1) Montana (1.015 Ma), 2) North Dakota (570 Ka), and 3) Idaho (540 Ka) (<https://www.nass.usda.gov>). As the WSU barley breeder my program is focused on applied research toward variety development and fundamental research that leverages breeding to enhance barley as a viable choice for producers and promote a positive trend in Washington barley acreage. Barley is an attractive option in rotation after winter wheat when consistent high yields are achieved and quality demand premium prices. However, when I began as the WSU breeder the goal was to transition the program to a malt

barley breeding program, yet it became apparent that malt quality genetics were lacking in the germplasm coming down the pipeline. To meet this goal we introduced new genetics into the program, developed molecular and quality analysis infrastructure to expedite spring and winter malt, feed, food, and forage varieties release with wide adaptability to achieve consistent yield and quality across variable years and environments. The benefits of barley in rotation will also be achieved by the introgression of IMI tolerance into all classes of barley to insure productivity in rotation after IMI-resistant wheat.

Approach We continue to utilize traditional breeding techniques to combine positive genetic loci for traits of interest including malt quality, yield, and disease resistance in both spring and winter lines as well as winter hardiness and seedling vigor in winter lines. We use a modified pedigree breeding scheme that utilizes single-seed descent to advance spring and winter barley populations. We have revamped the breeding procedure in 2023 to include early generation selection of ~100,000 single early generation plants from 100 crosses a year which will allow us to evaluate much larger numbers of crosses and early generation progeny for agronomic traits including yield, standability, height, tiller numbers, winter survival and seedling vigor. Following this early generation visual selection, the reduced number of individuals can then be screened with molecular markers for malt and food quality. Incorporating this early generation selection with molecular markers targeting malt and food quality, disease resistance, and agronomic traits expedites early generation selection for the identification and advancement of superior genotypes through the breeding cycle. In the last three growing seasons 288 elite WSU malting lines were selected and sequenced with the 50k Illumina bead express single nucleotide polymorphism (SNP) chip. This 50 thousand marker panel allowed for high marker density to identify positive malt quality loci in our breeding program utilizing genome wide association studies (GWAS). From these identified marker trait associations, we are developing the Oxford Nanopore MinION DNA sequencing technology to genotype early generation material for marker assisted and genomic selection. This infrastructure fulfilled our needs of a fully integrated spring malt barley breeding program that will also be utilized in the winter malt barley, spring food barley, spring feed barley and spring forage barley selection processes as we advance progeny from crosses made for these different market classes in the program.

Results From the genetic, quality, and agronomic analysis of thousands of experimental lines multiple genotypes have been identified that meet AMBA quality parameters for the first time in the program. Four of these promising lines (20WAM-248, 20WAM-487, 20WAM-721, and 20WAM-783) were entered into the WSU and University of Idaho variety testing trials in 2023. The lines 20WAM-721 and 20WAM-783 outperformed the yield and malt quality check ACC Connect for average yield across rainfall zones. All four experimental lines were entered into the AMBA pilot testing program in 2023 and we expect to release one or more as WSU malt barley varieties based on the AMBA and variety testing results in 2024.

Impact We now have the genetics, quality phenotyping and genetic and genomic analysis infrastructure in place to establish and maintain a world class barley breeding program. Now we have an excellent pipeline of experimental barley lines coming down the pipeline for consistent gains on quality and yield for the release of excellent WSU barley varieties with measurable gains on the current varieties being produced.

Outputs and Outcomes:

Peer-Reviewed Publications (17 total) and Book Chapter (1 total):

Published, Accepted or Submitted between January 1, 2023 – December 31, 2023

1. Richards, J.K., Li, J., Koladia, V., Wyatt, N.A., Rehman, S., **Brueggeman, R.S.**, and Friesen T.L. (2023) A Moroccan *Pyrenophora teres* f. *teres* population defeats the *Rpt5* broad-spectrum resistance on barley chromosome 6H. *Phytopathology*, (submitted)
<https://doi.org/10.1094/PHYTO-04-23-0117-R>
2. Karki, M., Chu, C., Anderson, K., Nandety, R.S., Fiedler, J., Schachterle, J., **Brueggeman, R.S.**, Liu, Z. and Yang, S., (2023). Genome-wide association study of host resistance to Hessian fly in barley. *Phytopathology*, <https://doi.org/10.1094/PHYTO-06-23-0192-R>
3. Li, J., Wyatt, N.A., Kariyawasam, G., Richards, J.K., Rehman, S., **Brueggeman, R.S.**, and Friesen T.L. (2022) Pathogen genetics identifies regions harboring avirulence genes associated with 6H host resistance in the *Pyrenophora teres* f. *teres* – barley interaction. *Theoretical and Applied Genetics* (submitted).
4. Ellur, V., Wei, W., Ghogare, R., Solanki, S., Vandemark, G., **Brueggeman, R.**, & Chen, W. (2023). Unraveling the genomic reorganization of polygalacturonase-inhibiting proteins in chickpea. *Frontiers in Genetics*, 14, 1189329-1189329.
5. Effertz K., Del Castillo, M., **Brueggeman, R.S.** (2023) First report of *Epicoccum nigrum* causing barley leaf spot disease in North America. *Plant Disease* (Accepted).
6. Effertz K., Richards, J.K., Clare, S.J., Del Castillo, M., Sharma Poudel, R., Li, M., Zhang, J., Moscou, M.J., Friesen, T.L., and **Brueggeman, R.S.** (2023) *Rpt5* encodes a receptor-like protein that provides broad and effective net form net blotch (*Pyrenophora teres* f. *teres*) resistance in barley. *Plant Biotechnology Journal* (Accepted).
7. Alhashel, A.F., Fiedler, J.D., Nandety, R.S., Skiba, R.M., **Brueggeman, R.S.**, Baldwin, T., Friesen, T.L., and Yang, S. (2023) Genetic and physical localization of a major susceptibility gene to *Pyrenophora teres* f. *maculata* in barley. *Theoretical and Applied Genetics* 136(5):118. doi: 10.1007/s00122-023-0436-1
8. Craine, E.B., Choi, H.M., **Brueggeman, R.S.**, Schroeder, K., Esser, A., and Murphey K.M. (2023) Spring barley malt quality in eastern Washington and northern Idaho. *Crop Science* <https://doi.org/10.1002/csc2.20924>
9. Clare, S.J., Oguz, A.C., Effertz, K., Karakaya, A., Azamparsa, M.R., and **Brueggeman, R.S.** (2023) Wild barley (*Hordeum spontaneum*) and landraces (*Hordeum vulgare*) from Turkey contain an abundance of novel *Rhynchosporium commune* resistance loci. *Theoretical and Applied Genetics* 136.1:15. <https://doi.org/10.1007/s00122-023-04245-w>
10. Friskop, A., Halvorson, J., Hansen, B., Meyer, S., Jordahl, J., Arens, A., Chapara, V., Gautam, P., Kalil, A., Tjelde, T., Fonseka, D., Schatz, B., **Brueggeman, R.**, Baldwin, T., Gross, P., Deplazes, C., and Ransom, J.K. (2023) Effects of Fungicides and Cultivar Resistance on Fusarium Head Blight and Deoxynivalenol in Spring Barley from 2014 to 2019. *Plant Health Progress* <https://doi.org/10.1094/PHP-05-22-0045-RS>
11. Poudel, R.S., Belay, K., Nelson Jr, B., **Brueggeman, R.** and Underwood, W. (2023) Population and genome-wide association studies of *Sclerotinia sclerotiorum* isolates collected from diverse host plants throughout the United States. *Frontiers in Microbiology*, 14.

12. Parajuli, A., **Brueggeman, R.**, Wagner, S., Warburton, M., Peel, M., Yu, L., See, D. and Zhang, Z., (2023) Linking Phenotypes to Protein Characteristics in 3D Structures Predicted by AlphaFold.
13. Parajuli, A., **Brueggeman, R.**, Wagner, S., Warburton, M., Peel, M., Yu, L., See, D. and Zhang, Z. (2023). Bulk Target Capture Sequencing Identified Numerous Genetic Loci Associated with Alfalfa Growth Vigor During Inbreeding.
14. Tang, Z., Wang, M., Schirrmann, M., Dammer, K.H., Li, X., **Brueggeman, R.**, Sankaran, S., Carter, A.H., Pumphrey, M.O., Hu, Y. and Chen, X. (2023) Affordable High Throughput Field Detection of Wheat Stripe Rust Using Deep Learning with Semi-Automated Image Labeling. *Computers and Electronics in Agriculture*, 207, p.107709.
15. Li, J., Wyatt, N.A., Skiba, R.M., Kariyawasam, G.K., Richards, J.K., Effertz, K., Rehman, S., **Brueggeman, R.S.** and Friesen, T.L. (2023) Pathogen genetics identifies avirulence/virulence loci associated with barley chromosome 6H resistance in the *Pyrenophora teres* f. *teres*–barley interaction. *bioRxiv*, pp.2023-02.
16. Upadhaya, A., Upadhaya, S.G.C., and **Brueggeman, R.** (2023) Identification of Candidate Avirulence and Virulence Genes Corresponding to Stem Rust (*Puccinia graminis* f. sp. *tritici*) Resistance Genes in Wheat. *Molecular Plant Microbe Interactions* (Accepted).
17. Massman, C., Hernandez, J., Clare, S.J., Brooke, M., Filichkin, T., Helgersson, L., del Blanco, I.a., Rouse, M.N., Steffenson, B., **Brueggeman, R.**, and Hayes, P. (2023) Registration of the Woodies Multi-Rust Resistant Barley Germplasm. *Journal of Plant Registration* (Accepted).

Book Chapters:

1. **Brueggeman, R.S.** (2023) Barley; 6th edition of *Agrios: Plant Pathology* (In Press)

WGC project number: 3019-3200
WGC project title: Improving Spring and Winter Barley Varieties for Malt, Feed and Food
Project PI(s): Robert Brueggeman
Project initiation date: July 1, 2021
Project year (3of 3-yr cycle):

Objective	Deliverable	Progress	Timeline	Communication
1	Progress towards the release of an adjunct malting barley cultivar suited for adjunct brewing with a malt profile that meets AMBA recommendation.	One advanced two-row malt barley has met or exceeded AMBA checks for adjunct malting in two years of testing. This line also outperformed ACC Connect in three rainfall zones in WSU and U of I variety testing. We also have a consistent pipeline of lines that met AMBA malt quality criteria with high yields, significant gain on ACC Connect, that will be entered into WSU and U of I variety testing and the AMBA testing program.	2024	Talks and presentations at field days; distribution of informative variety rack cards; Wheat Life articles; Pod Casts
1	Progress towards the release of a craft malting barley cultivar suited to craft all malt brewing with a malt profile that meets AMBA recommendation as well as lines with excellent quality that don't quite meet AMBA recommended parameters yet will perform well in craft malting, brewing and distilling.	Two advanced two-row malt barley haves met or exceeded AMBA checks for all malt brewing in two years of testing. One of the two line also outperformed ACC Connect in three rainfall zones in WSU and U of I variety testing. We also have a consistent pipeline of lines that met AMBA all malt quality criteria with high yields, significant gain on ACC Connect, that will be entered into WSU and U of I variety testing and the AMBA testing program..	2024	Talks and presentations at field days; distribution of informative variety rack cards; Wheat Life articles; Pod Casts
2	Progress towards the release of WSU winter malting barley varieties that meet AMBA recommended adjunct and all malt brewing specifications.	Two advanced two-row winter malt barley lines have met or exceeded AMBA checks for all malt brewing in two years of testing. The lines which were provided by Dr. Pat Haye's OSU program for testing also outperformed Thunder in the median (16" – 20") rainfall zone in 2023 WSU variety testing. These lines will continue to be entered into variety testing and entered into the AMBA pilot testing program once we have adequate yield and quality data from sufficient site years. We also have hundreds of lines continuing down the pipeline from crosses made with selected parents for quality, yield, winter survival and seedling vigor in replicated yield trials.	2024	Talks and presentations at field days; distribution of informative variety rack cards; Wheat Life articles; Pod Casts
3	Progress towards the release of IMI-tolerant barley varieties with high yield and excellent disease resistance to complement Survivor. This could also be in the food or malt market classes.	We had hundreds of known IMI-tolerant barley lines in our breeding pipeline, yet yield testing did not warrant release. We have made crosses of selected parental material containing the IMI-tolerance gene into high yielding feed, malt, food and forage lines that will continue to undergo greenhouse and field trials as well as yield trials to identify the superior lines for release and breeding parents.	2024	Talks and presentations at field days; distribution of informative variety rack cards; Wheat Life articles
4	Progress towards the release of hullless, waxy food barley varieties to complement non-waxy high beta glucan varieties Havener and Meg Song	Crosses have been made and hundreds of hullless, waxy, high Beta-glucan lines with high micronutrient accumulation are being selected. Some of the hullless, high Beta-glucan breeding lines performed well in single rep trials and will be included in advanced yield trials and quality analysis completed.	2024	Talks and presentations at field days; distribution of informative variety rack cards; Wheat Life articles; Pod Casts

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