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

PROJECT #: 30109-5345

Progress report year: 3 of 3

Title: Evaluation And Selection For Cold Tolerance In Wheat

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Executive summary:

- Evaluating freezing tolerance is difficult in the field because snow cover, slope, available moisture, and soil born diseases can all affect winter survival and rating varieties can only be conducted once a year. Therefore we developed a screening system that can be conducted year round using the growth chambers at the WSU Wheat Plant Growth Facility.
- Each year for the last three years, we have rated tolerance to freezing in the Washington State Extension Winter wheat variety trials and the Western Regional winter wheat nurseries. We have rated tolerance to freezing in the spring wheat and other Regional nurseries from the rest of the US in two of these years.
- The most cold tolerant hard winter wheat in the WSU nurseries was AP503CL2, Bauermeister, Boundary, DAS1, Eltan, Finley, Farnum, IDO1103, IDO816, Norstar, UI Silver, WA8158, WA8178, WA8179, WA8180, WA8181, WA8197, WA8207, and WB-Arrowhead. The most cold tolerant soft winter wheat was ARS010262, Bitterroot, Curiosity CL, Eltan, Masami, Mela CL, Norstar, Tubbs 06, and Jasper. In the winter regional nursery, ARS010260, Eltan, IDO1101, OR2080236H, and Yellowstone had the best cold tolerance. New germplasm that has been brought into the PNW from Europe is generally less winter tolerant than needed for the PNW. The WSU Winter Wheat Variety trials were rated for winter survival after the severe 2013/2014 and 2014/2015 winter. The field survival data was closely correlated with the results of our artificial screening testing (Complete field survival data is available at http://variety.wsu.edu/).
- In the US, the best overall winter tolerance is found in the winter wheat breeding programs in CO, MT, SD, and West Texas. New sources of resistance that have been identified from regional nurseries have been crossed to PNW adapted breeding lines in order to incorporate even better winter tolerance into winter wheat.
- We have rated freezing tolerance for winter wheat breeding lines and in progeny from intercrosses within the Brundage/Coda, Finch/Eltan, and Eltan/Oregon Feed Wheat5 wheat mapping populations, and the Winter Wheat Core Nursery. Using the survival data from analysis of these mapping populations we have identified interactions among different alleles of two loci on the wheat group 5 chromosomes, *Vrn-1* and *Fr2*, that substantially improve tolerance to freezing in both spring and winter wheat. At both loci, sequence variation and copy number variation are important. The selection of varieties carrying the *FR-A2-T* allele

and three copies of the recessive *vrn-A1* allele is a good strategy to improve frost tolerance in wheat. We have developed molecular markers for these specific alleles. Most PNW adapted germplasm possessed the tolerant alleles at both genes, likely due to selection by breeders for winter tolerance. We have to continued to search for additional genes that will explain a significant proportion of the variation for cold tolerance in adapted PNW germplasm.

- We discovered that freezing, followed by a thaw cycle and subsequent refreezing to a low target temperature, increases freezing tolerance. This increased freezing tolerance occurs even at very low target temperatures like -15^{o}C. Varieties differ in their ability to take advantage of these temperature fluctuations. We are examining the sources of genetic variation for this response. These fluctuating freeze-thaw cycles occur often in nature and may actually protect the wheat plants in the field, at least to some degree.
- There are some varieties, including Otto, Coda, Farnum, ARS-Selbu, Kaseberg and Skiles, that survive better in the field than our freezing tests would predict. These results are likely due to the soil-born disease resistance that many of these lines carry. Many of our soil-born diseases infect seedlings in the fall and weaken the plants so if plants are resistant, they have more resources to handle to freezing stress.

Impact

- The data from these cold tolerance trials was published in the seed buyers guide so that farmers could select winter wheat that is less sensitive to winter kill. This data was shared with breeders and used to select for improved cold tolerance in wheat targeted to the Pacific Northwest and to support release decisions for winter wheat cultivars.
- Our results from screening the regional nurseries, which was actually done so that we could identify new sources of resistance, have been used by breeders in the Great Plains to justify release of their cultivars.
- Varieties released from the WSU winter wheat breeding program have consistently excellent cold tolerance and this tolerance has been maintained because of testing using the procedures developed by this project.
- Because of the high correlation between our artificial screening trial and winter survival in the field, we are able to incorporate better cold tolerance into our early generation breeding lines.
- Most breeding programs have both winter tolerant and less tolerant breeding lines. The identification of molecular markers associated with freezing tolerance complements our screening system and increases our current screening capacity from about 1000 varieties and breeding lines to several thousand progeny from segregating populations per year.

D. Communication:

Refereed papers

Pearce, S., Zhu, J., Boldizsar, A., Vagujfalvi, A., Burke, A., Garland-Campbell, K., Galiba, G., Dubcovsky, J., 2013. Large deletions in the CBF gene cluster at the *Fr-B2* locus are associated with reduced frost tolerance in wheat. Theor Appl Genet. 126:2683-2697.

Case, A.J., Skinner, D.A., Garland-Campbell, K.A., Carter, A.H. 2014. Freezing Tolerance-Associated Quantitative Trait Loci in the Brundage × Coda Wheat Recombinant Inbred Line Population. Crop Sci. 54. 982-992.

Zhu, J, Pearce, S.' Burke,A, See, DR, Skinner, DZ, Dubcovsky' JD, Garland Campbell, K. 2014. Copy number and haplotype variation at the *VRN-A1* and central *FR-A2* loci are associated with frost tolerance in hexaploid wheat, Theor Appl Genet. DOI 10.1007/s00122-014-2290-

Skinner, D. Z. 2014. Time and temperature interactions in freezing tolerance of winter wheat. Crop Science. 54 No. 4, p. 1523-1529. doi:10.2135/cropsci2013.09.0623

Skinner, Daniel Z; Garland-Campbell, Kimberly; 2014. Measuring Freezing Tolerance: Survival and Regrowth Assays. pp 7-13 *In* Hincha, D.K., and Zuther E., (Eds) Plant Cold Acclimation: Methods and Protocols. Method in Molecular Biology. Springer New York

Cuevas, C., Bellinger, B.S., Skinner, D.Z. 2014. Membrane stability of winter wheat plants exposed to subzero temperatures for variable lengths of time. Communications in Plant Sciences. 5(1-2):9-14

Skinner, D.Z., Bellinger, B.S., Hansen, J.C., Kennedy, A.C. 2014. Carbohydrate and lipid dynamics in wheat crown tissue in response to mild freeze-thaw treatments. Crop Science. 54:1–8. DOI: 10.2135/cropsci2013.09.0604.

Skinner, D.Z. 2015. Genes upregulated in winter wheat (Triticum aestivum L) during mild freezing and subsequent thawing suggest sequential activation of multiple response mechanisms. PLoS One. 10(7):e0133166.

Abstracts

Zhu, J., Pearce, S., Burke, A., Skinner, D,Z., Dubcovsky, J., Campbell, K.A.G., 2013. Different haplotypes of Vrn-1 and Fr-2 effect the frezing tolerance of wheat. Plant Animal Genome XXI. San Diego CA Jan 12-16, 2013.

Popular Press

Garland-Campbell, K., Skinner, D., Murphy, L., Burke, A., Bellinger, B., Walker, C., 2009. The weather inside in chilly: Assessing and Enhancing Cold Tolerance in Wheat. Wheatlife:52:46-48.

Garland-Campbell, K. 2014. It's Freezing: Cold Weather Bad for Farmers but Good for Researchers. WheatLife. 57: 53-55.

Web

Garland-Campbell. Kim.. Has it Been Cold Enough to Kill my Wheat? Timely Topic. CAHNRS and WSU Extension Wheat and Small Grains. http://smallgrains.wsu.edu/

Presentations

Garland-Campbell, K.A. 2013. Dissecting Cold tolerance in Winter Wheat. Seminar to Dept. of Soil and Crop Sciences, Colorado State Univ., Nov. 18, 2013.

WGC project number: **3019-5345**
WGC project title: **Evaluation And Selection For Cold Tolerance In Wheat**
Project PI(s): **Kimberly Garland-Campbell, Dan Skinner and Arron Carter.**
Project initiation date: **7/1/13**
Project year: **Year 3**

Objective	Deliverable	Progress	Timeline	Communication
1. Evaluate Washington winter wheat variety trials.	Ratings for freezing tolerance for commonly grown and new winter wheat cultivars	Trials planted and rated each year. • The most cold tolerant hard winter wheat in the WSU nurseries was AP503CL2, Bauermeister, Boundary, DAS1, Eltan, Finley, Farnum, IDO1103, IDO816, Norstar, UI Silver, WA8158, WA8178, WA8179, WA8180, WA8181, WA8197, WA8207, and WB-Arrowhead. The most cold tolerant soft winter wheat was ARS010262, Bitterroot, Curiosity CL, Eltan, Masami, Mela CL, Norstar, Tubbs 06, and Jasper.	Sept 2012 - August 2015.	Presentation at grower meetings, Wheat commission meetings, field days, plot tours, Wheat Life and Research Review. Published on WSU Variety Testing Web-site
2. Evaluate cold tolerance of new breeding lines in US regional nurseries in order to identify germplasm to use in crossing for better winter survival	Ratings for freezing tolerance for advanced wheat germplasm from the US that can be used as new sources of cold tolerance for the PNW.	Trials planted and rated each year.In the winter regional nursery, ARS010260, Eltan, IDO1101, OR2080236H, and Yellowstone had the best cold tolerance.	Sept 2012 - August 2015.	Presentation at grower meetings, Wheat commission meetings, Wheat Life and Research Review. Email results to regional nursery cooperators and publish on regional nursery web sites
3. Evaluate cold tolerance of spring wheat variety trials.	Ratings for spring wheat cultivars.	Trials planted and rated in 2013.	Sept 2012 - August 2015.	Presentation at grower meetings, Wheat commission meetings, field days, plot tours, Wheat Life and Research Review. Published on WSU Variety Testing Web-site
4. Evaluate cold tolerance of advanced breeding lines contributed by PNW wheat breeders as well as those in the ARS breeding program	Ratings for freezing tolerance for breeding lines in regional breeding programs.	Trials planted and rated and information given to breeders. Information was used to justify cultivar release.	Sept 2012 - August 2015.	Direct communication with wheat breeders.

5. Evaluate cold tolerance of F_3-F_5 (early generation) wheat populations that are segregating for cold tolerance and select resistant progeny.	Populations segregating for other traits but selected to have superior cold tolerance.	The first round of selection was performed and lines are in the field for agronomioc traits.	Sept 2012 - August 2015.	Presentation at grower meetings, Wheat commission meetings, field days, plot tours, Wheat Life and Research Review.
6. Identify genes controlling cold hardiness in winter wheat. Rate freezing tolerance in tthree mapping populations, Finch/ARS15144, Finch/ARS14142 and Finch/Eltan. All three of these populations will be genotyped with SNP markers and quantitative trait loci for cold tolerance will be	Genes responsible for cold tolerance in Eltan, ARS15144 and ARS14142 identified. The best selections from the mapping poppulations will be entered into yield trials.New markers for cold tolerance will be identified.	Populations have been screened. • We have rated freezing tolerance for winter wheat breeding lines and in progeny from intercrosses within the Brundage/Coda, Finch/Eltan, and Eltan/Oregon Feed Wheat5 wheat mapping populations, and the Winter Wheat Core Nursery. QTLs have been identified and association mapping in underway to identify additional loci.	By the end of the third year of the grant.	Presentation at grower meetings, Wheat commission meetings, field days, plot tours, Wheat Life and Research Review. Publication in refereed journal.