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

PROJECT #: 30109-5345
Progress report year: *2 of 3 (maximum of 3 year funding cycle)*
Title: Evaluation And Selection For Cold Tolerance In Wheat
Investigators: K. Garland Campbell, A.H. Carter, D.Z. Skinner

Executive summary: We have rated tolerance to freezing in the Washington State Extension Winter and Spring wheat variety trials for 2014. We have also rated tolerance to freezing for the Western Regional winter wheat nurseries, and the Regional nurseries from the rest of the US. We have rated freezing tolerance for winter wheat breeding lines and in progeny from intercrosses within the Brundage/Coda wheat mapping population. The most cold tolerant hard winter wheats in the WSU nurseries were 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 wheats were ARS010262, Curiosity CL, Eltan, Masami, Mela CL, Norstar, Tubbs 06, and WA8169. In the winter regional nursery, ARS010260, Eltan, IDO1101, OR2080236H, and Yellowstone had the best cold tolerance. In the US, the best overall winter tolerance is found in the winter wheat breeding programs in CO, MT, SD, and West Texas. We reported winter survival ratings in the annual seed buyers guides published by Washington State Crop Improvement Assoc. 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. New germplasm that has been brought into the PNW from Europe is generally less winter tolerant than needed for the PNW.

These results from analysis of the mapping populations have allowed us to identify interactions among different alleles of two loci on the 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 would be a good strategy to improve frost tolerance in wheat. We have developed molecular markers for these specific alleles and screening a winter wheat panel for the presence of those loci. Most PNW adapted germplasm possessed the tolerant alleles at both genes, likely due to selection by breeders for winter tolerance. We have to continue to search for additional genes that will explain a significant proportion of the variation for cold tolerance in adapted PNW germplasm.

We identified a previously unknown cold response in winter wheat that results in some varieties surviving longer times at subfreezing temperatures better than they survive shorter times. Understanding the mechanisms behind this response will provide another tool to use in developing winter hardy wheat cultivars.

The WSU Winter Wheat Variety trials were rated for winter survival after the severe 2013/2014 winter. The field survival data was closely correlated with the results of our artifical screening testing (Complete field survival data is available at http://variety.wsu.edu/) (Fig. 4, Tables 1 and 2).

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. 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.

We have rated survival for cooperative nurseries from throughout the U.S. and around the world. Much of the U.S. experiences winters that are more severe than those in the PNW. Based on our screening, the winter wheat breeding programs with the best winter tolerance are in Montana, South Dakota, Colorado, and Illinois.

Most breeding programs have both winter tolerant and less tolerant breeding lines. The identification of molecular markers associated with freezing tolerance will complement our screening system and increase the current screening capacity from about 1000 varieties and breeding lines to several thousand progeny from segregating populations per year.

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 (Table 1). 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.

Although winter injury was a major problem for wheat growers in the state of Washington last growing season, its occurrence was beneficial to plant breeders who used the experience of winter kill in the field, combined with the freeze test screening results, to better predict the survival of their new releases and the correlation with the results of our freezing tests allows us to reliably predict the tolerance of new cultivars and breeding lines.

Communication:

Project # **5345**
Title: **Evaluation And Selection For Cold Tolerance In Wheat**

Researcher(s): **K. Garland Campbell, A.H. Carter, and D.Z. Skinner**
Year Initiated: **Date initiated: July 1, 2013**
This is year __2_ of _3__ (maximum 3 years) of the funding cycle.

Papers:

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/s00122-014-2290-2

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.

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.

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/

WGC project number: **3019-5345**
WGC project title: **Club wheat breeding**
Project PI(s): **Kimberly Garland-Campbell, Arron Carter and Dan Skinner.**
Project initiation date: **7/1/13**
Project year: **Year 2**

Objective	Deliverable	Progress	Timeline	Communication
1. **Evaluate Washington winter wheat variety trials**.	Ratings for freezing tolerance for commonly grown and new winter wheat cultivars	The 2012-2014 trials have been evalauted and analyzed. The 2015 winter trials have been planted and will be rated during the summer. Ratings were correlated with field results from 2014.	Sept 2012 - August 2015.	Presentation at grower meetings, Wheat commission meetings, field days, plot tours, Wheat Life and Research Review. Published on WSU Wheat 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.	The 2012-2014 trials have been evalauted and analyzed. The 2015 winter trials have been planted and will be rated during the summer.	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.	We did not rate spring wheat in 2014, but plan to do so again in 2015.	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 have been planted and will be rated during the summer. Ratings from 2012-2013 trials have been analyzed, the 2014 trials are now being analyzed.	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 has bene performed and selected populations were planted in the field in the fall of 2014. Another round of selection will take place during the summer of 2015.	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 identified.**	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 developed. The Finch/Eltan population was planted at Sidney MT for field screening and analyzed. All populations have been assayed for cold tolerance in artificial screening trials. Initial QTL analysis was conducted. Additional markers are being put on the linkage map.	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.