

Project #: 7768

Progress Report Year: 2 of 3 (*maximum of 3 year funding cycle*)

Title: A Genetic Arsenal for Drought Tolerance, Getting to the Root of the Problem

Cooperators: Karen A. Sanguinet, Camille M. Steber, Kimberly Garland-Campbell, Timothy Paulitz, Scot Hulbert, Arron Carter

Executive summary: Dryland farms in eastern Washington routinely experience yield losses due to drought stress. Improving wheat root structure can help to resist such stresses by increasing access to water. The combined issues of drought, no-till practices and the changing pathogen load affect all market classes of wheat and barley. Traditional breeding for wheat and barley has mainly focused on the health of the aboveground parts of the plant. As a result, many modern varieties have small and/or shallow root systems compared to landraces. The primary goal of this research project is to identify root architectures in current breeding populations of both spring and winter wheat cultivars associated with better yield under drought stress. We assessed the root structures of Hollis, Drysdale, Louise, and AUS28451, as well as the 10 best and worst yielding lines from Hollis/Drysdale population in the summers of 2015 and 2016 at the Lind Dryland Research Station. Quantification of the root traits is underway, but preliminary analysis shows differences between cultivars in rooting depth, volume and area. Winter wheat genotypes (*wt*, *Rht1*, *Rht2*, *Rht1 Rht2*) in the Brevor and Golden backgrounds were sown at Spillman Farm in October 2015 and November 2016. Scans were taken after planting and insertion of imaging tubes. All winter and spring cultivars are being measured in pots in the wheat greenhouse; repetition 1 was completed in Spring 2016 and repetition 2 is underway. Once all root traits have been quantified, selected genotypes, cultivars, and RIL and backcross populations will be planted at both Spillman and Lind in 2017 and 2018.

Impact: Combined drought and heat routinely experienced in the PNW can cause 20-50% losses in grain yields as experienced in recent years. The short-term impact of this research is to use root traits and overall architecture in current breeding lines under selection as an additional and crucial metric to improve drought tolerance. Previous research has shown root traits cannot be predicted or selected for using aboveground traits. The long-term impact of this research is to develop *in situ* root imaging technology for winter wheat, spring wheat, club wheat and barley cultivars under selection with the overall goal of improving the salient root traits important for drought tolerance. These could include seminal root establishment, crown root colonization, or lignin content for improving a number of root-related traits to both biotic and abiotic stresses. The ultimate goal of this research project is to improve root architecture in current breeding populations of both spring and winter wheat cultivars to improve yield under drought stress. Root imaging and phenotyping is a primary focus area and priority for federal funding agencies. This grant and support for root imaging has helped leverage a collaboration with Pacific Northwest National Labs (PNNL), which in turn has led to submission of proposals addressed to ARPA-E, the USDA-AFRI Foundational Program.

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Project PI(s): K. Sanguinet, C. Steber, K. Campbell, T. Paulitz

Collaborator: S. Hulbert, A. Carter

Project initiation date: 7/1/2015

Project year: 2017-2018, year 3

Objective	Deliverable	Progress	Timeline	Communication
1. Characterize the root systems of the five RIL parental lines: Louise, AUS28451, Dharwar Dry, Hollis and Drysdale using a digital in situ root imaging system to measure root traits such as root hair length and density root mass and root depth.	Methods and analysis of two key traits for drought stress: root architecture and lignin content in Louise, AUS28451, Dharwar Dry, Hollis and Drysdale (2017).	We have successfully imaged Louise, AUS28451, Hollis, and Drysdale in the field in Summer 2015. Serial scans every 3 days for Louise, AUS28451, Drysdale, Hollis, Dharwar Dry, and Alpowa are underway in the wheat greenhouse in the winter 2015-2016. Quantification of root architectural traits are underway using RootSnap! software.	The first round of field trials and quantification of root architecture was completed by the end of 2015. Lignin content measurements will be performed in the greenhouse in winter 2015-16 of the parental lines.	Our findings will be reported in the July 2016 issue of Wheat Life and at the CSA meeting in Fall 2016. In addition, we attended the Lind and Spillman field days in 2015, 2016 and will again in 2017. We will publish a short communication in a peer-reviewed journal regarding our spring wheat work, which will be submitted for review late spring/early summer 2017.
2. Examine the Hollis/Drysdale RIL population to determine if yield under drought and canopy temperature correlate with a specific root trait or traits.	Determine the link between canopy temperature, root architecture traits and yield (end of 2017).	With the aid of Dr. Hulbert, the 10 highest and lowest yielding RIL populations from Hollis/Drysdale RIL populations were sown at Lind in summer 2015. Images were taken every two weeks. We found that the 3 ft. long imaging tubes were too short and need to continue subsequent imaging in the field with 6 ft. long tubes. Nonetheless, informative data were obtained and differences in architecture and rooting depth were observed between Hollis and Drysdale. These analyses will be repeated in Summer 2016 at Lind and Spillman.	Field trials will be initiated in both dry and irrigated conditions in summer of 2015 of the parents and will be analyzed again in summer 2016 comparing 10 of the best yielding versus worst yielding RILs. Time and data permitting. This will be repeated again in summer 2017.	Our findings will be reported in Wheat Life and prepared for publication in a scientific journal.
3. Examine backcross lines in the Louise background with specific root traits from AUS28451 including higher root lignin, root depth, root branching, root biomass, and root hair density to improve yield under drought and to select breeding lines with vigorous roots. Also backcross lines of Dharwar Dry to Louise will be analyzed for improved drought resistance and root architecture traits.	Development of breeding lines with increased lignin and root vigor which are predicted to show enhanced drought tolerance (2018-2020).	We have begun analyzing the parental lines. With help from Dr. Garland-Campbell's group, backcrossing to Louise is advancing and we will be evaluating the Louise/AUS28451 advanced BC lines beginning in 2017.	Analysis and selection of backcross lines will commence in summer of 2015. The backcross lines will be further backcrossed to the Louise parent and will undergo several rounds of selection. The timeline for the selection of breeding lines will take 3-5 years.	Our findings will be communicated at field days at Lind and Spillman farms. In addition, we will again prepare a publication for Wheat Life.
4*. Examine root architectural traits in wild type, <i>Rht1</i> , <i>Rht2</i> and <i>Rht1 Rht2</i> dwarf winter wheat lines in the Brevor and Golden backgrounds.	Development tools and imaging to assess the importance of root growth and the <i>Rht</i> alleles on winter wheat cultivars (2017-2018).	With the help of Dr. Carter, <i>wt</i> , <i>Rht1</i> , <i>Rht2</i> , and <i>Rht1 Rht2</i> lines in the Brevor and Golden backgrounds were sown in October 2015 and November 2016 at Spillman Farm. Imaging tubes were placed after sowing. Seeds were be bulked for more expansive testing in Fall 2016-Summer 2017.	Imaging and analysis of root growth of winter wheat (<i>wt</i> , <i>Rht1</i> , <i>Rht2</i> , and <i>Rht1 Rht2</i>) will occur at Spillman Farm Winter 2015 until Summer 2016. A repetition of imaging will occur in the field in Fall 2016 to Summer 2017 to confirm and extend findings in the field. The same lines will be sown in vernalization chambers in the wheat greenhouse followed by growth in the WSU wheat greenhouse (performed Winter 2015-2016 and repeated Winter 2016-2017).	Our findings will be communicated at field days at Lind and Spillman farms, on the small grains website and in a publication for Wheat Life, and will be submitted for publication in a peer-reviewed journal.
Expected impacts over the next 3 years: Previous data has shown that root and shoot traits are not correlated. The proposed research uses <i>in situ</i> root imaging techniques to add another metric for selection of breeding lines and determination of the supposed link between deeper rooting, canopy temperature and yield by addressing which root traits (depth, branching, thickness, angle, root hairs, lignin content) most influence yield. Once precise traits and their impact on yield are determined, this provides another tool in the breeding tool box for selection of plant traits that correlate with increased yield particularly in drought or water-limiting conditions.				

The expected outcomes are:

- 1) Increasing the knowledge regarding root architecture and drought tolerance in wheat;
- 2) Selecting for key root architecture traits in wheat cultivars for improved drought tolerance;
- 3) Improving drought tolerance in the Spring White Wheat Louise in backcross populations with the landrace AUS28451 and the drought-tolerant cultivar ;
- 4) Determining the link between canopy temperature, yield and root architecture;
- 5) Determining the role of root lignin in drought stress and root pathogen resistance;
- 6) Development of in situ root imaging techniques for breeders as an additional metric and tool in their breeding arsenal
- 7)* Determine the impact of *Rht* mutations on root development in winter wheat genotypes adapted to the PNW

*-new objective and outcome for years 2-3.