Diversity of Root Traits in Winter Wheat Under Drought Stress

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Abstract

- Drought is among most serious environmental challenges farmers face and is considered the major cause for yield reduction in dry regions.
- The development of a deep and extensive root system is a drought adaptation mechanism to allow water and nutrient extraction from the soil profile.
- 30 entries (cultivars and advanced lines) from Colorado were evaluated for drought stress.
- Roots were analyzed with WinRhizo software, and other physiological and morphological traits such as water loss from the tubes and above ground biomass were measured.
- Entries differed significantly (*P*<0.05) for water loss from the tubes, above ground biomass, and WinRhizo root traits (average root diameter, total root length, bottom, middle, and top sections root length, as well as root length per diameter class for all classes and sections).
- Total root length of entries ranged from 4850 to 7204 cm and average root diameter ranged from 0.338 to 0.402 mm.
- Additionally, there were significant positive correlations (*P<0.05*) between total root length and both water loss from the tubes and above ground biomass (*r*= 0.56 and 0.50 respectively, n = 30).

Objective

The objective of this study was to investigate the variation in root architecture and its related physiological and morphological traits in winter wheat (*Triticum aestivum* L.) under drought stress.

Materials & Methods

Plant materials

- Thirty winter wheat entries, consisting of released cultivars and advanced breeding lines as part of a 300 hard winter wheat association mapping population.
- 28 entries developed by Colorado State University (CSU), one cultivar from Kansas State University, and a cultivar released by Agripro were evaluated in this study.

Experimental design

- The experimental design was a randomized complete block with four replications.
- Seed of 30 entries was planted in 1 m high, 10 cm inside diameter plastic tubes filled with fritted clay in a greenhouse at CSU on 16 Jan. 2012.

Root tubes setup in the greenhouse

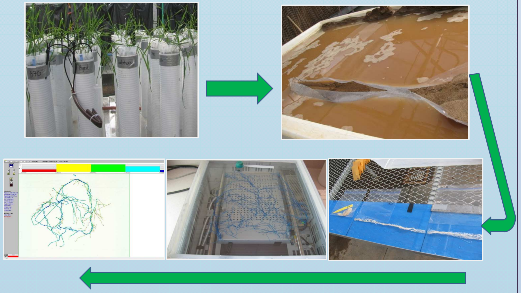
Measurements

Physiological & morphological measurements

1. Water loss from tubes (kg), using a hanging scale.
2. Above ground biomass (g).
3. Growth rate of the newest leaf after the initiation of the dry down treatment (mm/day).
4. Stomatal conductance (mmol m^{-2} s^{-1}), using a leaf porometer (Model SC-1, Decagon Devices, Inc. Pullman, WA).
5. Relative water content (%), using the formula from Barr and Weatherley (1962).
6. Osmotic adjustment (mmol kg^{-1}), using a vapor pressure Osmometer (model 5520, Wescor, Inc., Ut).

Root measurements

Roots were separated, washed, scanned, and analyzed with WinRhizo software, as shown in the photos below, step by step.



Statistical analysis

- Statistical analyses (proc corr and proc GLM) were performed with SAS 9.3 (SAS Institute, Cary, NC).
- In analysis of variance (ANOVA) entries were considered a fixed variable.

Acknowledgments

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Results

- Total root length of entries ranged from 4850 to 7204 cm.
- Average root diameter ranged from 0.338 to 0.402 mm.
- Average water loss was 788 and ranged from 701 to 872 g.
- Above ground biomass ranged from 0.76 to 1.23 g.
- Entries differed significantly (*P*<0.05) for root length per diameter class for all classes and sections.
- 50% of the root length in the bottom section was within the lower diameter class (from 0 to 0.25 mm, Fig. 3).

Traits with significant genotype effect

Variable	P-value
I. Root traits	
Average diameter	<0.01
▪ Average diameter for top section	<0.01
▪ Average diameter for middle section	<0.01
▪ Average diameter for bottom section	<0.05
Total length	<0.001
▪ Total length for top section	<0.001
▪ Total length for middle section	<0.01
▪ Total length for bottom section	<0.05
II. Physiological and morphological traits	
▪ Above ground biomass	<0.01
▪ Water loss from tubes	<0.01

Correlations of traits

There were significant positive correlations (*P*<0.05) between total root length and both water loss from the tubes and above ground biomass (*r*=0.56 & 0.50, respectively, n=30, Fig. 1 & 2).

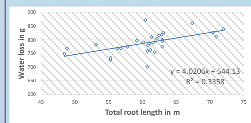

Fig 1. Relationship between water loss and total root length

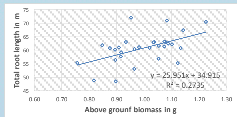

Fig 2. Relationship bet. total root length and above ground biomass

Fig 3. Root length % per diameter class for bottom root section

Conclusions

- Plants with more extensive root systems were able to transpire more water and produce more biomass.
- The variation in roots can be exploited in breeding programs to help design plants with the best adapted root traits to withstand drought stress.

Key Reference

Araus J.L., Slafer G.A., Reynolds M.P., Royo C. (2002) Plant Breeding and Drought in C3 Cereals: What Should We Breed For? Annals of Botany 89:925-940.