Diversity of Root Traits in Great Plains Winter Wheat Under Drought Stress

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Abstract

- Drought is considered the main 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.
- We conducted two studies to investigate the variation in root architecture and its related physiological and morphological traits in winter wheat (Triticum aestivum L.) under drought stress.
- The first study evaluated 30 genotypes from Colorado, and the second study included 30 entries from seven Great Plains states.
- Roots were separated, washed, scanned, and analyzed with WinRhizo software.
- Entries differed significantly (P<0.05) for root traits (average root diameter and total root length overall and for bottom, middle, and top sections, as well as root length per diameter class).
- Total root length of Colorado entries ranged from 4850 to 7204 cm. Additionally, there were significant positive correlations between total root length and both water loss from the tubes and above ground biomass (P<0.05).

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:
- The first study evaluated 30 genotypes from Colorado, and the second study included 30 entries from seven Great Plains states including CO.
- Entries, consisting of released cultivars and advanced breeding lines as part of a 300 hard winter wheat association mapping population.

Experimental design:
- The experimental design was a randomized complete block with four replications.
- Seed of all entries was planted in 1 m high, 10 cm inside diameter plastic tubes filled with fritted clay in a greenhouse at CSU in 2012 and 2013.

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.

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>P-value</th>
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<tbody>
<tr>
<td>I. Root traits</td>
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<tr>
<td>Average diameter</td>
<td>&lt;0.01</td>
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<td>Average diameter for top section</td>
<td>&lt;0.01</td>
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<td>Average diameter for middle section</td>
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<tr>
<td>Average diameter for bottom section</td>
<td>&lt;0.05</td>
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<tr>
<td>Total length</td>
<td>&lt;0.001</td>
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<tr>
<td>Total length for top section</td>
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<td>Total length for middle section</td>
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<td>Total length for bottom section</td>
<td>&lt;0.05</td>
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<tr>
<td>II. Physiological and morphological traits</td>
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<tr>
<td>Above ground biomass</td>
<td>&lt;0.01</td>
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<tr>
<td>Water loss from tubes</td>
<td>&lt;0.01</td>
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</tbody>
</table>

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).

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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- We would like to thank all Byrne lab graduate and undergraduate students for technical assistance.

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