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Impact of Drought Stress on Fine Roots

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Background

The most external lateral roots (Figure 1) have greater radial and endodermal permeability to water than roots higher up in the hierarchy. Coarser framework roots have greater axial conductivity. These trait differences between roots ensure efficient uptake of water and nutrients at the most external part of the root system, as well as rapid transport of water and nutrients from the root system to the shoot. Estimates of percentage of total root length actually active in direct water and nitrate uptake vary from 3 to 12 %. As roots age they show a marked reduction in the ability to take up nitrogen. Conditions that reduce new fine root production, such as chronic drought or reduced carbohydrate availability through canopy pruning, could thus hinder the ability of trees to acquire water and nutrients. In addition, a shift to long-lived drought resistant roots that have thicker cortex layers and enhanced exodermis suberization may also lead to reduced capacity of the root system to acquire nutrients and water. Root systems that develop a burst of new roots in response to irrigation may be much more effective at taking up water and nutrients when available than root systems that retain fine roots through a period of mild drought. Knowledge about fine root behavior in response to different types of drought can potentially be used to adjust irrigation strategies in such a way that root system composition can be manipulated to achieve the greatest efficiency in water and nutrient uptake.

We hypothesize that:
1) A tradeoff exists between producing more drought resistant roots (e.g., longer lived, more dense roots with thicker exodermal layers) versus more active physiology (i.e., greater nutrient uptake).
2) Trees exposed to chronic low level drought will likely produce more drought resistant, less physiologically active fine roots compared to trees exposed to fluctuating water stress levels.

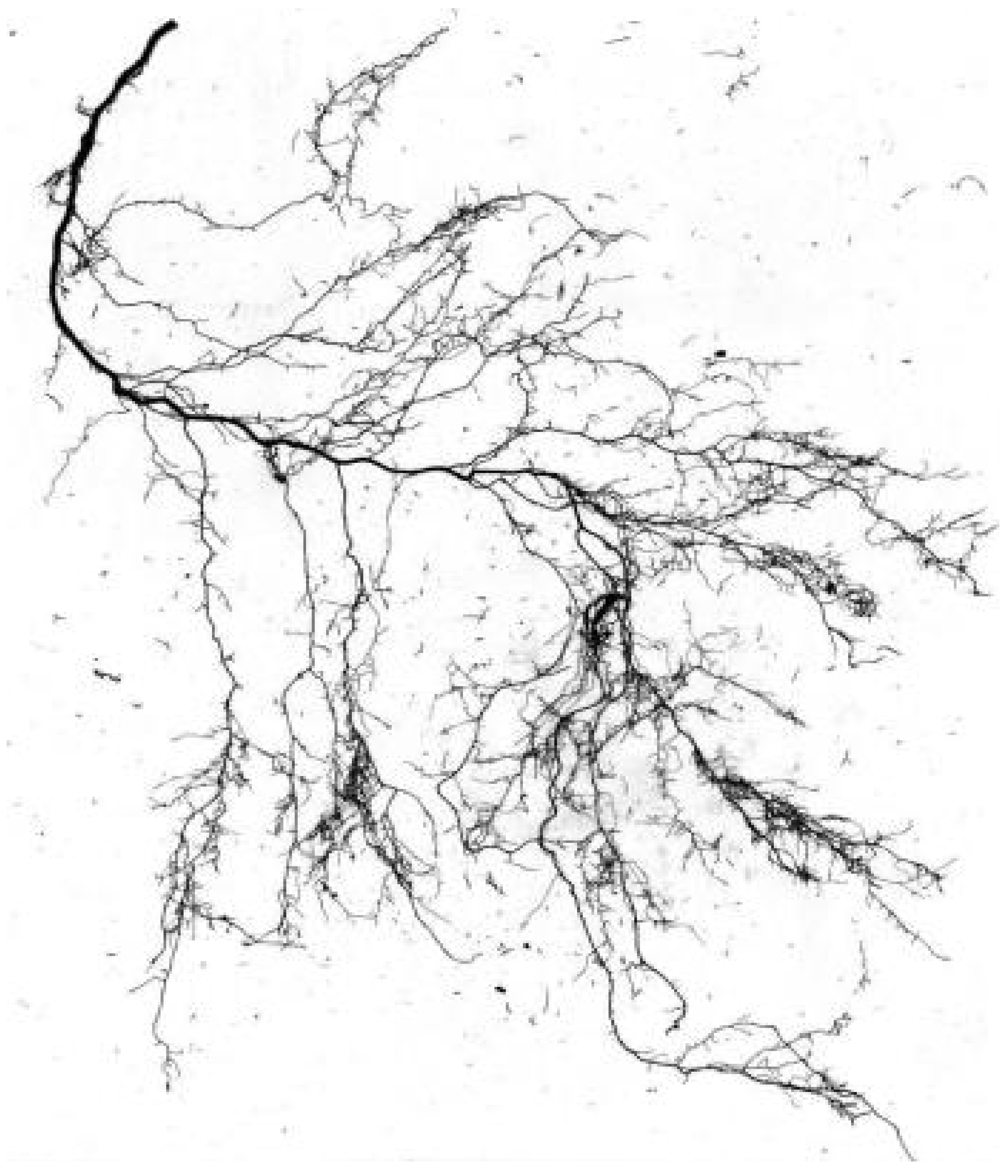

Figure 1. Scan of a fine root system. The most external fine roots are most active in water and nutrient uptake

Objectives

- Measure impact of water availability and irrigation pattern on fine root traits (production pattern, rooting depth, diameter distribution, suberization, lifespan, anatomy)
- Measure impact of water availability and irrigation pattern on fine root physiology (nitrogen uptake, water uptake, hydraulic conductivity)

Step 1 (in progress) – survey fine root traits in existing irrigation trials
- Samples collected in the Merced Water Production Function orchard in July and November
- More trials will be added

Step 2 (under development) – impact of irrigation on the ability of roots to acquire water & nutrients
- Establish controlled experimental site at UC Davis
- Three irrigation regimes with different timing and amount of water application
    - Measure impact on root traits (production pattern, rooting depth, diameter distribution, suberization, lifespan, anatomy)
    - Measure impact on root physiology (nitrogen uptake, water uptake, hydraulic conductivity)

Methods

Figure 2. (a,b) Collecting soil cores at 5 consecutive soil depths (10 cm increments), (c) washing roots out of soil cores down to a sieve size of 250 µm, (d) scanning root length in ten 0.1 mm increment diameter size classes using WinRhizo Pro. Dry mass was measured for all samples to allow calculation of both root mass density and root length density per volume soil.

Table 1. Water applied at the Merced irrigation trial from Feb to Sep, 2014, relative to the grower standard (100, green). SWP = average stem water potential across the season

Treatment Goal	Applied (Gal/tree)	Relative % achieved	Average SWP (bar)
110	7110	106	-12.7
100	6737	100	-14.0
90	6237	93	-13.3
80	5703	85	-14.5
70	5031	75	-15.8

Preliminary results

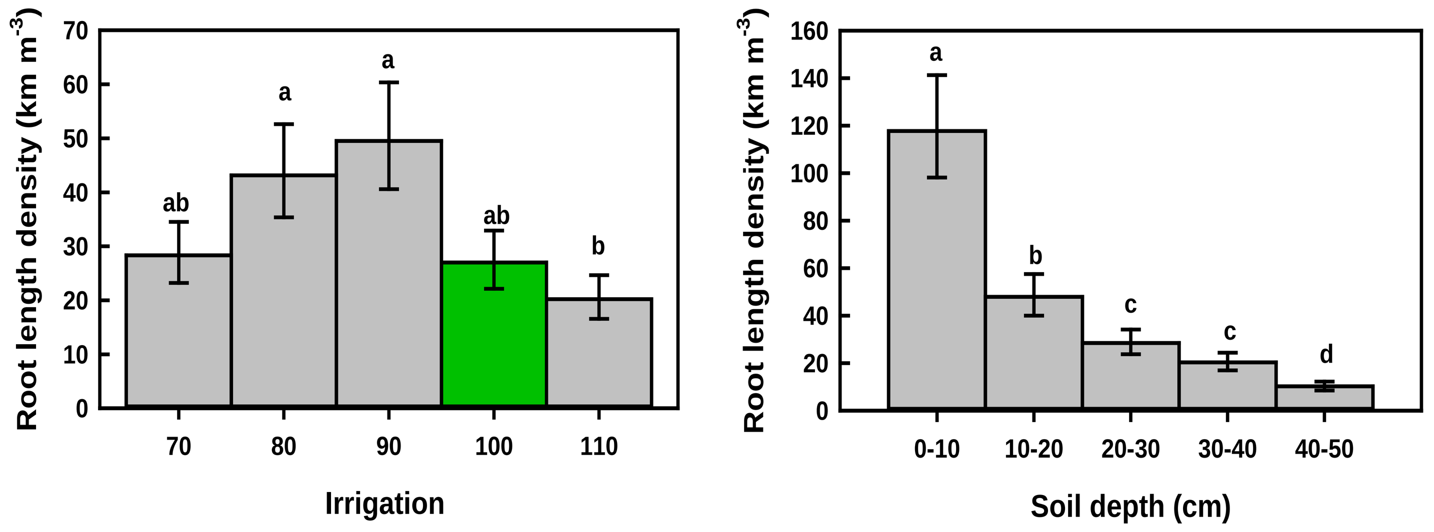

Figure 3. Fine root length density in response to (a) irrigation treatment and (b) soil depth. Different letters indicate statistically significant differences between treatments at *P* <0.05. 100 (green bar) indicates grower applied irrigation. Most fine root length was present in the shallowest depth and fine root length density was decreased at all depths when irrigation rate increased.

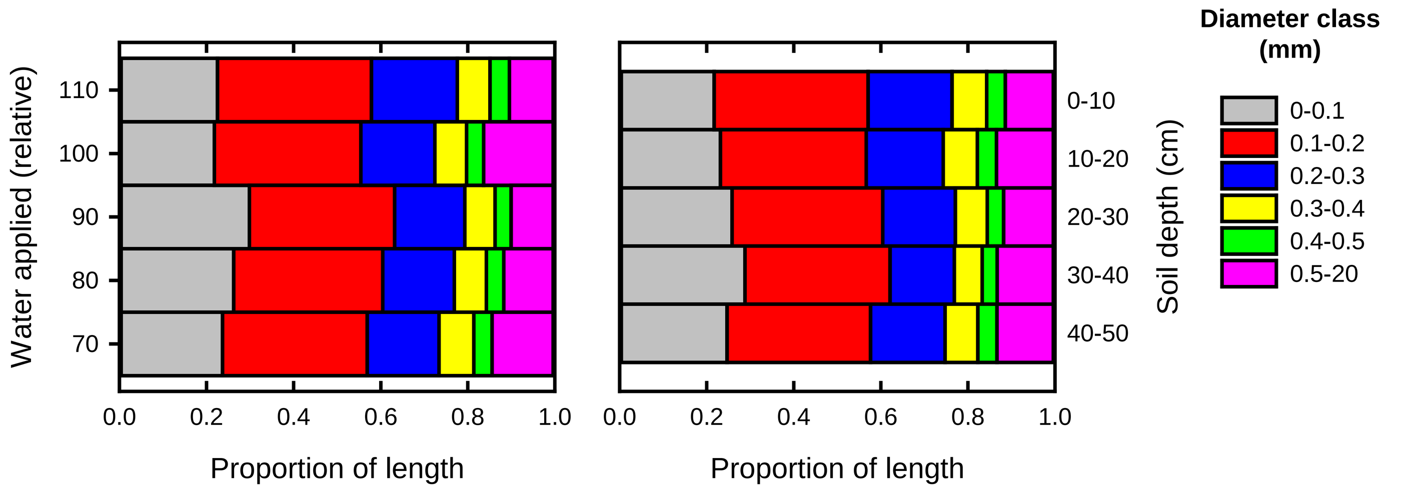

Figure 4. Proportion of root length in each root diameter class as a function of (a) irrigation treatment and (b) soil depth. Size class distribution was not affected by irrigation treatment or soil depth. Note that at least 80% of recovered root length was 0.5 mm or less in diameter.

Next steps
- Further characterization of fine roots in existing irrigation trials to measure impacts of seasonality and different soil types
- Installation of a controlled experimental site to study root responses in further detail

Potential impact

Understanding fine root production patterns and physiology in response to different types of drought can potentially be used to adjust tree management to maximize efficiency in water and nutrient uptake.

Collaborators

David Doll – UC ANR Cooperative Extension, Merced County
Ken Shackel - Department of Plant Sciences, UC Davis
Patrick Brown - Department of Plant Sciences, UC Davis

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