Towards a sustainable designer urban soil for trees

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Introduction

Engineered soils are needed in urban areas to support infrastructure and provide a substrate for trees[1]. The standard engineered soil is comprised mostly of sand and often includes soil that is screened for uniformity. These soil mixes tend to drain well, but have low water-holding and nutrient-supply capacities. The screening is expensive and also tends to omit large pore spaces, important for aeration and root growth. This soil specification is derived from the turf-grass industry, and may not be suited for trees.

This experiment is designed to compare the performance of the current engineered soil standard against a natural forest soil and also against a new designer soil for trees. The effects of mulching were also studied[2].

Our main hypothesis was: if the more "natural" soils are better substrates for landscape trees, then they will have greater surface respiration, soil moisture, stomatal conductance, indexed chlorophyll content, and total leaf area.

Methods

- This experiment is a full-factorial: 3 soil types (Urban, Tree and Native) x 2 surface types (mulched and non-mulched) x 11 replicates for 66 experimental units (Tab. 1)
- Native soil for all mixes was a silt loam with pH 6.5 and organic matter of 5%
- 66 *Tilia* Shamrock (3 cm branched, bare-root) were planted in individual 75 L pots. Tree roots and shoots were pruned, diameter measured, and tree mass recorded prior to planting
- Soils were mixed in the field and compacted to 80% proctor density[3]
- Wood-chip mulch was applied to 33 mesocosms (11 of each soil type) at a depth of 7.6 cm
- Trees were watered for the first 65 days at 24.6 L/tree/week. Watering was stopped after 7/17/2014 to assess performance in drought conditions
- Soil respiration (μmol/m^2/s) was assessed weekly, along with volumetric water content (%) and temperature (°C) (LI-COR Biosciences, Lincoln, NE)
- Stomatal conductance (mmol/m^2) was measured weekly (SC-1 Leaf Porometer 4.0 (Decagon Devices, Pullman, WA)
- Indexed chlorophyll content was assessed on two occasions (SPAD 502 Plus Chlorophyll Meter, Spectrum Technologies, Aurora, IL)
- Leaves were counted and leaf area measured (LI-3000C (LI-COR Biosciences, Lincoln, NE)

Table 1. *Screen size and volumetric composition of three soil types.*

Property	Urban	Tree	Native
Screen size (cm)	1	5	n/a
Sand (%)	60	25	0
Compost (%)	15	15	0
Soil (%)	25	60	100

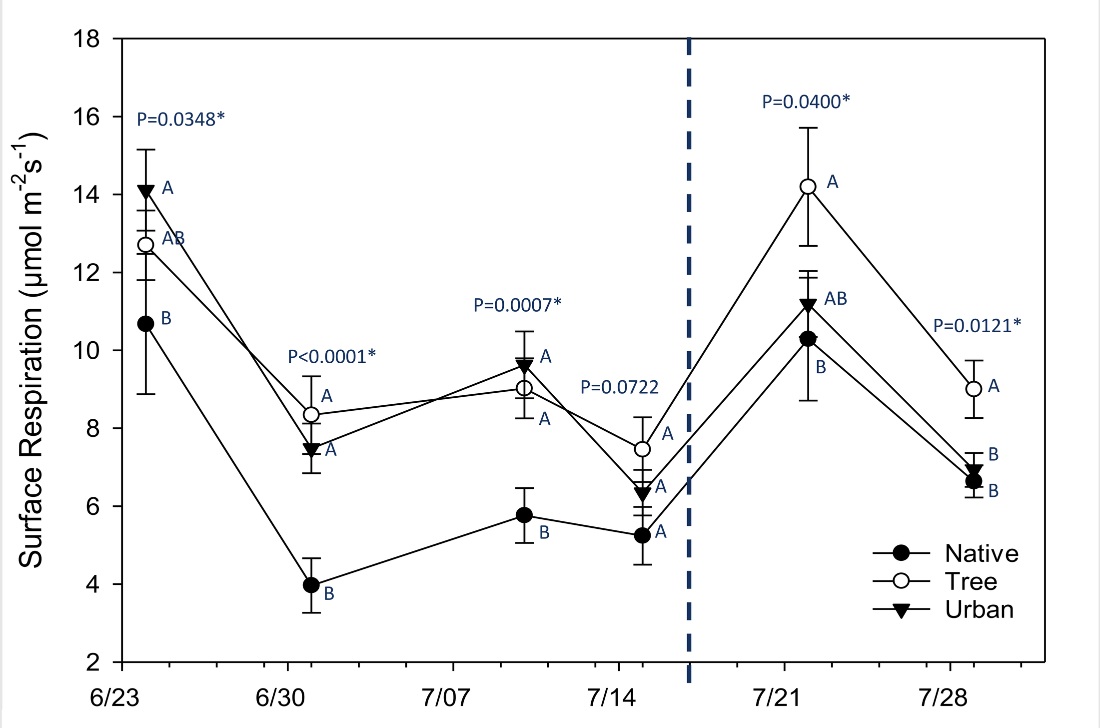
Figure 1. *Images of Urban, Tree, and Native soils with examples of larger aggregates outlined.*

Abstract

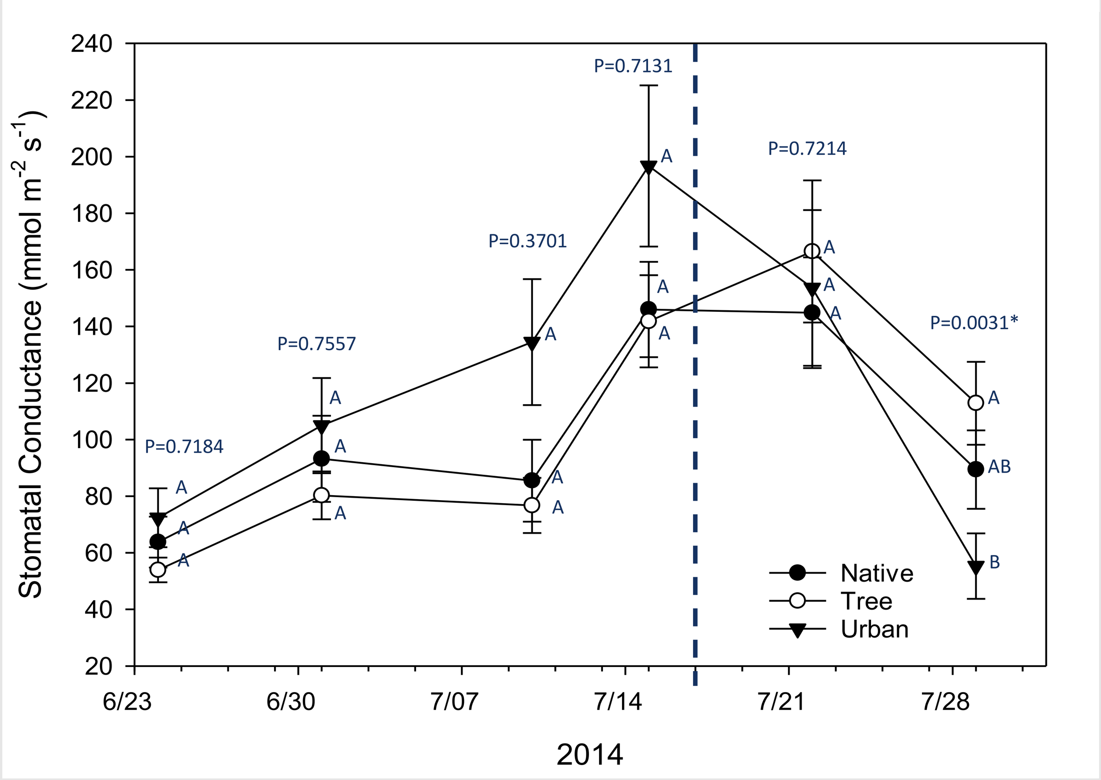
Growing healthy trees in artificial urban soils is challenging. The purpose of this study was to compare the performance of the current urban soil standard against a natural forest soil, as well as a new, intermediate specification. Urban soil is the current standard, which is mostly sand and screened soil. Native soil is without sand or compost, and Tree soil is a new specification with more soil and less sand. Surface respiration, soil temperature, volumetric water content, and stomatal conductance were measured weekly (June-August, 2014). Druing this time, Urban soil performed best during the watering period. The Tree soil performed best under drought conditions. Overall, the tree soil may be best for urban trees.

Image 2. *Soil moisture probe, temperature probe, and LI-8100A*

Image 3. *Potted Tilia shamrock*



Graph 1. *Surface respiration by soil type by date. Astericks indicate significate P values. Letters indicate Tukey-Kramer HSD test. Dashed line represents last day of watering.*



Graph 2. *Stomatal conductance by soil type by date. Asterisks indicate significate P values. Letters indicate Tukey-Kramer HSD test. Dashed line represents last day of watering.*

Results

Surface Respiration: Soil type had a significant effect on surface respiration (P<0.0001). During watering period, the Urban and Tree soils had the highest respiration. After watering was stopped, the Tree soil had significantly higher respiration than the other two soil types. Surface type had a significant effect on surface respiration (P<0.0001). Mulched soils consistently had significantly higher respiration than soils with a bare surface.

Volumetric water content (VWC): Soil Type had a significant effect on VWC (P<0.0001). The Native soil consistently had a significantly higher VWC than the Tree soil, which was higher than the Urban soil. Surface type had a significant effect on VWC (P<0.0001). The mulched soils consistently had significantly higher VWC than the bare ones.

Stomatal Conductance: Soil Type did not have a significant effect on stomatal conductance (P=0.5698). In the final week of measurements, the Tree soil was significantly higher than the Urban soil (P=0.0031). Surface type did not have a significant effect on stomatal conductance (P=0.2864).

Indexed Chlorophyll Content. No significant differences were found.

Leaf Area: No significant differences were found.

Discussion

Native soil: The Native soil had the highest respiration, although it was predicted to have the lowest. Stomatal conductance tended to be lower with the Native soil. We suspect that at 80% proctor density, the Native soil is too compacted for optimal root growth.

Urban soil: The Urban soil performed best (higher respiration and stomatal conductance) in non-water-stressed conditions. However, as watering was discontinued and soils began to dry, Urban soil performance began to drop. We suspect the Urban soil has a relative deficiency in micropores which are necessary for water retention.

Tree soil: The Tree soil was the best performer in drought conditions (highest respiration and stomatal conductance). We suspect that the Tree soil has a greater diversity of aggregates and pore sizes, and thus would be the best substrate under normal and drought conditions.

As expected, mulch was beneficial for all soil types, as is commonly observed in other research[2]. Preliminary data suggest that surface respiration is strongly controlled by temperature (P<0.0001) and moisture (P=0.0005), which is supported by the literature[4]. Conversely, stomatal conductance does not appear to be related to soil conditions, and may be more controlled by atmospheric conditions, such as humidity[5].

Soil characterization (including pore-size distribution) and tree growth assessments will be performed at the conclusion of this study and this information will be used to further investigate our hypotheses.

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