Comparing Hydraulic Properties of Soil-less Substrates with Natural Soils: A More Detailed Look at Hydraulic Properties and Their Impact on Plant Water Availability

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Introduction

Moisture release curves are often used when assessing plant-water relationships in soil-less substrates. However, differences between natural soils and soilless substrates make traditional assumptions about plant available water potentially invalid. If soil-less substrates are supposed to be treated like natural soils; why do plants begin wilting at very low water potentials (-10 to -30 kPa) and there is anywhere between 20 to 40 % water left (on a volumetric basis) in the soil (Abad et al., 2005; Arguedas et al., 2006; Ristvey et al, 2008) . We hypothesize that the fault lies in the methods used and the assumption that water potential is the only limiting factor in water availability to plants.

Hydraulic properties, including the relationships that exist between plant available water, water content, and hydraulic conductivity of soil-less substrates have traditionally been characterized using instrumentation such as pressure plates, hanging water columns, and tempe cells. These approaches typically take a months and only provide data on select segments of the soil moisture release curve, and in the case of pressure plates and hanging water columns hydraulic conductivity is ignored and not very well understood. Using the Wind/Schindler Evaporation method (Schindler and Müller, 2006) more detailed measurements of these hydraulic properties can be measured in a less than a week. A more detailed look at the hydraulic properties of soil-less substrates and how they compare with natural soils may give us more insight into soil-plant-water-relations and what limits availability of water to plants.

Methods

Soil moisture release curves and hydraulic conductivity curves of 4 different soil-less substrates were compared with curves from 3 typical agriculture soils to give insight into how these properties compare. The moisture release curves and unsaturated hydraulic conductivity curves were measured based on the Wind/Schindler Evaporation Method using the HyProp (UMS GmbH, Munich, Germany) (Figure 1). Additional points on the soil moisture releaser curve for the agricultural soils were generated with the WP4C Dew Point Hygrometer (Decagon Devices Inc., Pullman, WA). The soilless substrates were not run on the WP4C because most of the water was a

Results of the soil moisture release curves showed that some soil-less substrates had comparable moisture release curves to agricultural soils while others had bi-modal curves indicating gap-gradation in the pore size distribution. These soils that showed this non-typical curve had hydraulic conductivities that dropped very low (500 times lower than agricultural soils) at low water potentials (around 10 kPa). This dramatically lower hydraulic conductivity could lead to zones of depletion around the roots hindering plant water uptake.

Figure 1: Cutout of the HyProp showing placement of the two tensiometers in the soil.

Table 1: Information on Soil and Soil-less substrates measured for comparison of hydraulic properties.

Typical Agricultural Soils	
Palouse Silt Loam (SiL)	67.7 % Silt – 21 % Clay – 11.3 % Sand
Pasco Fine Sandy Loam (FSL)	27.3 % Silt – 7.5 % Clay – 65.2 % Sand
Schawana Loamy Fine Sand (LFS)	16.6 % Silt – 4 % Clay – 79.4 % Sand
Soil-Less Substrates	
Potting Soil	
McCorkle	Bark Based Substrate
Farfard 1P	Peat-Perlite Mix (80:20 v/v)
Turface	Calcinated Clay

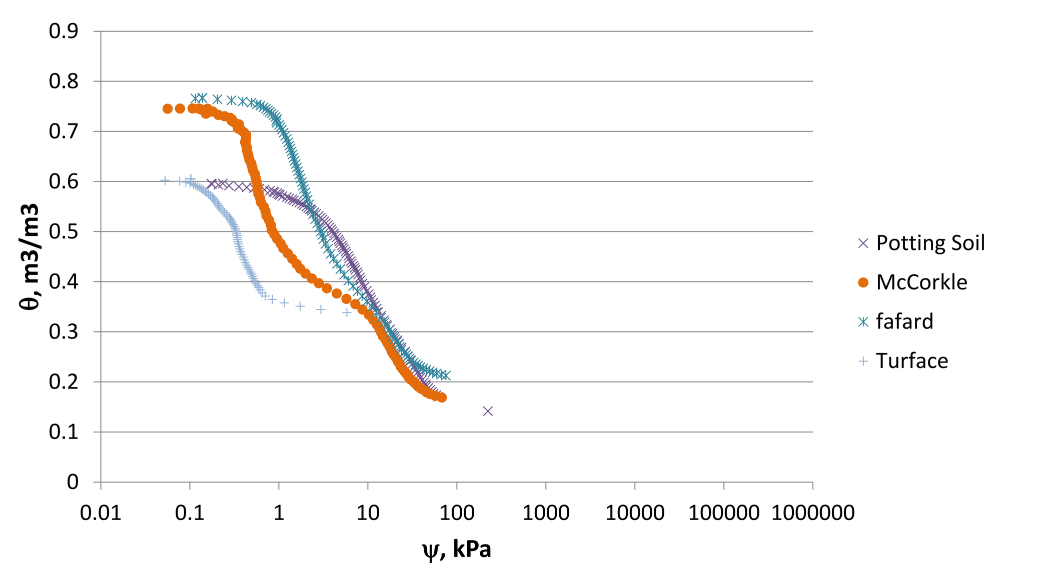

Figure 2: Soil moisture release curves showing the relationship between volumetric water content (θ) and water potential (ψ) of soil-less substrates generated from HyProp and WP4C measurements.

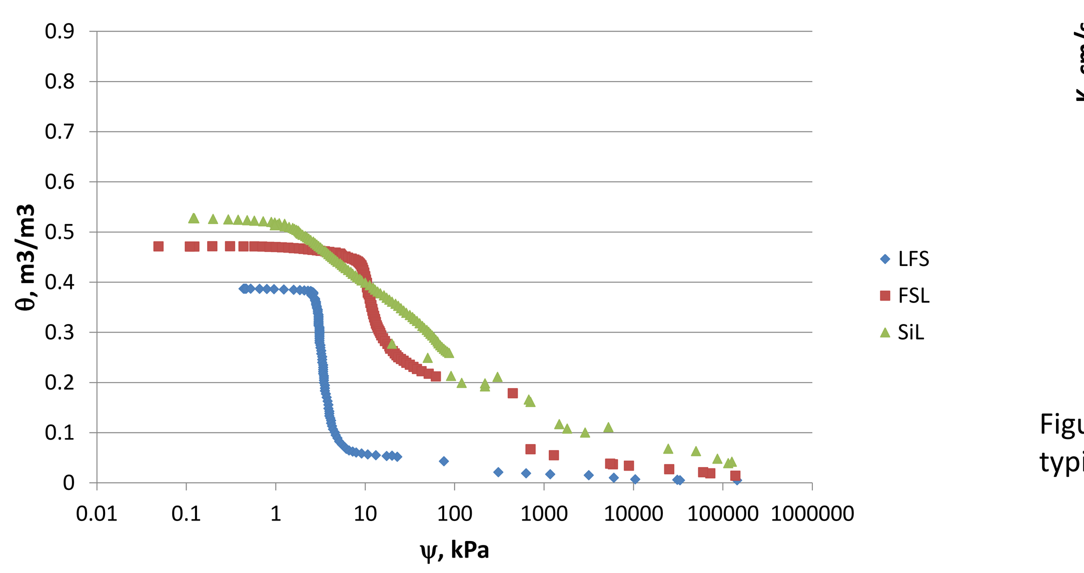

Figure 3: Soil moisture release curves showing the relationship between volumetric water content (θ) and water potential (ψ) of typical agricultural soils generated from HyProp and WP4C measurements.

Results

Results of the soil moisture release curves showed that some soil-less (Figure 2) substrates had comparable moisture release curves to agricultural soils (Figure 3) while others had bi-modal curves indicating gap-gradation in the pore size distribution. These soils that showed this non-typical curve had hydraulic conductivities that dropped very low (500 times lower than agricultural soils) at low water potentials (around 10 kPa) (Figure 4). This dramatically lower hydraulic conductivity could lead to zones of depletion around the roots hindering plant water uptake.

Soils and soilless substrates have a particle size distribution that can be defined into three categories: well graded, uniformly-graded, and gap graded (Figure 5). Soil gradation affects drainage and hydraulic conductivity. Traditionally, soils are graded using sieves. However, soilless substrates, which have smaller pores that are part of larger particles (i.e. bark material) cannot be graded in the traditional manner.

The stair step curves of the McCorkle and Turface substrates indicate that there are two air entry points which is typical of gap graded substrates. In gap graded substrates after the large pores have been drained of water it becomes incredibly difficult to move the water out of the smaller pores even though there is still plenty of water available. This is also apparent in the hydraulic conductivity curves where the McCorckle and Turface substrates have lower hydraulic conductivities in the 0 to 5 kPa range than any of the other substrates and soils. the unsaturated hydraulic conductivity is now primarily controlled (and limited) by the air-filled pores. The low hydraulic conductivity limits the movement of the remaining water in the substrate even though there is still "available" water. The stair step curves would have been missed using traditional methods for generating soil moisture release curves.

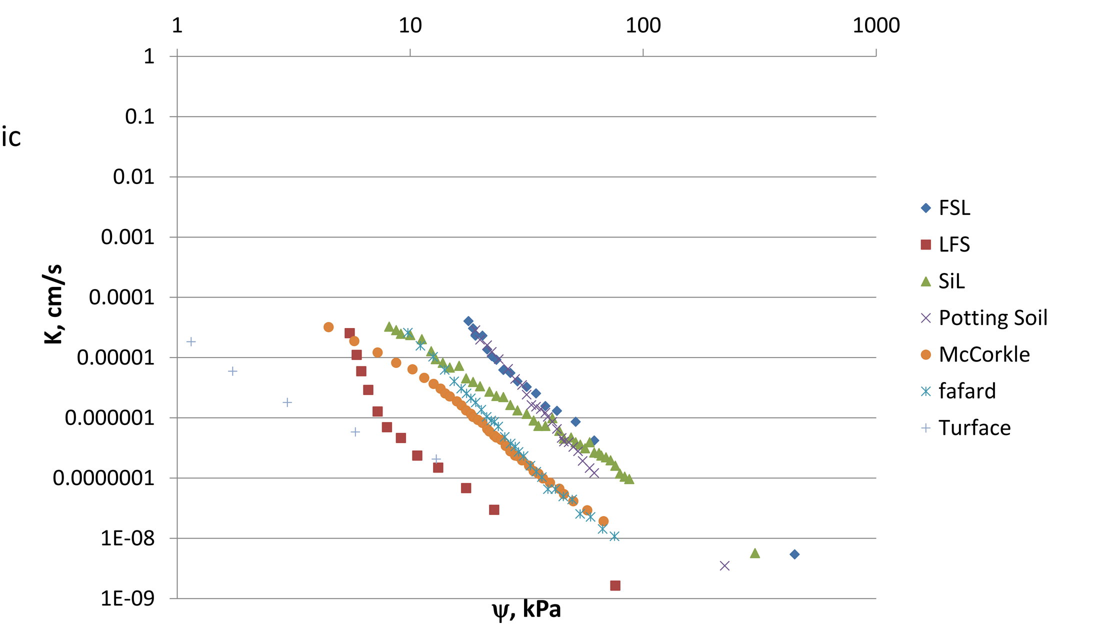

Figure 4: Unsaturated hydraulic conductivity (K) at different water potentials (ψ) for typical agricultural soils and soil-less substrates based on HyProp measurements.

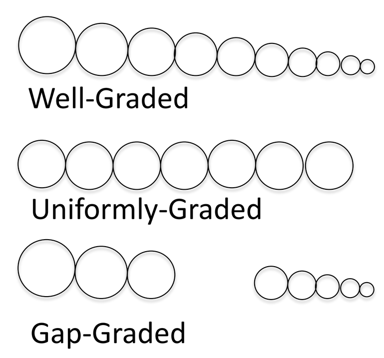

Figure 5: Example of pore-size distribution for well-graded, uniformly-graded, and gap-graded soils.

Conclusions

- Hydraulic conductivity can have a major effect on accessibility of water to plants even when it seems there would be plenty of available water.
- High resolution soil moisture release curves are needed to capture important information about the hydraulic properties of soils and soil-less substrates.

References

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