Soil Nutrient Effects on Suction and Volumetric Water Content in Heavily Compacted Vegetated Soil

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Abstract. Previous studies demonstrated that soil nutrients help plant growth and enhance the stability of bio-engineered slopes through plant-induced soil suction. Therefore, soil nutrient effects on the variations of suction and volumetric water content (VWC) in heavily compacted soil during evapotranspiration need to be studied. In this study, three replicates of *Schefflera heptaphylla* (Ivy tree) were grown for 6 months in nutrient poor and nutrient supplied compacted soil. Soil suction and VWC changes during drying of vegetated soils were measured after 3 and 6 months of plants growth. After the 3rd and 6th month of drying, suction increased by 5–10 kPa and 15–40 kPa, respectively in nutrient supplied vegetated soil compared to the nutrient poor soil due to increase in leaf area index (LAI) and root area index (RAI). In contrast, soil VWC was higher in all the vegetated soils after drying on the 6th month compared to the VWC after drying on the 3rd month. This might be due to soil-pore structure changes via bio-chemical root activities and organic matters.

Keywords: Vegetation · Nutrient · Suction

1 Brief Introduction and Methodology

Chemical composition of soil affects plant-growth and their effectiveness on infrastructures via hydrological reinforcement due to plant-induced soil suction changes [1]. NPK slow-release granular fertilizers are used for bio-engineering techniques in Hong Kong but lengthen establishment time of plants due to slow utilization of the fertilizers by plants, impairing their survival rate after transplantation [2, 3]. NPK fertilizer in a liquid form has shown to be a suitable substitute for a faster acclimation of plants in heavily compacted soil (used for man-made slopes) [7]. However, effects of NPK water soluble fertilizer on soil suction and volumetric water content (VWC) changes during drying of vegetated heavily compacted soil are not yet understood. This study investigates the effects of NPK (Nitrogen-Phosphorous-Potassium) water soluble fertilizer on the soil suction and VWC changes during drying of heavily compacted (Relative Compaction-95%) silty sand vegetated with Schefflera heptaphylla.

Six columns were constructed with an inner diameter of 200 mm and a height of 400 mm. Completely decomposed granite (CDG) soil was compacted up-to 390 mm

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depth at a RC of 95% (corresponding to a dry density of 1777 kg/m^3 and 12% moisture content) [7]. An individual *Schefflera heptaphylla* (Ivy tree) was transplanted at the centre of the six columns with similar basal diameter (10 ± 2 mm) and root depths (125 ± 10 mm) for fair comparison. Four miniature tip tensiometers at 50, 130, 210 and 290 mm depth were installed at the centre of the columns. SM-300 probes were installed at 50 and 130 mm depth right next to the tensiometer to monitor VWC (See Fig. 1). All columns were placed in a temperature (25 ± 1 °C) and humidity (55 ± 5%) controlled room under a cool white fluorescent lamp for the whole testing period. Two test series were conducted; one series with nutrient supply in soil and another series without nutrient supply. For each series, 3 replicates of plants (total 6 plants) were grown for 6 months while continuous measurements of suction and VWC were monitored. Every 2 days, all columns were irrigated with similar amount of water and every 8 days 3 columns were instead irrigated with NPK (30-10-10) nutrient (2 gm) mixed with water (1 litre). At the end of the 3rd and 6th month, ponding head was applied on the surface of all soil columns until suctions at all four depths registered 0 kPa and percolation through the holes at the column base was observed. Then the columns were exposed to the environment to quantify the effects of evapotranspiration by the plant and soil on suction and VWC responses.

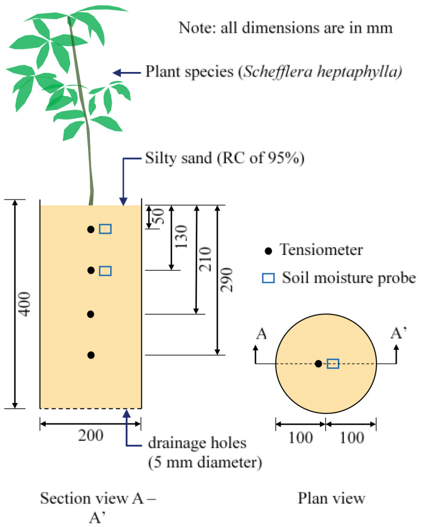

Fig. 1. Typical schematic setup and instrumentation of a tree-vegetated column in (a) Cross section view A–A' and (b) Plan view.

2 Interpretation of Test Results

Figures 2-(a) and (b) show the suction and VWC changes during 3 days of drying for vegetated soil with and without nutrient supply at 50 mm depth on the 3rd and 6th month. In Fig. 2-(a), bare soil suction was minimal (2–3 kPa) after drying for 3 days.

Vegetated soil suction increased by 15–75 kPa compared to bare soil due to water uptake by roots [5] and transpiration through stomata of leaves [4]. During drying on the 3rd month, 5–10 kPa more suction was observed in the nutrient supplied vegetated soil compared to the nutrient poor vegetated soil. This is due to the 50%–120% increase of LAI in nutrient supplied vegetated soil [7]. Both on the 3rd and 6th month, similar magnitude of suction was observed during drying in nutrient poor vegetated soil due to similar range (0.3–0.8) of LAI [7]. However, during drying on the 6th month, suction increased by 15–40 kPa in the nutrient supplied vegetated soil compared to the nutrient poor vegetated soil. This is because of the 160%–200% increase of LAI and 133% increase of RAI at 50 mm depth in nutrient supplied vegetated soil [7]. Larger root surface area can uptake more water [5] and larger leaf surface area has more stomata for water-transpiration in the atmosphere [4]. Moreover, 18–38 kPa suction increased on the 6th month in nutrient supplied vegetated soil compared to the suction measured on 3rd month due to 50%–70% increased LAI [7]. Increased soil suction can reduce soil permeability and increase soil shear strength [6].

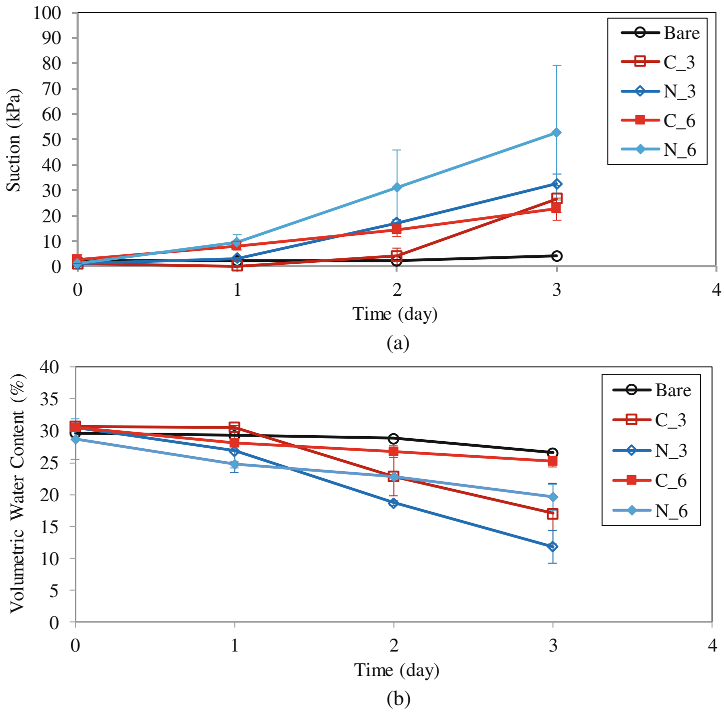

Fig. 2. Measured variations of (a) Suction and (b) VWC with time at 50 mm depth during drying of nutrient poor and nutrient supplied vegetated soil on the 3rd and 6th month of plant growth which are represented by 3 and 6, respectively. “C” represents the controlled tests without nutrient supply and “N” represents the tests with nutrient supply.

In Fig. 2-(b), during drying on the 3rd and 6th month, 3%–12% difference in VWC was observed between bare and vegetated soils and VWC decreased 6%–8% in nutrient supplied vegetated soil compared to the nutrient poor vegetated soil. Interestingly, VWC was higher in all vegetated soils during drying on the 6th month compared to the VWC on the 3rd month in contrast to the soil suction changes in Fig. 2-(a). This might be because of the biological factors such as the release of root exudates, organic matter or organic acid which takes place mainly within 2 mm from the root surface [8, 9]. These bio-chemical root activities and organic matters might have altered the soil pore structures which affected the VWC measurements in soil pores [9].

3 Conclusion

This study investigated the effects of NPK water soluble fertilizer on the soil suction and VWC changes during drying of heavily compacted (RC-95%) silty sand that were vegetated with *Schefflera heptaphylla* (Ivy tree) in a soil column.

During drying on the 6th month, suction increased by 15–40 kPa in the nutrient supplied vegetated soil compared to the nutrient poor vegetated soil due to increase of LAI and RAI. In contrast, soil VWC was higher in all vegetated soils during drying on the 6th month compared to the VWC during drying on the 3rd month due to changes in soil-pore structures through bio-chemical root activities and organic matters.

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