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HYDROMECHANICAL REINFORCEMENT OF PLANT ROOTS TO SOIL SLOPES

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Background

The use of vegetation to stabilise natural and man-made slopes has gained increasing interest as an environmentally friendly alternative to traditional engineering methods. Plants affect soil shear strength via (i) mechanical reinforcement provided by root anchorage (e.g., Boldrin et al. 2017b; Loades et al. 2013) and (ii) hydrologic reinforcement induced by transpiration as soil strength increases with soil drying (e.g., Boldrin et al. 2017a). Coupling effects between these two reinforcement mechanisms are not fully understood. The presentation will share some latest field and laboratory findings about the root drying effects due to plant transpiration on root biomechanical properties and soil strength.

Materials and methods

A full-scale field embankment (20 m wide, 3 m high, mean gradient of 45^o) at the James Hutton Institute, Dundee (UK, 56°27'N, 3°4'W) was used for planting, instrumentation and monitoring. The embankment was made of well-graded sand with gravel (SW) compacted at an average dry density of 1690 ± 53 kg/m^3. Three woody species that are widely spread in Europe, namely *Corylus avellana* L. (Ca), *Ilex aquifolium* L. (Ia) and *Ulex europaeus* L. (Ue), were transplanted. The embankment was divided into 20 plots, each of which was 0.5 m wide and planted with a test species (5 plants per plot) or left fallow for control. Hence, five replicates of each species were tested. Soil matric suction (Ψ_r) changes at 0.3 and 0.5 m depth were monitored from Aug 2016 to Oct 2017. Vane shear tests were conducted at 0.15 m depth at selected days.

To assist the interpretation of the field data and better understand the plant hydro-mechanical reinforcement mechanisms, Ue roots were sampled for laboratory biomechanical testing. Root specimens of different diameter classes were initially fully hydrated and were then left air dried on the bench in a controlled environment. At selected elapsed time, changes of root diameter and root water content were measured by a stereo microscope and a 3-decimal-place electronic balance, respectively. Uniaxial tensile tests (2 mm/min) were conducted to measure root tensile strength (T_r) at different root water content using a universal testing machine.

Key findings and discussion

During dry summer days (Fig. 1a), Ue induced much higher suction than the other two species, Ca and Ia, translating to higher peak vane shear strength (94 ± 14 kPa; mean ± standard error) contributed by hydromechanical reinforcement. On wet autumn days (Fig. 1b), some Ue replicates still contributed greater mechanical reinforcement to the soil, than the other species, resulting in peak vane shear strength up to 78 kPa (e.g. Ue5). Comparisons of the test results in Figs 1a and 1b suggest that transpiration-induced suction of 53 ± 9 kPa by Ue caused additional vane shear strength of 46 kPa (> 95%). We hypothesize that this is not only due to the increase in soil shear strength as suction increases (which is well-recognised), but could also be partly

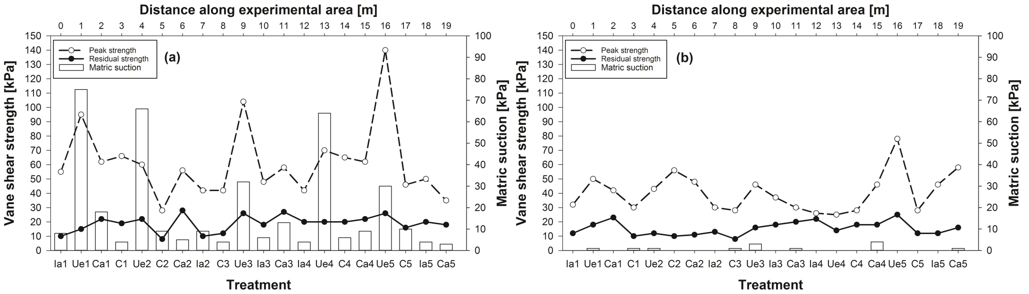

Figure 1. Vane shear strength measured in the 20 panels along the embankment (0.15 m depth) on a dry day on 17th Aug 2016 (a) and a wet day on 19th Oct 2016 (b)

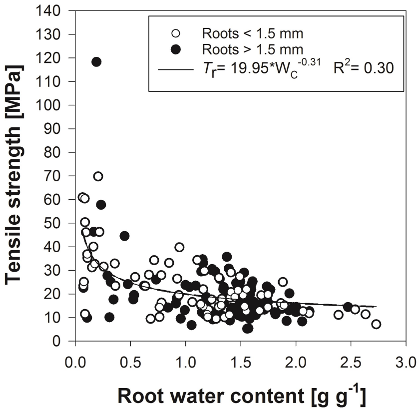

Figure 2. Root tensile strength-water content curve

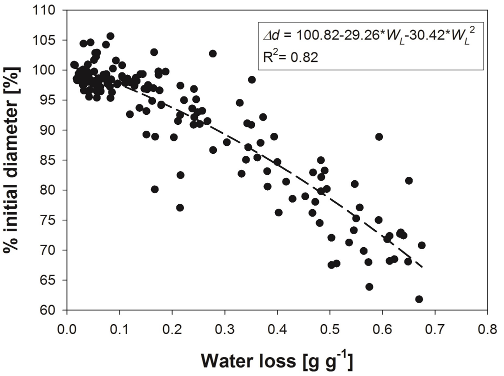

Figure 3. Effects of root moisture lost on diameter

attributable to increase in T_r as roots dry during water uptake (Fig. 2) – an evidence of coupled root hydromechanical reinforcement. A faster increase in T_r is observed when roots become drier than 1 g g^{-1}.

Root tensile strength was determined by dividing root tensile force by root cross-section area. The T_r reported in Fig. 2 was determined using the final root diameter after drying, and so T_r dependence on root moisture is partly due to shrinkage of root diameter as the roots lose moisture (Fig. 3). On-going constant-load root drying tests showed root tissue contraction and hence tensile force increase (data not shown), contributing to the observed increase in T_r in Fig. 2. More findings will be given in the presentation.

Keywords: Soil Bio-engineering, plant hydromecahnical reinforcement, matric suction, plant transpiration, root biomechanical properties, root water content.

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