The root-soil interface during uprooting

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Introduction

Pullout resistance of root systems has been investigated previously (Mickovski and Ennos 2003), but behaviour of the root-soil interface during pullout remains unclear.

We monitored planar soil deformations around roots during pullout, using an optical flow analysis of digital images - based on particle image velocimetry (PIV; White et al. 2003).

Figure 1. Experimental setup. Roots were pulled out at a constant rate while digital photos were taken at regular intervals.

Materials and Methods

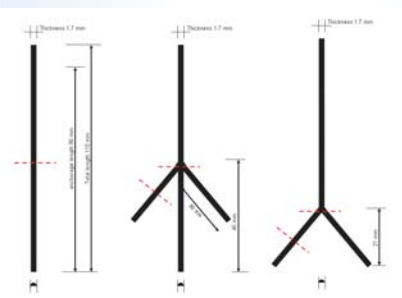

Figure 2. Idealised root architectures used in this study. Red dashed lines show the planes where soil movement was traced.

Root architectures tested (Fig 1): Taproot (T), herringbone (H) and dichotomous (D).
Root analogue materials tested: vitron rubber and balsa wood.
Soil media: dry loose sand (LS; γ_d=1.48 g/cm^3), dry dense sand (DS; γ_d=1.69 g/cm^3), lose sandy loam soil (LC; γ_d=1.2 g/cm^3), dense sandy loam (DC, γ_d=1.4 g/cm^3), partially saturated sand (WS). Dimensions and sampling planes are shown in Fig 2.
Pullout: 5mm/min, timelapse images 10 min apart (1min for HBLC).
PIV was used to track soil patches (Fig 3) during pullout. Relative movement of the patches between images is shown by the vector (Fig 3), and absolute deformation is obtained through photogrametic transformation.

Results

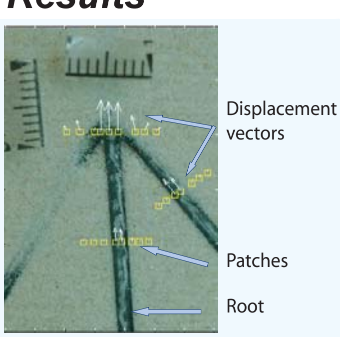

Figure 3. Soil patches (20 pixels) and displacment vectors

PIV showed different trends in soil disturbance around differentroot sections (Fig 4).
Magnitude of soil disturbance decreased with the distance from the root.
Largest disturbance was recorded around the joints; smallest around the taproots.
Larger movements in loose as opposed to dense media. Soil least disturbed in the wet sand.
Rigid balsa wood caused most movement during uprooting.

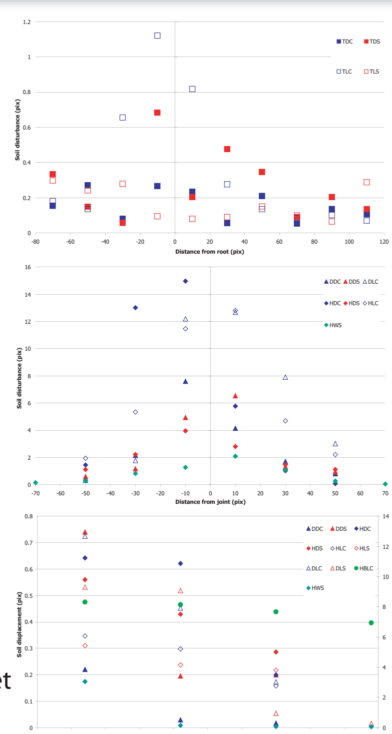

Figure 4. Soil disturbance around taproots, joints and lateral roots in herringbone and dichotomous root patterns

Conclusions

PIV was an appropriate tool for this experimental system.
Soil density, water content, and root mechanical properties strongly affected behaviour of the root-soil composite during pullout.
Soil disturbance around different parts of the root varied greatly with root and soil properties.

Way forward

- track root and soil movement in both pullout and shear.
- track smaller soil patches to study small soil movements at the soil-root interface zone.
- use combined image and stress analysis to investigate the mechanical properties of the root-soil interface zone (Hamza et al., 2004).

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References
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White, D.J., Take, W.A., & Bolton, M.D. 2003. Soil deformation measurement using particle image velocimetry and photogrammetry. Geotechnique 53(7): 619-631.