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Quantification of root-induced shear on sand

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Abstract:

This work presents an innovative experimental investigation on the mechanical response of sand to plant root growth. Root-soil interaction is investigated using the Maize root system growth in two different gradings of Hostun sand with two initial porosities. An original protocol is developed aiming to create samples with repetitive initial nominal properties and representative of the natural interaction. A 4D (3D+time) analysis is run on a series of samples with different initial properties. *In-vivo* observations of the root-soil interaction are carried out by using x-ray computed tomography. For each sample, a time-series of x-rays scans is performed, from the day of the seed sowing up to 7-days-old root system. An image processing technique has been developed and it is applied to the 3D images resulting from the reconstruction of the x-ray scans.

Through this image processing, the entire root system is identified, together with the sand grains and the water present in the system. Finally, a four-phased volume representative of the soil-root system can be defined for each state of the observed samples. Besides, from the 3D greyscale images of the samples, measurements of the kinematics of the system are obtained through local and discrete approaches of 3D digital image correlation (DVC). The porosity is measured with respect to the root position, and the results are in line with the one found in literature[1,2]. The comparison among different soil configurations shows, among other things, that the sand density plays a key role on the expansion and growth of the root systems.

The sand response to the root growth measured through the strain tensor computed with image correlation shows that a root shears the soil while growing and the sheared zone is wider when the initial bulk density is lower. Focusing the attention on the sand volumetric response to the root-induced shear, a dependency on the soil density is found. On the one hand, the root- induced shear translates into a dilatant response of the soil in the root vicinity, independently from the initial soil properties. On the other hand, as the shear effects dissipate with the distance from the root, sand response is purely dilatant for denser initial states, while the looser sand exhibits a contractant behaviour.

[1] Lucas, M., et al. (2019). *'Roots compact the surrounding soil depending on the structures they encounter', Scientific reports 9(1), 1–13.*
[2] Helliwell, J., et al. (2017).*'The emergent rhizosphere: imaging the development of the porous architecture at the root-soil interface', Scientific reports 7(1), 1–10.*