agropolis fondation

The mechanics of root growth

Rosom - Influence of mechanical root-soil intercations on the variability of root architecture

ABSTRACT

In a review article, Forde (2009) suggests that most of the phenotypic variability of plant root architecture is related to the developmental instability of meristems, a consequence of stochasticity at the cellular level. He suggests further that this "random" component (or noise) is good for the plant because it facilitates access to resources in heterogeneous soils. Starting from this point, we make the assumption that, in a granular soil, the structure and organization of grains are also deterministically involved in the variability of root shapes observed in nature.
Figure 1 : Growth of rice plants in the Rhizoscope, CIRAD, under controlled hydroponic conditions. Roots are developed within a granular medium composed of transparent glass beads (Photo credit : Alain Audebert, CIRAD)

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Project leader : Thierry Fourcaud Farhang Radjai
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GOAL

The main objective of this project was to understand and quantify the mechanical feedback between growing roots and a deformable granular substrate through a transformative interdisciplinary approach based on physics of granular materials. The methodology was built on 1- experiments of root growth in glass beads (ballotini) of different sizes carried out in the Rhizoscope plateform available in CIRAD, Montpellier; 2- Discrete Element Modelling (DEM) that will consider growing wire inclusions in a granular structure.

RESULTS

Experimental data:
Four different plant species, i.e. rice, pea, eucalyptus and date palm tree, were grown in hydroponic conditions within glass beads of different sizes (1mm and 5mm in diameter) Growth was followed recording pictures at different times for about 1 month. Variability of root shapes was then analysed with regards to the granular medium structure (see Fig. 1).
Development of a root analysis software :

Covering polygons were used to evaluate form features or to classify the growth strategy of root systems. The root system density was quantified through the analysis of hole distribution provided by the decomposition of background regions in circular elements (see Fig. 2).
Development of a DEM of root growth:
The model was developed in 2D using the Molecular Dynamics method. It allowed grain-grain and grain-root tip forces to be quantified during root growth. Force spectra and root flexuosity were analysed with regards to root mechanical properties and granular structure. They exhibited general trends that provided analytical mechanoperception equations. Estimating these forces gives useful information to quantify the biomechanical response of roots. Figure 2 : a- root analysing tool GT-Roots allows estimating space occupation; b- simulated force chains representing the intensity of mechanical contacts; c- example of force spectra calculated at root tip during growth.

PERSPECTIVES

The following steps of this project will be to 1- design a experience that will be closer to the developed 2D model for validation; 2- add branching processes in the growth model; 3- compare experimental and simulated root tortuosities; 4- analyse Rhizoscope data with regards to the force signal estimated with the model.