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GÖTTINGEN CAMPUS PLUS

# Shine a light on the dark side of plants

## Neutron radiography of hydraulic redistribution in roots

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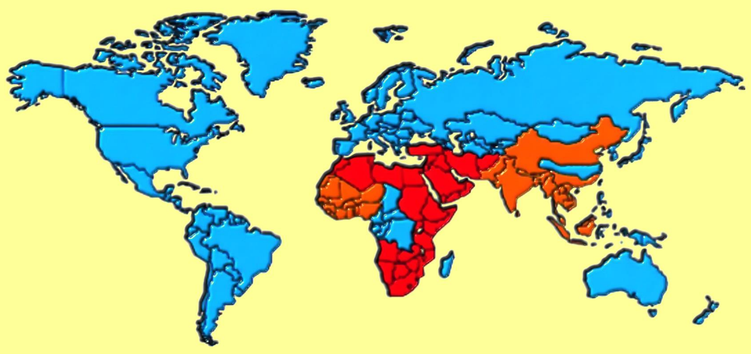
### *Problem: Increasing water scarcity*

Due to climate change there will be increasing water scarcity worldwide. Additionally the demand for food will increase by 50% in the coming 30 years due to the population growth (FAOAquastat, 2013).



*Global water scarcity in 2050. Regions are coded according to their per capita annual renewable freshwater resource. Red-less than 1000 $m^3$ per person per year, orange-between 1000 and 2000 $m^3$ per person per year and blue-greater than 2000 $m^3$ per person per year (data from Fischer and Heilig (1997))*

### *Question:*

How to secure food production for the growing world population in view of the reduced water availability?
Specifically, how to improve the acquisition by crops of the limited water resources? How can we grow more crops with less water?

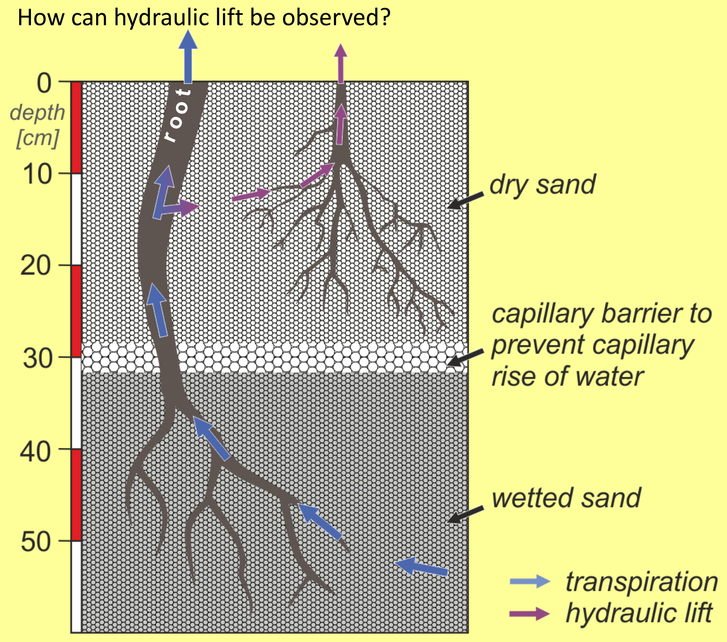
***more crop per drop!***

### *Hypothesis: Hydraulic lift*

- Deep rooted plants lift water from underground and may transport it to the topsoil (Hydraulic redistribution).
- Shallow rooted plants may take up the lifted water and can survive drought thanks to the deep rooted plants (Hydraulic lift).
- Hydraulic lift has an impact on nutrient uptake because nutrients are mainly located in the topsoil
- Hydraulic lift helps crops to tolerate drought and it play an important role in systems like agroforestry.

### *Research questions:*

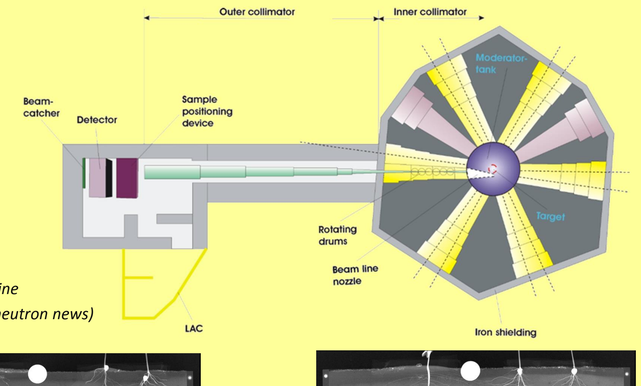
- Does hydraulic lift occur?
- How can hydraulic lift be observed?




### *Material & Methods*

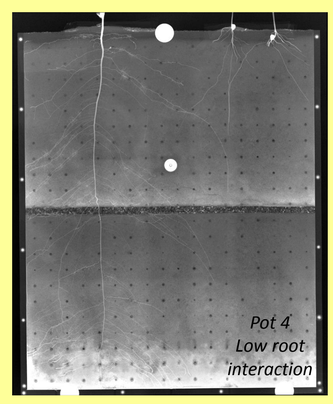
- Plants: lupines (*Lupinus albus* – deep rooted plants) and maize (*Zea mays* – shallow rooted)
- Containers: pots of aluminum with sides of 50 x 60 x 1 cm
- Irrigation: Water was only given to the lupines in the lower parts of the pots
- Neutron radiography was carried out at NEUTRA at the Paul-Scherrer-Institute (PSI) at Villigen (Switzerland)
- Soil and aluminum are transparent for neutron radiography
- Water is hardly to penetrate for neutrons, but deuterium ($D_2O$) is easier to penetrate → water flow inside plants can be observed
- Radiographs were taken every minute
- Deuterium was injected at certain times to follow the flow of water inside and outside of the roots
- The radiographs were processed to minimize effects of background signals and border effects of diffraction
- Processed radiographs were subtracted by the t = 0 radiographs to observe only differences in water content over time

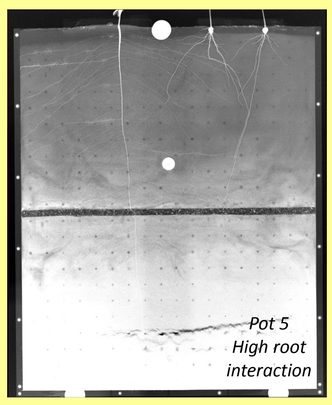

*NEUTRA at the Paul-Scherrer-Institute in Villigen, Switzerland (source: PSI)*




*NEUTRA beamline (source: Swiss neutron news)*


*Development stage of plants in pots before neutron radiography*



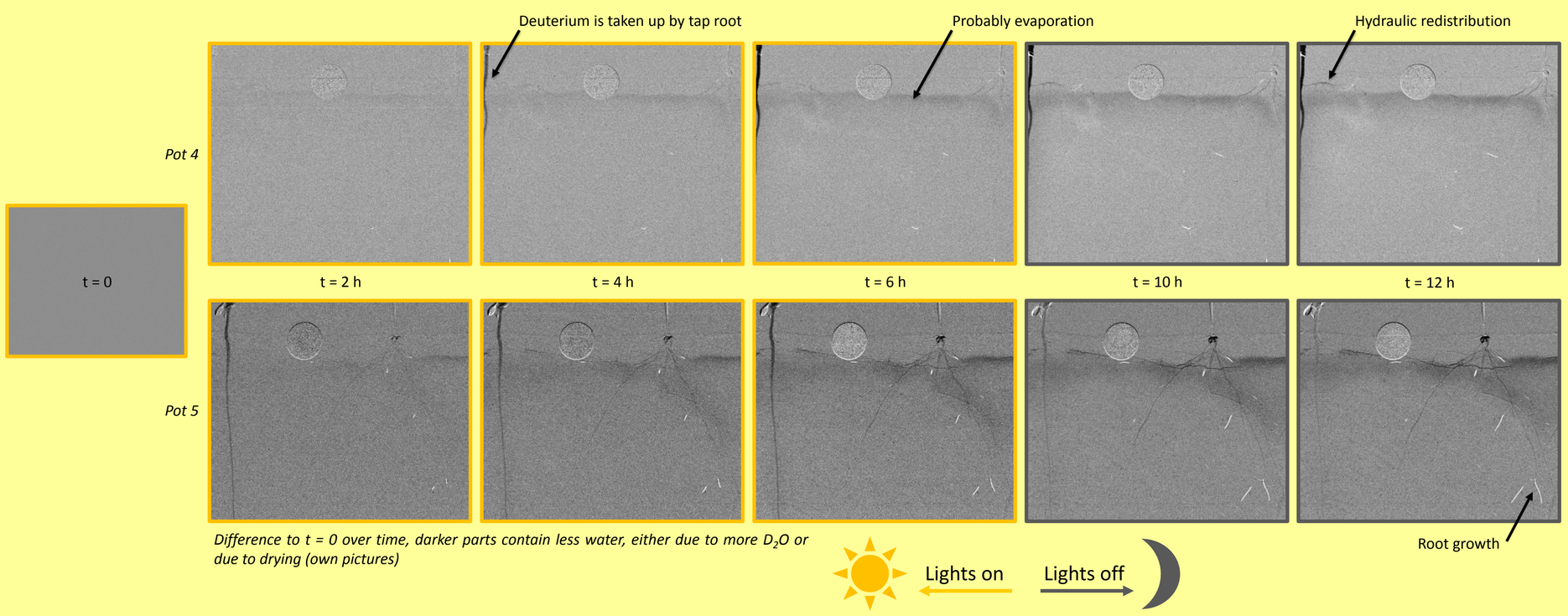




*Pot 4 & 5: Processed and stitched result of a scan with neutron radiography (dark: dry, bright: wet)*

### *Results & Discussion*

- $D_2O$ moved fast upwards in roots of lupine and inside lateral roots.
- There is a clear signal in the maize roots of Pot 5, where roots of lupines are in contact with those of maize! ***Hydraulic lift?***
- could be root shrinkage & root drying or uptake of $D_2O$ -> Hydraulic lift
- A combination of x-ray and neutron radiography could help to interpret the differences

**Hydraulic redistribution was observed and this technology is very promising to observe water flow inside plants and soil**




*Difference to t = 0 over time, darker parts contain less water, either due to more $D_2O$ or due to drying (own pictures)*

Aquastat, www.fao.org/nr/water/aquastat/main/index.stm, seen 10.10.14.
Fischer, G., Heilig, G.K. (1997): Population momentum and the demand on land and water resources. In Philosophical Transactions of the Royal Society (London), Vol. 352, 869–889.
Moradi, Ahmad B.; Oswald, Sascha E.; Menon, Manoj; Carminati, Andrea; Lehman, Eberhard; Hopmans, Jan W. (2013): Applications of Neutron Imaging in Soil-Water-Root Systems, In: Anderson, S. H.; Hopmans, J. W.: Soil-water-root processes. Advances in tomography and imaging (SSSA special publication, 61).
Paul Scherrer Institute, http://www.psi.ch/, seen 23.10.14.

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