Plants create water reserve in soil

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Ahmad Moradi in front of the Climate Chamber in the experimental hall at SINQ, the PSI Neutron Source. Plants are raised here under natural conditions before being investigated. Credit: M. Fischer/PSI

It has long been known that roots alter the soil in their immediate vicinity, where other microorganisms live and the chemical composition is altered compared to that further away from the roots. An international research team has now demonstrated in experiments at the Paul Scherrer Institute that the soil in the vicinity of roots also contains more water – contrary to the earlier belief that there must be less water in this region, as the plant takes up water from the soil. Apparently, however, plants create a small water reserve that helps to tide them over through short periods of drought. These findings could help, in the long term, in the breeding of plants to cope better during periods of drought or in support of the development of efficient irrigation systems. These results were obtained from experiments carried out with the benefit of neutron

tomography at the Paul Scherrer Institute, using a method that makes it possible to exactly show the distribution of water to a fraction of a millimetre, without having to remove a plant from the soil. The researchers have published their results in the prestigious journal *New Phytologist*.

"The question of how plants take up water is not only relevant to the development of new, water-efficient strains of plants, but also for improving climate models," explains Sascha Oswald, from the Institute of Earth and Environmental Science at the University of Potsdam, "because typically more than half of all the water that falls onto the earth's surface as rain in a humid climate is taken up by plants and then passes back to the atmosphere through the plants." A research project at the Helmholtz-Centre for Environmental Research – UFZ where he worked with a number of colleagues had the goal of showing what exactly happens at the place where a plant takes up water through its roots. "Plants take water up from the ground by means of fine roots, a few millimetres in diameter. Their thicker roots serve more as pipelines, to relay the water. We want to understand the water distribution around these roots," explains Ahmad Moradi, from the University of California Davis.

Neutrons reveal water content without damaging plants

"The decisive processes occur here at a scale of a few millimetres. In order not to miss these processes, we need a procedure that shows details that are smaller than a millimetre and that can be applied without needing to remove the plant from the soil," says Moradi of the technical challenge. The researchers found the appropriate method at the Paul Scherrer Institute in the form of neutron tomography. Here, they were able to send neutrons through plants, together with the soil around their

roots. Using these particles, it is possible to see inside different objects, in a similar manner to using X-rays but making different internal components visible. Specifically, neutrons are particularly attenuated and scattered away by water, whereas metal or sand are essentially invisible to them. "Roots consist to almost 90% of water. When one wants to examine them, or the movement of water in the soil, then neutrons are far better tools than X-rays," explains Moradi.

The researchers were thus able to create an exact three-dimensional image of the water distribution around the roots and determine how much water was present at different positions in the soil. "The microscope option of the facility was used for this measurement, so that images with a resolution of 20 pixels per millimetre could be generated. In this way, it was possible to make the water visible to the required accuracy," explains Eberhard Lehmann, whose group operates the facilities at PSI. "We have three measurement stations at which we can create images with neutrons – each with its own characteristics. Thus we were able to try out different options for the experiment. A great advantage of the PSI facility is also that it is in operation 24 hours a day, and thus plants could be observed over a complete day-night cycle." PSI is the only centre in Switzerland at which neutrons are available for research.

More water at the roots

The result obtained from this study is that the soil in a region within a few millimetres from roots contains about 30% more water than the rest of the soil. It has long been known that roots significantly alter their immediate environment. In this so-called rhizosphere a much higher number of different microorganisms than elsewhere can be found. They profit from organic root excudates. "Because of the water uptake by roots it has been assumed as a matter of course that the water content close to the roots is decreased and that water is flowing along a gradient

towards the roots" explains Hans-Jörg Vogel from the Department of Soil Physics at UFZ. . The experiments contradicted this belief, for all three types of plants tested – maize, lupines and chick peas.

Water reserve for bad times

"We can now only speculate about the question as to how the water concentration around the roots becomes higher. It is probable that a gel-like substance that the roots exude is responsible. This substance can absorb 10,000 times its own dry weight of water. In this way, plants could create an emergency supply for short periods of drought," explains the soil physicist Andrea Carminati, from the University of Göttingen. Even if this emergency supply does not suffice for longer periods of drought, it can help cover periods of up to 12 hours in which the plant would otherwise be cut off from a supply of water. "If one thinks about the practical applications of these results, then they can help in the breeding of plants which can survive dry periods better. One could also learn exactly how much to water plants, so that they do not come to long-lasting harm through drying out," adds Sascha Oswald.

More information: Moradi, A.B., Carminati, A., Vetterlein, D., Vontobel, P., Lehmann, E., Weller, U., Vogel, H.-J., Oswald, S.E. (2011): Three-dimensional visualization and quantification of water content in rhizosphere. New Phytol. dx.doi.org/10.1111/j.1469-8137.2011.03826.x

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