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Dynamics of air gap formation around roots with changing soil water content.

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Most models regarding uptake of water and nutrients from soil assume intimate contact between roots and soil. However, it is known for a long time that roots may shrink under drought conditions. Due to the opaque nature of soil this process could not be observed in situ until recently. Combining tomography of the entire sample (field of view of 16 x 16 cm, pixel side 0.32 mm) with local tomography of the soil region around roots (field of view of 5 x 5 cm, pixel side 0.09 mm), the high spatial resolution required to image root shrinkage and formation of air-filled gaps around roots could be achieved. Applying this technique and combining it with microtensiometer measurements, measurements of plant gas exchange and microscopic assessment of root anatomy, a more detailed study was conducted to elucidate at which soil matric potential roots start to shrink in a sandy soil and which are the consequences for plant water relations. For Lupinus albus grown in a sandy soil tomography of the entire root system and of the interface between taproot and soil was conducted from day 11 to day 31 covering two drying cycles. Soil matric potential decreased from -36 hPa at day 11 after planting to -72, -251, -429 hPa, on day 17, 19, 20 after planting. On day 20 an air gap started to occur around the tap root and extended further on day 21 with matric potential below -429 hPa (equivalent to 5 v/v % soil moisture). From day 11 to day 21 stomatal conductivity decreased from 467 to 84 mmol m-2 s-1, likewise transpiration rate decreased and plants showed strong wilting symptoms on day 21. Plants were watered by capillary rise on day 21 and recovered completely within a day with stomatal conductivity increasing to 647 mmol m-2 s-1. During a second drying cycle, which was shorter as plants continuously increased in size, air gap formed again at the same matric potential. Plant stomatal conductance and transpiration decreased in a similar fashion with decreasing matric potential and appearance of air gap as during the first cycle. Microscopic assessment of the tap root at day 31 showed that secondary thickening of the taproot occurred all along the region of interest observed during X-ray tomography. A large part of the cross sections consists of lignified tissue; no root hairs could be observed along the tap root.

Gaps are expected to reduce water transfers between soil and roots. Opening and closing of gaps may help plants to prevent water loss when the soil dries, and to restore the soil-root continuity when water becomes available.