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Water uptake by plant roots : Experimental and modelling study of water transfer in the soil / root system at the plant scale

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Soil water extraction by roots results from plant and soil transport processes interacting at different space and time scales and there is a need to link these processes on a formal basis. Specifically, architectural and physiological characteristics of the root system, as well as soil heterogeneity, are poorly taken into account in water uptake studies. This work aims at studying root water extraction at both the single root and root system scales, illustrating the influence of root system architecture and soil hydraulic properties on water uptake and imaging time variation of water depletion around roots. We worked with blue lupin plants whose root system architecture ranged from tap rooted to fibrous. Plants were grown in large rhizotron filled with sandy or loamy soil. Water transfer and uptake in the soil were determined in laboratory experiments with 2D imaging techniques: light transmission and X-ray imaging. This allowed measurement of water content and uptake with time, from the single to root system scales. These data are used in a model of water transfer in the soil/root system which combines the water transfer to/within the root system (hydraulic tree model of the root system) with water transport in soil. A detailed description of water uptake and dynamic, from the single root level to the whole root system, is given by the modelling. During the water uptake process, we clearly show the formation and movement of an uptake front and high gradients of soil water content next to the roots in the sandy soil. In contrast, water content variations were more gradual in the loamy soil. We also show the variations between tap root and fibrous root system during uptake. The simulations show that the soil water content and the root hydraulic conductance distributions have a strong impact on the water uptake.