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Models for root water uptake under deficit irrigation

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Modern agriculture, with its dependence on irrigation, fertilizers, and pesticide application, contributes significantly to the water and solute influx through the soil into the groundwater, specifically in arid areas. The quality and quantity of this water as it passes through the vadose zone is influenced primarily by plant roots. Root water uptake is a function of both a physical root parameter, commonly referred to as the root length density, and the soil water status. The location of maximum water uptake in a homogenous soil profile of uniform water content and hydraulic conductivity occurs in the soil layer containing the largest root length density. Under field conditions, in a drying soil, plants are both subject to, and the source of, great spatial variability in the soil water content. The upper soil layers containing the bulk of the root zone are usually the most water depleted, while the deeper regions of the soil profile containing fewer roots are wetter. Changes in the physiological functioning of plants have been shown to result from extended periods of water stress, but the short term effects of water stress on root water uptake are less well understood. While plants can minimize transpiration and the resulting growth rates under limiting conditions to conserve water, many plants maintain a constant potential transpiration rate long after the commencement of the drying process. Compensatory uptake, whereby plants respond to non-uniform, limiting conditions by increasing water uptake from areas in the root zone characterized by more favorable conditions, is one such mechanism by which plants sustain potential transpiration rates in drying soils.

The development of models which accurately characterize temporal and spatial root water uptake patterns is important for agricultural resource optimization, upon which subsequent management decisions affecting resource conservation and environmental pollution are based. Numerical simulations of root water uptake in various irrigation and fertilization regimes provide a much-needed alternative to tiring and expensive field work. These simulations can aid in raising agricultural water use efficiency while preserving soil and water resources.

In this research, controlled lab experiments were carried out in soil-packed lysimeters designed for plant cultivation. Both the water balance of the growing plants as well as the temporary matric head distribution in the soil profile were calculated and measured. The experiment was conducted with sweet sorghum grown in two different soil profiles with different hydraulic properties. The experiment provided the data necessary to calculate the parameters of various models used to simulate root water uptake, by using an inverse solution method imbedded in the HYDRUS-1D code.

The observed increase in uptake from the wetter soil regions under drying conditions, as measured and calculated, sheds light on the dominant role of soil hydraulic properties over the root distribution, and consequently root water uptake.