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Field measured and simulated soil-plant water relations in maize

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Sustaining world food production under a changing climate and a growing population demands for higher optimization of agricultural resources including water. This requires an accurate understanding and prediction of root water uptake from soils, which depends on several root traits. The role of root hairs in root water uptake is still under debate, with experimental data that both prove and reject the hypothesis that root hairs can facilitate root water uptake, especially under drought conditions. Our objective was to investigate the effect of root hairs in maize at the field scale. A wildtype maize variety (with root hairs) and a hairless mutant were grown in two substrates (loam and sand) at a field site near Halle, Germany (Vetterlein et al., 2020, JPLN). Transpiration, leaf water potential, soil water content and potentials were monitored during 2019 and 2020. Root length density and leaf area were measured at four different plant development stages. A version of Hydrus 1D coupled with Couvreur's macroscopic root water uptake model (Couvreur et al., 2012, HESS) was parameterized and used to further investigate soil-water relations in this field experiment. In both years, plants emptied the available water in the profile by July, and relied on rain and irrigation afterwards. Non-significant differences in cumulative water losses from the soil, estimated from soil water content measurements, were observed among the four treatments in both years. These results are in agreement with simulated water losses, which also showed small differences in cumulative transpiration among treatments. Mutant plants developed significantly smaller shoots while transpiring similar water volumes as wildtype plants, indicating lower water use efficiency. While there was no visible effect of the genotype in the soil-water relations, a clear effect of the soil type was observed. Simulated collar water potentials and field observations of rolled leaves indicated water stress occurred first in the loam compared to the sand treatments. Plants grew faster in the loam, leading to earlier onset of water stress. Even though plants in the loam produced less roots than in the sand, the onset of stress was not caused by the smaller root system since simulations presuming a larger root system did not predict a later onset of stress. Similarly, a simulation run using a smaller root system in the sandy soil did not predict a significantly earlier onset of stress. Finally, although our model simulations considered only differences in root density among treatments and did not consider different root or

rhizosphere properties of the different soils and genotypes, it simulated the observed water dynamics well. Water depletion in the loamy soil was simulated earlier than it was measured. We hypothesize that this is caused by changing root hydraulic properties when roots develop and mature, and suggest that young roots do not start taking up water immediately. Nevertheless, the data quantity and quality obtained in this field experiment exposes the difficulties and challenges we face to monitor water potentials and fluxes in the soil-plant continuum in annual grasses at the field scale.