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Assessment of Water Fluxes in the Root Zone of a Flood-irrigated Mature Pecan Orchard in Arid Southern New Mexico

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Tree canopies in mature pecan orchards have potential to modify the microclimate and soil surface conditions, characterized by localized conditions of soil water and thermal regime within tree canopies and outside tree driplines (bare), both of which can influence various water fluxes in unsaturated soils. However, information on various transport mechanisms associated with temporal variations in soil water content and soil temperature under unsaturated bare and under-canopy soil conditions of a flood-irrigated mature pecan orchard are still limited, especially in the lower Rio Grande Valley, a major agricultural area in southern New Mexico and one of the major pecan producers in the nation. Simulations of the coupled transport of liquid water, water vapor, and heat in the unsaturated zone of a mature pecan orchard in the lower Rio Grande Valley, Las Cruces, with (under-canopy) and without (bare) root water uptake were carried out using HYDRUS-1D to simulate isothermal and thermal water flux components. Soil evaporation, transpiration and root water uptake pattern were also simulated. The model was calibrated using TDR-measured soil water content at 5, 10, 20, 40, and 60 cm and soil temperature at 5, 10, 20, and 40 cm depths during a 27-day period (Day of Year (DOY) 204-230, 2009) at bare spot, while the model was validated during a 90-day period (DOY 231-320, 2009) and a 117-day period (DOY 204-320, 2009) at a bare spot and a under–canopy location, respectively. Measured soil water and heat transport parameters, hourly meteorological data, leaf area index, and root length density (RLD) distribution were used in model simulations. The temporal variations of plant water stress indicator midday shaded stem water potential (SWP) in response to the gradually varying rootzone soil water content were monitored. HYDRUS-1D simulated water contents and soil temperatures correlated well with the measured data at each depth and location. Isothermal water flux dominated the soil water movement in bare soils immediately after irrigation, while the contribution of primarily thermal vapor flux increased with increasing soil drying because of upward isothermal and much smaller thermal water, and water vapor fluxes within 20 cm depth. In contrast, isothermal water flux was predominant throughout the under-canopy soil profile. Simulated actual evaporation rate in bare soils showed two distinct evaporation stages: immediately after irrigation when actual and potential rates are similar, and when actual rate decreased with soil drying. Trends of under-canopy actual and potential soil evaporation rates were also similar immediately after irrigation; however, with soil drying, evaporation decreased sharply and actual transpiration substantially contributed to actual evapotranspiration, suggesting depletion of surface soil water due to root water extraction. Soil dry conditions at under-canopy location with the availability of water in deeper depths and water–stressed conditions in upper depths could completely reduce actual evaporation without affecting root uptake or actual transpiration rate. Patterns of uncompensated and compensated root water uptake at under-canopy location were similar immediately after irrigation and followed the RLD distribution. However, compensated water uptake remained always higher during water–stressed conditions, resulting in an increase in cumulative actual transpiration by 15% during simulation period. Sensitivity analysis of water stress index (w) revealed that decreasing w ($0<w<1$) generally increased compensated root water uptake, although not consistently for $0<w<0.5$.