Geophysical Research Abstracts
Vol. 17, EGU2015-**PREVIEW**, 2015
EGU General Assembly 2015

Impact of root growth and root hydraulic conductance on water availability of young walnut trees

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Walnut (Juglans regia L.) is a tree species of high economic importance in the Central Valley of California. This crop has particularly high water requirements, which makes it highly dependent on irrigation. The context of decreasing water availability in the state calls for efficient water management practices, which requires improving our understanding of the relationship between water application and walnut water availability. In addition to the soil's hydraulic conductivity, two plant properties are thought to control the supply of water from the bulk soil to the canopy: (i) root distribution and (ii) plant hydraulic conductance. Even though these properties are clearly linked to crop water requirements, their quantitative relation remains unclear. The aim of this study is to quantitatively explain walnut water requirements under water deficit from continuous measurements of its water consumption, soil and stem water potential, root growth and root system hydraulic conductance. For that purpose, a greenhouse experiment was conducted for a two month period. Young walnut trees were planted in transparent cylindrical pots, equipped with: (i) rhizotron tubes, which allowed for non-invasive monitoring of root growth, (ii) pressure transducer tensiometers for soil water potential, (iii) psychrometers attached to non-transpiring leaves for stem water potential, and (iv) weighing scales for plant transpiration. Treatments consisted of different irrigation rates: 100%, 75% and 50% of potential crop evapotranspiration. Plant responses were compared to predictions from three simple process-based soil-plant-atmosphere models of water flow: (i) a hydraulic model of stomatal regulation based on stem water potential and vapor pressure deficit, (ii) a model of plant hydraulics predicting stem water potential from soil-root interfaces water potential, and (iii) a model of soil water depletion predicting the water potential drop between the bulk soil and soil-root interfaces. These models were combined to a global optimization algorithm to obtain parameters that best fit the observed soil-plant-atmosphere water dynamics. Eventually, relations between root system conductance and growth as well as water access strategies were quantitatively analyzed.