Soil & Tillage Research 155 (2016) 216–224

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

# The influence of water uptake on matric head variability in a drip-irrigated root zone

Sharon Dabach[a,b,*], Uri Shani[a], Naftali Lazarovitch[c]

[a] Seagram Center for Soil and Water Sciences, The Robert H. Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot 76100, Israel
[b] Department of Viticulture and Enology, One Shields Avenue, Davis, CA 95616, USA
[c] Wyler Department of Dryland Agriculture, French Associates Institute for Agriculture and Biotechnology of Drylands, The Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus, 84990, Israel

ARTICLE INFO

*Article history:*
Received 21 March 2015
Received in revised form 14 August 2015
Accepted 18 August 2015

*Keywords:*
Drip irrigation
Tensiometer
Root water uptake
Coefficient of variation

ABSTRACT

Irrigation is a service provided to agricultural crops in order to improve their yields. This is also a rare situation where the location of the costumers (roots) is not known and the heterogeneity in the water delivery system (soil) effects the water distribution. This non-uniformity of soil-plant conditions in the agricultural field complicates decision-making parameters regarding irrigation management (where to place sensors, how many sensors are needed, when and how much to irrigate). Many aspects of this non-uniformity have been studied in the past decades, including soil hydraulic properties, tillage history, irrigation method, sensor location, measured volume, and more. One aspect that has been relatively neglected is how plant roots affect variability. In this work, we focus on the effect that growing roots have on the variability of tensiometer measurements.

Corn seeds were sown in a pre-designed experimental plot that consisted of three very distinct soils (sand, sandy loam, clay) to create high variation in investigated conditions. Subsurface drip irrigation was installed in the plot, and the drippers of the center line were wrapped with geotextile to create a geotextile-drip interface (GDI), i.e., a volume which has preferred conditions for root growth. Tensiometers were installed in the GDI (GDI treatment) and 10 cm away from the drip lines (S10 treatment); the matric head was monitored throughout the season.

The weekly averaged coefficient of variation (CV) of the GDI treatment decreased as the corn plants grew, for each soil type and the entire plot. As time passed and the corn plants grew, CV peaks, due to irrigation, and the duration of high CV decreased because of the increasing influence of root water uptake on fluxes in the measured volume. After harvest, the CV returned to initial values. S10 tensiometers showed higher CV values than the GDI tensiometers during the last week of growth. After harvest, the CV of the S10 tensiometer measurements decreased, contrary to the trend in the GDI tensiometers. The results point to the major influence of roots on matric head variability, first, by decreasing variability with time and second, through the effect of tensiometer location since the GDI tensiometers were located in volumes with high root density. This influence has major consequences regarding the methodology of tensiometer measurements to represent an agricultural field, and might provide means for global guidelines for tensiometer placement and irrigation management.



## 1. Introduction

To achieve an optimal irrigation regime and efficiency, it is essential to combine precise water application equipment and decision support system (Evans and Sadler, 2008). The decision support system comprises sensor networks to collect quantitative information about water requirements of crops. In recent years there has been a plethora of work regarding various sensors and sensor networks for improving irrigation management and efficiency (Capraro et al., 2008; Coates et al., 2013; Evett et al., 2011; Goumopoulos et al., 2014; Greenwood et al., 2009; Lea-Cox et al., 2013; van Iersel et al., 2013; Vellidis et al., 2008). However, information concerning the location of sensors is either non-existent, empirical, experiential, or based on complicated spatio-temporal experiments which are site and crop specific (Capraro

* Corresponding author at: Department of Viticulture and Enology, One Shields Avenue, Davis, CA 95616, USA.
*E-mail address:* sdabach@ucdavis.edu (S. Dabach).

http://dx.doi.org/10.1016/j.still.2015.08.012

et al., 2008; Dobbs et al., 2013; Hagen et al., 2014; Kloss et al., 2014; Pardossi et al., 2009; Phillips et al., 2014; Shi et al., 2015; Soulis et al., 2015; van Iersel et al., 2013). Among these sensors, the tensiometer is considered one of the best and simple devices to measure the matric head in soils (Taylor, 1965) and, hence, water availability. In agricultural fields, tensiometer measurements are used to evaluate a mean matric head, which provides information about water distribution from irrigation and the energy level of the water in the soil. Unlike soil water content sensors which only indicate how much water is in the soil. This information is then used with the concept of a threshold value below which the crops will suffer yield loss. Automated drip irrigation systems often utilize this concept to trigger irrigation. A major obstacle in obtaining a true mean value from tensiometer measurements, at the field scale, lies in the soil spatial variability (Webster, 1966) and root growth patterns (van Iersel et al., 2013), which causes tensiometer measurements to vary depending on their location. The higher the measurement variability, the more tensiometers are needed to evaluate the true matric head mean in the soil. The high costs and regular maintenance required to keep the tensiometers working properly often results in the installation of fewer tensiometers than necessary and hence over-irrigation to reduce the variability of yields (Russo, 1986).

Matric head variability in an agricultural field is caused and influenced by many parameters, which can be divided into two main categories: variability affected by field conditions, and variability affected by the measuring device. Included in the first category are soil hydraulic properties, mean water content, irrigation method, root growth patterns, sensor placement, climatic conditions and tillage history (Assouline et al., 1997; Coelho and Or, 1996; Dabach et al., 2015; de Tourdonnet et al., 2001; Hendrickx and Wierenga, 1990; Hendrickx et al., 1990; Or, 1995; Saddiq et al., 1985; Warrick and Nielsen, 1980; Warrick and Shani, 1996; Yeh et al., 1985). Included in the second category are measurement volume and frequency (Bear, 1972; Bear et al., 1968; Hendrickx et al., 1994; Shani et al., 2007). The wide-ranging research presented above has produced many solutions and procedures to overcome the problem and find the optimal locations for sensors. However, most of the procedures require extensive knowledge and work in order to characterize the field, and then the conclusions are valid only for the same soil, irrigation method and crop tested, rendering these methods useless for farmers.

A great deal of work has been dedicated to investigating how the spatial and temporal variabilities in soil water, matric head, aeration, and mechanical strength affect root distribution and activity (Armstrong and Drew, 2002; Bengough and Mullins, 1990, 1991; Herkelrath et al., 1977; Kaspar and Bland, 1992; Kay et al., 2006; Lampurlanes and Cantero-Martinez, 2003; Michelakis et al., 1993). On the other hand, there has been very little research into the influence of root growth and water uptake on water content and matric head variability. Root water uptake is assumed to have a negligible effect on matric head variability relative to the variability imposed by soil hydraulic properties (Clapp et al., 1983), because transpiration does not vary substantially in the field compared to the hydraulic properties of the soil. However, root water uptake of oak trees was found to be central to water content spatial variance, especially in dry soil conditions (Katul et al., 1997). Recently, Tripler (2012) found that the root development of onions reduced the representative elementary volume, REV, from 120 l at the early stages of development to 50 l when plants were well developed. To date, there seems to be no work that has investigated the effect of the developing crop roots on the variability of point measurements, even though theoretically, a tensiometer placed in the root zone should have a different reading than a tensiometer placed outside the root zone even if the soil is homogeneous. In previous work, Dabach et al. (2015) studied the variability of matric head measurements, using a numerical model, under a static root distribution, obtained by applying a geotextile material around buried drippers (GDI). They established that the geotextile material forms a preferred volume for root growth and that tensiometers installed in the GDI display lower variability of measurement by reducing the effect of soil spatial variability on measurements. Based on this, the objective of the present work was to evaluate the effect of crop root system on the variability of tensiometer measurements, with the underlying hypothesis that measuring matric head in a synthetic, standard medium will lower measurement variability at the field scale. Geotextile wrap around buried drippers will act as such a medium, will serve as a preferred medium for root growth, and will increase the effect of roots on the matric head there relative to the soil. Therefore, the measurements will be less sensitive to the spatial and temporal variations of soil hydraulic properties.

## 2. Materials and methods

### 2.1. Geotextile tensiometer (GT)

The tensiometer structure was modified in order to allow for better contact between the tensiometer and the outside of the dripper outlet based on the design of Segal et al. (2008). The GT (Fig. 1A) consisted of four parts a 10-mm-diameter polypropylene case, a cellulose nitrate filter with pore size 0.45 μm (Bel Gar LTD., Jerusalem), a geotextile wick (500 g $cm^{-2}$, Noam-Urim, Kibbutz Urim), anda 5-mm-diameter tube. The filter sat inside the case and served as an air entry barrier. The geotextile wick was inserted into one end of the case and connected the filter with the soil. Air entry

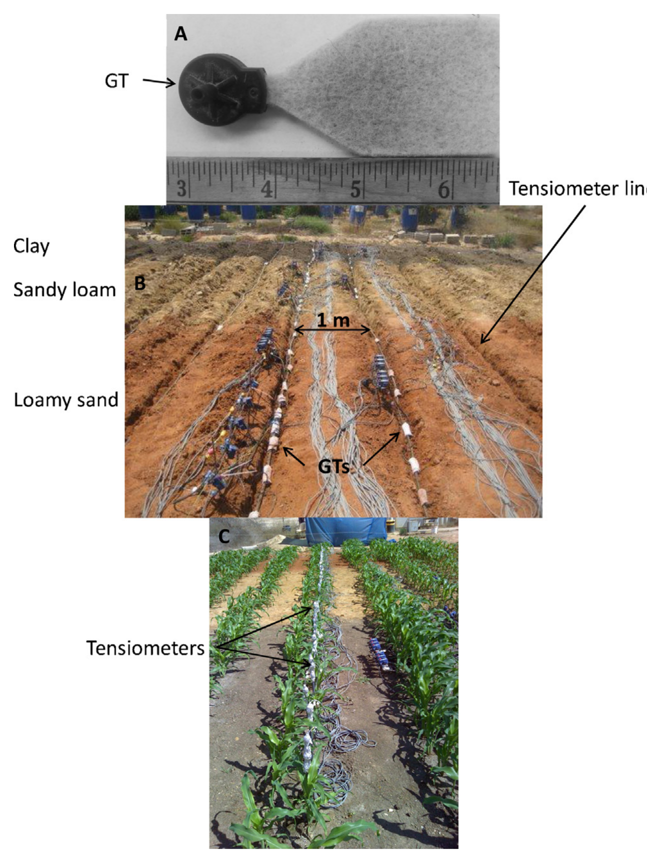


**Fig. 1.** (A) the structure and size of a GT, (B) experimental plot with three soils, two laterals showing the installation and positions of the GT and where the tensiometers were installed, and (C) the location of the tensiometers.