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Water relations and productivity of sugarcane irrigated with domestic wastewater by subsurface drip

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ABSTRACT

The water scarcity is one of the main factors contributing to the reduction of productivity in agricultural crops, and the use of alternative water source in the irrigation is an option to minimize water stress. The objective of this study was to evaluate the water relations, vegetative growth, productivity and technological quality of sugarcane irrigated with treated domestic sewage by subsurface drip during its second ratoon. The research was performed at the School of Agricultural Engineering of the State University of Campinas—SP, through a randomized block design with five treatments, with two depths of dripper lines installation and two water sources, which are: irrigation with wastewater from domestic sewage applied to 0.20 m depth, and to 0.40 m, irrigation with fresh water from a surface reservoir to 0.20 m depth and to 0.40 m and finally non-irrigated plots. Irrigation management was performed following the soil water balance through the time-domain reflectometry technique and all irrigated treatments were fertigated according to the water source applied. Leaf water potential, chlorophyll, gas exchange, leaf nutrition, vegetative growth, productivity and quality technological were measured during the second ratoon of sugarcane. Soil moisture changed according to the depth of the dripper lines installation, being higher for irrigated treatments. The leaf water potential, chlorophyll, gas exchange and nitrogen and magnesium concentration in the leaves also were higher for irrigated plots. The irrigated treatments with sewage had the largest stem and sugar yield compared with the rainfed, being the dripper line irrigated with sewage to 0.20 m presenting the greatest differences reaching 95% and 86% with a productivity of 233.69 Mg ha^{-1} and 37.06 Mg ha^{-1} for stem and total recoverable sugar, respectively; however, there were not significant differences between the irrigated plots. The technological quality of sugarcane was considered appropriate to all treatments.

1. Introduction

The sugarcane is originally from Southeast Asia, however, mainly due to edaphoclimatic conditions and areas available, Brazil became the world's largest producer, with an estimated area planted to the harvesting 2016/2017 of 9 million hectares with almost 700 million tons total. However, most crops are rainfed, which makes the national average productivity be considered low (76 Mg ha^{-1}) in relation to irrigated crops, pushing the expansion of sugarcane to new areas to supply the demand for biofuel and sugar influenced by population growth (CONAB, 2016).

Several studies in Brazil shows irrigation increases the sugarcane productivity in relation to non-irrigated crops, as verified by Bastos et al. (2015) at Midwest, Pires et al. (2013) at Southeast and Oliveira et al. (2011) at Northeast. This is because the water has a import role on the plant metabolism and its unavailability in the soil causes the reduction of leaf water potential, decreasing the gas exchange and negatively affecting the assimilation of CO_2 in chloro-

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plasts, limiting the production of assimilates to the development and production of sucrose (Taiz and Zeiger, 2013). Gonçalves et al. (2010) observed a significant reduction in stomatal conductance, transpiration, photosynthesis and water-use efficiency for non-irrigated plots in several sugarcane varieties under water stress in Brazil.

However, the lack of rainfall and the water resources scarcity for irrigation in recent years at the largest Brazilian producer centers of sugarcane (center-south of the São Paulo State) has been aggravated, and there is no water sufficiently available to the irrigation to supply the crop water demand throughout your growing season. According Doorenbos and Kassam (1994), sugarcane needs 1500–2500 mm of water to the entire cycle.

Given the above, a water alternative for irrigation to increase the productivity in sugarcane would be the use of treated domestic wastewater reuse (TDW), which in addition to providing savings on water and fertilizer also avoids the contamination of aquatic environment, keeping the fresh water for human and animal consumption, preserving still the fauna and flora aquatic of this waste (Thapliyal et al., 2013).

On the other hand, depending on the volume and irrigation frequency, TDW can adversely affect the agricultural production due to its high concentration of nutrients and salts, which reduces the water availability for the plants from the reduction in water potential in the root zone. The stress caused by Na^+ in the plant causes an antagonistic effect on K^+, reducing its concentration mainly in the leaves (Blumwald, 2000), affecting the regulation of opening and stomatal closing (Taiz and Zeiger, 2013) and consequently the productivity. In a study done by Leal et al. (2009), the TDW increased the Na^+ concentration in an Oxisol cultivated with sugarcane after 16 months under subsurface drip irrigation (SDI) with application of different effluent levels (from 100% to 200% the crop water demand); however, the productivity of irrigated treatments were statistically higher than without irrigation.

Among the different irrigation methods, the SDI appears as the safest to the application of TDW to crops, because it allows to apply the effluent directly on the root zone at low flow rates and high frequency reducing the leaching and evaporation, increasing the absorption efficiency of nutrients and water (Yao et al., 2011) thereby preventing the contamination of groundwater and the contact with the external environment, as well as keeps a superficial portion of the soil relatively dry reducing weeds development. In this regard, Charlesworth and Muirhead (2003) argue one of the most noted aspects is the proper installation depth of the dripper lines considering the structure and soil texture, and also the pattern of development of the root system.

Historically in Brazil, vinasse (waste from the ethanol production) is the residue commonly applied as alternative nutrient source in sugarcane, mainly due to short distance between cultivated areas and sugar–ethanol mills (De Resende et al., 2006). In relation to the TDW, despite being a water source potential in Brazil, its using is not applied to the irrigation of sugarcane, mainly due to lack of research that ensure the sustainability of its application in food production.

The objective of this study was to evaluate the water relations, vegetative growth, water quality, productivity and technological quality of sugarcane irrigated with treated domestic wastewater by subsurface drip during the second ratoon (third growing season).

2. Materials and methods

2.1. Study area and experimental design

The study was performed in the experimental field at the Faculty of Agricultural Engineering of the State University of Campinas, Campinas—SP, located at 22° 53′ S and 47° 05′ W at an altitude of 620 m. This research is part of a pilot study with TDW application by SDI located in the largest sugarcane producing region of the world (south-central Brazil).

According to the Köppen climate classification (Peel et al., 2007), the climate is subtropicaltropical (Cwa/Cfa), with an average annual temperature of 22.3 °C, relative humidity annual average of 62% and total annual rainfall of 1425 mm. The soil of the experimental area is an Oxisol (Jacomine, 2009). The climatic parameters were obtained from automatic weather station located 50 m from the growing area.

The variety cultivated was RB867515, which is the most planted in Brazil since 2007 (CTC, 2012). Planting was performed in May 2011, with 15 to 18 buds per linear meter, with planting depth of 0.30 m grown in three double rows per experimental plot, considering the two outermost lines as borders with the center one as the main line. Spacing between the center of the double rows (consisting of two rows spaced at 0.4 m apart) was 1.8 m. Thus, each experimental plot consisted of 97.2 m^2 (5.4 × 18 m) totaling a total area of 2430 m^2 (25 plots).

Two water sources to irrigation were applied: fresh water from surface water reservoir (SWR) with 1140 m^3 of capacity and TDW obtained from the sewage treatment system located at the experimental field.

The sewage treatment system is constituted by anaerobic reactor of 4.19 m^3 compartmentalized, and then through pipes, the sewage was pumped up to six wetlands cultivated with macrophytes with total volume of 2.3 m^3 (2.7 m × 1.7 m × 0.5 m, length, width and depth, respectively). Subsequently, the domestic wastewater was pumped to the control head, and finally applied to the crop by an automatic pumping system.

The experimental design was randomized blocks, in a double factorial plus additional treatment (2 × 2 + 1), two installation depths of the dripper line; two water sources and a non-irrigated treatment, totaling five treatments, being: irrigation with domestic sewage applied to 0.20 m depth (S20), and to 0.40 m (S40), irrigation with fresh water from a surface reservoir to 0.20 m depth (W20) and to 0.40 m (W40) and finally non-irrigated plots (NI). Since planting in 2011, the crop has been irrigated by following these treatments.

For individualizing each treatment, we installed on the control head, two sets of pressurized systems, one for each water source (Fig. 1). All irrigated treatments were fertigated with mineral chemical fertilization by following the absorption rate of nutrients by the sugarcane according to Haag et al. (1987), complementing the nutrients already applied by the TDW and SWR.

Thus, after passing through the control head, we collected every two months until the end of irrigation (early June/2014), samples of TDW and SWR to perform the physical, chemical and microbiological analysis (APHA, 2012) to sodium (Na), calcium (Ca), magnesium

Fig. 1. Control head for two sets of pressurized systems, one for each water source. TDW: treated domestic wastewater, SWR: surface water reservoir.