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Evapotranspiration and crop coefficient (Kc) of pre-sprouted sugarcane plantlets for greenhouse irrigation management

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ABSTRACT

The sugarcane pre-sprouted plantlets (PSP) production system is an innovative method to enhance crop multiplication rates. This system is greenhouse-grown, where correct irrigation management is essential to maintain the production quality. The purpose of this study was to determine the water requirement of three cultivars (CTC9005HP, RB966928, and SP87365) of pre-sprouted sugarcane plantlets, in which crop evapotranspiration (ETc) is a function of the product of the crop coefficient (Kc) and reference evapotranspiration (ETo). Three specifically built PSP-weighing lysimeters were used to determine ETc, while ETo was calculated by the FAO-56 method, making it possible to assess Kc values during the PSP cycle production. The ETc ranged from 3 to 6.9 mm d^{-1} for CTC9005HP, 3.1 to 6.8 mm d^{-1} for RB966928, and 2.9 to 6.6 mm d^{-1} for SP87365. Daily Kc values increased from 1.00 to 1.46 for CTC9005HP, 1.02 to 1.53 for RB966928, and 1.02 to 1.49 for SP87365. This research makes evident the importance of assessing appropriate Kc values in order to estimate crop water requirements and irrigation needs. Therefore, these results are appropriate for proper irrigation management in a greenhouse-grown sugarcane PSP.

1. Introduction

Brazilian sugar and ethanol production derived from sugarcane was the third most agricultural commodity exported by Brazilian agribusiness in 2016. The Brazilian 2017/2018 sugarcane harvest forecast is 647.6 million tons produced in 8.8 million harvesting hectares, with a yield of 73.27 Mg ha^{-1} (CONAB, 2017).

The sugarcane crop multiplication method, from the beginning, is based on burying the stalks in the planting furrow. In the past, manual crop planting used to spend 15 to 21 buds m^{-1} of planting furrow, with a stalk consumption of 11 to 14 Mg ha^{-1}. At present, mechanized planting is widely used, but planting failures are frequent in this system, despite advances in mechanization and planting methods. In an attempt to avoid yield reduction, planting density was increased from 24 to 60 buds m^{-1} of planting furrow, which increased the stalk consumption to 20 Mg ha^{-1}. In order to reduce the consumption of buds in sugarcane planting and increase crop multiplication rates, the sugarcane pre-sprouted plantlets (PSP) production system has been used as an efficient and innovative method. PSP production consists of growing plantlets derived of buds (species asexual reproductive structure), contained on stalk nodes nominated from mini-stalks, planted in plastic tubes filled with substrate (Landell et al., 2012).

Similar to other crops, sugarcane plantlet growth is determined by weather variables, as well as water and nutrient supply, which can be controlled by crop management practices. For this reason, greenhouses are ideal for growing plantlets, because weather variables can be controlled to ensure optimum plant growth and development, making it possible to shorten the production cycle (Pamungkas et al., 2013; Rodríguez et al., 2015).

PSP is grown in greenhouses, where proper irrigation management is an essential factor. Girardi et al. (2016) describes that in this production system, roots are limited to the recipient space. Therefore, deficit irrigation generally causes losses and reduces production quality; nevertheless, excessive irrigation increases crop disease

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Nomenclature

PSP	preplantlets
ETc	cropevapotranspiration (mm d^{-1})
Kc	crop coefficient
ETo	reference evapotranspiration (mm d^{-1})
DAT	days after transference
S	water storage at lysimeter (mm)
I	irrigation depth (mm)
D	drainage of lysimeter (mm)
S	slope of saturation vapor pressure curve (kPa $°C^{-1}$)
Rn	net solar radiation (MJ m^{-2} d^{-1})
G	soil heat flux (MJ m^{-2} d^{-1})
γ	psychometric constant (0.063 kPa $°C^{-1}$)
U_2	wind speed at 2 m from the ground (m s^{-1})
e_s	saturation vapor pressure (kPa)
e_a	actual vapor pressure (kPa)
T	mean air temperature (°C)
GDD	growing degree-day (°C d^{-1})
TM	maximum daily temperature (°C)
Tm	minimum daily temperature (°C)
TB	superior basal sugarcane temperature (°C)
Tb	inferior basal sugarcane temperature (°C)
CI	canopy cover index (%)
CPA	canopy projected area (cm^2)
LS	lysimeter surface (cm^2)
LAI	leaf area index

susceptibly, pumping costs, water waste, and environmental pollution triggered by nutrient leaching (Pardossi and Incrocci, 2011; Du et al., 2014; Contreras et al., 2017). Industry has offered many high-technology irrigation options; however, because of a lack of information on the quantity and timing of irrigation, this crop management practice is empirically performed (Pardossi and Incrocci, 2011; Repullo et al., 2015).

The correct and precise determination of the water fluxes involved in crop systems is essential to hydrological management, as well as basic scientific research to improve the knowledge of water exchange processes in these systems. Currently, several of those processes are not completely understood (Schrader et al., 2013). Among the available methods to determine crop water requirements, FAO-56 (Allen et al., 1998) is considered a standard method. In this method, crop evapotranspiration (ETc) is calculated by the product of the reference evapotranspiration (ETo) and crop coefficient (Kc). ETo is calculated using local weather variables, leaf area, and soil physical characteristics (Anapalli et al., 2016) where Kc is experimentally determined (Peres et al., 2015).

Weighing lysimeters are considered a standard tool for crop water requirement research (Anapalli et al., 2016; Hagenau et al., 2015; Mariano et al., 2015; Peres et al., 2015). Among lysimeters, weighing lysimeters stand out for their accuracy, precision, and operational conveniences (Peres et al., 2015). This equipment includes a tank to store target soil or crop and drainage water, which is supported by load cells to measure the mass variation by means of electrical signals registered in an acquisition data system (Peñalver et al., 2015; Schmidt et al., 2013). In such a system, it is possible to estimate the water balance components, such as ETc, drainage, runoff, precipitation, and irrigation depth. The ratio between ETc and ETo determines Kc during the crop cycle (Peters et al., 2017; Anapalli et al., 2016).

In the literature, there are no data on Kc for PSP sugarcane to determine the water requirement of greenhouse grown sugarcane, to differentiate from other traditional crops cultivated in that environment, such as eggplant (Loose et al., 2014), cucumber (Fathalian and Emamzadei, 2013), and rose (Oliveira et al., 2014). There are several reports in the literature on open-field sugarcane Kc over the production cycle (Doorenbos and Pruitt, 1977; Doorenbos and Kassam, 1979; Barbieri, 1981; Peres, 1988; Toledo Filho, 1988; Silva et al., 2013a). However, crop management under greenhouse conditions is different to open-field cultivation. The microclimate of a greenhouse is different to that of the external environment; thus, their Kc values are not similar (Sharna et al., 2017).

According to Silva et al. (2013b), the leaf area index (LAI) is the primary growing index that is correlated to water requirement; consequently, it is necessary to determine the water requirement of sugarcane PSP cultivars with distinct growth characteristics.

In this context, the objective of the present study was to determine the water requirements of three sugarcane cultivars grown in a greenhouse under irrigation, using weighing lysimeters to determine the crop evapotranspiration (ETc) and crop coefficient (Kc).

2. Material and methods

2.1. Location of study

The present study was carried out in a sugarcane pre-sprouted plantlet (PSP) greenhouse of São Martinho Mill (São Martinho S/A), located at the coordinates 21°19′23″ S and 48°06′47″ W and an altitude of 528 m, in the city of Pradópolis, SP, Brazil. According to Köppen, the region climate classification is Cwa (Alvares et al., 2013), characterized by a mean precipitation of 1400 mm and a mean temperature of 22.7 °C, with a dry and mild winter and hot and rainy summer (CEPAGRI, 2016). The study greenhouse was built with eight bows of 7 m width and 24 modules of 4.5 m length, totaling 6048 m^2 (56 m width and 108 m length). Ginegar Polysack diffuser anti-virus effect film was used as cover, with 150 µm thickness and ultraviolet ray treatment with 15% solar radiation filter, whereas the frontal and lateral side cover constituted of white net with 150 µm thickness and ultraviolet ray treatment with 30% solar radiation filter.

2.2. Treatments

Three sugarcane cultivars were chosen to compose the treatments of study (CTC9005HP, RB966928, and SP87365). The CTC9005HP cultivar was developed by the Sugarcane Research Center (Piracicaba, SP, Brazil), and is an early-to-medium maturation cultivar adapted in high fertility soil. This cultivar has a high multiplication rate due to a large number of buds per unit area, around 1.65 million buds per hectare. The RB966928 cultivar was developed by Paraná Federal University, and has a high sucrose content, tolerance to most sugarcane diseases (except for smut, *Sporisorium scitamineum*), good sprouts on plants and ratoons, high adaptation to mechanical harvesting, rare flowering, uncommon stool tipping, and medium herbicide tolerance. This cultivar is recommended for medium-to-high fertility soils and has an early maturation cycle. SP87365 was developed by the company formerly named Copersucar, currently the Sugarcane Research Center. It stands out for its great yield, high tolerance to sugarcane borer (*Diatraea saccharalis*), and low herbicide and hydric deficit tolerance. This cultivar is recommended for high fertility soils and has a medium maturation cycle.

2.3. Lysimeters characteristics

Three weighing lysimeters (CTC9005HP, RB966928, and SP87365) were built and installed in the greenhouse to support three trays composed of 54 tubes of 125 cm^3 of sugarcane PSPs, totalizing 162 plants per lysimeter.