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Effect of controlling the leaching fraction on the fertigation and production of a tomato crop under soilless culture

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ABSTRACT

In recent decades, the improvement of automated fertigation systems has gained great importance for the efficient use of water and fertilizers and for environmental sustainability. The objective of this study was to evaluate the performance of a new fertigation system compared to the fertigation-control tray system, which has been widely used in soilless cultures. A tomato crop (cv. Ramyle) was cultivated in coir crop units at the University of Almeria from November 2012 to May 2013. The fertigation-control tray method was used as a control (T0) and was compared to a new proportional integral derivative (PID) controlled method (T1), which was designed to maintain a constant leaching fraction. A plot design subdivided into three blocks was used, in which the drainage volume was automatically measured. The crop yield and some parameters related to fruit quality and size distribution were estimated. The results show a better distribution of the desired drainage fraction in T1. T1 had lower drainage electric conductivity (EC) values and significantly higher fertigation absorption. There were no improvements in the total crop yield or in most of the measured quality parameters. However, a significant improvement in the largest fruit size was recorded under the T1 treatment.

1. Introduction

There are a wide variety of fertigation methods to supply crops with nutrient solution (e.g., Urrestarazu, 2004; Van Os et al., 2008; Rodríguez et al., 2015; Steidle et al., 2014).

Some fertigation methods are based on the culture unit. For example, the gravimetric method used in fertigation systems detects the full weight of a culture unit and aims to maintain that unit at a constant weight (Helmer et al., 2005). This process is controlled by a continuous record of weight during cultivation. This method maintains the matric potential of soil moisture at which the roots must absorb water.

A great number of studies of fertigation methods focus on controlling the drainage of the nutrient solution that is applied to the culture unit. One of these fertigation methods is the so-called fertigation-control tray. This approach is one of the most widely used methods for automatically activating fertigation in soilless crops in greenhouses in Southeastern Spain (Urrestarazu, 2004; Cáceres et al., 2007), where there are approximately 5500 ha of soilless crops (Urrestarazu, 2013). This fertigation method works by means of an electric signal from a level control in the crop unit submerged in a tank filled with nutrient solution (Fig. 1). This method is both simple and economical (Cáceres et al., 2007). The calibration of the tray assumes that a new fertigation will be performed when 10% of the readily available water and an additional leaching fraction have been consumed. The leaching fraction is estimated as a function of the salinity of the drainage water and crop characteristics. The parameters that must be controlled for fertigation are the leaching fraction, electrical conductivity (EC), and pH of the obtained drainage (Urrestarazu et al., 2008a,b; Morales and Urrestarazu, 2013).

The aim of this work was to evaluate the effect of a new method of fertigation aimed at controlling the volume of the predetermined leaching fraction on parameter of fertigation and yield and quality production. The effects of this method on the fertigation parameters obtained from the drainage and on the productivity of a tomato crop were estimated.

2. Materials and methods

2.1. Cultivation conditions

Cultivation was performed at the facilities of the University of Almeria (Spain) in a multitunnel greenhouse (wall thickness:

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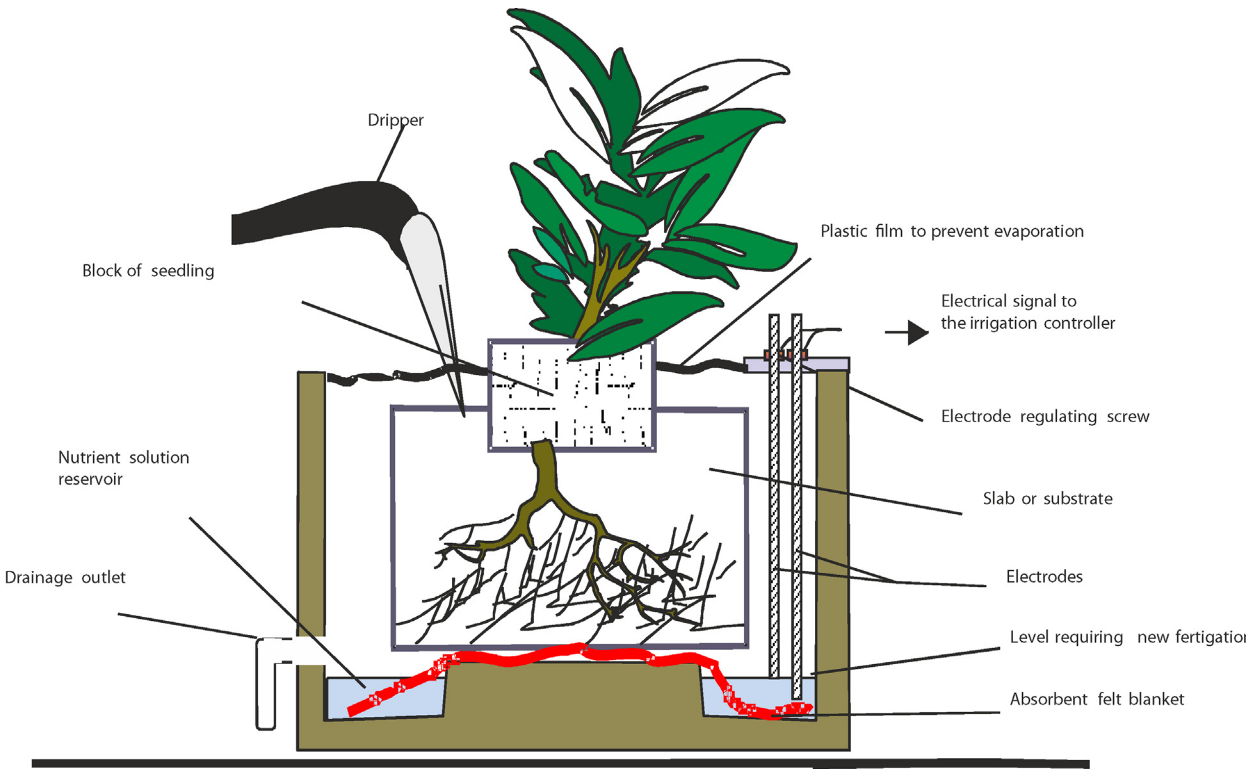

Fig. 1. Cross-section of a fertigation-control tray.

200 μm). Tomato seedlings were planted on November 9, 2012, during a stage in which the plants had six or seven true leaves. Ramyle F1 cv. tomatoes were used with two plants m^{-2}. The cultivation was managed following methods commonly used in the cultivation area.

2.2. Treatments applied and unit crop

The treatments consisted of two different fertigation methods. The fertigation-control tray method was used as a control treatment (T0). The treatment to be evaluated (T1) aimed to determine the leaching fraction in real time while replenishing 10% of the consumed readily available water, and successive learning from consecutive irrigations was applied (Fig. 2). This control system is based on a proportional integral derivative (PID) algorithm and allows for fully automatic operation with a minimum set of variables to reduce the cost of the equipment (Rodríguez et al., 2015). The model operates on the irrigation system that is being used while the model is being applied. This model learns from previous fertigations, correcting in real time to obtain the programmed leaching fraction. In both treatments, the water consumption for a given period is calculated by measuring the volume of nutrient solution fertigated and drained.

Irrigation was monitored for both of the treatments. A volume was applied in each treatment and new fertigation as a function of the consumption during cultivation plus the volume of a predetermined leaching fraction of 0.25. In addition to the calibration of the fertigation-control tray (T0) and that estimated by the PID algorithm (T1), the drainage volume was quantified through a mechanism specifically designed to estimate the calibration in each fertigation (Fig. 3).

For each treatment, two control points were established to monitor fertigation: one for fertigation input and another for drainage. Additionally, the pH, EC and applied volume of nutrient solution were measured. A control dripper and a drain pan served as points of measurement for the monitoring of supplied fertigation and the absorption response. The duration of each irrigation process for the fertigation-control tray (T0) was selected by adjusting the volume to be supplied to each cultivation unit, depending on the water-release curve obtained for the substrate (Fig. 4). This time was also the starting point for treatment T1, but it was adjusted in real time by PID algorithms. To obtain the water release curve of the coir substrate, the following volumes were calculated (v:v): total porosity, air volume (aeration capacity), readily available water, reserve water, and scarcely available water (AENOR, 2012). Physical analysis of the substrate was performed in triplicate. The water-release curve was adjusted using the Gregson equation (Gregson et al., 1987). The cultivation unit was a Pelemix GB1002410® coir grow bag (100 cm × 25 cm × 10 cm) with a cultivation volume of 25 L.

A nutrient solution was prepared with concentrated solutions of macronutrients in the final proportions indicated in Table 1.

2.3. Harvest sampling

The harvest took place from March 14 to June 15, 2013. Individual fruits were harvested on a weekly basis for tomatoes in the state of maturity corresponding to a uniform red color of the tomato skin. The tomatoes were sized according to their equatorial diameter and the prevailing commercial fruit category (DO, 2000). The yield of each size was clustered throughout culturing, and the median values are shown in Table 2. From each harvest, a subsample of three tomato fruits was used to make a homogenized solution to measure the pH, EC, and total soluble solids (expressed as °Brix), which were measured with a digital hand-held refractometer (Manufacture for Atago PAL-1). After the tomatoes were dried in a forced air oven at 85 °C for 72 h, the dry matter was obtained by weighing three tomatoes to an accuracy of one hundredth of a gram.