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Irrigation management of greenhouse zucchini with different soil matric potential level. Agronomic and environmental effects

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ABSTRACT

Greenhouse horticultural crops are characterized by high levels of efficiency and productivity of irrigation water. But they still can and must be improved, especially in arid areas. The objective of this research was to study the effect of the soil matric potential level on the bio-productivity of zucchini crop, the water use efficiency (WUE) and nutrients use efficiency by changing the threshold of soil matric potential. An experiment was conducted in greenhouse-grown zucchini on a sand-mulched soil and fertigation with inorganic fertilizer. Automatic activation of irrigation through an electronic tensiometer and three treatments were applied: Activation of irrigation to −10 kPa and application of volume of 1.5 L m^{-2} (T1), activation of irrigation to −25 kPa and application of volume of 2.0 L m^{-2} (T2) and activation of irrigation to −40 kPa and application of volume of 3.0 L m^{-2} (T3). Yield, leaf area, biomass, water consumption, WUE and nutrients, drainage volume and physical-chemical parameters of the soil were determined. The results show that T2 slightly reduced the weight of the fruit with respect to T1, but not the number of fruit, obtaining a significantly lower consumption of water. Lower weight fruits and less number of fruits were obtained by T3. Reducing the soil moisture tension level increased substantially water consumption as a result of the differences in vegetative growth (leaf area and biomass) in plants. Highest values of WUE and nutrients use efficiency were registered by T2 and T3. In none of the treatments, drainage was obtained. Soil physical-chemical parameters were not affected by treatments. Independently of soil matric potential, increased soil salinity occurred after the growing season. The soil matric potential of −25 kPa was the best considering agronomic and environmental aspects, as the most efficient use of water and nutrients obtaining a commercial production of 15 kg m^{-2}.

1. Introduction

Water is a scarce resource in arid and semi-arid regions such as the Mediterranean basin. Agriculture is the world's largest consumer of the world's fresh water, accounting for 70% of irrigation the extractions (WWAP, 2009). The increase of the water use efficiency (WUE) in agricultural systems, defined as the yield obtained per unit of water applied (Howell, 2003), it is possible with appropriate irrigation scheduling (Buttaro et al., 2015; Létourneau et al., 2015). This adequate irrigation scheduling will also reduce the environmental impacts associated with water losses by percolation and nutrient leaching.

Horticultural greenhouse crops are characterized by very high levels of irrigation water productivity (Ministry of Agriculture and Fisheries, 2011; Ministry of Environment, 2007). Zucchini squash (*Cucurbita pepo* L.) is an important plant in many countries for out of season greenhouse production, also it is an important commercial crop that has gained popularity for both open-field and protected cultivation in the Mediterranean region. Zucchini is normally grown in soil under greenhouse conditions using a drip-irrigation system during the spring-summer and the summer-fall seasons in order to respond to the high demand of this fresh product on both national and international markets. In Spain, zucchini is one of the main crops grown on the Mediterranean coast of Andalusia, Almeria being the main growing area with 7500 ha, but in comparison with other vegetables crops grown under protected cultivation, like pepper, melon, and tomato (Thompson et al., 2007a), there is a lack of information on the influence of the irrigation on fruit yield and WUE of zucchini grown in greenhouse soil culture.

A high percentage of farms have programmable irrigation automata to allow farmers greater control of irrigation parameters (Baeza et al., 2007). However the main areas of development are in deficit areas of water (Ministry of Environment, 2007) and studies at a regional scale show relatively significant levels of percolation

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of water to surface water systems, causing undesirable effects such as nitrate pollution (Thompson et al., 2007b; Pulido-Bosch, 2005).

The most recent research focuses on optimizing irrigation management, based primarily on the measured water status of the plant or direct measurement of soil water (Buttaro et al., 2015; Létourneau et al., 2015). The measured water status of the plant still has many theoretical and practical difficulties, most of which are discussed in the review by Jones (2004). However, direct measurement of soil water either water content or the soil matric potential is more feasible since it has the advantage of being relatively easy to measure and automate (Van Iersel et al., 2013) resulting in easier implementation at farm level.

Matric potential of the soil is most commonly measured using tensiometers. Tensiometers measure soil matric potential directly, and the results do not depend on soil type or texture. Tensiometers determine the soil matric potential and are fast, cheap, easy to handle and suitable for monitoring soil water status devices No soil specific calibration is needed. Most tensiometers require routine maintenance because they contain water, which needs to be replenished on a regular basis. In addition, maintaining good contact between the ceramic tensiometers tip and the surrounding soil/substrate is needed to prevent air from entering the ceramic tip (Lea-Cox, 2012). If the suction in the tensiometers becomes too great, cavitation can occur, rendering the data meaningless. Both air entering the tensiometers and cavitation are typically clearly visible in the data since they result in a sudden and rapid increase in matric potential. If such an increase occurs, and is not associated with rain or irrigation, it indicates a malfunction of the tensiometers (Van Iersel et al., 2013). These are often preferred to other types of soil moisture sensors because of their low cost, simplicity of use, high measurement accuracy, indifference to temperature and osmotic soil potential, and the possibility for electronic data acquisition by differential pressure transducers (Thalheimer, 2003) allowing the automation of fertigation.

The determination of the appropriate threshold for a particular crop remains a fundamental point for efficient irrigation management (Lemay et al., 2012). However it is crucial to establish a suitable soil matric potential value for each crop and growing conditions to optimize production, WUE and nutrients use efficiency as evidenced in Buttaro et al. (2015) and Létourneau et al. (2015).

Once an appropriate threshold for a particular crop has been determined (Lemay et al., 2012; Jia et al., 2013; Zheng et al., 2013; Létourneau et al., 2015), this threshold can be used in different situations, regardless of soil type. However, matric potential data provide no information on how much water should be applied. To determine this, an understanding of the properties of that soil is required, considering the curve of soil moisture retention for not applying excess irrigation.

There are numerous studies which aim to establish optimum threshold of soil matric potential of different crops and conditions for development (Bower et al., 1975; Smajstrla and Locascio, 1996; Wang et al., 2005; Taylor, 1965; Hanson et al., 2000) Most of these studies have been conducted with open field crops, and, for a given species, show a wide range of soil matric potential threshold values, suggesting that site-specific factors were influential. Most published soil matric potential threshold values for vegetable species have been conducted for tomato with reported values in a range of −10 kPa to −30 kPa (Smajstrla and Locascio, 1996; Bower et al., 1975; Wang et al., 2005), for pepper, reported soil matric potential threshold values of −25 kPa (Smittle et al., 1994; Beese et al., 1982), for melon, reported soil matric potential threshold values of −35 to −40 kPa (Taylor, 1965; Hanson et al., 2000). Research in the area of the cultivation of zucchini is very limited. For this reason it is very important to determine the threshold value of soil matric potential in developing specific conditions and for a particular crop.

The objective of the study was to evaluate the effects of various levels of soil matric potential on zucchini's growth, yield, water consumption, and water and nutrient productivity under greenhouse and drip irrigation condition, and to identify a suitable soil matric potential threshold as well as irrigation scheduling for zucchini irrigation management in greenhouse of Southeast Spain.

2. Materials and methods

2.1. Experimental site

The experiment was conducted in a 1700 m^2 polyethylene greenhouse at the Institute of Research and Training in Agriculture and Fisheries (IFAPA), located in La Mojonera City, Almería Province of Southeast Spain (longitude 2° 41′W, latitude 36° 47′N, elevation 160 m), in this place is located one of the highest concentrations of greenhouses of the world. The climate is Mediterranean with a mild winter (mean monthly temperature of 12.9 °C at winter) and a mean annual precipitation of 220 mm. Soil in the experimental greenhouse was artificial sand-mulched with silty loam soil, the standard soil of intensive horticultural crops peninsular Southeast (Contreras et al., 2014).

2.2. Experimental design, irrigation and cropping systems

The experiment consisted of three automatic activation treatments of irrigation through an electronic tensiometer based on soil matric potential. The experimental design used randomized complete block design with three replicates. The treatments applied were: Activation of irrigation to −10 kPa and application of volume of 1.5 Lm^{-2} (T1), activation of irrigation to −25 kPa and application of volume of 2.0 Lm^{-2} (T2) and activation of irrigation to −40 kPa and application of volume of 3.0 Lm^{-2} (T3). The volume of irrigation for each treatment was established considering the retention curve of soil moisture.

The greenhouse was divided into 9 experimental plots, in three blocks set out from east to west, with passage in the north. Plots measured 25 mx 6 m.

Considering these irrigation treatments, the total volumes applied differ for each treatment. The period of activation of irrigation was the same for all treatment and was 10:00 to 18:00 h in winter and from 8:00 to 20:00 h in the spring.

Moreover, each irrigation was followed by 2 h of pause to enable the acquisition of relevant tensiometry data.

Irrigation was applied through drip irrigation system, with pressure-compensating and no-draining emitters of 3 L h^{-1} (PCJ Dripper – Netafim®) and 2 emitters m^{-2} (spaced at 0.5 m in the drip line and 1 m between lines).

Irrigation water used in this experiment was the conventional water of the production area, groundwater, and its characteristics are shown in Table 1. The composition of nutrient solutions was

Table 1
Composition of irrigation water.

	pH	E.C.	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	$N\text{-}NO_3^-$	P	$N\text{-}NH_4^+$	Ca^{2+}	Mg^{2+}	Na^+	K^+	SAR
		dS m^{-1}	mM	mM	mM	mM	mM	mM	mM	mM	mM	mM	mM	
Irrigation Water	7.71	1.42	0.00	3.30	9.24	0.47	0.15	0.00	0.00	1.70	2.43	5.00	0.08	2.46

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