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RESPONSE OF AN AUTUMN-WINTER GREEN BEAN GREENHOUSE CROP TO A MILD WATER DEFICIT DURING CROP FLOWERING IN A MEDITERRANEAN REGION.

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Abstract

Greenhouse growers of autumn-winter green bean crops on the Almería coast use to reduce the soil water availability during crop flowering in order to increase the fruit number and, consequently, the crop productivity, but without measuring the soil or the plant water status. This reduced irrigation during crop flowering (RI), compared to full irrigation treatment (FI), was studied in a representative greenhouse during the 2001/02 cropping season. The total irrigation water supplied was similar for both irrigation treatments. The autumn-winter green bean crop with RI presented progressively lower soil matric potential (SMP) values than the FI treatment from the vegetative phase to the first fruit setting, reaching minimum SMP values of around -60 kPa, these SMP values are slightly lower than those recommended to prevent water stress in green bean crops grown in medium-fine textured soils. Hereafter, SMP values for the RI treatment maintained similar or slightly higher than for the FI. Overall, the autumn-winter green bean crop with lower soil water availability during crop flowering produced less aerial biomass (the vegetative one) than the FI treatment but did not affect the fruit production.

INTRODUCTION

The Southeast Spanish Mediterranean coastal area is one of the largest greenhouse areas in the world, sized approximately 37,599 ha and mainly dedicated to intensive vegetables production (Castilla and Hernández, 2005). In this area all greenhouse crops are drip irrigated and the irrigation water price is relatively high, but irrigation practices are still based on local growers' experience and high variations in irrigation water supply to each of the main vegetable crops have been observed (Fernández et al., 2007).

Green bean is one of the main greenhouse crops on the Spanish coast as well as in other Mediterranean areas. In Southeast Spain, green bean is usually scheduled from the beginning of autumn to the end of spring, using two or three short crop cycles (autumn, winter and spring).

In some phenological phases plants may be more tolerant to water stress and as such can be irrigated under a deficit regime (Chalmers et al., 1981). This irrigation strategy, has been successfuly studied for fruit trees and vines (Fereres and Soriano, 2007), but less attention has been paid for other cropping systems, especially for greenhouse crops (Katerji et al., 1993). Some growers and technical advisers in the

Spanish Mediterranean greenhouse area use to modify the soil water availability throughout the vegetable crop cycles with different purposes: enhancing root development, increasing fruit quality (Sanders et al., 1989), etc. In green bean the greenhouse growers use to reduce slightly the soil water availability during crop flowering for enhancing fruit number and, consequently the productivity (Villalobos, 1999; González, 2003; Bonachela et al., 2006). This practice is based on their own experience, is carried out by visual plant observations but without controlling or measuring soil or plant water status.

This work was aimed to study the influence of reducing the soil water availability during flowering on an autumn-winter green bean crop under Mediterranean greenhouse conditions. The development of irrigation scheduling practices for minimising water use and lixiviates, and improving vegetables yield and quality is becoming of primary importance.

MATERIAL AND METHODS

Experiment and site

The experiment was carried out from 2001 to 2002 at the “Cajamar Foundation” research station (2° 43' W; 36° 48' E; and 155 m a.s.l.) in the Campo de Dalías (Almería). A typical Mediterranean greenhouse was used: a low-cost structure covered with plastic film (0.2 mm-thick thermal polyethylene sheet), without heating equipment and passively ventilated by opening side panels and roof vents (Pérez Parra et al., 2004). The greenhouse soil, known as “*enarenado*”, is commonly used in greenhouses of the region (Wittwer and Castilla, 1995). Irrigation water of 0.4 dS m^{-1} electrical conductivity mixed with fertilizers was applied through a drip system with over 90% distribution uniformity. The greenhouse had four drainage lysimeters (4 m length, 2 m width and 0.7 m depth) located on the Southern side with the bottom and walls covered with a butyl rubber insulation sheet.

Green bean seeds (*Phaseolus vulgaris* L. ssp. *volubilis*, cv. Donna) were sown on 12 September 2001 and the crop cycle finished on 2 January 2002.

Two irrigation treatments were studied: a full irrigation (FI) and a crop with reduced irrigation during crop flowering (RI). These treatments were arranged in a randomised complete-block design with four replications and means were compared with a Least Squares Means procedure. The experimental plot per replicate and treatment was 54 m^2. The amount of water applied was determined from daily estimates of real-time crop evapotranspiration (ET) in both treatments. ET was calculated using the K_c-ET_o method (Doorenbos and Pruitt, 1977; Allen et al., 1998). ET_o was calculated with a locally calibrated radiation method (Bonachela et al., 2006) that requires daily solar radiation data and greenhouse transmissivity estimates. K_c values were determined based on Fernández (2000) and Orgaz et al. (2005). Real-time meteorological data required for determining ET values were taken from a nearby weather station located in the “Cajamar Foundation” research station.

In the FI treatment, irrigation water was usually applied when the soil matric potential was approximately between the locally recommended values of –15 and –30 kPa. These values are higher than those required to prevent water limitations in Mediterranean greenhouse grown vegetable crops (Thompson et al., 2007). In the RI treatment, the soil matric potential was progressively reduced from the vegetative phase to first fruit setting, reaching minimum values slightly lower than those that prevent water limitations according to Hegde and Srinivas (1990). After the first harvest, the soil matric potential values were maintained similar or slightly higher than those of the FI's.

Measurements

Global daily radiation was measured daily at 1.5 m above the experimental greenhouse with a pyranometer (CM21, Kipp and Zonen, Delft, Netherlands). Greenhouse air temperature (H08-032-08, HOBO, Onset Compute Corp. USA) at 1.5 m above the soil and greenhouse global radiation (H08-008-04, HOBO, Onset Compute Corp. USA) at 0.5 m above the crop canopy were also measured daily.

Soil matric potential (SMP) was measured daily with manual tensiometers (Irrometer, Copersa, Barcelona, Spain). Four tensiometers per treatment were installed at both 0.12 m and 0.27 m below the sand layer near the plant (Fernández, 2000). The applied irrigation water per treatment was measured with a water meter. The amount of lixiviated nutrient solution from the drainage lysimeters (two per treatment) was collected and measured daily.

Soil solution was extracted using suction samplers (Soil Water Sampler 1900, Soilmoisture, USA) in three replications per irrigation treatment. These samplers were installed at 0.20 m depth below the sand layer and near the plant. Subsequently, pH and electrical conductivity (EC) values were determined.

Green bean plants within an area of 6 m^2 were monitored per plot to determine final crop biomass and marketable and non-marketable productivity.

RESULTS AND DISCUSSION

Greenhouse growers and technical advisers on the Spanish Mediterranean coast use to modify the soil water availability throughout the vegetable crop cycle with different purposes: enhancing root development, increasing fruit quality, etc. (González, 2003; Bonachela et al., 2006). In the green crop, some greenhouse growers, based on their own experience, use to reduce the soil water availability during crop flowering to avoid an excessive vegetative growth and enhance the fruit number and, consequently, the crop productivity. However, this irrigation strategy is carried out without controlling or measuring the soil or the plant water status. To assess this irrigation practice, compared to full irrigation, an experimental study was carried out.

Total irrigation water applied throughout the crop cycle was similar for the two irrigation treatments: 99 mm and 111 mm for the FI and RI treatments, respectively. In the RI treatment, the irrigation water applied from the vegetative phase to first fruit setting was 24% less than the FI treatment (24 mm), subsequently, the water applied was similar or slightly higher than the FI treatment for to maintain the SMP values between -15 and -20 kPa (Fig. 1A).

Fig. 1B and C shows the seasonal dynamics of the soil matric potential (SMP) for both irrigation treatments at the two measured depths: 0.12 m and 0.27 m The SMP values within the wetted area where most vegetable roots are concentrated (González, 2003; Thompson et al., 2007) were between –15 and –30 kPa throughout most of the FI growth cycle (Fig. 1B-C). These SMP values are higher than those required to prevent water limitations in Mediterranean greenhouse–grown vegetable crops (Thompson et al., 2007) and, therefore, no crop water stress should have been occurred. The green bean crop with RI treatment showed progressively lower SMP values from vegetative phase to first fruit setting, reaching minimum SMP values around –60 kPa. These minimum SMP values are similar or slightly lower than those recommended to prevent water stress in green bean grown in medium-fine textured soil (Hegde and Srinivas, 1990). In addition, the SMP values for the generative growth phase were similar or slightly higher in the RI treatment than in FI treatment (Fig. 1B-C).

The cumulative lixiviated nutrient solution extracted from drainage lysimeters was 9 mm for FI treatment and 1 mm for RI treatment and most of the lixiviation in the FI treatment occurred at the beginning of the crop cycle (Fig. 2A). Moreover, no significant differences between irrigation treatments were found for the EC of the extracted soil solution (Fig. 2B). At both treatments, EC values maintained around the locally recommended range, although they were slightly higher for the RI treatment.

The vegetative and aerial biomass at the end of the green bean cycle was lower for the RI treatment, compared to FI, but no differences were found for the generative biomass (Table 1). Moreover, no significant differences in total and marketable yield were found between irrigation treatments (Fig. 3). The total green bean yield was 2878 and 2770 g m^{-2}, for RI and FI, respectively, and the marketable yield was 2732 g m^{-2} for RI treatment and 2633 g m^{-2} for FI treatment. A lower water availability from vegetative phase to first fruit setting in an green bean crop grown under low evaporative demand conditions reduced slightly the biomass production (Hsiao, 1973) without affecting the fruit yield, as the fraction of harvested biomass was slightly increased (Table 1). Finally, when the yield was separated into two harvesting periods (early and late productivity) not significant differences were neither observed (Fig. 3).

CONCLUSIONS

An autumn-winter green bean crop irrigated with reduced soil water availability during crop flowering (reaching minimum soil matric potential values of around –60 kPa) produced less aerial biomass (the vegetative one) than a full irrigation but did not affect the marketable fruit production.

Threshold values of soil matric potential can be used by greenhouse growers as a tool for controlling the equilibrium between the vegetative and generative plant growth.

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Tables

Table 1. Vegetative, generative and shoot biomass and harvest index (HI) of an autumn-winter green bean crop under two irrigation treatments; full irrigation (FI) and a crop with reduced irrigation during crop flowering (RI).

	Aerial biomass (g m^{-2})			**HI**
Treatments	Vegetative	Generative	Aerial	
RI	414 b	209	623 b	0.33 a
FI	457 a	201	658 a	0.30 b
LSD	*28*	*NS*	*36*	*0.02*

LSD Least significant difference (P<0.05); NS No significant differences (P<0.05)

Figures

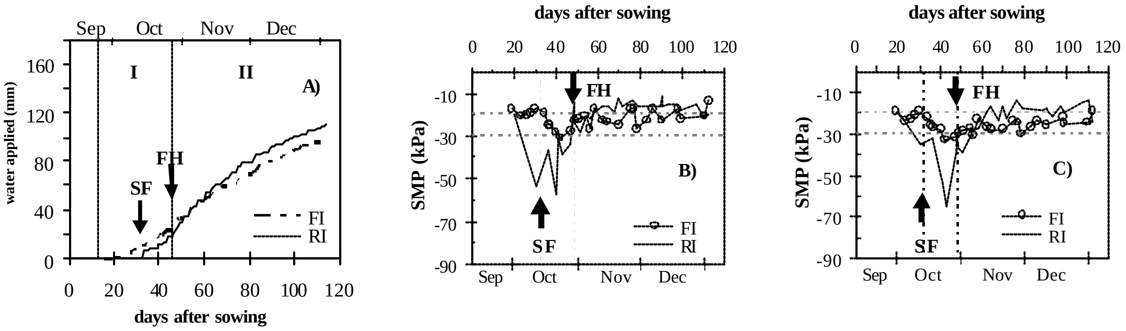

Fig. 1. Dynamics cumulative water applied (A) and seasonal evolution of the soil matric potential (SMP, kPa), at 0.12 m depth (B) and 0.27 depth (C) (below the sand layer and near the plant), for two irrigation treatments, full irrigation (FI) and a crop with reduced irrigation during flowering (RI). FH: First Harvest. SF: Start of Flowering.

I: Limited availability water during crop flowering in the RI treatment. II: Phase of flowering and production.

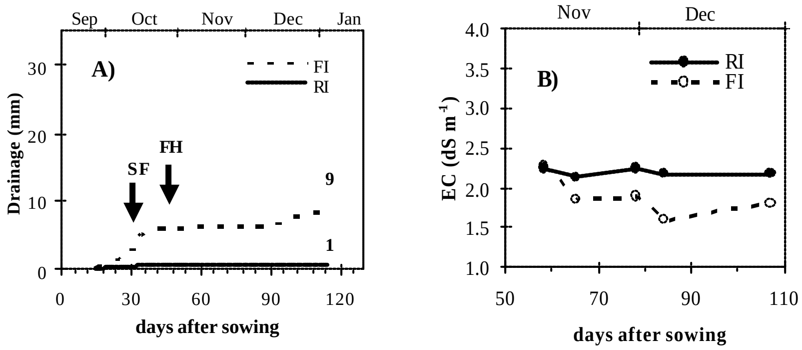

Fig.2. Dynamics cumulative water lixiviated nutrient solution from drainage lysimeters (A) and electric conductivity (EC) of extracted soil solution (B). Autumn-winter green bean crop with full irrigation (FI) and crop with reduced irrigation during flowering (RI). FH: First Harvest. SF: Start of Flowering.

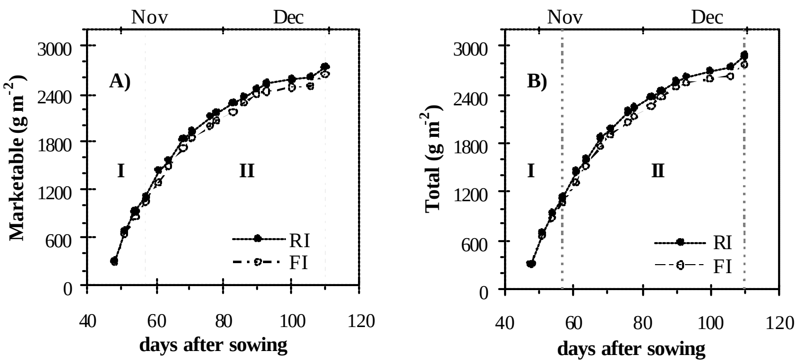

Fig. 3. Marketable (A) and total (B) cumulative yield of autumn-winter green bean under two irrigation treatments; full irrigation (FI) and a crop with reduced irrigation during flowering (RI). I: Early productivity. II: Late productivity.