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Short communication

Supplemental saline drip irrigation applied at different growth stages of two bell pepper cultivars grown with or without mulch in non-saline soil

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ABSTRACT

The effect of supplemental saline (2.5 dS m^{-1}) drip irrigation and black polyethylene mulch on two cultivars of bell peppers (*Capsicum annuum* L.) was investigated under field conditions using a randomized complete block design with split–split plot restriction. The research included six irrigation treatments (main plots): (i) non-saline irrigation control applied throughout growth (None), (ii) saline irrigation from transplanting until formation of the first fruit set (S1S2), (iii) saline irrigation from transplanting until appearance of the first flower and from first harvest to final harvest (S1S4), (iv) saline irrigation from appearance of the first flower to first harvest (S2S3), (v) saline irrigation from fruit set to final harvest (S3S4), and (vi) saline irrigation throughout growth (All); two mulch treatments (subplots): (i) black mulch and (ii) bare soil; and two bell pepper cultivars (sub-subplots): (i) Early Sunsation and (ii) Red Knight. Production of fully ripened fruits was higher in mulched plants regardless of saline irrigation treatments. In humid areas with non-saline soil, supplemental saline drip irrigation could be used with black polyethylene mulch to save water while maintaining fruit production.

1. Introduction

Worldwide, agriculture is the most important user of water (70%) regardless of quality (FAO, 2000). However, this figure could decline in the future due to competition among water users for better water quality (Bouwer, 2002) and decreases of available water. These problems are characteristic of semiarid or arid regions but could also extend to semihumid or humid areas (Parsons, 2000; Shalhevet, 1994).

Use of saline water may become an unavoidable alternative for irrigation, especially in regions where water is scarce (Oron et al., 1999). Therefore, appropriate water management and cultural practices must be included in production systems to reduce soil salinization and maintain crop productivity. Use of both saline and non-saline water could be one approach to water management in many areas around the world (Shalhevet, 1994). In this context, ideally, saline water should only be used during the most salt tolerant growth stages of any crop (Shannon and Grieve, 2000). Alternatively, blending water from both sources until a saline level tolerable to each specific crop is reached could also be another option (Dinar et al., 1986).

Drip irrigation, which allows for use of saline water and nutrient solutions (fertigation), improves water management because it reduces the irrigated area exposed to evaporation, thus diminishing water consumption (Dasberg and Or, 1999; Skaggs, 2001). Another strategy to reduce the amount of water to irrigate crops with high demand of water (e.g. horticultural crops) is mulching the soil with a black polyethylene film, which preserves soil moisture by minimizing evaporation (Hartz, 1996), and increases soil temperature (Tarara, 2000).

Bell pepper (*Capsicum annuum* L.) is a high value crop generally produced using a plasticultural system that includes drip irrigation and polyethylene mulch (Lamont, 1996). However, this crop should be carefully managed under saline condition because fruit marketable yield could decrease if electrical conductivity of the soil saturated paste extract (EC_e) is higher than 1.5 dS m^{-1} (Maas and Grattan, 1999). Selection of an appropriate cultivar also plays an important role in pepper production as they may differ in their response to saline condition (Aktas et al., 2006). However, there is a general lack of knowledge regarding the sensitivity or tolerance to saline irrigation of bell peppers at various growth stages (Bar-Yosef et al., 2001); particularly when drip irrigation and mulch are incorporated into the saline water management. Therefore, the objective of this research was to evaluate the effect of supplemental saline

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drip irrigation applied at different growth stages on marketable fruit yield of two bell pepper cultivars grown on black polyethylene mulch or bare soil.

2. Materials and methods

2.1. Site conditions

The experiment was established in 2005 at the Horticulture Research Centre, Macdonald Campus, McGill University, Ste-Anne-de-Bellevue, QC, Canada (latitude 45° 26′ N, longitude 73° 56′ W, elevation 39 m), the soil being a clay loam (31% sand, 37% silt, 32% clay) with an electrical conductivity in the soil saturated paste extract (EC_e) of 0.67 dS m^{-1}, pH of 7.9 and 7.4 (soil saturated paste extract and 2:1 soil/water, respectively) and 6.6% organic matter, field capacity at 0.3 at −30 kPa of soil matric potential (0.32 cm^3 cm^{-3}) and permanent wilting point at −1500 kPa of soil matric potential (0.18 cm^3 cm^{-3}). The field was ploughed in the fall of 2004 and harrowed in the spring of 2005.

Raised beds (6 m length × 1.1 m width and 0.3 m high) were made using a bed raiser and plastic mulch layer (Model 2550, Rain-Flo Irrigation, East Earl, PA, USA) on 1 June 2005. The machine laid a drip irrigation tape (T-Tape TSX-508-12-340, T-Systems International, San Diego, CA, USA) in the centre of the bed and covered the bed with black polyethylene mulch. For treatments on bare soil the mulch was then removed. Beds were of 2.5 m centre to centre and there was 1 m between blocks.

2.2. Treatments and experimental design

The experimental design was a randomized complete block design with split–split plot restriction and three replicates. Six levels of the saline or non-saline irrigation timing factor were randomly assigned to the main plots: (i) None (non-saline irrigation control), (ii) S1S2 (saline irrigation from transplanting to fruit set), (iii) S1S4 (saline irrigation from transplanting to flowering, then during harvest), (iv) S2S3 (saline irrigation from flowering to first harvest), (v) S3S4 (saline irrigation after fruit set), and (vi) All (only saline irrigation throughout growth). Subplots were either black polyethylene mulch (Climagro, Plastitech, St-Remi, QC, Canada) or bare soil; and sub-subplots were assigned to bell pepper (*Capsicum annuum* L.) cultivars: Red Knight (red, Petoseed, Oxnard, CA, USA) and Early Sunsation (yellow, Norseco, Laval, QC, Canada).

At the sub-subplot level, 13 seedlings with 8-true leaves (grown in a greenhouse with day and night temperatures of 16–30 and 12–15 °C, respectively) were mechanically transplanted (Rain-Flo Transplanter Model 1600, Rain-Flo Irrigation, East Earl, PA, USA) on 10 June 2005 in staggered rows (0.3 m apart) with 0.45 m between plants. Each seedling received 150 mL of a starter nutrient solution (in mg L^{-1}) with 500 N, 115 P, 42 K, 1.0 B, 2.5 Cu, 5.0 Fe, 2.5 Mn, 0.025 Mo, and 2.5 Zn (Plant Products, Brampton, ON, Canada). Within each sub-subplot, six central plants were used for experimental measurements and the remainder serving as guards.

2.3. Irrigation and crop management

Six independent containers were used to store saline (2.5 dS m^{-1}, 2:1 NaCl:$CaCl_2$ on a molar basis; Dalton et al., 1997) or non-saline water (0.2 dS m^{-1}) for the irrigation treatments. Water in each container was pumped (operating pressure of 57 kPa) by an electric submersible pump (Mastercraft Model 62-3515-0) through polyethylene pipes (19 mm inside diameter [ID], main line) to the corresponding main plot. At the main plot, this main line was split into two sub-lines (19 mm ID, pipes) with independent in-line valves installed prior to the subplots to control irrigation flow at the subplot levels in the closest block. To irrigate plants in each subplot, a drip irrigation tape with emitter discharge rates of 0.75 L h^{-1} (wall thickness 0.2 mm, 16 mm ID, emitter separation 30 cm) was connected to the sub-line. At the end of the subplot, the drip irrigation tape was reconnected to the sub-line and directed to its corresponding subplot in the next blocks.

Irrigation requirement varied according to the treatments and was determined on a daily basis considering evapotranspiration and precipitation data (Madramootoo et al., 1993):

$$I_r = I_{r(i-1)} + ET_{c(i-1)} - P_{i-1} - I_{i-1} \quad (1)$$

where I_r is the irrigation requirement on the *i*th day (mm), $I_{r(i-1)}$ is the irrigation requirement on the previous day (mm), $ET_{c(i-1)}$ is the crop evapotranspiration on the previous day (mm), P_{i-1} is the precipitation (rainfall) on the previous day (mm), I_{i-1} is the irrigation applied on the previous day (mm).

Crop evapotranspiration, ET_c (mm), was determined daily based on the use of a reference evapotranspiration, ET_0 (mm), and adjusted by the crop coefficient, K_c (dimensionless, single approach by Allen et al., 1998):

$$ET_c = ET_0 K_c \quad (2)$$

Data of wind speed, solar radiation, air temperature, and relative humidity were required to derive the parameters for daily ET_0 calculation following procedures outline by Allen et al. (1998). Wind speed data were obtained from the closest weather station located less than 1 km from the field experiment. Solar radiation was measured on site by using a pyranometer (Model LI-200, LI-COR Biosciences, Lincoln, NE, USA), and air temperature and relative humidity were measured by using a HMP45C-L probe (Campbell Scientific, Logan, UT, USA) installed on site at a height of 2 m. Both sensors were connected to a datalogger (CR10, Campbell Scientific, Logan, UT, USA) for data collection. The basic K_c values (no saline irrigation and bare soil) were defined for periods of 10 days as follow: 0.60, 0.60, 0.65, 0.75, 0.85, 0.95, 1.05, 1.05, 1.05, 1.05, 1.01, and 0.94. Depending on the treatments, these values were further reduced by approximately 30% (non-saline irrigation with mulch), 25% (saline irrigation without mulch), and 48% (saline irrigation with mulch) following procedures outlined by Allen et al. (1998) for these conditions.

Nitrogen, phosphorus and potassium (NH_4NO_3, $NH_4H_2PO_4$, KNO_3) fertilization was applied by fertigation at the beginning of each growth stage: vegetative stage (transplanting), appearance of the first flower, first fruit set, and first harvest of fruits at a rate of 25 kg ha^{-1} of N, and 10 kg ha^{-1} of P_2O_5 and K_2O each time. Weeding was done manually within plots and mechanically (mini-tractor and weeder) in the space between beds as needed. Plant staking was performed on 9 August 2005 to support fruit load. Pests were controlled by the use of the insecticide Orthene® (Acephate 75%) applied twice at a rate of 1.1 kg ha^{-1} during the experiment.

2.4. Soil temperature

The soil temperature was measured by using a pair of copper–constantan thermocouples at soil depths of 10 and 20 cm, respectively, within each sub-subplot. The thermocouples were connected to a datalogger (CR10, Campbell Scientific, Logan, UT, USA) to store information. Readings of averaged temperature were registered every hour.

2.5. Evaluation of fruit yield

Fruits of the centre six plants per sub-subplot were harvested when they reached maturity (90% of color developed), graded, counted and weighed (balance Model PB800, Mettler Toledo, Switzerland). Grading was based on size as follows: jumbo (≥10 cm