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Effects of Increasing Salinity on Fruit Development and Growth of Tomato Grown in Soil-less Culture

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Abstract

There is likely to be increased use of soil-less growing systems using re-circulation in the greenhouse-based horticultural systems of coastal south-eastern (SE) Spain, because of social pressure to reduce nutrient loss to the environment and the higher efficiencies in water and fertiliser use. In this region, irrigation is conducted with groundwater with moderate salinity, which is further increased by the continuous application of nutrients using fertigation. For the adoption of soil-less growing systems using re-circulation, it is essential that the effects of salinity on crops be understood, and that optimal management strategies be developed. The present study assessed the effects of salinity on flowering, fruit set and fruit growth of tomato grown in soil-less culture with re-circulation under SE Spanish conditions.

The experiment was carried out in Almería, Spain. Tomatoes were grown from December to June in a greenhouse, in perlite containers with re-circulation. Five treatments of increasing salinity (2.5 – the control, 3, 4, 6 and 8 dS m^{-1}) were applied. Increased salinity decreased the total number of flowers, but the total number of fruits did not show significant differences among treatments because the fruit set index increased with salinity except for the highest saline treatment. Fruit growth rate and fruit development period decreased with increasing salinity giving smaller fruits with lower fresh and dry weights. The percentage of dry matter in fruit increased linearly with salinity. This suggested that the flow of water into fruit was more sensitive to salinity stress than the transfer of assimilates.

INTRODUCTION

The management of vegetable crops grown under saline conditions is currently of considerable interest in Mediterranean coastal areas, because of (i) the commonly moderate water quality, (ii) declining water quality in some regions, and (iii) the interest in the future adoption of closed soil-less growing systems. In order to optimise agronomic production in these regions, it is necessary to understand the development and growth of crops grown in saline conditions. In Almeria and neighbouring provinces in coastal south-eastern (SE) Spain, approximately 30,000 ha of plastic greenhouses are used for vegetable production. Economically, tomato is the most important crop. Currently, there is very little information describing the effects of salinity on the development and growth of tomato grown under greenhouse conditions in SE Spain.

Total tomato production depends on the number of trusses per plant, number of flowers per truss, fruit set index and fruit weight. Salinity can reduce the number of trusses per plant when highly saline irrigation water is used (Cruz, 1990), and through prolonged exposure to moderate saline conditions (Ieperen, 1996). Some authors (González-Fernández and Cuartero, 1994; Grunberg et al., 1995) have suggested that there is a basic number of flowers per truss, to which plants suffering stress (e.g. salinity) are constrained, and that higher numbers are only obtained under favourable environmental and physiological conditions. With respect to fruit set, Adams and Ho (1992) did not obtain a reduction when increasing salinity to 10 dS m^{-1}, although a reduction occurred on the upper trusses at 15 dS m^{-1}.

The final size of tomato fruit is determined by the fruit growth rate (FGR) and the fruit development period (FDP), both of these parameters decrease with increasing salinity (Li, 2000). It is clear that salinity negatively affects both final size and fresh weight of tomato fruit. However, the effect of salinity on fruit dry weight is not clear, with both negative (Ieperen, 1996; Petersen et al., 1998) and no effects (Ehret and Ho, 1986; Adams and Ho, 1989) being reported. Increases in percentage fruit dry matter content with increasing salinity are generally observed (Li, 2000).

In the current paper, data describing the effect of increasing salinity on flowering, fruit set and fruit growth of a spring tomato crop grown in a greenhouse in SE Spain are presented.

MATERIALS AND METHODS

The experiment was conducted in Almería, Spain, in a multi-span greenhouse (960 m^2) covered with polyethylene, and without active climate-control systems. Tomato seedlings (*Lycopersicon sculentum* 'Boludo') were transplanted on 27 December 2001 and grown until 28 June 2002 in 28 L styrofoam containers, filled with perlite (3-6 mm diameter), which were placed in gutters. Crop density was 2 plants per m^2 in north-south oriented rows. Nutrient solutions were re-circulated in a semi-closed system; a drainage fraction of >80 % was used to ensure consistency between the salinity of the substrate and the nutrient solution. Cultural practices were typical of the area. The tomato cultivar was indeterminate and the plants were topped on 22 April 2002. Climatic data, for conditions inside the greenhouse, during the growing season are presented in Table 1.

Five different salinity treatments were compared. The target electrical conductivity (EC) of the nutrient solution of the control treatment (T1) was 2.5 dS m^{-1}. The target EC of the nutrient solutions of the other treatments were 3 (T2), 4 (T3), 6 (T4) and 8 dS m^{-1} (T5). Sodium chloride was added to adjust EC to target values. Each treatment had an independent recirculating system. At the beginning of the crop, the EC of all treatments was the same as that of the control. Eighteen days after transplanting, the increase in the EC of the nutrient solutions commenced and was carried out gradually over 10 days. Daily EC measurements in the applied nutrient solution and drainage were conducted in each treatment with a hand-held EC-meter to control salinity. The EC levels were very stable because of the high drainage fraction. Water and nutrients were added to each treatment from a "refresh" nutrient solution to replenish crop uptake, according to Sonneveld (2000). The recirculating solution was replaced when its EC was 0.5 dS m^{-1} more than the target value, because of the accumulation of elements such as magnesium, sodium and chloride.

The number of trusses, flowers and fruits per plant were measured on 16 plants per treatment. Average fresh weight per ripe fruit was determined from 4 replicates of 16 plants per treatment. Dry matter content of ripe fruit was determined fortnightly by drying 4 samples per treatment (one per replication of 16 plants) at 80 ºC until constant weight. Fruit growth rate (FGR) was assessed on 20 fruits per treatment, which were marked at anthesis on February 19th. Fruit diameter was measured weekly and a correlation between diameter and volume, previously established for each treatment, was used to estimate fruit volume and to calculate FGR. These fruits were also used to determine fruit development period (FDP). FDP was determined as the number of days between anthesis and fruit harvest. Fruits were considered ripe and were harvested when they turned red.

RESULTS

The number of flowers per plant decreased significantly with increasing salinity (Table 2). This parameter is determined by the total number of trusses per plant and the number of flowers per truss. Although neither of these two parameters showed significant differences between treatments, the number of flowers per truss decreased linearly with increasing EC until 5.9 dS m^{-1}, above which there was no further effect (Figure 1).

Despite the effect of salinity on flowering, the total number of fruits per plant was not affected because the fruit set index increased with salinity until 5.9 dS m^{-1} (Table 2). Mean fresh and dry weights of fruit decreased significantly with increasing salinity (Table 1). The relative reduction in dry weight was appreciably less than that in fresh weight (Table 2). Mean fresh weight per fruit decreased linearly with salinity (Table 2), and the percentage dry matter content increased linearly (Figure 2).

Fruit growth was slow for the first 2 weeks (cell division phase) followed by relatively linear growth from 24 to 56 days after flowering (cell expansion phase; Figure 3). Linear regression analysis of fruit growth during the cell expansion phase indicated significant differences between treatments (Table 3). FGR was negatively affected by salinity (Table 3, Figures 3 & 4), which was described by a negative linear regression (Figure 4). Salinity also reduced FDP, the relationship being negatively curvi-linear (Figure 5).

DISCUSSION AND CONCLUSIONS

The data on flowering are consistent with the hypothesis of a basic number of flowers per truss; values were similar for EC's of 5.9 and 7.7 dS m^{-1} and higher in less saline treatments. However, the less saline treatments tended to have lower fruit set indices which resulted in similar total fruit numbers across the range of EC's examined. Stanghellini et al. (1998) and Cuartero and Fernández-Muñoz (1999) also reported that total fruit number was unaffected by moderate salinity.

Salinity had a large negative effect on fruit growth, with the effect occurring during the cell expansion phase, which is in agreement with Ho (1995). Salinity influenced fruit growth by negatively affecting both FGR and FDP, as was observed by

Li (2000). In the current study, the negative effect on FGR was linear between 2.6 and 7.7 dS m^{-1}; the effect on FDP was that of a negative curvi-linear response with little reduction after 5.9 dS m^{-1}.

Both fresh and dry weight per fruit decreased with increasing salinity. The reduction in fresh weight was relatively larger than in dry weight, suggesting that plant water uptake was more affected than assimilate production. These data suggest that salinity has an appreciable negative effect on plant water status and a smaller negative effect on photosynthetic activity of tomato grown in greenhouses under SE Spanish conditions.

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Tables

Table 1. Average, maximum (Max.) and minimum (Min.) air temperature (T) and vapour pressure deficit (VPD) for 24 hour periods (24 h), and average air temperature and VPD values for daytime (Day) and night-time (Night) periods during the growing period. The average indoor daily integral of global radiation (GR) is also presented.

	24 h			Day	Night
	Average	Max.	Min.	Average	Average
T (ºC)	17.2	25.7	11.2	21.0	13.4
VPD (kPa)	0.7	1.8	0.1	1.1	0.2

GR ($MJ\ m^{-2}\ d^{-1}$)	10.2

Table 2. Summary of flowering, fruit set and fruit weight data. n.s., *, **: no statistically significant differences according to variance analysis, $p \leq 0.05$, $p \leq 0.01$. Different letters indicate a significant difference according to LSD test ($p \leq 0.05$).

Treatment	1	2	3	4	5	
Mean EC ($dS\ m^{-1}$)	2.59	3.02	3.92	5.89	7.74	
Number of trusses per plant	9.1	9.1	8.6	8.8	8.7	n.s.
Number of flowers per truss	9.2	8.9	8.7	8.3	8.3	n.s.
Number of flowers per plant	82.9 a	81.1 ab	75.0 bc	72.6 c	72.2 c	**
Number of fruits per plant	71.5	71.8	69.1	67.5	65.5	n.s.
Fruit set index (%)	86.6 c	89.0 bc	92.4 ab	93.0 a	91.1 ab	*
Mean fresh fruit weight (g)	150.8 a	150.9 a	143.3 b	122.3 c	106.7 d	**
Mean dry fruit weight (g)	8.6 a	8.7 a	8.5 ab	8.2 b	7.4 c	**

Table 3. Coefficients of best-fit linear correlation between fruit volume (cm^3) and time (days) for period 24 to 56 days after anthesis for the five treatments. n.s., *, **: no statistically significant differences according to variance analysis, $p \leq 0.05$, $p \leq 0.01$. Different letters indicate a significant difference ($p \leq 0.05$).

Treatment	1	2	3	4	5	
Slope	3.96 ab	3.99 a	3.51 bc	3.28 c	2.62 d	**
Intercept	-64.72 c	-67.46 c	-58.69 b	-51.11 b	-42.59 a	**

Figures

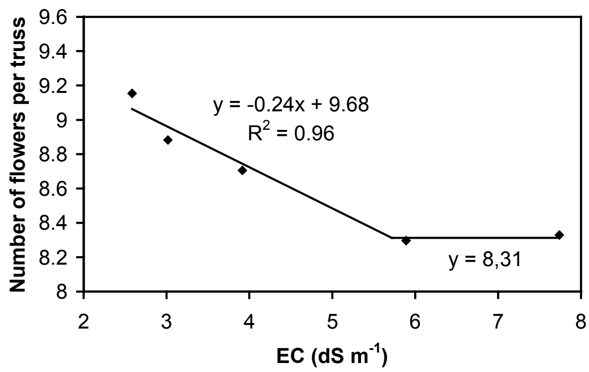

Fig. 1. Effect of salinity on the number of flowers per truss.

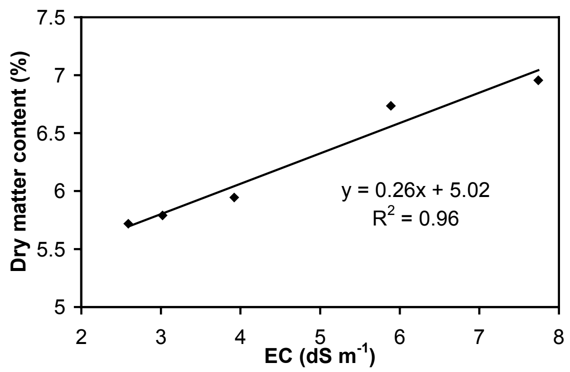

Fig. 2. Effect of salinity on percentage fruit dry matter content.

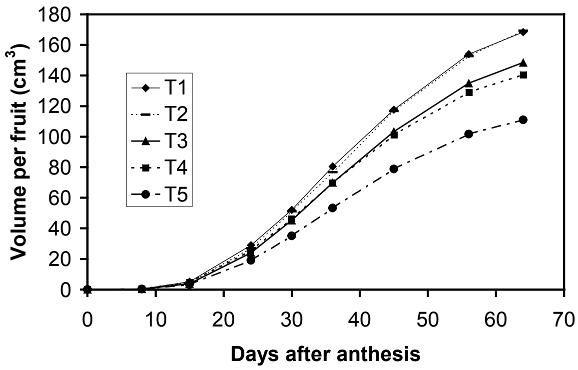

Fig. 3. Evolution of volume per fruit for the five salinity treatments.

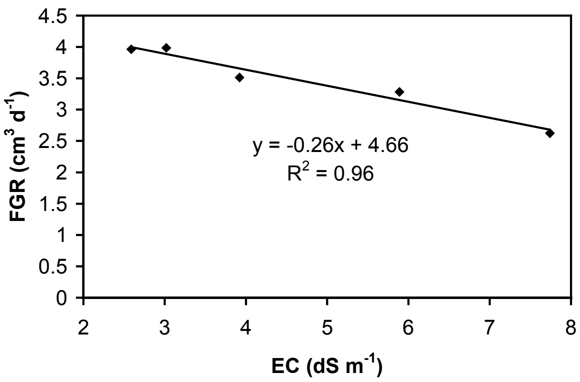

Fig. 4. Effect of salinity on fruit growth rate.

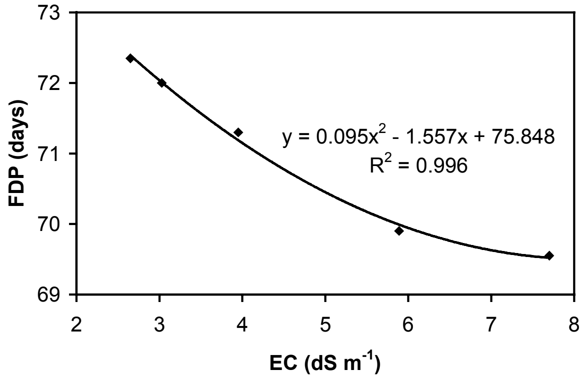

Fig. 5. Effect of salinity on fruit development period.