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Effects of electrical conductivity of irrigation water on the growth and production of *Solanum lycopersicum* L. var. *cerasiforme* grown in greenhouse

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Abstract. Tomato (*Solanum lycopersicum* L.) is commonly considered moderately tolerant to salinity and its tolerance varies in relation to genotype and the plant's organ. With regard to the latter aspect, it was found that the negative effects of salinity become apparent with electrical conductivity values of the circulating solution starting from 2.5 - 3.0 dS m⁻¹ for the fruits, from 4.5 - 5.0 dS m⁻¹ for the stems and leaves and from 6.0 dS m⁻¹ for the roots. Furthermore, cultivars with small fruits show less marked reductions in fruit weight and production; they may therefore represent a solution for environments with only saline water. The aim of the research was to study in tomato var. *cerasiforme* "Naomi" cultivated in greenhouse, the residual effects of irrigation carried out for 10 consecutive years with saline water. At 75 - 90 and 105 days after transplantation, five plants and corresponding soil samples from 0 to -40 cm, were collected from each plot. On each plant, the number and the weight of marketable fruits per cluster and the epigeal biomass dry weight (stems + leaves + fruits) were recorded. On each soil sample the electrical conductivity of extract saturated (EC_e) was determined. The use of irrigation water with EC_w fluctuating around 2.0 dS m⁻¹ over a decade, determined values of EC_e in the soil above the tolerance limit only for the fruit production (3.8 compared to 2.5 - 3.0 dS m⁻¹). With EC_w equal to 6.0 + 10.0 dS m⁻¹, levels of EC_e exceeded those considered detrimental to the production of dry epigeal biomass (stems + leaves + fruits). The effects of increasing EC_e on the fruit production were constantly determined through the reduction of fruit dry unit weight.

Keywords. Saline water – Long-term salinization – Tomato – Biomass – Production.

Les effets de la conductivité électrique de l'eau d'irrigation sur la croissance et la production de *Solanum lycopersicum* L. var. *cerasiforme* cultivé sous serre

Résumé. La tomate (*Solanum lycopersicum* L.) est souvent considérée modérément tolérante à la salinité et, cette tolérance varie en fonction du génotype et des organes de la plante. Considérant cet aspect, il s'avère que les effets négatifs de la salinité commencent à être évidents pour des valeurs de la conductivité électrique de la solution circulante à partir de 2.5 - 3.0 dS.m⁻¹ pour les fruits, 4.5 - 5.0 dS.m⁻¹ pour les tiges et les feuilles, et 6.0 dS.m⁻¹ pour les racines. En plus, les cultivars à petits fruits montrent des réductions moins considérables en terme de poids du fruit et production ; par conséquent, ils peuvent présenter une solution pour les environnements qui disposent seulement d'eau saline. L'objectif de cette expérimentation est d'étudier les effets résiduels de l'irrigation avec eau saline réalisée pour dix années consécutives sur la tomate var. *cerasiforme* «Naomi» cultivée sous serre. Aux jours 75, 90 et 105 après la transplantation, cinq plantes et les correspondants cinq échantillons de sol de 0 jusqu'à 40 cm, ont été collectés de chaque parcelle. Le nombre et le poids des fruits commercialisables par grappe et la biomasse en poids sec (tiges + feuilles + fruits) ont été enregistrés pour chaque échantillon de plante. La conductivité électrique de l'extrait de pâte saturé (EC_e) de chaque échantillon de sol, a été déterminée. L'utilisation, pour une décennie, d'une eau d'irrigation ayant une EC_w fluctuant autour de 2.0 dS m⁻¹, a déterminé des valeurs de la EC_e du sol au-dessus de la limite de tolérance seulement pour la production de fruits (3.8 comparé à 2.5 - 3.0 dS.m⁻¹). Avec des EC_w de 6.0 + 10.0 dS m⁻¹, les valeurs de l'EC_e ont dépassé les limites de tolérance de la biomasse (tiges + feuilles + fruits). Les effets de l'augmentation d'EC_e sur la production des fruits ont été déterminés par la réduction du poids sec unitaire des fruits.

Mots-clés. Eau saline – Salinisation à long terme – Tomate – Biomasse.

I – Introduction

Salt stress responses in crop plants throughout their growth cycle depend on several interacting variables, including the cultural environment, the plant developmental stage, the salt concentration and the duration of the stress over time (Munns, 2002). The damages to plants caused by saline irrigation may be enhanced by high temperatures and low relative humidity as well as long-term salinization of the soil that undergo to permanent modifications of its physicochemical properties; as a consequence in applying saline water for irrigation, an integrated approach, which should account for soil, crop and water management, should be adopted.

Plant salt tolerance may be expressed by plotting the relative yield as a continuous function of root zone salinity (Maas and Hoffman, 1977). This relationship is represented by two intersecting linear regions, which identify a threshold, after which the yield begins to decline as well as the yield reduction rate (slope) at increasing salinity. The salinity tolerance threshold is a specific target for improving plant salt stress tolerance (Maggio *et al.*, 2001; 2007).

Tomato (*Solanum lycopersicum* L.) is commonly included among the species that are moderately tolerant to salinity, and moreover it could be a model crop for saline water use because it is already grown in large areas with saline conditions, and because the physiology and genetics of this species are well known; its salt tolerance varies in relation to genotype (Cuartero *et al.*, 2006; Villalta *et al.*, 2007) and the plant's organ. With regard to the latter aspect, many researches showed that the negative effects of salinity become apparent with electrical conductivity values of the circulating solution starting from 2.5 - 3.0 dS m⁻¹ for the fruits, from 4.5 - 5.0 dS m⁻¹ for the stems and leaves (Cuartero and Fernandez-Munoz, 1999) and from 6.0 dS m⁻¹ for the roots (Nanawati and Maliwal, 1974; Papadopoulos and Rendig, 1983, reviewed by Cuartero and Fernandez-Munoz, 1999; Marchese *et al.*, 2007).

In researches conducted on large fruit cultivars, reductions in fruit weights by 10% with 5.0 - 6.0 dS m⁻¹, by 30% with 8.0 dS m⁻¹ and by 40% with over 10.0 dS m⁻¹ were observed (Gonzalez-Fernandez and Cuartero, 1993; Cuartero and Fernandez-Munoz, 1999; Reina-Sánchez *et al.*, 2005). Cultivars with small fruits reveal, however, less marked reductions in fruit weights (Cruz and Cuartero 1990) and production (Caro *et al.*, 1991). They may therefore represent a solution for environments with only saline water. The use of drip irrigation for irrigated vegetable cropping like tomato in soils exposed to salinization is a more general solution to the salinity problem, reducing the effects of salt stress as the drip irrigation is applied more frequently and keeps the soil water content high enough, thus reducing the osmotic pressure and the negative impact of salinity on water uptake (Flowers *et al.*, 2005; Malash *et al.*, 2005; Hanson *et al.*, 2006; Incrocci *et al.*, 2006; Karlberg *et al.*, 2007).

The objective of this experiment was to study the residual effects of irrigation carried out for 10 consecutive years with saline water on salt accumulation in the soil and on growth and yield of tomato var. *cerasiforme*.

II – Materials and methods

The trials of this research were conducted in an area south east of Sicily, highly representative for the cultivation of tomato in greenhouse and for saline irrigation.

The study was conducted in Pachino (Southern-East Sicily) on sandy soil (sand > 80%), lying on particularly permeable limestone owing to the fissures. An unconditioned greenhouse was used that during the period 1997-2006 hosted tomato crops for fresh use (two cycles per year) irrigated with water whose electrical conductivity (ECw) fluctuated around 2.0 dS m⁻¹ (well water) or 6.0 dS m⁻¹ in the seven years from 1997-2004 and 10.0 dS m⁻¹ in the next three years (well water + table salt).

Irrigation was performed by dripping near the plants. In 2006, the residual effects of irrigation were assessed in "Naomi" cultivated in winter-spring cycle. An experimental design with randomized blocks, repeated 3 times, was adopted; the plot measured 17 m² (8.5 x 2.0 m). At 75 - 90 and 105 days after transplantation, five plants and corresponding soil samples from 0 to -40cm, were collected from each plot.

On each plant the number and the weight of marketable fruits per bunch, and the epigeal biomass dry weight (stems + leaves + fruits) were recorded. On each soil sample the electrical conductivity of extract saturated (ECe) was determined.

The relationships between the ECe and the productions were evaluated through Pearson's correlation and regression analysis. For the calculation of the latter, values for the biomass and fruit production, expressed as percentages of the maximum recorded, were used.

III – Results and discussion

The increase of ECw from 2.0 to 6 +10 dS m⁻¹ led to a significant increase in ECe (Fig. 1). This latter appeared appreciable already after 75 days from transplanting and after 105 days was equal in average to 4.7 dS m⁻¹ (3.4 compared to 6.1 dS m⁻¹); the highest values of ECe occurred since late spring were due probably to saline irrigation associated to intense evapotranspiration.

Owing to the ECe increase, the dry weight of the epigeal biomass and fruits per cluster showed significant decreases which, after 105 days from transplant, reached the maximum values equal to 20% and 15%, respectively (Figs. 2 and 3).

Of the production components, only the average dry unit weight of the fruit revealed a significant ($P \leq 0.01$) and negative correlation with ECe ($r = -0.680$); also this parameter showed a significant decrease which, after 105 days from transplant, was 8% (Fig. 4).

The regression analysis between ECe and the parameters examined, expressed as percentages of the maximum recorded (relative values), showed that the increase of ECe determined a significant ($P \leq 0.01$) decrease of epigeal biomass, fruit production per cluster and fruit unit dry weight. The b coefficient identifies a specific slope, which defines the parameter reduction at increasing salinity. The increase of 1 dS m⁻¹ of ECe, led to a calculated reduction of 8% for epigeal biomass and of 7% both for production per cluster as well as for fruit unit weight (Figs. 5-6-7) showing that the decrease of fruit unit weight determined the production reduction.

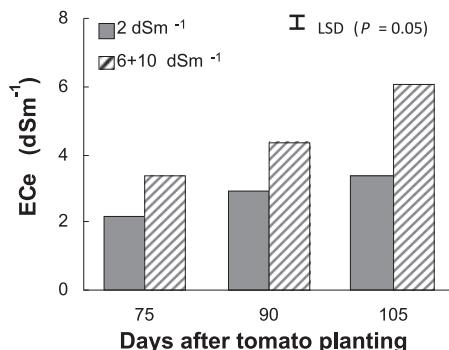


Figure 1. ECe variation in relation to ECw.

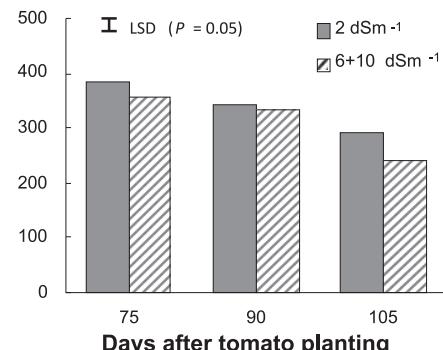


Figure 2. Dry epigeal biomass in relation to ECw.

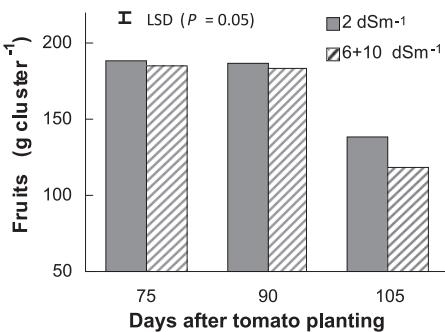


Figure 3. Fruit dry weight per cluster in relation to ECw.

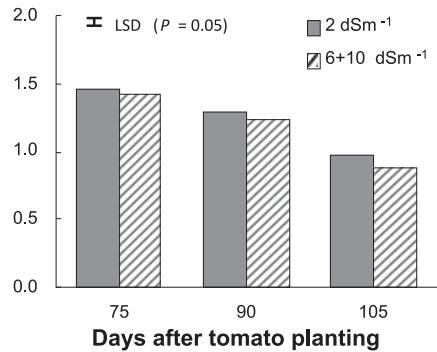


Figure 4. Fruit dry unit weight in relation to ECw.

At maximum ECe value observed (6.0 dS m^{-1}), the calculated decreases were 43%, 36% and 40% for epigeal biomass, fruits per cluster and dry unit weight of the fruit, respectively.

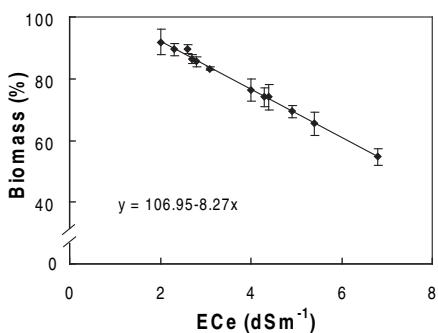


Figure 5. Relative plant dry biomass in response to increasing of ECe.

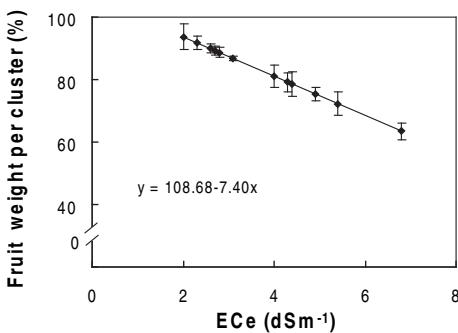


Figure 6. Relative fruit dry weight production per cluster in response to increasing of ECe.

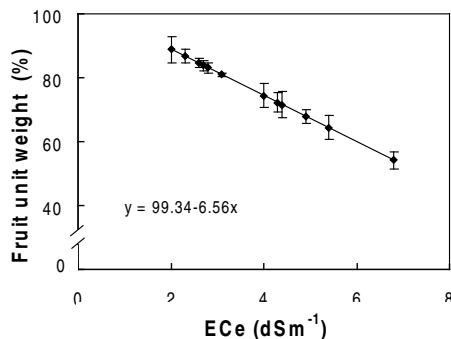


Figure 7. Relative fruit unit dry weight in response to increasing of ECe.

IV – Conclusions

The results gathered after 10 years of irrigation with saline water on tomato indicate that, in the given conditions, the use of irrigation water with EC_w fluctuating around 2.0 dS m⁻¹ over a decade, determined values of EC_e in the soil above the tolerance limit only for the fruits production (3.8 compared to 2.5 - 3.0 dS m⁻¹). With EC_w equal to 6.0 +10.0 dS m⁻¹, levels of EC_e exceeded those considered detrimental to the production of dry epigeal biomass (stems + leaves + fruits). The effects of increasing EC_e on the fruit production were constantly determined through the reduction of fruit dry unit weight.

The effect of salt stress on growth and production depends by EC_w as well as evapotranspiration and water management strategies, in particular by irrigation method.

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