200435

estación experimental

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IX International Symposium on Growing Media and Hydroponics. 14-19 November 2004
Almería - Spain

Uptake Concentrations of a Tomato Crop in Different Salinity Conditions

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Keywords: closed system, *Lycopersicon esculentum,* nutrient uptake, recirculation, sodium chloride, soil-less culture.

Abstract

In the near future, it is likely that closed soil-less growing systems will be increasingly adopted in Mediterranean countries because they reduce water and fertiliser use, and appreciably reduce nutrient loss to the environment. However, closed systems increase the salinity of the re-circulating nutrient solution through the progressive accumulation of ions not required by crops and/or applied in excess of crop requirements. Additionally, it is necessary that nutrients be added to the solution according to crop absorption to avoid fluctuations of nutrient concentrations in the re-circulating solution. To obtain information for the management of re-circulating nutrient solutions in soil-less systems in a Mediterranean environment, an experiment was conducted with tomato during the 2002-03 growing season. Five different salinity treatments (2.5, 4.0, 5.5, 7.0 and 8.5 dS m^{-1} in the drainage solution) were compared. The first treatment was the control, the higher salinity levels were obtained by adding sodium chloride. Total aerial dry matter production, and the absorption of macronutrients and of sodium and chlorine were measured for each treatment. Uptake concentrations of the macronutrients, and sodium and chlorine were determined for each treatment.

With increasing salinity, both dry matter production and nutrient uptake tended to decrease, while sodium and chlorine uptake increased. An antagonistic effect of sodium chloride on potassium and nitrogen uptake was observed. For the other nutrients, no antagonistic effects were observed with the decreases in uptake being proportional to the decrease in dry matter production. Uptake concentrations for each nutrient were almost constant with increasing salinity except for potassium, sodium and chlorine. Uptake concentration of potassium decreased linearly with increasing salinity by 3% per dS m^{-1} above the electrical conductivity (EC) of the control treatment, whereas the uptake concentrations of sodium and chlorine increased linearly by, respectively, 74 and 61% per dS m^{-1} above the EC of the control treatment.

INTRODUCTION

The formulation of nutrient solutions in soil-less growing systems is based on nutrient concentration. The use of nutrient concentrations rather than of absolute quantities is preferred because concentrations are more constant and easier to manage. To ensure relatively constant concentrations of individual nutrients, it is useful to know the rates of absorption of those nutrients. Crop absorption of individual nutrients can be evaluated relative to the absorption of water; this ratio is referred to as the uptake concentration of a nutrient (Sonneveld, 2000, p94). This ratio does not have a physiological basis but is a very useful concept for the practical management of nutrient solutions.

In addition to being a management aid for essential plant nutrients, uptake concentrations can also be used for the management of potentially harmful ions, such as sodium and chloride. By knowing the concentrations in irrigation water and the volumes of the added and absorbed nutrient solutions, uptake concentrations can be used to calculate accumulation in the growing system and to estimate the flushing fraction required to maintain the concentrations of potentially harmful ions beneath those where production may be affected.

Several authors have published information about uptake concentrations for tomato (e.g., Sonneveld, 2000, p95; Malorgio et al., 2001; Stanghellini et al., 2003). However, very little information is available for greenhouses in the coastal region of southeastern Spain. The objective of the current study was to determine the uptake concentrations of nutrients for a tomato crop grown with different levels of salinity in a greenhouse in this region.

MATERIALS AND METHODS

The experiment was conducted in a multi-span greenhouse with polyethylene cover and passive climate control in Almería, Spain. Tomato (*Lycopersicon sculentum* 'Boludo') was grown from 10 September 2002 to 3 June 2003 at a crop density of 2 plants per m^2. The plants were grown in perlite (3-6 mm) in 28 L styrofoam containers located in gutters. Nutrient solutions were re-circulated in a semi-closed system with a drainage percentage of >90 %, which ensured that substrate and drainage solutions were very similar.

Five different salinity treatments were compared. The EC of the drainage solution of the control treatment was 2.5 dS m^{-1}. The target EC's of the other treatments (4, 5.5, 7 and 8.5 dS m^{-1}) were obtained by adding sodium chloride (NaCl) to the re-circulating solution to increase EC. This addition started one week after transplanting and was made gradually over seven days until the target EC's were reached. Replacement of water and nutrients absorbed by the crop was done by adding "fresh" nutrient solution, adjusted for crop nutrient absorption to the collector tank corresponding to each EC treatment. The re-circulating solution was flushed when its EC was consistently 0.5 dS m^{-1} more than the target value, due to the accumulation of ions such as sodium, chloride or magnesium.

Re-circulating and "fresh" solutions were analysed weekly. The volumes of each addition of fresh nutrient solution to each treatment were measured. The volumes and composition of the flushed re-circulating solutions were also measured. With this information, regular nutrient and water balances were calculated which enabled calculation of the quantities of water and nutrients absorbed by each treatment and of the uptake concentrations for each nutrient. Fresh fruit production and fruit dry matter content were measured on 4 replications of 16 plants each per treatment. Fruit dry matter production was calculated using these data. Shoot dry matter production was measured on 8 plants per treatment. The fruit and shoot dry matter data enabled the total aerial dry matter production of the crop to be determined.

RESULTS

The increase in the EC of the re-circulating nutrient solution by the addition of NaCl reduced total aerial dry matter production and macro-nutrient uptake (Table 1). However, the uptake of sodium and chlorine increased with increasing EC. There were positive linear relationships between dry matter production and total nutrient uptake for each nutrient examined (Fig. 1). For phosphorus, calcium, magnesium and sulphur, the straight line passed through the origin, whereas for potassium and nitrogen it passed below this point indicating a decreased absorption of both elements relative to dry matter production when salinity increases. There was a negative linear relationship between nutrient uptake and dry matter production for sodium and chlorine, indicating a strong accumulation of both elements in plant material with increasing salinity.

Uptake concentrations were more stable, with increasing salinity, than the absolute absorption of nutrients (Table 2). However, the uptake concentrations of sodium, chlorine and potassium were influenced by increasing salinity by the addition of NaCl. There was a strong positive linear correlation between the uptake concentration of sodium and its concentration in the re-circulating solution (Fig. 2a), with its uptake concentration increasing by 74 % per dS m^{-1} above the control treatment. For chlorine, the uptake concentrations were slightly higher than those of sodium (Fig. 2b), and increased with salinity by 61 % per dS m^{-1} above the control treatment. In contrast, the uptake concentration of potassium decreased linearly with salinity, by 3 % per dS m^{-1} above the control treatment. There was a clear negative linear correlation between the uptake concentration of potassium and the concentration of sodium in the re-circulating solution (Fig. 3).

The effects of increasing salinity from 2.5 to 8.5 dS m^{-1} on the uptake concentrations of the other nutrients were very small or non-existent (Table 2). Those of calcium and magnesium increased slightly with salinity, increasing from 2.6 to 2.8 mmol L^{-1}, and from 0.9 to 1.0 mmol L^{-1}, respectively. The uptake concentration of nitrogen decreased slightly from 10.9 to 10.6 mmol L^{-1}. The uptake concentrations of phosphorus and sulphur were unaffected by salinity, being maintained at 1.2 and 0.9 mmol L^{-1}, respectively.

DISCUSSION

The higher absorption of sodium by plants in the more saline treatments, which occurred as a consequence of the higher sodium concentration in the re-circulating solution, apparently had an antagonistic effect on potassium uptake which was reduced with increasing salinity. A similar but weaker antagonistic effect was observed between chlorine and nitrogen. Both of these antagonistic effects are reported in the literature (Grattan and Grieve, 1999).

The effect of EC on total dry matter production of tomato is a matter of debate in the literature, with both no effect (Li, 2000) and negative effects (Ieperen, 1996) being reported. The reduced dry matter production found with increasing salinity in the current study possibly decreased the absolute requirements for nutrients, which is suggested by the the strong linear relationships between dry matter production and nutrient uptake. These linear relationships are similar to those indicated by Sonneveld (2000, p94) for cucumber and chrysanthemum, which were reported for fresh weight production.

With the exceptions of sodium, chlorine and potassium, uptake concentrations were relatively constant with EC. The lack of an effect of EC on these uptake concentrations suggests that for these nutrients the formulation of nutrient solutions may be straightforward. In general, the uptake concentration values determined in this study are similar to those reported by Sonneveld (2000, p95) for tomato grown in Dutch greenhouse conditions. However, we did not find an increase of the uptake concentration of nitrate and potassium with salinity, as was reported by Stanghellini et al. (2003). This could be related to the reduced needs of nutrients at high salinity in the present study, as a consequence of the lower dry matter production compared to the control treatment.

The positive linear relationships between the uptake concentrations of sodium and chlorine and their respective concentrations in the nutrient solution, agrees with results from studies conducted in Mediterranean (Malorgio et al., 2001) and northern Europe climatic conditions (Sonneveld, 2000, p96). These relationships can be useful for the evaluation of water use in closed soil-less growing systems. The quality of irrigation water will determine its suitability for total or partial re-circulation of the nutrient solution where an objective is to control the EC to ensure optimal production and quality. Much of the water used for irrigation in south-eastern Spain has concentrations of sodium and chloride in excess of the uptake concentrations determined in the current study (Dirección General de Investigación y Extensión Agraria, 1991), suggesting that often only partial re-circulation will be possible in this region. The enhanced use of rainwater will assist in the management of these systems.

Literature Cited

Dirección General de Investigación y Extensión Agraria. 1991. Estudio aguas-suelo de la provincia de Almería. Consejería de Agricultura y Pesca de la Junta de Andalucía. 133 pp.

Grattan, S.R. and Grieve, C.M. 1999. Salinity-mineral nutrient relations in horticultural crops. Scientia Horticulturae, 78: 127-157.

Ieperen, W. van. 1996. Effects of different day and night salinity levels on vegetative growth, yield and quality of tomato. Journal of Horticultural Science, 71: 99-111.

Li, Y.L. 2000. Analysis of greenhouse tomato production in relation to salinity and shoot environment. PhD thesis. University of Wageningen. 96 pp.

Malorgio, F.; Incrocci, L.; Carmassi, G.; Pardossi, A. and Tognoni, F. 2001. Accumulo di sali (NaCl) e consumo minerale in pomodoro coltivato in systemi idroponici a ciclo chiuso. Italus Hortus, 8 (6): 43-48.

Sonneveld, C. 2000. Effects of salinity on substrate grown vegetables and ornamentals in greenhouse horticulture. PhD thesis. University of Wageningen. 151 pp.

Stanghellini, C.; Kempkes, F.; Heuvelink, E.; Bonasia, A.; Karas, A. and Botden, N. 2003. Water and nutrient uptake of sweet pepper and tomato as (un)affected by watering regime and salinity. Acta Horticulturae, 614: 591-597.

Tables

Table 1. Effects of EC (dS m^{-1}) on total aerial dry matter production (g m^{-2}) and nutrient uptake (g m^{-2}) during the experiment.

CE	**2.7**	**4.0**	**5.5**	**6.9**	**8.4**
Dry matter production	2118	2165	1985	1863	1752
N	69.9	68.6	61.1	54.9	51.0
P	17.3	16.3	14.7	13.2	12.5
K	100.1	95.0	82.4	68.2	62.6
Ca	47.2	47.0	43.6	39.9	37.7
Mg	10.3	10.8	9.8	8.9	8.3
S	13.9	13.0	12.0	10.7	10.1
Na	7.9	14.8	19.4	25.4	30.7
Cl	15.8	25.8	34.3	44.4	51.9

Table 2. Effect of EC (dS m^{-1}) on average uptake concentration (mmol L^{-1}) of each nutrient during the experiment.

CE	**2.7**	**4.0**	**5.5**	**6.9**	**8.4**
N	10.8	10.9	10.7	10.7	10.6
P	1.2	1.2	1.2	1.2	1.2
K	5.6	5.4	5.2	4.8	4.7
Ca	2.6	2.6	2.7	2.7	2.8
Mg	0.9	1.0	1.0	1.0	1.0
S	0.9	0.9	0.9	0.9	0.9
Na	0.8	1.4	2.1	3.0	3.9
Cl	1.0	1.6	2.4	3.4	4.3

Figures

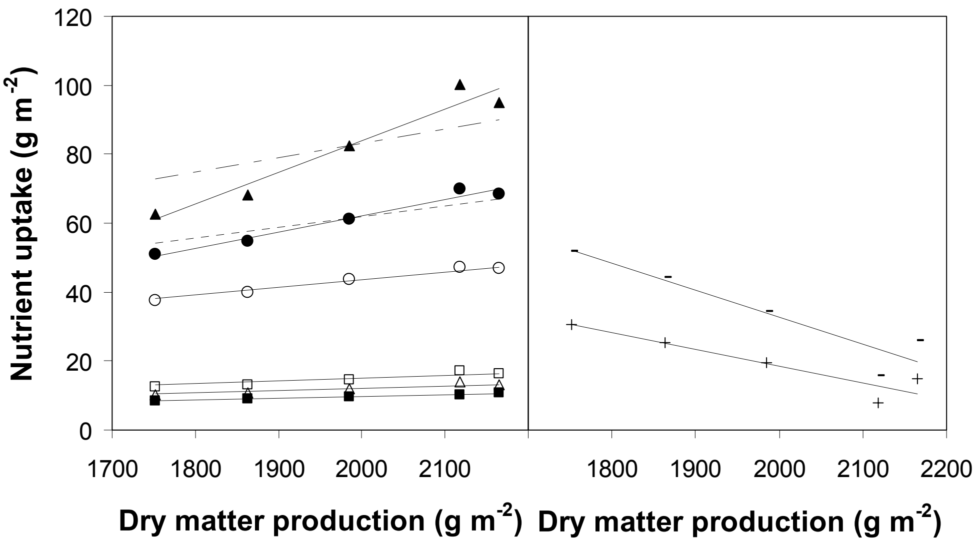

Fig. 1. Relation between the total aerial dry matter production and the total nutrient uptake of macronutrients, and sodium and chlorine (●, N; □, P; ▲, K; ○, Ca; ■, Mg; Δ, S; +, Na; ─, Cl). Solid lines are the best fit (lines corresponding to P, Ca, Mg and S pass through the origin). Dotted lines are the fit that, hypothetically, would pass through the origin for N ( ) and K ( ).

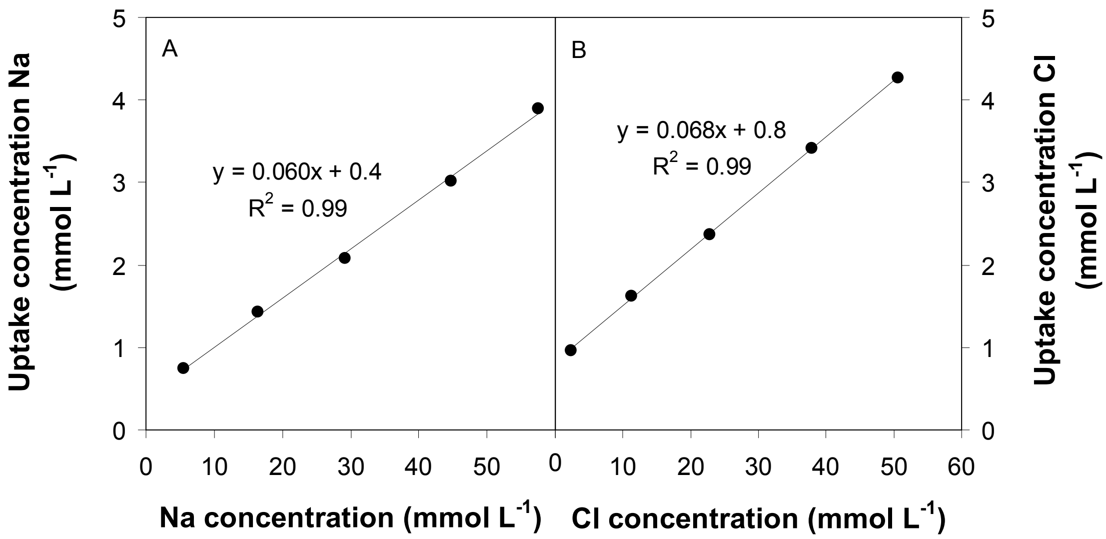

Fig. 2. (A) Relation between the average concentration of sodium in the re-circulating solution and the average uptake concentration of sodium, and (B) between the average concentration of chloride in the recirculating solution and the average uptake concentration of chlorine during the experiment. Solid lines are the best fit lines.

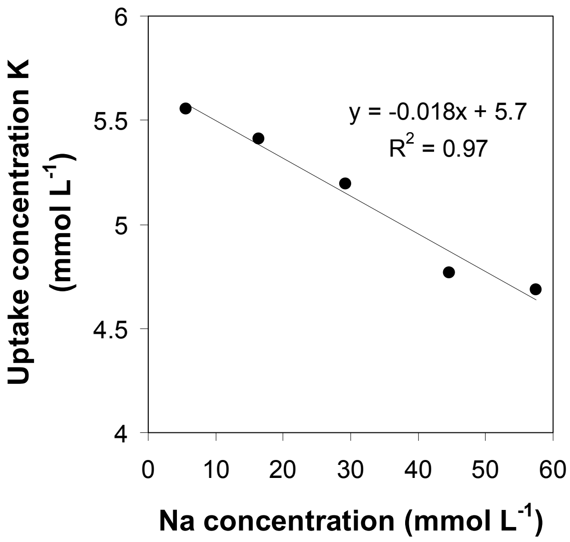

Fig. 3. Relation between the average concentration of sodium in the re-circulating solution and the average uptake concentration of potassium during the experiment. Solid line is the best fit line.