COMBINED EFFECT OF CLIMATE AND CONCENTRATION OF THE NUTRIENT SOLUTION ON A GREENHOUSE TOMATO CROP. II: YIELD QUANTITY AND QUALITY

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Abstract

Growing systems that recirculate the nutrient solution are attractive, because they couple saving of water and fertilizers with decreased leaching. However, the longer irrigation water is collected and re-used, the higher the concentration of salts. Maintaining the EC of the nutrient solution within (conservative) boundaries requires flushing rates of 30% or more, in spite of the recirculating facilities. In order to determine the processes responsible for the reduction of fresh yield, that is often the consequence of growth under salinity stress, we investigated the effect on production (that is, yield quantity and quality) of a tomato crop, of high EC in combination with two water uptake rates. Associated results about leaf growth are presented in the first paper of this series.

Climate in two identical glasshouses was controlled to maintain a constant ratio (65%) of potential evaporation, while preserving equal assimilation levels. Half of the rows in each house were given a 2 dS/m treatment in the root medium whereas the other half were given 10 dS/m. Leaf growth, canopy development and fresh and dry yield were traced during a whole spring growing season. Parameters of yield that were measured were: total fresh and marketable yield, fruit size distribution, fruit elasticity, fruit dry matter and sugar content, acidity and salinity.

Fresh yield was affected by both treatments as follows: high EC significantly reduced yield, whereas the low transpiration treatment only mitigated the effect of high EC. In particular, in the high transpiration treatment marketable yield was reduced by 30% (due both to 25% smaller fruits and to 20% blossom-end rot, BER), whereas in the low transpiration treatment high EC reduced both size and yield by 15%, and incidence of BER was only 2%. Dry matter and sugar content were higher in the high EC treatments, so that total dry matter yield was the same everywhere, except the high EC, high transpiration treatment, where BER reduced marketable dry matter by 25%. Fruit elasticity (both at harvest and after one week) was not affected by any treatment, if differences in size were accounted for.

It is concluded that an appropriate use of available tools for manipulating indoor climate, makes it possible to offset the effect of a high salinity of irrigation water. In particular, it is shown that a grower could accept a decrease in yield if there were a sufficient increment in quality of the product.

1. Introduction

Owing both to environmental regulations and to decline in both quantity and quality of

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irrigation water, re-use of drained irrigation water is becoming a common practice. The ensuing accumulation of salts (either present in the water source or unused fertilizers) means that growers will have to learn to grow crops with higher EC-salinity of irrigation water. Higher solute content is known to reduce yield (e.g. Sonneveld, 1988) and is related to some fruit disorders (for instance, Adams and Ho, 1992; Ho *et al.*, 1993; Willumsen *et al.*, 1996). However, high salinity is also believed to improve quality of fruits (Matan and Golan, 1988; van Ieperen, 1996). Weather/climate conditions during growth are suspected to modulate all of the above mentioned effects. In particular, a number of fruit physiological disorders are known to be caused by some mismatch in the water/nutrient balance. For instance, Bradfield and Guttridge, 1984 and Banuelos *et al.*, 1985 observed effects of ambient humidity, albeit conflicting, upon the incidence of blossom-end rot (BER) in tomato. The working hypothesis is that advanced greenhouse management may take advantage of the ability to control plant water balance by regulating solute content and (to an extent) water outflow, through climate control, thereby getting the opportunity to increase fruit quality and avoid fruit physiological disorders, to offset a reduction in yield. Such a cost-benefit balance, requires some insight into the yield response to both salinity and selected factors of the climate within the house. Gathering knowledge about this aspect is the specific aim of this work.

2. Materials and Methods

The experiment has been described in more detail in the previous paper of this series (Stanghellini *et al.*, 1997), but will be briefly described here. The experimental design entailed two "potential evaporation" treatments in factorial combination with two nutrient concentrations of the irrigation water, in order to achieve an EC of 2 and 10 dS/m, respectively, in the root medium. This was done in two identical glasshouse compartments (each 300 m^2): the climate of one (the reference), was controlled according to standard cultural practices in Holland (high transpiration) while the air temperature and humidity of the other (low transpiration) were controlled in order to have 65% of the potential evaporation calculated for the reference compartment. Solar radiation and CO$_2$ concentration (400 vpm) were the same in the two compartments. In order to avoid large differences in ambient temperature, the climate control algorithm allowed differences in temperature only when manipulation of humidity alone (by a combination of venting and high-pressure misting) did not suffice in ensuring the required difference in potential transpiration. Day- and night-time water use of each section (treatment), calculated from sunrise and sunset readings of water supply and drain, were used to check that the desired difference in water uptake was achieved (*Fig. 1*).

The nutrition treatments were given to half of the crop rows (round tomato *cv. Chaser* on rockwool slabs) in each house. In order to ensure uniformity of EC in the slabs, continuous recirculation took place for about two hours each night. EC of drained solution (that was monitored) seldom diverged significantly from EC of irrigation water (the one that was controlled). The crop was planted on December 15th, 1995 and both treatments were started on February 1st, 1996 (third truss), in order to ensure similar root development. Yield was monitored until the end of June.

Yield from each treatment was analyzed with respect to the following parameters: fresh yield (both total and marketable); yield size distribution; dry matter, sugar and ash content; EC-salinity and acidity. Whole fruit elasticity (load/displacement ratio) was also monitored. In order to get information about the inter-treatment variation to be expected, 7 simulated replicas were selected within each treatment, each a 4-plant section of a row. Both total and marketable yield of each section were counted and weighed separately. However, in order to have a sizable sample for determining the size distribution, the marketable yield of the replicas of each treatment were pooled. Subsequent chemical analysis were performed only on class-A yield, i.e. fruit with a diameter between 47 and 57 mm, that was the most common. In addition, only fruits of colour 9 (red) on the Dutch auction scale between green (1) and purple red (11) were selected. Sometimes the resulting sample had to be packed with fruits picked outside the reference fields.

Dry matter content was determined by gravimetric methods in duplicates of five samples per treatment, of 10 pre-mixed fruits each, dried 18 hours at 105 °C. Sugar content (Brix index), acidity and electroconductivity were measured on the centrifuged juice of the same samples.

3. Results

Yield was highest (and equal) in the two low EC treatments and significantly lower in the other two, *Fig. 2*. The effect of the potential evaporation was obvious in the high EC treatments, where the low transpiration clearly reduced the incidence of BER, *Fig. 3*. There were almost exactly the same number of fruits per plant in all treatments, except the low transpiration low EC one, where 10% less were harvested, the difference was significant ($P<0.01$). As we did not collect information about number of flowers/fruits per truss, no conclusion is attempted about the cause of this difference. Harvested fruits, however, were on the average 8% heavier in the low transpiration, low EC treatment, which accounts for the yield being the same as in the high transpiration, low EC one. High EC reduced mean fruit weight in both houses, *Fig. 4*. In short, both high transpiration and high EC reduce fruit size.

With respect to other yield quality aspects (size is presently the only one that market prices reflect), dry matter and sugar content were significantly higher for both high EC treatments, as can be deduced from the summary given in *Tab. I*. In fact, both absolute dry matter, *Fig. 5*, and sugar yield were the same for all treatments, except the high transpiration/high EC treatment, where yield was reduced by BER.

EC of the fruit sap (not shown) was, as expected, obviously related to the EC treatment and not to the climate. Acidity, on the other hand, increased ($P<0.01$) with EC of irrigation water, as determined also by Willumsen *et al.* (1996). In our case, the difference was much larger (and more significant, $P<0.001$) in the low transpiration house. A quality aspect that does not seem to be affected is fruit elasticity (load/displacement ratio, not shown), that was not significantly different across treatments, when corrected for the differences in size, neither right after harvest, nor after one week at 18 °C.

4. Discussion

There are various aspects about our results, that are worthwhile to relate to previous literature on the subject. A decrease in fresh yield due to increased salinity is simply what everybody expects, and only the reverse would deserve any discussion. In the low transpiration house, the decrease in yield was around 2% for each unit EC exceeding 2 dS/m, the EC threshold value for yield decrease in tomato, according to Sonneveld (1988). However, he determined a decrease rate of 7%, that is much higher even than our value in the high transpiration house, that was roughly 4%. A possible explanation is given by Adams and Ho (1992) who found large variations of susceptibility to BER among tomato cultivars.

The correlation of BER with high salinity is, by now, received wisdom. Our finding that depressing transpiration may significantly reduce incidence of BER is given support by the current understanding that reduced Ca transport to the distal part of the fruit is the main cause of BER, Ho *et al.* (1995). For instance, El-Gizawy and Adams (1986) were able to cause BER by reducing

Ca content of the nutrient solution, without modifing either EC or water uptake. More commonly, high transpiration rates are thought to induce BER by creating a preferential flow to leaves, that inhibits Ca diversion to the fruits. Both Bradfield and Guttridge (1984) and Adams and Holder (1992) did measure a higher Ca accumulation in fruits under conditions of high humidity.

Aside from the incidence of BER, our result that individual fruit size and not fruit setting is affected by salinity, confirms recent findings, for instance of Van Ieperen (1996) and Willumsen *et al.* (1996). Van Ieperen, however, detected a decrease also in fruit numbers after 12 weeks of harvest, something we were not able to detect, neither after four months harvest, nor in the unripe fruit remaining after that.

5. Conclusion

A high solute content of irrigation water is likely to reduce fresh yield of greenhouse tomato by a few percent for each dS/m that EC of irrigation water exceeds 2. However, dry matter and sugar yield will be reduced only by the fraction of unmarketable fruits. Steering the greenhouse climate in order to depress transpiration, may significantly reduce the incidence of BER. It also might enlarge fruit size, thereby improving yield value.

Present market prices reflects only fresh yield, that is quantity and grading. However, if other quality aspects like dry matter or sugar content were priced, maximal returns for growers could be obtained at higher salinities than are presently accepted.

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Table I. A summary of the most important yield and yield quality parameters. The high transpiration, low EC treatment has been taken as the reference, being the nearest to Dutch commercial practice.

climate treatment	**high Tr.**	**high Tr.**	**low Tr.**	**low Tr.**
EC	**2**	**10**	**2**	**10**
fresh yield (% of reference)	100	69	100	85
unmarketable yield (% of fresh)	0.1	19.5	0.6	1.8
mean number of fruits per plant	126	124	114	124
number of unmark. fruits (% of total)	0	21	1	2
mean fruit weight (% of reference)	100	74	108	86
mean dry matter content (g/kg)	49.9	66.0	50.7	63.2
total dry matter yield (% of reference)	100	91	106	108
dry matter marketable yield (% of ref.)	100	75	105	106
mean sugar content (g/kg)	43.2	56.6	43.2	53.2

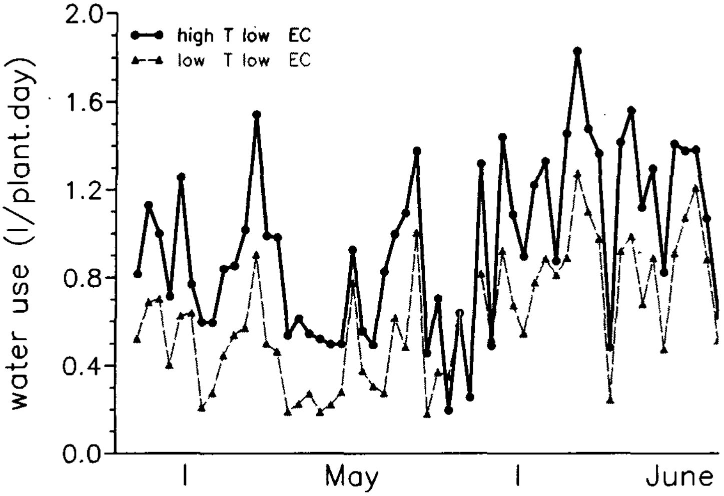

Figure 1. Daytime water use of the two low EC treatments, l/plant, for a couple of months. Full line: high potential transpiration compartment; dashed: low transpiration one.

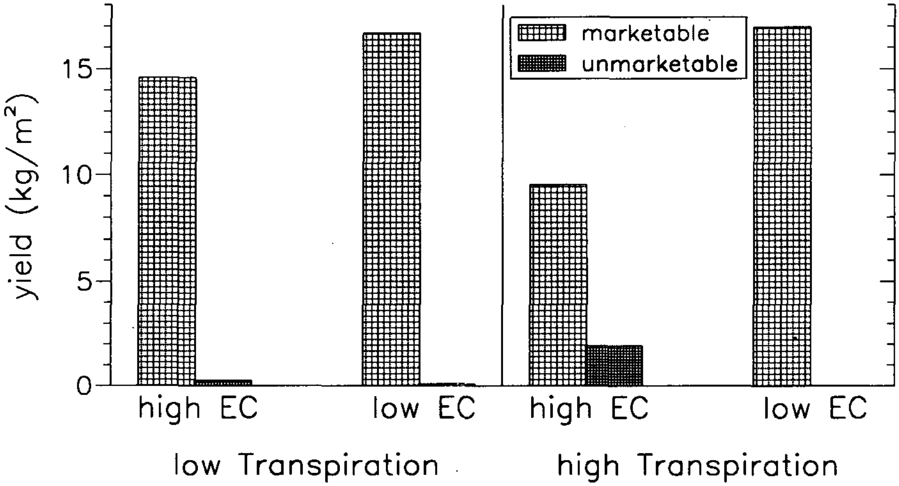

Figure 2. Cumulative yield (kg m^{-2}), both marketable and not, from the first harvest (last week of February) until the first week of July.

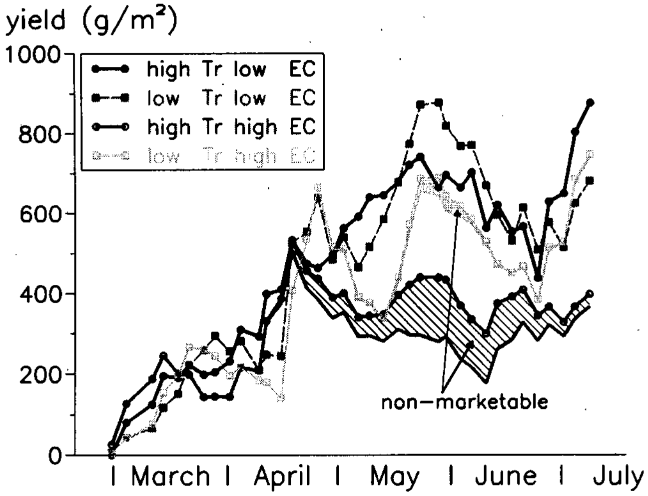

Figure 3. Fresh yield, g m^{-2} per harvest day. Points are running means over three consecutive yield values for each treatment. Unmarketable yield is shaded.

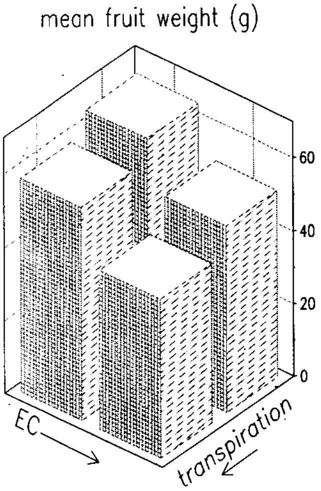

Figure 4. (left). Mean fruit weight (g), calculated as the ratio of marketable yield to number of marketable fruits, for the whole season.

Figure 5. (right). Total dry matter yield (g m^{-2}), calculated by summing over the whole season the dry matter fraction of each harvest.