studies will determine the survival of *E. carotovora* subsp. *carotovora* exposed to different copper-based compounds over time and assess the effectiveness of postplant applications of copper-based compounds. Also, studies should be conducted on the survival of *Erwinia* bacteria in subirrigation systems. Wounding the rhizomes with a sterile knife before planting or calcium fertilization during forcing did not increase the disease incidence. The calcium nutrition may have been applied too late in the production cycle, as calcium applied during the field growth phase of potatoes increased the resistance against *Erwinia* sp. affecting potatoes in storage (Palta, 1996).

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Fertilizer Substitutions in Hydroponically Grown Greenhouse Tomatoes

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ADDITIONAL INDEX WORDS. **nutrient film technique, added salts**

SUMMARY. Experiments were carried out to evaluate two salts, K_2SO_4 and NaCl, as materials to supplement the electrical conductivity (EC) of the basic nutrient solution in nutrient film technique (NFT). The effects of these materials on the growth, yield and fruit quality of greenhouse tomato (*Lycopersicon esculentum* Mill.) grown by NFT were quantified. These effects were tested by increasing the recirculating solution EC from a base value of $1500 \mu S \cdot cm^{-1}$ to that suitable for the crop growth stage with normal feed (macronutrients), 0.38 M (0.53 lb/gal) K_2SO_4 or 1.14 M (0.55 lb/gal) NaCl, at a common pH of 6.2. In 1995 and 1996, there were no significant effects of the treatments on crop growth. In 1995, the early marketable yield was significantly lower when K_2SO_4 was used but the yield at the end of the season did not differ among the treatments. Furthermore, with K_2SO_4 , the proportion of grade #1 fruit in early total yield was lower than in the control, while, fruit biomass content was higher than in the NaCl treatment. In 1996, the cumulative marketable fruit weight was unaffected by the treatments. A trend toward high number of large grade fruit occurred with the NaCl treatment. The pH and EC of the fruit homogenate were favorably affected by the NaCl treatment. Adding K_2SO_4 or NaCl in partial substitution of macronutrients in the

recirculating solution may have a role in NFT systems in not only reducing environmental pollution (from nitrates and phosphates) and fertilizer costs, but also in improving fruit quality and, therefore, profit margins.

For environmental and economical reasons, reducing the supply of nutrients to tomatoes grown in hydroponic systems, including the nutrient film technique (NFT) culture, is desirable. As the supply of macronutrients is reduced, either K_2SO_4 or NaCl, salts that are financially and environmentally more attractive, may be added to raise the electrical conductivity (EC) of the recirculating solution to appropriate levels according to plant needs. A practical question is whether the addition of above salts, when used as partial substitutes for common greenhouse fertilizers, will affect the growth, yield, and fruit quality of tomato grown by NFT.

In soil-grown greenhouse tomato, low levels of K_2SO_4 reduced yields (Winsor et al., 1967) while, increasing rates of K_2SO_4 reduced the incidence of ripening disorders and of puffy fruit, and increased the acidity of the fruit juices and the firmness of the fruit (Winsor, 1979). In tomato grown by NFT, Adams and Grimmett (1986) reported that although K_2SO_4 levels did not affect fruit yields, the number of fruit per plant increased as the concentration of K^+ was raised. Fruit biomass and the titratable acidity of fruit juice increased with the concentration of K^+ supplied.

In closed hydroponic systems such as NFT, the efficient exclusion of Na^+ by horticultural crops (Baas et al., 1995; Sonneveld and van der Burg, 1991) may cause an accumulation of Na^+ in the root environment. Salinity can inhibit plant growth by a) lowering external osmotic potential and thus inducing water stress b) ion toxicity, or c) ion imbalance (Greenway and Munns, 1980). Increasing the NaCl concentration in the circulating solution of an NFT system for tomato from 0 to $200 mg \cdot L^{-1}$ (0 to 200 ppm) resulted in small fruit, the greatest effect corresponding to the highest conductivity of the circulating solution (Attenburrow and Waller, 1980). Sonneveld and van der Burg (1991) suggested that the favorable effect of

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Fig. 1. The electrical conductivity (EC) of the recirculating solution at different growth stages of a greenhouse tomato crop raised by nutrient film technique.

NaCl on the fruit quality of greenhouse tomato, cucumber and sweet pepper could largely be ascribed to the increase of nutrient solution EC from 2500 to 5200 $\mu\text{S}\cdot\text{cm}^{-1}$ ($\mu\text{S} = \mu\text{mho}$) with the addition of extra 1.21 $\text{g}\cdot\text{L}^{-1}$ (1210 ppm) NaCl. At high EC values the shelf life and acid content of these fruit increased as was the proportion of fruit affected by blossom-end rot.

The aim of this investigation was to determine the growth, yield and fruit quality of greenhouse tomato grown by NFT in response to supplementing the EC of the recirculating solution by the addition of either K_2SO_4 or NaCl to the base feed.

Materials and methods

Experiments were carried out during the spring of 1995 and 1996 in a glass greenhouse compartment with environmental control where a day/night air temperature regime of 21/17 °C (69.8/62.6 °F, 1995) or 21/19 °C (69.8/66.2 °F, 1996) and a minimum humidity of 50% were maintained. 'Trust' tomato seedlings were raised in rockwool cubes and placed in NFT gullies on 5 Jan. 1995 and 29 Dec. 1995. Each gully contained seven plants, of which five were test plants, while the remaining two served as guard plants, one at each end of the gully. Plant density was 2.3 plants/ m^2 (9312 plants/acre). The treatments consisted of raising the recirculating solution EC

from a base value of 1500 $\mu\text{S}\cdot\text{cm}^{-1}$ to that appropriate for the stage of crop growth (Fig. 1; Papadopoulos and Pararajasingham, 1998) by the addition of a) normal feed (macronutrients), b) 0.38 M (0.53 lb/gal) K_2SO_4 or c) 1.14 M (0.55 lb/gal) NaCl. The base feed was prepared by mixing equal volumes of stock solutions A [$\text{Ca}(\text{NO}_3)_2$, 65.8; KNO_3 , 49.2 $\text{g}\cdot\text{L}^{-1}$] and B [KH_2PO_4 , 17.4; K_2SO_4 , 22.7; MgSO_4 , 40.0; Fe chelate (13%), 1.2; micronutrients, 4 $\text{g}\cdot\text{L}^{-1}$] in water to a base EC of 1500 $\mu\text{S}\cdot\text{cm}^{-1}$. Treatments were arranged in a randomized complete block design with three replications. A single gully was used for each treatment for a total of nine gullies. Plants grown on rockwool slabs, and placed at the outside edges in parallel to the gullies served as guard rows. The greenhouse compartment was enriched with CO_2 to 1000 volumes per million until late April.

Each gully was provided with a holding tank [mean volume 120 L (31.8 gal)] for nutrient solution, a catchment tank [volume 10 L (2.5 gal)] for gully discharge, and a pump. The EC and the pH of the recirculating solution in each treatment were checked daily using the Oakton (Cole Parmer, Vernon Hill, Ill.) TDSTestr (model WD 35661-40) and pHtestr 1 (model 35624-00), respectively. The EC of the solutions was corrected as necessary by manual addition of appropriate stock solutions to the desired EC depending upon crop growth stage and season (Fig. 1), while the pH of the solutions was controlled at ≈ 6.2 by the addition of 25% (v/v) phosphoric acid. During the course of experi-

ments, recirculating solutions were renewed thrice at 42, 86, and 159 d after transplanting in 1995; and, in 1996, twice at 109 and 200 d after transplanting. In 1996, 46 d after transplanting, a sample of the recirculating solution [500 mL (16.9 fl oz)] was withdrawn from each treatment for chemical analysis to examine the effect of the treatments on nutrient uptake by the early tomato crop. The crop was topped 159 (1995) or 165 d (1996) after transplanting.

In 1995, the fifth youngest fully expanded leaf of all test plants was collected 71, 98, and 134 d after transplanting, combined, weighed, dried at 70 °C (158 °F), and biomass determined. In 1996, the following crop related measurements were made at 40, 55, and 76 d after transplanting: plant height, number of leaves and clusters, and, stem diameter just below the fifth fully expanded leaf from the top. When the experiment ended at 202 d after transplanting in 1996, three plants from each treatment were removed, leaf number counted, leaf area measured using a leaf area meter (LI-3100; LI-COR Inc., Lincoln, Nebr.), and fresh and dry weights of leaves, stem, and root were determined.

Fruit harvest began 84 (1995) or 87 (1996) d after transplanting and continued until the end of the experiment. In both years, green fruit with an orange tint was harvested twice weekly, graded according to Ontario commercial standards (Ontario Ministry of Agriculture, Food and Rural Affairs, 1987) and the number and weight of fruit in each grade recorded. In 1995, at 105, 139, and 170 d after transplanting, a representative fruit of the extra large or large grade from each test plant was allowed to ripen at ambient temperature, weighed, diced, dried at 70 °C (158 °F) and biomass determined. In 1996, representative samples (three to four fruit) of ripe extra large and/or large grade fruit were tested for various fruit quality measures as follows: fruit firmness was determined with the Ottawa texture measuring system (Voisey, 1971) by measuring the load required to just crack an intact fruit; total ion concentration and acidity of the fruit were determined by homogenizing the fruit in a blender, and measuring the EC and pH of the homogenate using Oakton testers.

All data were subjected to analysis

Table 1. Effects of added salts for electrical conductivity (EC) control on leaf biomass of greenhouse tomato crop grown by nutrient film technique in 1995. Values are means of three replications $\pm$ SE.

Days after transplanting	Leaf biomass (g/leaf)			Leaf biomass (% fresh wt)		
	Control	K ₂ SO ₄	NaCl	Control	K ₂ SO ₄	NaCl
71	0.78 $\pm$ 0.06	0.72 $\pm$ 0.02	0.87 $\pm$ 0.03	11.10 $\pm$ 0.07	11.50 $\pm$ 0.17	11.30 $\pm$ 0.23
98	0.68 $\pm$ 0.05	0.68 $\pm$ 0.04	0.70 $\pm$ 0.03	10.00 $\pm$ 0.12	10.40 $\pm$ 0.24	10.30 $\pm$ 0.13
134	0.83 $\pm$ 0.08	0.81 $\pm$ 0.04	0.85 $\pm$ 0.03	9.60 $\pm$ 0.15	9.60 $\pm$ 0.23	9.50 $\pm$ 0.03

Table 2. Effects of added salts for electrical conductivity (EC) control on fruit production and proportion² of different fruit grades in greenhouse tomato grown by nutrient film technique in 1995. Values³ are means of three replications.

Treatment	Total yield (kg/plant)	Fruit						
		Marketable					Unmarketable ^x	
		Yield (kg/plant)	Size (g/fruit)	Grade		Grade #2 (%)		
				#1 (%)	Commercial (%)		BER (%)	CF (%)
Early yield (until 30 Apr.; 147 d after transplanting)								
Control	3.57	3.43	198	82.6	10.6	3.3	0.4	3.1
K ₂ SO ₄	3.01	2.18	192	67.3	1.7	3.5	26.8	0.7
NaCl	3.63	3.53	201	90.4	6.6	0.5	1.0	1.5
LSD _(0.05)	NS	1.11	NS	9.0	NS	NS	5.6	NS
Final yield								
Normal	12.94	12.81	184	92.1	5.0	1.9	0.1	0.9
K ₂ SO ₄	12.21	11.14	166	88.9	1.2	1.2	6.6	2.1
NaCl	12.62	12.31	174	93.5	2.9	1.1	0.3	2.2
LSD _(0.05)	NS	NS	17	NS	NS	NS	1.7	NS

²Percentage of total fruit weight.

³1 g = 0.002 lb; 1 kg = 2.205 lb.

^xBER = blossom end rot; CF = cat-faced.

of variance using the ANOVA or GLM procedure of SAS (SAS Institute Inc., Cary, N.C.), and all main effects and interactions were tested for significance. Treatment means were compared using Fischer's protected LSD procedure at the 5% probability level (Steel and Torrie, 1980).

Results

SPRING 1995. No detrimental effects on leaf growth were evident in using either K₂SO₄ or NaCl as a partial substitute for NFT base feed in controlling EC (Table 1). Both early and final fruit yields were identical among the three treatments (Table 2). The early marketable yield was reduced significantly when K₂SO₄ was used (Table 2) but the final marketable yield did not differ significantly among the treatments (Table 2). The proportion of marketable yield as a percentage of early or final total yield, was reduced significantly with the use of K₂SO₄ (data not shown). When K₂SO₄ was used to control the EC, the proportion of grade #1 fruit in early total yield decreased markedly ($p < 0.05$), while, the proportion of fruit affected by blossom

end rot increased significantly (Table 2). Treatments had no effect on the proportion of different grade fruit in final total yield, but the use of K₂SO₄ caused a marked increase in the proportion of fruit with blossom end rot (Table 2). Early fruit size was unaffected by the treatments (Table 2). Combining early and late season figures, overall fruit size was smaller ($p < 0.05$) when EC was controlled with K₂SO₄ than with base feed. Fruit biomass content (percentage of fresh weight) of tomato harvested in the early fruit production period was higher ($p < 0.05$) when the EC was regulated with K₂SO₄ than with NaCl (Table 3).

SPRING 1996. Over a 46 d period, beginning at transplanting, the use of salts for EC control resulted in K⁺ or Na⁺ concentration reaching, on an average, values of 701 mg·L⁻¹ (701 ppm) K⁺ or 380 mg·L⁻¹ (380 ppm) Na⁺ in the respective recirculating solution. In the same period, K⁺ and Na⁺ concentrations in the control treatment reached 446 and 68 mg·L⁻¹, respectively. The Na⁺ in the control treatment was from tap water.

Crop growth of greenhouse tomato in the K₂SO₄ or NaCl treatment (Table 4) was as good as in the control treatment. A mean leaf number of 19.3 leaves/plant in the NaCl treat-

Table 3. Effects of added salts for electrical conductivity (EC) control on fruit biomass content of greenhouse tomato grown by nutrient film technique in 1995. Values are means of three replications.

Treatment	Fruit biomass content (%)		
	Crop age (d)		
	105	139	170
Control	4.14	4.48	4.61
K ₂ SO ₄	4.34	4.6	4.78
NaCl	3.9	4.42	4.72
LSD _(0.05)	NS	0.13	NS

Table 4. Effects of added salts for electrical conductivity (EC) control on pretopping growth of a greenhouse tomato crop raised by nutrient film technique in 1996. Values are means of eight or nine observations $\pm$ SE.

Crop growth parameters	Crop age (d)								
	40			55			76		
	Control	K ₂ SO ₄	NaCl	Control	K ₂ SO ₄	NaCl	Control	K ₂ SO ₄	NaCl
Height (cm)	110 $\pm$ 2.0	111 $\pm$ 5.0	115 $\pm$ 5.0	153 $\pm$ 2.5	159 $\pm$ 2.8	158 $\pm$ 4.9	207 $\pm$ 1.9	213 $\pm$ 1.6	210 $\pm$ 3.6
Leaf no.	13.3 $\pm$ 1.0	14.2 $\pm$ 1.2	14.3 $\pm$ 0.7	18.1 $\pm$ 0.3	18.3 $\pm$ 0.5	20.0 $\pm$ 0.2	21.6 $\pm$ 0.6	20.7 $\pm$ 1.0	23.7 $\pm$ 0.7
Cluster no.	3.7 $\pm$ 0.3	3.9 $\pm$ 0.7	4.4 $\pm$ 0.3	6.0 $\pm$ 0.2	6.2 $\pm$ 0.2	6.2 $\pm$ 0.3	8.2 $\pm$ 0.1	8.7 $\pm$ 0.4	8.8 $\pm$ 0.2
Diameter (mm)	18.6 $\pm$ 0.4	18.5 $\pm$ 0.2	17.9 $\pm$ 0.7	12.9 $\pm$ 0.1	12.8 $\pm$ 0.1	13.0 $\pm$ 0.4	12.5 $\pm$ 0.4	12.2 $\pm$ 0.3	13.2 $\pm$ 0.6

ment in early tomato was greater ($p < 0.05$) than the 17.7 leaves/plant obtained from either the control or K₂SO₄ treatments.

The marketable yield at the end of the experiment (Fig. 2a) was as good in the K₂SO₄ [12.0 kg/plant (26.5 lb/plant)] and NaCl (11.9 kg/plant) treatments as in the control treatment (11.6 kg/plant). Differences in fresh weight accumulation rates between the treatments occurred as harvesting progressed (Fig. 2a). Initially, the rank order of fruit weight accumulation rate among the treatments was: control, 124 $\pm$ 5; K₂SO₄, 111 $\pm$ 5; and NaCl, 122 $\pm$ 4 g·d⁻¹. Between 122 and 164 d after transplanting, fresh weight accumulation rate was lower in the control treatment (88 $\pm$ 2 g·d⁻¹) as compared to either K₂SO₄ (97 $\pm$ 2 g·d⁻¹) or NaCl (95 $\pm$ 2 g·d⁻¹) treatment. However, by 200 d after transplanting the difference among the three rates disappeared resulting in overall rates of 95 $\pm$ 2, 96 $\pm$ 1, and 96 $\pm$ 1 g·d⁻¹ for the control, K₂SO₄ and NaCl treatments, respectively.

In the five months yield was recorded, plants growing in the control, K₂SO₄ and NaCl treatments produced a total of 76.5, 85.5, and 85.1 fruit/plant, respectively (Fig. 2b). The highest number of marketable fruit was obtained from the NaCl treatment and the lowest from the control treatment (80.6 vs. 71.7 fruit/plant, $p < 0.05$). Throughout the cropping season, fruit production rate was greater in the NaCl treatment as compared to the control treatment (Fig. 2b). The overall mean cumulative fruit production rates for the three treatments were control, 0.59

$\pm$ 0.011; K₂SO₄, 0.64 $\pm$ 0.007; and NaCl, 0.66 $\pm$ 0.008 fruit/day.

Fruit quality assessed in terms of number and weight of various fruit grades differed little between the treatments with respect to grade #1 and

grade #2 fruit (Table 8) while commercial grade fruit from the control treatment was heavier ($p < 0.05$) than the fruit from the other two treatments (Table 8). The proportion of grade #1 fruit as a percentage of mar-

Fig. 2. Effects of added salts to control electrical conductivity (EC) on (a) cumulative marketable fruit fresh weight and (b) cumulative marketable fruit number of a greenhouse tomato crop raised by nutrient film technique.

Table 5. Effects of added salts for electrical conductivity (EC) control on final leaf area and plant biomass of a greenhouse tomato crop raised by nutrient film technique in 1996. Values are means of eight or nine observations $\pm$ SE.

Treatment	Leaf area (cm ² /plant) ^z	Final leaf biomass (g/plant)		
		Leaf	Stem	Root
Control	792 $\pm$ 53.1	134 $\pm$ 10.5	100 $\pm$ 3.5	24.2 $\pm$ 5.9
K ₂ SO ₄	699 $\pm$ 40.4	135 $\pm$ 6.5	114 $\pm$ 3.6	24.0 $\pm$ 2.3
NaCl	768 $\pm$ 66.0	149 $\pm$ 7.6	100 $\pm$ 2.6	24.9 $\pm$ 0.4

^z1 cm² = 0.001 ft²; 1 g = 0.002 lb.

ketable fruit was control, 65.4%, K₂SO₄, 70.9%, and NaCl, 73.1%. A trend was evident suggesting higher proportion of large grade fruit in the NaCl treatment compared with the other treatments (Table 7) although this trend was not statistically significant. The proportion of waste fruit as a percentage of total fruit number was significantly lower in the NaCl treatment

(4%) compared with either the control (5.4%) or K₂SO₄ (6.8%) treatment. The proportion of fruit affected by blossom end rot or cat face did not differ significantly among treatments (Table 7).

Other measures of fruit quality, pH and EC of the fruit homogenate, were significantly improved by the NaCl treatment (Table 8) while fruit

firmness did not differ among treatments.

Discussion

The work reported in this paper showed that it is possible to grow greenhouse tomato by NFT by partially substituting macronutrients in the recirculating solution with K₂SO₄ or NaCl without detrimental effect on

Table 6. Effects of added salts for electrical conductivity (EC) control on the final number and fresh weight of different fruit grades from a greenhouse tomato crop raised by nutrient film technique in 1996. Values are means of three replications.

Treatment	Fruit								
	Marketable (no./plant)					Grade #2	Unmarketable ^z (no./plant)		
	Grade #1				BER		CF	Waste fruit	
	X-large	Large	Small	Commercial					
	Fruit number								
Control	20.1	23.8	3	1.3	23.5	0.07	0.5	4.1	
K ₂ SO ₄	20.5	32.1	3.3	0.47	22.4	0.2	0.7	5.9	
NaCl	17.1	38.2	3.7	0.53	21.1	0.00	1.1	3.4	
LSD _(0.05)	NS	NS	NS	0.68	NS	NS	NS	1.9	
	Fruit wt ^y (kg/plant)								
Control	4.29	3.1	0.15	0.46	3.65	0.02	0.2	0.66	
K ₂ SO ₄	4.16	4.3	0.17	0.15	3.23	0.06	0.1	0.91	
NaCl	3.42	5.01	0.2	0.19	3.03	0.00	0.3	0.45	
LSD _(0.05)	NS	NS	NS	0.22	NS	NS	NS	0.31	

^zBER = blossom end rot; CF = cat-faced.

^y1 kg = 2.205 lb.

Table 7. Effects of added salts for electrical conductivity (EC) control on the final proportions (%) of different fruit grades from a greenhouse tomato crop raised by nutrient film technique in 1996. Values are means of three replications.

Treatment	Fruit							
	Marketable (%)					Unmarketable ^z (%)		
	Grade #1				Grade #2			
	X-large	Large	Small	Commercial		BER	CF	Waste fruit
Fruit number								
Control	26.4	31.2	3.9	1.7	30.6	0.08	0.7	5.4
K ₂ SO ₄	24.4	37.1	3.8	0.55	26.3	0.22	0.78	6.8
NaCl	20.1	45	4.4	0.63	24.7	0.00	1.24	4
LSD _(0.05)	NS	NS	NS	0.96	NS	NS	NS	1.9
Fruit wt ^y (kg/plant)								
Control	34.3	24.9	1.2	3.7	29.1	0.12	1.4	5.3
K ₂ SO ₄	31.5	33.2	1.3	1.1	24.5	0.48	1	6.9
NaCl	27.1	40.2	1.6	1.5	23.9	0.00	2	3.6
LSD _(0.05)	NS	NS	NS	1.9	NS	NS	NS	2.2

^zBER = blossom end rot; CF = cat-faced.

^y1 kg = 2.205 lb.

Table 8. Effects of added salts for electrical conductivity (EC), control on some fruit quality measures of ripe fruit from greenhouse tomato raised by NFT in 1996. Values^z are means averaged over harvesting periods.

Treatment	Fruit firmness (N·mm ⁻²) ^y	EC (μS·cm ⁻¹) ^y	pH
Control	8.6 ± 0.19	3582 ± 59	4.8 ± 0.01
K ₂ SO ₄	8.8 ± 0.46	3579 ± 65	4.8 ± 0.01
NaCl	8.6 ± 0.53	3738 ± 17	4.7 ± 0.03

^z1 N·mm⁻² = 10 bar = 145 lb/inch²; 1 μS·cm⁻¹ = 1 μmho·cm⁻¹.

growth, yield or fruit quality of the crop. The use of K₂SO₄ will, however, require judicious management of Ca nutrition and crop water status. Studies of nutrient uptake by greenhouse tomato have indicated daily absorption rates of 290 mg (0.01 oz) K⁺/plant (Adams, 1986). Adams and Winsor (1979) measured a daily uptake by tomatoes of 144 mg K⁺ during the period when the first cluster was in flower and 293 mg at the time of flowering on the ninth cluster. Potassium, a regulator of many cellular processes including protein synthesis is essential in greenhouse tomato to prevent uneven ripening of the fruit (Adams, 1986), and to increase fruit acidity (flavor) (Adams, 1994). Adams (1994) reported that as the K⁺ concentration in the recirculating solution was increased from 20 to 800 mg·L⁻¹, daily K⁺ uptake increased by a factor <2, while the fruit K⁺ concentration increased from 0.88 to 1.04 mmol·g⁻¹ (0.55 to 0.65 oz K⁺/lb) fruit biomass. A K⁺ concentration of 350 mg·L⁻¹ in the recirculating solution is normally sufficient to ensure good fruit quality (Adams and Bailey-Anguish, 1988). In our experiments, using K₂SO₄ to control EC, resulted in K⁺ concentrations in the recirculating solution exceeding 350 mg·L⁻¹. In consequence, the concentration of sugars and acids in the fruit juice increased and fruit quality in early tomato improved (Table 2). The high K⁺ requirement during the fruit production phase has been found to increase the absorbed K:N ratio up to 2.6:1 from the 1.1:1 reported for early tomato (Adams, 1994). The similarity in the responses of growth, yield and fruit quality of the plants under the K₂SO₄ and control treatments suggests that the K₂SO₄:base feed ratio used in this study provided the appropriate K:N ratio for satisfactory fruit production during the cropping season.

Potassium reduces Ca uptake by

NFT tomato (Adams, 1992). This antagonism between K and Ca might account for the high incidence of blossom end rot, a condition associated with local Ca deficiency in the fruit, under the K₂SO₄ treatment in 1995 (Table 2). The insignificant incidence of blossom end rot with the use of K₂SO₄ in 1996 suggests that the greenhouse environment was more conducive to blossom end rot development in 1995.

Unlike K⁺, high concentrations of Na⁺ and Cl⁻ in the root zone can affect crop production adversely (Sonneveld and van der Burg, 1991). Although it would have been of interest to measure added Na and Cl concentrations in the root zone and their uptake by the crop, comparable crop growth and fruit yield between NaCl and control treatments suggest Na⁺ and Cl⁻ in the recirculating solutions did not exceed concentrations that may be considered adverse to crop performance. With respect to fruit quality, detailed analysis of fruit number data indicated that the significantly high cumulative marketable fruit number in the NaCl treatment was mainly associated with a 14% increase in large grade fruits over the control indicating the use of NaCl in the basic feed solution improved fruit quality. Beneficial effects of adding NaCl to the basic nutrient solution on fruit quality have also been reported by Adams and Bailey-Anguish (1988) and Adams (1991).

As for the other measures of fruit quality, pH and EC of the fruit homogenate were favorably affected by the NaCl treatment. An increase in fruit acidity was considered an improvement in fruit quality and has been associated with the K⁺ status of the crop. Adams (1991) suggested high fruit acidity was due to reduced water content of the fruit and not the K⁺ content per se. In greenhouse cucumber and tomato, increasing the Na⁺ concentration in the nutrient solution

has been reported to have decreased K⁺ uptake (Adams, 1991; 1992) due to the competing effect of Na⁺ and, therefore, in a decline in the K:N ratio (Adams, 1992). In rockwool grown tomato, Adams (1991) found that the Na⁺ content of fruit grown at 800 and 1200 μS·cm⁻¹ with added NaCl was 0.28% in both treatments as compared with 0.05% in the control treatments. The increase in fruit EC under the NaCl treatment (Tables 4 and 5) suggests a specific role for NaCl in influencing fruit water relations and, as a result, fruit acidity in greenhouse tomato. Papadopoulos and Pararajasingham (1998) found a 14% increase in NFT tomato fruit yield when Cl⁻ was added in the form of HCl for pH control as compared to the use of either H₃PO₄ or HNO₃.

In conclusion, added K₂SO₄ or NaCl in the nutrient solution may have a positive role in greenhouse tomato production by NFT in not only reducing environmental pollution and fertilizer cost but also in improving fruit quality and, therefore, profit margins.

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Effect of Ethrel on Bloom Delay, Harvest Date, and Fruit Weight of 'Empress' Peach

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ADDITIONAL INDEX WORDS. *Prunus persica*, (2-chloroethyl) phosphonic acid

SUMMARY. Ethrel [(2-chloroethyl)phosphonic acid] was applied at 0, 100 or 200 ppm (mg·L⁻¹) for 3 years to the early maturing 'Empress' peach [*Prunus persica* (L.) Batsch] to determine if bloom delay by Ethrel reduces fruit weight at harvest. Trees were hand thinned at 0 or 3 weeks after full bloom to equalize cropload across Ethrel treatments and to determine if any reduction in fruit weight by Ethrel can be compensated by harvest with earlier thinning. Ethrel at 200 ppm (mg·L⁻¹) delayed bloom by 3, 0, and 7 days in 1994, 1996 and 1997, respectively. Despite bloom delay, Ethrel did not delay harvest or reduce fruit weight. Thus, earlier hand thinning was not necessary. Ethrel did not affect blossom density and was not phytotoxic to vegetative or reproductive organs. These results indicate that even with the shorter fruit growth period of early maturing peach cultivars such as 'Empress', there is sufficient time for fruit growth to recover on Ethrel treated trees so that fruit weight at harvest is not reduced.

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Late spring frost is the most important limiting factor for peach production in the southeastern U.S.A. Ethrel can increase survival of peach flower buds to late spring frosts by delaying bloom for up to 2 weeks when applied from late fall to early winter (Coston et al., 1986; Crisosto et al., 1990; Dennis, 1976; Sloan and Matta, 1996). The delay in development is apparently by prolonged endodormancy and delayed flower bud development after rest is completed (Coston et al., 1986; Durner and Gianfagna, 1988, 1991; Gianfagna et al., 1986). Ethrel also increases cold hardiness of peach flower buds (Crisosto et al., 1989; Durner and Gianfagna, 1988, 1991).

Reports have shown that Ethrel also affects harvest date, yield and its components especially fruit weight, but the reports have often been contradictory (Crisosto et al., 1990; Sloan and Matta, 1996). Ethrel can but does not always delay bloom, which delays early fruit growth. In some reports, Ethrel reduced early cropload by reducing flower bud density, but the phytotoxicity has not been consistent (Crisosto et al., 1989, 1990; Sloan and Matta, 1996). Ethrel may increase early cropload by increasing flower bud survival when late spring frosts occur. What is not clear is whether Ethrel's effect on fruit weight at harvest is a secondary effect due to its impact on cropload established earlier in the season. The effect on cropload is important since cropload affects fruit weight at harvest. An additional consideration is that Ethrel may delay physiological maturity of fruit (Funt and Ferree, 1986), although whether this is true under all conditions is not known.

The compounding effect of Ethrel on cropload and fruit weight at harvest may be more important for early maturing cultivars that have less time for fruit growth to recover than later maturing cultivars. The following study was conducted to determine whether Ethrel applied to delay bloom affects fruit weight and harvest date for the early season cultivar 'Empress' peach that were carefully hand thinned to levels similar to untreated trees. Two hand thinning dates were also included to determine whether earlier hand thinning could compensate for any loss in fruit weight at harvest of Ethrel treated trees.