grade 1 kernels in 1 season in a heavily irrigated plot. They stated that:

"The substandard count of 1 in every 4 nuts in 1963 in the heavily irrigated plot, if confirmed by future work, may indicate that irrigation can be overdone in clay soils similar to those in this experiment even with a tree from the tropical rain forest".

Irrigation was not used in our trial at Dunoon while nuts were on the ground, therefore, the reduction in grade 1 kernels associated with irrigation (Table 5) cannot be explained by mould infections (Firth and Loebel 1987) of nuts on the ground.

Conclusion

Our study shows that irrigation had no significant effect on tree size and nut number, but reduced both nut size and kernel quality. These results vindicate the choice of many macadamia growers in the district to buy more land at about $10 000/ha instead of investing about $4000/ha to install irrigation.

In a comparison of the season UED values in Table 2 with the expected long-term mean (246 mm), 3 of 8 years of the trial were drier than the long-term average and offered ample opportunity for the macadamias to show a positive response to irrigation. However, on the long-term basis, 1 in 6 years were as dry as, or drier than, the driest years of the trial. A positive response to irrigation in those drier years is possible, but still may not make irrigation economic. For macadamias grown at closer spacings, or on a different soil type with less water-holding capacity than a deep krasnozem soil, or in a drier climate, irrigation may be required.

Although canopy area increased 3-fold between 1979 and 1987, yield per unit canopy area fluctuated between 800 and 1000 g/m^2, averaging 900 g/m^2. Yield per unit of canopy area may prove to be a useful productivity index when evaluating yields of macadamia trees.

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Use of high electrical conductivity of nutrient solution to improve the quality of salad tomatoes (*Lycopersicon esculentum*) grown in hydroponic culture

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Summary. The effect of the electrical conductivity (EC) of nutrient solution on total soluble solids (TSS) and fruit yield was studied, using table tomatoes grown outdoors in hydroponic culture, with the aim of seeing if salt stress could be used to increase TSS and thereby improve fruit quality. Two initial experiments compared the responses of 3 different cultivars and compared responses to different salts. The main experiment aimed to quantify the trade-off between yield and TSS as EC was raised with NaCl.

In the main experiment, TSS of cv. Flora Dade increased linearly from 4.40 to 5.94°Brix over an EC range of 1.5–9.0 mS/cm. Over all 3 experiments, the mean TSS of Flora Dade increased by 0.16°Brix/mS.cm rise in EC above the control EC of 1.5–2.0 mS/cm. The 3 cultivars responded similarly to raised EC, although they ranged in TSS from 4.1 to 5.4°Brix under non-saline conditions. Raising solution EC with NaCl, KCl, or a mixture of $NaCl/CaCl_2$ all gave significant increases in TSS. Increasing EC also increased titratable acidity and reduced fruit size, but had no effect on fruit firmness.

Yield in the main experiment declined with increasing EC, but not linearly. Over all experiments, it was shown that salt stress could be used to achieve an increase in TSS of about 0.5°Brix with little or no effect on yield. However, the EC at which this increase occurred appeared to depend on weather conditions.

Introduction

The flavour of salad tomatoes and the value of processing tomatoes is closely related to the concentration of total soluble solids (TSS) in the fruit. Field research in arid Israel (Pasternak *et al.* 1986) and California (Mitchell *et al.* 1991) has shown that irrigation with saline water has the potential to increase TSS in processing tomatoes. In the U.K., growers of glasshouse salad tomatoes use NaCl to increase the electrical conductivity (EC) of hydroponic nutrient solutions in order to increase TSS and so improve the quality of fruit (Adams 1987). This practice is supported by evidence from glasshouse experiments in the U.K. (Ehret and Ho 1986; Adams 1988) and Canada (Charbonneau *et al.* 1988). These reports suggest that salinity can be increased to a point which significantly increases TSS or percentage dry matter in fruit with little or no effect on yield.

In Australia, field grown salad tomatoes in a coastal, high rainfall environment gave only small and inconsistent responses to irrigation water salinised with KCl (Cornish and Nguyen 1989). It was suggested that spatial and temporal variation in the EC of soil solution, due mainly to leaching, may have allowed roots to exploit soil with relatively low EC and so avoid greater salt stress. Salt stress is therefore not seen as a useful way of improving the quality of field-grown tomatoes on the coast. However, the technique may still be useful where EC of the rooting medium can be controlled more precisely, for example in hydroponics or in soil in more arid areas. The use of salt stress in these situations would depend on yields as well as the magnitude of the response in TSS that can be achieved.

This paper reports on experiments using salad tomatoes grown outdoors in hydroponic culture with conventional trellising or staking, to assess the potential increase in TSS and the effect on yield when roots are treated uniformly with salinised nutrient solution.

Materials and methods

There were 3 experiments. The first examined responses to 3 EC levels, varied by using KCl. The second experiment examined responses to high EC achieved by using either KCl or a mixture of NaCl and $CaCl_2$. The third experiment used NaCl alone to raise solution EC, and aimed to quantify the relationship between yield and TSS in response to increasing salinity.

In experiment 1 (1988–89) cvv. Flora Dade and

Sunny were grown in standard nutrient solution with an EC of 2 mS/cm until the first fruit were about 2 cm in diameter, when treatments were imposed. Treatments comprised a control (2 mS/cm), and ECs of 4 and 8 mS/cm were achieved by adding KCl to the standard nutrient solution. Conductivity treatments were assigned to main plots which were split for cultivar. There were 2 replicates arranged in a randomised block design, and 8 plants per subplot.

In experiment 2 (1989–90) Flora Dade and Momotaro, a Japanese F_1 hybrid with a potential for high TSS (V. Q. Nguyen pers. comm.), were grown at an EC of 2 mS/cm until treatments commenced as in experiment 1. Treatments comprised a control (2 mS/cm) and an EC of 8 mS/cm achieved by adding to the nutrient solution either KCl or a mixture of NaCl and $CaCl_2$ in a 3 to 1 ratio (Pasternak *et al.* 1986). The 3 EC treatments comprised main plots which were split for cultivar. There were 2 replicates, with 8 plants per subplot.

In experiment 3 (1990–91) Flora Dade was grown in nutrient solution with an EC of 2 mS/cm until treatments commenced after first fruit set. The EC of the control was then lowered to 1.5 mS/cm (nutrient solution only) and NaCl was added to other treatments to achieve ECs of 3, 5, 7 and 9 mS/cm. There were 4 replicates in a randomised block design, with 8 plants per replicate.

The hydroponic systems were based on the nutrient film principle in which nutrient solution was recirculated through enclosed 150 mm pipes (7.5 m long, 1.5 m apart) with openings at 50 cm spacings where plants were grown, without support for the roots. Flow rate through each pipe was approximately 4 L/min and the supply tanks held 25 L nutrient solution per plant. Experiment 3 required construction of a larger hydroponic system than in experiments 1 and 2, but the designs were identical.

Seedlings were established in a standard potting mix in experiment 1 and in 7.5 cm rockwool cubes in experiments 2 and 3. At 6 weeks of age seedlings were transferred to the hydroponic pipes (7 December 1988, 3 December 1989, and 27 November 1990). Young plants in experiment 1 were supported in the openings to the pipes with polyurethane foam. Older plants in experiments 1 and 2 were supported by a standard tomato trellis, whilst plants in experiment 3 were tied to stakes. Pests and diseases were controlled effectively with routine sprays, except for an outbreak of *Botrytis* sp. late in experiment 2.

The nutrient solution was made up from a commercially available, ammonium-free formulation (Simple Grow, North Parramatta, N.S.W.). At the standard concentration the solution gave an EC of 2.0 mS/cm and pH 6.5. Nutrient concentrations (μg/mL) at this EC were: N (190); P (58); K (280); Ca (176); Fe (2); S (46); Mn (0.28); Zn (0.08); B (0.3); Co (0.015); Cu (0.09); Mo (0.015); Mg (36). Conductivity and pH were returned to these values by the addition of nutrients daily and concentrated H_3PO_4 as required, until treatments commenced on 23 January 1989, 17 January 1990 and 19 December 1990. Thereafter, all treatments received daily the same quantities of nutrients as required by the control treatment, to which no salt was added. The conductivity of treatments with added salt was finally adjusted daily by the addition of stock solutions of known EC prepared from either fertiliser-grade KCl (experiments 1 and 2) or food-grade $CaCl_2$ and NaCl (experiments 2 and 3). The stock solution of KCl was prepared by dissolving fertiliser in tap water and pouring off any floating residues then decanting the clear KCl solution, leaving any undissolved matter. Conductivity was maintained within ± 0.5 mS/cm of the nominal treatment means.

Nutrient solutions were replaced once before treatments commenced and twice subsequently to ensure that the composition of the solution remained satisfactory for growth. Additional Fe-chelate was supplied after fruit set at the rate of 25 mg/L about weekly.

Fruit was harvested once or twice weekly. In experiment 1, harvesting proceeded over 9 weeks (13 February–14 April) until fruit yields were negligible (<350 g/week.bush). This was about 3 weeks later than in commercial practice for a crop at this time of year. Picking would normally cease because of sharply declining fruit size and yields and increasing skin blemishes. In experiment 2, harvesting concluded after 5 weeks of picking (9 February–15 March) following an outbreak of *Botrytis* sp. during a period of wet weather. In experiment 3, fruit were harvested from 4 February to 19 March.

At each pick, all fruit at or beyond colour stage (CS) 2 (McGlasson *et al.* 1986) was harvested. In experiments 1 and 2 the fruit was sorted into seconds (misshapen, diseased) and large (>80 mm or about 300 g), medium (60–80 mm, 100–300 g), and small (<60 mm or 100 g) size classes. Fruit was not graded in experiment 3.

For each of the 8 harvests up to 23 March in experiment 1 (i.e. 6-week harvest period) and for all harvests in experiments 2 and 3, a sample of 10 medium-sized fruit at CS2, from each treatment/replicate, was ripened at 20°C to CS7 for quality assessments. Fruit firmness was measured with a compression meter (Sumeghy *et al.* 1983) in experiment 1. Then, in all experiments, longitudinal segments were cut from all fruit within a treatment/replicate and bulked. These were either frozen and stored for later analysis (experiment 1) or prepared for analysis immediately (experiments 2 and 3). Frozen fruit was thawed and prepared for analysis whilst still cold (<5°C).

Prior to analysis, fruit was processed in a kitchen blender and the juice allowed to separate for a few minutes. Juice, free of particulate matter, was withdrawn for analysis and allowed to warm to 20°C. Analysis comprised total soluble solids (Atago hand-held refractometer, 0–10°Brix) and titratable acidity (calculated from the volume of 0.1 mol NaOH/L required to raise the juice pH to 8.1), plus conductivity and pH in experiment 1.

Aspects of plant water relations were measured in experiment 1 on cv. Flora Dade on 4 occasions in the treatment period: 3 and 6 February, 8 and 10 March. Only the 2 and 8 mS/cm treatments were sampled. Thermocouple hygrometers (Wescor Inc., Logan, UT, U.S.A.) in C-30 sample chambers were used with a HR33T Microvolt meter or HP115 Data System. Leaf samples of about 3 cm^2 were taken from the distal ends of the youngest fully expanded leaves at about noon. Weather was sunny on each occasion. The leaf samples (1 per replicate) were immediately sealed in the C-30 chambers and returned to an air conditioned laboratory. The chambers were enclosed in a polystyrene box which was then enclosed in a second polystyrene box. Adequate temperature control was thus achieved, as judged by zero offset voltages. Total leaf water potential (Ψ) was recorded after equilibrium was reached, usually about 4 h. Leaf sections then were removed and quick-frozen using a fine jet of freon gas. Upon thawing (about 1 min) the sections were swabbed dry with facial tissues to remove atmospheric water vapour which had condensed on the leaves during freezing. They were then returned to the C-30 chambers for measurement of osmotic potential (π). Turgor pressure potential (P) was calculated by assuming no matric potential: $\Psi = P + \pi$. At the time of measurement, nutrient solution was sampled for measurement of osmotic potential, also using thermocouple hygrometers.

Temperature and solar radiation were recorded during the treatment period in all experiments but temperature data only are available for experiments 1, 2, and 3 because of failure in the data logger after experiment 1. Mean daily temperatures during fruiting for the 3 experiments were 20.1, 20.6 and 22.9°C, compared with the long-term average for mid February–March of 21.0°C.

Statistical analyses

Statistical analyses of data for yield and fruit number were performed on weekly totals and on the total of all harvests, except for experiment 3 where total yields only were analysed. All laboratory data were first analysed within harvests, and then harvests were combined in a split-plot (in time) analysis to compute mean treatment effects and their interaction with harvest time. Data on plant water relations were analysed by treating replicates within samplings as duplicates and the 4 samplings as replicates in time.

Table 1. Experiment 1. Responses of tomato fruit (cvv. Flora Dade and Sunny) to the electrical conductivity (EC) of the nutrient solution

Means of eight harvests, split-plot (in-time) analysis
TSS, total soluble solids; TA, titratable acidity

EC and cultivar	TSS (°Brix)	TA (m.e./100 mL)	TSS/TA	Firmness (compression, mm)	Conductivity (mS/cm)	pH
2 mS/cm						
Flora Dade	4.02	7.34	0.55	1.14	5.04	4.11
Sunny	3.90	6.87	0.58	1.32	5.31	4.12
Mean	3.96	7.11	0.57	1.23	5.17	4.11
4 mS/cm						
Flora Dade	4.28	9.10	0.48	1.27	6.36	4.09
Sunny	4.28	7.92	0.55	1.40	6.12	4.17
Mean	4.28	8.51	0.51	1.33	6.24	4.13
8 mS/cm						
Flora Dade	4.72	10.38	0.46	1.32	7.15	4.06
Sunny	4.96	9.41	0.53	1.43	6.86	4.15
Mean	4.84	9.90	0.48	1.37	7.01	4.11
l.s.d. ($P = 0.05$)	0.77	2.51	0.06	n.s.	1.77	n.s.
Significance						
EC	*	*	*	n.s.	*	n.s.
Cultivar	n.s.	*	*	*	n.s.	n.s.
EC x cultivar	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* $P<0.05$; n.s., not significant.

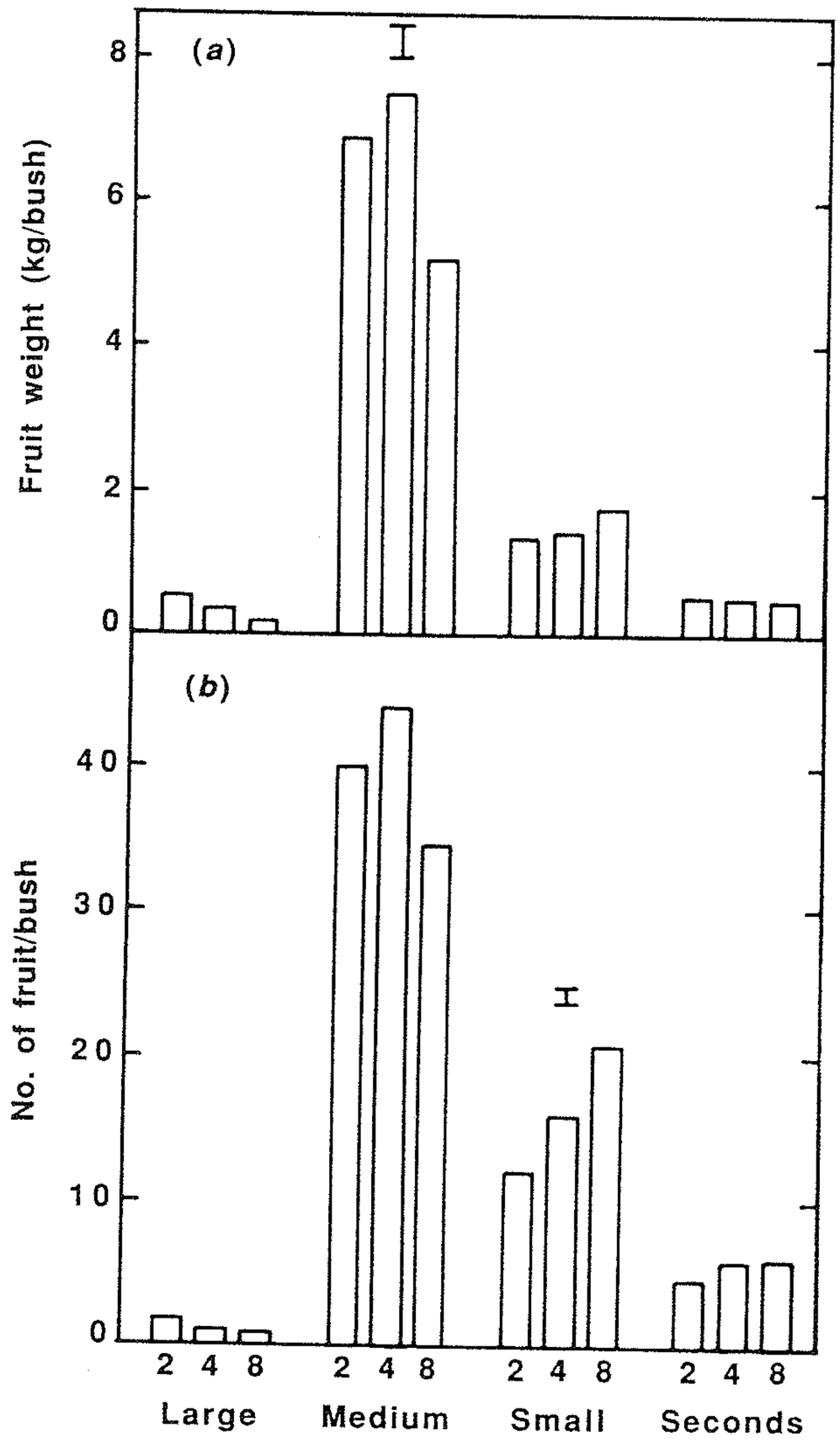

Fig. 1. Effects of electrical conductivity of nutrient solution on (*a*) fruit weight, and (*b*) number of fruit in different size classes in experiment 1. Treatments were 2, 4, and 8 mS/cm, mean of 2 cultivars. Vertical bar is l.s.d. ($P = 0.05$) within size class where main effect of EC is significant.

Results

Experiment 1

Increasing the nutrient solution EC from 2 to 4 or 8 mS/cm increased mean TSS over all harvests from 3.96°Brix to 4.28 and 4.84°Brix, respectively (Table 1). TSS at 8 mS/cm was significantly ($P<0.05$) higher than at 2 mS/cm. The main effect of EC on TSS was significant in 5 of the 8 harvests (individual harvest data not presented) and the trend in the remaining 3 harvests was consistent with this mean result. On no occasion did the cultivars differ (mean TSS = 4.34 and 4.38°Brix); nor was the cultivar x KCl interaction significant ($P>0.05$). The interaction between KCl and harvest was not significant ($P>0.05$), although the mean TSS for the three treatments varied ($P<0.05$) with harvest.

Increasing EC also increased ($P<0.05$) titratable acidity, decreased ($P<0.01$) the ratio of TSS to titratable acidity and increased ($P<0.05$) the conductivity of fruit juice. EC had no significant effect on pH or fruit firmness.

The main effect of EC on the total yield of fruit was significant ($P<0.05$) but there was no interaction with cultivar (Table 2). Total yield was lower at 8 mS/cm (7.72 kg/bush) than at either 2 or 4 mS/cm (9.21 and 9.73 kg/bush, respectively). Lower total yield at 8 mS/cm was due to a decrease in the total weight of the medium-size class (Fig. 1*a*). The yield of medium-sized fruit was significantly increased at an EC of 4 mS/cm (Fig. 1*a*). The effect of high EC on yield at 8 mS/cm only occurred towards the end of the fruit-bearing period: cumulative yields in the first 5 weeks were not different ($P>0.05$, Fig. 2*a*).

High EC increased the number of fruit smaller than 60 mm (Fig. 1*b*) but had no statistically significant effect on the total number of fruit produced (Table 2). Therefore the yield reduction at 8 mS/cm was due to reduced mean fruit size: 123 g compared with 158 g in the control.

Reduced yield after the fifth week of harvest was associated with a fall in solar radiation received in the 2-week period prior to each harvest (Fig. 2*c*). Falls in both mean TSS and the response in TSS to high EC were

Table 2. Experiment 1. The response of yield and fruit number per bush to the electrical conductivity (EC) of the nutrient solution for cvv. Flora Dade and Sunny

EC and cultivar	Total yield (kg)	No. of fruit per bush	Mean weight (g)
2 mS/cm			
Flora Dade	8.84	56	158
Sunny	9.58	61	157
Mean	9.21	58	158
4 mS/cm			
Flora Dade	10.32	74	140
Sunny	9.14	61	151
Mean	9.73	67	145
8 mS/cm			
Flora Dade	7.55	66	115
Sunny	7.88	60	131
Mean	7.72	63	123
l.s.d. ($P = 0.05$)	1.04	n.s.	16
Significance			
EC	*	n.s.	*
Cultivar	n.s.	n.s.	*
EC x cultivar	n.s.	n.s.	*

*$P<0.05$; n.s., not significant.

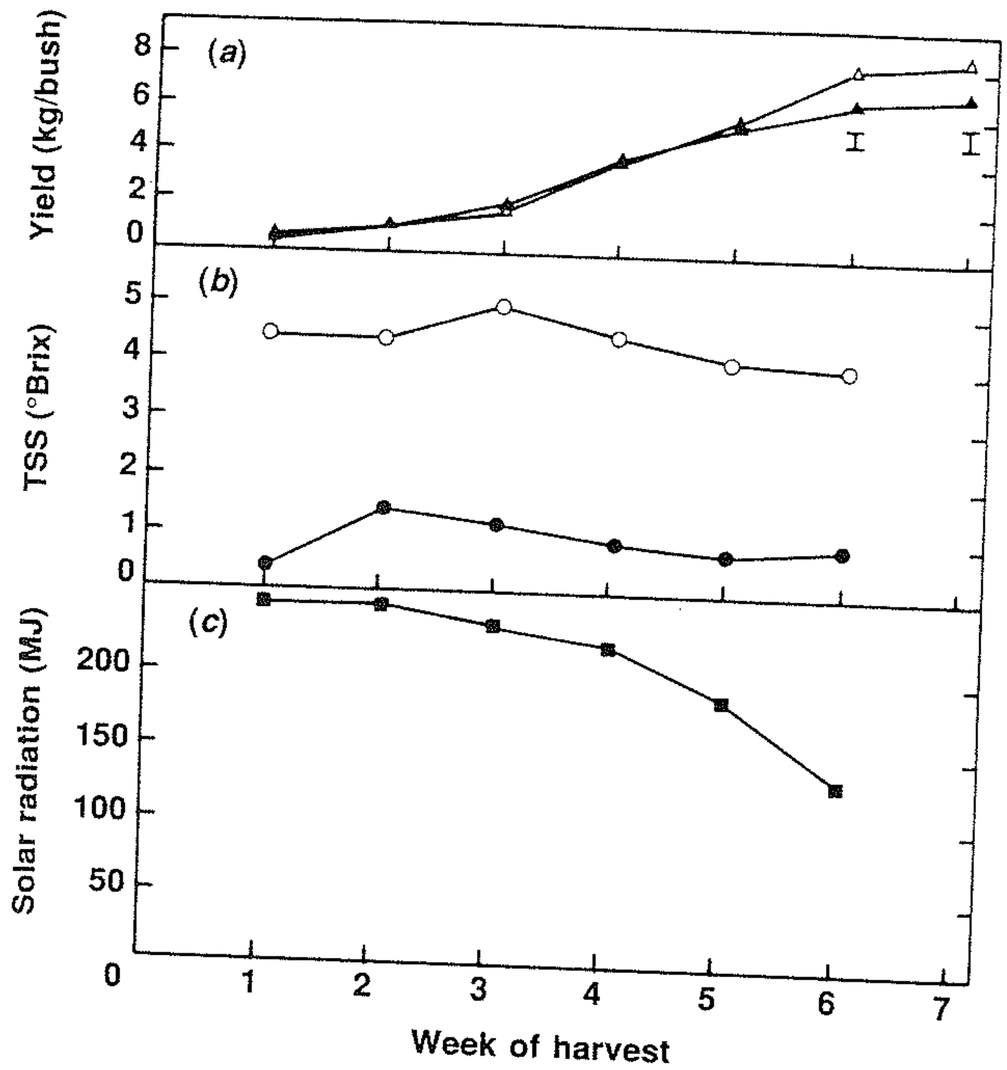

Fig. 2. Effects of electrical conductivity of nutrient solution on (*a*) weekly cumulative yield (EC2, △; EC8, ▲), and (*b*) weekly mean TSS (all treatments ○) and the difference in TSS between EC2 and EC8 (●). Also (*c*) solar radiation received in the two-week period before each harvest. Vertical bars on Fig. 2*a* indicate significant difference in yield in the week indicated. Weekly TSS in Fig. 2*b* is based on more than 1 harvest in some weeks.

also associated with falling radiation (Fig. 2*b*). The greatest responses in TSS (to raised solution EC) were obtained when there was no treatment effect on yield (Fig. 2*b*).

The osmotic potential of the nutrient solution averaged –0.09 MPa at 2 mS/cm and –0.38 MPa at 8 mS/cm over the 4 sample times. In response to the lower osmotic potential, total leaf water potential fell from an average of –0.68 MPa to –0.85 MPa, osmotic potential fell from –0.85 to –0.99 MPa and, by difference, the mean turgor potential fell from 0.17 to 0.13 MPa. All responses in components of water potential were significant ($P<0.05$).

There were no visible symptoms in any treatment of either salt toxicity or nutrient deficiency although plants in the highest EC treatment were darker green in appearance.

Experiment 2

Increasing EC by using either KCl or a mixture of NaCl and $CaCl_2$ significantly ($P<0.05$) increased mean TSS and titratable acidity and reduced the ratio of TSS to acidity (Table 3). There were no significant differences between the KCl and NaCl/$CaCl_2$ treatments. Momotaro had higher TSS than Flora Dade, in all treatments, but there was no interaction ($P>0.05$) between treatment and cultivar.

EC had no significant ($P>0.05$) effect on yield. The mean yield of the 2 treatments with high EC was 6.26 kg/bush, almost identical to the control (6.30 kg/bush). There was no interaction ($P>0.05$)

Table 3. Experiment 2. Responses in fruit quality and yield to the electrical conductivity (EC) of the nutrient solution for cvv. Flora Dade and Momotaro

EC of the nutrient solution was altered using either KCl or a mixture of NaCl and $CaCl_2$ in the ratio 3 to 1
Values are means of 9 harvests. TSS, total soluble solids; TA, titratable acidity

EC and cultivar	TSS (°Brix)	TA (m.e./100 mL)	TSS/TA	Yield (kg/bush)	No. of fruit per bush	Mean fruit weight (g)
2 mS/cm						
Flora Dade	4.13	6.71	0.62	5.61	39	144
Momotaro	5.42	6.34	0.85	6.99	48	145
Mean	4.78	6.52	0.73	6.30	43	144
8 mS/cm (KCl)						
Flora Dade	4.90	11.24	0.44	7.06	56	126
Momotaro	6.22	9.48	0.66	6.55	51	128
Mean	5.56	10.36	0.55	6.81	53	127
8 mS/cm (NaCl/$CaCl_2$)						
Flora Dade	5.18	10.49	0.49	5.94	46	130
Momotaro	6.41	9.10	0.70	5.50	48	123
Mean	5.80	9.80	0.60	5.72	47	127
l.s.d. ($P = 0.05$)	0.75	2.30	0.08	n.s.	n.s.	n.s.
Significance						
EC	*	*	*	n.s.	n.s.	n.s.
Cultivar	*	*	*	n.s.	n.s.	n.s.
EC x cultivar	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* $P<0.05$; n.s., not significant.

Table 4. Experiment 3. Yield and total soluble solids (TSS) response to solution electrical conductivity

	Electrical conductivity (mS/cm): 1.5	3.0	5.0	7.0	9.0	l.s.d. ($P = 0.05$)
TSS (°Brix)	4.40	4.75	5.08	5.42	5.94	0.19
Yield (kg/bush)	5.12	5.02	4.81	4.56	2.74	0.31

between EC treatment and cultivar. EC had no significant ($P>0.05$) effect on fruit number or fruit weight, although there was a trend for fruit to be smaller at the high EC (126 g) compared with the control (144 g).

Experiment 3

TSS increased linearly with rising EC, from 4.40°Brix at an EC of 1.5 mS/cm to 5.94°Brix at 9.0 mS/cm (Table 4). Yield, however, did not decrease significantly until an EC of 5 mS/cm (Table 4). The result of these different responses was a curvilinear decline in yield with rising TSS due to salt stress (Fig. 3).

Blossom end rot was observed at 7 and 9 mS/cm. None was observed at lower conductivities, or in experiments 1 and 2.

Discussion

Previous field experiments gave an indication that salt stress could improve the quality of tomato fruit in terms of the concentration of total soluble solids (Cornish and Nguyen 1989). However, responses were small and inconsistent and it was suggested that variability in EC of the soil solution may have prevented full expression of the potential effect of salt stress.

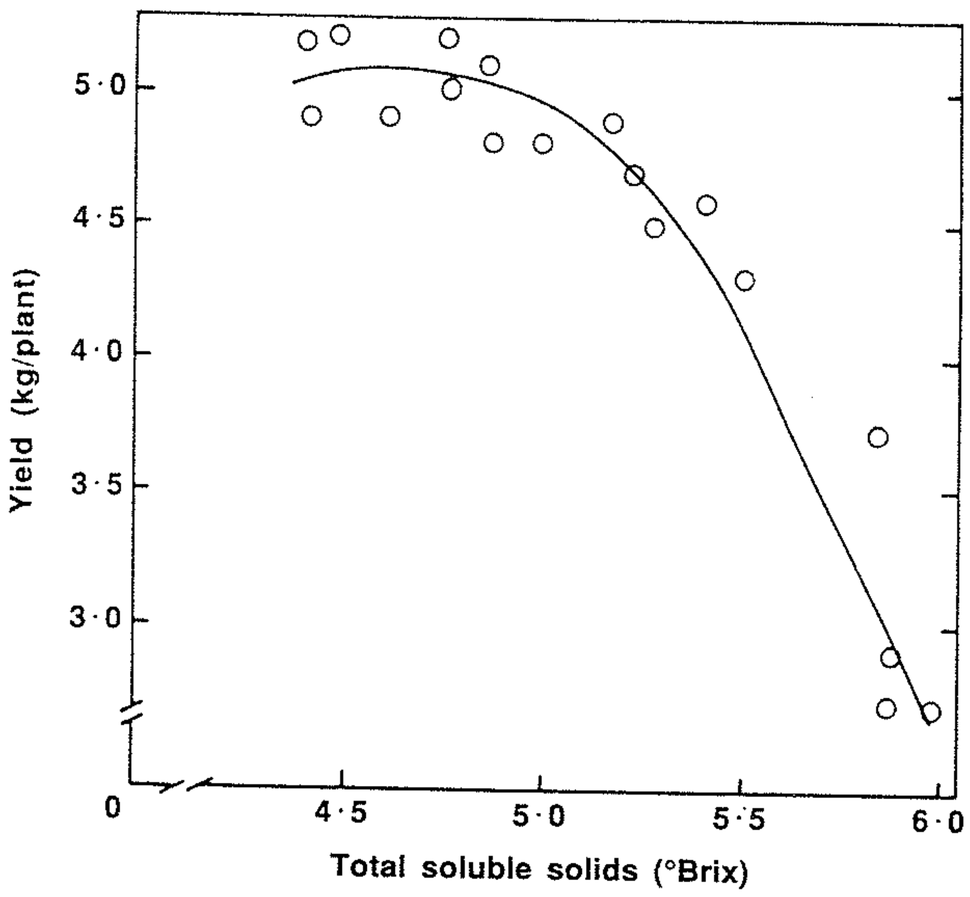

Fig. 3. The relationship between yield and total soluble solids (TSS) for experiment 3. The equation of the line is:

$$\text{Yield} = -23.07 + 12.16\ \text{TSS} - 1.31\ \text{TSS}^2 \quad (r^2 = 0.93)$$

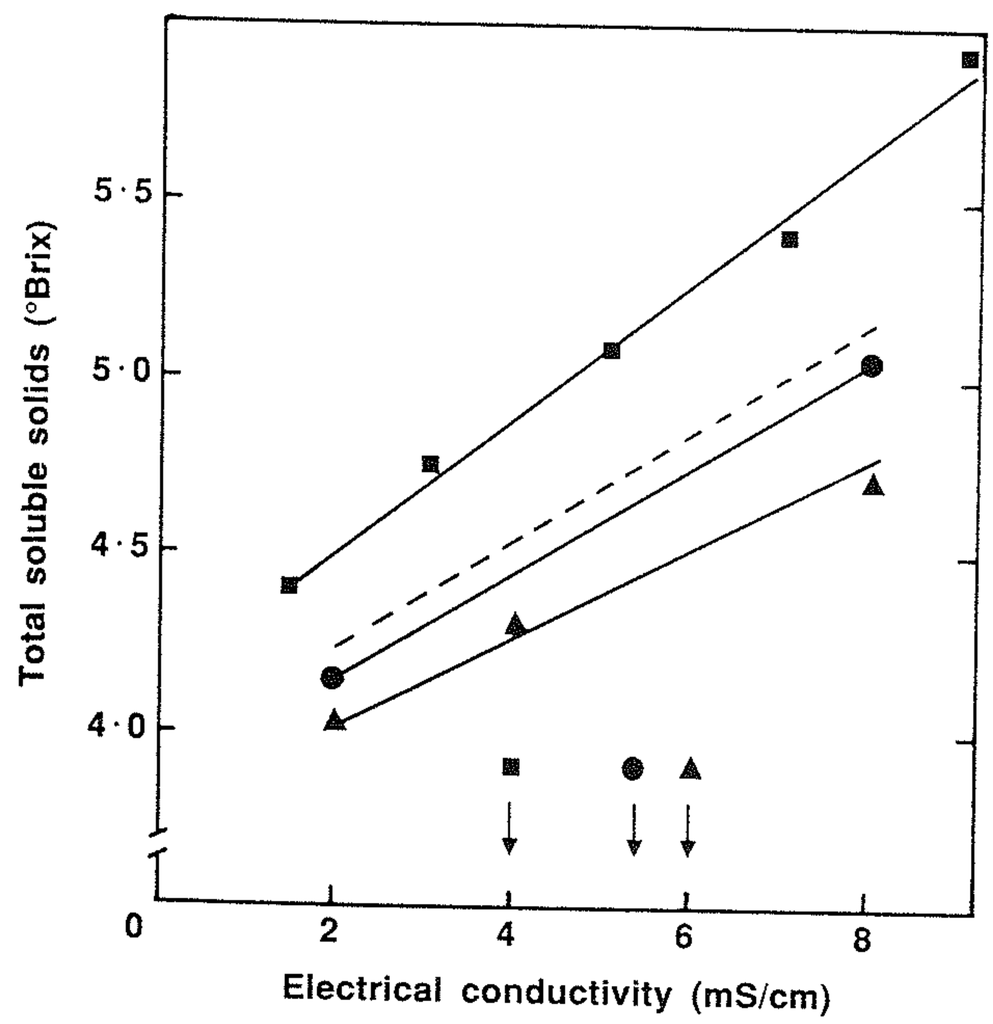

Fig. 4. Total soluble solids (TSS) for cv. Flora Dade in all experiments. The vertical arrows indicate the nutrient solution conductivity (EC) required to raise TSS by 0.5°Brix above the control in experiments 1 (▲), 2 (●) and 3 (■). Statistical treatment of data is not possible because the shape of the response to EC is not known for experiments 1 and 2.

The 3 experiments in hydroponic culture reported here confirm that substantial increases in TSS can be obtained under salt stress when the roots are treated uniformly with salinised water. An increase in EC from 2.0 to 8.0 mS/cm resulted in increases in TSS of 0.88 and 0.90°Brix in experiments 1 and 2, whilst the increase in EC from 1.5 to 9.0 mS/cm raised TSS by 1.5°Brix in experiment 3. With cv. Flora Dade, the average response to EC over all experiments was 0.16°Brix per mS/cm rise in EC over the range from 2 to 8 mS/cm (Fig. 4). The response to salinity was obtained in 3 different cultivars of salad tomatoes which varied from 3.9 to 5.4°Brix under non-saline conditions.

Different salts appeared to be equally effective in raising TSS, suggesting that osmotic effects on plant water relations underlie the response, rather than specific ionic effects. This conclusion is supported by reductions in leaf water potential and osmotic potential in response to increasing salt levels in experiment 1.

It has been shown that the cultivated tomato maintains turgor when under sub-lethal salt stress by accumulating organic solutes in leaves in order to osmotically balance the increased concentration of

inorganic ions in the growing medium (Rush and Epstein 1976). The increase in organic solutes in leaves is associated with increased percentage dry matter and TSS in fruit and reduced fruit size (Adams 1988; Ehret and Ho 1986; Pasternak *et al.* 1986). The increase in both TSS and titratable acids in the present experiments points to a role for both sugars and organic acids in this osmotic adaptation in fruit.

The refractometer used to measure TSS responds to inorganic solutes as well as to sugars and organic acids. As improvements in fruit quality depend on increased concentrations of organic rather than inorganic solutes, it is important to establish whether the increased refractometer readings reflect increased salt uptake or organic solute concentration. Inorganic ions in fruit juice were not measured. However, fruit juice conductivity (Table 1) will increase with the concentration of inorganic solutes and organic acids, but not sugars. Juice conductivity rose by 1.8 mS/cm when nutrient solution EC was increased from 2 to 8 mS/cm. A.R.-grade NaCl and KCl solutions with an EC of 1.8 mS/cm gave refractometer readings of only 0.1°Brix. Therefore, the rise in TSS of 0.9°Brix in fruit juice is unlikely to have resulted primarily from increased salt uptake.

Titratable acids also increased with high solution EC. This has implications for flavour, which depends on both TSS and the ratio of TSS to titratable acidity (Stevens *et al.* 1979; Hobson and Bedford 1989). The low ratio for cvv. Sunny and Flora Dade, under saline conditions, may not be acceptable to consumers. Conversely, the higher ratio in Momotaro, together with high TSS, should give intense flavour with an appropriate balance between the components of flavour.

Benefits of increased TSS will be offset by any loss in yield from salt-treated plants. High EC did reduce yield in experiment 3, but only at an EC of 5 mS/cm or above. Salt stress increased TSS by more than 0.5°Brix with no yield penalty (Fig. 3). Similar increases in TSS were obtained in experiments 1 and 2 with no yield penalty: an increase of 0.3°Brix at 4 mS/cm in experiment 1, and of 0.9°Brix at 8 mS/cm in experiment 2. An increase in TSS of 0.5°Brix is sufficient to alter the perception of flavour (McGlasson pers. comm.). Over all experiments there is reasonable evidence that salt stress can increase TSS by at least 0.5°Brix without reducing yield.

It is noteworthy that TSS under non-saline conditions, and perhaps the slope of the response to increased salinity, appeared to vary between experiments (Fig. 4). (Statistically valid comparisons cannot be made because the shape of the response curve in experiments 1 and 2 is not known.) The apparently higher TSS and greater responsiveness to salinity in experiment 3 may result from higher mean temperature during the fruiting period (22.9°C) compared with experiments 1 (20.1°C) and 2 (20.6°C). Whilst the reasons for differences between experiments are not known with certainty, the importance of the difference is clear: weather conditons will probably determine the nutrient solution EC at which useful increases in TSS can be obtained without reducing yield. Estimated conductivities of 6.0, 5.4 and 4.0 mS/cm resulted in estimated increases in TSS of 0.5°Brix in experiments 1, 2, and 3, respectively (Fig. 4).

The finding that TSS can increase up to a point under salt stress without reducing yield is consistent with experiments in hydroponic culture in glasshouses in the U.K. (Ehret and Ho 1986; Adams 1988) and Canada (Charbonneau *et al.* 1988). Adams (1988) found that an EC of about 5 mS/cm actually increased yield and there was no reduction at about 7.0 mS/cm compared with controls (EC 2 mS/cm). Ehret and Ho (1986) stressed that increased percentage dry matter in fruit would be obtained, without effects on yield, only if the supply of assimilate was not limiting. In experiment 1, low irradiance and reduced assimilation may have been responsible for the reduced yield of 8 mS/cm late in the harvest period. The finding that TSS can increase with salinity, without reducing yield, is also consistent with field experiments with processing cultivars in arid climates (Pasternak *et al.* 1986; Mitchell *et al.* 1991).

These results have 2 implications for tomato growers. The first is that hydroponic culture with high solution EC could be used to grow fruit with high TSS for a premium market niche. However, further work would be needed to define the nutrient solution EC that optimises yield and TSS in different climatic conditions, and to select cultivars with an appropriate acid to TSS ratio and good flavour. The effect of high EC on fruit size would also need to be considered when designing a production system targeting a niche market.

Secondly, the response of TSS to salinity could be useful for growers of processing tomatoes where prices reflect the concentration of soluble solids. This industry is based mainly in southern New South Wales and northern Victoria, in areas where saline drainage and ground water are available and environmentally acceptable strategies for re-use of saline water on other crops and pastures are being developed.

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Potassium nutrition of Kennebec and Russet Burbank potatoes in Tasmania: effect of soil and fertiliser potassium on yield, petiole and tuber potassium concentrations, and tuber quality

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Summary. The response of potato (*Solanum tuberosum* L.) cultivars Russet Burbank and Kennebec to soil and fertiliser potassium (K) was studied on basaltic krasnozems of north-west Tasmania. Yield increases in response to fertiliser K were recorded at sites with up to 300–400 mg/kg of bicarbonate-extractable soil K. The close correlation between relative yield and soil K indicated that soil K can reliably predict fertiliser requirements. Petiole K concentrations at early tuber set increased with fertiliser K at responsive sites; maximum yields were achieved with 12–14% petiole K for Kennebec and 11–13% for Russet Burbank. Petiole K concentrations provide an excellent indication of the K status of a growing crop. Tuber K concentrations increased with both soil and fertiliser K, and yields of 50–80 t/ha removed 180–380 kg K/ha in the tubers. At severely deficient sites specific gravity and crisp colour increased with low rates of fertiliser K, but the general trend was for fertiliser K to reduce specific gravity and crisp colour. Bruising susceptibility decreased with fertiliser K at some sites but the physiological disorder, 'hollow heart', was not influenced by fertiliser K. There were consistent differences between the 2 cultivars. Russet Burbank required higher soil K, had lower petiole and tuber K concentrations and removed less K in the marketable tubers.

Introduction

Between 1963 and 1973 an extensive series of NPK factorial experiments was undertaken with potatoes in Tasmania (Stackhouse 1967; K. M. Stackhouse and P. J. Fountain pers. comm.). Since then, cultural changes, particularly the use of more efficient irrigation and the change of cultivar from Kennebec to Russet Burbank, have necessitated reassessment of the nutritional needs of potatoes. Also, with the increasing acceptance by growers of soil and tissue analysis as predictors of fertiliser requirements, more emphasis needed to be placed on relating soil and tissue analyses to yield responses. We are not aware of any reports of potassium (K) requirements of Russet Burbank on the basaltic krasnozems (Loveday and Farquhar 1958) used for growing potatoes in Tasmania.

This paper reports work on K in the 1985–86 and 1986–87 seasons. Subsequent work on phosphorus (P) and nitrogen (N) will be reported elsewhere.

Materials and methods

Field experiments

Sites were chosen in commercial potato crops, and on Department of Primary Industry, Tasmania (DPI) research stations, to provide a wide range of soil K levels. Characteristics of the sites are summarised in Table 1. All sites were on basaltic krasnozems, the major potato-growing soil in Tasmania. Annual rainfall in 1985 and 1986 was near average (1006–1202 mm) but rainfall was 22–34% above average during the 1985–86 growing season (October–February).

The experiments were set out in randomised block designs with 3 replicates. Potassium chloride was applied at rates of 0, 80, 160, 240, 320, and 400 kg K/ha to each of the cultivars, Kennebec and Russet Burbank. P and N were applied as diammonium phosphate at rates of 170 kg N and 190 kg P/ha to all plots at each site.

Experiments were planted with a tractor-mounted twin-row potato planter, modified by the addition of extra fertiliser bins and gearboxes to enable the simultaneous application of 2 fertilisers at a wide range of rates. Fertiliser was placed in 2 bands about 50 mm under and 50 mm each side of the sets. Rows were 800 mm apart and within row spacing was 440 mm (2.8 plants/m^2) for Russet Burbank and 220 mm (5.7 plants/m^2) for Kennebec. Each plot consisted of 2 rows of 10–14 m. Guard rows between plots were included for sites 1–4 but omitted from sites 5–8 because no significant cross-feeding occurred (Maier *et al.* 1991). Sites 3–6 were cultivated 2 or 3 times and ridges then remoulded about 6 weeks after planting. Chemical weed