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168

Effects of Potassium in the Liquid Feed, Lime Type in the Base Dressing and Cultivar on the Yield, Quality and Composition of Tomatoes Grown in Peat

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Abstract

Three concentrations of K in the liquid feed, two lime sources and three cultivars were compared in a long-season crop of tomatoes grown in a peat substrate with 14 l per plant. Increasing the K concentration from 180 to 280 mg/l increased the yield but a further rise to 380 mg/l did not give a significant increase. The higher levels of K reduced uneven ripening and increased the levels of soluble solids, titratable acidity and electrical conductivity of the fruit purée.

The use of dolomitic limestone only or a blend of dolomitic and ground limestones as lime sources had no effect on fruit yield, visual quality or composition.

Two modern cultivars, Sonatine and Virosa, had better early yields than Ailsa Craig, an old cultivar, but similar total yields. Ailsa Craig produced a much higher proportion of fruit with uneven ripening, and early in the season its fruit had a lower soluble-solids content than did the modern cultivars.

A seasonal decline in the electrical conductivity of the fruit purée was noted.

Introduction

Production of tomatoes from long-season crops grown in small volumes (14 l per plant) of peat substrate in polythene pillows or modules has become commercially widespread in Ireland. A number of studies have been carried out on tomato nutrition in peat, e.g., Woods (1), Adams *et al* (2, 3). These were related to shorter-term crops and larger volumes of peat per plant. It may be expected that as the volume of substrate is reduced the importance of the liquid-feeding programme of N and K throughout the season increases while that of the initial base dressing diminishes. This experiment studied the effect of 3 concentrations of K in the liquid feed on a long-season tomato crop grown in peat modules.

Lime was added to the peat to bring the pH into the range 5.5 to 6.0 with dolmitic limestone or ground limestone. Using dolomitic limestone by itself would be more convenient but Wilson and McGregor (4) have reported that tomatoes are more susceptible to blossom-end-rot when grown in peat limed only with dolomitic limestone as against a mixture of dolomitic and ground limestones. The use of a blend of limestone types may make the plants more susceptible to Mg deficiency. This was tested in the experiment described here.

A criticism is sometimes made of modern

high-yielding, disease-resistant tomato cultivars that flavour has been sacrificed for other desirable traits. To examine this aspect two modern cultivars were compared in this study with an older cultivar with a reputation for good flavour.

Experimental

The experiment was carried out in a north-south, 30 × 9 m vinery type glasshouse. The plants were grown in three-plant modules, each module containing 42 1 of peat. Drainage slits were provided at the base of each module and the modules were placed on a sheet of white on black polythene which covered the glasshouse floor. Except for the lime a standard base dressing of fertiliser was applied to the peat before filling the modules. The crop was planted at the end of January, when the first truss was in flower. Subsequently, except for the experimental treatments, cultural methods and environmental regime were those recommended for early tomato production in Ireland (5). Picking commenced in early April and continued until the end of October.

Concentration of K in liquid feed

The crop was fed each day through a drip irrigation system which was controlled automatically by an evaporimeter. Three concentrations of K in the liquid feed were compared, i.e., 180, 280 and 380 mg/1. Urea was added to each feed to bring the N concentration to 180 mg/1. Stock solutions for the three feeds were made up and applied at a dilution of 1 in 100 using Volmatic dilutors. The liquid feed treatment was applied directly after planting.

Rate of Mg

The addition of Mg in the base dressing was varied by adding either 9 kg/m^3 of dolomitic limestone containing 10% Mg or 4.5 kg/m^3 of dolomitic limestone together with 2.7 kg/m^3 of ground limestone. This amounted to additions of Mg of 900 and 450 g/m^3, respectively. The addition of Ca was the same in both cases.

Cultivar

Three cultivars were included, Sonatine and Virosa, which are modern cultivars widely grown by commercial growers in Ireland and Ailsa Craig, an old cultivar which has a reputation for good flavour. Ailsa Craig is not resistant to TMV, so the plants of this cultivar were inoculated with a mild strain of TMV as a precaution against natural infection.

General

Treatments were combined in a 3 × 2 × 3 random factorial with two replications. There were 18 plants in each plot. Fruit was harvested twice weekly and the number and weight of fruit in the following categories were recorded: round uniformly coloured, non-uniformly coloured (NUC) and those with other defects, mainly misshapen. Samples of peat from the modules were analysed each month and leaf tissue samples were taken on two occasions.

Fruit composition, colour, firmness and flavour

Samples of fruit were taken on 6 occasions during the season, i.e., April 21, May 11, June 2, August 17, September 7 and September 22, and were tested for soluble-solids content (SS), titratable acidity (TA) and electrical conductivity value (EC) using a macerate and the procedures reported by Buret *et al* (6). Colour and firmness were measured on each of 10 fruit per plot with a Hunter Colour Difference meter and shear press, respectively (7).

Taste panels were used to test for flavour a number of times during the season. These included rank-type taste panels (8), i.e., 3 samples × 20 tasters, comparing the flavour of the 3 cultivars at each liquid feed K level (3 panels) and comparing the flavour of fruit from the 3 K levels for each cultivar (3 panels).

Samples of tomatoes from the June 2 harvest (10 fruit per plot) were frozen as whole fruit in a deep freeze cabinet in triple polythene bags for subsequent analysis at a later date. The freezing and thawing procedures used were those reported by Buret *et al* (6). The samples were tested for contents of Na, K, Mg, Ca, Zn, Cu and Cr by atomic absorption spectrophotometry (9) and for contents of ß-carotene, NO_3 and alcohol-insoluble solids (AIS) (9).

Results

Peat and leaf tissue analysis

The K levels in the peat for the three rates of K in the liquid feed, sampled at monthly intervals from March to September, are shown in Figure 1. The levels in March had

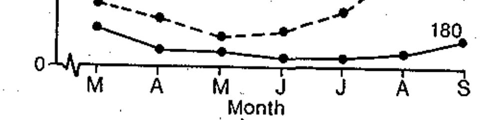

Fig. 1: Effect of K concentration in the liquid feed on levels of K in peat modules through the season

fallen from an initial value of about 800 mg/l. Thereafter the peat K levels in the two lower treatments continued to decline until mid-summer. Then the 280 mg K/l rate tended to increase the peat K level whereas this did not happen until September at the lowest rate and the effect was marginal. A concentration of 380 mg K/l in the feed increased the peat K level steadily through the season, especially during July and August. On all sampling dates differences between the three rates were highly significant.

The high rate of Mg addition consistently increased the Mg level in the peat through the season. There was no consistent trend in the levels and the average values over the season were 610 and 383 mg Mg/l for the 900 and 450 g Mg/m^3 rates of addition, respectively.

Samples of leaf tissue were taken on March 26 and July 16. On the first date the highest rate of K in the feed increased the leaf K level. In July the overall level of leaf K had declined but showed a positive response to increases in the rate of K in the feed (Table 1). Around this time, plants in the low K treatment began to show leaf symptoms of K deficiency which continued to occur into September. The relationship between leaf and peat K levels at the two sampling dates is shown in Figure 2a. A much higher leaf K level was obtained at the March sampling for the same K level in the peat. This indicated that as the season progressed the uptake of K was inhibited even where levels in the growing medium were maintained. The relationship between leaf K and the conductivity of the puréed fruit shown in Figure 2b could be represented by one line for the two sampling dates.

Plants receiving the low rate of K had higher levels of Ca and Mg in the leaves on

July 16 while the trend was opposite (not significant) on March 26. The high rate of Mg in the base increased leaf Mg levels on both dates but reduced the Ca content in the spring (Table 1).

Yield and quality

Rate of K did not affect the yield to the end of April, about 4 weeks after harvesting commenced (Table 2). However, from June onwards the yield at the lowest K concentration was depressed and this resulted in a significantly lower total yield. Increasing the rate of K had a marked effect on the proportion of NUC fruit but did not affect the percentage of remnant fruit.

TABLE 1: Effect of K concentration in the liquid feed and rate of Mg in the base dressing on leaf levels of Ca, K and Mg (% in DM)

	March 26			July 16		
	Ca	K	Mg	Ca	K	Mg
K (mg/l)						
180	1.59	5.80	0.55	2.09	3.27	0.43
280	1.64	5.51	0.59	1.64	4.06	0.39
380	1.70	6.39	0.58	1.66	4.73	0.38
F-test	NS	***	NS	***	***	**
SE (df = 16)	0.06	0.16	0.01	0.07	0.13	0.01
Mg (g/m³)						
900	1.54	5.81	0.62	1.77	3.92	0.43
450	1.74	5.99	0.53	1.82	4.12	0.38
F-test	*	NS	***	NS	NS	***
SE (df = 16)	0.05	0.13	0.01	0.06	0.11	0.01

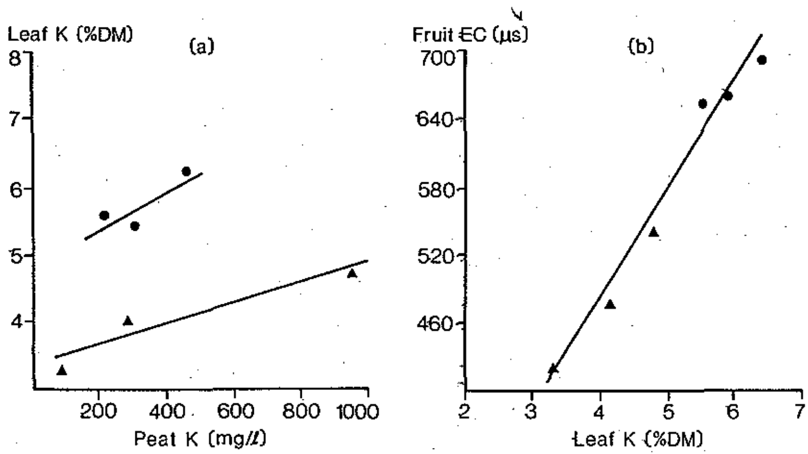

Fig. 2: (a) Relationship between peat and leaf K levels in March (●) and July (▲) and (b) relationship between leaf K levels and EC of the fruit purée

TABLE 2: Effect of K concentration in the liquid feed on the yield and quality of tomatoes

K (mg/l)	Yield (kg/m^2) to end of Apr.	Yield (kg/m^2) to end of Oct.	% NUC	% Remnant
180	3.1	24.9	39.5	6.8
280	3.1	27.2	20.5	5.0
380	3.4	28.8	11.5	6.8
F-test	NS	***	***	NS
SE (df = 16)	0.1	0.7	0.2	0.6

The rate of Mg in the base had no effect on the yield, size or visual quality of the fruit. Both of the modern cultivars produced higher early yields than did Ailsa Craig although the total yield from all three cultivars was similar (Table 3).

TABLE 3: Effect of cultivar on yield and quality

Cultivar	Yield (kg/m^2) to end of Apr.	Yield (kg/m^2) to end of Oct.	% NUC	% Remnant
Ailsa Craig	2.7	26.5	45.1	7.6
Sonatine	3.4	27.4	7.5	3.6
Virosa	3.5	27.1	18.9	7.5
F-test	**	NS	***	***
SE (df = 16)	0.1	0.7	2.2	0.6

Sonatine produced the smallest proportion of remnant fruit, indicating that it was more uniform in shape than the other cultivars. Ailsa Craig produced a very high proportion of NUC fruit while Sonatine produced least. There was, however, a significant interaction between cultivar and rate of K on the amount of NUC fruit (Table 4).

TABLE 4: Effect of K concentration in the liquid feed and cultivar on the proportion (%) of NUC fruit

Cultivar	K (mg/l) 180	K (mg/l) 280	K (mg/l) 380
Ailsa Craig	59.9	50.9	24.6
Sonatine	14.7	3.5	4.4
Virosa	43.9	7.2	5.6
F-test interaction		**	
SE (df = 16)		3.9	

At the lowest rate of K, Sonatine produced a much smaller proportion of NUC fruit than did the other two cultivars. At the two higher rates of K the amount of NUC fruit occurring for the two modern cultivars fell sharply. Ailsa Craig, however, continued to produce a significant amount of NUC fruit even at the highest K level.

Fruit composition, colour, firmness and flavour

Statistically significant differences for the effects of K in the liquid feed on tomato fruit SS, TA, EC and firmness values are shown in Table 5; data for cultivars are shown in Table 6. Effects that were not statistically significant are not included in order to reduce table size. Significant effects on firmness are shown only when there were no significant differences in colour.

The K level in the feed influenced fruit SS levels on four of the six testing dates (Table 5). In general increasing K raised fruit SS but the effect was not consistent. The feed K had no influence on fruit acidity until the fourth testing date (Table 5); from then on fruit acidity values were in accordance with the K level in the feed. The level of K in the feed influenced fruit EC values on five of the six testing dates with increasing levels of feed resulting in a corresponding rise in fruit EC values.

Firmness values were different on the last three of the testing dates (Table 5); in general the lowest level of K in the feed resulted in the firmest tomatoes.

Compositional differences between cultivars were most noticeable in the early part

TABLE 5: Effect of K concentration in the liquid feed on tomato fruit composition and firmness on six testing dates — statistically significant effects only

Test[1]	Date	K (mg/l) 180	280	380	F-test	SE (df = 16)
Soluble solids (%)	1. Apr. 21	4.3	4.7	4.2	***	0.07
	2. May 11	4.2	4.2	4.6	**	0.08
	3. June 2	4.8	5.1	5.0	*	0.06
	6. Sept. 22	4.7	4.9	5.1	**	0.07
Titratable acidity (meq)[2]	4. Aug. 17	6.0	6.9	7.2	***	0.17
	5. Sept. 7	6.1	6.8	7.6	**	0.29
	6. Sept. 22	6.1	6.6	8.0	***	0.27
Electrical conductivity (μS)[3]	2. May 11	650	672	721	***	10.9
	3. June 2	612	629	688	***	9.1
	4. Aug. 17	422	477	542	***	13.0
	5. Sept. 7	507	513	584	*	19.0
	6. Sept. 22	425	462	523	***	13.0
Firmness (g)	4. Aug. 17	2514	2223	2076	**	76
	5. Sept. 7	2629	2296	2314	**	75
	6. Sept. 22	2813	2437	2511	***	80

[1]All tests carried out on each of the six testing dates.
[2]meq per 100 g purée.
[3]For a dilution of 1 part purée + 9 parts distilled water (w/w).

of the season (Table 6). Fruit of Ailsa Craig had the lowest SS levels; Ailsa Craig fruit also had the lowest TA values with the exception of the August 17 testing date. Ailsa Craig had softer fruit on August 17. There were no significant differences in the EC of the fruit purée of the different cultivars on any of the six testing dates.

The two Mg treatments in the base dressing had little effect on fruit composition. The dolomitic limestone treatment gave a higher fruit EC value ($p < 0.05$, September 7) than that from the dolomitic and ground limestone treatment.

Significant interactions were found for K × cultivar on May 11 ($p < 0.05$, SS), and K

TABLE 6: Composition and firmness of three tomato fruit cultivars on six testing dates — statistically significant effects only

Test[1]	Date	Cultivar: Ailsa Craig	Sonatine	Virosa	F-test	SE (df = 16)
Soluble solids (%)	1. Apr. 21	4.1	4.6	4.5	***	0.07
	2. May 11	4.3	4.6	4.5	*	0.08
	3. June 2	4.8	5.3	4.8	***	0.06
Titratable acidity (meq)[2]	1. Apr. 21	8.1	9.0	8.3	*	0.27
	2. May 11	7.8	8.5	8.0	*	0.17
	4. Aug. 17	6.8	7.0	6.3	*	0.17
Firmness (g)	4. Aug. 17	2062	2386	2365	**	77

[1]All tests carried out on each of the six testing dates.
[2]meq per 100 g purée.

× Mg on September 7 ($p < 0.05$, firmness). On May 11 Sonatine fruit had the highest SS value of three cultivars at the first two K feed levels but the lowest fruit SS value at the highest K feed level. Firmness value was highest for fruit from the dolomitic and ground limestone treatment at the low K level and lowest at the high K level in comparison with samples from the dolomitic limestone treatment on September 7.

Statistically significant flavour differences were found in only two out of the six taste panels. Virosa fruit was better flavoured ($p < 0.01$) and Ailsa Craig fruit worse flavoured ($p < 0.01$) in comparison with Sonatine fruit; these samples were from the highest K (380 mg/1) treatment. In another panel, fruit from the highest K feed plots (cultivar Sonatine) was better flavoured ($p < 0.05$) than Sonatine fruit from the other K feed treatments.

Correlation matrices were drawn up for SS, TA, EC, colour and firmness on each of the six testing dates. The results showed that only SS × TA (positive correlation) and EC × TA (positive correlation) had mean correlation coefficients outside the range ± 0.40.

The seasonal trend in the composition of fruit from the highest K treatment is shown in Table 7. Soluble solids were lowest early in the season and then maintained their level from June onwards. The titratable acidity was initially high, then fell in the late summer but rose again on the last sampling date. The EC of the fruit purée fell dramatically after the June sampling and did not recover. These trends took place against the background of a rising level of peat K as shown in Figure 1.

The effect of the K and Mg treatments, and the influence of cultivars on the mineral, NO_3 and AIS contents of the fruit was generally small. Statistically significant effects were found for K in the fruit, which was highest ($p < 0.05$) at the high K feed level and for fruit Ca and NO_3 which were lowest ($p < 0.05$) at the intermediate K feed level. The Mg treatments showed no statistically significant effects. Ailsa Craig fruit had higher levels of NO_3 ($p < 0.05$) and ß-carotene ($p < 0.05$) than fruit of the other two cultivars. Grand mean values for these constituents (mg/100g) in the fruit were as follows: Na 2.3, K 242, Ca 8, Mg 8, Zn 0.07, Cu 0.02, Cr 0.009, NO_3 1.2, vitamin C 10.5 and ß-carotene 0.53; the value for AIS was 1.75%.

TABLE 7: Soluble solids (SS), titratable acidity (TA) and electrical conductivity (EC) of puréed fruit from the high K treatment through the season

Date	SS (%)	TA (meq)[1]	EC[2] (μS)
Apr. 21	4.2	8.4	696
May 11	4.6	8.3	721
June 2	5.0	8.2	688
Aug. 17	5.0	7.2	542
Sept. 9	4.6	7.6	584
Sept. 22	5.1	8.0	523

[1]All tests carried out on each of the six testing dates.
[2]meq per 100 g purée.

Discussion

The reduction in yield at the 180 mg/1 K concentration underlines the importance of providing adequate levels of K in the liquid feed for a long-season crop growing in a small volume of substrate. Adams *et al* (3) found that the yield of tomatoes was depressed only when a low rate of K in the liquid feed (100 mg K/1) was combined with a low base dressing (200 g potassium sulphate per m^3).

However, they were growing in a volume of 45 1 of peat per plant and the crop duration was 26 weeks. In the present experiment the peat volume per plant was

14 l and the crop duration 40 weeks. The amount of K supplied by the base dressing of 1400 g potassium sulphate per m^3 was just over 8 g per plant while the liquid feed at the middle concentration of K supplied 64 g K per plant through the season which is 88% of the total supply.

Adams *et al* (3) reported a tendency for yield to be reduced by a level of 300 mg K/l in the feed where a rate of 1200 g/m^3 potassium sulphate was given in the base dressing. In the present experiment the 380 mg K/l rate raised the peat K to rather high levels from July onwards. Had this happened earlier in the season it may have affected the yield. The decline in the peat K levels at the two lower rates of K indicates that the increasing fruit load during the spring increased the uptake of K above the supply. From midsummer on, as the fruit load lightened, the levels tended to rise. This suggests that a long-season crop in peat modules needs a high rate of K in the liquid feed during spring and that this should be reduced from summer onwards.

The effect of high rates of K in reducing the proportion of NUC fruit agrees with previous work in soil by Roorda van Eysinga (10) and Winsor and Long (11) and in peat by Adams *et al* (3) although Prasad (12) found no effect of K on the proportion of round uniformly coloured fruit in tomatoes grown in peat which cropped from April to July. Differences in the K rates in the present experiment only began to be significant in June, after 9 weeks cropping. Up to the end of May the incidence of NUC fruit at all rates was low.

Increasing the rate of K had a beneficial effect on fruit composition, giving higher levels of soluble solids, titratable acidity and electrical conductivity. This agrees with previous work by Davies and Windsor (13), Gormley and Gallagher (14) and Adams *et al* (2). The effect of K level in reducing fruit firmness, however, is contrary to results obtained by Shafshak and Winsor (15) who found that high levels of K in a soil-grown crop reduced the compression of tomatoes under a known weight. Buitelaar (16) reported that tomatoes from low K treatments in a peat substrate had a shelf life on average 1 day shorter than fruit from normal and high K treatments.

The sharp fall in EC (fruit EC correlates highly with fruit K content, (17)) of the fruit from the early to the late part of the season even where the peat K levels were increasing is similar to a decline in the K content of the fruit sap found by Winsor and Adams (11) in a commercial crop grown in a peat substrate. This may be a seasonal effect; Gormley (18) reported that fruit from autumn crops tested over a number of years had a lower K content than fruit from spring crops. It may be a normal phenomenon at this stage of development of a long-season crop or may be due to an avoidable physiological stress although this was not apparent from the appearance of the crop. It would be of interest to compare directly a long-season crop with a double-cropped system in this regard.

The small effect of Mg agrees with previous work in soil by Winsor and Long (19) and in peat by Adams *et al* (2).

The increased early yield and improvement in visual quality are clear advantages of the modern hybrids over the older cultivar Ailsa Craig. The composition data in Table 6 indicate that this has been achieved without loss of internal quality. Previous work (20) has shown that Ailsa Craig produces fruit with high titratable acidity and it might be expected to produce higher values than the modern cultivars. This, however, was not the case. The current data suggest that if the flavour of present-day tomatoes is inferior to those produced in the past this would have more to do with production techniques and not the introduction of new cultivars.

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