Project Title:	**Tomatoes: The role of Potassium and Calcium nutrition in optimising fruit quality in summer**
Report:	**Final Report (February 1998)**
Project Number:	**PC 122**

Project Leaders:	**Mike Fussell** **HRI Efford** **Lymington** **Hants SO41 0LZ**	
	Lim Ho **HRI Wellesbourne** **Warwick CV35 9EF**	
Key Workers:	**Jo Basham**	**Scientific Officer**
	Sarah Williams	**Assistant Scientific Officer**
	Mark Pearce	**Nursery Staff**
	Jon Webb	**Nursery Staff**
	Jane Milling	**ResearchAssistant (Wellesbourne)**
	John Andrews	**ResearchAssistant (Wellesbourne)**
	Rodney Edmondson	**Statistician (Wellesbourne)**
Location:	**HRI Efford, Lymington, Hants SO41 0LZ**	
Project Co-Ordinator:	**Nigel Dungey**	

Date Commenced:	**1 May 1996**
Completion Date:	**1 May 1997**
Keywords:	**Tomatoes, quality, softness, blotchy ripening, dark patches, goldspot, acidity, potassium, calcium**

CONTENTS

PRACTICAL SECTION FOR GROWERS

Objectives and background

Summer fruit quality in U.K. tomatoes can be reduced by softness, blotchy ripening, netting, gold spot, low acidity and a range of other disorders. The trend of increasing inputs of CO_2 has led to many growers raising summer ventilation set points in order to conserve CO_2. This has the effect of allowing glasshouse temperatures and humidities to rise with possible implications for fruit quality.

Deficiencies of Potassium (K) and Calcium (Ca) are believed to play a role in causing a number of defects and through manipulation of the concentration of these elements in feed solutions it may be possible to reduce the incidence and severity of some disorders.

The aim of this project was to determine the importance of K and Ca nutrition in combination with high temperatures in causing fruit softness, blotchy ripening, netting, gold spot, low acidity, and other disorders. This was acheived by imposing two ventilation regimes together with two K and two Ca concentrations in feed solutions.

Results

Higher air temperatures, and perhaps also higher humidities, that resulted from the use of higher ventilation set points (25°C Day/21°C Night vs 20°C Day/16°C Night) had a marked effect on fruit quality. While total yield was unaffected by the elevated temperature the percentage of Class I fruit was reduced by 3%.

The high temperature treatment increased fruit softness, blotchy ripening and the occurrence of tender dark patches within two weeks of the start of treatments, suggesting that processes occurring during ripening were responsible for these disorders. In contrast, increased incidence and severity of gold spot became apparent some 5 weeks after treatments started, suggesting that processes occurring during fruit development were responsible.

High temperature also reduced the incidence of gooseberry veining and apparently reduced fruit juice pH.

High concentrations of Ca in the feed solution (250 vs 100ppm) increased the fruit Ca status and also increased levels of gold spot but reduced the incidence of netting.

Low concentrations of K in the feed solution (230 vs 400ppm) had very little effect on fruit K status and did not influence levels of blotchy ripening or fruit acidity. However low concentrations of K did appear to increase fruit Ca status and resulted in increased levels of gold spot and reduced levels of netting.

Action points for growers

* Excessively high temperatures should be avoided to prevent fruit softness, blotchy ripening, dark patches and gold spot.

* Potassium levels of 400 ppm did not result in significantly reduce blotchy ripening or increase acidity compared to 230 ppm K. This suggests that increasing applied K concentrations (over 400 ppm) as a measure to prevent blotchy ripening or increase acidity are not likely to succeed.

* High applied concentrations of Ca should be avoided in order to reduce gold spot.

Practical and financial benefits from study

This study clearly demonstrates that delaying ventilation until glasshouse air temperatures reach 25°C in summer can result in increased fruit softness, blotchy ripening, dark patches and gold spot. These defects result in fruit being downgraded with a loss of income to the grower. The overall appearance of Class I fruit is also reduced, having a negative effect on the image of U.K. tomatoes with consumers and ultimately an effect on demand for the product. By maintaining lower ventilation set points these potential problems can be avoided.

There are occasions when bright conditions result in high fruit temperatures even with low ventilation set points and fruit quality defects result. Further research is underway in a Horticulture LINK project to identify the mechanisms responsible for causing these defects both under these conditions and at reduced ventilation to allow more effective use of CO_2.

EXPERIMENTAL SECTION

Introduction

The U.K. tomato industry faces increasing competition from Southern Europe and North Africa where growers are aiming to produce tomatoes for the North European market not only during the winter period but all year round. The quality of fruit from the Mediterranean region has in the past been poor in comparison with U.K. produce but rapid improvements in cultural techniques are resulting in better quality. If U.K. growers are to compete effectively with their Spanish and Moroccan competitors they must maintain a superior fruit quality.

Despite the fact that UK summer conditions are not considered harsh, high light levels, high temperatures and low humidities are apparently sufficient to reduce fruit quality in the summer months. Common defects include (a) fruit softness which can lead to physical damage during picking, grading and marketing, (b) blotchy or uneven ripening, (c) fine net cracking of the fruit surface, (d) gold spot (yellow specks at calyx-end), (e) gold marbling (flecking at blossom-end) and (f) blossom-end rot. Poor taste can sometimes occur in summer as a result of low fruit acidity at a time when sugar concentrations in fruit are high.

High levels of solar radiation resulting in high temperatures in the glasshouse environment affect a range of processes that may impact on fruit quality. These may be long term effects over the period of fruit development, short term effects during the period of fruit ripening or an interaction between the two.

Generally, high temperatures result in rapid fruit development resulting in an increased demand for nutrients and water. At the same time the uptake of different nutrients can be influenced by both the shoot environment and the root environment. Calcium (Ca) is known to play an important role in the structure of cell walls and a deficiency of Ca in the distal end of fruits is implicated in the occurrence of blossom-end rot (Ho et al 1993). Factors affecting Ca uptake and deposition in fruit are likely to be important in determining fruit softness and also disorders such as gold spot. There is evidence that blotchy ripening has been related to the Potassium (K) content of leaves and it has been enhanced by low supply of K (Hobson, Davies & Winsor 1977). The uptake of K by tomato plants declines in summer (Voogt, 1993) perhaps as a result of reduced root absorption capacity. The K content of the juice is also lower in defective fruit and this coincides with reduced fruit acidity (Davies & Winsor, 1967; Winsor & Adams, 1976). Alternatively, low acidity may be the consequence of increased losses of malic acid through faster respiration at higher temperatures.

High fruit temperatures may disrupt some of the processes that occur during ripening. The synthesis of the colour pigments lycopene (red) and carotene (yellow) are both affected by temperature but in different ways. Lycopene synthesis is inhibited at 30°C or higher but carotene will continue to be produced at up to 40°C. As a result temperatures between 30 and 40°C can result in blotchy ripening where patches fail to develop a red coloration. Other processes that occur during ripening such as the degradation of cell walls and changes in the organic acid composition are also likely to be affected by temperature, but not necessarily in the same way. High temperatures may result in different ripening processes proceeding at different rates and this lack of synchrony may produce defects such as softness.

The most obvious solution to the problem of poor summer fruit quality is shading. However shading inevitably results in reduced yields as the amount of light incident on the crop is reduced. In Holland the use of individual fruit caps to protect from incident solar radiation has been investigated but was found to be too labour intensive. Maintaining a dense leaf canopy by the use of higher plant densities or more vigorous varieties can provide some protection but quality problems can still occur, particularly at the ends of rows and around the edges of glasshouses. Depending upon the relative importance of long term effects of temperature during fruit development and short term effects during ripening new strategies may be developed for optimising summer quality which do not compromise yield and which are economically viable.

HDC funded work in 1991/92 demonstrated that summer humidification was not an effective means of improving summer fruit quality (Fussell & Hand 1995a). Higher humidities had only a small effect in reducing the incidence of blotchy ripening but also had an effect of increasing fruit softness and to a lesser degree levels of gold spot. Work in Holland has shown that the use of sun-caps to protect individual trusses from exposure to bright solar radiation was effective in preventing blotchy ripening (van Holsteijn G.P.A. and Janse J. 1990), but this technique has not been widely adopted due to the high labour costs associated with fitting the caps.

Materials and methods

Site details

The experiment utilised the M-Block multi-factorial glasshouse facility at HRI Efford.

Plant material: Tomato (*Lycopersicon esculentum* Mill.) plants cv Solairo that had been sown on 29 November 1995, were delivered by the propagator on 20 December 1995.

Treatments

Two temperature treatments were imposed at a compartment level in M-Block utilising different ventilation temperatures.

High - 25°C Day/21°C Night
Low - 20°C Day/16°C Night

A P-Band of 50% (adjusted according to wind speed and outside temperature) was utilised so that on a still, warm day a one degree increase in glasshouse temperature above the vent set point would result in 50% vent and a two degree difference would result in 100% vent.

Four nutritional sub-treatments were imposed within compartments

Treatment	Target Potassium mg/l	Target Calcium mg/l
A	234	96
B	468	250
C	468	96
D	234	250

The different treatments were achieved by using different combinations of Potassium Nitrate, Potassium Chloride, Calcium Nitrate, Calcium Chloride, Sodium Nitrate and Sodium Chloride in applied feed solutions which were of similar EC. The recipes for the different feed mixes are in Appendix 1.

Both ventilation and nutrition treatments commenced on 18 June 1996 (week 25).

The experimental layout is shown in Appendix 2.

Cultural techniques

Plants were grown in the 'V'- System on Grodan 90 x 15 x 15cm rockwool slabs. The plant population was 3.04 heads/m² (12,300/acre) with two in three plants having a sideshoot.

The CO_2 level was raised from ambient to a target 450 vpm (sunrise to sunset; using pure CO_2) with individual gap meters serving each compartment adjusted to allow higher flow rates into compartments with lower ventilation set points.

Records

1. Total yield and gradeout (including BER) (grading - comps 1-8 one week, 9-16 the next)

2. Fruit appearance - Shininess (0 - very dull, 1 - dull, 2 - moderately shiny, 3 - very shiny), incidence of physical disorders (especially blotchy ripening, gold spot, gold marbling, netting (for scoring system see Appendix 3). Assessments done on same day as harvest (plots 49-64 weekly, all 64 plots when high levels of disorders present).

3. Fruit Softness - load/deformation at the point of penetration using 5mm diameter round-ended probe and maximum load (at penetration). Assessments to be done 1 day after harvest (plots 49-64 weekly, all 64 plots when soft fruit were apparent).

4. Fruit sugar and acid, Ca and K determinations were undertaken at Wellesbourne. Fruit were juiced for assessment of concentrations of sugars, acids and pH. Pericarp discs were taken for dry matter, Ca and K and other element contents.

5. A taste panel assessment was done on 29 August.

6. Additional assessments were made on: firmness minus skin and pericarp thickness

7. Some fruit were sampled for Electron Microscopy studies at Wellesbourne.

8. Root exudates: On two occasions, at the beginning of the experiment (week 28) and prior to the stopping of heads (week 36) root exudation was collected from one single stem plant per plot. Exudate was collected for 3 hours after cutting. The volume of the 32 samples was recorded and N, P, K and Ca determinations carried out at Wellesbourne.

9. Calcium and Potassium budget: Using the target plants cut for the root exudate samples and the fruit and deleafings removed from the target plants between the two sampling occasions, a budget for Calcium, Potassium and dry matter accumulation was calculated.

10. Routine chemical analysis of applied and drain solutions for 4 applied feed and 10 drain solutions were done weekly.

11. Routine monitoring of applied and root zone solution pH and EC (4 applied and 4 slab or drain (alternating across temperature treatments).

12. Monitoring of the glasshouse environment - data capture of CO_2, air temperature (daily average and max/min), light sum and vpd. Local measurement of fruit temperatures were made on 18 and 19 July using an infra red thermometer gun.

Statistical Analysis

Data were subjected to analysis of variance to produce tables of means, standard errors of the difference between means (SED) and hence significance levels (N.S - Not Significant, *- P<0.05 (probability of result occuring by chance if there is no true treatment effect is less than 5%), ** - P<0.01, *** - P<0.001) and least significant differences between means (LSD). For some variables, an angular transformation was performed in order to normalise the distribution of the data. For these variables means are presented for the untransformed data and full statistics for transformed data.

Results and discussion

Air and fruit temperatures

The ventilation treatments were successful in achieving a consistent difference in air temperature. The average difference in daytime air temperature between the two treatments was 2.8 °C between weeks 25 and 42. Weekly average daytime air temperatures are shown in Figure 1. The difference in night time temperature over the same period was 2.7 °C. The average 24 hour temperatures over this period were 23.1 and 20.4 °C for the high and low temperature treatments respectively. Weekly day, night and 24 hour average temperatures are listed in Appendix 4. Mean daytime temperatures closely matched daily light sums (Appendix 5).

A similar difference was also evident between the average maximum and minimum air temperatures for the two treatments. The average daily maximum temperature was 28.1 °C for the high treatment and 25.4 °C for the low treatment. However, as Figure 2 shows, on the hottest days there was only a very small difference in the maximum air temperature between the treatments. On day 204 (22 July) a maximum air temperature of 32 °C was recorded in the high temperature treatment and 31.7°C in the low temperature treatment.

Fruit pericarp temperature measurements also revealed differences between the two ventilation treatments and demonstrated that fruits in full sun can reach temperatures as high as 39 °C and that fruits in full shade can also reach temperatures in excess of 30°C, even when measured glasshouse air temperatures are much lower (Table 1 and Appendices 6 and 7).

Table 1. Effects of ventilation treatment on fruit temperature

	Mean Fruit temperature °C			
	18 July		**19 July**	
Temperature treatment	**High**	**Low**	**High**	**Low**
Sun	37.6	31.6	31.4	27.3
Shade	33.7	28.5	29.4	25.8

Vapour pressure deficits and CO_2 concentrations

The ventilation treatments inevitably affected the vapour pressure deficit (vpd) as well as air temperature. In the low temperature treatment which received more ventilation, the average daytime vpd was 0.63 kPa and vpds were consistently greater than in the high temperature treatment where the average was 0.42 kPa (Table 2). The difference in vpd was similar at night with the average vpd at 0.34 and 0.55 for the high and low temperature treatments respectively.

Figure 1. Achieved average day temperature

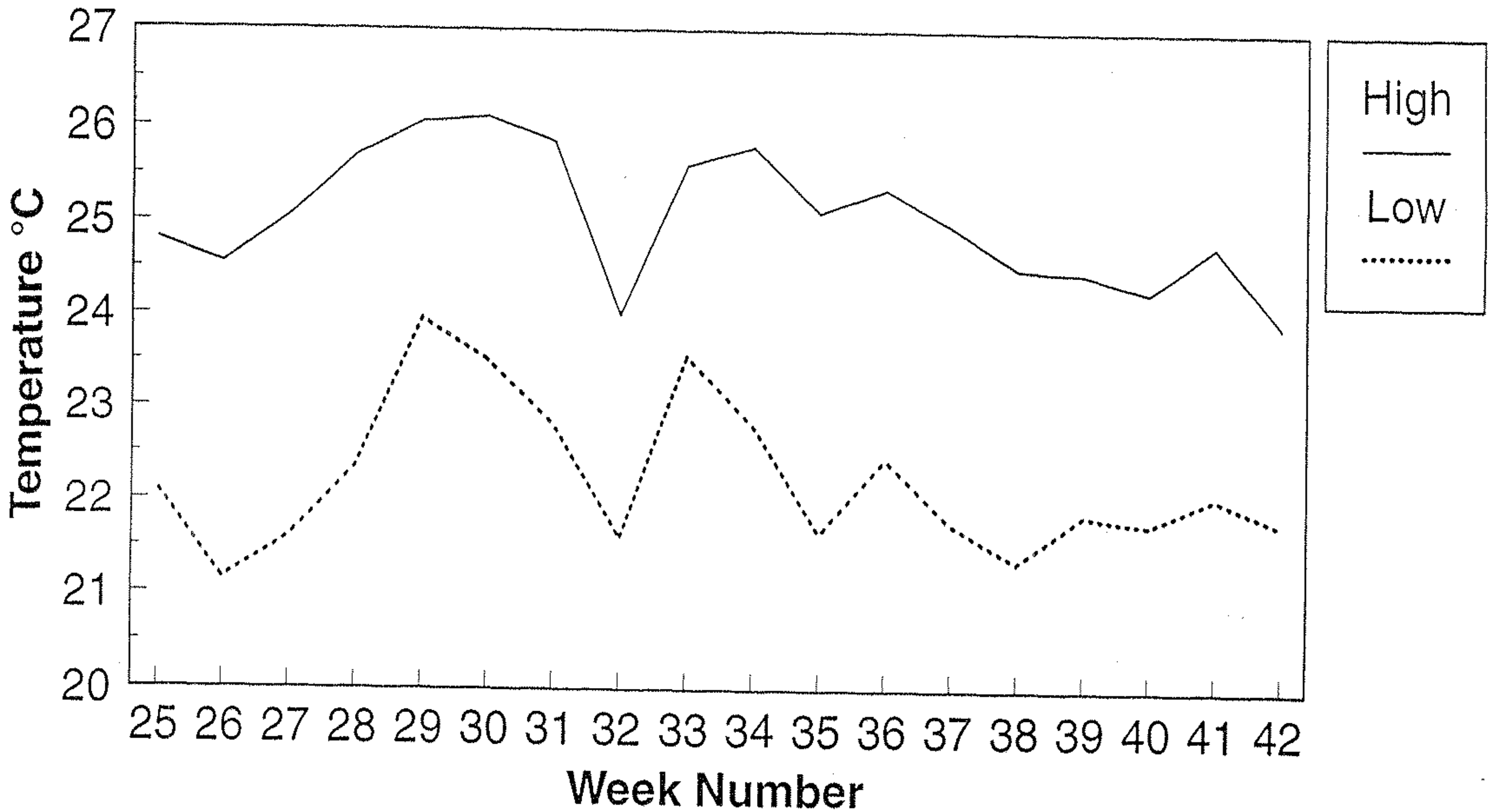


Figure 2. Effect of temperature treatments on maximum daily air temperature

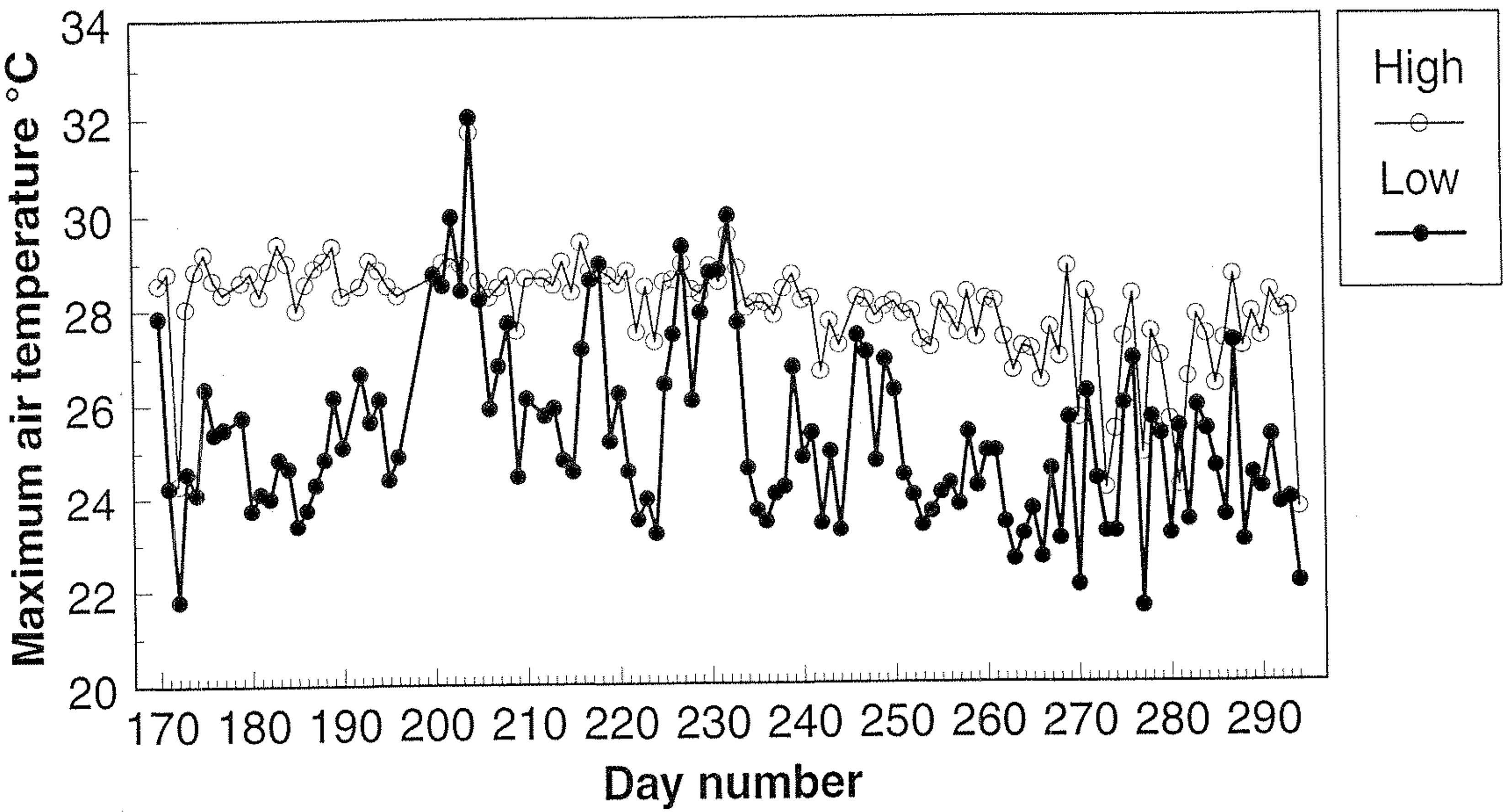


Table 2. Effect of ventilation treatments on daytime vapour pressure deficits

Week	Vapour pressure deficit (kPa) High temperature	Low temperature
25	0.40	0.56
26	0.39	0.57
27	0.30	0.48
28	0.36	0.52
29	0.59	0.81
30	0.51	0.70
31	0.49	0.67
32	0.38	0.55
33	0.51	0.69
34	0.44	0.61
35	0.37	0.61
36	0.43	0.70
37	0.43	0.77
38	0.35	0.66
39	0.31	0.51
40	0.38	0.60
41	0.39	0.62
42	0.48	0.68
Mean	0.42	0.63

Higher flow rates of CO_2 into low temperature (high venting) compartments were used in an attempt to minimise differences in CO_2 concentration between the two treatments. However, over weeks 25 to 42 the average day-time CO_2 concentration in the high temperature compartments was higher, at 545 vpm compared with 492 vpm in the low temperature compartments.

Applied and run-off Ca and K

The average Ca concentrations of applied feed solutions were 250ppm and 121ppm for the high and low Ca treatments respectively. The average K concentrations of feed solutions were 401ppm and 237ppm for the high and low K treatments respectively.

Run-off Ca concentrations were not affected by the temperature treatments. Average Ca concentrations in run-off were 294ppm and 140ppm for the high and low Ca treatments respectively and 227ppm and 207ppm for the high and low K treatments suggesting a possible effect of high K reducing Ca uptake.

Run-off K concentrations were slightly higher in the high temperature treatment, (mean = 352ppm), than in the low temperature treatment, (mean = 331ppm), suggesting a possible lower rate of uptake at high temperature. Average K concentrations in run-off were 439ppm and 241ppm for the high and low K treatments indicating that plants were not depleting the feed solution of its K even when applied at only 230ppm. At high applied Ca the run-off K was 329ppm, a little lower than at low applied Ca, 354ppm, suggesting that high Ca may promote K uptake. Weekly run-off Ca and K concentrations are listed in Appendix 8.

Yield and gradeout

The total yield was unaffected by the ventilation or K/Ca treatments. However, there were significant effects of the ventilation treatments on marketable yield, % Class I, II and waste fruit (Table 3) and on the proportion of Class I fruit in the different size grades (Table 4). The high temperature treatment resulted in a reduced proportion of Class I fruit and more Class II and waste fruit relative to the low temperature regime. Fruit size was smaller under high temperatures resulting in more size grade E fruit and less size grade C.

Table 3. Effects of ventilation regimes on total and marketable yield, percentage Class I, II and waste fruit from July to September.

Treatment	Total yield	Marketable yield	% Class I fruit	% Class II fruit	% Waste fruit
High Temperature	19.14	17.53	81.2	10.4	8.1
Low temperature	19.43	18.09	84.3	8.8	6.5
SED (7 d.f.)	0.221	0.188	1.02	0.56	0.44
LSD (5%)	0.52	0.44	2.4	1.3	1.0
Significance	N.S.	*	*	*	**

Table 4. Effects of ventilation treatments on size gradeout from July to September.

Treatment	% of Class I fruit in size grade		
	C (>57 mm)	D (47 - 57 mm)	E (40 - 47mm)
High Temperature	4.1	76.9	17.1
Low temperature	10.9	75.7	12.2
Significance	***	N.S.	***
SED (7 d.f.)	1.20	1.27	0.66
LSD (5 %)	2.8	3.0	1.6

Firmness and Texture

The high temperature treatment reduced fruit firmness consistently through the season (Figure 3a). This effect was apparent within 2 weeks of the start of treatments. The difference between the ventilation regimes was significant for firmness measured as N/mm and also for force (N) required to penetrate the fruit (Table 5).

Table 5. Effect of ventilation regimes on fruit firmness (N/mm) and force required to penetrate fruit pericarp (N) (weeks 27 - 42)

Treatment	N/mm	N
High Temperature	1.74	11.21
Low temperature	2.01	12.67
Significance	*	*
SED (2 d.f.)	0.051	0.259
LSD (5 %)	0.22	1.11

While neither applied Calcium or Potassium levels affected firmness (N/mm), low Calcium levels appeared to slightly increase the force required to penetrate fruits (Figure 3b) and Table 6. However this effect was small in comparison with the effect of ventilation regime.

Table 6. Effect of applied Calcium level on fruit firmness (N/mm) and force required to penetrate (N) (weeks 27 - 42)

Treatment	N/mm	N
250ppm Ca	1.89	11.81
120ppm Ca	1.87	12.07
Significance	N.S.	*
SED (6 d.f.)	0.019	0.104
LSD (5 %)	-	0.25

Figure 4 shows the effect of the temperature treatments on samples of fruit with the skin intact and Figure 5 shows that a similar effect of high temperature reducing firmness remains when the skin has been removed from the equator. This suggests that high temperatures reduce the firmness of the pericarp tissue itself rather than just the strength of the epidermis.

Figure 3a. Effect of temperature treatments on fruit firmness

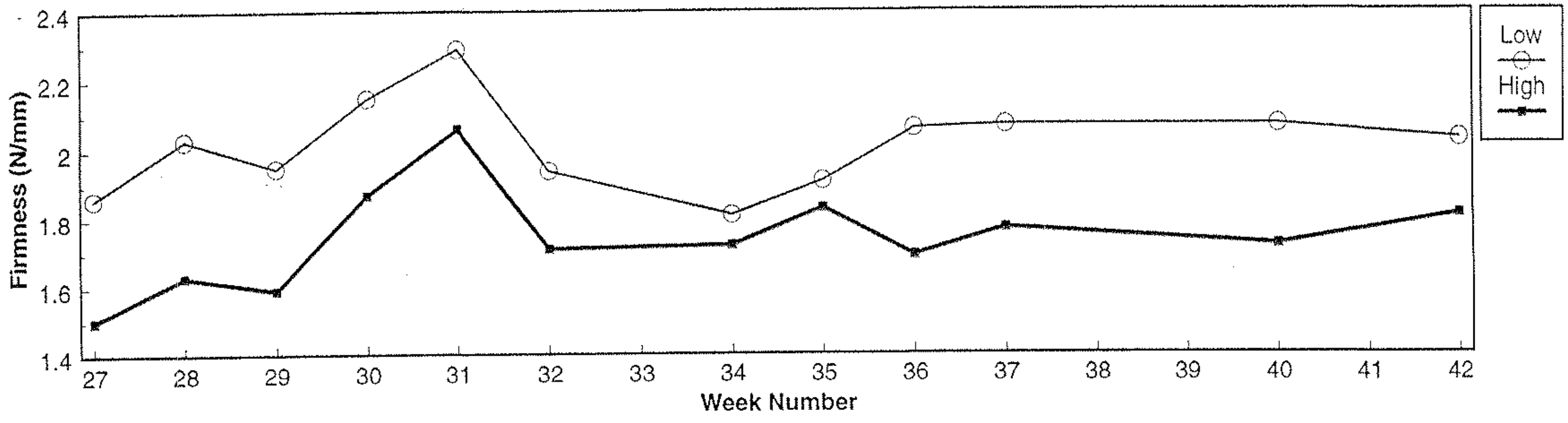


Figure 3b. Effect of applied Calcium level on force required to penetrate fruit

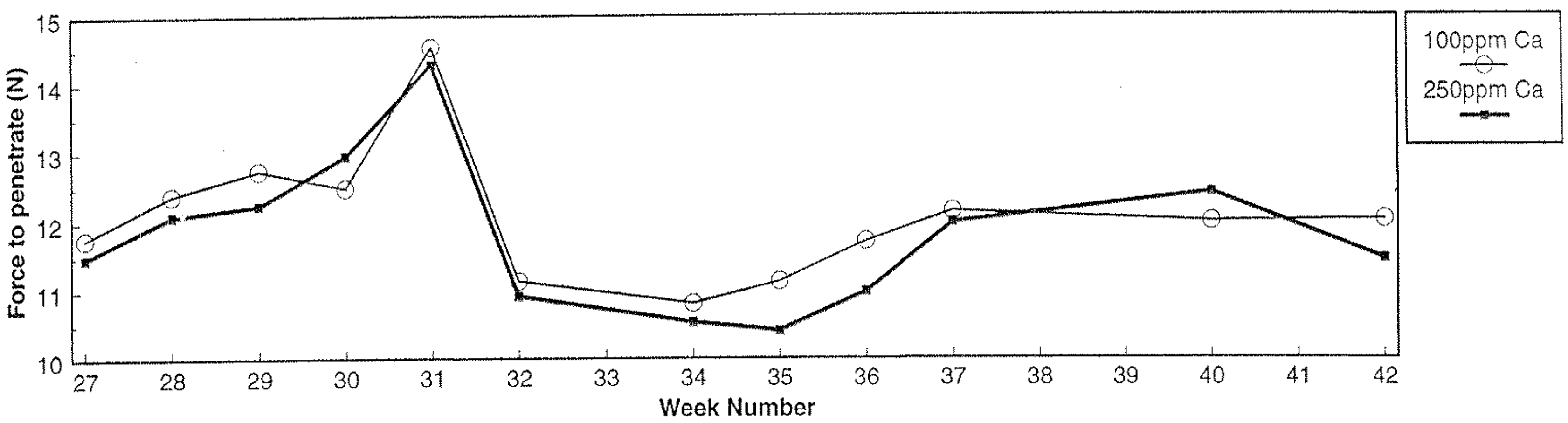
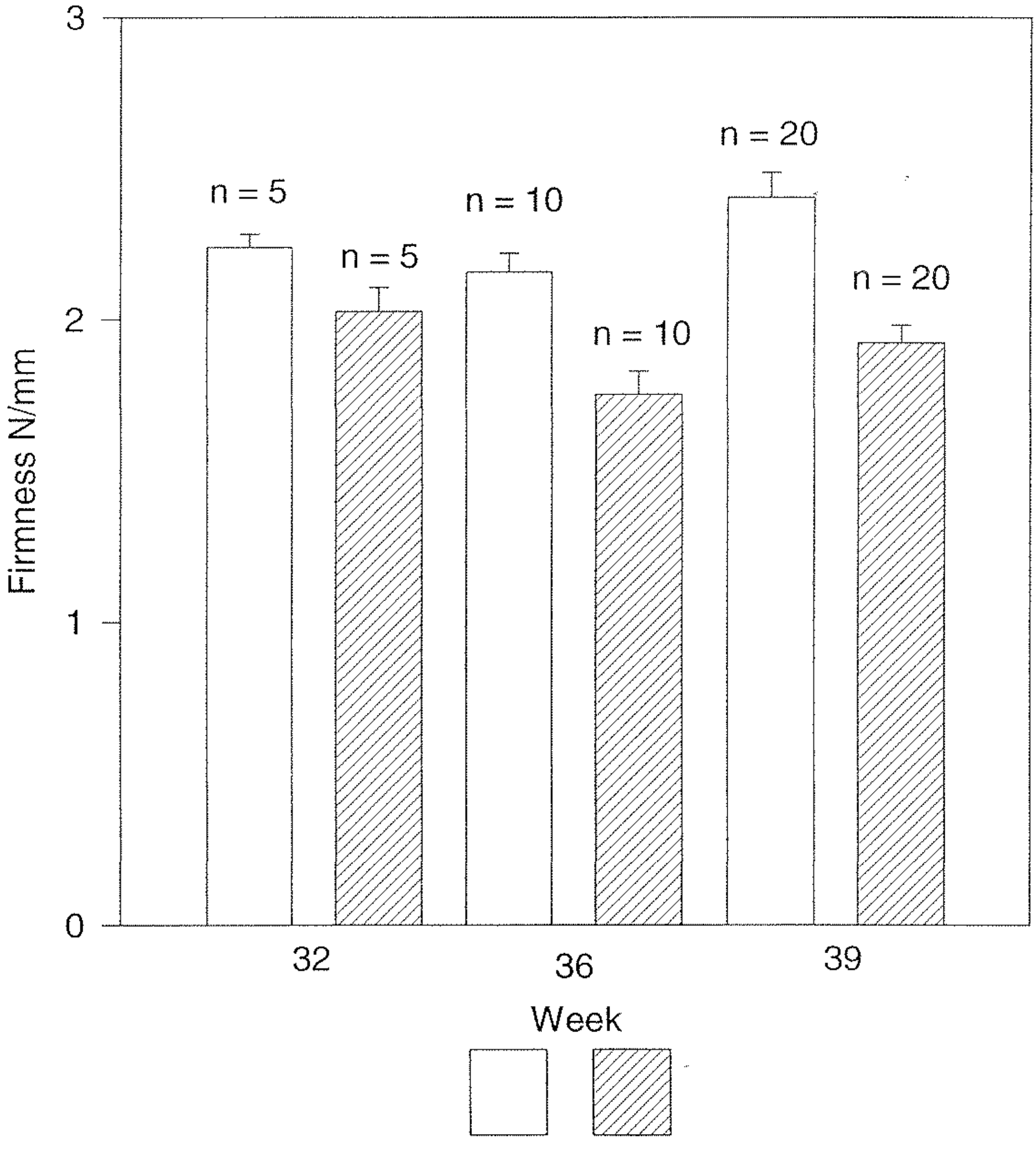


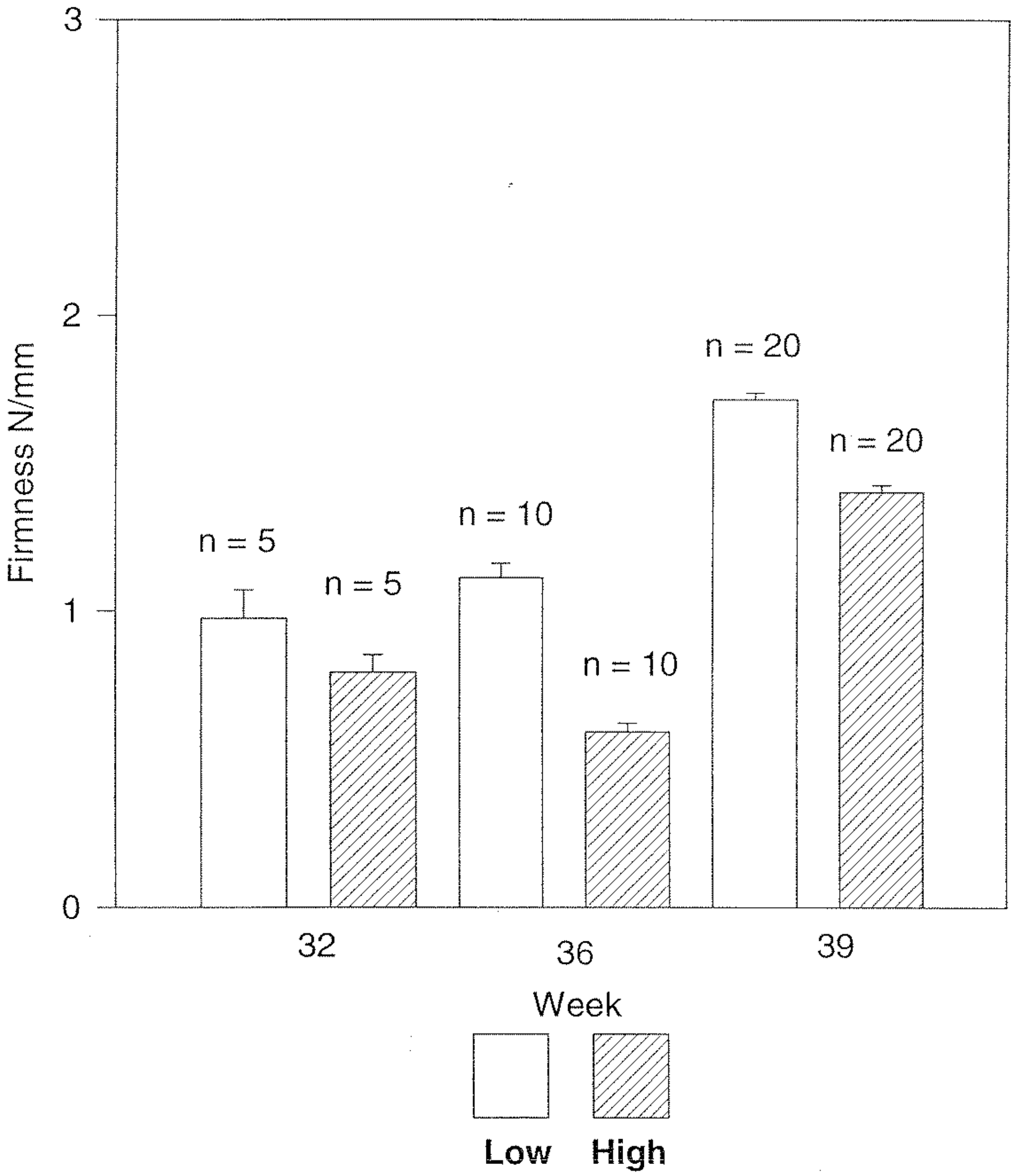
Figure 4. Effect of Temperature on Firmness with skin intact



Error bars represent the standard error of the mean

[n = number of samples]

Figure 5. Effect of Temperature on Firmness with skin removed from around the equator



Error bars represent the standard error of the mean

[n = number of samples]

Taste panel assessments on 29 August appeared to confirm that fruit grown at high temperatures had reduced flesh firmness compared to fruit grown at lower temperatures but that the high temperature fruit also had tougher skins. (Figure 6). Measurements have indicated that the pericarp thickness for fruit from the high temperature treatment was greater than that for fruit from the low temperature treatment. (Table 7). Thus there is no apparent effect of increased firmness as a result of pericarp thickness.

Table 7. Effect of ventilation regime on pericarp thickness (mm)

Treatment	**Week 32** mm	SEM	**Week 36** mm	SEM	**Week 39** mm	SEM
		(n = 5)	(n = 10)		(n = 20)	
High temperature	7.7	0.25	8.4	0.16	7.4	0.16
Low temperature	7.4	0.24	7.9	0.15	7.0	0.18

Blotchy Ripening

High temperature increased the incidence of blotchy ripening (Figure 7 and Appendix 8) and as with firmness, this effect was apparent within 2 weeks of treatments starting. The only time that the low temperature treatment produced as much blotchy fruit as the high temperature treatment was in weeks 29 and 30. As Figure 2 shows, between days 200 (Thursday 18 July - week 29) and 205 (Tuesday 23 July - week 30), the maximum daily air temperature for the low temperature treatment was in excess of 28°C and similar to that in the high temperature treatment. Over the summer (weeks 25 - 42) 4% of fruit from the high temperature treatment and 1% of fruit from the low temperature treatment had sufficient levels of blotchy ripening to be downgraded to Class II or waste.

Applied Ca and K levels did not have any consistent effects on the incidence or severity of blotchy ripening.

A small number of mature green fruit used for fruit temperature measurements on 19 August were tagged and subsequently levels of blotchy ripening were recorded. Figure 8 indicates that there may be a weak relationship between the average fruit temperature (measured on only two occasions here) and subsequent levels of blotchy ripening. Continuous fruit temperature measurements will be needed to determine the magnitude and duration of high temperatures that are critical in causing blotchy ripening.

Figure 6. Effect of ventilation regimes on skin toughness and flesh firmness assessed by taste panelists on August 29th 1996

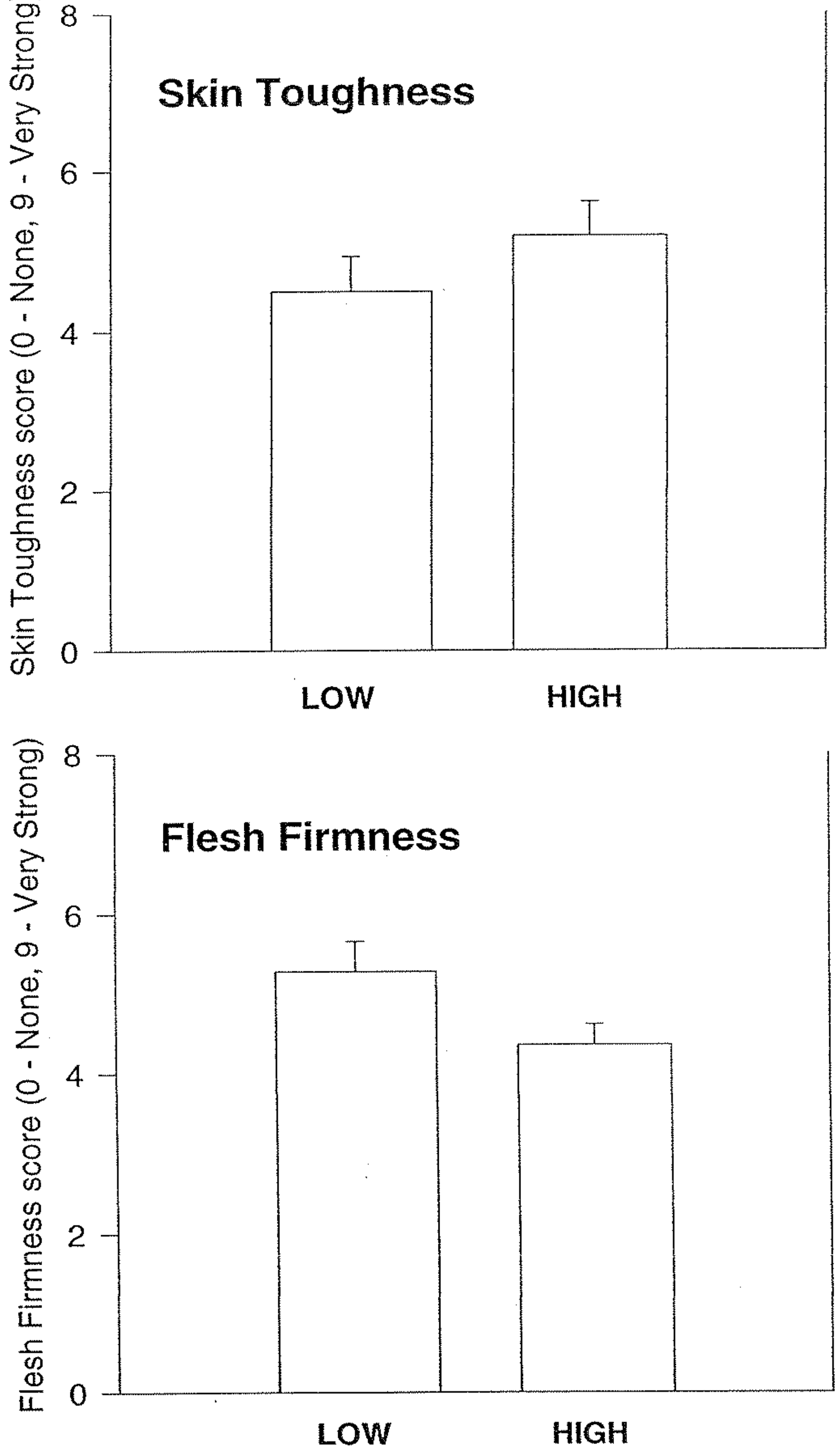


Figure 7. Effect of temperature treatments on the incidence of blotchy ripening

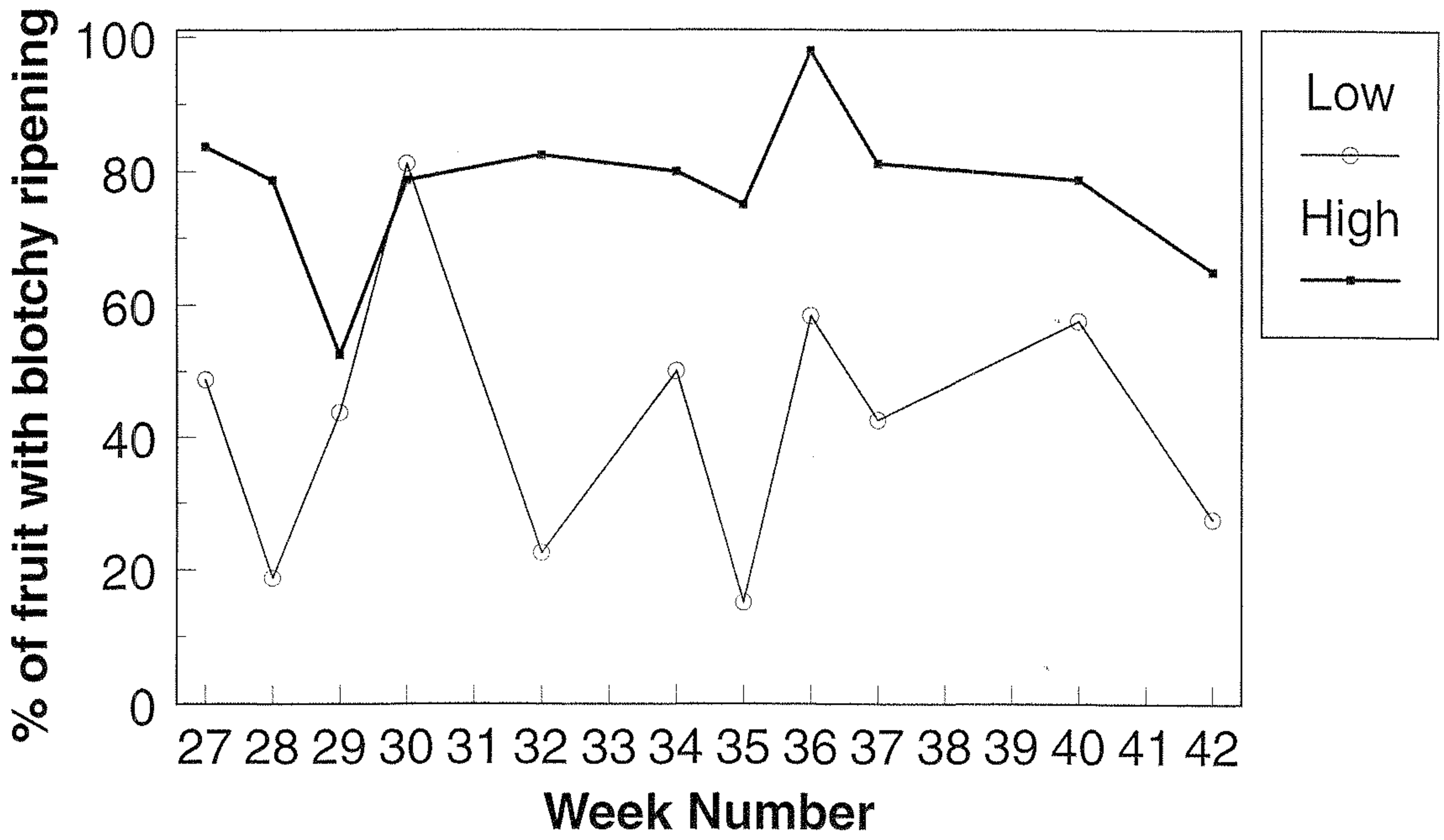
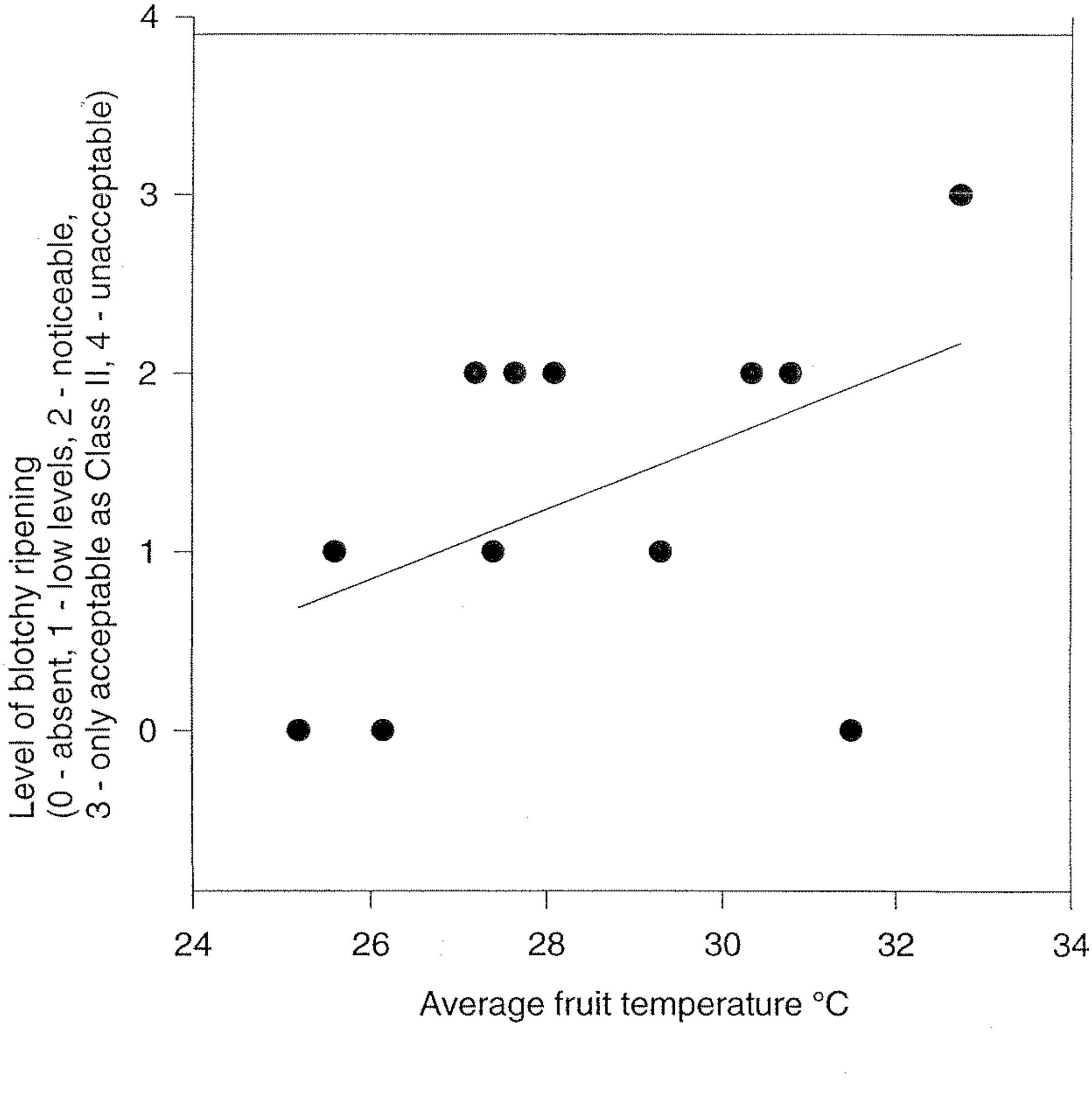


Figure 8. Effect of fruit temperature on blotchy ripening



Dark Patches

A less well documented defect but one observed by growers as 'dull' or 'bruised fruit' takes the form of a darkened area of soft fruit tissue. The defect is apparent on fruit prior to picking and was not therefore the result of rough handling. These darkened areas were much more common in the high temperature treatment (Figure 9 and Appendix 9). As with blotchy ripening and softness, these dark patches were also evident shortly after the start of the high temperature treatment suggesting that high temperature during ripening caused the defects. Over the summer 3% of fruit from the high temperature treatment and 2% of fruit from the low temperature treatment had sufficient levels of dark patches to be downgraded.

Red Noses

In week 35 a number of fruits were recorded with the disorder 'red noses' where ripening occurs earlier at the blossom end of the fruit. The high temperature treatment resulted in significantly more red noses than the low temperature treatment. (Appendix 10).

Gold Spot

Gold spot was also more common at high temperature, but unlike the other disorders the effect was not evident until five weeks after the start of the temperature treatments (Figure 10 and Appendix 11), suggesting that the gold spot may have been the result of temperature influencing the calcium supply during the development of the fruit. Gold Spot was much more severe at 250 ppm Ca than at 100ppm (Figure 11a). At 400ppm K levels of gold spot were lower than at 230ppm K (Figure 11b and Appendix 12), suggesting a possible effect of low K increasing fruit Ca status. Over the summer 7% of fruit from the high temperature treatment and 2% of fruit from the low temperature treatment had sufficient levels of gold spot to be downgraded.

Netting

Netting (fine cuticular cracks) were common towards the end of the summer. High temperatures appeared to reduce the incidence of netting (Appendix 13) but perversely also increased the severity of netting when it did occur, as the proportion downgraded was greater at high temperature. High Ca and low K levels reduced the incidence of netting and high Ca also reduced the severity (Appendix 14).

Figure 9. Effect of temperature treatments on the incidence of dark areas

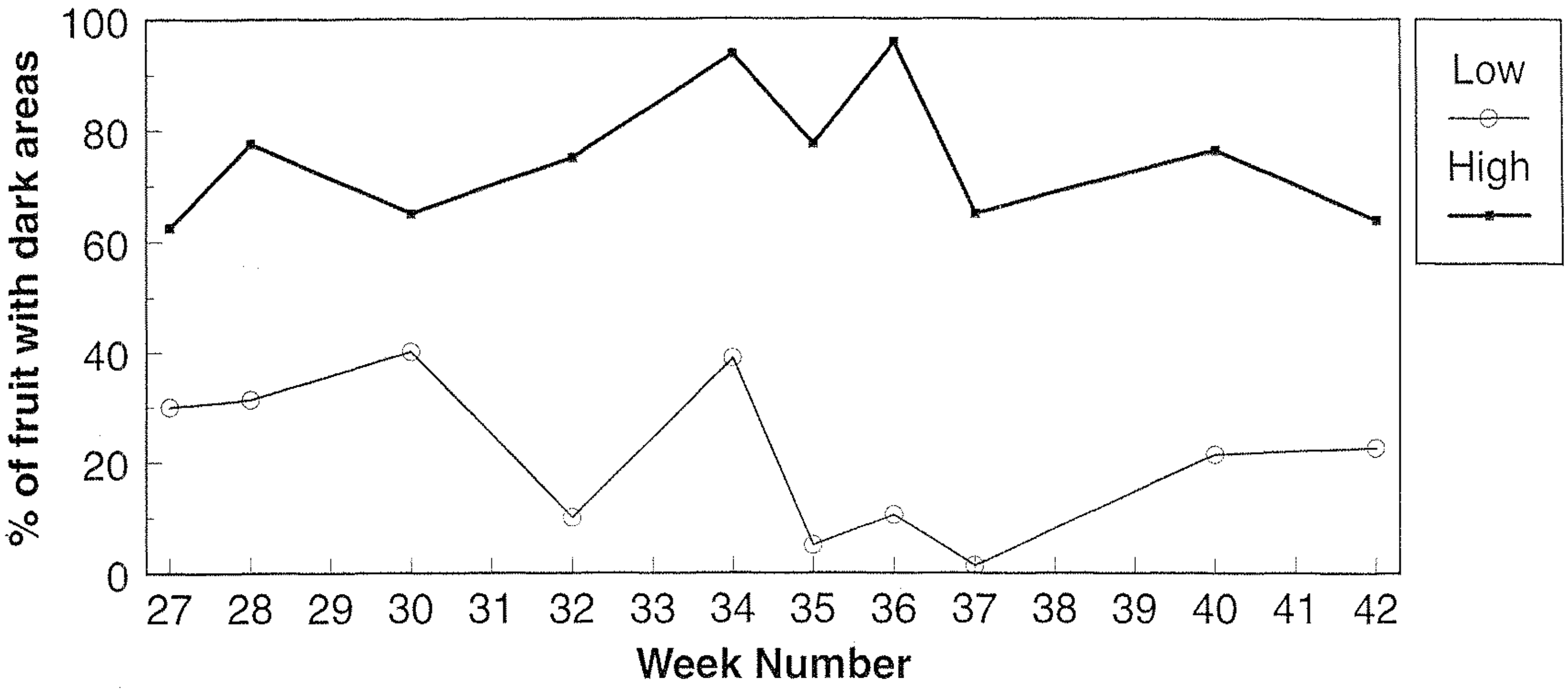


Figure 10. Effect of temperature treatments on the incidence of gold spot

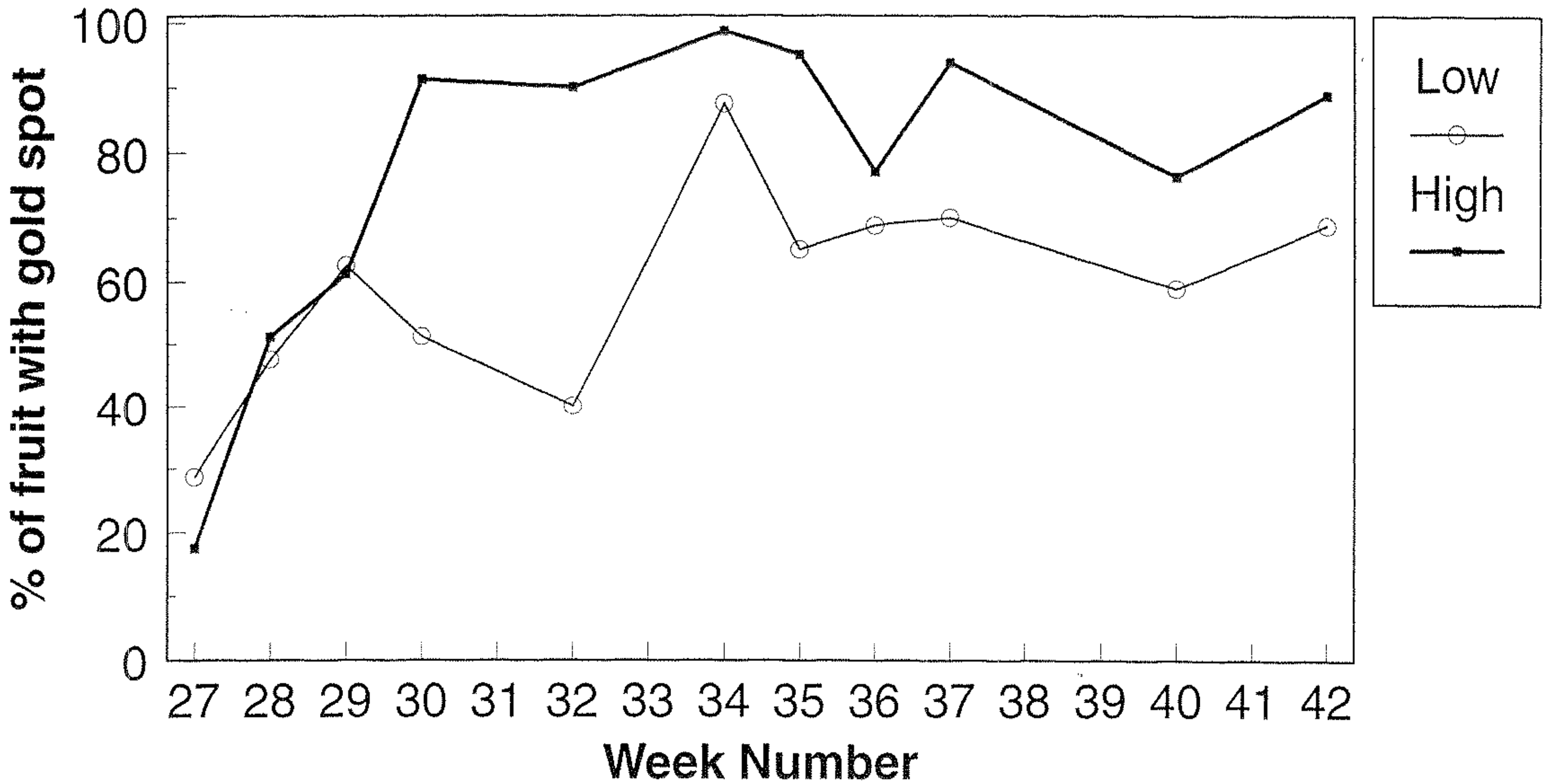


Figure 11a. Effect of applied Calcium level on the incidence of Gold Spot

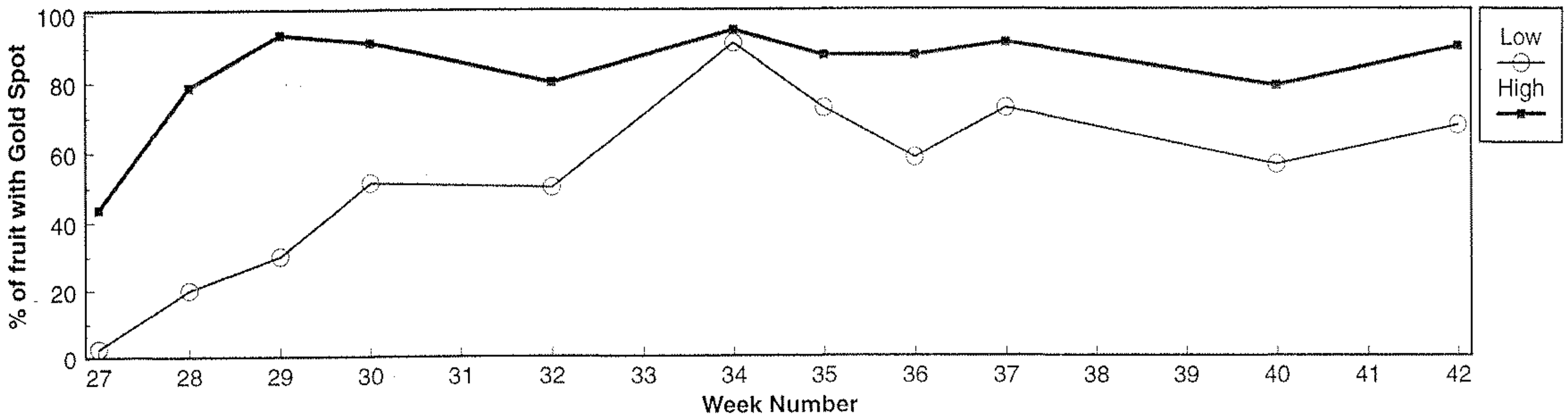
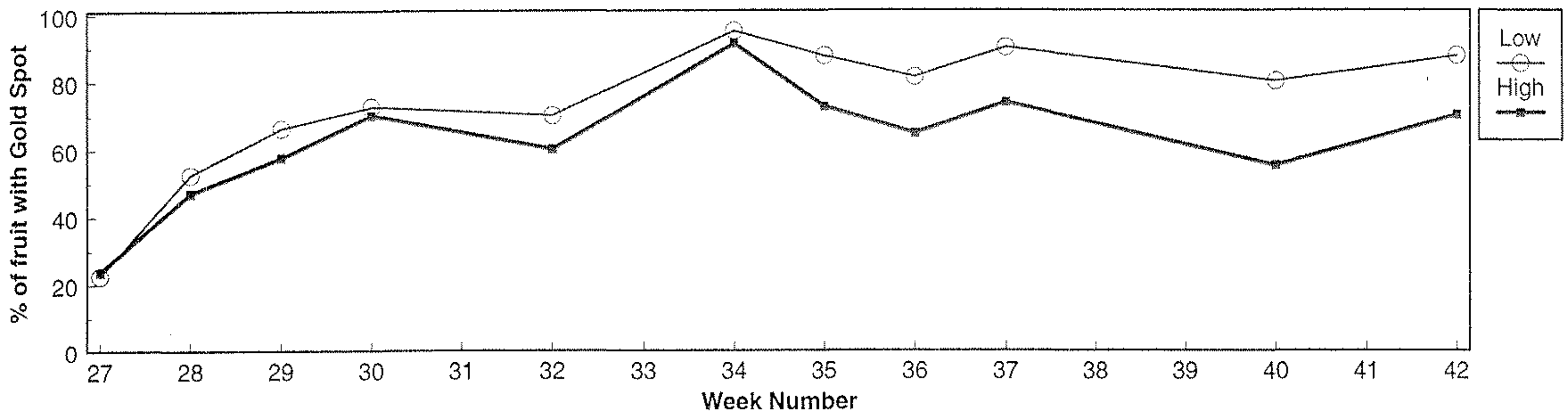


Figure 11b. Effect of applied Potassium level on the incidence of Gold Spot



Other disorders

The incidence of gooseberry veining was significantly less at high temperature than at low temperature (Figure 12 and Appendix 15).

There was some evidence of a small decrease in gold marbling at high temperature (Appendix 16) but no effect of applied Ca level indicating that the factors controlling this disorder are quite different from those controlling gold spot.

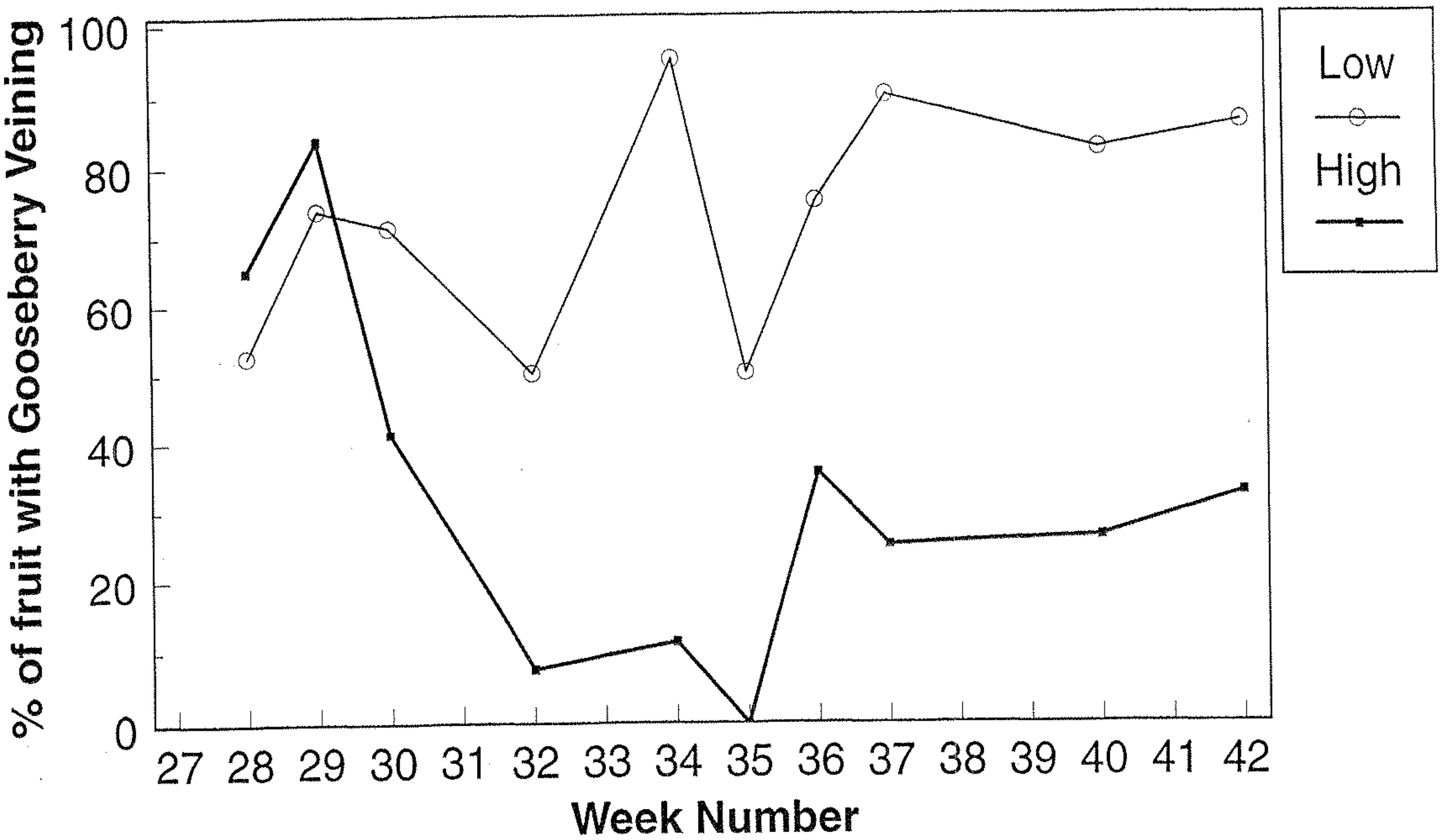
Fruit shininess was not found to be consistently affected by the temperature (Appendix 15) or nutritional treatments.

The incidence of BER was very low (less than 1% of fruit) but was more than 20 times higher at 100ppm Ca than 250ppm Ca (Table 8).

Table 8. Effects of applied Calcium level on the incidence of blossom-end rot from July to September.

Treatment	% BER by weight	Number of BER fruit/m²
250 ppm Ca	0.03	0.11
100 ppm Ca	0.69	2.33
Significance	***	***
SED (7 d.f.)	0.086	0.256
LSD (5%)	0.20	0.61

Figure 12. Effect of temperature regimes on the incidence of gooseberry veining



Fruit acidity and sugar content

Fruit from the high temperature treatment had slightly lower pH than those from the low temperature treatment. There were no effects of Ca or K level in applied feed on fruit pH. These findings do not support the hypothesis that a reduction in fruit acidity in summer is a function of temperature reducing the availability of K to fruits. The difference in pH between temperature treatments is not simply a reflection of increased total solutes, since % dry matter and % Brix did not show a similar trend. The dry matter content was higher for the low temperature treatment and there was no trend in % Brix (Table 10).

Table 10. Effect of temperature on fruit acidity, dry matter and soluble solids content

	pH			% Dry Matter			% Brix		
Harvest date	**22 Jul**	**5 Aug**	**4 Sep**	**22 Jul**	**5 Aug**	**4 Sep**	**22 Jul**	**5 Aug**	**4 Sep**
High temperature	4.04	4.11	4.06	5.47	5.68	5.51	3.63	3.73	3.80
Low temperature	4.09	4.14	4.12	5.86	5.70	5.63	3.50	3.72	4.02
LSD 5 %		0.02	0.03	0.07		0.11			
Significance	N.S.	*	**	**	N.S.	*	N.S.	N.S.	N.S.

The high temperature treatment tended to encourage higher concentrations of malate and lower concentrations of citrate compared to the low temperature treatment (Table 11). This does not support the hypothesis that high temperatures might result in increased conversion of malate to citrate as a result of increased rates of respiration.

Table 11. Effect of temperature on malate and citrate concentrations (mg/g fresh weight pericarp)

	Malate				Citrate			
Harvest date	**10 Jul**	**22 Jul**	**5 Aug**	**4 Sep**	**10 Jul**	**22 Jul**	**5 Aug**	**4 Sep**
High temperature	2.388	2.295	2.672	2.702	3.614	4.05	3.860	3.202
Low temperature	2.168	2.289	2.513	2.531	3.904	4.29	4.215	3.593
LSD 5 %			0.146					0.308
Significance	N.S.	N.S.	*	N.S.	N.S.	N.S.	N.S.	*

By using the sums of malate and citrate concentrations as a crude measure of acidity we find that for the pericarp, the high temperature treatment had reduced acidity (Table 12). This is contrary to the data on pH for the juice.

Table 12. Effect of temperature on summation of malate and citrate (mg/g fresh weight pericarp)

Harvest date	10 Jul	22 Jul	5 Aug	4 Sep
High temperature	6.00	6.35	6.53	5.90
Low temperature	6.07	6.58	6.73	6.12

Malate and citrate concentrations were unaffected by Ca or K levels in applied feed.

Fruit Ca and K status

The temperature treatments did not have a consistent effect on the Calcium or Potassium status of fruits (Table 13).

Table 13. Effect of temperature on fruit Calcium and Potassium status.

	% Ca				% K			
Harvest date	**10 Jul**	**22 Jul**	**5 Aug**	**4 Sep**	**10 Jul**	**22 Jul**	**5 Aug**	**4 Sep**
High temperature	0.096	0.108	0.109	0.118	3.882	3.570	3.663	3.153
Low temperature	0.097	0.103	0.120	0.107	4.128	3.843	3.646	3.042
LSD 5 %		0.003	0.007	0.011		0.268		
Significance	N.S.	*	**	*	N.S.	*	N.S.	N.S.

The supply of Ca and K had different effects on the Ca and K status of the fruit tissue (Table 14). High levels of applied Ca increased the Ca content of the fruit by around 25%. Thus higher applied Ca results in higher fruit Ca, some of which may be deposited as gold spot. Higher levels of applied Ca also appear to have had an effect of increasing K content slightly in the later harvests.

Hence a low K/high Ca feed could increase fruit Ca status beyond optimum and increase the incidence of gold spot.

High levels of applied K did not have a significant effect on levels of K in fruit, although the low K treatment did generally produce fruit with up to 5% less K. However, there was an indication that low levels of applied K could increase the Ca content of fruit and this was most pronounced in the last sample taken on 4 September where low applied K produced fruit with 14% higher levels of Ca. Hence by increasing fruit Ca status the low K content of the feed also has the effect of increasing levels of gold spot.

Table 14. Effect of Calcium and Potassium concentrations in applied feed on fruit Calcium and Potassium status.

	% Ca				% K			
Harvest date	**10 Jul**	**22 Jul**	**5 Aug**	**4 Sep**	**10 Jul**	**22 Jul**	**5 Aug**	**4 Sep**
Calcium								
250ppm	0.107	0.119	0.129	0.121	4.010	3.679	3.731	3.258
100ppm	0.085	0.093	0.100	0.104	4.001	3.734	3.579	2.937
LSD 5%	0.013	0.010	0.008	0.009				0.219
Significance	**	***	***	***	N.S.	N.S.	N.S.	**
Potassium								
400ppm	0.095	0.104	0.113	0.105	3.973	3.760	3.741	3.147
230ppm	0.098	0.108	0.116	0.120	4.037	3.652	3.568	3.049
LSD 5%				0.009				
Significance	N.S.	N.S.	N.S.	**	N.S.	N.S.	N.S.	N.S.

The applied K treatments only had a small effect on the K content of fruits which was not statistically signifcant. This may explain the limited effects of the K treatments on fruit quality.

Low levels of applied Ca also increased the concentration of magnesium in fruits. (Table 15). There was no effect of applied K level on magnesium content of fruits.

Table 15. Effect of Calcium concentration in the applied feed on Magnesium status of the fruit.

Harvest date	%Mg			
	10 Jul	22 Jul	5 Aug	4 Sep
Calcium				
250ppm	0.123	0.104	0.102	0.101
100ppm	0.124	0.114	0.113	0.109
LSD 5%			0.010	0.007
Significance	N.S.	N.S.	*	*

Root exudate Ca and K content

The high temperature treatment did not have any consistent effect on the Ca content of sap but there is an indication that at high temperature the K content might be reduced (Table 16). The higher level of applied Ca increased Ca content of the sap and also appeared to have increased the K content. The higher level of applied K resulted in a small increase in K content but did not affect Ca content.

Table 16. Effect of temperature, Ca and K treatments on Ca and K content of root exudate.

Date	10 July		4 September	
Temperature	%Ca	%K	%Ca	%K
High	259	625	347	552
Low	256	634	327	575
Ca				
250	298	660	368	582
100	224	606	308	545
K				
400	260	643	342	597
230	261	624	334	530

Conclusions

Delayed ventilation (25°C Day/21°C Night) raised air temperatures by an average of 3°C compared to a more standard ventilation regime (20°C Day/16°C Night). However, as well as increasing temperature, the reduced ventilation also resulted in smaller vapour pressure deficits and slightly higher CO_2 concentrations.

The high temperature treatment had an immediate impact on softness, blotchy ripening and dark patches such that the incidence of all of these defects was increased within 2 weeks of treatments commencing. This suggests that these defects were the result of high temperature affecting ripening processes in some way. The higher humidity accompanying the high temperature treatment may have played a role in causing the increased softness (HDC PC30/30a).

Gold spot was also increased as a result of the reduced ventilation regime, but in contrast to the defects mentioned above, there was a longer period of time (5 weeks) before treatment effects were apparent. This suggests that processes occurring during fruit development rather than during ripening were being affected. As with softness it is possible that higher humidities as well as higher temperatures may have contributed to this effect.

High temperature also reduced the incidence of gooseberry veining and reduced fruit juice pH.

Temperature treatments had no consistent effect on fruit Ca and K status.

However, applying high levels of Ca (250 ppm) resulted in increased levels of Ca in root exudate and in fruits compared to Ca at 100 ppm. High levels of applied Ca increased levels of gold spot and also reduced the incidence and severity of netting.

Applying low levels of K (230 ppm) had very little effect on fruit K status and did not influence levels of blotchy ripening or levels of fruit acidity. However applying K at 230 ppm rather than 400 ppm did appear to increase fruit Ca status and resulted in increased levels of gold spot and reduced levels of netting.

Further research into the causes of summer fruit quality defects is underway in a Horticulture LINK project.

References

Davies, J.N. and Winsor, G.W. (1967). Effects of nitrogen, phosphorous, potassium, magnesium and calcium on the composition of tomato fruit. *J. Sci. Food Agr.* **18**, 459-66.

Fussell, M. and Hand, D.J. (1995a) Tomatoes: The effects of summer humidification on fruit quality and yield. *HDC Project Report PC30/30a*, pp. 68.

Fussell, M. and Hand, D.J. (1995b) Tomatoes: The influence of reduced nitrate input on yield and fruit quality. *HDC Project Report PC55a*, pp.109.

Ho, L.C., Belda, R., Brown, M., Andrews, J. and Adams, P. (1993). Uptake and transport of calcium and the possible causes of blossom-end rot in tomato. *Journal of Experimental Botany,* **44**, 509-518.

Hobson, G.E., Davies, J.N. and Winsor, G.W. (1977). Ripening disorders of tomato fruit. *Grower's Bull.* **4**, GCRI.

Holsteijn, G.P.A. van, & Janse, J. (1990) Caps for good quality tomatoes even right by the wire. *Groenten en Fruit* 6 April 1990 p34-35.

Voogt, W. (1993). Nutrient uptake of year round tomato crops. *Acta Horticulturae* **339**, 99-112.

Winsor,G.W. and Adams, P. (1976). Changes in the composition and quality of tomato fruit throughout the season. *Annual Report GCRI 1975*, 134-42.

5. Appendices

Appendix 1 Feed recipes used to achieve target Ca and K levels.

Quantities per x litres

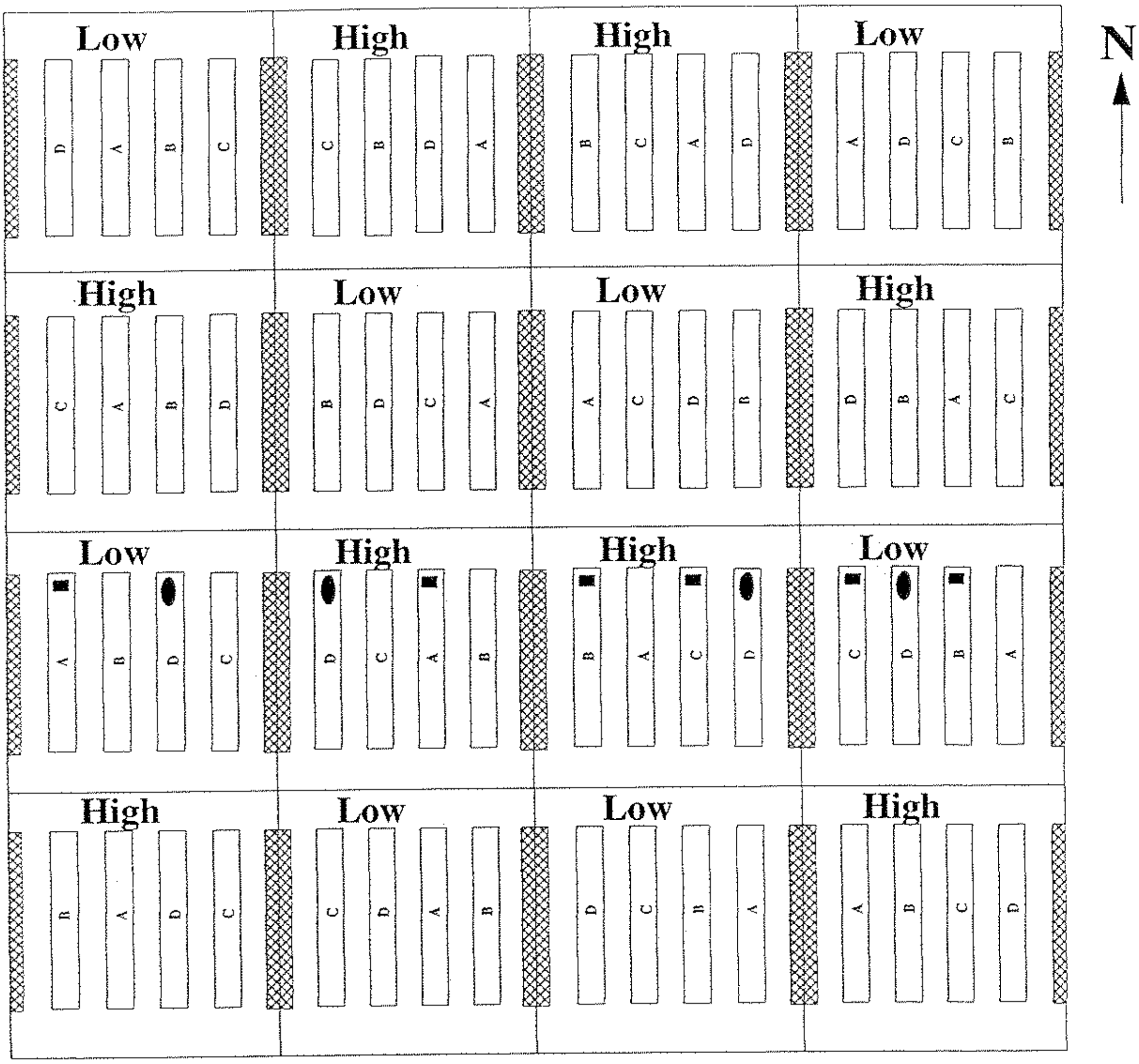
Tank A1 (low K/low Ca) Treatment A	100	750	1500
Potassium Nitrate	4.67kg	35kg	70kg
Sodium Nitrate	3.6kg	27kg	54kg
Sodium Chloride	4.13kg	31kg	62kg
Iron EDTA	267g	2kg	4kg
Tank A2 (high K, high Ca) Treatment B			
Calcium Nitrate pure crystals	9.6kg	72kg	144kg
Potassium Nitrate	2.8kg	21kg	42kg
Potassium Chloride	5.2kg	39kg	78kg
Iron EDTA	267g	2kg	4kg
Tank A3 (high K/low Ca) Treatment C			
Potassium Nitrate	9.07kg	68kg	136kg
Potassium Chloride	0.67kg	5kg	10kg
Sodium Chloride	3.53kg	26.5kg	53kg
Iron EDTA	267g	2kg	4kg

Tank A4 (low K/high Ca) Treatment D			
Calcium Nitrate pure crystals	5.33kg	40kg	80kg
Potassium Nitrate	4.67kg	35kg	70kg
Sodium Nitrate	1.47kg	11kg	22kg
Calcium Chloride	2.8kg	21kg	42kg
Sodium Chloride	1.87kg	14kg	28kg
Iron EDTA	267g	2kg	4kg

Quantities per x litres

Tank B (common to all A feeds)	100	750	1500
Potassium Phosphate	1.67kg	12.5kg	25kg
Magnesium Sulphate	5kg	37.5kg	75kg
Ammonium Nitrate	400g	3kg	6kg
Manganese Sulphate	16.7g	125g	250g
Copper Sulphate	3.3g	25g	50g
Zinc Sulphate Monohydrate	26.7g	200g	400g
Solubor	18.3g	137.5g	275g
Ammonium Molybdate	0.5g	4g	8g

Appendix 2. Experimental layout



▮ Tipping bucket

■ Drain collection pit

Treatments

Temperature (Vent set points)

High	25°C Day/21°C Night
Low	20°C Day/16°C Night

Nutritional sub-treatments

	Potassium (mg/l)	Calcium (mg/l)
A =	234	96
B =	468	250
C =	468	96
D =	234	250

Cultivar - Solairo

Sowing date - 29.11.95

Plant density - 3.04 heads/m^2

(2 in 3 plants with shoots)

Plot size - 14.81m^2

Appendix 3. Physical disorders scoring system

The scoring system for disorders is based on the EC common standards for quality of round tomatoes.

Score	Disorder level	Grade
1a	Absent or virtually absent	Class I
1b	Present at a low levels - not distracting from overall appearance	Class I
1c	Noticeable but still acceptable for	Class I
2	Present at acceptable level for	Class II
3	Unacceptable level	Waste

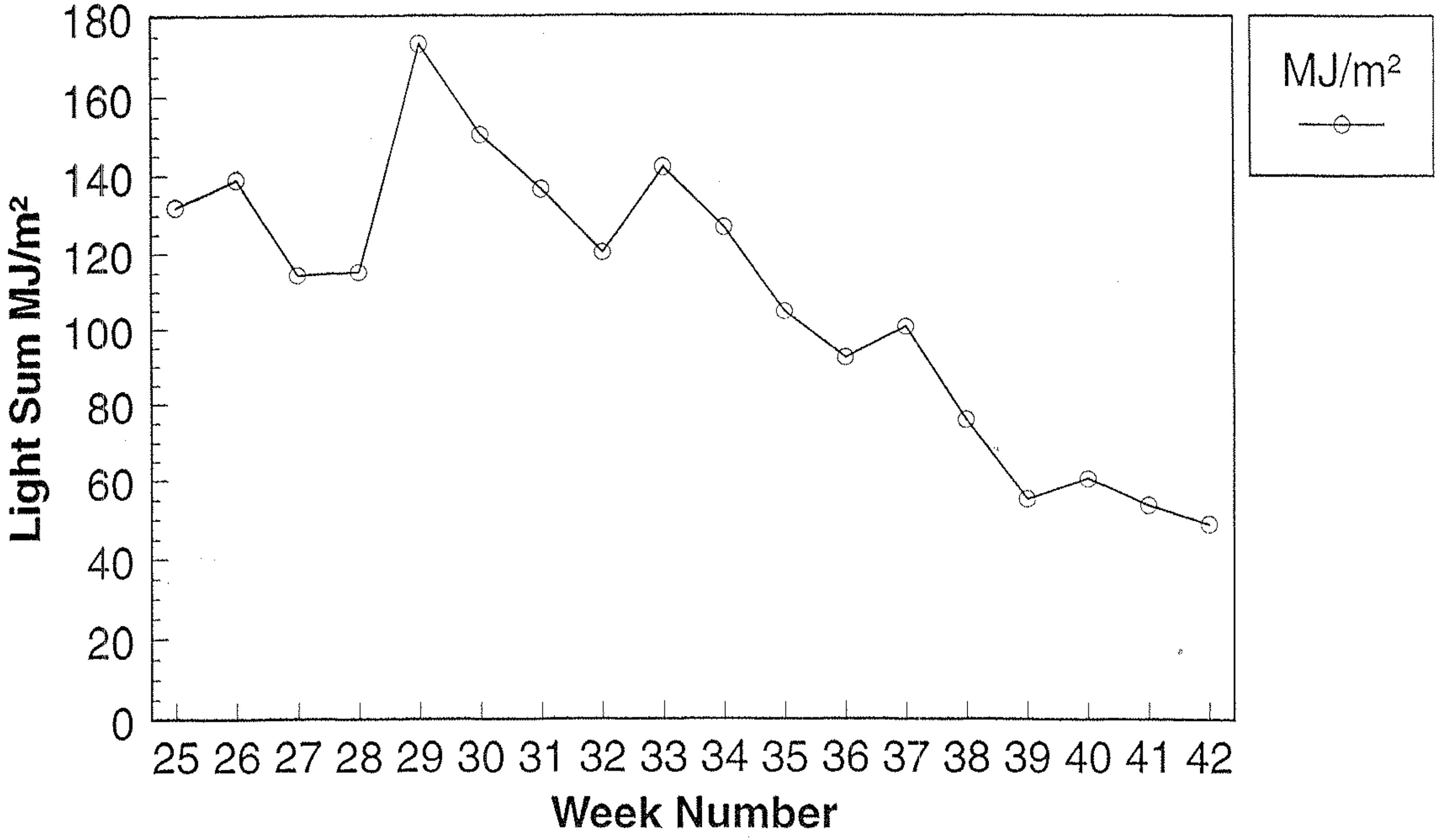
Acceptable levels of common disorders

Disorder	1b	1c	2	3
Blotchy Ripening	1-3 blotches < 5mm diam.	4-6 blotches any one 6 - 10mm	> 6 blotches or any one 11-30mm	Any one blotch > 30mm diam.
Dark Patches (like bruises)	1-3 blotches < 5mm diam.	4-6 blotches any one 6 - 10mm	> 6 blotches or any one 11-30mm	Any one blotch > 30mm diam.
Uneven Ripening	1 ATB Col Stage difference	> 1 ATB Col Stage difference	-	-
Gooseberry Veining	<30% surface area	>30% surface area		
Gold Spot	< 100 spots/cm² or < 10mm radius around calyx	> 100 spots/cm² and 11-20mm radius around calyx	> 100 spots/cm² and > 20mm radius around calyx	-
Gold Marbling (flecking)	1-20mm diam.	21-40mm diam.	>40mm diam.	-
Net Cracking (russetting)	wide net or < 1cm² close net	1 - 2 cm² close net	< 50% close net	> 50% close net
Concentric Cracking	Total length of all cracks < 5mm	Total length of all cracks 6 - 10 mm	Total length of all cracks 11 - 30mm	Total length of all cracks > 30mm
Blossom-End Rot	-	-	-	Any

Appendix 4 Weekly achieved average temperatures °C.

	High			Low		
Week	**Day**	**Night**	**24 hr**	**Day**	**Night**	**24 hr**
25	24.80	20.60	23.50	22.10	17.55	20.65
26	24.55	21.05	23.40	21.15	17.90	20.10
27	25.05	20.55	23.60	21.60	17.25	20.20
28	25.70	21.35	24.25	22.35	18.40	21.00
29	26.05	20.70	24.25	23.95	17.65	21.80
30	26.10	21.40	24.45	23.50	18.70	21.85
31	25.85	21.10	24.15	22.80	18.05	21.10
32	24.00	18.25	21.80	21.60	17.05	19.90
33	25.60	20.50	23.55	23.55	18.25	21.45
34	25.80	21.35	23.95	22.80	18.55	21.05
35	25.10	20.55	23.15	21.65	17.15	19.75
36	25.35	20.85	23.35	22.45	17.80	20.35
37	24.95	20.00	22.65	21.75	17.15	19.55
38	24.50	19.75	22.20	21.35	17.05	19.30
39	24.45	20.65	22.50	21.85	18.10	19.95
40	24.25	19.60	21.75	21.75	17.35	19.35
41	24.75	20.50	22.40	22.05	17.95	19.75
42	23.90	19.45	21.40	21.75	17.55	19.40
Mean	25.04	20.46	23.13	22.22	17.75	20.36

Appendix 5. weekly light sums (MJ/m²) summer 1996



Appendix 6. Effects of ventilation treatment and light intensity on air and fruit temperature in sun and shade 18 July 1996.

High temperature treatment

Time: 15.03 - 15.21 **Outside Light Intensity:** 73.1 - 75.3 mW/cm²
Glasshouse air temperature: 27.3 - 28 °C

Fruit temperature °C	Range	Mean	No of readings
Sun	35.2 - 39.2	37.6	3
Shade	33.1 - 34.6	33.7	5

Low temperature treatment

Time: 15.21 - 15.38 **Outside Light Intensity:** 69.8 - 73.1 mW/cm²
Glasshouse air temperature: 25.3 - 25.8 °C

Fruit temperature °C	Range	Mean	No of readings
Sun	28.3 - 33.5	31.6	5
Shade	27.2 - 29.2	28.5	5

Appendix 7. Effects of ventilation treatment and light intensity on air and fruit temperature in sun and shade 19 July 1996.

High temperature treatment

Time: 09.36 - 11.36 **Outside Light Intensity:** 51.9 - 62.1 mW/cm²
Glasshouse air temperature: 26.9 - 28.3 °C

Fruit temperature °C	Range	Mean	No of readings
Sun	30.2 - 32.7	31.4	8
Shade	27.6 - 31.1	29.4	12

Low temperature treatment

Time: 09.48 - 11.32 **Outside Light Intensity:** 52.1 - 60.2 mW/cm²
Glasshouse air temperature: 23.7 - 25.8 °C

Fruit temperature °C	Range	Mean	No of readings
Sun	26.5 - 28.3	27.3	7
Shade	24.6 - 27.2	25.8	12

Appendix 8. Effects of temperature and nutrition on concentrations of Ca and K in run-off.

Run-off Ca ppm

Week	Temperature High	Temperature Low	Applied Ca 100 (Averaged over 2 potassium treatments)	Applied Ca 250 (Averaged over 2 potassium treatments)	Applied K 230 (Averaged over 2 calcium treatments)	Applied K 400 (Averaged over 2 calcium treatments)
28	187	256	141	302	175	268
29	273	225	126	373	304	194
30	200	242	149	293	218	214
31	180	211	131	260	180	211
32	194	225	141	278	198	221
33	152	202	116	238	157	197
34	203	244	145	301	211	236
35	178	214	130	261	177	215
36	204	229	142	292	201	233
37	211	260	134	337	220	251
38	229	174	141	261	218	185
39	237	212	153	297	215	234
40	235	202	144	293	198	239
41	232	239	160	311	213	258
42	235	232	151	315	229	238
Mean	210	224	140	294	207	227

Run-off K ppm

Week	Temperature High	Temperature Low	Applied Ca 100	Applied Ca 250	Applied K 230	Applied K 400
			Averaged over 2 potassium treatments		Averaged over 2 calcium treatments	
28	304	323	332	295	244	382
29	290	282	311	261	207	366
30	372	345	346	371	223	457
31	334	307	314	328	236	405
32	325	320	323	321	232	413
33	316	309	309	315	232	392
34	385	338	367	355	259	464
35	308	299	308	299	206	401
36	406	372	399	379	303	475
37	334	301	342	304	237	409
38	374	343	360	357	232	485
39	370	354	383	340	241	483
40	344	321	347	318	234	430
41	386	365	405	346	265	486
42	424	383	466	341	261	547
Mean	352	331	354	329	241	439

Appendix 9. Effect of temperature treatments on blotchy ripening (weeks 27 - 42)

Fruits were graded on the basis of blotchy ripening alone

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
High Temp	22.3	24.5	41.4	39.1	28.8	30.4	3.9	10.0	0	-
Low temp	57.7	50.5	30.9	31.7	9.3	12.7	1.1	3.40	0	-
Significance	-	***	-	**	-	**	-	*	-	-
SED (2 d.f.)	-	0.55	-	0.45	-	0.99	-	1.27	-	-
LSD (5 %)	-	2.37	-	1.72	-	4.26	-	5.46	-	-

Appendix 10. Effect of temperature treatments on Dark Patches (weeks 27 - 42)

Fruits were graded on the basis of dark patches alone

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
High Temp	23.4	24.5	38.2	35.9	26.6	27.9	3.0	14.1	0	-
Low temp	80.0	68.4	17.7	19.8	2.3	3.5	2.0	0.0	0	-
Significance	-	**	-	*	-	*	-	***	-	-
SED (2 d.f.)	-	2.98	-	3.05	-	3.01	-	0.05	-	-
LSD (5 %)	-	12.8	-	13.1	-	13.0	-	0.23	-	-

Appendix 11. Effect of temperature treatments on the incidence of red noses in week 35

Fruits were graded on the basis of red noses alone

Treatment	% of Class Ia fruit (red noses absent)	Angular transform
High Temperature	70.0	60.4
Low temperature	95.6	85.1
Significance	-	***
SED (7 d.f.)	-	4.46
LSD (5 %)	-	10.3

Appendix 12. **Effect of temperature treatments on Gold Spot (weeks 27 - 42)**

Fruits were graded on the basis of Gold Spot alone

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
High Temp	23.6	22.9	42.7	39.1	26.6	27.8	7.2	8.9	0.0	0.0
Low temp	41.0	38.5	39.5	37.3	17.2	19.0	2.2	2.9	0.1	0.2
Significance	-	*	-	N.S.	-	N.S.	-	N.S.	-	N.S.
SED (2 d.f.)	-	1.54	-	3.25	-	2.57	-	1.52	-	0.20
LSD (5 %) -	6.6	-	-	-	-	-	-	-	-	

Appendix 13. **Effect of applied Calcium and Potassium level on Gold Spot (weeks 27 - 42)**

Fruits were graded on the basis of Gold Spot alone

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
250ppm Ca	16.6	18.3	45.2	41.5	31.5	32.1	6.7	8.3	0.0	0.0
96ppm Ca	48.0	43.1	37.0	34.8	12.3	14.7	2.6	3.4	0.1	0.2
Significance	-	***	-	N.S.	-	***	-	*	-	N.S.
SED (6 d.f.)	-	1.75	-	2.35	-	1.21	-	1.88	-	0.21
LSD (5 %)	-	4.3	-	-	-	3.0	-	4.6	-	-

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
468ppm K	37.8	35.3	41.3	38.1	17.5	19.3	3.4	4.8	0.0	0.0
230ppm K	26.8	26.1	40.9	38.3	26.3	27.5	2.2	7.0	0.1	0.2
Significance	-	**	-	N.S.	-	***	-	N.S.	-	N.S.
SED (6 d.f.)	-	1.75	-	1.75	-	1.21	-	1.88	-	0.21
LSD (5 %)	-	4.3	-	-	-	3.0	-	-	-	-

Appendix 14. **Effect of temperature treatments on Netting (weeks 27 - 42)**

Fruits were graded on the basis of netting alone

Treatment	Class Ia		Class Ib		Class Ic		ClassII		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
High Temp	84.1	74.5	7.8	9.7	2.5	3.2	3.9	4.6	1.7	2.5
Low temp	77.8	67.6	19.3	19.7	1.7	2.3	1.1	2.0	0.2	0.3
Significance	-	N.S.	-	N.S.	-	N.S.	-	N.S.	-	*
SED (2 d.f.)	-	3.36	-	2.50	-	0.59	-	0.99	-	0.41
LSD (5 %)	-	-	-	-	-	-	-	-	-	1.8

Appendix 15. **Effect of applied Calcium and Potassium level on Netting (weeks 27 - 42)**
Fruits were graded on the basis of netting alone

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
250ppm Ca	86.3	75.5	9.4	11.1	1.9	2.4	2.0	2.5	0.5	0.9
96ppm Ca	75.6	66.6	17.7	18.3	2.3	3.2	3.0	4.1	1.4	1.9
Significance	-	**	-	***	-	N.S.	-	N.S.	-	*
SED (6 d.f.)	-	2.01	-	1.02	-	1.21	-	0.80	-	0.41
LSD (5 %)	-	4.9	-	2.5	-	-	-	-	-	1.0

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
468ppm K	76.1	66.8	17.6	18.2	2.5	3.4	3.0	3.9	0.8	1.4
230ppm K	85.7	75.3	9.5	11.2	1.7	2.2	2.0	2.7	1.1	1.3
Significance	-	**	-	***	-	N.S.	-	N.S.	-	N.S.
SED (6 d.f.)	-	2.01	-	1.02	-	1.21	-	0.80	-	0.41
LSD (5 %)	-	4.92	-	2.50	-	-	-	-	-	-

Appendix 16. **Effect of temperature treatments on Gooseberry Veining (weeks 27 - 42)**

Fruits were graded on the basis of Gooseberry Veining alone

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
High Temp	67.2	59.0	27.0	26.6	5.8	7.0	0	0	0	-
Low temp	27.4	27.1	54.5	47.8	17.9	20.4	0	0	0	-
Significance	-	*	-	*	-	N.S.	-	-	-	-
SED (2 d.f.)	-	3.27	-	2.26	-	4.76	-	-	-	-
LSD (5 %)	-	14.1	-	9.72	-	-	-	-	-	-

Appendix 17. Effect of temperature treatments on Gold Marbling (weeks 27 - 42)

Fruits were graded on the basis of Gold Marbling alone

Treatment	Class Ia		Class Ib		Class Ic		Class II		Waste	
	% of fruit Class Ia	Angular transform	% of fruit Class Ib	Angular transform	% of fruit Class Ic	Angular transform	% of fruit Class II	Angular transform	% of fruit Waste	Angular transform
High Temp	39.8	36.8	37.5	34.2	19.1	20.6	2.0	5.1	0	-
Low temp	31.9	30.4	47.4	41.7	16.3	18.2	3.0	5.6	0	-
Significance	-	*	-	*	-	N.S.	-	N.S.	-	-
SED (2 d.f.)	-	1.05	-	1.43	-	1.20	-	2.49	-	-
LSD (5 %)	-	4.52	-	6.15	-	-	-	-	-	-

Appendix 18. Effect of temperature treatments on shininess (weeks 27 - 42)

Treatment	Shiny		Moderately Shiny		Dull		Very dull	
	% of fruit	Angular transform	% of fruit	Angular transform	% of fruit	Angular transform	% of fruit	Angular transform
High Temp	5.4	5.6	62.6	54.7	29.3	29.3	2.6	3.6
Low temp	6.4	6.7	63.6	57.4	24.7	23.6	5.3	6.9
Significance	-	N.S.	-	N.S.	-	*	-	N.S.
SED (2 d.f.)	-	1.4	-	0.86	-	0.86	-	1.82
LSD (5 %)	-	-	-	-	-		-	-