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CONTRACT REPORT

Tomatoes: The effects of summer humidification on fruit quality and yield

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Tomatoes: The effects of summer humidification on fruit quality and yield

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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

Application

To determine if summer humidification is worthwhile for improving tomato fruit quality, yields and CO_2 use. Humidification was found to have minimal impact on yield and CO_2 use but to have a deleterious effect on fruit quality. Humidification is not considered worthwhile as a means of improving summer fruit quality.

Summary

Tomato fruit quality problems such as Blotchy Ripening and fruit softness are common in summer and are believed to be related to bright conditions producing high air and fruit temperatures and high vapour pressure deficits. Excessively high temperatures may also reduce growth and affect yield.

Humidification, achieved by the atomisation of softened water (fogging) was evaluated in this trial as a means of reducing high vapour pressure deficits and temperatures in order to improve fruit quality and perhaps also yield. If humidification is effective in reducing air temperatures it may also have the effect of reducing the amount of ventilation resulting in better use of limited supplies of CO_2.

The humidification treatment aimed to control vpds over 0.5 kPa. Thus when the ambient vpd reached or exceeded 0.5 kPa fogging commenced. The humidification treatment was compared with a control where no fogging took place and vpds were allowed to exceed 0.5 kPa. In both the treatment and control, small vpds (below 0.3 kPa) were avoided by using a combination of increased pipe temperature and ventilation.

The humidification treatment was evaluated over two summers, 1991 and 1992. Light levels in the summer of 1991 were low relative to the long-term average until August. The low light levels resulted in only small differences in achieved vapour pressure deficit between the treatment and control as ambient vpds rarely exceeded 0.5 kPa, the point at which the humidification treatment started. It was not suprising that in 1991 there were no apparent benefits from humidification. However it was a suprise to find that humidification had the effect of reducing the percentage of Class I fruit. Humidification resulted in the production of softer fruit and seemed to increase the incidence of poor shape, Gold Spot and Red Noses.

Light levels in 1992 were high in late May and in June allowing a fair evaluation of the humidification treatment to be made. There was some indication of improved yields in July and August but over the summer as a whole (May to September) there was no significant difference in yield between the treatment and the control. Percentage Class I fruit was higher for the treatment than the control in July but again as with yield there was no significant benefit over the summer as a whole.

There was some evidence that humidification reduced levels of Blotchy Ripening but as in 1991 humidification resulted in softer fruit. Fruit temperatures were reduced as a result of humidification.

Humidification had a substantial effect on vapour pressure deficit and a small effect on air temperature but any benefit in terms of CO_2 conservation resulting from reduced venting was too small to detect.

The conclusion drawn from this work is that the capital cost of installing a humidification system is not justified in terms of improved fruit quality, yields or CO_2 conservation.

EXPERIMENTAL SECTION

INTRODUCTION

The effects of humidity during the winter on tomato crops have been investigated in MAFF funded trials in 1987, 1988, 1991 and 1992. High humidity during the winter has been shown to reduce leaf expansion, yield and fruit quality. There is an optimum vapour pressure deficit of around 0.3 to 0.4 kPa below which humidity control by manipulating pipe temperatures and ventilation is economically worthwhile.

In summer, small vapour pressure deficits are rare due to higher levels of solar radiation, higher temperatures and resultant increased venting. However on bright days it is possible that vapour pressure deficits and temperatures inside the glasshouse get too high and may cause disorders, such as Blotchy Ripening and softness problems, and may inhibit normal crop growth and hence affect yield.

In addition to potential fruit quality benefits and possible yield benefits, humidification in order to avoid high vapour pressure deficits may have the effect of reducing air temperatures so that venting is reduced and valuable Carbon-dioxide conserved.

The effects of humidity during winter have been shown to differ depending upon the variety grown. The effects of humidification in summer are also likely to differ depending upon variety. Vigorous varieties are likely to be less susceptable to disorders such as Blotchy Ripening than less vigorous ones.

High conductivity generally has the effect of improving fruit quality at the expense of yield. However high conductivity sometimes results in increased levels of Blossom-End Rot. There may be interesting interactions between summer humidity and conductivity.

MATERIALS AND METHODS

Two trials were done, in the 1990/1991 and 1991/1992 growing seasons.

Both trials followed MAFF funded trials investigating the effects of winter humidity. The summer treatments were commenced following a minimum 'neutral' period of six weeks. Thus enabling the crop to recover from earlier treatment efforts.

Site details

Each trial was done at HRI Efford utilising the 16 compartment M-Block multifactorial Venlo-type glasshouse facility. The layout of each trial is illustrated in Appendix I, page 34 and II (page 36).

Treatments

Humidified	0.5 kPa or less by night and day
Control	Ambient

Humidification was achieved using atomisation of softened water (fogging) when vapour pressure deficits exceeded 0.5 kPa. Humidity control using pipe heat and ventilation was used to avoid vapour pressure deficits of less than 0.3 kPa in both Humidified and Control compartments.

Sub Treatments

1990/1991

Varieties
Counter and Spectra

Conductivity (applied feed) 2 mS and 4 mS

1991/92

Varieties
Counter, Spectra and Pronto

Conductivity (applied Leed) 2.5 mS and 4.5 mS (Counter only)

Cultural Techniques 1990/1991

Seeds of tomato (*Lycopersicon esculentum* Mill) cvs Counter and Spectra were sown on 22 October 1990 in rockwool multiblocks wetted up with a feed solution with a pH of 5.0 and an EC of 1.5 mS. Following germination EC was raised to 2.5 mS coincident with the expansion

of the cotyledons. From blocking on to the time when the third true leaf reached 10 mm in length, the EC of the applied feed was raised from 2.5 to 3.5 mS. The EC was then raised to 5.0 mS in preparation for slab contact.

Propagation temperatures

Stage		Day	Night	Vent
0	Sowing to Germination (4 days)	24	24	26
1	Germination to blocking on	20	20	24
2	Blocking on to first bud	20	16	24

Glasshouse CO_2 was enriched to 1000 vpm from stage 0 until late March using pure CO_2. Subsequently CO_2 levels were maintained at ambient levels.

The plant population was 10,600/acre throughout.

Winter humidity treatments were imposed from 9 December to 1 March.

Summer humidity treatments were imposed from 24 April.

Cultural techniques 1991/1992

These were as for 1990/1991 except that cvs Counter, Spectra and Pronto were sown on 24 October and slab contact was made on 23 December 1991.

The plant population was 10,600/acre initially but 1 in 4 sideshoots were taken in Week 17 to raise it to 13,250/acre.

Winter humidity regimes were imposed from 3 February to 15 March.

Summer humidity regimes were imposed from 11 May.

Details of both cropping seasons are listed in Appendix III, page 36.

Assessments

- Full monitoring of glasshouse aerial environment.
- CO_2 use
- Fogging frequency
- Daily monitoring of applied and slab solution EC and pH
- Weekly nutrient analysis of applied and slab solutions
- Graded and total marketable yield, percentage Class I fruit.
- Fruit temperatures
- Assessments of tomato fruit quality and shelf-life

Disorder Assessments

Ten fruit were sampled at random from each plot and each fruit assessed for the following disorders.

Boxiness (hollow fruit)
Slab-sidedness
Ribbing
Nippling
Netting (fine net cracking)
Concentric cracking
Gold spot (calyx end)
Gold Marbling (flecking - blossom end)
Blotchy ripening
Red Noses

Disorders were scored from 0 (none) - 4 (severe) for each of the 10 fruit and a mean score calculated for each plot.

Shelf-Life Assessments and Chemical Analysis

Fruit were sampled at ATB Colour stage 4. Where possible 10 Class 1, Grade D fruit were chosen. However when fruit picks were small or when fruit did not fulfill the above criteria, fewer fruit were selected or Size C or E fruit included.

Tomatoes were passed through a handling simulator (500-600mm drop) and placed in plastic trays in the shelf-life room where they remained for 6 days. The shelf-life room was maintained at around 20°C and 50-60% Relative Humidity, with 12 hours of fluorescent lighting per day.

The sample of fruit for each plot was weighed at the beginning and end of the shelf-life period and the percentage weight loss calculated for the plot.

At the end of the shelf-life period, the calyx was removed from each individual fruit before measurement of its compression (mm) under a 1kg load in a firmness meter. A mean compression was calculated for each plot.

Fruit were taken at the end of the shelf-life assessments and divided for dry weight determination and acidity and soluble solids determinations.

% Dry Weight: For each plot, quarters from each of 5 fruit were placed in a tray, weighed and then dried in an oven at 60°C for 3 days. The samples of fruit were weighed again and the percentage dry matter calculated taking into account the percentage weight loss during shelf-life.

% Soluble Solids: The remaining tomatoes, not used in the dry matter determinations, were placed in plastic bags (one for each plot) and frozen. After thawing, fruit was pulped by hand and filtered for 2 hours to separate the juice. Two measurements of percentage soluble solids of the juice were made for each plot using a sugar refractometer (range 0-10% Brix) and an average taken. Readings were adjusted according to the temperature of the solution.

Acidity: This was determined by dissolving 0.38g tri-sodium orthophosphate ($Na_3PO_4.12H_2O$) in 20ml filtered juice and after 10 minutes measuring the endpoint pH with a hand held pH meter.

EXPLANATION OF STATISTICAL TERMS

In both studies the data was subjected to a full analysis of variance allowing statistical significance to be assigned to any treatment differences. Throughout the main body of this report the significance of differences between treatments are referred to in terms of the probability of the result occuring by chance.

i.e.

$P < 0.05$	The probability of this result occuring by chance is equal to or less than 1 in 20 (0.05 = 5%)
$P < 0.01$	The probability of this result occuring by chance is equal to or less than 1 in 100 (0.01 = 1%)
$P < 0.001$	The probability of this result occuring by chance is equal to or less than 1 in 1000 (0.001 = 0.1%)

In some instances the standard error of the difference between means (SED) is given.

RESULTS

Yield and Gradeout

In June 1991 the humidified compartments yielded significantly higher than the control but overall from May to September the control yielded slightly higher (not significant) (Table 1, page 10). The 4.0 mS sub-treatment resulted in lower yield than the 2.0 mS sub-treatment and Spectra outyielded Counter but there were no interactions with the humidity treatments (see Appendix IV, page 37).

In 1992 the humidified compartments produced higher yields in June (not significant), July ($P<0.01$) and August ($P<0.05$)(Table 2, page 11). However the maximum difference in yield was 3% and in May and September the trend was reversed so that overall from May to September there was no significant difference in yield. As in 1991 Spectra yielded higher than Counter and Pronto was intermediate between the two. High conductivity again reduced yield in Counter (see Appendix IV, page 37).

Table 1 Effect of Summer Humidification on Total Yield ($kg.m^{-2}$) in 1991

	May	June	July	August	September	Total
Humidified	6.81	7.47	7.09	6.85	7.84	36.12
Control	7.06	7.18	7.33	6.99	8.08	36.68
SED (24 d.f)	*0.112*	*0.099*	*0.256*	*0.181*	*0.140*	*0.444*
LSD (5%)	-	*0.204*	-	-	-	-
Significance	*N.S.*	*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Table 2 **Effect of Summer Humidification on Total Yield ($kg.m^{-2}$) in 1992**

	May	June	July	August	September	Total
Humidified	6.25	9.39	8.51	5.87	10.38	40.40
Control	6.31	9.10	8.39	5.70	10.60	40.09
SED (24 d.f)	*0.192*	*0.228*	*0.013*	*0.054*	*0.150*	*0.337*
LSD (5%)	-	-	*0.27*	*0.111*	-	-
Significance	*N.S.*	*N.S.*	**	*	*N.S.*	*N.S.*

Humidification did have an effect on fruit quality. However it was a negative effect rather than a positive one. In 1991 the humidified compartments consistently produced less Class I fruit than the control (Table 3, page 11) and from May to September this difference was significant ($P<0.05$).

There were differences in the response of the two varieties to humidification in terms of Percentage Class I fruit. The effect of humidification in reducing percentage Class I fruit was much greater for Counter than for Spectra ($P<0.05$ for May to September) (see Appendix V, page 38).

In 1992 the effect of humidification on percentage Class I fruit was less consistent. In July the humidified compartments resulted in a higher percentage of Class I fruit but in September this effect was reversed so that overall from May to September there was no significant effect (Table 4, page 12).

Table 3 **Effect of Summer Humidification on Percentage Class I Fruit in 1991**

	May	June	July	August	September	Total
Humidified	88.5	90.7	68.0	68.7	40.1	79.1
Control	88.3	91.7	74.7	75.5	44.4	82.5
SED (24 d.f)	*0.85*	*0.58*	*0.72*	*1.24*	*0.36*	*0.87*
LSD (5%)	-	-	*1.49*	*2.56*	*0.74*	-
Significance	*N.S.*	*N.S.*	*	*	**	*

Table 4 Effect of Summer Humidification on Percentage Class 1 Fruit in 1992

	May	June	July	August	September	Total
Humidified	84.8	92.5	88.2	88.3	77.1	85.9
Control	84.5	92.6	87.4	88.6	80.2	86.5
SED (24 d.f)	*0.37*	*0.15*	*0.23*	*0.34*	*0.59*	*0.24*
LSD (5%)	-	-	*0.47*	-	*1.21*	-
Significance	*N.S.*	*N.S.*	*	*N.S.*	*	*N.S.*

In 1991 the humidification treatments had no effect on fruit size (Table 5, page 12). However in 1992 the humidified compartments produced larger fruit than the control (Table 6, page 13).

Table 5 Effect of Summer Humidification on fruit size from May to September 1991

	% of Class I fruit in size grade		
	C (>57mm diam.)	D (47-57 mm diam.)	E (40 - 47 mm diam.)
Humidified	34.1	60.1	5.5
Control	32.9	61.9	4.9
SED (24 d.f.)	*1.41*	*1.10*	*0.28*
LSD (5%)	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*

Table 6 Effect of Summer Humidification on fruit size from May to September 1992

	% of Class I fruit in size grade		
	C (>57mm diam.)	D (47-57 mm diam.)	E (40 - 47 mm diam.)
Humidified	15.0	73.2	11.5
Control	11.5	74.8	13.3
SED (28 d.f.)	*0.37*	*0.76*	*0.48*
LSD (5%)	*0.76*	-	*0.98*
Significance	**	*N.S.*	*

Fruit Quality

Disorder Assessments

Scores for each disorder, averaged across replicates are listed in Appendix IV, page 37 for 1991, Appendix V, page 38 for the Northern Array (compartments 1-8) in 1992 and Appendix VI, page 39) for the Southern Array (compartments 9-16) in 1992.

Boxiness

Levels of this disorder were low throughout the trials in both years. However, in 1992 some differences were apparent between varieties and treatments. The variety, Counter, generally showed higher levels of boxiness than other varieties and significantly higher levels in weeks 26 (North), 28 (South) and 34 (North).

Levels of boxiness were frequently higher in the humidified compartments than in the control ones.

Ribbing

This disorder was recorded only at very low levels in both years. There were some significant differences but they were not consistent through the season. Spectra sometimes showed significantly higher levels of ribbing as did the high humidity regime.

Slab-sidedness

In 1991 moderate and in 1992 moderate to low levels of slab-sidedness were recorded. In both years Counter consistently showed higher levels than the other varieties, significantly higher in all assessments in 1991 and in weeks 34 (North) and 36 (South) in 1992.

The high conductivity treatments in 1991 reduced the levels of slab-sidedness in every assessment, significantly so in weeks 31 and 37. In 1992, this effect was less pronounced (only Counter received high conductivity) but was significant in week 32.

Higher levels of slab-sidedness resulted from the control regime in 1991 in each assessment, although never significantly lower. However in week 37 the 2 varieties behaved significantly differently from one another. Counter showed higher levels of slab-sidedness in the control whereas Spectra showed higher levels in the humidified treatment. In 1992 each assessment from week 26 onwards revealed higher levels of slab-sidedness in the humidified compartments and significantly higher in weeks 32 (South) and 36 (South).

Nippling

This disorder was recorded at very low levels and no differences between varieties or treatments were apparent.

Radial Cracking

In 1991, moderate and in 1992, low levels of radial cracking were recorded. In every assessment in 1991 Spectra had higher levels than Counter and significantly so in weeks 31, 35 and 37. In 1992, Spectra showed significantly higher levels than other varieties in week 28 (South).

In week 37, in 1991, the high conductivity treatment showed significantly higher levels of radial cracking than the low conductivity treatment. Also in week 37 Spectra behaved significantly differently to Counter in the 2 humidity regimes. Counter showed increased levels of radial cracking in humidified compartments whereas Spectra showed the reverse.

Netting

Moderate levels of netting were found in both years. In every assessment in 1991 Spectra showed significantly higher levels than Counter. In 1992, Pronto showed significantly higher levels than other varieties in weeks 24 (North), 26 (North) and 28 (South). Counter usually showed the lowest levels.

The low conductivity treatment produced significantly higher levels of netting in weeks 29, 31 and 35 in 1991 and in week 26 (North) in 1992. However this effect was not consistent across all weeks and in week 37 in 1991 the high conductivity treatment showed significantly higher levels.

The humidity regimes showed little effect on levels of netting other than in week 37 in 1991 when Counter showed increased levels and Spectra showed reduced levels in humidified compartments.

Red Noses

Red Noses were very common in 1991 but rare in 1992 until end of the season when moderate to low levels were recorded. Counter showed significantly higher levels than Spectra in every assessment in 1991 and Pronto showed significantly lower levels than other varieties in week 36 (South) in 1992.

The low conductivity treatment produced significantly higher levels of red noses than the high conductivity treatment in every assessment in 1991 and in weeks 30 (North) and 36 (South) in 1992.

Higher levels of red noses were found in the humidified compartments in every assessment in 1991 (Figure 1, page 18), and significantly higher levels in week 37. Towards the end of the season in 1992 higher levels of red noses were recorded for the humidification treatment and in week 36 (South) Counter and Pronto both showed higher levels in the humidified compartments whereas Spectra showed the reverse.

Blotchy Ripening

Moderate levels of blotchy ripening were recorded in both years. There was some evidence of higher levels in Counter than other varieties.

In 1992 higher levels were frequently recorded in the low conductivity treatment, significantly higher in week 34 (North).

Higher levels of blotchy ripening were often associated with the control regime. Significantly higher levels were recorded in the control in week 31 in 1991. In week 37 in 1991 Spectra and Counter behaved significantly differently to one another, Counter showed higher levels in humidified compartments but Spectra the reverse.

Gold Spot

This disorder was common in both years. Counter showed consistently higher levels than other varieties, significantly higher in weeks 24 (North), 26 (North), 28 (South), 30 (North) and 34 (North)in 1992.

The low conductivity treatment produced significantly higher levels of gold spot than the high conductivity treatment in weeks 31, 35 and 37 in 1991 and in weeks 24 (North), 32 (South) and 34 (North) in 1991.

In 1991 levels of gold spot were generally higher in humidified compartments, significantly higher in week 29. In 1992, week 24 (South), Spectra and Counter, but not Pronto, showed higher levels in the humidified treatment. However there was no clear trend through the season.

Gold Marbling

Higher levels of this common disorder were recorded in Counter than other varieties, significantly higher in weeks 31 and 35 in 1991 and in weeks 26 (North) and 30 (North) in 1992.

In every assessment in 1991 higher levels of gold marbling were found in the high conductivity treatment, significantly higher in week 37. In 1992, significantly higher levels were found in the high conductivity treatment in week 30 (North).

The humidification treatment had little effect on levels of gold marbling other than in week 30 (North) in 1992 when higher levels were recorded for humidified plots for all varieties except Counter at low conductivity.

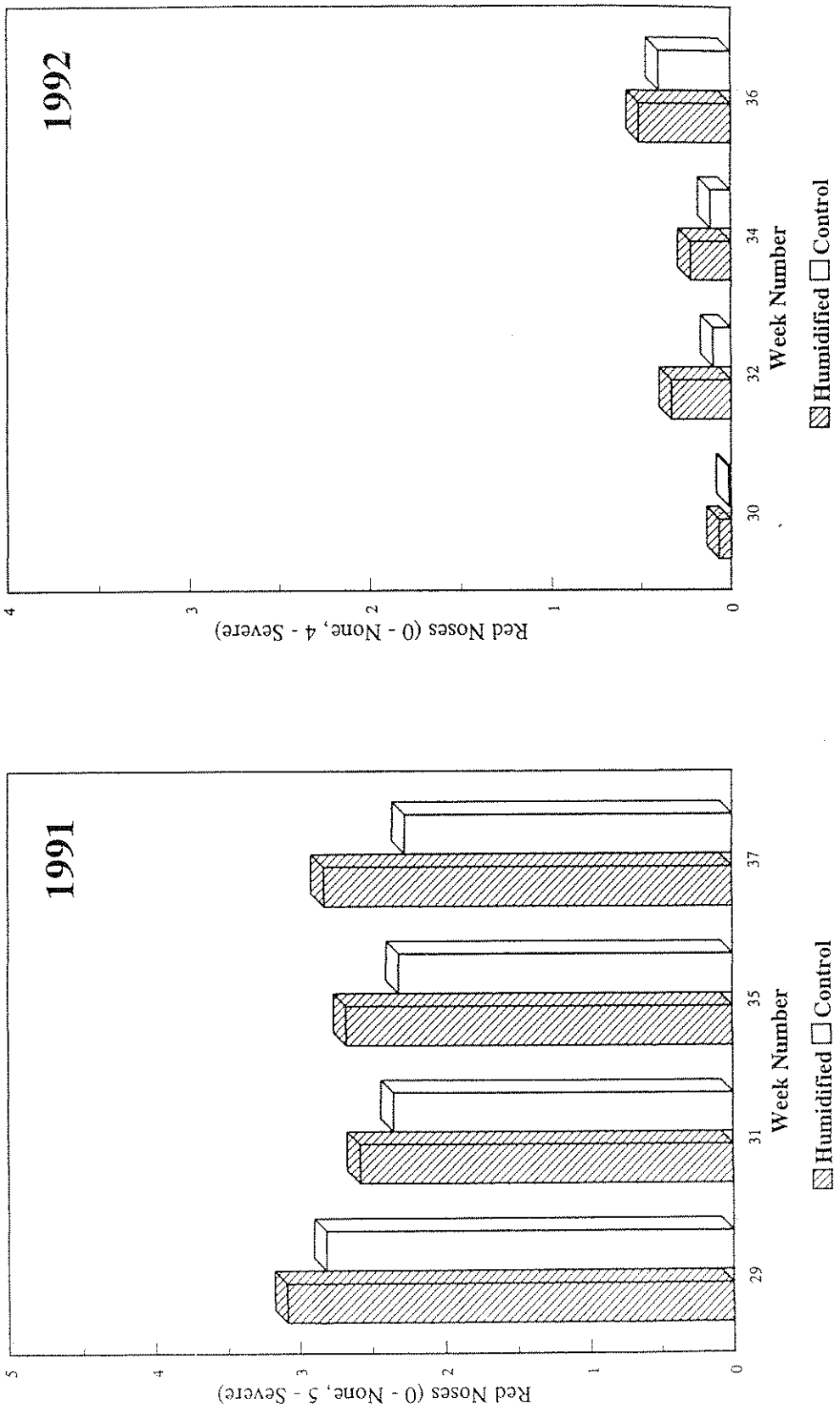


Figure 1. Effect of humidification on levels of Red Noses

Shelf-Life and Internal Composition

The full results of assessments of compression, percentage weight loss during shelf-life, acidity, soluble solids and dry matter content for all regimes, treatments and varieties are listed in Appendix IX, page 51 for 1991, Appendix X, page 60 for the Northern Array in 1992 and Appendix XI, page 64 for the Southern Array in 1992.

Compression

There were marked differences in firmness between varieties, conductivity treatments and humidity regimes that were consistent in both 1991 and 1992.

In every assessment, in both years, Counter had significantly softer fruit than other varieties.

The high conductivity treatment produced significantly firmer fruit than the low conductivity treatment in weeks 27 and 30 in 1991. Lower compression figures were recorded for the high conductivity treatment in every assessment in 1992 and significantly lower in weeks 30 (North) and 36 (South).

Humidification resulted in softer fruit after week 25 in 1991 and in every assessment except week 24 (North) in 1992 (Figure 2, page 22). Differences in compression between the treatment and control were significant in weeks 34 and 36 in 1991 and in all assessments in 1992 except for weeks 24 (North) and 34 (North).

There was some evidence in 1991 of Spectra being less affected than Counter by humidification. In weeks 30 and 33 there were significant interactions between variety and humidity treatment. Spectra had slightly lower compression figures in humidified compartments in contrast to Counter which had much softer fruit.

Percentage Weight Loss During Shelf-Life

Counter lost significantly less weight by percentage during shelf-life than other varieties in weeks 27, 30, 32, 34 and 36 in 1991 and in all assessments in 1992. Pronto generally showed higher weight loss relative to other varieties in 1992.

High conductivity had the effect of reducing weight loss. This effect was significant in weeks 21, 27 and 32 in 1991 and in all assessments except week 34 (North) in 1992.

The humidification treatment consistently increased weight loss during shelf-life in both years (Figure 3, page 23). Significant effects were found in weeks 27, 30, 32, 34 and 36 in 1991 and in all assessments in 1992.

Acidity

Levels of acidity were consistently lower (higher endpoint pH) in Counter than in Spectra in both years. Differences were significant in all assessments in 1991 and in weeks 26 (North), 28 (South), 30 (North), 32 (South) and 36 (South) in 1992.

High conductivity generally increased the acidity of fruit, significantly so in weeks 25, 30, 32, 34 and 36 in 1991 and in week 30 (North) in 1992.

Humidification generally lowered the acidity of fruit. Significantly lower endpoint pH values were recorded in weeks 26 (North) and 30 (North) in 1992. However in week 32 in 1991 the reverse effect was found to be just significant at the 5% level of confidence.

Soluble Solids Content

In 1991, Spectra contained significantly higher levels of soluble solids than Counter in weeks 23, 27, 30, 32, 33 and 36. In 1992 Pronto had significantly lower levels than other varieties in weeks 28 (South) and 32 (South).

High conductivity consistently resulted in higher levels of soluble solids. This effect was significant in week 21 and from week 27 in 1991 and in all assessments from week 26 (North) in 1992.

There was no consistent effect of humidification. In week 34 in 1991 significantly higher levels of soluble solids were recorded. In 1992 significantly lower levels of soluble solids were recorded for the humidified compartments in weeks 24 (North) and 34 (North).

Dry Matter Content

In 1991 Spectra contained significantly higher percentages of dry matter than Counter from week 27 onwards. In 1992 Counter was found to contain significantly higher percentages than other varieties in weeks 28 (South) and 32 (South).

High conductivity consistently increased dry matter content, significantly so in weeks 23, 27, 30, 32, 33, 34 and 36 in 1991 and in weeks 28 (South), 32 (South) and 34 (North) in 1992.

Humidification had little effect on dry matter content in 1991 but in 1992 consistently lower percentages of dry matter were recorded for humidified plots, significantly lower in weeks 26 (North) and 32 (South).

Summary of Humidity Effects on Fruit Quality

The humidification treatment had a marked negative effect upon the shelf-life of fruit in terms of higher weight loss during shelf-life and softer fruit.

There was also some evidence that the internal composition of fruit grown in humidified compartments was of lower quality in terms of acidity, soluble solids and dry matter content.

Humidity effects on the occurance of fruit disorders were genearlly small but negative. Levels of red noses increased with humidification and there was some evidence of higher levels of slab-sidedness, boxiness, ribbing and gold spot.

The only positive effect of humidification on fruit quality was some evidence for slightly reduced levels of blotchy ripening.

Figure 2. Effect of humidification on fruit softness

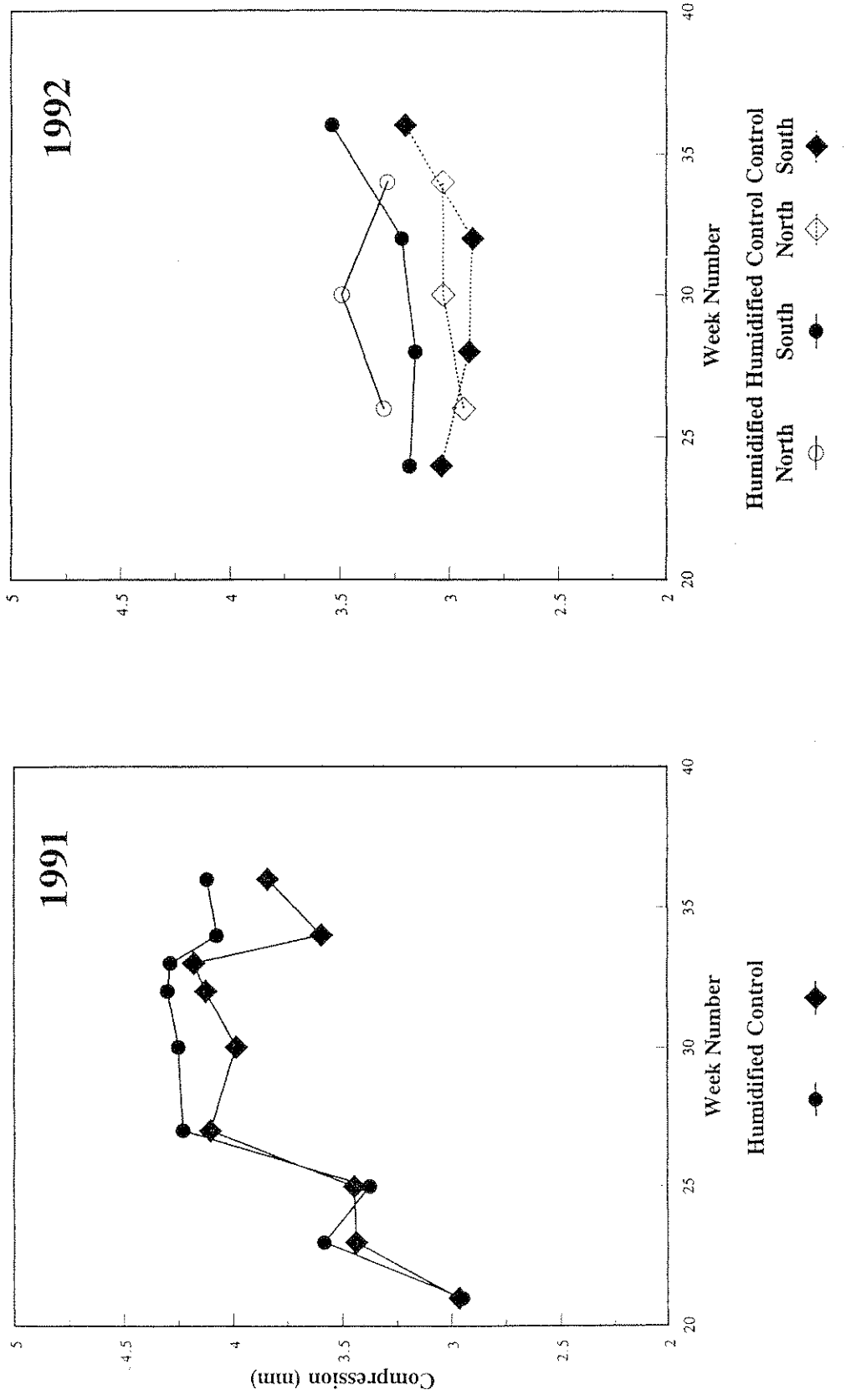
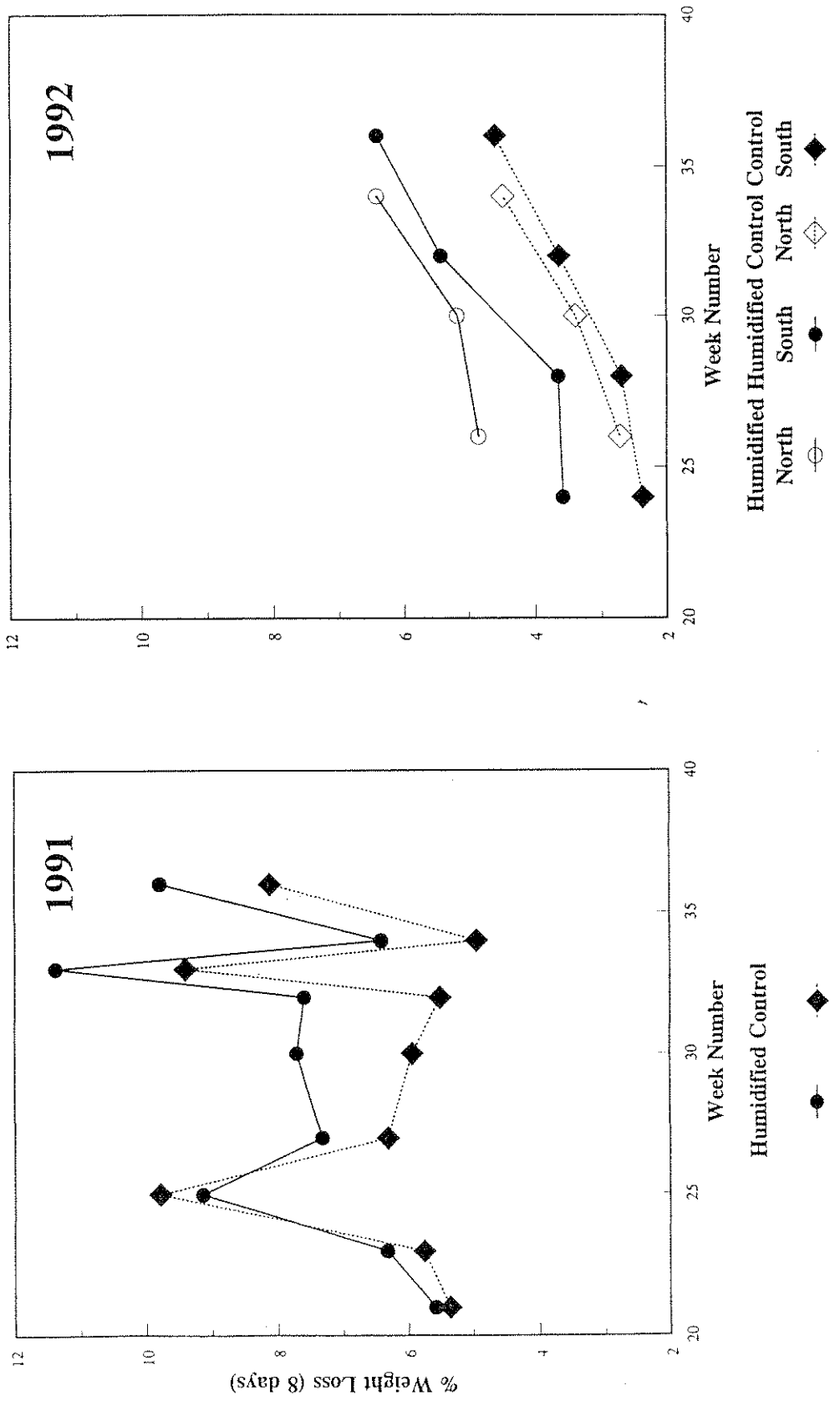


Figure 3. Effect of humidification on percentage weight loss during shelf-life



Fruit Temperatures

On 31 August 1991, a bright day (23.2 MJ/m^2), temperature measurements were made on exposed green fruit on the uppermost trusses and on fruit in semi shade four to five trusses below (Table 7, page 24).

Table 7 **Effect of Summer Humidification on average fruit surface temperature ^{0}C (N=4) 31 August 1991**

	Exposed	Semi-Shade
Humidified	34.9	31.2
Control	39.3	35.5

On 3 August 1992 (18.7 MJ/m^2) a far greater number of measurements were taken. Surface and internal fruit temperature measurements were taken from four plants per plot allowing positional effects within M-Block (see Appendix II, page 35) to be compared (Table 8, page 24). The humidification appeared to reduce both surface and internal fruit temperaures by around 2˚C in the northern part of the glasshouse but not in the southern part of the glasshouse where fruit temperatures were generally higher.

Table 8 **Effect of Summer Humidification and position in glasshouse on fruit temperature 3 August 1992**

Surface temperatures

Compartments	1-4 Northern Array	5-8 Central Array	9-12 Central Array	13-16 Southern Array
Humidified	19.3	20.0	20.6	22.0
Control	21.8	22.3	20.5	21.3

Internal temperatures

Compartments	1-4 Northern Array	5-8 Central Array	9-12 Central Array	13-16 Southern Array
Humidified	21.4	22.9	23.4	24.2
Control	23.5	24.1	23.1	24.6

CO_2 use and glasshouse environmental conditions

Over the two summers there was no consistent difference between humidified and control compartments in terms of the amount of CO_2 pumped into each compartment or the achieved concentrations. Target concentrations were 450 vpm at 0-5% vent and at over 5% vent CO_2 was pumped in to avoid depletion from ambient levels. In 1991 the humidified compartments received 10% less CO_2 than the control but in 1992 the humidified compartments received 8% more than the control (Table 9, page 25). In terms of achieved levels, in 1991 CO_2 levels were consistently higher in the humidified compartments than in the control, although the differences were always small. In 1992 however the reverse was the case, lower CO_2 levels were measured in humidified compartments than in the control (Figure 4, page 27).

Table 9 **Elapsed Time (hrs) of CO_2 flow to compartments up to 31 August 1991 and up to 29 September 1992**

	1991		1992	
Compartment	**Control**	**Humidified**	**Control**	**Humidified**
1	1022.82			753.03
2	1429.45			871.71
3		1439.83	866.14	
4		1168.63	820.83	
5		1015.60		761.02
6		1261.75		838.27
7	1194.60		807.94	
8	1161.83		759.25	
9	1041.00		954.52	
10	1036.23		993.18	
11		958.10		846.55
12		1123.53		991.49
13		1069.27	775.55	
14		1160.35	847.14	
15	1872.42			1336.45
16	1465.35			958.35
Mean	1277.96	1149.63	853.07	919.61

Humidification had the effect of reducing day-time air temperature in both years although the magnitude of the difference was very small, the scale of the difference was greatest when temperatures were highest (Figure 5, page 28).

The humidified compartments resulted in smaller daytime vapour pressure deficits than the control compartments in both years (Figure 6, page 29). The largest differences occured at high vpd but unfortunately there were few weeks when the average vpd in the control compartments exceeded 0.5 kPa and as a result for most of the summer, vpds for both the control and humidified compartments ranged between 0.3 and 0.5 kPa in both years.

The humidification treatment (fogging) had the effect of reducing incident solar radiation slightly in both years (Figure 7, page 30).

The weekly light figures for the summers of 1991 and 1992 are compared to the average figures over the period 1961 to 1988 in Figure 8, page 31. It is apparent that in 1991 light levels were generally below the long term average until weeks 33 to 36 by which time the potential for very high light sums was past. In 1992 however the light levels were higher than the long term average in weeks 21-22, 24-26 and 30-31 and exceeded /80MJ/m^2 per week in weeks 21 and 24.

The fogging system only operated at over 0.5 kPa and the total time the system was operational each month is indicated in Table 10, page 26 for the two years.

Table 10 **Total operational time of the fogging system (hours)**

	1991	**1992**
May	25.16	26.97
June	6.80	60.84
July	26.45	31.78
August	42.63	23.60

Figure 4. Effect of humidification on Carbon dioxide levels

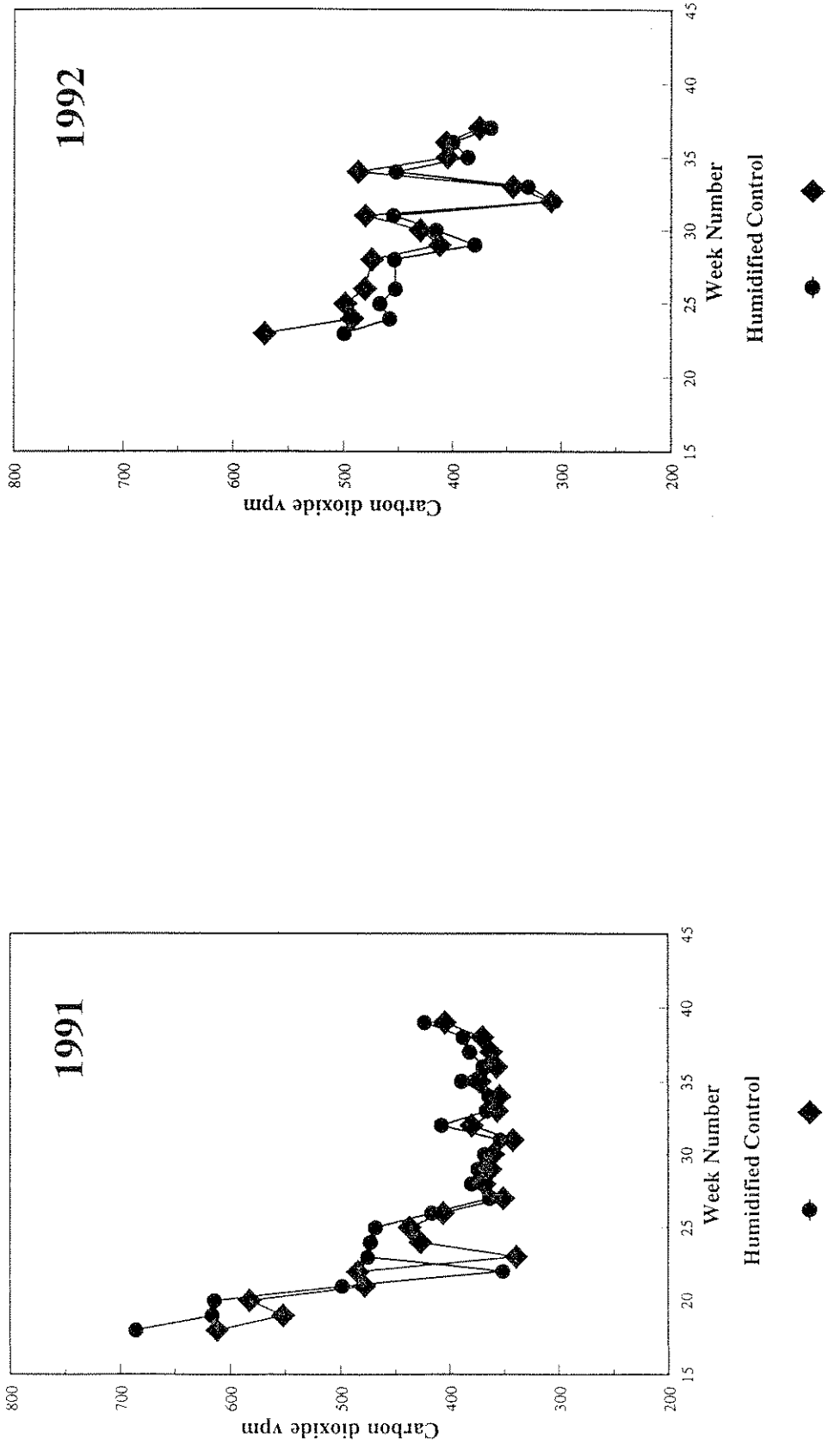
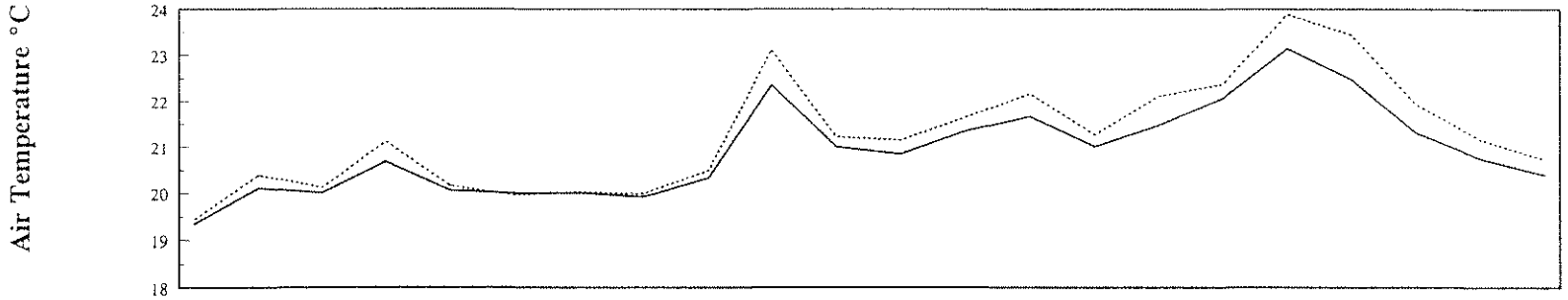


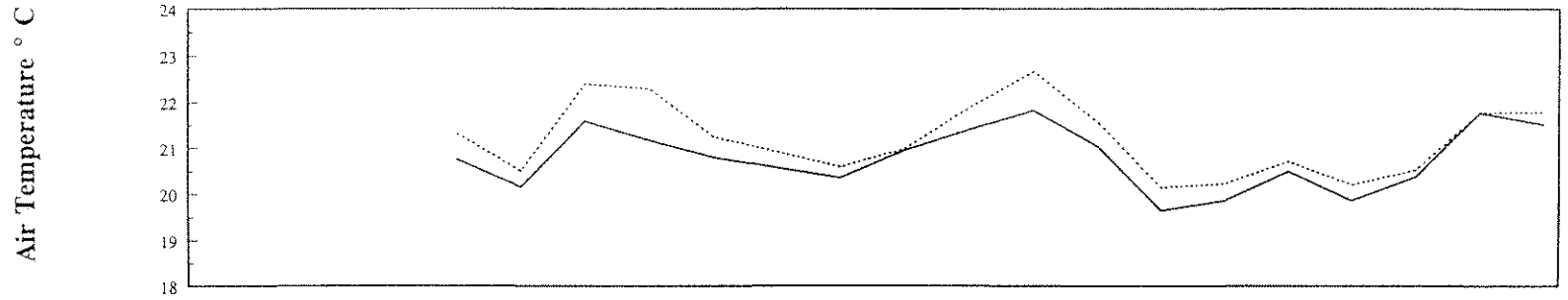
Figure 5. Effect of humidification on day-time air temperature

1991



Week Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Humidified —	19.34	20.11	20.01	20.69	20.06	20.00	20.01	19.92	20.33	22.36	21.00	20.85	21.35	21.67	21.01	21.48	22.07	23.15	22.48	21.31	20.74	20.40
Control ·····	19.43	20.39	20.12	21.12	20.17	19.95	20.02	19.99	20.49	23.12	21.22	21.15	21.65	22.17	21.27	22.12	22.38	23.90	23.45	21.94	21.15	20.72

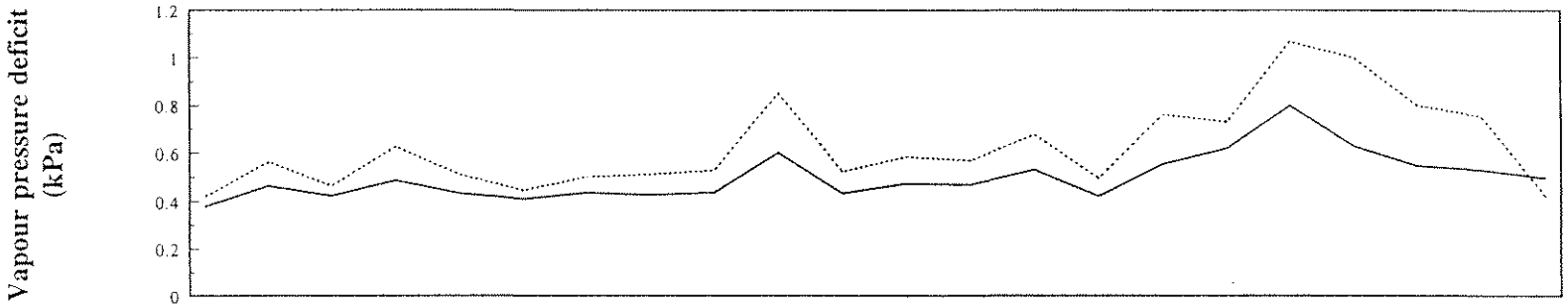
1992



Week Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Humidified —					20.77	20.16	21.59	21.17	20.81		20.36	20.95	21.40	21.82	21.04	19.65	19.86	20.50	19.86	20.38	21.76	21.51
Control ·····					21.33	20.51	22.40	22.29	21.25		20.59	20.99	21.88	22.67	21.57	20.15	20.23	20.71	20.21	20.53	21.77	21.77

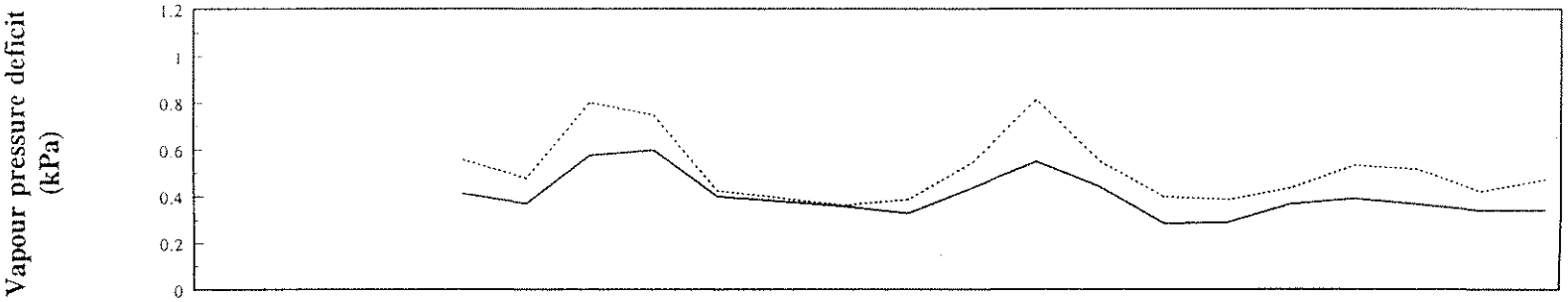
Figure 6. Effect of humidification on day-time vapour pressure deficit

1991



Week Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Humidified ——	0.38	0.46	0.42	0.49	0.43	0.41	0.44	0.43	0.44	0.60	0.43	0.47	0.47	0.53	0.42	0.55	0.62	0.80	0.63	0.55	0.53	0.50
Control ·····	0.42	0.56	0.46	0.63	0.51	0.45	0.50	0.51	0.53	0.85	0.52	0.58	0.57	0.68	0.50	0.76	0.73	1.07	1.00	0.80	0.75	0.42

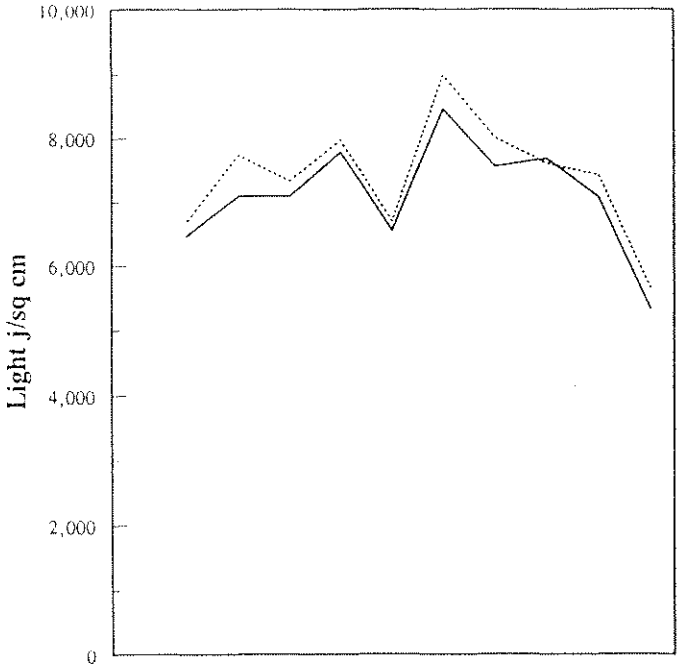
1992



Week Number	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Humidified ——					0.41	0.37	0.58	0.60	0.40		0.36	0.33	0.44	0.55	0.44	0.28	0.29	0.37	0.39	0.37	0.34	0.34
Control ·····					0.56	0.48	0.80	0.75	0.42		0.36	0.39	0.54	0.81	0.55	0.40	0.38	0.43	0.53	0.51	0.42	0.47

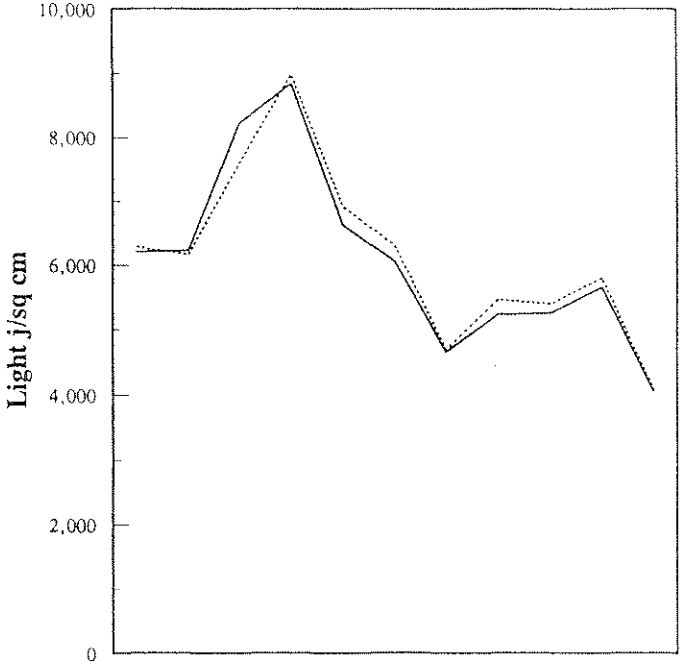
Figure 7. Effect of humidification on levels of incident solar radiation.

1991



Week number	28	29	30	31	32	33	34	35	36	37	38
Humidified —		6,476	7,089	7,089	7,782	6,558	8,463	7,556	7,682	7,082	5,326
Control ····		6,694	7,729	7,327	7,972	6,700	8,989	8,005	7,601	7,422	5,663

1992



Week number	28	29	30	31	32	33	34	35	36	37	38
Humidified —	6,211	6,235	8,225	8,836	6,640	6,066	4,657	5,244	5,256	5,661	4,058
Control ····	6,296	6,169	7,602	8,981	6,925	6,320	4,699	5,467	5,401	5,806	4,107

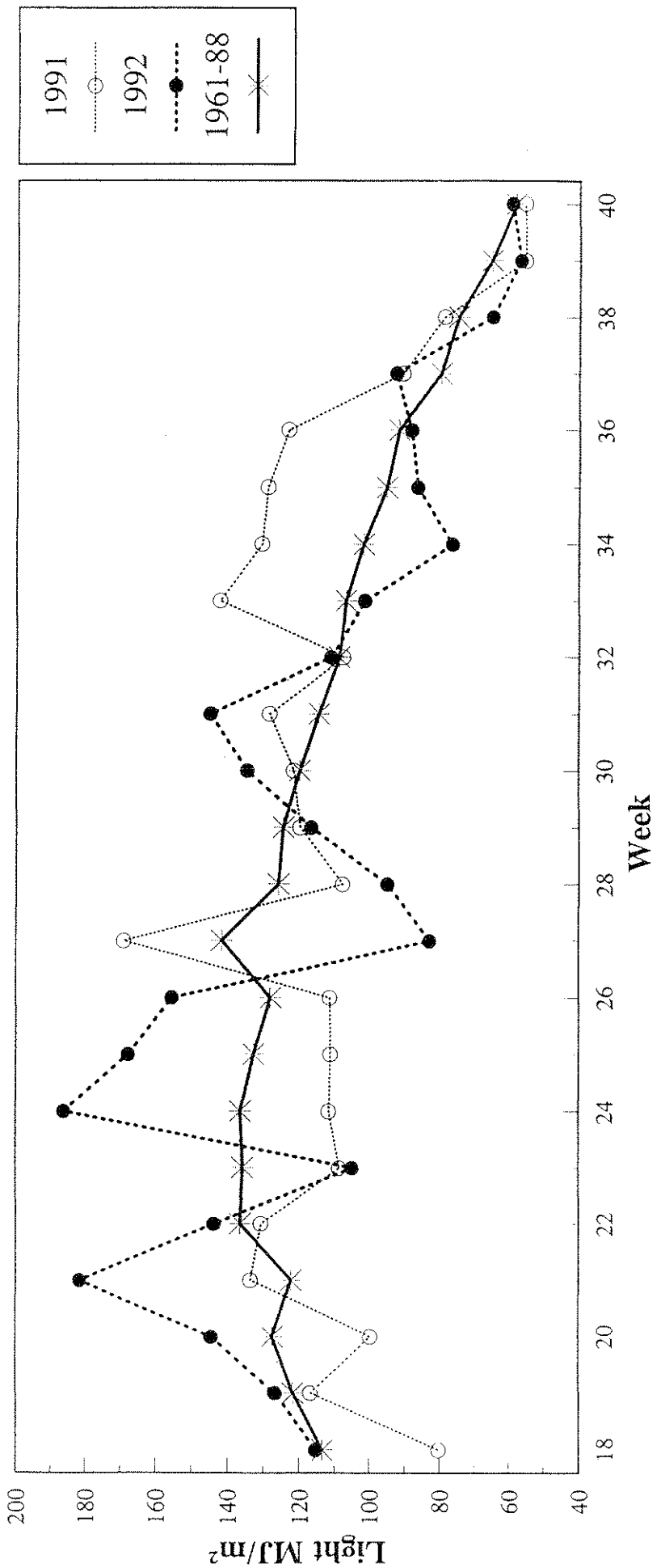


Figure 8. Light levels in 1991 and 1992 and the long term average

DISCUSSIONS AND CONCLUSIONS

Beneficial effects of humidification were expected to result in these trials if, by humidifying, extremely high temperatures (particularly fruit temperatures) and vapour pressure deficits could be avoided. In 1991 light levels in June were very low and as a result ambient vapour pressure deficits rarely exceeded 0.5 kPa, the point at which humidification began. Indeed in 1991 the fogging system was not needed very much until August when the potential for the most damaging temperatures and vapour pressure deficits was past. In 1992 light levels were high in late May and in June and the value of humidification could be fairly assessed.

In 1992 the yields in July and August were significantly higher from the humidified compartments. However taking the summer as a whole these effects disappeared. Any benefits in terms of yield were only temporary.

Humidification did result in a higher proportion of Class I fruit in July 1992 perhaps as a result of the high solar radiation in June. However in September 1992 and in most of the summer of 1991, humidification resulted in a reduction in the percentage of Class I fruit. The detailed fruit quality assessments showed that humidification might have had a small beneficial effect of reducing levels of Blotchy Ripening but that it also increased fruit softness, reduced shelf-life and increased the levels of Gold Spot and the incidence of fruit shape disorders. The deleterious effects of humidification on fruit quality were similar to those occuring at high humidity in the winter humidity trials.

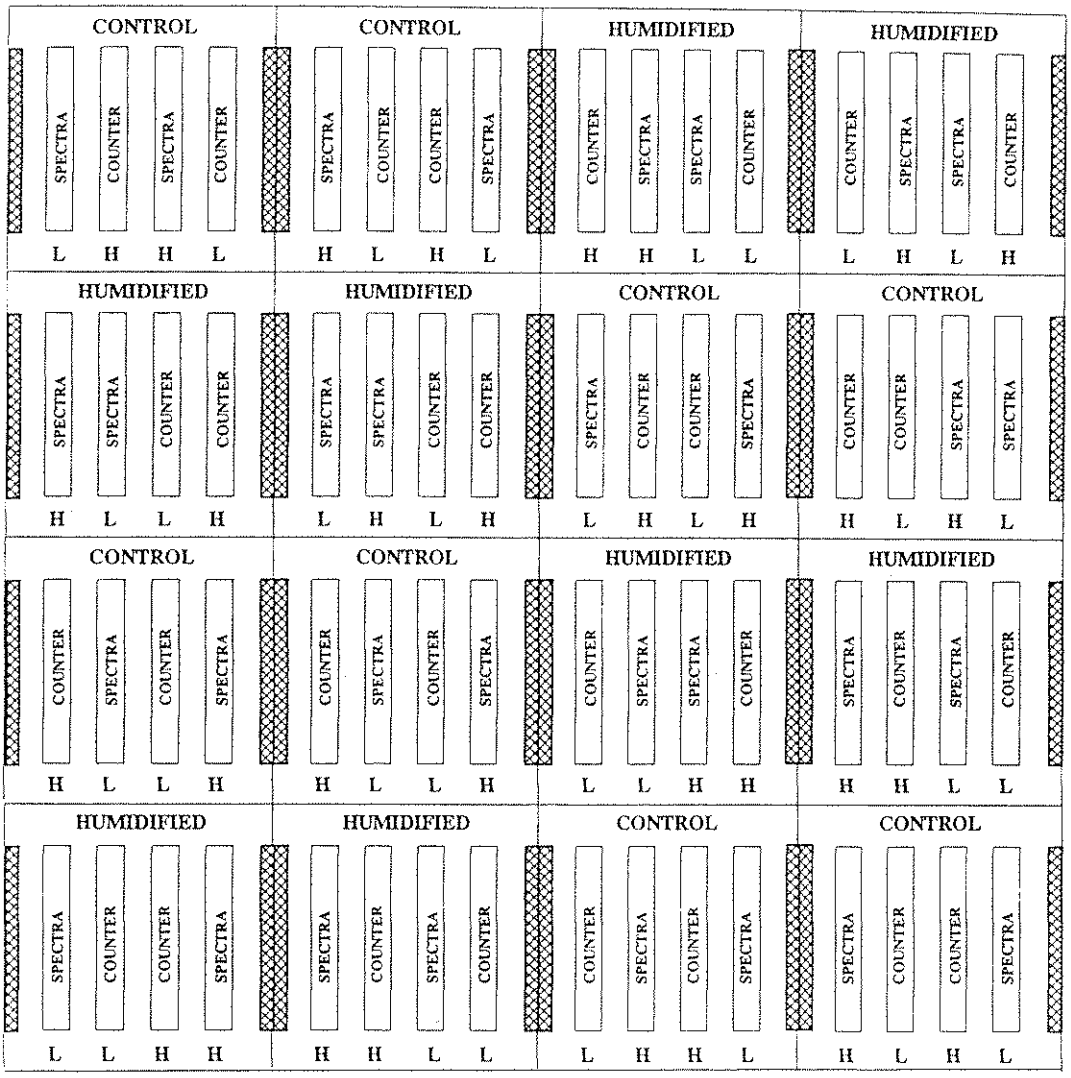
Humidification did have the capacity to reduce both surface and internal fruit temperatures. Large differences were apparent (4°C) in the limited assessment done under high light conditions in 1991 but the larger scale survey in August 1992 showed smaller differences under lower light conditions. There was an indication that humidification only had an effect in the Northern array of the glasshouse. However this effect may have been due to variations in the levels of solar radiation with time as the survey was undertaken.

The humidification had a clear effect of reducing vpd, especially when vpds were high, on bright days. The humidification also had the effect of reducing the air temperature slightly and reducing the amount of solar radiation reaching the crop. Levels of Carbon-dioxide were largely unaffected.

The conclusion drawn from this work is that the capital cost of installing a humidification system is not justified in terms of improved fruit quality, yields or CO_2 conservation.

APPENDICES

Appendix I. Trial Plan 1991



Main Treatments = Humidified and Control

Sub Treatments: Varieties = Spectra and Counter

Conductivity - H - High = 4.0 mS

L - Low = 2.0 mS

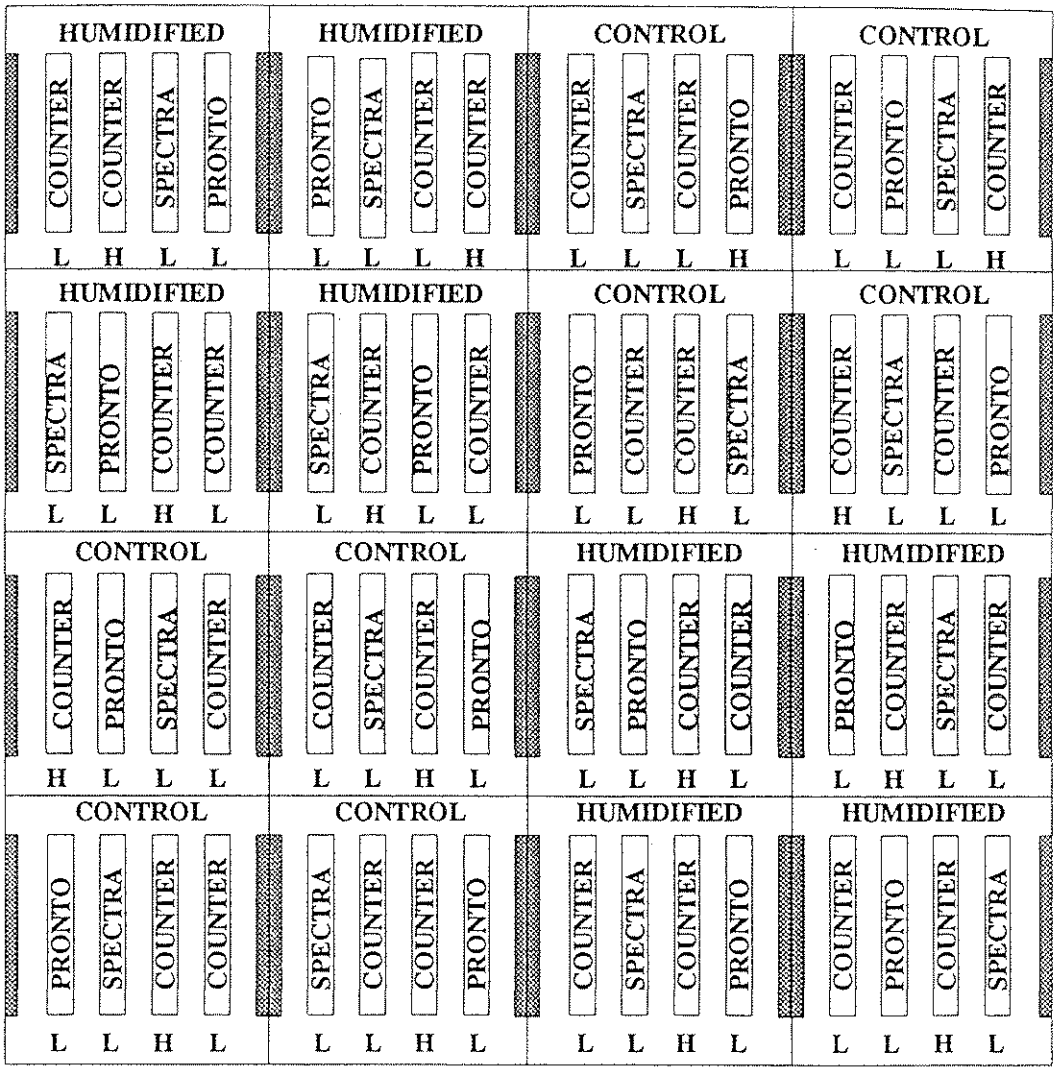
Guard row

Inter plant spacing = 476mm

Plot area = 12.98 sq m

2.62 plants/sq m = 10,600 plants/acre

Appendix II. Trial Plan 1992



Main Treatments - Humidified and Control

Sub treatments - Conductivity H - High - 4.5mS, L - 2.5mS

Varieties = Spectra, Counter and Pronto

Guard rows - Pronto

Inter plant spacing = 476mm Plot Area = 12.98 sq m

2.62 plants/sq m = 10,600 plants/acre

Week 17 Sideshoots taken (1 in 4 plants) - 3.28 plants/sq m = 13,250 plants/acre

APPENDIX III

Crop Diary

	Year 1
Sowing	22 October 1990
Winter treatments stopped	1 March 1991
Summer treatments commenced	29 April 1991

	Year 2
Sowing	24 October 1991
Plants moved into final positions	26 November 1991
Slab Contact	23 December 1991
Winter treatments stopped	18 March 1992
Summer treatments commenced	18 May 1992
Ethrel Spray	16 September 1992

APPENDIX IV

Effect of summer humidification on Total Yield ($kg.m^{-2}$)

			1991					
	Variety	EC	May	June	July	Aug	Sept	Total
Humidified	Spectra	2.0	6.87	7.93	7.35	7.50	8.58	38.27
	Counter	2.0	6.91	7.10	6.98	6.89	7.15	35.06
	Spectra	4.0	6.60	7.96	7.26	6.87	8.46	37.20
	Counter	4.0	6.87	6.90	6.77	6.16	7.19	33.93
Control	Spectra	2.0	6.94	7.63	7.65	7.58	8.77	38.60
	Counter	2.0	7.07	6.70	7.37	7.30	7.75	36.23
	Spectra	4.0	7.16	7.54	7.23	6.63	8.50	37.11
	Counter	4.0	7.07	6.84	7.07	6.45	7.31	34.79

Effect of summer humidification on Total Yield ($kg.m^{-2}$)

			1992					
	Variety	EC	May	June	July	Aug	Sept	Total
Humidified								
	Spectra	2.5	6.28	9.98	9.34	6.04	11.19	42.83
	Pronto	2.5	5.85	9.16	8.78	6.08	10.65	40.52
	Counter	2.5	6.29	9.29	7.83	5.85	10.00	39.26
	Counter	4.0	6.53	9.15	8.10	5.52	9.69	38.98
Control	Spectra	2.5	6.27	9.56	8.76	5.92	11.50	42.01
	Pronto	2.5	6.12	9.03	8.86	6.05	11.07	41.12
	Counter	2.5	6.29	8.96	8.05	5.59	10.19	39.08
	Counter	4.0	6.59	8.86	7.87	5.23	9.62	38.16

APPENDIX V

Effect of summer humidification on Percentage Class I fruit : 1991

	Variety	EC	May	June	July	Aug	Sept	Total
Humidified	Spectra	2.0	89.9	91.4	69.3	65.5	48.7	72.3
	Counter	2.0	85.8	87.3	46.9	44.9	26.3	58.4
	Spectra	4.0	90.3	93.7	89.4	92.7	55.1	83.4
	Counter	4.0	87.8	90.3	66.4	71.6	30.3	68.8
Control	Spectra	2.0	88.1	91.8	73.2	70.9	54.1	75.0
	Counter	2.0	85.6	88.3	59.2	64.9	33.3	64.8
	Spectra	4.0	91.7	95.4	89.8	88.9	54.3	83.2
	Counter	4.0	87.6	91.2	76.4	80.3	35.8	73.6

Effect of summer humidification on Percentage Class I fruit : 1992

	Variety	EC	May	June	July	Aug	Sept	Total
Humidified								
	Spectra	2.5	86.3	93.1	90.8	91.9	78.0	87.6
	Pronto	2.5	84.1	92.8	89.8	88.7	76.7	86.2
	Counter	2.5	83.5	91.3	84.9	85.0	75.1	83.7
	Counter	4.0	84.8	92.8	87.1	87.6	78.6	86.0
Control	Spectra	2.5	84.8	93.4	89.5	92.0	81.1	87.9
	Pronto	2.5	84.0	92.9	88.8	88.8	81.9	87.2
	Counter	2.5	84.3	92.1	86.2	87.1	79.3	85.6
	Counter	4.0	85.0	92.2	85.1	86.6	78.6	85.4

APPENDIX VI

DISORDER ASSESSMENTS 1991

Week Number 29

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.0	0	0	0.00	2.69	0.17	0.67	2.46	2.63	3.08	1.69
		2.0	0	0	0.10	3.08	0.26	1.23	2.90	2.17	4.27	1.87
	Spectra	4.0	0	0	0.05	1.94	0.33	1.63	2.44	2.47	1.84	1.26
		2.0	0	0	0.17	2.06	0.51	2.07	2.26	2.39	3.17	1.38
Control	Counter	4.0	0	0	0.05	3.03	0.40	0.86	2.06	2.63	2.63	1.64
		2.0	0	0	0.15	2.99	0.33	1.11	2.16	2.76	4.02	1.65
	Spectra	4.0	0	0	0.05	1.76	0.60	1.94	1.56	2.77	1.68	1.53
		2.0	0	0	0.10	1.99	0.44	2.31	2.26	2.53	2.92	1.60
SED (d.f = 24)			*0*	*0*	-	*0.312*	*0.181*	*0.354*	*0.274*	*0.248*	*0.356*	*0.269*
*SED**			*0*	*0*	-	*0.305*	*0.176*	*0.331*	*0.269*	*0.254*	*0.349*	*0.242*

* to be used when comparing within humidification regimes

APPENDIX VI

DISORDER ASSESSMENTS 1991

Week Number 31

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing Sidedness	Slab-Cracking	Radial	Netting Spot	Gold Marbling	Gold Noses	Red Ripening	Blotchy
Humidified	Counter	**4.0**	0	0.08	0.15	2.79	0.46	1.02	2.49	3.20	2.63	2.23
		2.0	0	0.07	0.10	3.08	0.65	1.77	2.84	2.82	3.59	2.27
	Spectra	**4.0**	0	0.28	0.00	2.04	1.00	1.98	2.54	2.72	1.17	2.29
		2.0	0	0.05	0.05	2.44	1.68	3.02	2.87	2.66	2.94	2.30
Control	Counter	**4.0**	0	0.00	0.07	2.82	0.41	0.94	2.39	3.00	1.65	2.60
		2.0	0	0.05	0.15	3.30	0.63	1.68	2.85	3.10	3.98	2.85
	Spectra	**4.0**	0	0.13	0.00	2.07	1.20	2.06	1.97	2.67	1.11	2.48
		2.0	0	0.12	0.27	2.43	0.93	2.52	2.45	2.46	2.64	2.77
SED (d.f = 24)			*0*	-	-	*0.242*	*0.374*	*0.400*	*0.228*	*0.221*	*0.473*	*0.297*
SED'			*0*	-	-	*0.221*	*0.350*	*0.348*	*0.223*	*0.194*	*0.497*	*0.284*

' to be used when comparing within humidification regimes

APPENDIX VI

DISORDER ASSESSMENTS 1991

Week Number 35

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.0	0	0	0	2.63	0.96	1.31	0.74	2.88	2.23	2.55
		2.0	0	0	0	3.27	1.09	1.89	1.93	2.99	4.00	2.25
	Spectra	**4.0**	0	0	0	1.94	1.74	2.36	1.10	1.99	1.01	1.95
		2.0	0	0	0	2.30	1.92	3.17	2.47	2.05	3.44	2.25
Control	Counter	**4.0**	0	0	0	3.25	0.47	0.91	1.10	3.12	1.66	2.20
		2.0	0	0.10	0	2.98	0.78	1.80	1.90	2.88	3.34	2.41
	Spectra	**4.0**	0	0	0	2.18	1.20	2.04	0.83	2.41	1.60	2.37
		2.0	0	0	0	2.19	1.46	2.70	1.44	2.22	2.63	2.00
SED (d.f = 24)			*0*	-	*0*	*0.316*	*0.338*	*0.470*	*0.363*	*0.335*	*0.500*	*0.390*
*SED**			*0*	-	*0*	*0.329*	*0.295*	*0.496*	*0.376*	*0.281*	*0.508*	*0.363*

* to be used when comparing within humidification regimes

APPENDIX VI

DISORDER ASSESSMENTS 1991

Week Number 37

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.0	0	0	0	2.80	1.33	1.79	1.95	2.67	2.48	2.21
		2.0	0	0	0	3.37	0.45	0.95	2.18	2.38	3.86	2.07
	Spectra	4.0	0	0	0	1.97	1.83	2.80	1.56	2.44	1.92	2.12
		2.0	0	0	0	2.25	1.09	2.34	2.19	2.27	3.03	2.01
Control	Counter	4.0	0	0	0	3.32	0.68	1.16	1.48	2.73	1.95	1.75
		2.0	0	0	0	3.43	0.26	0.92	2.44	2.40	3.06	1.92
	Spectra	4.0	0	0	0	1.65	2.41	3.47	1.62	2.63	1.33	2.29
		2.0	0	0	0	2.05	1.84	2.86	2.18	2.17	2.72	2.45
SED (d.f = 24)			*0*	*0*	*0*	*0.235*	*0.389*	*0.366*	*0.242*	*0.198*	*0.336*	*0.263*
*SED**			*0*	*0*	*0*	*0.223*	*0.286*	*0.359*	*0.238*	*0.165*	*0.340*	*0.259*

* to be used when comparing within humidification regimes

APPENDIX VII

DISORDER ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 24

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.15	0.15	0.10	0.05	0.00	0.03	0.28	0.53	0.08	0.65
		2.5	0.18	0.25	0.03	0.10	0.00	0.00	0.48	0.45	0.03	0.63
	Spectra	2.5	0.05	0.15	0.08	0.03	0.00	0.05	0.18	0.28	0.00	0.48
	Pronto	2.5	0.03	0.03	0.05	0.08	0.03	0.20	0.40	0.48	0.00	0.38
Control	Counter	4.5	0.15	0.15	0.20	0.10	0.00	0.00	0.43	0.45	0.03	0.45
		2.5	0.05	0.13	0.05	0.00	0.00	0.00	0.70	0.73	0.00	0.83
	Spectra	2.5	0.00	0.20	0.20	0.08	0.00	0.10	0.08	0.50	0.03	0.35
	Pronto	2.5	0.05	0.05	0.08	0.08	0.00	0.10	0.23	0.50	0.03	0.83
SED (d.f = 28)			*0.094*	*0.101*	*0.092*	*0.065*	*0.013*	*0.061*	*0.166*	*0.321*	*0.035*	*0.259*
*SED**			*0.083*	*0.102*	*0.093*	*0.064*	*0.013*	*0.060*	*0.154*	*0.232*	*0.036*	*0.253*

* to be used when comparing within humidification regimes

APPENDIX VII

DISORDER ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 26

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.23	0.03	0.13	0.10	0.00	0.03	0.63	0.65	0.00	0.53
		2.5	0.13	0.00	0.10	0.00	0.03	0.20	0.65	0.95	0.08	0.85
	Spectra	2.5	0.00	0.00	0.18	0.03	0.08	0.00	0.08	0.48	0.00	0.60
	Pronto	2.5	0.05	0.00	0.03	0.05	0.15	0.25	0.43	0.35	0.00	0.23
Control	Counter	4.5	0.18	0.00	0.08	0.15	0.00	0.05	0.80	0.75	0.00	0.60
		2.5	0.15	0.03	0.10	0.05	0.03	0.23	0.48	0.80	0.00	0.85
	Spectra	2.5	0.00	0.08	0.28	0.13	0.00	0.05	0.15	0.35	0.00	0.48
	Pronto	2.5	0.05	0.03	0.03	0.03	0.03	0.43	0.30	0.60	0.00	0.85
SED (d.f = 28)			*0.070*	*0.032*	*0.085*	*0.063*	*0.087*	*0.113*	*0.174*	*0.222*	*0.038*	*0.285*
*SED**			*0.066*	*0.029*	*0.085*	*0.057*	*0.092*	*0.110*	*0.145*	*0.232*	*0.038*	*0.264*

* to be used when comparing within humidification regimes

APPENDIX VII

DISORDER ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 30

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.05	0	0.00	0.10	0.00	0.03	1.18	0.08	0.00	0.53
		2.5	0.20	0	0.00	0.28	0.00	0.03	1.30	0.15	0.15	0.23
	Spectra	2.5	0.08	0	0.03	0.08	0.00	0.00	0.73	0.00	0.13	0.43
	Pronto	2.5	0.08	0	0.00	0.13	0.00	0.18	1.08	0.08	0.00	0.20
Control	Counter	4.5	0.03	0	0.00	0.18	0.00	0.10	0.98	0.53	0.00	0.48
		2.5	0.05	0	0.00	0.18	0.00	0.05	0.58	0.15	0.05	0.28
	Spectra	2.5	0.03	0	0.00	0.08	0.03	0.00	0.50	0.10	0.00	0.33
	Pronto	2.5	0.03	0	0.00	0.25	0.00	0.08	0.65	0.15	0.00	0.25
SED (d.f = 28)			*0.086*	*0*	*0.013*	*0.088*	*0.013*	*0.079*	*0.247*	*0.090*	*0.080*	*0.185*
*SED**			*0.091*	*0*	*0.013*	*0.093*	*0.013*	*0.077*	*0.219*	*0.094*	*0.068*	*0.186*

* to be used when comparing within humidification regimes

APPENDIX VII

DISORDER ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 34

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.05	0.00	0.05	0.30	0.00	0.38	0.73	0.23	0.35	0.025
		2.5	0.08	0.00	0.05	0.63	0.03	0.33	1.00	0.13	0.33	0.28
	Spectra	2.5	0.08	0.00	0.00	0.25	0.05	0.15	0.33	0.03	0.18	0.18
	Pronto	2.5	0.00	0.00	0.10	0.20	0.00	0.40	0.98	0.08	0.05	0.05
Control	Counter	4.5	0.03	0.00	0.00	0.23	0.03	0.38	1.00	0.15	0.08	0.08
		2.5	0.08	0.00	0.03	0.20	0.03	0.33	1.28	0.15	0.13	0.25
	Spectra	2.5	0.00	0.03	0.08	0.15	0.03	0.15	0.43	0.15	0.13	0.28
	Pronto	2.5	0.00	0.00	0.10	0.03	0.03	0.35	0.73	0.25	0.13	0.15
SED (d.f = 28)			*0.035*	*0.013*	*0.060*	*0.121*	*0.031*	*0.229*	*0.189*	*0.105*	*0.175*	*0.113*
*SED**			*0.033*	*0.013*	*0.066*	*0.108*	*0.017*	*0.162*	*0.170*	*0.095*	*0.164*	*0.107*

* to be used when comparing within humidification regimes

APPENDIX VIII

DISORDER ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 24

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.00	0.18	0.00	0.05	0	0.08	0.43	0.50	0.00	0.68
		2.5	0.00	0.13	0.03	0.00	0	0.10	0.25	0.33	0.15	0.68
	Spectra	2.5	0.05	0.05	0.05	0.05	0	0.03	0.03	0.28	0.00	0.35
	Pronto	2.5	0.08	0.08	0.05	0.08	0	0.03	0.68	0.48	0.03	0.25
Control	Counter	4.5	0.08	0.15	0.08	0.00	0	0.03	0.58	0.55	0.03	0.63
		2.5	0.18	0.10	0.08	0.18	0	0.00	0.45	0.45	0.03	0.35
	Spectra	2.5	0.13	0.13	0.08	0.18	0	0.00	0.28	0.40	0.00	0.68
	Pronto	2.5	0.08	0.00	0.08	0.08	0	0.05	0.28	0.15	0.00	0.38
SED (d.f = 28)			*0.099*	*0.090*	*0.061*	*0.113*	*0*	*0.106*	*0.152*	*0.218*	*0.078*	*0.230*
*SED**			*0.040*	*0.085*	*0.064*	*0.104*	*0*	*0.110*	*0.148*	*0.235*	*0.080*	*0.253*

* to be used when comparing within humidification regimes

APPENDIX VIII

DISORDER ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 28

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.18	0	0.10	0.28	0.00	0.05	1.00	0.28	0.00	0.03
		2.5	0.18	0	0.00	0.38	0.03	0.10	1.05	0.20	0.05	0.25
	Spectra	2.5	0.00	0	0.00	0.08	0.15	0.23	0.05	0.15	0.00	0.23
	Pronto	2.5	0.13	0	0.00	0.10	0.00	0.28	0.73	0.20	0.00	0.05
Control	Counter	4.5	0.23	0	0.00	0.10	0.03	0.08	0.78	0.53	0.00	0.18
		2.5	0.28	0	0.03	0.38	0.00	0.03	0.55	0.30	0.03	0.13
	Spectra	2.5	0.00	0	0.10	0.08	0.13	0.13	0.18	0.20	0.00	0.18
	Pronto	2.5	0.03	0	0.05	0.05	0.00	0.35	0.55	0.08	0.00	0.08
SED (d.f = 28)			*0.109*	*0*	*0.035*	*0.166*	*0.049*	*0.106*	*0.206*	*0.169*	*0.028*	*0.107*
*SED**			*0.092*	*0*	*0.034*	*0.159*	*0.051*	*0.086*	*0.205*	*0.156*	*0.028*	*0.116*

* to be used when comparing within humidification regimes

APPENDIX VIII

DISORDER ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 32

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.18	0.00	0.03	0.40	0.00	0.03	0.98	0.08	0.15	0.35
		2.5	0.28	0.03	0.03	0.70	0.00	0.08	1.45	0.03	0.43	0.78
	Spectra	2.5	0.08	0.05	0.10	0.43	0.00	0.00	0.98	0.10	0.38	0.53
	Pronto	2.5	0.20	0.00	0.00	0.48	0.00	0.08	1.25	0.08	0.38	0.35
Control	Counter	4.5	0.08	0.00	0.00	0.15	0.00	0.08	0.80	0.00	0.03	0.70
		2.5	0.15	0.00	0.00	0.48	0.00	0.10	0.93	0.03	0.15	0.75
	Spectra	2.5	0.05	0.03	0.00	0.10	0.03	0.05	0.88	0.10	0.18	0.45
	Pronto	2.5	0.00	0.00	0.00	0.18	0.00	0.23	0.78	0.23	0.05	0.55
SED (d.f = 28)			*0.105*	*0.031*	*0.027*	*0.161*	*0.013*	*0.088*	*0.211*	*0.067*	*0.280*	*0.245*
*SED**			*0.114*	*0.032*	*0.028*	*0.173*	*0.013*	*0.081*	*0.148*	*0.069*	*0.303*	*0.209*

* to be used when comparing within humidification regimes

APPENDIX VIII

DISORDER ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 36

Humidity Treatments	Variety	Conductivity	Boxiness	Nippling	Ribbing	Slab-Sidedness	Radial Cracking	Netting	Gold Spot	Gold Marbling	Red Noses	Blotchy Ripening
Humidified	Counter	4.5	0.03	0.03	0.03	1.18	0.00	0.40	1.33	0.15	0.13	0.20
		2.5	0.08	0.13	0.03	1.58	0.00	0.48	1.65	0.35	1.00	0.58
	Spectra	2.5	0.03	0.13	0.13	0.58	0.10	0.75	1.25	0.23	0.68	0.38
	Pronto	2.5	0.00	0.00	0.05	1.08	0.05	0.55	1.03	0.13	0.25	0.43
Control	Counter	4.5	0.03	0.13	0.05	1.13	0.08	0.50	1.03	0.33	0.05	0.38
		2.5	0.00	0.03	0.25	1.05	0.03	0.48	1.35	0.28	0.30	0.35
	Spectra	2.5	0.00	0.13	0.08	0.35	0.00	0.58	1.38	0.38	1.13	0.50
	Pronto	2.5	0.03	0.00	0.13	1.28	0.05	0.55	0.95	0.08	0.13	0.33
SED (d.f = 28)			*0.035*	*0.071*	*0.090*	*0.269*	*0.053*	*0.281*	*0.245*	*0.133*	*0.224*	*0.203*
*SED**			*0.033*	*0.074*	*0.082*	*0.300*	*0.053*	*0.275*	*0.239*	*0.134*	*0.211*	*0.206*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 21

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	3.16	4.92	9.52	4.05	5.90
		2.0	3.09	6.14	9.89	3.63	5.82
	Spectra	4.0	2.76	5.49	9.02	4.01	5.77
		2.0	2.77	5.66	9.68	3.65	5.81
Control	Counter	4.0	3.15	4.81	9.64	3.89	5.87
		2.0	3.23	4.81	9.78	3.87	5.84
	Spectra	4.0	2.73	4.83	9.25	4.03	5.99
		2.0	2.74	5.86	9.10	3.95	5.84
SED (d.f = 24)			*0.137*	*0.514*	*0.3393*	*0.171*	*0.101*
*SED**			*0.120*	*0.539*	*0.3491*	*0.170*	*0.106*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 23

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	3.75	6.34	9.94	3.85	6.12
		2.0	3.71	5.61	9.65	3.94	5.81
	Spectra	4.0	3.46	7.08	8.91	4.31	6.10
		2.0	3.41	6.26	8.87	4.49	5.93
Control	Counter	4.0	3.65	6.21	9.78	3.65	5.90
		2.0	3.60	5.56	9.89	3.80	5.93
	Spectra	4.0	3.27	5.34	9.13	4.26	6.03
		2.0	3.23	5.34	9.13	4.26	6.03
SED (d.f = 24)			*0.162*	*0.959*	*0.308*	0.308	0.131
*SED**			*0.131*	*0.902*	*0.262*	*0.264*	*0.124*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 25

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	3.64	9.52	9.26	4.27	6.05
		2.0	3.68	9.04	9.44	4.01	5.91
	Spectra	4.0	2.99	8.32	9.02	4.17	6.10
		2.0	3.18	9.69	9.24	3.97	6.04
Control	Counter	4.0	3.64	9.48	9.30	4.17	6.06
		2.0	3.76	8.41	9.62	4.14	5.99
	Spectra	4.0	3.20	12.09	8.87	4.31	6.15
		2.0	3.18	9.17	9.14	4.21	6.00
SED (d.f = 24)			*0.164*	*1.248*	*0.229*	*0.210*	*0.128*
*SED**			*0.166*	*1.244*	*0.227*	*0.179*	*0.112*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 27

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	4.14	5.93	9.36	4.53	5.84
		2.0	4.61	7.64	9.65	4.24	5.54
	Spectra	4.0	4.02	7.26	9.20	4.39	5.95
		2.0	4.15	8.43	8.82	4.37	5.72
Control	Counter	4.0	4.03	5.15	9.70	4.40	5.81
		2.0	4.26	5.53	9.50	4.24	6.11
	Spectra	4.0	3.79	6.83	8.78	4.82	6.11
		2.0	4.35	7.74	9.24	4.39	5.71
SED (d.f = 24)			*0.191*	*0.555*	*0.291*	*0.118*	*0.115*
*SED**			*0.158*	*0.505*	*0.295*	*0.105*	*0.116*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 30

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	4.59	7.13	9.75	4.37	5.73
		2.0	4.51	7.26	10.37	3.67	5.36
	Spectra	4.0	3.80	8.02	9.52	4.43	5.95
		2.0	4.09	8.39	10.00	4.08	5.57
Control	Counter	4.0	3.68	4.58	10.08	4.14	5.81
		2.0	4.21	4.87	10.30	4.12	5.34
	Spectra	4.0	3.95	7.10	9.63	4.63	6.01
		2.0	4.10	7.16	10.00	4.26	5.55
SED (d.f = 24)			*0.211*	*0.585*	*0.163*	*0.278*	*0.166*
*SED**			*0.167*	*0.534*	*0.162*	*0.260*	*0.171*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 32

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	4.62	6.40	9.97	4.63	5.94
		2.0	4.32	6.97	10.37	4.15	5.44
	Spectra	4.0	4.21	8.32	9.53	4.95	6.25
		2.0	4.05	8.85	9.87	4.42	5.84
Control	Counter	4.0	4.32	4.25	10.15	4.60	5.86
		2.0	4.36	5.08	10.43	4.24	5.48
	Spectra	4.0	3.95	5.98	9.56	4.83	6.18
		2.0	3.86	6.67	9.92	4.51	5.72
SED (d.f = 24)			*0.174*	*0.399*	*0.131*	*0.128*	*0.100*
*SED**			*0.174*	*0.395*	*0.144*	*0.119*	*0.096*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 33

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	4.51	10.11	9.90	4.07	5.77
		2.0	4.51	13.11	10.05	3.77	5.36
	Spectra	4.0	4.07	10.90	9.72	4.25	6.08
		2.0	4.06	11.40	9.73	3.97	5.54
Control	Counter	4.0	4.19	8.50	10.10	4.21	5.78
		2.0	4.21	7.58	10.18	3.80	5.11
	Spectra	4.0	4.14	9.98	9.43	4.46	6.16
		2.0	4.17	11.54	9.65	4.03	5.61
SED (d.f = 24)			*0.217*	*1.744*	*0.236*	*0.131*	*0.095*
*SED**			*0.172*	*1.620*	*0.240*	*0.126*	*0.097*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 34

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	4.26	6.00	10.00	4.37	5.91
		2.0	4.09	5.04	10.48	3.87	5.43
	Spectra	4.0	3.93	7.01	9.86	4.23	6.19
		2.0	4.00	7.62	9.99	3.81	5.59
Control	Counter	4.0	3.72	3.45	10.16	4.00	5.99
		2.0	3.86	5.10	10.41	3.66	5.40
	Spectra	4.0	3.45	5.56	9.46	4.19	6.18
		2.0	3.35	5.63	10.07	3.77	5.71
SED (d.f = 24)			*0.142*	*0.694*	*0.131*	*0.135*	*0.108*
*SED**			*0.154*	*0.691*	*0.125*	*0.149*	*0.109*

* to be used when comparing within humidification regimes

APPENDIX IX

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS 1991

Week Number 36

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.0	4.46	9.43	10.10	4.20	6.40
		2.0	4.52	9.02	10.42	3.65	5.64
	Spectra	4.0	3.65	10.23	9.50	4.62	6.65
		2.0	3.84	10.43	9.80	3.96	6.00
Control	Counter	4.0	4.21	7.27	9.96	4.38	6.35
		2.0	4.20	7.16	10.26	3.93	5.69
	Spectra	4.0	3.55	9.37	9.36	4.47	6.68
		2.0	3.40	8.65	9.69	4.14	5.91
SED (d.f = 24)			*0.153*	*0.554*	*0.222*	*0.145*	*0.101*
*SED**			*0.151*	*0.537*	*0.178*	*0.152*	*0.109*

* to be used when comparing within humidification regimes

APPENDIX X

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 24

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.22	2.79	9.10	4.53	5.50
		2.5	3.24	3.76	8.87	4.58	5.48
	Spectra	2.5	3.04	3.88	8.81	4.49	5.40
	Pronto	2.5	3.10	4.10	8.69	4.56	5.48
Control	Counter	4.5	3.16	2.13	9.14	4.65	5.63
		2.5	3.15	2.14	9.07	4.74	5.70
	Spectra	2.5	2.78	2.42	8.75	4.69	5.58
	Pronto	2.5	3.10	2.82	8.89	4.71	5.73
SED (d.f = 24)			*0.124*	*0.411*	*0.214*	*0.074*	*0.138*
*SED**			*0.103*	*0.290*	*0.209*	*0.067*	*0.122*

* to be used when comparing within humidification regimes

APPENDIX X

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 26

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.44	4.22	8.76	4.68	5.67
		2.5	3.51	5.23	8.84	4.69	5.73
	Spectra	2.5	3.10	4.82	8.45	4.70	5.78
	Pronto	2.5	3.16	5.13	8.40	4.66	5.78
Control	Counter	4.5	2.96	2.25	8.43	4.94	6.17
		2.5	3.13	2.53	8.65	4.68	5.98
	Spectra	2.5	2.82	2.95	7.84	4.85	6.06
	Pronto	2.5	2.84	3.13	8.09	4.84	6.06
SED (d.f = 24)			*0.0931*	*0.358*	*0.210*	*0.092*	*0.125*
*SED**			*0.0979*	*0.356*	*0.187*	*0.077*	*0.112*

* to be used when comparing within humidification regimes

APPENDIX X

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 30

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.53	4.10	8.45	4.68	5.93
		2.5	3.80	5.60	8.98	4.39	5.53
	Spectra	2.5	3.38	5.49	7.99	4.56	5.58
	Pronto	2.5	3.26	5.52	8.26	4.50	5.64
Control	Counter	4.5	3.09	2.72	8.44	4.71	6.10
		2.5	3.16	2.84	8.95	4.34	5.90
	Spectra	2.5	2.98	4.14	8.19	4.50	5.67
	Pronto	2.5	2.89	3.87	4.41	5.97	
SED (d.f = 24)			*0.093*	*0.481*	*0.218*	*0.084*	*0.224*
*SED**			*0.097*	*0.512*	*0.179*	*0.076*	*0.246*

* to be used when comparing within humidification regimes

APPENDIX X

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS NORTHERN ARRAY (COMPARTMENTS 1-8) 1992

Week Number 34

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.41	5.57	9.20	4.51	5.76
		2.5	3.43	6.77	9.22	4.36	5.53
	Spectra	2.5	3.32	6/96	9.26	4.30	5.43
	Pronto	2.5	2.98	6.43	9.12	4.35	5.49
Control	Counter	4.5	3.11	4.00	9.32	4.73	5.94
		2.5	3.21	3.96	9.44	4.35	5.48
	Spectra	2.5	3.01	5.35	9.22	4.56	5.77
	Pronto	2.5	2.81	4.62	8.78	4.45	5.64
SED (d.f = 24)			*0.162*	*0.634*	*0.276*	*0.094*	*0.097*
*SED**			*0.150*	*0.572*	*0.301*	*0.102*	*0.092*

* to be used when comparing within humidification regimes

APPENDIX XI

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 24

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.24	2.94	8.92	4.65	5.64
		2.5	3.35	3.69	9.04	4.59	5.56
	Spectra	2.5	3.09	3.43	8.82	4.64	5.45
		2.5	3.06	4.25	8.75	4.59	5.56
Control	Counter	4.5	3.23	2.01	9.03	4.65	5.65
		2.5	3.27	2.17	9.01	4.70	5.65
	Spectra	2.5	2.86	2.44	8.82	4.68	5.61
	Pronto	2.5	2.80	2.87	8.68	4.54	5.52
SED (d.f = 24)			*0.103*	*0.421*	*0.224*	*0.100*	*0.150*
*SED**			*0.078*	*0.269*	*0.219*	*0.076*	*0.099*

* to be used when comparing within humidification regimes

APPENDIX XI

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 28

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.25	2.90	8.44	4.76	6.04
		2.5	3.40	3.57	8.33	4.50	5.75
	Spectra	2.5	2.90	3.79	8.12	4.59	5.73
	Pronto	2.5	3.09	4.36	8.07	4.58	5.78
Control	Counter	4.5	3.02	1.95	8.18	4.91	6.26
		2.5	3.04	2.53	8.63	4.59	5.80
	Spectra	2.5	2.77	3.31	7.95	4.68	5.87
	Pronto	2.5	2.82	30.1	8.36	4.59	5.84
SED (d.f = 24)			*0.077*	*0.344*	*0.225*	*0.084*	*0.080*
*SED**			*0.082*	*0.352*	*0.198*	*0.050*	*0.077*

* to be used when comparing within humidification regimes

APPENDIX XI

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 32

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.33	4.43	9.05	4.63	6.07
		2.5	3.39	5.53	9.04	4.41	5.76
	Spectra	2.5	3.06	5.30	8.69	4.50	5.80
	Pronto	2.5	3.10	6.46	8.80	4.46	5.56
Control	Counter	4.5	3.01	3.12	8.78	4.85	6.37
		2.5	2.96	3.25	8.98	4.46	5.74
	Spectra	2.5	2.85	4.01	8.35	4.59	5.93
	Pronto	2.5	2.78	4.17	8.77	4.45	5.89
SED (d.f = 24)			*0.096*	*0.389*	*0.186*	*0.069*	*0.087*
*SED**			*0.094*	*0.399*	*0.198*	*0.064*	*0.091*

* to be used when comparing within humidification regimes

APPENDIX XI

SHELF-LIFE AND INTERNAL COMPOSITION ASSESSMENTS SOUTHERN ARRAY (COMPARTMENTS 9-16) 1992

Week Number 36

Humidity Treatments	Variety	Conductivity (MS)	Compression (mm)	% Weight Loss (8 Days)	Endpoint pH	% Soluble Solids	% Dry Matter
Humidified	Counter	4.5	3.47	5.26	9.17	4.48	5.80
		2.5	3.77	6.34	9.74	4.19	5.56
	Spectra	2.5	3.57	7.22	8.93	4.48	5.65
	Pronto	2.5	3.35	6.89	8.91	4.39	5.72
Control	Counter	4.5	3.22	3.71	9.66	4.40	5.67
		2.5	3.34	4.26	9.71	4.25	5.64
	Spectra	2.5	3.21	5.31	8.84	4.48	5.66
	Pronto	2.5	3.07	5.14	9.01	4.41	5.72
SED (d.f = 24)			*0.115*	*0.561*	*0.325*	*0.104*	*0.124*
*SED**			*0.082*	*0.428*	*0.234*	*0.093*	*0.114*

* to be used when comparing within humidification regimes

Contract between HRI (hereinafter called the "Contractors") and the Horticultural Development Council (hereinafter called the "Council") for a research/ development project.

PROPOSAL

1. TITLE OF PROJECT **Contract No: PC 30a**

TOMATOES: THE EFFECT OF HUMIDIFICATION ON PLANT GROWTH, YIELD AND FRUIT QUALITY

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Studies undertaken during 1987 and 1988 demonstrated the effect of a limited number of humidity regimes on tomato growth and yield when applied during the early part of the season. These studies were extended further during the 1990/91 season; data collected were consistent across all three experiments. High humidities reduced leaf expansion, yield and fruit quality.

Whilst the effects of humidity on 'early' season production have been and continue to be studied extensively, little attention has been directed towards establishing the effects of humidification during the spring, ie. from April onwards when declining ambient humidities and increased air and fruit temperature are believed to be detrimental to fruit quality.

In an attempt to address this deficiency in our knowledge an HDC funded study was undertaken during the spring/summer of 1991. The objectives of this study were:

To evaluate the effect of humidification on crop growth and yield. To study its effects on the severity of physical disorders of the fruit including blossom end rot; and internal fruit composition.

Preliminary analysis of the results from this study have shown inconsistencies between individual months. However, it is believed that elements of this study warrant further investigation. These data are outlined in section 3 below.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

The financial benefits to the industry while difficult to assess accurately are likely to fall within the following areas. ~~Firstly, there may be an increase in marketable yield and fruit quality in the following areas~~. Firstly, there may be an increase in marketable yield and fruit quality associated with positive humidification of the crop. Data from 1991 indicated that whilst yield was increased by humidification in June (0.3 kg/m^{-2}) this effect was transient; total yield over the experimental period being equivalent in both humidified and control treatments. Fruit quality expressed as the percentage class 1 fruit was reduced over the period July-September, by humidification due to increased incidence of defects such as radial, and

fine net cracking, uneven ripening and gold spot. This despite the fact that during periods of high insolation, humidification was shown to reduce the surface temperature of fully exposed fruit by 5-6°C; clearly this response warrants further investigation. Strong interactions between environment and variety were also evident; it is proposed that in 1992 these interactions be further tested by the inclusion of an additional variety.

Secondly Short
~~A second hypothesis was that production~~ costs may be reduced if humidification was shown to reduce air temperature resulting in later ventilation of the crop and hence more efficient use of summer CO_2. Preliminary analysis of the environmental data for 1991 showed that on days with high levels of insolation humidification could reduce air temperature by 2-3°C. Data pertaining to CO_2 use and levels achieved in the glasshouse were similar in both humidified and control treatments. More detailed analysis of CO_2 use may reveal higher levels achieved coincident with greater insolation.

Studies aimed at optimising the greenhouse aerial environment are clearly prone to considerable seasonal effects. If a direct comparison is to be made of increased returns against the capital costs associated with the installation of humidification equipment, with the aim of fully evaluating the practise of spring/summer humidification, a further study is warranted.

Studies of this type may also have major implications for other commodities. There is presently interest in the use of humidification to manipulate the aerial environment associated with the production of pot plants. System comparisons of the type proposed here for tomato may therefore provide valuable indications prior to such studies being undertaken.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

The study outlined in this proposal must, as in 1991, aim to quantify the effect of positive humidification in association with a number of sub treatments on:-

a. The growth, yield and fruit quality of a long season tomato crop.

b. The aerial environment, measured as achieved air temperature, vapour pressure deficit, and CO_2 level.

c. Treatment effects on financial returns must also be fully evaluated.

5. CLOSELY RELATED WORK

It is proposed that in 1991/92 the multifactorial unit at HRI Efford will be used to expand, using alternative

Examination of the effects of summer conductivity is likely to be of interest not only because of the implications for fruit quality but also the clear response to high EC (4mS applied vs 2 mS) in increasing the yield of class 1 fruit recorded in 1991.

Records taken will include:

1. Total and graded yield.
2. Incidence and severity of fruit disorders (including blossom end-rot).
3. Fruit internal composition. CO_2 use.
4. Shelf life data.
5. Fruit temperature data.
6. Full monitoring of the greenhouse aerial environment including CO_2 use.
7. Time elapse meter readings for all fog solenoids indicating fogging frequency.
8. Daily monitoring of root zone pH and EC levels.
9. Weekly nutrient analysis of applied feed and slab solution.

Availability of Results

Interim results will be made available to HDC through the course of the treatments with a full report to follow on completion of the work.

7. COMMENCEMENT DATE AND DURATION

October 1991 (MAFF element)

April 1991 (HDC element)

The HDC element will run for the duration of the season, unless otherwise determined by the severity of treatment effects.

8. STAFF RESPONSIBILITIES

Project leader (local): Dr David J Hand - HRI-Efford

Project leader/Optimisation of the aerial environment: Dr K E Cockshull - HRI Littlehampton

9. LOCATION

HRI Efford (M-Block).

Contract No: PC/30a

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature.....

Position... Commercial Marketing Manager....

Date..... 20.1.92.....

Signed for the Contractor(s)

Signature.....

Position.....

Date.....

Signed for the Council

Signature.....

Position... CHIEF EXECUTIVE.....

Date..... 16.12.91.....