Horticulture Research International, Stockbridge House, Cawood, Selby, N.Yorks.

PROJECT REPORT

To:
Horticultural Development Council
Bradbourne House
Stable Block
East Malling
Kent
ME19 6DZ

Tomatoes CO_2 Survey

PC110

July 1996

Commercial – In Confidence

FINAL REPORT

Project Number:	PC110
Project Title:	Tomatoes: CO_2 Survey
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Key Words:	Tomatoes: CO_2 enrichment, distribution, cropping systems.

Authentication

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

Signature .....Caroline Hufton.....

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Contents

Aim

The primary aim of the survey was to collect information on current CO_2 practices, in terms of setpoints, achieved levels and methods of introduction.

A second objective was to provide information on cropping systems, growing environment and crop productivity.

The work will include monitoring distribution of CO_2 in crops. These results will be reported in a separate report during 1996.

Introduction

CO_2 enrichment is now universally accepted as beneficial to tomato production and the prctice is widely carried out. Many sytems have developed and growers have independently devised their own systems. Introduction systems, setpoints and acheived levels vary widely.

By collating the data collected in this survey it is aimed to gain an understanding of how CO_2 use could be optimised.

Materials and Methods

A questionnaire (see Appendix I) was developed in collaboration with representatives of the tomato industry. 19 members of both the Northern Tomato Grower Group and Tomato Working Party completed questionnaires and provided yield data at the end of the season.

Data from the questionnaires was collated and graphically presented to show spread and variation in practices.

Summary

A survey was carried out to determine the range of growing practices and CO_2 enrichment regimes in use by growers in the North and South of the UK.

The primary aim of the survey was to collect information on current CO_2 practices, in terms of setpoints, achieved levels and methods of introduction.

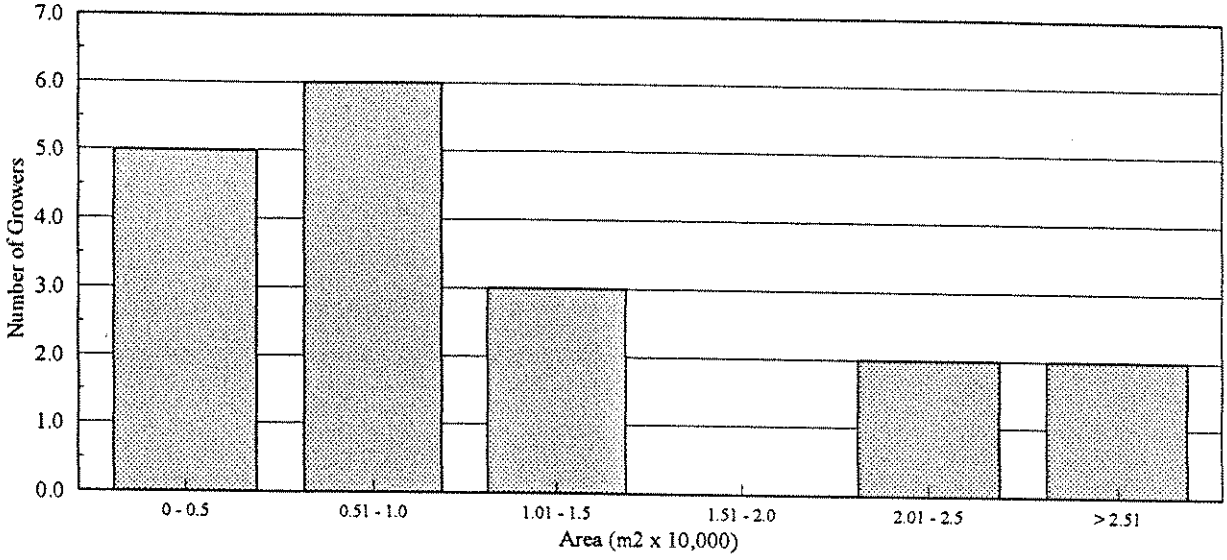
A second objective was to provide information on cropping systems, growing environment and crop productivity.

Conclusions

- Growing practices varied widely between growers and there was no standard system for CO_2 enrichment across the UK.
- Setpoints for CO_2 enrichment ranged between 900 - 1500 ppm in the winter with no clear differences between those growers using gas to provide the CO_2 and those using pure CO_2.
- Several growers using pure CO_2 (5 growers) were able to supply figures on CO_2 usage during the winter. Usage varied widely, ranging from 1.86 to 7.0 T/ha/week. There was no correlation between setpoint and usage.
- Summer CO_2 setpoint varied widely ranging from 0 - 1200 ppm.
- Several growers reducted the CO_2 enrichment setpoint as glasshouse ventilation percentage increased (7 out of 19 growers), reducing the CO_2 setpoint to 100 - 450 ppm. Growers who did not reduce their CO_2 setpoint with ventilation were growers who were burning gas to obtain their CO_2.
- 5 out of the 19 growers had incorporated a change in CO_2 setpoint with light.
- Summer CO_2 use varied greatly, from 2.88 to 9.0 T/ha/week for those growers who were using summer enrichment.
- There was no correlation between summer usage and CO_2 enrichment setpoint or between summer usage and reported acheived level. This may indicate that other factors have a greater effect in determining the amount of CO_2 used, for example leakiness of the glasshouse.
- All eight growers burning gas to obtain their CO_2 had buffer tanks installed on the nursery. These tanks ranged in capacity from 54,000 to 135,000 l/ha.
- Information on the calibration of CO_2 analysers indicated that there was no standard calibration method and no standard frequency of calibration. The wide variation in measured outside CO_2 concentration suggests that calibration of analysers as currently practiced may not be accurate.
- There was no clear correlation between summer yields (May - Early Sept) and either summer CO_2 setpoint or measured achieved level.

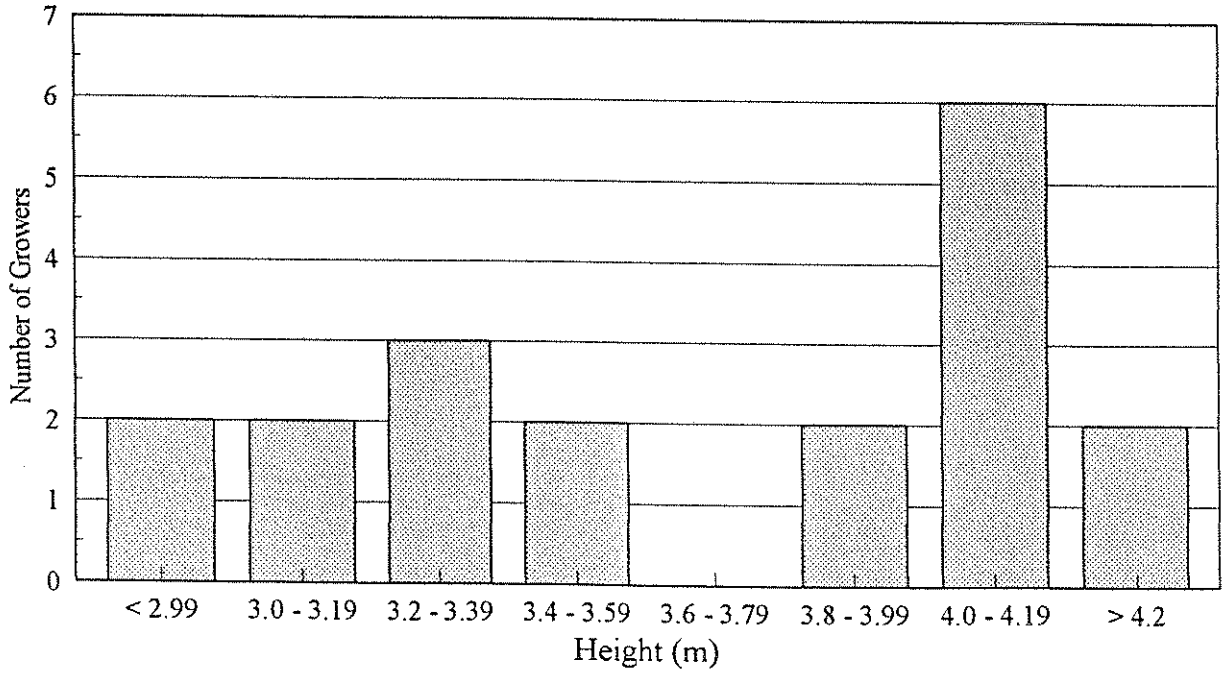
Section 1: Nursery and Glasshouse Details

Figure 1 - Glasshouse Area (m2) of Sampled Blocks



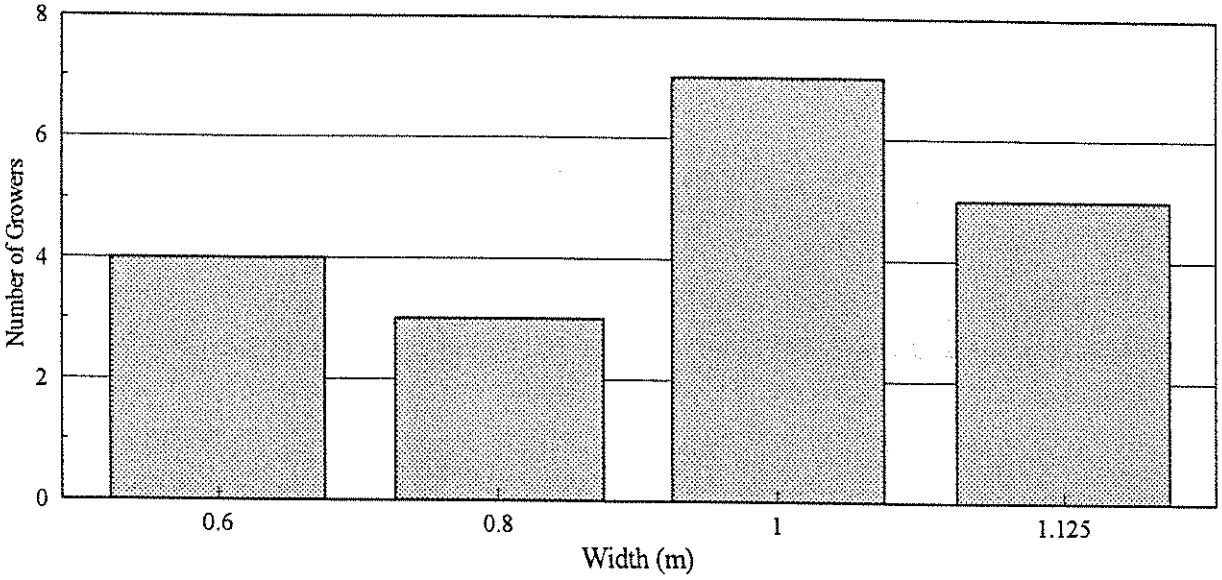
The survey covered 19 growers, and the blocks chosen for assessment varied in size from 0.09 ha (0.22 acre) to 4.51 ha (11.15 acre).

Figure 2 - Height of Glasshouse to Gutter (m)



The height of the glasshouses to the gutter ranged from 2.6 m to 4.2 m. 42 % of growers were growing in houses with guttersat least 4.0 m high

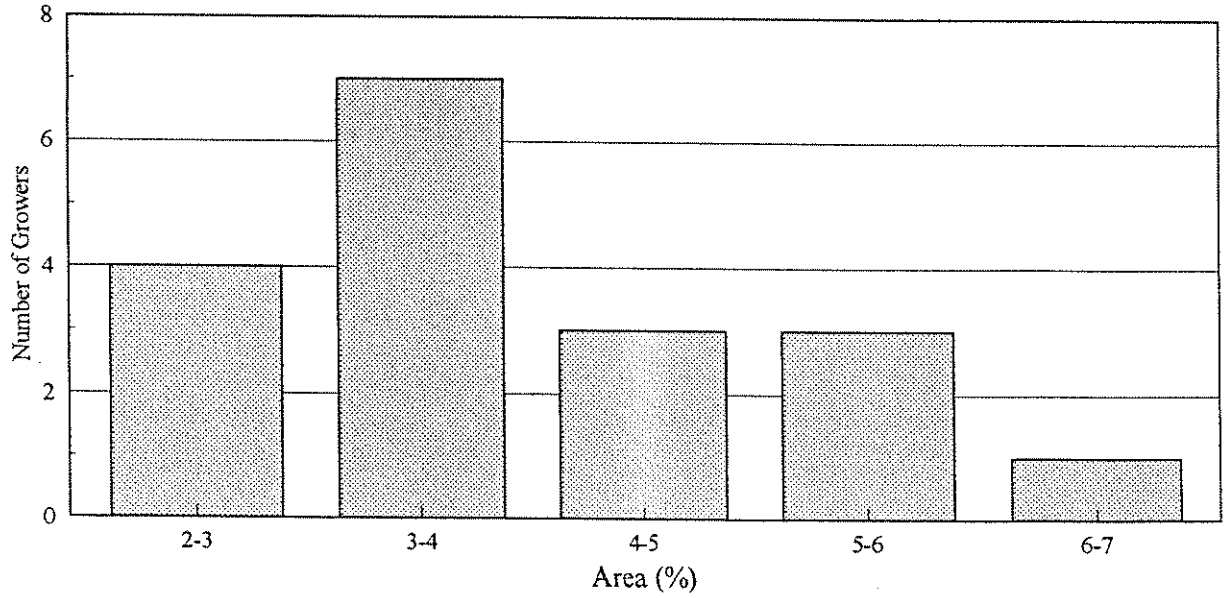
Figure 3 - Width of Glass Panes (m)



Glass width varied from 0.6 m to 1.125 m. 63 % of growers use glasshouses where the glass is at least 1.0 m wide.

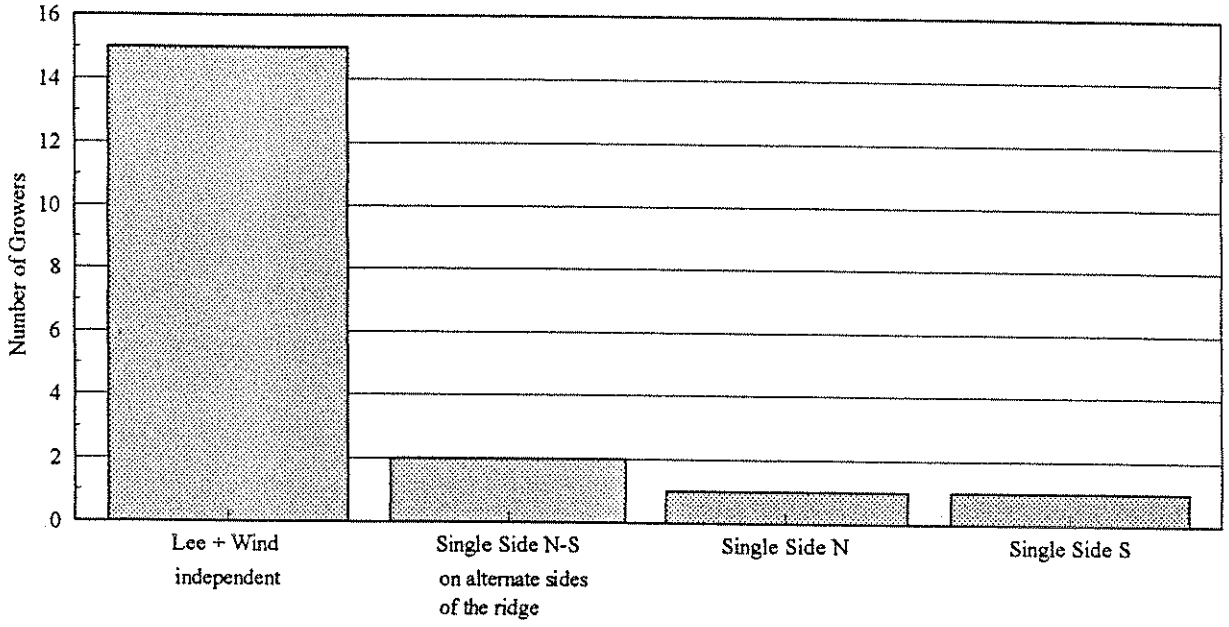
74 % of the growers who responded to the survey are growing in Venlo glasshouses. The remaining 26 % are growing in Hancock 1122, Frampton Ferguson and Cambridge.

Figure 4 - Percentage Uncropped Area



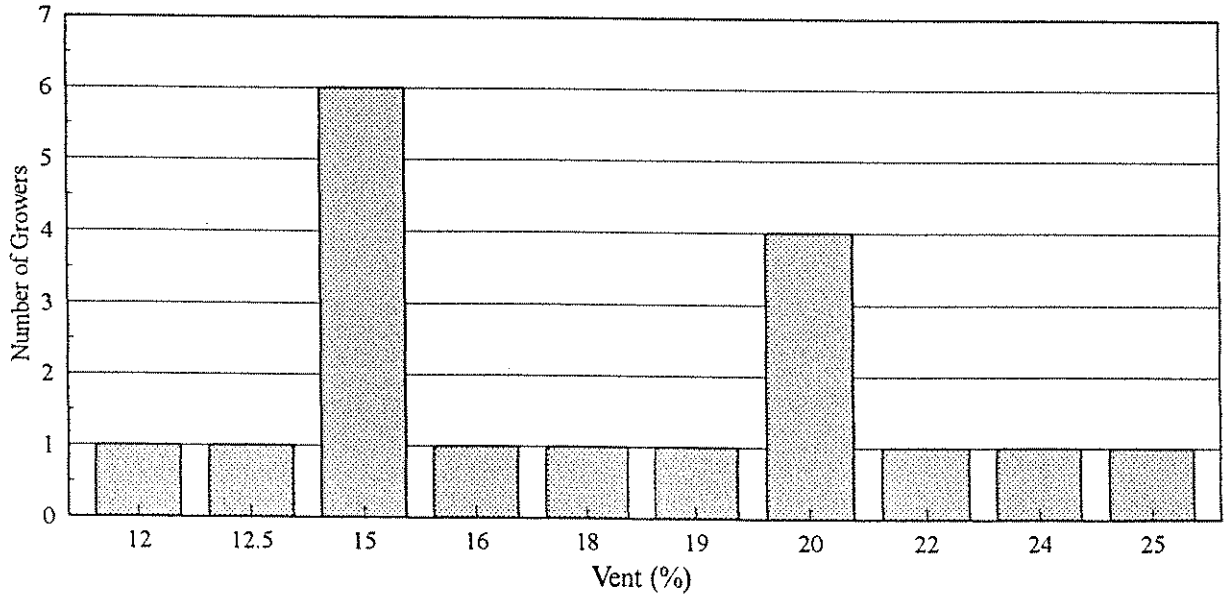
Most growers (58 %) work with less than 4 % uncropped area. The maximum uncropped area was 6.3 %.

Figure 5 - Vent Arrangement and Control



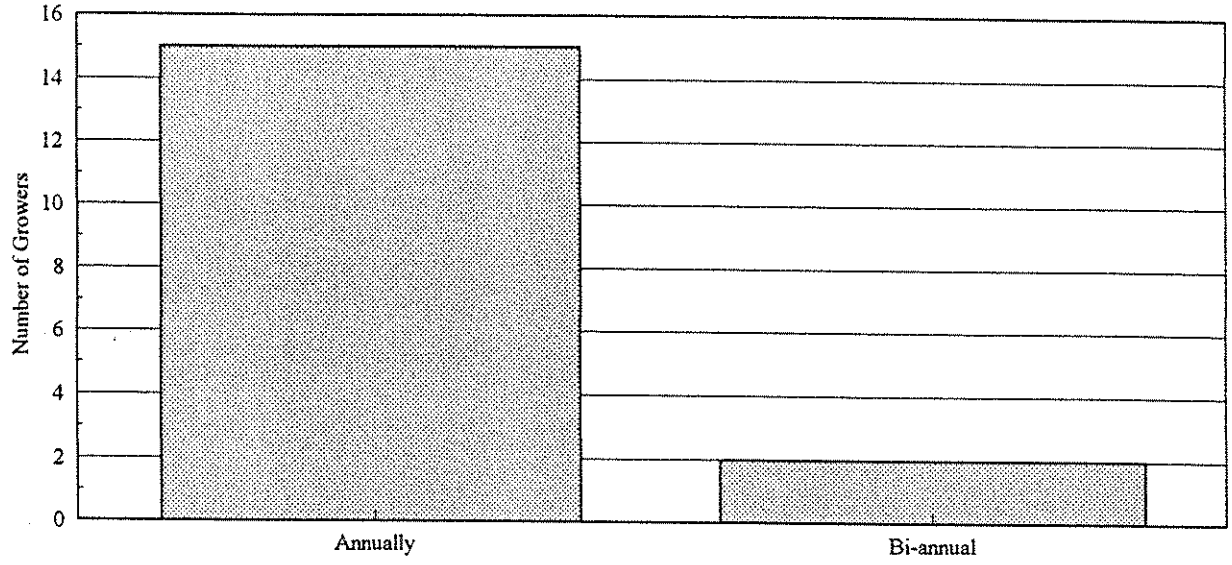
Most growers (79 %) had Leeward and Windward vents which could be controlled independently by the environmental computer. The remaining 21 % only had single sided ventilation.

Figure 6 - Ventilation Area (As a Percentage of Glasshouse Floor Area)



Only 11 % of growers had less than 15 % ventilation, 22 % had an area of greater than 20 %.

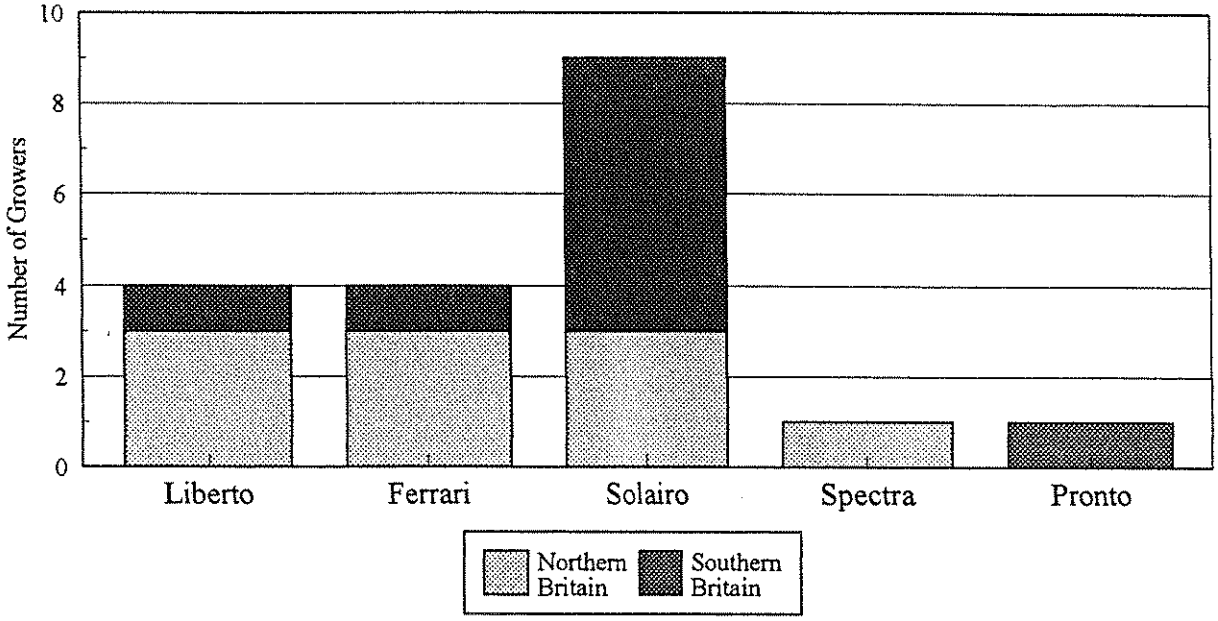
Figure 7 - Glass Cleaning Frequency



Most growers (79 %) wash their glass once a year and two growers wash their glass twice a year.

Section 2: Crop Details

Figure 8 - Variety



In 1995 only 5 varieties were grown in the blocks used in the survey. The varieties Liberto, Ferrari and Solairo were grown across the country with Solairo being grown mostly in the South. Spectra was grown by only one grower in the North and Pronto by one grower in the South.

Figure 9 - Density Increase With Sideshoots

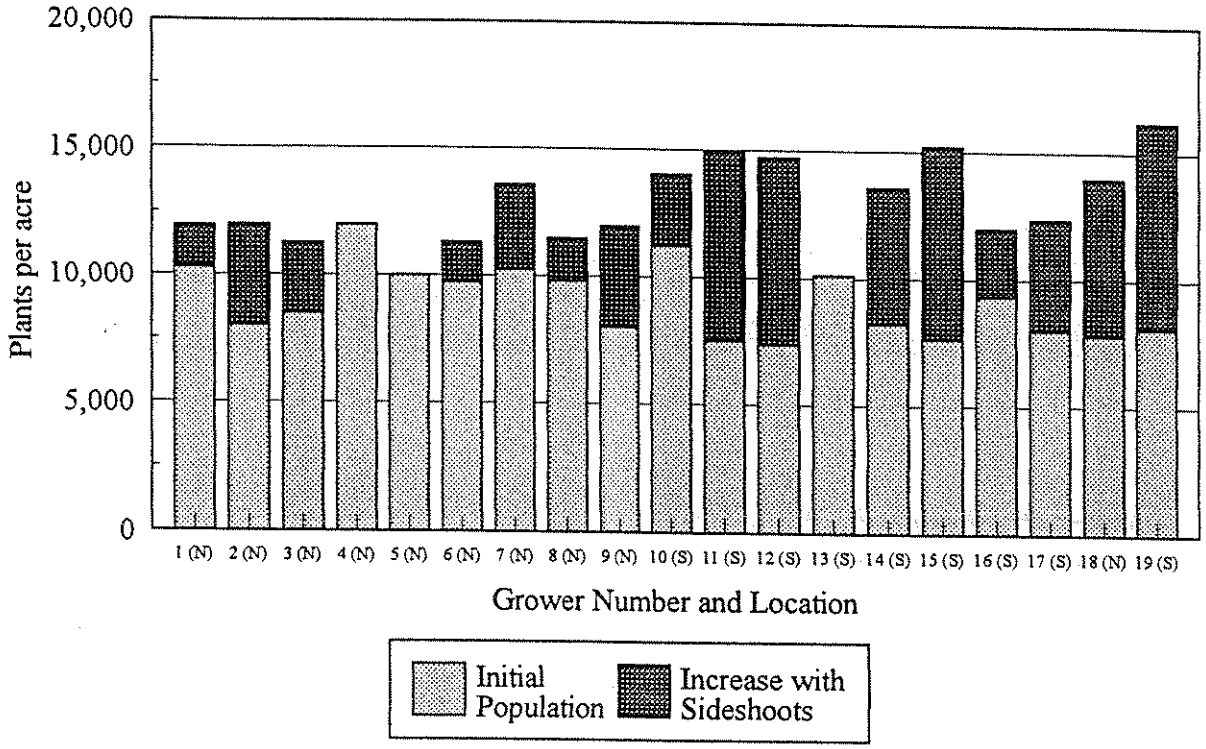
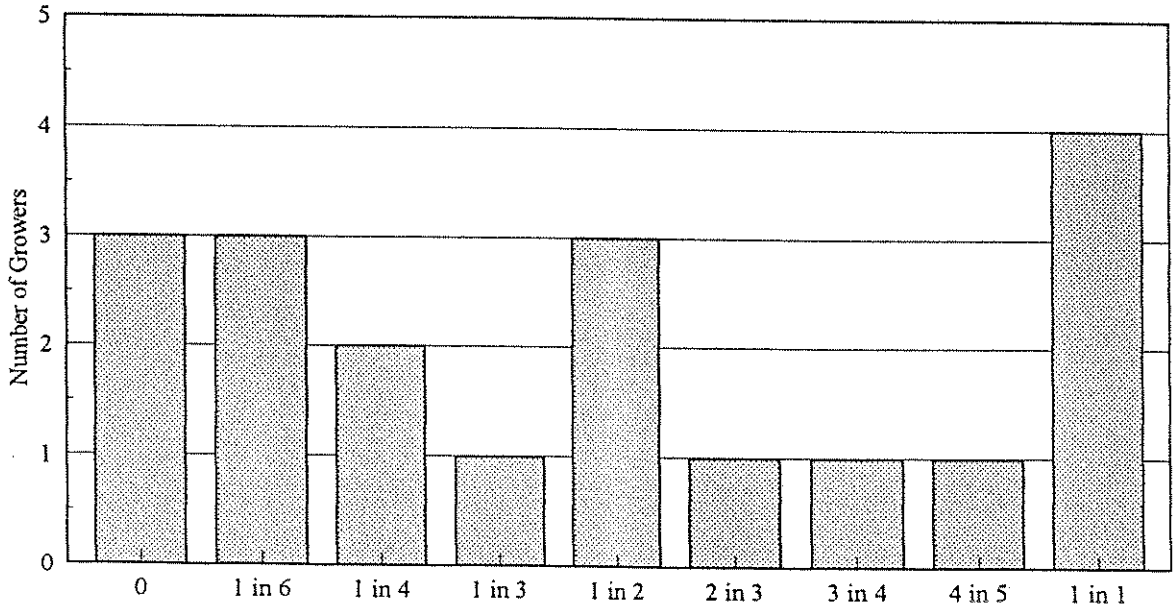
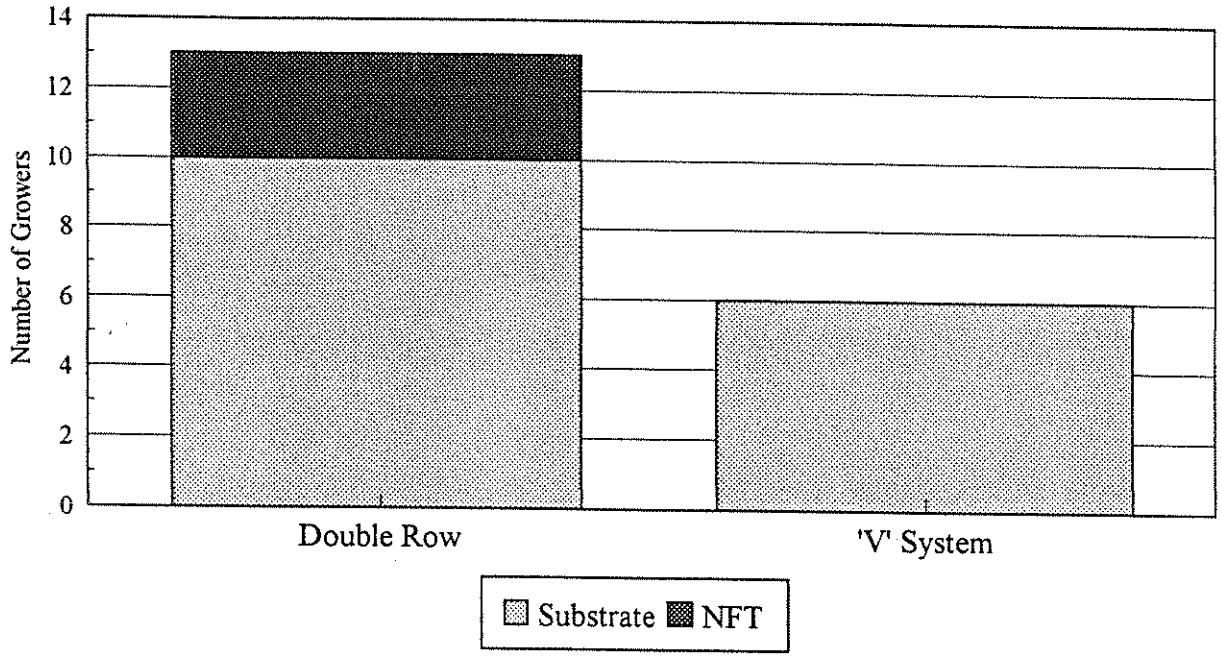


Figure 10 - Number of Sideshoots Taken



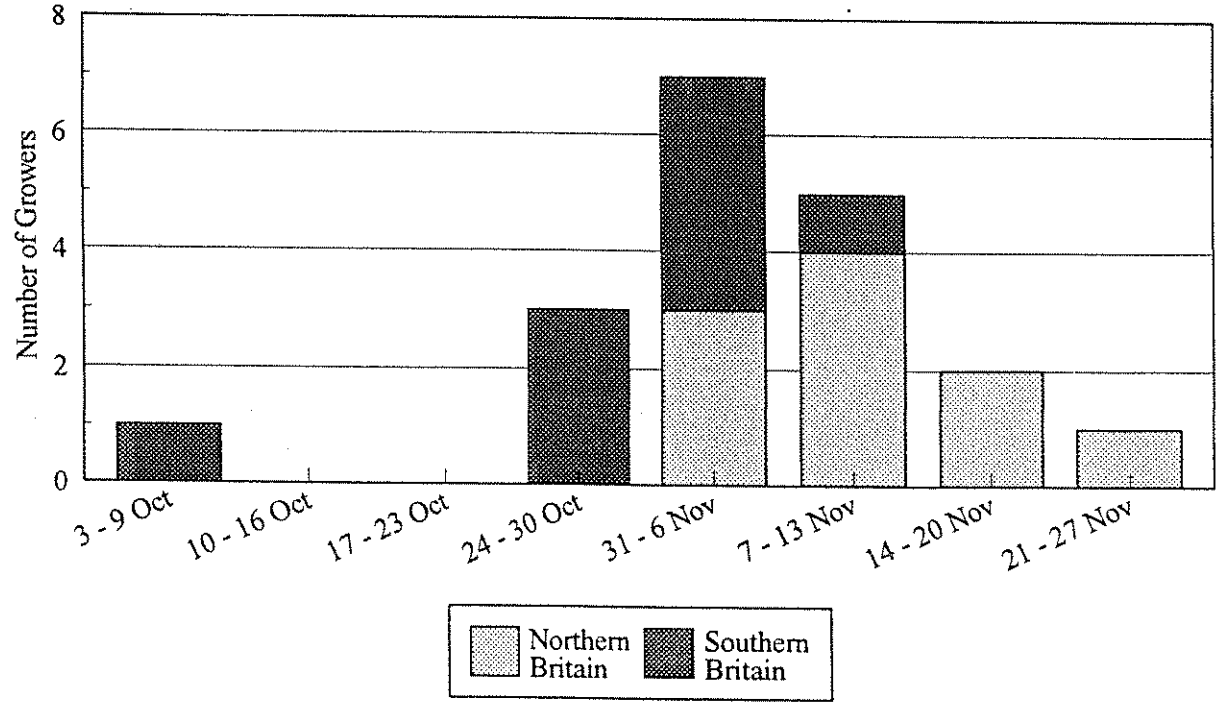
Initial plant densities ranged from 7,366 to 12,000 plants per acre (18,200 to 29,650 plants per ha). 84 % of growers increased their population using sideshoots to give final populations ranging from 11,280 to 15,200 plants per acre (27,900 to 37,600 plants per ha). The number of sideshoots taken varied from 1 shoot in 6 heads to 1 every plant. Generally growers in the south took more sideshoots than those in the north.

Figure 11 - Training System



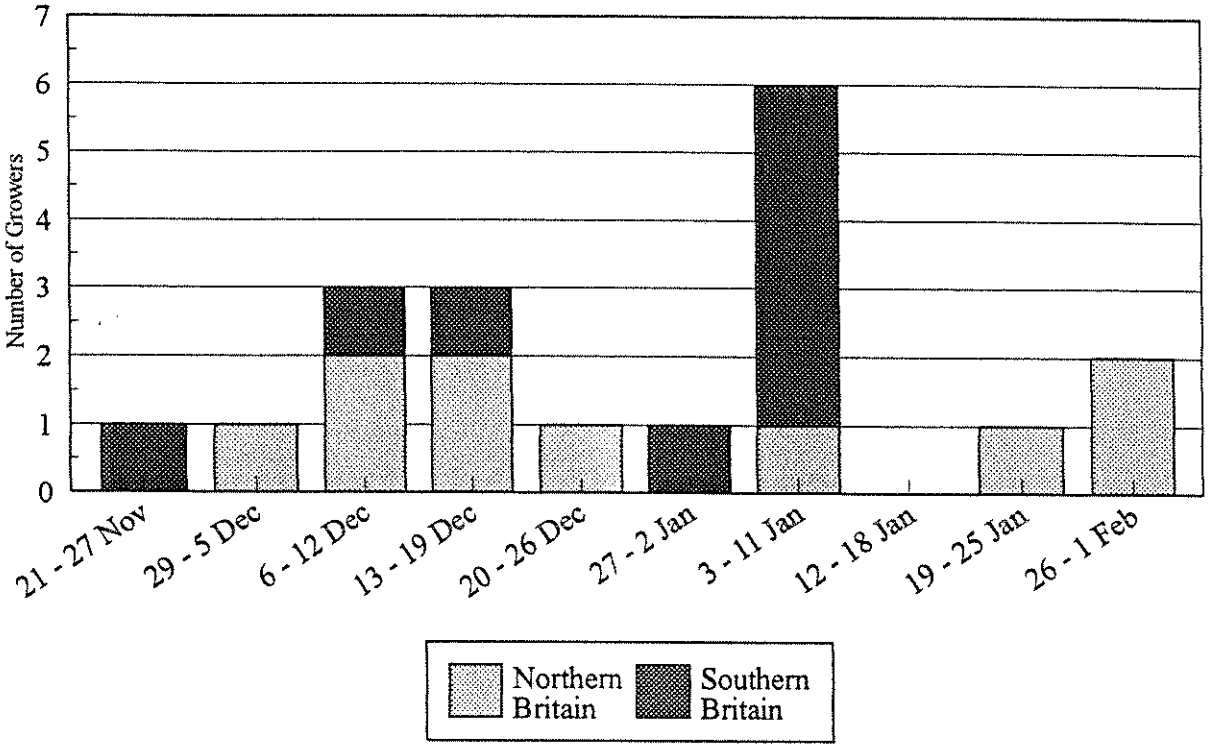
Of the 19 growers, 6 were growing in the 'V' system. 3 growers use double row NFT.

Figure 12 - Sowing Date



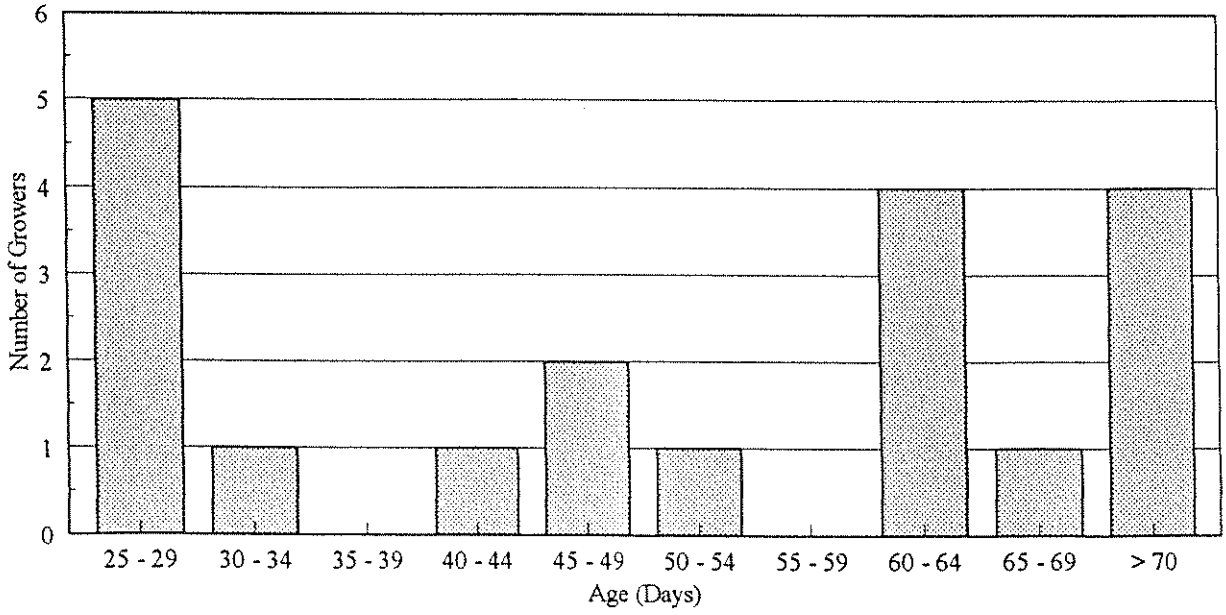
Sowing date ranged from 3 October 1994 to 22 November 1994. Most of the early sowings (during October) were made by growers in the South while only Northern growers sowed after 10 November.

Figure 13 - Planting Date



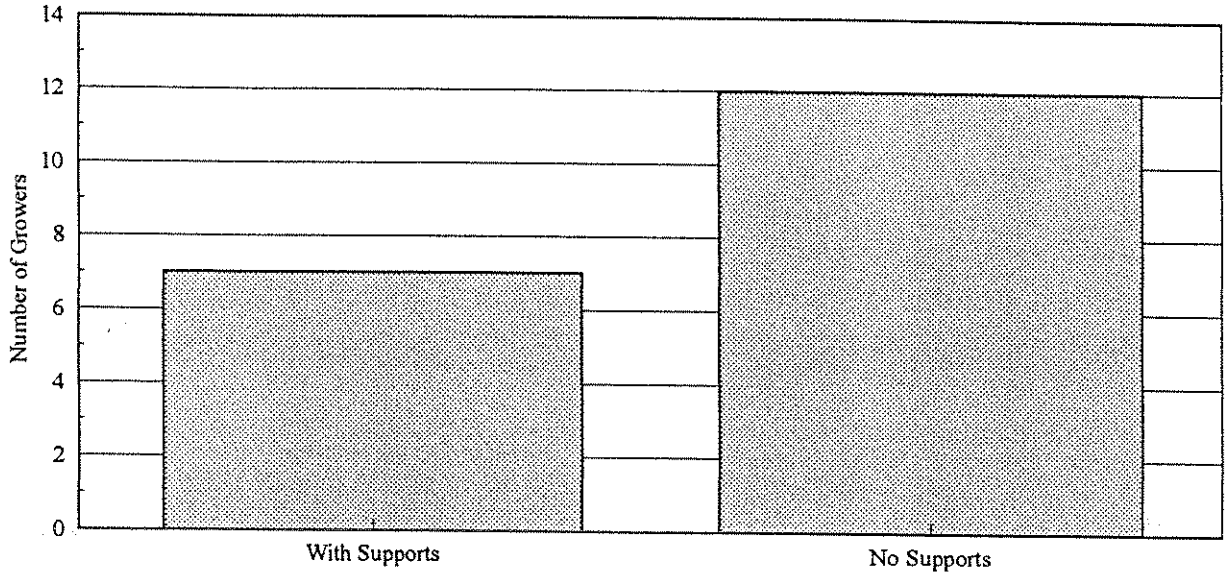
Planting date ranged from 22 November 1994 to 30 January 1995. These dates varied across the country.

Figure 14 - Age at Planting



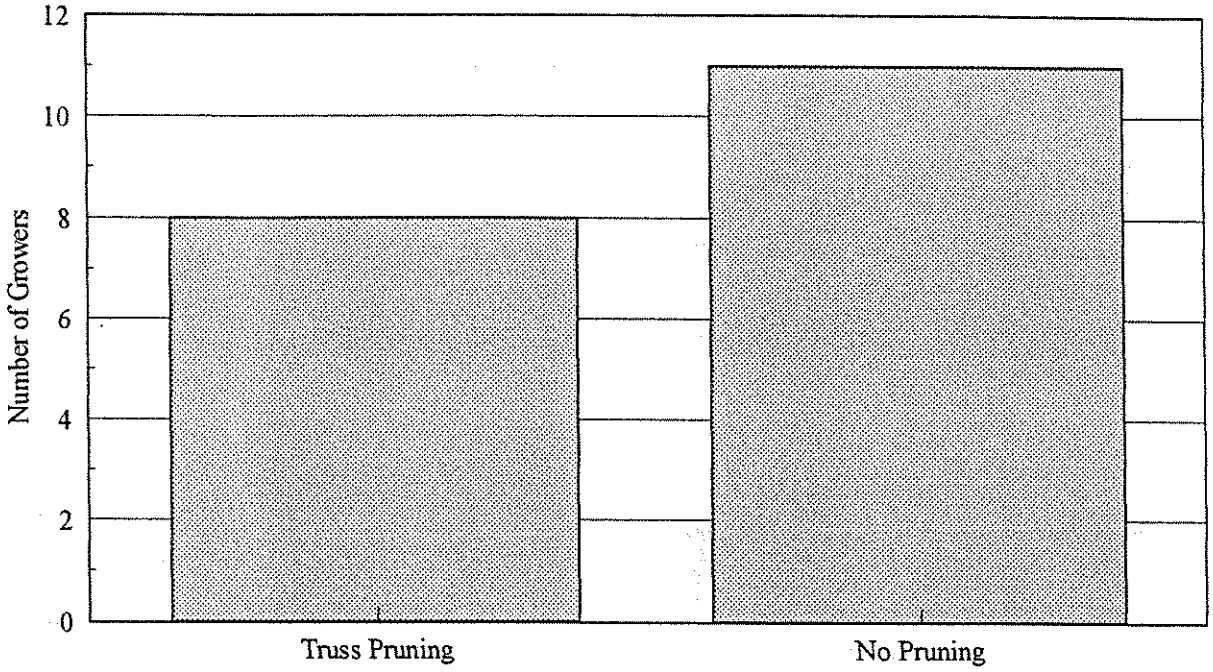
Growers reported planting ages ranging from 25 - 84 days. The variation may be attributed to differences in interpretation between standing out and slab contact. The differences may also be accounted for by the reporting of the date NFT growers turned to full flow NFT.

Figure 15 - Truss Supports



5 growers used truss supports. The trusses supported were generally trusses 1 to 8 with some growers selecting a few trusses within this range i.e. trusses 4, 5 and 6.

Figure 16 - Truss Pruning



42 % of growers truss pruned. The trusses pruned were generally trusses 1 to 8 and the number of fruit left on the truss varied from 6 to 8 with some growers pruning all trusses to the same number and others pruning the lower trusses to less than the higher ones.

An example truss pruning regime from one grower.

Truss Pruned	Number of Fruit Pruned to
1	6
2	7
3	8
4	8
5	8
6	8

Figure 17 - EC set-points - To First Pick *

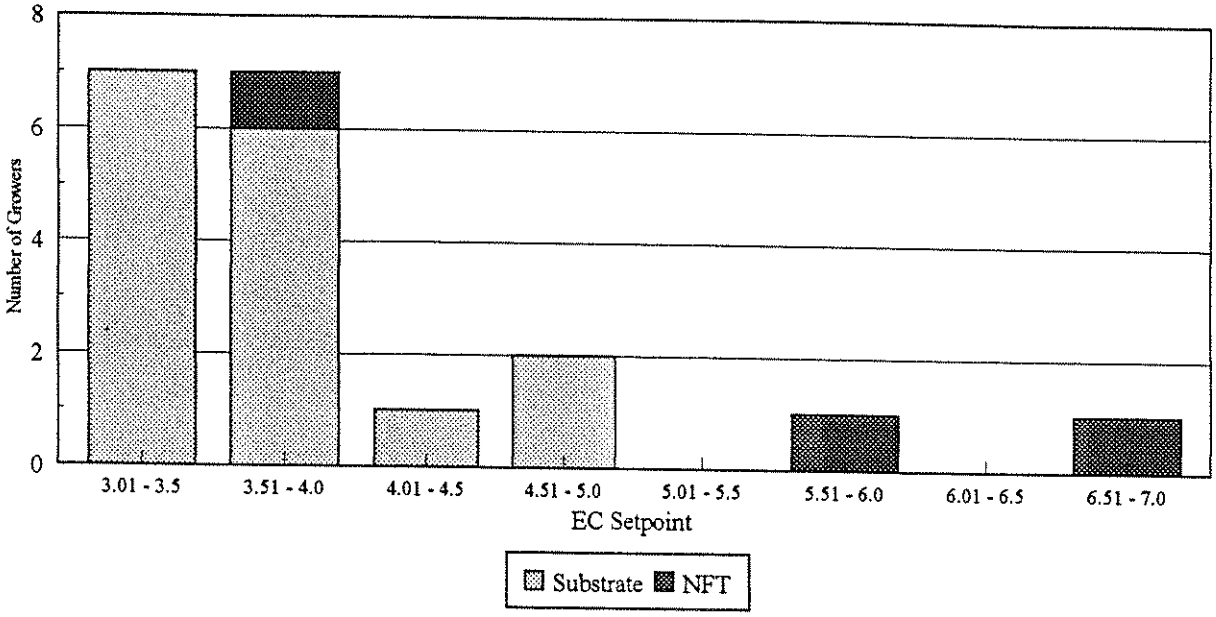
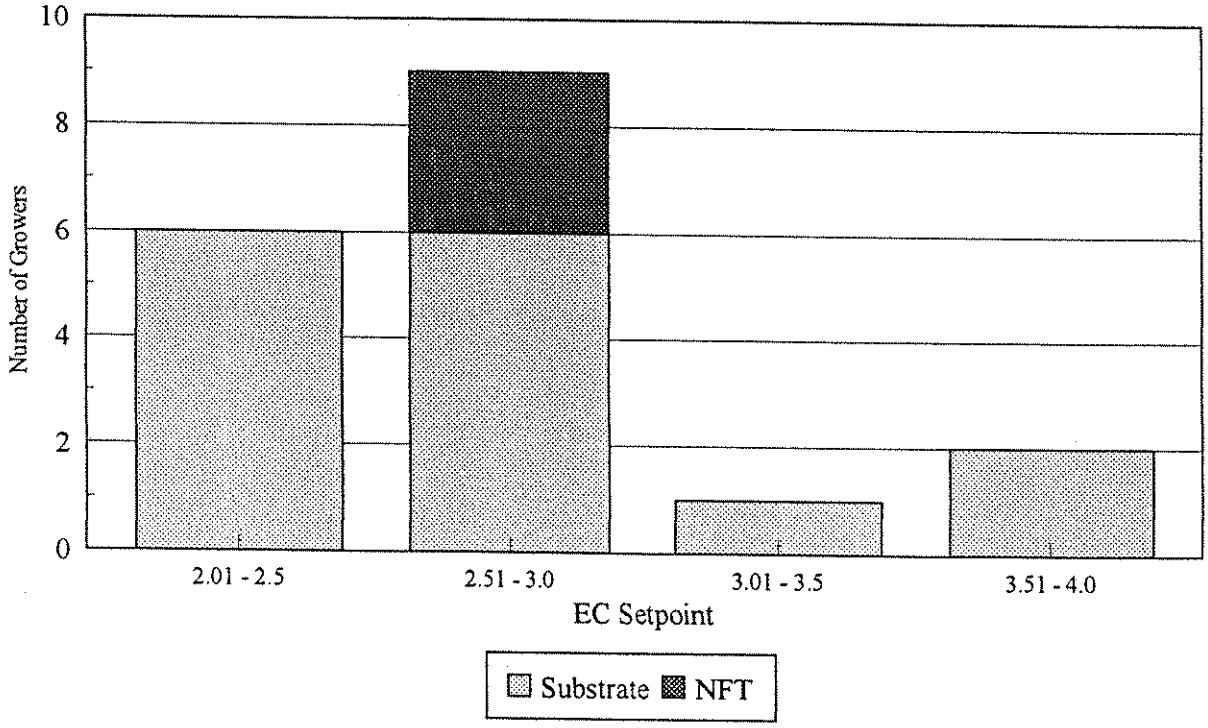


Figure 18 - EC set-points - Main Season *

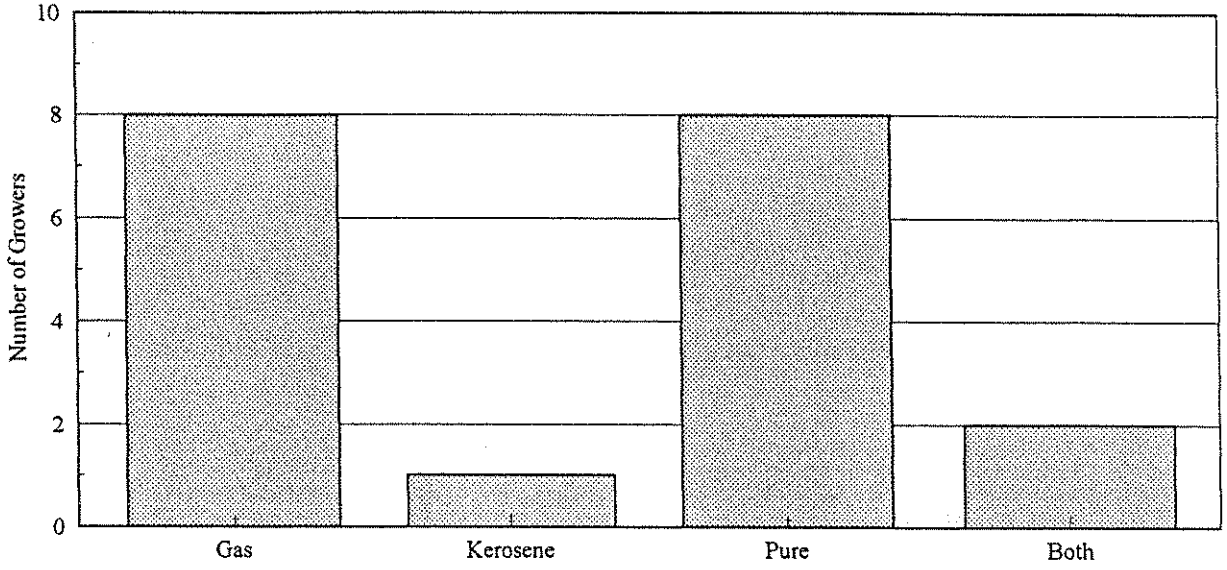


EC setpoint varied from 3.2 to 7.0 (to first pick) and 2.0 to 4.5 (for main season cropping). The highest settings were used by those growers using NFT in the early season, but in the main season NFT setpoint were no higher than rockwool setpoints. 3 growers reported using drain control techniques to maintain EC control.

* - For those growers who reported an EC range the median value has been selected.

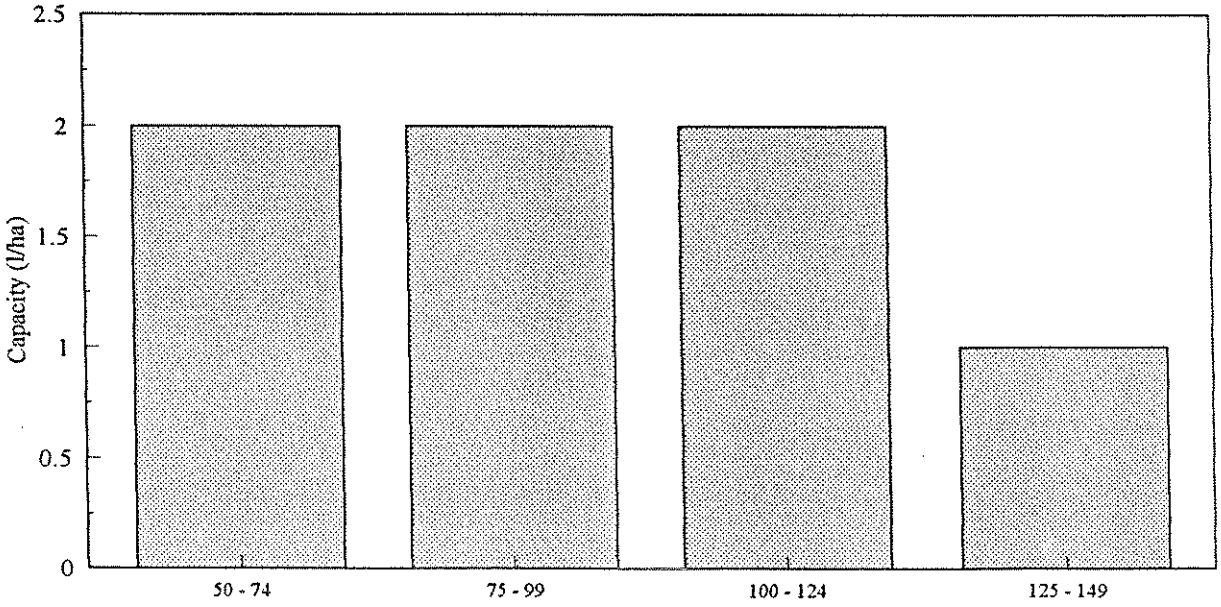
Section 3: CO2 Source and Enrichment

Figure 19 - CO2 Source



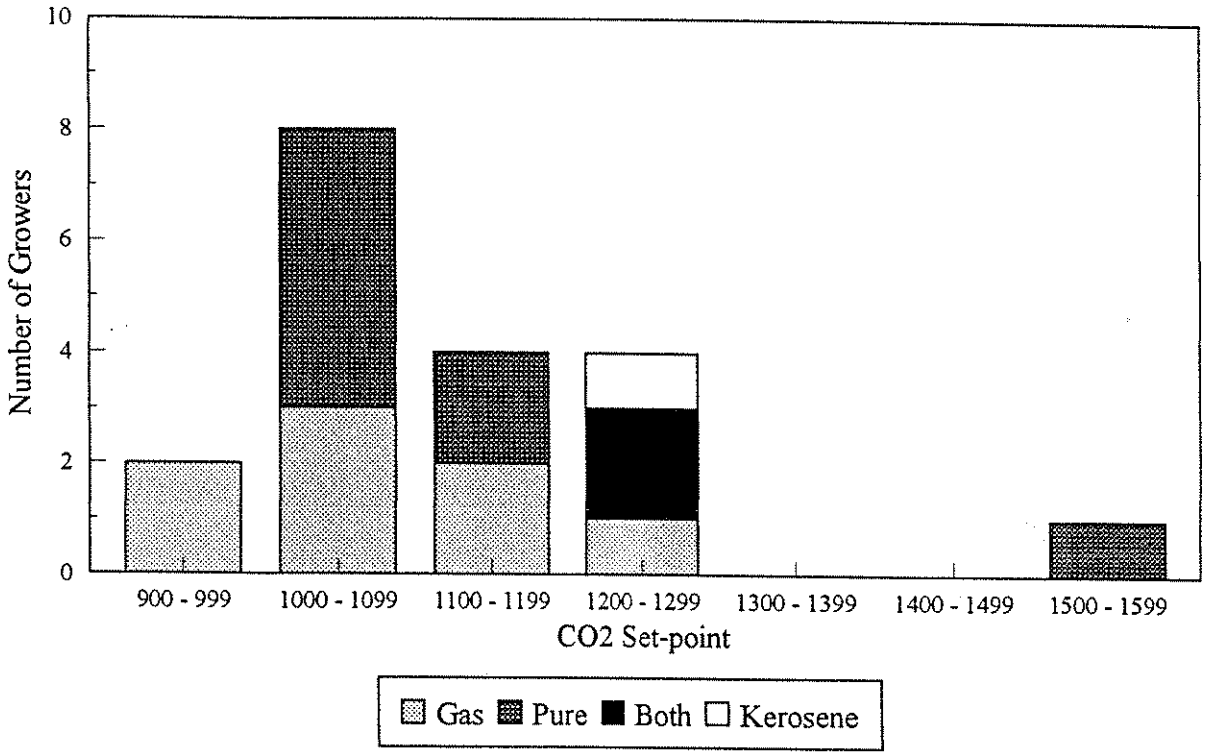
8 growers obtain their CO2 by burning gas, and 1 from burning kerosene.
8 growers rely on pure CO2. 2 growers had both systems, gas and pure, installed.

Figure 20 - Buffer Tank Capacity



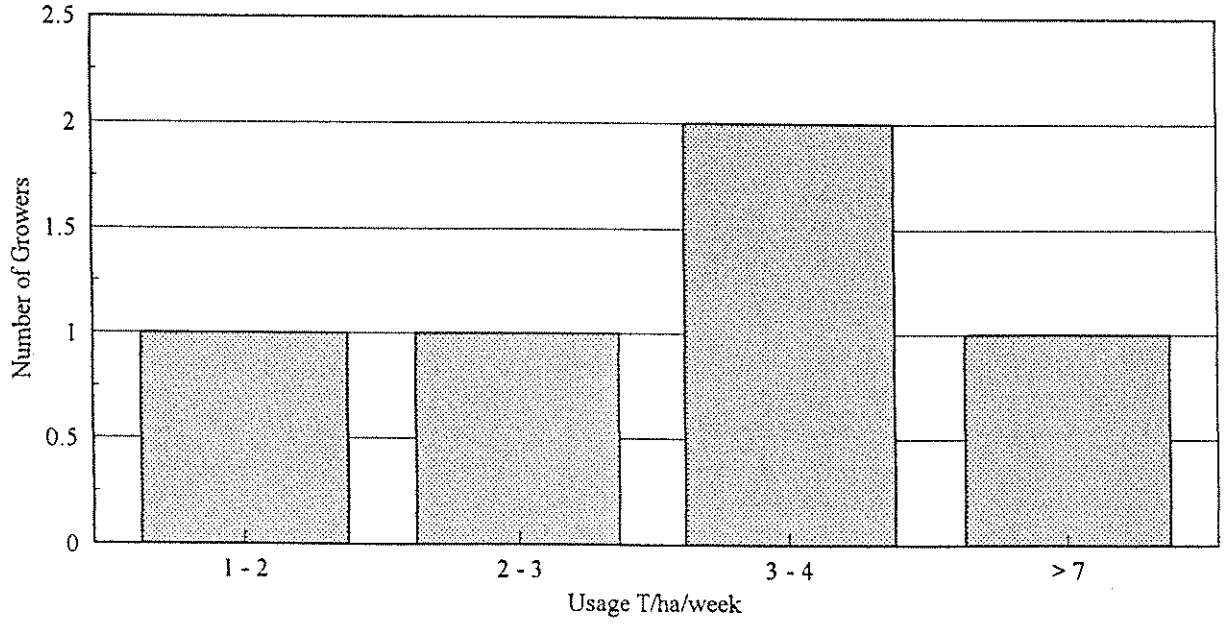
Of the growers using gas for the production of CO2, all had buffer tanks, varying in capacity from 54,000 to 135,000 l/ha (reported volumes).

Figure 21 - Winter CO2 Regime



Winter CO2 setpoint ranged from 900 to 1500 ppm.

Figure 22 - Winter CO2 Usage



5 growers could provide this information, these were growers who enriched using pure CO2. Usage ranged from 1.86 to 7.0 T/ha/week.

Figure 23 - Summer CO2 Regime, setpoint with no vent

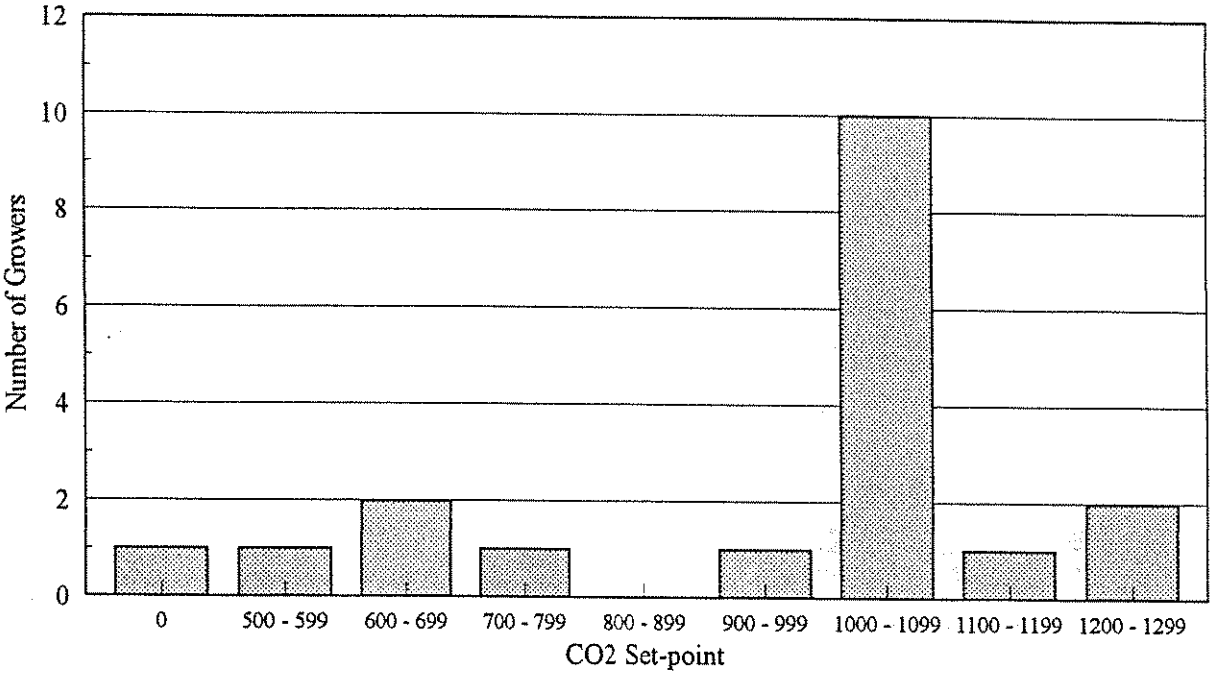
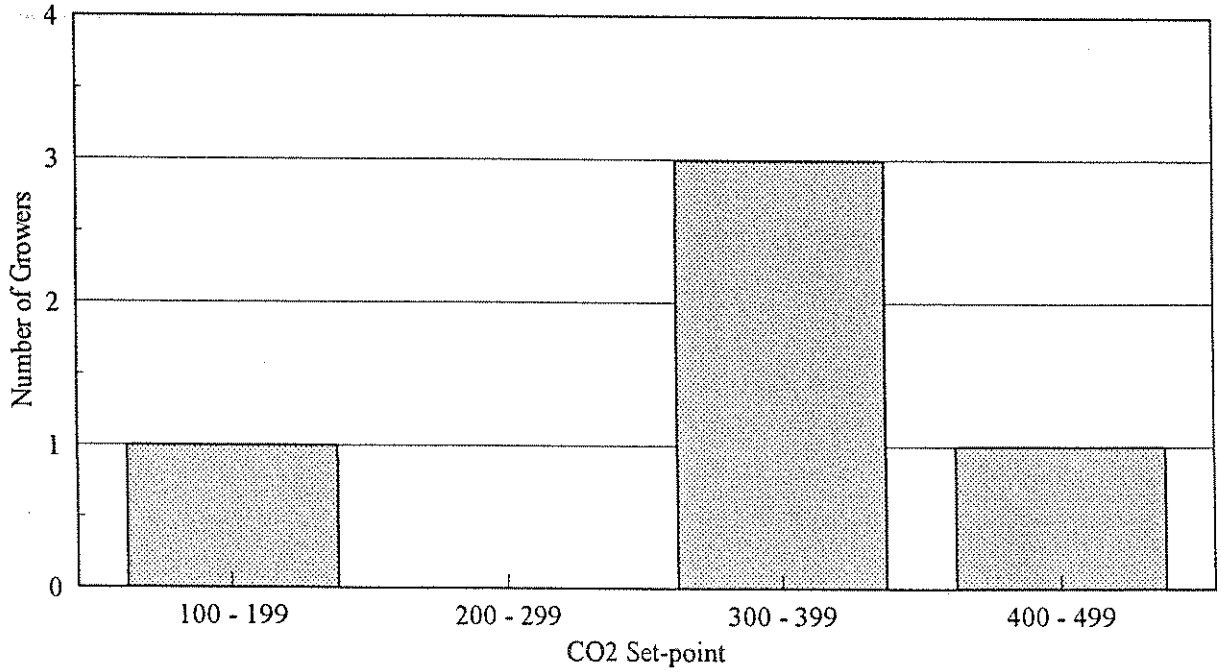
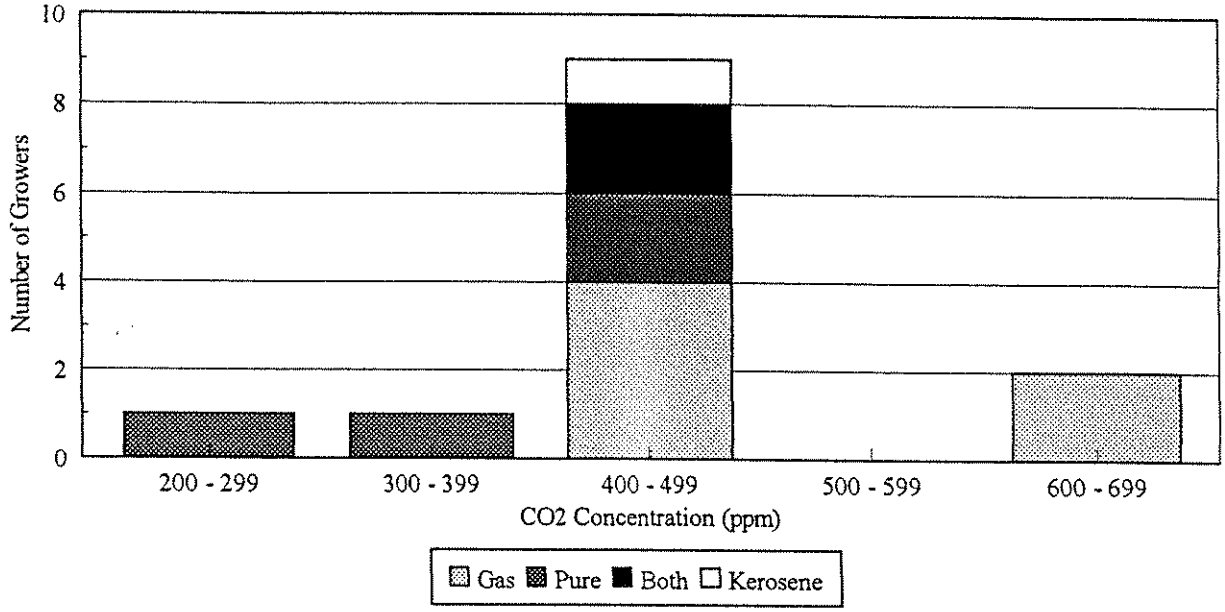


Figure 24- Summer CO2 Regime, setpoint with vent



Summer CO2 setpoints ranged from no enrichment to 1200 ppm when the vents were shut. With a ventilation percentage setpoint ranging from 5 to 50% 7 growers reported lowering CO2 setpoints. Most of the growers who didn't change setpoints with ventilation (10 out of 11) were growers using gas. 5 growers indicated a change in CO2 regime with light intensity.

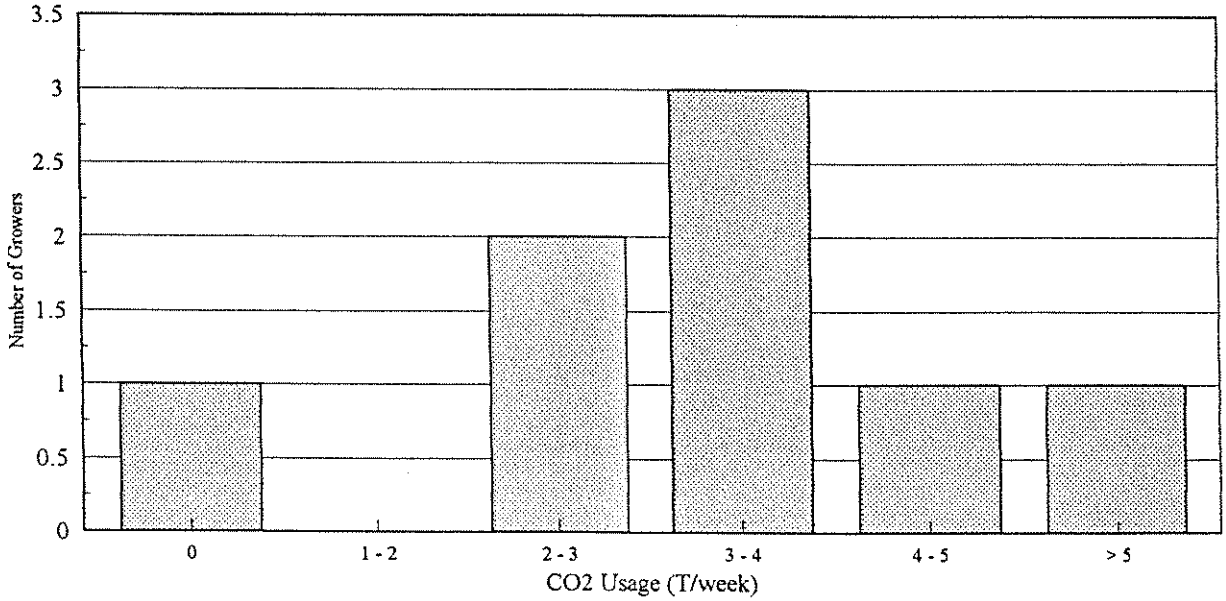
Figure 25 - Typical CO2 Level Achieved during the Summer Period



14 growers provided information on level of enrichment acheived during the summer period. This ranged from 280 to 600 ppm.. Higher levels of enrichment were maintained by growers using gas than those using pure CO2.

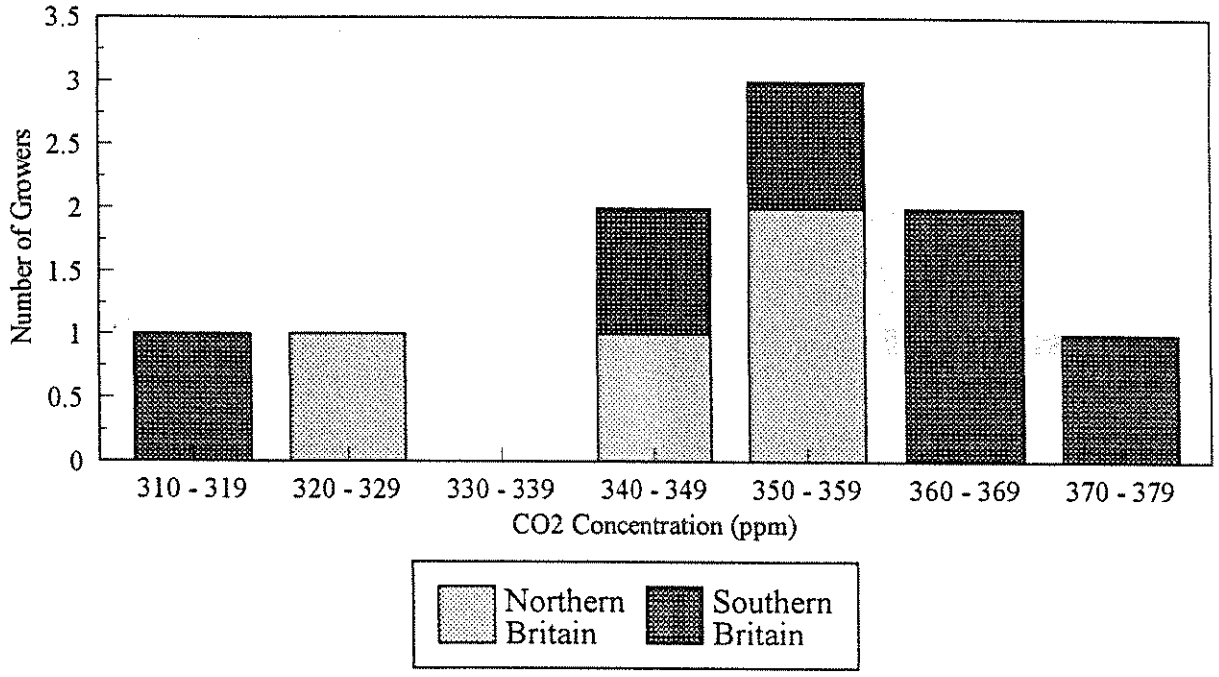
Monthly achieved CO2 levels are shown in Appendix I, where available. Many growers were unable to provide accurate data on achieved levels.

Figure 26 - Summer CO2 Usage



Summer CO2 usage ranged from 2.88 to 9.0 T/ha/week. Growers who were able to report CO2 usage were those growers using pure CO2.

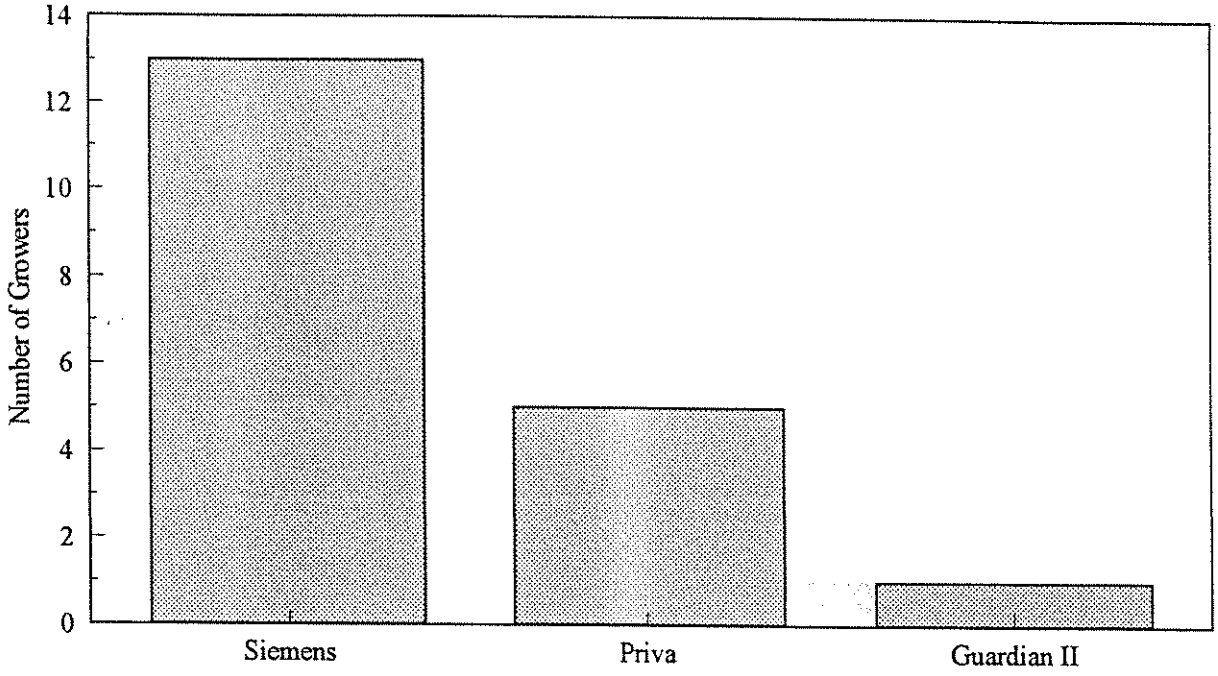
Figure 28 - Outside CO2 Levels



10 growers measured outside CO2 concentration, which ranged from 315 to 370 ppm.

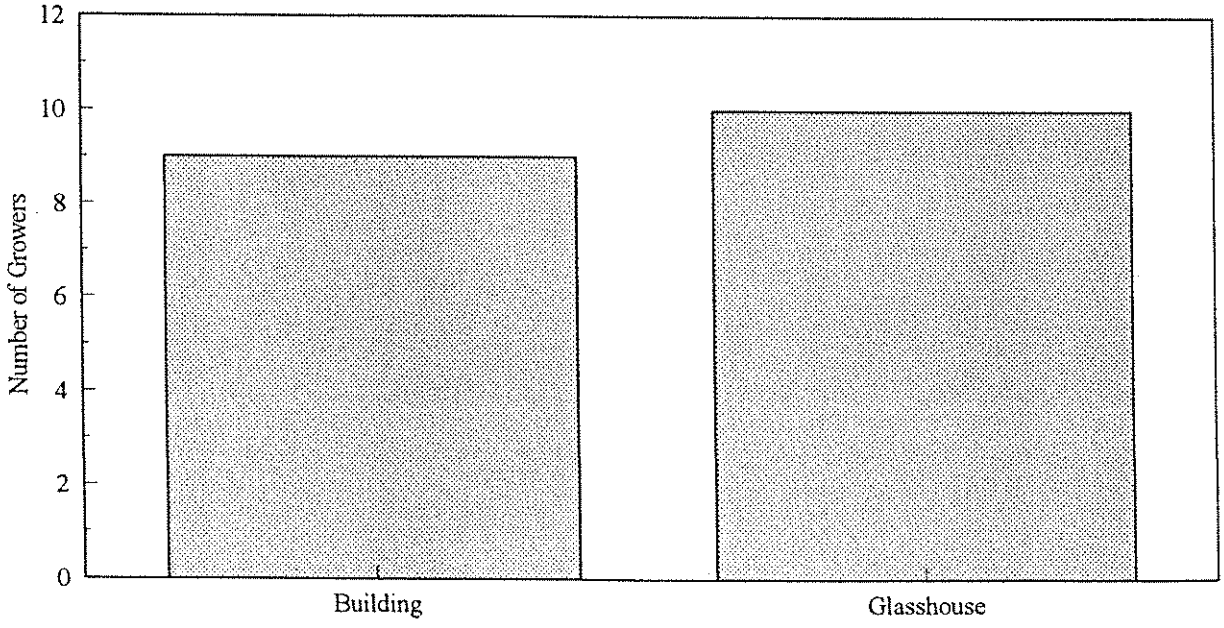
Section 4: CO2 Control System

Figure 29 - Type of CO2 analyser used



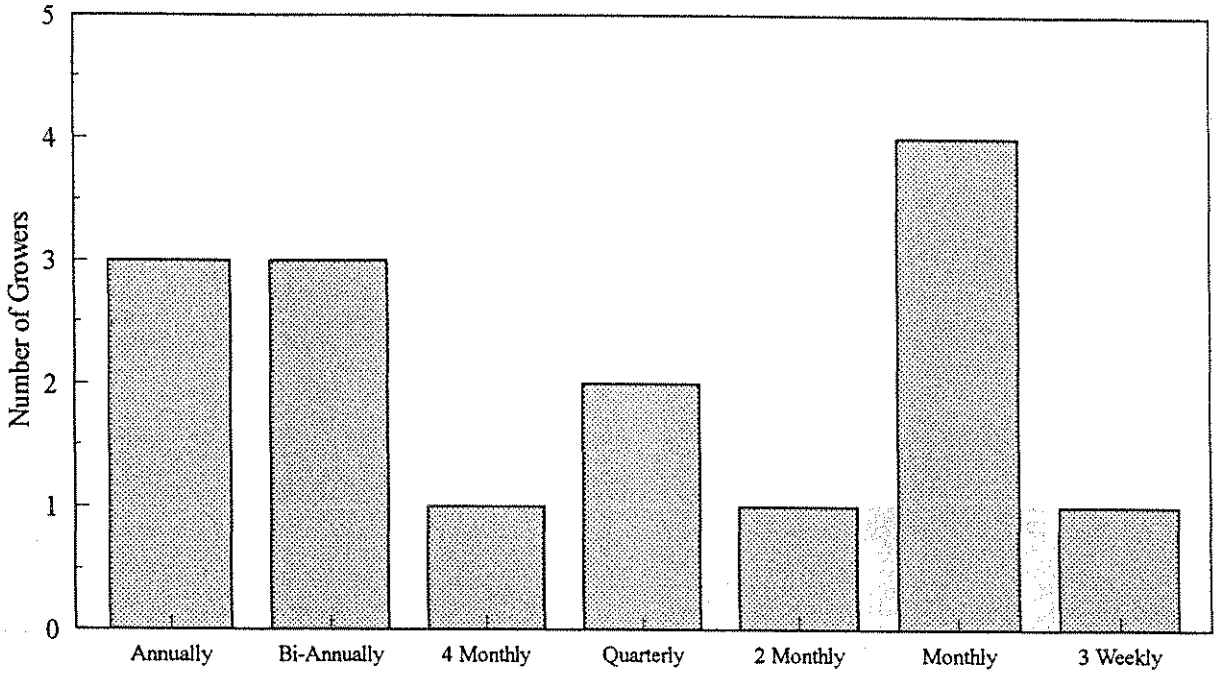
13 growers used Siemens analysers, 5 used Priva type and 1 used a Guardian II.

Figure 30 - Siting of CO2 Analyser.



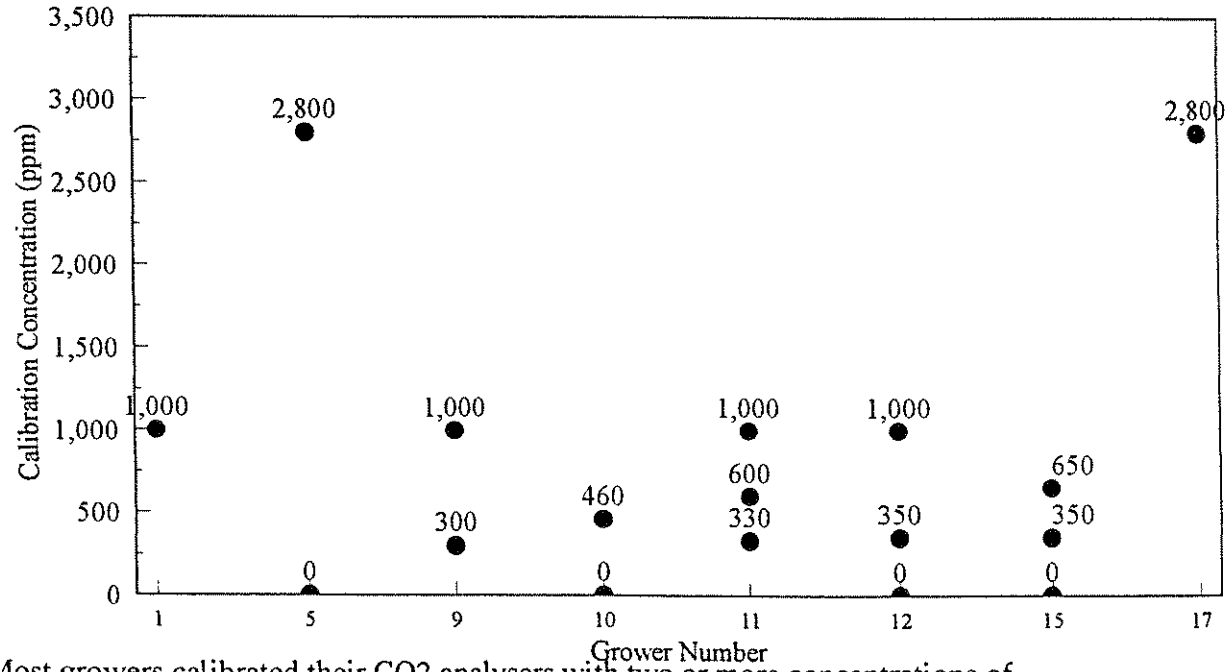
Out of the 19 growers 10 sited their CO2 analysers in a glasshouse rather than in a building.

Figure 31 - Calibration frequency of CO2 Analyser.



Most growers calibrated their CO2 analysers regularly, ranging from every 3 weeks to once a year. Most were calibrated either annually, twice per year or monthly.

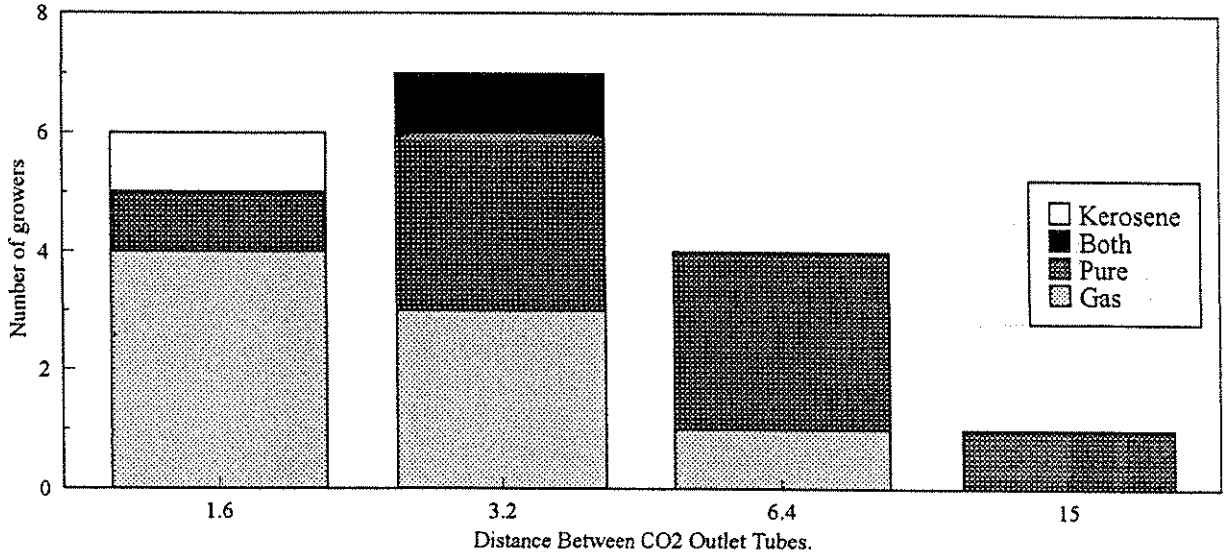
Figure 32 - Calibration Gas Concentration Used.



Most growers calibrated their CO2 analysers with two or more concentrations of calibration gas. 6 growers used calibration gas concentrations which were close to the setpoint level, which will produce more accurate measurement in the required range. 2 growers calibrated the analyser at it's maximum scale reading, 2800 ppm.

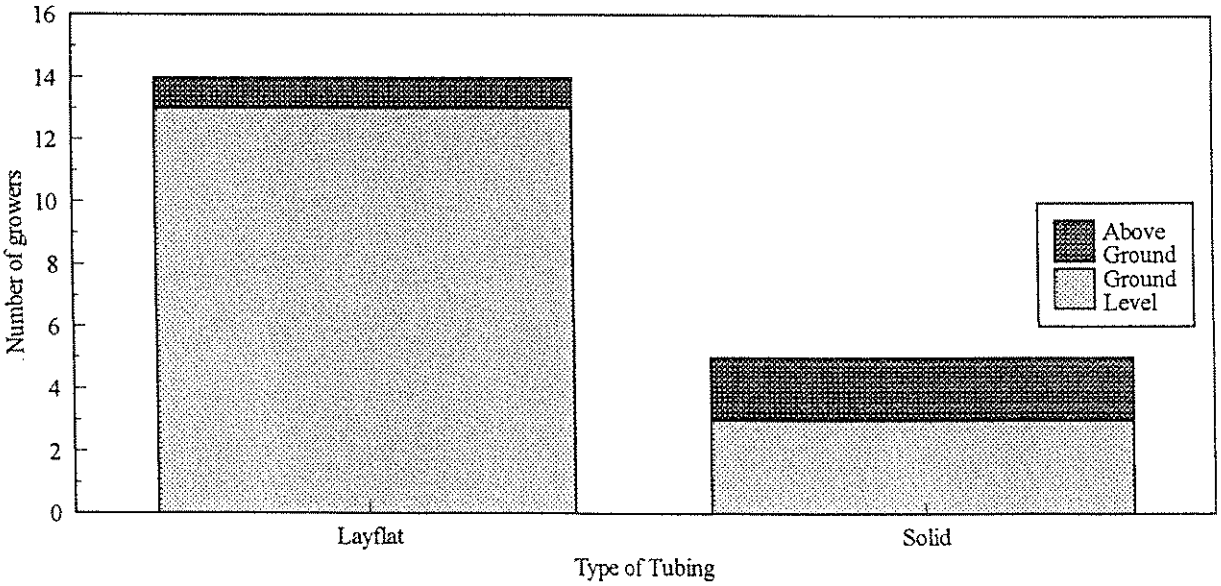
Section 5: CO2 Distribution System

Figure 33 - Spacing of Distribution Tubes.



The spacing of the distribution tubes varied from 1.6 m (i.e. one every row) to 15 m The commonest spacing was 3.2 m apart (i.e. one every other row). Hole spacing on the tubes ranged from 30 cm to 6.0 m and hole size was mostly 0.75 mm with a 2 growers having smaller holes (0.5 mm) and a 2 larger holes (1.0 mm).

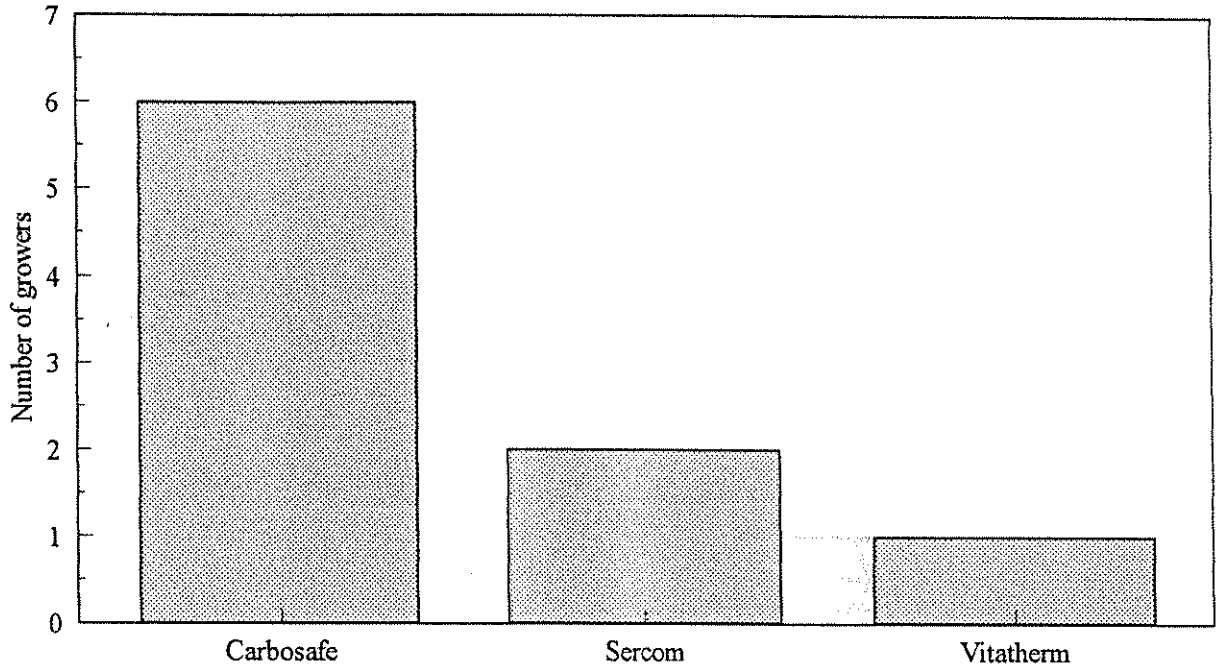
Figure 34 - Type of Tubing and Situation in Glasshouse.



Most growers use layflat tubing positioned at ground level for their CO2 distribution system. Only 3 growers placed their tubes above ground level with the distance above the ground varying from 0.5m to 3m. One grower had CO2 tubes at two heights within the same crop, 1m and 3m. The type of tubing used was dependant on the source of CO2 with all the growers using solid tubes using pure CO2 and all the growers using gas having layflat tubing..

Section 6: Pollution Monitoring System

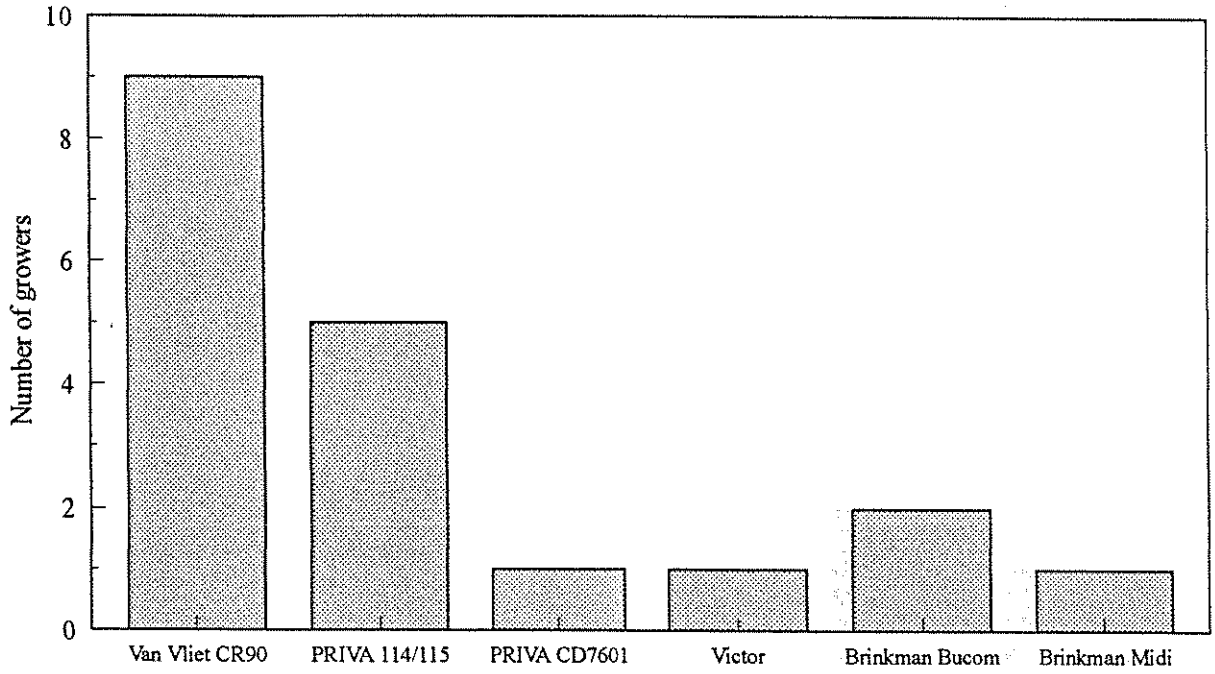
Figure 35 - Pollution Monitoring Equipment.



Nine growers have a pollution monitoring analyser, mostly Carbosafe analysers from Priva. The control mechanism used varied from immediate system shutdown on detection of any carbon monoxide (CO) to switching off at 10, 12, 15 and 30 ppm CO. Only one grower reported pollution problems of yellowing leaves due to high levels of pollutants in the glasshouse.

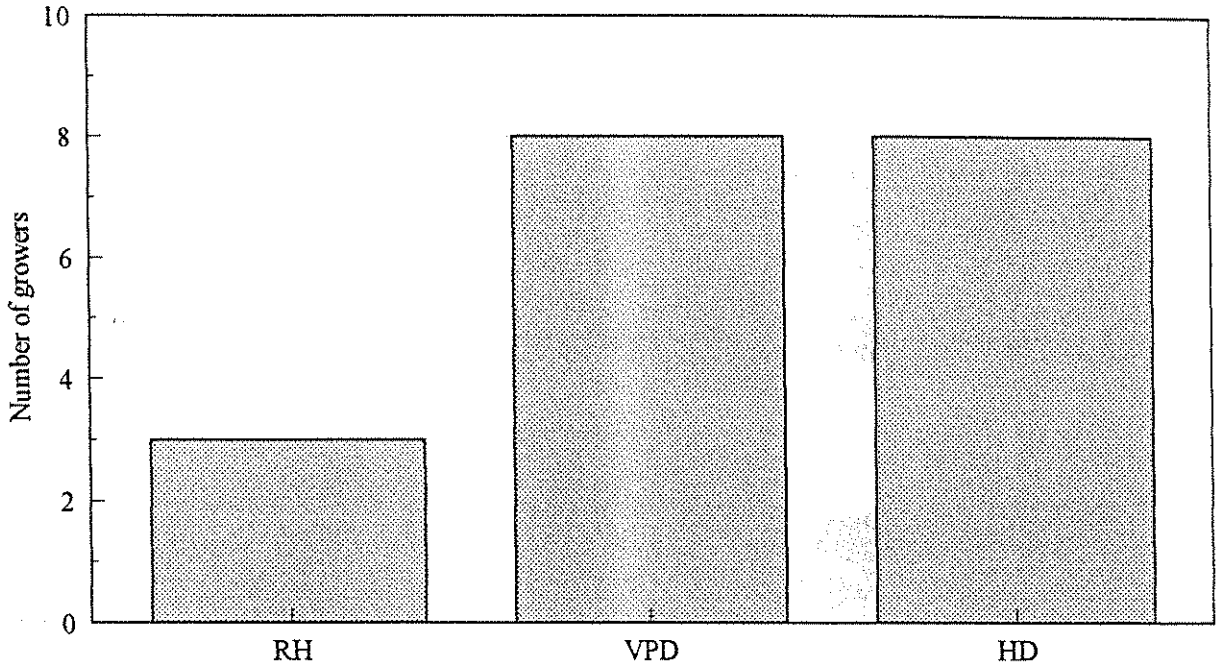
Section 7: Environmental Control System

Figure 36 - Environmental Monitoring Computer.



The most commonly used environmental monitoring computer reported in the survey was a Van Vliet CR90 computer.

Figure 37 - Humidity Control.

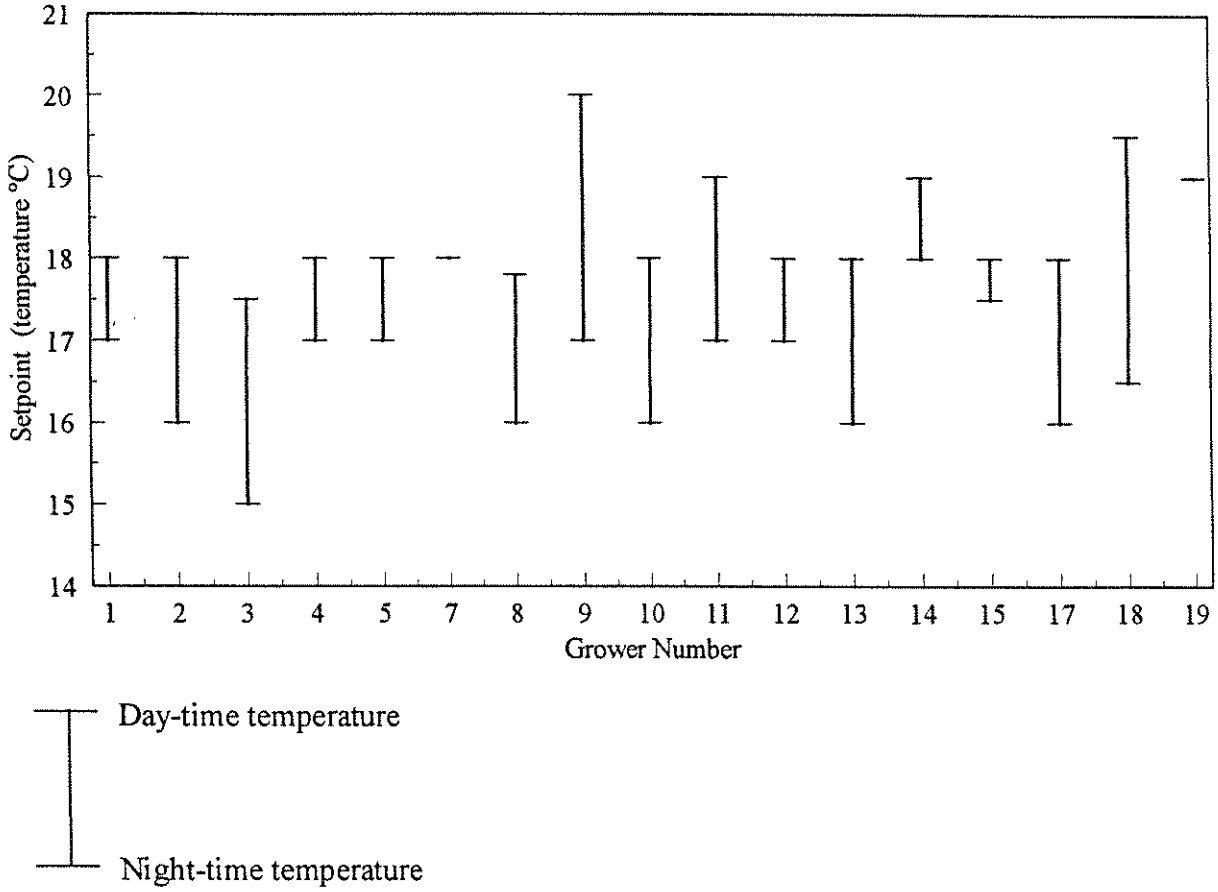


Most growers now control humidity using Vapour Pressure Deficit or Humidity Deficit rather than Relative Humidity. This allows the computer to relate the moisture content of the air to the temperature. The control method was linked to the type of computer controlling the environment.

The setting varied between growers. This variation is indicated in the table below.

RH (%)	VPD	HD
85	0.375 - 0.40	3.1 - 3.5
80 (D) 85 (N)	0.35 - 0.375	2.4
82	0.43 - 0.45	2.4 - 3.2
	0.35 - 0.375	1.6 - 2.4
	0.35 - 0.365	2.2 - 3.5
	0.35 - 0.40	2.1 - 2.95
		2.7 - 3.0
		2.5 - 3.0

Figure 37 - Temperature Setpoints.



Day-time temperature setpoint ranged from 17.5 °C to 25 °C, with several growers increasing this by 2 °C with increasing light levels.

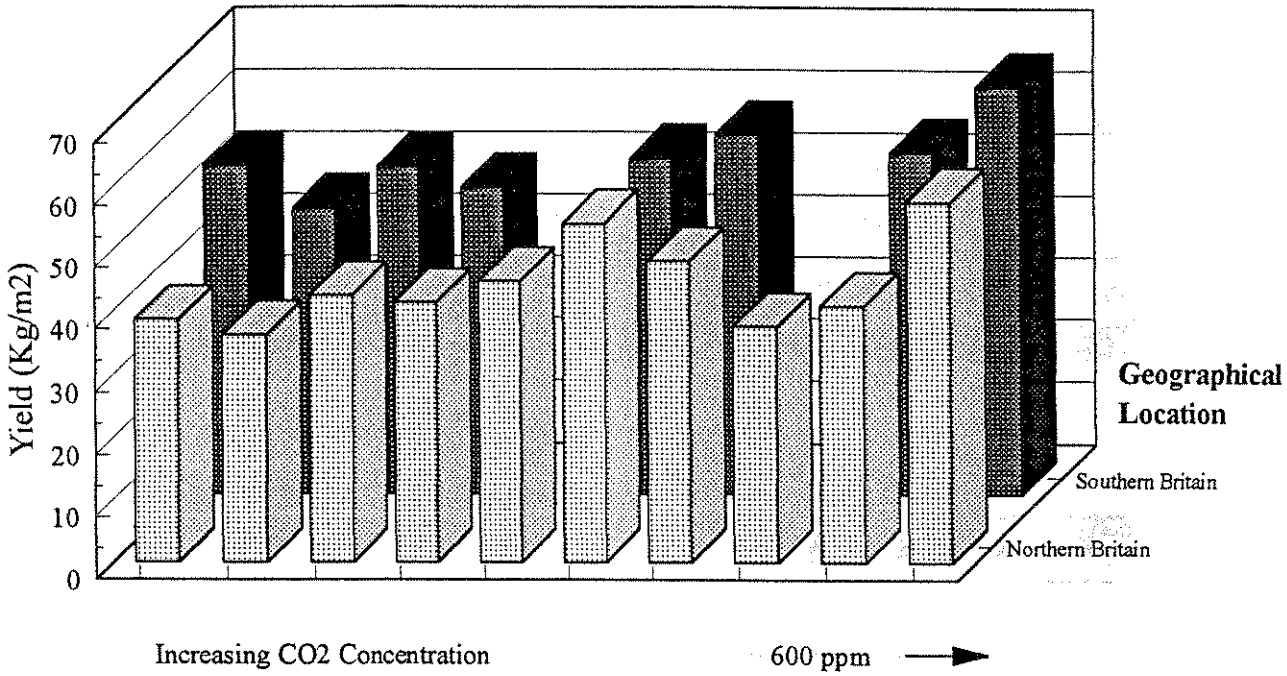
Night-time temperature setpoint ranged from 15 °C to 17.5 °C, again with several growers raising this by 2 °C after a sunny day.

Ventilation temperature setpoint was generally 0.5 to 1 °C above the heating setpoint. Some growers maintained a standard ventilation temperature irrespective of heating setpoint, ranging from 20 - 24 °C.

The P-band and % lagging of vents varied depending on the computer type. Most growers used a 2 - 5 °C P-band setting and 75 - 100 % lagging on wind side vents.

Section 8: Yield and Quality Measurements

Figure 38: The Effect of CO2 concentration on Yield



When the CO2 setpoint is plotted against the marketable fruit yield for each growerincreasing CO2 concentration showed a slight trend towards increased yield. The trend may not be as pronounced as expected because acheived CO2 concentration is not the same as setpoint level. The actual acheived concentration will depend on the efficiency of the CO2 control, supply and distribution systems.

Yields from Southern Britain were higher than Northern Britain at all CO2 enrichment setpoints. Total yields varied from 36.45 to 65.71 kg/m2. (Table 1; page 37).

Gradeout figures were not supplied by all growers but of those that provided data, mean percentage in grade C (>57 mm) ranged from 0.0 to 18.37 %. Mean percentage in grade D (47 - 57 mm) ranged from 66.40 to 89.82 % and mean percentage grade E (40 - 47 mm) 4.61 to 15.88 %.

Figure 39 - Correlation between summer CO2 setpoint and summer yield

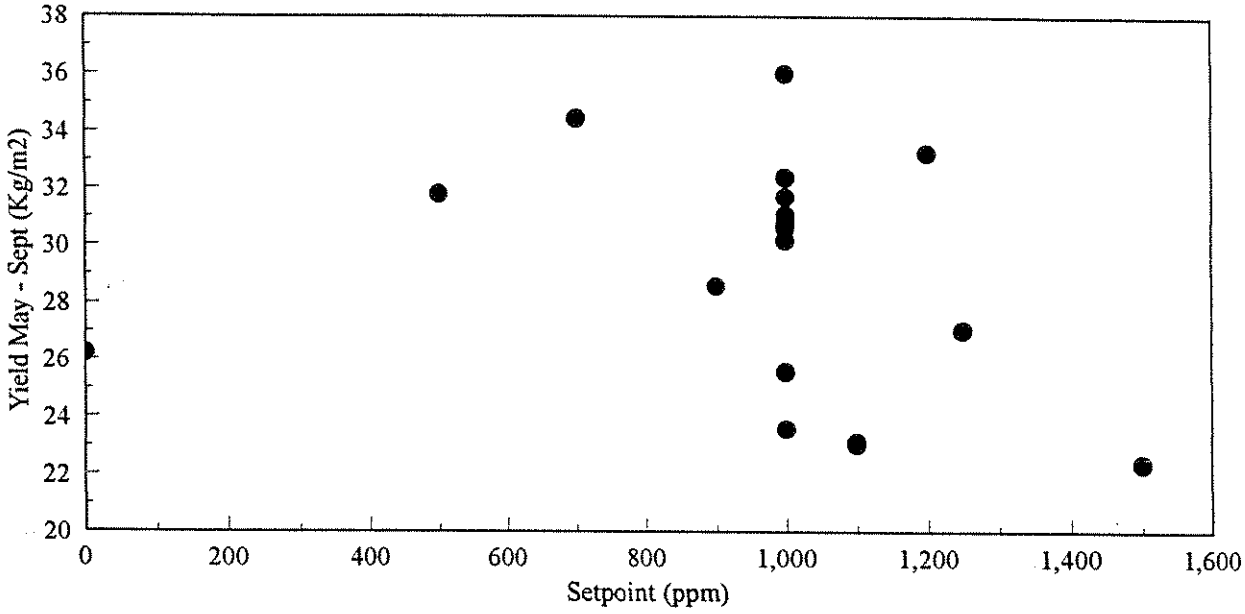
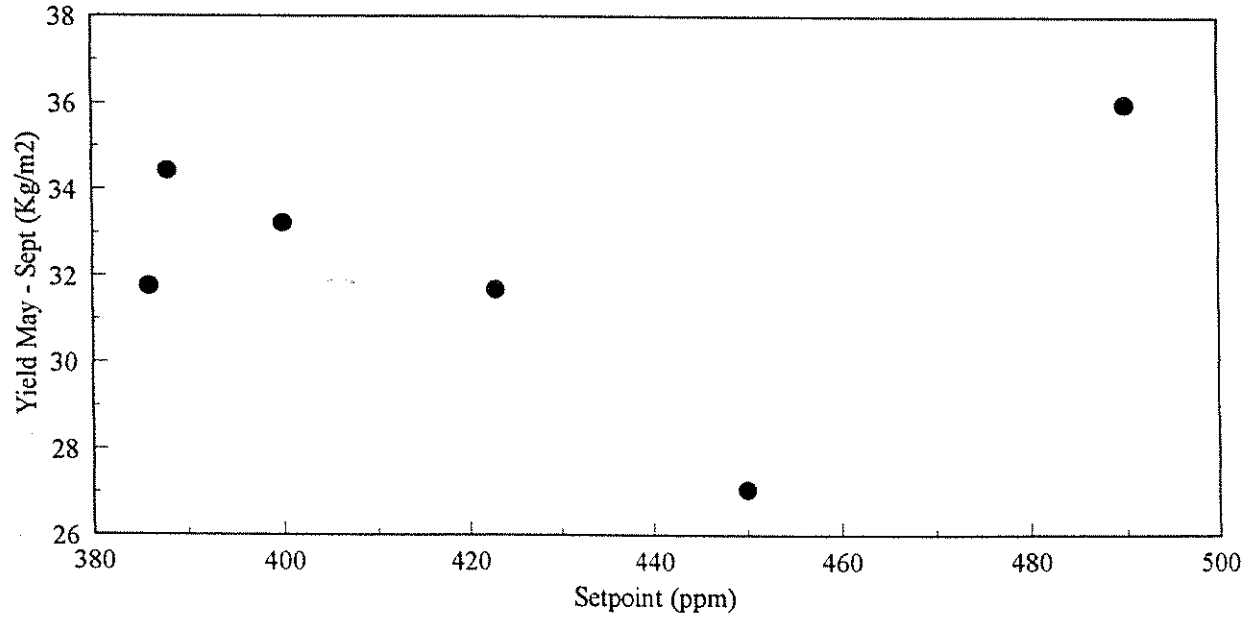


Figure 40 - Correlation between actual summer CO2 level and summer yield



There appears to be no correlation between either summer CO2 setpoint or acheived CO2 levels and summer (May - early Sept) yields.

Variation in growing practices, for example,
- variety
- environmental conditions
- irrigation setpoints,
- age of glass may account for this.

Summary

- Growing practices varied widely between growers and there was no standard system for CO_2 enrichment across the UK.
- Setpoints for CO_2 enrichment ranged between 900 - 1500 ppm in the winter with no clear differences between those growers using gas to provide the CO_2 and those using pure CO_2.
- Several growers using pure CO_2 (5 growers) were able to supply figures on CO_2 usage during the winter. Usage varied widely, ranging from 1.86 to 7.0 T/ha/week. There was no correlation between setpoint and usage.
- Summer CO_2 setpoint varied widely ranging from 0 - 1200 ppm.
- Several growers reducted the CO_2 enrichment setpoint as glasshouse ventilation percentage increased (7 out of 19 growers), reducing the CO_2 setpoint to 100 - 450 ppm. Growers who did not reduce their CO_2 setpoint with ventilation were growers who were burning gas to obtain their CO_2.
- 5 out of the 19 growers had incorporated a change in CO_2 setpoint with light.
- Summer CO_2 use varied greatly, from 2.88 to 9.0 T/ha/week for those growers who were using summer enrichment.
- There was no correlation between summer usage and CO_2 enrichment setpoint or between summer usage and reported acheived level. This may indicate that other factors have a greater effect in determining the amount of CO_2 used, for example leakiness of the glasshouse.
- All eight growers burning gas to obtain their CO_2 had buffer tanks installed on the nursery. These tanks ranged in capacity from 54,000 to 135,000 l/ha.
- Information on the calibration of CO_2 analysers indicated that there was no standard calibration method and no standard frequency of calibration. The wide variation in measured outside CO_2 concentration suggests that calibration of analysers as currently practiced may not be accurate.
- There was no clear correlation between summer yields (May - Early Sept) and either summer CO_2 setpoint or measured achieved level.

Appendix: Yield Data, Quality Data and CO2 Measurements.

Table 1: Marketable Yield(Kg/m2)

Week No.	Grower No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0.13	0.03	0	0	0	0	0.12	0	0.66
9-12	0.81	0	0.27	0.59	0.57	0.04	0.09	0.05	0.7	0	2.22	1.50	1.56	1.85	1.64	0.49	1.73	2.21	2.93
13-16	4.60	3.63	3.14	3.66	4.11	3.67	4.05	3.48	3.27	5.33	4.46	3.90	4.82	5.17	5.39	5.62	4.19	4.28	5.31
17-20	6.67	5.28	4.53	5.06	5.88	6.28	6.69	5.96	4.58	7.62	7.17	6.41	5.77	8.01	7.14	7.25	6.41	7.14	7.72
21-24	7.00	5.71	5.69	6.16	5.97	6.69	8.59	6.39	5.75	8.25	8.27	7.32	6.84	8.95	7.60	8.16	7.36	7.88	8.58
25-28	7.66	6.06	5.98	6.28	6.99	7.36	9.01	-	6.41	8.61	8.91	8.41	6.39	9.52	9.07	8.25	8.16	7.66	10.45
29-32	7.24	6.06	6.17	6.07	6.73	6.73	8.94	-	6.30	7.29	7.33	8.03	7.22	7.95	8.56	7.10	8.67	8.38	9.24
33-36	5.25	5.16	4.42	4.85	5.16	6.09	6.54	-	5.47	7.49	6.25	6.57	4.63	5.78	7.17	3.79	5.07	6.88	7.69
37-40	5.01	3.47	3.65	3.98	4.13	4.68	4.77	-	4.94	4.93	5.14	5.15	5.02	5.76	5.58	5.04	0.00	6.15	6.32
41-44	4.25	2.53	2.60	2.29	3.30	3.68	5.44	-	3.84	3.15	4.11	4.69	3.70	4.83	4.72	3.63	0.00	4.41	6.61
45-48	0	0	0	0	0	0	0.43	-	0	0	0	0.79	0	0	1.23	0	0	0	0.2
Total	48.49	37.9	36.45	38.94	42.84	45.22	54.55	15.88	41.26	52.67	53.99	52.8	45.95	57.82	58.1	49.33	41.71	54.99	65.71

0 = No yield

- = No yield data supplied

Table 2: % Grade C of Class I (57-67mm)

Week No. \ Grower No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1-4	0	0	-	-	-	0	0	0	0	0	0	0	0	0	0	0	-	0	0
5-8	0	0	-	-	-	0	0	0	0	0	0	0	0	0	0	0	-	0	3.80
9-12	0	0	-	-	-	0	0.6	0	0	0	6.00	0	0	7	0	0	-	2.00	3.00
13-16	0.54	4	-	-	-	20.24	7	10.95	0	13.05	8.00	2.00	3.00	12.00	5.00	5.00	-	12.00	5.50
17-20	1.37	4.00	-	-	-	26.62	25.00	12.1	0.00	12.84	10.00	7.00	3.00	22.00	4.00	7.00	-	14.00	18.80
21-24	1.99	7.00	-	-	-	24.83	24.00	14.83	0.00	4.68	10.00	8.00	4.00	24.00	2.00	14.00	-	19.00	17.70
25-28	3.35	10.00	-	-	-	29.83	34.00	16.9	0.00	1.74	8.00	8.00	4.00	24.00	3.00	10.00	-	12.00	10.80
29-32	0.82	3.00	-	-	-	23.76	29.00	13.13	0.00	1.14	3.00	5.00	3.00	14.00	3.00	8.00	-	5.00	1.80
33-36	0.47	4.00	-	-	-	16.15	9.00	10.5	0.00	1.14	3.00	2.00	1.00	10.00	1.00	4.00	-	4.00	4.40
37-40	0.61	4.00	-	-	-	10.57	11.00	0	0.00	1.60	3.00	2.00	1.00	8.00	3.00	5.00	-	4.00	0.80
41-44	11.51	5.00	-	-	-	10.83	18.00	0	0.00	1.17	1.00	6.00	1.00	8.00	9.00	13.00	-	3.00	4.50
45-48	0.94	0.00	-	-	-	2.68	8.00	0	0.00	0.00	0.00	6.00	0.00	0.00	8.00	0.00	-	0.00	0.00
Average	2.40	5.29	-	-	-	18.39	16.56	13.07	0.00	4.67	5.78	5.11	2.50	12.90	4.22	8.25	-	7.5	7.11

Table 3: % Grade D of Class I (47-57mm)

Week No.	Grower No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1-4	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	-	0	0
5-8	0	-	-	-	-	0	0	0	0	0	88.00	91.00	0	0	0	0	-	0	91.40
9-12	68.2	-	-	-	-	0	89.00	0	97.00	0	88.00	80.00	95.00	87.00	93.00	81.00	-	91.00	91.10
13-16	85.50	85.00	-	-	-	74.63	87.00	82.98	87.00	80.88	78.00	86.00	85.00	73.00	86.00	87.00	-	82.00	87.80
17-20	87.10	78.00	-	-	-	65.64	68.00	81.03	71.00	77.27	83.00	85.00	83.00	70.00	86.00	86.00	-	78.00	77.20
21-24	87.00	80.00	-	-	-	67.75	72.00	76.10	82.00	77.55	84.00	84.00	83.00	70.00	86.00	81.00	-	75.00	77.60
25-28	90.60	79.00	-	-	-	64.36	58.00	73.93	91.00	76.50	86.00	84.00	83.00	68.00	85.00	85.00	-	81.00	81.00
29-32	94.20	86.00	-	-	-	72.93	67.00	79.15	90.00	82.80	88.00	89.00	82.00	75.00	87.00	86.00	-	86.00	94.30
33-36	93.60	81.00	-	-	-	80.65	75.00	83.10	91.00	80.06	85.00	90.00	84.00	79.00	88.00	88.00	-	86.00	90.00
37-40	92.20	84.00	-	-	-	83.49	73.00	0	91.00	76.97	83.00	87.00	84.00	76.00	88.00	85.00	-	86.00	80.00
41-44	88.60	85.00	-	-	-	70.17	69.00	0	88.00	78.00	80.00	84.00	73.00	66.00	82.00	74.00	-	73.00	83.00
45-48	89.60	0.00	-	-	-	53.71	43.00	0	0.00	0.00	0.00	84.00	0.00	0.00	83.00	0.00	-	0	0.00
Average	89.82	81.86	-	-	-	70.37	70.10	79.38	87.56	78.75	83.89	85.89	82.13	66.40	85.67	84.00	-	73.8	85.34

Table 4: % Grade E of Class I (40-47mm)

Week No.	Grower No. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1-4	0	0	-	-	-	0	0	0	0	0	0	0	0	0	0	0	-	0	0
5-8	0	0	-	-	-	0	0	0	0	0	12.00	8.00	0	0	0	0	-	0	4.40
9-12	28.88	0	-	-	-	0	6.40	0	1.00	0	6.00	19.00	1.00	6.00	7.00	17.00	-	5.00	4.40
13-16	10.55	6.00	-	-	-	5.13	6.00	2.88	10.00	5.59	14.00	7.00	5.00	9.00	3.00	6.00	-	4.00	6.20
17-20	8.79	14.00	-	-	-	7.74	7.00	4.50	25.00	9.53	7.00	5.00	8.00	5.00	6.00	6.00	-	5.00	3.70
21-24	8.98	11.00	-	-	-	8.10	4.00	6.03	15.00	16.90	6.00	4.00	8.00	3.00	8.00	5.00	-	3.00	4.30
25-28	4.65	8.00	-	-	-	5.81	7.00	5.90	8.00	20.67	8.00	4.00	8.00	4.00	7.00	4.00	-	4.00	7.60
29-32	2.88	7.00	-	-	-	3.31	4.00	4.45	6.00	15.13	9.00	4.00	9.00	5.00	6.00	4.00	-	5.00	3.50
33-36	5.39	12.00	-	-	-	3.21	16.00	3.90	4.00	18.29	12.00	5.00	7.00	6.00	7.00	6.00	-	6.00	5.30
37-40	6.44	8.00	-	-	-	5.94	16.00	0	5.00	20.93	14.00	8.00	9.00	11.00	6.00	10.00	-	7.00	17.00
41-44	7.48	6.00	-	-	-	19.00	13.00	0	6.00	20.01	19.00	7.00	18.00	23.00	5.00	8.00	-	21.00	10.70
45-48	7.19	0.00	-	-	-	43.61	51.00	0	0.00	0.00	0.00	7.00	0.00	0.00	5.00	0.00	-	0	0.00
Average	6.93	9.43	-	-	-	11.32	13.04	4.61	8.00	15.88	10.56	5.67	9.00	7.20	5.89	6.13	-	6	6.71

Table 5: Achieved CO2 Level (ppm)

Week No.	Grower No. 1	2 *	3	4	5	6	7	8	9 *	10	11	12	13	14	15	16	17	18	19
1-4	-	-	-	-	-	1200	-	-	-	612	970	-	-	1080	-	-	-	-	1222
5-8	-	-	-	-	-	1200	-	-	-	710	992	-	-	962	-	-	-	-	1104
9-12	-	-	-	-	-	1200	800	-	-	740	1059	-	-	973	-	-	-	-	1129
13-16	-	-	-	-	-	1200-450	600	-	-	525	906	-	-	750	-	-	-	-	928
17-20	-	-	-	-	-	450	400	-	-	427	788	-	-	586	-	-	-	-	780
21-24	-	-	-	-	-	450	400	-	-	449	698	-	-	625	-	-	-	-	786
25-28	-	-	-	-	-	450	400	-	-	410	587	-	-	488	-	-	-	-	477
29-32	-	-	-	-	-	450	400	-	-	386	423	-	-	388	-	-	-	-	490
33-36	-	-	-	-	-	450	500	-	-	371	568	-	-	388	-	-	-	-	508
37-40	-	-	-	-	-	450	600	-	-	370	760	-	-	627	-	-	-	-	719
41-44	-	-	-	-	-	-	600	-	-	381	720	-	-	725	-	-	-	-	843
45-48	-	-	-	-	-	-	-	-	-	396	-	-	-	-	-	-	-	-	-