HORTICULTURE RESEARCH INTERNATIONAL

STOCKBRIDGE HOUSE

A REPORT TO THE HORTICULTURAL DEVELOPMENT COUNCIL, 18 LAVANT STREET, PETERSFIELD, HANTS, GU32 3EW

Project Leader: M Hardgrave, HRI Stockbridge House, Cawood, Selby, North Yorkshire YO8 0TZ

Contract Number: PC23d

Period Covered: 1991

TOMATOES: EVALUATION OF RECIRCULATION SYSTEMS

CAWOOD · SELBY · NORTH YORKSHIRE YO8 0TZ
TELEPHONE: SELBY (0757) 268275 · FACSIMILE: SELBY (0757) 268996

Contents

Summary

The excess nutrient solution was collected and recirculated from a long season tomato crop grown on both the standard double row system and the V-System. Crop performance was compared with plants grown on the same 2 systems where excess nutrient solution ran to waste.

Use of recirculation did not reduce total yield or percentage of Class I fruit but there was some association with slightly higher levels of some fruit defects. The recirculation system needed regular monitoring to control solution nutrient levels.

Similarly the V-System did not reduce yield or fruit quality. Fruit size was equal to the double row system when grown with excess nutrient solution running to waste but in recirculation the V-System tended to give larger fruit.

There were no differences in monetary returns between the growing systems.

Objective

To evaluate the effect of recirculation of nutrient solution on crop performance, in terms of growth, yield and fruit quality, of a long season tomato crop and to compare the standard double row with the 'V-System' of production.

Introduction

The area of tomatoes grown on rockwool is increasing. To minimise the effects of uneven irrigation systems, irrigation of these crops is 15-30% above requirement and excess solution runs to waste. There is potential for pollution due to fertilisers and pesticides in the run-off and there is increasing pressure to reduce this. In Holland the problem is particularly severe and alternative growing systems are being developed. By the Year 2000 all Dutch salad crops must be grown in closed systems such as recirculation and it is possible that European legislation could impose the same rules on UK growers.

Increased use of rockwool as a substrate has led to problems disposing of the slabs after use. It has been common practise to dump the material in landfill sites but these are becoming unavailable particularly in areas of intensive protected cropping.

This makes it necessary to investigate the use of alternative substrates or reduced volumes. The 'V-System' involves growing a double row of tomatoes in a single row of rockwool and layering alternate plants to either side. If this system were successful both disposal problems and substrate cost could be reduced by 50%.

This experiment compared double row rockwool and the V-System in both run-to-waste and recirculating solution.

Materials and Methods

Varieties:	Liberto (PTR) Spectra (RZ) Blizzard (ENZ)
Sowing Date:	19 November 1990
Planting Date:	3 January 1991

(plants moved to growing house and slab contact made)

Late Planting Date for V-System:
30 January 1991

First Harvest:	13 March
Final Harvest	4 November
Plant Population:	Sideshoots taken in mid March, one in every four plants increased population from 11,000 plants/acre to 13,750 shoots/acre.
Pollination:	Bumble Bees
Environment Temperature:	Blueprint - See Appendix I
Carbon Dioxide:	1000 vpm until end of April then 350 vpm regardless of ventilator position.
Irrigation:	Independant systems were used to feed the separate treatments.
Shelf Life Conditions:	20 °C. 12 hours illumination/24 hours. 65% Relative humidity.

Treatments

1. Double rockwool, run-to-waste

2. Double rockwool, with recirculation

3. V-System, run-to-waste

4. V-System, with recirculation

V-System comprised of single rows of 15 cm wide rockwool slabs for each double row with plants planted at double the standard density and then alternate plants trained in opposite directions. To avoid early competition half the plants were not placed in slab contact until the second truss began to flower.

In the recirculating system the slabs were placed on narrow polystyrene bridges in 20 cm wide plastic channels and slit in the normal way. Run-off was collected and returned to the mixing tank.

Experimental Design

The trial comprised 12 treatments in a 2 system x 2 training x 3 varieties factorial structure. The varieties were assigned to blocks of 4 plots in a 3 x 3 Latin Square arrangement. The 4 system/training treatments were applied to whole sub-columns across the 3 cultivars in 4 blocks of 4 treatments down the house. Thus there were 4 replicates of each treatment.

Records

The crop was harvested and graded three times each week. Yield in size grades and percentages in each class were recorded. Shelf life and detailed fruit quality assessments were made in May and September.

Full nutrient analysis of slab, drip and run-off were carried out weekly.

Results

Fruit Yield

Table 1: Total Yield (kg/m^2)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct/ Nov
Means								
Run-to-waste	1.13	4.72	9.53	8.48	9.07	8.56	6.22	9.25
Recirculation	1.30	4.80	9.27	8.26	9.07	8.58	6.45	8.84
Double	1.19	4.81	9.41	8.18	8.87	8.58	6.31	9.01
V-System	1.24	4.71	9.38	8.56	9.27	8.56	6.36	9.09
SED (6 df)	0.046	0.199	0.216	0.222	0.146	0.136	0.108	0.184
LSD (P = 0.05)	0.11	-	-	-	0.36	-	0.26	0.45
Significance:								
Run to Waste v. Recirculation	**	NS	NS	NS	NS	NS	* 7%	* 6%
Double v. V-System	NS	NS	NS	NS	*	NS	NS	NS
Run-to-Waste								
Double	1.07	4.77	9.57	8.38	8.93	8.66	6.25	9.11
V-System	1.18	4.68	9.48	8.58	9.21	8.46	6.19	9.40
Recirculation								
Double	1.31	4.85	9.25	7.97	8.82	8.50	6.37	8.90
V-System	1.29	4.75	9.29	8.55	9.33	8.66	6.53	8.79
SED (6 df)	0.065	0.281	0.305	0.314	0.207	0.193	0.153	0.260
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS

Note: Yields are expressed as the mean of 3 varieties.

Key

***	Significant at 0.1% level
**	Significant at 1% level
*	Significant at 5% level
NS	Not Significant

Table 2: Cumulative Yields (kg/m^2)

	To End of May	All Season
Means		
Run-to-waste	15.38	56.96
Recirculation	15.36	56.57
Double	15.41	56.36
V-System	15.33	57.18
SED (6 df)	0.393	0.971
LSD (P = 0.05)	-	-
Significance	NS	NS
Run-to-Waste		
Double	15.41	56.74
V-System	15.35	57.18
Recirculation		
Double	15.40	55.98
V-System	15.32	57.17
SED (6 df)	0.556	1.373
LSD (P = 0.05)	-	-
Significance	NS	NS

Tables 1 and 2 show that differences in total yield between treatments were small. There was no evidence at any stage of a yield reduction from the V-System treatments and in July there was a significant improvement over the double row system.

Similarly there was no evidence of significant yield differences between run-to-waste and recirculation treatments, although in some months there was a suggestion of some yield loss from the recirculation treatments. The difference was larger on the double row than the V-System.

There was no interaction between variety and growing system treatments.

Table 3: Percentage Class I Fruit of Total

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct/ Nov
Means								
Run-to-waste	95.7	92.9	83.6	90.6	82.0	72.9	58.0	59.4
Recirculation	95.4	92.9	85.3	91.3	80.2	71.7	57.1	55.1
Double	94.6	92.6	84.2	90.7	82.3	73.7	58.0	57.6
V-System	96.6	93.2	84.7	91.3	80.0	71.7	57.1	56.8
SED (6 df)	1.20	0.65	0.79	0.40	0.78	1.49	2.19	0.88
LSD (P = 0.05)	-	-	-	-	1.9	-	-	2.15
Significance:								
Run to Waste v. Recirculation	NS	NS	NS	NS	* 6%	NS	NS	**
Double v. V-System	NS	NS	NS	NS	*	NS	NS	NS
Run-to-Waste								
Double	95.3	92.6	83.5	90.3	82.3	73.0	58.2	59.5
V-System	96.2	93.2	83.7	91.0	81.7	72.7	57.9	59.3
Recirculation								
Double	93.9	92.7	84.8	91.1	82.2	74.3	57.8	55.7
V-System	96.9	93.1	85.7	91.6	78.2	70.6	56.3	54.4
SED (6 df)	1.70	0.91	1.11	0.56	1.10	2.11	3.09	1.24
LSD (P = 0.05)	-	-	2.7	-	2.7	-	-	-
Significance	NS	NS	* 8%	NS	* 7%	NS	NS	NS

Table 4: Cumulative Quality (% Class I)

	To End of May	All Season
Means		
Run-to-waste	87.4	77.1
Recirculation	88.6	76.4
Double	87.7	77.0
V-System	88.3	76.5
SED (6 df)	0.57	0.49
LSD (P = 0.05)	-	-
Significance	NS	NS
Run-to-Waste		
Double	87.2	77.1
V-System	87.6	77.2
Recirculation		
Double	88.1	77.0
V-System	89.0	75.9
SED (6 df)	0.81	0.69
LSD (P = 0.05)	-	-
Significance	NS	NS

Tables 3 and 4 show that throughout the season there was no evidence of treatment effects on fruit quality. At the end of the season there was some loss in percentage Class I fruit due to fine net cracking and uneven ripening; this led to significantly lower Class I yields from the recirculation treatments in October/November, compared with the run-to-waste.

Table 5: Percentage Grade C of Class I (57-67 mm)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct/ Nov
Means								
Run-to-waste	20.1	25.2	15.2	6.9	3.6	4.2	9.5	4.1
Recirculation	21.9	25.3	17.6	8.9	5.2	8.2	11.6	3.5
Double	21.3	23.9	14.1	5.8	3.1	4.9	9.2	3.8
V-System	20.6	26.6	18.7	9.8	5.7	7.4	11.9	3.9
SED (6 df)	3.16	2.48	2.01	1.21	0.68	1.40	2.15	0.74
LSD (P = 0.05)	-	-	4.9	2.9	1.7	3.4	5.3	-
Significance:								
Run to Waste v. Recirculation	NS	NS	NS	NS	*	*	NS	NS
Double v. V-System	NS	NS	*6%	*	**	NS	NS	NS
Run-to-Waste								
Double	22.7	24.4	14.0	6.1	2.7	3.7	8.9	4.1
V-System	17.4	26.0	16.4	7.6	4.4	4.7	10.1	4.2
Recirculation								
Double	19.9	23.4	14.1	5.4	3.5	6.1	9.6	3.5
V-System	23.8	27.2	21.1	11.9	7.0	10.2	13.7	3.6
SED (6 df)	4.47	3.51	2.85	1.71	0.96	1.98	3.05	1.05
LSD (P = 0.05)	-	-	-	4.2	-	-	-	-
Significance	NS	NS	NS	* 8%	NS	NS	NS	NS

Table 6: Cumulative Fruit Size (% Grade C) (57-67 mm)

	To End of May	All Season
Run-to-Waste		
Double	18.0	9.0
V-System	19.6	10.3
Recirculation		
Double	17.8	9.4
V-System	23.3	14.0
SED (6 df)	3.17	
LSD (P = 0.05)	-	-
Significance	NS	NS
Means		
Run-to-waste	18.8	9.7
Recirculation	20.5	11.7
Double	17.9	9.2
V-System	21.4	12.1
SED (6 df)	2.24	
LSD (P = 0.05)	-	-
Significance	NS	NS

Generally there was no significant reduction in fruit size from plants grown on the V-System although in March on the run-to-waste system there were 5% less Grade C fruit from the V-System than the double row (Table 5).

In recirculation there was more large fruit from the V-System than from the double row.

Table 7: Percentage Grade D of Class I (47-57 mm)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct/ Nov
Means								
Run-to-waste	75.2	69.5	79.1	80.5	88.4	90.6	57.8	83.9
Recirculation	73.0	69.3	77.6	79.5	88.8	88.1	86.0	83.1
Double	73.9	70.7	80.2	80.3	88.9	90.3	88.1	83.7
V-System	74.2	68.2	76.5	79.6	88.4	88.4	85.6	83.4
SED (6 df)	2.83	2.10	1.72	0.83	0.63	1.08	1.98	1.79
LSD (P = 0.05)	-	-	4.2	-	-	2.6	-	-
Significance:								
Run to Waste v. Recirculation	NS	NS	NS	NS	NS	*	NS	NS
Double v. V-System	NS	NS	*7%	NS	NS	NS	NS	NS
Run-to-Waste								
Double	72.2	69.7	79.7	80.2	88.8	91.2	88.6	83.7
V-System	78.1	69.3	78.5	80.8	88.0	89.9	86.9	84.2
Recirculation								
Double	75.6	71.6	80.8	80.5	89.0	89.4	87.7	83.6
V-System	70.3	67.0	74.5	78.5	88.7	86.9	84.3	82.6
SED (6 df)	4.01	2.97	2.43	1.17	0.89	1.53	2.80	2.53
LSD (P = 0.05)	9.8	-	-	-	-	-	-	-
Significance	* 9%	NS	NS	NS	NS	NS	NS	NS

Table 8: Cumulative Fruit Size (% Grade D) (47-57 mm)

	To End of May	All Season
Means		
Run-to-waste	75.8	82.7
Recirculation	74.5	81.5
Double	76.6	83.0
V-System	73.7	81.2
SED (6 df)	1.92	1.21
LSD (P = 0.05)	-	-
Significance	NS	NS
Run-to-Waste		
Double	76.0	83.0
V-System	75.6	82.4
Recirculation		
Double	77.2	83.1
V-System	71.8	80.0
SED (6 df)	2.72	1.72
LSD (P = 0.05)	-	-
Significance	NS	NS

On the run-to-waste system the reduction in fruit size in March on the V-System was related to an increase in the percentage Grade D fruit. The V-System treatment gave significantly more fruit in the 47-57 mm diameter size band when grown in the run-to-waste system than in recirculation (Table 7).

Results at the end of the trial showed that the V-system had produced less small fruit than the double row system over the season as a whole (Table 10).

Table 9: Percentage Grade E of Class I (40-47 mm)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct/ Nov
Means								
Run-to-waste	4.2	4.5	5.3	11.8	7.6	4.9	2.6	11.5
Recirculation	4.7	4.7	4.3	11.2	5.6	3.5	2.2	12.9
Double	4.3	4.7	5.3	13.1	7.5	4.5	2.5	12.2
V-System	4.7	4.5	4.3	9.9	5.7	4.0	2.3	12.2
SED (6 df)	0.27	0.50	0.49	0.92	0.63	0.81	0.43	1.67
LSD (P = 0.05)	-	-	-	2.2	1.5	-	-	-
Significance:								
Run to Waste v. Recirculation	NS	NS	NS	NS	*	NS	NS	NS
Double v. V-System	NS	NS	NS	**	*	NS	NS	NS
Run-to-Waste								
Double	4.4	4.9	5.9	12.8	8.0	4.8	2.3	11.9
V-System	4.0	4.1	4.7	10.9	7.2	5.1	2.8	11.1
Recirculation								
Double	4.1	4.5	4.7	13.4	7.1	4.3	2.7	12.5
V-System	5.3	4.8	4.0	9.0	4.2	2.8	1.8	13.3
SED (6 df)	0.38	0.71	0.70	1.30	0.90	1.14	0.61	2.36
LSD (P = 0.05)	0.9	-	-	-	-	-	-	-
Significance	*	NS	NS	NS	NS	NS	NS	NS

Table 10: Cumulative Fruit Size (% Grade E) (40-47 mm)

	To End of May	All Season
Means		
Run-to-waste	4.9	7.1
Recirculation	4.5	6.4
Double	5.0	7.3
V-System	4.4	6.2
SED (6 df)	0.44	0.50
LSD (P = 0.05)	-	-
Significance	NS	NS Recirculation * V- System
Run-to-Waste		
Double	5.4	7.5
V-System	4.4	6.8
Recirculation		
Double	4.6	7.1
V-System	4.3	5.7
SED (6 df)	0.62	0.71
LSD (P = 0.05)	-	-
Significance	NS	NS

Table 11: Monetary Returns (£/m²)

	Whole Season
Means	
Run-to-waste	34.71
Recirculation	34.50
Double	34.43
V-System	34.78
SED (6 df)	0.58
LSD (P = 0.05)	-
Significance	NS
Run-to-Waste	
Double	34.56
V-System	34.87
Recirculation	
Double	34.30
V-System	34.69
SED (6 df)	0.82
LSD (P = 0.05)	-
Significance	NS

Monetary returns were calculated using average UK prices (MAFF figures) and the yield from the treatments to calculate potential financial returns of the treatments.

In this trial there was no evidence of significantly reduced returns from either the V-System or recirculation.

Nutrition

Table 12 shows how nutrient levels in the slab solution were influenced by the V-System and recirculation treatments.

Table 12: Average Nutrient Levels in Slab Solution (mg/l)

	Double	Double Recirc	V	V Recirc
pH	5.5	5.9	5.6	6.0
EC	4309	5054	4389	4826
NH4-N	5	2	4	4
NO3-N	465	576	498	555
P	33	23	31	19
K	631	599	618	559
Ca	378	522	398	504
Mg	95	136	94	121
Na	36	63	38	62
Fe	4.66	3.63	3.36	3.24
Mn	0.53	0.24	0.52	0.28
Cu	0.14	0.21	0.15	0.24
Zn	1.27	1.40	1.37	1.34
B	0.50	0.47	0.52	0.41
Cl	45	79	44	66
SO4	82	102	90	84
HCO3	16	35	26	29

Drip conductivity and pH setpoints were equal for all treatments and equal volumes of solution were applied per plant. There was however a trend throughout the year for the slab conductivity to rise in the recirculation treatments due to build up of elements such as calcium and magnesium in the solution (see Table 12).

Sodium and chlorine also built up in the solution but did not reach excessive levels due to the relatively pure water supply on the site.

In the run-to-waste system differences between the V-System and the double row were small but in recirculation the build up of conductivity was not as severe on the V-System treatment.

Drip nutrient levels are shown in Appendix II.

Fruit Quality

All results are presented as the mean of 3 varieties.

Russetting

In May there were small amounts of russetting (fine net cracking) on fruit from all treatments. Differences were small but overall, levels were slightly lower on fruit from the standard double row, run-to-waste treatment (Figure 1).

In September there was more russetting on all treatments. In both double row and the V-System treatments there was more russetting where run-off solution was recirculated. The double row system was less severely affected than the V-System.

Boxiness

In May there was very little fruit with boxiness. The double row treatment with recirculation was slightly worse than the other treatments. In September boxiness had decreased further and was a very minor problem. The V-System treatment with recirculation was the most severely affected.

Goldspot

Goldspot was only present at very low levels in May and there were no differences between treatments (Figure 3). In September the level was slightly higher but again severity was not affected by the irrigation or growing system treatments.

Uneven Ripening

In May there was more uneven ripening on fruit from the V-System, in both the run-to-waste and the recirculation treatments. In September both recirculation treatments and the run-to-waste V-System treatment had more severe uneven ripening than the standard double row run-to-waste treatment (Figure 4).

Flecking

Flecking was present at fairly high levels on fruit from all treatments in May but there was no evidence of treatment differences (Figure 5). In September the problem had increased and was more severe on both the V-System and the recirculation treatments.

FIGURE 1: RUSSETTING

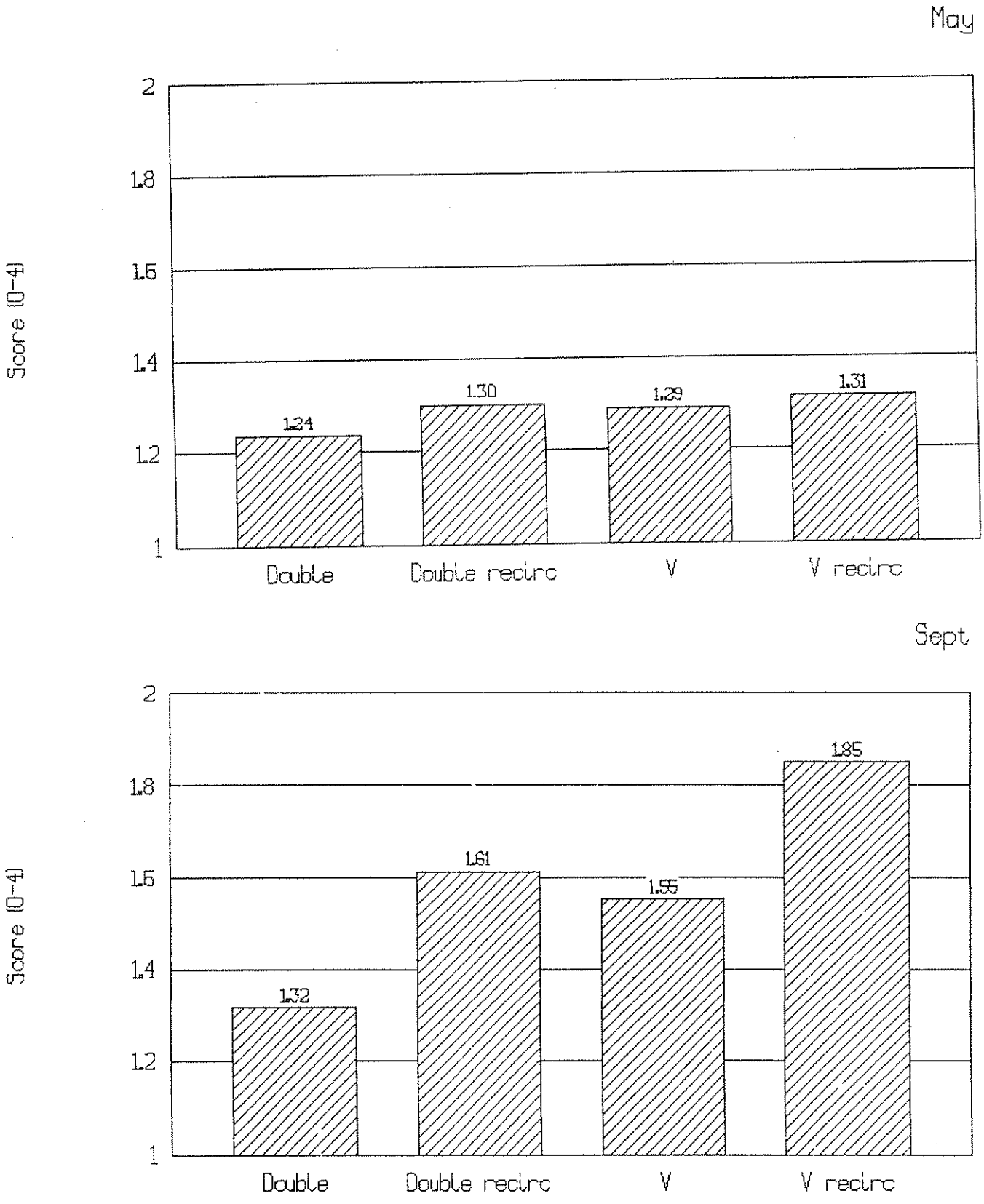


FIGURE 2: BOXINESS

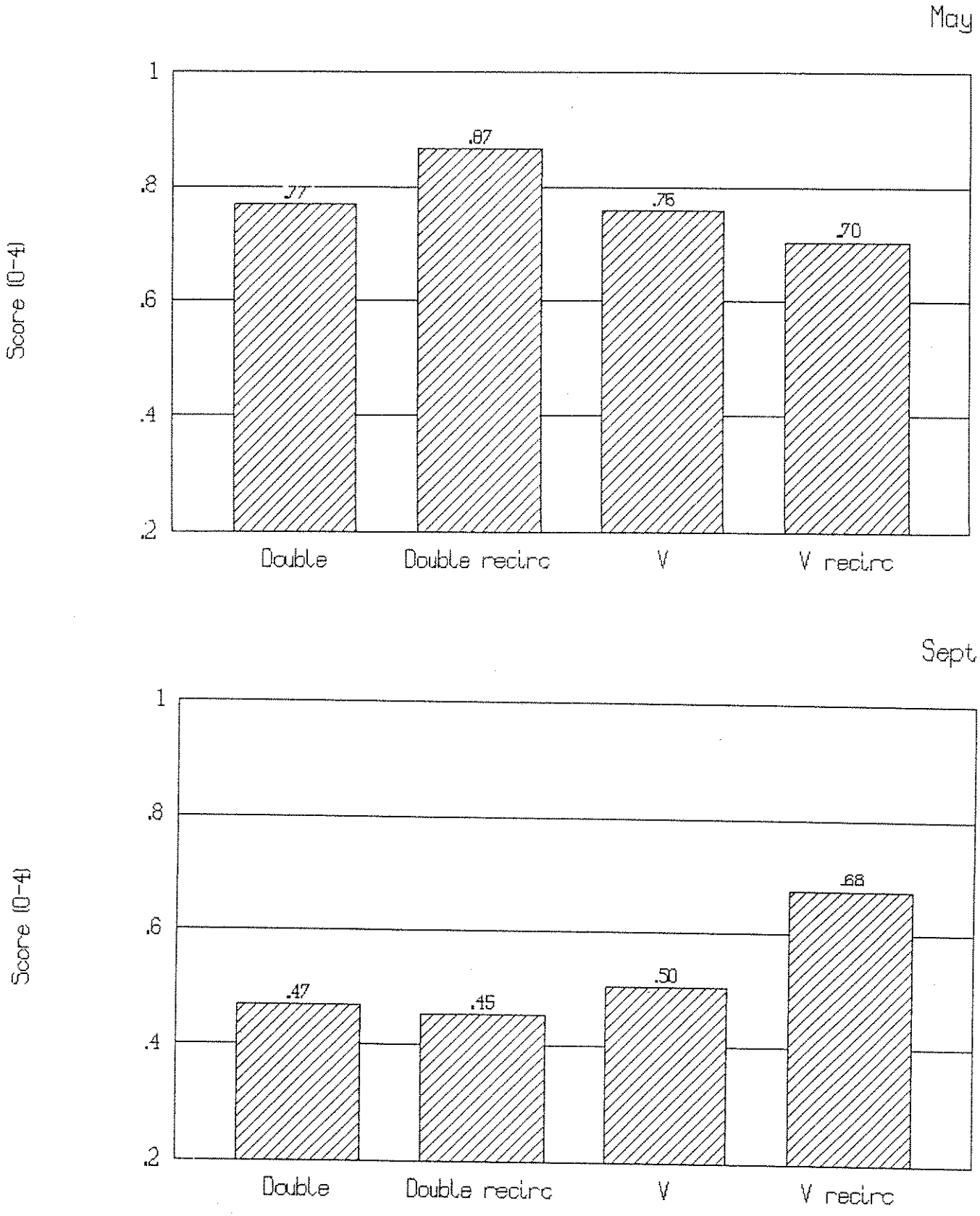


FIGURE 3: GOLDSPOT

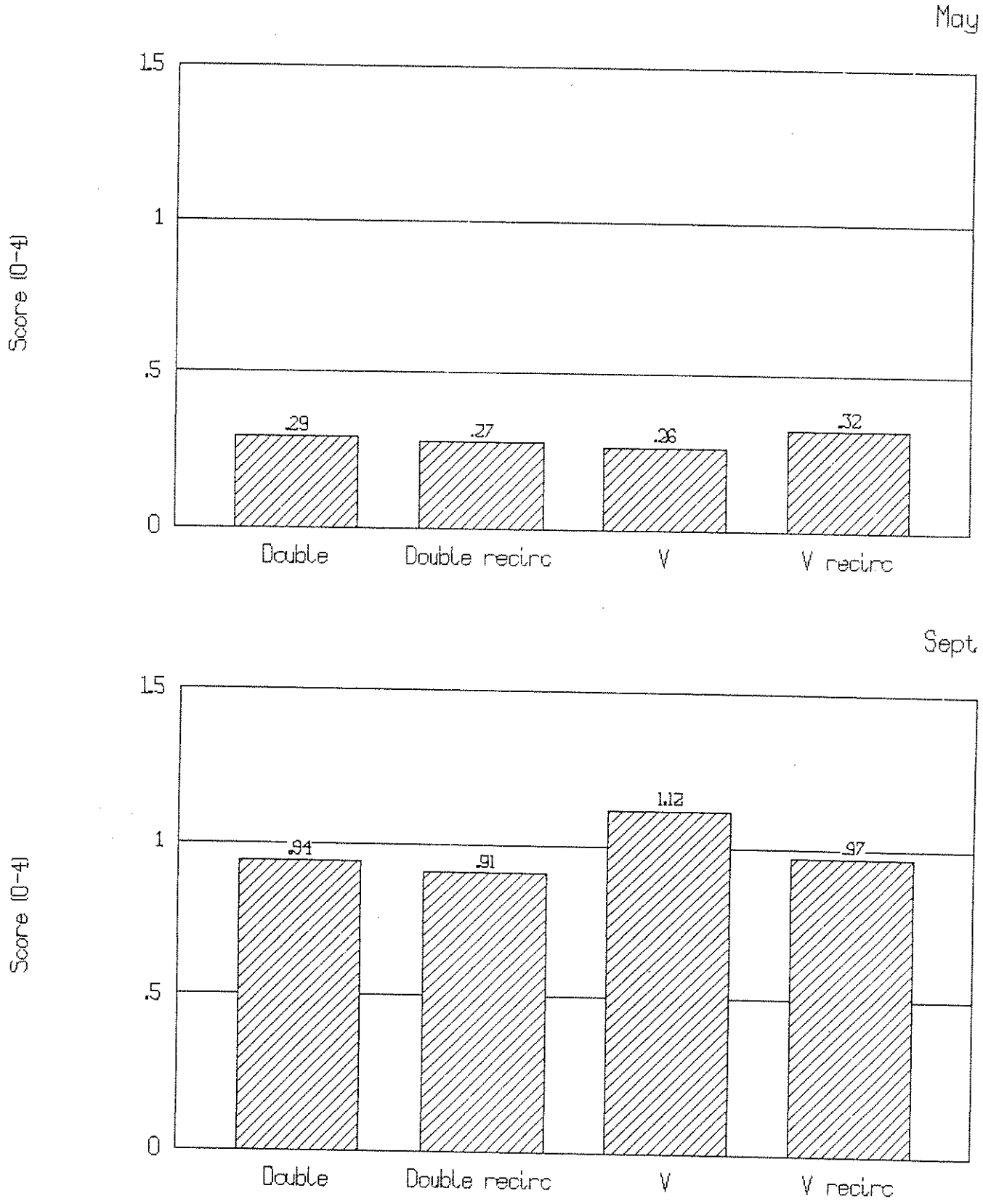
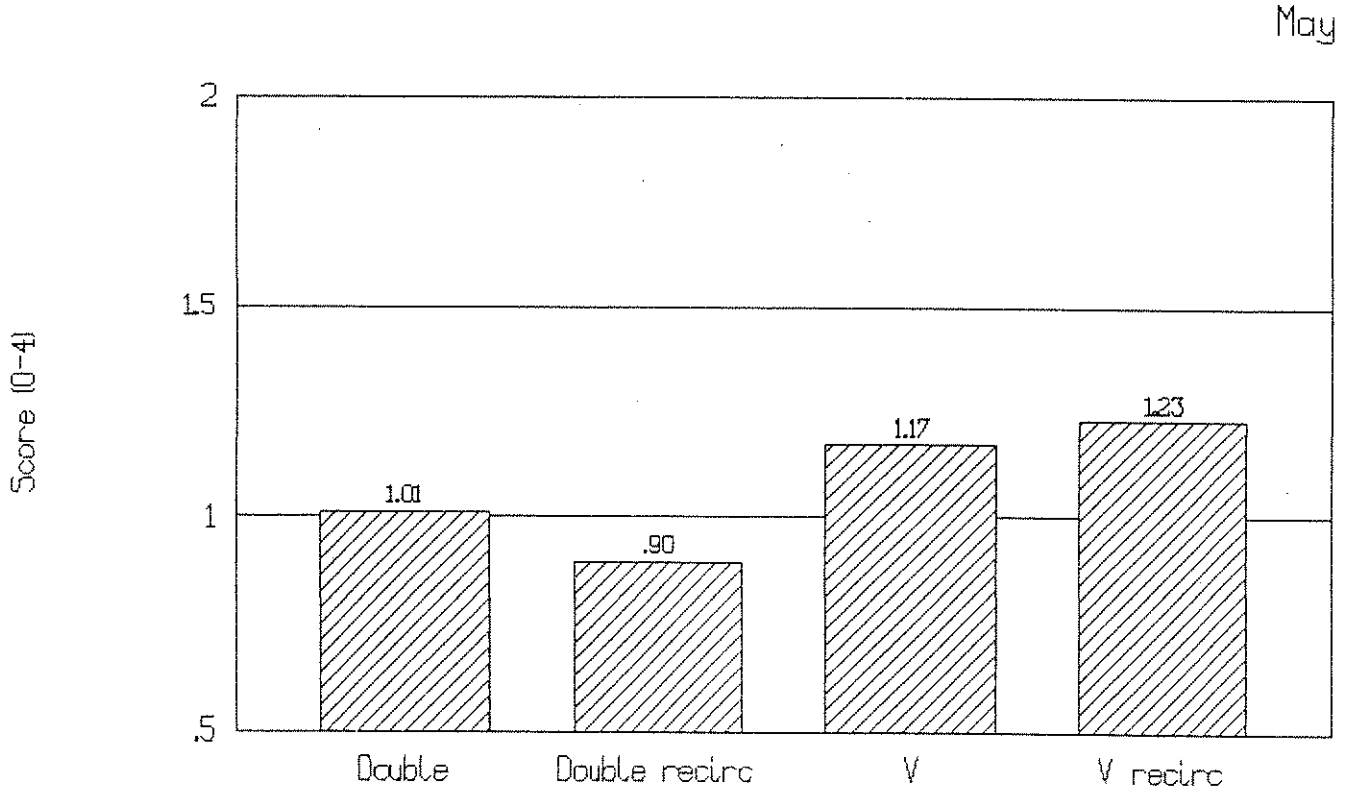


FIGURE 4: UNEVEN RIPENING



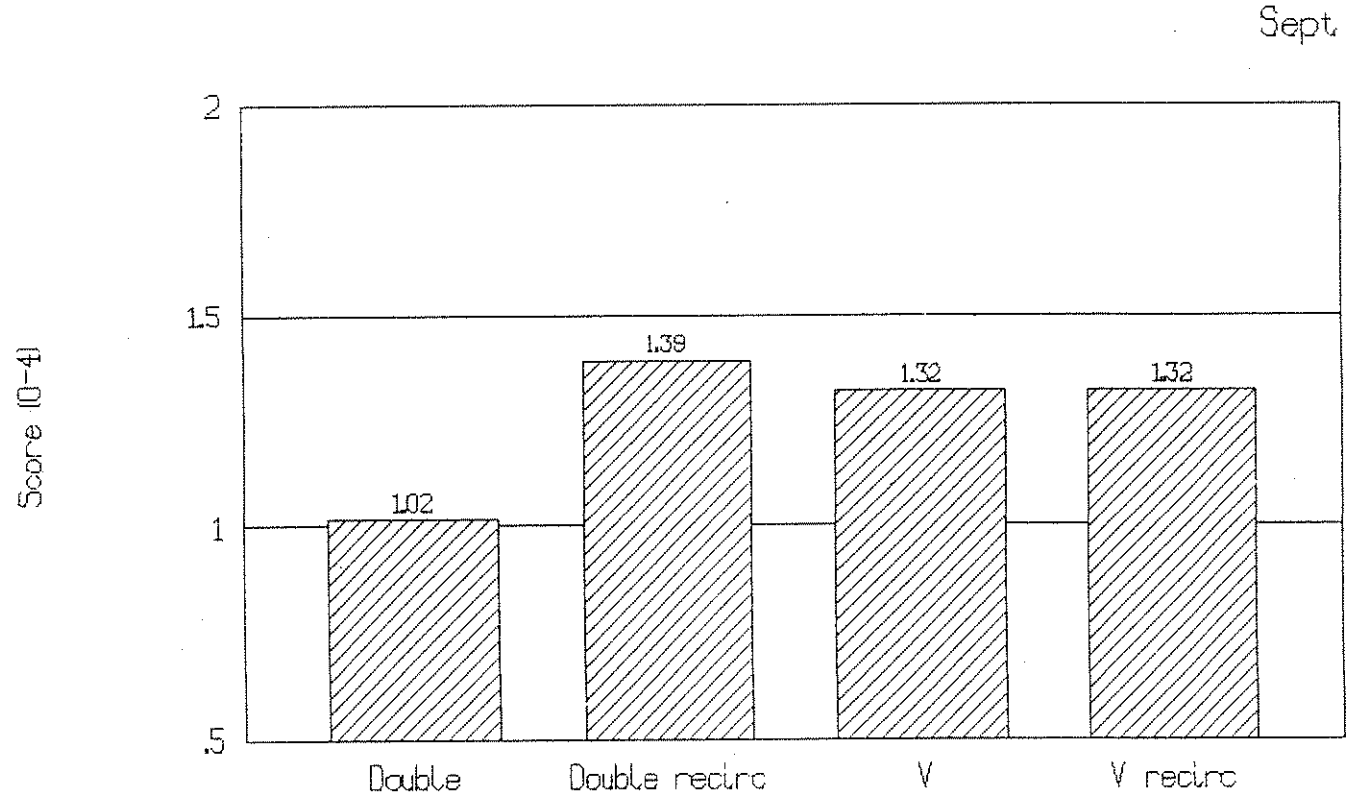
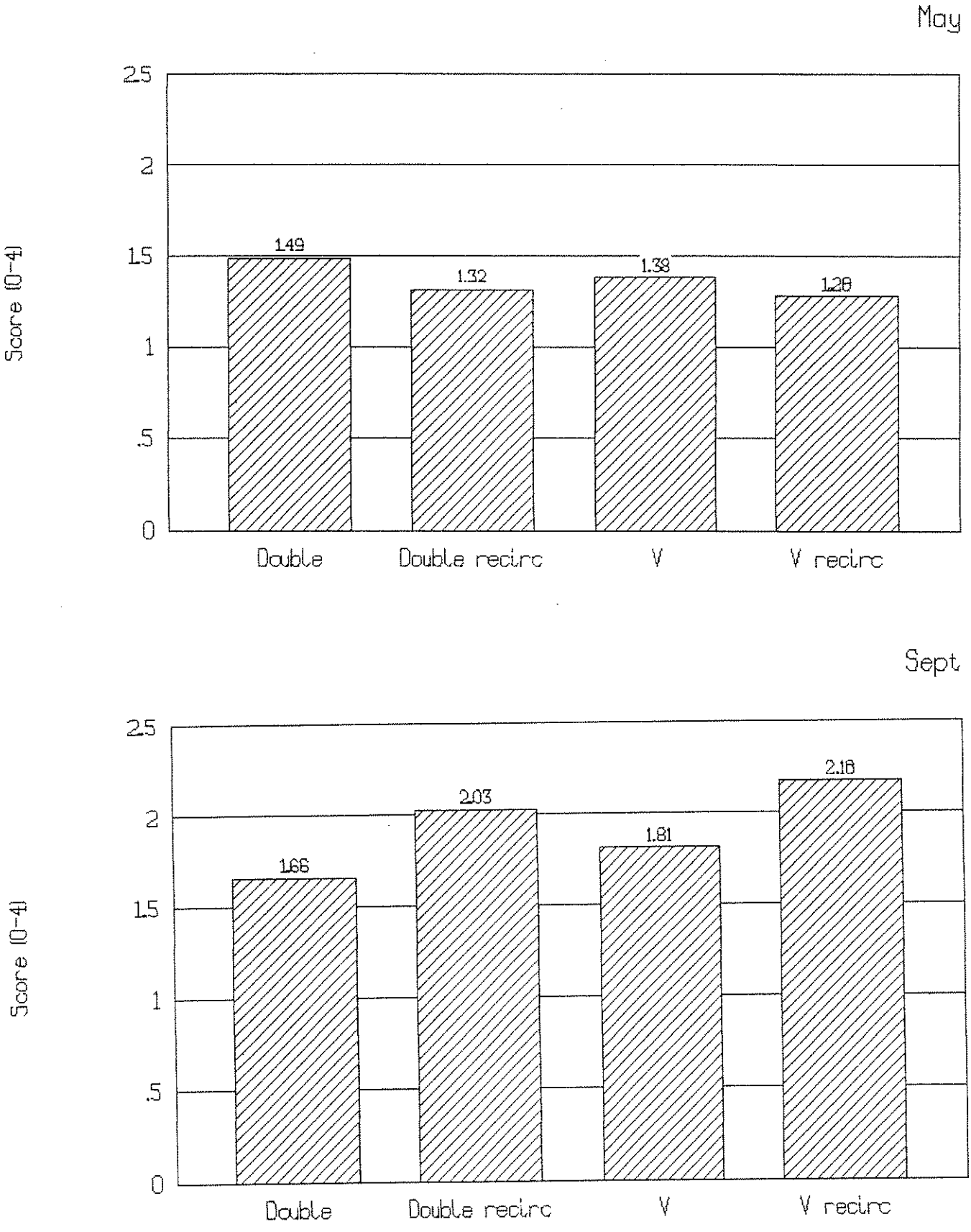


FIGURE 5: FLECKING



Shelf Life and Internal Composition

Firmness

Fruit firmness was measured after 6 days under shelf life conditions, and was recorded as millimetres of depression when a given pressure was exerted on each fruit.

In May fruit remained fairly firm and depression was small. Fruit from the recirculation treatments was less firm than that from the run-to-waste treatments.

In September fruit became much softer during the period under shelf life conditions. At this time fruit from the V-System treatment with recirculation was firmer than fruit from the other 3 treatments (Figure 6).

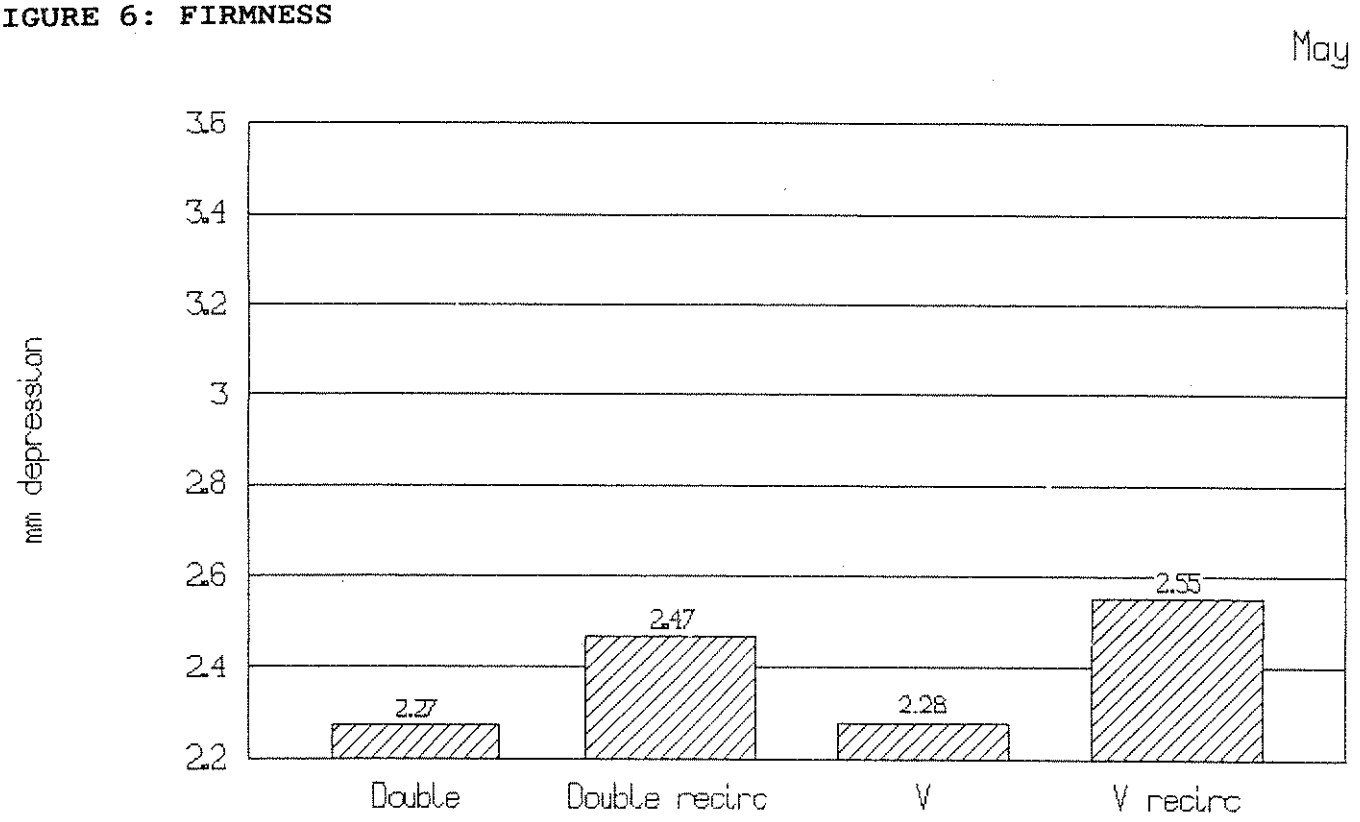
Weight Loss

Weight loss during the 6 days under shelf life conditions was related to fruit firmness to some extent. In May weight loss was small with no significant treatment differences but in September weight loss was almost double that in May. The worst treatments in September were the V-System with recirculation and the standard double row.

Sugar Content

The percentage sucrose was measured using a hand held refractometer on juice from frozen and then defrosted fruit. The level was higher in September than it was in May, but treatment differences were inconsistent. In May the run-to-waste treatments had a higher sucrose content but in September these treatments were lower than the recirculation treatments (Figure 8).

FIGURE 6: FIRMNESS



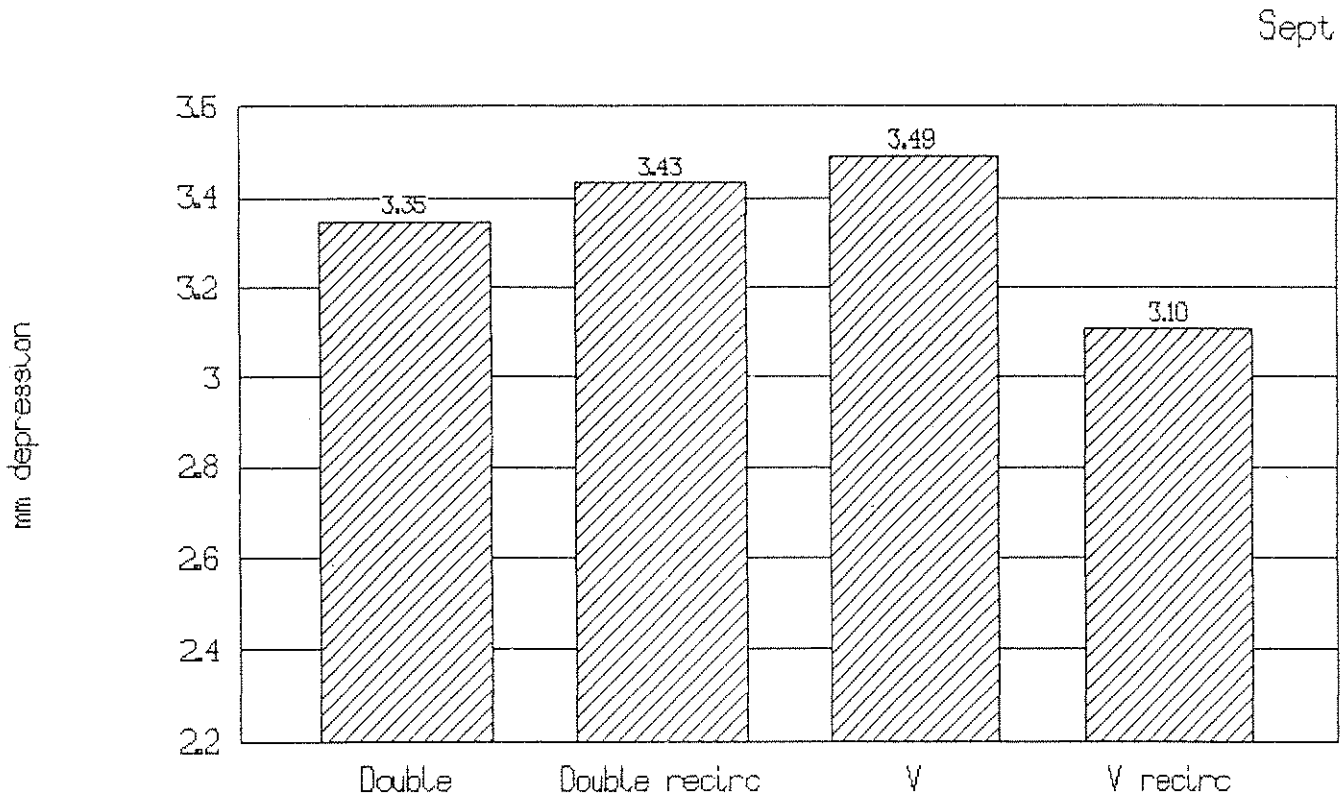


FIGURE 7: WEIGHT LOSS

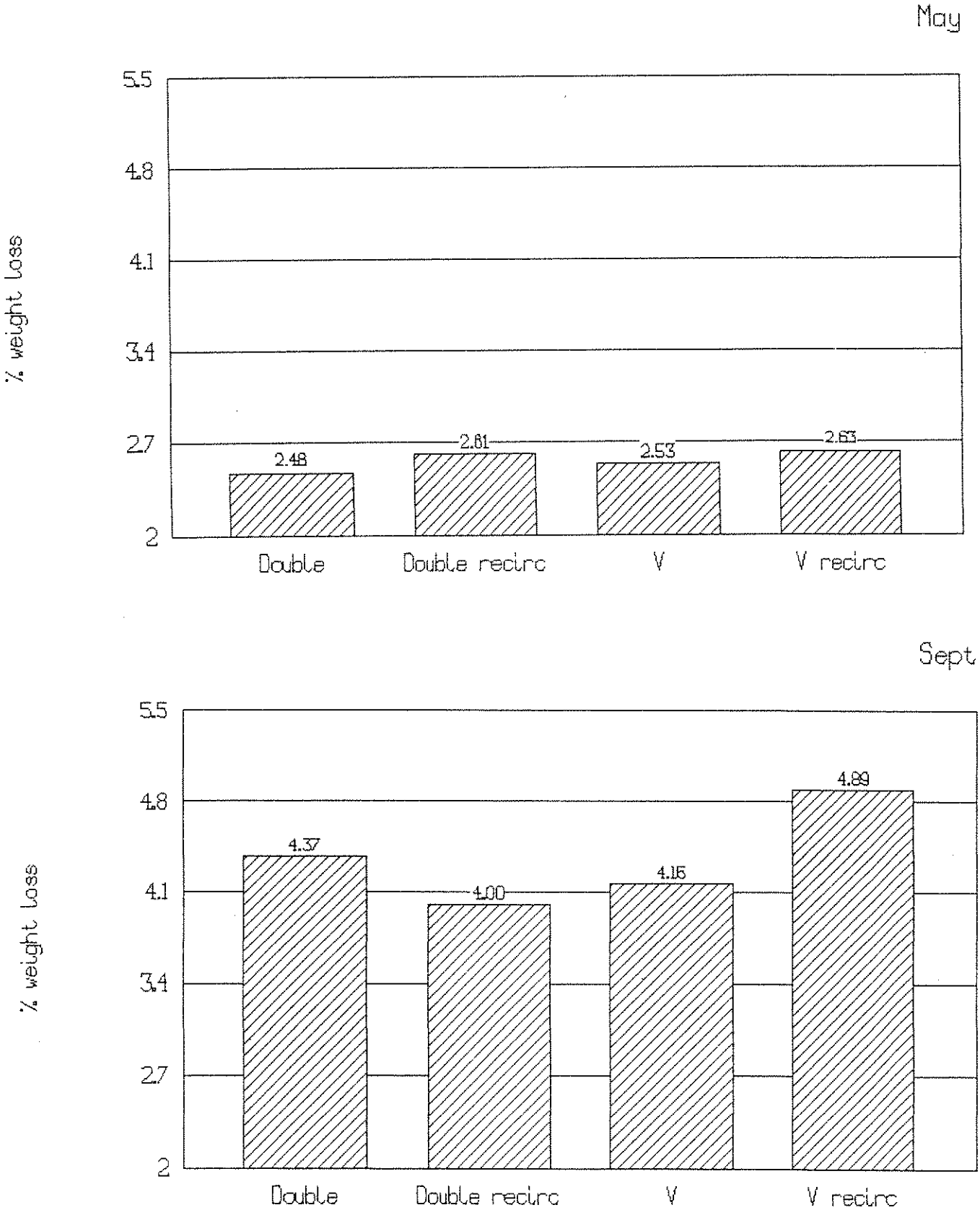
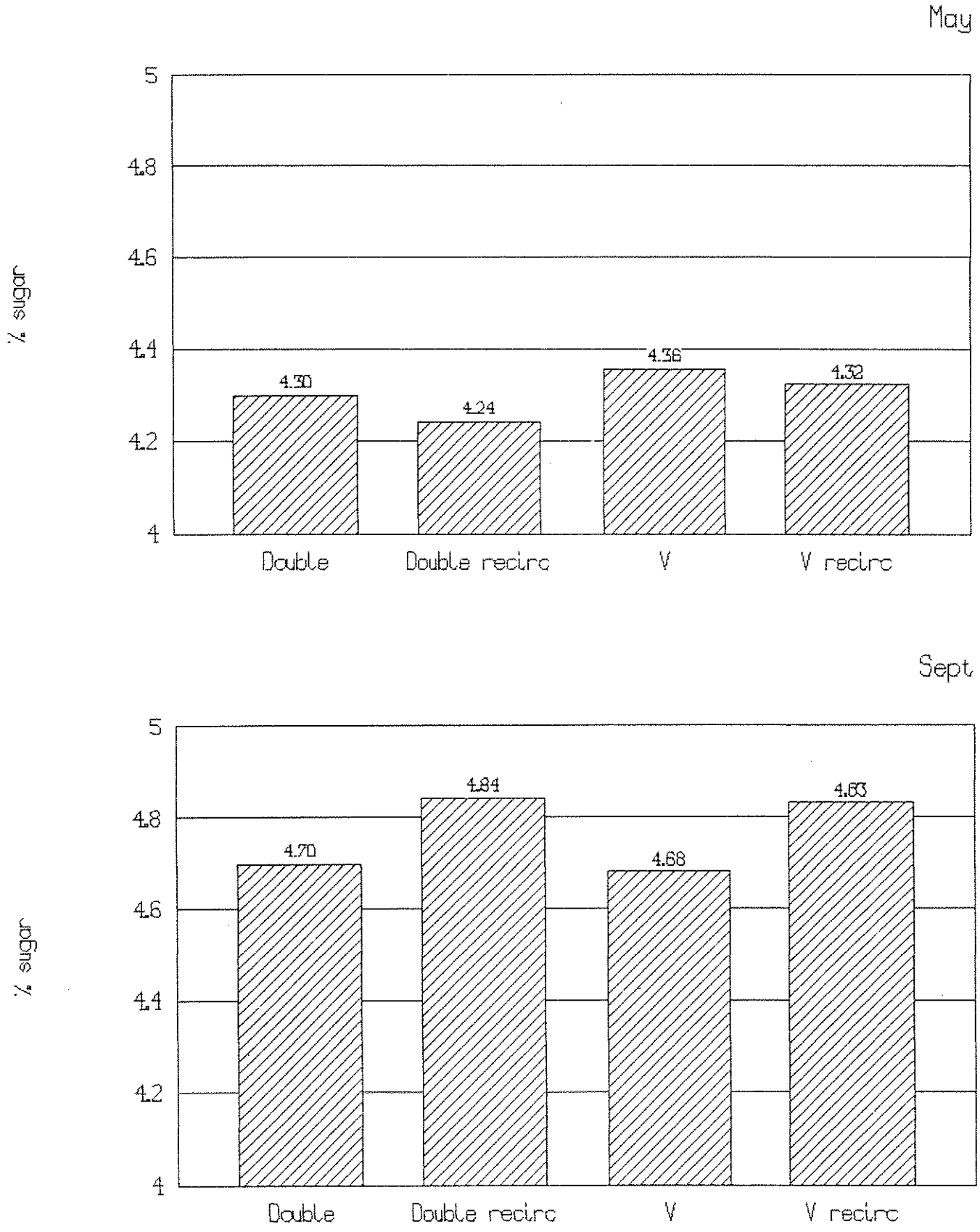


FIGURE 8: SUGAR CONTENT



Discussion

The results of this trial showed that over the season as a whole there were no significant yield differences between the run-to-waste and recirculation treatments. The trend however was towards reduced yields from the recirculation system although this effect was smaller where the V-System of training was used.

Likewise there were no significant differences in percentage Class I fruit until October, when quality was lower from the recirculation treatments. Detailed quality assessments showed that use of recirculation increased problems such as flecking and russetting although this was not always sufficient to cause downgrading.

Plants grown on the V-system produced the same percentage of Class I fruit as the double row but again detailed quality assessments showed that fruit defects were likely to be slightly more severe on the V-System.

The recirculation treatments did not influence fruit size where the double row system was used but on the V-System there was more large fruit where the run-off was recirculated than where it ran to waste. This effect could be related to slab conductivity since high initial densities of the V-System would be expected to decrease fruit size compared with the double row. The analysis of nutrient levels however showed an increased average slab conductivity for the recirculation treatments compared with the run-to-waste, for both the double row and the V-System, which would have led to a reduction in fruit size. The results do however show that in recirculation the V-system had a slightly lower conductivity than the double row.

There is therefore no obvious explanation for this fruit size effect. Optimum irrigation and nutrient regimes for the V-System need further evaluation as increased nutrient volumes flushing through each bag may have influenced crop performance.

In practise the recirculation system was not difficult to control, although frequent monitoring was required to ensure increases in slab conductivities were minimised and the correct nutrient balance was maintained.

Conclusions

1. Recirculation of run-off solution and the V-System of training did not reduce total yield compared with the standard system.

2. The percentage of Class I fruit was not influenced by recirculation or the V-System although both treatments tended to slightly increase fruit defects.

3. In the double row system use of recirculation did not influence fruit size.

4. In the V-System there was a tendency towards production of larger fruit when nutrient solution was recirculated.

5. Frequent monitoring and solution analysis was necessary to minimise nutrient imbalances and increases in solution conductivity.

APPENDIX I: STANDARD ADAS BLUEPRINT TEMPERATURES

Germination on heated base panels at 20-30 °C

Air Temperatures

Stage of Growth	Night	Day	Ventilation
0 Sowing to blocking on	20	20	24
1 Blocking onto first truss visible	15	20	24
2 Truss visible to first flower open	15	20	24
3 Planting to 2 weeks after start of picking	13-16	20	24
4 To the end of crop	13-16	18	21

APPENDIX II: AVERAGE NUTRIENT LEVELS IN APPLIED SOLUTION (mg/l)

	Standard (Double Row & V-System)	Double Recirculation	V-System Recirculation
pH	6.3	6.0	6.1
EC	3626	3346	3513
NH4-N	14	6	6
NO3-N	382	350	384
P	34	28	23
K	556	429	448
Ca	299	304	338
Mg	70	76	79
Na	25	34	38
Fe	2.40	2.0	2.02
Mn	0.63	0.38	0.37
Cu	0.11	0.14	0.17
Zn	1.06	0.88	0.91
B	0.45	0.30	0.30
Cl	37	51	50
SO4	60	71	66
HCO3	77	34	32