HORTICULTURE RESEARCH INTERNATIONAL

STOCKBRIDGE HOUSE

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

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

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

Contract Number: PC23b

Period Covered: 1991

CUCUMBERS: RECIRCULATION OF RUN-OFF SOLUTION FROM HYDROPONIC SYSTEMS

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

Index

Summary

The cucumber variety Rebella was planted in February in a long season trial to evaluate the effect of recirculation of nutrient solution on both rockwool and foam grown crops.

Use of recirculation showed yield benefits and had no detrimental effects on crop growth. Nutrition was controlled without difficulty and there was no plant death due to root diseases.

The crop on foam required frequent irrigation with small volumes due to its low water holding capacity but yield and crop quality were not reduced.

There was some reduction in plant death due to stem diseases when either foam slabs or recirculation was used.

Objective

To evaluate the effect of recirculation of the hydroponic solution for crops on rockwool and foam, compared with the two substrates in standard run-to-waste systems.

Introduction

Most of the cucumbers in the UK are grown on hydroponic substrates. At present the main substrate is rockwool but other substrates are always under consideration. Irrigation of nutrient solution is approximately 20% above the crop requirement to minimise risks from uneven irrigation systems. Excess runs to waste. There are increasing pressures to restrict run-off in order to prevent possible pollution from nutrients and pesticides which it may contain. Alternative systems involve collection and re-use of run-off in a system similar to NFT. As this method has never been used successfully for long season cucumbers the recirculating systems need careful evaluation.

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 alternative substrates such as Aggrofoam which can potentially be re-used for many seasons.

Materials and Methods

Variety:	Rebella
Sowing Date:	22 January
Planting Date: (slab contact)	14 February
First Harvest:	18 March
Final Harvest:	13 September
Plant Population:	5,500 plants/acre (45 cm row spacing)
Training System:	Cordon
Environment Temperature:	21°C day, 19°C night, 23°C vent with some fluctuation according to plant growth.
Carbon Dioxide:	1000 vpm until late April then 350 vpm.

Treatments

1. Rockwool, run-to-waste (standard).
2. Rockwool, recirculation.
3. Aggrofoam, run-to-waste.
4. Aggrofoam, recirculation.

In the recirculating system the slabs were placed on narrow polystyrene bridges approximately 3 cm high in plastic channels and slit in the normal way. Run-off was collected and returned to the mixing tank as the collection tank became full.

Irrigation Regimes

Both run-to-waste and recirculation systems received the same watering regime, 0.2-0.4 l/plant of approximately every 60 minutes, or when radiation exceeded 100 J/cm^2.

Target Nutrient Levels in the Slab (mg/l)

pH	5.8 - 6.2
EC	1500 - 2800
NO3-N	180
NH4-N	<1
K	240
Ca	180
Mg	30
P	40
Fe	3.0
Zn	0.5
Mn	0.5
Cu	0.1
B	0.3
Na	As little as possible (<100 ml/l)
Cl	As little as possible (<100 ml/l)

Experimental Design

The trial comprised 4 treatments in a 2 substrates x 2 irrigation systems factorial design. Two blocks of 4 double rows were available and each double row was used as a main plot for irrigation systems. Double rows were split into 2 sub-plots for the 2 substrate treatments with each sub-plot comprising 28 plants. Within each block, irrigation systems were replicated twice and the sub-plot treatments were allocated as a 2 x 2 row and column arrangements within irrigation system replicates.

Records

Fruit was harvested 3 times per week and graded for size and quality.

Applied, slab and run-off solution nutrient levels were analysed weekly and pH/EC of slab solution monitored daily.

Fruit Assessments:

- Fruit Length monthly

Shelf life of fruit was measured in May and July.

- Shelf Life Room Conditions
  20 °C, 50-60% RH
  12 hours light per 24 hours

- Assessments

Colour	0-9, where 9 is dark green and 0 is yellow.
Weight Loss	Percentage weight loss over seven days under shelf life conditions.

Firmness — Measured using a tensile strength machine.

Pressure (Newtons) required to bend a fruit 8 mm when held at both ends and pressed at the centre.

- Plant Measurements

  Plant height
  Leaf numbers
  Stem diameter

- Number of dead plants in September

Results

Crop Yield and Quality

The yields for individual months (cucumbers/m^2) show an overall trend towards higher production from the recirculation treatments than from those with excess solution running to waste (Table 1). A significant difference was recorded in April, May and June and at the end of the season there was 4.5% yield improvement for recirculation compared with the standard system (run-to-waste). The final yield difference did not reach the 5% significance level.

Differences in yield between substrates were smaller but from June onwards there was a suggestion of higher yields from plants grown on foam. Differences were largest in August and September. Total yield for the season was 3% higher from the foam treatments, which again was not a significant difference.

There was no evidence of an interaction between substrates and recirculation treatments, ie plants on both rockwool and foam showed the same yield increases when grown in recirculation.

Table 1: Yield (cucumbers/m^2)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Run-to-Waste								
Rockwool	5.4	24.0	18.5	13.3	19.8	9.6	2.7	93.4
Foam	5.7	23.5	18.1	14.9	21.3	10.7	3.8	98.1
Recirculation								
Rockwool	5.3	24.8	20.4	15.3	21.1	9.5	2.9	99.4
Foam	5.4	24.2	20.5	15.4	21.9	10.0	3.1	100.5
SED (12 df)	0.32	0.70	0.97	0.72	1.59	1.07	0.54	4.00
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Means								
Run-to-Waste	5.6	23.8	18.3	14.1	20.6	10.2	3.2	95.7
Recirculation	5.4	24.5	20.5	15.3	21.5	9.8	3.0	100.0
SED (7 df)	0.27	0.32	0.83	0.46	0.76	0.98	0.45	2.64
LSD (P = 0.05)	-	0.8	2.0	1.1	-	-	-	-
Significance	NS	*	*	*	NS	NS	NS	NS
Rockwool	5.4	24.4	19.5	14.3	20.5	9.6	2.8	96.4
Foam	5.5	23.8	19.3	15.1	21.6	10.4	3.5	99.3
SED (12 df)	0.17	0.62	0.49	0.55	1.39	0.44	0.31	3.00
LSD (P = 0.05)	-	-	-	-	-	0.9	0.7	-
Significance	NS	NS	NS	NS	NS	* 9%	*	NS

Key

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

Table 2 shows the fruit yield results represented as weight (kg) per m^2. The trends shown previously as number of fruit harvested were apparent again and differences in total yield were the same.

Differences in production between recirculation and run-to-waste systems were largest in May.

Table 2: Weight of Cucumbers (kg/m^2)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Run-to-Waste								
Rockwool	2.63	10.63	8.56	6.14	9.6	4.6	1.08	43.24
Foam	2.72	10.64	8.64	6.89	10.6	5.2	1.53	46.19
Recirculation								
Rockwool	2.60	11.10	9.44	7.22	10.5	4.5	1.22	46.55
Foam	2.64	10.79	9.50	7.24	10.9	4.6	1.24	46.96
SED (12 df)	0.193	0.360	0.335	0.398	0.825	0.545	0.235	1.968
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Means								
Run-to-Waste	2.68	10.63	8.60	6.51	10.1	4.9	1.31	44.72
Recirculation	2.62	10.95	9.47	7.23	10.7	4.6	1.23	46.75
SED (7 df)	0.173	0.255	0.233	0.233	0.403	0.495	0.202	1.161
LSD (P = 0.05)	-	-	0.55	0.55	-	-	-	-
Significance	NS	NS	**	*	NS	NS	NS	NS
Rockwool	2.62	10.86	9.00	6.68	10.0	4.5	1.15	44.90
Foam	2.68	10.72	9.07	7.07	10.7	4.9	1.38	46.58
SED (12 df)	0.087	0.255	0.241	0.323	0.720	0.228	0.120	1.589
LSD (P = 0.05)	-	-	-	-	-	-	0.26	-
Significance	NS	NS	NS	NS	NS	NS	* 7%	NS

There were no significant differences in average fruit weight between rockwool and foam or fruit from run-to-waste and recirculation systems.

Table 3 shows that weights were variable but in the standard run-to-waste system there was a suggestion that plants grown on foam produced heavier fruit than plants grown on rockwool

Table 3: Mean Fruit Weight (g)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Run-to-Waste								
Rockwool	483	443	465	464	485	474	399	463
Foam	480	452	477	464	498	482	402	471
Recirculation								
Rockwool	491	446	462	472	496	472	417	468
Foam	488	447	464	470	498	461	395	467
SED (12 df)	10.0	11.6	14.6	14.1	8.8	9.2	16.2	8.0
LSD (P = 0.05)	-	-	-	-	-	2.0	-	-
Significance	NS	NS	NS	NS	NS	* 9%	NS	NS
Means								
Run-to-Waste	481	447	471	464	491	478	400	467
Recirculation	489	447	463	471	497	467	406	468
SED (7 df)	9.0	10.5	13.6	13.0	7.2	7.3	13.2	7.4
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Rockwool	487	445	463	468	491	473	408	466
Foam	484	450	471	467	498	471	398	469
SED (12 df)	4.3	4.9	5.3	5.6	5.1	5.5	9.4	3.0
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS

There were no corresponding differences in fruit length (Table 4). Average figures for the season suggest that plants on foam slabs with excess solution running to waste produced the heaviest fruit but also the shortest. Fruit grown on recirculation tended to be longer.

Table 4: Fruit Lengths

	25 Mar	10 Apr	17 May	12 Jun	17 Jul	4 Sep	Mean
Run-to-Waste							
Rockwool	34.6	28.3	35.5	36.9	37.1	33.6	34.3
Foam	33.9	29.0	35.0	35.8	35.8	34.4	34.0
Recirculation							
Rockwool	35.2	29.0	35.9	36.0	37.4	34.4	34.6
Foam	34.9	29.5	34.5	37.4	37.6	33.8	34.6

Results for fruit quality (Table 5) show that in the early part of the season the recirculation systems produced a higher percentage of fruit in Class I. This continued until June when the trend was reversed. The average for the whole season showed no significant difference between the two systems.

Between the two substrate treatments there was a similar pattern. The foam treatment gave better quality in March and April but was poor in August and September. Overall, plants grown on foam produced an equal amount of Class I fruit to those grown on rockwool.

Table 5: Percentage Class I (by number)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Run-to-Waste								
Rockwool	89.6	91.4	87.8	79.3	74.3	61.9	64.3	81.5
Foam	92.3	92.3	86.4	79.4	75.2	60.9	61.4	80.9
Recirculation								
Rockwool	93.2	91.4	89.2	79.0	74.6	56.6	62.9	81.4
Foam	97.5	95.3	90.5	80.8	74.7	53.2	61.6	82.5
SED (12 df)	2.27	1.17	1.20	1.86	4.03	3.16	3.40	1.01
LSD (P = 0.05)	-	2.5	-	-	-	-	-	-
Significance	NS	* 7%	NS	NS	NS	NS	NS	NS
Means								
Run-to-Waste	91.0	91.9	87.1	79.4	74.8	61.4	62.8	81.2
Recirculation	95.3	93.3	89.8	79.9	74.6	54.9	62.3	81.9
SED (7 df)	1.23	0.85	0.75	1.44	2.87	2.57	2.10	0.86
LSD (P = 0.05)	2.9	-	1.8	-	-	6.1	-	-
Significance	**	NS	**	NS	NS	*	NS	NS
Rockwool	91.4	91.4	88.5	79.2	74.5	59.3	63.6	81.4
Foam	94.9	93.8	88.4	80.1	74.9	57.1	61.5	81.7
SED (12 df)	1.91	0.80	0.94	1.18	2.83	1.84	2.67	0.53
LSD (P = 0.05)	4.2	1.7	-	-	-	-	-	-
Significance	* 9%	**	NS	NS	NS	NS	NS	NS

When the season was considered as a whole there was no significant difference in production of Class II fruit between substrates or irrigation treatments (Table 6). There was however evidence that plants grown on foam produced more Class II fruit when grown in the standard run-to-waste system than when grown in recirculation.

Table 6: Percentage Class II Fruit (by number)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Run-to-Waste								
Rockwool	10.4	7.8	9.6	18.8	20.0	27.1	31.2	15.0
Foam	7.4	6.7	11.1	16.9	19.9	29.4	33.7	15.5
Recirculation								
Rockwool	6.8	7.7	9.1	17.5	20.1	32.2	30.7	15.1
Foam	2.3	4.0	7.0	16.8	20.1	35.5	32.6	14.0
SED (12 df)	2.28	1.02	0.97	1.90	3.48	3.35	4.14	0.85
LSD (P = 0.05)	-	2.2	2.1	-	-	-	-	1.8
Significance	NS	* 7%	*	NS	NS	NS	NS	* 6%
Means								
Run-to-Waste	8.9	7.3	10.3	17.8	20.0	28.3	32.4	15.3
Recirculation	4.6	5.9	8.1	17.1	20.1	33.8	31.7	14.6
SED (7 df)	1.25	0.77	0.62	1.33	2.50	3.01	2.13	0.75
LSD (P = 0.05)	3.0	-	1.5	-	-	-	-	-
Significance	**	NS	**	NS	NS	NS	NS	NS
Rockwool	8.6	7.8	9.3	18.1	20.1	29.6	30.9	15.1
Foam	4.9	5.4	9.1	16.9	20.0	32.5	33.1	14.8
SED (12 df)	1.91	0.67	0.74	1.36	2.42	1.47	3.55	0.40
LSD (P = 0.05)	4.2	1.5	-	-	-	3.2	-	-
Significance	* 7%	**	NS	NS	NS	* 8%	NS	NS

There was no overall difference between irrigation treatments in the size of Class I fruit produced (Tables 7-10) although in July there was more Grade A fruit (250-400 g) and less Grade C fruit (500-650 g) from the run-to-waste system.

Comparing the two substrates, plants on rockwool generally produced more small fruit, with significant differences in April and July. In September fruit size fell, for rockwool the highest percentage went into Grade B (400-500 g) but for foam the highest percentage was in Grade A (250-400 g).

Plants on rockwool produced less fruit in Grade C (500-650 g) over the season as a whole.

Table 7: Percentage Grade A Fruit (250-400 g)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Run-to-Waste								
Rockwool	11.2	30.2	23.8	25.5	19.9	24.1	43.3	24.8
Foam	14.4	25.5	22.3	23.9	16.2	20.9	45.9	22.3
Recirculation								
Rockwool	15.9	28.6	24.1	23.1	17.8	25.7	35.5	23.8
Foam	15.0	25.5	25.0	21.7	15.2	28.3	49.0	22.7
SED (12 df)	3.16	5.55	3.82	4.17	1.20	4.27	6.59	2.86
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Means								
Run-to-Waste	12.8	27.9	23.0	24.7	18.0	22.5	44.6	23.5
Recirculation	15.5	27.1	24.5	22.4	16.5	27.0	42.3	23.3
SED (7 df)	2.20	5.22	3.32	3.56	0.79	3.28	4.06	2.64
LSD (P = 0.05)	-	-	-	-	1.9	-	-	-
Significance	NS	NS	NS	NS	* 9%	NS	NS	NS
Rockwool	13.6	29.4	23.9	24.3	18.8	24.9	39.4	24.3
Foam	14.7	25.5	23.7	22.8	15.7	24.6	47.5	22.5
SED (12 df)	2.28	1.88	1.90	2.16	0.89	2.73	5.19	1.09
LSD (P = 0.05)	-	4.1	-	-	1.9	-	-	-
Significance	NS	* 6%	NS	NS	**	NS	NS	NS

Table 8: Percentage Grade B Fruit (400-500 g)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Run-to-Waste								
Rockwool	39.3	44.0	36.2	37.5	36.0	35.9	43.3	39.0
Foam	39.3	43.6	35.1	38.9	37.6	37.2	36.8	39.0
Recirculation								
Rockwool	34.4	44.3	37.1	36.8	35.2	35.8	48.8	38.7
Foam	36.0	42.8	38.2	38.8	34.7	33.7	33.8	38.4
SED (12 df)	3.83	3.00	2.52	2.88	2.09	3.84	5.2	1.37
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Means								
Run-to-Waste	39.3	43.8	35.7	38.2	36.8	36.5	40.0	39.0
Recirculation	35.2	43.6	37.7	37.8	34.9	34.8	41.3	38.6
SED (7 df)	2.81	2.72	2.14	2.54	1.77	2.75	2.89	1.19
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Rockwool	36.8	44.1	36.7	37.2	35.6	35.9	46.1	38.9
Foam	37.7	43.2	36.7	38.9	36.1	35.4	35.3	38.7
SED (12 df)	2.59	1.26	1.32	1.35	1.11	2.67	4.33	0.69
LSD (P = 0.05)	-	-	-	-	-	-	9.4	-
Significance	NS	NS	NS	NS	NS	NS	*	NS

Table 9: Percentage Grade C Fruit (500-650 g)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Run-to-Waste								
Rockwool	43.5	23.2	32.0	30.1	33.4	29.7	9.9	29.6
Foam	41.8	27.6	33.7	29.2	33.4	32.3	15.7	31.2
Recirculation								
Rockwool	41.4	24.2	29.6	32.9	36.4	29.3	13.9	30.2
Foam	43.4	28.5	30.2	32.7	39.4	31.5	15.0	32.5
SED (12 df)	3.54	3.71	3.91	3.72	1.95	2.96	5.56	2.12
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Means								
Run-to-Waste	42.6	25.4	32.9	29.6	33.4	31.0	12.8	30.4
Recirculation	42.4	26.4	29.9	32.8	37.9	30.4	14.4	31.4
SED (7 df)	2.82	3.41	3.45	3.15	1.17	2.16	3.51	1.92
LSD (P = 0.05)	-	-	-	-	2.8	-	-	-
Significance	NS	NS	NS	NS	**	NS	NS	NS
Rockwool	42.4	23.7	30.8	31.5	34.9	29.5	11.9	29.9
Foam	42.6	28.0	31.9	31.0	36.4	31.9	15.3	31.8
SED (12 df)	3.14	1.47	1.83	1.98	1.55	2.02	4.31	0.88
LSD (P = 0.05)	-	3.2	-	-	-	-	-	1.9
Significance	NS	**	NS	NS	NS	NS	NS	*

Table 10: Percentage Grade D Fruit (650-800 g)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
Run-to-Waste								
Rockwool	6.0	2.6	8.0	6.9	10.6	10.2	3.5	6.7
Foam	4.5	3.3	8.8	8.0	12.8	9.6	1.7	7.5
Recirculation								
Rockwool	8.3	2.8	9.2	7.2	10.6	9.2	1.8	7.2
Foam	5.6	3.2	6.6	6.8	10.7	6.4	2.2	6.3
SED (12 df)	2.15	1.01	2.12	2.47	1.86	1.80	1.78	1.17
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Means								
Run-to-Waste	5.2	3.0	8.4	7.5	11.7	9.9	2.6	7.1
Recirculation	6.9	3.0	7.9	7.0	10.7	7.8	2.0	6.8
SED (7 df)	1.88	0.85	1.81	2.23	1.24	1.24	0.80	1.03
LSD (P = 0.05)	-	-	-	-	-	-	-	-
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Rockwool	7.2	2.7	8.6	7.0	10.6	9.7	2.6	6.9
Foam	5.0	3.3	7.7	7.4	11.7	8.0	1.9	6.9
SED (12 df)	1.06	0.55	1.10	1.05	1.39	1.30	1.59	0.55
LSD (P = 0.05)	2.3	-	-	-	-	-	-	-
Significance	* 7%	NS	NS	NS	NS	NS	NS	NS

Monetary value (Table 11) is calculated using the yields and quality from the treatments throughout the season together with average UK prices. It shows the expected financial returns if these treatments were applied.

Table 11 shows that differences between treatments were not significant although both recirculation and foam treatments gave slight financial benefits compared with the standard.

The return of £22.26 per m^2 for the best treatment, foam in recirculation, was over 8% higher than the standard (rockwool, run-to-waste) at £20.43.

Table 11: Monetary Value (£/m^2)

	March - September
Run-to-Waste	
Rockwool	20.43
Foam	21.69
Recirculation	
Rockwool	21.89
Foam	22.26
SED (12 df)	0.808
LSD (P = 0.05)	-
Significance	NS
Means	
Run-to-Waste	21.06
Recirculation	22.07
SED (7 df)	0.515
LSD (P = 0.05)	-
Significance	NS
Rockwool	21.16
Foam	21.98
SED (12 df)	0.622
LSD (P = 0.05)	-
Significance	NS

Plant Measurements

Plant height measurements taken 5 days before the first harvest suggest that plants on rockwool were slightly further advanced than those on foam (Table 12). The number of leaves which had developed on that date confirm this slight difference although there was no difference in vigour, measured as stem diameter.

Table 12: Plant Measurements on 13 March

	Plant Height (cm)	Leaf Number	Stem Diameter (mm)
Run-to-Waste			
Rockwool	189	18.3	10.5
Foam	185	18.0	10.5
Recirculation			
Rockwool	185	18.2	10.7
Foam	181	17.8	10.6

Assessments at Crop Termination

In September large numbers of plants were dying due to stem diseases and the total number of dead plants in each treatment was counted (Table 13).

There was strong evidence to suggest that the level of plant losses was higher in the run-to-waste system than in the recirculation, there was also a difference between rockwool and foam, with more dead plants on rockwool. Plot yields were not adjusted to account for missing plants as the losses seemed to be treatment related.

Table 13: Percentage Dead Plants

	2 September 1992
Run-to-Waste	
Rockwool	54.5
Foam	36.6
Recirculation	
Rockwool	33.9
Foam	31.3
SED (12 df)	10.83
LSD (P = 0.05)	-
Significance	NS
Means	
Run-to-Waste	45.5
Recirculation	32.6
SED (7 df)	9.67
LSD (P = 0.05)	-
Significance	NS
Rockwool	44.2
Foam	33.9
SED (12 df)	4.87
LSD (P = 0.05)	-
Significance	NS

The slabs were slit open and turned over so that the roots could be assessed. Table 14 shows that in the foam slabs there was a large amount of root on the bottom of the slabs, while in the rockwool the root was more evenly spread through the slab. Roots on the foam slabs were also finer than those on rockwool.

Slabs from the recirculation treatments had less healthy white root, which may indicate that root disease was present in the system at low levels although no symptoms had been observed.

Table 14: Root Assessment at Crop Termination (19 September)

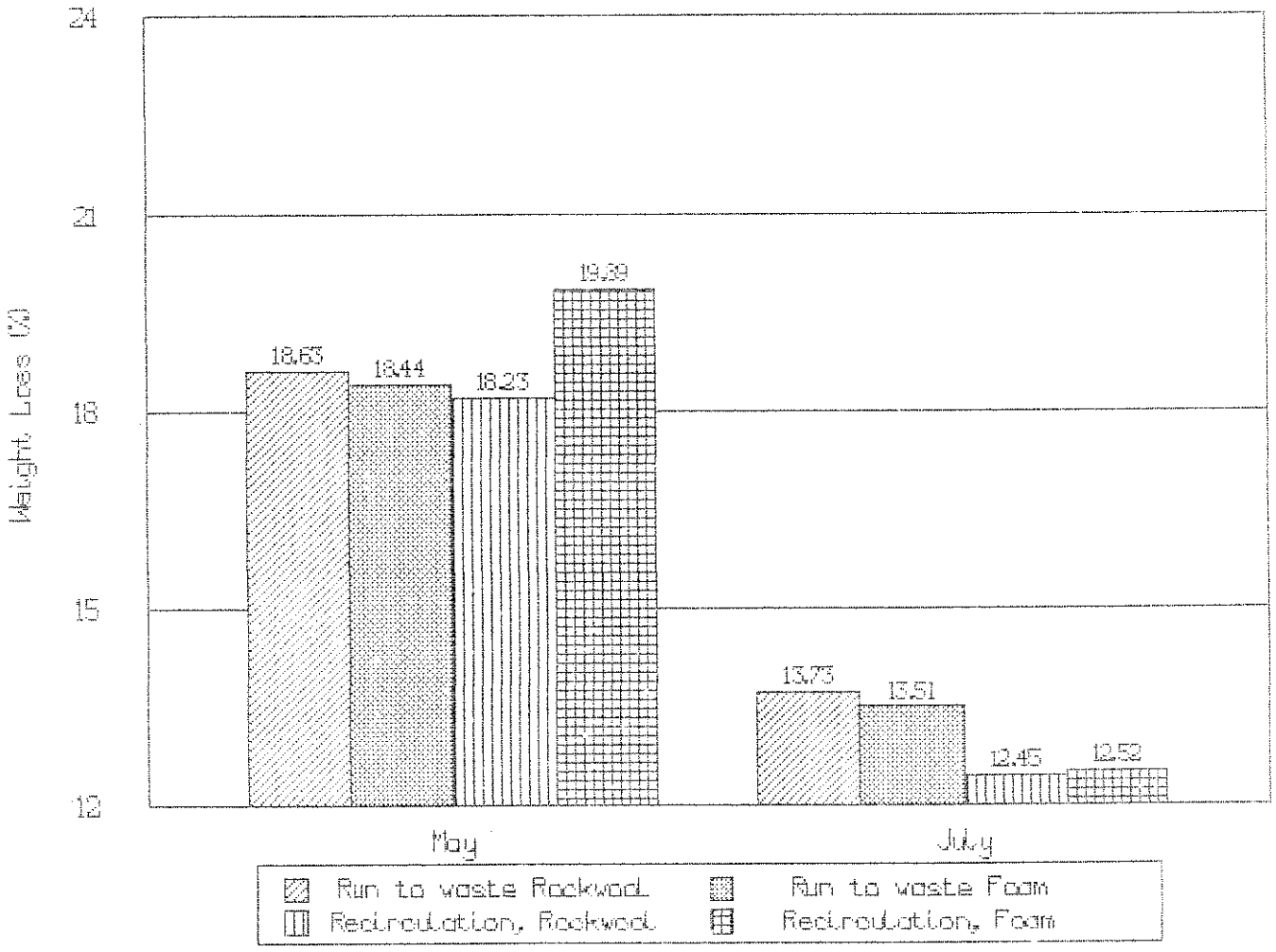
	% of Base covered with Root	% White Root of of Total on Base
Run-to-Waste		
Rockwool	37	37
Foam	77	27
Recirculation		
Rockwool	58	12
Foam	73	8

Shelf Life

Fruit was tested for shelf life qualities in May and July. Over the 7 day period under shelf life conditions fruit lost more weight from the July harvest but the pattern between treatments was similar (Figure 1).

In the run-to-waste system fruit grown on foam lost less weight than fruit grown on rockwool, but in recirculation the reverse was true. For rockwool, fruit from the recirculation treatment showed less weight loss than fruit from the run-to-waste system, and the same applied for the foam treatment in July, but in May there was very high weight loss for fruit from the foam slabs in recirculation.

Figure 1



Fruit colour was assessed on a scale of 0 to 9 where 9 was very dark green. In May fruit from the run-to-waste system was generally darker than fruit from the recirculation treatment (Figure 2) and fruit from rockwool became pale faster than fruit from foam.

In July fruit grown on rockwool was darker than fruit grown on foam at harvest and remained darker over the shelf life period. Differences between recirculation and run-to-waste were small at harvest but as the fruit aged that from the run-to-waste system became pale faster (Figure 3).

Figure 2

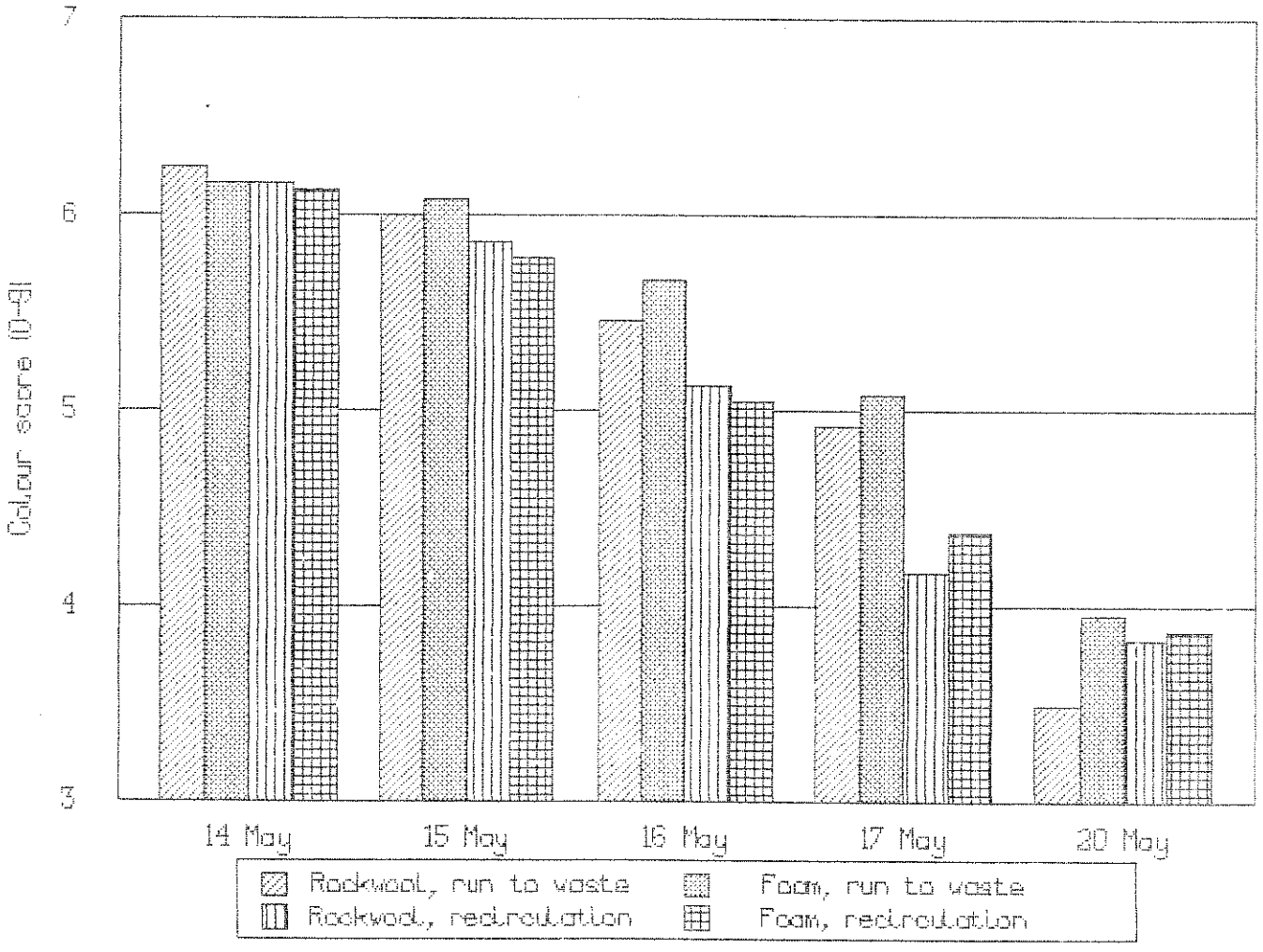
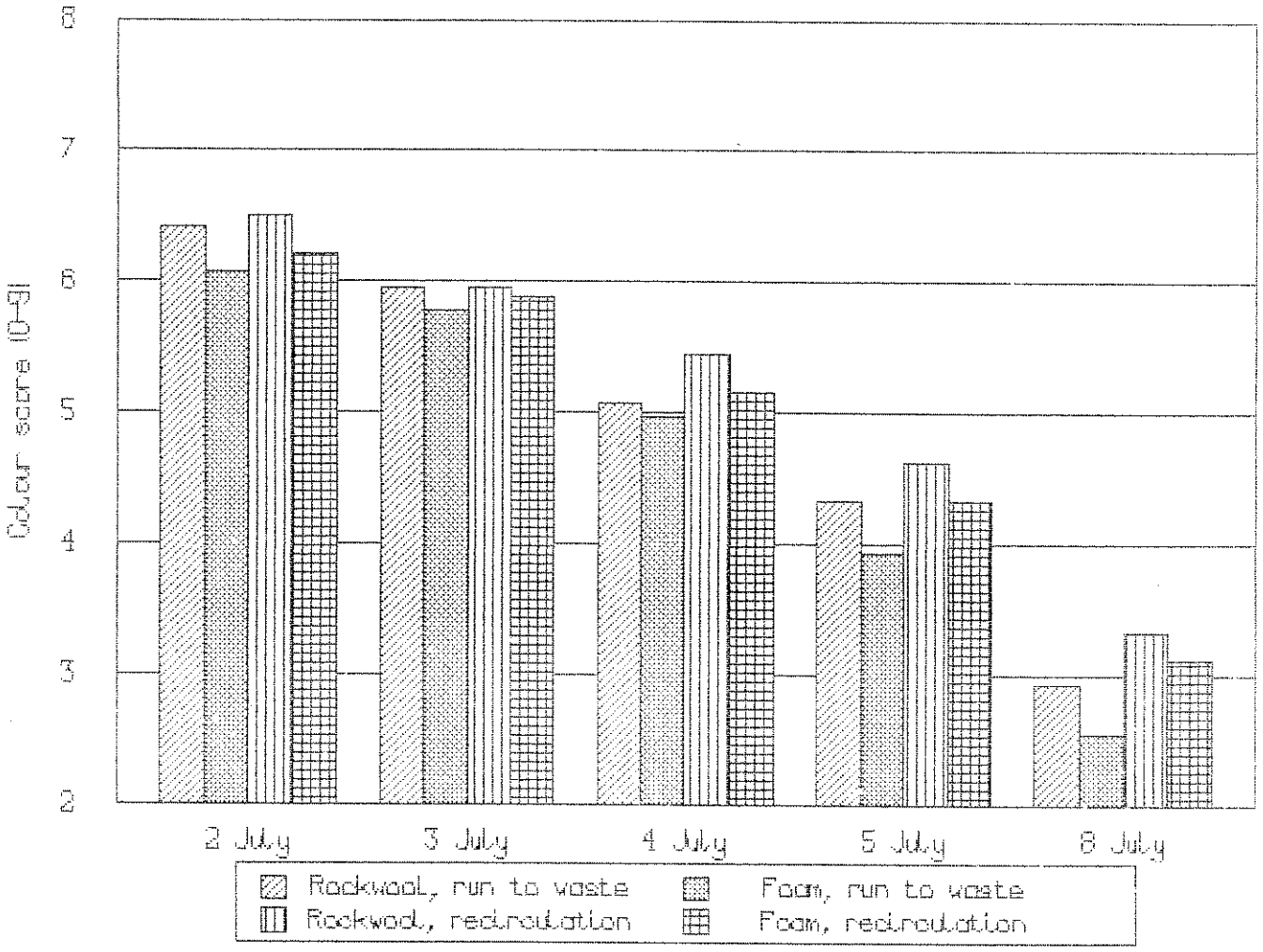


Figure 3


Odour score (0-9)
8
7
6
5
4
3
2
2 July
3 July
4 July
5 July
8 July
Rockwool, run to waste
Rockwool, recirculation
Foam, run to waste
Foam, recirculation

Fruit harvested in July was considerably firmer than fruit harvested in May, when tested on a tensile strength machine although the difference could not be detected manually. In May fruit grown on foam was firmer than fruit grown on rockwool (Figure 4) and this was also true for the run-to-waste system in July (Figure 5). From the recirculation system however fruit grown on foam was much softer in the July assessment. At both periods there was little difference in firmness between fruit grown on the two irrigation systems.

Figure 4

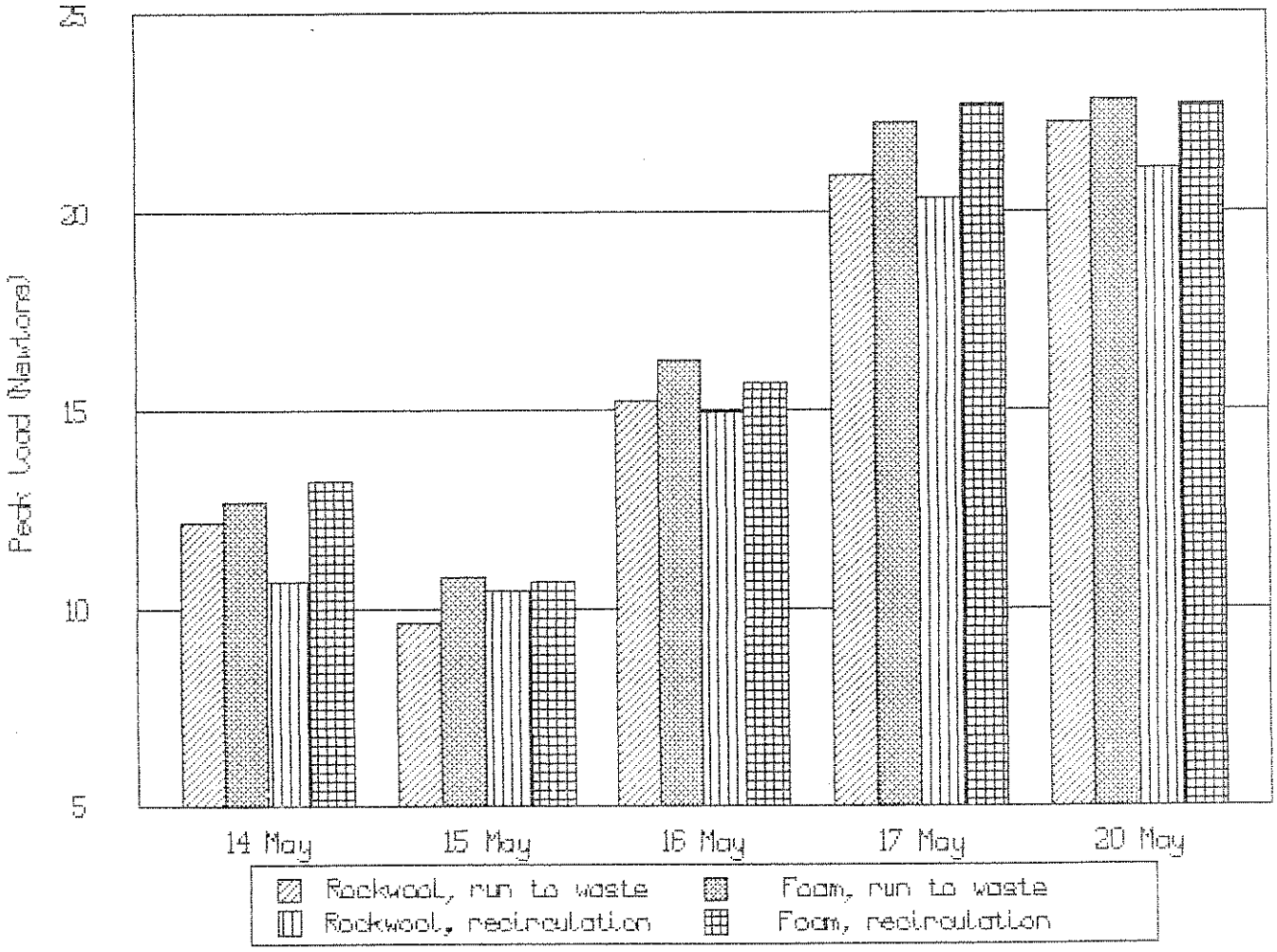
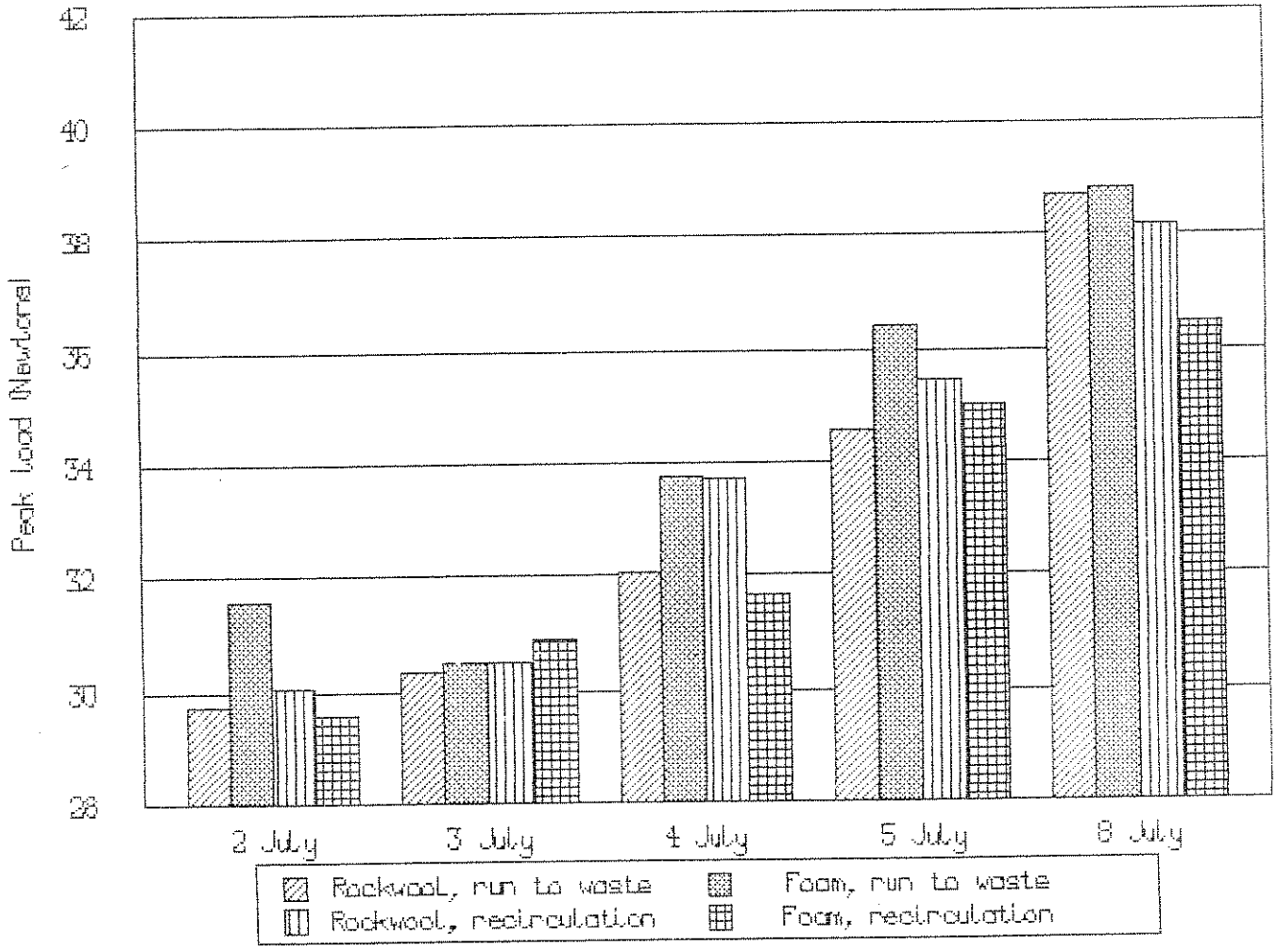


Figure 5


Peak load (Newtons)
42
40
38
36
34
32
30
28
2 July
3 July
4 July
5 July
8 July
Rockwool, run to waste
Rockwool, recirculation
Foam, run to waste
Foam, recirculation

Nutrition

Figure 6 demonstrates the differences in slab conductivity between the recirculation and run-to-waste systems throughout the season. Elements such as calcium tended to accumulate and led to increases in conductivity. The irrigation units were unable to inject fresh water to reduce conductivity and at times it was necessary to release controlled amounts of solution from the system in order to correct imbalances. The points when this occurred are indicated on Figure 6. Average conductivity for the season was 2768 for run-to-waste and 3035 for recirculation although the aim was to keep them as close as possible.

Figure 6

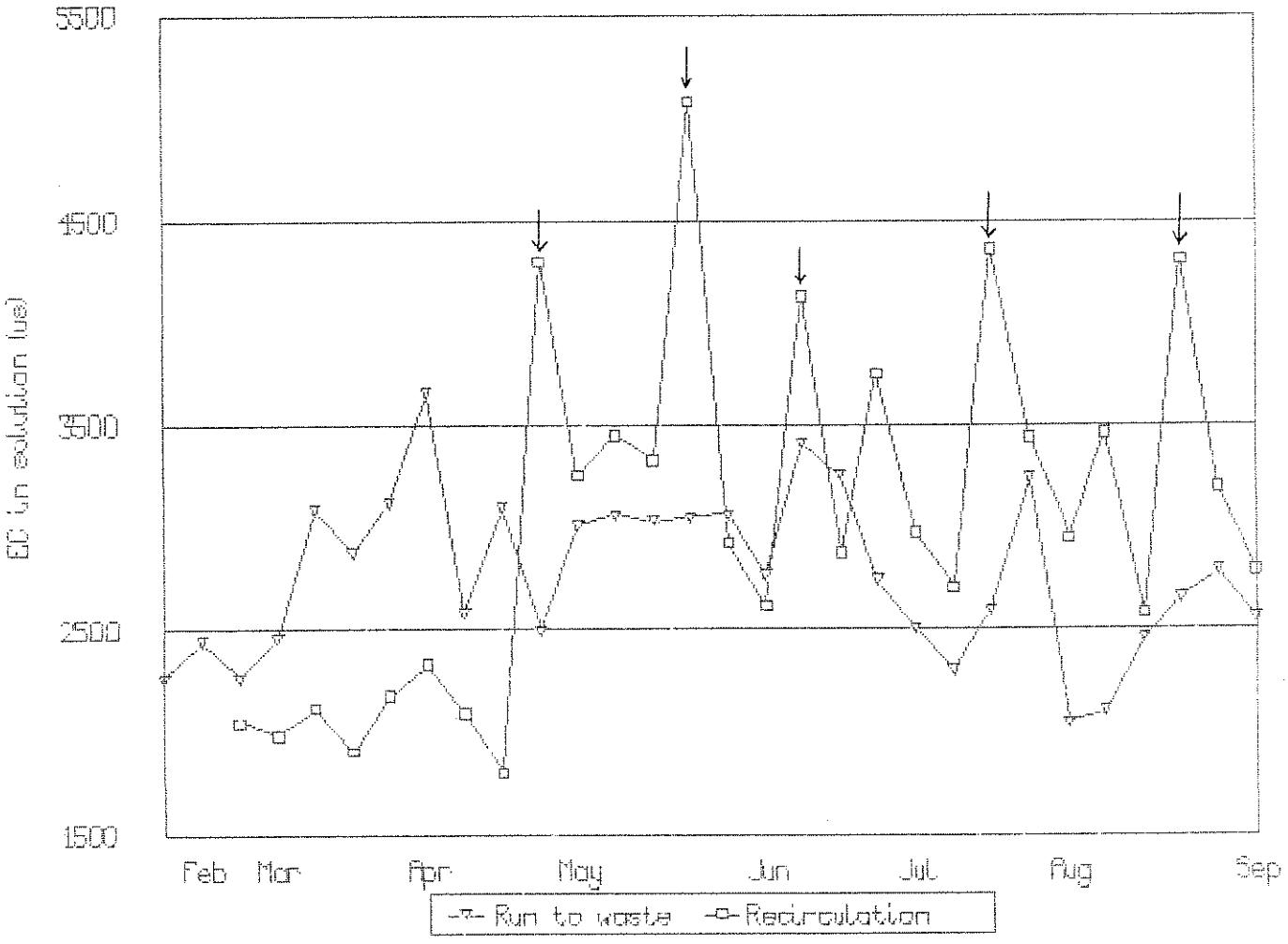


Figure 7 demonstrates how calcium tended to build up in solution and contributed to the high conductivity levels. Sodium also increased but as base levels in the water were low the level was never critical (Figure 8).

Figure 7

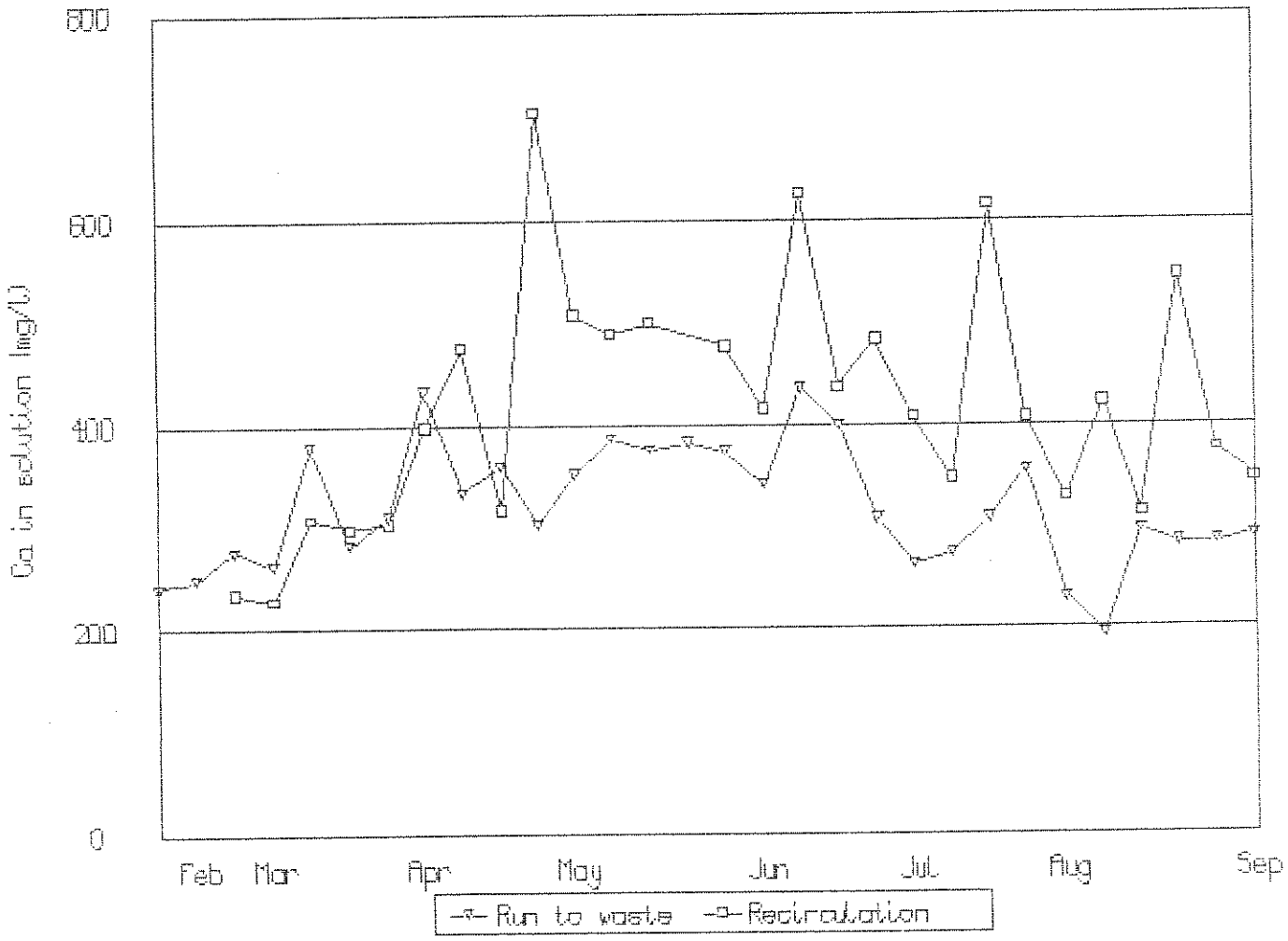
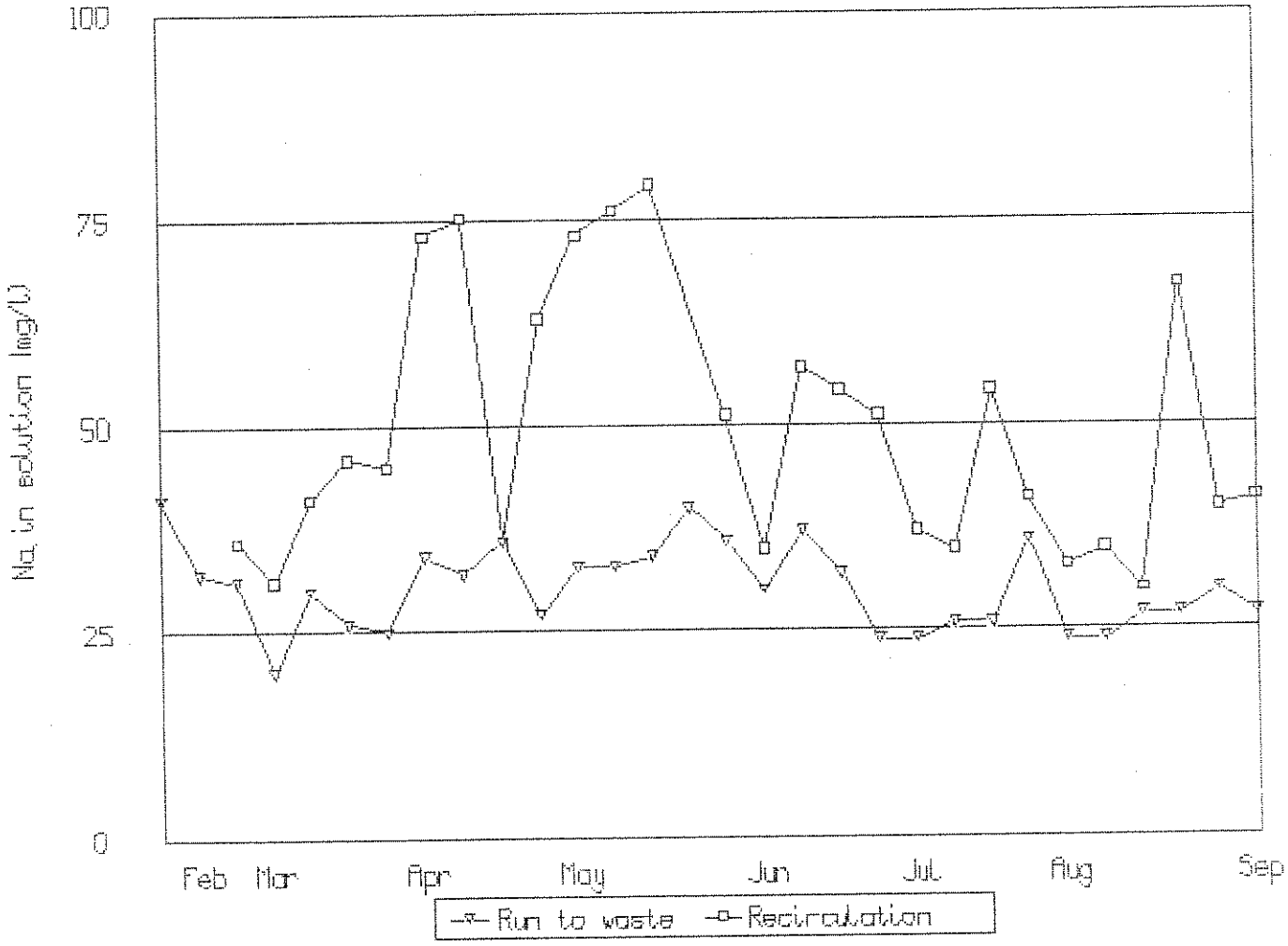


Figure 8


100
75
50
25
0
Na in solution (mg/l)
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Run to waste
Recirculation

Discussion

The results from this trial were very promising in that both foam and recirculation treatments gave results that equalled or exceeded the standard (rockwool), run-to-waste).

Plant growth in the recirculation treatment was equal to that in the run-to-waste system for both substrates. At times plants on foam showed a slight reduction in vigour compared with those on rockwool. This could have been due to differences in slab wetness. Foam had a much lower water holding capacity than rockwool and therefore needed frequent irrigations with small volumes of water. If slabs became dry due to faulty irrigation nozzles they were more difficult to re-wet than rockwool and it is therefore particularly important that the irrigation system is reliable.

The higher volume of air in the foam slabs should be beneficial to root growth. Examination of the slabs showed that a high percentage of the root was confined to the bottom where there was most water but the root was much finer and therefore possibly more active than the root in rockwool slabs.

Future trials will involve re-use of foam slabs after sterilisation as research from Belgium suggests that the water holding capacity improves when the slab is re-used.

When collecting and recirculating run-off solution there is always a risk of spreading root disease from infected plants to the whole crop. In this trial there was no solution sterilisation but the slabs were treated with propamocarb hydrochloride (Filex) at planting and twice after planting as a preventative measure. No plants were lost through root diseases but the amount of root discolouration at crop termination suggest that disease had been spreading throughout the system at low levels. Although the results of this trial are encouraging it is not recommended that cucumber growers use recirculation without solution sterilisation until more research has been completed.

It is difficult to draw any positive conclusions from the shelf life measurements carried out as part of this trial. Differences between substrates were larger than differences between recirculation and run-to-waste and the foam seemed to be particularly variable. "Real" shelf life/quality effects that could be detected without specialised equipment were negligible. Shelf life should be examined more frequently in future work in order to pick up treatment trends.

Despite a tendency towards rising conductivity the nutrition of the crop in recirculation did not present any serious problems. Close monitoring allowed imbalances to be corrected by adjustment of stock solution or by solution dumping. The water at HRI Stockbridge House is very clean and growers in other areas may experience more problems.

There was evidence of differences in numbers of dead plants between the treatments, with both recirculation and foam showing lower plant losses. These were the higher yielding treatments and this would suggest that higher plant numbers caused the increases. Large yield differences occurred early in the season however, before plant losses started and there may be some factor which has led to both improved early yield and reduced plant losses. Less free water beneath the crop may have contributed by reducing humidity but no measurements are available to support this.

Conclusions

1. Total marketable fruit yield was higher from plants grown in recirculation than from plants grown with the standard run-to-waste system.

2. There was a slightly higher yield from plants grown on foam, particularly towards the end of the season.

3. At times plant vigour was lower for plants grown on foam, but did not affect yield.

4. Foam slabs had low water holding capacity and required frequent irrigation with small volumes of solution.

5. Plant losses due to stem diseases were lower for the foam and recirculation treatments.

6. Crop nutrition in recirculation was not difficult to control in this trial.