HORTICULTURE RESEARCH INTERNATIONAL

Stockbridge House, Cawood, Selby, North Yorkshire

FINAL REPORT

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

The effect of reduced nitrogen feeds on growth and yield of cucumber plants

May 1997

Project title:	The effect of reduced nitrogen feeds on growth and yield of cucumber plants.
Project number:	PC 111
Project agronomist:	Dr C Hufton, HRI Stockbridge House
Project soil scientist:	Dr J Vaughan, ADAS
Project manager & joint author of report:	Mrs M Hardgrave, HRI Stockbridge House
Location:	Horticulture Research International Stockbridge House Cawood Selby North Yorkshire YO8 0TZ Tel: 01757 268275 Fax: 01757 268996
Project co-ordinator:	Mr D Hargreaves
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The results and conclusions in this report are based on one experiment. The conditions under which the experiment was carried out and the results have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results especially if they are used as the basis for commercial product recommendations.

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 ....

Mrs M Hardgrave
Project Manager
Horticulture Research International
Stockbridge House

Date ...7/5/97...

Report authorised by ....
(signature)

M R Bradley
Head of Station
Horticulture Research International
Stockbridge House
Cawood
Selby
North Yorkshire
YO8 0TZ

Tel. 01757 268275
Fax. 01757 268996

Date ...7.5.97...

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PRACTICAL SECTION FOR GROWERS

Background and objectives

It has been demonstrated (HDC Project PC55a) that nitrate levels in the feed applied to long season tomatoes can be greatly reduced, giving savings in fertiliser costs and reducing the risk of nitrogen run-off into ground and surface waters.

This project aimed to determine whether similar reduction were possible for cucumber crops, without loss of yield or deterioration in fruit quality.

Summary of results

Experiments were carried out over two years using early and replanted crops in both years.

In Year 1 cucumber plants were fed, from wetting up, with nutrient solution containing nitrogen at 80, 130, 180 (standard), and 230 ppm. At the lowest N concentration deficiency symptoms were seen in the vegetative parts of the plant, with reduced growth, delayed lateral production and leaf chlorosis. The generative parts of the plant did not deteriorate with lower nitrogen levels in terms of yield or quality.

As nitrogen concentration increased the plants became more vigorous, green and healthy. Yield was increased slightly at the highest nitrogen concentration in the replanted crop.

In Year 2, the range of the nitrogen treatments was widened to determine at what level it would limit productivity. Concentrations of 70, 130, 190, and 250 ppm were evaluated.

Total yield was reduced significantly in the 70 ppm N treatment and plant growth was severely restricted, with marked chlorosis (yellowing) of the leaves. In the 250 ppm N treatment vigour was reduced and there was a slight loss of productivity.

In both years there was no effect on productivity by reducing the N concentration of the applied feed to 130 ppm N.

Regular solution analysis of the slab and run-off in both years indicated that early in the growth of the plants there is a high demand for nitrogen, but once plants are mature and in full fruit production much lower levels of nitrogen are sufficient.

Reducing the nitrogen content of the approved feed from the current standard of 180 ppm N to 130 ppm resulted in a drop in the average N content of the run-off of 111 ppm N for the early crop, and 46 ppm for the second crop. This indicates that this method would be suitable for greatly reducing the amount of nitrogen in run-off whilst maintaining optimum growth and productivity.

Action points for growers

- The target nitrogen concentration of the applied feed for cucumbers should be reduced to 150 ppm N (150 mg/l).

  This includes a 'safety margin' to allow for practical difficulties in achieving the target and variability in percentage run-off.

- Total N included nitrate-N (NO_3-N) plus ammonium-N (NH_4-N).

- A reduction in the nitrogen concentration of the applied feed could be achieved by exchanging Potassium nitrate for Potassium chloride.

- During establishment cucumber plants have a high demand for nitrogen and concentrations should not be reduced during this period.

  Recommendations for applied nitrogen levels during establishment will be available at the end of the 1997 season, together with information on the recommended growth stage when a reduction should be made.

Practical and financial benefits from study

Reducing the nitrogen concentration of the applied feed by just 30 mg/l has been shown to have a large effect on the nitrogen concentration of the run-off.

Customers are putting ever increasing pressures on growers to take environmental factors into consideration and this simple method should help to reduce the pressure to change to expensive recirculation systems.

There are likely to be savings in fertiliser costs of £385-£535 per ha. Use of the cheaper Potassium Chloride could increase this further.

SCIENCE SECTION

INTRODUCTION

Hydroponic waste solution which runs off from glasshouse crops can be defined as polluting matter, according to certain of the components it contains. The nitrate and phosphate remaining in the solution after crop uptake, and any pesticides, are the most important compounds to consider.

Under Section 85 of the Water Resources Act (1991) it is an offence to allow polluting run-off from a nursery to enter controlled waters without proper authority (usually a discharge consent from the National Rivers Authority). Controlled waters means all ground water, coastal or inland waters including rivers, steams and most lakes and ponds.

Most growers, when irrigating greenhouse hydroponic crops, allow at least 30% run-off to ensure that all plants receive adequate irrigation (J Vaughan, 1991). This run-off is generally allowed to soak into the soil of the greenhouse where it percolates down through the soil profile. If this contaminates ground water it is known as diffuse pollution. A second type of pollution, point source pollution, may occur if the run-off from a nursery is collected before being discharged to controlled waters. This includes surface troughs or pipe systems as well as underground land drains. Horticulture is governed by the same legislation covering agriculture and this includes the levying of fines if pollution is caused. Pollution offenses are regarded very seriously and carry a penalty of up to £20,000 in the Magistrates court or an unlimited amount in the Crown Court. It may also be necessary to pay for any clean-up costs resulting from the pollution.

Holland and Denmark have designated the whole of their territories as Nitrate Vulnerable Zones (NVZs) and will require their growers to conform to action programmes designed to reduce nitrate levels in water. The NVZs announced for England and Wales in May 1995 are less extensive, covering about 650,000 hectares. The UK government published an outline action programme as part of a Consultation Document but at present it does not appear to include crops grown under glass or polythene. This could change following consultation.

The Nitrate Directive also requires Member States to guard against pollution by establishing a Code of Practice for farmers and growers to follow on a voluntary basis throughout the country. The first edition of this Code does not include specialised horticulture but the next revision will do.

To minimise the risk of nitrate pollution entering the soil, one strategy would be to lower the amount of nitrate supplied to the crop. HDC Project PC55a demonstrated that nitrate levels in the feed solutions applied to long season tomato crops could be greatly reduced without significant loss of yield or deterioration in fruit quality. Tomato growers are already benefitting from this work with reduced levels of nitrate in the run-off entering the soil and reduced fertiliser costs of £640-£890/ha for every 50 mg/l reduction in nitrate in the applied feed.

Although the recommended level of nitrate-N for cucumbers is lower than previously considered optimum for tomatoes there is limited evidence that cucumbers can also be grown with lower nitrogen levels than at present.

This trial used a range of nitrogen application rate to determine whether applied concentrations could be reduced without adversely influencing crop yield, quality or shelf life, and what the effects on run-off concentrations would be.

Materials and Methods

Cultural Details

Early Crop

Varieties:	Jessica and Pyralis
Sowing Date:	17 December 1995
Planting Date:	15 January 1996
First Harvest:	23 February 1996
Final Recorded Harvest:	21 June 1996

Replanted Crop

Varieties:	Jessica and Bronco
Sowing Date:	10 June 1996
Planting Date:	2 July 1996
First Harvest:	19 July 1996
Final Recorded Harvest:	14 October 1996

Plant Population:	5,620 plants per acre
Irrigation:	Aiming to produce maximum 30% run-off
Shelf Life Conditions:	20°C, 12 hours illumination per 24 hours, 65°C

In all respects crop management followed best commercial practice.

Treatments

1. 250 ppm total* N in the applied feed.

2. 190 ppm total* N in the applied feed.

3. 130 ppm total* N in the applied feed.

4. 70 ppm total* N in the applied feed.

* Total N includes nitrate-N (NO_3-N) plus ammonium-N (NH_4-N).

Records and Assessments

Growth Assessments

1. Overall vigour score.

2. Lateral diameter.

3. Leaf colour.

Yield Records

4. Number of fruit harvested.

5. Weight of fruit harvested kg/m^2

6. Individual fruit weight

7. Percentage of fruit in size grades
   A (250 - 400 g)
   B (400 - 500 g)
   C (500 - 650 g)
   D (650 - 800 g)

Fruit Quality

8. Fruit length.

9. Percentage of fruit in quality grades
   Class I
   Class II
   Waste

Fruit quality assessments after 6 days under shelf life conditions.

10. Fruit colour

11. Fruit firmness

12. Weight loss

To calculate a **Nutrient Balance** the following records were also taken.

13. Weight of 6 plants at planting stage and dried for analysis.(Record percentage dry matter)

14. Save all trimmings, all fruit including bent fruit and weight immediately after sampling.

15. Dry a sample of trimmings in the first week of each month for analysis. Record percentage dry matter.

16. Dry a sample of fruit in week 1 of each month for analysis. Record percentage dry matter.

17. In mid July take a sample of root from beneath the slab in a guard area, dry and carry out nutrient analysis as above.

18. At the end of the season separate all the plants into root, stem, leaf and fruit and weigh each part. Dry a sample for analysis.

19. Analyse all the dry samples for nitrogen and phosphorus.

Nutrient solution records

20. Measure volume of applied solution and run-off daily.

21. Record all fertilisers and acid used in stock solutions.

22. Carry out standard solution of drip and run-off solution weekly.

23. Carry out standard analysis of slab solution fortnightly.

Explanation of Statistical Analysis

Throughout the report a number of statistical terms are used; these are:

SED	=	The standard error of the difference when comparing two means in that column of data.

A statistical term easier to interpret:

LSD 5%	=	The least (minimum) difference when comparing any two figures within a given column that is required for those figures to be statistically different.

A number of common notations are also used to indicate the degree to which values are significantly different.

NS	=	Not significant.
*	=	P <0.05, ie. the probability of this result occurring by chance is equal to or less than 1 in 20 (0.05 = 5%).
**	=	P <0.01, ie. the probability of this result occurring by chance is equal to or less than 1 in 100 (0.01 = 1%).
***	=	P <0.001, ie. the probability of this result occurring by chance is equal to or less than 1 in 1000 (0.001 = 0.1%).

Results

Growth and Development

Plant Vigour (Figure 1)

In all varieties tested, and in both early and replanted crops, vigour was reduced in the 70 ppm N treatment.

From June onwards the 250 ppm N treatment also gave reduced vigour, compared with the 130 and 190 ppm N treatments.

Lateral Diameter (Fig 2)

There were little variation in lateral diameter between the treatments.

Colour (Figures 3 and 4)

In the first crop, colour was measured both visually and using a chlorophyll meter.

The 70 ppm N treatment produced consistently paler leaves throughout both early and replanted crops. Differences between the other three treatments were smaller and more variable.

Reading from the chlorophyll meter showed that the colour of Jessica was more responsive to the N treatments than that of Pyralis. The 70 ppm treatment gave the palest leaves for both cultivars but at Nitrogen levels above 190 ppm the leaves of Jessica were much darker than those of Pyralis.

Figure 1: Plant Vigour

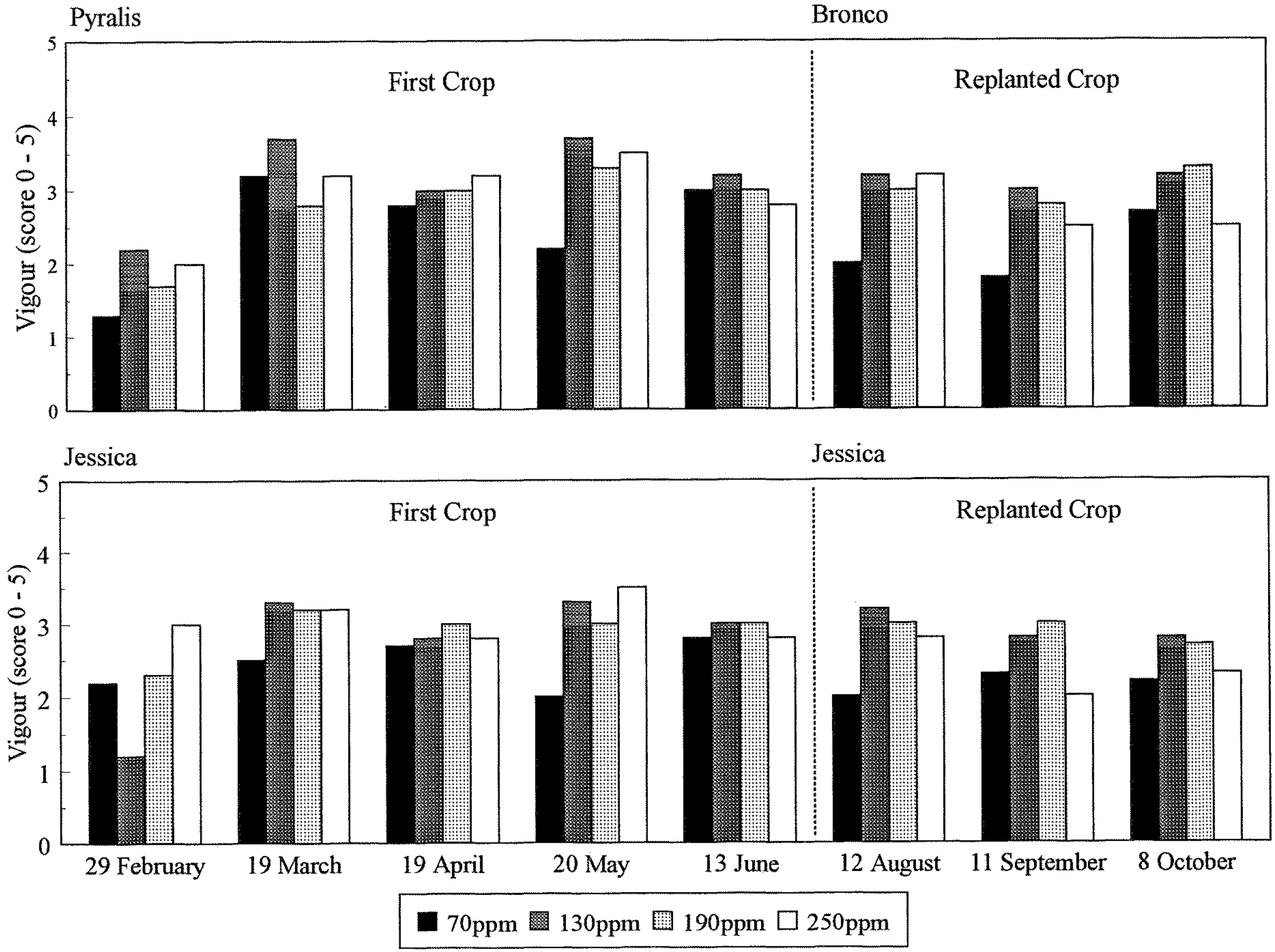


Figure 2: Lateral Diameters

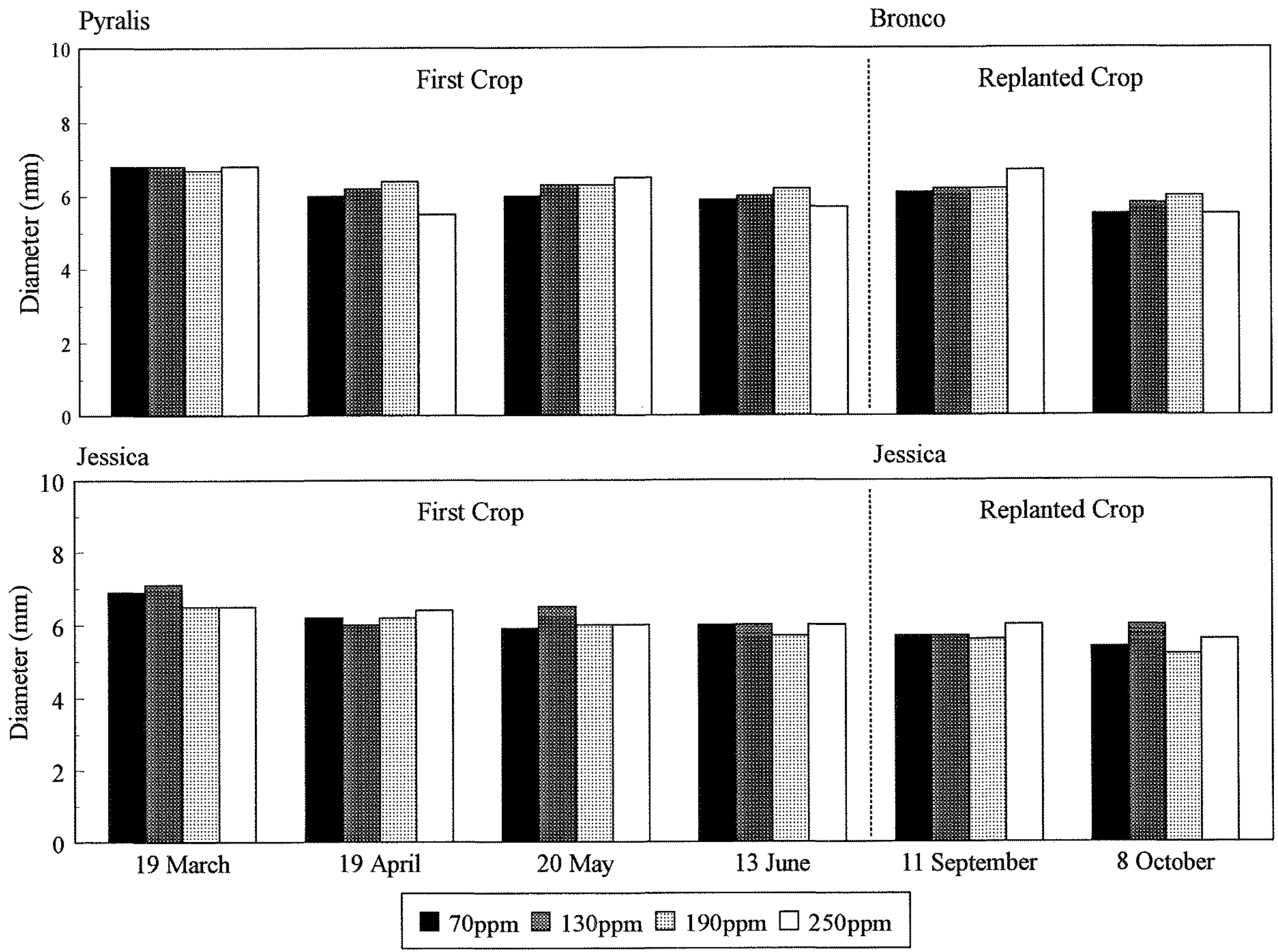


Figure 3: Leaf Colour

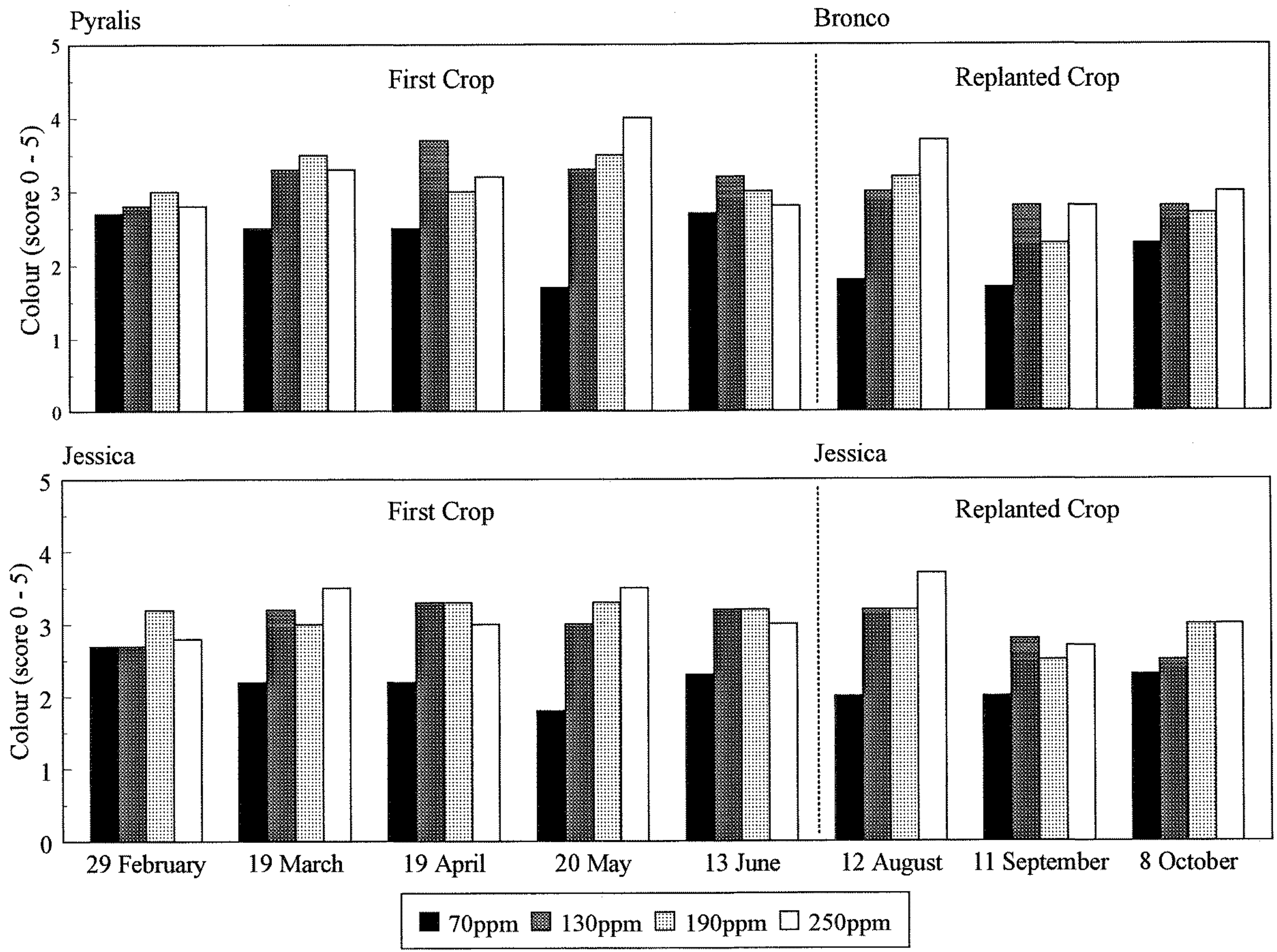
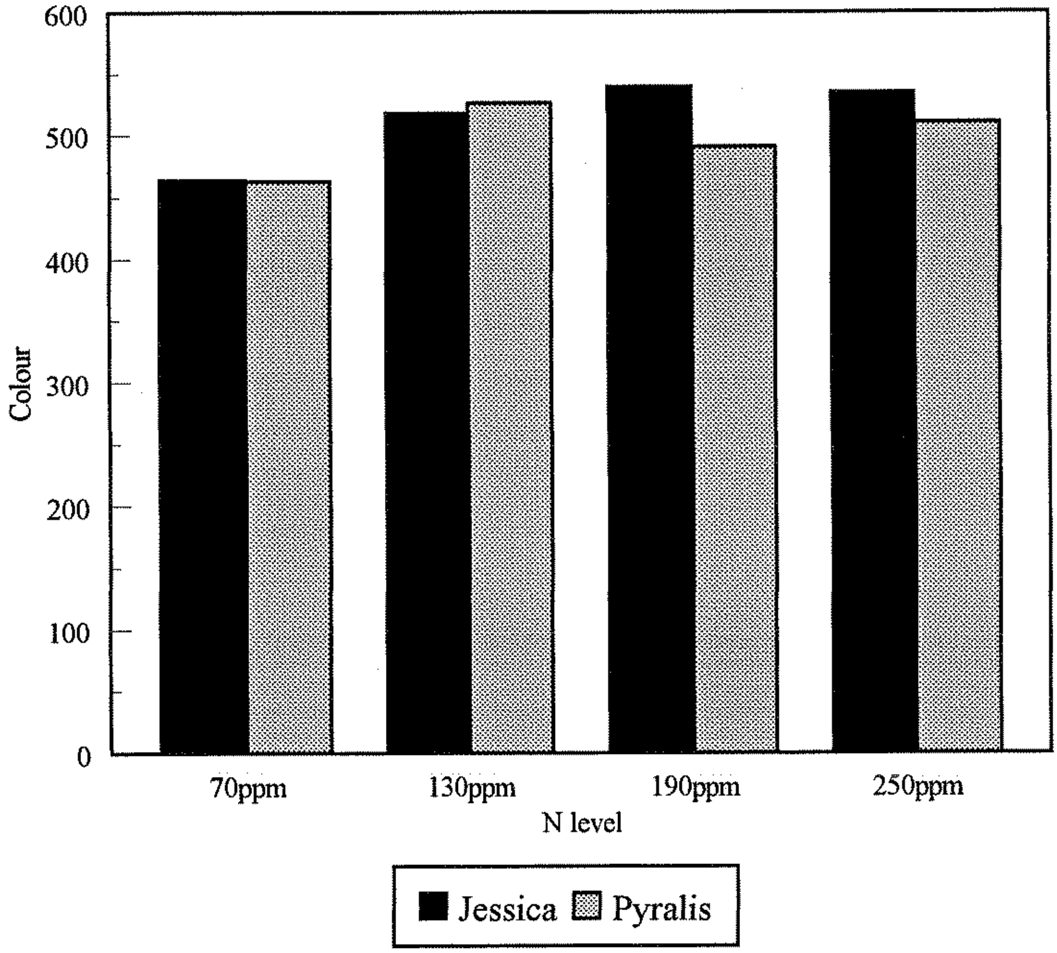


Figure 4 Leaf Colour (Chlorophyll meter readings) 29 February



First Harvest Date

In the first crop Nitrogen treatments did not influence first harvest date, but Pyralis tended to be harvested slightly later than Jessica.

In the replanted crop Bronco at the lowest N treatment was harvested 3 days later than the remaining treatments.

Response to Changing Nitrogen Concentration

Yield and Monetary Return (Tables 1-3)

First Crop

There was no significant difference in early fruit production between the Nitrogen treatments. From April onwards the yield from the 70 ppm N treatment was significantly lower than all the other treatments. Yield from the 250 ppm N treatment was also lower than from the 130 and 190 ppm N treatments, although not significantly so. At the end of the first crop yields from the 70 ppm N treatment were approximately 9 fruit/m^2 or 4 kg/m^2 less than the other treatments. The highest yields were produced from the 130 and 190 ppm N treatments.

Replanted Crop

Yield from the 70 ppm N treatment was reduced from the start of production when compared with the higher N treatments.

The total number and weight of marketable fruit in the replanted crop was reduced in the 70 ppm N treatment by approximately 10 fruit/m^2 and 5 kg/m^2.

The number of fruit from the 130-250 ppm N treatments was similar at the end of the replanted crop. The weight of fruit was significantly lower in the 250 ppm N treatment.

Total Value

Monetary returns from the 70 ppm N treatment were £400-£500 lower than from the other treatments over the season as a whole.

Fruit Weight (Tables 4-8)

Mean fruit weight from the 70 ppm N treatment was particularly low in May, June and August (Table 4), but averaged over the whole crop, treatment differences were insignificant. Fruit size effects tended to be more evident in the early crop than in the replanted crop when fruit size was higher.

Fruit Quality (Tables 9-11)

The effect of the Nitrogen treatments on fruit quality was small, and variable. Percentage Class I was low from the 70 ppm N treatment in April and May but high at other times, particularly in the replanted crop. There was no difference in waste fruit production between the treatments.

Varietal Responses

First Crop

Jessica produced more fruit than Pyralis at the beginning of the season but less at the end. At the end of the crop the amounts and weights of from both varieties were similar. Jessica gave a slightly higher monetary value.

Replanted Crop

Both varieties produced similar quantities of fruit.

Interaction between Nitrogen Concentration and Variety

In the replanted crop the 2 varieties responded differently in terms of fruit weight. Jessica showed a linear increase in fruit weight as the nitrogen concentration increased while Bronco showed very little response, with only a slight increase in fruit weight at the intermediate Nitrogen concentrations (Fig 5).

Figure 5 : Mean Fruit Weight by Variety

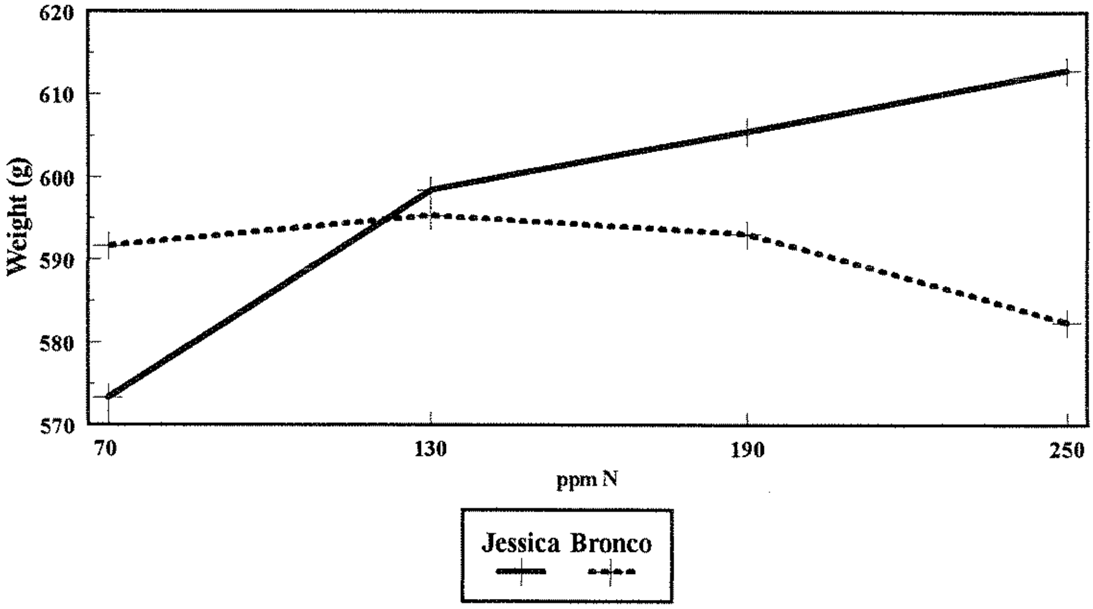


Table 1: **Number of Marketable Fruit (/m2)**

	First Crop					Replanted Crop					
	March	April	May	June	To End 1st Crop		July	August	Sept	Oct	To End 2nd Crop
NITRATE						**NITRATE**					
70 ppm	5.6	18.7	15.4	13.0	52.6	**70 ppm**	6.8	11.2	6.8	1.8	26.5
130 ppm	5.5	21.0	18.4	16.8	61.7	**130 ppm**	10.9	13.9	9.5	2.6	36.9
190 ppm	5.3	20.5	18.5	16.0	60.2	**190 ppm**	11.4	12.4	9.9	2.6	36.3
250 ppm	5.9	20.0	17.8	15.9	59.7	**250 ppm**	11.2	12.2	9.2	2.5	35.1
Stats											
SED (5df)	0.19	0.59	0.64	0.47	1.07		0.50	0.22	0.54	0.27	0.78
LSD (p=0.05)	-	1.5	1.7	1.2	2.7		1.3	0.6	1.4	0.7	2.0
significance	NS	*	*	**	***		***	***	**	6%	***
VARIETY						**VARIETY**					
Jessica	6.1	20.1	17.7	14.8	58.7	**Jessica**	10.1	11.9	9.1	2.3	33.4
Pyralis	5.0	19.9	17.4	16.0	58.4	**Bronco**	10.1	13.0	8.6	2.4	34.1
Stats											
SED (6df)	0.26	0.42	0.19	0.42	0.67		0.20	0.49	0.31	0.15	0.74
LSD (p=0.05)	0.6	-	-	1.0	-		-	-	-	-	-
significance	**	NS	NS	*	NS		NS	NS	NS	NS	NS

Table 2. **Total Marketable yield (kg/m2)**

	First Crop					Replanted Crop					
	March	April	May	June	To End 1st Crop		July	August	Sept	Oct	To End 2nd Crop
NITRATE						**NITRATE**					
70 ppm	2.00	7.83	6.81	5.50	22.13	**70 ppm**	3.67	6.51	3.44	0.81	14.43
130 ppm	2.00	8.66	8.51	7.40	26.57	**130 ppm**	5.77	8.27	5.04	1.17	20.25
190 ppm	1.82	8.35	8.57	7.16	25.90	**190 ppm**	6.00	7.43	5.24	1.18	19.85
250 ppm	2.10	8.11	8.09	7.18	25.48	**250 ppm**	5.79	7.29	4.88	1.15	19.11
Stats											
SED (5df)	0.086	0.190	0.278	0.193	0.449		0.133	0.147	0.232	0.105	0.236
LSD (p=0.05)	-	0.49	0.72	0.50	1.16		0.34	0.38	0.60	0.27	0.61
significance	NS	*	**	***	***		***	***	**	*	***
VARIETY						**VARIETY**					
Jessica	2.19	8.29	8.12	6.64	25.24	**Jessica**	5.33	7.10	4.79	1.06	18.28
Pyralis	1.77	8.19	7.87	6.97	24.80	**Bronco**	5.29	7.65	4.51	1.09	18.54
Stats											
SED (6df)	0.090	0.190	0.075	0.206	0.325		0.097	0.278	0.146	0.072	0.382
LSD (p=0.05)	0.22	-	0.18	-	-		0.23	-	-	-	-
significance	**	NS	*	NS	NS		NS	NS	NS	NS	NS

Table 3. **Monetary Value (£/m2)**

	First Planting	Replanted Crop		Total
NITRATE			**NITRATE**	
70 ppm	12.71	6.35	**70 ppm**	19.06
130 ppm	15.19	8.89	**130 ppm**	24.08
190 ppm	14.84	8.73	**190 ppm**	23.57
250 ppm	14.70	8.39	**250 ppm**	23.10
Stats				
SED (5df)	0.251	0.103		
LSD (p=0.05)	0.6	0.26		
significance	***	***		
VARIETY			**VARIETY**	
Jessica	14.43	8.03	**Jessica**	
Pyralis	14.29	8.16	**Bronco**	

Table 4. **Mean Fruit Weight (g)**

	First Crop					Replanted Crop					
	March	April	May	June	Mean To End 1st Crop		July	August	Sept	Oct	Mean To End 2nd Crop
NITRATE						**NITRATE**					
70 ppm	360	420	441	424	421	**70 ppm**	542	582	510	450	544
130 ppm	362	413	463	442	431	**130 ppm**	530	597	530	443	548
190 ppm	342	408	464	450	430	**190 ppm**	528	599	531	447	547
250 ppm	354	406	454	451	427	**250 ppm**	517	598	532	465	545
Stats											
SED (5df)	4.8	0.6	5.8	7.6	4.6		22.5	2.8	8.2	10.5	8.1
LSD (p=0.05)	12	-	15	20	-		58	7	-	-	-
significance	*	NS	*	*	NS		NS	**	NS	NS	NS
VARIETY						**VARIETY**					
Jessica	357	413	460	449	430	**Jessica**	533	598	526	452	548
Pyralis	352	411	452	434	424	**Bronco**	526	591	524	451	545
Stats											
SED (6df)	1.8	4.1	2.8	5.6	1.8		8.8	4.4	3.4	14.9	3.0
LSD (p=0.05)	4	-	7	13	4		21	-	-	-	-
significance	0.06	NS	*	*	*		NS	NS	NS	NS	NS

Table 5. **% Grade A of Class I (250-400 g)**

	First Crop				Mean To End	Replanted Crop					Mean To End
	March	April	May	June	1st Crop		July	August	Sept	Oct	2nd Crop
NITRATE						**NITRATE**					
70 ppm	85.8	54.3	43.5	50.7	54.1	**70 ppm**	15.7	10.4	16.2	37.4	14.3
130 ppm	85.0	54.5	31.6	46.3	48.8	**130 ppm**	12.8	4.4	11.0	29.4	9.9
190 ppm	93.2	56.1	33.5	45.7	50.5	**190 ppm**	15.0	5.0	10.9	35.2	11.3
250 ppm	88.3	58.6	37.0	45.3	52.1	**250 ppm**	18.2	6.4	13.5	29.4	13.6
Stats											
SED (5df)	2.50	1.03	1.41	1.34	0.98		1.33	1.08	3.22	9.62	1.38
LSD (p=0.05)	-	2.6	3.6	3.5	2.5		3.4	2.8	-	-	-
significance	NS	*	*	*	*		*	**	NS	NS	NS
VARIETY						**VARIETY**					
Jessica	85.9	56.4	35.6	44.0	50.7	**Jessica**	14.3	6.5	12.9	30.5	11.9
Pyralis	90.2	55.3	37.2	50.0	52.1	**Bronco**	16.6	6.8	12.9	35.2	12.7
Stats											
SED (6df)	1.20	0.89	1.27	1.48	0.77		1.76	0.50	1.53	3.23	1.09
LSD (p=0.05)	3.0	-	-	3.5	-		-	-	-	-	-
significance	*	NS	NS	**	NS		NS	NS	NS	NS	NS

Table 6. **% Grade B of Class I (400-500 g)**

	First Crop					Replanted Crop					
	March	April	May	June	Mean To End 1st Crop		July	August	Sept	Oct	Mean To End 2nd Crop
NITRATE						**NITRATE**					
70 ppm	14.1	25.9	33.0	30.8	27.8	**70 ppm**	25.0	24.9	32.8	38.90	27.1
130 ppm	14.7	31.5	38.6	31.3	31.8	**130 ppm**	30.5	18.0	31.7	41.80	26.2
190 ppm	6.6	28.6	37.7	30.5	29.6	**190 ppm**	31.8	20.7	29.8	34.60	27.4
250 ppm	10.7	29.1	37.2	29.7	29.6	**250 ppm**	32.0	18.9	31.3	37.60	27.4
Stats											
SED (5df)	2.21	0.66	1.88	0.72	0.52		6.32	2.63	2.67	7.26	1.48
LSD (p=0.05)	5.7	1.6	-	-	1.3		-	-	-	-	-
significance	*	*	NS	NS	**		NS	NS	NS	NS	NS
VARIETY						**VARIETY**					
Jessica	13.6	27.1	36.5	31.0	29.2	**Jessica**	29.9	20.0	31.5	41.0	27.2
Pyralis	9.5	30.4	36.8	30.1	30.1	**Bronco**	29.7	21.2	31.3	35.6	26.9
Stats											
SED (6df)	0.91	1.21	1.08	1.19	0.62		1.14	1.15	1.33	3.70	0.43
LSD (p=0.05)	2.2	3.1	-	-	-		-	-	-	-	-
significance	**	**	NS	NS	NS		NS	NS	NS	NS	NS

Table 7. **% Grade C of Class I (500-650 g)**

First Crop	March	April	May	June	Mean To End 1st Crop
NITRATE					
70 ppm	0.2	15.6	18.6	13.6	14.0
130 ppm	0.3	11.9	23.0	15.5	14.9
190 ppm	0.2	13.0	21.1	16.5	15.0
250 ppm	1.0	10.5	19.4	17.7	13.9
Stats					
SED (5df)	0.35	0.74	0.76	1.55	0.45
LSD (p=0.05)	-	1.9	2.0	-	-
significance	NS	**	**	NS	NS
VARIETY					
Jessica	0.5	13.4	21.3	16.8	15.0
Pyralis	0.3	12.1	19.8	14.9	13.9
Stats					
SED (6df)	0.33	0.41	0.44	0.85	0.21
LSD (p=0.05)	-	1.0	1.0	-	0.5
significance	NS	*	*	NS	***

Replanted Crop	July	August	Sept	Oct	Mean To End 2nd Crop
NITRATE					
70 ppm	35.70	30.74	32.42	18.40	32.14
130 ppm	37.52	33.47	36.84	25.80	35.21
190 ppm	34.05	34.95	36.30	26.70	34.59
250 ppm	36.06	34.85	35.23	27.70	34.94
Stats					
SED (5df)	0.98	1.81	3.30	6.48	1.19
LSD (p=0.05)	-	-	-	-	-
significance	NS	NS	NS	NS	NS
VARIETY					
Jessica	35.0	33.3	33.8	24.4	33.6
Bronco	36.6	33.7	36.6	25.0	34.8
Stats					
SED (6df)	1.71	0.76	1.92	2.84	0.95
LSD (p=0.05)	-	-	-	-	-
significance	NS	NS	NS	NS	NS

Table 8. **% Grade D of Class I (650-800 g)**

	First Crop					Replanted Crop					
	March	April	May	June	Mean To End 1st Crop		July	August	Sept	Oct	Mean To End 2nd Crop
NITRATE						**NITRATE**					
70 ppm	0.0	4.2	4.9	5.0	4.1	**70 ppm**	23.6	34.1	18.5	5.2	26.5
130 ppm	0.0	2.2	6.9	6.9	4.6	**130 ppm**	19.3	44.1	20.5	3.0	28.7
190 ppm	0.0	2.3	7.8	7.4	5.0	**190 ppm**	19.2	39.3	23.0	3.5	26.7
250 ppm	0.0	1.9	6.3	7.3	4.4	**250 ppm**	13.7	39.6	20.1	5.2	24.1
Stats											
SED (5df)	0.00	0.37	1.32	0.39	0.58		2.48	3.23	2.46	1.00	1.57
LSD (p=0.05)	0.0	0.9	-	1.0	-		6.4	-	-	-	-
significance	0.0	**	NS	**	NS		*	NS	NS	NS	NS
VARIETY						**VARIETY**					
Jessica	0.0	3.1	6.7	8.2	5.1	**Jessica**	20.8	40.3	21.8	4.2	27.3
Pyralis	0.0	2.2	6.2	5.1	3.9	**Bronco**	17.1	38.2	19.3	4.2	25.6
Stats											
SED (6df)	0.00	0.40	0.63	0.56	0.35		1.16	0.83	1.48	2.44	0.53
LSD (p=0.05)	0.0	-	-	1.3	0.8		2.7	2.0	-	-	1.3
significance	0.0	NS	NS	***	*		*	*	NS	NS	*

Table 9. **% Class I by number**

	First Crop					Replanted Crop					
	March	April	May	June	Mean To End 1st Crop		July	August	Sept	Oct	Mean To End 2nd Crop
NITRATE						**NITRATE**					
70 ppm	95.0	85.3	79.7	87.9	85.3	**70 ppm**	98.19	95.56	76.28	56.40	89.12
130 ppm	93.3	87.8	82.4	83.5	85.5	**130 ppm**	97.62	93.36	76.03	56.40	87.62
190 ppm	95.3	88.5	80.5	86.4	86.0	**190 ppm**	97.24	93.83	79.73	59.50	88.52
250 ppm	96.5	89.0	85.0	84.6	87.2	**250 ppm**	98.31	91.07	75.63	61.50	87.29
Stats											
SED (5df)	1.93	0.90	1.16	1.39	0.89		0.70	1.60	1.15	1.22	0.79
LSD (p=0.05)	-	2.3	3.0	3.6	-		-	-	2.95	3.15	-
significance	NS	*	*	NS	NS		NS	NS	*	*	NS
VARIETY						**VARIETY**					
Jessica	93.0	86.9	81.3	85.2	85.3	**Jessica**	97.30	92.74	77.15	57.80	87.53
Pyralis	97.0	88.5	82.5	86.1	86.7	**Bronco**	98.38	94.67	76.68	59.10	88.75
Stats											
SED (6df)	1.05	0.72	1.09	0.70	0.50		0.49	0.82	1.14	3.45	0.53
LSD (p=0.05)	2.6	-	-	1.6	1.2		-	1.95	-	-	1.3
significance	**	NS	NS	NS	*		NS	*	NS	NS	*

Table 10. **% Class II by number**

First Crop	March	April	May	June	Mean To End 1st Crop
NITRATE					
70 ppm	5.0	15.0	20.3	12.1	14.7
130 ppm	6.8	12.2	17.6	16.5	14.5
190 ppm	4.8	11.5	19.5	13.6	14.0
250 ppm	3.5	11.0	15.0	15.4	12.8
Stats					
SED (5df)	1.93	0.90	1.16	1.39	0.89
LSD (p=0.05)	-	2.3	3.0		-
significance	NS	*	*	NS	NS
VARIETY					
Jessica	7.0	13.1	18.8	14.9	14.7
Pyralis	3.0	11.5	17.5	13.9	13.3
Stats					
SED (6df)	1.05	0.72	1.09	0.70	0.50
LSD (p=0.05)	2.6	-	-	-	1.2
significance	**	NS	NS	NS	*
significance					

Replanted Crop	July	August	Sept	Oct	Mean To End 2nd Crop
NITRATE					
70 ppm	1.8	3.4	23.7	43.6	10.9
130 ppm	2.4	6.6	24.0	43.6	12.4
190 ppm	2.8	6.2	20.3	40.5	11.5
250 ppm	1.7	8.9	24.4	38.5	12.7
Stats					
SED (5df)	0.70	1.60	1.15	1.22	0.79
LSD (p=0.05)	-	-	3.0	3.2	-
significance	NS	NS	*	*	NS
VARIETY					
Jessica	2.7	7.3	22.9	42.2	12.5
Bronco	1.6	5.3	23.3	40.9	11.3
Stats					
SED (6df)	0.49	0.82	1.14	3.45	0.53
LSD (p=0.05)	-	1.9	-	-	1.3
significance	NS	*	NS	NS	*

Table 11. **% Waste of Total Yield**

	First Crop				
	March	April	May	June	Mean To End 1st Crop
NITRATE					
70 ppm	0.5	5.0	10.9	12.1	8.2
130 ppm	0.6	4.6	12.2	12.4	8.8
190 ppm	1.0	4.5	12.4	13.5	9.3
250 ppm	0.3	5.0	11.1	11.6	8.3
Stats					
SED (5df)	0.51	0.64	1.09	1.32	0.76
LSD (p=0.05)	-	-	-	-	-
significance	NS	NS	NS	NS	NS
VARIETY					
Jessica	0.4	5.1	11.8	14.1	9.1
Pyralis	0.8	4.5	11.5	10.7	8.1
Stats					
SED (6df)	0.30	0.54	0.67	0.80	0.34
LSD (p=0.05)	-	-	-	1.9	0.8
significance	NS	NS	NS	**	*

	Replanted Crop				
	July	August	Sept	Oct	Mean To End 2nd Crop
NITRATE					
70 ppm	2.0	3.9	17.3	31.5	9.6
130 ppm	0.9	5.0	20.3	32.3	10.8
190 ppm	1.2	6.7	19.2	31.5	11.2
250 ppm	1.1	6.0	22.7	25.1	11.1
Stats					
SED (5df)	0.56	1.16	1.68	2.40	0.78
LSD (p=0.05)	-	-	-	-	-
significance	NS	NS	NS	NS	NS
VARIETY					
Jessica	1.4	6.1	20.7	31.0	11.4
Bronco	1.2	4.7	19.1	29.3	10.0
Stats					
SED (6df)	0.26	1.20	0.97	1.91	0.72
LSD (p=0.05)	-	-	-	-	-
significance	NS	NS	NS	NS	NS

Shelf Life

Fruit Colour (Figures 6-9)

Fruit colour at harvest tended to be slightly paler from the 70 ppm N treatment. In the samples taken early in the life of both crops, as the N level increased the fruit colour increased. After 7 days under shelf life conditions there was a more marked reduction in the colour of fruit from the 70 ppm N treatment in most cases. This was particularly evident for Jessica where fruit colour generally increased as N concentration in the applied feed increased.

Fruit Firmness (Figures 10-13)

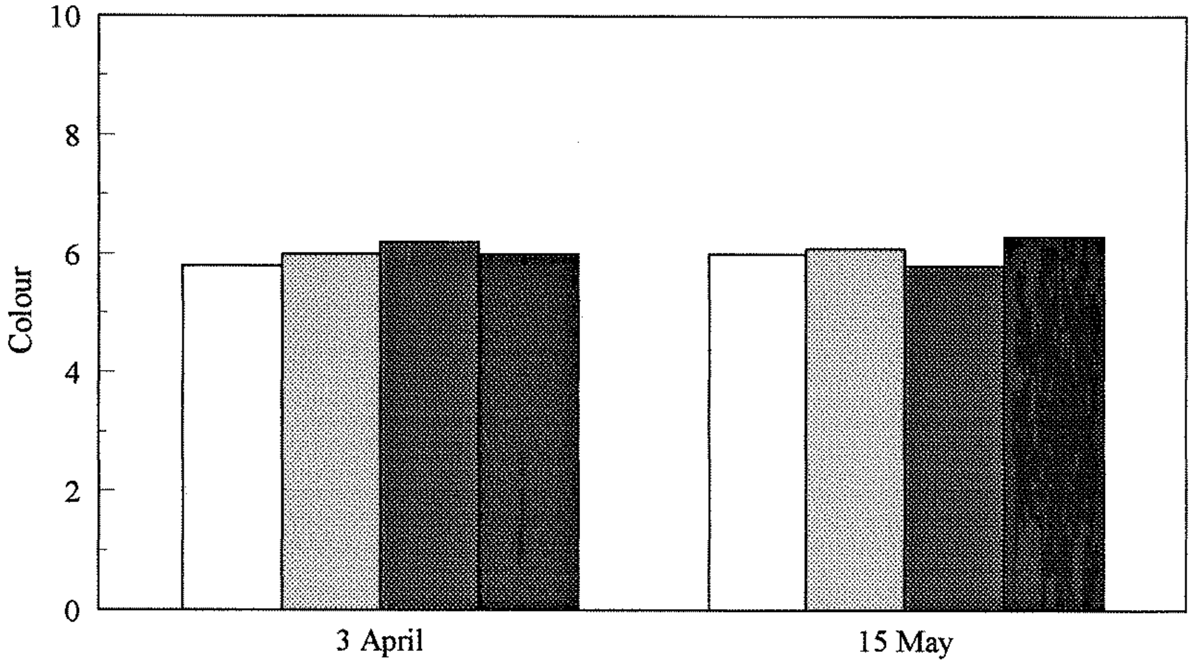
Fruit firmness at harvest showed no consistent treatment effects. Samples taken in July from the replant crop, showed a clear decrease in firmness as the N concentration increased in both varieties. Fruit were generally firmer after 7 days under shelf life conditions, but no significant treatment effects were recorded.

Percentage Weight Loss after 7 days in Shelf Life Conditions (Tables 14-15)

Percentage weight loss was variable. Late in the season, the 70 ppm N treatment lost most weight and as the N level rose the percentage weight loss decreased.

Fig. 6. Fruit Colour at Harvest - First Crop

a) Pyralis



b) Jessica

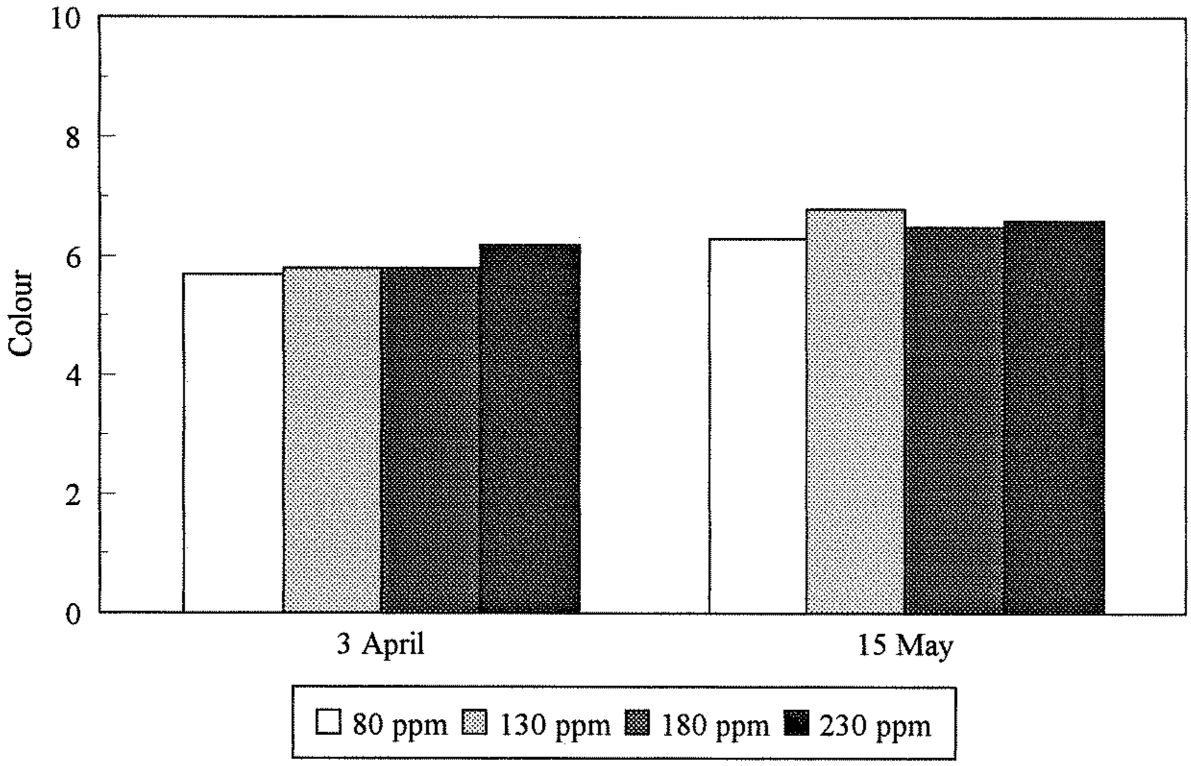
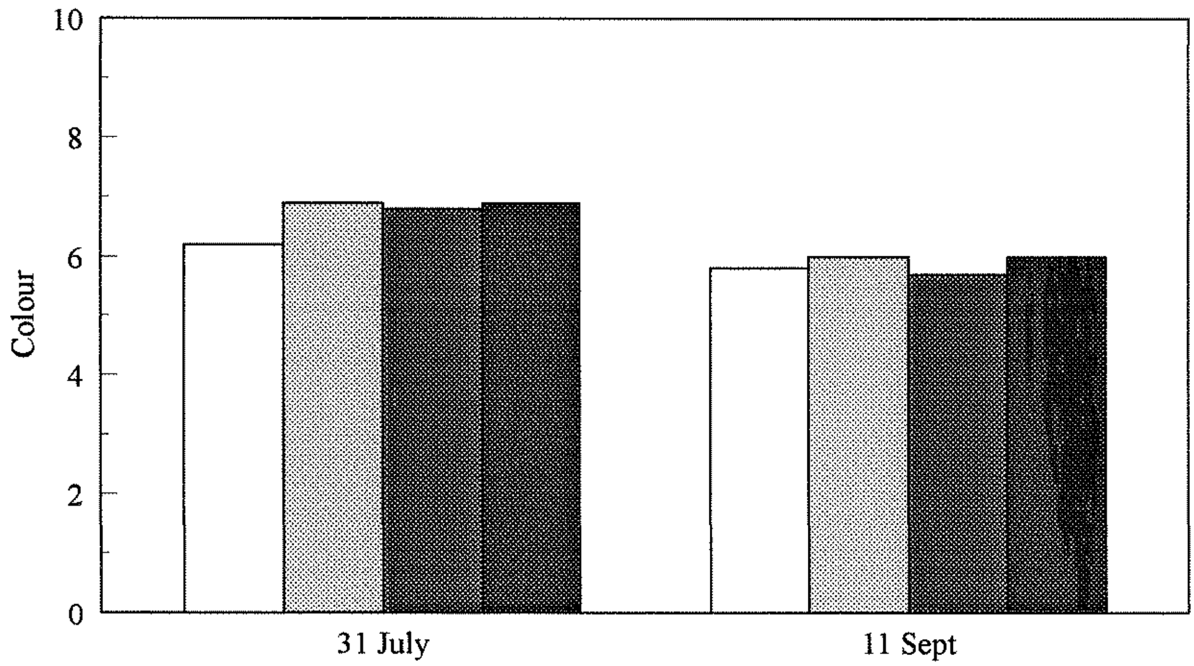


Fig. 7. Fruit Colour at Harvest - Replanted Crop

a) Bronco



b) Jessica

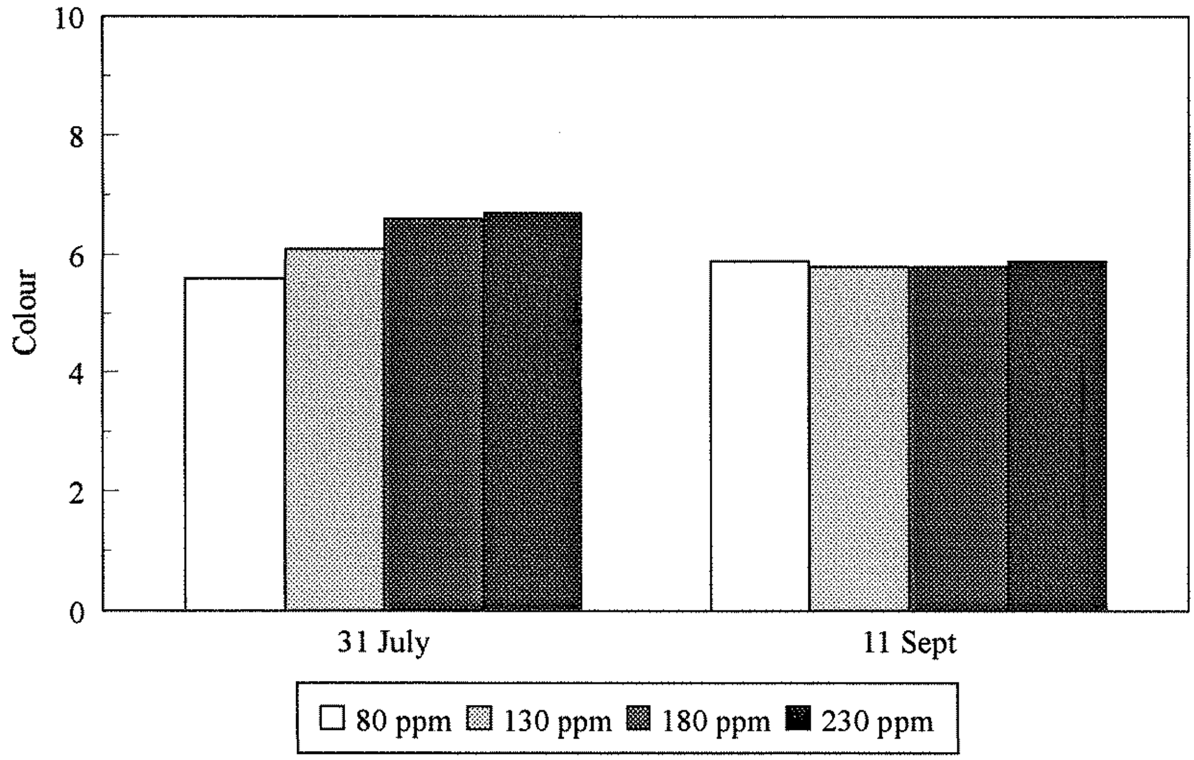
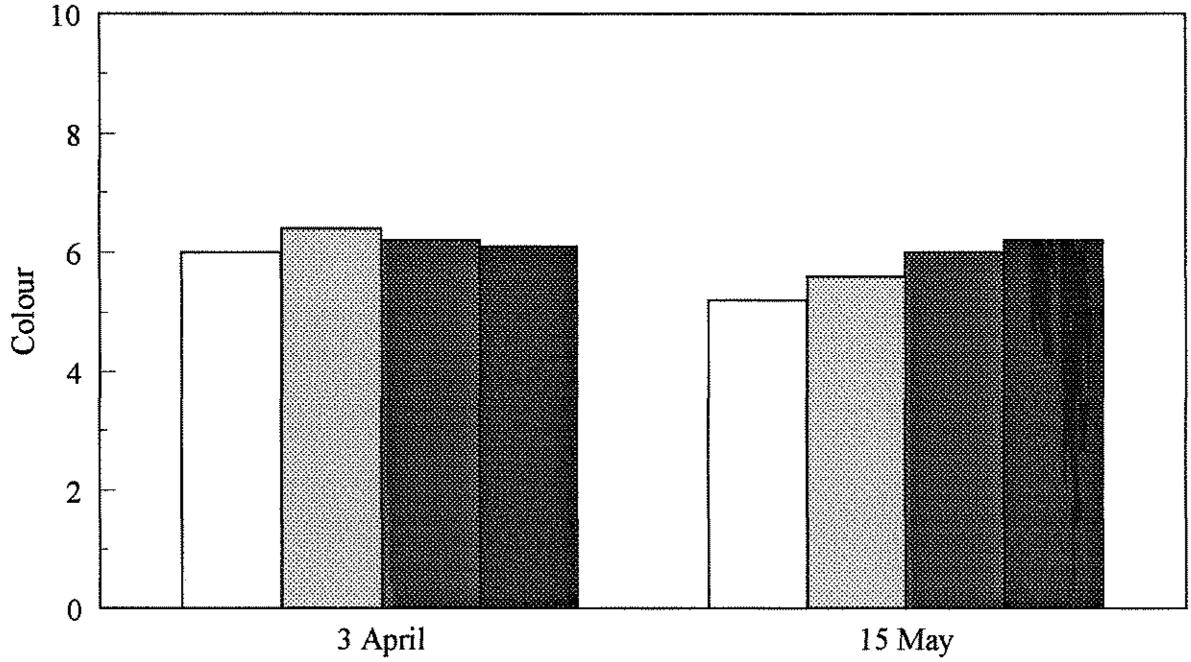


Fig. 8. Fruit Colour after 7 days - First Crop

a) Pyralis



b) Jessica

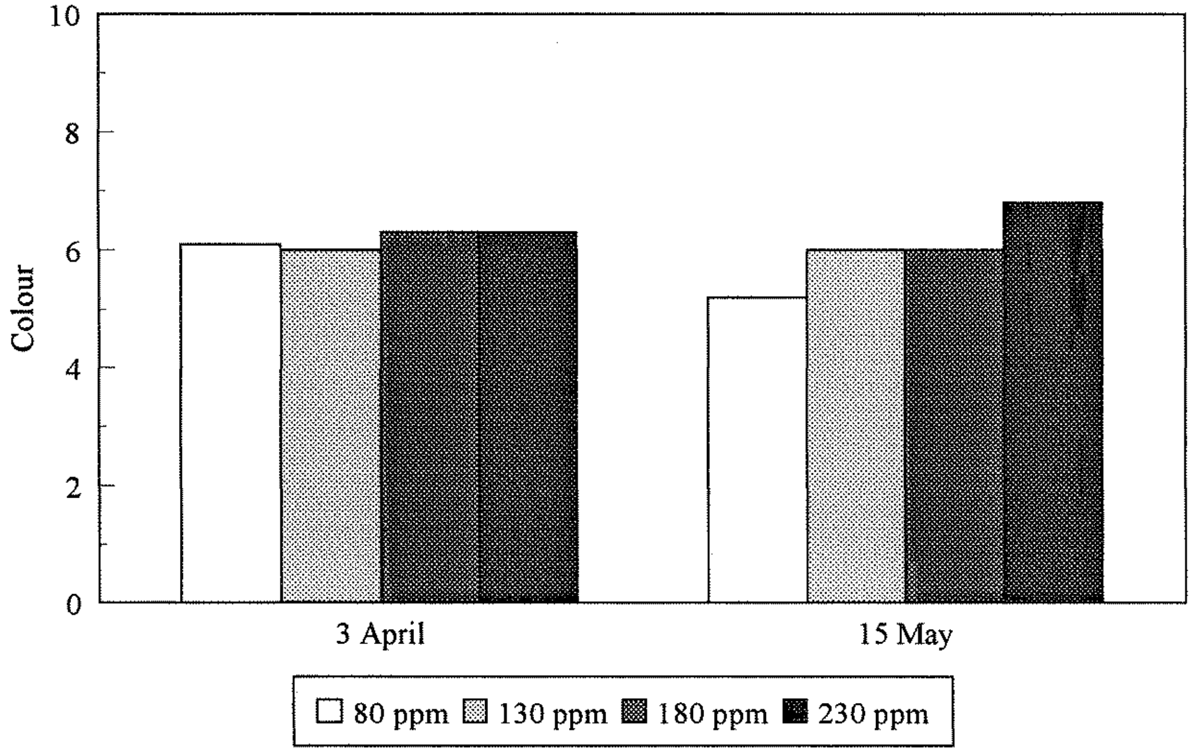


Fig. 9. Fruit Colour after 7 days - Replanted Crop

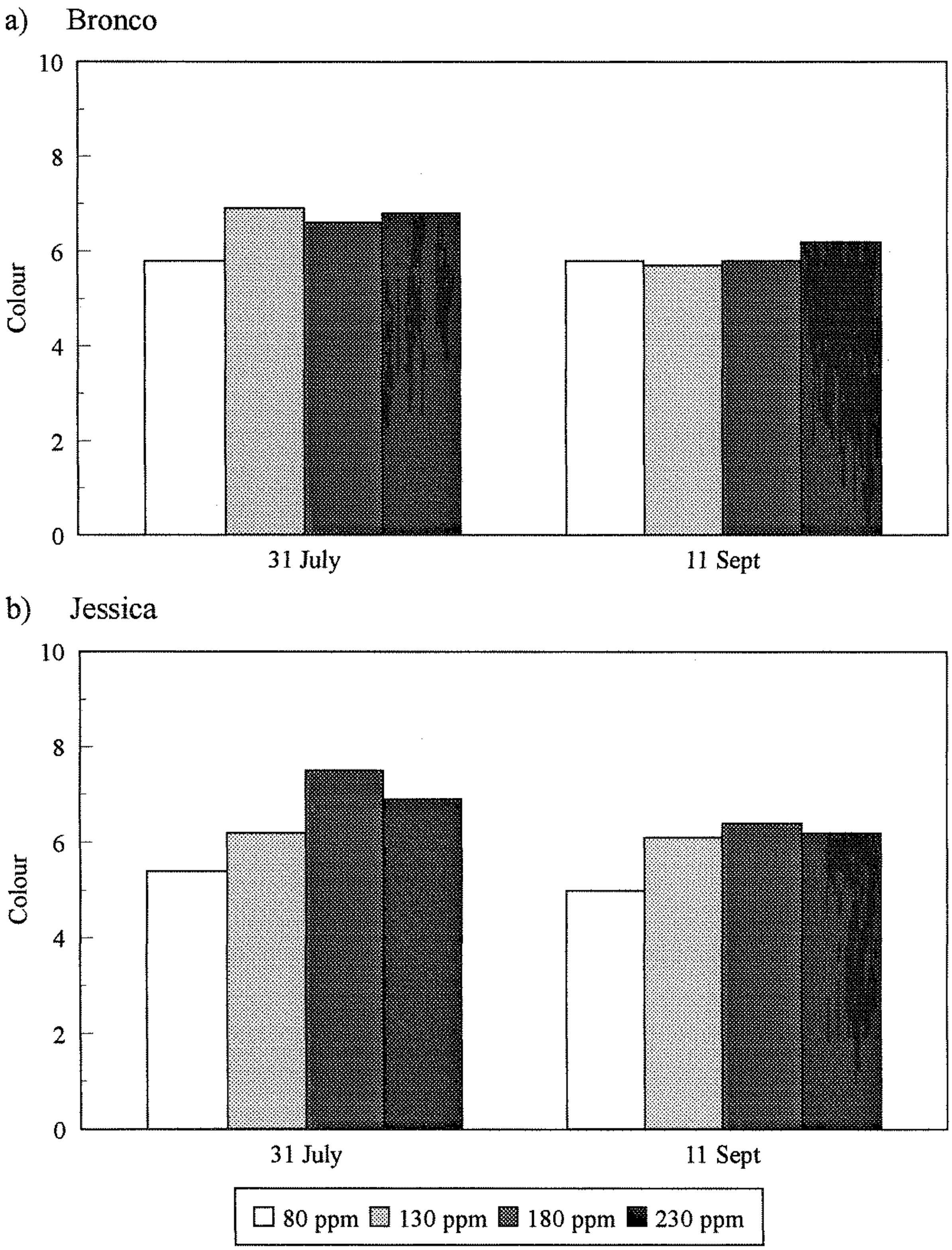
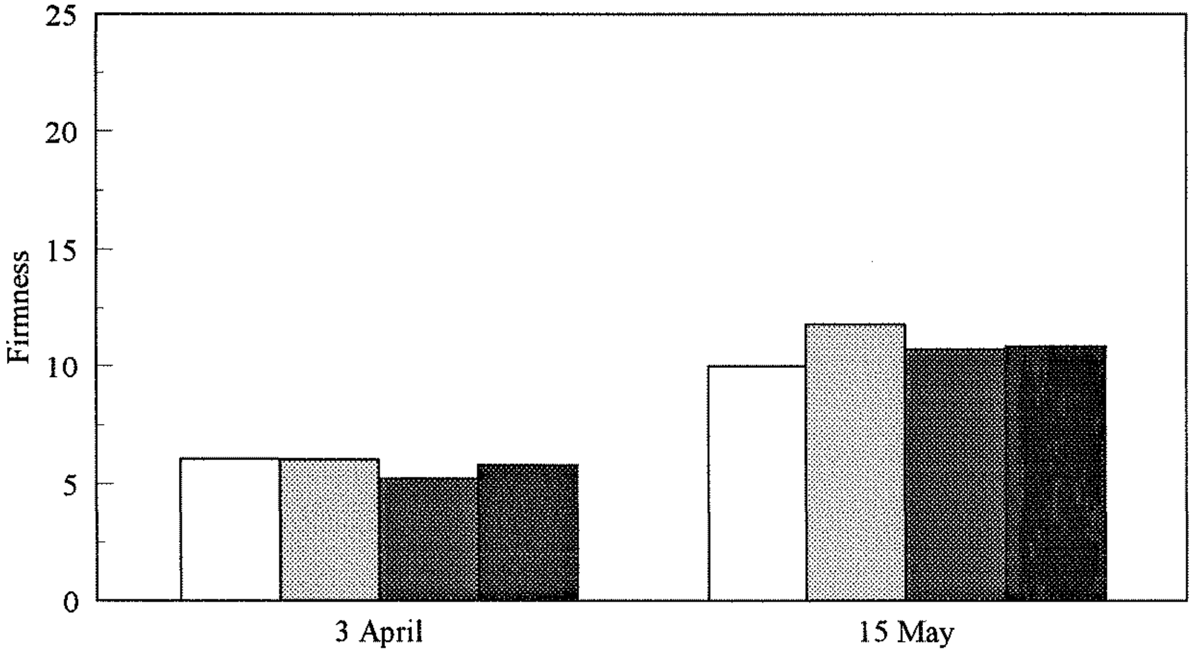


Fig. 10. Fruit Firmness at harvest - First Crop

a) Pyralis



b) Jessica

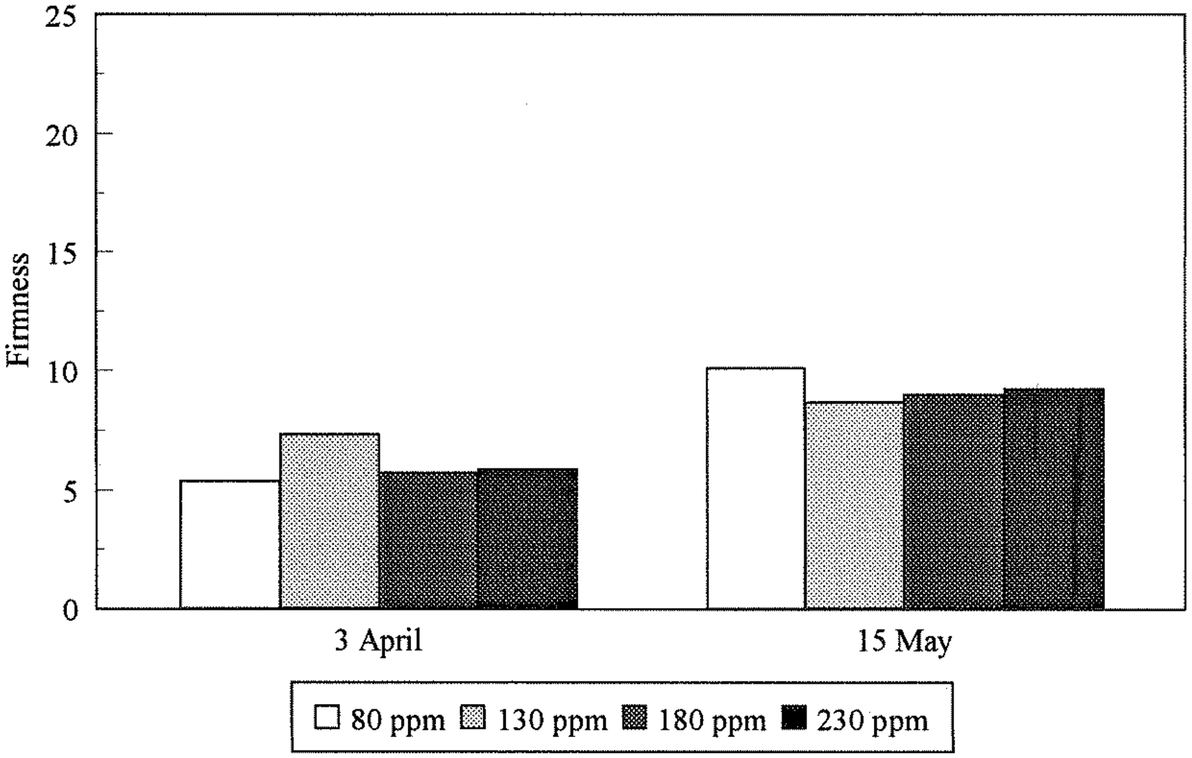
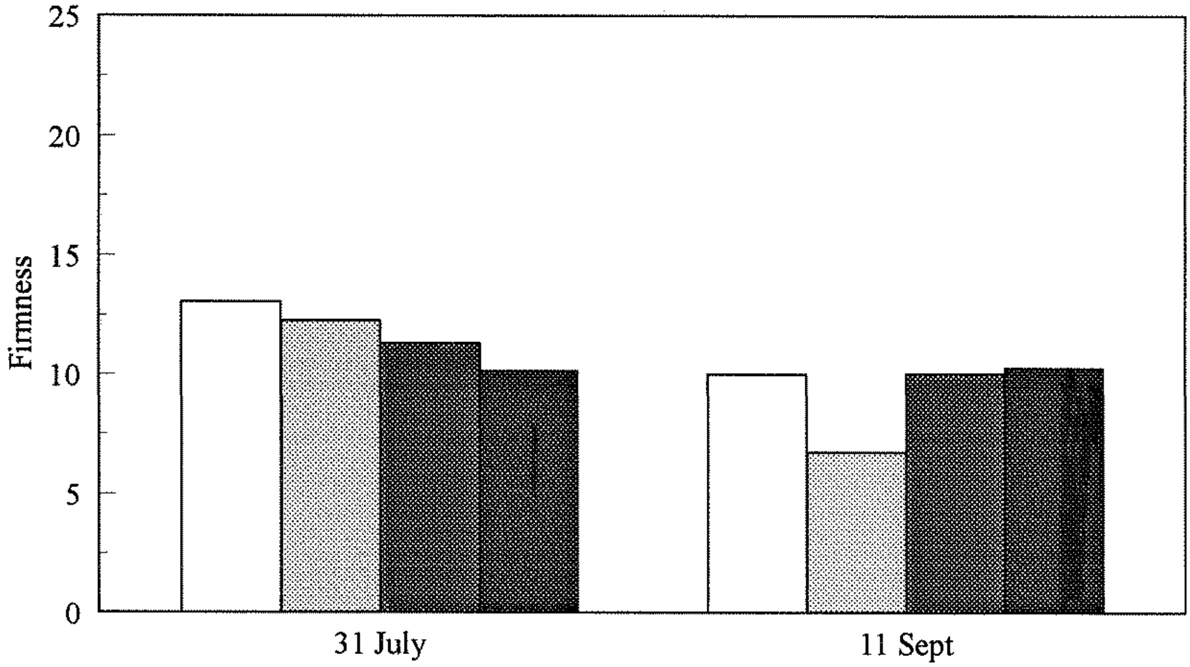


Fig. 11. Fruit Firmness at Harvest - Replanted Crop

a) Bronco



b) Jessica

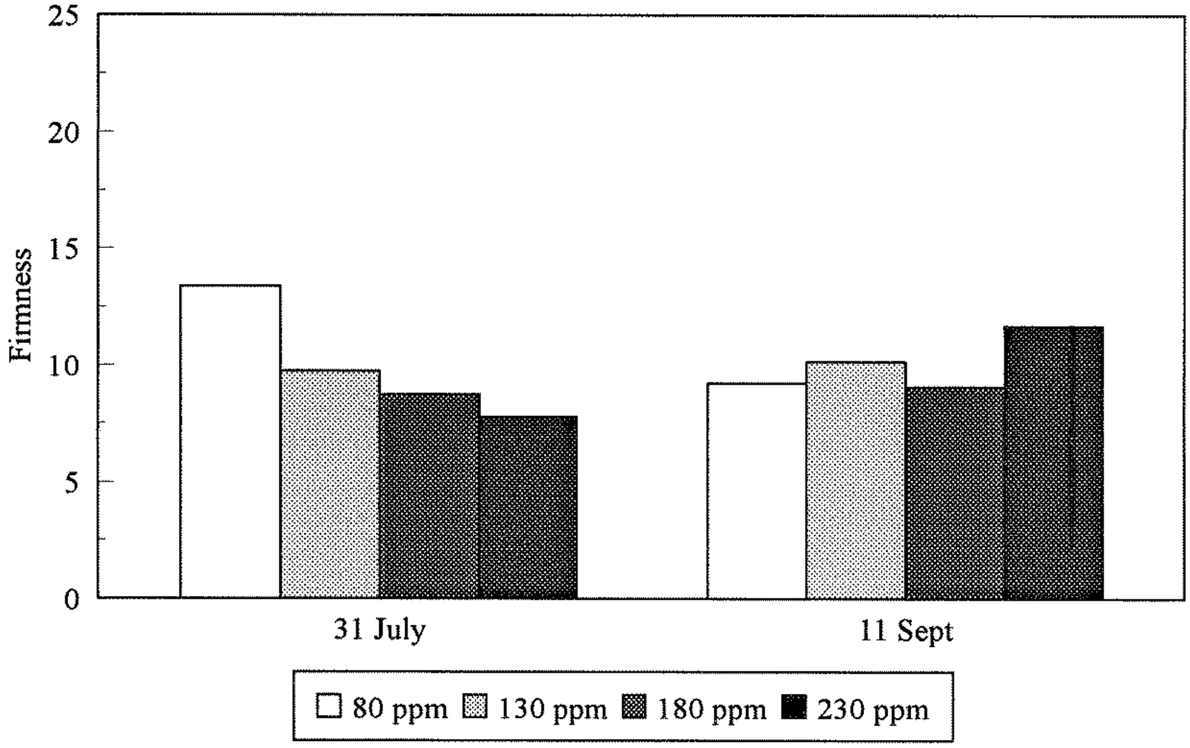
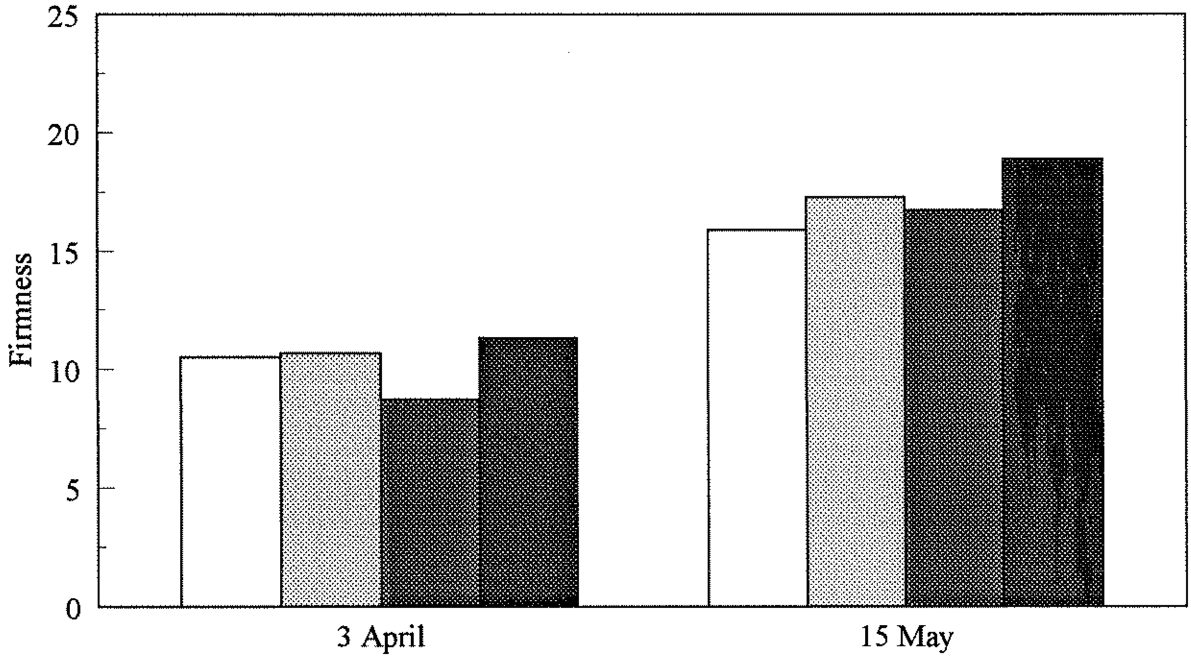


Fig. 12. Fruit Firmness after 7 days - First Crop

a) Pyralis



b) Jessica

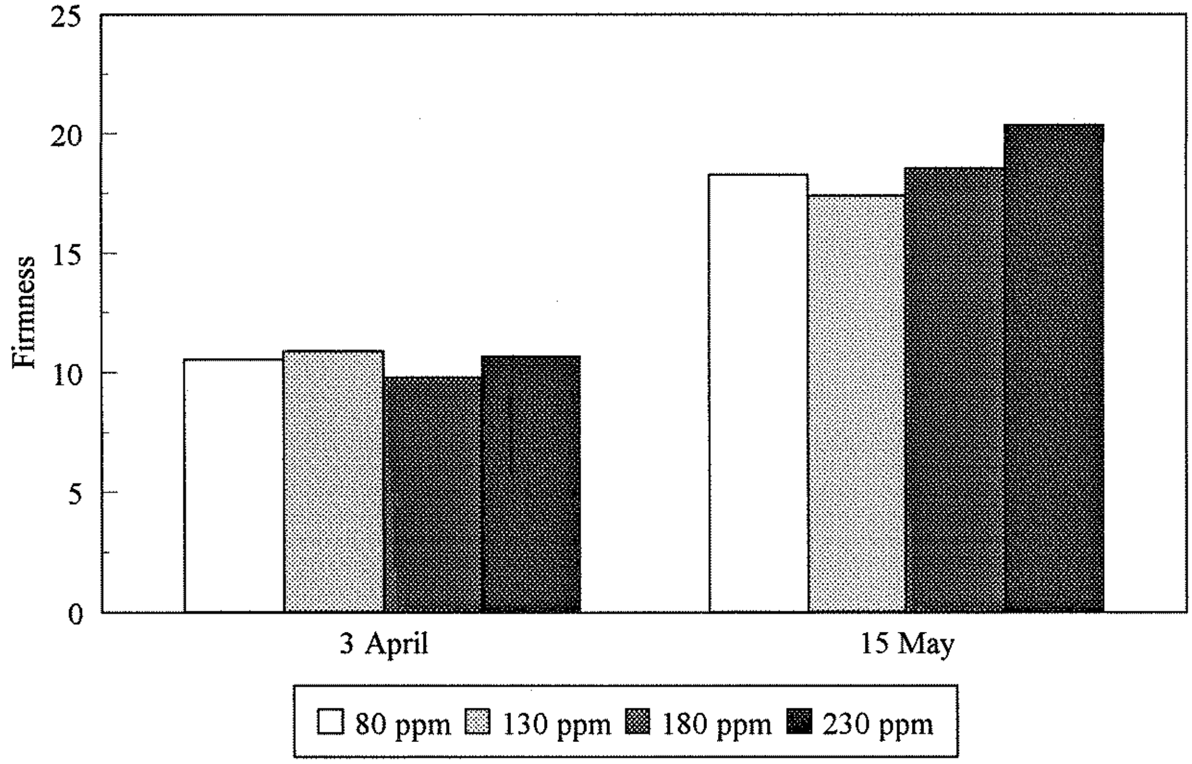
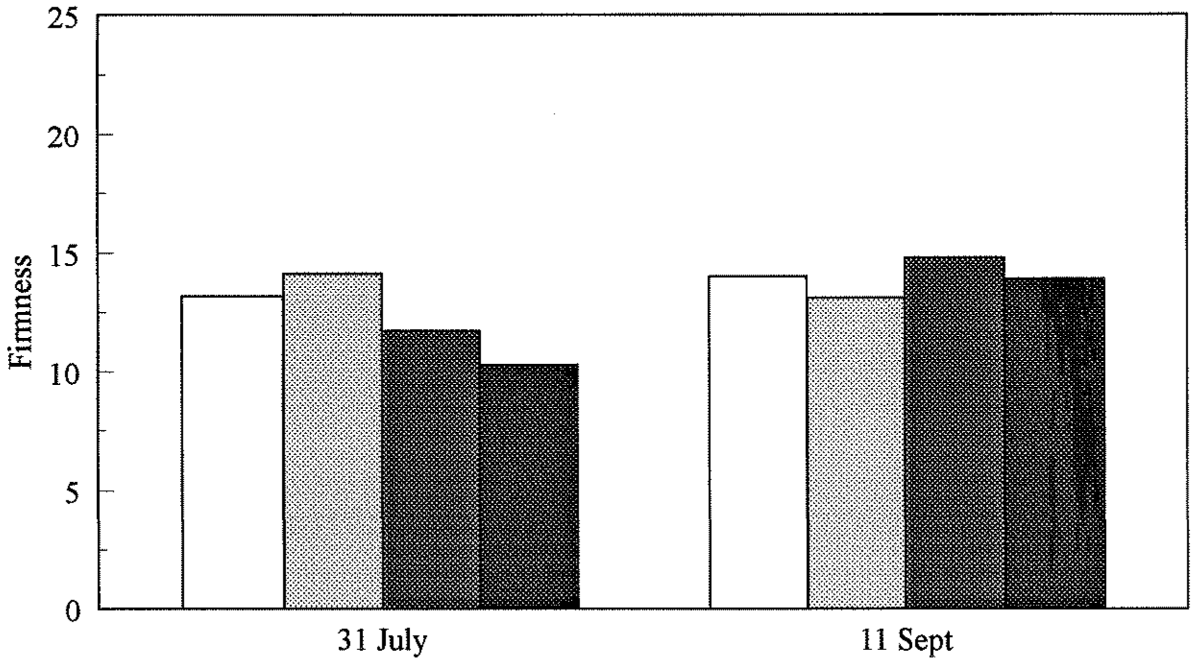


Fig. 13. Fruit Firmness after 7 days - Replanted Crop

a) Bronco



b) Jessica

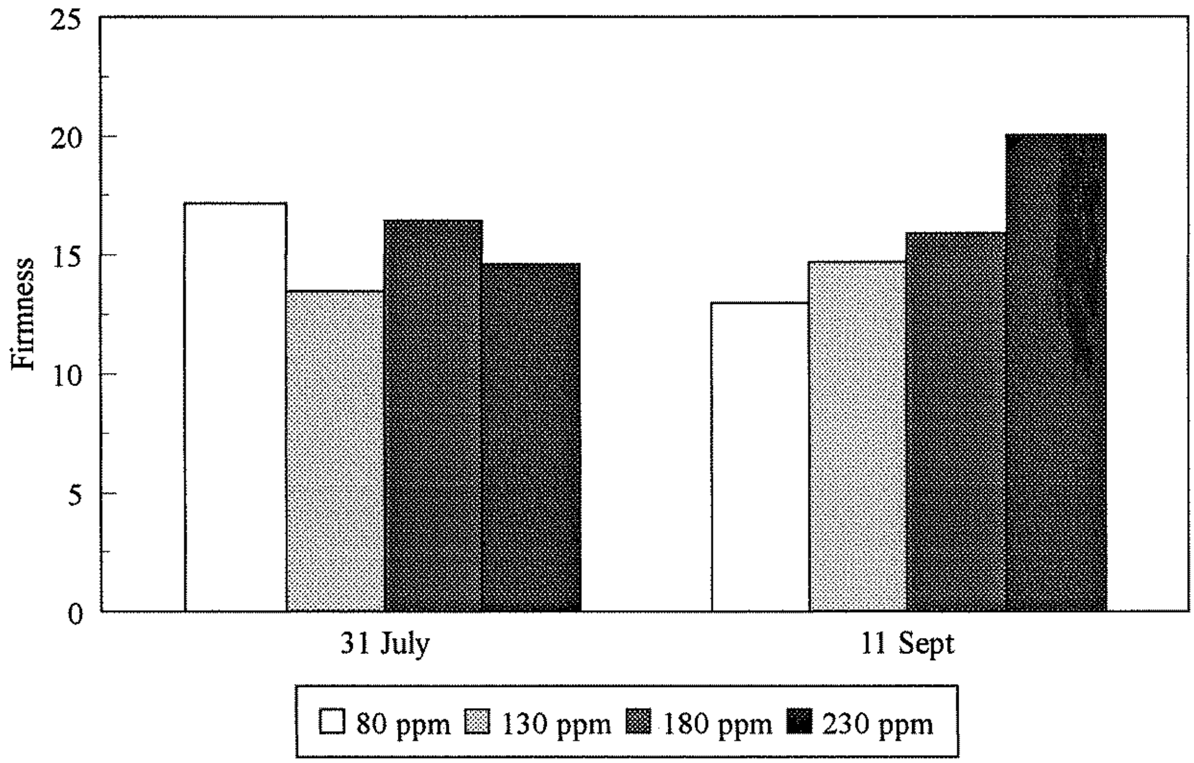
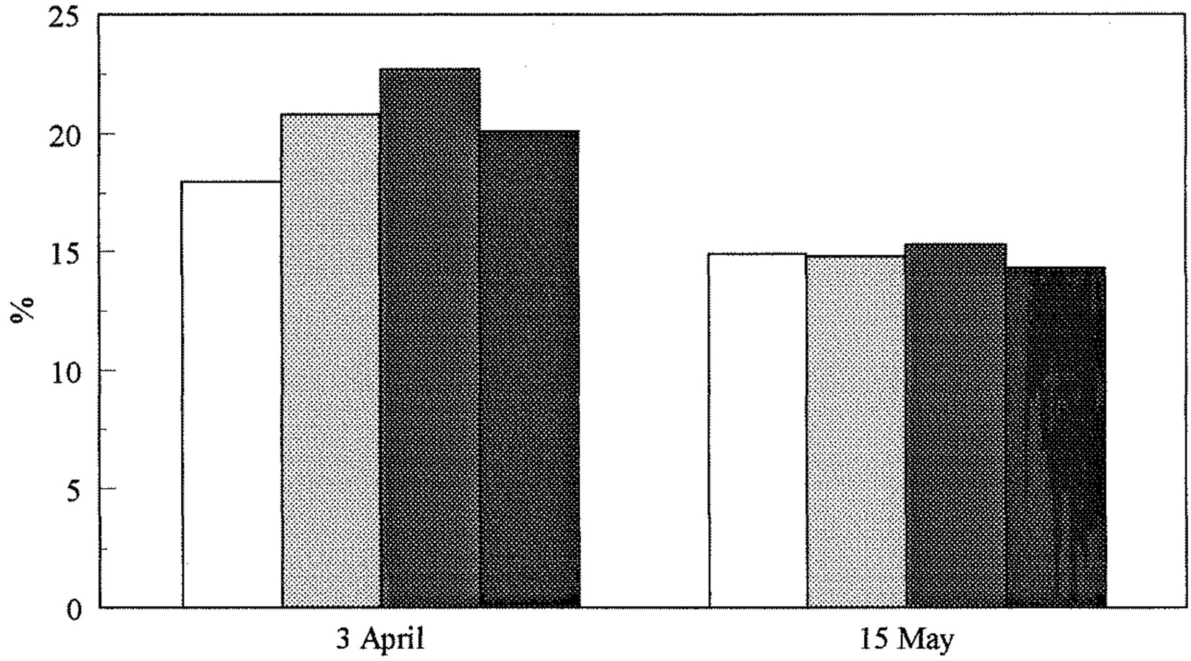


Fig. 14. % Weight Loss after 7 days - First Crop

a) Pyralis



b) Jessica

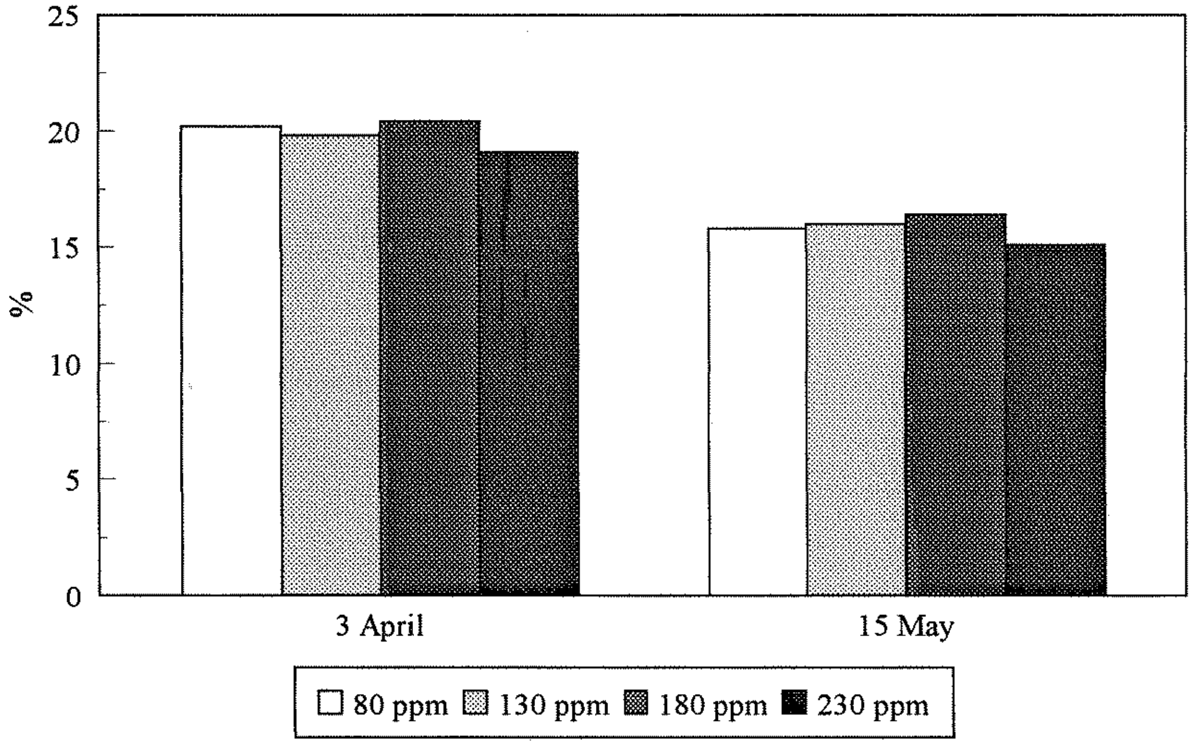
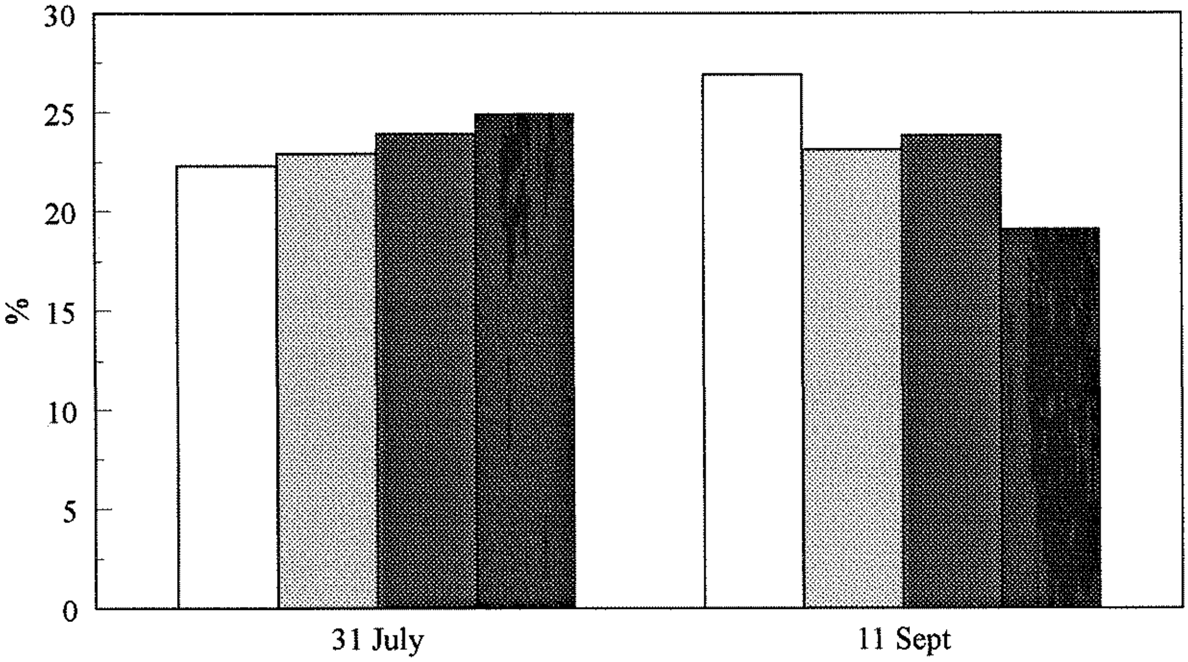
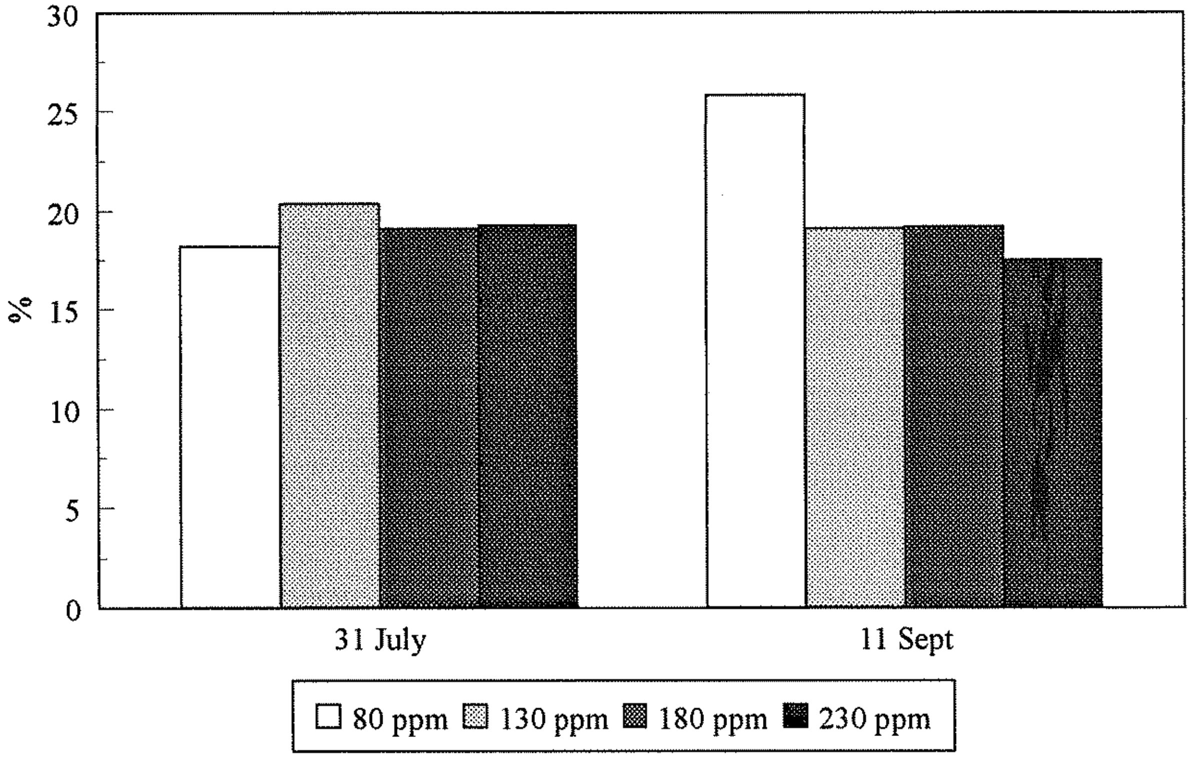


Fig. 15. % Weight Loss after 7 days - Replanted Crop

a) Bronco



b) Jessica



Nitrogen Content of Solutions

The results of the solution analyses are shown in Figures 17 a to d (first crop) and 18 a to d (replanted crop). All N values shown are total N, ie nitrate and ammonium-N values added together.

First Crop

The applied N levels tended to be higher than the target at the beginning of the season. In week 9 a new recipe was formulated and applied to the crop, subsequently the N values were close to and often lower than the target. The exception to this was the 130 ppm N treatment which remained high for a large percentage of the crop.

In the lowest N treatment both slab and run-off N levels were depleted compared to the applied value from week 8 onwards, on some occasions these values were close to zero.

In the 130 and 190 N treatments the N level in the run-off was frequently less than in the applied solution, although in the 190 ppm N treatment it remained closer to the applied level at times, particularly towards the end of the season.

The highest N level produced higher levels of N in the slab and run-off than in the applied solution throughout most of the crop.

Replanted Crop

For the replanted crop 70 and 130 N treatments, slab and run-off N concentrations were depleted below the applied N level for most samples.

Even for the 190 treatment, the run-off N value only exceeded the applied value during weeks 35, 36 and at the very end of the crop.

For the 250 N treatment, run-off N values exceeded applied N levels after week 33.

Chloride Content of Solutions (Figures 19-20)

Chloride levels in the slab and run-off remained high for all treatments throughout most of the trial. In the first crop the level in the 250 ppm N treatment took several weeks to build up.

Conductivity of Solutions

Applied Feeds (Figure 21)

EC varied throughout the season. Levels were generally low in the first crop. They started low in the second crop, achieved a period where they were close to the target value then reduced towards the end of the crop.

Slab and Run-off Solutions (Figures 22-23)

Conductivity in the slab remained below 3500 µS for most of the season, rising above this once in the replanted crop.

Run-off EC began the season below 3500 and remained around 3000 µS for the 130 N and 190 N treatments. Chloride accumulation in the 70 N treatment pushed the EC to 5000 in week 14 and a similar pattern was observed in the 250 N where Nitrogen was the accumulating factor.

In the replanted crop run-off EC rose from 2000 µS to 3500 to 4000 in the first 3-4 weeks. During weeks 34 to 36 a peak in EC was observed, the 70 N treatment reached 5000 µS.

Combined figures showing Nitrogen, Chloride and Conductivity of run-off are given in Appendices I and II.

Run-off Percentages

At the beginning of the first crop run-off percentage was higher than the target of 30%. In February, when watering could be controlled better, the percentage began to drop and reached 30% (Figure 16).

Table 12: Run-off percentage, slab and run-off EC.

	First Crop			Replanted Crop		
N Treatment	% run-off	EC slab	EC run-off	% run-off	EC slab	EC run-off
70	40	2860	3097	46	2353	2721
130	39	2491	2905	43	2441	2804
190	36	2588	2928	46	2340	2810
250	35	2794	3449	34	2546	2974
	37			42		

As the run-off percentage decreased to nearer the target value of 30%, the EC of the slab and run-off tended to increase.

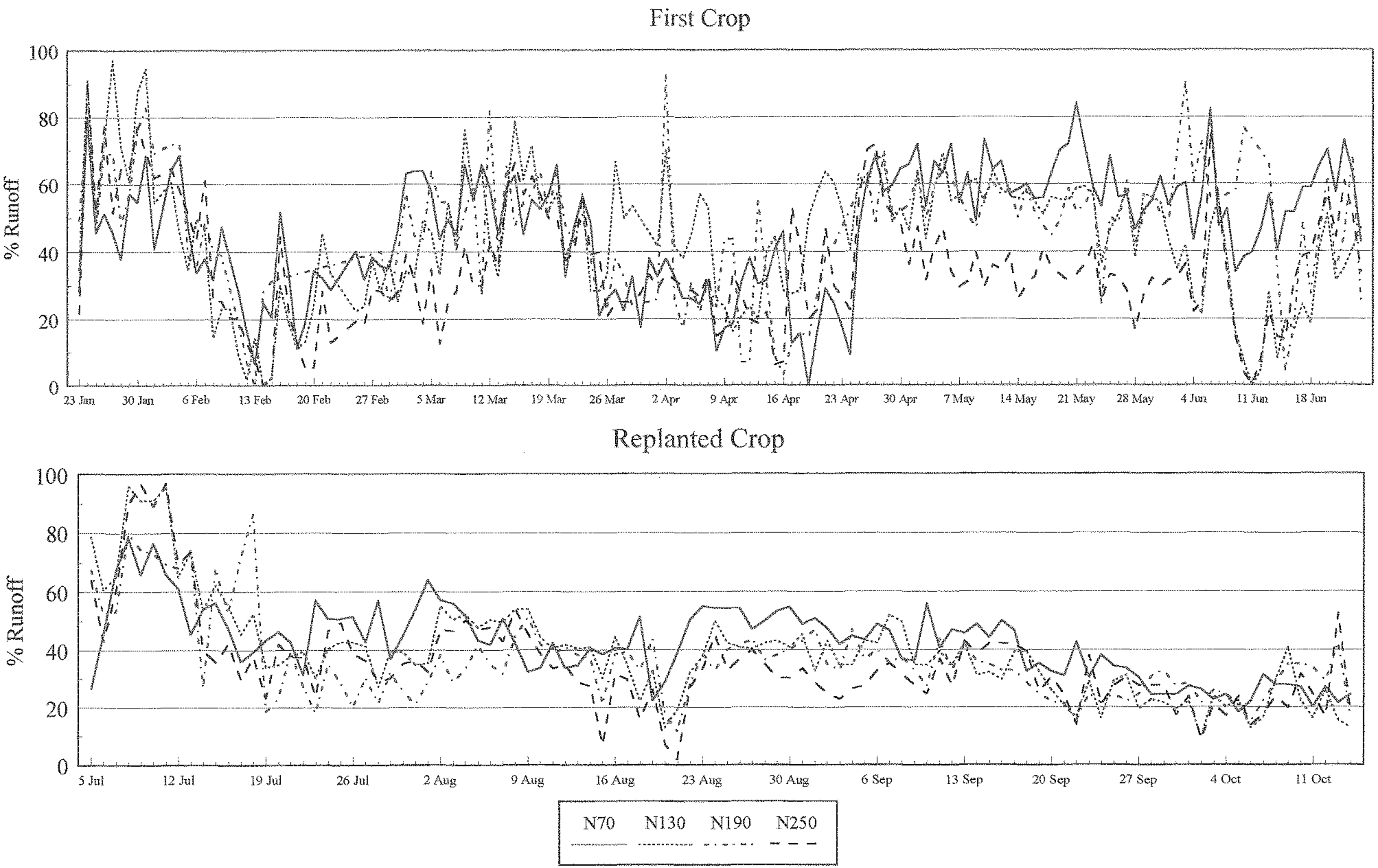
Run-off percentage was generally close to the target percentage for most of the season.

Nutrient Balance

A full nutrient balance has been calculated for Years 1 and 2 of this study.

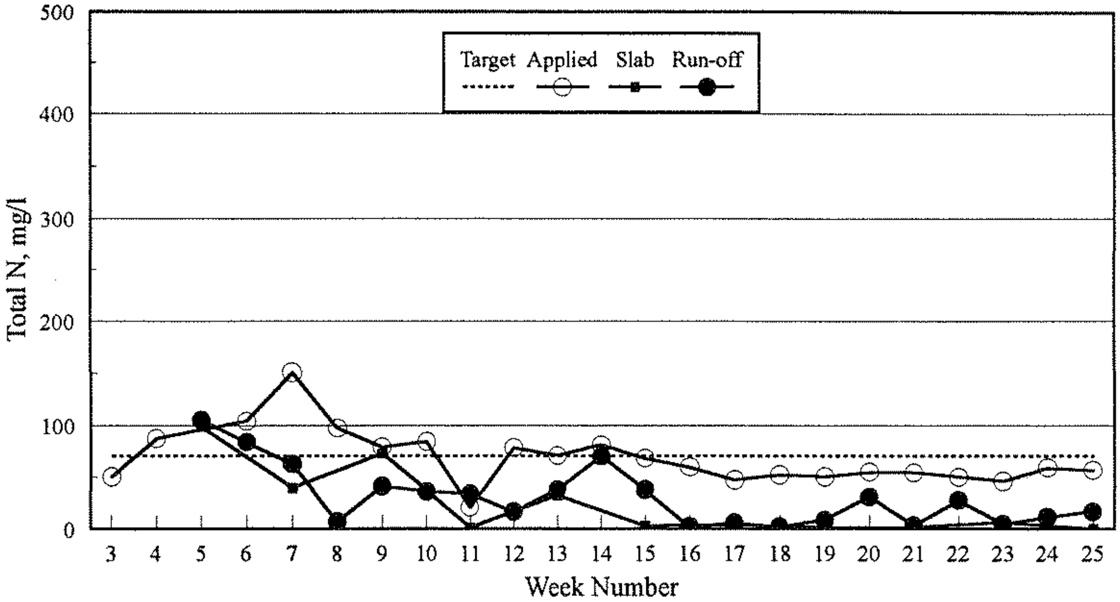
The data is presented in a separate Addendum.

Fig. 16. Percentage Runoff

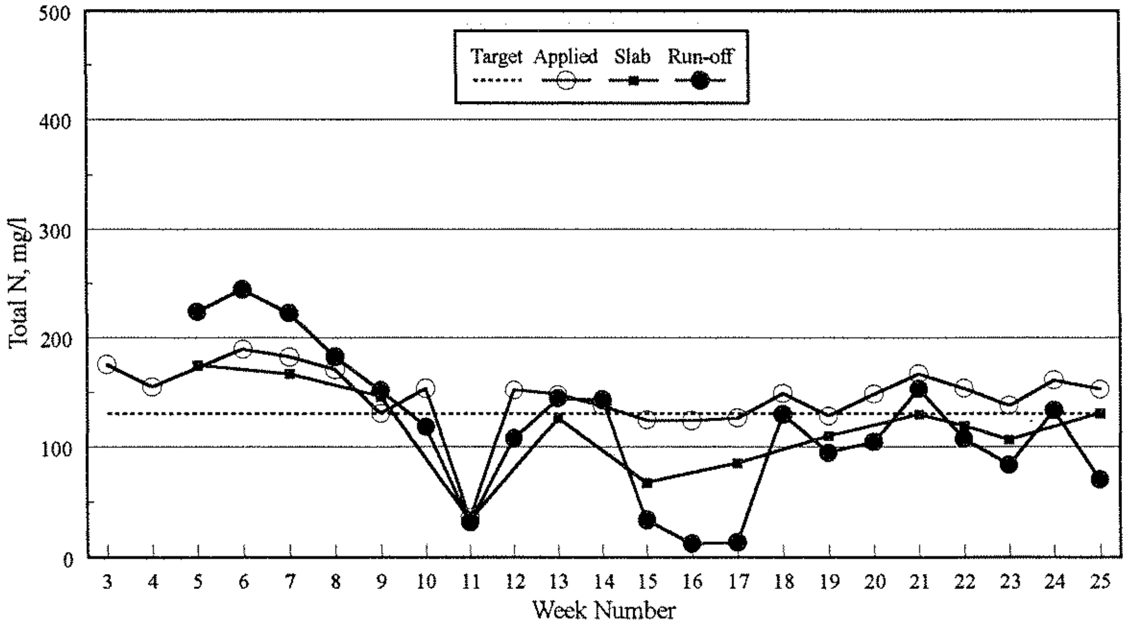


Figures 17a and b - Nitrogen content of solutions

17a) 70 N Treatment - First crop

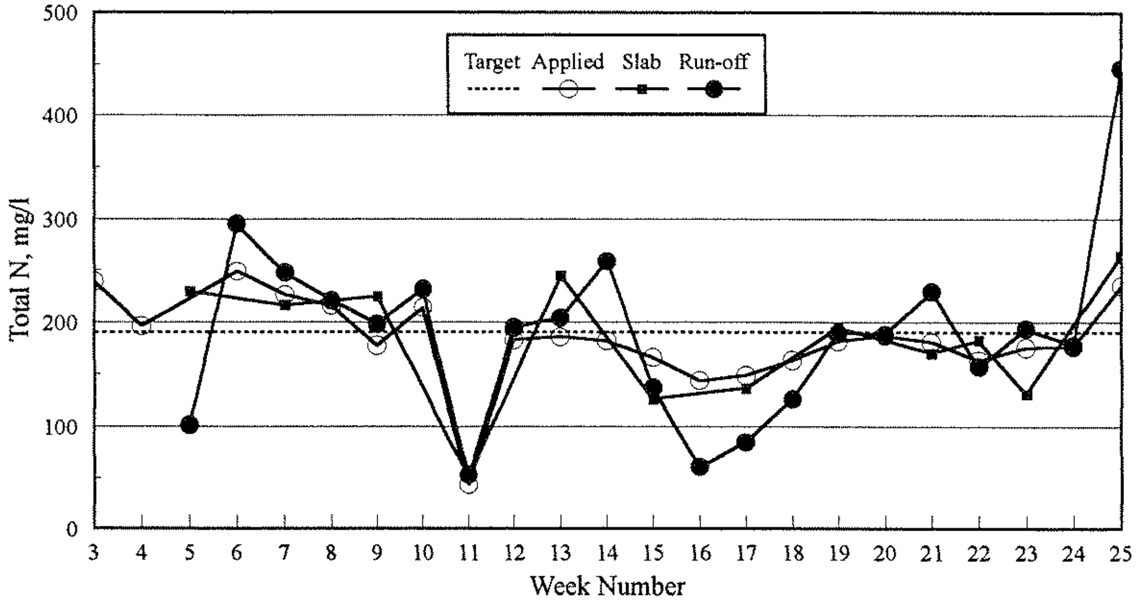


17b) 130 N Treatment - First crop

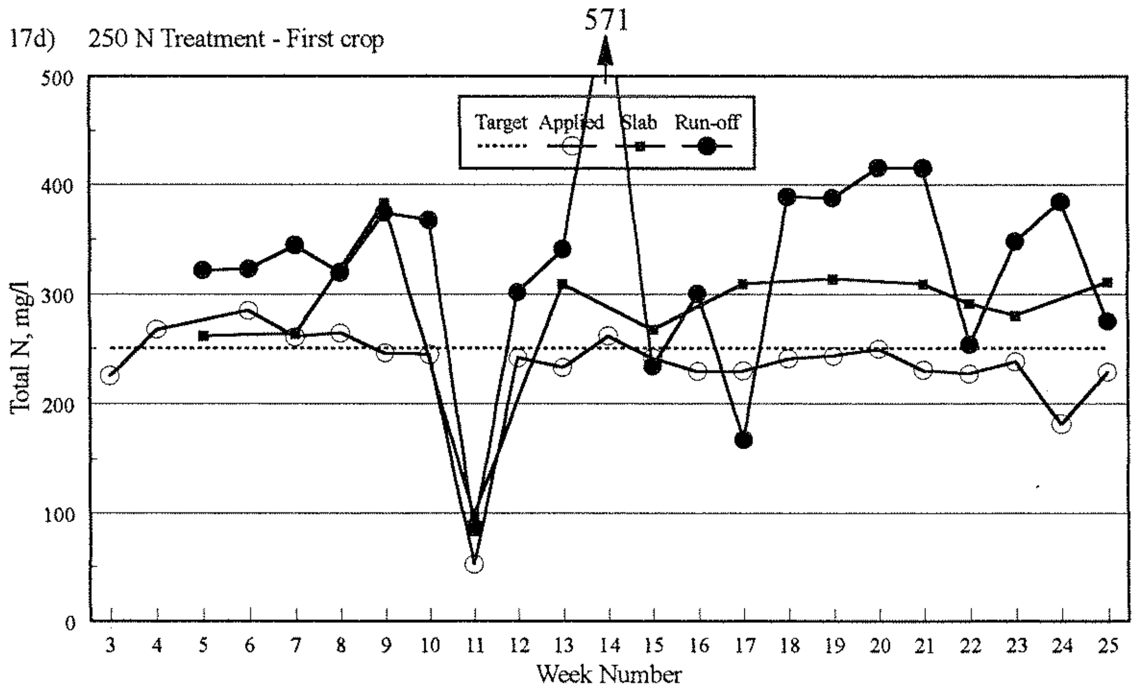


Figures 17c and d - Nitrogen content of solutions

17c) 190 N Treatment - First crop

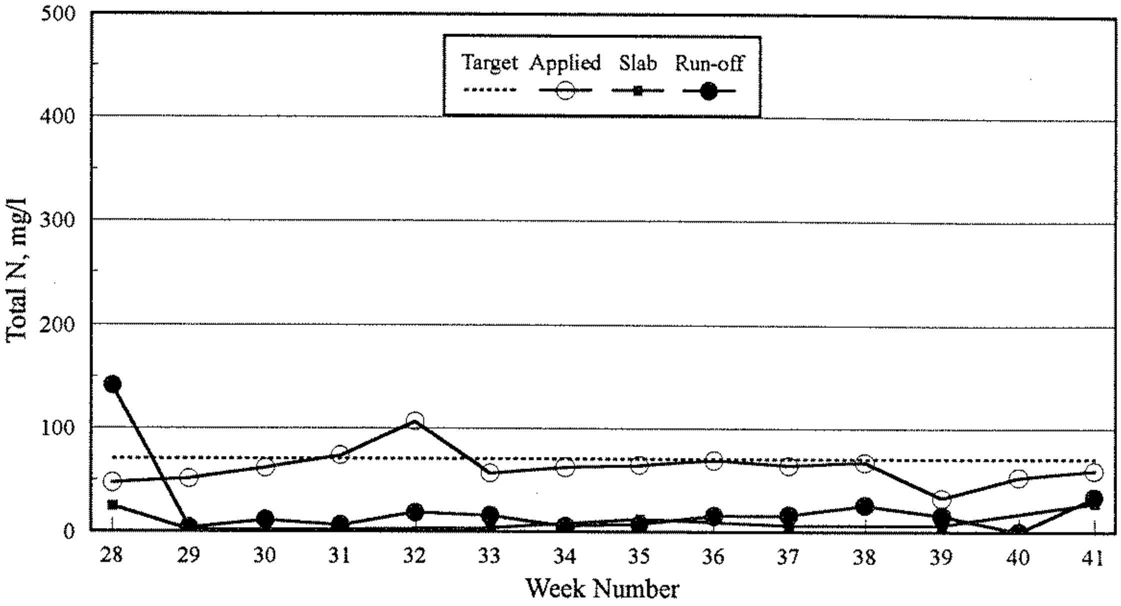


17d) 250 N Treatment - First crop

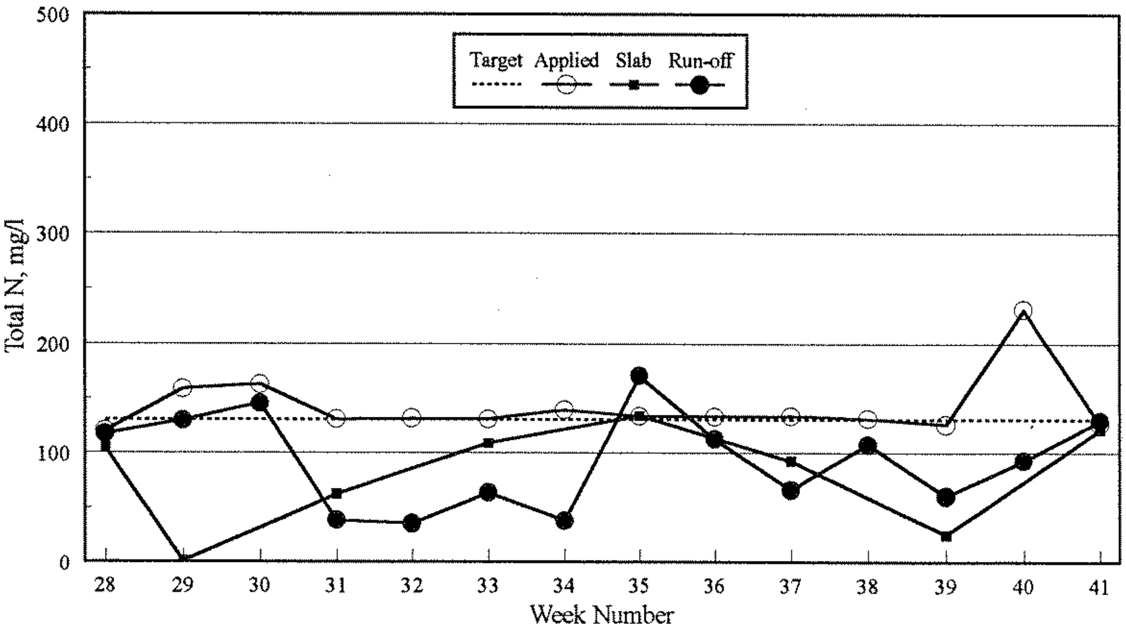


Figures 18a and b - Nitrogen content of solutions

18a) 70 N Treatment - Replanted crop

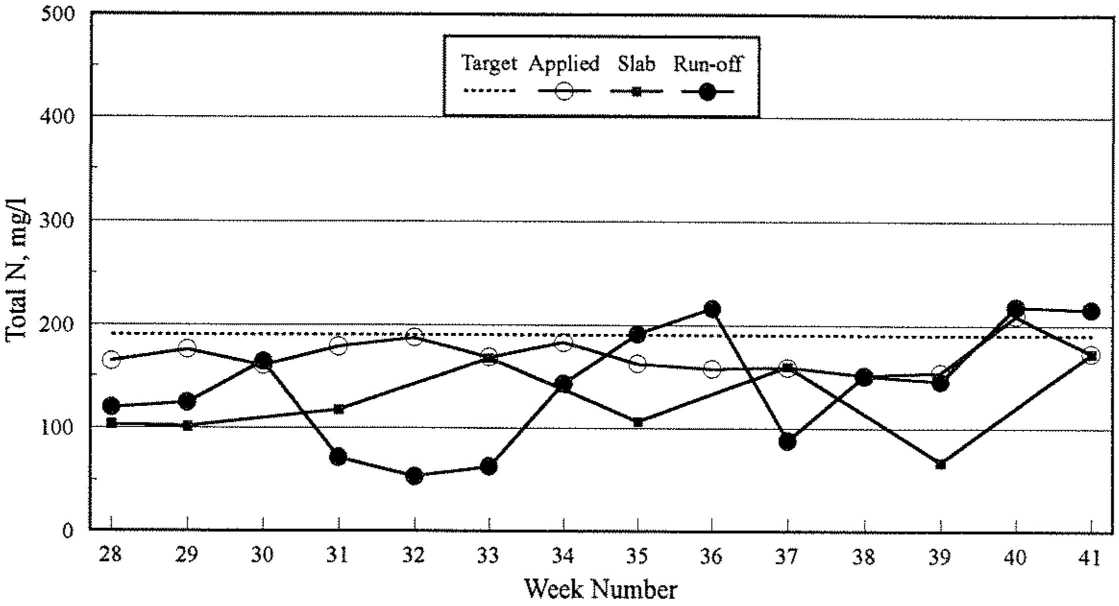


18b) 130 N Treatment - Replanted crop

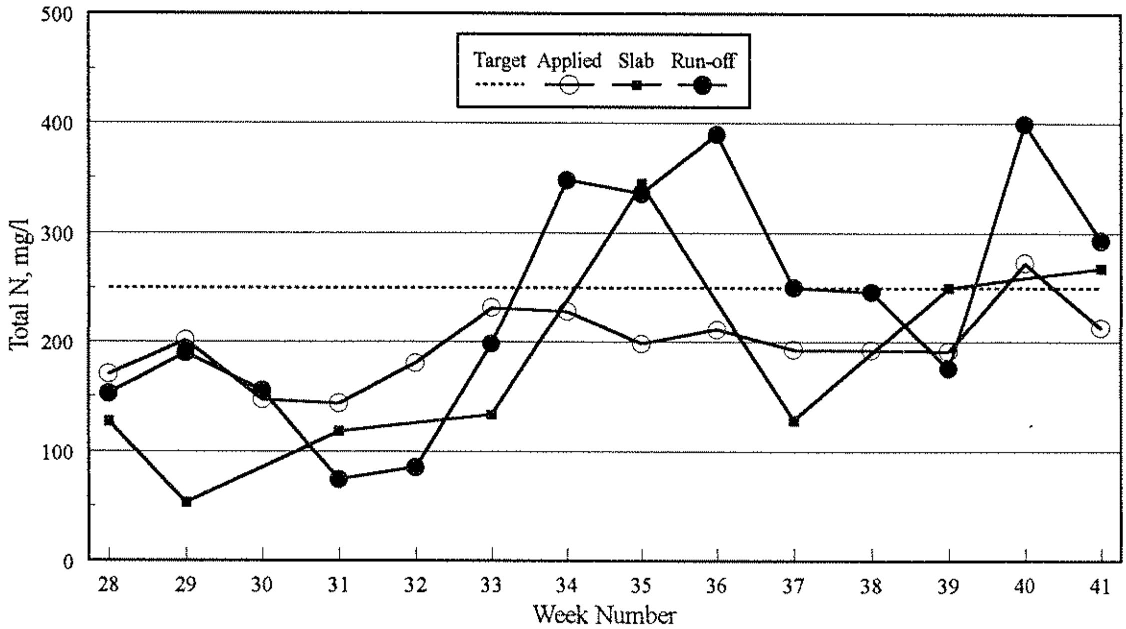


Figures 18c and d - Nitrogen content of solutions

18c) 190 N Treatment - Replanted crop

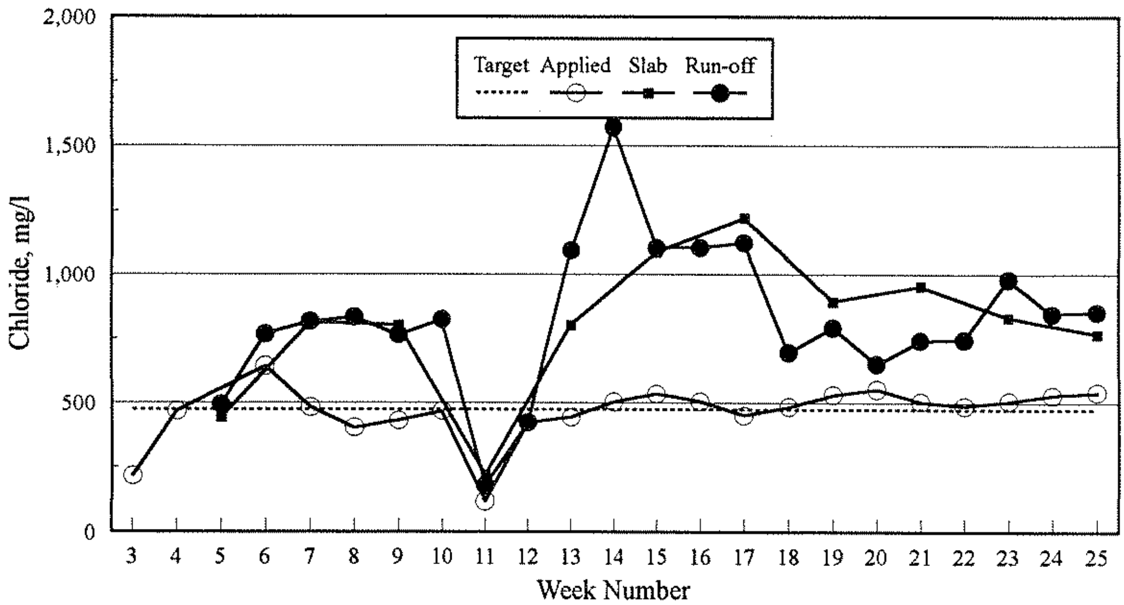


18d) 250 N Treatment - Replanted crop

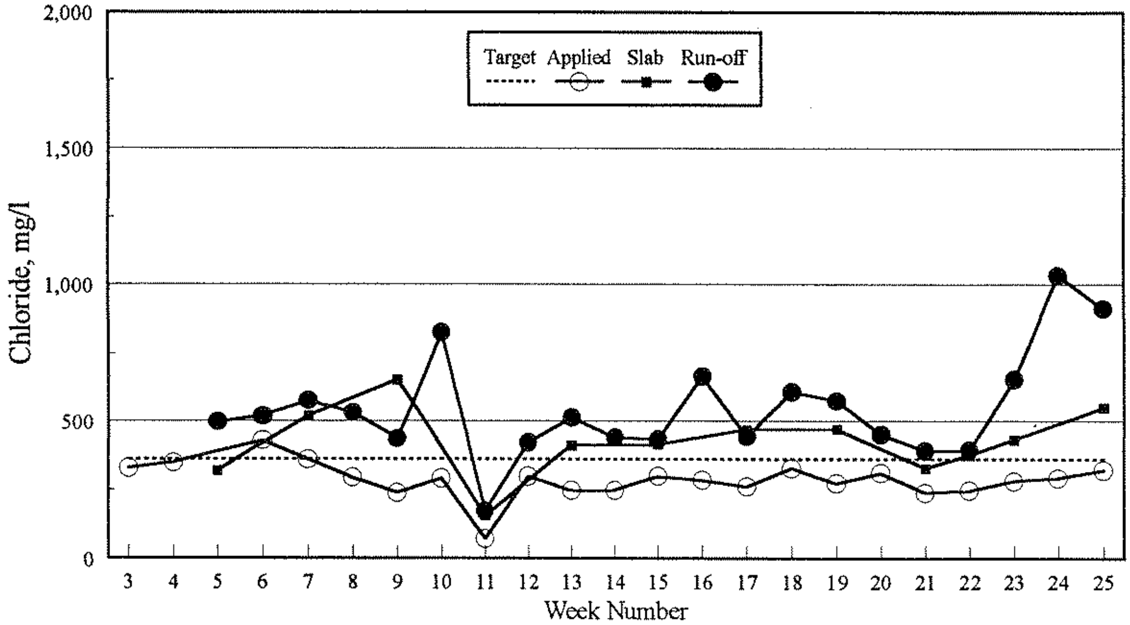


Figures 19a and b - Chloride content of solutions

19a) 70 N Treatment - First crop

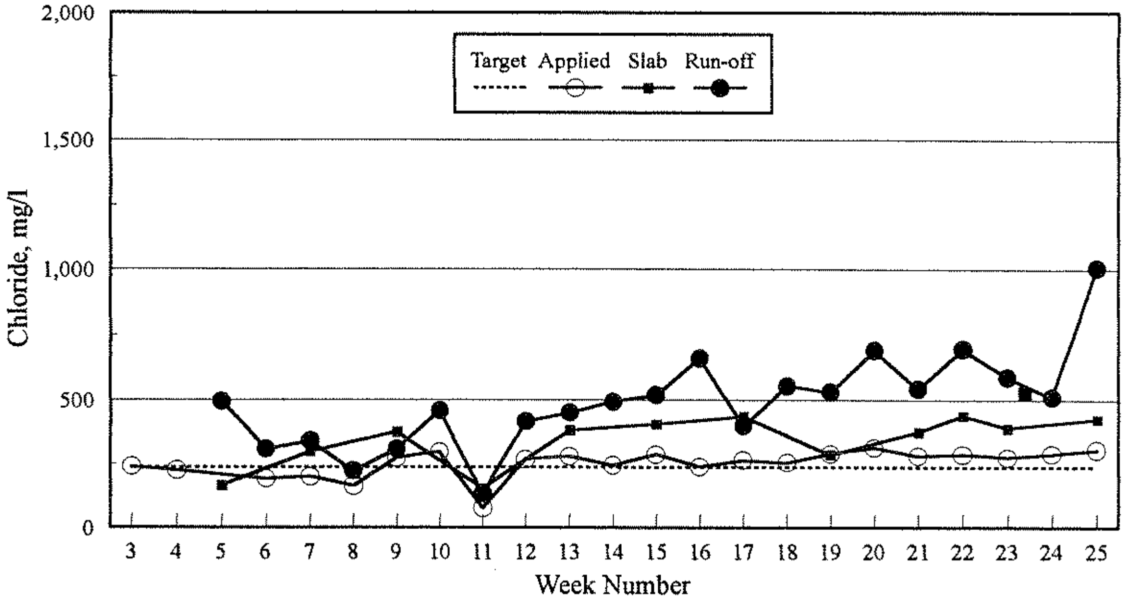


19b) 130 N Treatment - First crop

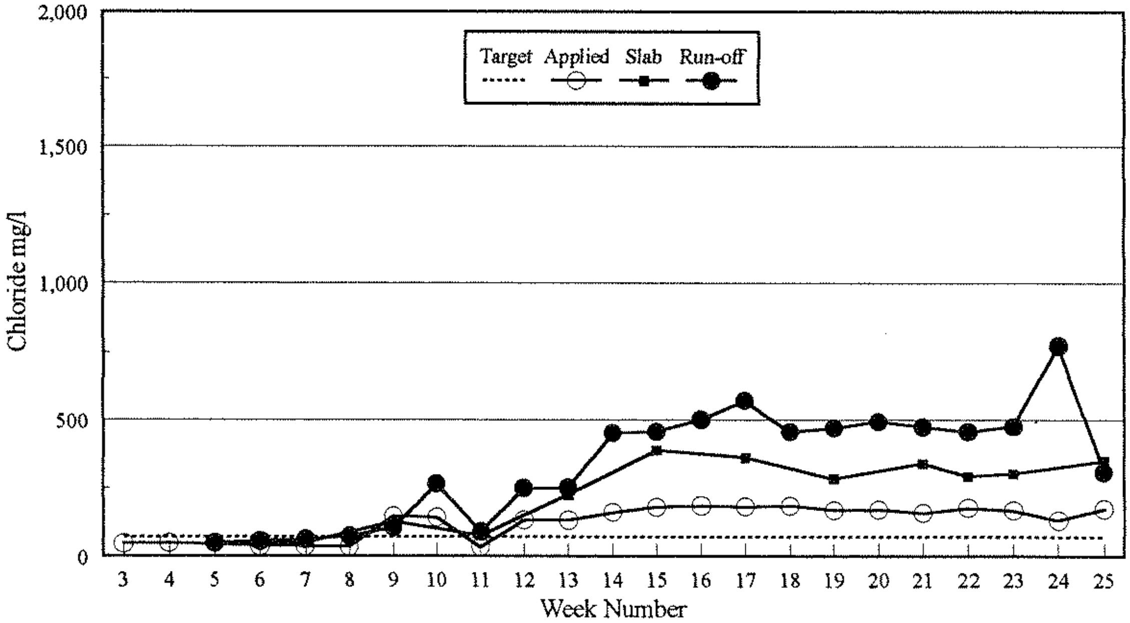


Figures 19c and d - Chloride content of solutions

19c) 190 N Treatment - First crop

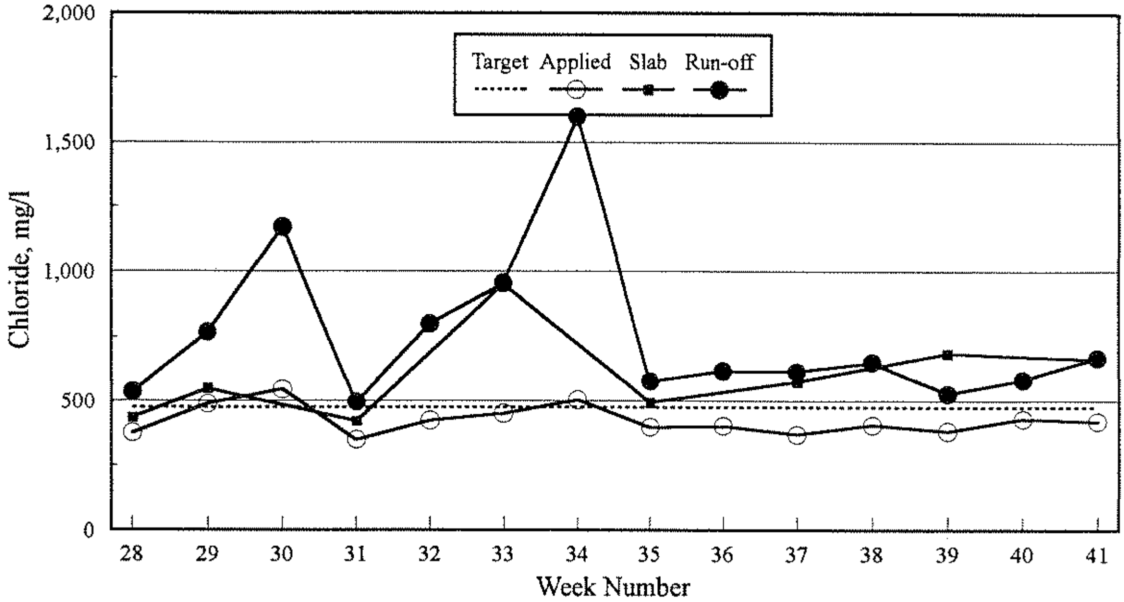


19d) 250 N Treatment - First crop

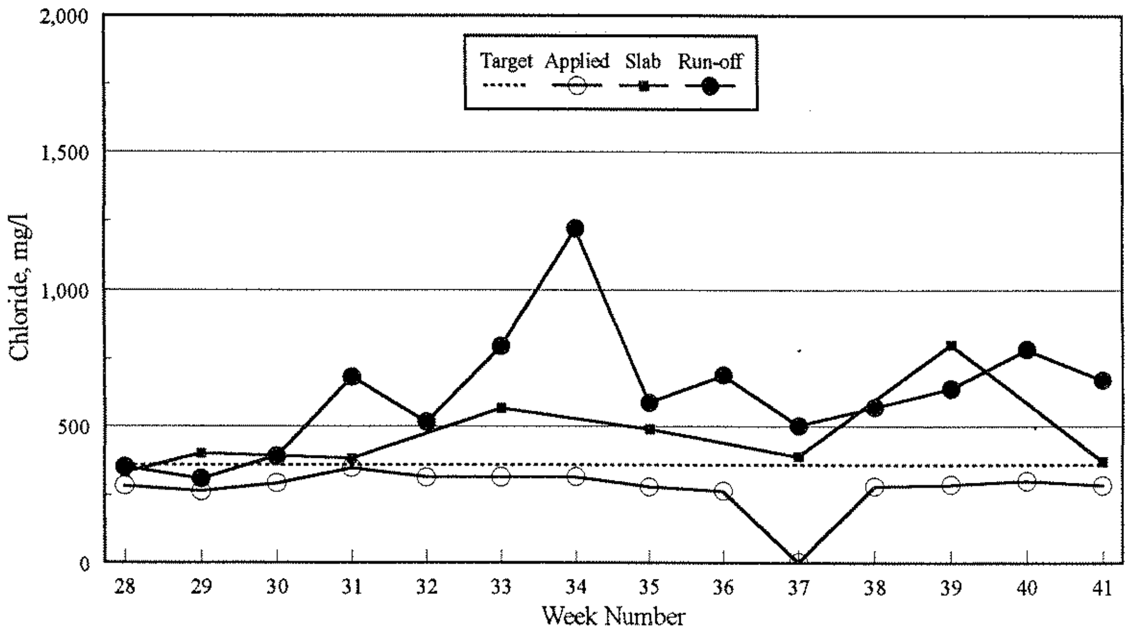


Figures 20a and b - Chloride content of solutions

20a) 70 N Treatment - Replanted crop

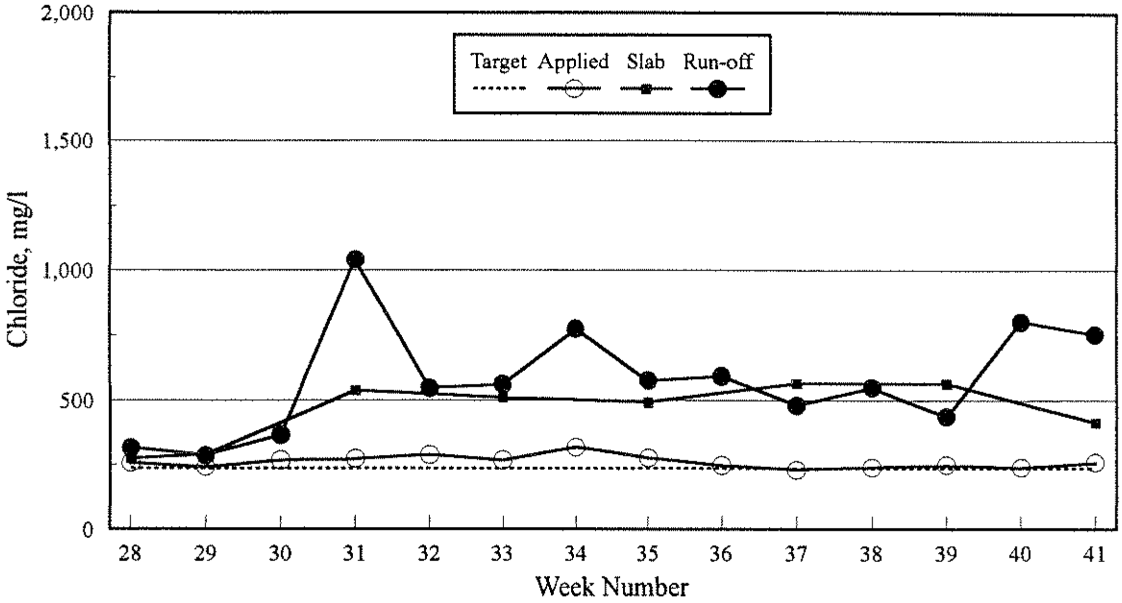


20b) 130 N Treatment - Replanted crop

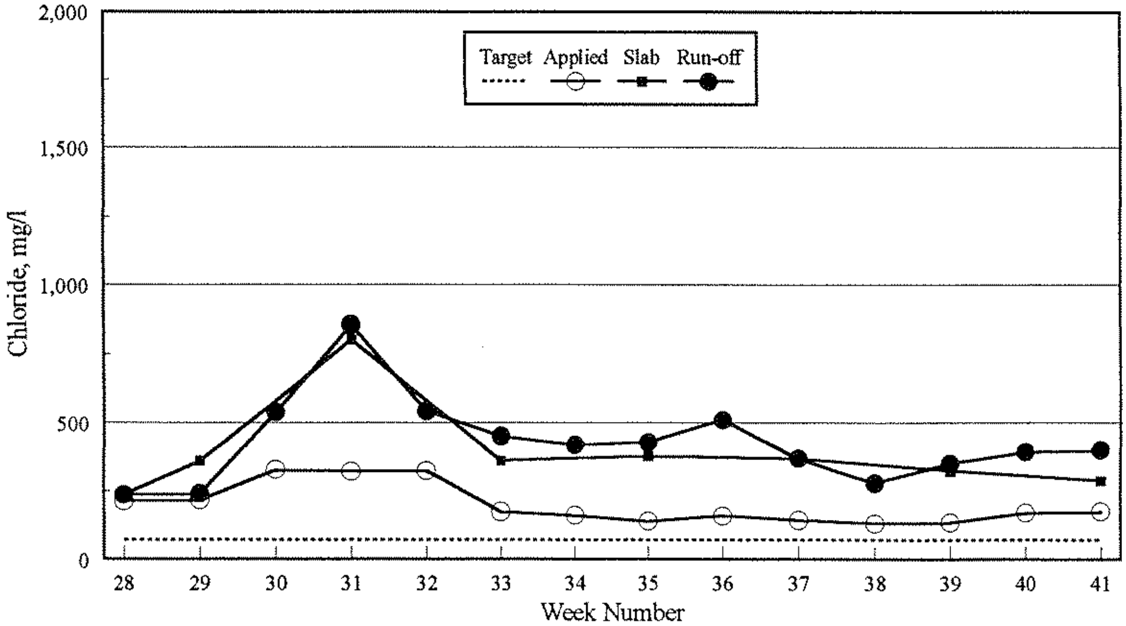


Figures 20c and d - Chloride content of solutions

20c) 190 N Treatment - Replanted crop

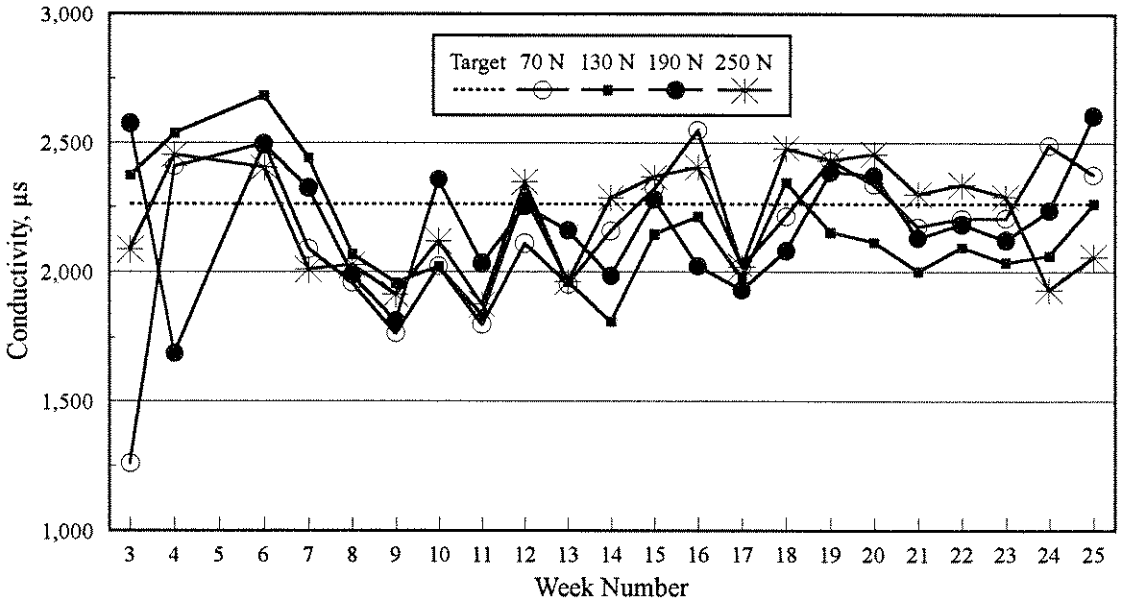


20d) 250 N Treatment - Replanted crop

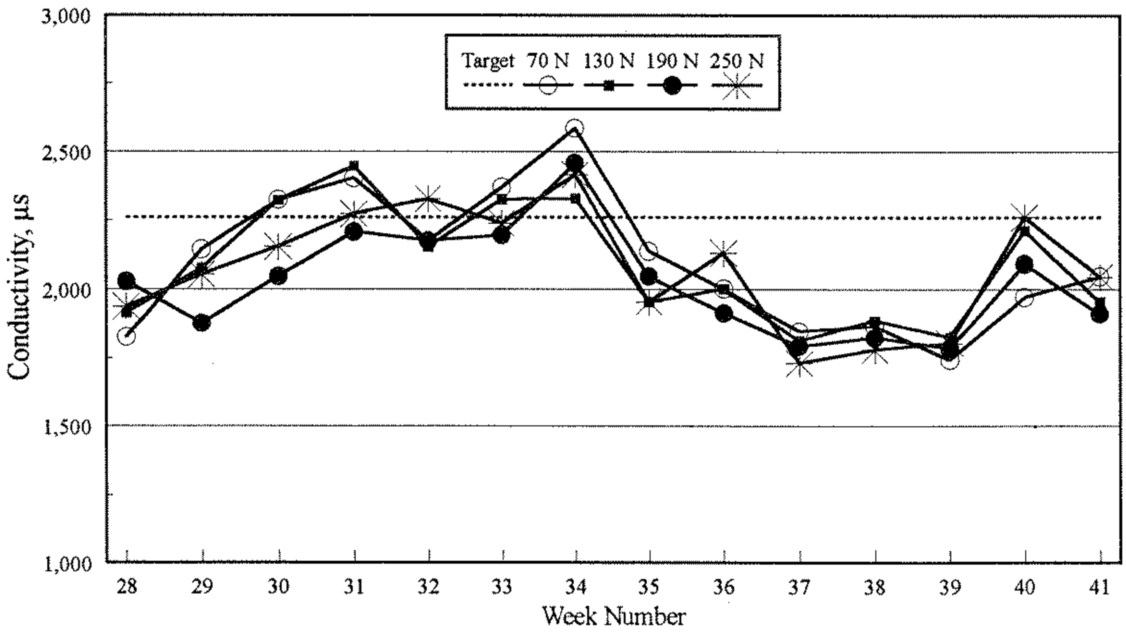


Figures 21a and b - EC of Applied feeds

21a) First crop

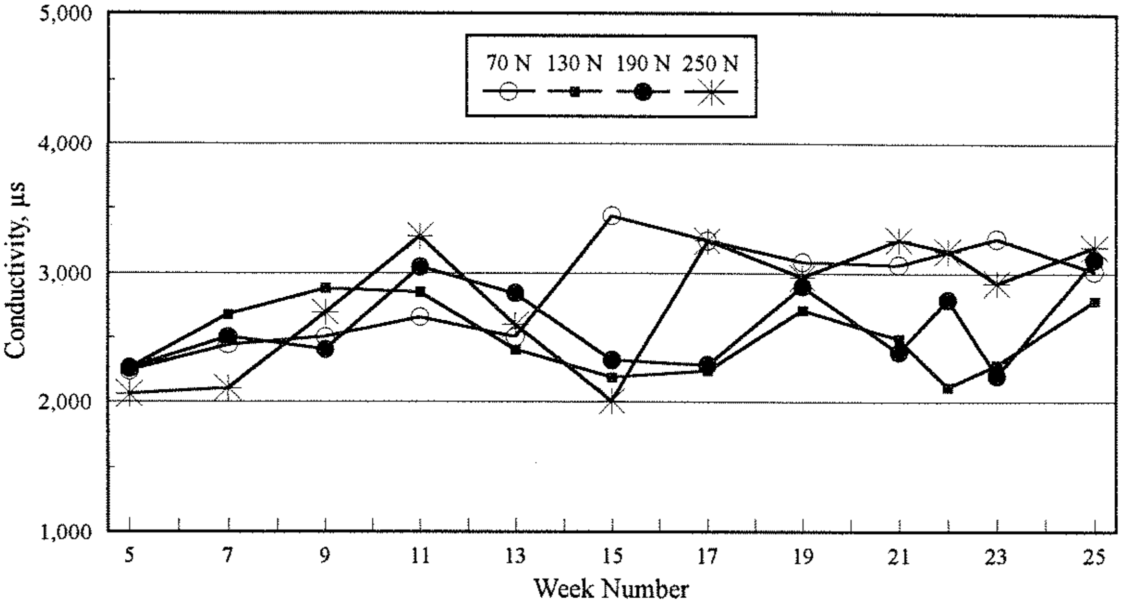


21b) Replanted crop

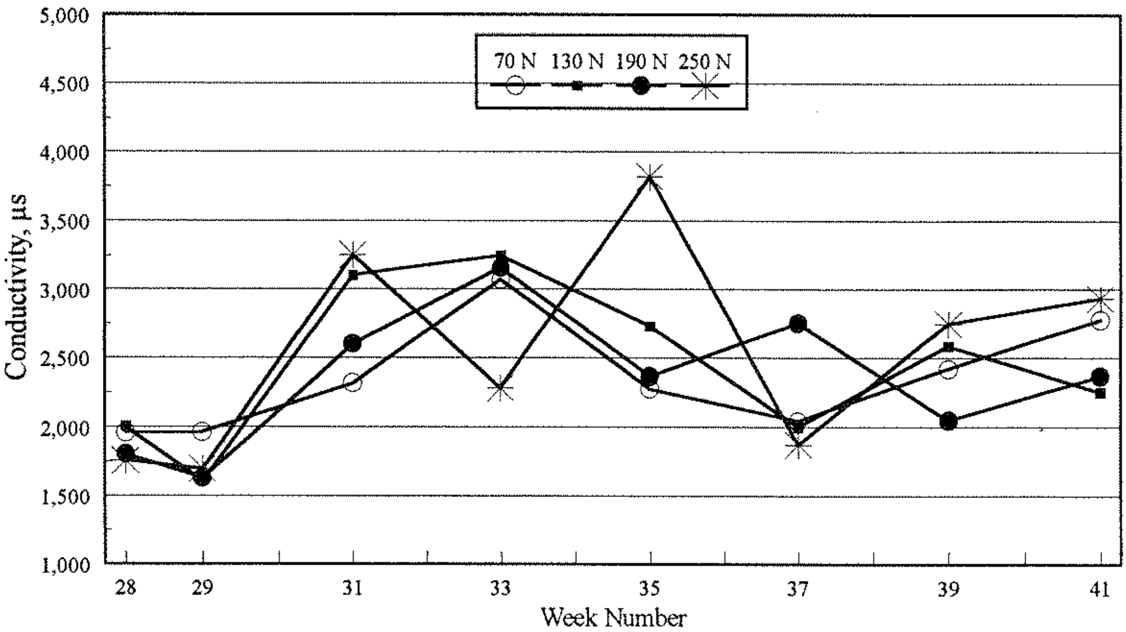


Figures 22a and b - EC of slab solution

22a) First crop

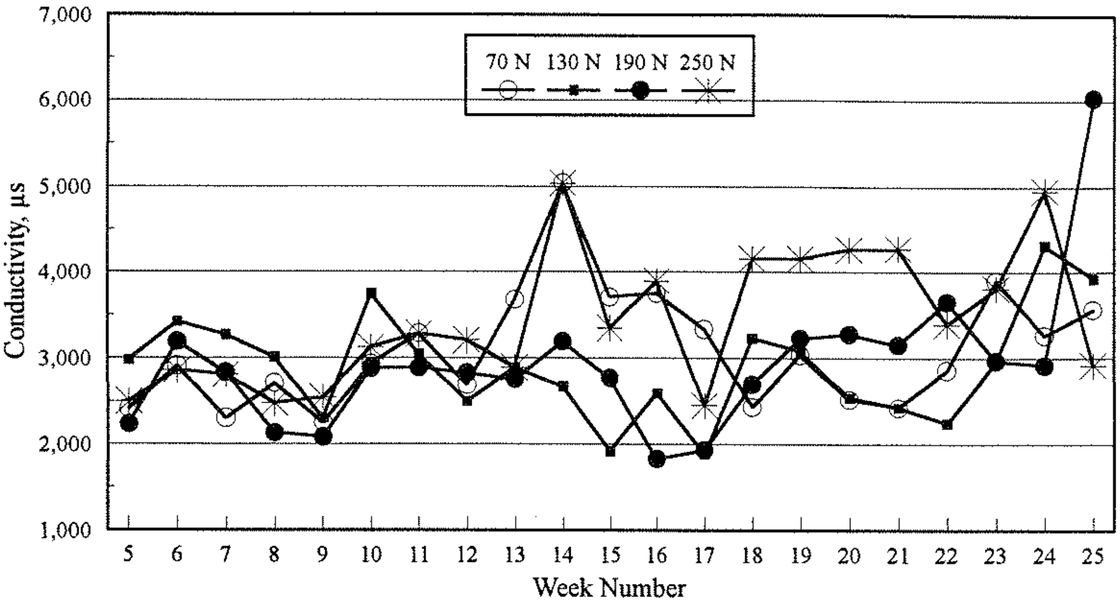


22b) Replanted crop

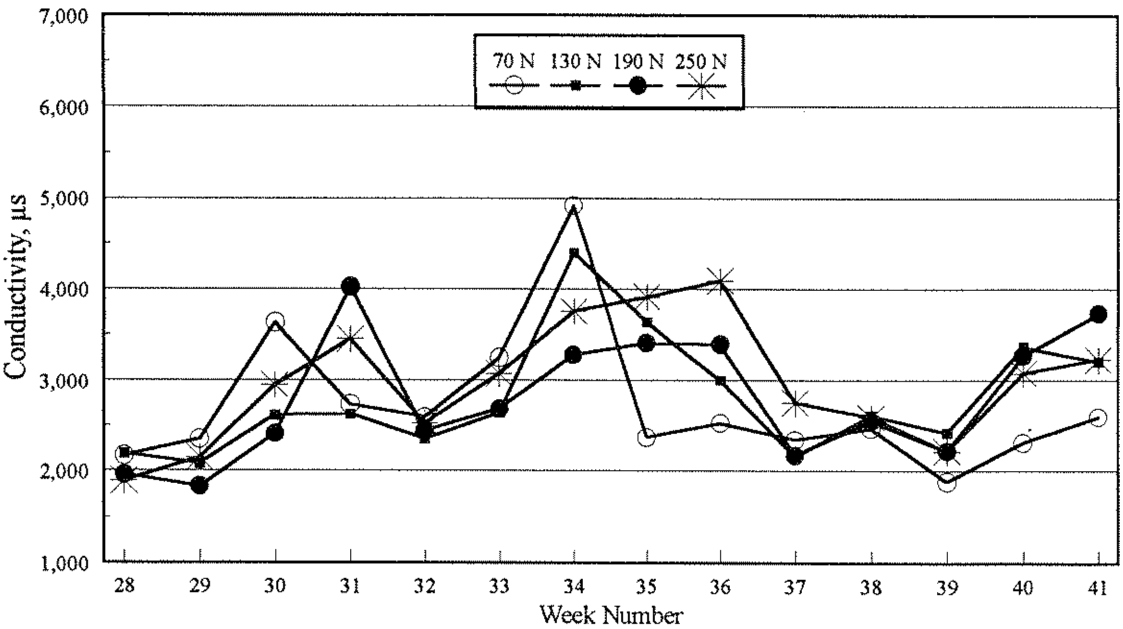


Figures 23a and b - EC of run-off solution

23a) First crop



23b) Replanted crop



Discussion

In the first year of this project a range of Nitrogen concentrations in the applied feed ranging from 80 to 230 ppm was tested. Although plant vegetative growth was affected by changing the treatments (ie at low N levels growth was reduced and colour was paler) fruit yield was not significantly affected.

Reducing the nitrogen in the feed to 70 ppm severely restricted plant growth for the whole of the first crop with marked chlorosis (yellowing) of the leaves. As the nitrogen level in the feed increased the growth and 'greenness' of the plants improved, particularly in the 190 ppm treatment. At 250 ppm N the plants were marginally greener than with 190 ppm but growth was not increased.

Total yield was reduced significantly from the 70 ppm N treatment. Overall this treatment produced 17 fruit per m^2 less than the 130 and 250 ppm treatments. There was no consistent effect of N treatment fruit production between the 190 and 250 ppm treatments, although the 250 ppm treatment tended to be less productive.

Reducing the applied N from 190 to 130 ppm decreased the N in the run-off by 71 ppm (average for the whole of the first crop). Nitrogen in the run-off and slab solutions was generally depleted when the applied N was 170 ppm or less, a similar result to the first year. The conductivity in the slabs was maintained below 2.9 mS for the 130 ppm treatment even though the applied chloride was nearly 400 ppm (slab Chloride levels were generally between 400 and 600 ppm).

In the first crop 130 and 190 ppm N treatments N levels were similar in the slab and run-off, to the applied concentration. During a period of rapid growth after planting slab and run-off levels in the replanted crop dropped significantly. This was also noticeable in the 250 N treatment but levels then rose dramatically.

Slightly higher percentage run-offs were obtained in the second year than the first. This was because slab ECs were maintained at less than 4000 μS (ie if levels rose above this extra water was supplied to reduce slab EC).

Both trials (1995 and 1996) indicate that there is potential to reduce the amount of Nitrogen applied to the plant without reducing fruit yield or quality. The 130 N treatment produced the best combination of yield, quality and monetary value, however, on the basis of two years' work the target applied N should be reduced to 150 ppm as for tomatoes. This includes a 'safety margin' to allow for practical difficulties in achieving the target and variability in percentage run-off. This will save about £385-£535 per ha compared to a target of 180 ppm. Higher N values are required for the first 2-3 weeks after planting. Growers aiming at high ECs can save even more by using chlorides instead of increasing the nitrate.

Conclusions

1. Cucumber plants can be grown in hydroponics at lower nitrogen concentrations than have previously been recommended without loss of yield or quality. A rate of 150 ppm N is now recommended.

2. During establishment the plants have a high demand for nitrogen and a higher concentration in the applied feed may be required at this time.

3. Mature plants that are producing fruit have a reduced demand for nitrogen.

4. Vegetative growth was affected by nitrogen deficiency before any effect on fruit production was recorded.

5. Reducing the applied nitrogen concentration to 70 ppm significantly reduced growth and productivity.

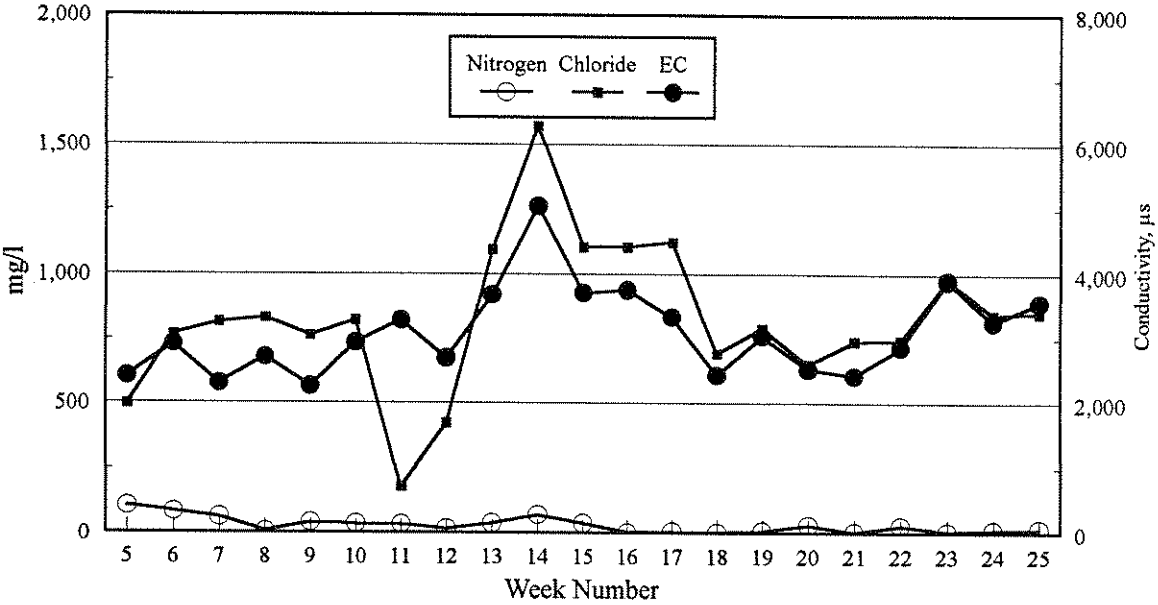
6. An applied nitrogen concentration of 250 ppm tended to reduce plant vigour and led to some yield reduction, compared with application rates of 130 and 190 ppm N.

7. Applied nitrogen concentration did not affect fruit quality except at 70 ppm N.

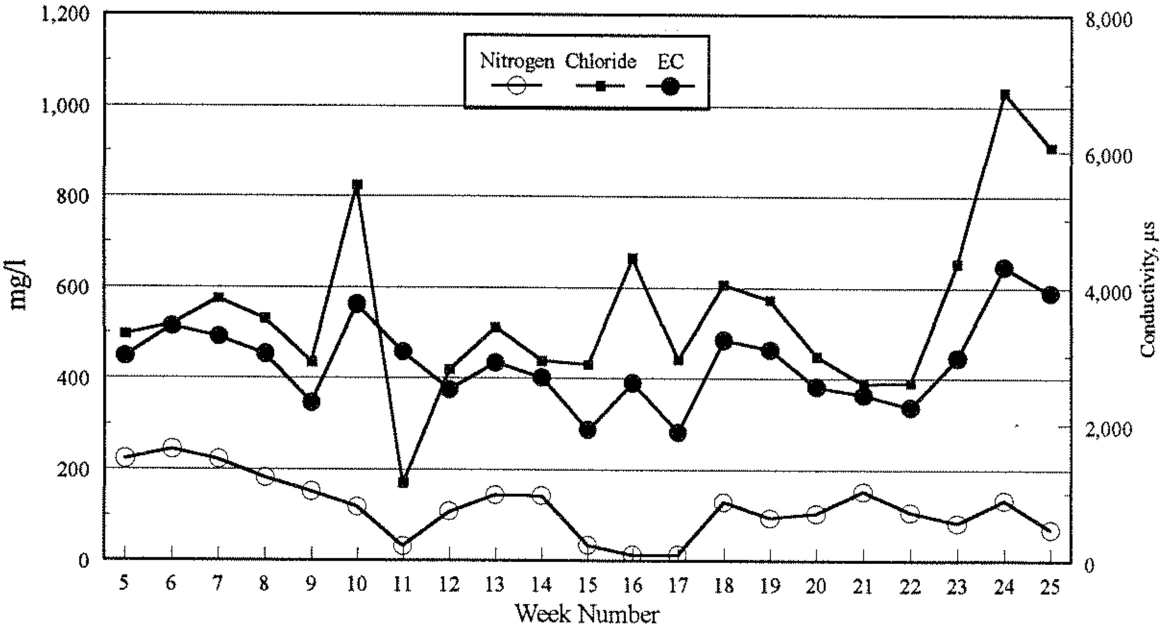
8. There are differences in varietal response. Fruit weight of Jessica increased with increasing N concentration but in Bronco this effect was not recorded.

Appendix I - Nitrogen, Chloride and Conductivity of run-off

70 N Treatment - First crop

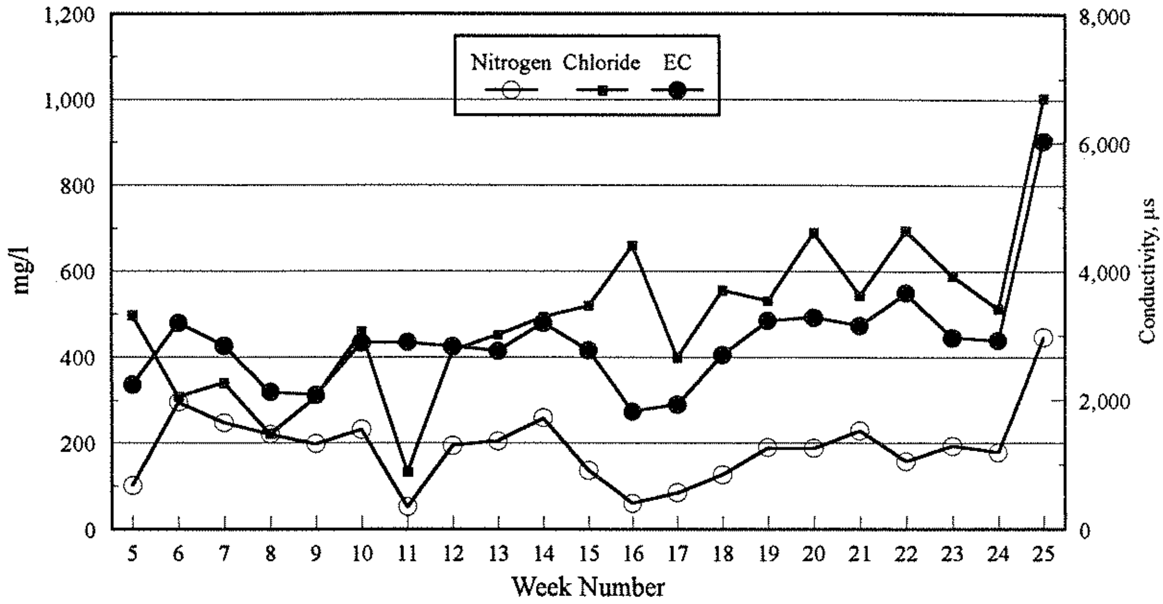


130 N Treatment - First crop

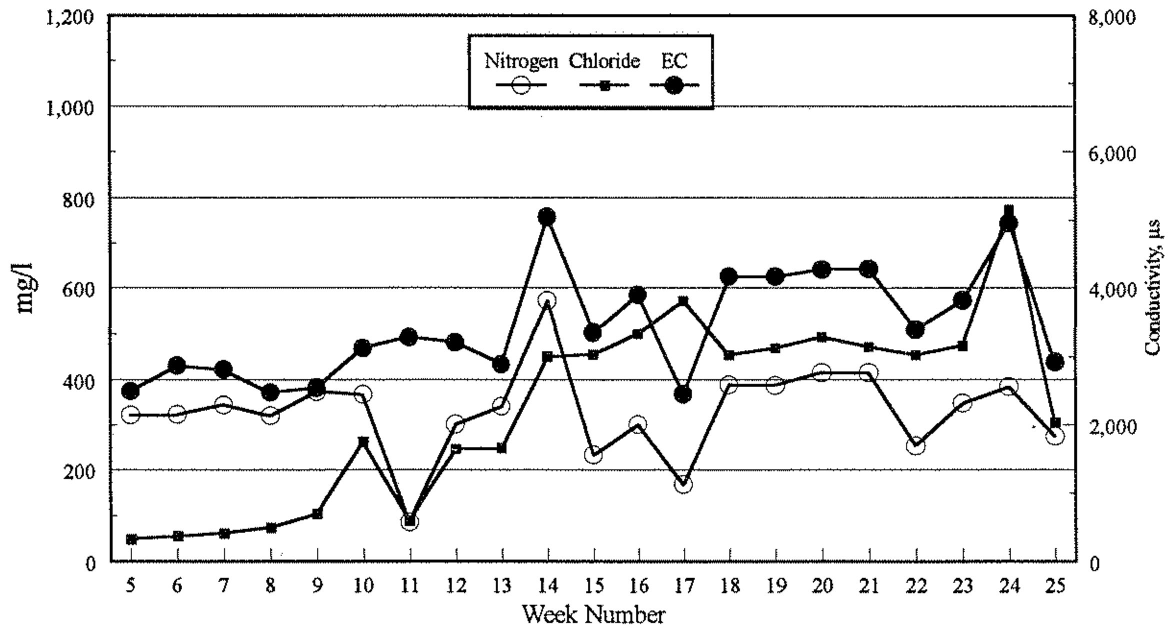


Appendix I - Nitrogen, Chloride and Conductivity of run-off

190 N Treatment - First crop

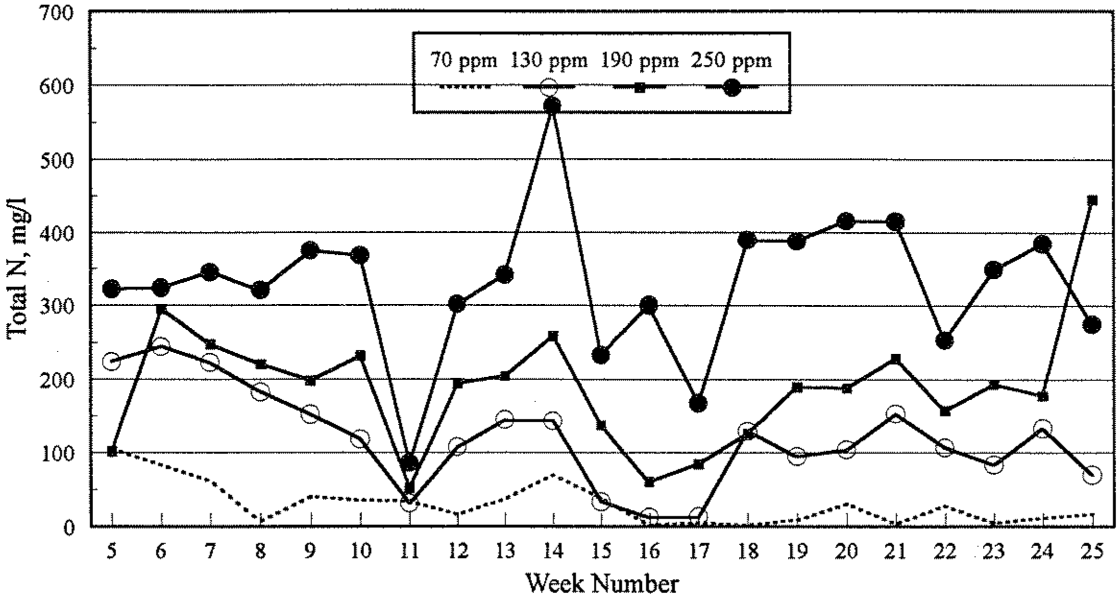


250 N Treatment - First crop



Appendix II - The Effect of Applied N Concentration on N Content of Run-off

First crop



Replanted crop