HORTICULTURE RESEARCH INTERNATIONAL

EFFORD

Report to: Horticultural Development Council
18 Lavant Street
PETERSFIELD
Hampshire GU32 3EW

Tel: 01730 263736
Fax: 01730 265394

HRI Contract Manager: Dr D J Hand
HRI Efford
LYMINGTON
Hampshire SO41 0LZ

Tel: 01590 673341
Fax: 01590 671553

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FINAL CONTRACT REPORT

Tomatoes: The influence of reduced nitrate input on yield and fruit quality

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Final Report April 1995

HDC PC55a

Tomatoes: The influence of reduced Nitrate input on yield and fruit quality

Dr D J Hand
HRI Efford

Mr M Fussell
HRI Efford

Co-ordinator: Dr N O Dungey

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PRINCIPAL WORKERS

HRI EFFORD

Dr D J Hand BSc (Hons), PhD, M.I.Hort.	Head of Protected Crops
Mr M Fussell BSc (Hons) (Author of Report)	Technical Officer
Mrs S Foster	Scientific Officer
Mr M Wainwright BSc	Assistant Scientific Officer
Miss J Basham	Assistant Scientific Officer
Mr M Leppard	Assistant Scientific Officer
Mr C Vigor	Nursery Staff
Mr P DeVries	Nursery Staff
Mr K Herridge	Nursery Staff
Mr M Reay	Computer Systems Maintenance

HRI LITTLEHAMPTON

Mr R H Edmondson MSc	Statistician

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 ....

Dr D J Hand
Head of Protected Crops

Date 25-4-97

Report Authorised by ....
Signature

Dr M R Shipway
Head of Station

HRI Efford
Lymington
Hants
SO41 0LZ

Date 26:4:97

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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

Application

By partially substituting Potassium Nitrate with Potassium Chloride in hydroponic feed solutions, levels of nitrate released into the environment from long season tomato crops grown in rockwool can be reduced. This project aimed to determine how far nitrate inputs could be reduced before yield losses occurred in a long season tomato crop grown in rockwool. It was concluded that yield losses are likely if Nitrate-Nitrogen (NO_3-N) concentrations in the root zone fall below 100 mg/l.

Summary

Previous nutrition trials funded by the HDC (PC55 and PC55a) showed that reduced nitrate inputs to long season tomato crops grown in rockwool could be achieved without loss of yield by partially substituting Potassium Nitrate with Potassium Chloride. As Potassium Chloride is less expensive than Potassium Nitrate substantial savings on the cost of fertilizers were possible. In 1992/93 NO_3-N concentrations of 60, 120, 180 and 242 mg/l resulted in no significant differences in yield. The aim of the 1993/94 trial was to validate these results and to determine at what concentration NO_3-N begins to limit yield, on a long season rockwool crop grown to best commercial practise.

Treatments comprised four NO_3-N levels 30, 60, 120 and 180 mg/l in the applied feed solution. Half the treatments were started on 3 January, the remainder 6 weeks later on 17 February.

Effects of low N on growth and yield:

The 30 mg/l NO_3-N treatment had a pronounced effect on the crop by April and resulted in stunted growth. Leaves were small and chlorotic and fruits were smaller as well as less numerous than in other treatments. Fruits and their calyces became pale yellow in colour. The effects on growth were so severe that the treatment was terminated and the NO_3-N concentration was raised from 30 to 120 mg/l in order to observe the sequence of recovery. After increasing NO_3-N concentrations to 120 mg/l, vigour returned but severe Blossom-End Rot affected the fruit, and yields never recovered.

The effect of treatment start time was restricted to the 30 mg/l treatment where shorter stems and lower yields resulted from the earlier start.

The 30 mg/l treatment resulted in a 28% yield reduction to the end of May compared to the 180 mg/l treatment. The 60 mg/l treatment also showed a significant yield reduction of 6% to the end of May which increased to 18% to the end of October. The 120 mg/l treatment yielded 2.5% less than the 180 mg/l treatment to the end of October but this difference was not statistically significant.

Effect of low N on fruit quality:

While 30 and 60 mg/l applied NO_3-N resulted in slightly softer fruit, reducing applied NO_3-N to 120 mg/l had no effect on softness or shelf-life and overall, reduced NO_3-N had no effect on percentage Class I fruit. Lower NO_3-N levels reduced the acidity of fruit but had no detrimental effect on tomato flavour as assessed by a taste panel.

Conclusions:

The combined results of the 1992/93 and 1993/94 trials suggest that yield reductions occur when NO_3-N concentrations in the root zone fall below 100 mg/l. This happened for the 30, 60 and 120 mg/l treatments in 1993/94. It is suggested that yield losses will be avoided if applied levels of NO_3-N are kept at around 150 mg/l.

Monitoring of the slab or drain solution is recommended in order to assess the Nitrogen status of crops. Levels of NO_3-N over 200 mg/l would indicate that NO_3-N is being supplied to excess whereas levels below 100 mg/l indicate that the crop is not receiving enough.

By reducing nitrate inputs to the levels suggested growers will avoid unnecessary nitrate pollution and improve the image of the industry held by consumers. There is also the opportunity to make savings on the cost of fertilizers.

INTRODUCTION

Recent European Community directives on nitrate levels in drinking water and also surface and ground waters have emphasised the need for growers to reduce the amount of nitrate released to the environment. Work has been undertaken or is underway on developing recirculation techniques and water treatment methods (reedbeds) in order to reduce or eliminate nitrate pollution. While these developments show much promise there are costs, sometimes in terms of yield and always in terms of capital expenditure which make them less attractive as short-term solutions to the pollution problem.

However, by manipulating irrigation regimes and feed solution recipes it is possible to reduce nitrate pollution without capital outlay or loss of yield. Recent studies at Efford have shown that reduced nitrate inputs can be achieved without loss of yield by partially substituting Potassium Nitrate in feed solutions with other materials. The HDC funded trial, PC55 in 1991/92 demonstrated that partial replacement of Potassium Nitrate with Potassium Chloride or Calcium Chloride had no detrimental effects on yield where NO_3-N concentrations in the applied feed were reduced from 290 to 205 mg/l. Fruit quality was also generally unaffected other than an increase in levels of Gold Spot where Calcium salts were used.

In 1992/93 four levels of NO_3-N were tested, 60, 120, 180 and 242 mg/l in PC55a. Surprisingly, even reducing the applied level to 60 mg/l in the applied feed did not result in a significant yield reduction. Fruit quality was again generally unaffected apart from increased levels of Gold Spot associated with the low nitrate/high chloride treatments and a small increase in the softness of fruit. The levels of fruit acidity were found to be lower at low levels of applied NO_3-N. However, the 60 mg/l regime was not achieved consistantly until April (week 15). It is possible that had the `low' regime been established earlier this treatment might have had more effect on the crop.

It is not clear whether tomato plants have a constant demand for Nitrogen or whether the demand is variable depending upon growth stage or light levels. A greater understanding of the Nitrogen requirements of the crop would help growers to closely match their supply of Nitrogen with the requirements of the plant rather than supplying to excess and losing nitrate to the environment.

MATERIALS AND METHODS

Site details

The trial was done at HRI Efford utilising the new B-Block venlo type glasshouse. The layout of the trial is illustrated in Appendix I, page 61.

Treatments

Four target nitrate levels in the applied feed of 30, 60, 120 and 180 mg/l NO_3-N were imposed on the variety Pronto. The treatments were commenced in two stages, close to the time slab contact was made or at the time of first fruit pick. These were the sub-treatments in the experiment. The treatment target nitrate levels were made up and supplied by the Brighton Systems irrigation rig to half the plots from 3 January (13 days after planting) whereas the other plots remained on 180 mg/l NO_3-N supplied by the B-Block irrigation rig until 17 February (first pick).

As in previous years the four nitrate levels were achieved by augmenting a base feed (Table 1) with different blends of Potassium Chloride and Potassium Nitrate to produce applied feeds of common conductivity. Early season growth was controlled by using Sodium Chloride in the same quantities for each treatment to raise conductivity. Subsequently EC was reduced from 5000 μs to 2800 μs by reducing the amount of Sodium Chloride in the feed recipe. It should be noted that due to a problem with A feed dosing treatments started on 2 January suffered low levels of applied Iron for weeks 1-5. Applied levels of Iron were approximately half the target concentration during this period. Each feed solution was applied at a rate of 150 ml per plant. Irrigation rounds were triggered by light, one round per 100 J/cm^2, except on dull days when irrigation commenced after a set time period.

Calibration

Checks on the volume of feed solution applied in each treatment were made and set points adjusted on the irrigation rig accordingly. (See Appendix II, page 62).

Cultural techniques

Seeds of tomato (*Lycopersicon esculentum Mill*) cv Pronto were sown on 28 October 1993, in rockwool multiblocks (40 x 40 x 40mm) which had been wetted up the day before using a feed solution with a pH of 5.0 and an EC of 1500 μs. Following germination the EC was raised to 2500 μs coincident with expansion of the cotyledons. Prior to blocking on, the 0.65 litre rockwool blocks were wetted up with a feed at pH 5.0 and an EC of 2500 μs, the aim being to achieve a stable block pH of circa 6.0. From blocking on to the time taken for the third true leaf to reach 10mm in length, the EC of the applied feed was raised from 2500 to 3500 μs.

The EC was then raised in stages to 5000 μs. Plants were placed in their final positions in B-Block on 2 December. Slabs were wetted up with a feed solution containing 180 mg/l NO_3-N at 5,000 μS. Planting was carried out on 20 December 1994. Modified 'Blueprint' temperatures were applied throughout propagation.

Stage	Target Air temperatures °C Day	Night	Vent
0. Sowing to germination	24	24	26
1. Germination to blocking-on	20	20	24
2. Blocking on to 1st visible bud	20	16	24

Table 1: Tank mixes and composition of background and applied feeds

Tank Mixes (Quantities in g/100 litres)	**Tank** A	B	C^{30}	C^{60}	C^{120}	C^{180}
Ammonium Nitrate	143	143	-	-	-	-
Potassium Nitrate	717	717	0	2160	6490	10810
Potassium Chloride	-	-	7970	6380	3180	0
Sodium Chloride	-	-	11700	11700	11700	11700
Calcium Chloride	3997	-	-	-	-	-
Iron DTPA	1350	-	-	-	-	-
Phosphoric Acid (81%)	-	1.112l/100l	-	-	-	-
Magnesium Sulphate	-	7665	-	-	-	-
Manganese Sulphate	-	30	-	-	-	-
Zinc Sulphate (Monohydrate)	-	13	-	-	-	-
Copper Sulphate	-	4	-	-	-	-
Sulphur	-	25	-	-	-	-
Ammonium Molybdate	-	0.93	-	-	-	-

Hydrochloric Acid used in the Acid Tank

Composition (mg/l) Element	**Background**	**Target NO_3-N level** 30	**60**	**120**	**180**
NO_3-N	30	30	60	120	180
NH_4-N	5	5	5	5	5
P	47	47	47	47	47
K	61	480	480	480	480
Ca	200	200	200	200	200
Mg	75	75	75	75	75
Na	15	475	475	475	475
Cl	150	1420	1344	1192	1041
EC	1650	5000	5000	5000	5000

Lighting was provided during propagation for 16 hours a day (1.00 hrs to 17.00 hrs) at 3500 lux.

The CO_2 level in the glasshouse was raised from ambient to a target 1000 vpm (sunrise to sunset, using pure CO_2) during winter and ambient levels (circa 350 vpm) were maintained in summer.

Plants were grown in the 'V-System' and trained to a 3.6m crop wire.

The initial plant density was 1.88 plants/m^2 or 7600 plants/acre. Sideshoots were taken from two in three plants in two stages to produce a final population of 3.13 plants/m^2 or 12,700 plants/acre. In all respects crop management followed best commercial practice. Full details of the crop diary, including pest and disease control, are listed in Appendix III, page 63.

Assessments

The following records were taken during the course of the trial:

- Graded and total marketable yield, percentage Class I, II and Waste fruit.
- Estimates of leaf size on selected trusses.
- Estimates of the incidence and severity of any mineral deficiencies as required.
- Severity of fruit physical disorders.
- Shelf-life potential of fruit.
- Taste characteristics of fruit (taste panel assessments and internal composition).
- Analysis of fruit nutritional content.
- Daily monitoring of applied and slab solution pH and EC.
- Full monitoring of the glasshouse aerial environment.
- Photographic record of the crop.
- Stem length and truss count at the end of the season.

The following assessments were made in order that calculations of total nitrogen budgets could be made for each treatment. Records were taken from 8 plots.

- Weights of deleafings and sideshoots and nutritional content.
- Volume of applied solution and nutritional composition.
- Volume of run-off and nutritional composition.
- Weights of stem and leaf and nutritional content at the end of the season.

Fruit Disorder Assessments

Ten fruit were sampled at random from each plot and each fruit assessed for physical disorders using the Efford Physical Disorder Assessment Scoring System outlined in Appendix IV, page 64.

Shelf-life Assessments and Chemical Analysis

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

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

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

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

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

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

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

Acidity: This was determined by dissolving 0.38 g tri-sodium orthophosphate ($Na_3PO_4.12H_20$) in 20ml filtered juice and after 10 minutes measuring the endpoint pH with a hand held pH meter.

Taste Panel Assessments

Four assessments were made throughout the season, in weeks 12, 20, 28 and 40. Sixteen (8 in weeks 28 and 40) participants were asked to taste four pairs of tomatoes over a 2 day period and to ensure that each session was separated by at least 30 minutes. At each session a specified pair of tomatoes were tasted in a predetermined order. A fully balanced design was used so that each participant tasted one fruit from each of the nutritional treatments and compared it to a control fruit taken from the commercial plots in B-Block. The replicated design of the trial was maintained in the taste panel assessments so that two tomatoes from each of the 32 plots were used in the comparisons.

Scores were allocated for the attributes sweetness, sharpness, firmness and overall flavour to differentiate between the second tomato tasted and the first as follows:

Score		
2	-	second sample has more than the first
1	-	second sample has slightly more than the first
0	-	second sample has the same as the first
-1	-	second sample has slightly less than the first
-2	-	second sample has less than the first

Experimental design and explanation of statistical terms

Throughout the main body of this report and selected appendices a number of statistical terms are referred to; 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 two means within a given column that is required for the means to be statistically different.

N.S. = Not Significant.

* = $P<0.05$, i.e. the probability of this result occurring by chance is equal to or less than 1 in 20 (0.05 = 5%)

** = $P<0.01$, i.e. the probability of this result occurring by chance is equal to or less than 1 in 100 (0.01 = 1%)

*** = $P<0.001$, i.e. the probability of this result occurring by chance is equal to or less than 1 in 1000 (0.001 = 0.1%)

RESULTS

Applied levels of Nitrate-Nitrogen and Chloride

The achieved NO_3-N concentrations in the applied solution are presented in Figure 1 (page 13). Target levels of 30, 60, 120 and 180 mg/l were successfully achieved for most of the season. However it can be seen that although treatments commenced on 2 January for half of the plots it was not until week 5 that the target levels were reached. Also the target of 60 mg/l was exceeded from week 37 to the end of the season. The 30 mg/l treatment was terminated in week 20.

The treatments with low levels of nitrate in the applied feed were achieved by substituting Potassium Chloride for Potassium Nitrate. Hence the low nitrate feeds contained higher levels of chloride. Figure 2 (page 14) shows the levels of chloride in the applied feed throughout the season. The higher levels early in the season were due to the use of Sodium Chloride to raise conductivity at that time. During the main part of the season the 60 mg/l treatment resulted in levels around 500 mg/l whereas the 180 mg/l N treatment resulted in around 250 mg/l Cl in the applied feed.

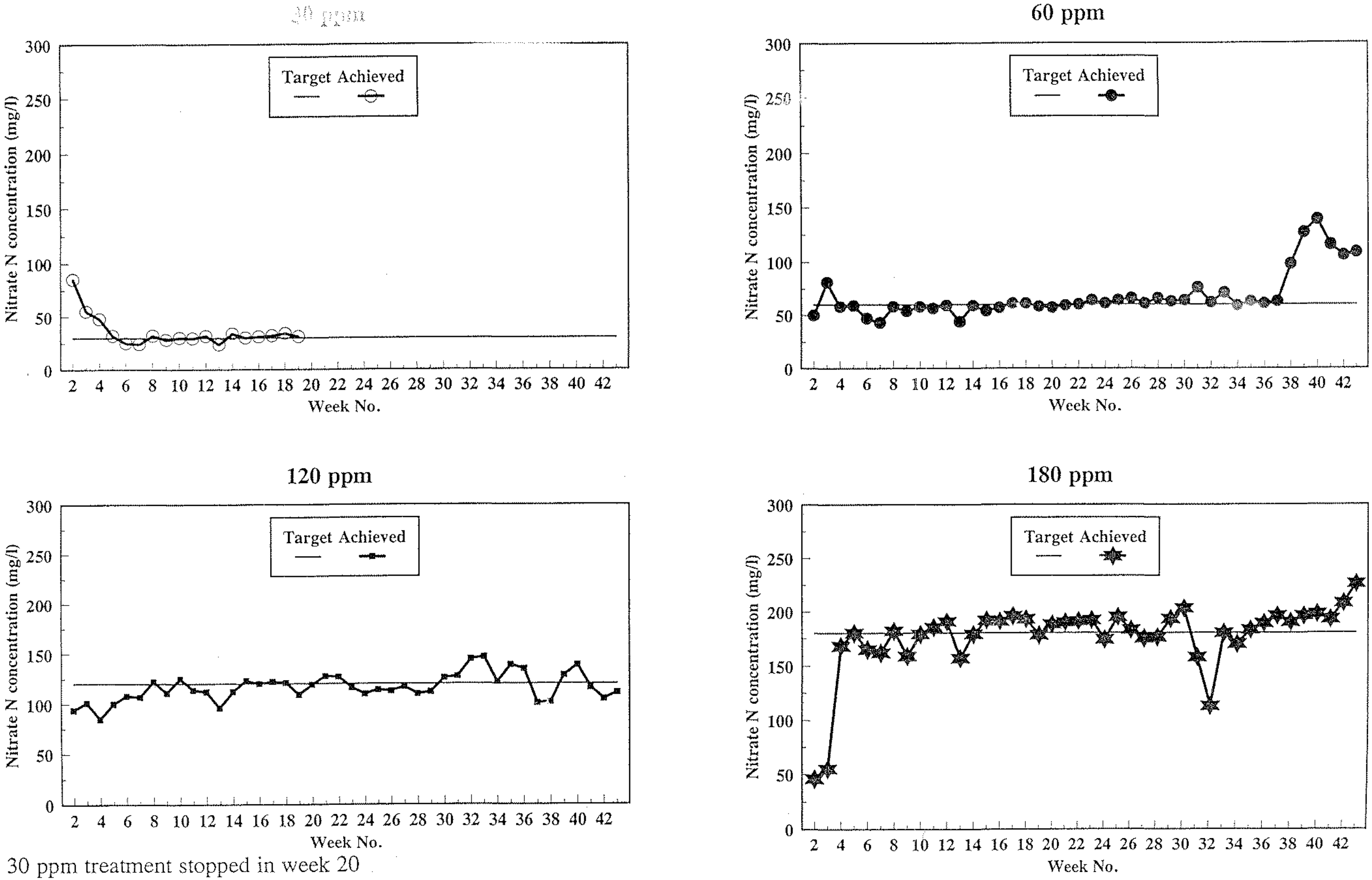
Plant Growth and Development

The 30 mg/l NO_3-N treatment had a major effect on plant growth. Figure 3 (page 15) shows plants from the four main treatments in April. The yellow colour and less vigorous growth of the 30 mg/l treatment are visually apparent. A leaf area assessment, carried out on 27 April indicated that leaf size for 30 mg/l treatment plants was significantly ($P<0.001$) smaller than for any of the other treatments (Table 2) and Figure 4 (page 16). Leaf positions correspond to leaves subtending alternate trusses starting with the lowest truss with subtending leaves. The 60 mg/l treatment plants also had significantly smaller leaves than the 180 mg/l treatment. There was also a significant ($P<0.001$) interaction between leaf position and nutrition regime such that lower leaves showed little difference but higher leaves showed large differences between treatments. This may reflect the larger exposure to treatments for leaves higher up the plant.

Table 2. Effect of nutrition regime on leaf area estimate (length x breadth, cm^2)on 27 April 1994

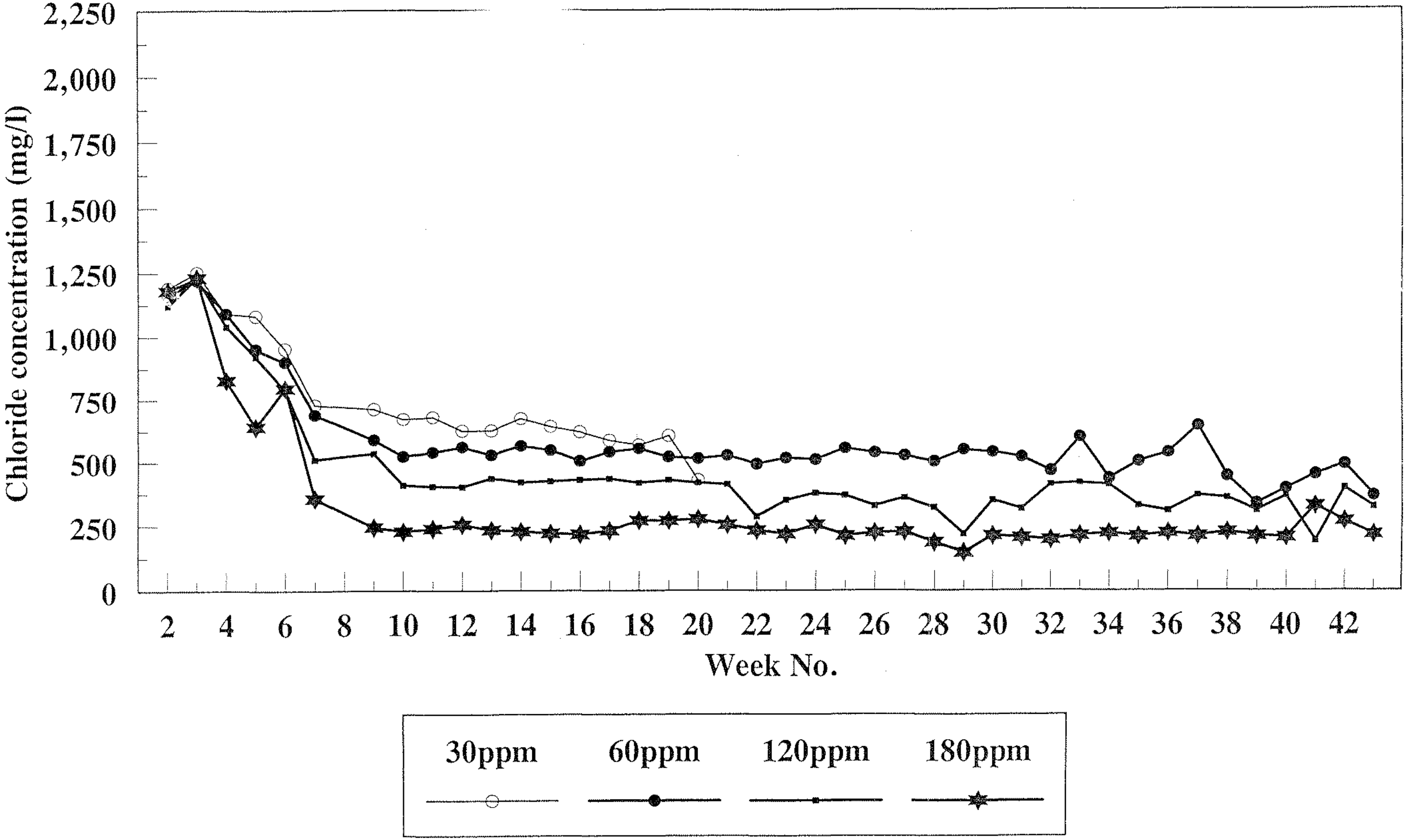
Leaf Position	1 (Base)	2	3	4	5 (Top)	Mean
30 mg/l	2072	2056	1445	975	275	1365
60 mg/l	2351	2099	2001	1759	945	1831
120 mg/l	2269	2091	2121	1909	1441	1966
180 mg/l	2229	2222	2189	2117	1575	2066
SED			*84.0*	*(98 df)*		*47.6 (20 df)*
LSD 5%			*167*	*(Interaction)*		*99*
Significance			***			***

Figure 1. Target and Applied Nitrate-Nitrogen Concentrations



30 ppm treatment stopped in week 20

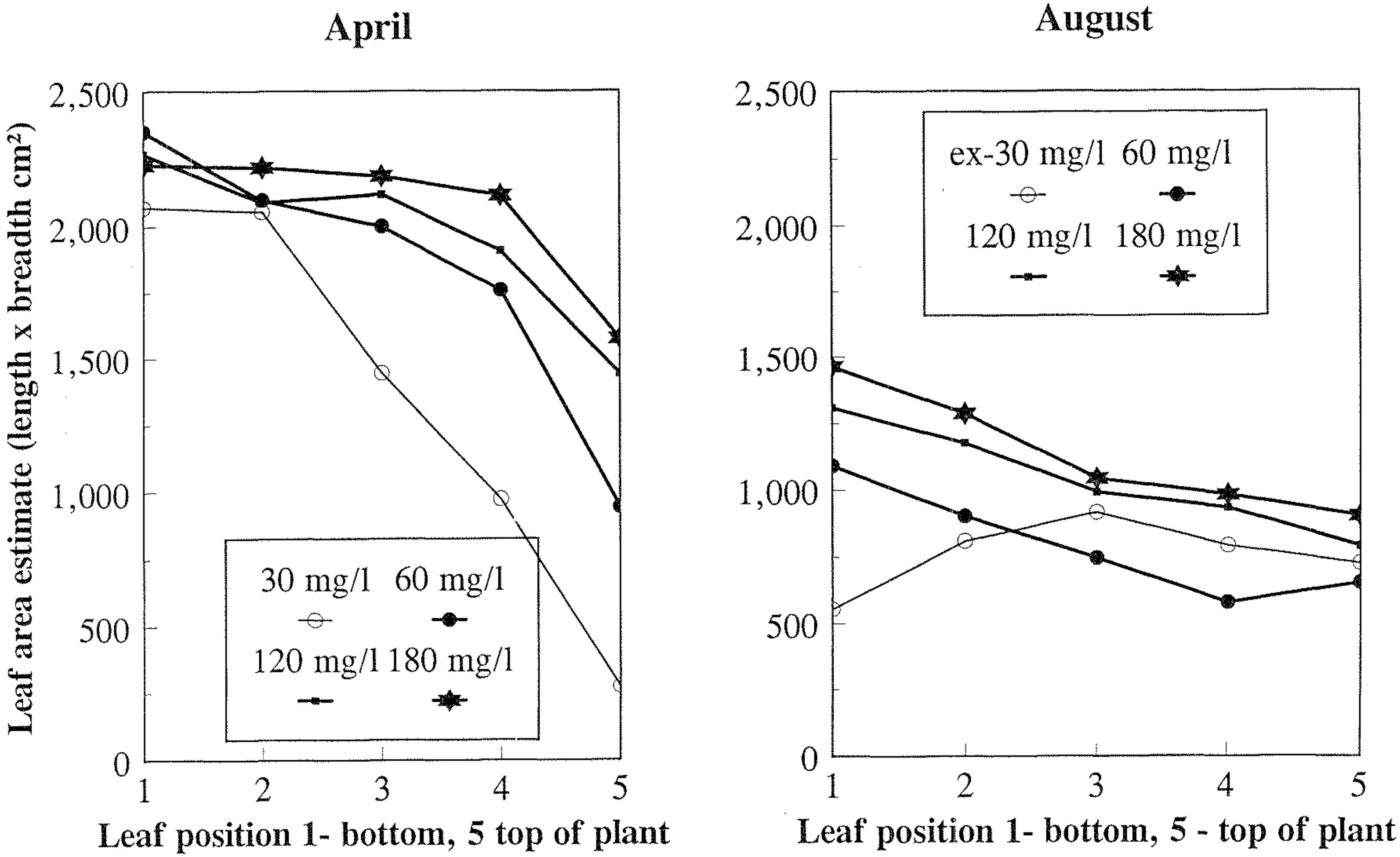
Figure 2. Effect of Nutrition Regime on Chloride Concentration in Applied feed



30 ppm regime was stopped in week 21

Figure 3: The four treatments applied from 2 January. 30mg/l (plot 215, top left), 60 mg/l (plot 223, bottom left), 120 mg/l (plot 213, top right) and 180 mg/l (plot 221, bottom right) as seen in April 1994

Figure 4. Effect of nutrition regimes on leaf size



The severe effect of the 30 mg/l treatment created a problem because the very thin plants were liable to influence the environment for neighbouring treatments. Plots next to 30 mg/l plots were likely to receive more light and to experience larger vapour pressure deficits than other plots. There was little to be gained from continuing the 30 mg/l treatment other than determining whether or not the plants would in fact be killed. Therefore the decision was taken to terminate the 30 mg/l NO_3-N treatment in week 20 and to replace it with 120 mg/l in order to determine whether or not the crop could recover. Prior to terminating the 30 mg/l treatment one plant (without sideshoots) per plot was removed to assess the amount of growth in terms of stem length and weight (fresh and dry), leaf number and weight (fresh and dry) and the standing crop of set fruit.

Table 3 shows that the 30 mg/l plants were much shorter than plants from the other treatments and that in week 19 there was little difference in stem length between the 60, 120 and 180 mg/l treatments. The difference between the 30 mg/l treatment and the other treatments was highly significant ($P<0.001$) and there was also a significant interaction ($P<0.05$) between the main nutritional treatments and the sub-treatment start times. The 30 mg/l treatment resulted in much shorter plants when the treatments were begun earlier.

Table 3. Effect of nutrition regime and start time on stem length (m) in week 19

Treatment	Start Time 02.01.94	17.02.94	Mean
30 mg/l	4.44	5.08	4.76
60 mg/l	5.66	5.78	5.72
120 mg/l	5.84	5.75	5.80
180 mg/l	5.63	5.78	5.71
SED (20 df)	*0.156*		*0.110*
LSD 5%	*0.33*		*0.23*
Significance	* *(Interaction)*		***

Figure 5 (page 18) shows that the effect of the treatments on the total fresh weight of the stems sampled was similar to the effect on length. The 30 mg/l stems were much lighter ($P<0.001$) than the stems from the other treatments. It is also apparent that there is a trend of increasing stem weight with increasing concentrations of NO_3-N in the applied feed. However the differences between treatments in stem dry weight were less marked. The 30 mg/l and 60 mg/l stems contained less dry matter than the 180 mg/l treatment but the difference was not statistically significant (Appendix V, page 65). The reason for this discrepancy was that the 30 mg/l stems contained a significantly higher ($P<0.001$) percentage of dry matter than the other treatments (Table 4).

Figure 5. Effect of nutrition regime on stem fresh and dry weight in week 19

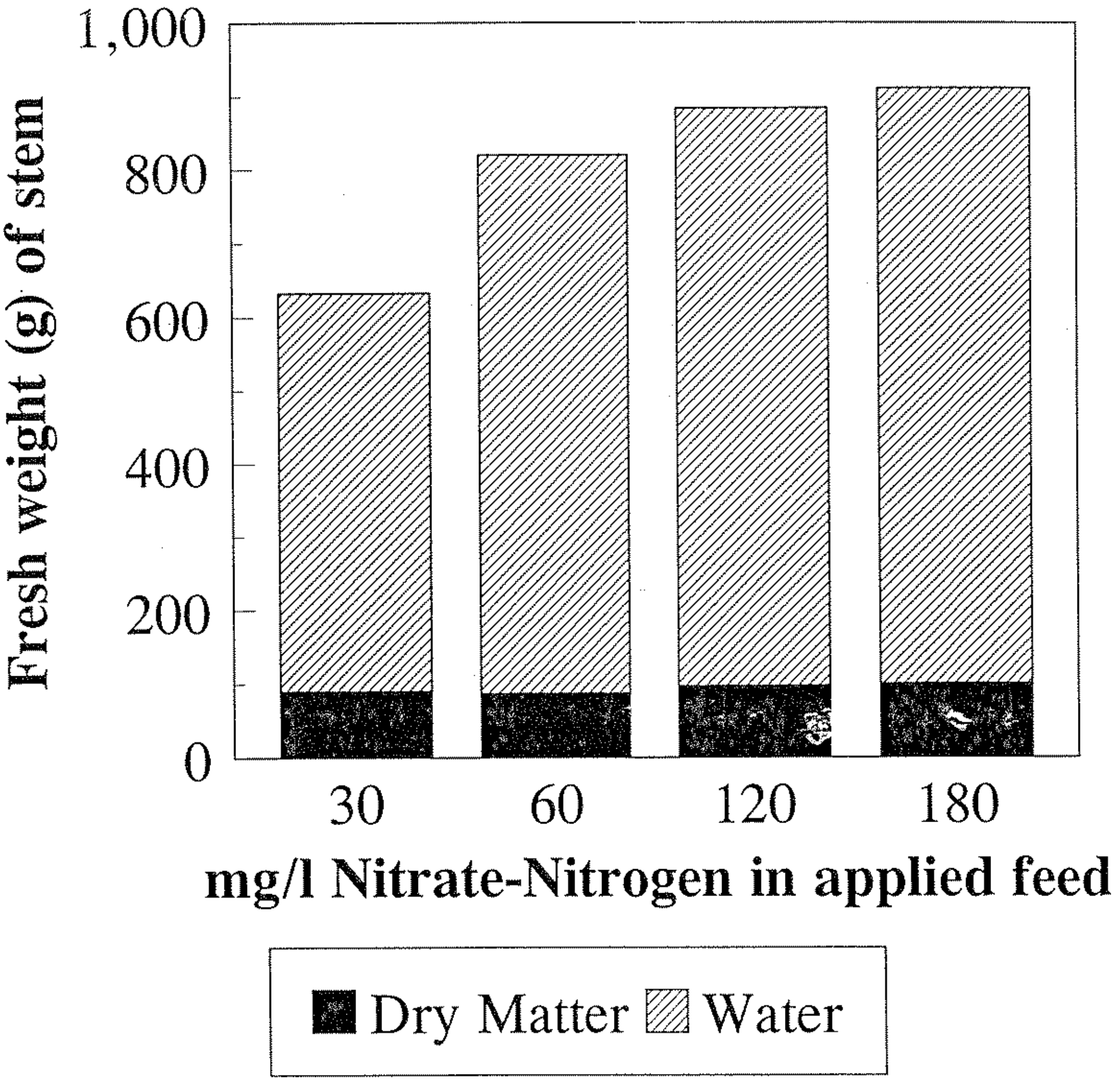


Table 4 Effect of nutrition regimes dry matter content of plant components

Treatment	% Dry matter Stem	% Dry matter Leaf	% Dry matter Fruit
30 mg/l	14.4	12.7	7.3
60 mg/l	10.8	10.5	6.9
120 mg/l	11.1	11.0	7.1
180 mg/l	11.0	11.5	7.0
SED (20 df)	*0.45*	*0.63*	*0.15*
LSD 5%	*0.9*	*1.3*	*0.3*
Significance	***	*	*

As with stems the dry matter content of leaves and fruit was higher for the 30 mg/l treatment than the other treatments (Table 4). However, the difference was proportionately much greater for stems than for leaves and was considerably less clear for fruit.

The total number of leaves, the fresh and dry weight of leaves per stem were all much lower for the 30 mg/l treatment than the other treatments ($P<0.001$) (Table 5). There was a trend of increasing number and weight with increasing concentrations of NO_3-N in the applied feed.

Table 5 Effect of nutrition regime on number, fresh and dry weight of leaves per stem in week 19

Treatment	Number	Fresh Weight (g)	Dry Weight (g)
30 mg/l	24.9	352	45
60 mg/l	31.3	592	62
120 mg/l	31.4	667	73
180 mg/l	32.9	771	89
SED (20 df)	*0.71*	*36.4*	*5.8*
LSD 5%	*1.5*	*76*	*12*
Significance	***	***	***

The number of fruits set per stem gives an indication of potential future yield and this was much lower for the 30 mg/l treatment than the others (Table 6). The total fresh weight of fruit per stem for the 30 mg/l treatment was less than half that for the 180 mg/l treatment. The lower fruit weight reflected not only a reduction in number of set fruits but also a reduction in the average weight of individual fruits. The total dry matter of fruit per stem was also significantly lower for the 30 mg/l treatment ($P<0.001$).

The 60 mg/l and 120 mg/l treatments both had an average of 67.5 fruits set per stem. However the total fresh weight (and dry weight) was higher for the 120 mg/l treatment as a result of higher average fruit weight.

Table 6. Effect of nutrition regime on number, fresh and dry weight of all set fruit per stem in week 19

Treatment	Number	Total Fresh Weight (g)	Average Fresh Weight (g)	Total Dry Weight (g)
30 mg/l	44.4	1233	27.8	90
60 mg/l	67.5	2179	32.6	150
120 mg/l	67.5	2542	37.7	180
180 mg/l	73.9	2659	36.0	185
SED (20 df)	*3.37*	*134.3*	*1.55*	*9.9*
LSD 5%	*7.0*	*280*	*3.2*	*21*
Significance	***	***	***	***

The 60 mg/l treatment plants continued to grow less vigorously as the season progressed. A second leaf area assessment done on 4 August showed that leaf size was much reduced in all treatments compared to April and that there were consistent differences between treatments irrespective of the position of leaves on the plant (Table 7 and Figure 4, page 16).

Table 7. Effect of nutrition regime on leaf area estimate (length x breadth), cm^2 on 4 August 1994

Treatment	Leaf Position 1 (Base)	2	3	4	5 (Top)	Mean
30 mg/l	554	809	916	792	725	759
60 mg/l	1090	902	746	578	652	794
120 mg/l	1309	1176	992	933	790	1040
180 mg/l	1462	1287	1042	981	903	1135
SED			*63.3*			*40.9*
LSD 5%			*126*			*85*
Significance			*N.S.*			***

At the end of the season as plants were pulled out measurements of stem length and counts of number of trusses per stem were made for four plants (without sideshoots) per plot (2 North side, 2 South side). As Table 8 shows the shorter plants that resulted from lower levels of applied NO_3-N also produced fewer trusses. The statistics refer only to the 60, 120 and 180 mg/l treatments. The 30 mg/l treatment was increased to 120 mg/l in week 20 and is therefore excluded from the statistical analysis here.

Table 8. Effect of nutrition regime on stem length and number of trusses per stem at the end of October

NO_3-N Treatment	Stem Length	Number of Trusses
(30 mg/l	7.59	30.1)
60 mg/l	8.26	31.4
120 mg/l	8.97	33.9
180 mg/l	9.10	34.6
SED (20 df)	*0.192*	*0.42*
LSD 5%	*0.40*	*0.9*
Significance	***	***

Yield, Gradeout and Monetary Returns

To the end of May the 30 mg/l NO_3-N treatment yielded 12.7 $kg.m^{-2}$, 28% less than the 180 mg/l treatment (Table 9). The 60 mg/l treatment also yielded significantly less (5.7%) than the 180 mg/l treatment to the end of May. The time at which treatments commenced had an effect on yield such that plots receiving treaments from 2 January yielded less than plots that did not receive treatments until 17 February. Yield differences occurred across all treatments, not only the low NO_3-N treatments. Figure 6 (page 22) shows that the difference in yield between the two start times was greater for the 30 mg/l treatment than for the other treatments indicating that earlier imposition of very low NO_3-N levels may result in greater yield loss. However, this interaction between start time and nutrition treatment was not statistically significant (Appendix VI, page 66) and the 60 mg/l treatment did not result in greater yield loss relative to the 180 mg/l treatment when treatments were started early.

Figure 6. Difference in yield between treatment start times 17 February and 2 January

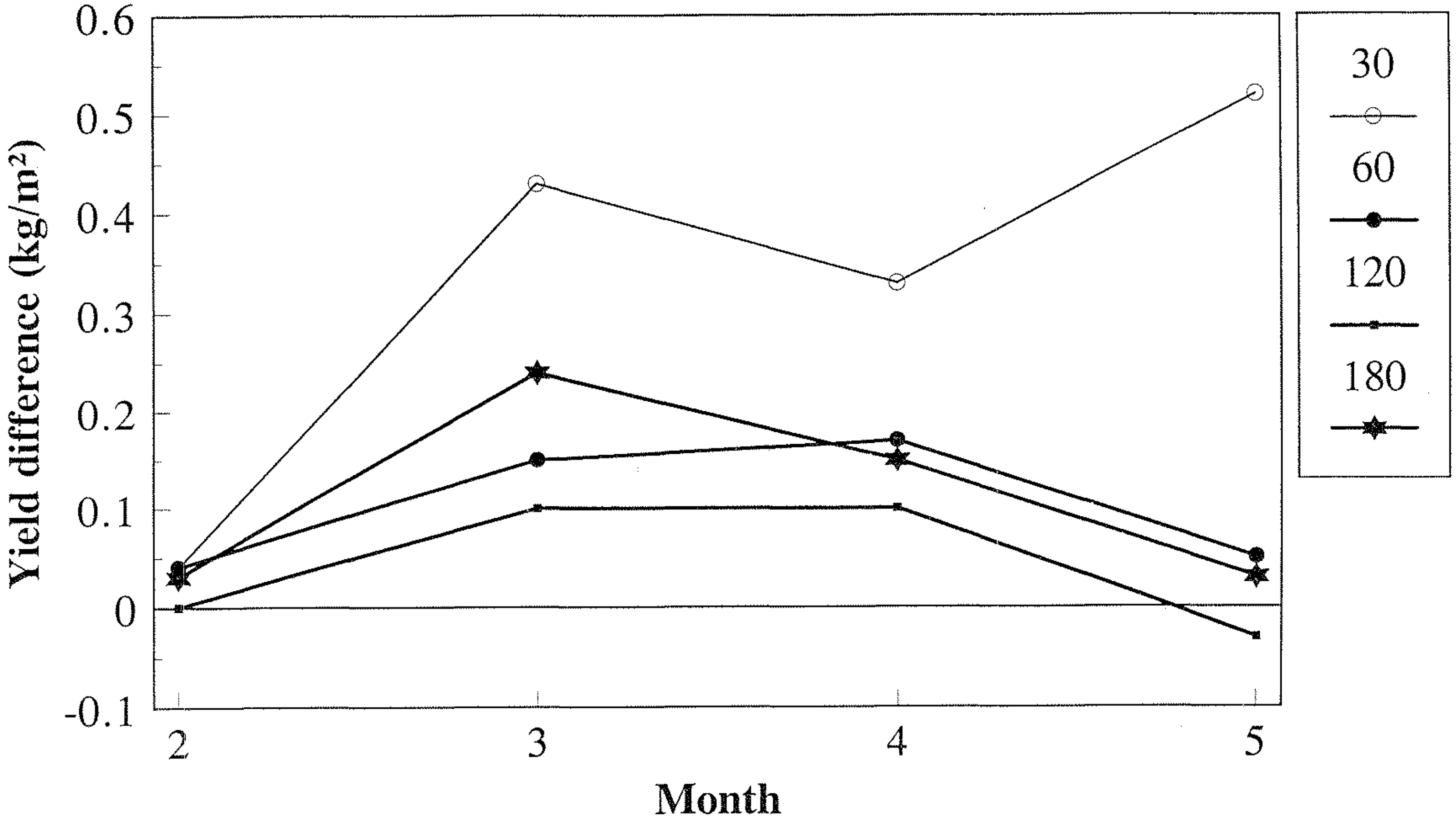


Table 9. **Effect of nutrition regime on total yield ($kg.m^{-2}$), gradeout and monetary return ($£.m^{-2}$) to the end of May**

			% Class I fruit in size grade			
Applied NO_3-N	**Total Yield**	**% Class I**	**C >57mm**	**D 47-57mm**	**E 40-47mm**	**£m²**
30 mg/l	12.70	90.1	3.0	77.4	17.7	11.16
60 mg/l	16.53	92.1	7.0	82.0	10.7	14.24
120 mg/l	17.18	88.9	7.7	83.7	8.4	14.49
180 mg/l	17.52	90.4	10.3	82.6	6.9	14.86
SED (20 df)	*0.262*	*0.60*	*0.78*	*0.76*	*0.39*	*0.212*
LSD 5%	*0.55*	*1.3*	*1.6*	*1.6*	*0.8*	*0.44*
Significance	***	***	***	***	***	***

There was no consistent trend across treatments in the percentage of Class I fruit to the end of May (Table 9), although the 120 mg/l resulted in significantly less and the 60 mg/l treatment significantly more than the other two treatments. The nutrition regimes had a marked effect on fruit size. The 30 mg/l treatment produced many more E grade fruit and fewer C grade fruit whereas the 180 mg/l treatment produced more Cs and less Es. Thus there was a trend of increasing fruit size with increasing concentrations of NO_3-N in the applied feed solution. In terms of monetary returns the considerable differences in yield converted to a difference of £3.70 per m² or £37,000 per hectare between the 30 mg/l treatment and the 180 mg/l treatment to the end of May.

To the end of the season the 180 mg/l treatment produced 56.8 $kg.m^{-2}$ (Table 10). The 60 mg/l treatment yielded 46.57 $kg.m^{-2}$, 18% less than the 180 mg/l treatment and proportionately a much bigger difference than to the end of May. The 120 mg/l treatment produced 55.36 $kg.m^{-2}$, 2.5% less than the 180 mg/l treatment, a difference not quite large enough to be statistically significant at the 5% level of probability.

The percentages of Class I fruit were similar across treatments except that the 60 mg/l treatment resulted in a slightly higher percentage (Table 10, page 24). The 30 mg/l treatment is excluded from the statistical analysis. Appendix VI (page 66) lists the data in full for total yield, total marketable yield, percentage Class I, II and waste fruit and size gradeout. There were differences in the percentage of Class II fruit between treatments but these were not consistent. However, there was a significant difference to the end of the season in the amount of waste fruit such that the 180 mg/l treatment produced the most waste and the 60 mg/l treatment the least. This difference had the effect of reducing the size of the difference in marketable yield between the 180 and 120 mg/l treatments to 2% as compared to the 2.5% difference in total yield.

As with the data to the end of May there was a trend of increasing fruit size with increasing concentrations of NO_3-N in the applied feed. Interestingly the percentage of D grade fruit, the most valuable size grade, was highest for the 60 mg/l treatment.

The monthly size gradeout figures are presented in Figure 7 (page 25) for each treatment. It is interesting to note how the size of fruit from the 30 mg/l treatment increased once the NO_3-N level in the applied feed had been increased to 120 mg/l in May.

Table 10. **Effect of nutrition regime on total yield (kg.m^{-2}), gradeout and monetary return (£.m^{-2}) to the end of October**

			% Class I fruit in size grade			
Applied NO_3-N	**Total Yield**	**% Class I**	**C >57mm**	**D 47-57mm**	**E 40-47mm**	**£m²**
(30 mg/l	38.87	68.5	15.6	73.8	9.6	23.96)
60 mg/l	46.57	74.7	11.1	82.7	6.1	30.03
120 mg/l	55.36	71.4	14.8	80.9	4.1	34.35
180 mg/l	56.80	71.6	16.8	79.3	3.8	35.16
SED (20 df)	*0.732*	*1.36*	*0.93*	*0.79*	*0.29*	*0.440*
LSD 5%	*1.53*	*2.8*	*1.9*	*1.6*	*0.6*	*0.92*
Significance	***	*	***	***	***	***

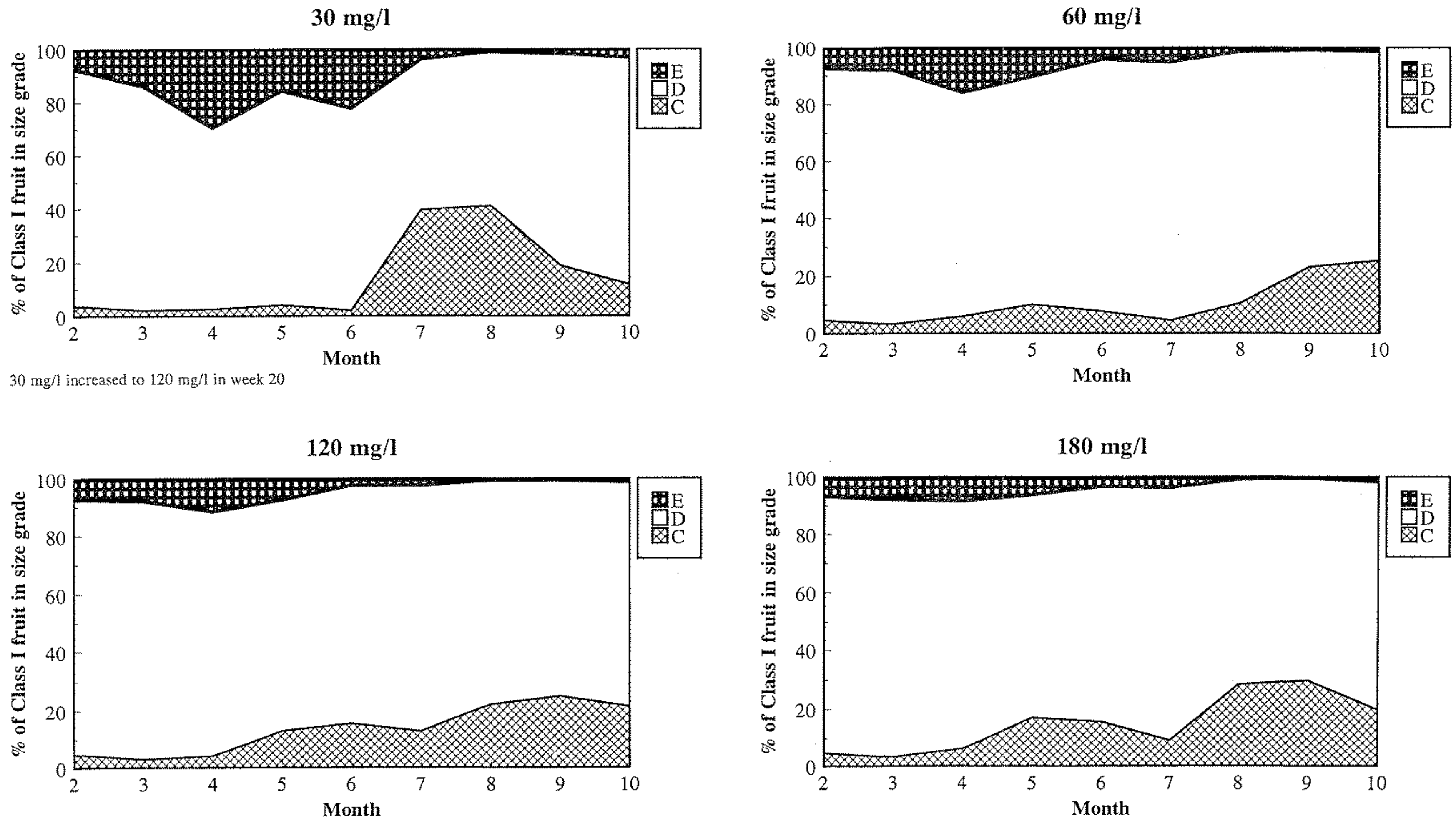
The monetary returns to the end of October (Table 10) indicate that the 60 mg/l treatment resulted in a loss of £5.13 per m² or £51,300 per hectare relative to the 180 mg/l treatment, a significant difference ($P<0.001$). The difference in monetary return between the 180 mg/l and 120 mg/l treatments was £0.81 per m² or £8,100 per hectare and this difference was not statistically significant.

Fruit Quality

Physical Disorders

The levels of the most frequent physical disorders to affect fruit are listed in Appendix VII (page 74). Levels of the disorders, poor shape, cracking and blotchy ripening were generally unaffected by the treatments.

Figure 7. Effect of level of nutrition regime on fruit size



30 mg/l increased to 120 mg/l in week 20

Levels of Gold Spot were generally slightly higher where NO_3-N inputs were low. As Figure 8 (page 28) shows, the 180 mg/l treatment generally produced more fruit with low levels of Gold Spot (Class Ia and Ib) and fewer fruit with higher levels (Class Ic and Class II) compared with the 60 mg/l treatment. The largest differences between treatments occurred in week 25 when levels of Gold Spot were high enough to result in the downgrading to Class II of more than 50% of fruit from the ex-30 mg/l treatment, 10% of 60 and 120 mg/l fruit and 4% of 180 mg/l fruit.

Levels of Gold Marbling were very high in the trial and a large quantity of fruit was downgraded because of it. Figure 9 (page 29) shows that there were some treatment effects between week 21 and week 31 when levels of Gold Marbling were highest, but thereafter all treatments showed similar levels. The most striking feature of the area plot in Figure 10 is the consistently high (>50%) percentage of fruit downgraded to Class II due to Gold Marbling from the ex-30 mg/l treatment. However, there is also a trend of increasing levels of Gold Marbling with increasing levels of NO_3-N inputs between week 21 and week 25 (see Appendix VII, page 84).

Yellowing

Fruit from the 30 mg/l treatment sampled in week 19 shortly before the termination of the treatment showed distinct yellowing and had very pale calyces. This symptom was scored as for other disorders. Table 11 shows that these symptoms were more frequent and more severe in the 30 mg/l treatment. None of the fruit were downgraded because of the yellowing.

Table 11. **Effect of NO_3-N concentration in the applied feed on the incidence and severity of yellow fruit with pale calyces**

	% of fruit in quality class			
Treatment	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**
30 mg/l	11.3	55.0	33.8	-
60 mg/l	58.8	37.5	3.8	-
120 mg/l	75.0	23.8	1.3	-
180 mg/l	76.3	23.8	0.0	-
SED (20 df)	*11.10*	*9.55*	*4.80*	-
LSD 5%	*23.2*	*19.9*	*10.0*	-
Significance	***	*	***	-

Blossom-End Rot

Blossom-End Rot was virtually absent in the 60-120 mg/l NO_3-N treatments but in the ex-30 mg/l treatment fruit developed severe Blossom-End Rot as Table 12 (page 27)shows. The data for Blossom-End Rot in fruit picked underestimates the level of the disorder as many fruit developed severe BER very early in their development and were never picked. Thus BER had an unquantified effect on total yield as well as marketable yield. A detailed assessment of percentage fruit with BER on whole plants undertaken on 4 August (week 31) showed that 8.8% of all fruit from the ex-30 mg/l treatment were affected by BER whereas less than 1% of fruit from the other treatments were affected at that time (Table 13, page 27).

Table 12. The effect of NO_3-N concentration and a change in NO_3-N concentration on the incidence of Blossom-End Rot in fruit in fruit picked

	Percentage of fruit sampled at picking with Blossom-End Rot in week								
	25	27	29	31	33	35	37	39	41
ex-30 mg/l	0	9	35	19	6	0	0	4	0
60 mg/l	0	0	0	0	0	0	0	0	0
120 mg/l	0	0	0	0	0	0	0	0	0
180 mg/l	0	0	0	0	0	0	0	0	0

Table 13. The effect of NO_3-N concentration and a change in NO_3-N concentration on the percentage of Blossom-End Rot on plants on 4 August 1994

	Percentage of fruit with Blossom-End Rot
ex-30 mg/l	8.79
60 mg/l	0.52
120 mg/l	0.02
180 mg/l	0.64
SED (21 df)	*1.058*
LSD 5%	*2.20*
Significance	***

Figure 8. Effect of nutrition regime on the incidence and severity of Gold Spot

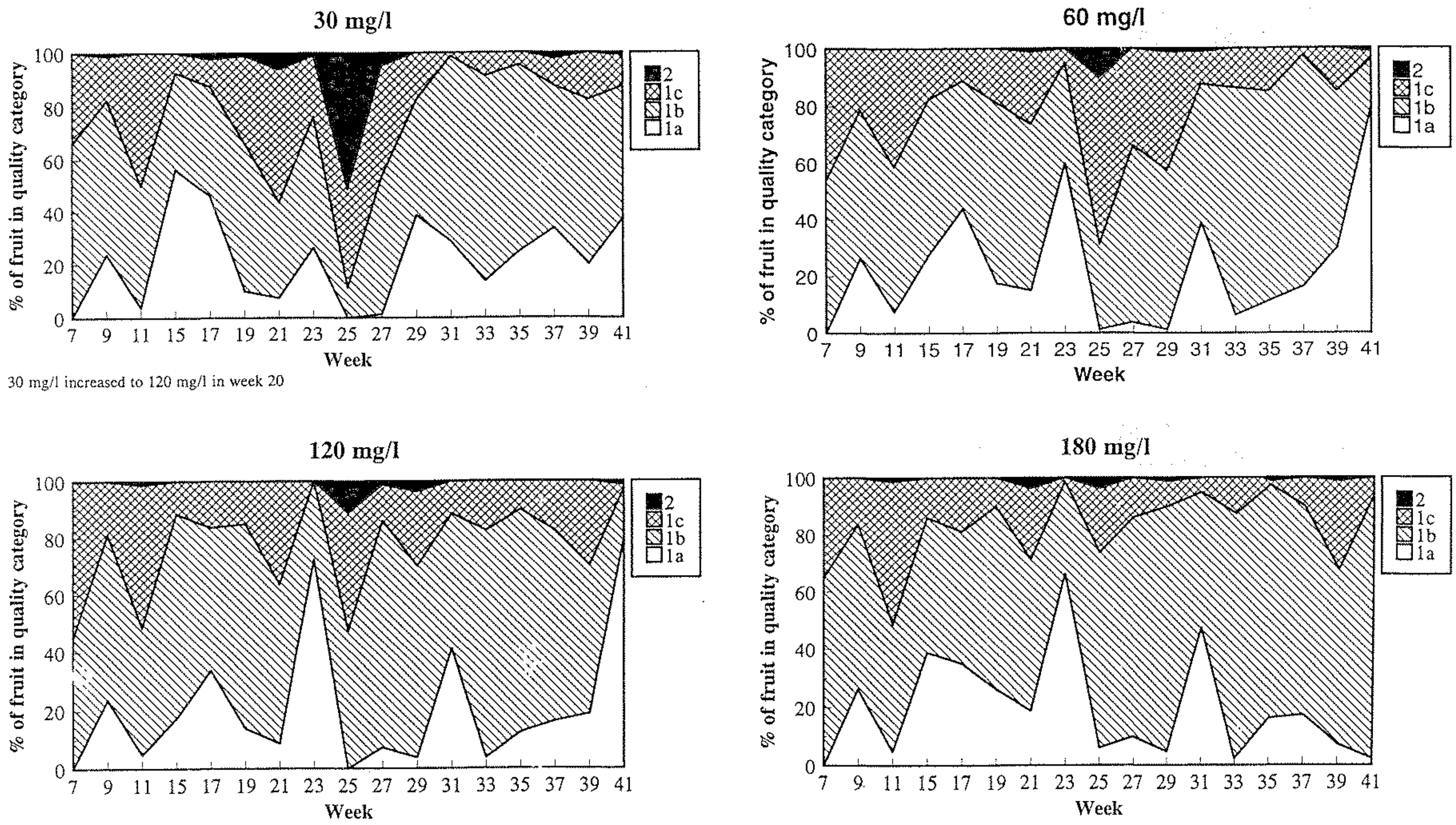
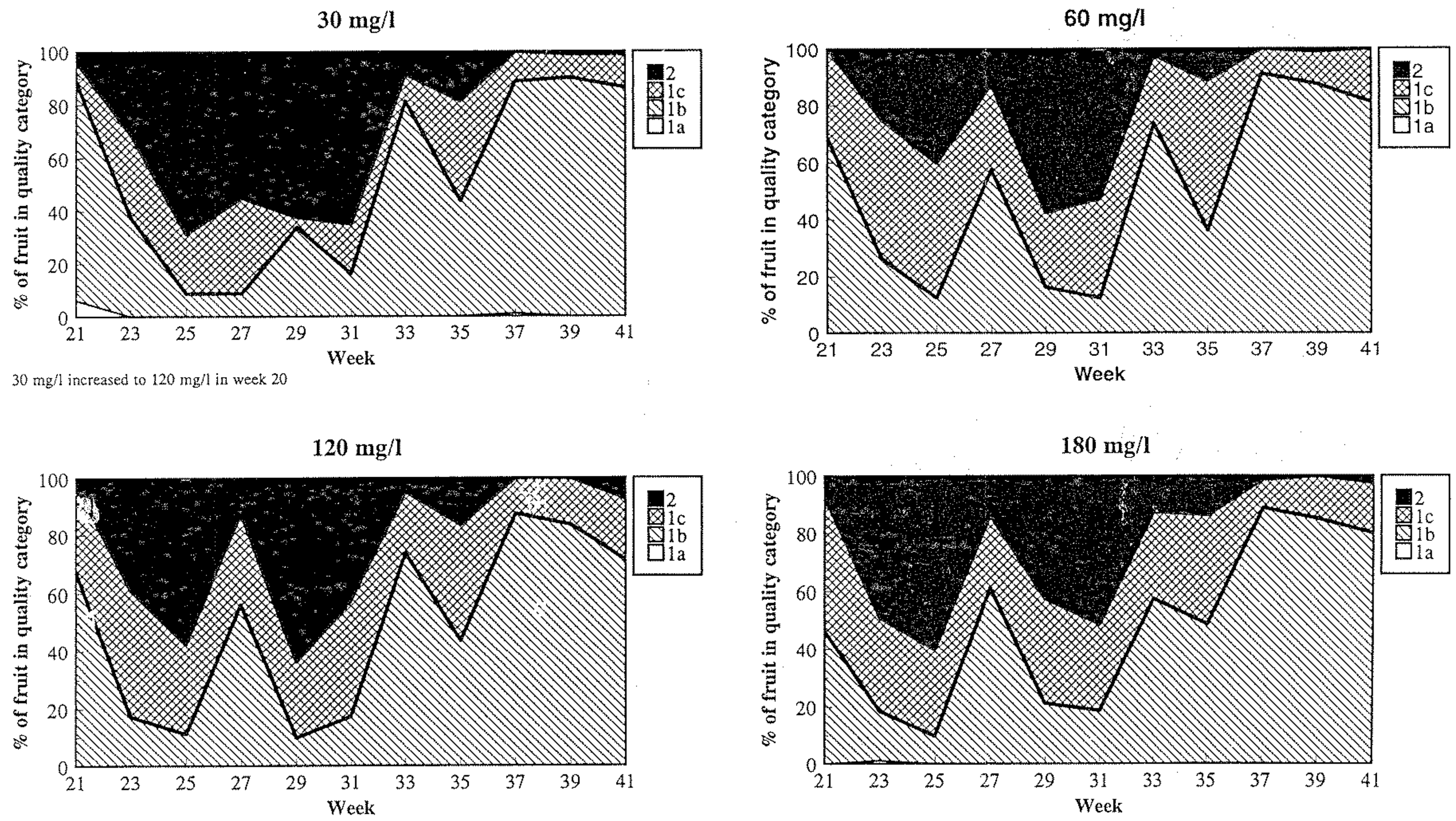


Figure 9. Effect of nutrition regime on the incidence and severity of Gold Marbling



30 mg/l increased to 120 mg/l in week 20

Shelf-life characteristics

The NO_3-N treatments had no effect on compression or percentage weight loss after 6 days storage up until week 20 (Figure 10, page 31). From week 21 to 27 the ex-30 mg/l treatment produced much softer fruit which lost weight more quickly in storage than the other treatments. From week 27 to the end of the season the 60 mg/l treatment produced softer fruit with higher rates of weight loss in store than the 120 mg/l treatment which in turn generally showed slightly poorer shelf-life characteristics than 180 mg/l fruit. All data and statistics relating to shelf-life are listed in Appendix VIII, page 94.

Internal composition

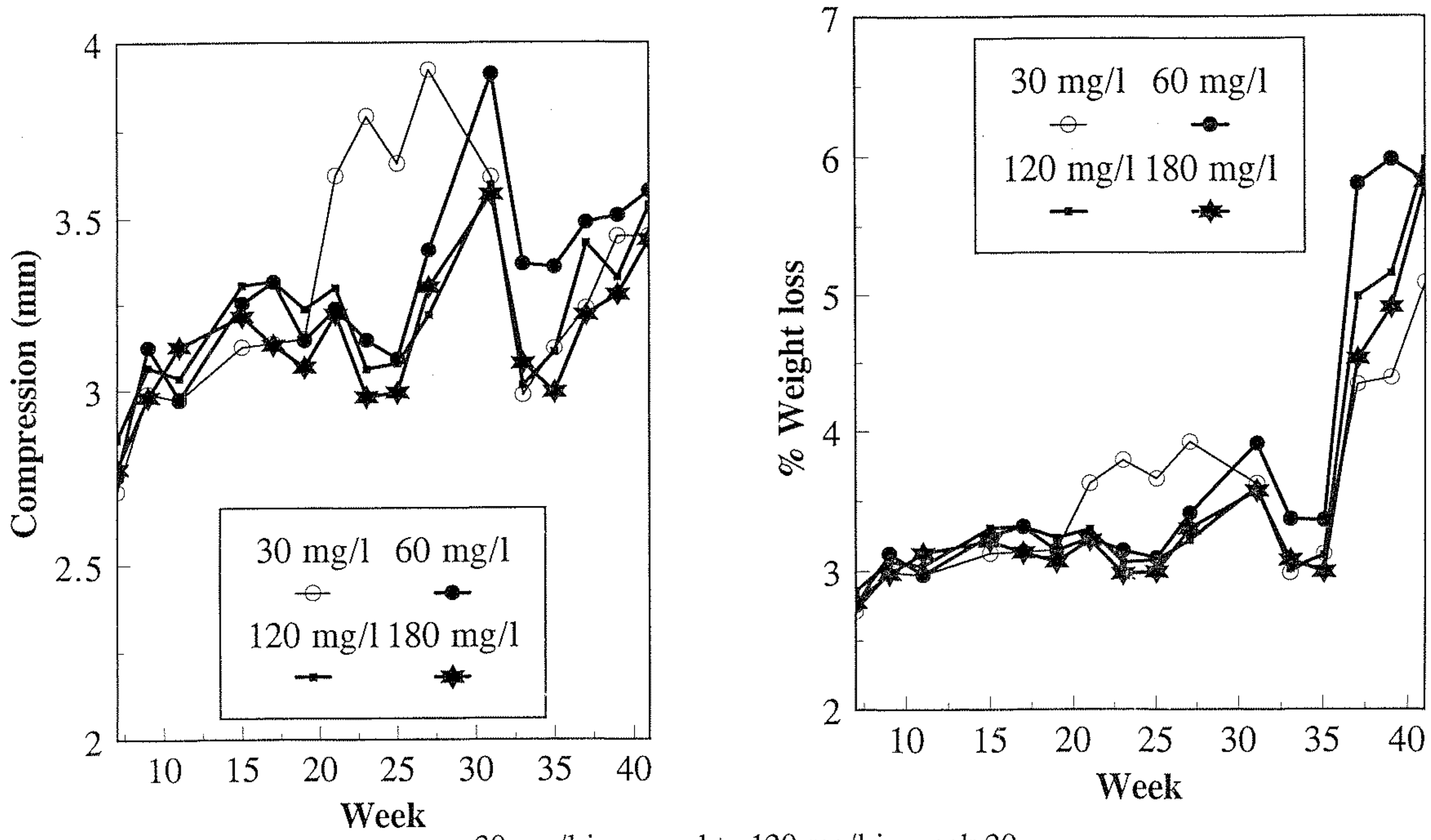
The low NO_3-N treatments had a consistent and significant effect on the acidity of fruit (Figure 11, page 32 and Appendix VIII, page 94). There was a consistent trend of increasing acidity (lower pH) with increasing levels of NO_3-N in the applied feed from 60 to 180 mg/l.

There were no major differences in the levels of soluble solids or dry matter between the 60, 120 and 180 mg/l treatments (Figure 12, page 33). However, the 30 mg/l treatment resulted in higher levels of both soluble solids and dry matter up until the treatment was replaced by 120 mg/l NO_3-N. Subsequently the ex-30 mg/l treatment produced fruit with lower soluble solids and dry matter content than the other treatments.

Taste panel assessments

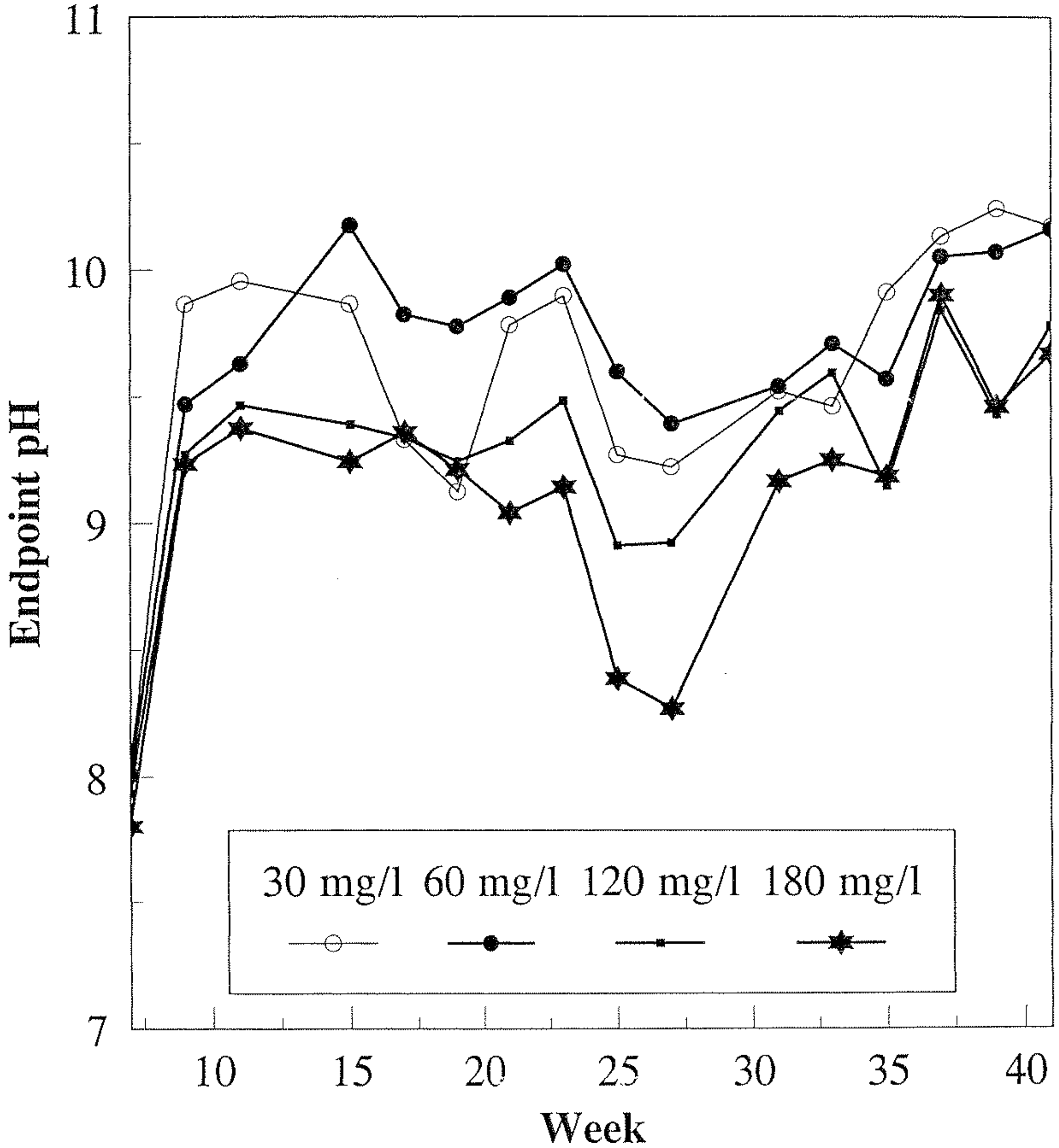
The taste panel assessments did not reveal any significant differences between treatments in terms of fruit 'sweetness', 'sharpness', 'toughness' or 'overall goodness' (Appendix IX, page 100). However, there were some indications of possible effects. The differences between treatments in fruit acidity were not detected by taste panels in terms of fruit 'sharpness' (Figure 13, page 34). However, the 'sweetness' score for the 60 mg/l fruit was consistently higher than for the 120 and 180 mg/l treatments (Figure 14, page 35). There were no consistent differences in 'toughness' (Figure 15, page 36). In terms of 'overall goodness' the 30 mg/l treatment scored highest in week 12 and the 180 mg/l treatment consistently scored the lowest compared with the 60 and 120 mg/l treatments (Figure 16, page 37).

Figure 10. Effect of nutrition regime on the shelf-life of fruit as measured by compression and % weight loss after 6 days storage



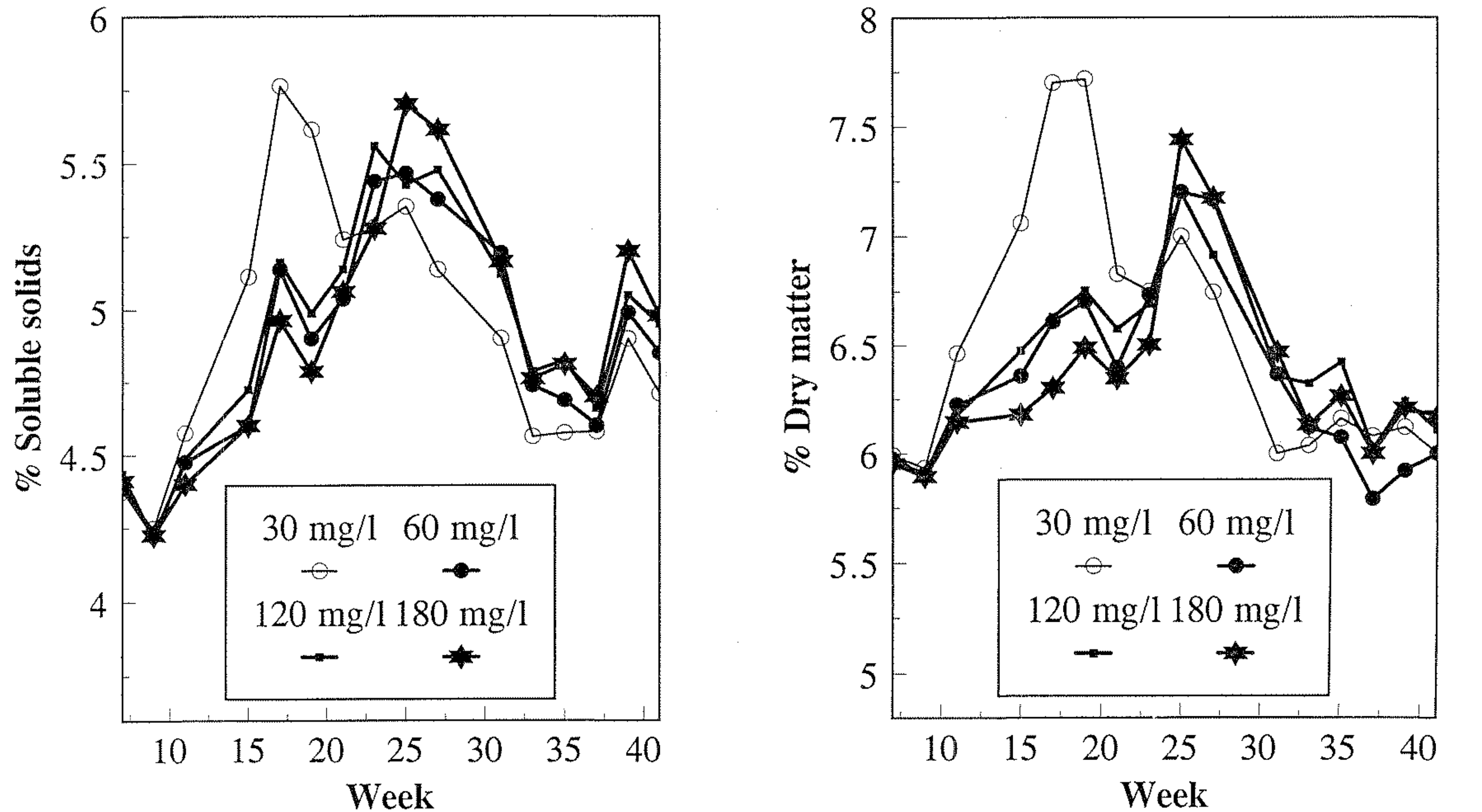
30 mg/l increased to 120 mg/l in week 20

Figure 11. Effect of nutrition regime on the acidity of fruit juice after neutralization with a fixed quantity of alkali



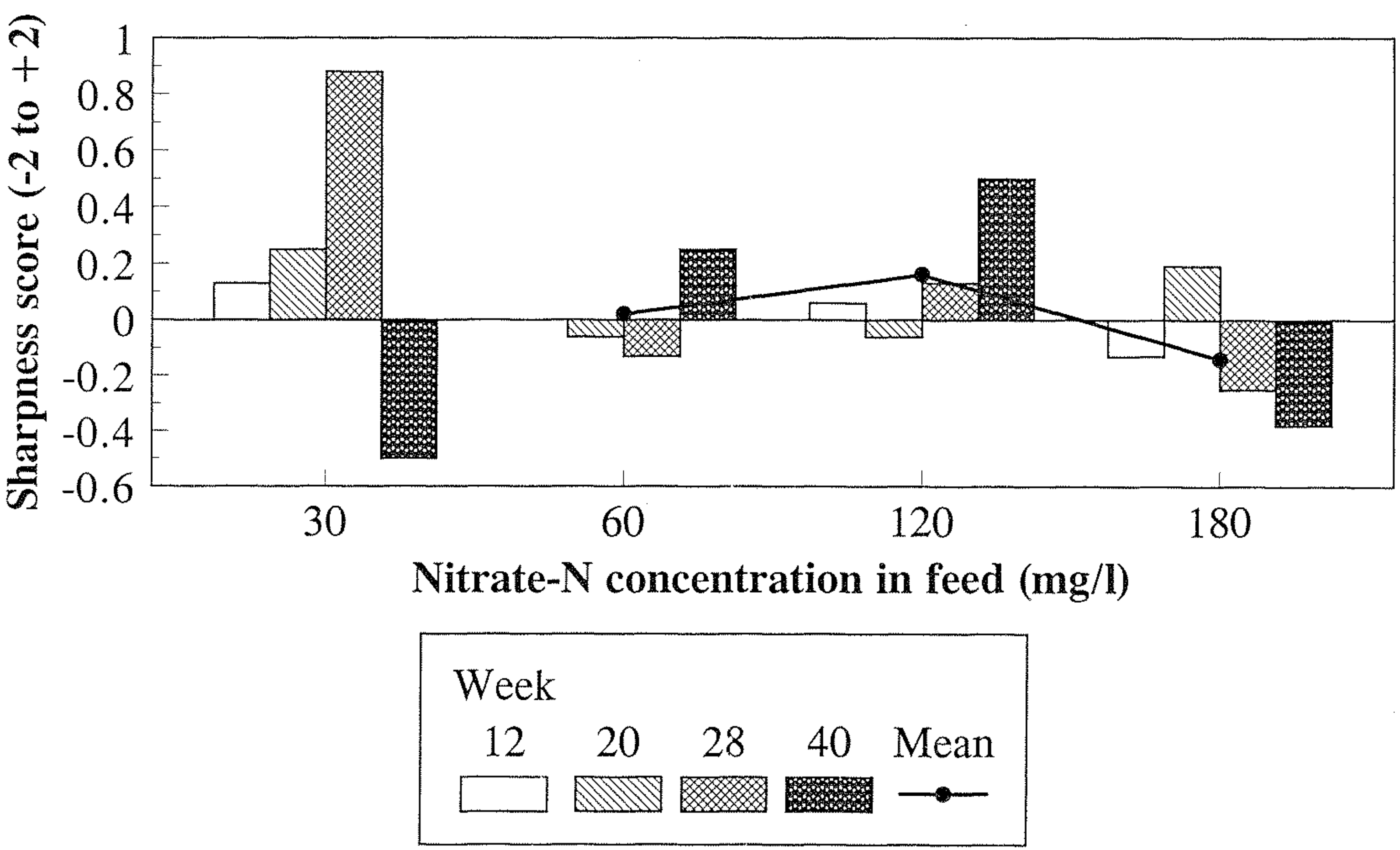
30 mg/l increased to 120 mg/l in week 20

Figure 12. Effect of nutrition regime on the soluble solids content of juice and the dry matter content of fruit



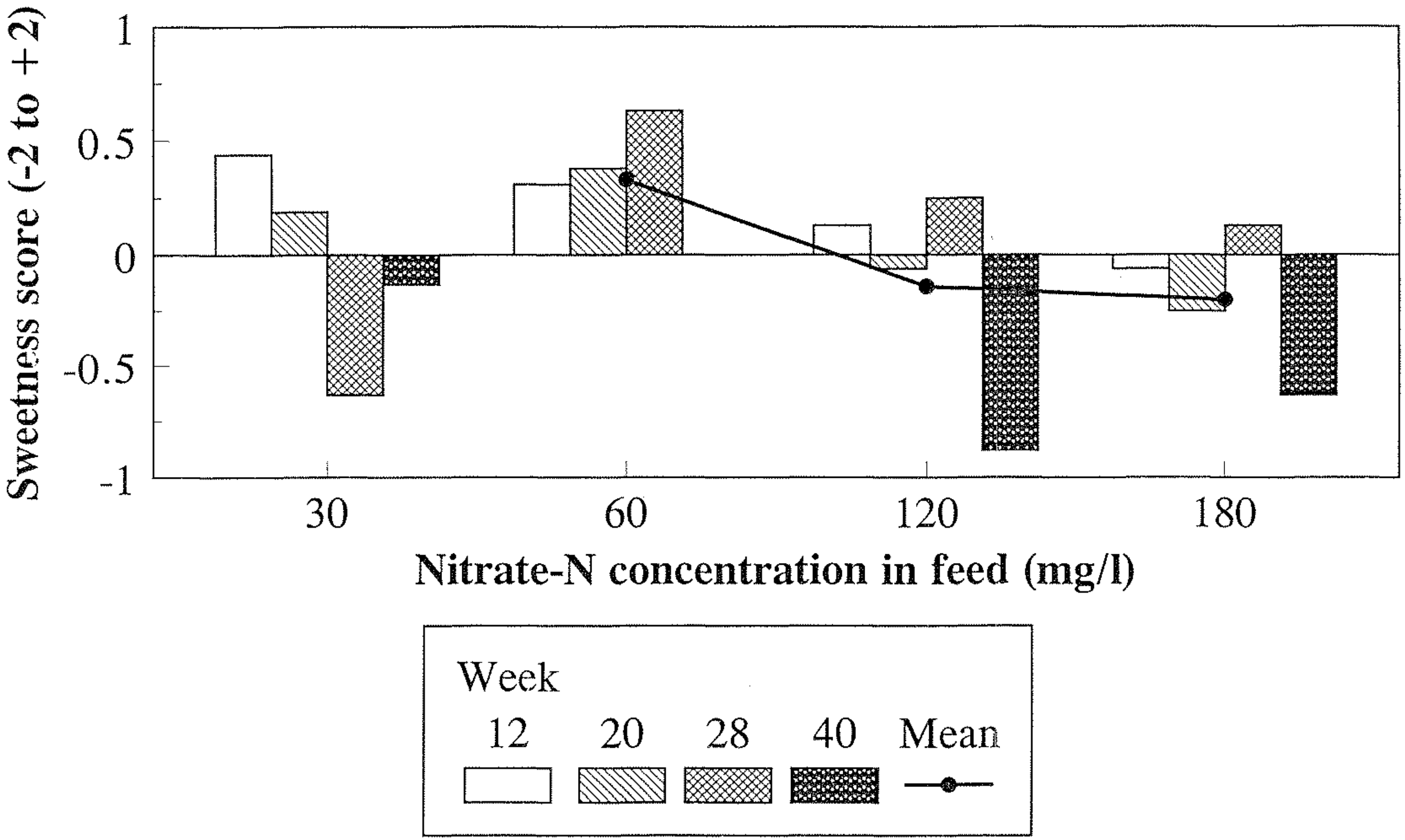
30 mg/l increased to 120 mg/l in week 20

Figure 13. Effect of nutrition regime on the 'Sharpness' of flavour as assessed by taste panel



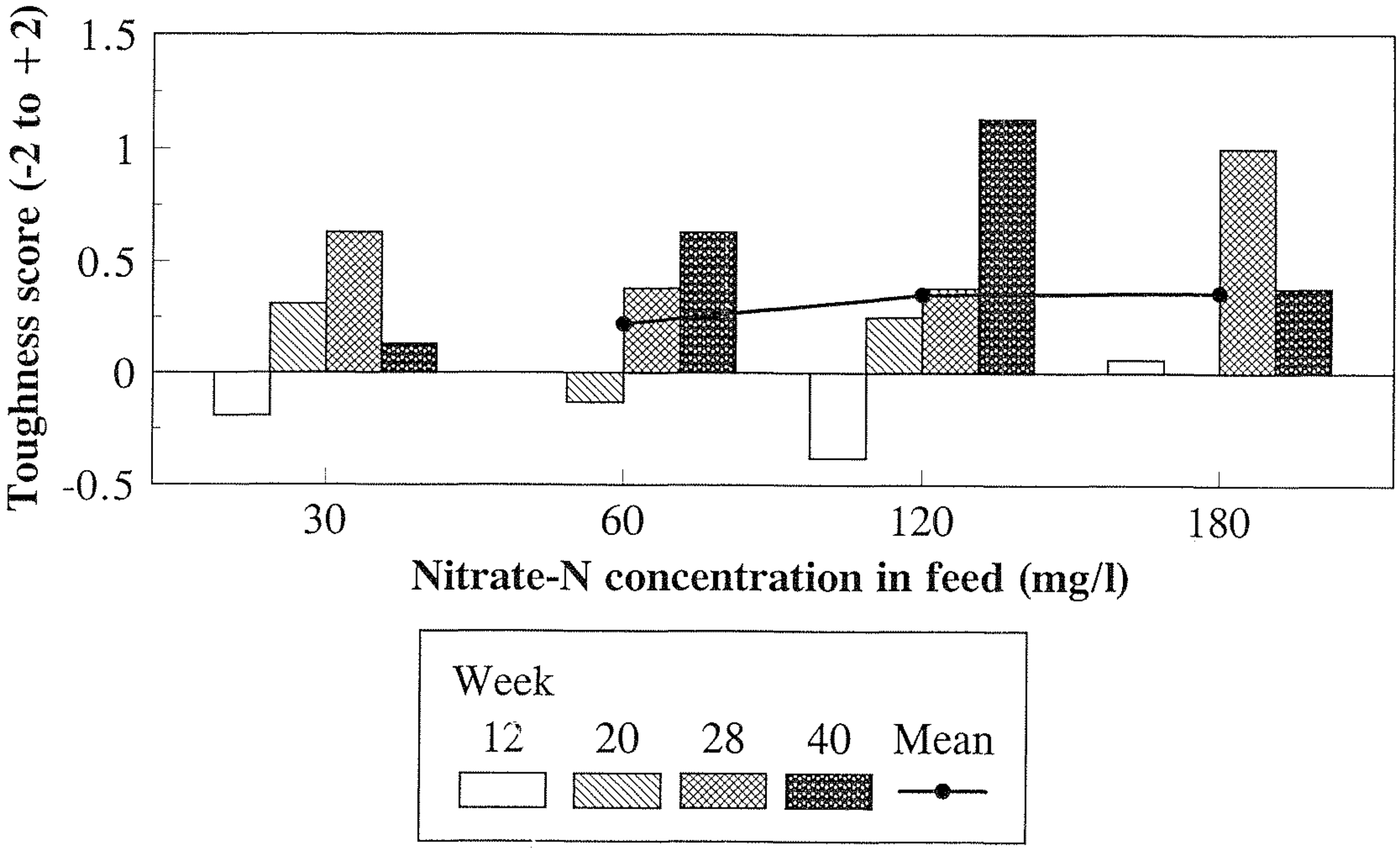
30 mg/l treatment replaced by 120 mg/l in week 20

Figure 14. Effect of nutrition regime on the 'Sweetness' of flavour as assessed by taste panel



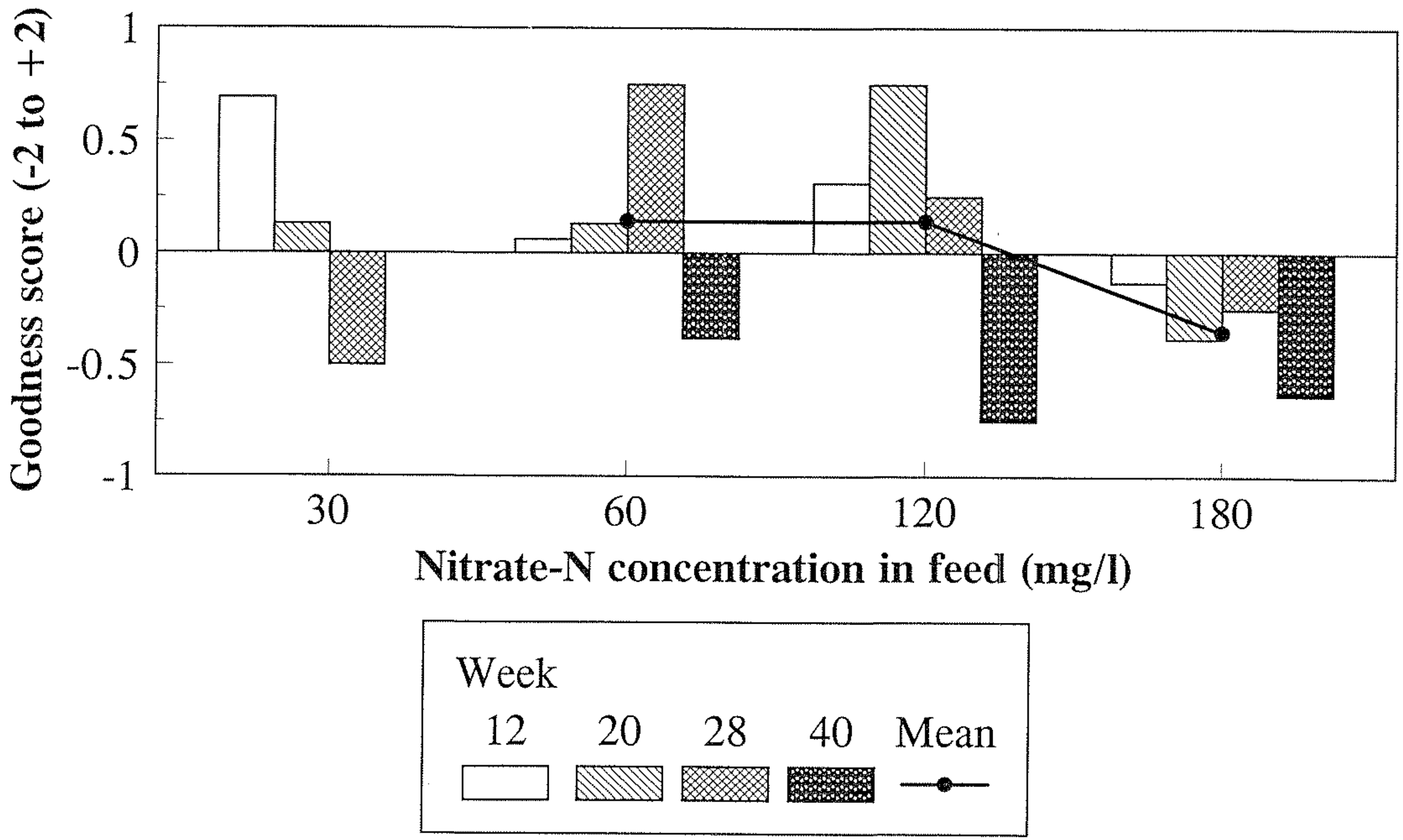
30 mg/l treatment replaced by 120 mg/l in week 20

Figure 15. Effect of nutrition regime on'Toughness' as assessed by a taste panel



30 mg/l treatment replaced by 120 mg/l in week 20

Figure 16. Effect of nutrition regime on the 'Goodness' of flavour as assessed by a taste panel



30 mg/l treatment replaced by 120 mg/l in week 20

Nutritional Content of Plant Material

Fruit

Fruit samples taken at monthly intervals and assessed for nutrient content showed no consistent differences between treatments in the levels of Nitrogen (Figure 17, page 40). However, levels of chloride in fruit were greatly affected, the 60 mg/l NO_3-N treatment resulted in the highest levels of chloride at between 5,000 and 8,500 mg/kg, except early in the season when the 30 mg/l treatment resulted in levels of 9,000 mg/kg in fruit. The 180 mg/l NO_3-N treatment fruit consistently had the lowest chloride content at around 4,000 mg/kg dry matter. Levels of Potassium and Calcium in fruit were similar for all treatments except that the ex-30 mg/l NO_3-N treatment showed higher levels of Calcium in June (Figure 18, page 41).

Leaf (Sideshoots)

There were consistent differences in the Nitrogen content of sideshoots. The young shoots generally contained higher levels early in the season than towards the end. There were very clear treatment effects from March-April onwards (Figure 19, page 42). The 30 mg/l NO_3-N treatment resulted in the lowest N content from March to May and there was a consistent trend of increasing N content with increasing levels of applied NO_3-N from 60-180 mg/l.

Stem

Samples of stem taken in week 19 and at the end of the season showed that as with sideshoots there was a trend of increasing N content with increasing levels of applied NO_3-N (Figure 20, page 43).

Nitrogen Budget calculated from plant sample data

Using the weights of all plant material removed (fruit, deleafings, sideshoots and tops at stopping) and samples of the plant material remaining at the end of the season in conjunction with the analyses of dry matter content and Nitrogen content it was possible to calculate the total Nitrogen uptake by the crop throughout the season. The Nitrogen uptake over the whole season by the 180 mg/l treatment was 85.6 $g.m^{-2}$ (856 $kg.ha^{-2}$) compared to 81.39 $g.m^{-2}$ for the 120 mg/l treatment and 66.1 $g.m^{-2}$ for the 60 mg/l treatment. Figure 21 (page 44) shows that there was a trend of increasing Nitrogen uptake for use in stem, leaf and fruit with increasing levels of applied NO_3-N. Table 14 (page 39) shows that the division of available nitrogen between stem, leaf and fruit was relatively constant between treatments. There was an indication that a higher proportion was used in fruit where Nitrogen was in short supply (30 and 60 mg/l treatments).

The distribution of Nitrogen between stem, leaf and fruit is the result of the distribution of dry matter between stem, leaf and fruit (table 15) and the Nitrogen content of stem, leaf and fruit (Appendix X, page 102). The total dry matter production for the crop is also listed in Appendix X.

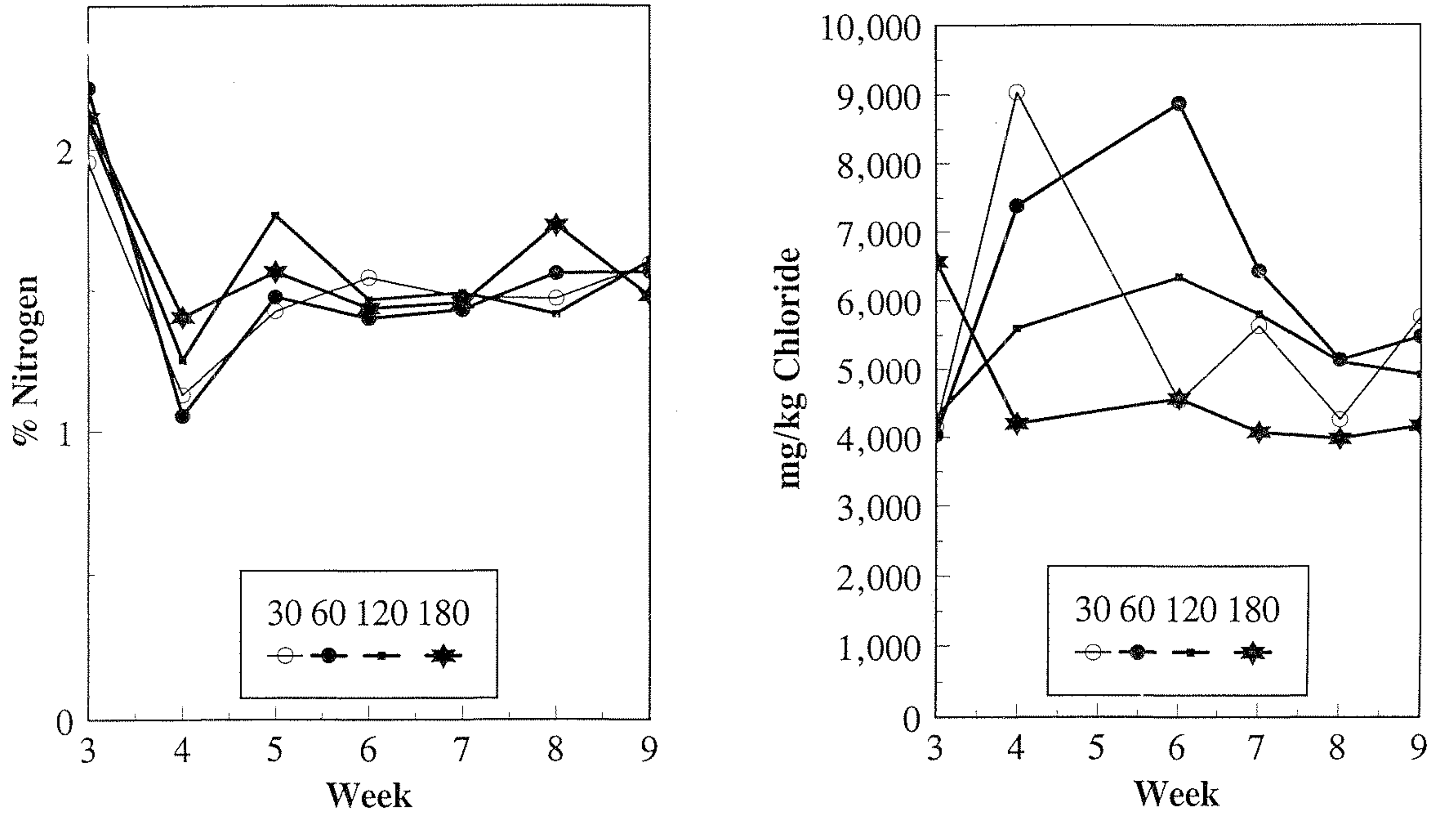
Table 14. Effect of nutrition regime on the percentages of total Nitrogen absorbed by the crop used in stem, leaf and fruit

	To the end of May			To the end of the season		
	Stem	**Leaf**	**Fruit**	**Stem**	**Leaf**	**Fruit**
30 mg/l	5.9	30.8	63.2	-	-	-
60 mg/l	5.5	29.5	65.0	8.3	24.1	66.7
120 mg/l	7.8	31.7	60.5	9.0	26.4	64.6
180 mg/l	8.1	31.9	60.0	9.5	26.5	64.1

Table 15. Effect of nutrition regime on the percentages of total dry matter produced by the crop as stem, leaf and fruit

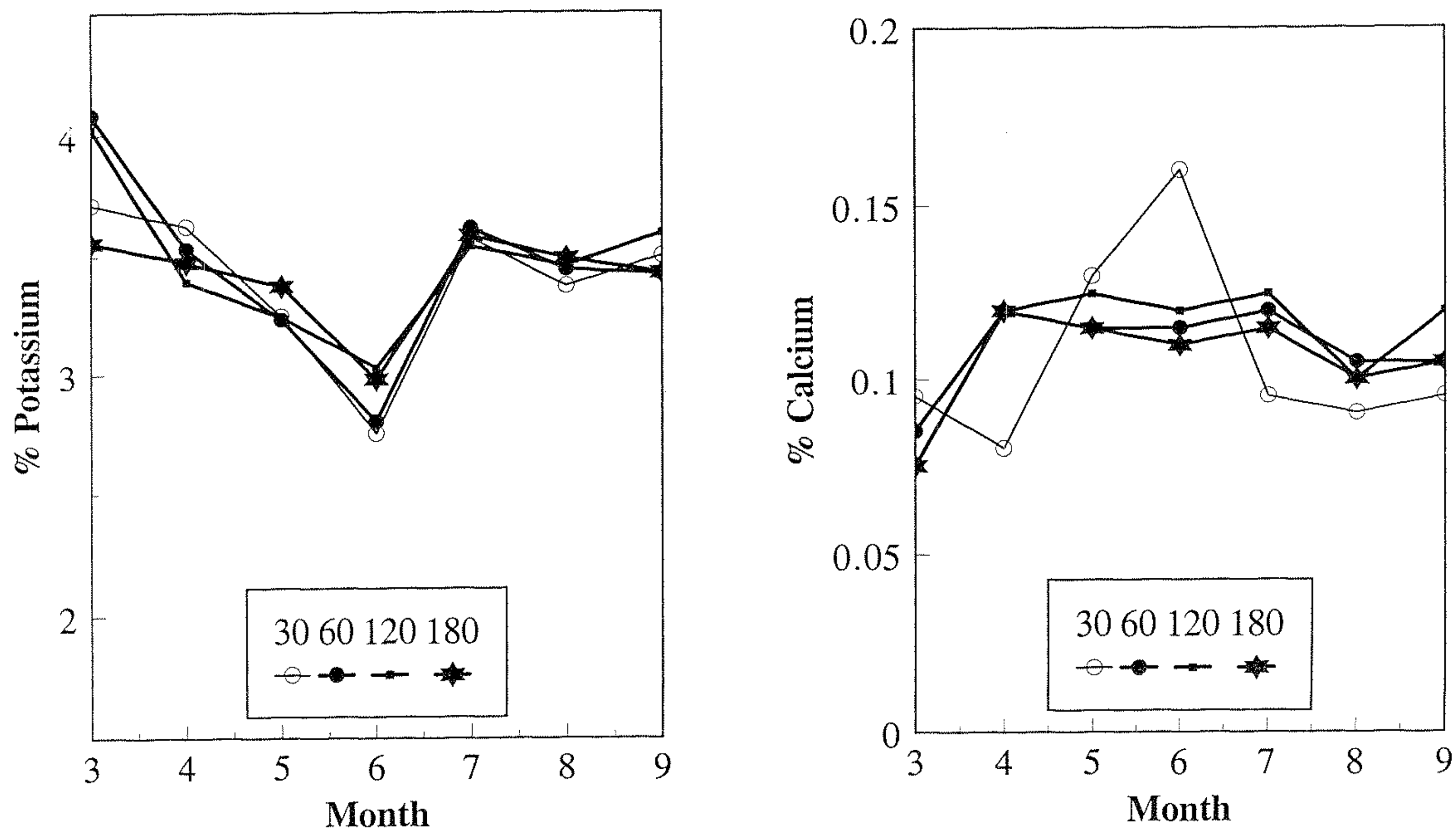
	To the end of May			To the end of the season		
	Stem	**Leaf**	**Fruit**	**Stem**	**Leaf**	**Fruit**
30 mg/l	13.3	15.5	71.1	-	-	-
60 mg/l	10.2	14.9	74.8	11.8	15.1	73.1
120 mg/l	10.5	16.6	72.9	11.9	16.6	71.5
180 mg/l	10.6	17.1	72.3	11.8	16.5	71.7

Figure 17. Effect of nutrition regime on the Nitrogen and Chloride content of fruit dry matter



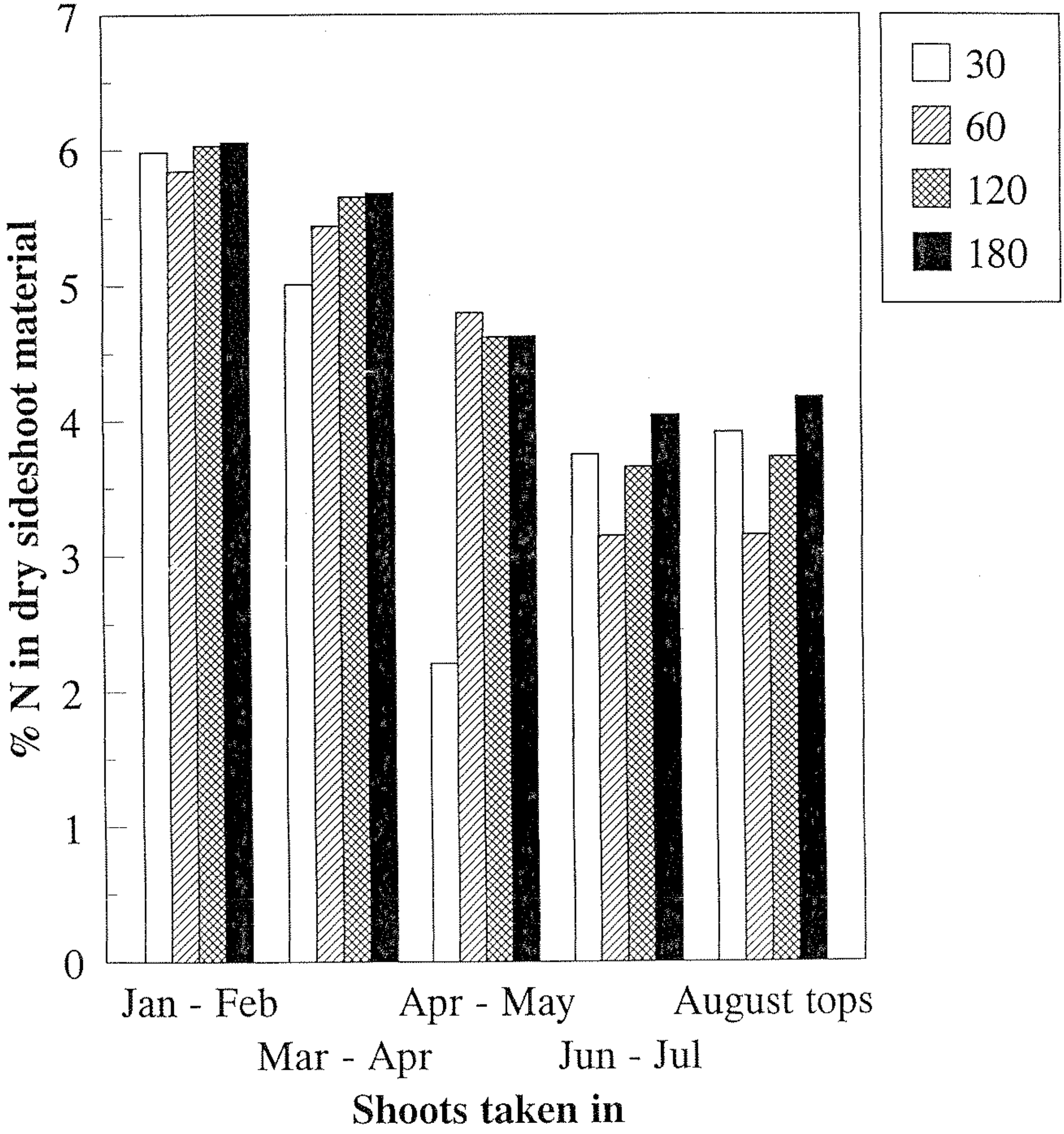
30 mg/l treatment replaced by 120 mg/l in week 20

Figure 18. Effect of nutrition regime on the Potassium and Calcium content of fruit dry matter



30 mg/l treatment replaced by 120 mg/l in week 20

Figure 19. Effect of nutrition regime on the Nitrogen content of sideshoots, and tops removed at stopping



30 mg/l treatment replaced by 120 mg/l in week 20

Figure 20. Effect of nutrition regime on the Nitrogen content of stem material at the end of the season

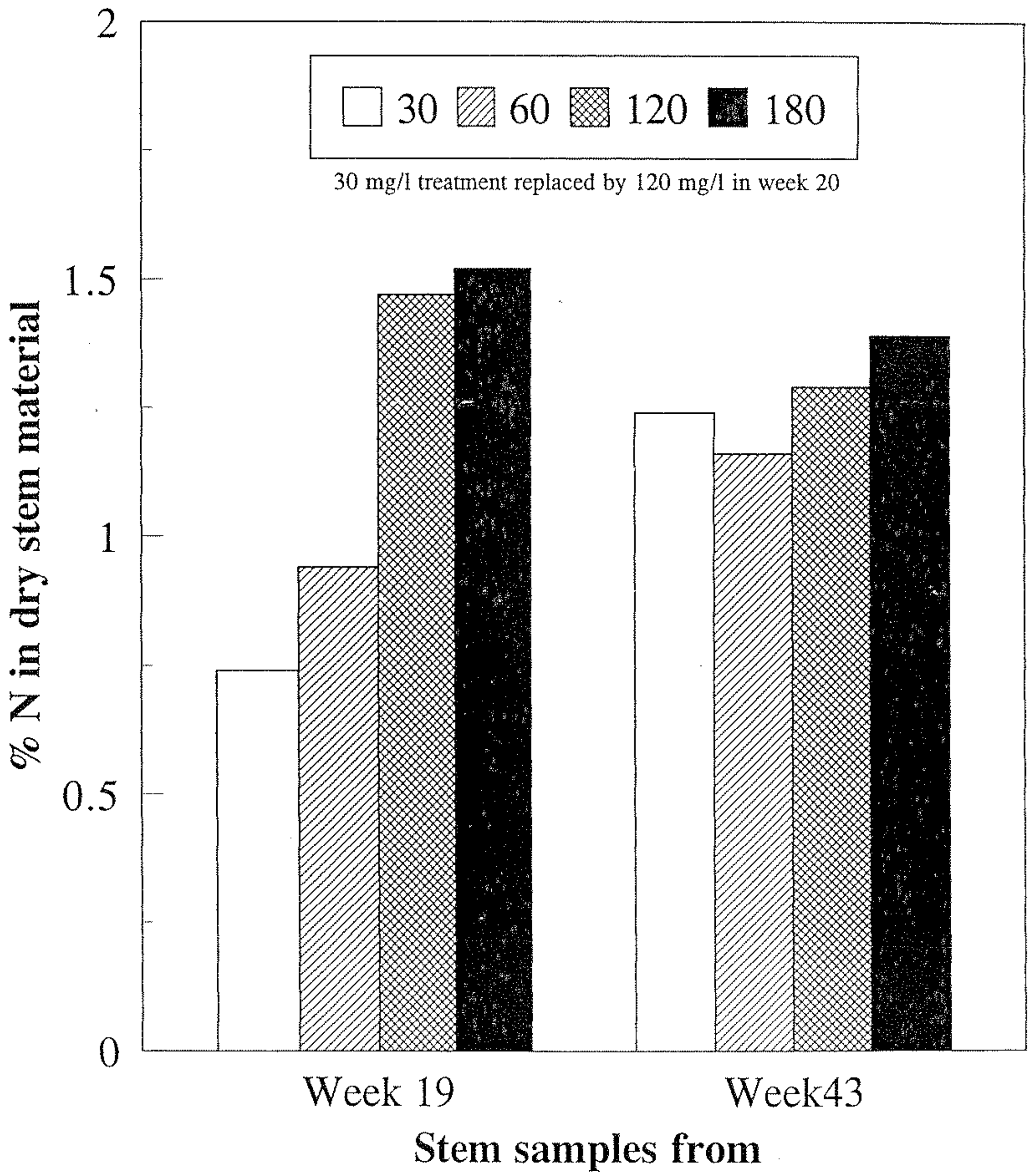
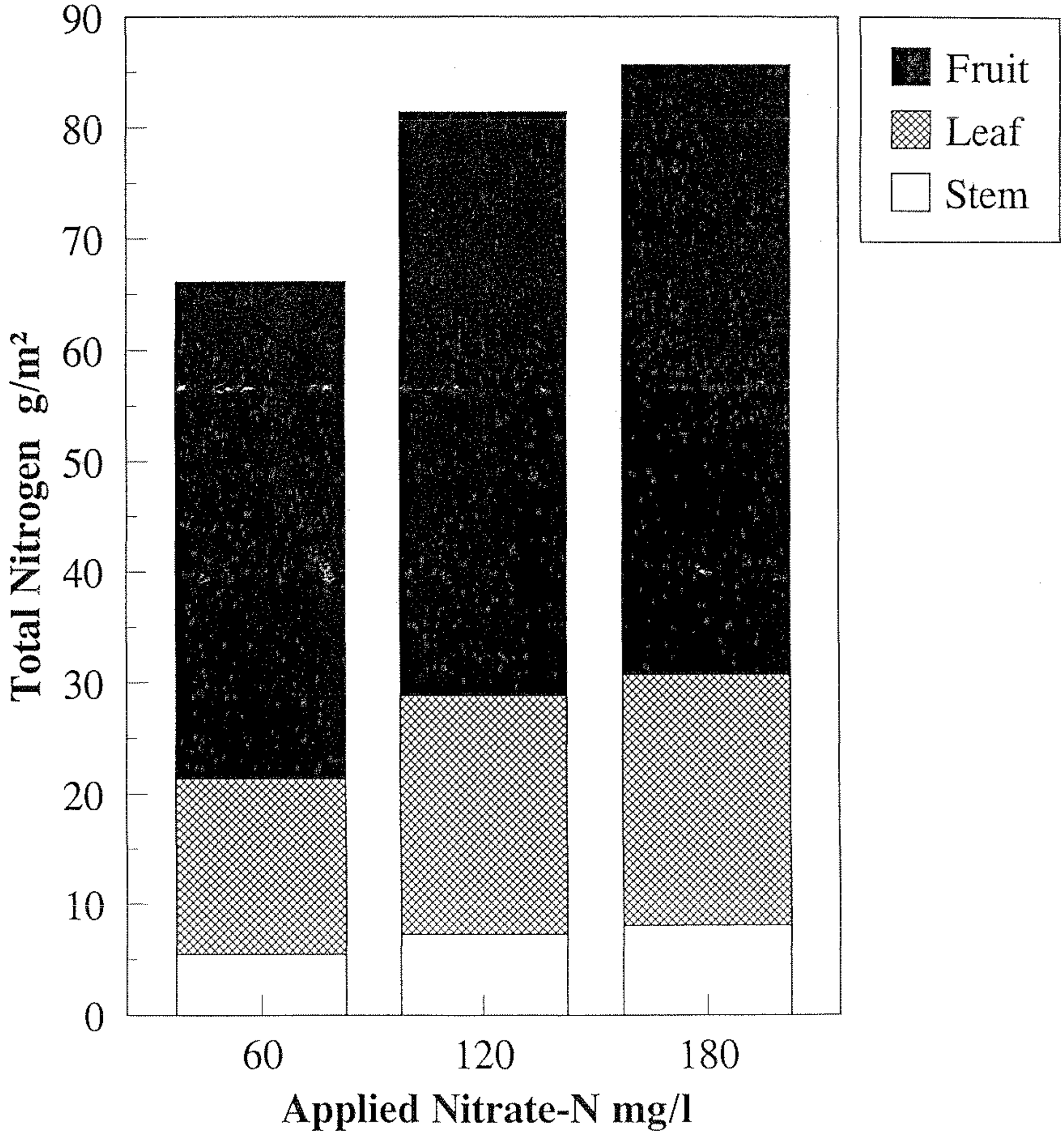


Figure 21. Effect of nutrition regime on Nitrogen uptake by tomato stem, leaf and fruit over the complete growing season



Run-off NO_3-N and Chlorides

Nitrates:

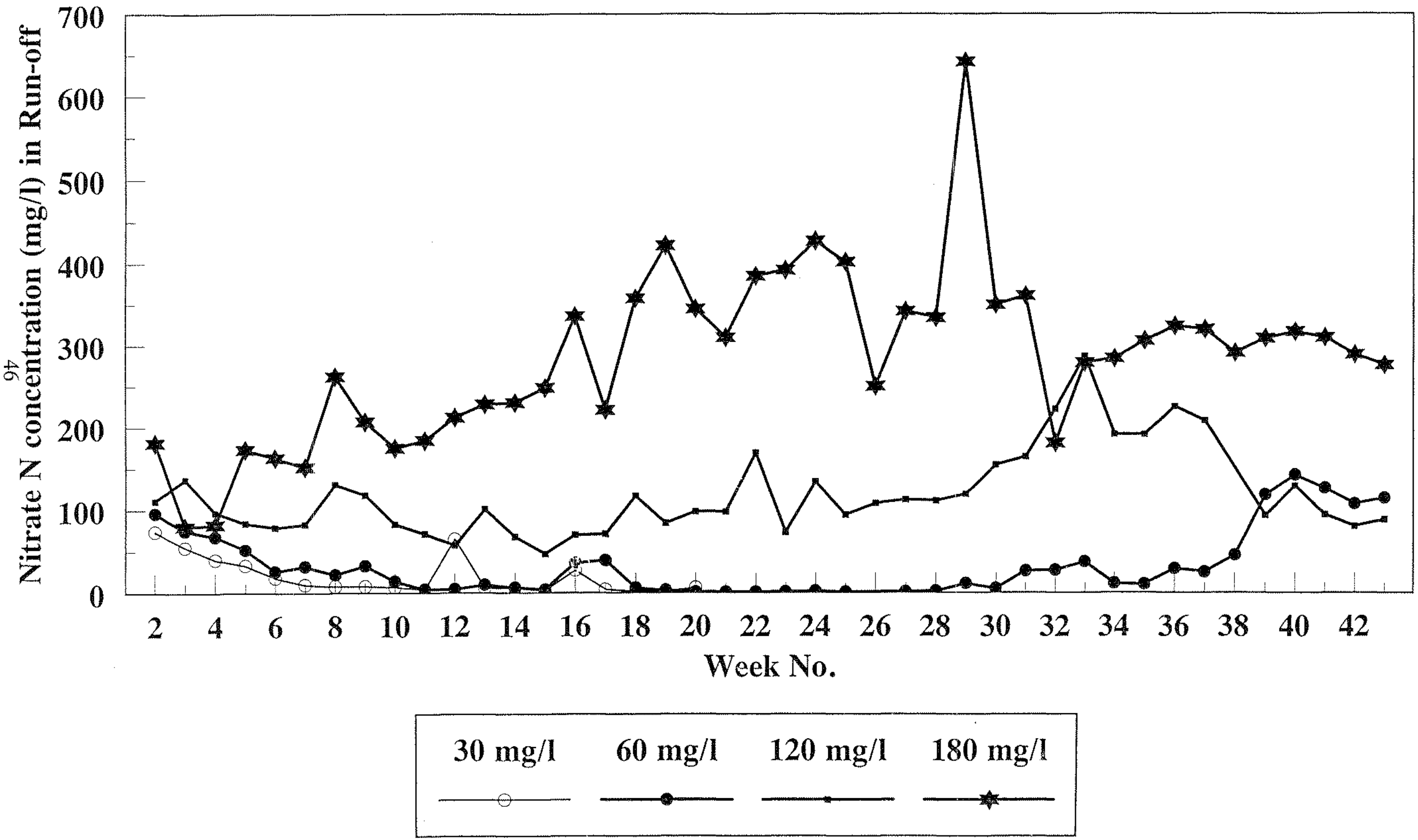
Figure 22 (page 46) shows the NO_3-N concentration in run-off for the treatments that commenced on 2 January (week 1). The levels of NO_3-N fell from 100 mg/l at the start of treatments to less than 20 mg/l by week 7 for the 30 mg/l treatment and by week 10 for the 60 mg/l treatment. Between week 18 and week 28 the NO_3-N concentration in run-off was virtually zero for the 60 mg/l treatment. Thereafter concentrations from the 60 mg/l treatment increased slightly reflecting higher levels in the applied feed after week 37. The 120 mg/l treatment resulted in relatively constant levels of NO_3-N in the run-off of between 60 and 100 mg/l except for an increase to around 200 mg/l between week 31 and week 37. The 180 mg/l treatment resulted in a steady increase in the concentration of NO_3-N in run-off from the 100 mg/l at the start of the treatment to around 400 mg/l in week 18. Thereafter NO_3-N concentrations remained relatively stable at 300-400 mg/l.

The run-off NO_3-N concentrations showed a similar pattern for treatments started on 17 February except that the achievement of very low NO_3-N concentrations were not delayed.

Chlorides:

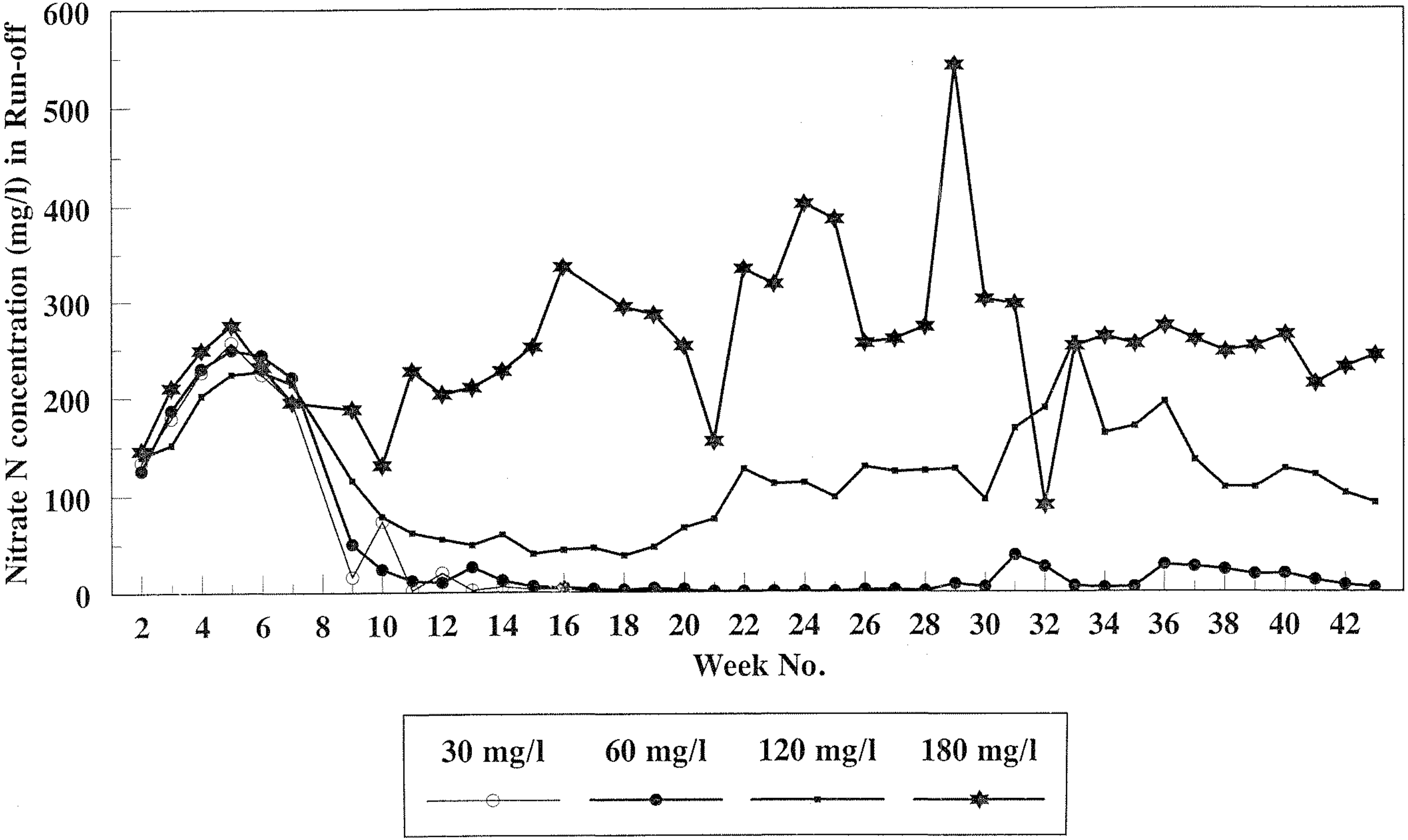
Chloride concentrations were high for all treatments at the start of the season due to the use of Sodium Chloride to achieve high EC. Subsequently the 180 mg/l treatment showed a general decline in Chloride concentration in run-off to around 500 mg/l at the end of the season. The 120 and 60 mg/l NO_3-N treatments resulted in between 900 and 1200 mg/l Chloride at the end of the season (Figures 24 and 25, pages 48 and 49).

Figure 22. Effect of nutrition regime on nitrate concentration in run-off for treatments started on 2 January



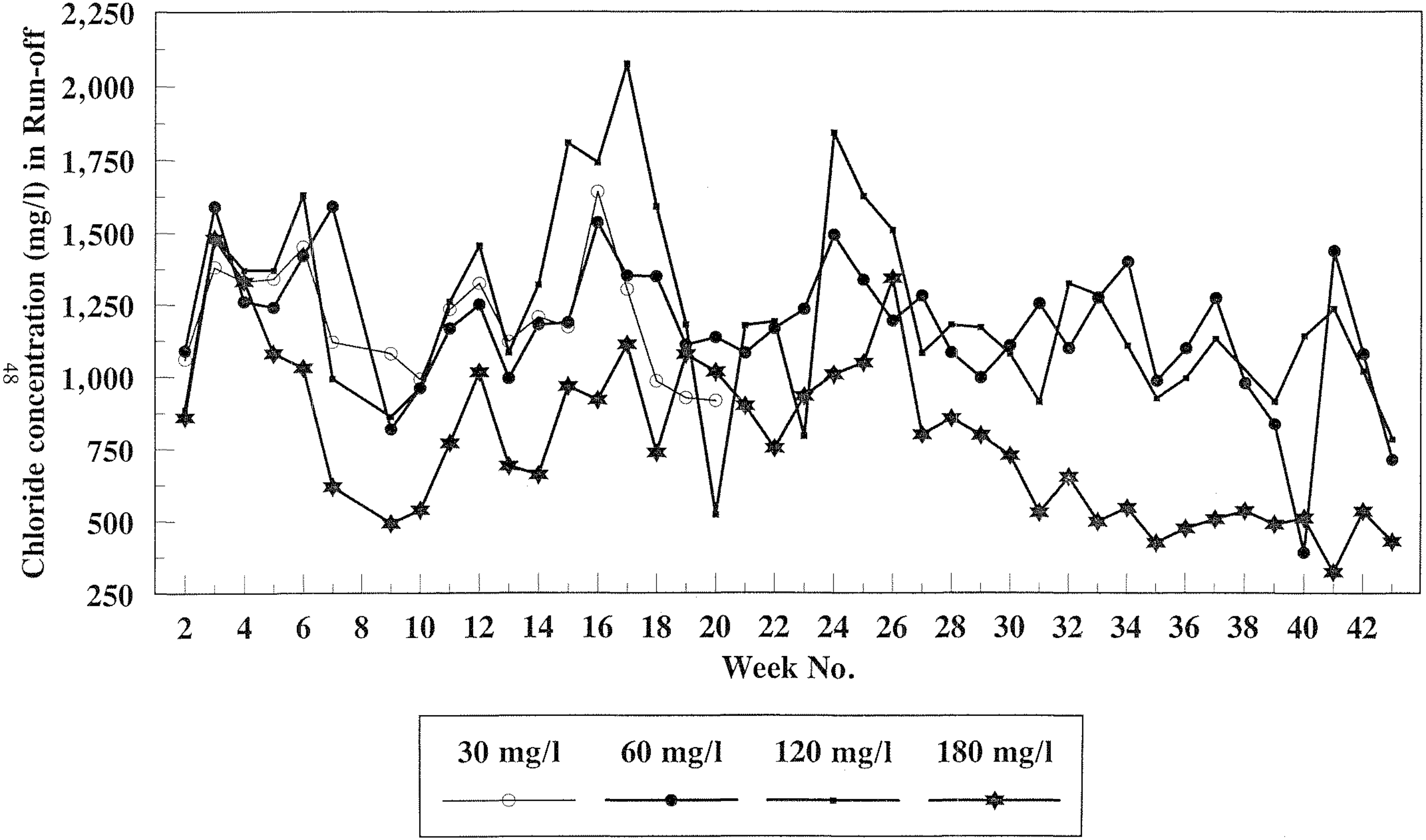
30 mg/l regime was stopped in week 20

Figure 23. Effect of nutrition regimes on Nitrate-Nitrogen Concentration in run-off for treatments started on 17 February



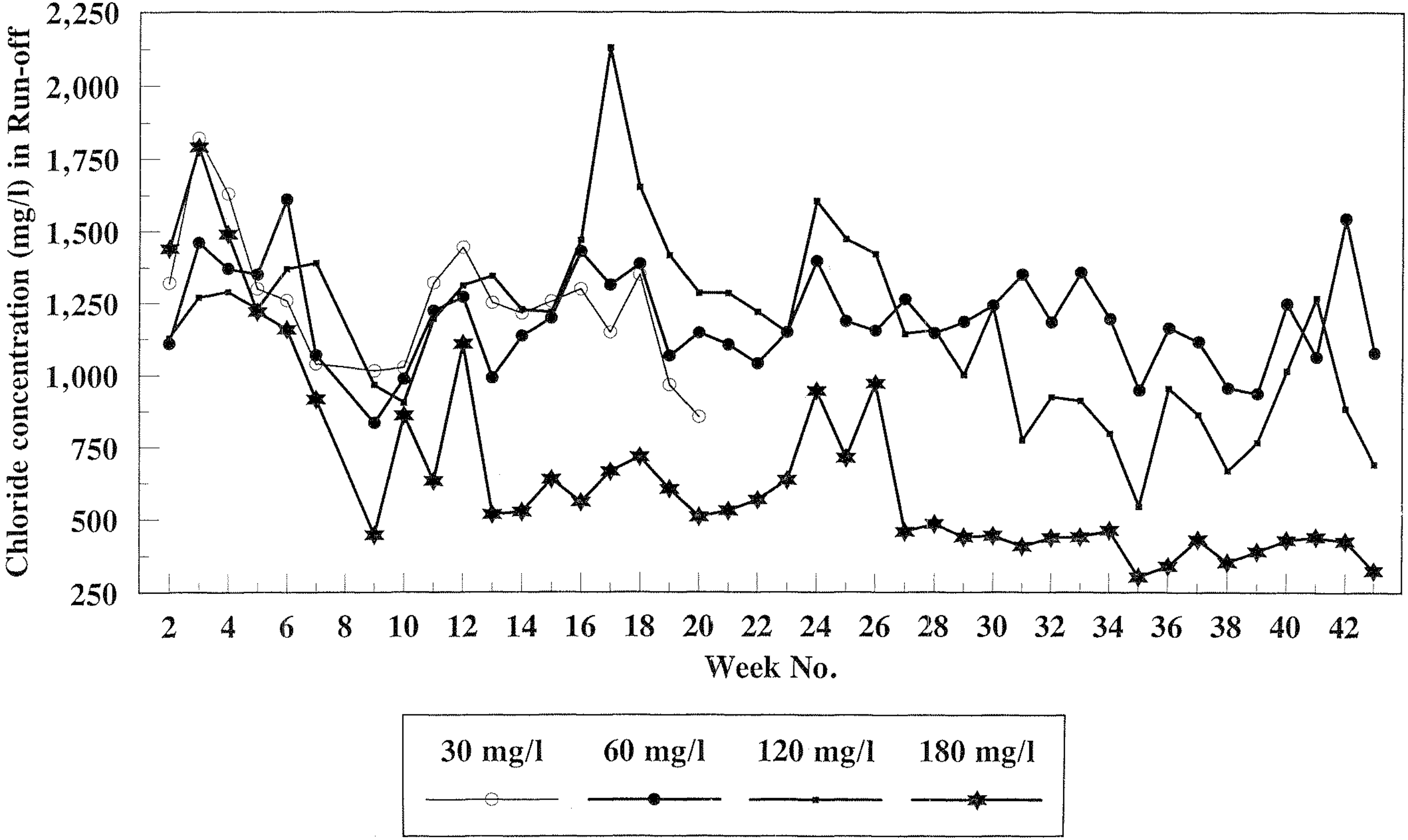
30 mg/l regime was stopped in week 20

Figure 24. Effect of nutrition regime on Chloride concentration in run-off for treatments started on 2 January



30 mg/l regime was stopped in week 20

Figure 25. Effect of nutrition regimes on Chloride concentration in run-off for treatments started on 17 February



30 mg/l regime was stopped in week 20

% Run-off and water uptake

Unfortunately the volume of applied feed for the 120 mg/l treatment was consistently less than for the other treatments throughout most of the season as measured by flow meters on plots 213 and 217 (Appendix XI, page 103). Irrigation calibrations undertaken on all plots (Appendix II, page 62) show that the volume applied per irrigation round was sometimes lower for the120 mg/l treatment but not normally by such a great margin as is indicated by the flow meter readings. However, higher slab EC early in the season does suggest that the 120 mg/l treatment received less water (see Appendix XII, page 104). Applied EC and pH were similar across all treatments. The comparison of measured applied volume from flow meters and calculated applied volume from the irrigation calibrations (assuming 160 ml/irrigation) and the recorded number of waterings suggests that flow meters may have over recorded applied volume from about week 25 onwards. The measured values were sometimes double the calculated value. Inevitably differences in the measured applied volume have a major impact on the water uptake calculations. Thus plants given the 120 mg/l treatment were apparently found to have used less water than the 60 and 180 mg/l treatments (Figure 26, page 52). There is some evidence that the 180 mg/l treatment used more water than the 60 mg/l treatment, percentage run-off was generally higher for the 60 mg/l treatment (Figure 27, page 53).

Nitrogen uptake calculated from applied and run-off solutions

The effects of erroneous applied volume measurements carry through to the calculation of the Nitrogen budget. However, as Figure 28 (page 54) shows, much more NO_3-N was removed from the feed solution by the 180 mg/l treatment than the 60 mg/l treatment. The seasonal pattern of Nitrogen and water uptake are closely matched with low uptake early and late in the season and peak uptake between weeks 24 and 28.

The total Nitrogen removed by plants from Nitrate in the feed solutions over the whole season as calculated from applied and run-off volumes and NO_3-N concentrations for the four treatments are listed in Table 16 (page 51). Over the whole season the 180 mg/l treatment resulted in more than double the Nitrogen uptake of the 60 mg/l treatment. The figures for the Nitrogen budget as calculated from applied and run-off volumes and NO_3-N concentrations do not closely match those from the samples of plant material (page 38). The figures are much higher when calculated from the applied and run-off solutions and the difference between the 120 and 180 mg/l treatments is much greater.

Table 16. **Effect of nutrition regimes on the total Nitrogen uptake by plants as calculated from applied and run-off volumes and NO_3-N concentrations**

Treatment mg/l NO_3-N	Applied N $g.m^{-2}$	Run-off N $g.m^{-2}$	Total N uptake $g.m^{-2}$	% N removed
60 mg/l	137	14	123	90
120 mg/l	197	45	152	77
180 mg/l	355	94	261	74

Figure 26. Effect of nutrition regime on water use

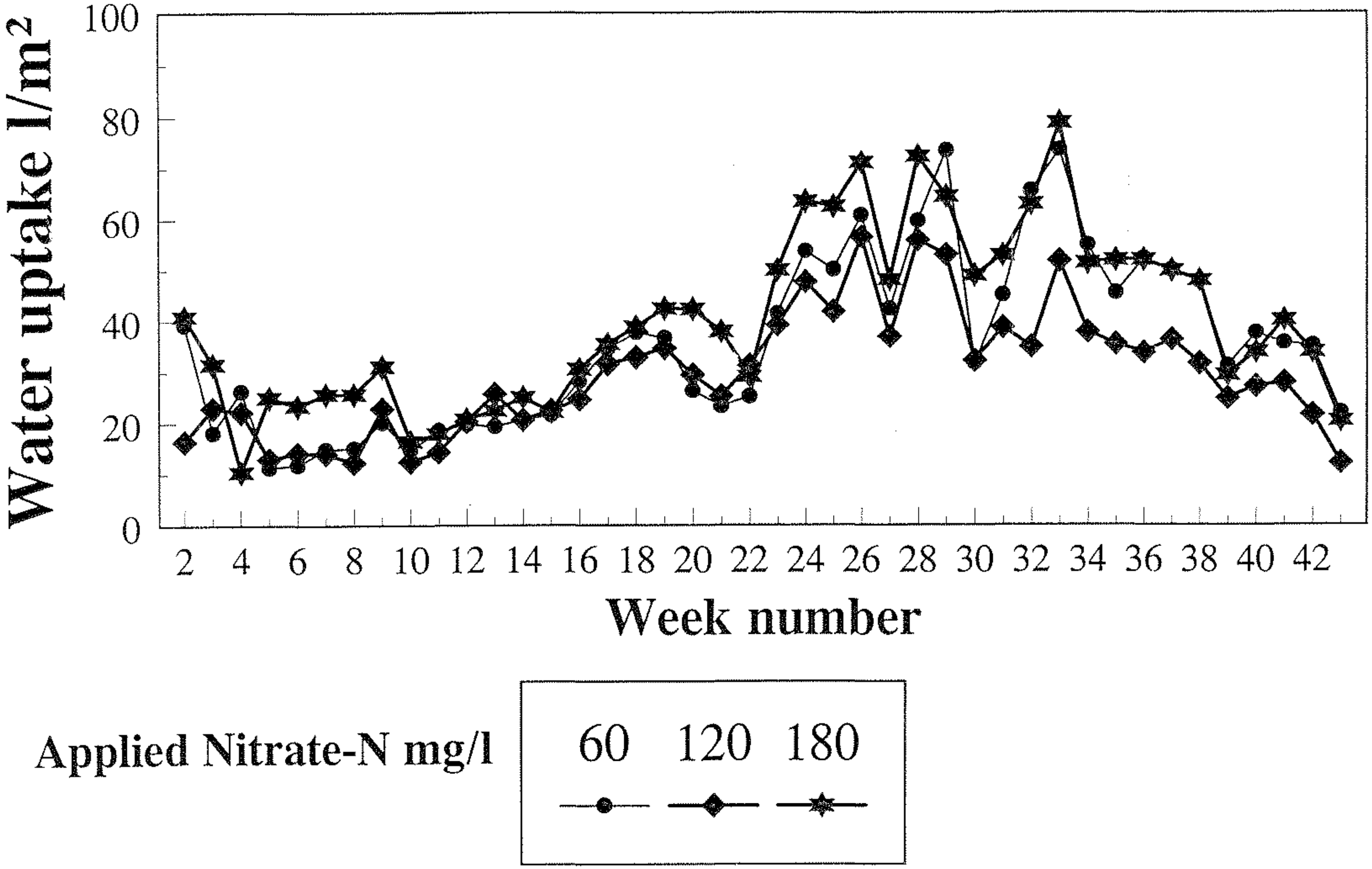


Figure 27. Effect of nutrition regime on Percentage Run-off

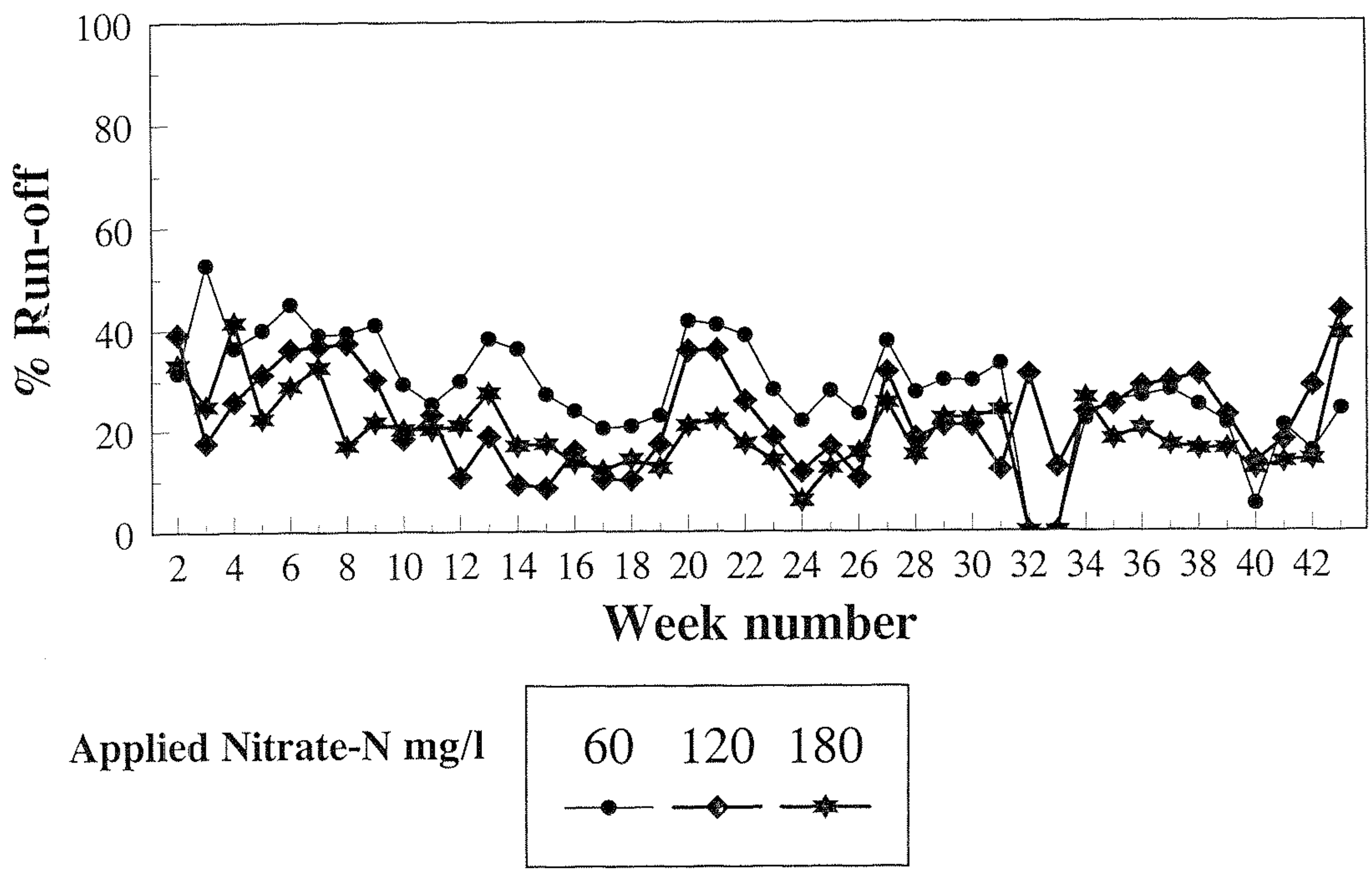
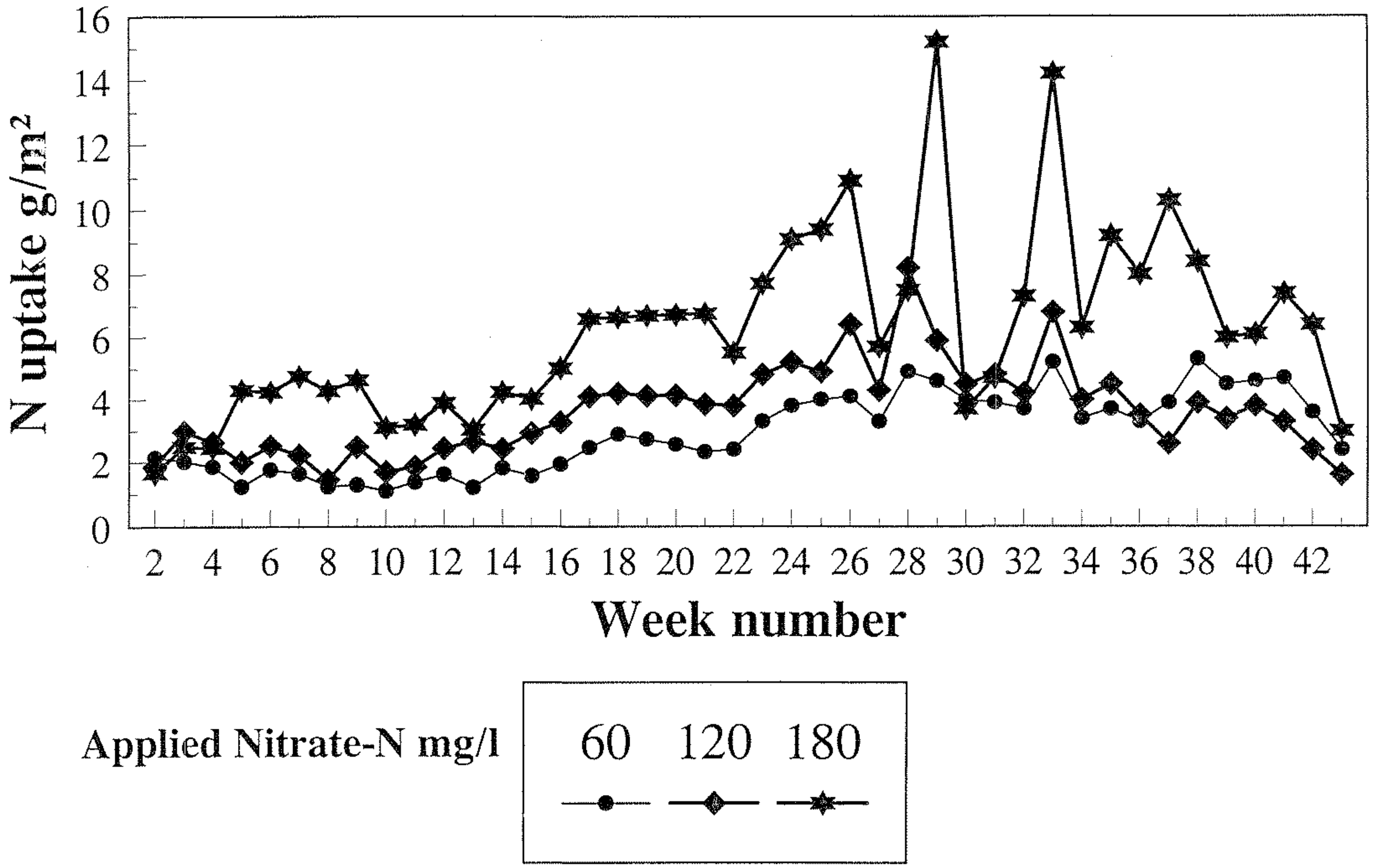


Figure 28.Effect of nutrition regime on Nitrate-N uptake



DISCUSSION

The effects of extremely low levels of NO_3-N (30 mg/l) in the applied feed solution were very great and were evident early on in the trial. Leaves and fruit became pale and yellow. The 30 mg/l plants lost vigour, produced fewer leaves, smaller leaves, fewer trusses, fewer fruit and smaller fruit than the other treatments. Total yield to the end of May was 28% less than for the 180 mg/l treatment. Colour and vigour returned when the NO_3-N level was increased to 120 mg/l but fruit developed severe Blossom-End Rot and ex-30 mg/l treatment yields for the remaining months never matched those from the 120 mg/l treatment.

The comparison of the three remaining treatments 60 mg/l, 120 mg/l and 180 mg/l in the applied feed showed that in this trial 60 mg/l was too low. The 60 mg/l treatment yielded 18% less than the 180 mg/l treatment. The 120 mg/l treatment yielded 2.5% less than the 180 mg/l treatment but this difference was not statistically significant. There was also some evidence that the volumes of applied feed were slightly lower for the 120 mg/l treatment than for other treatments. This may have had the effect of increasing the slab EC and may have had a negative effect on yield.

In contrast to the results of this trial, the results of a previous trial (Hand and Fussell, 1994) indicated that reductions in the level of NO_3-N in applied feed to 60 mg/l had no significant effect upon yield. The difference in the results for the two years might be explained by the hypothesis that it is the NO_3-N concentration in the run-off or in the slab that influences yield and not necessarily the level in the applied solution although the levels must be related. Figure 29, page 56 shows the effect of average NO_3-N concentration in the run-off on the yield of the four treatments in the 1992/93 and 1993/94 trials to the end of May as a percentage of the 180 mg/l treatments in each year. The graph indicates that yield losses occurred only where NO_3-N levels in run-off fell below 100 mg/l. Despite the levels of applied NO_3-N being the same in each of the two years for three of the treatments, the levels of NO_3-N in run-off were lower in 1993/94 than in 1992/93 and only in the 30, 60 and 120 mg/l treatments in 1993/94 did the level fall below 100 mg/l.

Using the results of this 1993/94 trial to formulate advice for growers wishing to reduce nitrate inputs but at the same time avoid yield loss, it is suggested that growers should aim for a NO_3-N concentration of around 150 mg/l in the applied feed which will effectively prevent levels in the slab falling below 100 ppm.

In 1992/93 the crop produced a much lower yield than in 1993/94 (Table 17, page 57) and as a result had a lower demand for Nitrogen. There may be many reasons for the difference in yield, such as the use of new glass in 1993/94 but whatever the reasons it would seem that factors other than NO_3-N supply were limiting yield; foe example in 1993/94 treatments commenced and were established earlier than in 1992/93 and therefore low levels of NO_3-N in the slab occurred earlier and had a greater effect on yield.

Figure 29. Effect of Nitrate-N in run-off on relative yield to the end of May

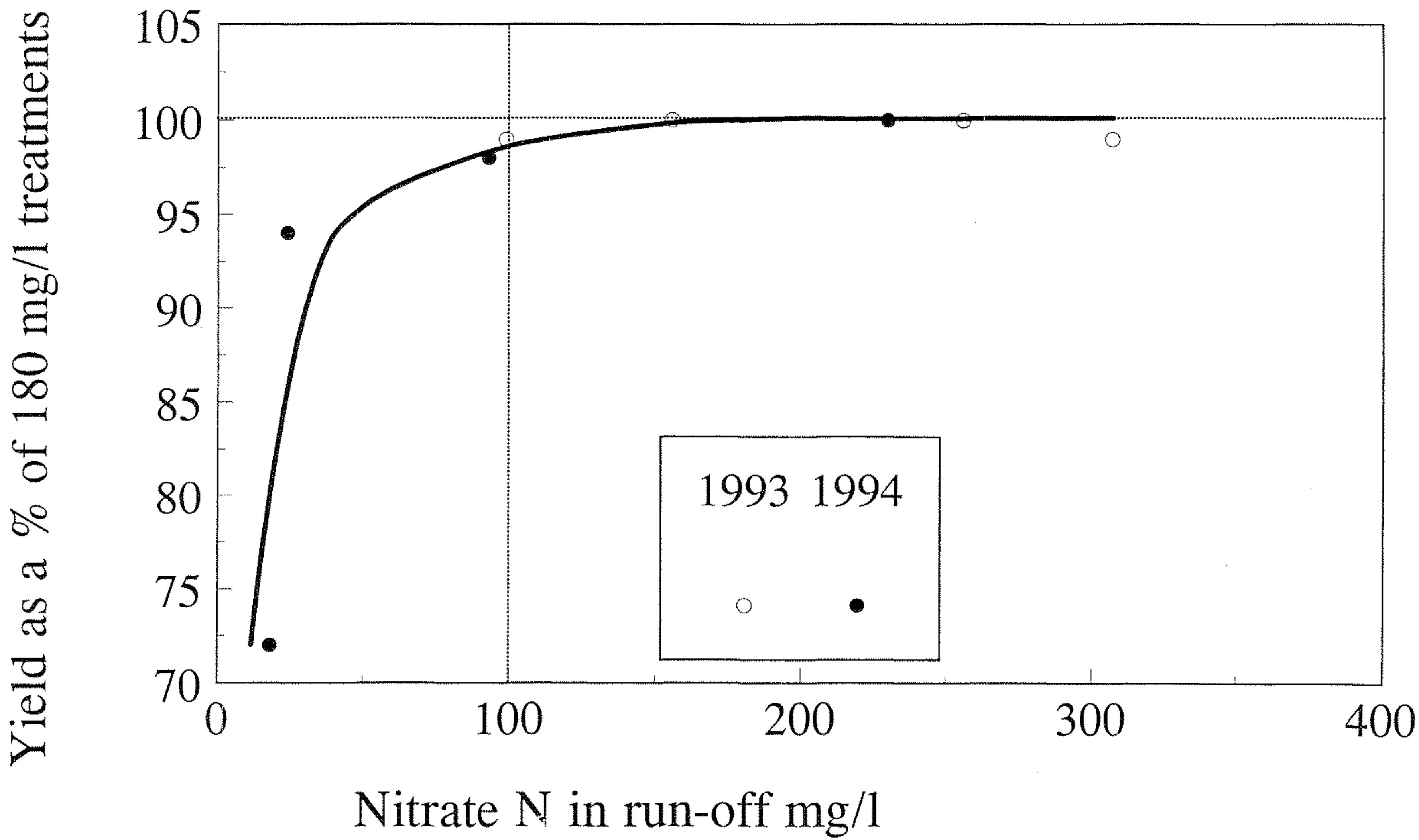


Table 17. Effect of nutrition regime on total yield to the end of October

Treatment mg/l NO_3-N	1992/93	1993/94
60	42.96	46.57
120	42.77	55.36
180	44.23	56.80
242	42.22	-

The 1992/93 trial revealed higher levels of Gold Spot and slightly softer fruit at low levels of applied NO_3-N. This finding was repeated in 1993/94 although differences in levels of Gold Spot were less marked. The highest levels of Gold Spot were found in the ex-30 mg/l treatment in June and it may be significant that at that time ex-30 mg/l fruit contained higher levels of Calcium than other treatments. The 60 mg/l treatment produced softer fruit towards the end of the season and also showed higher weight loss during shelf-life. Differences between the 120 and 180 mg/l treatments were very slight. Again as in 1992/93 the low NO_3-N treatments produced fruit with lower acidity. However there was no indication of any difference in the levels of Potassium in fruit. The reduced acidity did not result in loss of flavour as assessed by taste panels. The flavour parameter perceived as changing by the taste panel was not a reduction in sharpness but an increase in sweetness.

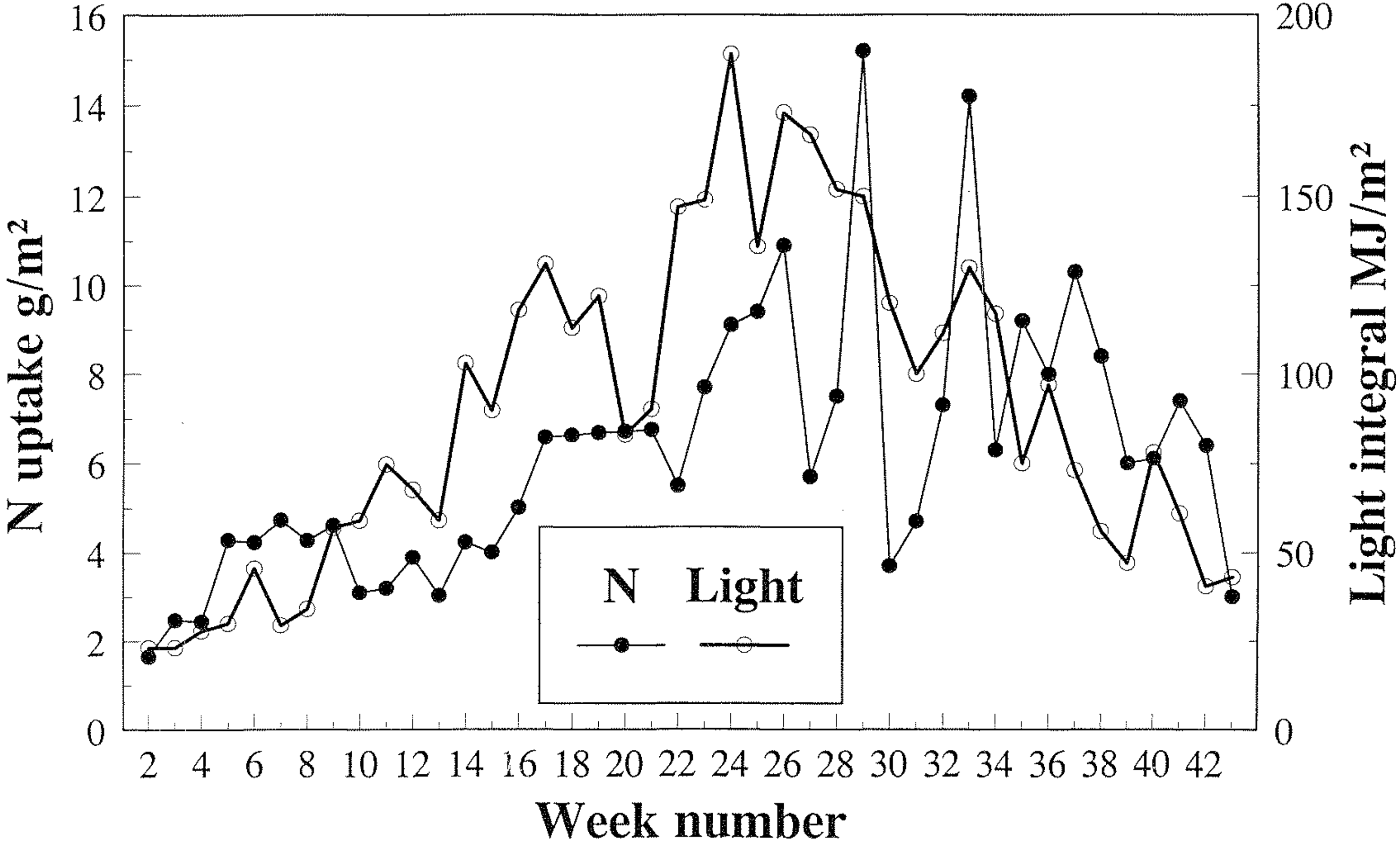
The effects of the early treatment start time (2 January) are difficult to separate from the effects of the iron deficiency resulting from the A tank dosing problem. However, there was some evidence of an effect on plant development and yield but only for the very low NO_3-N treatment (30 mg/l). Stem length was much shorter in week 19 for 30 mg/l plots when the treatment was imposed on 2 January than on 17 February. Also the difference in yield to the end of May between the two start times was greater for the 30 mg/l treatment than the other treatments. Figure 23, page 47 shows that the imposition of the 30 and 60 mg/l treatments in week 2 resulted in a slow reduction in the level of NO_3-N in run-off, while in the first few weeks the other plots being supplied with 180 mg/l showed an increase in NO_3-N concentration (Figure 24, page 48), suggesting that far more Nitrogen was being supplied than was being used by the crop at that stage. However, when the 30 and 60 mg/l treatments were started on 17 February the level of NO_3-N in run-off fell much more rapidly. This is consistent with the view that the demand for Nitrogen is low when the plants are small and increases as the plants get bigger.

There is some evidence that towards the end of the season the level of NO_3-N in run-off increased again, particularly in the 60 mg/l treatment. However, it should be noted that the applied level exceeded the set point from week 37. Also, once plants have been stopped a reduced demand for Nitrogen might be expected.

The weekly Nitrogen demand of the crop and the overall Nitrogen budget was calculated from the applied and run-off volumes and NO_3-N concentrations. The results should be treated with caution as there is evidence that flow meters over recorded volumes of applied solutions and that the level of error differed between treatments. In particular the lower volumes recorded for the 120 mg/l treatment are possibly responsible for the lower calculated Nitrogen uptake. However, a trend was apparent of increasing Nitrogen demand as the season progressed to a maximum between weeks 27 and 37. This trend is matched by the trend in water uptake and also the weekly light integral (Figure 30, page 59).

The Nitrogen budget calculated from the plant material is likely to be more reliable. The calculations indicate that the tomato crop grown at 180 mg/l utilised 86 $g.m^{-2}$. This figure is similar to the 79.5 $g.m^{-2}$ estimated by Vaughan (1994). However, the results of this trial suggest that in a standard rockwool growing system Nitrogen needs to be supplied in excess of the requirement because at concentrations below 100 mg/l N in the root environment the plants suffered a yield loss. Further advances in reducing the amount of nitrate pollution from rockwool crops may depend upon maximising the efficiency of irrigation systems so that volumes of run-off are reduced.

Figure 30. Weekly Nitrogen uptake by 180 mg/l treatment and weekly light integral



CONCLUSIONS

1. Substantial yield losses occurred where applied concentrations of NO_3-N were reduced to 30 and 60 mg/l.

2. A lower yield was produced by the 120 mg/l treatment than the 180 mg/l treatment but this difference was not statistically significant and may have been related to higher drain EC's resulting from a slightly reduced feed volume.

3. The combined results of this trial and the 1992/93 HDC Nutrition trial (PC55a) suggest that yield losses can be expected if levels of NO_3-N fall below 100 mg/l in the root environment.

4. Yield reductions were accompanied by reduced stem length and number of trusses, reduced leaf number and size and reduced fruit number and size.

5. Percentage Class I fruit was generally unaffected by reduced levels of NO_3-N.

6. Reduced NO_3-N resulted in reduced fruit acidity.

7. Extremely low NO_3-N treatments resulted in softer fruit with reduced shelf-life but there were no significant differences between fruit grown at 120 mg/l and 180 mg/l NO_3-N.

8. Increasing the concentration of NO_3-N from 30 to 120 mg/l resulted in widespread Blossom-End Rot.

9. The tomato crop grown at 180 mg/l utilised 86 $g.m^{-2}$ Nitrogen over the growing season.

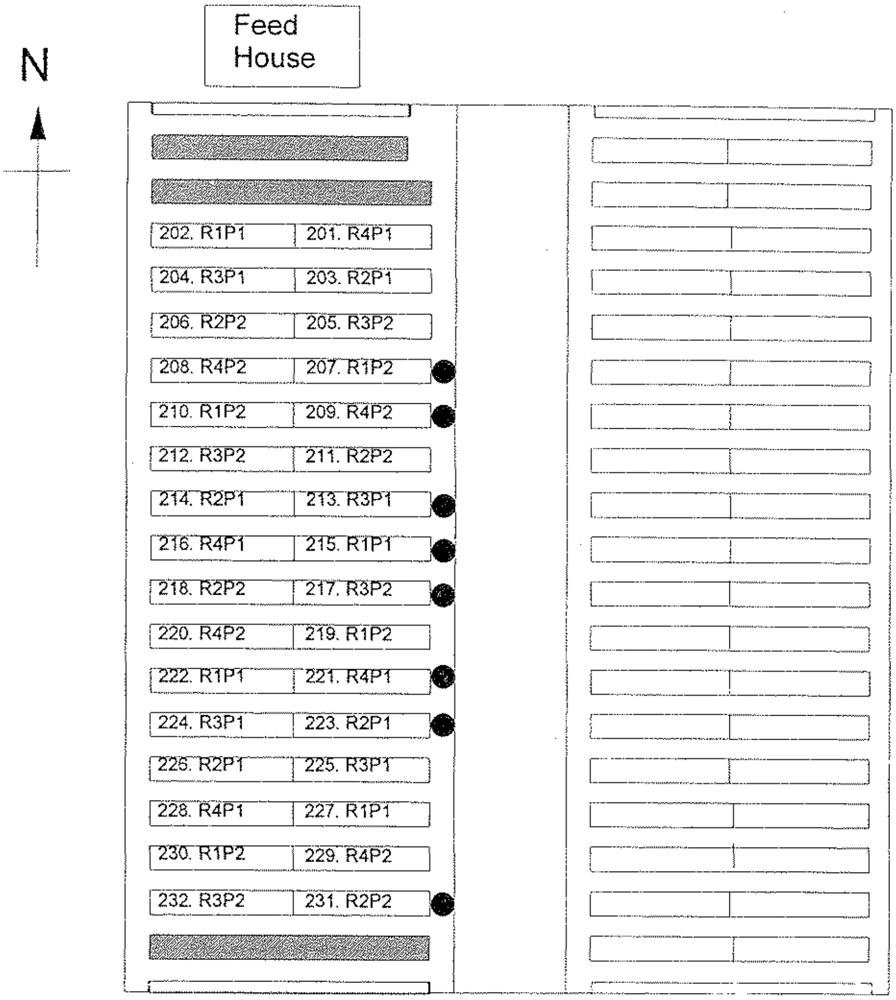
References

Vaughan, J (1994) Environmental impact of waste solutions from hydroponic systems for the production of edible crops. HDC Project Report for PC59.

Hand, D.J. and Fussell, M. (1993) Tomatoes: An assessment of the Nitrate and Chloride salts of Potassium and Calcium; their effects on yield and fruit quality. HDC Project Report for PC55

Hand, D.J. and Fussell, M. (1994) Tomatoes: The influence of reduced nitrate input on yield and fruit quality. HDC Project Report for PC55a (Year One)

Appendix I. Trial Plan (B-Block 1993/94)



Treatments 4 Nitrate-Nitrogen levels
R1 - 30 ppm
R2 - 60 ppm
R3 - 120 ppm
R4 - 180 ppm

Sub-treatments 2 treatment starting times
P1 - Slab Contact
P2 - Pre-first pick

Plot Area = 14.4 m² Plant Spacing = 300mm

27 plants/plot Initial Density = 7599/acre = 1.88/m²

● Run-off collection pit

Growing System - 'V' Substrate - Grodan 70

Variety - Pronto Sowing Date - 28 October

Guard Rows
- Single row cross trained
- Standard 'V'

APPENDIX II

Irrigation Calibrations - Mean volume applied per plant per irrigation round

Date	30 mg/l	60 mg/l	Treatments 120 mg/l	180 mg/l	P2 (180 mg/l) North	P2 (180 mg/l) South
21 January	308	319	294	340	144	213
28 January	173	140	185	165	169	174
4 February	140	143	140	160	161	161
18 February	121	125	108	128	-	-
24 March	174	166	159	161	-	-
12 April	171	160	150	163	-	-
21 July	155	146	170	155	-	-

APPENDIX III

Crop Diary

Seed sown	28.10.93
Blocked on	04.11.93
Plants moved to B-Block	02.12.93
Plants strung and knocked over	06.12.93
Bumblebees introduced for pollination	14.12.93
Slab Contact	20.12.93
First sideshoots taken	31.01.94
First fruit picked	31.01.94
Second sideshoots taken	28.02.94
Heads stopped	05.09.94
Final pick and end of trial	27.10.94

Pest and Disease Control

A number of beneficial insects were introduced to control the following pests:

Predator	**Pest**
Encarsia formosa	Whitefly
Dacnusa/Diglyphus	Leaf miner
Aphidius	Aphids
Phytoseulis	Red spider mite

Insecticide applications

Product	**Date**	**Target**
Torque (Fenbutatin Oxide)	01.07.94	Red spider mite
Torque (Fenbutatin Oxide)	15.07.94	Red spider mite
Torque (Fenbutatin Oxide)	12.08.94	Red spider mite
Torque (Fenbutatin Oxide)	26.08.94	Red spider mite
Hostaquick (Heptenophos)	07.10.94	Leafhopper
Savona (Fatty acids)	19.10.94	Whitefly
Childion (Dicofol + Tetradifon)	21.10.94	Red spider mite

Fungicide applications

Product	**Date**	**Target**
Bravo (Chlorothalonil)	04.03.94	*Botrytis*
Elvaron (Dichlofluanid)	22.04.94	*Botrytis*
Bravo (Chlorothalonil)	17.06.94	*Botrytis*
Elvaron (Dichlofluanid)	08.07.94	*Botrytis*
Bravo (Chlorothalonil)	19.08.94	*Botrytis*
Elvaron (Dichlofluanid)	09.09.94	*Botrytis*

APPENDIX IV

HRI Efford Tomato Physical Disorder Scoring System

The scoring system used is based upon the EC common standards of quality for round tomatoes.

Score	Disorder level	Grade
1a	Absent or virtually absent	Class I
1b	Present at low level - not distracting from overall appearance	Class I
1c	Noticeable but still acceptable for	Class I
2	Present at acceptable level for	Class II only
3	Unacceptable level	Waste

Acceptable levels of common disorders

Disorder Score	**Class I 1b**	**1c**	**Class II 2**	**Waste 3**
Blotchy ripening and Whitewall	1-3 spots <5mm diam.	4-6 blotches or any one 6-10mm	>6 blotches or any blotch 11-30mm diam.	Any one blotch >30mm diam.
Red Noses	<10mm diam.	11-20mm diam.	>20mm diam.	-
Uneven Ripening	1 ATB Col Stage difference	>1 ATB Col Stage difference	-	-
Gold Spot	<100 spots/cm² or <10mm radius around calyx	11-20mm radius around calyx end with >100 spots/cm²	>20mm radius around calyx end with >100 spots/cm²	-
Gold Marble	1-20mm diam.	21-40mm diam.	>40mm diam.	-
Gooseberry Veining	<30% surface area	>30% surface area	-	-
Fine net cracking	<1cm² wide net close net	wide net or <1cm² <50% area	close net >50%	close net area
Concentric cracking	Total length of all cracks <5mm	Total length of all cracks 6-10mm	Total length of all cracks 10-30mm	Total length of all cracks >30mm
Catface	-	-	<1cm²	>1cm²
Other healed scars	<5mm	6-10mm	10-30mm	>30mm
Blossom End Rot	-	-	-	Any level
Shape	Non-spherical	Bi/tri-locular appearance	Angular appearance or longest diam >1.5 x shortest	Major deformity
Nippling	Point <2mm	Point 2-5mm	Point 5-10mm	Point >10mm

APPENDIX V

Effect of nutrition regime on stem dry weight in week 19

Treatment	Dry Weight
30 mg/l	90.6
60 mg/l	87.8
120 mg/l	97.7
180 mg/l	100.6
SED (20 df)	*5.05*
LSD 5%	-
Significance	*N.S.*

APPENDIX VI

EFFECT OF NUTRITION REGIME ON YIELD AND GRADEOUT

Effect of nutrition regime on total yield (kg.m^{-2})

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	1.74	3.22	3.95	3.78	(3.29	4.92	7.65	5.05	5.27	38.87)
60	1.74	3.40	4.89	6.51	6.77	6.33	6.40	4.69	5.85	46.57
120	1.74	3.33	4.88	7.23	8.89	8.28	8.91	5.38	6.73	55.36
180	1.70	3.27	5.07	7.48	9.10	8.62	9.19	5.67	6.70	56.80
SED (20 df)	*0.033*	*0.065*	*0.092*	*0.166*	*0.141*	*0.138*	*0.219*	*0.109*	*0.084*	*0.598*
LSD 5%	-	-	*0.191*	*0.346*	*0.294*	*0.287*	*0.456*	*0.227*	*0.175*	*1.247*
Significance	*N.S.*	*N.S.*	***	***	***	***	***	***	***	***

Note figures in parenthesis indicate records taken after the 30 mg/l treatment was changed to 120 mg/l.

Effect of start time of nutrition treatments on total yield (kg.m^{-2})

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	**30**	1.72	3.00	3.78	3.54	(3.30	4.84	7.58	5.04	5.32	38.12)
	60	1.72	3.33	4.80	6.48	6.75	6.21	6.15	4.63	5.80	45.87
	120	1.74	3.28	4.83	7.24	8.93	8.26	8.99	5.47	6.68	55.43
	180	1.68	3.15	4.99	7.47	9.05	8.58	9.06	5.55	6.68	56.21
17.02.94	**30**	1.76	3.43	4.11	4.06	(3.27	5.00	7.72	5.06	5.22	39.62)
	60	1.76	3.48	4.97	6.53	6.80	6.44	6.65	4.75	5.89	47.28
	120	1.74	3.38	4.93	7.21	8.85	8.30	8.83	5.29	6.77	55.29
	180	1.71	3.39	5.14	7.50	9.16	8.66	9.31	5.79	6.72	57.38
SED (20 df)		*0.047*	*0.092*	*0.130*	*0.235*	*0.245*	*0.238*	*0.379*	*0.189*	*0.145*	*1.036*
LSD 5%		-	-	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VI

Effect of nutrition regime on total marketable yield (kg.m^{-2})

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	1.73	3.16	3.88	3.69	(3.09	3.86	6.55	4.65	5.11	35.71)
60	1.73	3.35	4.83	6.42	6.66	4.80	5.90	4.53	5.71	43.93
120	1.73	3.25	4.80	7.11	8.80	5.80	8.15	5.02	6.51	51.17
180	1.69	3.20	4.98	7.39	9.00	5.90	8.06	5.47	6.54	52.22
SED (20 df)	*0.033*	*0.066*	*0.091*	*0.163*	*0.174*	*0.238*	*0.289*	*0.135*	*0.114*	*0.670*
LSD 5%	-	-	*0.190*	*0.341*	*0.363*	*0.497*	*0.603*	*0.282*	*0.238*	*1.380*
Significance	*N.S.*	*N.S.*	***	***	***	***	***	***	***	***

Effect of start time of nutrition treatments on total marketable yield (kg.m^{-2})

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	30	1.72	2.95	3.73	3.45	(3.10	3.76	6.46	4.64	5.16	34.96)
	60	1.71	3.27	4.75	6.40	6.64	4.54	5.62	4.48	5.66	43.09
	120	1.73	3.21	4.75	7.12	8.84	5.70	8.12	5.02	6.44	50.93
	180	1.68	3.08	4.90	7.37	8.94	5.70	7.85	5.34	6.51	51.35
17.02.94	30	1.75	3.37	4.03	3.93	(3.09	3.95	6.63	4.67	5.06	36.47)
	60	1.75	3.42	4.91	6.45	6.68	5.05	6.17	4.58	5.76	44.77
	120	1.74	3.29	4.85	7.09	8.75	5.91	8.17	5.02	6.59	51.41
	180	1.70	3.32	5.06	8.41	9.05	6.10	8.27	5.60	6.57	53.08
SED (20 df)		*0.047*	*0.093*	*0.129*	*0.231*	*0.246*	*0.338*	*0.409*	*0.192*	*0.161*	*0.948*
LSD 5%		-	-	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VI

Effect of nutrition regime on percentage Class I fruit

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	97.1	90.1	89.8	87.3	(36.4	31.9	63.9	73.1	72.7	68.5)
60	97.4	90.6	91.3	92.1	87.7	35.5	62.4	70.6	68.7	74.7
120	97.0	89.0	88.6	87.2	82.6	38.8	69.3	66.7	58.3	71.4
180	96.5	89.8	88.8	90.4	84.3	37.4	58.7	74.9	63.7	71.6
SED (20 df)	*0.377*	*0.59*	*0.87*	*1.09*	*3.17*	*3.14*	*2.48*	*2.02*	*2.56*	*1.36*
LSD 5%	-	-	*1.81*	*2.26*	-	-	*5.18*	*4.21*	*5.33*	*2.84*
Significance	*N.S.*	*N.S.*	*	***	*N.S.*	*N.S.*	**	**	**	*

Effect of start time of nutrition treatments on percentage Class I fruit

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	30	96.6	89.9	90.2	86.3	(31.7	33.3	63.0	71.3	73.0	67.5)
	60	97.2	91.2	91.3	91.1	88.6	32.5	59.0	68.7	66.3	73.5
	120	96.6	89.1	88.3	87.2	83.6	39.6	68.4	65.1	58.7	71.3
	180	97.0	89.7	87.8	90.0	84.6	34.9	55.4	72.7	61.7	70.1
17.02.94	30	97.5	90.2	89.3	88.3	(41.0	30.5	64.8	84.9	72.4	69.4)
	60	97.6	90.1	81.2	92.2	86.8	38.5	65.8	72.6	71.1	75.8
	120	97.3	89.0	88.9	87.3	81.6	38.0	70.3	68.3	58.0	71.5
	180	96.0	89.8	89.7	90.8	84.0	39.9	62.0	77.1	65.8	73.1
SED (20 df)		*0.53*	*0.84*	*1.23*	*1.54*	*4.48*	*4.44*	*3.52*	*2.86*	*3.62*	*1.93*
LSD 5%		-	-	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VI

Effect of nutrition regime on percentage of Class I fruit in size grade C (>57mm diameter)

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	3.8	2.0	2.5	4.0	(2.0	39.5	41.1	18.9	11.7	15.6)
60	4.7	3.3	6.0	10.2	7.7	4.6	10.5	23.3	25.5	11.1
120	4.6	3.0	4.2	13.1	15.6	12.9	22.3	24.9	21.5	14.8
180	4.7	3.3	6.3	17.2	15.7	9.3	28.6	29.9	20.0	16.8
SED (20 df)	*0.88*	*0.52*	*0.76*	*1.53*	*1.42*	*1.96*	*2.04*	*2.52*	*1.89*	*0.93*
LSD 5%	-	-	*1.59*	*3.18*	*2.96*	*4.08*	*4.26*	*5.26*	*3.94*	*1.95*
Significance	*N.S.*	*N.S.*	***	***	***	**	***	*	*	***

Effect of start time of nutrition treatments on percentage of Class I fruit in size grade C (>57mm)

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	30	2.6	1.8	2.2	3.5	(3.3	40.6	42.2	20.0	12.2	16.3)
	60	4.6	3.3	5.6	9.5	6.1	4.71	8.3	24.0	28.5	10.7
	120	5.4	4.0	4.4	13.7	14.4	11.6	22.7	26.3	21.1	14.9
	180	5.5	2.5	5.6	16.8	14.8	7.7	27.5	30.1	20.6	16.2
17.02.94	30	4.9	2.2	2.9	4.6	(0.8	38.5	40.1	17.9	11.2	15.0)
	60	4.7	3.2	6.3	11.0	9.3	4.6	12.8	22.6	22.4	11.4
	120	3.9	2.1	4.0	12.5	16.9	14.3	21.8	23.5	21.9	14.8
	180	4.0	4.1	7.0	17.6	16.6	10.9	29.7	29.6	19.4	17.4
SED (20 df)		*1.25*	*0.73*	*1.08*	*2.16*	*2.01*	*2.77*	*2.89*	*3.57*	*2.68*	*1.32*
LSD 5%		-	*1.52*	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VI

Effect of nutrition regime on percentage of Class I fruit in size grade D (47-57mm diameter)

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	88.7	84.1	65.6	78.1	(75.7	56.7	57.9	79.4	85.1	73.8)
60	88.1	88.7	78.3	79.6	88.1	90.4	88.1	76.0	73.2	82.7
120	88.1	89.2	84.3	79.5	82.0	84.7	77.1	74.5	77.3	80.9
180	88.8	88.9	85.4	76.7	81.2	87.1	70.6	69.8	78.4	79.3
SED (20 df)	*1.09*	*1.12*	*1.03*	*1.21*	*1.70*	*1.77*	*1.96*	*2.37*	*1.87*	*0.79*
LSD 5%	-	*2.33*	*2.16*	*2.52*	*3.53*	*3.69*	*4.09*	*4.95*	*3.89*	*1.65*
Significance	*N.S.*	***	***	*	***	*	***	*	*	**

Effect of start time of nutrition treatments on percentage of Class I fruit in size grade D (47-57mm diameter)

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	30	89.0	80.4	66.1	79.5	(76.7	55.9	56.9	78.1	84.1	73.1)
	60	87.2	86.8	78.9	80.5	89.9	90.6	90.6	75.3	70.4	82.9
	120	87.1	87.7	84.3	78.7	83.3	85.9	76.4	73.2	77.5	80.8
	180	87.6	88.7	86.3	76.5	82.2	89.3	71.6	69.5	77.7	79.7
17.02.94	30	88.4	87.8	65.1	76.8	74.7	57.6	58.8	80.8	86.0	74.6)
	60	89.1	90.6	77.6	78.7	86.3	90.2	86.7	76.8	76.0	82.5
	120	89.1	90.8	84.3	80.3	80.7	83.5	77.8	75.8	77.0	81.1
	180	90.0	89.1	84.5	76.8	80.2	85.0	69.6	70.1	79.2	78.9
SED (20 df)		*1.54*	*1.58*	*1.46*	*1.71*	*2.40*	*2.50*	*2.78*	*3.36*	*2.64*	*1.12*
LSD 5%		-	*3.29*	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VI

Effect of nutrition regime on percentage of Class I fruit in size grade E (40-47mm diameter)

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	7.5	13.7	28.3	15.2	(22.0	3.3	0.7	1.6	3.1	9.6)
60	7.2	8.0	15.4	9.6	4.1	4.8	1.3	0.6	1.3	6.0
120	7.2	7.7	11.3	7.1	2.3	2.3	0.6	0.6	1.2	4.1
180	6.4	7.7	8.2	6.0	3.1	3.4	0.8	0.3	1.5	3.8
SED (20 df)	*0.84*	*0.79*	*0.91*	*0.75*	*1.14*	*0.65*	*0.25*	*0.36*	*0.35*	*0.29*
LSD 5%	-	*1.64*	*1.89*	*1.55*	-	*1.36*	*0.51*	-	-	*0.60*
Significance	*N.S.*	**	***	***	*N.S.*	**	*	*N.S.*	*N.S.*	**

Effect of start time of nutrition treatments on percentage of Class I fruit in size grade E (40-47mm diameter)

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	30	8.3	17.5	27.7	15.0	(19.8	2.8	0.6	1.9	3.4	9.7)
	60	8.2	9.9	15.0	9.3	3.9	4.5	1.1	0.7	1.1	6.2
	120	7.4	8.3	11.0	7.3	2.3	2.5	0.8	0.5	1.3	4.2
	180	6.8	8.7	8.0	6.4	3.0	2.9	0.8	0.3	1.6	4.0
17.02.94	30	6.7	10.0	29.0	15.4	24.2	3.8	0.8	1.3	2.7	9.5)
	60	6.2	6.1	15.7	9.9	4.2	5.2	1.4	0.5	1.5	5.9
	120	7.0	7.1	11.6	7.0	2.4	2.2	0.4	0.7	1.1	4.1
	180	5.9	6.7	8.4	5.5	3.2	4.0	0.7	0.3	1.4	3.7
SED (20 df)		*1.18*	*1.11*	*1.26*	*1.06*	*1.61*	*0.92*	*0.35*	*0.51*	*0.49*	*0.41*
LSD 5%		-	*2.32*	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	**	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VI

Effect of nutrition regime on percentage Class II fruit

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	2.5	8.2	8.5	9.9	(57.7	46.5	21.6	19.0	24.3	23.4)
60	2.3	7.7	7.7	6.6	10.6	40.1	29.8	25.8	29.0	19.7
120	2.6	8.6	9.7	11.1	16.4	31.2	22.1	26.5	38.5	21.0
180	3.1	8.1	9.5	8.4	14.5	31.0	29.0	21.5	33.8	20.4
SED (20 df)	*0.34*	*0.55*	*0.69*	*0.98*	*3.03*	*2.47*	*1.67*	*1.88*	*2.37*	*0.96*
LSD 5%	-	-	*1.45*	*2.05*	-	*5.15*	*3.48*	*3.93*	*4.94*	-
Significance	*N.S.*	*N.S.*	*	***	*N.S.*	**	***	*	**	*N.S.*

Effect of start time of nutrition treatments on percentage Class II fruit

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	30	3.0	8.5	8.4	11.1	(62.1	44.5	22.2	20.6	24.0	24.2)
	60	2.4	7.1	7.7	6.8	9.9	40.7	32.5	27.9	31.3	20.5
	120	2.8	8.8	10.0	11.1	15.4	29.4	22.0	26.6	37.6	20.6
	180	2.9	8.1	10.4	8.8	14.3	31.5	31.2	23.5	35.8	21.3
17.02.94	30	2.0	7.9	8.6	8.7	53.4	48.4	21.0	17.4	24.5	22.6)
	60	2.1	8.3	7.6	6.5	11.4	39.6	27.1	23.6	26.7	18.9
	120	2.4	8.4	9.5	11.2	17.3	33.1	22.3	26.4	39.4	21.5
	180	3.3	8.1	8.6	8.0	14.8	30.5	26.8	19.6	31.9	19.5
SED (20 df)		*0.49*	*0.78*	*0.98*	*1.39*	*4.29*	*3.50*	*2.36*	*2.67*	*3.35*	*1.36*
LSD 5%		-	-	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VI

Effect of nutrition regime on percentage waste fruit

Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
30	0.4	1.7	1.7	2.8	(5.9	21.6	14.5	7.9	3.1	8.1)
60	0.4	1.6	1.1	1.3	1.7	24.4	7.8	3.6	2.3	5.7
120	0.5	2.3	1.7	1.7	1.1	30.0	8.6	6.8	3.2	7.6
180	0.4	2.2	1.7	1.2	1.2	31.6	12.3	3.6	2.4	8.0
SED (20 df)	*0.13*	*0.22*	*0.28*	*0.20*	*0.31*	*2.47*	*1.26*	*0.90*	*0.58*	*0.53*
LSD 5%	-	*0.45*	-	*0.41*	-	*5.16*	*2.63*	*1.88*	-	*1.10*
Significance	*N.S.*	**	*N.S.*	***	*N.S.*	*	**	**	*N.S.*	***

Effect of start time of nutrition treatments on percentage waste fruit

Start Time	Applied NO_3-N (mg/l)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
02.01.94	30	0.4	1.5	1.4	2.7	(6.2	22.2	14.9	8.1	3.0	8.3)
	60	0.4	1.7	1.0	1.3	1.5	26.8	8.5	3.4	3.1	6.1
	120	0.5	2.1	1.7	1.7	1.0	31.1	9.7	8.4	2.4	8.1
	180	0.2	2.2	1.8	1.2	1.2	33.6	13.4	3.9	2.2	8.6
17.02.94	30	0.5	1.9	2.0	3.0	5.6	21.1	14.2	7.7	3.7	8.0)
	60	0.4	1.6	1.2	1.3	1.8	21.9	7.2	3.8	2.7	5.3
	120	0.4	2.6	1.6	1.6	1.1	28.9	7.5	5.2	2.6	7.0
	180	0.7	2.1	1.7	1.2	1.1	29.6	11.2	3.3	2.3	7.5
SED (20 df)		*0.18*	*0.31*	*0.39*	*0.28*	*0.43*	*3.50*	*1.79*	*1.27*	*0.83*	*0.75*
LSD 5%		-	-	-	-	-	-	-	-	-	-
Significance of interaction between start time and nutrition regime		*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VII

Effect of nutrition regime on levels of fruit physical disorders

Week 7	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
30 mg/l	-	50.0	45.0	5.0	-
60 mg/l	-	52.5	42.5	5.0	-
120 mg/l	-	43.8	53.8	2.5	-
180 mg/l	-	43.8	50.0	6.3	-
SED (20 df)	-	*0.754*	*0.767*	*0.356*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 9	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
30 mg/l	11.3	53.8	35.0	-	-
60 mg/l	6.3	41.3	48.8	3.6	-
120 mg/l	6.3	52.5	37.5	3.7	-
180 mg/l	8.8	46.3	43.8	1.1	-
SED (20 df)	*5.41*	*10.10*	*8.97*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 11	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
30 mg/l	7.5	36.3	51.3	5.0	-
60 mg/l	7.5	53.8	36.3	2.5	-
120 mg/l	6.3	46.3	45.0	2.5	-
180 mg/l	10.0	33.8	52.5	3.8	-
SED (20 df)	*3.54*	*9.06*	*10.28*	*3.04*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VII

Effect of nutrition regime on levels of fruit physical disorders

Week 15	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
30 mg/l	47.5	43.8	5.0	3.7	-
60 mg/l	38.8	51.3	6.3	3.6	-
120 mg/l	40.0	46.3	11.3	2.4	-
180 mg/l	36.3	55.0	8.8	-	-
SED (20 df)	*6.33*	*7.58*	*3.94*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 19	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
30 mg/l	56.3	37.5	6.3	-	-
60 mg/l	37.5	53.8	7.5	1.2	-
120 mg/l	45.0	45.0	10.0	-	-
180 mg/l	33.8	55.0	11.3	-	-
SED (20 df)	*9.51*	*9.39*	*5.15*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 21	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
30 mg/l	47.5	46.3	6.2	-	-
60 mg/l	56.3	42.5	1.2		-
120 mg/l	53.8	45.0	1.2		-
180 mg/l	56.3	42.5	1.2		-
SED (20 df)	*8.43*	*8.63*	-	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VII

Effect of nutrition regime on levels of fruit physical disorders

Week 23	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
30 mg/l	26.3	50.0	22.5	1.2	-
60 mg/l	60.0	35.0	5.0	-	-
120 mg/l	72.5	27.5	0.0	-	-
180 mg/l	66.3	32.5	1.3	-	-
SED (20 df)	*8.02*	*7.46*	*3.64*	-	-
LSD 5%	*16.7*	*15.6*	*7.6*	-	-
Significance	***	*	***	*N.S.*	*N.S.*

Week 25	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
(30 mg/l	28.8	43.8	22.5	4.9	-)
60 mg/l	36.3	58.8	3.8	1.2	-
120 mg/l	48.8	43.8	7.5	-	-
180 mg/l	48.8	46.3	5.0	-	-
SED (20 df)	*10.10*	*8.56*	*4.41*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 27	Class Ia	Class Ib	Shape Class Ic	Class II	Waste
(30 mg/l	71.3	25.0	3.8	-	-)
60 mg/l	45.0	45.0	7.5	2.5	-
120 mg/l	55.0	40.0	5.0	-	-
180 mg/l	50.0	45.0	5.0		-
SED (20 df)	*7.32*	*8.41*	*3.20*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	-	*N.S.*	*N.S.*	*N.S.*

APPENDIX VII

Effect of nutrition regime on levels of fruit physical disorders

			Shape		
Week 37	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	88.7	11.3	-	-	-)
60 mg/l	98.7	1.3	-	-	-
120 mg/l	93.7	6.3	-	-	-
180 mg/l	92.5	7.5	-	-	-
SED (20 df)	*3.97*	*3.24*	-	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Shape		
Week 39	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	46.3	51.3	2.7	-	-)
60 mg/l	46.3	52.5	1.2	-	-
120 mg/l	40.0	60.0	-	-	-
180 mg/l	46.3	51.3	2.4	-	-
SED (20 df)	*7.93*	*7.32*	-	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Shape		
Week 41	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	31.3	62.5	6.2	-	-)
60 mg/l	53.8	46.3	-		-
120 mg/l	51.3	47.5	1.2		-
180 mg/l	57.5	41.3	1.2		-
SED (20 df)	*9.48*	*9.65*	-	-	-
LSD 5%	-	-	-	-	-
Significance	**	-	*N.S.*	*N.S.*	*N.S.*

APPENDIX VII

Effect of nutrition regime on levels of fruit physical disorders

Week 7	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
30 mg/l	-	66.3	33.8	-	-
60 mg/l	-	53.8	46.3	-	-
120 mg/l	-	45.0	55.0	-	-
180 mg/l	-	65.0	35.0	-	-
SED (20 df)	-	*5.93*	*5.93*	-	-
LSD 5%	-	*12.4*	*12.4*	-	-
Significance	*N.S.*	**	**	*N.S.*	*N.S.*

Week 9	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
30 mg/l	23.8	58.8	16.3	1.2	-
60 mg/l	26.3	52.5	21.3	-	-
120 mg/l	23.8	57.5	18.8	-	-
180 mg/l	26.3	57.5	16.3	-	-
SED (20 df)	*0.668*	*0.525*	*0.626*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 11	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
30 mg/l	3.8	46.3	50.0	-	-
60 mg/l	7.5	51.3	41.3	-	-
120 mg/l	5.0	43.8	50.0	1.2	-
180 mg/l	7.5	41.3	50.0	1.2	-
SED (20 df)	*0.334*	*0.913*	*0.815*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VII

Effect of nutrition regime on levels of fruit physical disorders

Week 15	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
30 mg/l	56.3	36.3	7.5	-	-
60 mg/l	27.5	55.0	17.5	-	-
120 mg/l	17.5	71.3	11.3	-	-
180 mg/l	38.8	47.5	13.8	-	-
SED (20 df)	*8.20*	*6.98*	*6.70*	-	-
LSD 5%	*17.1*	*14.6*	-	-	-
Significance	***	***	*N.S.*	*N.S.*	*N.S.*

Week 17	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
30 mg/l	46.3	41.3	10.0	2.5	-
60 mg/l	43.8	45.0	11.3	-	-
120 mg/l	33.8	50.0	16.3	-	-
180 mg/l	35.0	46.3	18.8	-	-
SED (20 df)	*11.4*	*11.3*	*6.4*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 19	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
30 mg/l	10.0	56.3	32.5	-	-
60 mg/l	17.5	63.8	18.8	-	-
120 mg/l	13.8	71.3	15.0	-	-
180 mg/l	26.3	63.8	10.0	-	-
SED (20 df)	*6.4*	*8.87*	*6.76*	-	-
LSD 5%	-	-	*14.1*	-	-
Significance	*N.S.*	*N.S.*	*	*N.S.*	*N.S.*

APPENDIX VII

Effect of nutrition regime on levels of fruit physical disorders

			Gold Spot		
Week 21	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
30 mg/l	7.5	36.3	50.0	6.3	-
60 mg/l	15.0	58.8	25.0	1.3	-
120 mg/l	8.8	55.0	36.3	0.0	-
180 mg/l	18.8	52.5	25.0	3.8	-
SED (20 df)	*3.78*	*6.72*	*4.68*	*3.19*	-
LSD 5%	*7.9*	*14.0*	*9.8*	-	-
Significance	*	*	***	*N.S.*	*N.S.*

			Gold Spot		
Week 23	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
30 mg/l	26.3	50.0	22.5	1.2	-
60 mg/l	60.0	35.0	5.0	-	-
120 mg/l	72.5	27.5	0.0	-	-
180 mg/l	66.3	32.5	1.3	-	-
SED (20 df)	*8.02*	*7.46*	*3.64*	-	-
LSD 5%	*16.7*	*15.6*	*7.6*	-	-
Significance	***	*	***	*N.S.*	*N.S.*

			Gold Spot		
Week 25	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	11.3	37.5	51.3	-)
60 mg/l	1.2	30.0	58.8	10.0	-
120 mg/l	-	47.5	41.3	11.3	-
180 mg/l	6.2	67.5	22.5	3.8	-
SED (20 df)	-	*9.10*	*9.30*	*5.69*	-
LSD 5%	-	*19.0*	*19.4*	-	-
Significance	*N.S.*	***	*N.S.*	*N.S.*	*N.S.*

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Week 27	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
(30 mg/l	1.3	52.5	41.3	4.9	-)
60 mg/l	3.8	62.5	33.8	-	-
120 mg/l	7.5	78.8	12.5	1.2	-
180 mg/l	10.0	76.3	13.8	-	-
SED (20 df)	*3.88*	*7.63*	*7.13*	-	-
LSD 5%	-	-	*14.9*	-	-
Significance	*N.S.*	*N.S.*	*	*N.S.*	*N.S.*

Week 29	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
(30 mg/l	38.8	43.8	17.5	-	-)
60 mg/l	1.2	56.3	41.3	1.2	-
120 mg/l	3.8	66.3	26.3	3.6	-
180 mg/l	5.0	85.0	8.8	1.2	-
SED (20 df)	*5.58*	*7.91*	*8.05*	-	-
LSD 5%	-	*16.5*	*16.8*	-	-
Significance	*N.S.*	**	**	*N.S.*	*N.S.*

Week 31	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
(30 mg/l	28.8	70.0	1.2	-	-)
60 mg/l	38.8	48.8	11.3	1.2	-
120 mg/l	41.3	47.5	11.3	-	-
180 mg/l	47.5	47.5	5.0	-	-
SED (20 df)	*15.35*	*14.62*	*5.42*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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Week 33	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
(30 mg/l	13.8	77.5	8.8	-	-)
60 mg/l	6.3	80.0	13.8	-	-
120 mg/l	3.8	78.8	17.5	-	-
180 mg/l	2.5	85.0	17.5	5.0	-
SED (20 df)	*5.29*	*9.28*	*8.54*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 35	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
(30 mg/l	25.0	70.5	5.0	-	-)
60 mg/l	11.3	73.8	15.0	-	-
120 mg/l	12.5	77.5	10.0	-	-
180 mg/l	16.3	81.2	1.3	1.2	-
SED (20 df)	*6.04*	*7.95*	*5.04*	-	-
LSD 5%	-	-	*10.5*	-	-
Significance	*N.S.*	*N.S.*	*	*N.S.*	*N.S.*

Week 37	Class Ia	Class Ib	Gold Spot Class Ic	Class II	Waste
(30 mg/l	33.8	53.8	10.0	2.4	-)
60 mg/l	16.3	81.2	2.5	-	-
120 mg/l	16.3	66.3	17.5	-	-
180 mg/l	17.5	72.5	10.0	-	-
SED (20 df)	*6.62*	*7.20*	*4.45*	-	-
LSD 5%	-	-	*9.3*	-	-
Significance	*N.S.*	*N.S.*	*	*N.S.*	*N.S.*

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			Gold Spot		
Week 39	Class Ia	Class Ib	Class Ic	Class II	Waste
(30 mg/l	20.0	62.5	17.5	-	-)
60 mg/l	30.0	55.0	15.0	-	-
120 mg/l	18.8	51.3	30.0	-	-
180 mg/l	7.5	60.0	31.3	1.2	-
SED (20 df)	*6.12*	*6.58*	*6.53*	-	-
LSD 5%	*12.8*	-	-	-	-
Significance	**	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Gold Spot		
Week 41	Class Ia	Class Ib	Class Ic	Class II	Waste
(30 mg/l	37.5	50.0	11.3	1.2	-)
60 mg/l	80.0	16.3	2.5	1.2	-
120 mg/l	80.0	17.5	1.2	1.2	-
180 mg/l	91.2	6.3	0.0	2.5	-
SED (20 df)	*7.03*	*9.28*	*2.41*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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			Gold Marbling		
Week 21	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
30 mg/l	6.2	82.5	7.5	3.8	-
60 mg/l	-	68.8	31.3	-	-
120 mg/l	-	67.5	30.0	2.5	-
180 mg/l	-	46.3	46.3	7.5	-
SED (20 df)	-	*6.41*	*6.20*	-	-
LSD 5%	-	*13.4*	*12.9*	-	-
Significance	*N.S.*	***	***	*N.S.*	*N.S.*

			Gold Marbling		
Week 23	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
30 mg/l	-	37.5	31.3	31.3	-
60 mg/l	-	26.3	48.8	25.0	-
120 mg/l	-	17.5	43.8	38.8	-
180 mg/l	1.2	17.5	32.5	48.8	-
SED (20 df)	-	*9.95*	*5.06*	*10.42*	-
LSD 5%	-	-	*10.6*	-	-
Significance	*N.S.*	*N.S.*	**	*N.S.*	*N.S.*

			Gold Marbling		
Week 25	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	8.8	22.5	68.8	-)
60 mg/l	-	12.5	47.5	40.0	-
120 mg/l	-	11.3	31.3	56.3	-
180 mg/l	-	10.0	30.0	60.0	-
SED (20 df)	-	*7.48*	*9.31*	*8.85*	-
LSD 5%	-	-	-	*18.5*	-
Significance	*N.S.*	*N.S.*	*N.S.*	*	*N.S.*

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			Gold Marbling		
Week 27	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	8.8	36.3	55.0	-)
60 mg/l	-	57.5	30.0	12.5	-
120 mg/l	-	56.3	31.3	12.5	-
180 mg/l	-	61.3	25.0	13.8	-
SED (20 df)	-	*9.15*	*7.53*	*7.14*	-
LSD 5%	-	*19.1*	-	*14.9*	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Gold Marbling		
Week 29	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	33.8	3.8	62.5	-)
60 mg/l	-	16.3	26.3	57.5	-
120 mg/l	-	10.0	26.3	63.8	-
180 mg/l	-	21.3	36.3	42.5	-
SED (20 df)	-	*7.98*	*7.10*	*11.08*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Gold Marbling		
Week 31	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	16.3	18.8	65.0	-)
60 mg/l	-	12.5	35.0	51.3	-
120 mg/l	-	17.5	40.0	42.5	-
180 mg/l	-	18.8	30.0	51.3	-
SED (20 df)	-	*9.17*	*6.24*	*11.79*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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			Gold Marbling		
Week 33	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	81.2	10.0	8.8	-)
60 mg/l	-	73.8	23.8	2.5	-
120 mg/l	-	73.8	21.3	5.0	-
180 mg/l	-	57.5	30.0	12.5	-
SED (20 df)	-	*8.69*	*6.93*	*5.80*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Gold Marbling		
Week 35	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	43.8	37.5	18.8	-)
60 mg/l	-	36.2	52.5	11.3	-
120 mg/l	-	43.8	40.0	16.3	-
180 mg/l	-	48.8	37.5	13.8	-
SED (20 df)	-	*10.26*	*10.08*	*6.83*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Gold Marbling		
Week 37	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	1.2	87.5	11.3	-	-)
60 mg/l	-	91.2	8.8	-	-
120 mg/l	-	87.5	12.5	-	-
180 mg/l	-	88.7	10.0	1.2	-
SED (20 df)	-	*5.75*	*5.47*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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			Gold Marbling		
Week 39	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	90.0	8.8	1.2	-)
60 mg/l	-	87.5	11.3	1.2	-
120 mg/l	-	83.7	16.3	-	-
180 mg/l	-	85.0	15.0	-	-
SED (20 df)	-	*6.60*	*6.80*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Gold Marbling		
Week 41	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	86.2	12.5	1.2	-)
60 mg/l	-	81.2	18.8	-	-
120 mg/l	-	71.3	21.3	7.5	-
180 mg/l	-	80.0	17.5	2.5	-
SED (20 df)	-	*6.90*	*4.82*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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			Blotchy Ripening		
Week 23	Class Ia	Class Ib	Class Ic	Class II	Waste
30 mg/l	23.8	7.5	62.5	6.3	-
60 mg/l	26.3	15.0	56.3	2.5	-
120 mg/l	23.8	11.3	60.0	5.0	-
180 mg/l	22.5	17.5	52.5	7.5	-
SED (20 df)	*7.10*	*6.75*	*8.65*	*4.55*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Blotchy Ripening		
Week 25	Class Ia	Class Ib	Class Ic	Class II	Waste
(30 mg/l	10.0	45.0	32.5	12.5	-)
60 mg/l	2.5	65.0	31.3	1.3	-
120 mg/l	2.5	52.5	33.8	11.3	-
180 mg/l	6.3	41.3	37.5	13.8	-
SED (20 df)	*3.19*	*5.85*	*5.57*	*3.95*	-
LSD 5%	-	*12.2*	-	*8.2*	-
Significance	*N.S.*	**	*N.S.*	*	*N.S.*

			Blotchy Ripening		
Week 27	Class Ia	Class Ib	Class Ic	Class II	Waste
(30 mg/l	3.8	61.3	31.3	3.8	-)
60 mg/l	2.5	67.5	26.3	3.7	-
120 mg/l	0	57.5	37.5	5.0	-
180 mg/l	5.0	65.0	26.3	3.8	-
SED (20 df)	-	*6.35*	*7.17*	*3.16*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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Week 31	Class Ia	Class Ib	Blotchy Ripening Class Ic	Class II	Waste
(30 mg/l	16.3	47.5	21.3	15.0	-)
60 mg/l	18.8	38.8	33.8	8.8	-
120 mg/l	18.8	42.5	31.3	7.5	-
180 mg/l	17.5	52.5	21.3	8.8	-
SED (20 df)	*6.03*	*8.47*	*3.03*	*5.01*	-
LSD 5%	-	-	*6.3*	-	-
Significance	*N.S.*	*N.S.*	*	*N.S.*	*N.S.*

Week 33	Class Ia	Class Ib	Blotchy Ripening Class Ic	Class II	Waste
(30 mg/l	-	67.5	25.0	7.5	-)
60 mg/l	-	57.5	40.0	2.5	-
120 mg/l	1.2	75.0	22.5	1.2	-
180 mg/l	-	68.8	30.0	1.2	-
SED (20 df)	·	*7.70*	*7.41*	*2.07*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 35	Class Ia	Class Ib	Blotchy Ripening Class Ic	Class II	Waste
(30 mg/l	1.2	70.0	25.0	3.8	-)
60 mg/l	2.5	77.5	17.5	2.5	-
120 mg/l	-	78.8	18.8	2.5	-
180 mg/l	-	60.0	35.0	5.0	-
SED (20 df)	-	*7.61*	*6.25*	*3.47*	-
LSD 5%	-	*15.9*	*13.0*	-	-
Significance	*N.S.*	*	*	*N.S.*	*N.S.*

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			Blotchy Ripening		
Week 37	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	68.8	27.5	3.7	-)
60 mg/l	1.2	81.2	17.5	-	-
120 mg/l	2.5	83.7	12.5	1.2	-
180 mg/l	1.2	85.0	13.8	-	-
SED (20 df)	-	*8.37*	*8.26*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Blotchy Ripening		
Week 39	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	2.5	82.5	15.0	-	-)
60 mg/l	-	72.5	27.5	-	-
120 mg/l	-	75.0	23.8	1.2	-
180 mg/l	-	75.0	25.0	-	-
SED (20 df)	-	*6.15*	*6.13*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

			Blotchy Ripening		
Week 41	**Class Ia**	**Class Ib**	**Class Ic**	**Class II**	**Waste**
(30 mg/l	-	81.2	18.8	-	-)
60 mg/l	1.2	70.0	28.8	-	-
120 mg/l	-	70.0	21.3	-	-
180 mg/l	-	66.3	31.3	2.5	-
SED (20 df)	-	*7.92*	*7.06*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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Week 23	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	58.8	5.0	28.8	7.5	-)
60 mg/l	60.0	3.8	30.0	6.3	-
120 mg/l	42.5	10.0	32.5	15.0	-
180 mg/l	53.8	5.0	23.8	17.5	-
SED (20 df)	*12.54*	*4.39*	*12.98*	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 27	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	35.0	20.0	33.8	11.3	-)
60 mg/l	60.0	18.8	11.3	10.0	-
120 mg/l	46.3	26.3	22.5	5.0	-
180 mg/l	61.3	13.8	15.0	10.0	-
SED (20 df)	*14.49*	*6.19*	*6.46*	*7.38*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 29	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	75.0	15.0	6.3	3.8	-)
60 mg/l	22.5	27.5	22.5	25.0	2.5
120 mg/l	7.5	28.8	18.8	37.5	7.5
180 mg/l	23.8	22.5	26.3	22.5	5.0
SED (20 df)	*8.20*	*8.20*	*6.32*	*8.58*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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Week 31	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	11.3	55.0	18.8	15.0	-)
60 mg/l	1.3	45.0	15.0	38.8	-
120 mg/l	7.5	46.3	25.0	21.3	-
180 mg/l	5.0	37.5	21.3	36.3	-
SED (20 df)	*7.73*	*8.85*	*7.21*	*10.15*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 33	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	23.8	50.0	18.8	7.5	1.2)
60 mg/l	7.5	56.3	22.5	12.5	1.2
120 mg/l	15.0	51.3	26.3	7.5	-
180 mg/l	2.5	53.8	20.0	22.5	1.2
SED (20 df)	*7.86*	*13.08*	*13.08*	*6.34*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 35	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	21.3	65.0	10.0	3.8	-)
60 mg/l	15.0	70.0	10.0	5.0	-
120 mg/l	6.3	66.3	13.8	12.5	1.2
180 mg/l	5.0	66.3	15.0	13.8	-
SED (20 df)	*5.59*	*8.23*	*5.29*	*6.51*	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

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Week 37	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	51.3	35.0	10.0	3.8	-)
60 mg/l	16.3	57.5	21.3	5.0	-
120 mg/l	37.5	45.0	10.0	7.5	-
180 mg/l	51.3	42.5	3.7	2.5	-
SED (20 df)	*9.74*	*9.80*	*5.40*	*4.02*	-
LSD 5%	*20.3*	-	*11.3*	-	-
Significance	**	*N.S.*	*	*N.S.*	*N.S.*

Week 39	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	93.7	6.3	-	-	-)
60 mg/l	78.8	16.3	4.9	-	-
120 mg/l	87.5	8.8	3.7	-	-
180 mg/l	85.0	13.8	1.2	-	-
SED (20 df)	*8.54*	*7.45*	-	-	-
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 41	Class Ia	Class Ib	Cracking Class Ic	Class II	Waste
(30 mg/l	78.8	18.8	2.5	-	-)
60 mg/l	40.0	53.8	6.3	-	-
120 mg/l	15.0	67.5	12.5	5.0	-
180 mg/l	28.8	61.3	8.8	1.2	-
SED (20 df)	*8.50*	*6.67*	*5.64*	-	-
LSD 5%	*17.7*	-	-	-	-
Significance	*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX VIII

Effect of nutrition regime on shelf-life and internal composition

Week 15	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	3.13	2.80	9.86	5.11	7.06
60 mg/l	3.25	2.86	10.17	4.60	6.34
120 mg/l	3.31	2.72	9.39	4.73	6.48
180 mg/l	3.21	2.84	9.24	4.60	6.18
SED (20 df)	*0.061*	*0.144*	*0.159*	*0.084*	*0.096*
LSD 5%	*0.127*	-	*0.331*	*0.176*	*0.200*
Significance	*	*N.S.*	***	***	***

Week 17	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	3.14	2.96	9.33	5.76	7.70
60 mg/l	3.32	3.02	9.82	5.14	6.61
120 mg/l	3.32	3.00	9.34	5.16	6.63
180 mg/l	3.13	2.87	9.36	4.96	6.30
SED (20 df)	*0.077*	*0.120*	*0.121*	*0.079*	*0.099*
LSD 5%	*0.161*	-	*0.252*	*0.165*	*0.206*
Significance	*	*N.S.*	**	***	***

Week 19	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	3.15	3.16	9.12	5.61	7.72
60 mg/l	3.14	3.10	9.78	4.90	6.70
120 mg/l	3.24	2.82	9.24	4.99	6.75
180 mg/l	3.07	2.80	9.21	4.79	6.49
SED (20 df)	*0.055*	*0.142*	*0.173*	*0.112*	*0.099*
LSD 5%	*0.114*	*0.295*	*0.361*	*0.234*	*0.205*
Significance	*	*	**	***	***

APPENDIX VIII

Effect of nutrition regime on shelf-life and internal composition

Week 7	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	2.71	2.32	8.04	4.38	5.99
60 mg/l	2.75	2.40	8.01	4.39	5.97
120 mg/l	2.86	2.44	7.94	4.44	5.99
180 mg/l	2.77	2.47	7.80	4.41	5.96
SED (20 df)	*0.066*	*0.062*	*0.102*	*0.096*	*0.067*
LSD 5%	-	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 9	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	2.99	2.47	9.87	4.25	5.93
60 mg/l	3.12	2.77	9.47	4.23	5.91
120 mg/l	3.07	2.55	9.27	4.21	5.89
180 mg/l	2.98	2.61	9.23	4.23	5.89
SED (20 df)	*0.050*	*0.092*	*0.109*	*0.062*	*0.074*
LSD 5%	*0.104*	*0.192*	*0.227*	-	-
Significance	*	*	***	*N.S.*	*N.S.*

Week 11	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	2.97	2.39	9.96	4.58	6.46
60 mg/l	2.97	2.51	9.63	4.48	6.23
120 mg/l	3.04	2.64	9.47	4.49	6.18
180 mg/l	3.13	2.75	9.38	4.40	6.15
SED (20 df)	*0.039*	*0.148*	*0.134*	*0.049*	*0.051*
LSD 5%	*0.081*	-	*0.278*	*0.102*	*0.106*
Significance	**	*N.S.*	**	*	***

APPENDIX VIII

Effect of nutrition regime on shelf-life and internal composition

Week 21	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	3.62	4.29	9.78	5.24	6.83
60 mg/l	3.24	2.92	9.89	5.04	6.40
120 mg/l	3.30	2.94	9.33	5.14	6.58
180 mg/l	3.22	2.76	9.04	5.06	6.35
SED (20 df)	*0.074*	*0.160*	*0.143*	*0.118*	*0.114*
LSD 5%	*0.155*	*0.334*	*0.297*	-	*0.237*
Significance	***	***	***	*N.S.*	**

Week 23	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
30 mg/l	3.79	4.73	9.90	5.28	6.75
60 mg/l	3.15	2.84	10.02	5.44	6.73
120 mg/l	3.06	2.87	9.48	5.56	6.69
180 mg/l	2.98	2.51	9.14	5.28	6.50
SED (20 df)	*0.082*	*0.195*	*0.161*	*0.105*	*0.094*
LSD 5%	*0.172*	*0.406*	*0.335*	*0.219*	-
Significance	***	***	***	*	*N.S.*

Week 25	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	3.66	5.19	9.27	5.35	7.00)
60 mg/l	3.09	3.01	9.60	5.46	7.20
120 mg/l	3.08	2.94	8.91	5.43	7.20
180 mg/l	2.99	2.54	8.39	5.70	7.44
SED (20 df)	*0.084*	*0.342*	*0.103*	*0.074*	*0.071*
LSD 5%	-	-	*0.215*	*0.154*	*0.148*
Significance	*N.S.*	*N.S.*	***	**	**

APPENDIX VIII

Effect of nutrition regime on shelf-life and internal composition

Week 27	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	3.92	5.87	9.22	5.14	6.75)
60 mg/l	3.41	3.65	9.39	5.38	7.17
120 mg/l	3.22	3.24	8.92	5.48	6.92
180 mg/l	3.30	3.18	8.27	5.61	7.18
SED (20 df)	*0.090*	*0.293*	*0.157*	*0.081*	*0.236*
LSD 5%	-	-	*0.328*	*0.170*	-
Significance	*N.S.*	*N.S.*	***	*	*N.S.*

Week 31	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	3.62	6.14	9.52	4.90	6.00)
60 mg/l	3.91	7.77	9.54	5.19	6.37
120 mg/l	3.60	5.91	9.44	5.12	6.35
180 mg/l	3.57	5.89	9.17	5.16	6.47
SED (20 df)	*0.072*	*0.306*	*0.163*	*0.063*	*0.080*
LSD 5%	*0.151*	*0.638*	-	-	-
Significance	***	***	*N.S.*	*N.S.*	*N.S.*

Week 33	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	2.99	3.88	9.46	4.56	6.04)
60 mg/l	3.37	5.28	9.71	4.74	6.12
120 mg/l	3.01	3.80	9.59	4.79	6.32
180 mg/l	3.08	4.17	9.25	4.76	6.13
SED (20 df)	*0.069*	*0.273*	*0.125*	*0.061*	*0.066*
LSD 5%	*0.144*	*0.570*	*0.261*	-	*0.137*
Significance	***	***	**	*N.S.*	**

APPENDIX VIII

Effect of nutrition regime on shelf-life and internal composition

Week 35	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	3.12	4.66	9.91	4.56	6.16)
60 mg/l	3.36	6.03	9.57	4.69	6.07
120 mg/l	3.11	4.58	9.15	4.83	6.43
180 mg/l	3.00	4.82	9.18	4.81	6.27
SED (20 df)	*0.085*	*0.396*	*0.137*	*0.105*	*0.062*
LSD 5%	*0.177*	*0.826*	*0.286*	-	*0.129*
Significance	**	**	*	*N.S.*	***

Week 37	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	3.24	4.34	10.13	4.58	6.08)
60 mg/l	3.49	5.81	10.05	4.60	5.79
120 mg/l	3.43	4.99	9.84	4.66	6.02
180 mg/l	3.22	4.53	9.90	4.70	6.00
SED (20 df)	*0.076*	*0.326*	*0.122*	*0.084*	*0.065*
LSD 5%	*0.159*	*0.680*	-	-	*0.136*
Significance	**	**	*N.S.*	*N.S.*	**

Week 39	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	3.45	4.39	10.24	4.90	6.12)
60 mg/l	3.51	5.98	10.07	4.99	5.92
120 mg/l	3.33	5.16	9.43	5.05	6.24
180 mg/l	3.28	4.91	9.46	5.20	6.21
SED (20 df)	*0.092*	*0.421*	*0.159*	*0.102*	*0.075*
LSD 5%	*0.191*	*0.878*	*0.332*	-	*0.156*
Significance	*	*	**	*N.S.*	***

APPENDIX VIII

Effect of nutrition regime on shelf-life and internal composition

Week 41	Compression	% Weight Loss	Endpoint pH	% Soluble Solids	% Dry Matter
(30 mg/l	3.45	5.09	10.17	4.71	6.00)
60 mg/l	3.58	5.83	10.16	4.85	6.00
120 mg/l	3.54	5.98	9.78	4.95	6.11
180 mg/l	3.44	5.82	9.67	4.98	6.17
SED (20 df)	*0.147*	*0.712*	*0.161*	*0.071*	*0.083*
LSD 5%	-	-	*0.335*	-	-
Significance	*N.S.*	*N.S.*	*	*N.S.*	*N.S.*

APPENDIX IX

Effect of nutrition regime on taste panel assessments of texture and flavour

Week 12	'Sweetness'	'Sharpness'	'Toughness'	'Overall Goodness
30 mg/l	0.44	0.13	-0.19	0.69
60 mg/l	0.31	0.00	0.00	0.06
120 mg/l	0.13	0.06	-0.38	0.31
180 mg/l	-0.06	-0.13	0.06	-0.13
SED (20 df)	*0.41*	*0.35*	*0.23*	*0.32*
LSD 5%	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 20	'Sweetness'	'Sharpness'	'Toughness'	'Overall Goodness
30 mg/l	0.19	0.25	0.31	0.13
60 mg/l	0.38	-0.06	-0.13	0.13
120 mg/l	-0.06	-0.06	0.25	-0.06
180 mg/l	-0.25	0.19	0.00	0.31
SED (20 df)	*0.38*	*0.38*	*0.34*	*0.36*
LSD 5%	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*

Week 28	'Sweetness'	'Sharpness'	'Toughness'	'Overall Goodness
30 mg/l	-0.63	0.88	0.63	-0.51
60 mg/l	0.63	-0.13	0.38	0.75
120 mg/l	0.25	0.13	0.38	0.25
180 mg/l	0.13	-0.25	1.00	-0.25
SED (20 df)	*0.55*	*0.54*	*0.39*	*0.52*
LSD 5%	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX IX

Effect of nutrition regime on taste panel assessments of texture and flavour

Week 40	'Sweetness'	'Sharpness'	'Toughness'	'Overall Goodness
30 mg/l	-0.13	-0.50	0.13	0.00
60 mg/l	0.00	0.25	0.63	-0.38
120 mg/l	-0.88	0.50	1.13	-0.75
180 mg/l	-0.63	-0.38	0.38	-0.63
SED (20 df)	*0.65*	*0.52*	*0.40*	*0.42*
LSD 5%	-	-	-	-
Significance	*N.S.*	*N.S.*	*N.S.*	*N.S.*

APPENDIX X

Effect of nutrition regime on the average Nitrogen content of stem, leaf and fruit

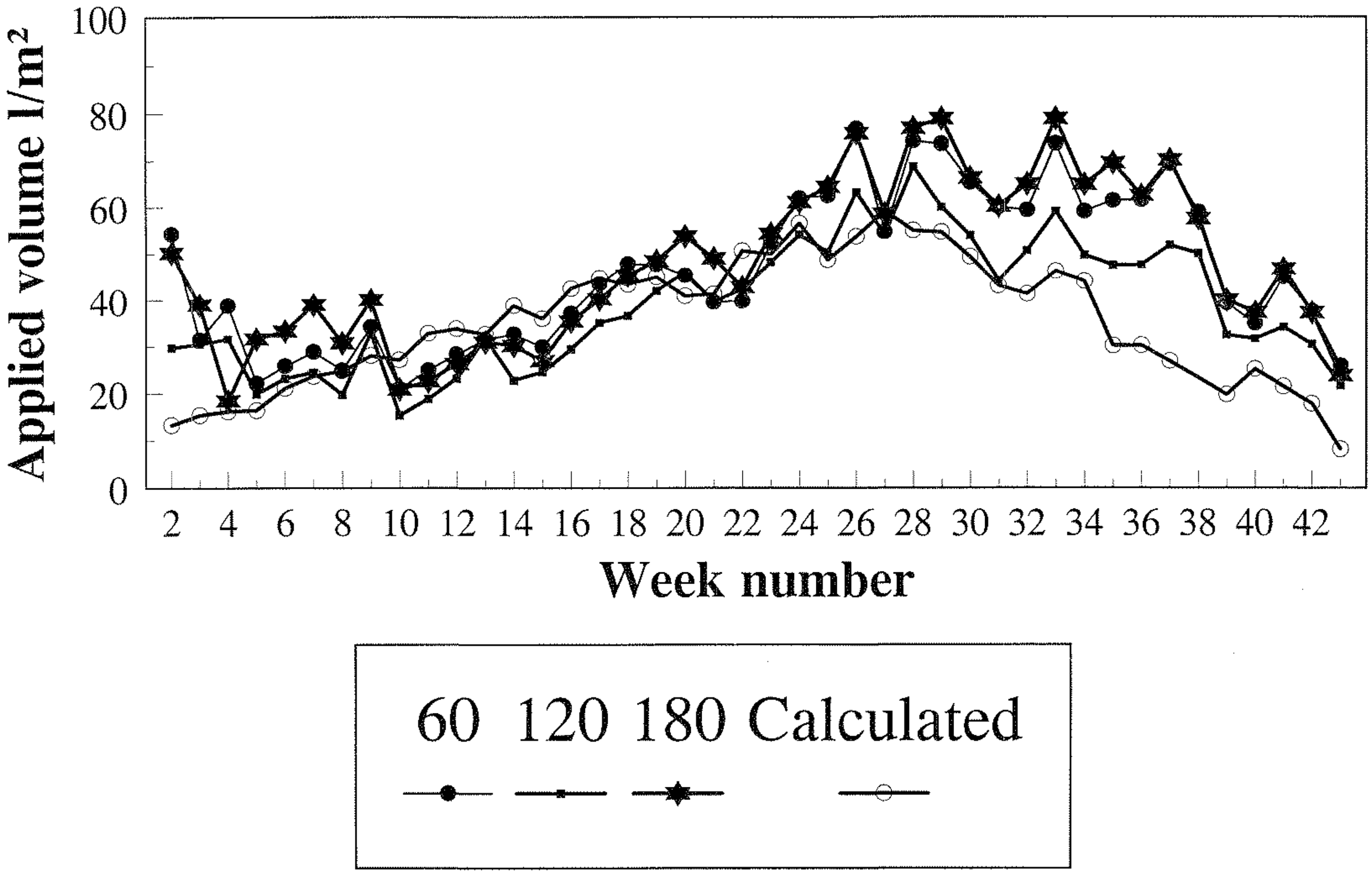
Treatment	% N of dry matter Stem	 Leaf	 Fruit
60 mg/l	1.16	2.59	1.51
120 mg/l	1.29	2.74	1.56
180 mg/l	1.39	2.80	1.56

Leaf material includes deleafings, sideshoots removal, tops removed at stopping and leaf remaining on the plant at the end of the season.

Effect of nutrition regime on total dry matter production g/m²

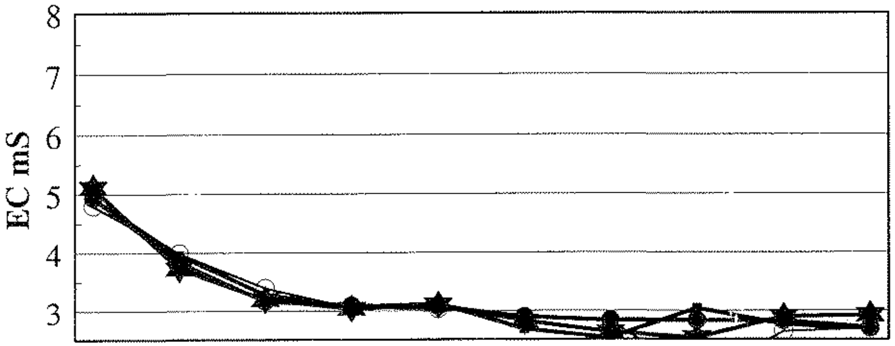
Treatment	Stem	Leaf	Fruit	Total
60 mg/l	476	613	2962	4051
120 mg/l	560	785	3376	4720
180 mg/l	578	811	3523	4912

Appendix XI. Volumes of feed applied for 60, 120 and 180 mg/l treatments as measured and calculated



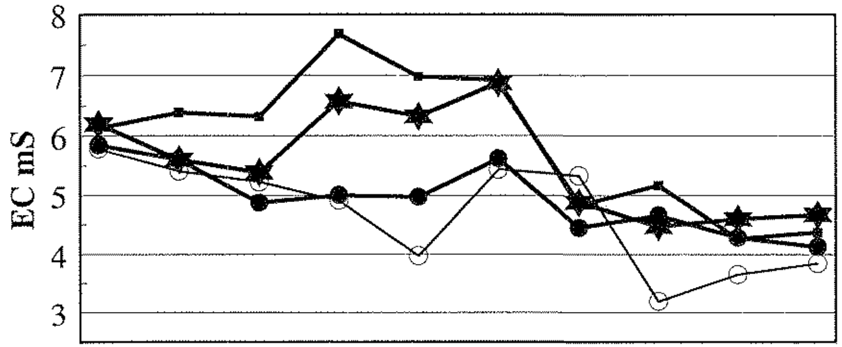
Appendix XII
Applied and slab EC and pH for the four nutritional treatments

Applied EC



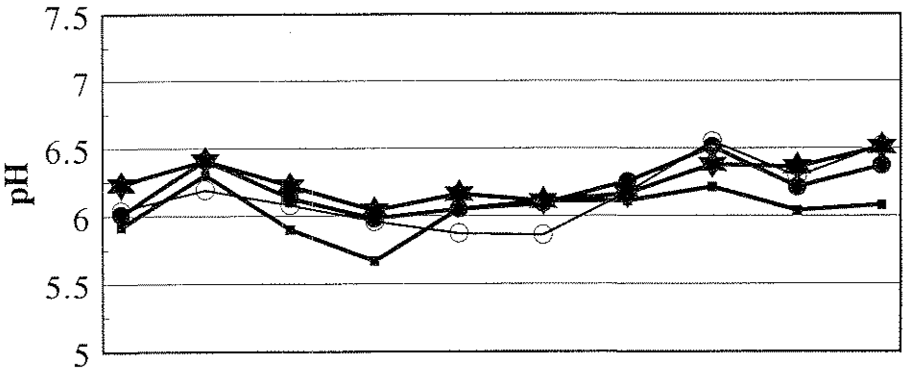
Month	Jan	Fed	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
30 ⊖	4.80	3.99	3.39	3.05	3.03	2.88	2.82	1.85	2.64	2.69
60 ●	4.94	3.84	3.16	3.09	3.07	2.89	2.83	2.83	2.82	2.70
120 ▬	4.93	3.96	3.28	3.07	3.12	2.68	2.53	3.04	2.76	2.68
180 ✱	5.11	3.73	3.19	3.04	3.10	2.82	2.63	2.53	2.89	2.92

Slab EC



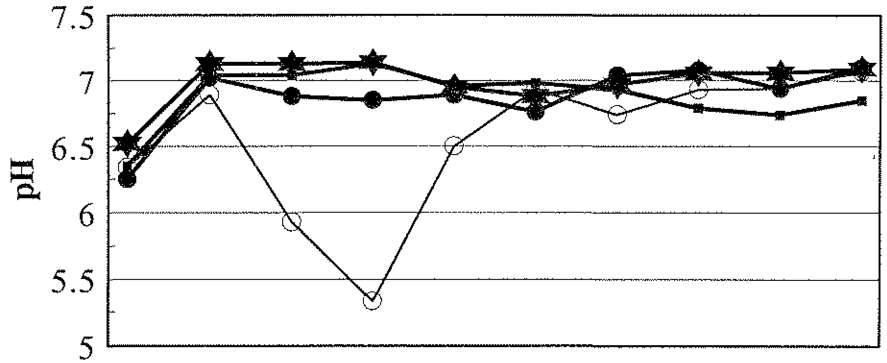
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
30 ⊖	5.78	5.41	5.23	4.91	3.97	5.44	5.33	3.19	3.65	3.84
60 ●	5.84	5.60	4.87	5.00	4.97	5.62	4.45	4.66	4.28	4.12
120 ▬	6.12	6.39	6.32	7.68	6.98	6.92	4.82	5.17	4.26	4.37
180 ✱	6.19	5.60	5.39	6.58	6.32	6.88	4.88	4.47	4.60	4.67

Applied pH



Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
30 ⊖	6.04	6.19	6.08	5.96	5.87	5.86	6.17	6.55	6.29	6.52
60 ●	6.01	6.41	6.13	5.98	6.05	6.09	6.25	6.51	6.21	6.37
120 ▬	5.92	6.30	5.90	5.67	6.05	6.11	6.11	6.21	6.04	6.08
180 ✱	6.23	6.41	6.22	6.04	6.16	6.11	6.16	6.38	6.36	6.51

Slab pH



Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
30 ⊖	6.34	6.89	5.93	5.33	6.50	6.93	6.74	6.93	6.94	7.07
60 ●	6.25	7.02	6.88	6.85	6.89	6.76	7.04	7.08	6.94	7.10
120 ▬	6.35	7.04	7.04	7.13	6.96	6.98	6.93	6.79	6.74	6.85
180 ✱	6.52	7.13	7.13	7.14	6.95	6.88	6.97	7.06	7.06	7.09

APPENDIX XIII

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

1. TITLE OF PROJECT

Contract No: PC/55a
Contract Date: 27.10.92

THE INFLUENCE OF REDUCED NITRATE INPUT ON TOMATO YIELD AND FRUIT QUALITY

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Work on the nutrition of a long season tomato crop undertaken at HRI Efford throughout the 1991-92 season, has clearly demonstrated the facility for partial substitution of Potassium Nitrate with Potassium Chloride or the Chloride and Nitrate salts of Calcium. To date this has been achieved with little or no detrimental effects on yield or fruit quality. Reflecting current commercial practice, it is proposed that a further study is undertaken to fully evaluate the degree to which nitrate input may be reduced. Such a study not only has clear environmental implications, but if successful represents a nett saving to the grower as Potassium Chloride for example, is less expensive than Potassium Nitrate.

Nutritional manipulation of this type must also be evaluated in the context of changing husbandry practices. The increased uptake of the 'V'-system and its concomitant reduction in the volume of the root environment may place restrictions on the degree to which nitrate input may be safely reduced, relative to conventional techniques, where root competition is less of a limiting factor.

The commercial objectives of this study are therefore to:-

a. Evaluate the efficacy of Potassium Chloride as a substitute for Potassium Nitrate.

b. Quantify its effects on fruit physical characteristics, shelf life, yield and taste.

c. Further assess crop response as measured by nutritional uptake and run-off composition.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

The financial benefits to the industry while difficult to quantify are likely to be derived from improvements in fruit quality/flavour. Reduction in the use of Potassium Nitrate would clearly result in fertiliser savings and, although at present less quantifiable there are likely to be major environmental benefits.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

The study outlined in this proposal must aim to evaluate and quantify the benefits of substituting Potassium Chloride for

Potassium Nitrate and the resultant effects on crop growth, yield and fruit quality.

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

The effect of potassium nitrate and chloride and calcium nitrate and chloride on tomato yield and quality has been examined in earlier HDC-funded work at Efford (PC55).

6. DESCRIPTION OF THE WORK

Main treatments:

These will comprise four target nitrate levels in the applied feed of 60, 120, 180 and 240 ppm; to commence coincident with, or slightly before first fruit pick.

Treatments will be achieved by the following mixtures of Potassium Chloride and Potassium Nitrate.

1. 100% Potassium Chloride.

2. 33% Potassium Nitrate, 66% Potassium Chloride

3. 66% Potassium Nitrate, 33% Potassium Chloride

4. 100% Potassium Nitrate.

These regimes will result in levels of NO_3-N of 65, 125, 185 and 247 ppm for 1-4 respectively.

Sub treatments:

It is proposed that the specified nutrient regimes be applied to the single variety Calypso, grown both as a conventional double row and 'V'-system crop. This would facilitate a study of the possible interactions between low nitrate input and root volume.

Each of the eight treatments (four nitrate levels x 2 row types) will be replicated four times. Allocation of individual treatments to the resultant 32 plots will aim to maximise the precision with which statistical analyses can separate nutritional and nutritional x row type effects. A full experimental plan would be provided following consultation with the statistician. The trial will occupy approximately 320 m^2 of glasshouse space with individual plots comprising c.16 plants. Provision will be made for guard rows immediately adjacent to the sides of the trial.

Nutrient regimes would be controlled using dedicated hardware installed during the Autumn of 1991 and used successfully throughout the current season.

The precise husbandry requirements will follow best commercial practice, and be the subject of a more detailed experimental protocol.

Records taken would include:

1. Graded and total marketable yield, percentage class I fruit.

2. Average fruit weight within grade to be determined every 2 weeks.

3. Assessment of fruit quality; to include physical fruit appearance, shelf life studies and fruit sugar and acid levels.

Shelf life: based on 10 class I D grade fruit per plot taken every second week. Following 6 days under standard conditions, fruit firmness, % weight loss and the % dry matter content of each sample will be determined. Samples for sugar/acid determinations will be taken at the same time. Physical fruit defects will be assessed every alternate week.

4. Taste panel assessments to be undertaken on four occasions throughout the season.

5. Daily monitoring of root zone pH and conductivity for all nutrient regimes.

6. Routine analyses of applied feed and slab solution for nutritional content. To include N, P, K, Mg Ca all trace elements and Cl.

7. Monthly analyses of leaf and fruit tissue for mineral content. The plot size may require treatment replicates to be bulked.

8. Photographic record of crop development, where appropriate.

9. Full monitoring of the glasshouse aerial environment.

10. Date of first anthesis, first fruit pick, number of fruit set and the number of marketable fruit on truss 1-10 for four plants per plot.

11. Additional assessments as required, eg. the incidence of Blossom end rot. The latter would be carried out *in situ* with every other plant and every fifth truss being labelled. The number of fruit with BER and their location (truss position) could then be accurately monitored.

Availability of results

Interim results will be made available to the HDC and visiting groups throughout the season. A full report will be completed on behalf of the HDC at the end of the trial.

7. COMMENCEMENT DATE AND DURATION

Start date 01.10.92; duration 2 years.

The results from year 1 of the project will be reviewed in autumn 1993 and the treatments for year 2 of the project will be adjusted accordingly.

8. STAFF RESPONSIBILITIES

Project leader: Dr D J Hand - HRI Efford

9. LOCATION

HRI Efford (P-Block)

APPENDIX XIII

Contract No: PC/55a

TERMS AND CONDITIONS

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

Signed for the Contractor(s)

Signature..

Position..

Date..

Signed for the Contractor(s)

Signature..

Position..

Date..

Signed for the Council

Signature..

Position.......CHIEF EXECUTIVE.......

Date..........27.10.92..........