Final Report December 1995

HDC PC24b & PC24c

Chrysanthemums: Factors influencing quality of production of AYR Chrysanthemums - hydroponic systems and aspects of disease control

Dr D P Wilson
HRI Efford

Dr T Pettitt
HRI Efford

Co-ordinator: Mr D Abbott

Commenced: October 1992

Completed: December 1995

Key words: Chrysanthemums, All Year Round, Hydroponic, Soil-less production, Etradiazole, Low pH

PRINCIPAL WORKERS

HRI EFFORD

D. P. Wilson, BSc, PhD (Author of report)	Technical Officer (from October 1993)
A. R. Finlay, BSc, PhD	Technical Officer (until October 1993)
Mrs E. Hemming, BSc	Scientific Officer
Miss S. Williams, BSc	Assistant Scientific Officer
Miss S. Horsley	Assistant Scientific Officer
Mr C. Vigor	Nursery Staff
Mr M. Verran	Nursery Staff
Mr G. Stancer	Nursery Staff
T. Pettitt, BSc, PhD (Author of Pathology Section)	Pathologist

HRI LITTLEHAMPTON

Mr R. Edmonson, Msc	Statistician

HRI WELLESBOURNE

A. Entwhistle, BSc, PhD	Pathologist

HDC CO-ORDINATOR

Mr D Abbott

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 3-1-96

Report Authorised by .....
Signature

Dr M R Shipway
Head of Station
HRI Efford
Lymington
Hants
SO41 0LZ

Date 3-1-96

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

Period of investigation: October 1992 - March 1994
Date of issue of report: December 1995
No. of pages in report: 166
No. of copies of report: 6
This is copy no. 3 : Issued to Horticultural Development Council

CONTRACT REPORT

Chrysanthemums: Factors Influencing Quality of AYR Chyrsanthemums - Hydroponic Systems and Aspects of Disease Control

HDC PC24b & PC24c
1992/94

CONTENTS

Appendices

RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

Application

A range of treatments were evaluated on hydroponic growing systems with the aim of assessing potential disease suppression and risk as well as methods for reducing economic costs. In addition, applying post-planting etridiazole (as Aaterra) drenches to soil-grown plants was assessed as a spin-off treatment from hydroponic cultivation.

Hydroponic sand-based systems initially investigated in 1990/92 (PC24) continued to produce good quality crops which out-performed soil-grown crops over the winter periods of 1992/93 and 1993/94. Assessment of root systems indicated a low level of *Pythium* infection throughout (i.e. including soil-grown and hydroponic crops) with little response to the treatments applied. Seven successive plantings were successfully grown on the oldest sand-based system with no signs of yield decline. In contrast, yield of the fourth successive planting on soil with no sterilisation declined in comparison with freshly steam-sterilized soil. Reducing sand depth to cut capital costs had a slight negative impact on the crop but shows potential as a method for the future with refined irrigation regimes. Thin layer matting was also demonstrated to be a potentially successful alternative hydroponic system.

Summary

i. Background and trial details

Interest in hydroponic systems for AYR Chrysanthemums arose partly from the environmental benefits that closed systems provide in terms of minimising run-off of feed and pesticide residues into the sub-soil. This issue had become of particular interest following the introduction of legislation in Holland obliging protected crop producers to convert to closed systems. It has also been well demonstrated by the protected edibles industry that hydroponics have yield and quality advantages as a result of the high degree of control exerted over the root environment. Studies at HRI Efford funded by HDC (PC24) had demonstrated that a sand-based hydroponic system in particular could successfully produce AYR Chrysanthemums with benefits over the soil-grown crop in terms of increased fresh weight and leaf area as well as speed of production.

Several issues were raised regarding the hydroponic system developed including what disease risks are involved and how set-up costs may be reduced for it to become commercially viable. Work under projects PC24b (1992/93) and PC24c (1993/94) addressed these issues and assessed how the benefits of growing hydroponically may be applied to the standard soil-grown crop.

The trials in both years were conducted over the winter period with a November planting and a February flowering. A standard schedule of 28 long days and 10 days of interruption timed according to average light integral was maintained for both crops.

The first objective of these trials focused on how information from hydroponic cultivation may be applied to soil grown crops. One of the differences between these two production methods in previous trials was the use of the fungicide etridiazole (as Aaterra) in the feed solution for hydroponic crops and hence its continual presence in the growing medium. To assess if Aaterra may have contributed to the benefits observed, post-planting drenches of Aaterra at 0.5 g/l (applying 10 litres of solution per m^2), were applied at the following intervals:

- 2 days and 2½ weeks post planting
- 2 days, 2½ weeks and 5 weeks post planting.

These treatments were compared against a standard crop with no drenches and were assessed on both freshly steam-sterilized soil and soil which had previously grown three successive crops with no steaming treatments between them or prior to planting the trial.

The second objective was to assess methods of suppressing the incidence of root disease in hydroponic sand beds. Treatments included adding etridiazole (as Aaterra) to feed recirculation tanks (at 60 g per 1000 litres, replenished every 6 weeks) and lowering the pH of the recirculation solution to pH 4.5 (following indication from Dutch research that low pH will suppress *Pythium*). These treatments were assessed in the following combinations:

- Aaterra added, standard pH (5.8)
- Aaterra added, low pH (4.5)
- No Aaterra added, standard pH (5.8)
- No Aaterra added, low pH (4.5)

The above treatments were assessed on both new sand beds (i.e. planting I) and planting IV on sand beds with no sterilization treatments used between crops (i.e. where risk from root disease may be expected to have increased).

The third objective was to investigate the impact of repeated cropping on sand to assess the re-use potential of the system and hence how may crops the capital costs of setting up may be spread over. Repeated cropping treatments on sand and soil (with no sterilisation between crops) over the two years were as follows:

- Planting I (soil)
- Planting IV (soil)
- Planting I (sand)
- Planting IV (sand)
- Planting VII (sand)
- Planting VII (Probase)

The fourth objective also focused on improving the economics of hydroponic systems. In this investigation the impact of reducing the depth of sand (and therefore capital outlay) by half was assessed on new sand beds and replanted beds as follows:

- Planting I (sand - 15 cm depth)
- Planting I (sand - 7.5 cm depth)
- Planting IV (sand - 15 cm depth)
- Planting IV (sand - 7.5 cm depth)

Two further objectives were included in the PC24c (1993/94) trial only. The first of these investigated the potential for propagating cuttings directly into hydroponic sand beds with the aims of reducing production time by removing the shock of planting experienced with peat block stuck plants, as well as reducing propagation costs (i.e. labour and materials to manufacture peat blocks). Cuttings direct stuck in sand beds were treated in the same way as peat block stuck cuttings, but were stuck directly at final spacing and then kept in situ. The second of the additional objectives in PC24c was to assess a thin layer matting (which had previously been studied in Germany) as an alternative hydroponic system. The bed design for matting was a camber shape with side drainage channels. This was irrigated on a run-to-waste basis using the standard hydroponic feed applied as two minute pulses of feed through the low level irrigation every hour during the day period only (i.e. 07.00 - 18.00 hrs).

The varieties Snowdon and Delta were used in all investigations to represent both double and single commercial varieties. Assessments were made throughout development at the following key stages:

- end of long days
- start of interruption
- end of interruption
- maturity

ii. Results

Drenching soil-grown plants with Aaterra provided no consistent benefits over the two plantings assessed. Furthermore assessment of root systems indicated no differences in the incidence of *Pythium* infection in response to the drench treatments. Similarly there was no evidence from the Aaterra and low pH treatments on hydroponic sand beds that incidence of root disease was influenced by either of these disease control methods. Overall, however, assessments of root systems found only low levels of *Pythium* infection throughout the treatments assessed.

There was a marked difference between soil-grown crops and hydroponically grown crops in response to successive planting treatments. As expected, repeated cropping on soil quickly resulted in yield declines due to slower establishment and development, with clear differences between planting on freshly steam-sterilized soil and successive planting IV on soil. In contrast, crop development improved on sand-based hydroponic systems through successive planting (with no sterilization treatment between crops). Disease assessments found no increase in the incidence of *Pythium* infection in sand based systems, even up to successive planting VII.

Differences were observed in the comparison between full depth (15 cm) and half depth (7.5 cm) sand. Both planting I and planting IV on half depth sand had poorer early development. By final harvest however differences were small. In this trial both depths of sand were compared on the same irrigation regime which was apparently too wet for the half depth of sand. By modification of irrigation it is likely that improved performance on half depth sand may be achieved. There would therefore appear to be potential for saving costs by reducing sand depth without losing quality.

Direct sticking cuttings into sand beds was a very successful propagation method in the winter with benefits in terms of fresh weight and plant height recorded after the end of long days (or vegetative growth). This method of propagation would provide cost savings in terms of labour and capital required to produce peat blocks and transfer them for planting after propagation. These savings would however need to be balanced against less efficient use of space since direct sticking involves placing plants at final spacing 14 days earlier than peat block propagation where plants may be moved around.

Initial attempts at producing plants on a hydroponic system based on thin layer matting were also successful. Roots quickly established and grew through the matting material. At harvest, it was still possible to pull plants up in the conventional manner without damaging the matting material. This system as an observation was operated on a run-to-waste basis which would prove expensive in terms of lost feed. The suitability of matting systems in closed systems therefore warrants further investigation. The system may then provide an alternative to sand beds which is potentially easier to establish in existing nurseries.

iii. Application

PC24b and PC24b have further illustrated the potential for improving winter cropping through the use of hydroponic systems with additional benefits of reducing environmental pollution. The costs of establishing the sand-bed type system may be lower than originally anticipated since a smaller volume of sand may be suitable as the growing medium. In addition, setting up costs may be spread over at least seven crops before additional inputs are required to sterilize the growing medium. Irrigation control equipment would, of course, last longer than this. Other benefits of hydroponics would include faster turn around between crops since the requirement for sterilization treatment is at least reduced. Furthermore, rotovation and the application of base fertilizers between crops would not be necessary. The control over the root environment in terms of air/water balance as well as nutrition is much greater with these systems. A baseline of information on nutrition during cropping and as beds age has also been established through this work, which would be a useful reference for any future commercial applications.

INTRODUCTION

The commercial production of AYR Chrysanthemums both in the UK and in Europe continues to use the glasshouse soil as the main growing medium. Potential benefits of moving towards hydroponic cultivation have been well demonstrated by the protected edibles industry. Trials at HRI Efford funded by HDC (PC24) have also demonstrated the successful production of AYR Chrysanthemums in hydroponic systems, particularly where sand or Probase was used as the growing medium.

Coupled with the potential benefits in terms of production, closed hydroponic systems (i.e. where returning irrigation solution is recirculated) also reduce emission of nutrients and other chemicals into the sub-soil. Hence there is also a potential environmental benefit, which has become increasingly important in recent years. This is perhaps best demonstrated by the Dutch industry where the intensity of glasshouse production has led to the introduction of legislation requiring nurseries to convert to closed irrigation systems. There is a need therefore to gain relevant practical experience with closed systems for AYR Chrysanthemums in order to support the UK industry in the event that similar legislation is imposed either by the UK or EEC or that increased quality in imports from Dutch systems force growers into closed systems through marketing pressures.

Included in the many unanswered questions regarding hydroponic systems for AYR Chrysanthemums, is what are the disease risks, particularly where a closed system is operating? Linked to this question is what measures can be taken to minimize risks from disease spread? These questions have been addressed in PC24b and PC24c firstly through assessing the use of the fungicide etridiazole (as Aaterra) in the recirculating solution. Secondly, reflecting Dutch research work, treatments to lower the pH of the recirculating solution were assessed for effectiveness in the suppression of root disease pathogens.

Furthermore it is recognised that closed systems require relatively high investment to establish. Hence methods to reduce these costs were also assessed for their impact on plant performance and disease risks. These included assessing the re-use of hydroponic substrates without sterilisation between crops since prolonged re-use would permit the capital costs to be spread over a greater number of crops. The costs of bed sterilization in terms of labour and chemical or energy inputs would also be reduced. Reducing the quantity of substrate by, for example, reducing depth may also improve the economics of establishing closed systems.

Additional enhancement of the economics of hydroponic production may be achieved if the cropping time and material costs can be reduced by direct-sticking cuttings into hydroponic substrates rather than into conventional peat blocks. Potential also exists to reduce the length of crop schedule through direct-sticking and hence increase returns per unit area with time.

Research on hydroponic systems may also generate useful information for the soil-grown crop and an additional study will evaluate the use of etridiazole (as Aaterra - used routinely in the closed systems) on a soil-grown crop. This will be assessed on steam sterilised soil and soil which has previously been planted with crops but has not been steam sterilised to examine the treatment under conditions where the risk from root disease varies.

A final observation will focus on the use of 'alternative' hydroponic systems. Thin layer mats have been investigated by German researchers and a similar investigation will be included in the current trial for comparison with the sand bed system.

OBJECTIVES

The objectives were:

1. To evaluate the influence of etridiazole (as Aaterra) drenches on plant performance and disease incidence in a conventional soil-grown crop.

2. To evaluate the influence of the interaction between etridiazole (as Aaterra) and low pH treatments on plant performance and disease incidence in a hydroponic crop, both newly planted and following successive plantings.

3. To examine the effects of 'direct-sticking' cuttings into hydroponic substrate compared with conventional sticking in peat blocks.

4. To examine the effects on plant quality of successive planting in hydroponic substrates without sterilization between crops.

5. To assess the influence of reduced depth of sand in combination with successive plantings.

6. To observe the potential of thin layer matting as an alternative hydroponic system.

MATERIALS AND METHODS

1. The Influence of Etridiazole (as Aaterra) Drenches on Plant Performance in a Soil-Grown Crop.

In the first year (1992/93), three freshly steam sterilized beds were divided into three blocks to receive the following treatments:

A. No Aaterra application post-planting.

B. Aaterra drench 2 days and 2½ weeks post-planting.

C. Aaterra drench 2 days, 2½ weeks and 5 weeks post-planting.

Aaterra drenches at the rate of 0.5g/l (applying 10 litres of water per m^2)

Note: All peat blocks had Aaterra WP incorporated at 37 g/m^3 at mixing.

In the second year (1993/94), these treatments were repeated on just one soil bed. The bed was again divided into three blocks and treated as described above. In this case however, the bed had grown three previous successive crops without sterilization between crops and treatments were combined with the fourth successive crop (and hence increased risk of root disease) in this case.

2. The Interaction of Etridiazole (as Aaterra) with Low pH Treatments on Plant Performance in a Hydroponically Grown Crop.

In the first year (1992/93), treatments were assessed on fresh sand beds with no previous crops grown. In the second year (1993/94), treatments were assessed under conditions of successive planting, and the fourth successive crop with no sterilization treatments between crops was assessed.

Four beds were included in this trial with one of the following treatments on each bed.

1. Aaterra added, standard pH (5.8) nutrient solution.

2. Aaterra added, low pH (4.5) nutrient solution.

3. No Aaterra added, standard pH (5.8) nutrient solution.

4. No Aaterra added, low pH (4.5) nutrient solution.

Aaterra was added to the recirculating solution (where appropriate) at a rate of 60 g per 1000 litres of recirculating solution. This was replenished, at the same rate, every six weeks. The standard pH of 5.8 (from previous trials) was compared with a low pH of 4.5. The composition of nutrient solution had to be adjusted slightly to achieve the low pH treatment (Appendix I, page 93).

3. The Effects of 'Direct-Sticking' Cuttings into the Hydroponic Substrate.

Direct-sticking was assessed in the 1993/94 trial only. Plants were direct-stuck in sand beds on their fourth successive planting without sterilisation between crops. Comparisons were made under different conditions by direct-sticking cuttings in the four beds receiving the treatments described in 2 above. This included the 'standard' system with Aaterra incorporated in a nutrient solution set at pH 5.8. These beds also contained control plots where peat-block propagated plants were planted.

4. The Effects of Successive Planting in Hydroponic Substrates without Sterilization Between Crops.

In the first year (1992/93), fresh sand beds (i.e. planting I) were compared with the fourth successive planting (planting IV) without sterilization between crops on sand and Probase beds. Comparisons were also made with a conventional soil-crop (freshly steam sterilised soil) and planting IV on soil.

In the second year (1993/94), planting IV on sand beds was compared with planting VII on sand and Probase beds (all without sterilization treatments between crops). Comparisons were again also made with a conventional soil-crop on freshly steam sterilized soil.

5. The Influence of Reduced Depth of Sand in Combination with Successive Plantings.

In 1992/93, comparisons between sand depths of 15 cm (standard) and 7.5 cm (half-depth) were made on newly prepared sand beds. Due to the slope design of the bottom of the bed, the sand depth varied across the bed's width. Depths of sand were set at the centre of the bed (i.e. at the deepest part) and levelled to the edges.

In 1993/94, comparisons were made between 15 cm and 7.5 cm sand depths on the fourth successive crop (without sterilization between crops).

6. The Potential of Thin Layer Matting as an Alternative Hydroponic System.

Thin layer matting was investigated in 1993/94 only. A soil bed was profiled to produce a camber shape, sloping 1 in 100 from the central high point to each edge. A ditch was also dug out along each edge of the bed to allow excess nutrient solution to drain away. (The system was operated on a run to waste basis.)

The camber surface was covered firstly by black polythene to direct drainage to the side gutters and isolate the system from soil contamination. The 0.5 mm thick polyester mat was then laid out over the bed surface, with drip irrigation on the mat surface in the conventional layout (i.e. 6 lines evenly spaced across the width of the bed).

Cultural Methods and Conditions

i. Plant Material

Cuttings of Delta and Snowdon were purchased, unrooted from Yoder Toddington Limited.

ii. Propagation - Peat Blocks

Cuttings were stuck in peat blocks (5 cm x 5 cm x 3 cm) made from ICI blocking compost with Etridiazole (as Aaterra WP) at 37 g/m^3 at mixing. Bottom heating was used to achieve a compost temperature of 20^{0}C. After sticking, blocks were covered with clear polythene, sealed down at the edges. Covers were removed after 7 days to wean the plants. Plants were propagated for 14 days in this environment with night break lighting supplied for 5 hours per night using 100 watt tungsten lamps (8 minutes on, 8 minutes off cycle) to achieve a minimum light level of 100 lux.

Sprays of manocozeb (as Karamate Dry Flow) at 2.0 g/l^1 and deltamethrin (as Decis) at 0.7 ml/l^1 were applied four days after sticking. Iprodione (as Rovral WP) at 0.5 g/l was applied 2 days prior to planting.

iii. Propagation - Direct Sticking

Cuttings were stuck directly into the sand at conventional winter spacing (i.e. 85% using alternate plants only every third row). A standard nutrient solution (see Appendix I, page 93) was recirculated around the bed at standard frequency (i.e. 2 minutes pulse, 3 minutes pause). The controller for feed dosing was set at 1.1 mS/cm during initial establishment and was gradually raised to normal set point (1.52 mS/cm) as root initials formed on the cuttings (Appendix VI, plate 3, page 149). The sand beds and recirculating solution were maintained at greenhouse air temperatures throughout propagation.

Cuttings were covered with clear polythene which loosely sat on top of the cuttings and was sealed at the edges. The polythene was removed after 7 days. Night break light as described above was used during propagation of the direct-stuck cuttings.

Etridiazole (as Aaterra WP) was incorporated in the recirculating solution at 60 g per 1000 litres solution.

i. Crop Schedule

1992/93

Peat blocks were planted on all trial plots in week 45 at 85% density (i.e. alternate plants only every third row).

Plants were given long day lighting using 100 watt tungsten lamps to provide night break lighting for 5 hours with an 8 minutes on, 8 minutes off cycle. Long days were maintained until week 49, giving a total of 28 long days.

Initial short days were calculated according to PAR light integral with interruption commencing after 18 short days. Interruption lighting continued for 10 days before reverting to short day conditions until flowering.

1993/94

Peat blocks were planted on all trial plots in week 45 at 85% density (i.e. alternate plants only every third row).

Peat block stuck and direct-stuck plants were maintained in long day conditions (as described above) for 28 days (i.e. until week 49).

Initial short days were calculated according to PAR light integral with interruption commencing after 17 short days. The interruption continued for 10 days before reverting to short day conditions until flowering.

v. Glasshouse Environment

The temperature regime was set to heat to 18^{0}C day and night with ventilation at 21^{0}C. Thermal screen and blackout covers were drawn across at 1800 hrs and removed at 0700 hrs daily.

Enrichment with pure CO_2 was given to 1000 v.p.m. when vents were less than 5% open and to 500 v.p.m. with vents at or above 5% open.

vi. Nutrition, Growth Regulation and Pest and Disease Control

Nutrient solutions used for sand, Probase and matting hydroponic systems are specified in Appendix I, table 1 (page 94). The feed solution was applied via low level irrigation lines as a 2 minute pulse every 5 minutes day and night. Soil beds were irrigated via low level irrigation lines using the feed recipe in Appendix 1, table 2 (page 96). Frequency and volumes were calculated according to solar radiation levels.

Daminozide was applied (as B-Nine) to Snowdon two weeks after planting (at 1.0 g/l product or 850 mg/l active ingredient), at the start of short days (at 1.0 g/l product or 850 mg/l active ingredient) and at the start of interruption (0.5 g/l product or 425 mg/l active ingredient).

A routine programme alternating dichlorvos (as Nuvan 500 EC), malathion and endosulfan (as Thiodan) was used for the prevention of WFT with spot treatments of pirimicarb (as Pirimor) and heptenophos (as Hostaquick) for aphid control as necessary.

Etridiazole (as Aaterra WP) was added to recirculation tanks at 60 g per 1000 litres nutrient solution (unless otherwise detailed in specific treatments) for the control of root pathogens, particularly *Pythium* spp.

Assessments

Destructive samples were taken on each of 4 occasions as follows:

1992/93:
1. 2 days before the start of short days. (1/12/92)
2. At the end of interruption. (31/12/92)
3. 10 days after the end of interruption. (11/1/93)
4. At maturity (i.e. final harvest). (15/2/93)

1993/94:
1. 2 days before the start of short days. (6/12/93)
2. At the start of interruption. (23/12/93)
3. One week after the end of interruption. (6/1/94)
4. At maturity (i.e. final harvest). (18/2/94)

These samples were assessed on each occasion for plant performance as follows:

i. Stem length (cm) of 20 plants per treatment per variety.
ii. Fresh weight (g) of 20 plants per treatment per variety.
iii. Dry weight (g) of the bulk sample of 20 plants per treatment per variety.
iv. Leaf area (cm^2), 1992/93 only, of 5 plants per treatment per variety.

Each destructive sample was also sub-sampled for root systems (10 samples per plot 1992/93, 5 samples per plot 1993/94) which were assessed for root disease.

Foliage samples were taken from each plot at the mid-point and end of the crop for leaf mineral analysis.

At maturity, each plot was also harvested to commercial standard (Appendix VI, plate 2, page 148) and a record of mean bunch weight per grade and number of bunches per grade was taken. A sub-sample of plants was also assessed for shelf-life performance.

Shelf-life simulation included sleeving bunches and placing in a standard cut flower box with dry storage for day 1 at 2-5^{0}C (cold room) and dry storage on day 2 at 10-15^{0}C (packing shed). Stems were re-cut by removing 3-5 cm from the base, and placed in plain water (with no leaves below water level) on day 3, with fluorescent lighting 12 hours per day, and temperatures of 18-20^{0}C day and night and 70-80 % RH.

Recirculating tanks were monitored daily for pH and conductivity levels with fortnightly samples sent away for full mineral analysis.

Photographs were also taken as appropriate.

Statistical Analyses

Since the majority of individual treatments were not replicated, only limited valid statistical significance testing could be performed. A full analysis of variance with significance testing was carried out on the 1992/93 data assessing the influence of Etridiazole drenches on the soil-grown crop.

Statistical terms used include:

N.S.	Not significant
L.S.D.	The least (minimum) difference, when comparing 2 means within a given column, that is required for the means to be statistically different.
$P<0.05$	The probability of this result occurring by chance is equal to or less than 1 in 20 (0.05 = 5%).
$P<0.01$	The probability of this result occurring by chance is equal to or less than 1 in 100 (0.01 = 1%).
$P<0.001$	The probability of this result occurring by chance is equal to or less than 1 in 1000 (0.001 = 0.1%).

RESULTS

1. The Influence of Etridiazole (as Aaterra) Drenches on a Soil-Grown Crop

1.1 1992/93

1.1.1 Plant Performance

There were no significant differences in plant heights in response to Aaterra drench treatments (Figure 1a, page 18).

There were also no significant differences in fresh weights in response to the drench treatments for the first three samples assessed, or until the end of interruption (Figure 1b, page 18). By maturity (sample 4) however, a significant ($P<0.01$) increase in fresh weight was found for both treatments where Aaterra was applied (i.e. both the drenching at 2 days and 2½ weeks post-planting and at 2 days, 2½ weeks and 5 weeks post-planting). Snowdon was particularly responsive to this treatment with mean stem weight increases of 2.8 g and 5.2 g respectively for the two and three drench treatments in comparison with no drenching.

Since bulk dry weight was a single measure for each plot, it was not analysed statistically. It is clear from Figure 1c (page 18) however that these data followed the same trend as described above for fresh weight. As may therefore be expected, percentage dry matter (Figure 1d, page 19) was not apparently influenced by the drench treatments.

Leaf area was not significantly influenced by Aaterra drench treatments (Figure 1e, page 19). It should be noted that there was no increase in leaf area between samples 3 and 4 (i.e. when the plant was no longer growing vegetatively and was maturing). In some cases, leaf area actually decreased between samples 3 and 4 (e.g. Delta treated at 2 days and 2½ weeks post-planting with an Aaterra drench). This may partly be a result of loss of lower leaves as the plants matured and may also reflect the level of variability in this parameter from plant to plant within the same plot.

Harvest grade-out in terms of percentage of stems in grades 1, 2 and 3 was not generally influenced by drench treatment (Figure 3a, page 22). There is certainly no indication that the drench treatments increased the percentage of stems in the top grade or decreased the percentage of stems at grade 3.

Shelf-life of both varieties was not influenced by Aaterra drenching treatments (Appendix II, table 1a, page 98). The total shelf-life of Delta was overall 3.3 days longer than that of Snowdon.

Overall, there is some indication from the data that Aaterra drenching on a freshly steam sterilised bed increases individual stem weight (particularly for Snowdon) without increasing height (i.e. indicating greater stem strength). Other indicators of plant performance were not however influenced by the drenching treatment.

1.1.2 Disease Assessment

Low levels of *Pythium* spp infection were commonly detected in samples (Appendix III, page 103) but there were no differences detected between treatments in level of infection.

1.1.3 Mineral Analyses - Foliage Samples

The nutritional status of the plants (Appendix V, tables 1a and 1b, pages 133 and 134) was not affected by the drench treatments. The major nutrients analysed were all at least within the satisfactory range. Potassium (K) levels were notably high throughout the samples with a consequently low N:K ratio.

1.2 1993/94

1.2.1 Plant Performance

The Aaterra drench treatments produced similar results in 1993/94 when the soil bed assessed had previously grown three crops with no sterilisation treatment. It was not possible to test the 1993/94 data for significance however since the plots were no longer replicated. Figures of plant heights (Figure 2a, page 20), bulk dry weights (Figure 2c, page 20) and percentage dry matter (Figure 2d, page 21) all remained comparable across the treatments assessed. There was an increase in stem fresh weight (figure 2b, page 20) where Aaterra drenches had been applied to plots of Delta sampled at the end of long days. This early improved establishment was however less apparent as the plants developed and further destructive samples were assessed.

Shelf-life of Delta was again not influenced by Aaterra drench treatments (Appendix II, Table 1b, page 98). The onset of the first signs of deterioration of Snowdon was approximately 2.5 days faster following three Aaterra drenches (i.e. 2 days, 2½ weeks and 5 weeks). Total shelf-life was therefore also shorter for this treatment.

Harvest grade-out data (Figure 3b, page 22) again indicated no benefits either in terms of a greater proportion of grade 1 stems or a smaller proportion of grade 3 stems in relation to Aaterra drenching.

1.2.2 Disease Assessment

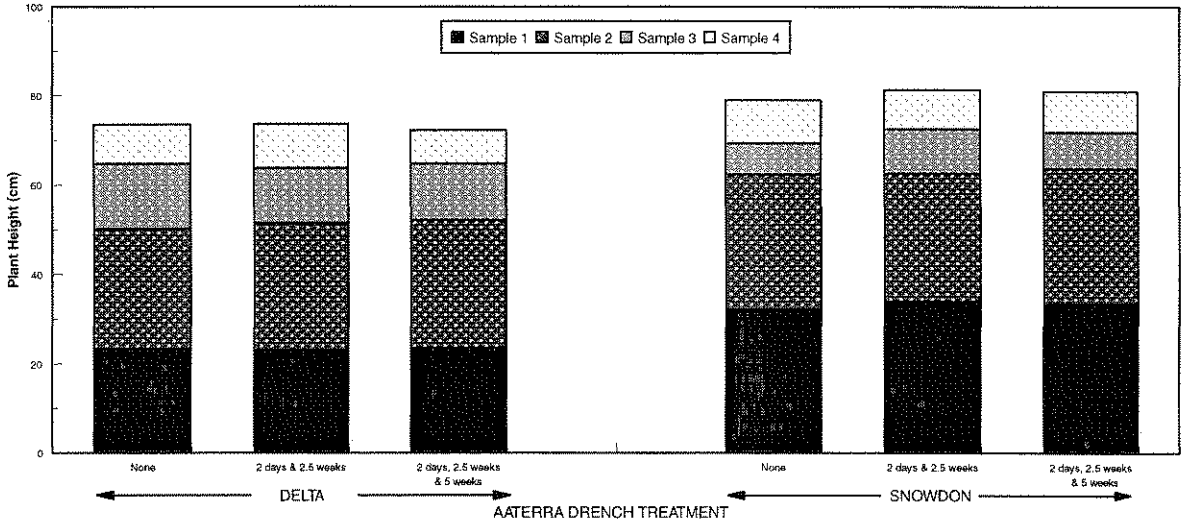
Infection by *Pythium* spp was again detected throughout the samples assessed (Appendix IV, page 112) with no apparent response to Aaterra drench treatments or symptoms of root rot in the plants themselves.

1.2.3 Mineral Analyses - Foliage Samples

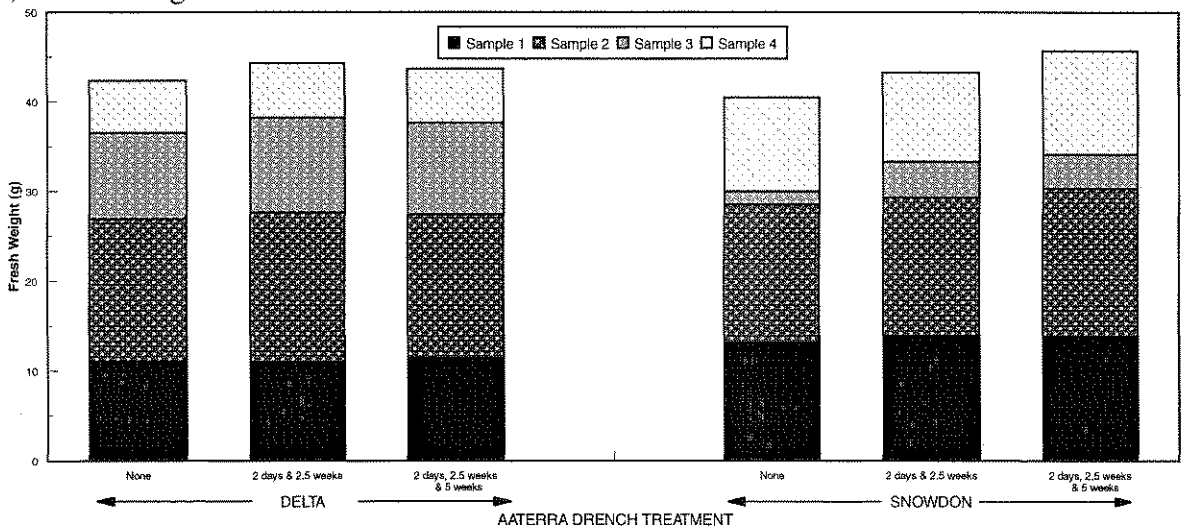
Drench treatments again had no apparent influence on nutritional status of the plants (Appendix V, tables 1c and 1d, pages 135 and 136). Potassium levels were lower in the 1993/94 samples compared with the previous year of the trial and hence N:K ratios were more acceptable. Boron and Copper were below satisfactory levels in some of the samples taken at maturity but it is not possible to link this to treatment differences.

Figure 1. The Influence of Aaterra Soil Drenches on Plant Performance (1992/93)

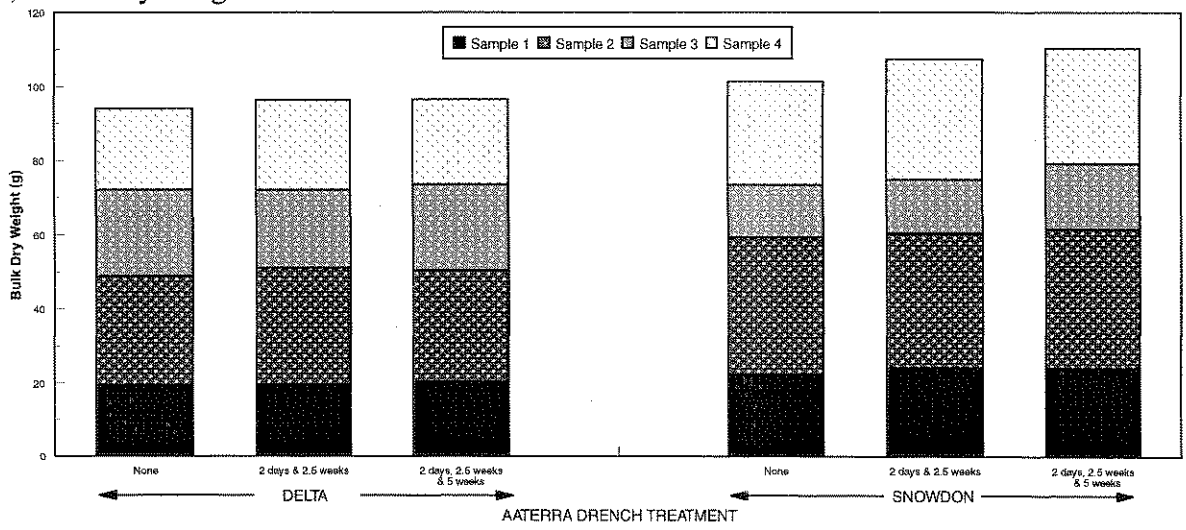
a, Plant height



b, Fresh weight



c, Bulk dry weight

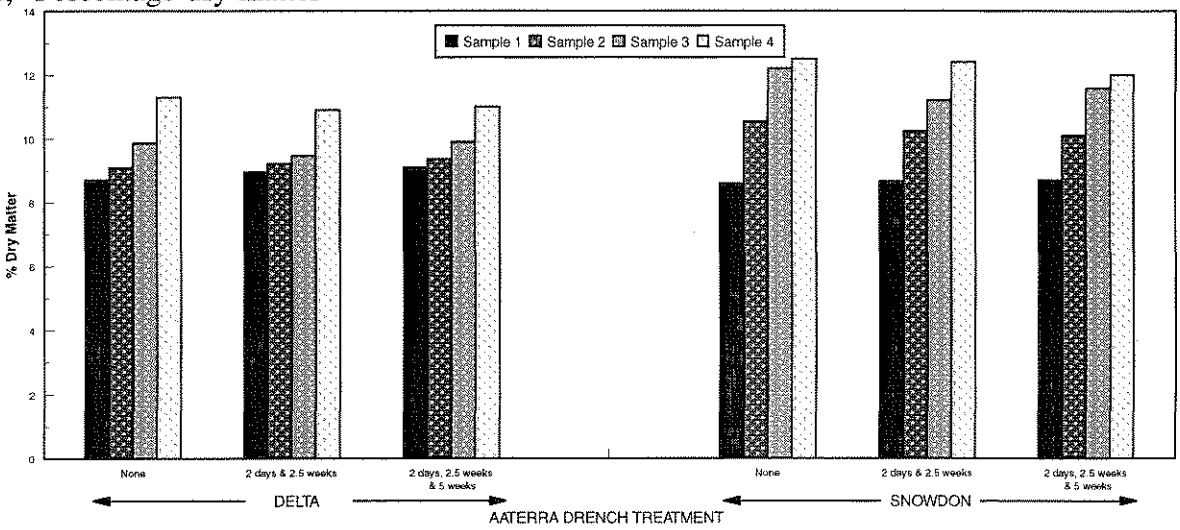


KEY TO CHARTS:

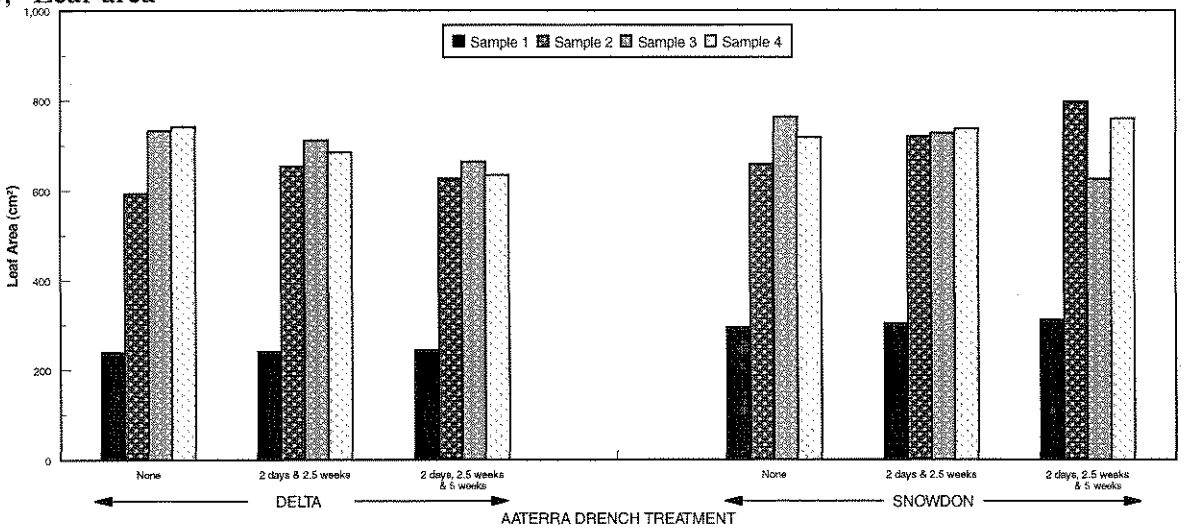
- Sample 1 - start of short days
- Sample 2 - end of interruption
- Sample 3 - 10 days after the end of interruption
- Sample 4 - final harvest

Figure 1.(Continued) The Influence of Aaterra Soil Drenches on Plant Performance (1992/93)

d, Percentage dry matter



e, Leaf area

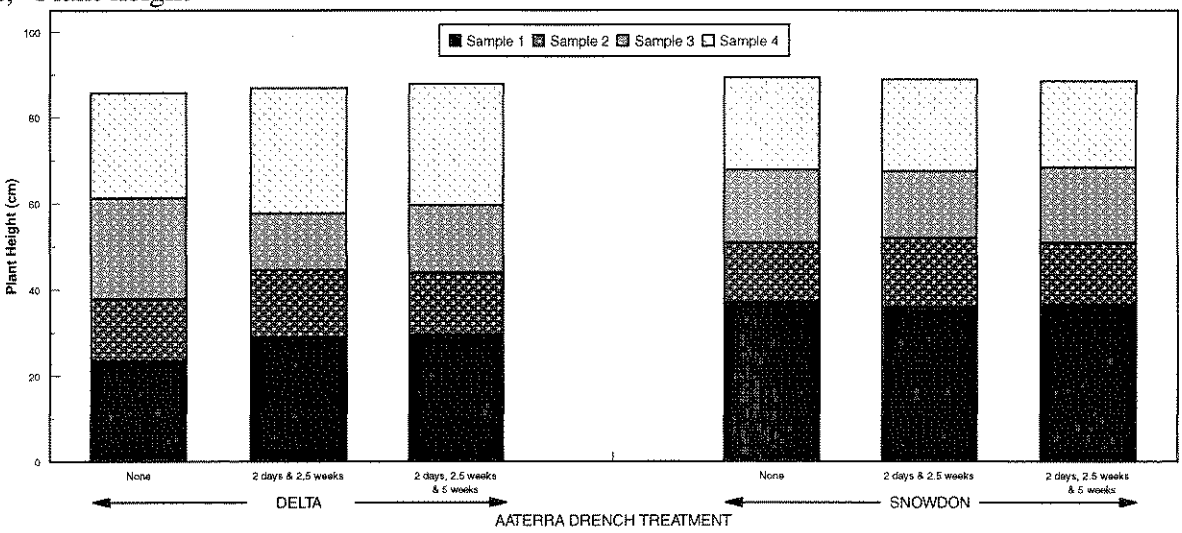


KEY TO CHARTS:

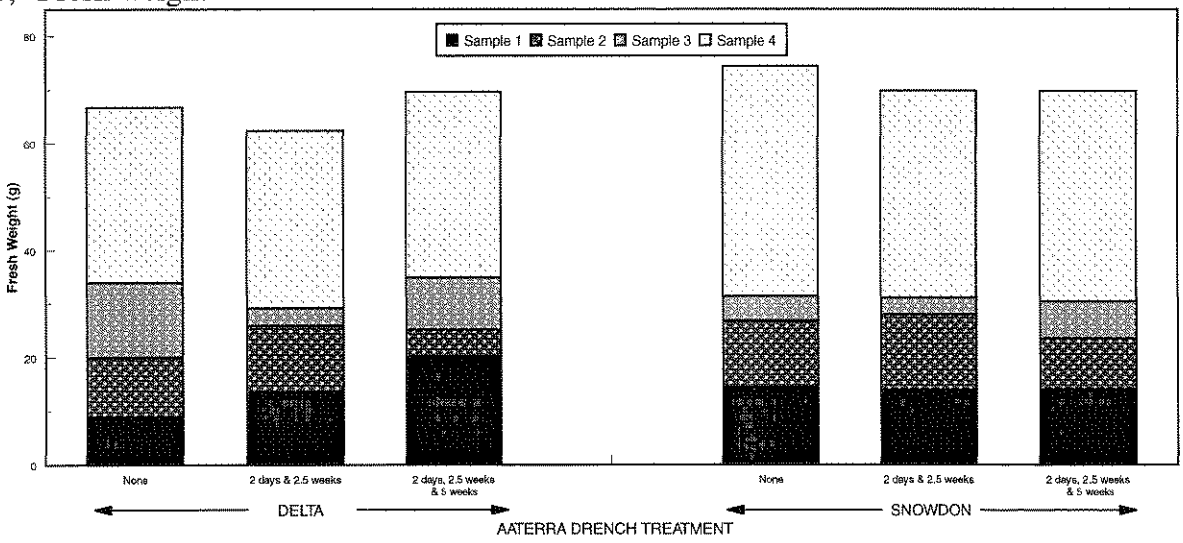
- Sample 1 - start of short days
- Sample 2 - end of interruption
- Sample 3 - 10 days after the end of interruption
- Sample 4 - final harvest

Figure 2. The Influence of Aaterra Soil Drenches on Plant Performance (1993/94)

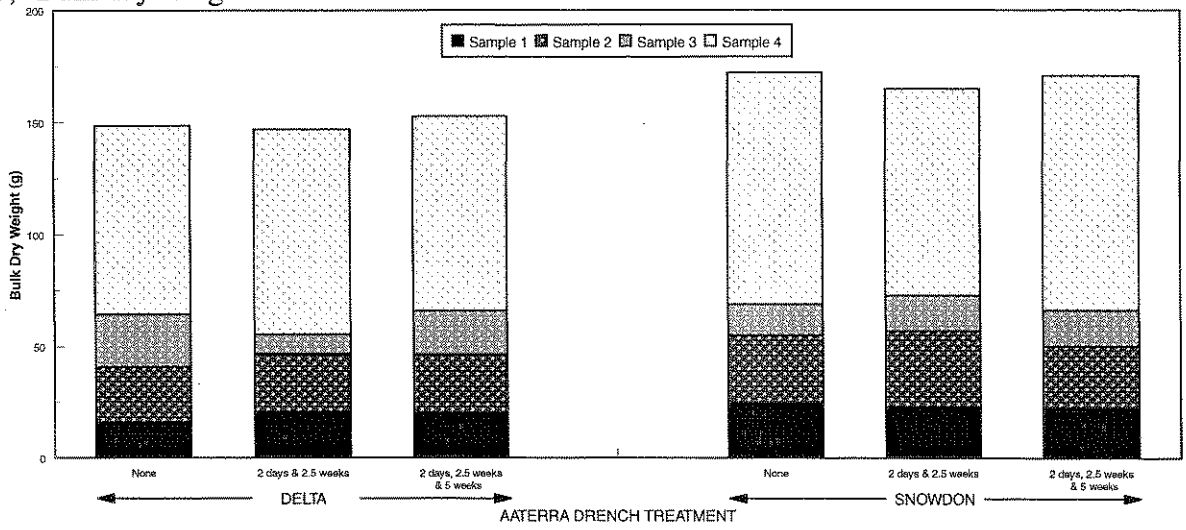
a, Plant height



b, Fresh weight



c, Bulk dry weight

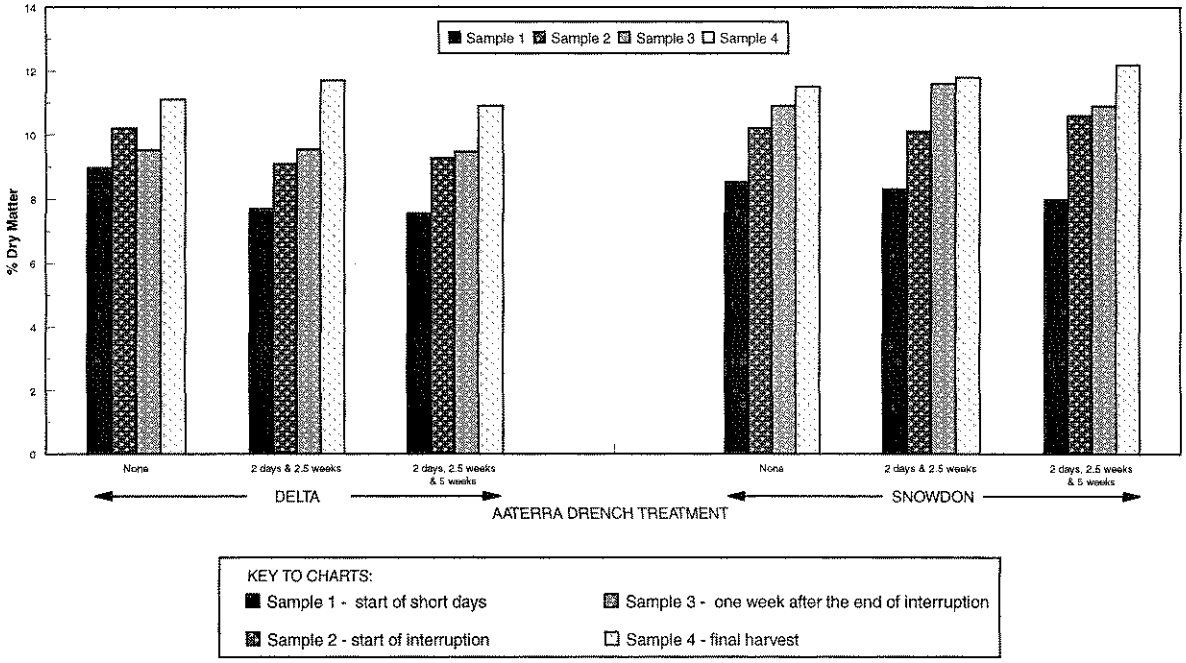


KEY TO CHARTS:

- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 2.(Continued) The Influence of Aaterra Soil Drenches on Plant Performance (1993/94)

d, Percentage dry matter



KEY TO CHARTS:

Sample 1 - start of short days

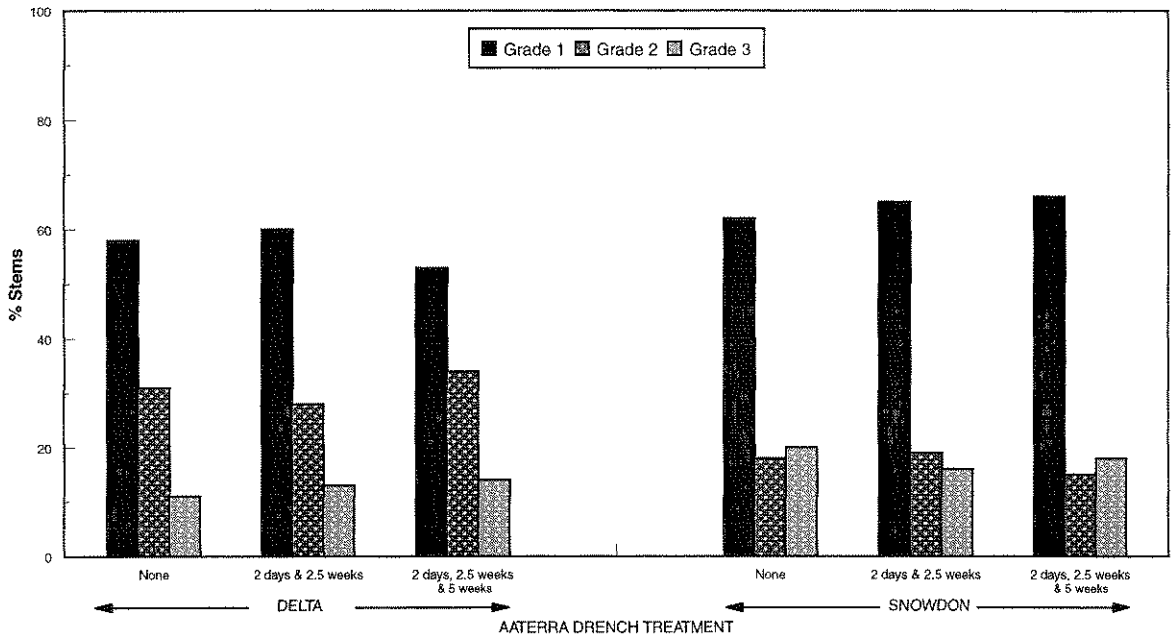
Sample 2 - start of interruption

Sample 3 - one week after the end of interruption

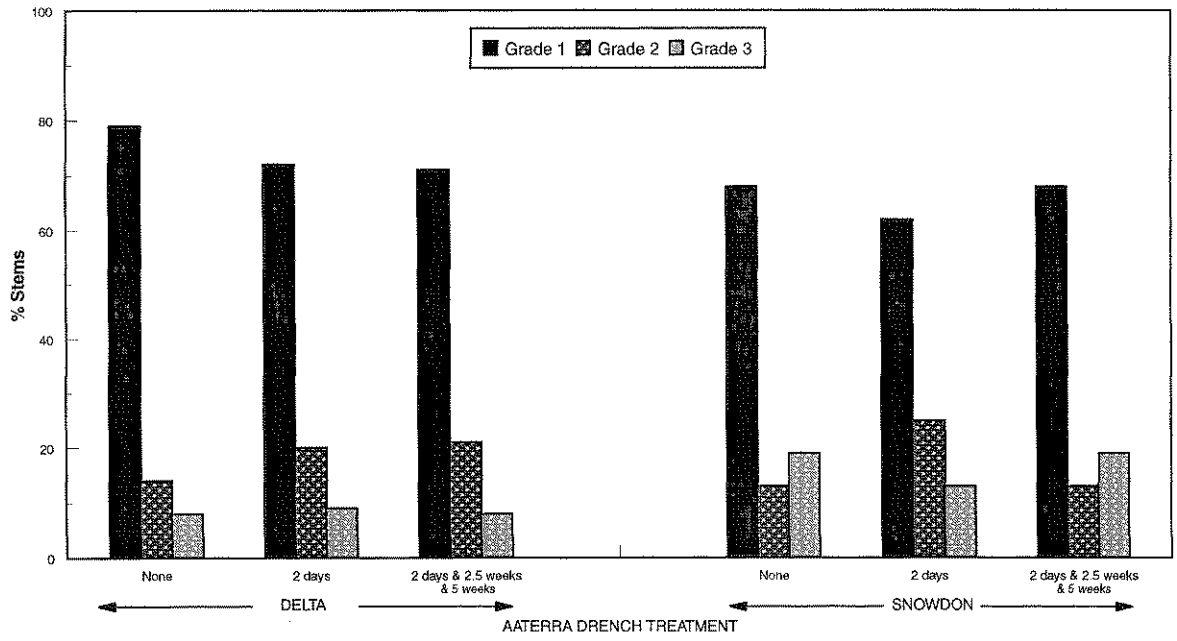
Sample 4 - final harvest

Figure 3. The Influence of Aaterra Soil Drenches on Harvest Grade Out

a, 1992/93



b, 1993/94



2. The Interaction of Etridiazole (as Aaterra) with Low pH Treatments

Since beds were not replicated for each of the treatment combinations assessed, it was not possible to conduct significance testing on the following data. General trends are however described.

2.1 1992/93

2.1.1 Plant Performance

The heights of plants of the variety Delta were generally comparable across all treatment combinations (Figure 4a, page 30). Snowdon was taller overall when grown on the low pH system with Aaterra added while heights were again comparable across the remaining treatments.

Stem fresh weights of Delta were also comparable across all treatments until the end of interruption sample (Figure 4b, page 30). By final harvest however, a lower stem fresh weight was associated with the standard pH with Aaterra added treatment compared with the other treatments.

Stem fresh weights of Snowdon were also similar for all treatments by the end of long days. From sample 2 (start of interruption) onwards, however, low pH with Aaterra added gave the greatest stem fresh weights overall. Systems with Aaterra added also produced the higher fresh weights with Snowdon compared with those with no Aaterra added at comparable pH levels. Similar trends to the fresh weight data were noted from the results of bulk dry weight (Figure 4c, page 30).

There were no consistent trends in the data for leaf area (Figure 4d, page 31) or percentage dry matter (Figure 4e, page 31) in relation to the Aaterra/pH treatments. Again, the data for leaf areas were variable overall.

Harvest grade-out (Figure 6a, page 34) was not apparently influenced by the presence or absence of Aaterra in the system. Where Aaterra was included, low pH treatment gave a higher percentage of grade 1 stems with little difference in percentage of grade 3 stems. Where Aaterra was not included, the higher percentage of grade 1 stems was harvested from the standard pH treatment.

The total shelf-life of both varieties was not influenced by the Aaterra/pH treatments (Appendix II, table 2a, page 99). The first signs of deterioration appeared 3 to 4 days earlier for stems grown without Aaterra in the recirculation system but these differences were compensated by slower deterioration to stage 3.

Overall, plant performance indicated no consistent benefits of either a lower pH of the recirculating solution or of adding Aaterra to the system. It was apparent however that Snowdon responded favourably to the low pH treatment with Aaterra added to the system.

2.1.2 Disease Assessment

Although higher levels of *Pythium* spp infection were detected in roots sampled from the sand beds than from the soil beds (Appendix III, page 103), there was no evidence that either pH or Aaterra treatment influenced incidence of root disease. It should also be noted that the plants themselves indicated no signs of root infection causing problems during development.

2.1.3 Mineral Analyses - Recirculating Solution

Results of the weekly analyses of the recirculating nutrient solution are presented in Figure 7 (pages 35-38). They have been set out to allow comparisons of treatments for each parameter analysed (e.g. one graph to compare pH, one for Ec etc.), and there is also a band on each graph to indicate target levels for each element as specified in Appendix I (page 94). (Note the graphs for pH and Ec actually have two bands representing the different set points for the low and standard pH treatments). Thus desired values may also be compared with achieved values using these figures. It should be noted that due to the dosing system used (i.e. which added A and B or C and D feed in equal proportions as the Ec level in the collection tank dropped below set point), it was not possible to compensate for depletion or accumulation of individual elements during production.

As expected, pH of the low pH treatment was lower than that for the standard treatment (Figure 7a, page 35). There was some apparent instability in the system early on but the four systems generally settled to pH levels consistent with target levels by the fourth sample. Aaterra treatment did not appear to interact with achieved pH levels.

Achieved conductivity levels (Figure 7b, page 35) were also influenced by pH treatment since, as specified in Appendix I (page 94), the set point for the low pH treatment was higher than that for the standard pH treatment. It was also noted that for each pH treatment, the system with Aaterra included had higher achieved conductivity levels. A wide spread of achieved conductivity levels was noted for the four systems and conductivity level generally declined with time (although set points remained constant).

Nitrate-nitrogen (NO_3-N) generally behaved in a similar patter to conductivity as may be expected for such a readily soluble ion (Figure 7c, page 35). Achieved NO_3-N concentration was generally within or close to the desired range throughout. Low pH treatments had higher achieved NO_3-N concentrations throughout reflecting the greater dosing of nitric acid to achieve the lower pH set point.

Ammoniacal-nitrogen (NH_4-N) was rapidly depleted in all systems (Figure 7d, page 35) which may be attributed to the activity of nitrifying bacteria converting NH_4-N to NO_3-N. Depletion of NH_4-N was apparently affected by the low pH and plus Aaterra treatments. That is, rate of depletion was slowest for both of the low pH treatments, particularly where Aaterra was also added. It was also slower for the standard pH treatment where Aaterra was added in comparison with the standard treatment where Aaterra was not added.

Levels of NO_3-N increased with the decline in NH_4-N but additional NO_3-N from this source would be minor relative to the overall concentration of NO_3-N in the system.

Similar trends were observed for both Potassium (K) and Phosphorus (P) (Figures 7e and 7h, page 36), with both elements well below target concentrations throughout. In both cases, the standard pH treatment with Aaterra added contained higher levels than the other treatments.

Calcium (Ca) concentration was higher for the low pH treatments than the standard pH treatments and was also above target range for the low pH treatments (Figure 7f, page 36). This may be partly a result of the higher conductivity set point and there may also have been some release of calcium from calcium carbonates in the sand which are more soluble at lower pH levels.

Magnesium (Mg) concentration was within the target range for all treatments (Figure 7g, page 36). There was no apparent trend in relation to pH treatment, but the addition of Aaterra to each of the pH treatments was apparently linked with a higher achieved magnesium concentration.

Minor elements (i.e. Iron (Fe), Zinc (Zn), Managanese (Mn), Copper (Cu) and Boron (B) (Figures 7i, 7j, 7k, 7l, 7m, pages 37 and 38) were not consistently influenced by either pH or Aaterra treatment. Fe concentration was generally within range initially but depleted below target range with time. There was a consistently low Fe concentration in the standard pH without Aaterra added treatment. B concentration was also consistently below the target level. Zn, Cu and Mn concentrations generally varied around the desired concentration according to both treatment and time of sampling. It should be noted however that there were no broad target ranges for these elements as there were for Fe and the major nutrients and variation in concentration was not actually any more extreme for these elements than other elements discussed above.

2.1.4 Mineral Analyses - Foliage Samples

Overall there were no consistent differences in foliage analyses in relation to pH level or addition of Aaterra to the recirculating solution (Appendix V, tables 2a and 2b, pages137 and 138).

Concentration of % total N was towards the upper end of satisfactory levels. It was notable that despite the extra N in recirculation in the low pH treatments, foliage N was similar for both low and standard pH treatments at each sampling date.

Concentration of % total K was high and consequently N:K ratios were consistently low for all treatments despite the low levels of K recorded in the recirculating solution. It would therefore seem possible that K was being made available to the plants from the substrate as well as the recirculating solution (or simply the plants were particularly efficient at absorbing K from recirculation).

Similarly, concentration of % total P was satisfactory in all treatments, despite the very low levels in recirculation.

2.2. 1993/94

2.2.1 Plant Performance

For peat block stuck plants, height of the variety Delta was shorter for the low pH without Aaterra added treatment for all samples up to the end of interruption in comparison with the other treatments (Figure 5a, page 32). By final harvest, all Delta plant heights were comparable. Direct stuck plants of Delta were generally also comparable with each other across the treatments assessed with the exception of the standard pH with Aaterra added treatment, which was slightly taller at each sampling date.

For peat block stuck Snowdon plants, there was a similar trend in terms of plant height to that discussed above. That is, shorter heights were recorded from the first three samples on the low pH treatment with Aaterra added. At final harvest, all treatments were comparable in terms of plant height. Direct stuck Snowdon plants however were taller for both pH treatments when Aaterra had been added to the system compared with no Aaterra added. Plant height was particularly short for the plants direct stuck into the standard pH treatment without Aaterra added.

For the first three samples, fresh weights of peat block stuck plants of Delta were also lowest for the low pH treatment without Aaterra added (Figure 5b, page 32). By final harvest, however, the treatments had comparable weights except for the standard pH without Aaterra added treatment where stems were heavier. Direct stuck plants of Delta were comparable in terms of fresh weight throughout for the low and standard pH treatments without Aaterra added. Where Aaterra was added to the system, the standard pH treatment produced greater stem fresh weight than the low pH treatment.

Fresh weights of peat block stuck Snowdon plants were comparable across the treatments for the first three samples. By final harvest, for both Aaterra treatments, heavier stems were recorded from the standard pH treatment beds. A mixed result was recorded for fresh weights of direct stuck Snowdon plants in terms of pH but heavier stems were recorded from the treatments which included Aaterra in the systems (reflecting plant height data) compared with treatments where no Aaterra was added.

Bulk dry weight data (Figure 5c, page 33) again reflected the trends noted above for stem fresh weight.

Percentage dry matter (Figure 5d, page 33) was generally in the range of 7 to 12% and increased with age of plant. These data were generally mixed with no consistent trends emerging relative to treatments.

The total shelf-life of Snowdon was on average 9.5 days shorter than of Delta for the combined treatments assessed (Appendix II, table 2b, page 100). Shelf-life performance was variable across the treatments assessed. In particular, the shelf-life of Delta grown on the standard pH treatment with Aaterra included was short in comparison with the remaining treatments for Delta. Overall, however, there were no consistent trends linking either pH or Aaterra treatments to differences in shelf-life.

Harvest grade-out data in 1993/94 (Figure 6b, page 34) did not reflect all the trends in 1992/93 data (Figure 6a). For Delta without Aaterra, standard pH produced the most favourable grade-out figures compared with low pH. Snowdon without Aaterra however gave the most favourable grade-out data for the low pH treatment.

Overall there was a mixed response in plant performance in relation to the pH and Aaterra treatments. Certain combinations apparently favoured individual plant performance indicators, but no treatment performed consistently well overall. Propagation method also apparently interacted with the Aaterra/pH treatments which may be expected since all peat blocks had Aaterra incorporated. One system which appeared to perform particularly poorly with Snowdon during day to day visual observations, was the standard pH treatment without Aaterra added. This treatment also had low figures of height and weight as noted above.

2.2.2 Disease Assessment

Assessment of root systems (Appendix IV, page 112) reflected the plant performance results above as well as the findings of the 1992/93 trial. That is that despite detecting low levels of *Pythium* spp infection in all samples there was no indication of root disease affecting any of the treatments. Consequently there is no evidence that either the low pH or addition of Aaterra treatments reduced the incidence of disease in this trial.

2.2.3 Mineral Analyses - Recirculating Solution

Routine analysis indicated that the pH in the solution for two pH treatments generally followed the set point levels (Figure 8a, page 39). pH also appeared to be more stable in comparison with the 1992/93 trial (Figure 7a, page 35).

Conductivity levels in solution also followed set point levels and were again more stable than those achieved on the newly planted beds in the 1992/93 trials (Figures 7b, 8b, pages 35 and 39). In agreement with observed trends in 1992/93, of the two low pH treatments, the system with Aaterra added gave higher achieved conductivity levels than the system without Aaterra added. This trend was not, however, reflected in the two standard pH treatments. Conductivity levels also tended to increase with time on all systems in 1993/94 in contrast with the decline observed in 1992/93.

NO_3-N was again generally within the desired range (Figure 8c, page 39). In contrast with 1992/93 data, NO_3-N concentrations were generally higher for the standard pH (and therefore lower conductivity set point) treatments.

NH_4-N was again depleted in all systems and depletion was more rapid in 1993/94 (Figure 8d, page 39) than in 1992/93. This may have been due to the build up of populations of nitrifying bacteria with the beds as they aged and were replanted.

K and P were again below the desired range throughout reflecting 1992/93 data (Figures 8e and 8h, page 40). Concentrations of these elements did appear to increase with time through the samples analysed over the winter 1993/94 planting period.

Concentration of Ca reflected the 1992/93 results and was generally above the desired levels (Figure 8f, page 40). Low pH treatments again produced higher Ca concentrations in recirculation.

Mg was within the desired range and was generally stable throughout the 1993/94 trial (Figure 8g, page 40).

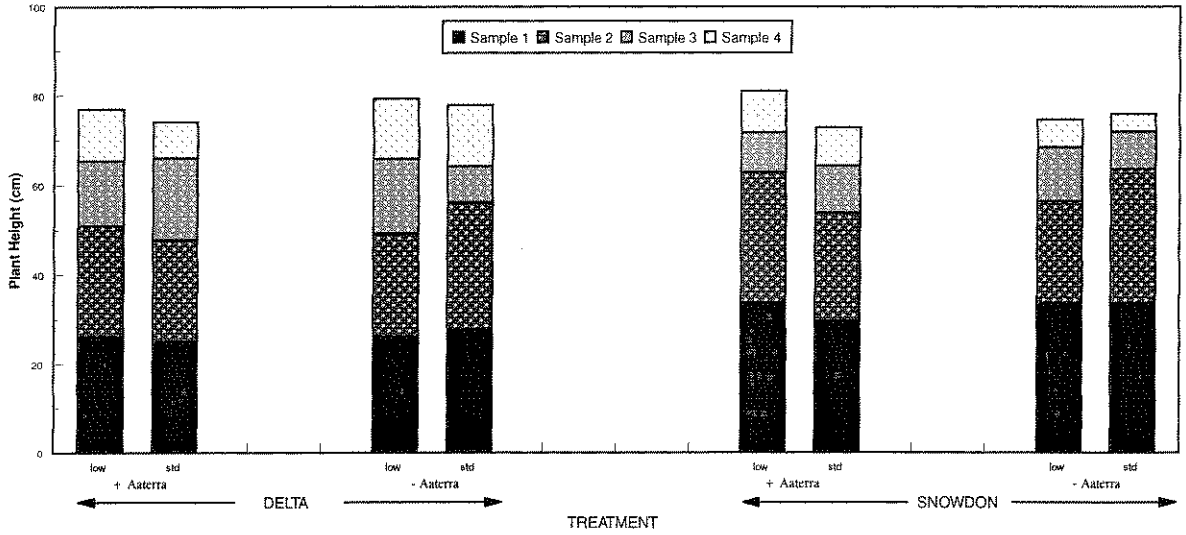
Fe concentration remained closer to the desired range compared with the 1992/93 trial with some accumulation in the low pH system without Aaterra added (Figure 8i, page 41). Zn was also close to desired levels and stable throughout production (Figure 8j, page 41). Mn was however below the desired level throughout and was also lower than the achieved levels in 1992/93 (Figure 8k, page 41). B was similarly below target levels throughout (Figure 8m, page 42) while Cu levels were all higher than those achieved in 1992/93 and were at least as high as the set point level (Figure 8l, page 41).

2.2.4 Mineral Analyses - Foliage Samples

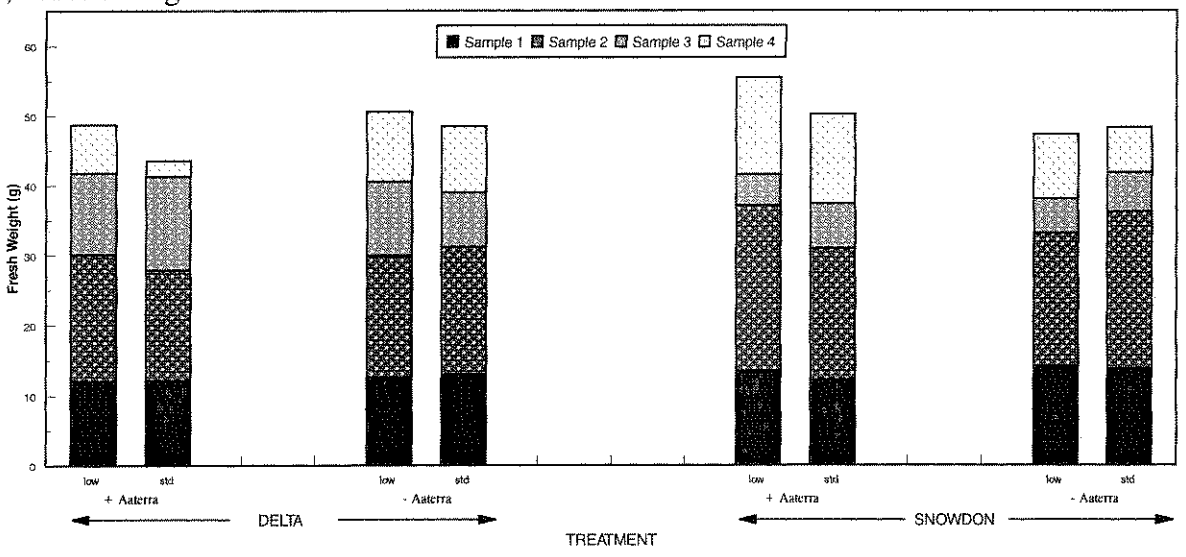
In agreement with the 1992/93 results, there were no consistent trends linking foliage nutrient status to Aaterra or pH treatments. (Appendix V, tables 2c and 2d, pages 139 and 140). A wider range of elements were analysed in 1993/94 and the majority of these were within satisfactory ranges. K levels were lower compared with the 1992/93 data, producing more acceptable N:K ratios The low levels of B in recirculation noted above were reflected in low levels in foliage which fell below satisfactory levels, particularly in the mature crop (sample 3). Higher levels of Fe noted in recirculation were again reflected in every high foliage Fe, particularly at maturity. Despite these apparent deficiencies and excesses, there were no indications from plant performance of mineral disorders.

Figure 4. The Influence of Aaterra and pH on Plant Performance (1992/93)

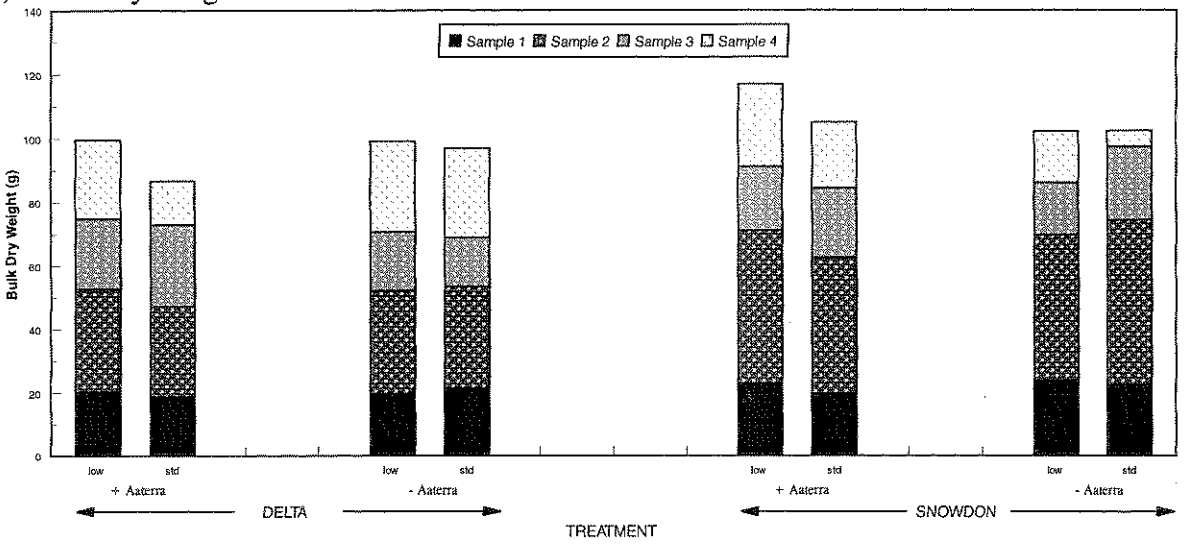
a, Plant height



b, Fresh weight



c, Bulk dry weight

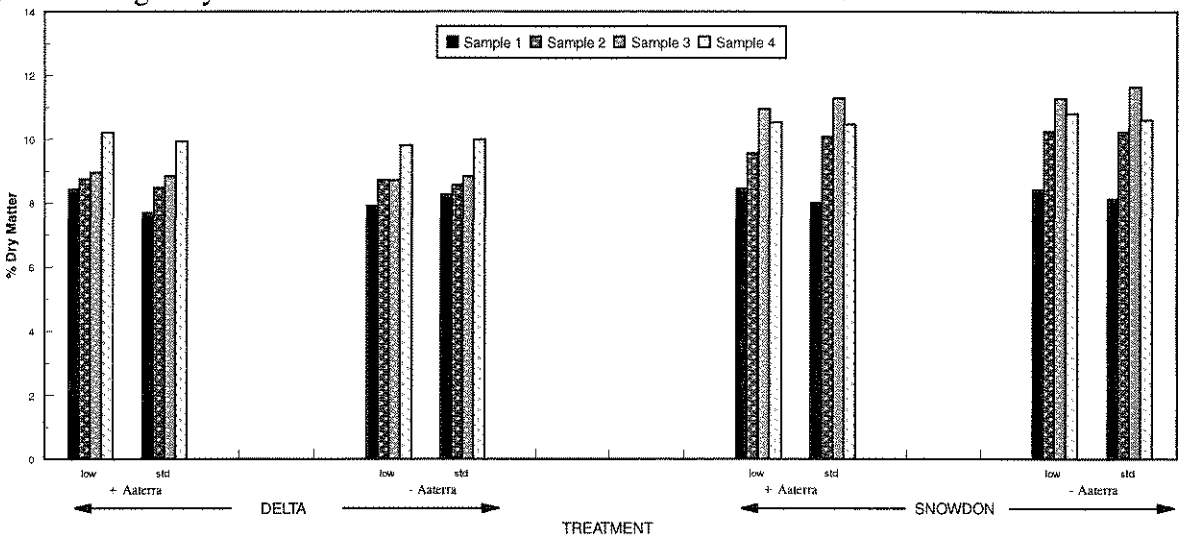


KEY TO CHARTS:

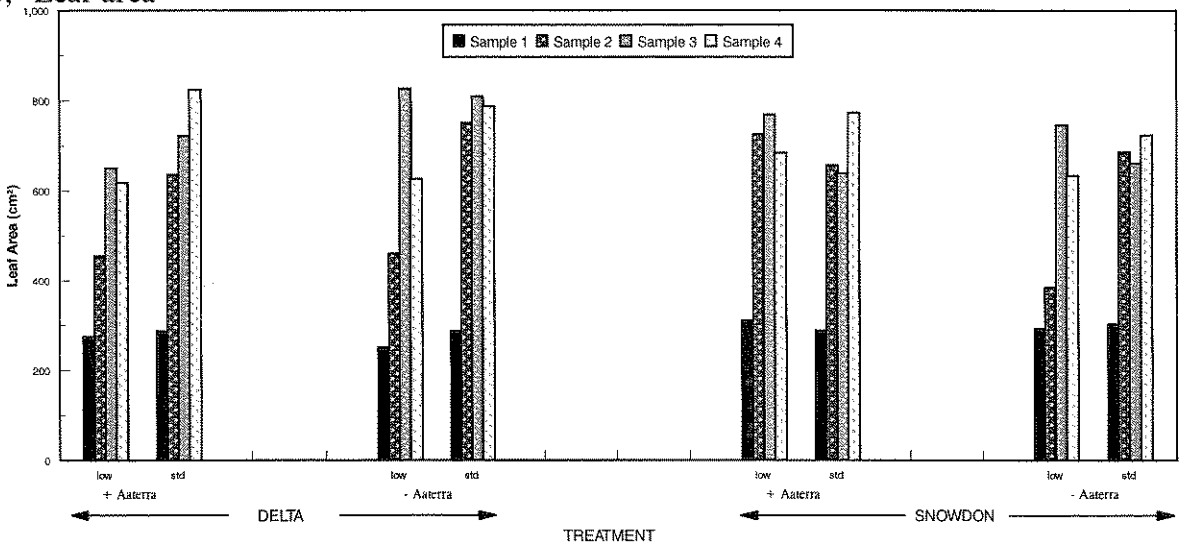
- Sample 1 - start of short days
- Sample 2 - end of interruption
- Sample 3 - 10 days after the end of interruption
- Sample 4 - final harvest

Figure 4.(Continued) The Influence of Aaterra and pH on Plant Performance (1992/93)

d, Percentage dry matter



e, Leaf area



KEY TO CHARTS:

Sample 1 - start of short days

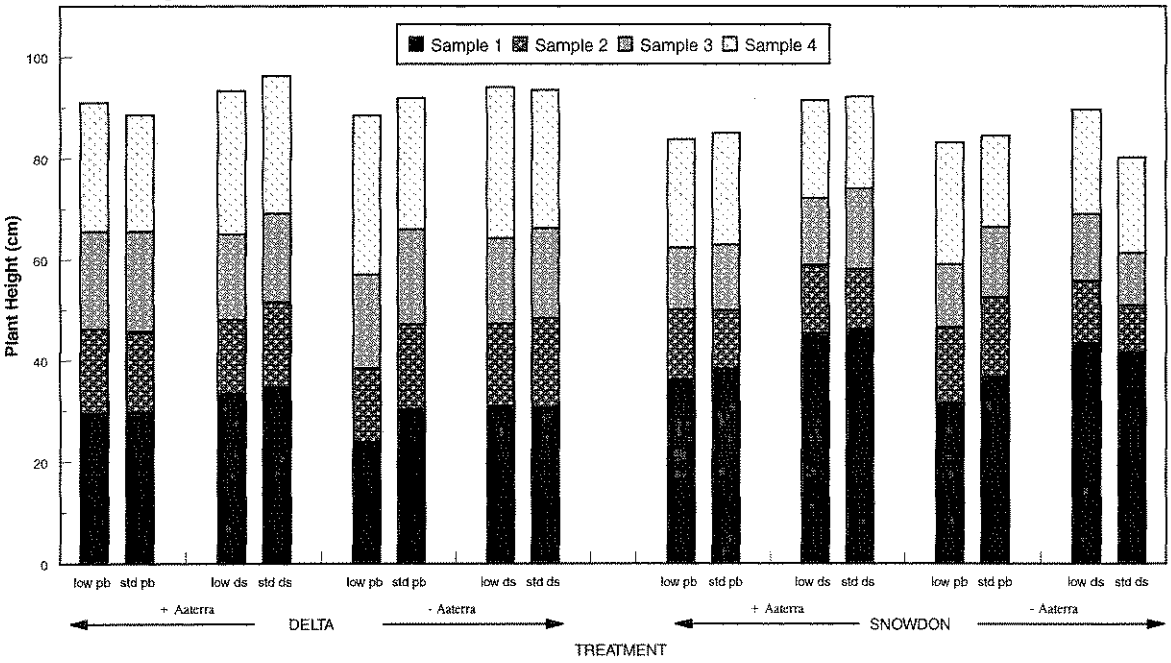
Sample 2 - end of interruption

Sample 3 - 10 days after the end of interruption

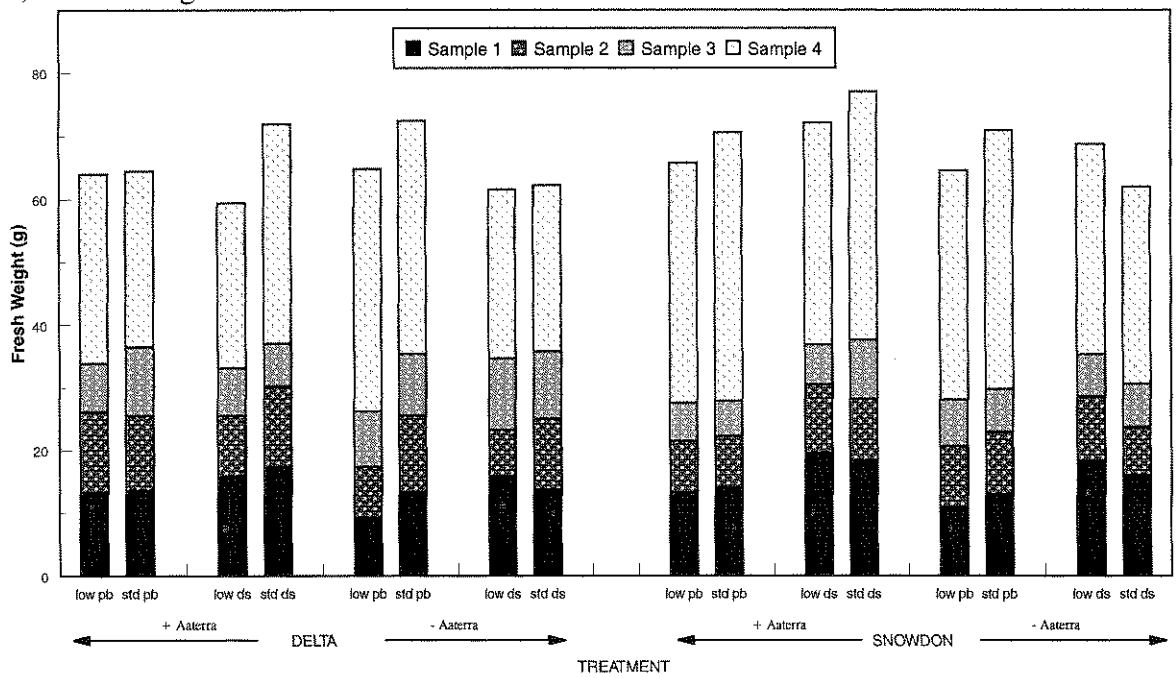
Sample 4 - final harvest

Figure 5. The Influence of Aaterra and pH on Plant Performance (1993/94)

a, Plant height



b, Fresh weight

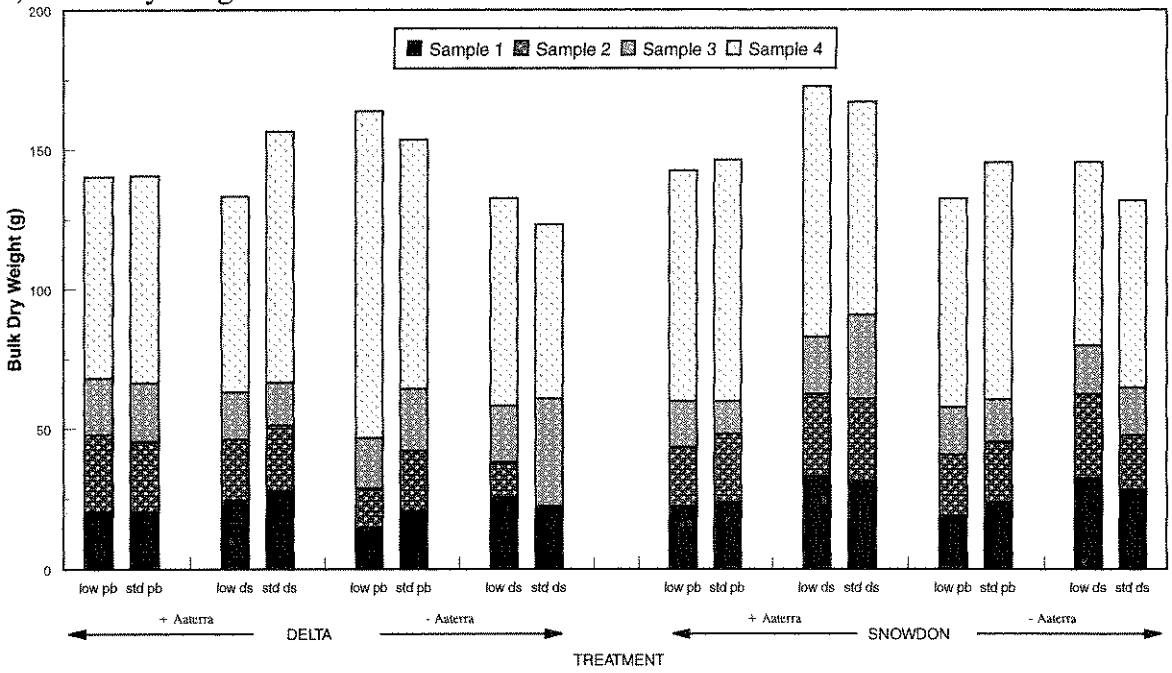


KEY TO CHARTS:

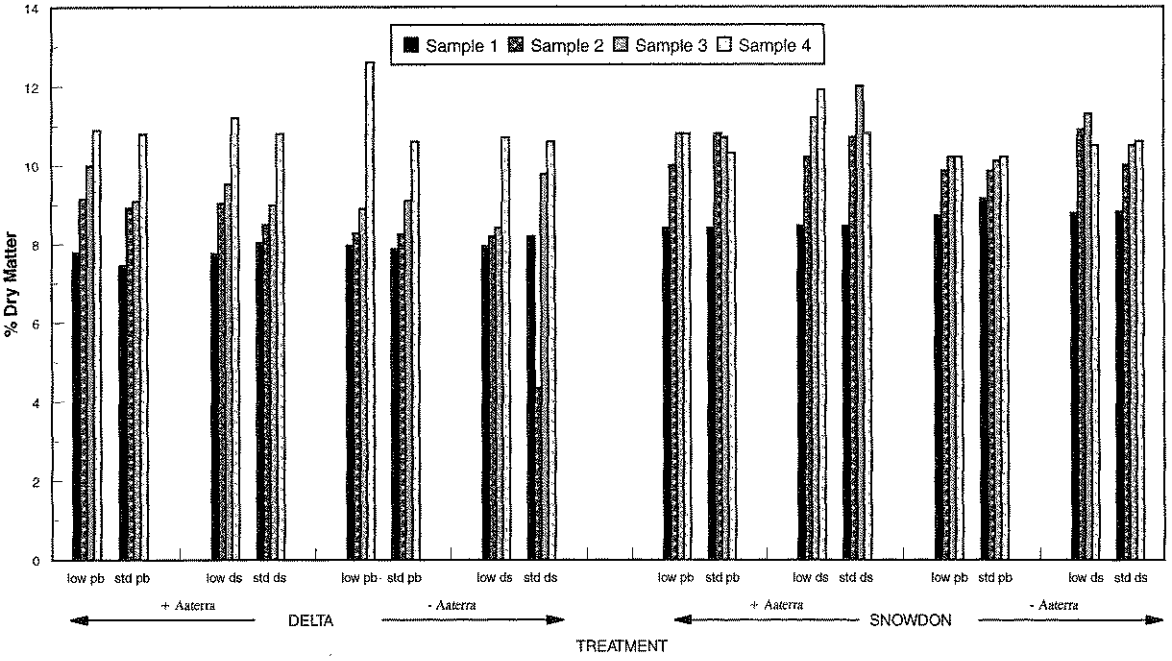
- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 5.(Continued) The Influence of Aaterra and pH on Plant Performance (1993/94)

c, Bulk dry weight



d, Percentage dry matter



KEY TO CHARTS:

Sample 1 - start of short days

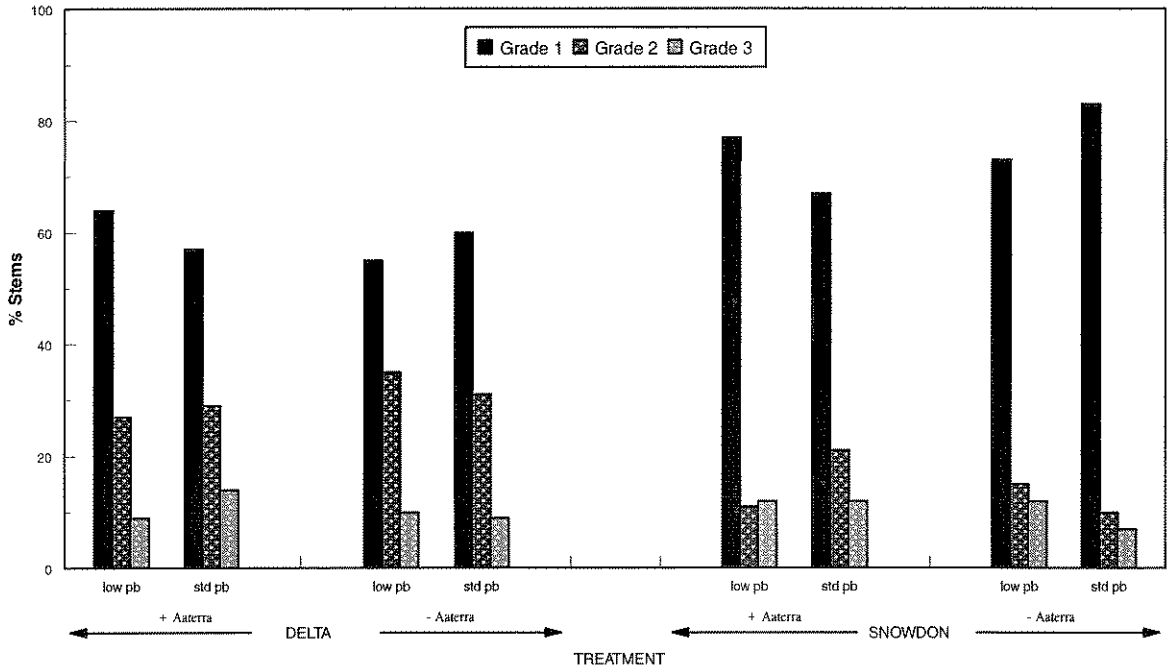
Sample 2 - start of interruption

Sample 3 - one week after the end of interruption

Sample 4 - final harvest

Figure 6. The Influence of Aaterra and pH on Harvest Grade Out

a, 1992/93



b, 1993/94

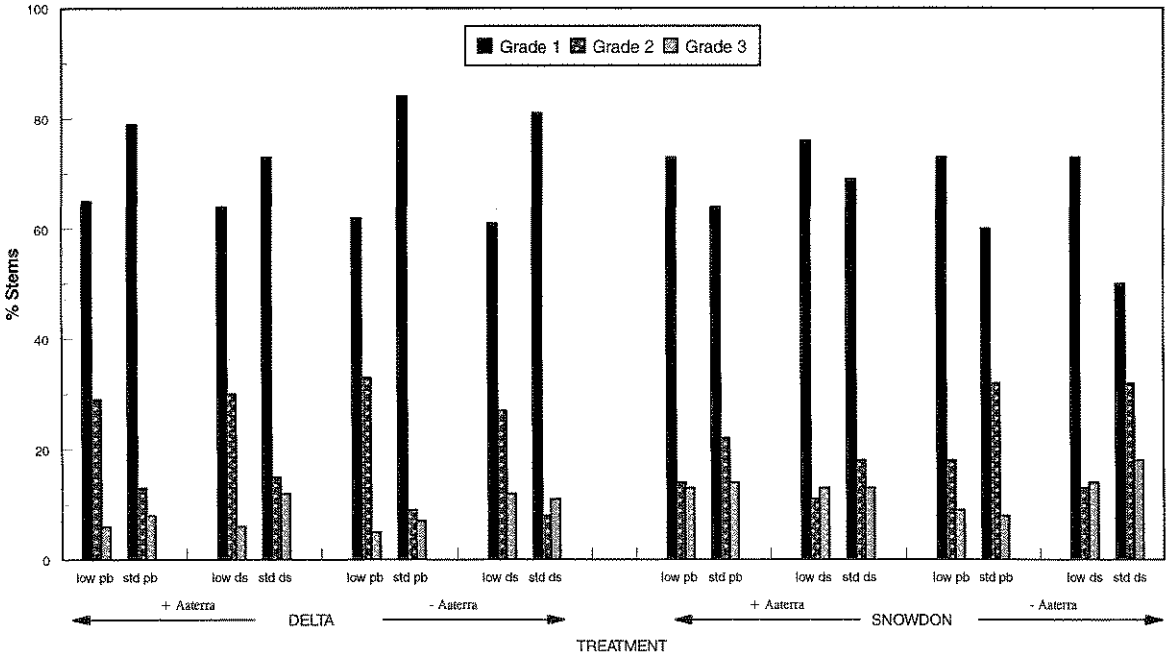


Figure 7. The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1992/93

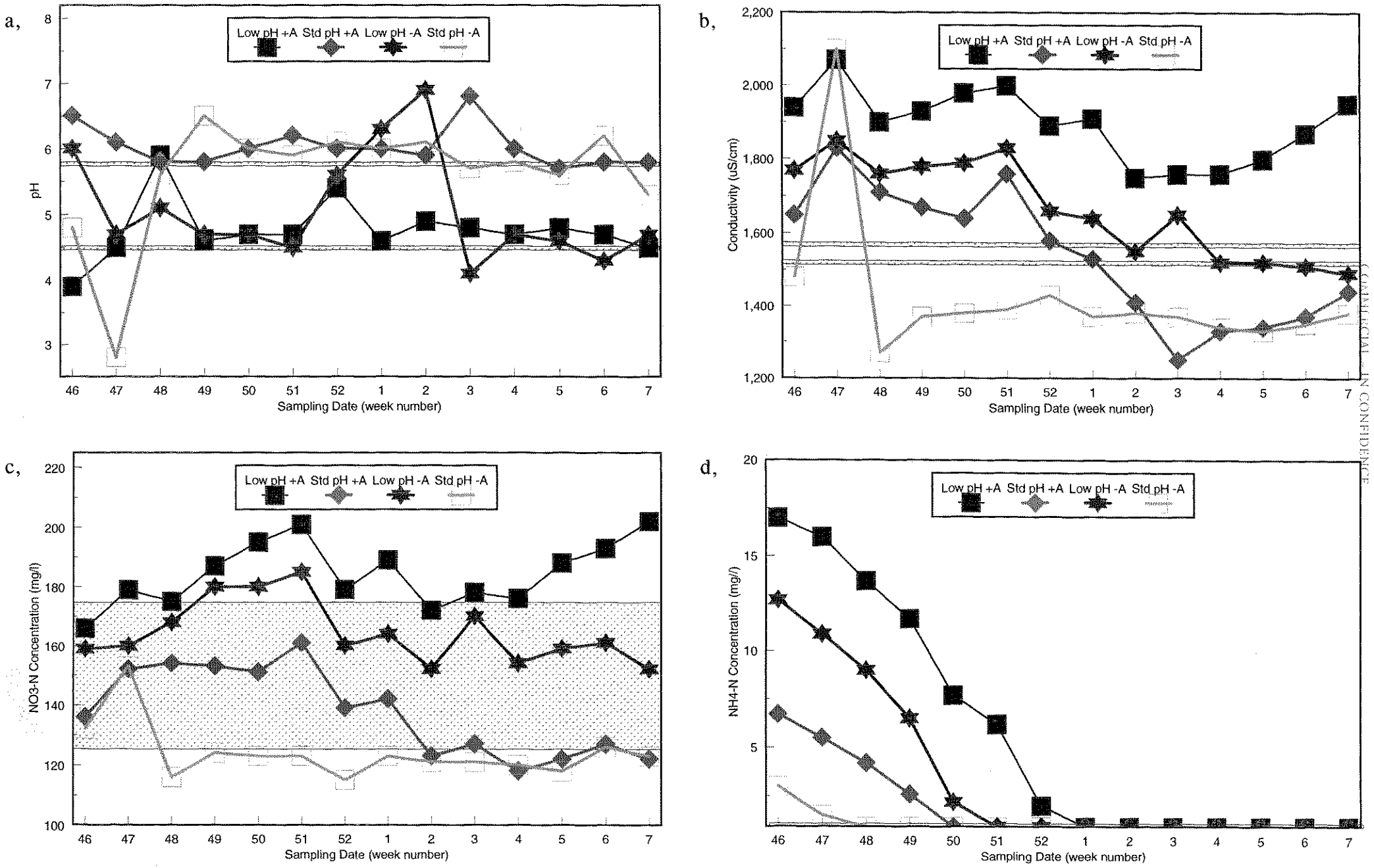
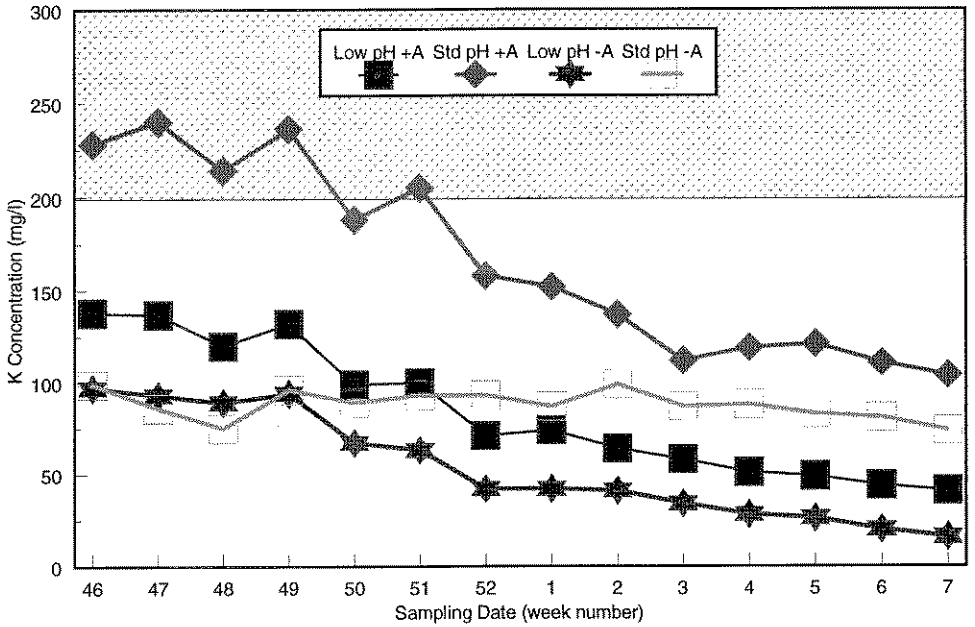
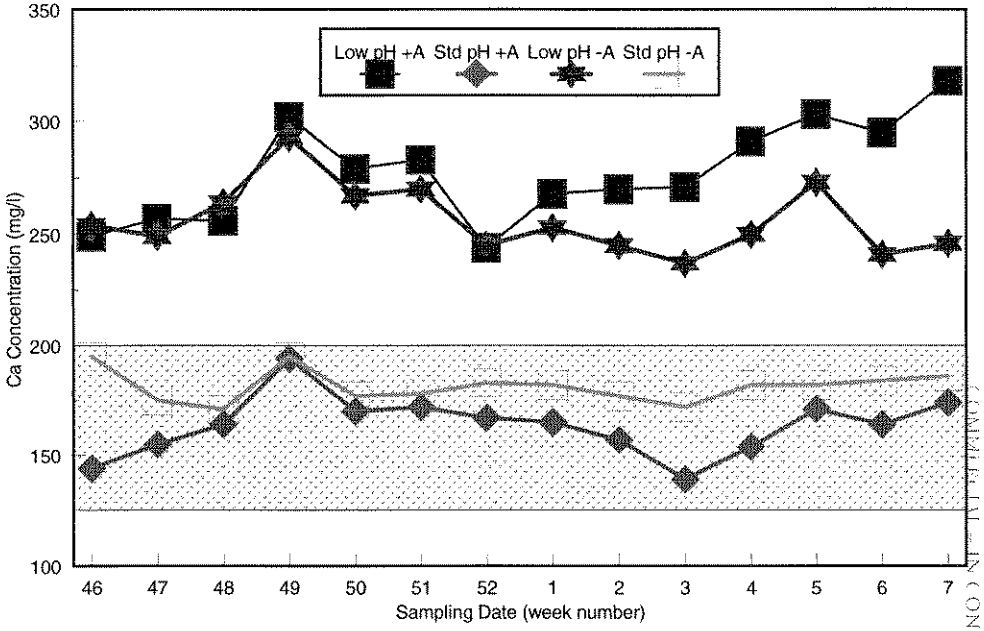


Figure 7.(Continued) The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1992/93

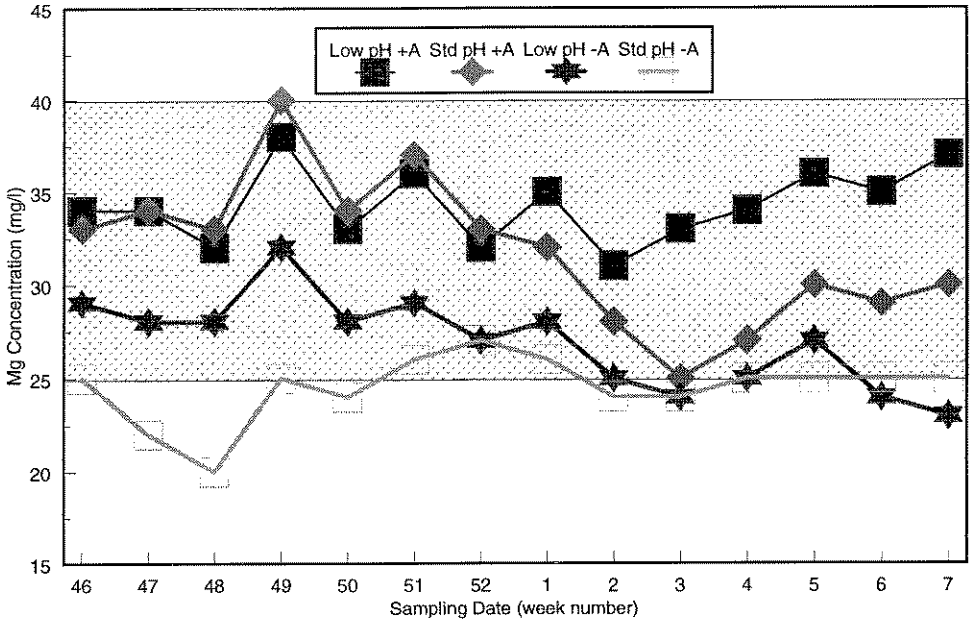
e,



f,



g,



h,

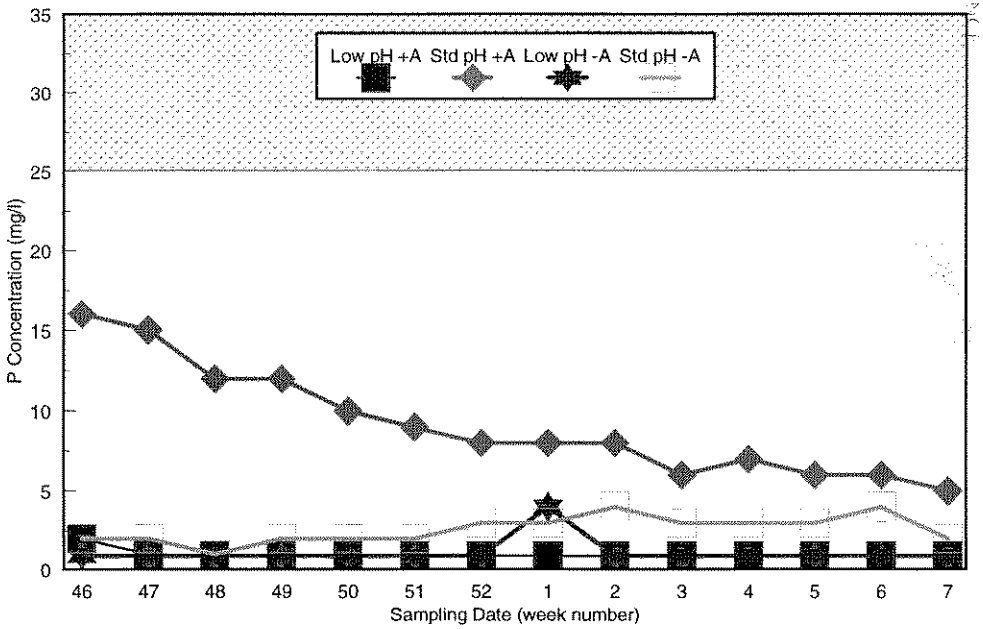
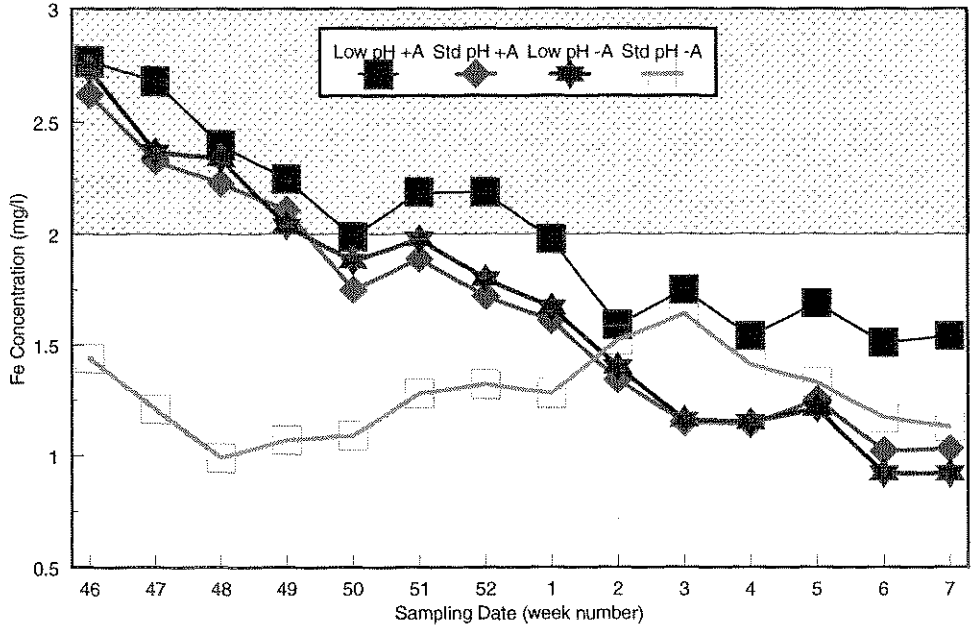
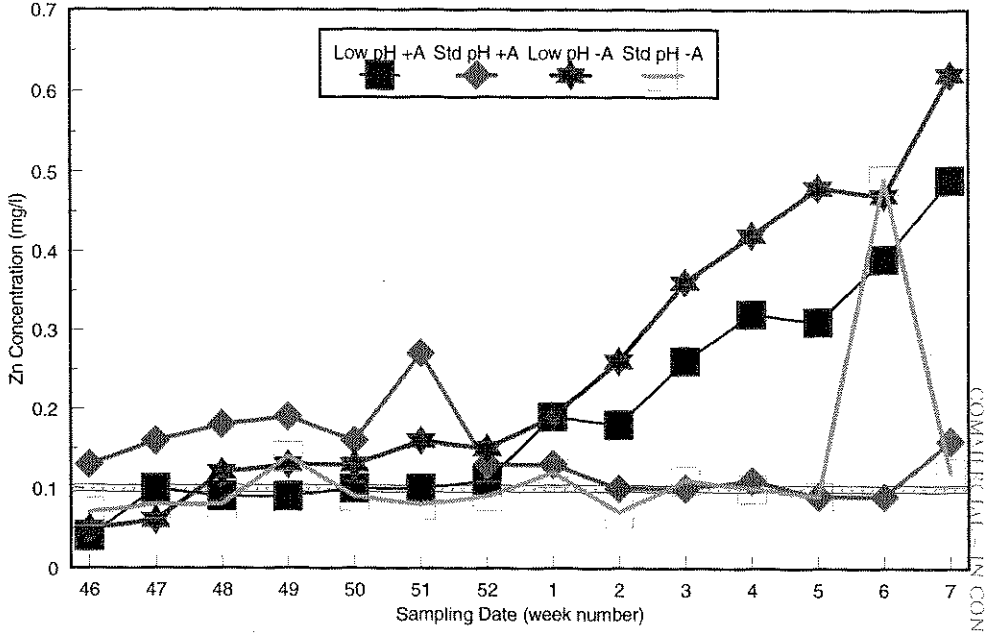


Figure 7.(Continued) The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1992/93

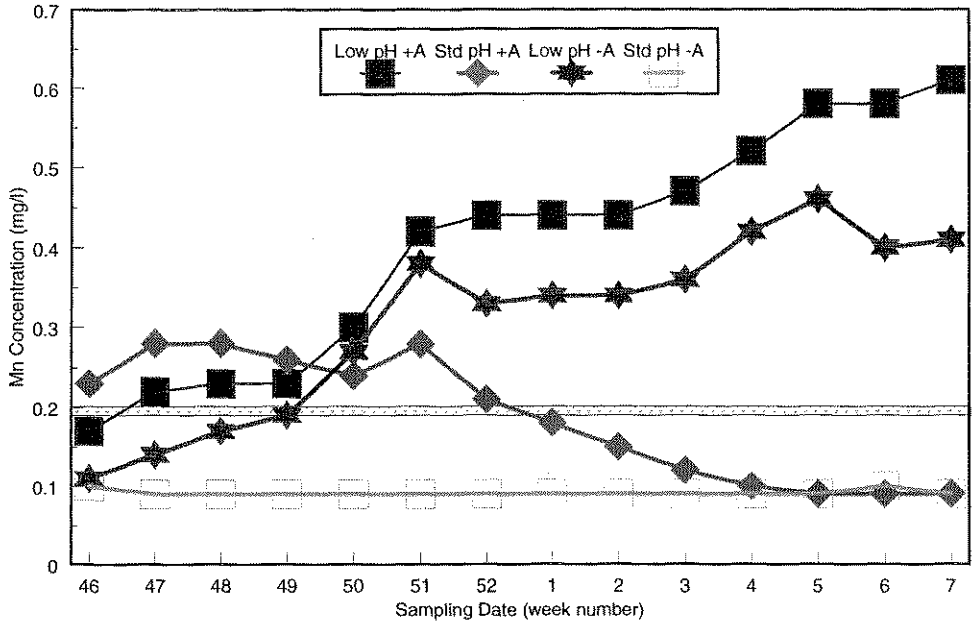
i,



j,



k,



l,

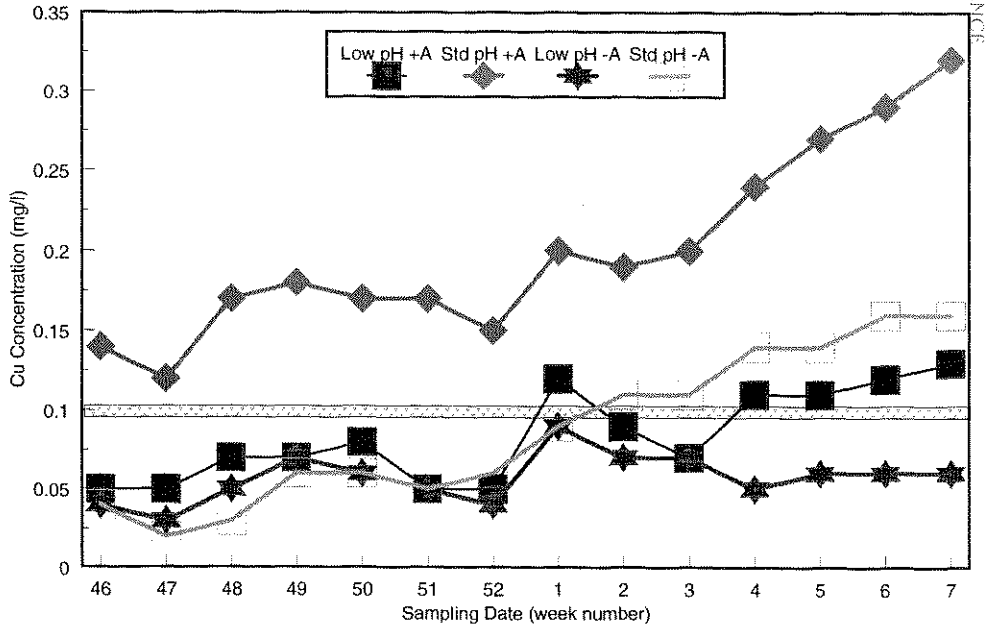
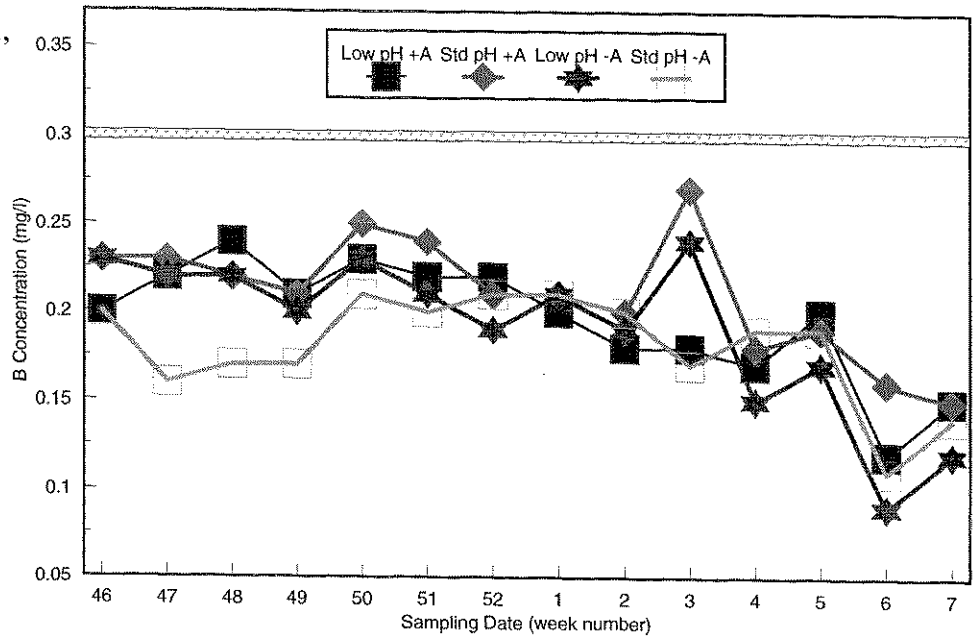
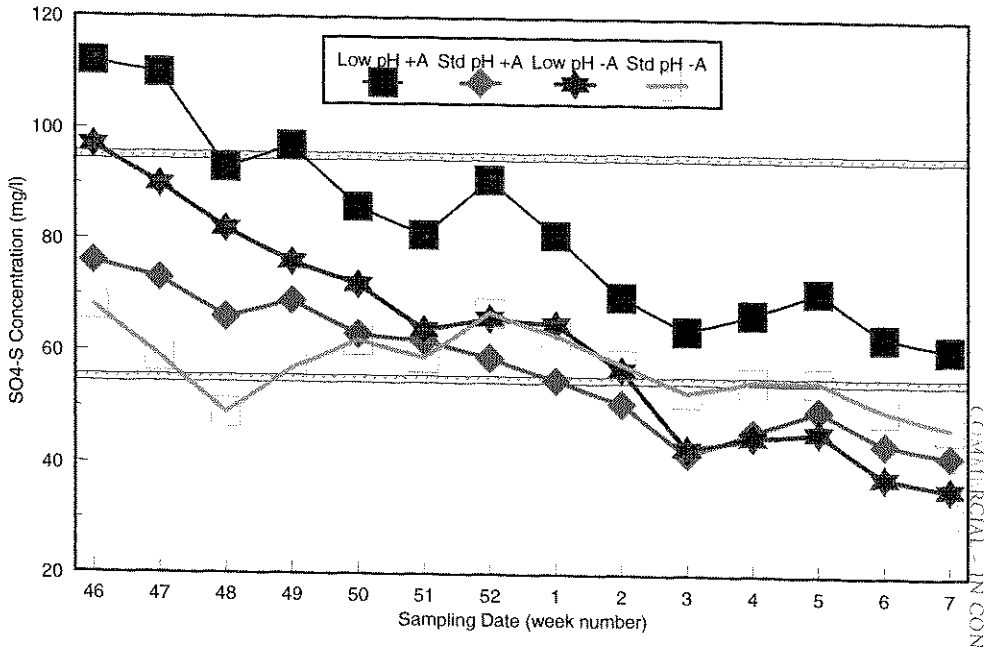


Figure 7.(Continued) The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1992/93

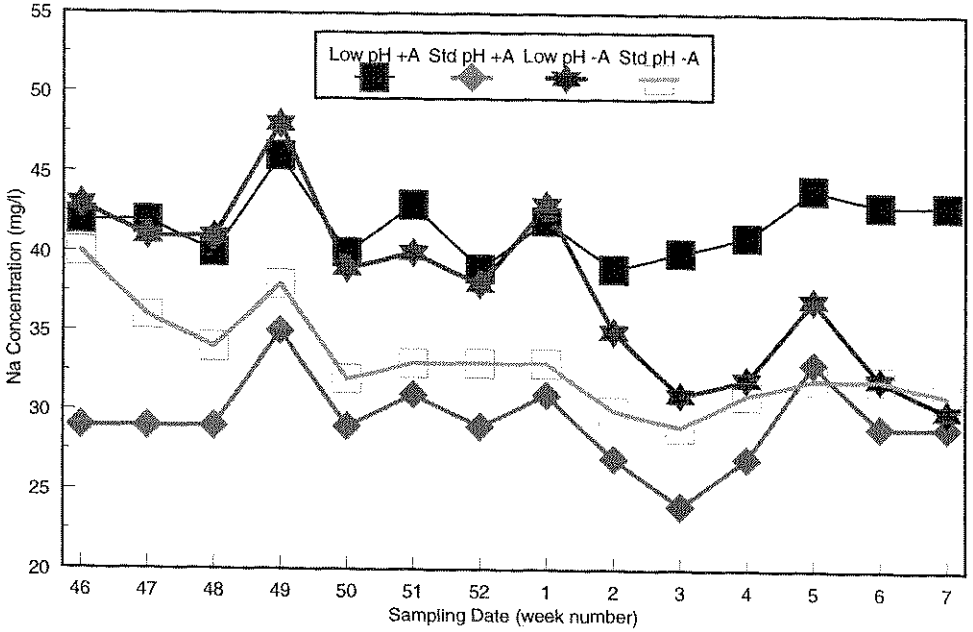
m,



n,



o,



p,

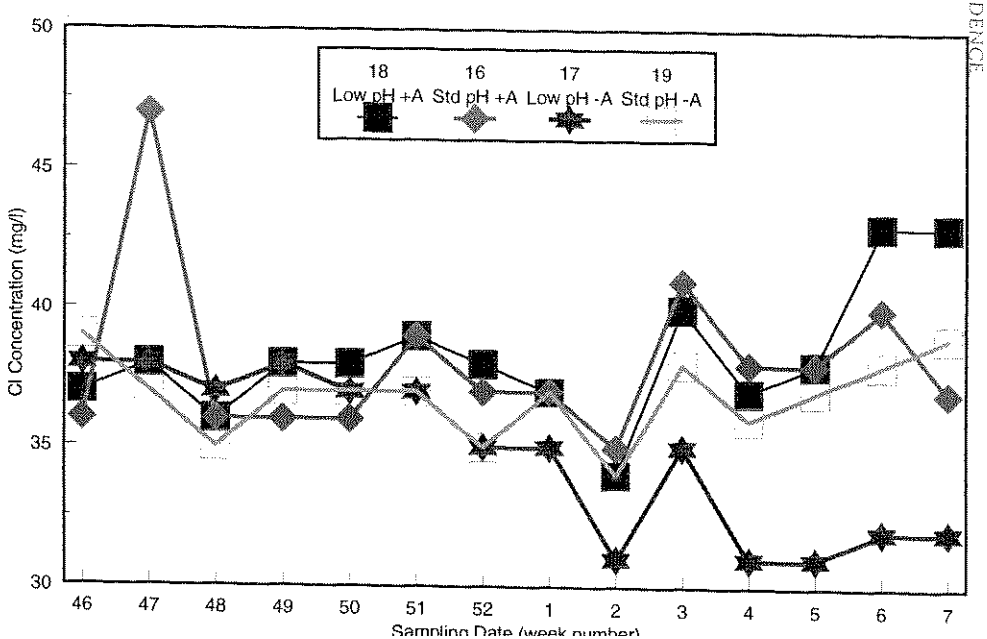


Figure 8. The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1993/94

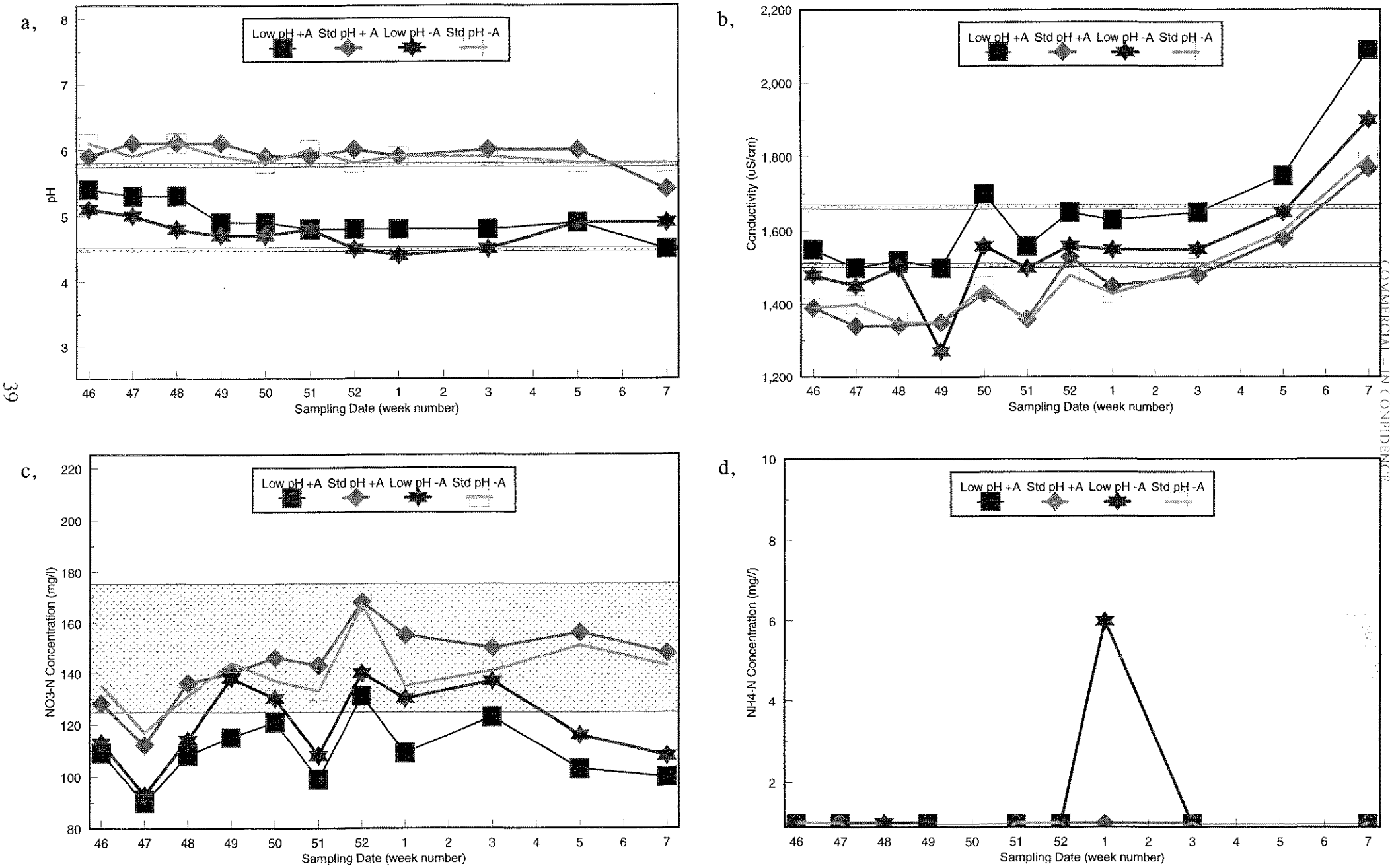
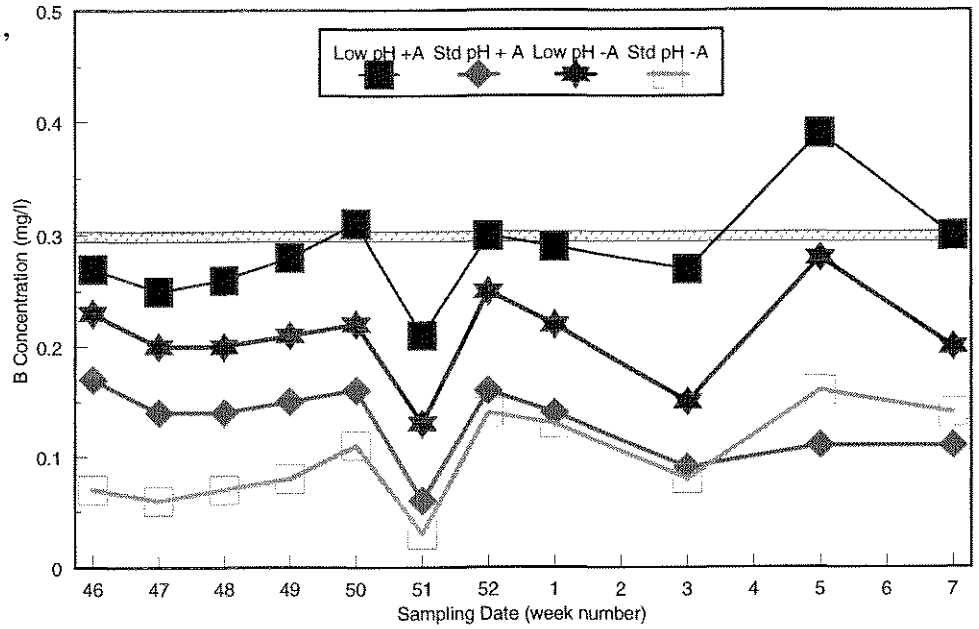
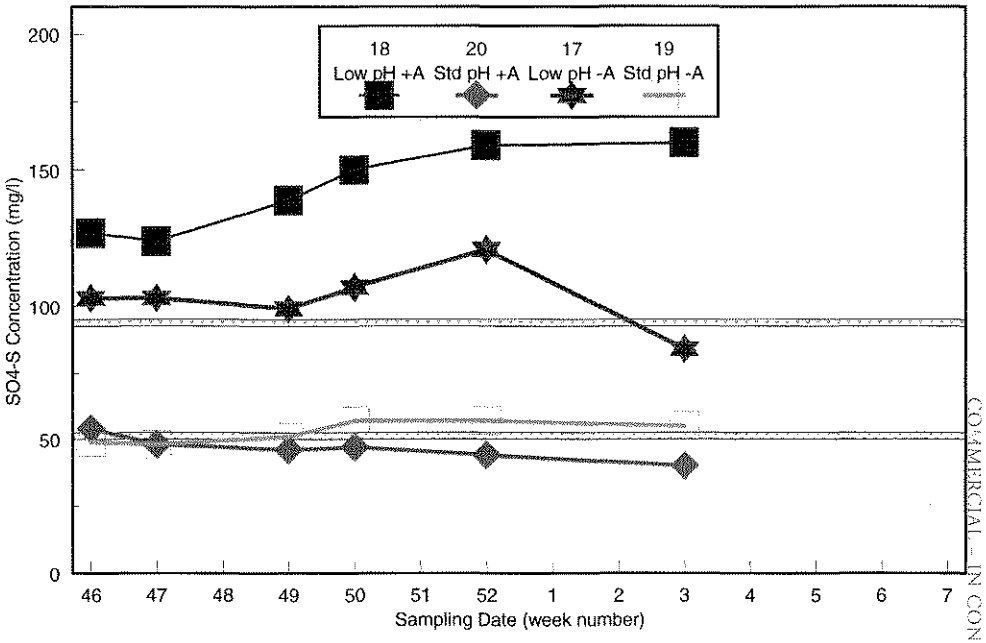


Figure 8.(Continued) The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1993/94

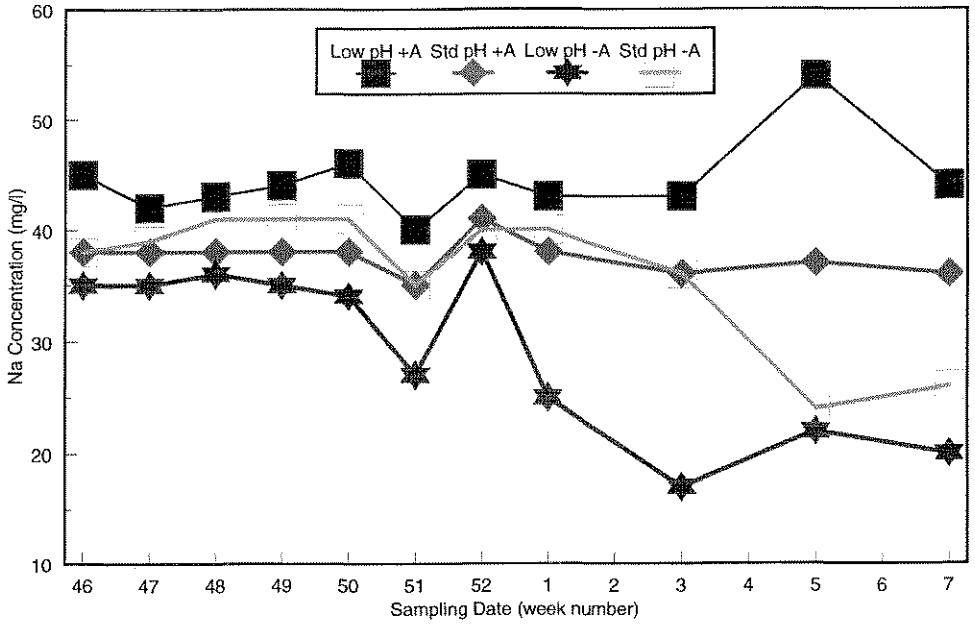
m,



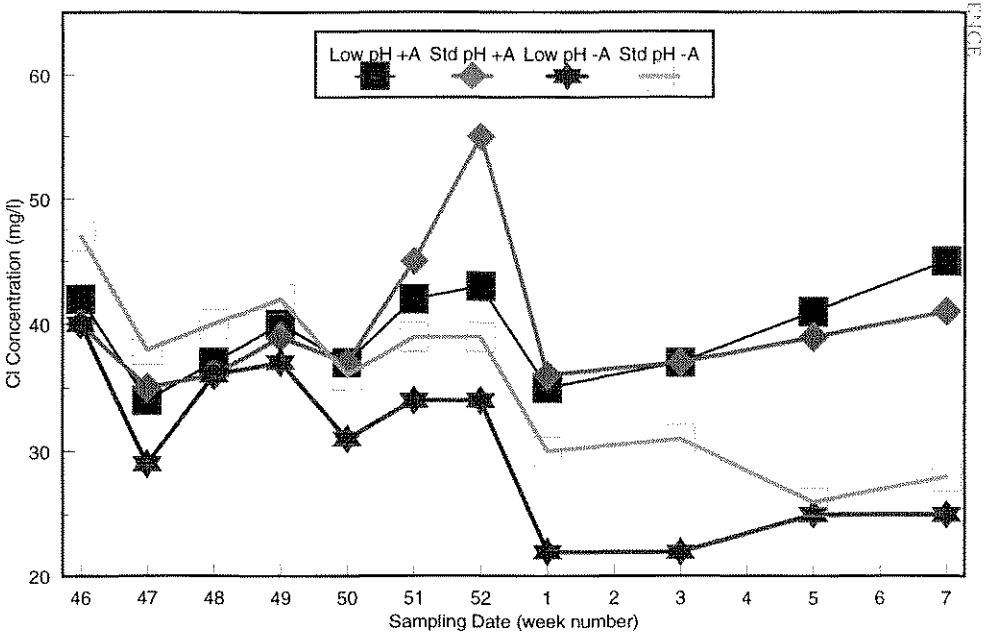
n,



o,



p,



3. The Effects of 'Direct-Sticking' Cuttings into the Hydroponic Substrate

This assessment was carried out in the 1993/94 trial only. Direct sticking was compared with sticking in peat blocks on four different systems but since these systems had separate regimes it is not possible to treat them as replicates for statistical analysis The data has therefore been grouped for each propagation method in the following comparisons. It is however possible to use Figure 5 (pages 32 and 33) (discussed above) to compare direct sticking with peat-block sticking on the four independent systems used to compare the interaction of Aaterra and low pH treatments on plant performance.

3.1 Plant Performance

Direct stuck plants were taller than peat-block stuck plants (Figure 9a, page 45). (Height was taken as the distance from the apex to the surface of the sand for direct stuck plants or the surface of the peat block). This difference was particularly noticeable from the first sample (i.e. end of long days) where Delta was on average 4 cm taller from direct sticking compared with peat-block sticking and the difference for Snowdon was on average 8 cm. These differences decreased as the crop matured and subsequent samples were taken.

Stem fresh weight (Figure 9b, page 45) followed a similar trend to plant height with direct sticking producing stems which were on average 3 g and 5 g heavier than peat-block sticking for Delta and Snowdon respectively. By maturity however stem fresh weights were comparable for both propagation methods. Bulk dry weights (Figure 9c, page 45) followed the same trends as stem fresh weights.

Percentage dry matter figures (Figure 9d, page 46) were not consistently affected by the propagation method.

At final grade-out (Figure 10, page 47), the two propagation methods with Snowdon were comparable in terms of percentage of grade one stems. Mean percentage of grade two stems of Snowdon was however lower from direct stuck plants with a resulting increase in percentage of stems at grade 3 and below. Grade-out figures for Delta were more comparable overall for the two propagation methods. A slight reduction in percentage grade 1 stems with a resultant increase in percentage of stems at grade 3 or below was noted for direct sticking.

Shelf-life of direct stuck Delta stems was 4.5 days longer than for peat block stuck stems. For Snowdon, however, shelf-life of peat block stuck stems was 2.8 days longer than that of direct stuck stems (Appendix II, table 3, page 101).

3.2 Disease Assessment

Direct sticking increased the incidence of *Pythium* spp infection of both Delta and Snowdon (Appendix IV, page 112). Degree of root browning also apparently increased through direct sticking in comparison with sticking in peat blocks. As with previous samples however, there was no indication from the stems of any rot problems within the root systems.

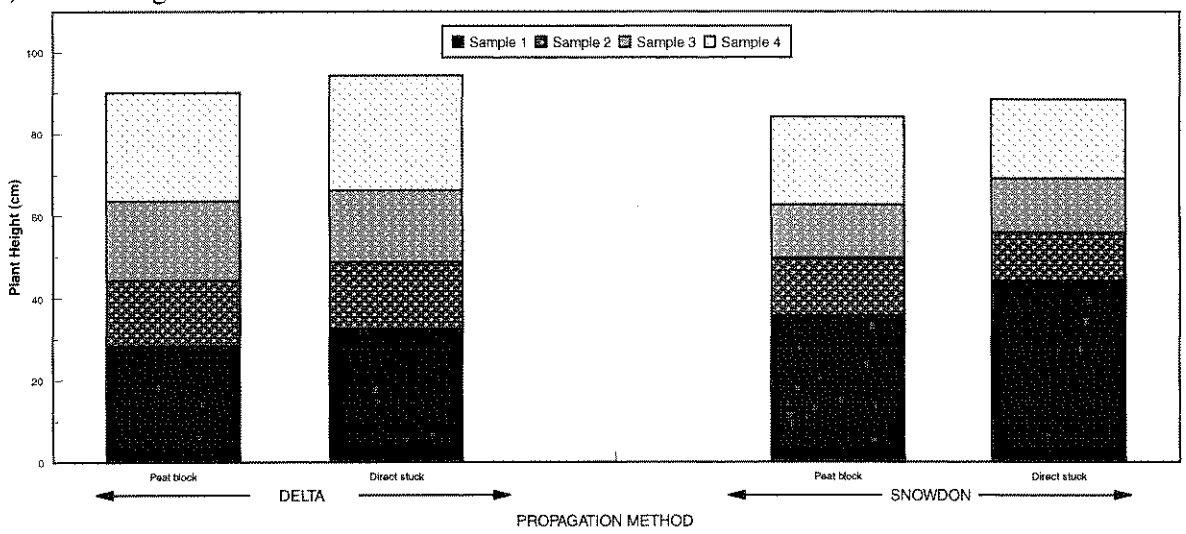
It should also be noted that root systems of direct stuck plants were much easier to remove from beds and clean up for assessment. Root systems in peat blocks however were very difficult to separate from the substrate and it is likely that the weaker parts of the root system were lost during washing which may have influenced these assessments.

3.3 Mineral Analysis - Foliage Samples

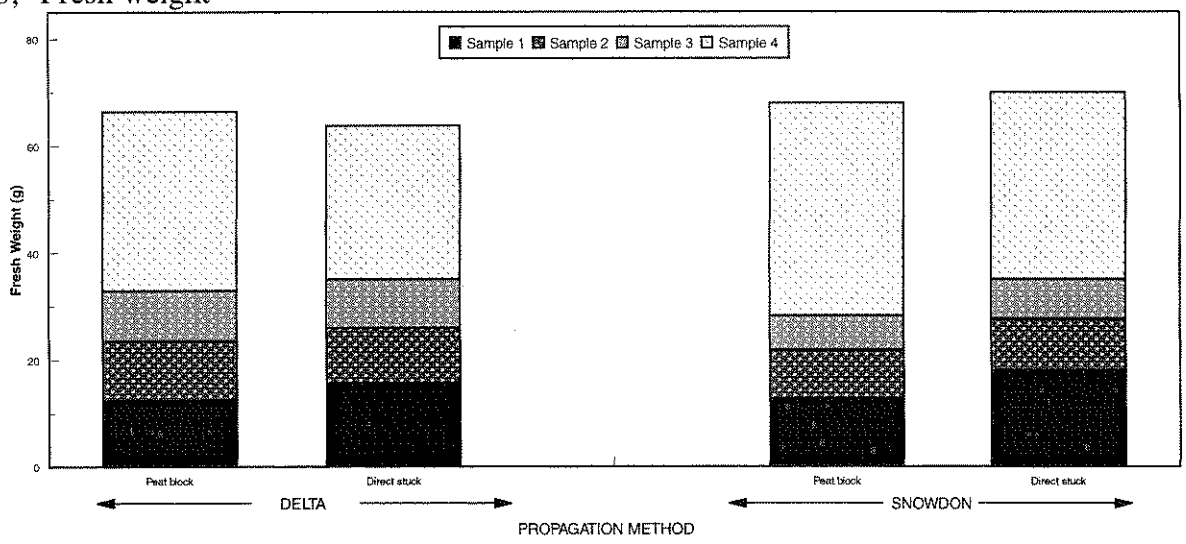
Foliage samples of both direct stuck and peat block stuck plants generally had average mineral levels within the desired ranges (Appendix V, table 3, page 141). As noted previously K and Fe levels generally high but this was not influenced by propagation. Similarly some B levels were low, particularly at maturity.

Figure 9. The Influence of Direct Sticking on Plant Performance (1993/94)

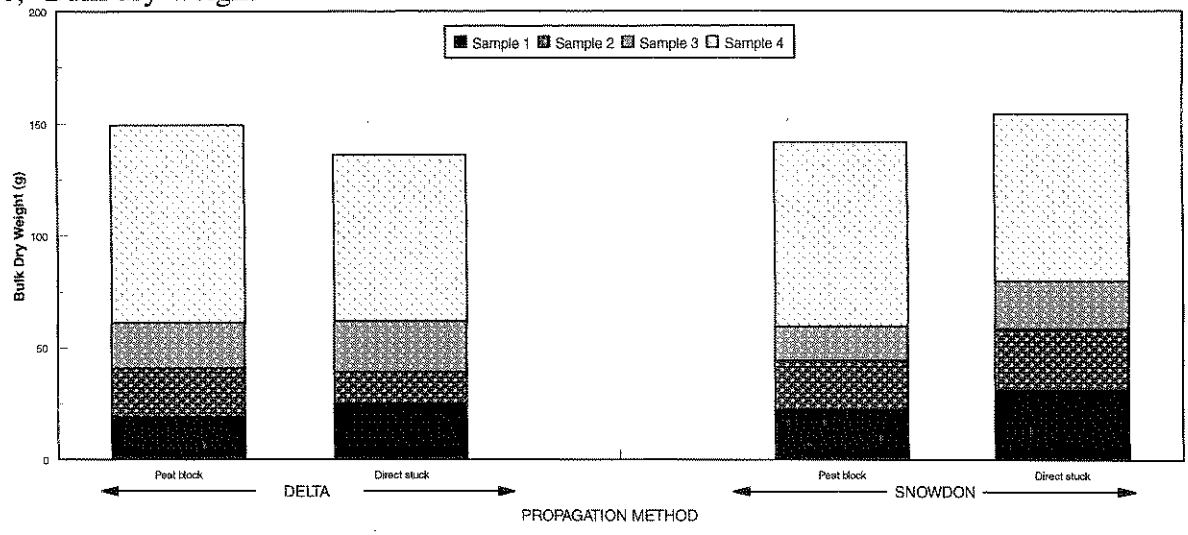
a, Plant height



b, Fresh weight



c, Bulk dry weight

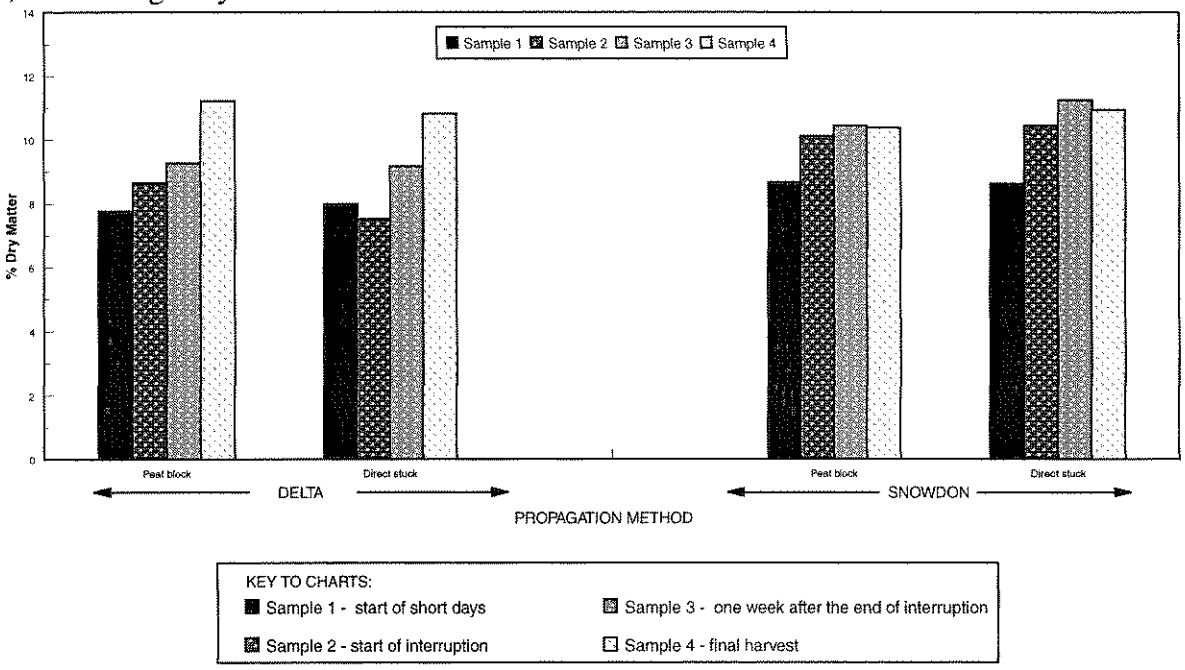


KEY TO CHARTS:

- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 9.(Continued) The Influence of Direct Sticking on Plant Performance (1993/94)

d, Percentage dry matter



KEY TO CHARTS:

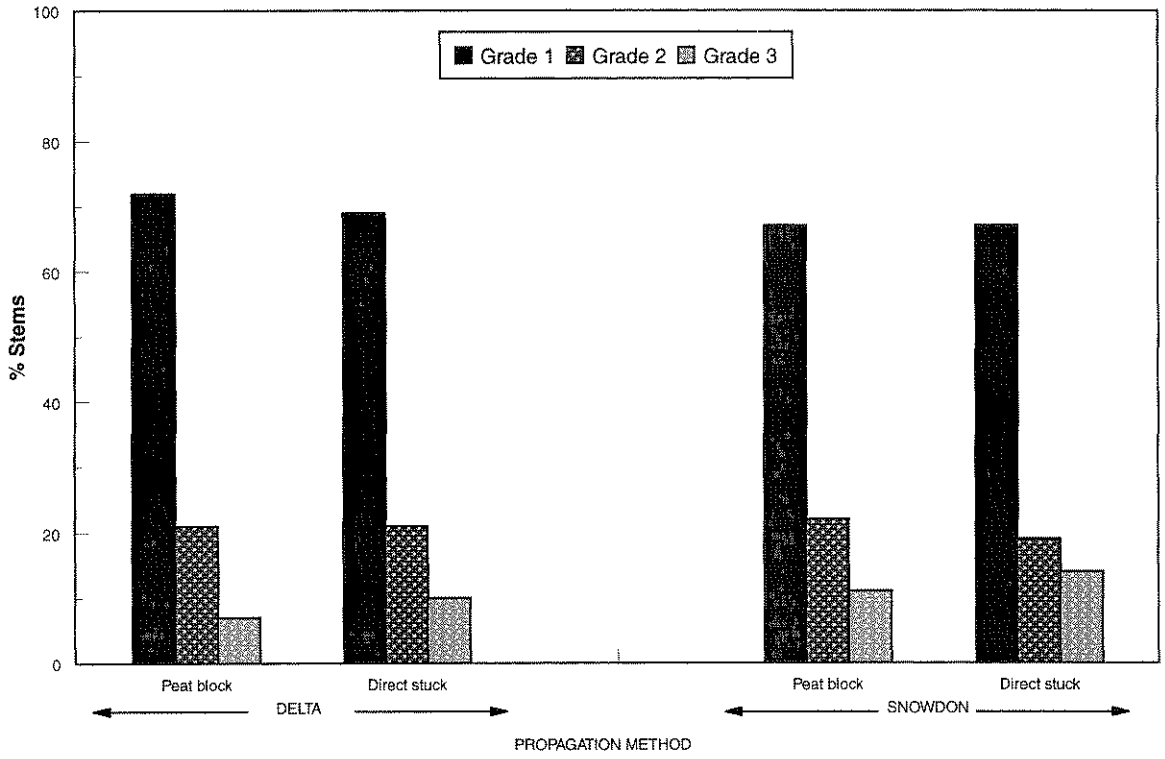
Sample 1 - start of short days

Sample 2 - start of interruption

Sample 3 - one week after the end of interruption

Sample 4 - final harvest

Figure10. The Influence of Direct Sticking on Harvest Grade Out (1993/94)



4. The Effects of Successive Planting in Hydroponic Substrates without Sterilization Between Crops

Plots in this comparison were not replicated on different beds and hence data was not tested for statistical significance.

4.1 1992/93

4.1.1 Plant Performance

Planting IV on sand produced taller plants than Planting I for both varieties (Figure 11a, page 53). In contrast, Planting I on soil produced taller plants than Planting IV on soil. Planting IV on Probase continued to perform well in comparison with the sand based hydroponic systems.

Fresh stem weight (Figure 11b, page 53) and bulk dry weight (Figure 11c, page 53) data responded to successive plantings in the same way as plant height. In particular, early establishment from the fourth successive planting on soil (as indicated by sample 1) was poor.

Percentage dry matter (Figure 11d, page 54) was generally not influenced by the treatments with the exception of planting IV on soil. Percentage dry matter for both varieties from the first sample date was notably higher than from the remaining treatments indicating the harder nature of these poorly established plants.

Leaf area (Figure 11e, page 54) as noted previously was very variable overall. Successive planting did not appear to influence this parameter but planting IV on Probase consistently had smaller leaf area for both varieties compared with both soil and sand-based systems.

Harvest grade-out figures (Figure 13a, page 57) generally reflected the trends discussed above. That is, a greater proportion of stems harvested from Planting IV on sand were of grade 1 quality in comparison with planting I on sand.

Planting IV on Probase produced comparable grade-out to Planting IV on sand. Differences in grade-out between the soil treatments were not consistent. With Delta, planting IV on soil produced slightly higher proportions of grade 3 stems than Planting I on soil and fewer grade 2 stems. With Snowdon however Planting IV on soil produced more grade 2 stems but fewer grade 3 stems than planting I.

Comparable shelf-life performance was recorded from both new and successively planted treatments (Appendix II, table 4a, page 102). The shortest total shelf-life was recorded from the fourth successive planting on soil but the difference recorded was only small.

4.1.2 Disease Assessment

The incidence of *Pythium* spp infection was not influenced by successive planting on sand beds or soil beds despite the decline in performance recorded after four successive plantings on soil (Appendix III, page 103).

4.1.3 Mineral Analyses - Recirculating Solution

pH levels were comparable in both the planting I and IV treatments on sand and close to the set point of 5.8 throughout (Figure 14a, page 58). The pH of the recirculating solution with planting IV on Probase was similarly close to 5.8 throughout the trial.

Conductivity levels remained just below set point throughout for both the planting IV sand and Probase systems (Figure 14b, page 58). Conductivity within the new sand bed system (i.e. Planting I) was initially above set point but declined with time.

NO_3-N remained within the desired concentration range for all treatments throughout the trial period but was generally at the lower end of this range, particularly towards the later stages of production (Figure 14c, page 58).

Changes in NH_4-N concentration again indicated the presence of nitrifying bacteria in the system (Figure 14d, page 58). In particular, the planting IV systems had less than 1 mg/l of NH_4-N in recirculation from the first sampling date (i.e. after one week of long days). In contrast, NH_4-N concentration did not fall to 1 mg/l until the fifth week after planting in the new sand system (planting I).

K and P levels were below desired levels or just within the satisfactory range for all treatments throughout the trial (Figures 14e, 14h, page 59). It is notable that K levels were actually within the desired range for the newly planted sand bed for the first five to six weeks after planting. K concentration in this system then declined throughout the remainder of the trial.

P concentration followed an opposite trend. That is, P in the new sand-based system remained low throughout whilst in the older system P concentration was low initially but increased with time. P concentration in recirculation was higher in the Probase system than either the new or old sand systems.

Calcium and magnesium levels were generally within the desired range although magnesium within the older sand-based system was low initially (Figures 14f, 14g, page 59).

The concentration of both Fe and Zn in the older sand-based system was higher than the new sand or Probase systems (Figures 14i, 14j, page 60).

Mn and B concentrations in all systems were below the target level throughout (Figures 14k, 14m, pages 60 and 61). Cu was generally at or slightly above target levels and increased with time in the new sand and old Probase systems (Figure 14l, page 60). The older sand-based system however had a constant level of Cu in recirculation throughout the trial.

New sand also had higher levels of SO_4-S, Na and Cl throughout the trial than the older sand or Probase systems (Figures 14n, 14o, 14p, page 61).

4.1.4 Mineral Analyses - Foliage Samples

All foliage samples contained above the satisfactory levels of major nutrients analysed (Appendix V, table 4a and 4b, pages 142 and 143). As noted previously, K concentrations were high in the foliage sampled throughout the trial and hence N:K ratios were lower than desired. Differences between treatments were generally small in terms of foliage nutrient status but levels of all elements analysed were consistently lower from plants on the older sand-based system than the new system.

4.2 1993/94

4.2.1 Plant Performance

In 1993/94 the seventh successive planting on sand and Probase was assessed alongside the fourth successive planting on sand and planting I on soil. In agreement with the 1992/93 trial, the older sand-based system produced greater plant height (Figure 12a, page 55), fresh weight (Figure 12b, page 55) and bulk dry weight (Figure 12c, page 55) than the newer sand-based system. The main advantage becoming obvious towards the end of production (i.e. samples 3 and 4). Planting VII on Probase produced comparable results to the sand-based systems.

Comparison of the freshly steam-sterilized soil beds with these systems was mixed. The older sand-based systems produced greater fresh weight (particularly with Snowdon) than new soil. Plant height was shorter in soil-grown plants initially (i.e. sample 1) but largely comparable by maturity.

Percentage dry matter (Figure 12d, page 56) was generally variable but was notably greater at sample 4 from plants grown on new soil compared with the hydroponic systems assessed.

Percentage of grade I stems at final harvest (Figure 13b, page 57) was superior on all hydroponic systems compared with planting on steam-sterilized soil. The hydroponic crops therefore also had fewer lower grade stems than the soil crops. Delta had a better grade-out from planting VII on sand compared with planting IV on sand in terms of higher grade stems. Grade-out results for Snowdon however were comparable for all the hydroponic systems assessed.

Shelf-life of Delta was 15.2 days shorter from planting IV on sand compared with planting VII (Appendix II, table 4b, page 102). This result was not however repeated for Snowdon which had a shorter shelf-life from planting VII on sand in comparison with planting IV.

4.2.2 Disease Assessment

There were no significant differences between the successive plantings on hydroponic systems or planting on freshly steam-sterilised soil in terms of either incidence of *Pythium* spp infection or degree of root browning (Appendix IV, page 112).

4.2.3 Mineral Analyses - Recirculating Solution

The results of mineral analysis of the recirculating solution (Figure 15, pages 62-65) were comparable to the 1992/93 figures except for the following observations.

Conductivity levels were comparable for all treatments in contrast to 1992/93 when levels were higher initially from the new sand-based system (Figure 15b, page 62). In the 1993/94 trial however there were no completely new sand-based systems.

NH_4-N was low in all systems throughout the 1993/94 trial, but again there were no new sand-based systems (Figure 15d, page 62).

K levels were much lower in the planting IV on sand system than either the older sand or older Probase systems (Figure 15e, page 63). P concentration in recirculation was also higher from the older sand system (i.e. planting VII) than the newer system (planting IV) (Figure 15h, page 63).

Mn levels were again below the target level in 1993/94 and were lower overall than in the 1992/93 trial (Figure 15k, page 64). The differences in Cu concentration between the newer and older sand-based systems were greater in 1993/94 than in 1992/93 (Figure 15l, page 64). That is, the newer sand-based system contained much higher Cu levels in recirculation than the older sand-based system throughout the trial.

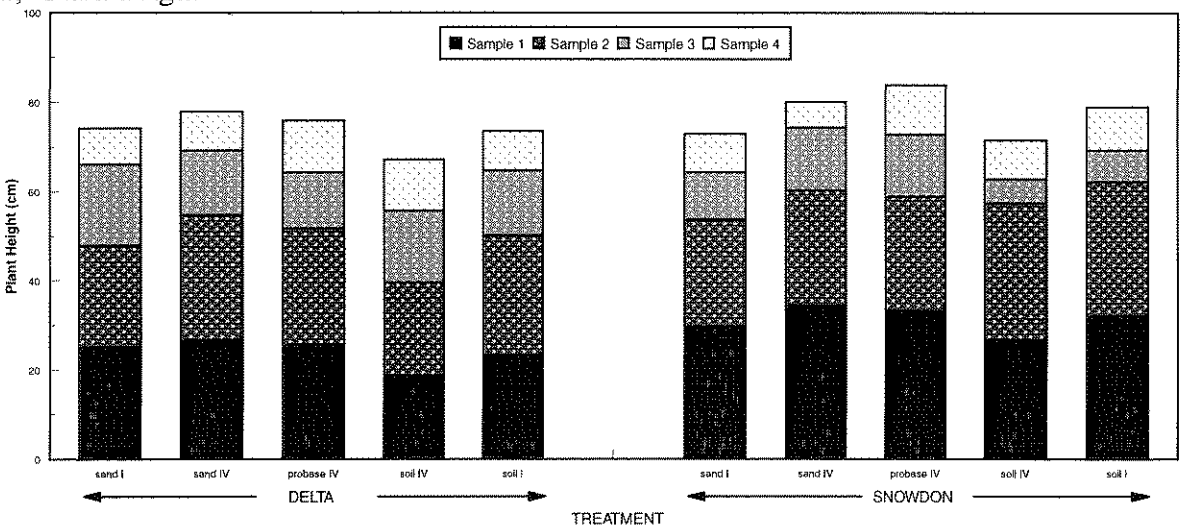
4.2.4 Mineral Analyses - Foliage Samples

Nutrient levels in foliage samples were broadly satisfactory (Appendix V, tables 4c, 4d (pages 144 and 145). K levels were more acceptable than in 1992/93 with more favourable N:K ratios. There were individual samples, particularly of Snowdon, with low levels of particular nutrients (e.g. Mg, B) but this was not apparently the result of successive planting as it was not consistently linked with one treatment. Fe levels were also high from several samples but this again was not consistently caused by one of the treatments.

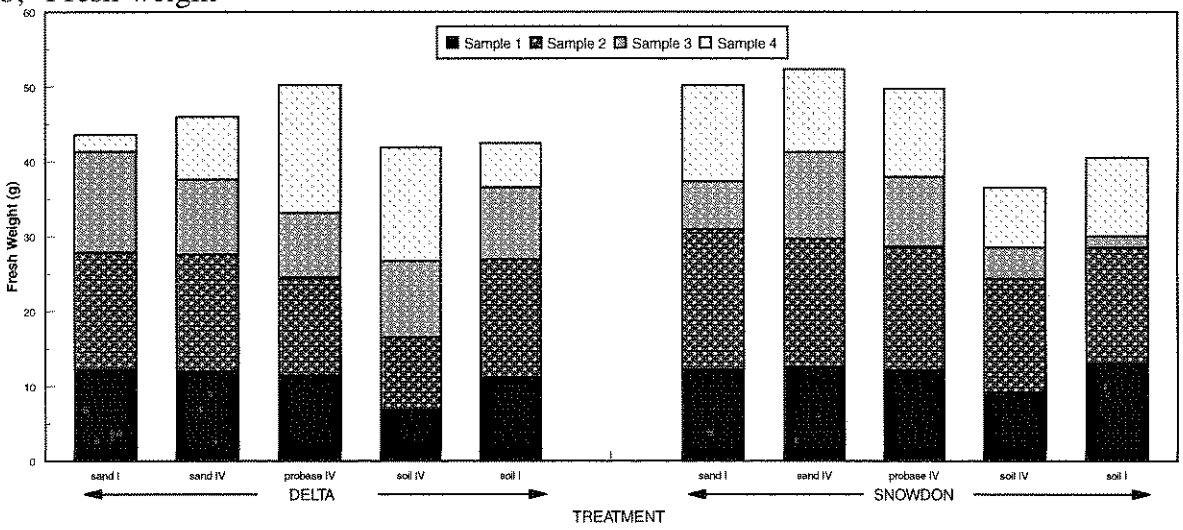
The observation noted from the 1992/93 data that older sand consistently had lower (although still satisfactory) levels of all nutrients that the new sand system was not repeated for the 1993/94 data.

Figure 11. The Influence of Successive Plantings on Plant Performance (1992/93)

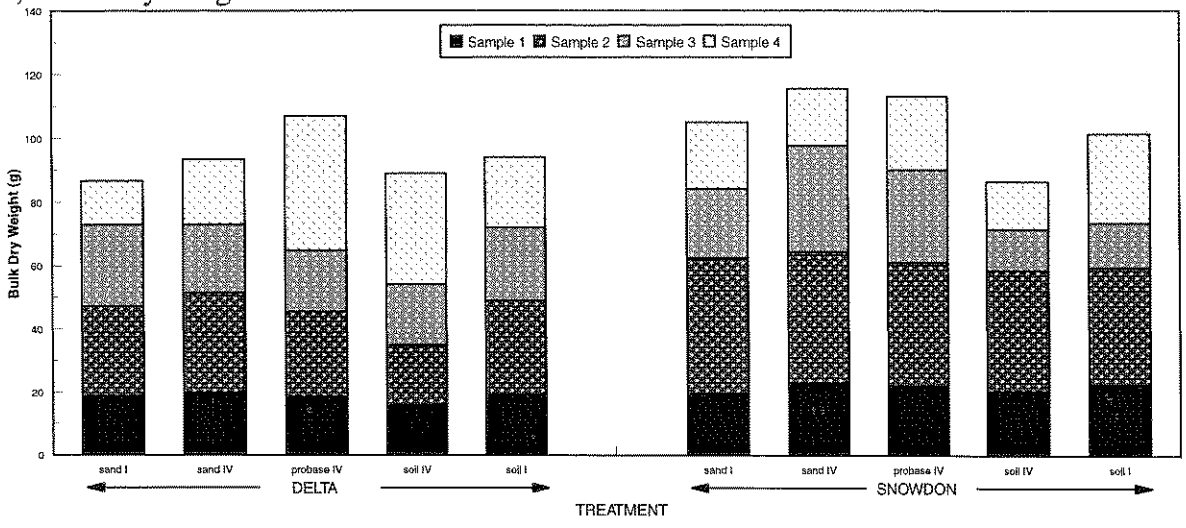
a, Plant height



b, Fresh weight



c, Bulk dry weight

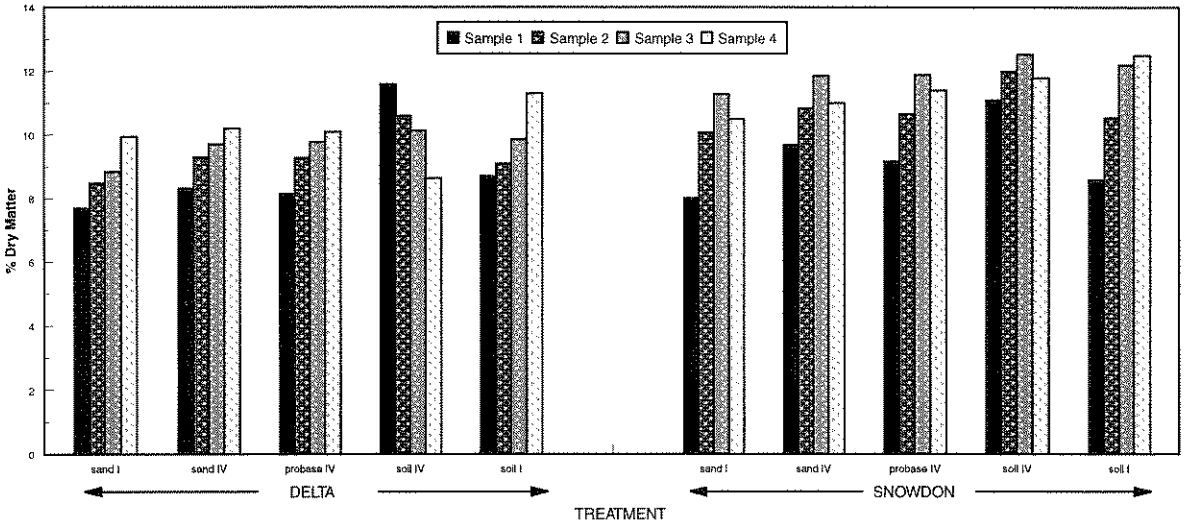


KEY TO CHARTS:

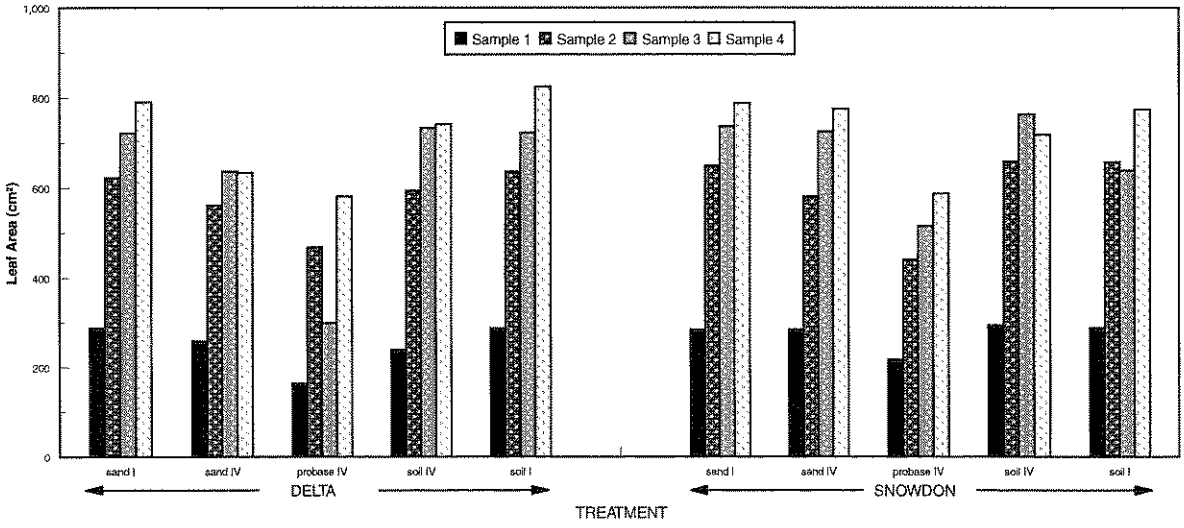
- Sample 1 - start of short days
- Sample 2 - end of interruption
- Sample 3 - 10 days after the end of interruption
- Sample 4 - final harvest

Figure 11.(Continued) The Influence of Successive Plantings on Plant Performance (1992/93)

d, Percentage dry matter



e, Leaf area

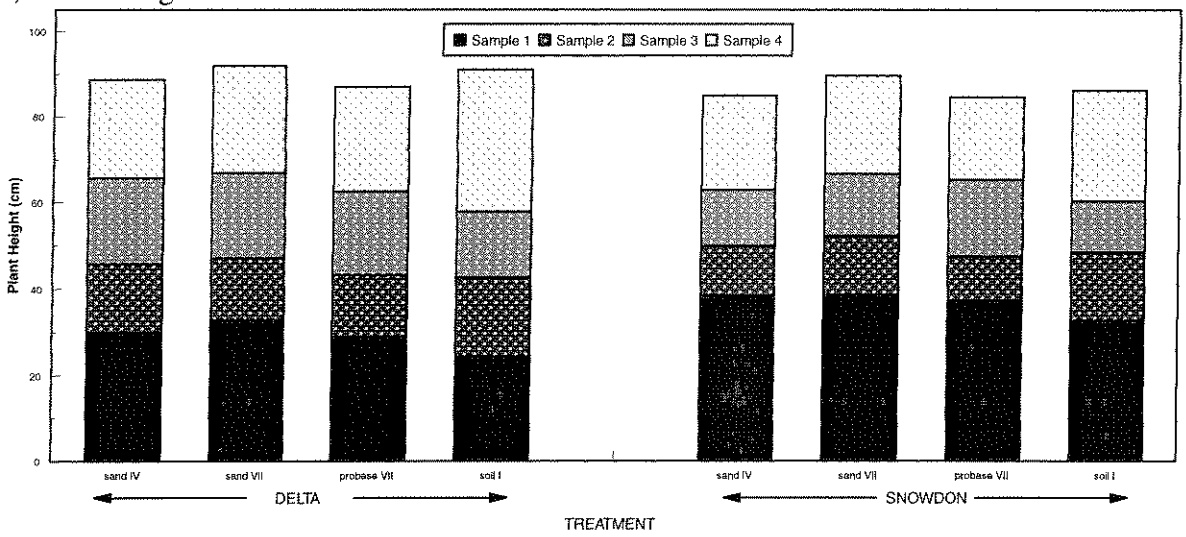


KEY TO CHARTS:

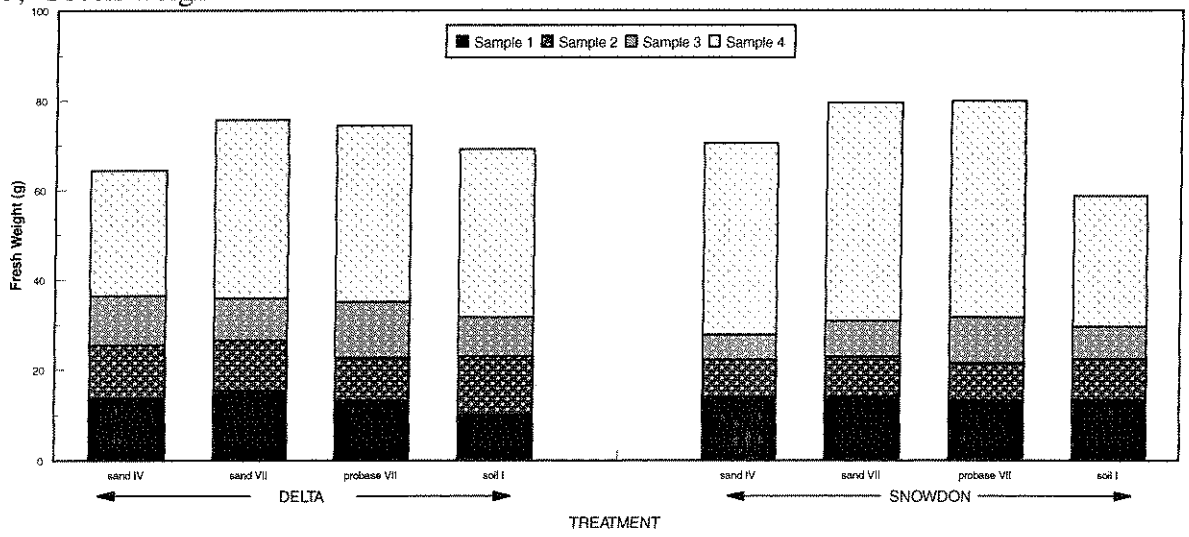
- Sample 1 - start of short days
- Sample 2 - end of interruption
- Sample 3 - 10 days after the end of interruption
- Sample 4 - final harvest

Figure 12. The Influence of Successive Plantings on Plant performance (1993/94)

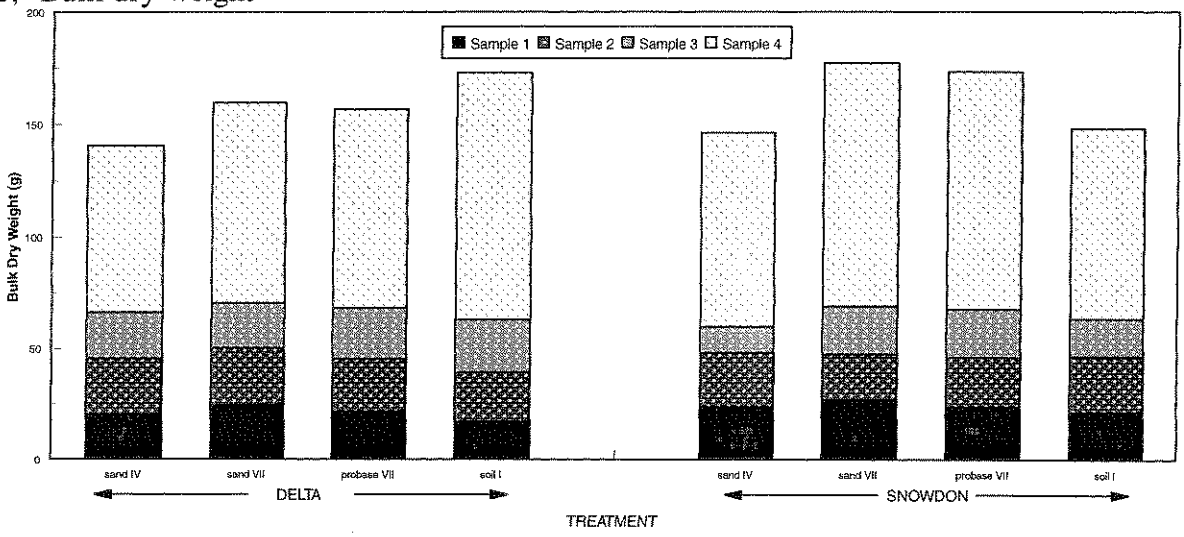
a, Plant height



b, Fresh weight



c, Bulk dry weight

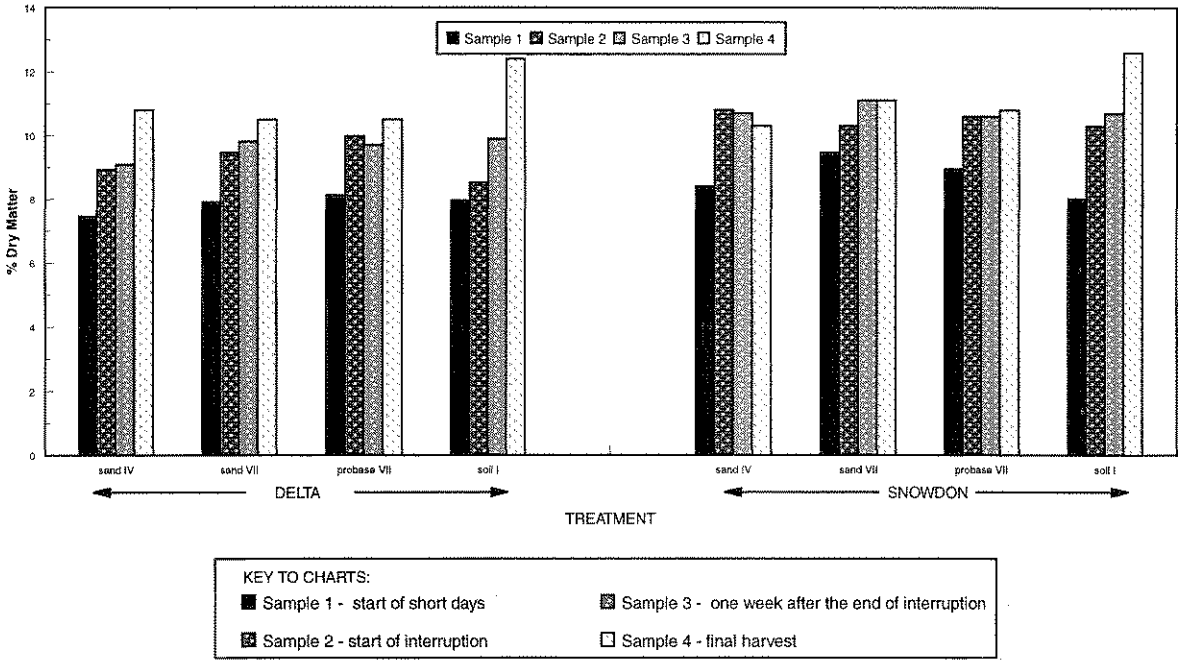


KEY TO CHARTS:

- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 12.(Continued) The Influence of Successive Plantings on Plant Performance (1993/94)

d, Percentage dry matter

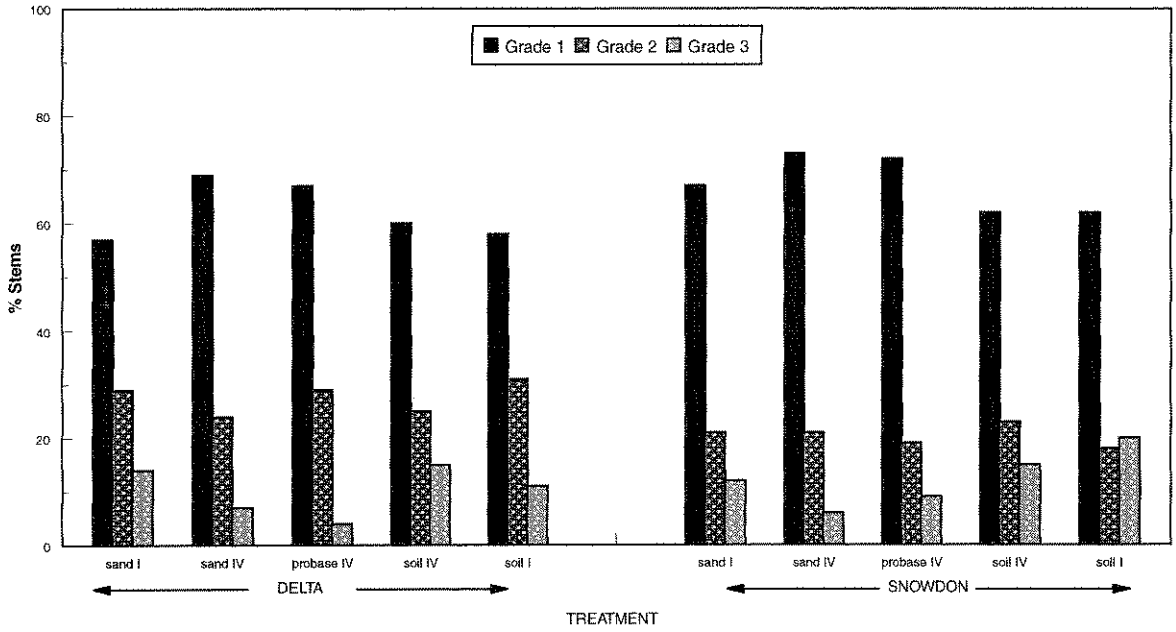


KEY TO CHARTS:

- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 13. The Influence of Successive Plantings on Harvest Grade Out

a, 1992/93



b, 1993/94

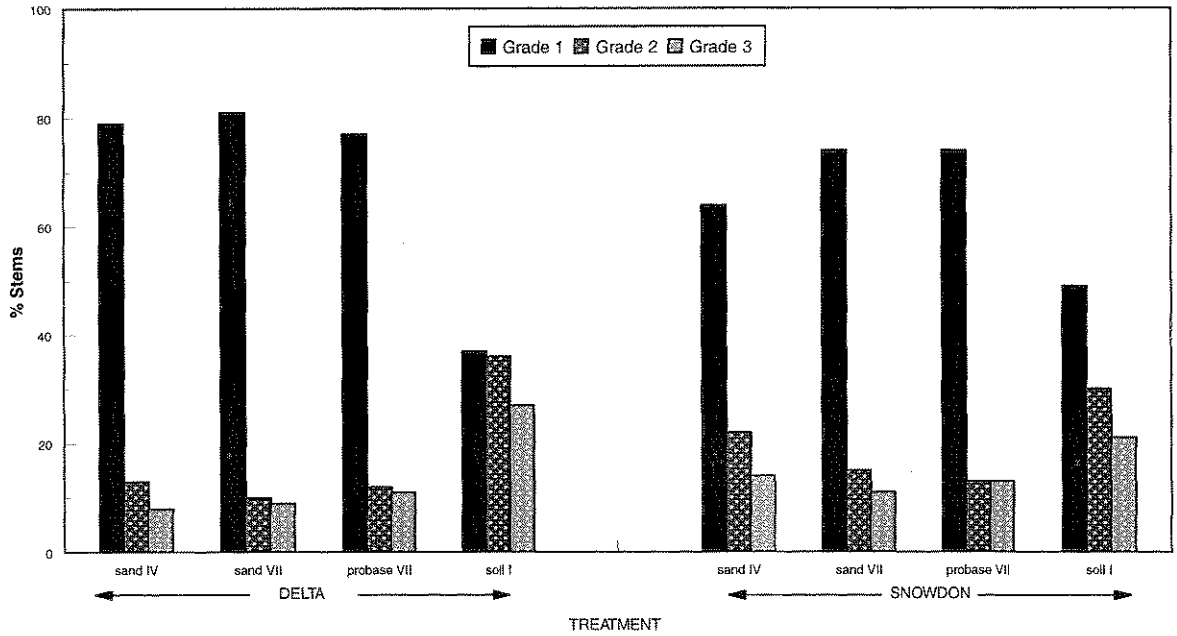


Figure 14. The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1992/93

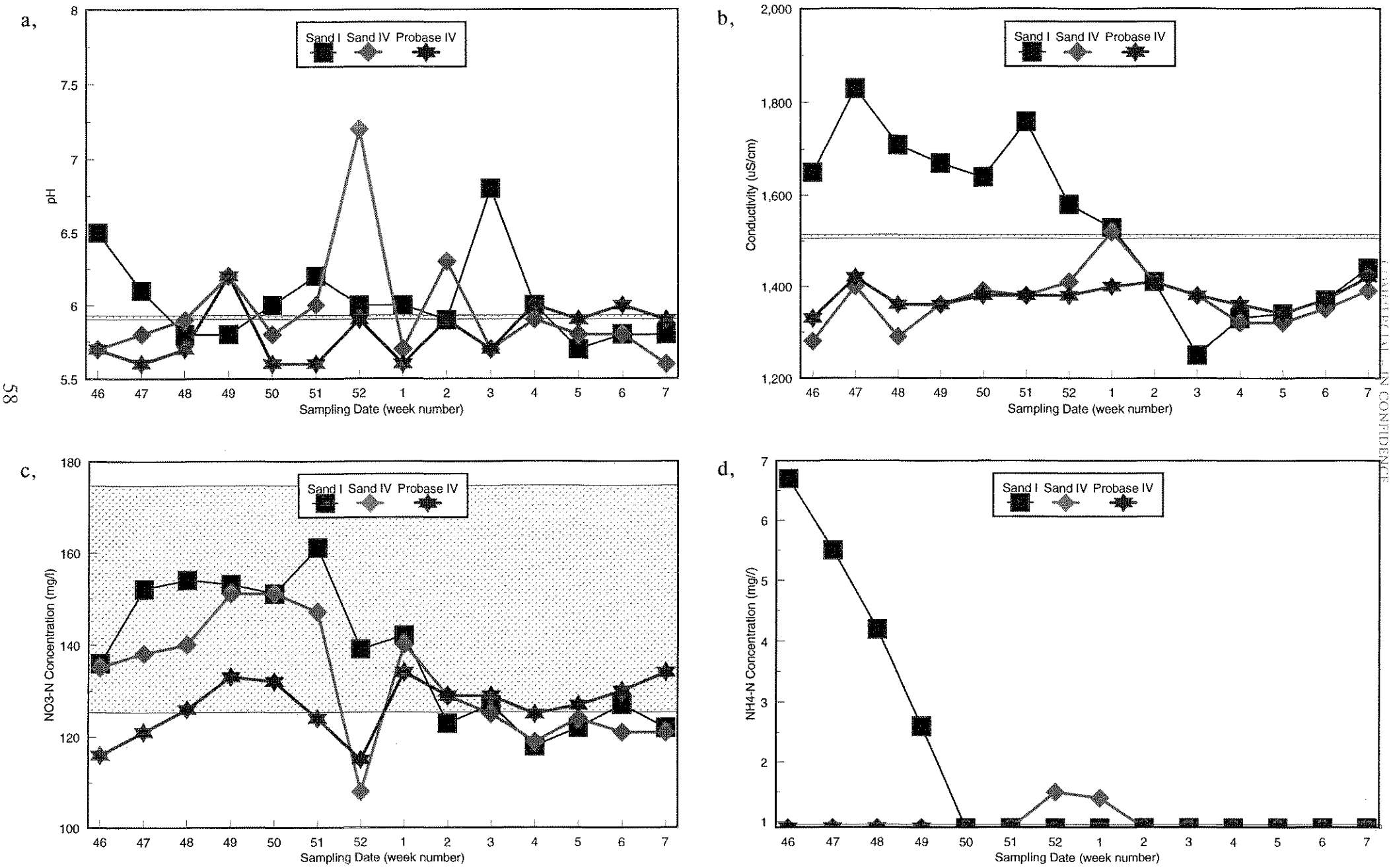
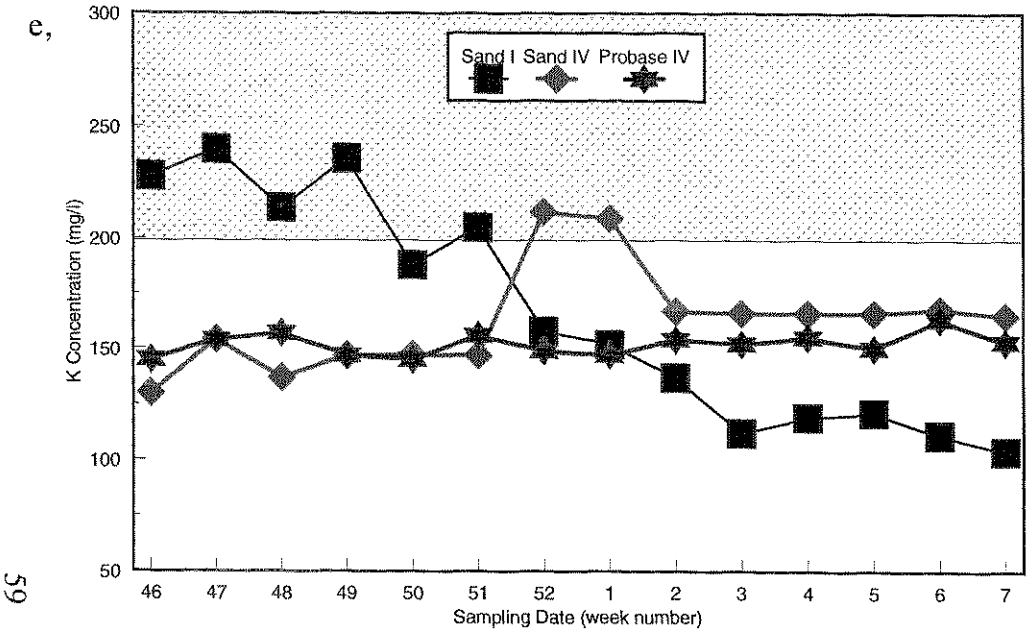
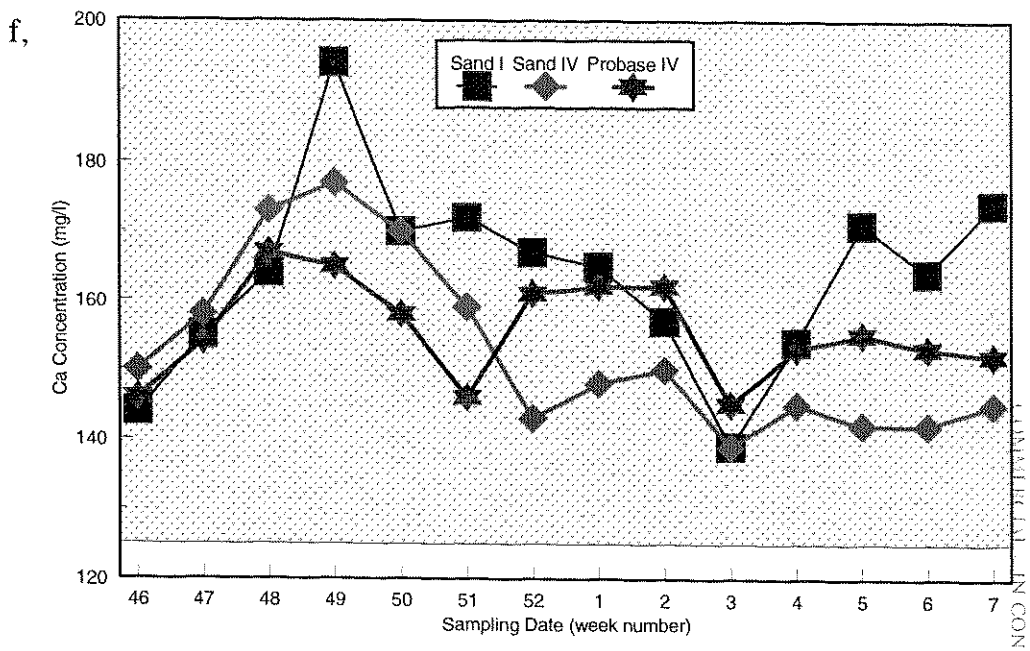
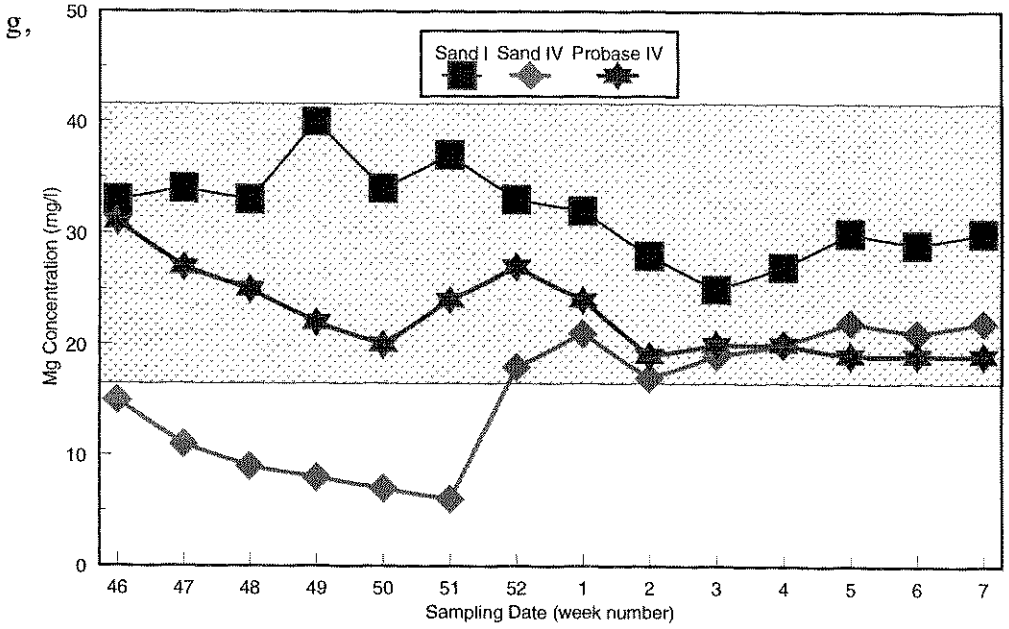


Figure 14.(Continued) The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1992/93







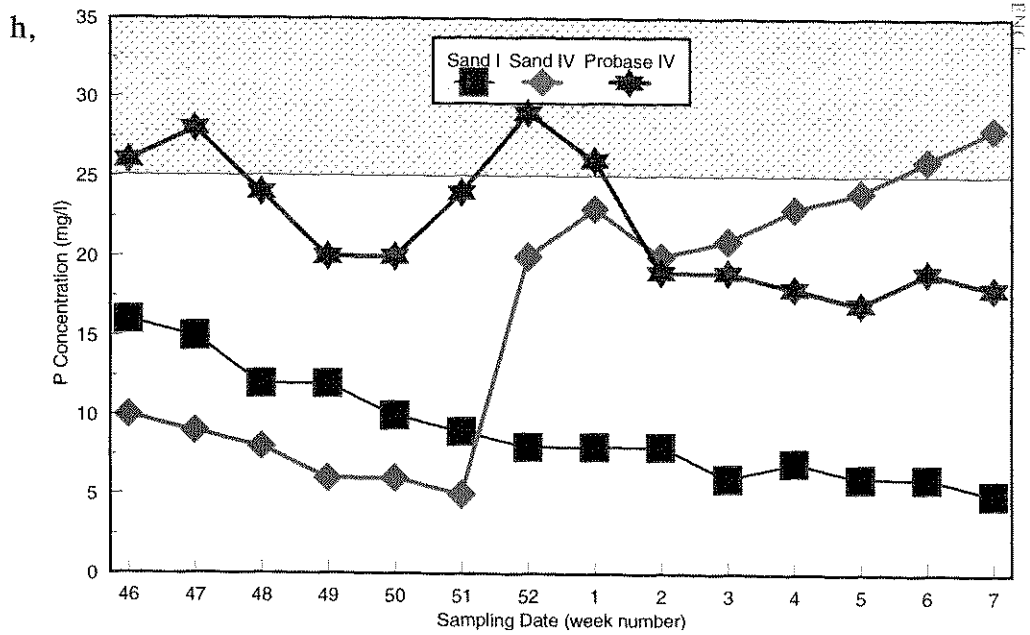
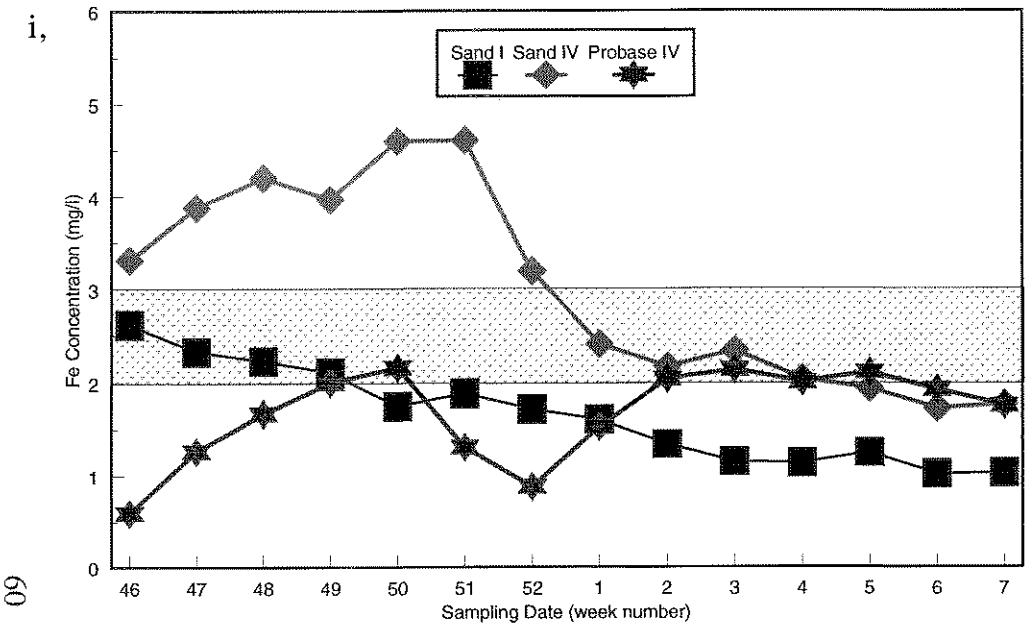
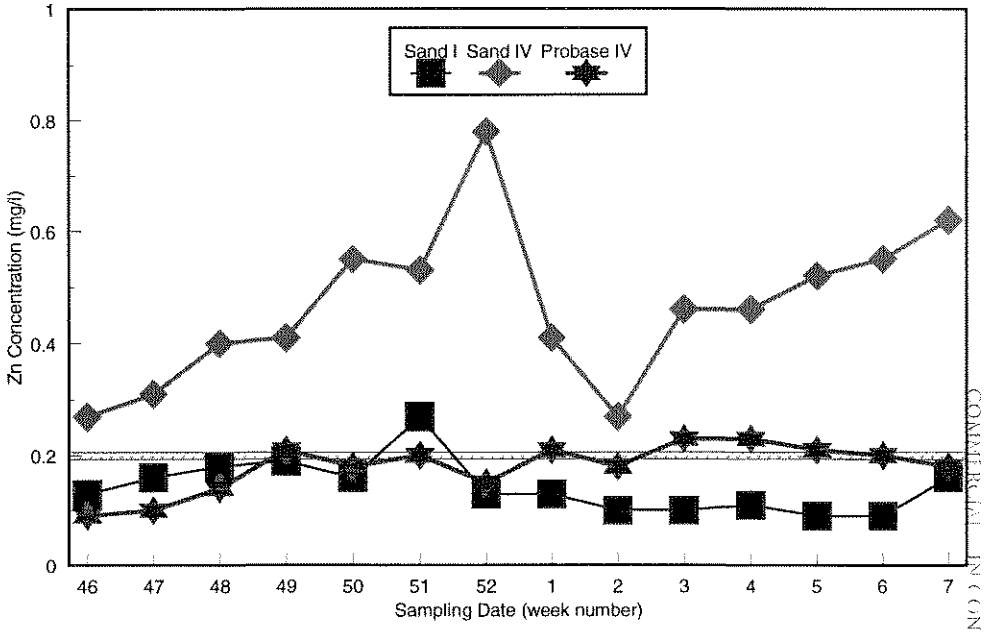
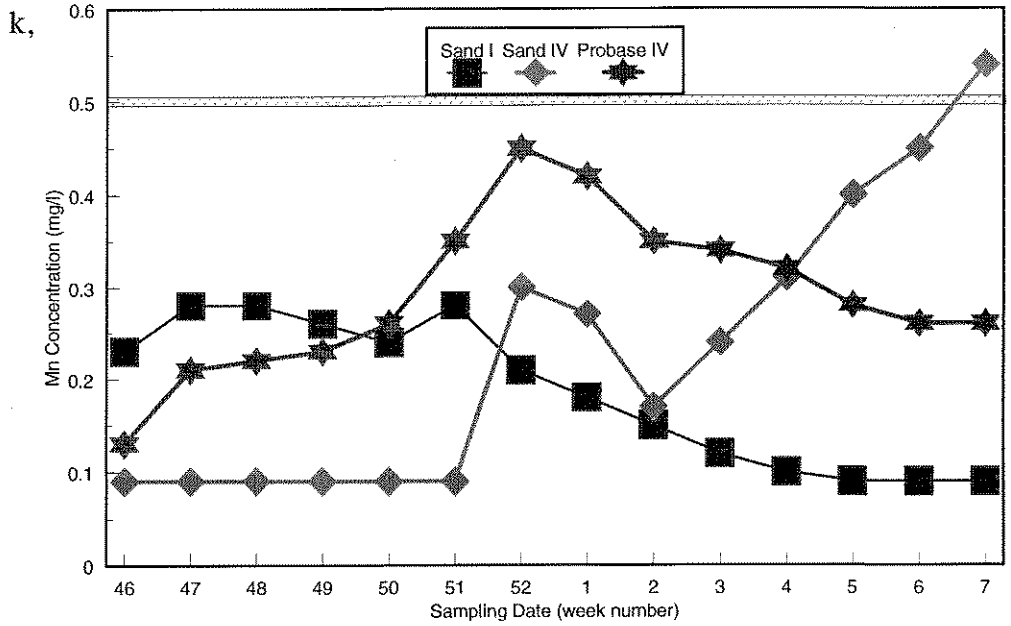


Figure 14.(Continued) The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1992/93







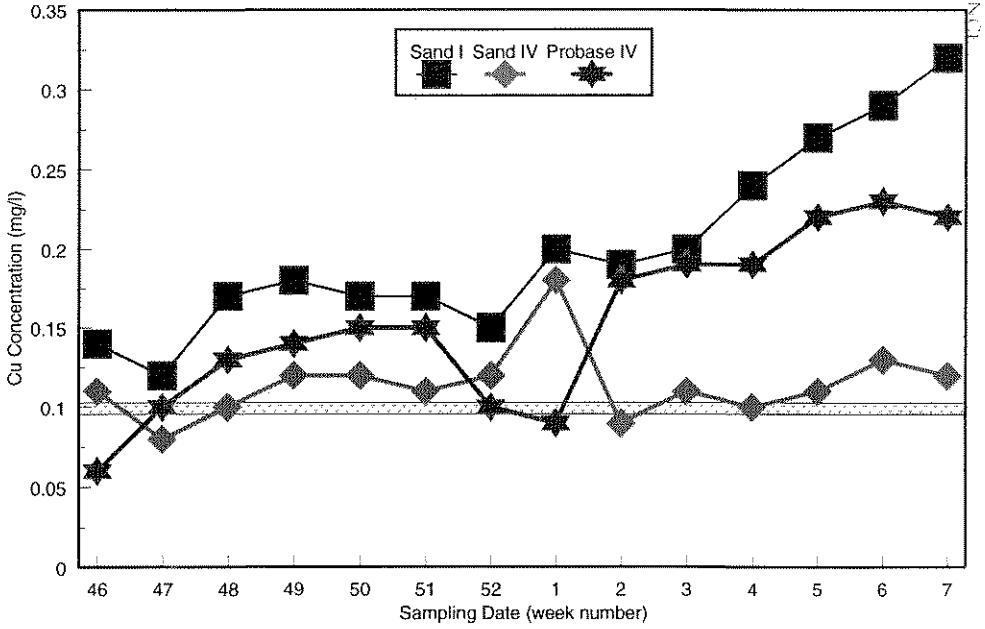
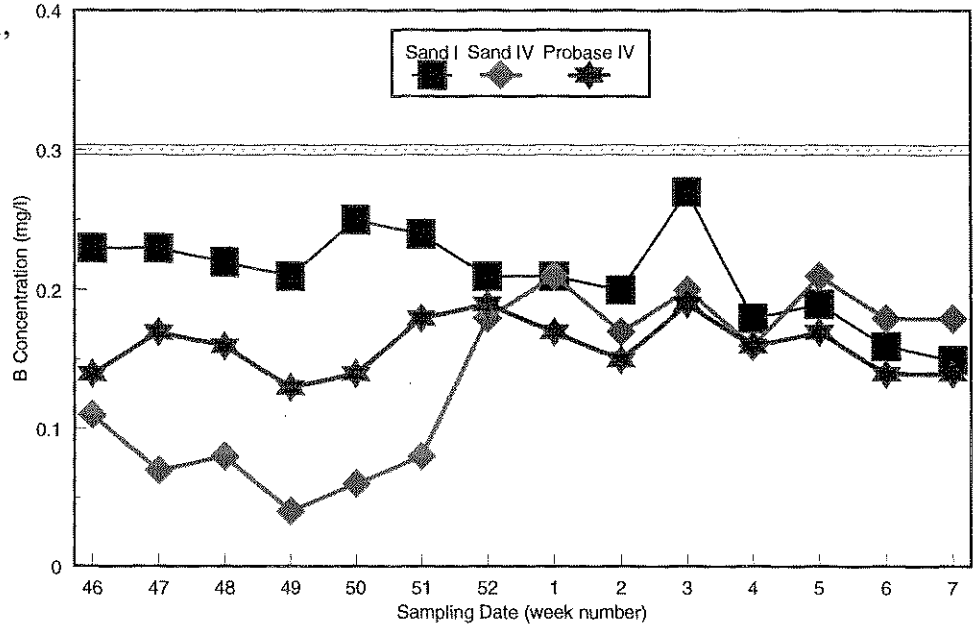
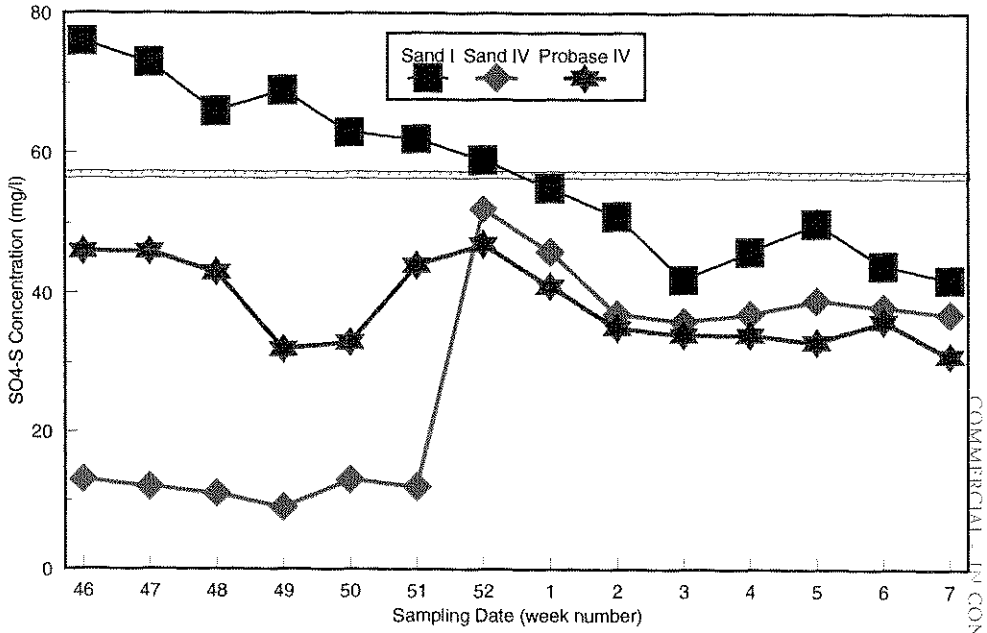


Figure 14.(Continued) The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1992/93

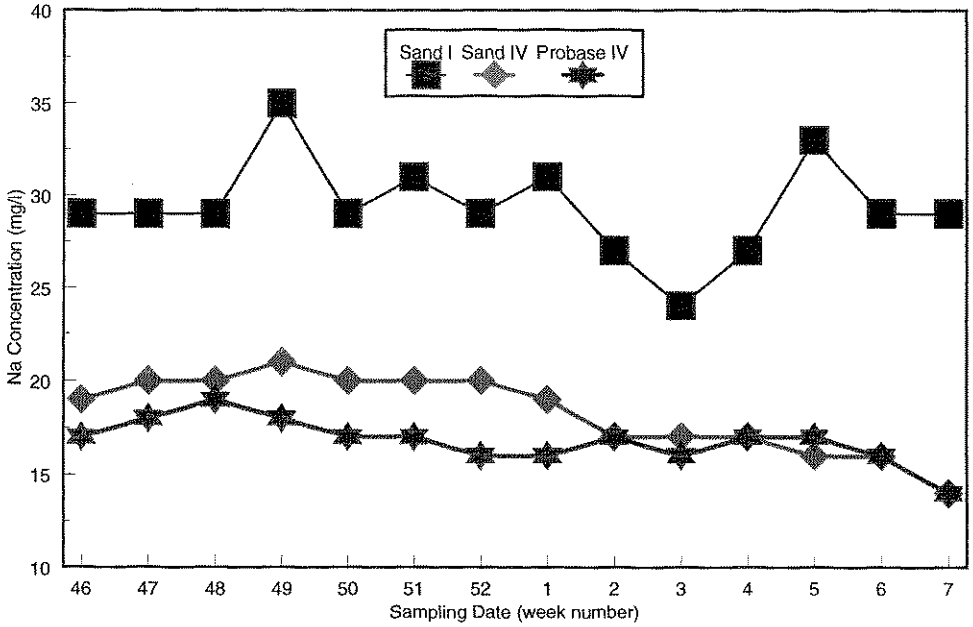
m,



n,



o,



p,

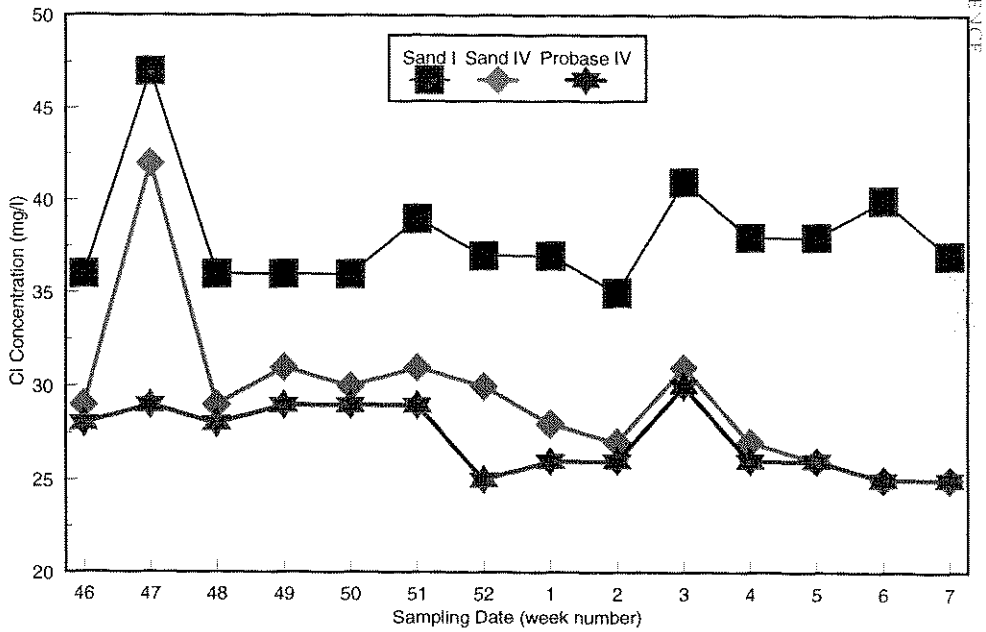


Figure 15. The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1993/94

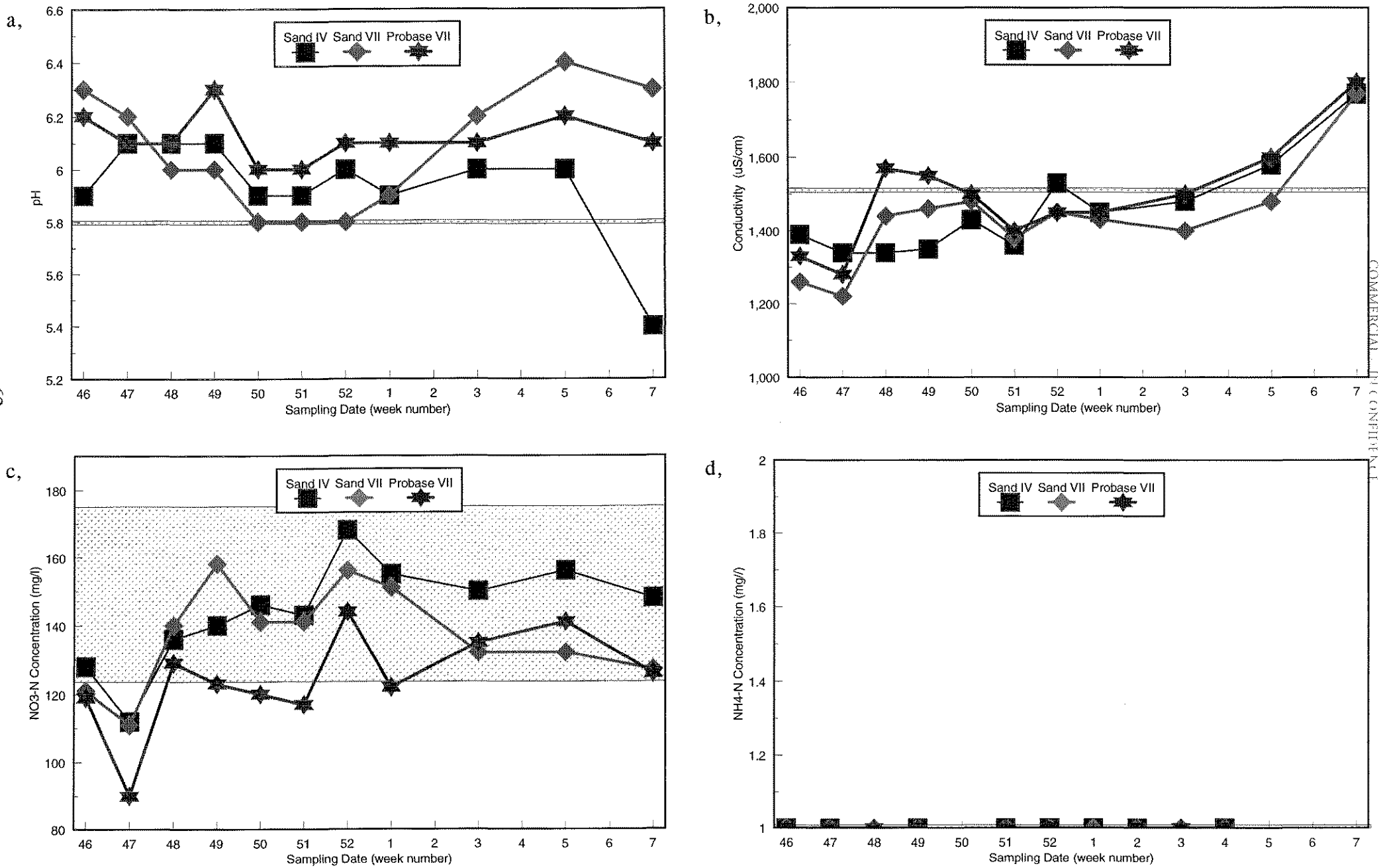
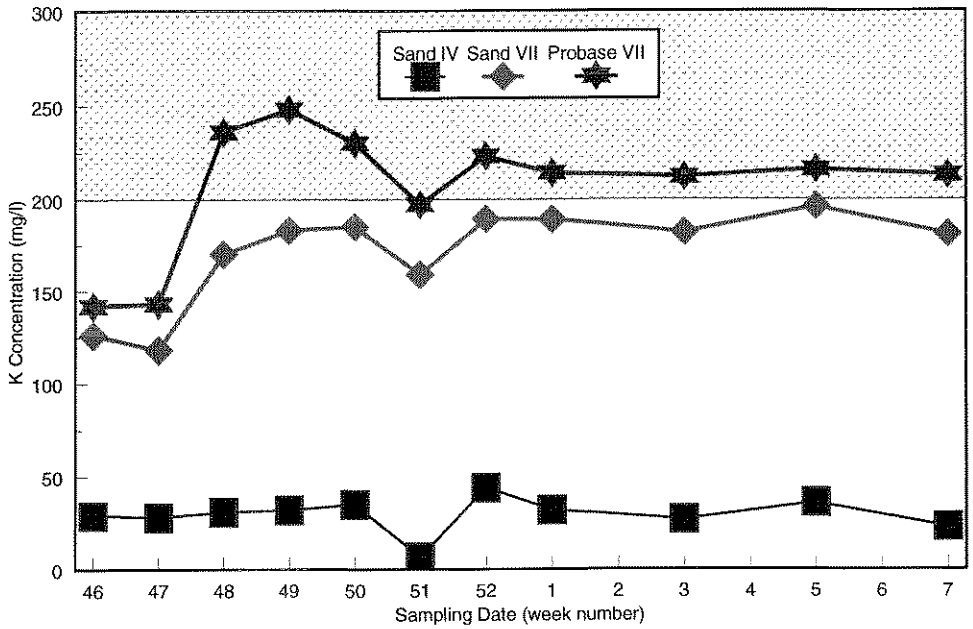
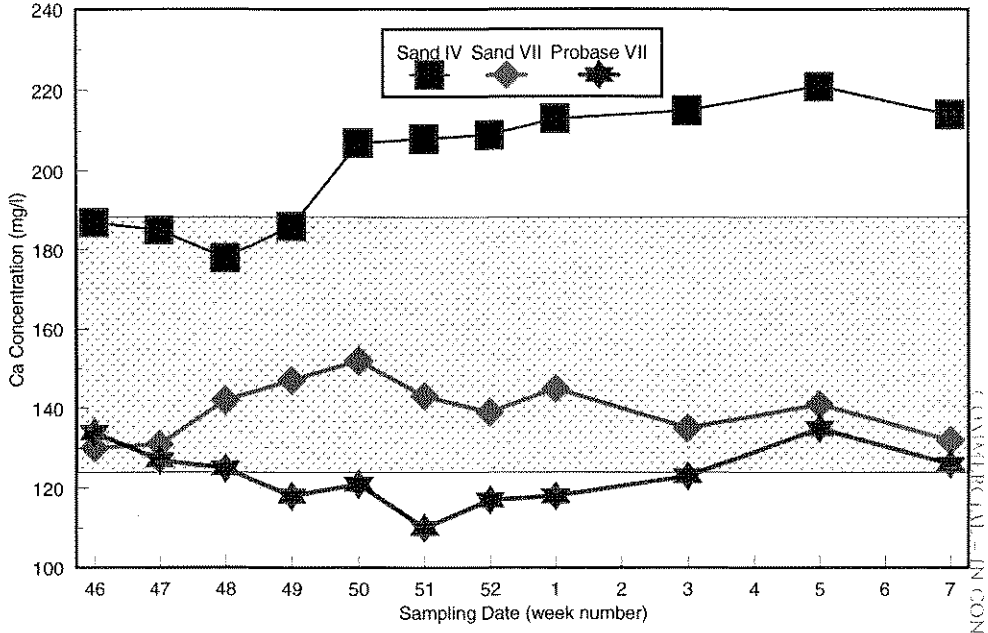


Figure 15.(Continued) The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1993/94

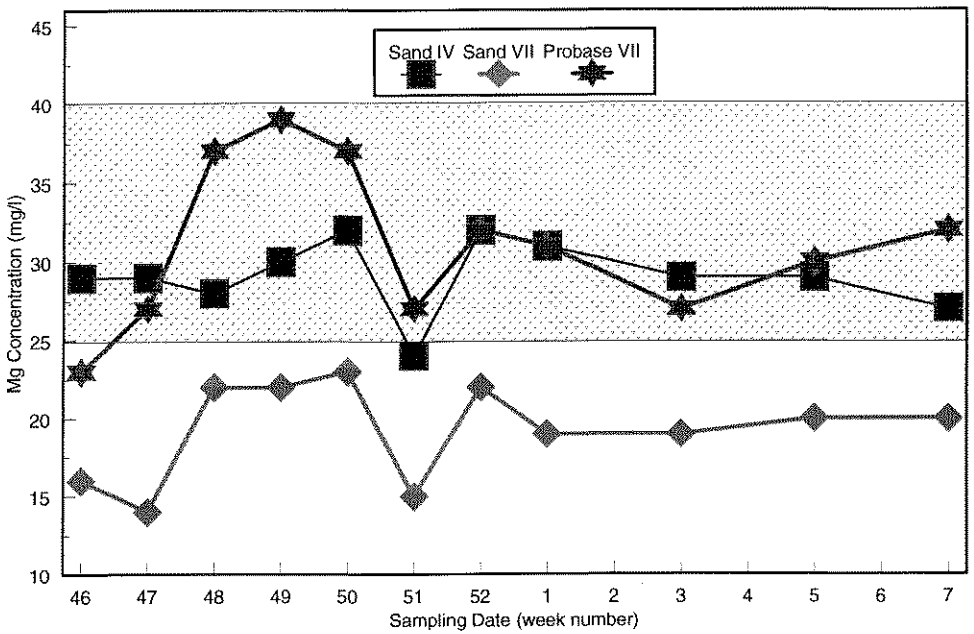
e,



f,



g,



h,

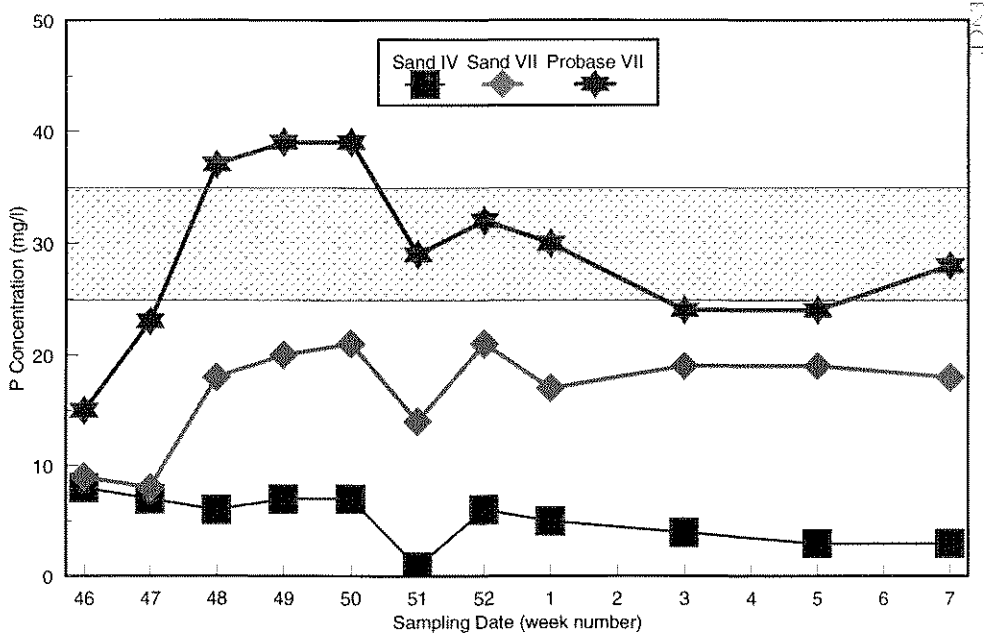
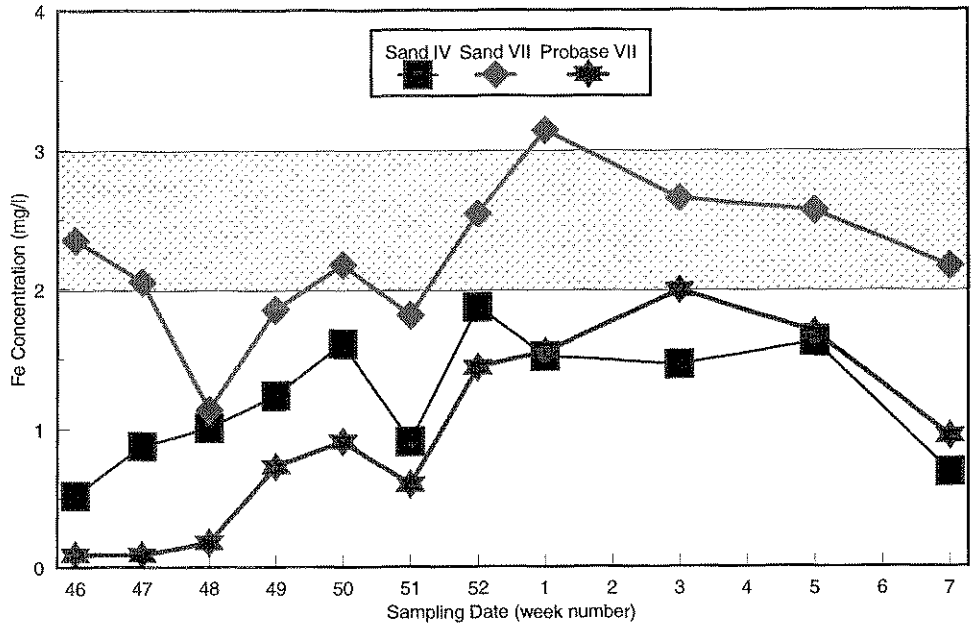
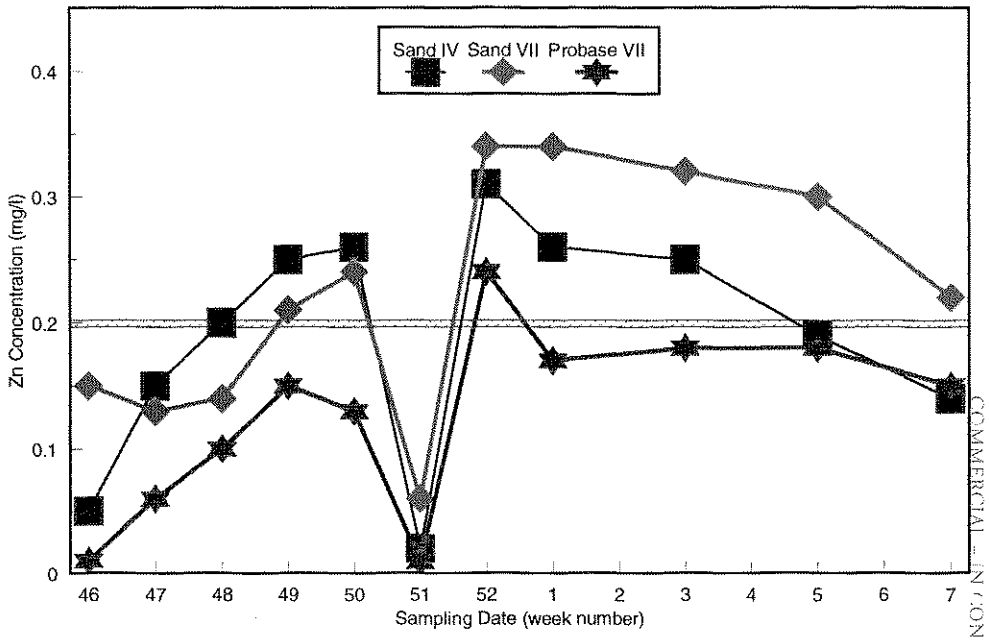


Figure 15.(Continued) The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1993/94

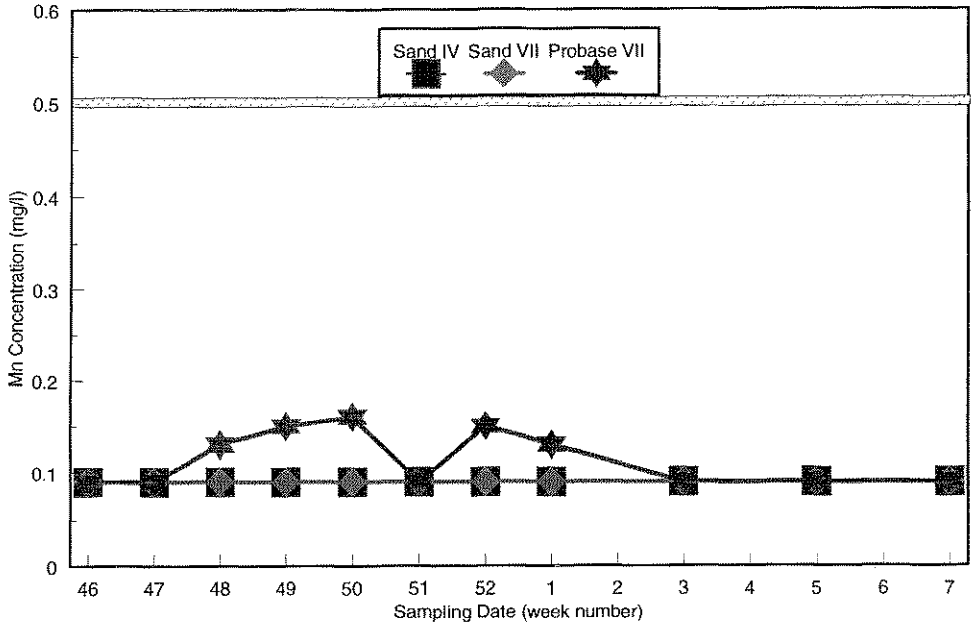
i,



j,



k,



l,

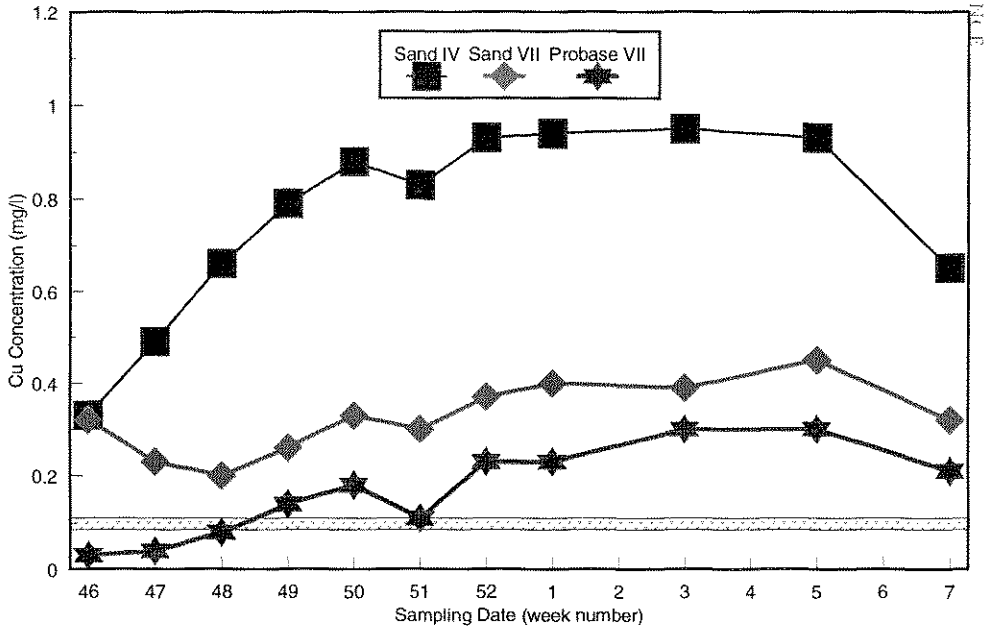
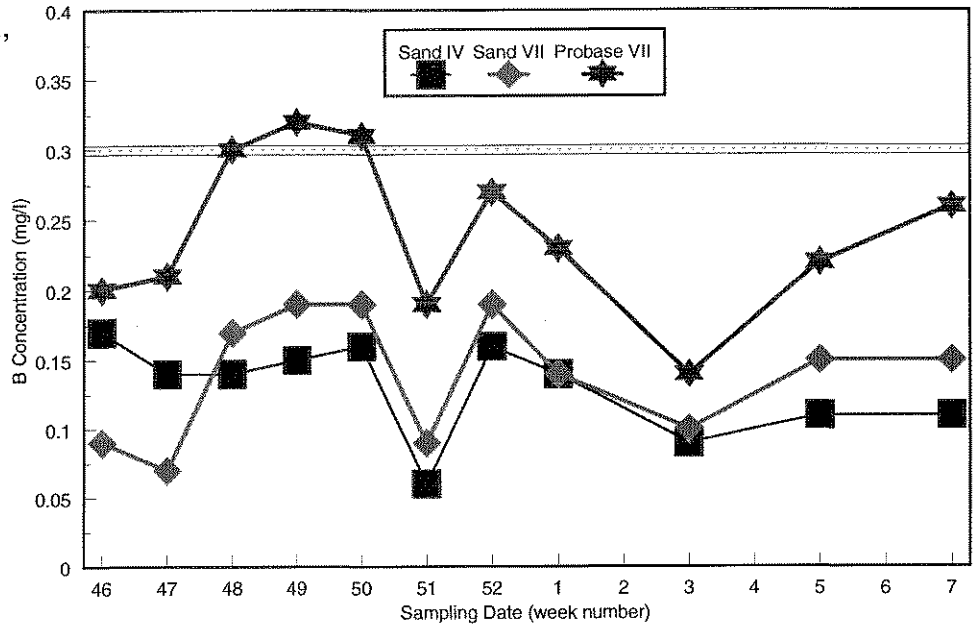
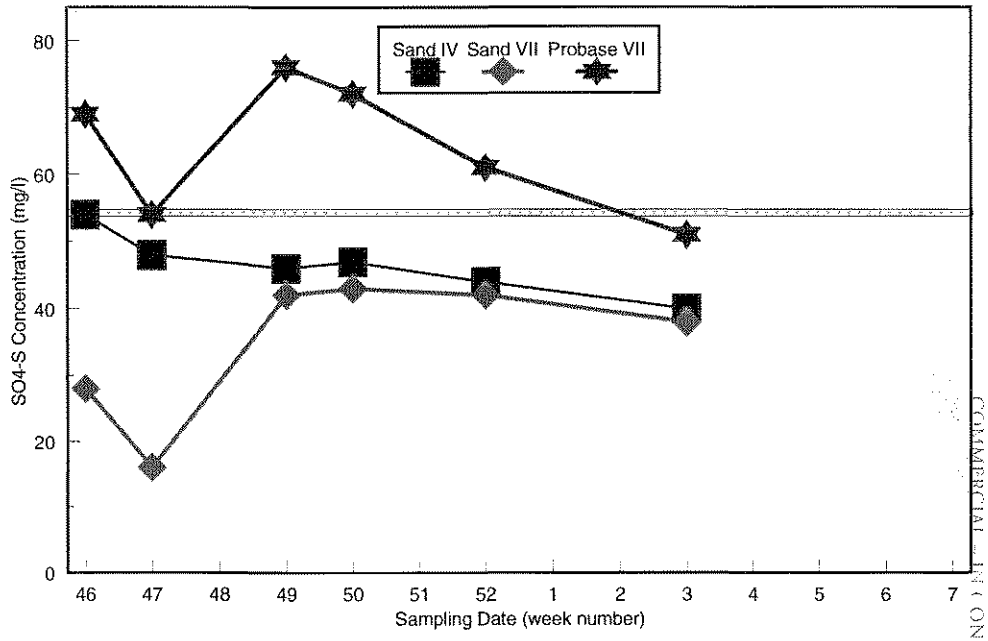


Figure 15.(Continued) The Influence of Successive Plantings on the Nutritional Composition of the Recirculation Solution - 1993/94

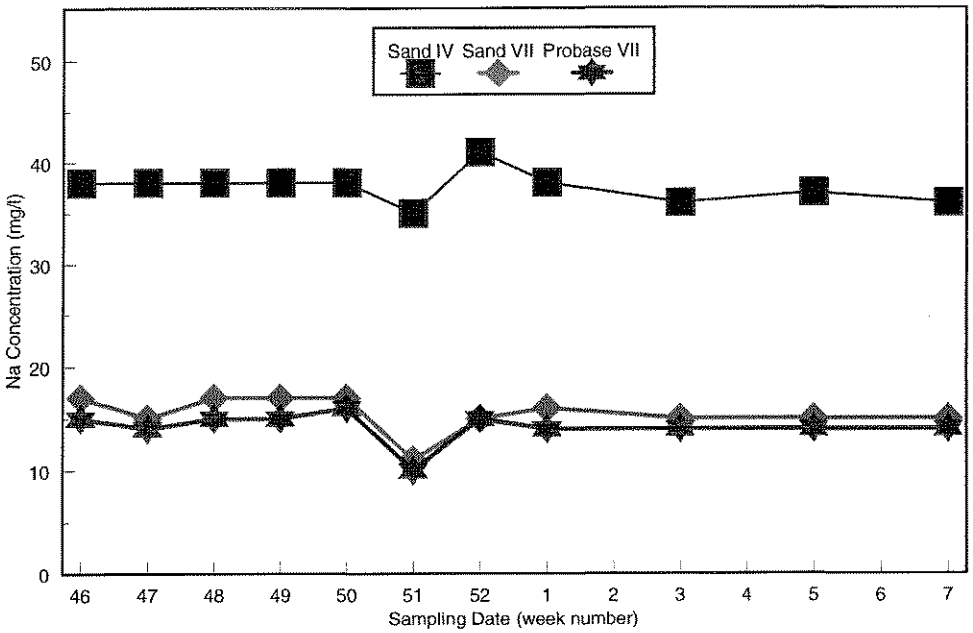
m,



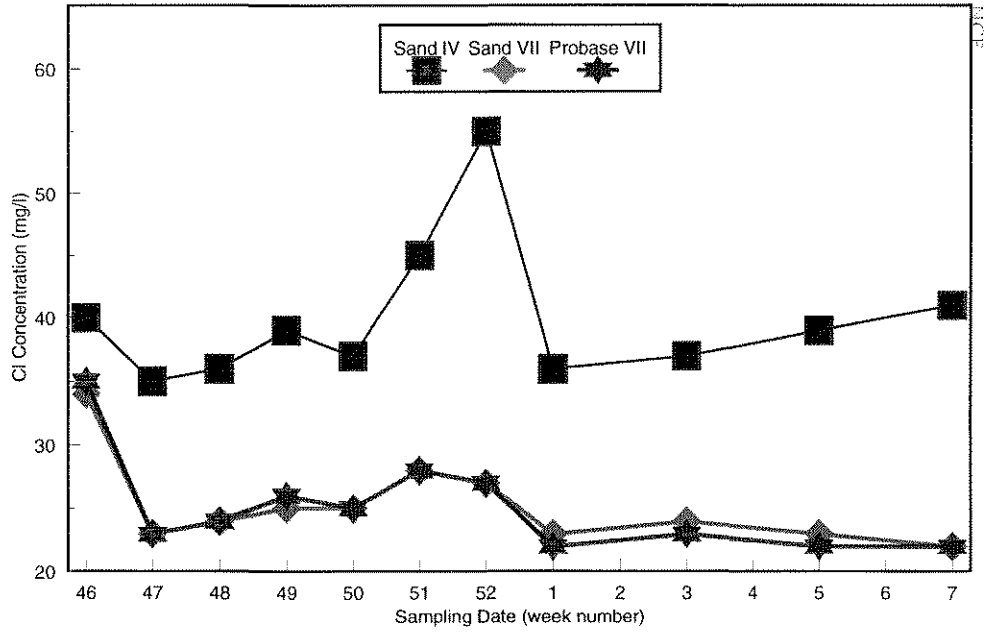
n,



o,



p,



5. The Influence of Reduced Depth of Sand in Combination with Successive Plantings.

Treatment plots were not replicated for this comparison and hence significance testing was not carried out on the data.

5.1 1992/93

5.1.1 Plant Performance

Plants grown on half depth (7.5 cm) sand were taller than those grown on full depth sand throughout production (Figure 16a, page 69). In contrast, fresh weights of stems grown on half depth sand were smaller at maturity than those grown on full depth sand (Figure 16b, page 69). Bulk dry weight (Figure 16c, page 69) was comparable for Delta on the two sand depths but for Snowdon was smaller from the half depth system.

Percentage dry matter (Figure 16d, page 70) was comparable for both sand depths initially but was slightly higher for half depth sand than full depth sand for the third and fourth samples. Given the variability of leaf area measurements it is unlikely that the small differences between treatments at different sampling dates were significant (Figure 16e, page 70).

Harvest grade-out for Delta reflected the trend in fresh weight data with a greater proportion of higher grade stems on the full depth sand system than the half depth sand system (Figure 18a, page 73). Grade-out for Snowdon however was not apparently influenced by depth of sand.

Sand depth did not significantly influence the shelf-life of either variety assessed (Appendix II, table 4a, page 102).

5.1.2 Disease Assessment

There were no differences in incidence of *Pythium* spp infection between the two depths of sand (Appendix III, page 103).

5.1.3 Mineral Analyses - Recirculation Solution

Analysis of the recirculation solution (Figure 19, pages 74-77) indicated the following differences between depth of sand treatments.

Conductivity levels over the first seven weeks of planting were higher within the full depth system (Figure 19b, page 74). They were then comparable between the two systems for the remainder of the trial.

NO_3-N (Figure 19c, page 74) was generally higher within the full depth system for the first half of the trial (reflecting the changes observed in conductivity levels). K and Fe levels followed the same trend as NO_3-N (Figures 19e, 19i, pages 75 and 76).

5.1.4 Mineral Analyses - Foliage Samples

There were no consistent trends to indicate either improved or reduced concentrations of the nutrients analysed in response to depth of sand (Appendix V, tables 4a, 4b, pages 142 and 143). As reported in previous comparisons all nutrients assessed were at least above the satisfactory level. K concentration was again high with low N:K ratios resulting.

5.2 1993/94

5.2 Plant Performance

In contrast to 1992/93 results, Delta plants grown on half depth sand were shorter initially than those grown on full depth sand (Figure 17a, page 71). By maturity (or sample 4) however there was little difference in plant height of Delta on these two systems. The height of Snowdon was not apparently influenced by depth of sand in 1993/94.

Results of fresh weight however agree with the trends observed in 1992/93 (Figure 17b, page 71). That is, both varieties generally had smaller stem fresh weights when grown on half depth sand in comparison with full depth.

Results of percentage dry matter (Figure 17d, page 72) were variable with no consistent differences linked to depth of sand.

Harvest grade-out gave a mixed response to depth of sand (Figure 18b, page 73). Delta on full depth of sand produced greater proportions of higher grade stems in comparison with half depth sand. In contrast, the more favourable grade-out for Snowdon came from the half depth sand system.

Shelf-life performance of Delta stems from the full depth, standard feed, sand-based system was poor as seen previously. Delta stems harvested from the half depth sand system therefore lasted longer in shelf-life than those from the full depth system (Appendix II, table 4b, page 102). In contrast, Snowdon stems had a shorter shelf-life when grown on half depth sand in comparison with full depth.

5.3 Disease Assessment

In agreement with the 1992/93 results, there was no indication from either assessment of incidence of *Pythium* spp infection of degree of root browning that depth of sand affected root disease incidence (Appendix IV, page 112).

5.4 Mineral Analyses - Recirculation Solution

The following observations were noted (Figure 20, pages 78-81).

In contrast with 1992/93, conductivity levels were similar for both depths of sand throughout the 1993/94 trial (Figure 20b, page 78).

NO_3-N was again lower in the half depth system than the full depth system (Figure 20c, page 78).

K, P and Mn levels were low for both systems throughout the trial (Figures, 20e, 20h and 20k, pages 79 and 80).

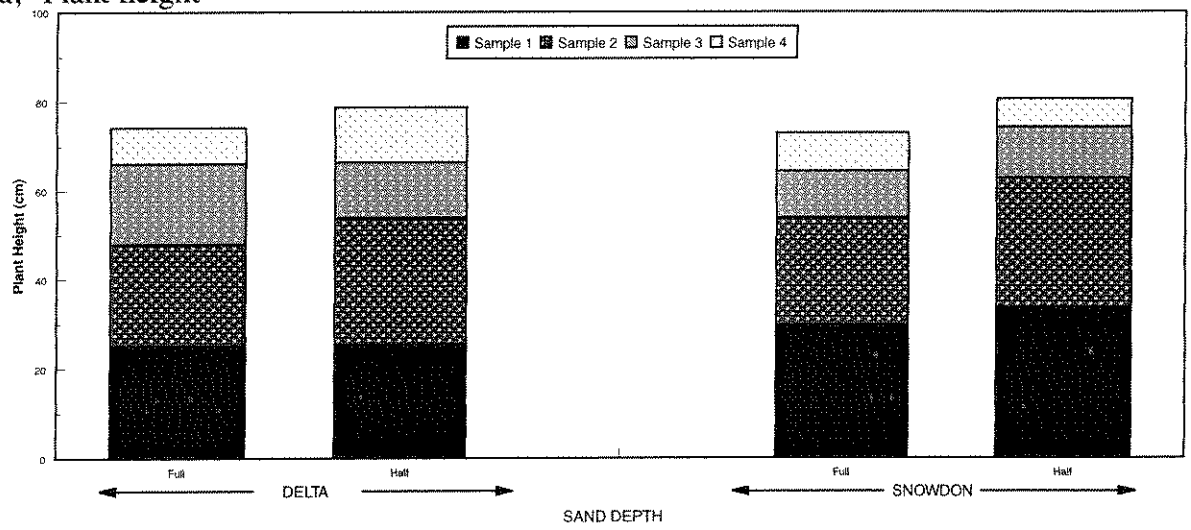
Fe concentration was again low in both systems but increased with time (Figure 20i, page 80).

5.5 Mineral Analyses - Foliage Samples

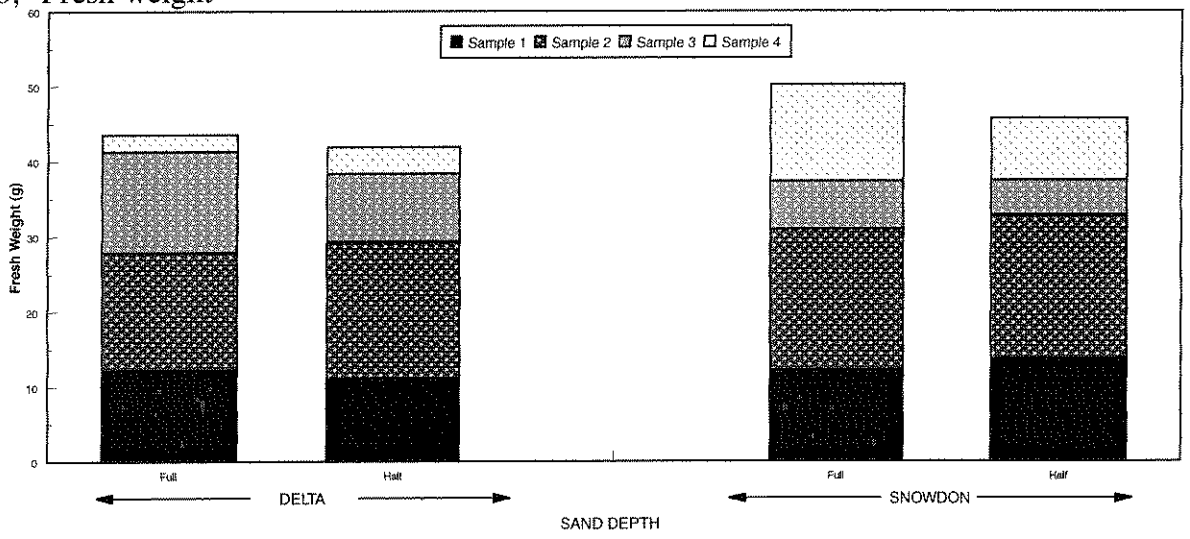
As noted in the 1992/93 trial, there was no indication from foliage analyses that the two depths of sand compared influenced nutrient status (Appendix V, tables 4c and 4d, pages 144 and 145). Concentration of nutrient elements were generally comparable between treatments or no consistent trends emerged where differences were observed.

Figure 16. The Influence of Depth of Sand on Plant Performance (1992/93)

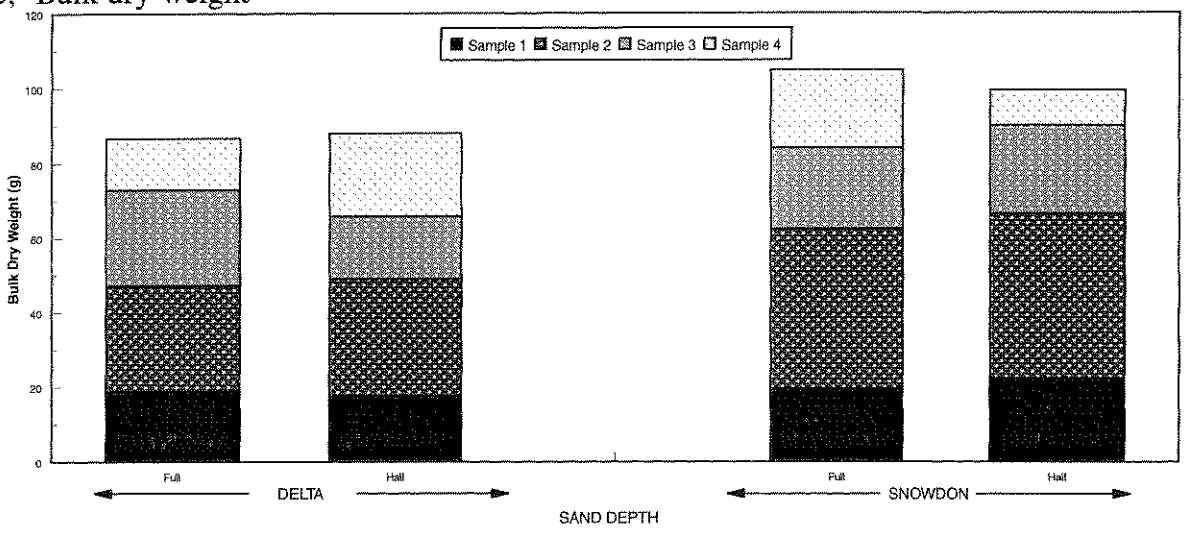
a, Plant height



b, Fresh weight



c, Bulk dry weight

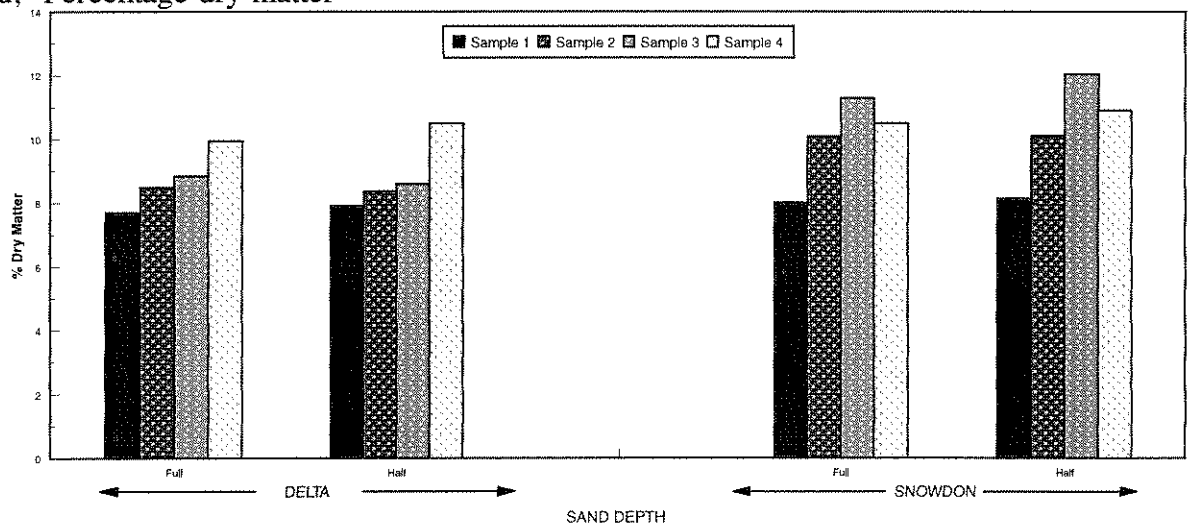


KEY TO CHARTS:

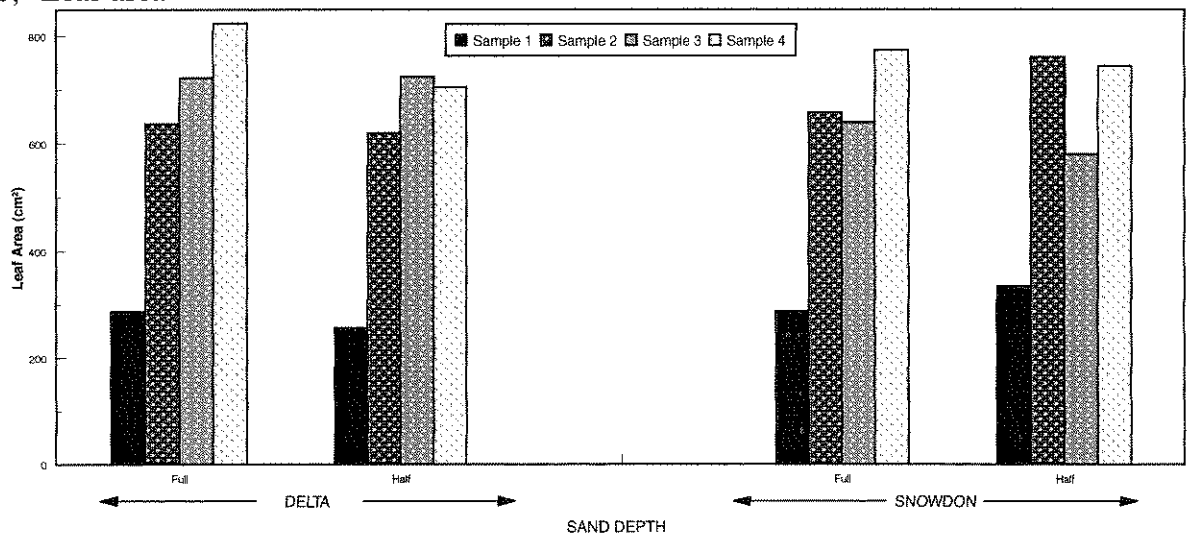
- Sample 1 - start of short days
- Sample 2 - end of interruption
- Sample 3 - 10 days after the end of interruption
- Sample 4 - final harvest

Figure 16.(Continued) The Influence of Depth of Sand on Plant Performance (1992/93)

d, Percentage dry matter



e, Leaf area

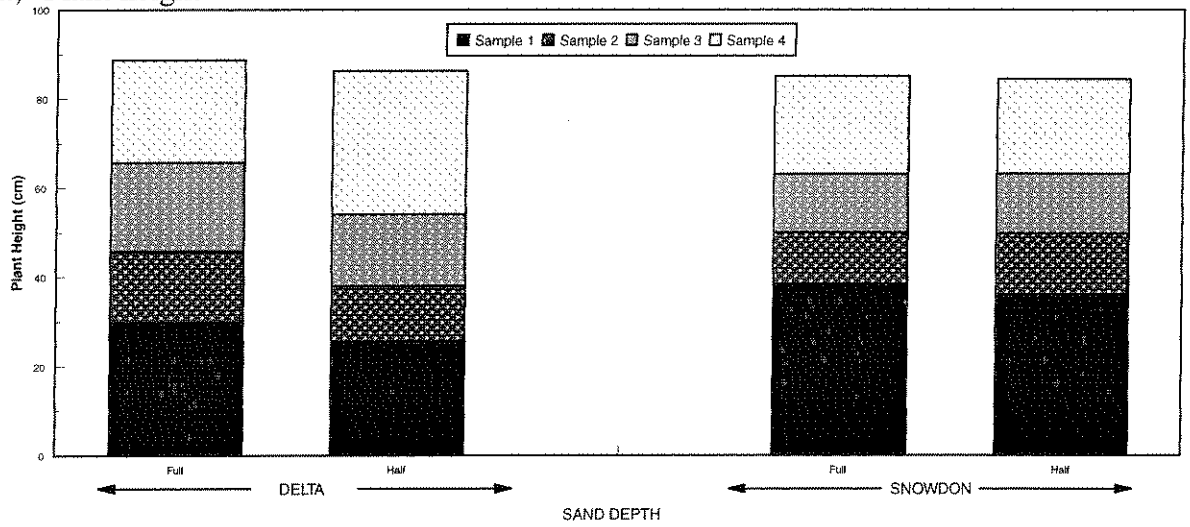


KEY TO CHARTS:

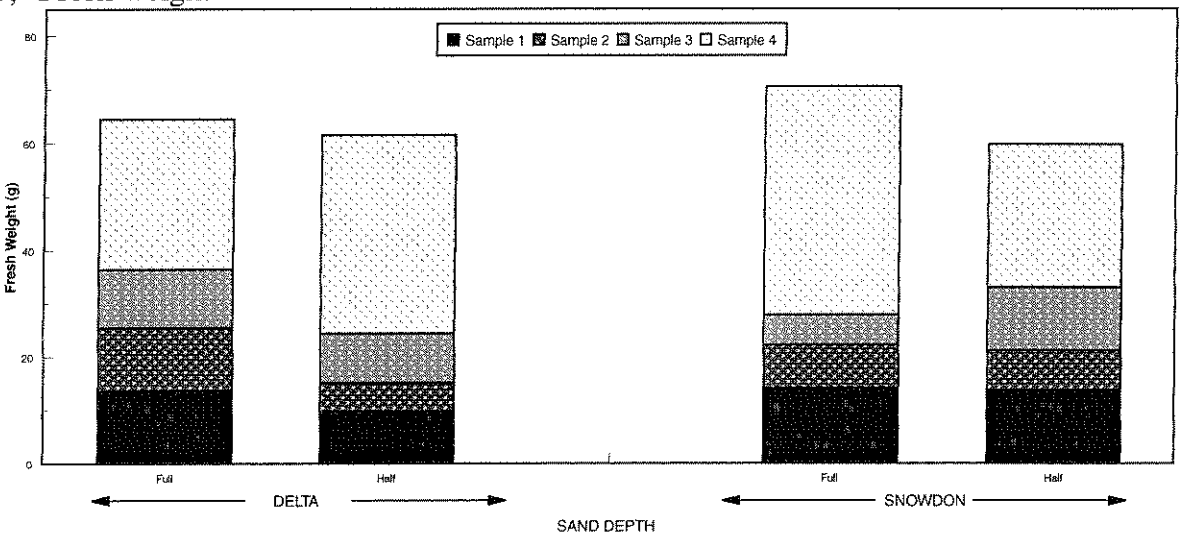
- Sample 1 - start of short days
- Sample 2 - end of interruption
- Sample 3 - 10 days after the end of interruption
- Sample 4 - final harvest

Figure 17. The Influence of Depth of Sand on Plant Performance (1993/94)

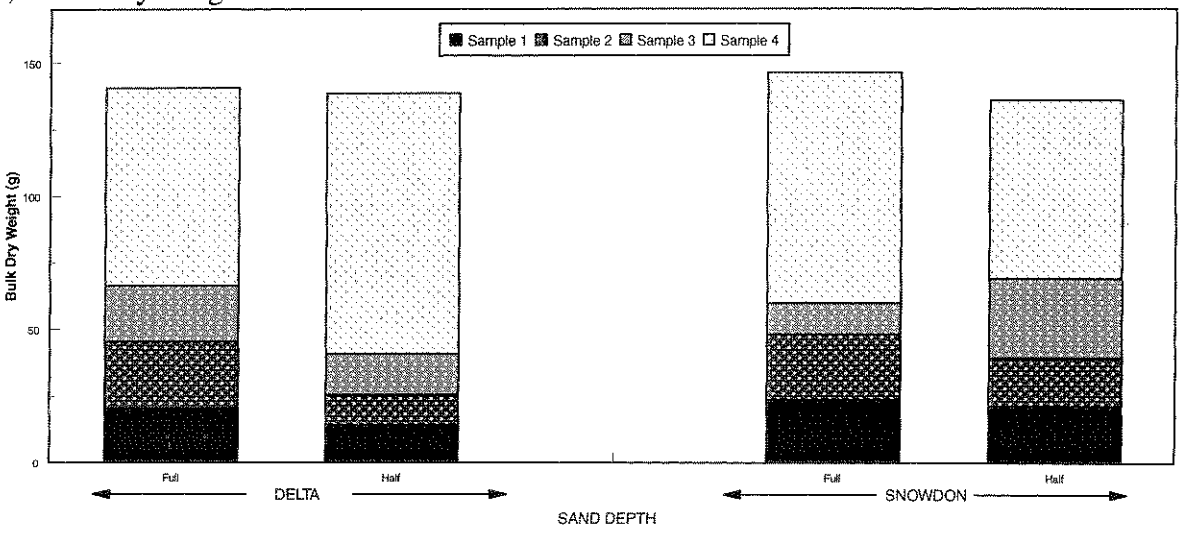
a, Plant height



b, Fresh weight



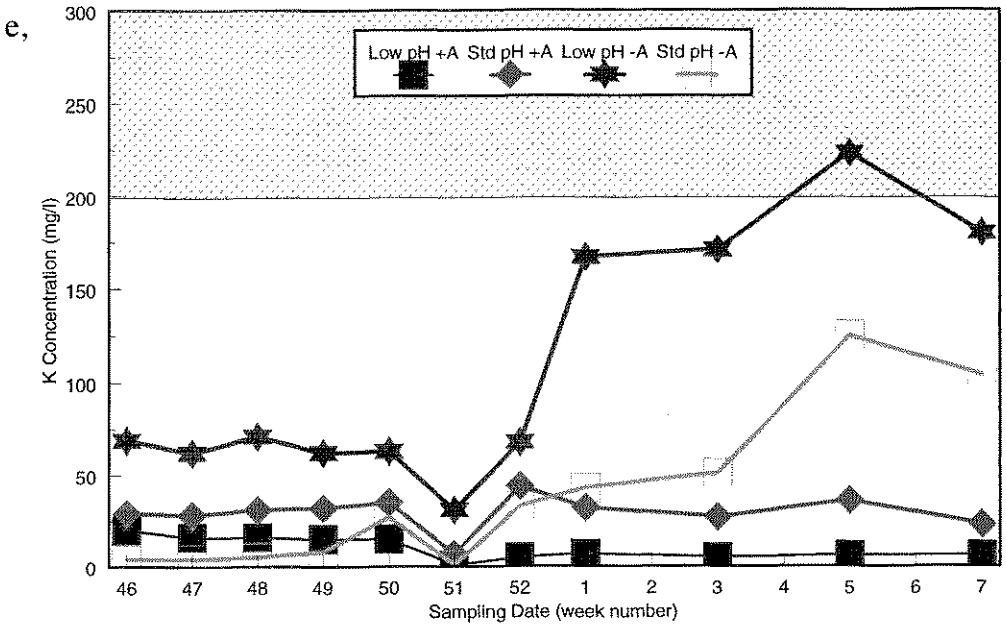
c, Bulk dry weight

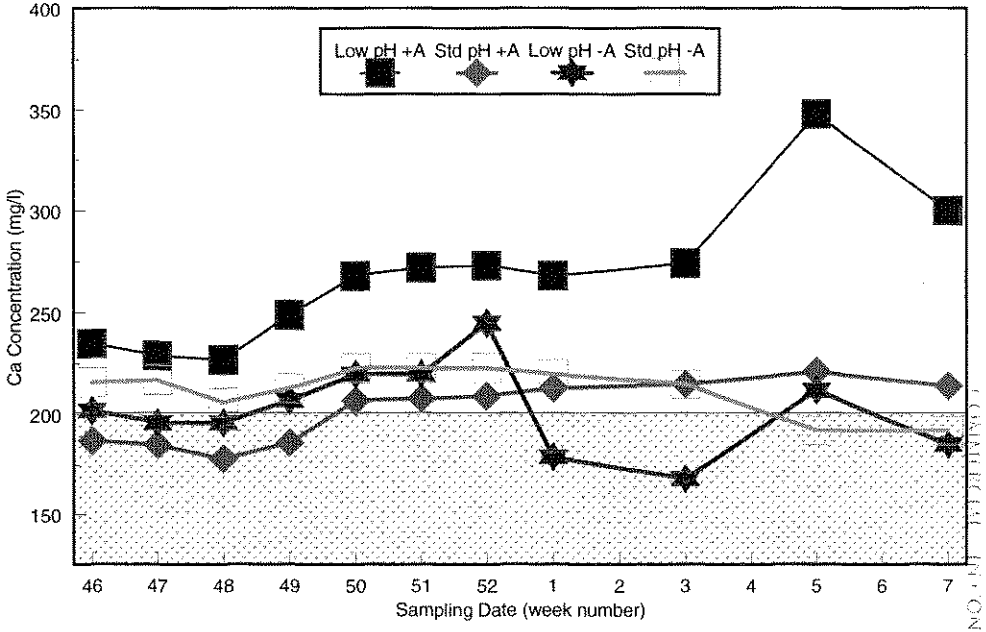


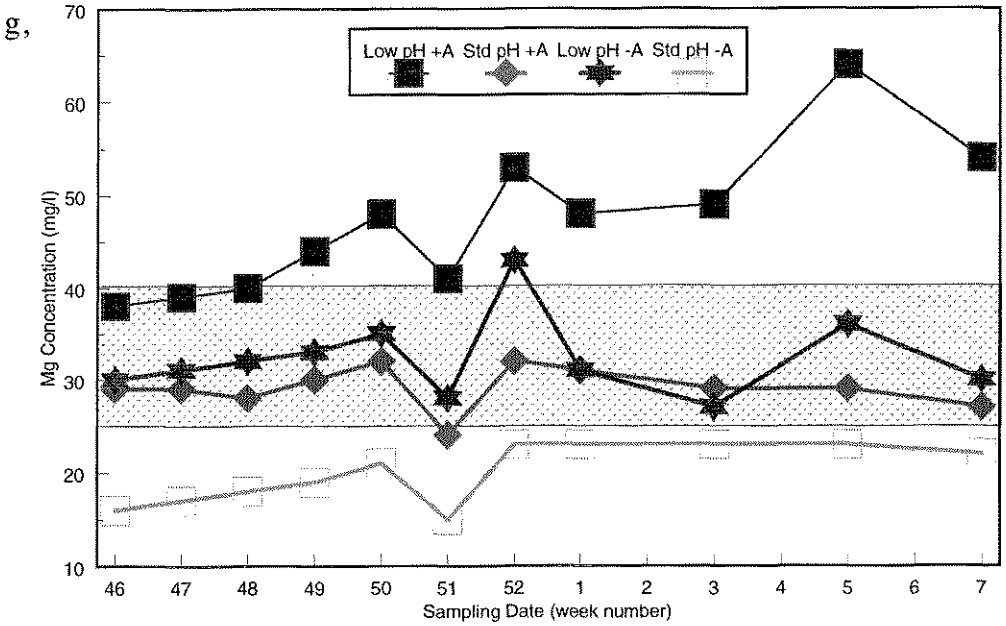
KEY TO CHARTS:

- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 8.(Continued) The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1993/94







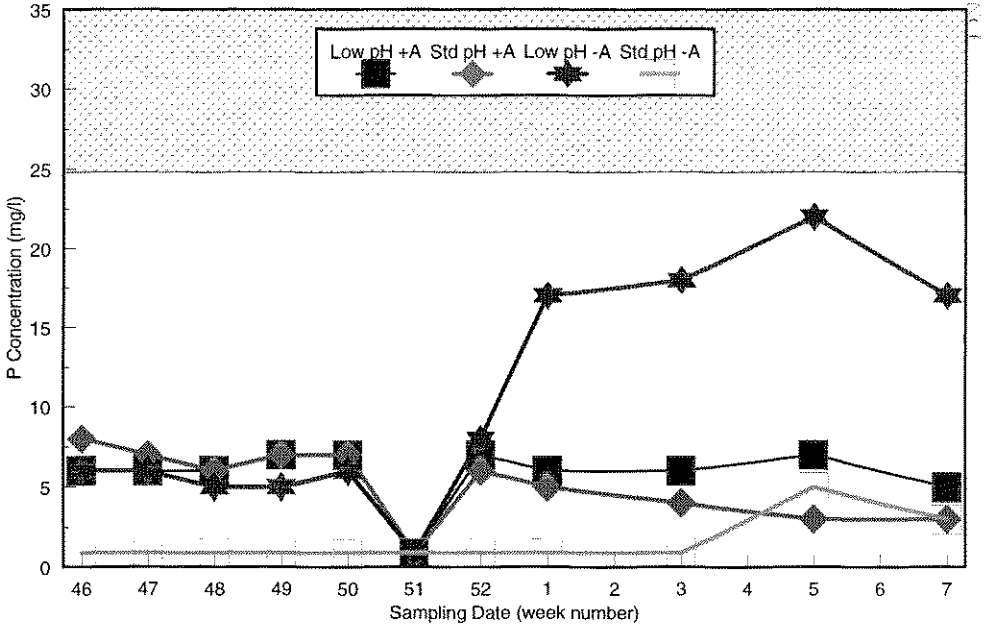
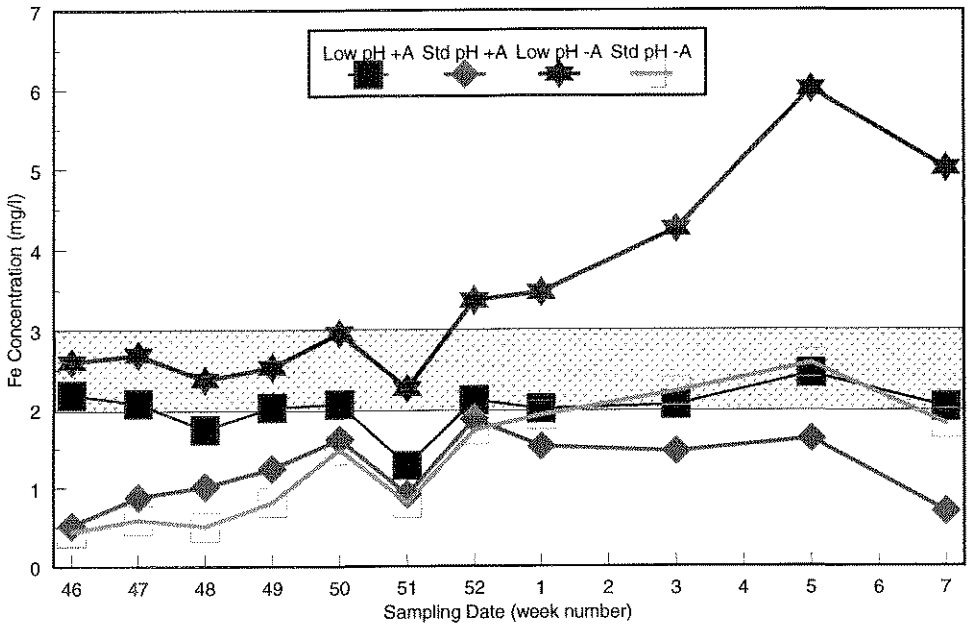
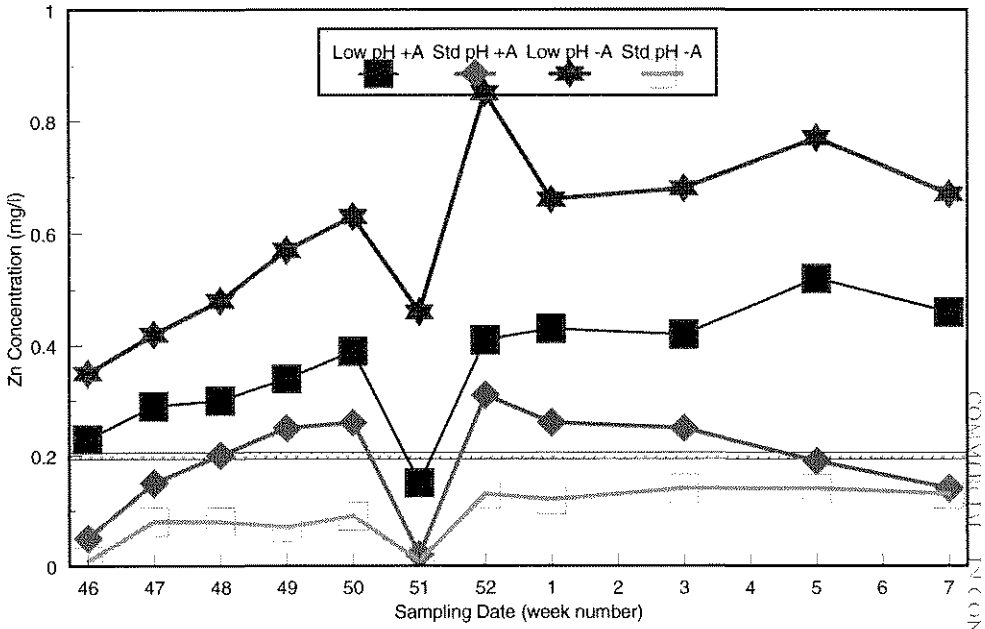


Figure 8.(Continued) The Influence of Aaterra and pH Treatments on the Nutritional Composition of the Recirculation Solution - 1993/94

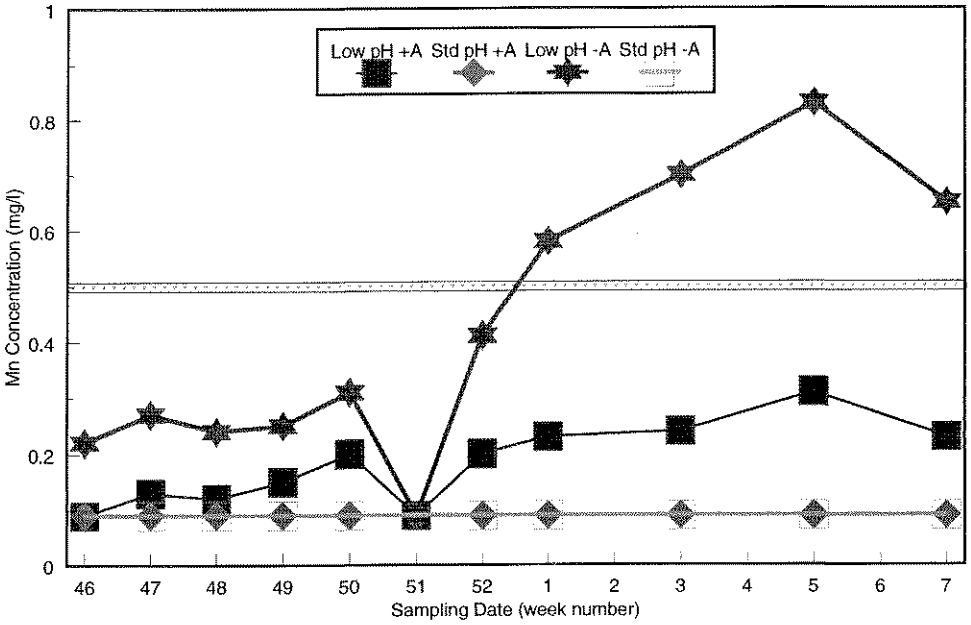
i,



j,



k,



l,

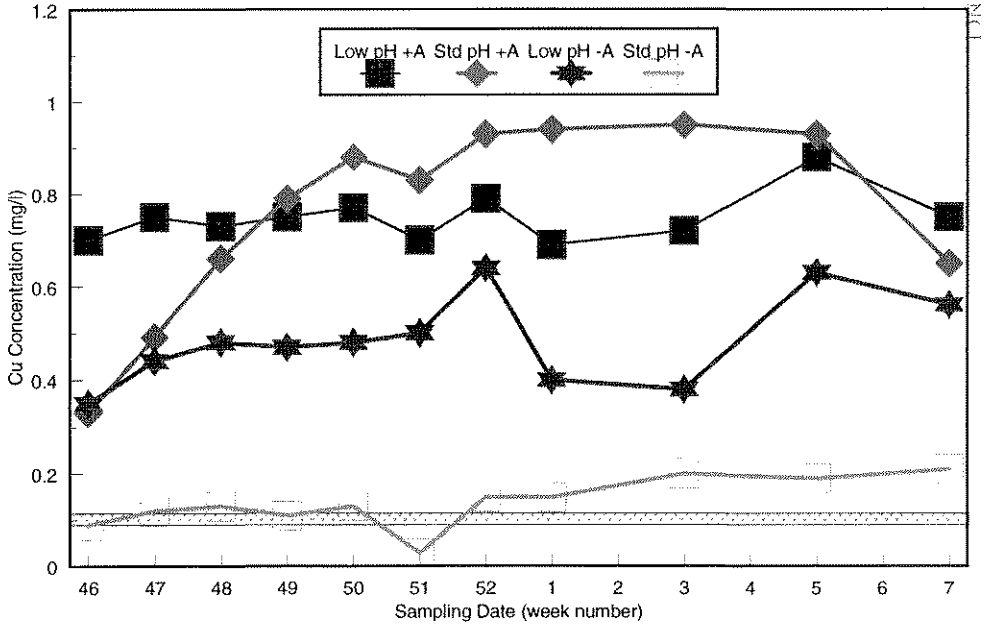
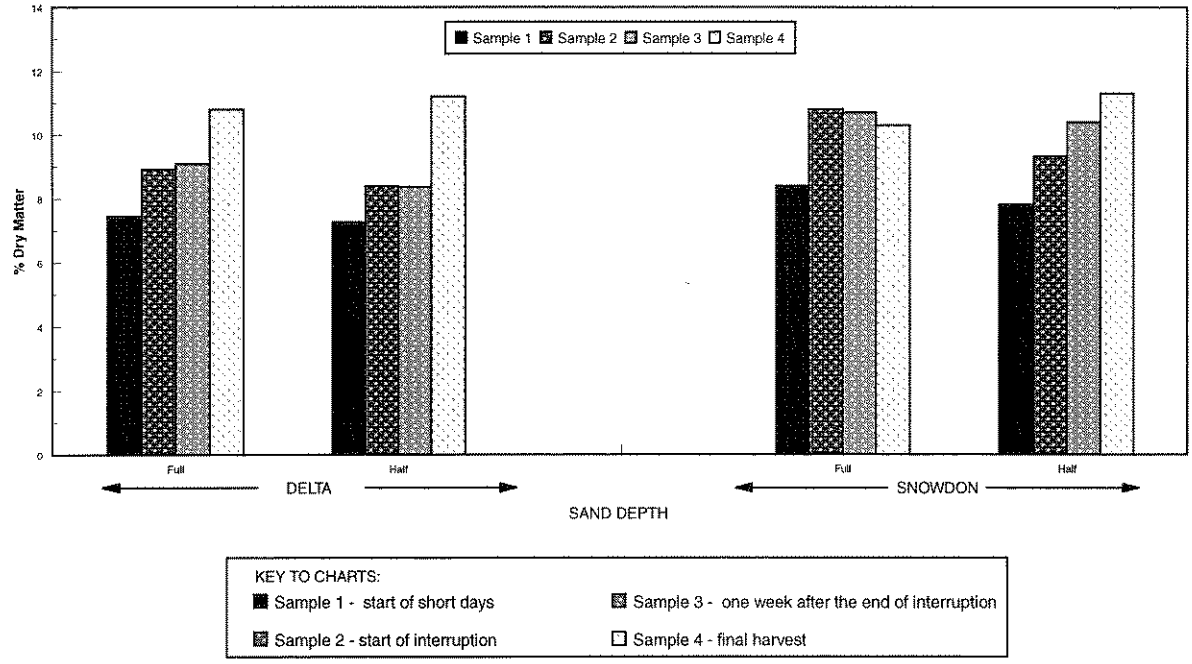


Figure 17.(Continued) The Influence of Depth of Sand on Plant Performance (1993/94)

d, Percentage dry matter



KEY TO CHARTS:

Sample 1 - start of short days

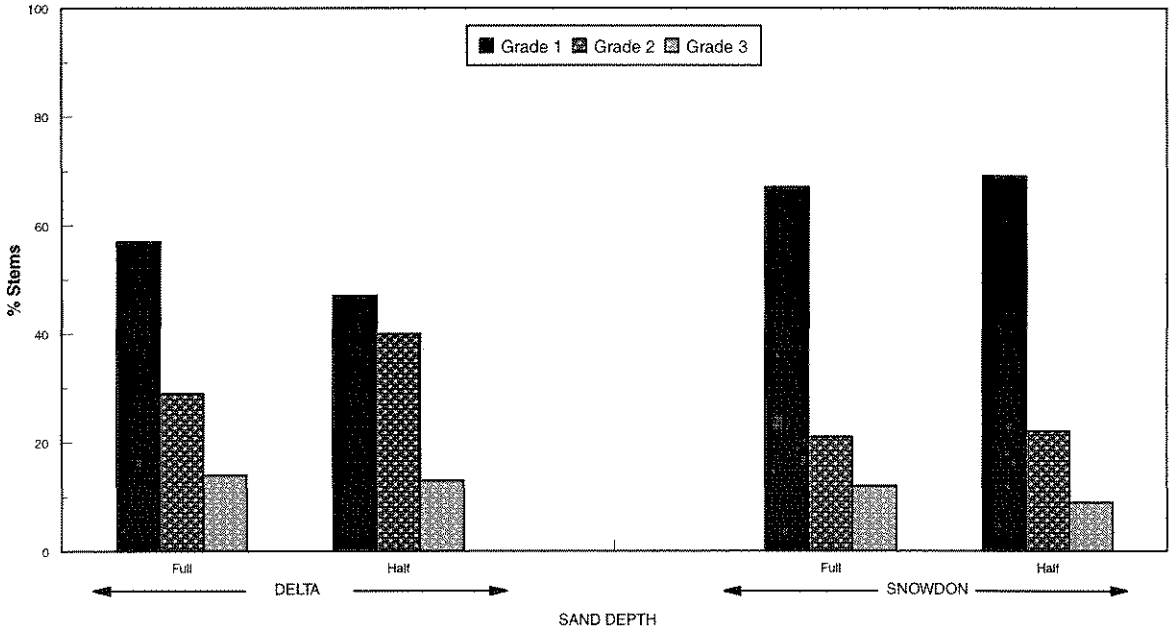
Sample 2 - start of interruption

Sample 3 - one week after the end of interruption

Sample 4 - final harvest

Figure 18. The Influence of Depth of Sand on Harvest Grade Out

a, 1992/93



b, 1993/94

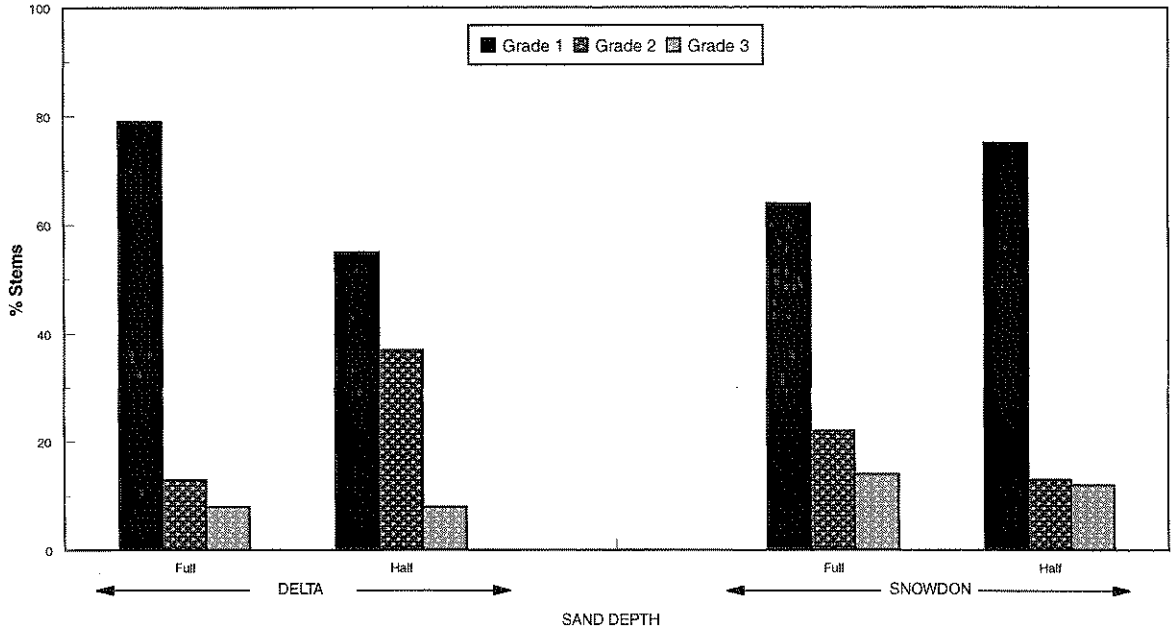


Figure 19. The Influence of Sand Depth on the Nutritional Composition of the Recirculation Solution - 1992/93

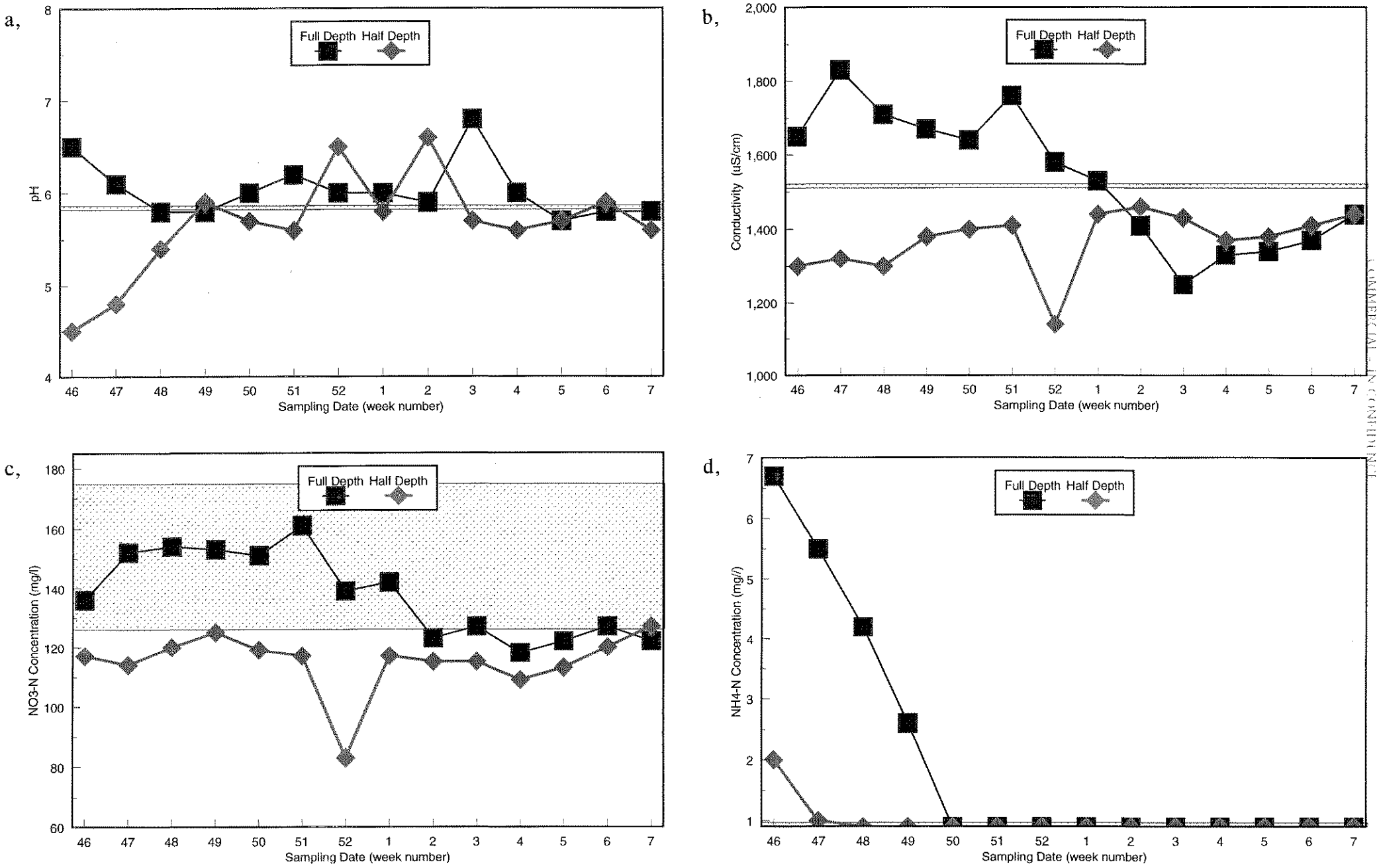
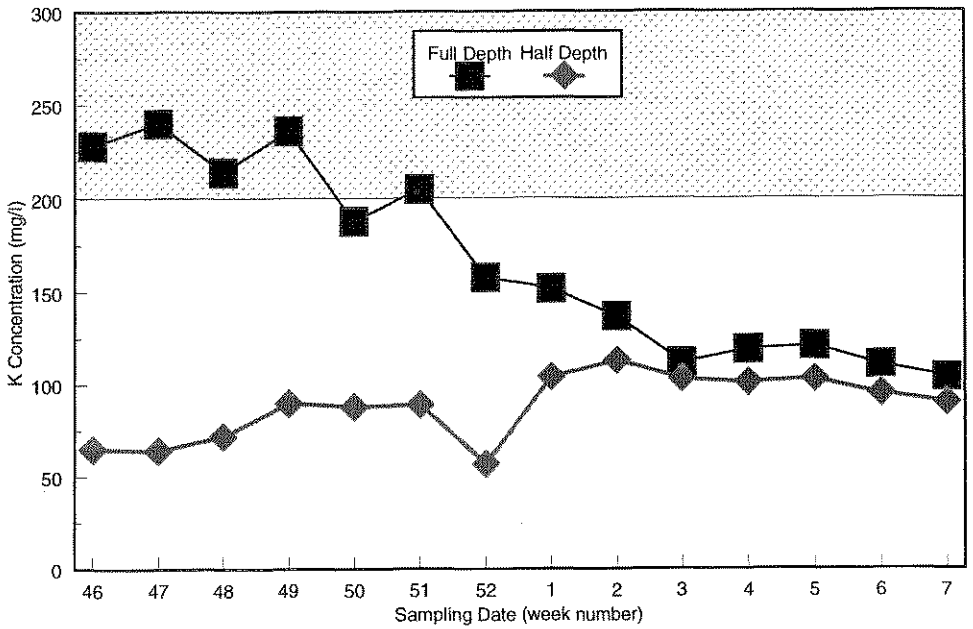
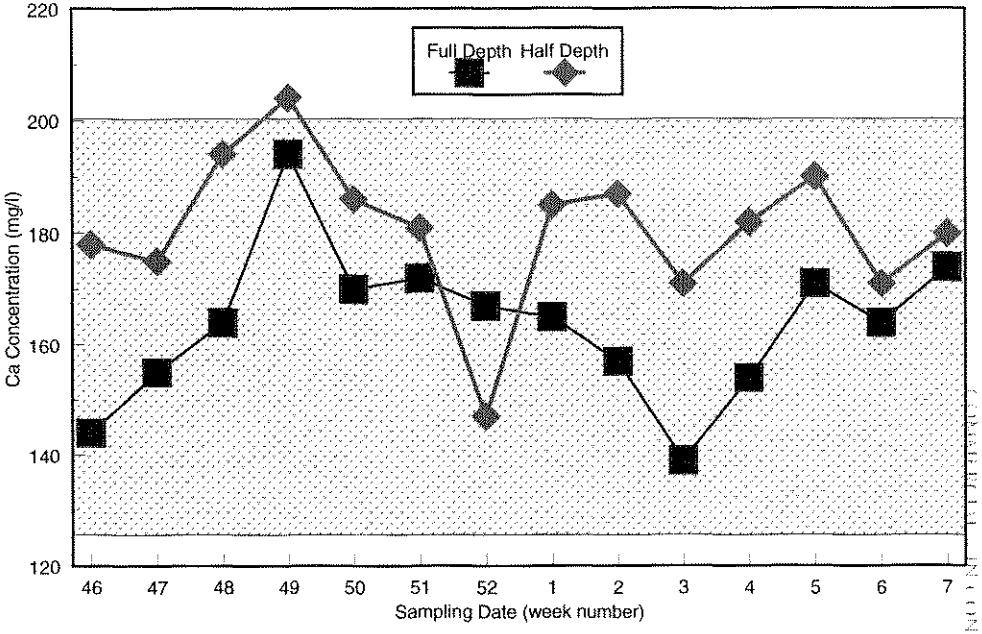


Figure 19. (Continued) The Influence of Sand Depth on the Nutritional Composition of the Recirculation Solution - 1992/93

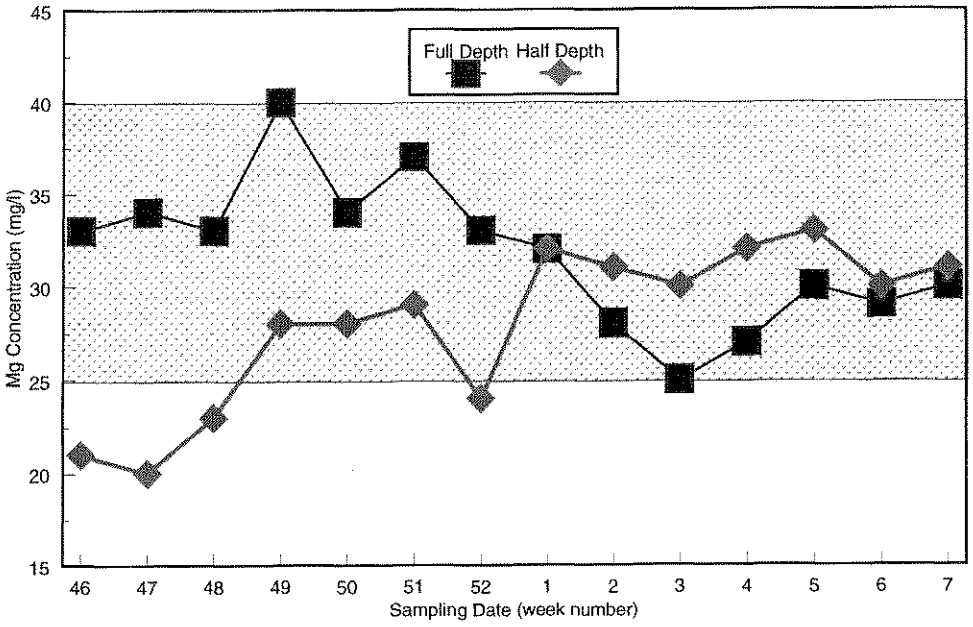
e,



f,



g,



h,

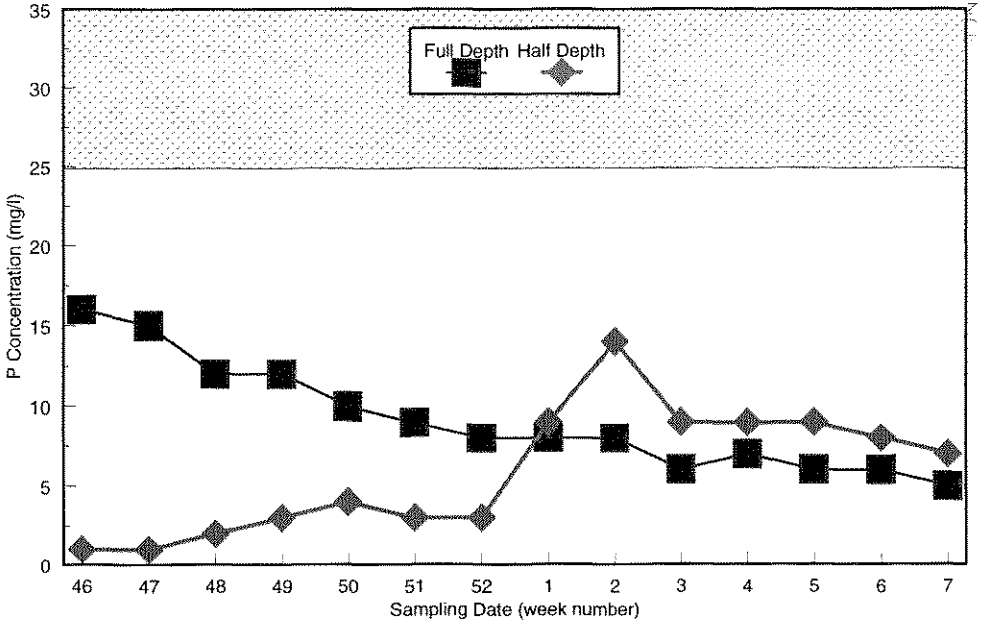
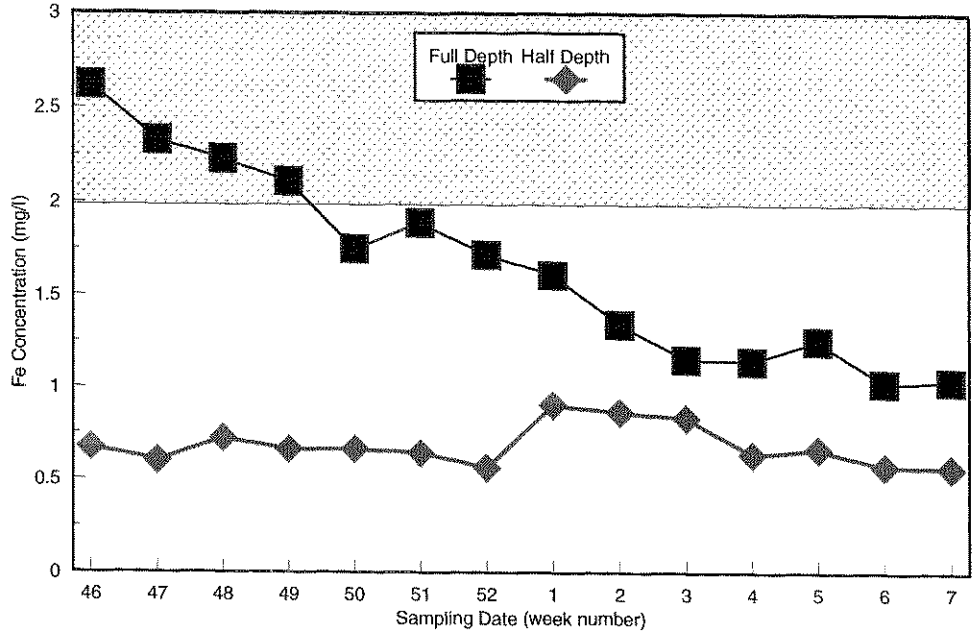
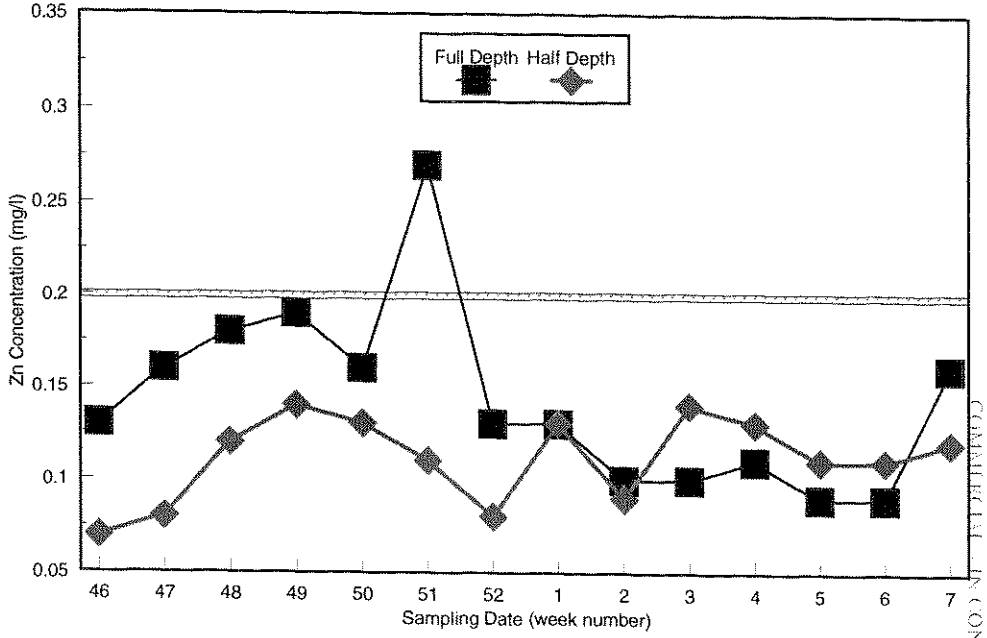


Figure 19.(Continued) The Influence of Sand Depth on the Nutritional Composition of the Recirculation Solution - 1992/93

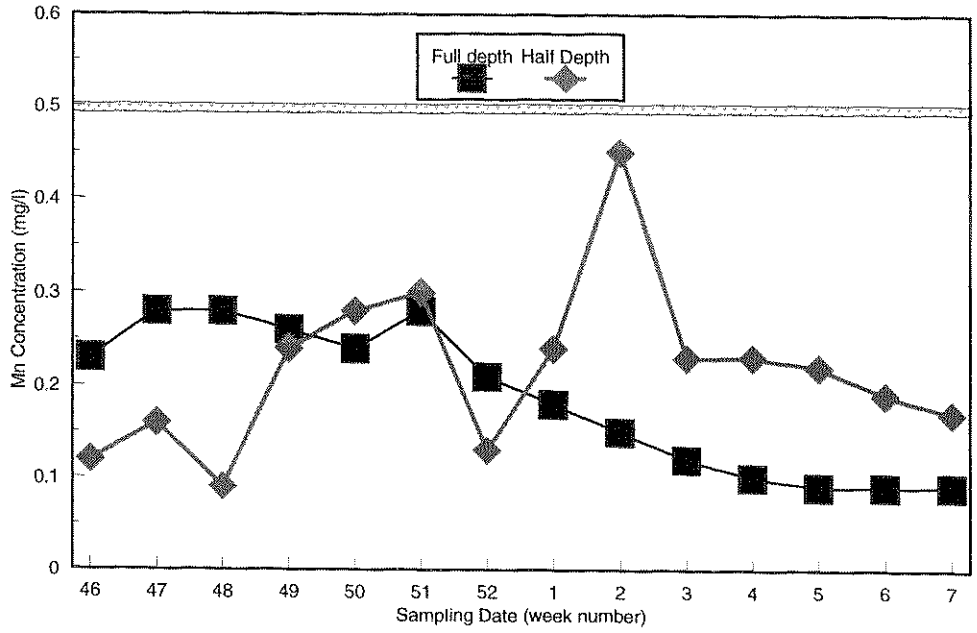
i,



j,



k,



l,

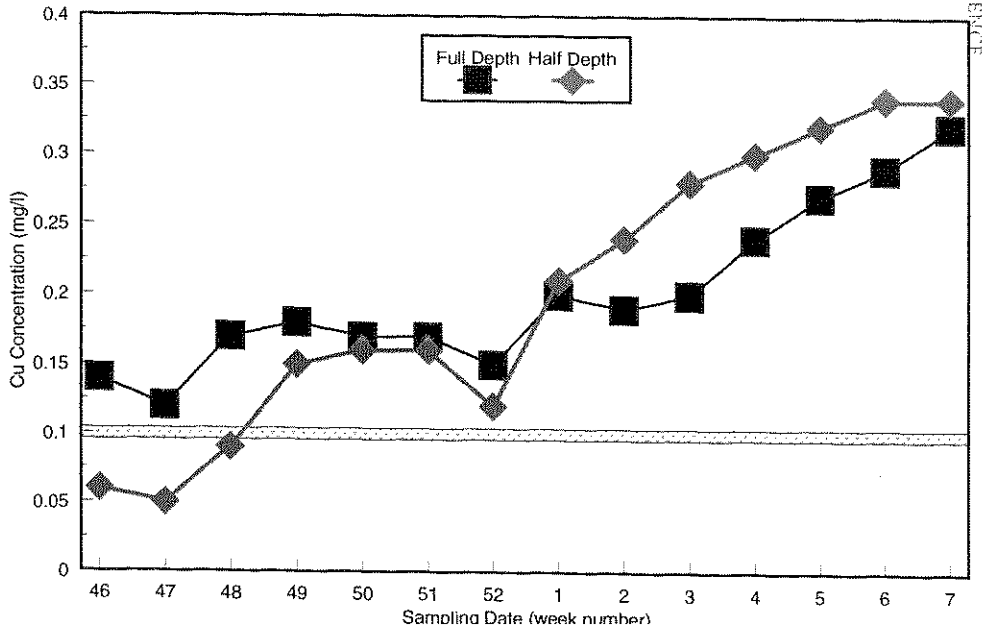
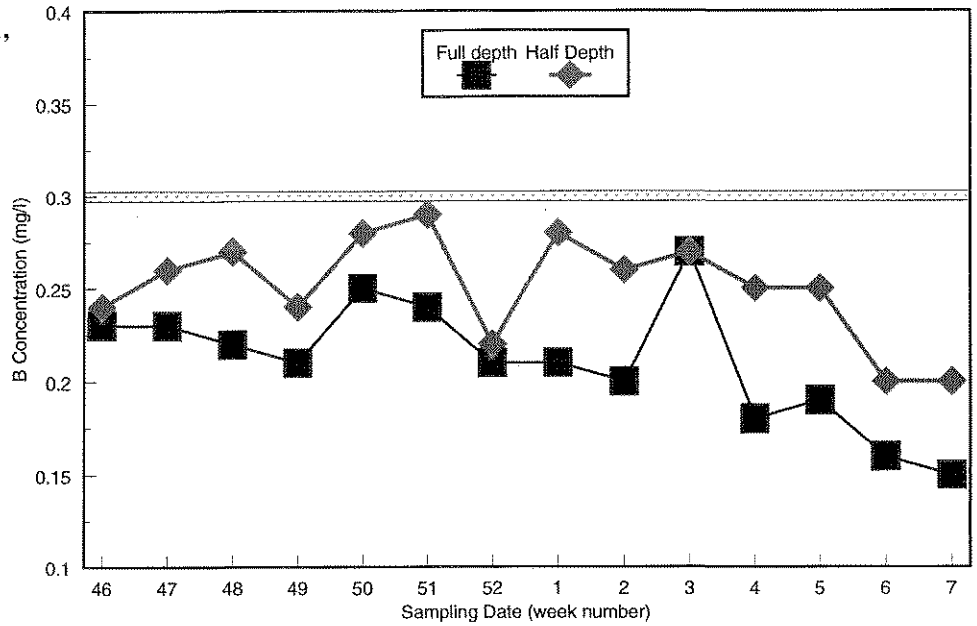
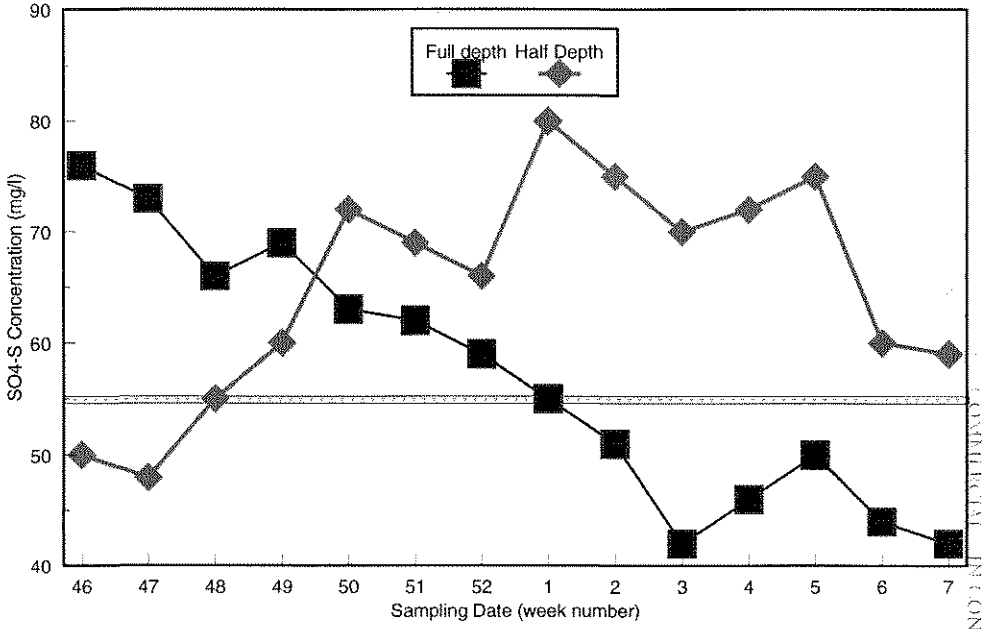


Figure 19.(Continued) The Influence of Sand Depth on the Nutritional Composition of the Recirculation Solution - 1992/93

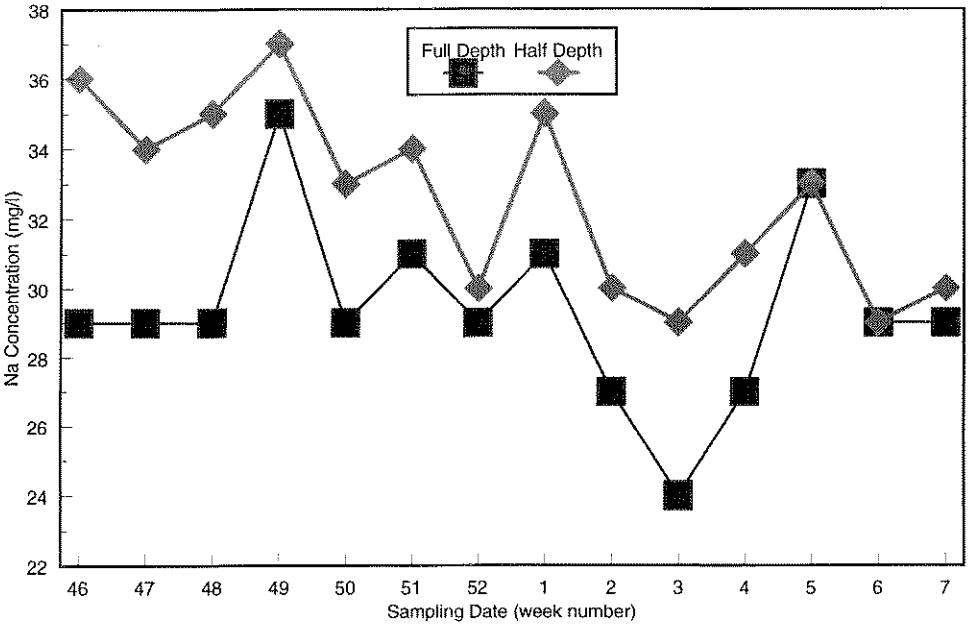
m,



n,



o,



p,

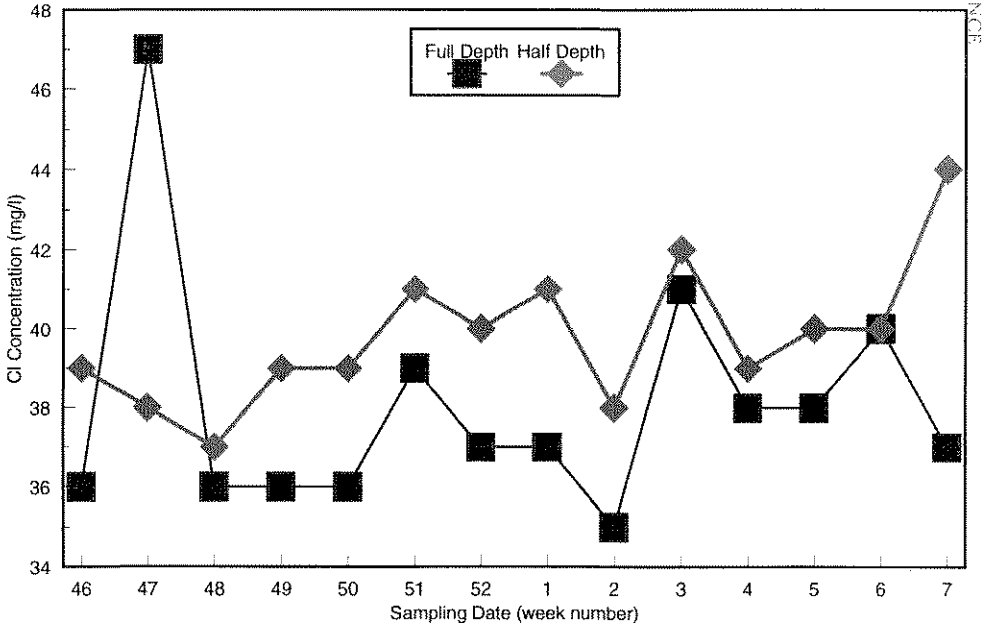
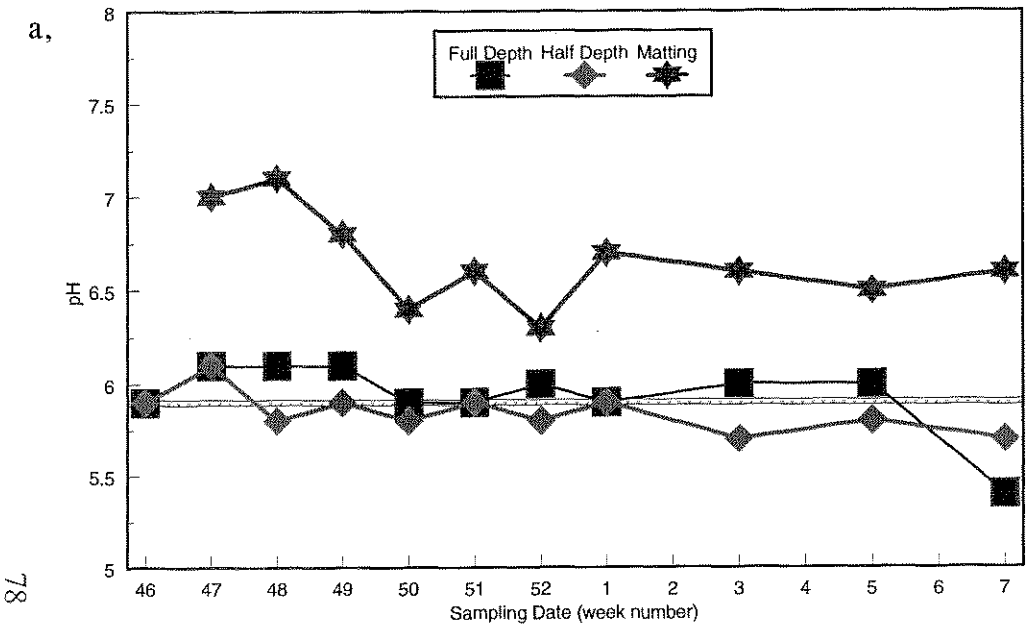
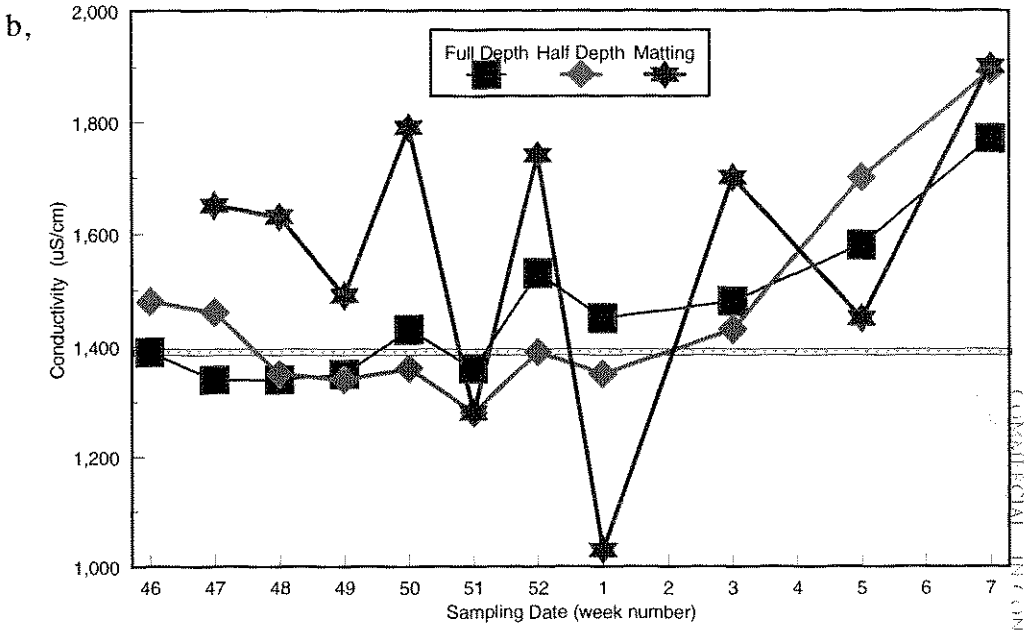
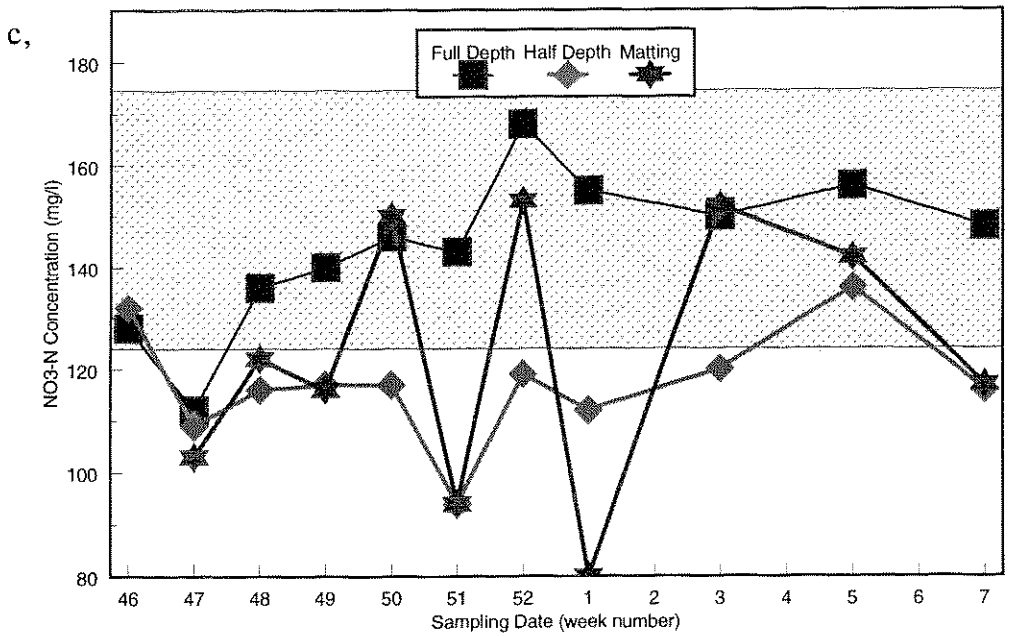


Figure 20. The Influence of Sand Depth and Thin Layer Matting on the Nutritional Composition of the Recirculation Solution - 1993/94
(Note: Treatments involving matting are discussed in section 6, pages 82-83.)







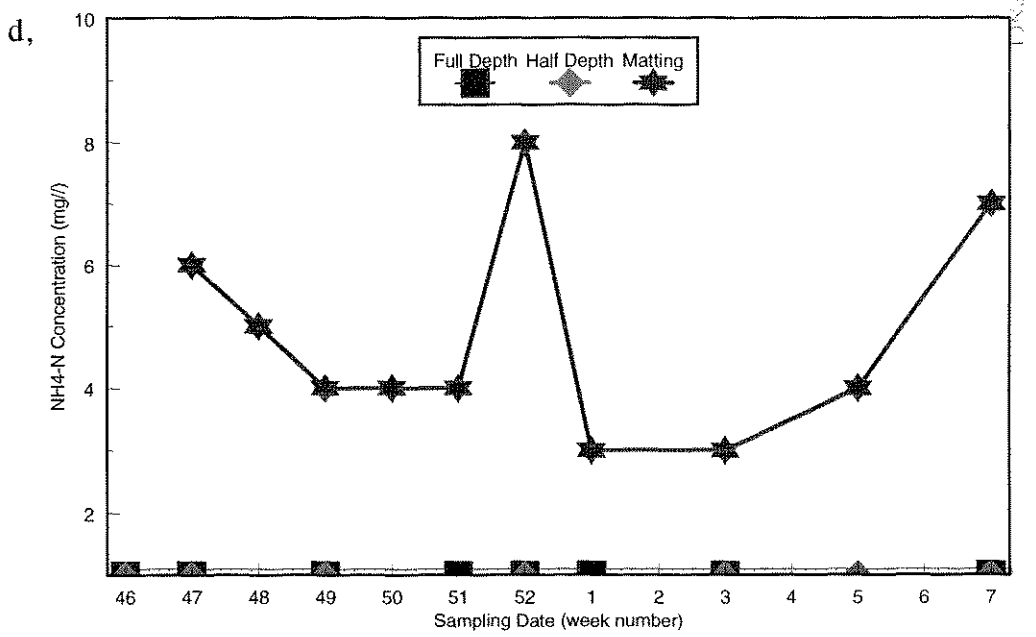
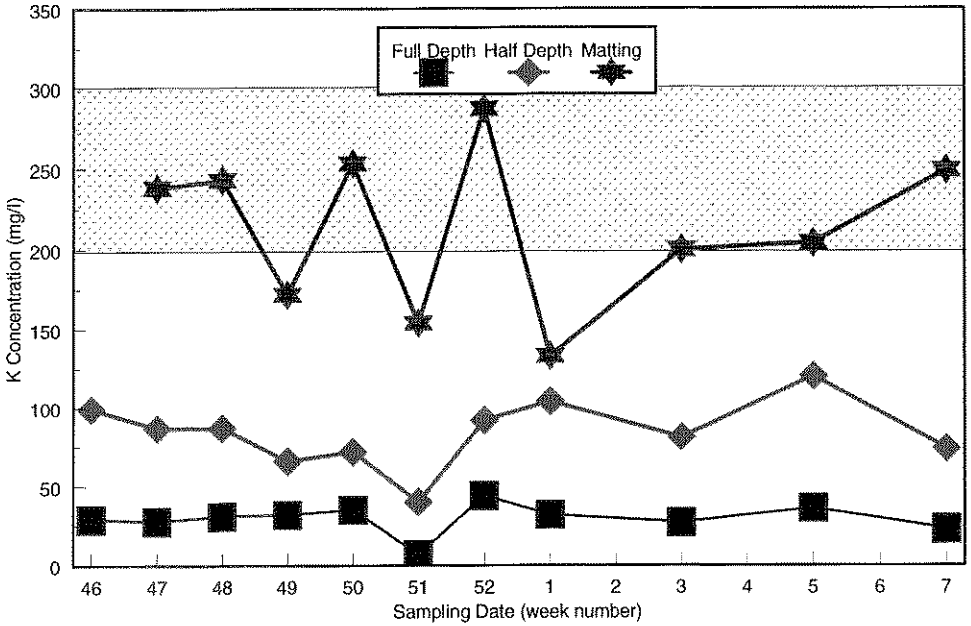
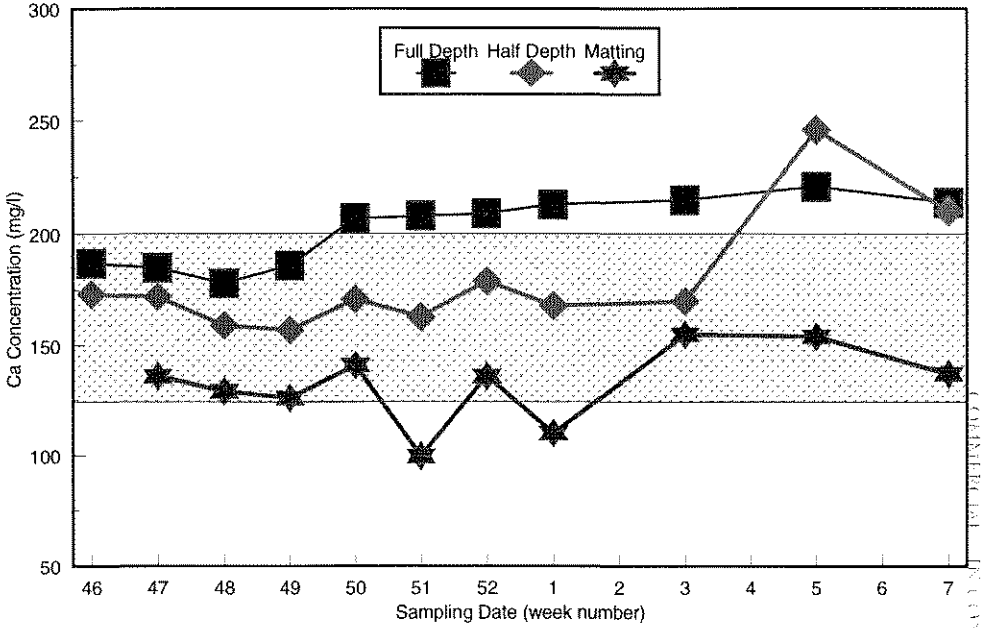


Figure 20.(Continued) The Influence of Sand Depth and Thin Layer Matting on the Nutritional Composition of the Recirculation Solution - 1993/94
(Note: Treatments involving matting are discussed in section 6, pages 82-83.)

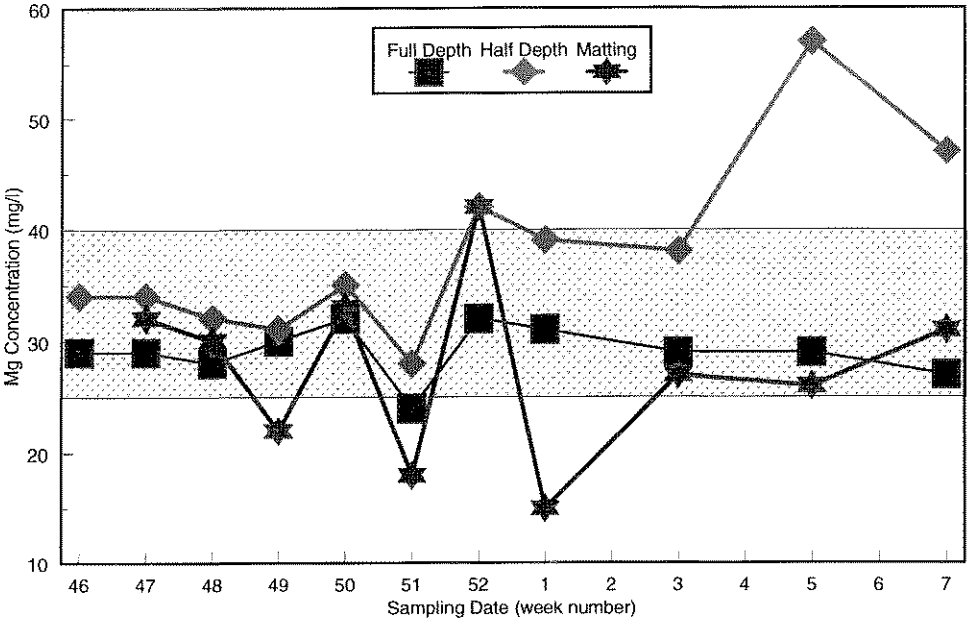
e,



f,



g,



h,

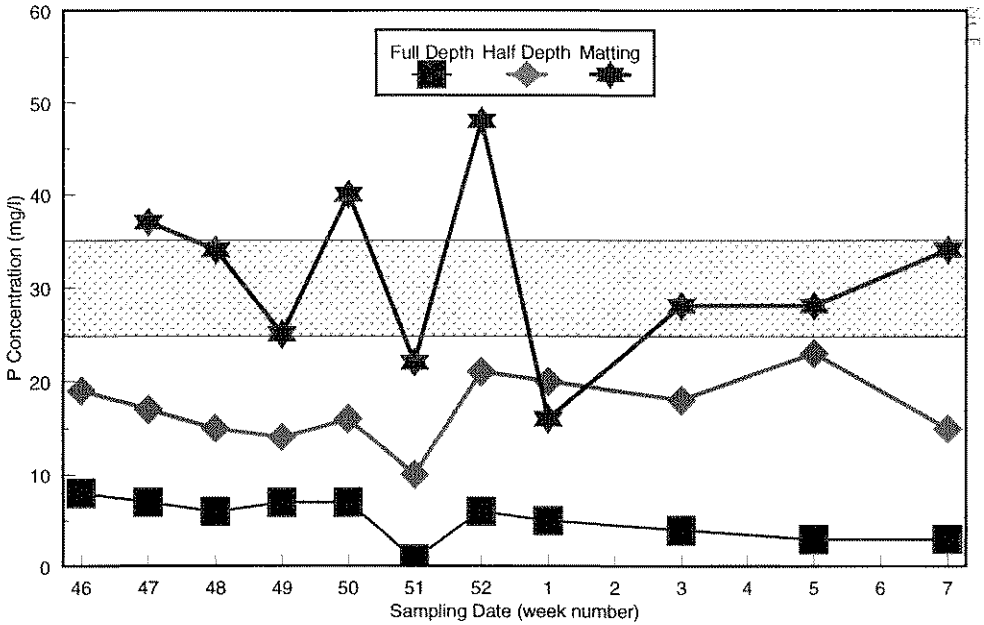
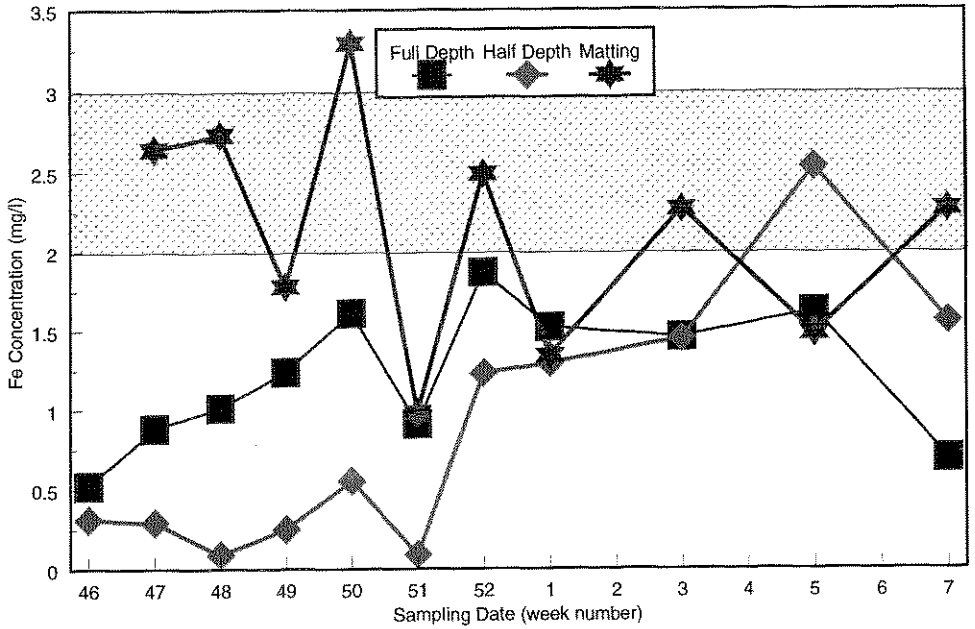
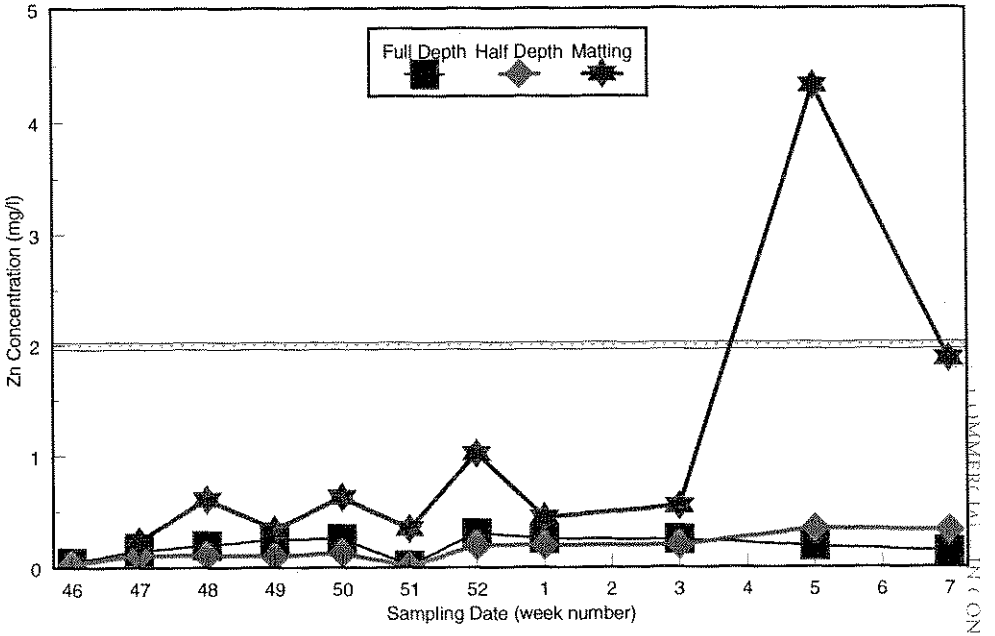


Figure 20.(Continued) The Influence of Sand Depth and Thin Layer Matting on the Nutritional Composition of the Recirculation Solution - 1993/94
(Note: Treatments involving matting are discussed in section 6, pages 82-83.)

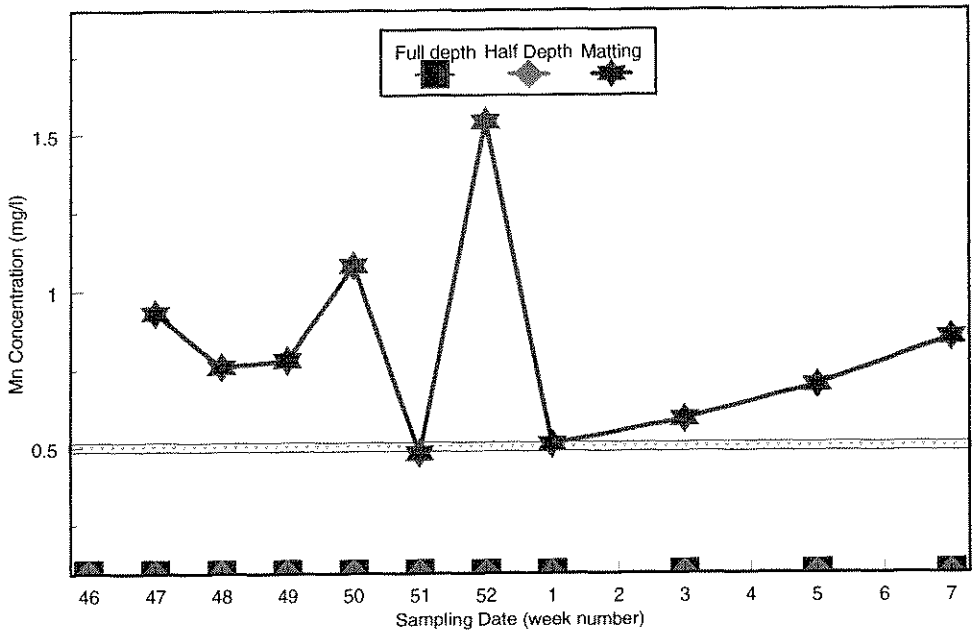
i,



j,



k,



l,

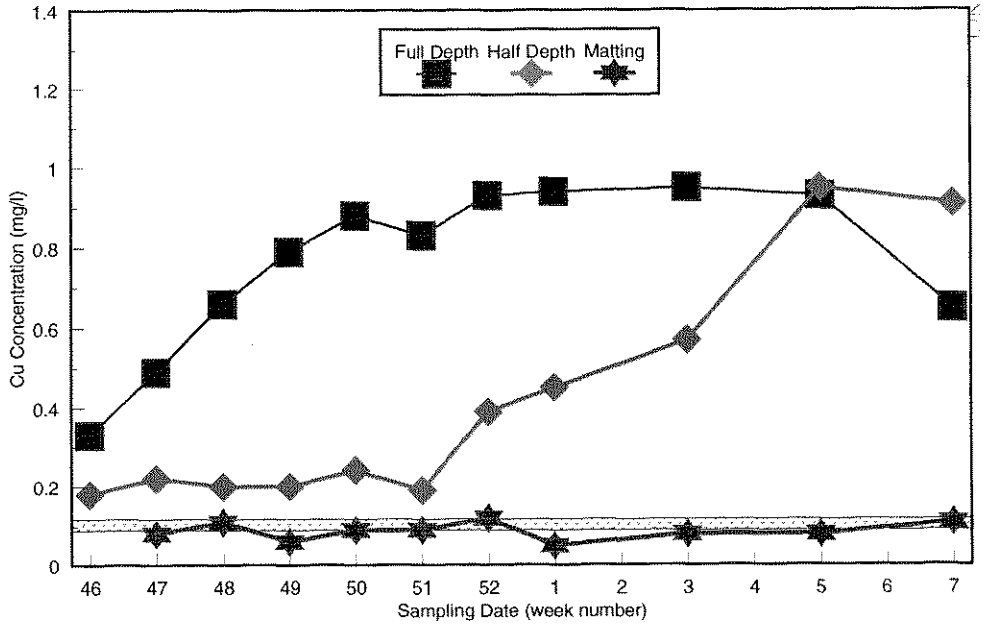
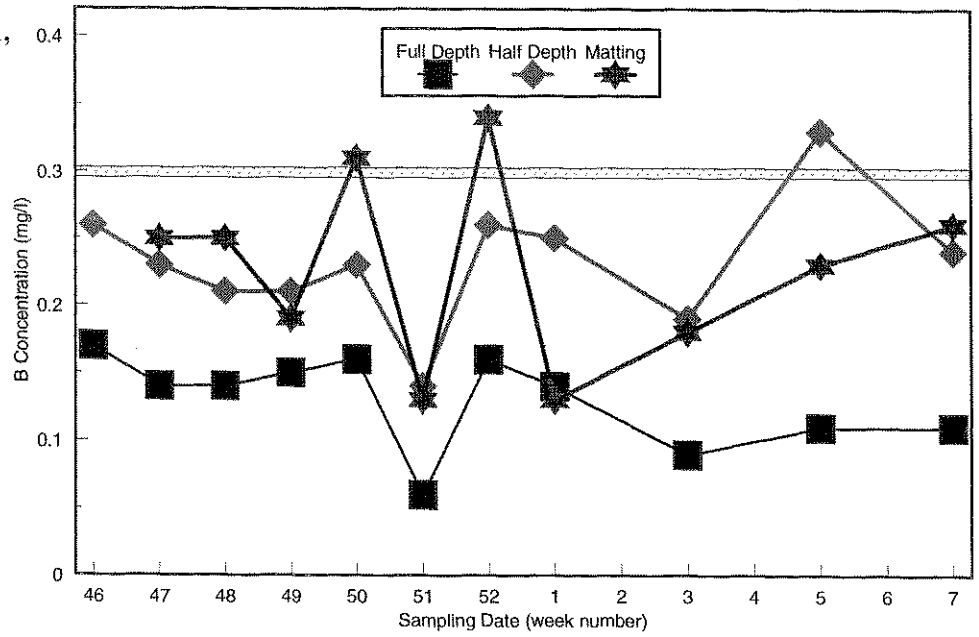
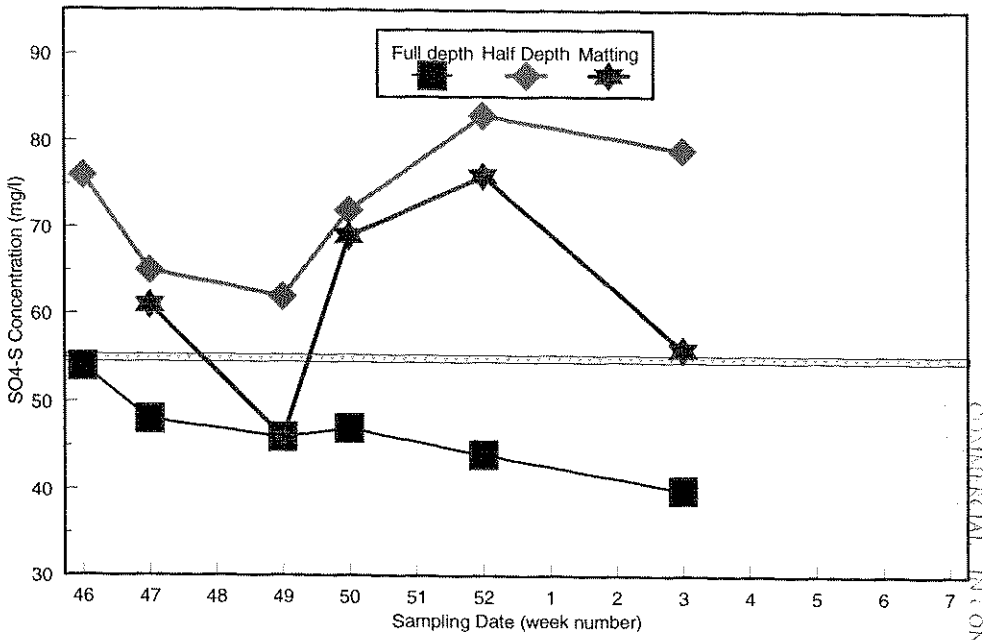


Figure 20.(Continued) The Influence of Sand Depth and Thin Layer Matting on the Nutritional Composition of the Recirculation Solution - 1993/94
(Note: Treatments involving matting are discussed in section 6, pages 82-83.)

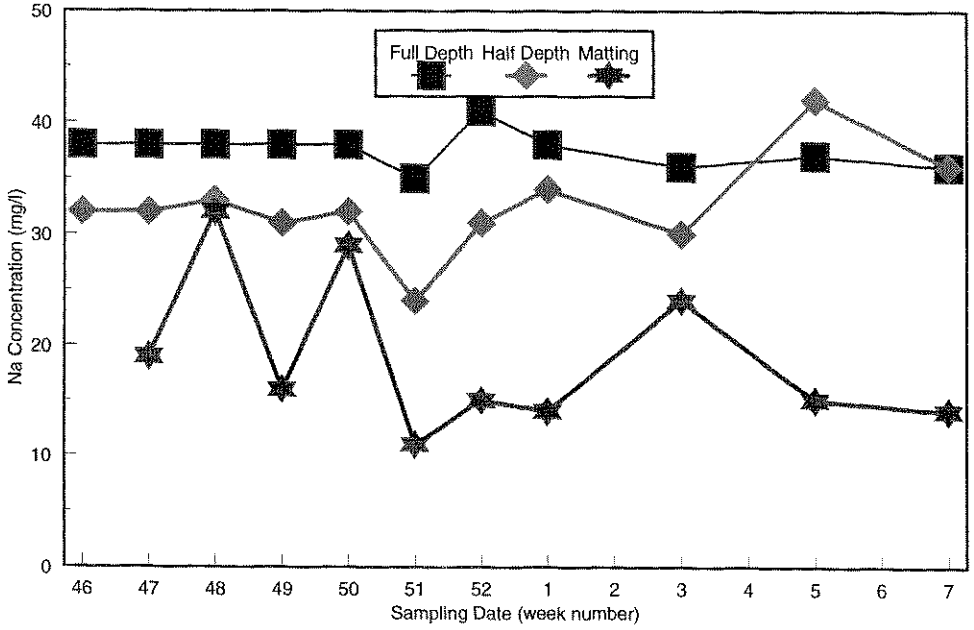
m,



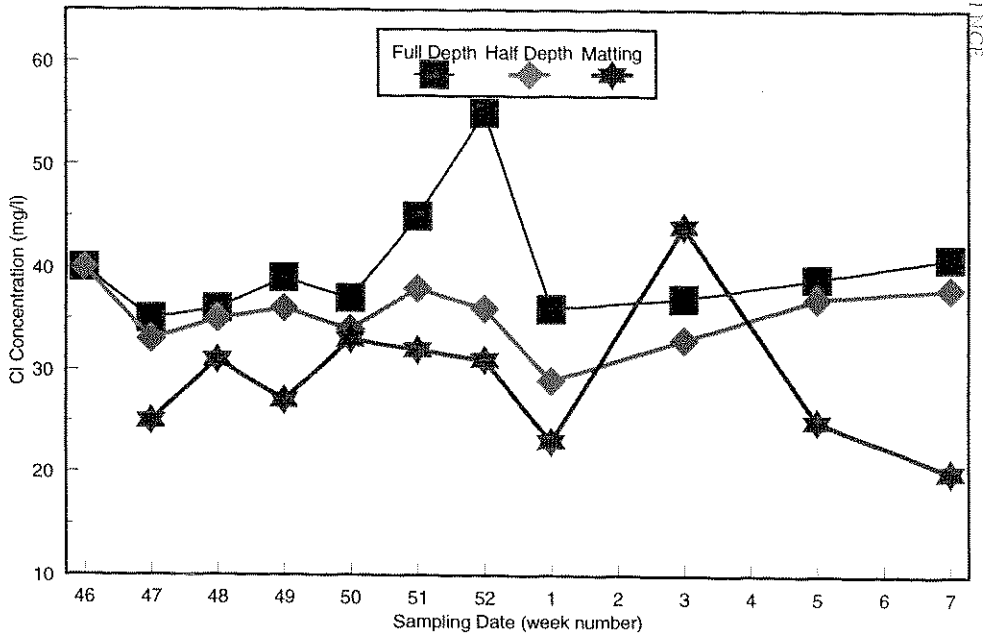
n,



o,



p,



6. The Potential of Thin Layer Matting as an Alternative Hydroponic System

Statistical significance analyses were again not conducted because treatment plots were not replicated in this comparison.

6.1 Plant Performance

For the purpose of this observation, the thin layer mat substrate was compared with the standard (i.e. 15 cm depth, standard feed) sand-based hydroponic system.

Both varieties assessed had smaller plant height (Figure 21a, page 84), fresh weight (Figure 21b, page 84), bulk dry weight (Figure 21c, page 84) and percentage dry matter (Figure 21d, page 85) during early development (i.e. samples 1 and 2) when grown on the thin layer matting. By maturity however performance of Delta grown on matting was either equivalent to or better than that on sand. Snowdon however remained poorer on the mat system than on the sand system. It should be noted, however, that the matting system was a first observation whereas previous experience has already been gained with the sand-based system. Further modification of the matting system may therefore improve plant performance.

Harvest grade-out figures were largely contrary to plant performance observations in this study (Figure 22, page 86). The sand-based system with Delta produced a more favourable grade-out, in terms of percentage grade 1 stems, from the sand-based system than from matting. For Snowdon, percentage of grade 1 stems was comparable on both systems but the matting system produced a lower percentage of the lowest grade stems.

Shelf-life of stems grown on matting was generally shorter than that from stems grown on the other hydroponic systems assessed (Appendix II, table 4b, page 102).

6.2 Disease Assessment

As root systems grew through the matting substrate it was not possible to sample intact samples from the matting system without destroying the substrate. Disease assessments were therefore not made on the matting system. As for the rest of the trials conducted throughout this project however, there was no indication that any of the plants on the matting system were suffering from root disease problems.

6.3 Mineral Analyses - Feed Solution

Since the feed solution was applied as run-to-waste to the thin layer matting system, it was analysed by collecting run-off from the side drainage channels. This solution has been compared in Figure 20 (pages 78-81) with the recirculation solution from the full depth sand system. It should be noted however that these two feed systems were very different since with thin-layer matting, freshly mixed feed solution was always applied. With recirculation systems the returning feed solution is dosed back up to the desired conductivity with a small amount of fresh feed and so ratios of different elements can become altered by the system itself with time.

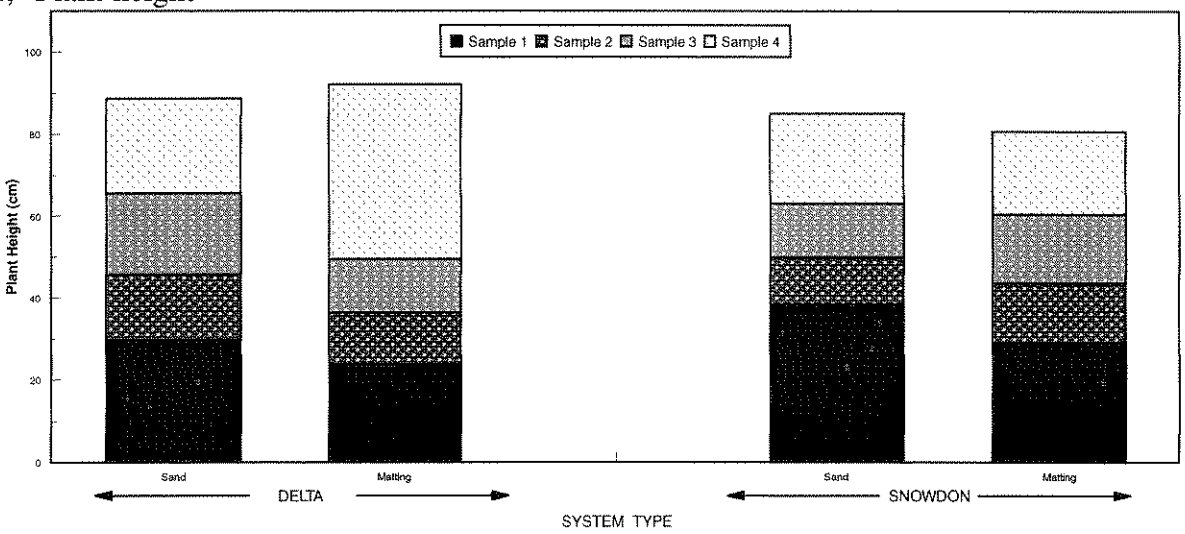
pH was above set point throughout the trial (Figure 20a, page 78) reflecting the difficulty in dosing the solution by hand in comparison with continual automatic dosing with the sand-based system. Conductivity of the matting system was generally closer to set point (Figure 20b, page 78) but the large fluctuations from sample to sample again reflect the inaccuracies of manual dosing. Other notable differences between the thin layer matting and standard sand-based systems are as follows: Higher levels of NH_4-N, K, P and Mn (Figures 20d, 20e, 20h and 20k, pages 78, 79 and 80). NH_4-N indicates the lower levels of biological activity in the system, as well as reflecting the short period over which the solution may have been exposed to nitrifying bacteria before being collected as run-off. K, P, Fe and Mn levels again indicate less interaction between the substrate and the feed solution in comparison with sand (Figures 20e, 20h, 20i and 20k, pages 79 and 80).

6.4 Mineral Analyses - Foliage Samples

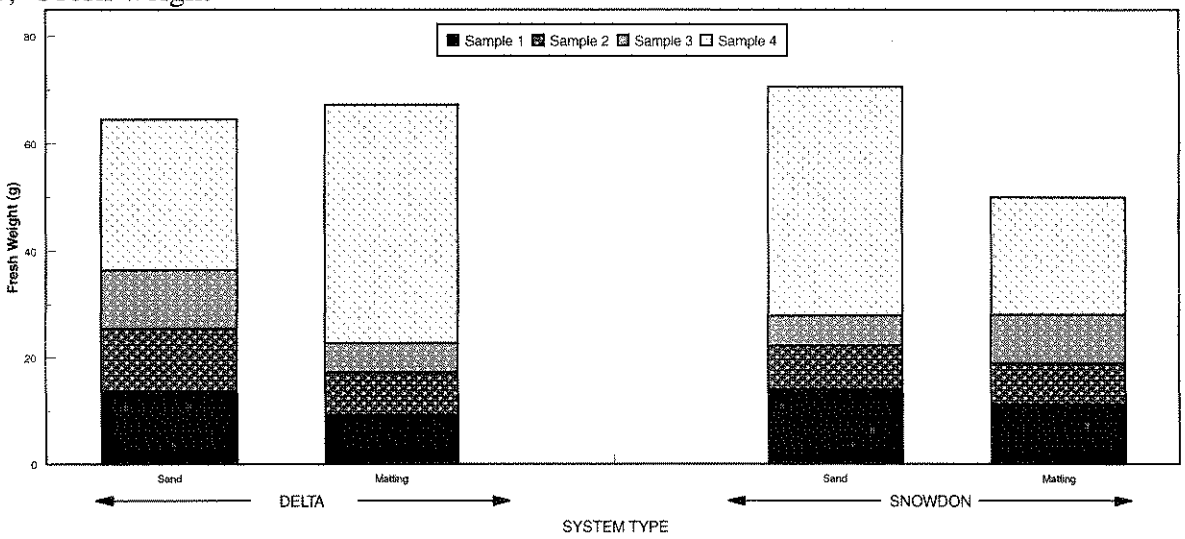
Foliage from the thin layer matting system again generally contained satisfactory levels of the mineral elements analysed (Appendix V, tables 4c, 4d, pages 144 and 145). In comparison with sand, higher levels of P, Fe and Mn were noted in samples from the thin layer matting system. This largely reflects the greater availability of these elements as noted from the results of the analyses of the feed solution.

Figure 21. The Influence of Alternative Systems on Plant Performance (1993/94)

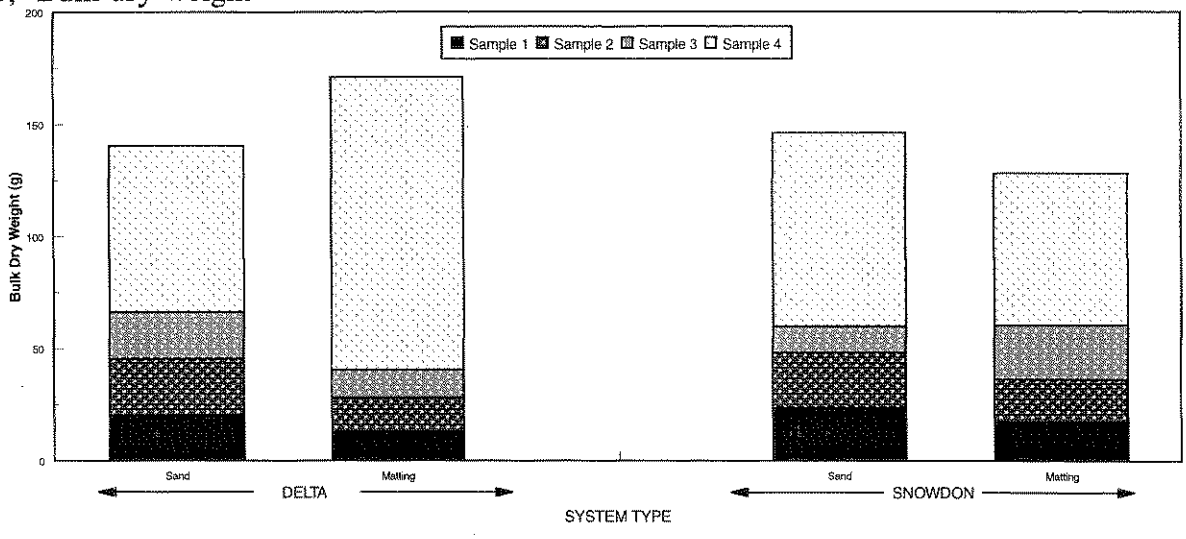
a, Plant height



b, Fresh weight



c, Bulk dry weight

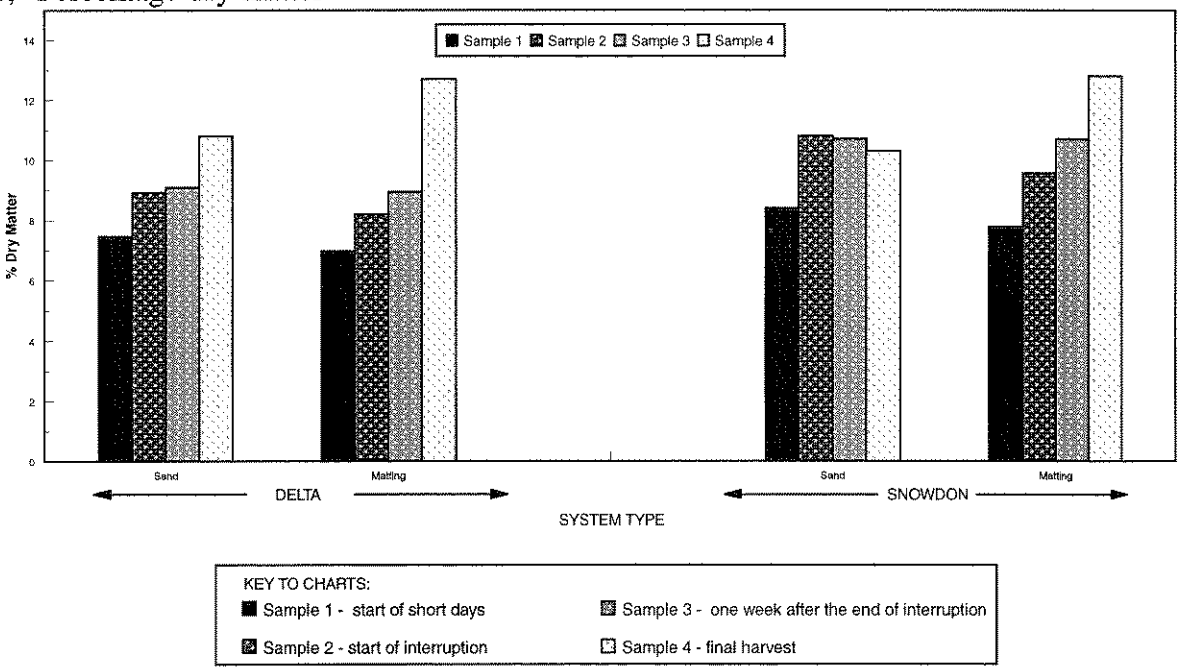


KEY TO CHARTS:

- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 21.(Continued) The Influence of Alternative Systems on Plant Performance (1993/94)

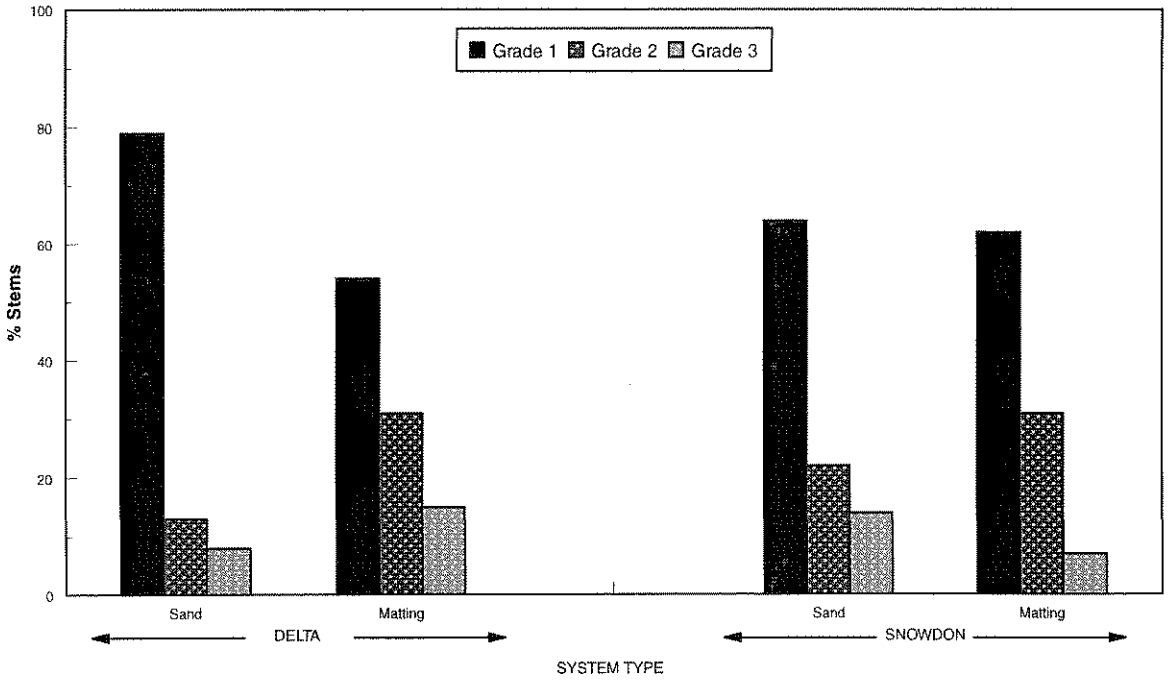
d, Percentage dry matter



KEY TO CHARTS:

- Sample 1 - start of short days
- Sample 2 - start of interruption
- Sample 3 - one week after the end of interruption
- Sample 4 - final harvest

Figure 22. The Influence of Alternative Systems on Harvest Grade Out (1993/94)



DISCUSSION

Drenching soil-grown plants with Aaterra produced a mixed response over the two years of the trial. In 1992/93 statistics highlighted a significant increase in stem weight in response to drench treatments, particularly with the variety Snowdon. This difference was not however apparent early in crop development, when Aaterra may be envisaged to improve take-off by suppressing root disease, but later on in development (i.e. from the end of the interruption). In 1993/94 drench treatments were applied to a bed which had been replanted for the fourth time without sterilization treatment. The threat from root pathogens was therefore potentially greater in the 1993/94 trial (as illustrated in the assessment of successive plantings discussed below). In the second year however there was no significant improvement, either during establishment or later development in plants treated with drenches compared with those not drenched. Assessment of root systems also indicated that the levels of root disease detected were not influenced by the drenching treatment. Overall, Aaterra drenching the soil after planting did not consistently benefit the crop. It should be noted that all peat blocks had Aaterra incorporated at 37 g/m^3, even for those plants grown on plots not treated with post-planting drenches. It is possible that clearer benefits from Aaterra drenches may have been demonstrated if all peat blocks, or at least peat blocks for planting on the 'no drench' plots had not been treated with Aaterra.

The use of Aaterra in hydroponic systems in combination with low pH treatments produced a similarly mixed result. The aim of this trial was to assess Aaterra and low pH as methods of root disease suppression in hydroponic sand-based systems. Neither Aaterra treated systems nor low pH systems consistently produced better results in comparison with the other treatments. This result may however reflect that the incidence of root disease was consistently low both during planting I in 1992/93 and planting IV in 1993/94. Assuming low or negligible levels of root disease it is unlikely that methods designed to reduce the incidence of root pathogens would produce any obvious benefits. These treatments did have a slight impact on the mineral analysis of the recirculation solution. Most notably the increased acid dosing required to maintain the low pH treatment increased the levels of nitrate-nitrogen available for uptake. The use of Aaterra also appeared to slow the rate of nitrification of ammoniacal-nitrogen and hence increase levels of available ammoniacal-nitrogen early on in the crop. These changes in available nitrogen may have been linked to the improved performance of Snowdon in the 1992/93 trial when grown on the low pH system with Aaterra added. Analysis of foliage samples did not however indicate increased %N with this treatment.

Direct stuck plants were apparently more responsive to the Aaterra/pH treatments. In particular, where differences were noted, the addition of Aaterra to the recirculation system was the most favourable. There were however no differences between these treatments in terms of incidence of root disease.

throughout. Assuming a build up of phosphate within the system had occurred, there is a potential risk in the longer term of phosphate toxicity. Similarly, other elements which were below target levels during production e.g. iron and potassium may build up in the longer term if these are being absorbed into the system. It is of course also possible that the supply of some of these elements met the demand by the plant very closely and hence were quickly taken up out of solution.

Response of plant development to depth of sand varied with variety, sampling date and trial to a certain extent. The overriding observation however was that plants generally established better on the full depth sand (i.e. 15 cm) than the half depth (7.5 cm), particularly in the 1993/94 trial. Irrigation and nutrition regimes were constant for both depths of sand in 1992/93 and 1993/94. It is likely that better development may be achieved on the half depth sand if the irrigation regime was reduced to produce a drier substrate. There certainly appears to be potential for reducing sand depth and hence the capital costs of establishing sand-bed systems. It is interesting that the wetter nature of the half depth sand had no apparent influence on the incidence of root disease. This result may reflect the low risk from root disease within the systems assessed, even on the fourth successive planting on a half depth (or wetter) system.

As an early attempt, results from the thin layer matting system were very promising, particularly with Delta. One previous trial had been conducted at HRI Efford where the same matting material was assessed on a bed sloping across the bed width. This attempt had been less successful because of an over-dry area at the high point of the bed and an over-wet area at the low point. Variability in establishment and overall performance therefore resulted. The observation on thin layer matting in the 1993/94 trial was therefore carried out on a bed with a camber design. This new bed design in conjunction with the use of 6 low level irrigation lines helped to maintain a much more even distribution of feed and water and hence more successful crop development. Plant roots quickly grew through the thin layer mat and spread out over the black polythene below the mat and where feed and water from each irrigation pulse would have been readily available. At harvest, the growth of roots through the mat did not cause any difficulties with pulling plants up and hence harvesting methods did not have to be adapted to suit this system.

Since the thin layer matting was operated as a run-to-waste system in this trial, freshly mixed feed was applied on each occasion. In contrast, the sand-based systems recirculated the drainage feed solution with fresh feed dosing in only when conductivity levels fell. The differences this made to availability of nutrients are illustrated in Figure 20 (Pages 78-81) but generally levels were higher in the run-off from the matting bed than the sand beds. While this may be an advantage in terms of availability for uptake, it is costly in terms of feed and creates an environmental problem due to high levels of nutrients in run-off draining into the sub-soil. Conversion of such a system to recirculation or reduction in irrigation frequencies would therefore merit further investigation.

Comparison of the hydroponic systems with soil-grown crops was not a specific objective of PC24b and PC24c, as it was in previous HDC funded work (Finlay, 1993). It is however possible to make these comparisons on the data produced in 1992/93 and 1993/94. This is perhaps easiest to do by referring to Figures 11, 12 and 13 (pages 53 to 57). Plant height and fresh weight, particularly of Snowdon, were greater from hydroponically grown stems than soil-grown stems. Differences for Delta were smaller overall but still generally in favour of hydroponics. Harvest grade-out was also improved from growing on the hydroponic systems. These improvements have all been achieved with a standard system comprising of standard irrigation frequencies and feed recipes. There is tremendous scope to investigate both of these factors to optimise production in terms of quality and cost efficiency. In terms of economics, the current trials have indicated potential cost savings from the possibility of reducing the quantity of sand required and reducing the need for sterilization treatments. Alternatively, matting-based systems may lead to further cost savings, depending on how they are set up and how often they can be re-used.

CONCLUSIONS

The studies conducted under PC24b and PC24c continue to demonstrate the potential of producing good quality plants on hydroponic systems during the winter period. Successful production of the varieties Delta and Snowdon was achieved on the experimental systems in the 1992/93 and 1993/94 winter periods which further supports results in the PC24 report (Finlay, 1993). The following main observations were noted:

- There was no consistent benefit from applying post-planting Aaterra drenches to soil-grown plants which had been propagated in peat blocks.

- Overall, the incidence of root disease pathogens, particularly *Pythium sp.* was low in all hydroponic treatments assessed. Consequently Aaterra and low pH treatments on sand-based hydroponic systems had little impact on plant performance.

- Sticking cuttings directly into sand-based hydroponic beds was a successful propagation method with particular improvements in early establishment of both varieties.

- Successive planting of sand-beds, without sterilisation between crops, has to date proved very successful with none of the resultant declines in plant performance as was recorded for the soil-grown crop. Potential therefore exists for reducing the costs and time involved in sterilization treatments.

- Analysis of the recirculating nutrient solution indicated potential interactions between the sand substrate and individual nutrient elements in solution. This factor would need attention when the use of these systems becomes established commercially.

- Reducing the depth of sand substrate impaired the early development of crops using standard irrigation settings. Later development was however less influenced by reducing sand depth and there appears to be potential for successfully producing crops on systems with less sand and hence lower capital costs.

- Matting materials as the basis for alternative hydroponic systems have considerable potential. Further evaluation to optimize irrigation and nutrition as well as system design and economics would be valuable.

RECOMMENDATIONS FOR FURTHER WORK

The experiments conducted at HRI Efford over the 1992 to 1994 period have continued to demonstrate the potential of hydroponic sand-based systems to produce good quality crops. The many lines of investigation pursued under PC24b and PC24c have inevitably raised several other questions in terms of further developing the system as well as identifying potential benefits which may be applied to the soil grown crop. These include:

- Further evaluation of the economics of the system by optimising irrigation to maintain quality whilst reducing the usage of pumps and control equipment and ideally reducing the depth of substrate necessary for production.

- Investigation of nutrition both to understand the potential interactions between applied feed solution and the substrate and to investigate how crop quality and scheduling may be manipulated (which may then be applied to soil-grown crops).

- Continued evaluation of successive planting to estimate the life of the systems as designed and hence enable a more realistic costing of converting to hydroponics.

- Assessment of risks from root pathogens should they become introduced to hydroponic systems and investigation of control measures.

- Development of matting systems and evaluation as alternatives to sand based systems, including re-use potential and performance under conditions of successive plantings.

Quality in the winter period continues to present difficulties to commercial growers. Hydroponic systems may in the future provide one tool which permits greater control over the root environment, particularly in the winter when very little irrigation can be applied to soil beds due to the risk of waterlogging. Other cultural techniques which may be applied to the soil-grown crop should also be pursued to optimise winter quality. One such technique, the use of supplementary lighting, is examined under the new programme of HDC funded work at Efford. Development of hydroponic systems will continue with the support of MAFF funding.

APPENDIX I

FEED RECIPES FOR HYDROPONIC AND SOIL SYSTEMS

APPENDIX I

a. Sand and Probase Hydroponic Systems

1. Hydroponic target nutrient concentrations

	Diluted Feed (mg/litre)		Recirculated Solution (mg/litre)
	Standard pH 5.8	Low pH 4.5	Standard and Low pH Treatments
NO_3N	150	150	125-175
NH_4-N	7	25	< 1
P	35	35	25-35
K	250	250	200-300
M	30	30	25-40
Ca	125	125	125-200
SO_4-S	55	96	-
Fe	3.0	3.0	2-3
Mn	1.0	1.0	0.5
Cu	0.1	0.1	0.1
Zn	0.2	0.2	0.2
B	0.3	0.3	0.3
Mo	0.05	0.05	0.05

APPENDIX I

2. Hydroponic feed recipe

		Standard pH 5.8	Low pH 4.5
Conductivity	at 20°C	1510 μS	1670 μS
	at 25°C	1660 μS	1840 μS
Acid Tank	(100 litres)		
	Nitric acid (60%)	7 litres	7 litres
A Tank	(100 litres)		
	Calcium nitrate (Norsk)	2.5 kg	2.5 kg
	Potassium nitrate	3.3 kg	1.3 kg
	Fe EDTA (13% Fe)	340 g	340 g
B Tank	(100 litres)		
	Potassium nitrate	3.3 kg	1.3 kg
	Potassium sulphate	1.0 kg	4.3 kg
	Magnesium sulphate	4.1 kg	4.1 kg
	Ammonium nitrate	420 g	2.0 kg
	Monopotassium phosphate (KH_2PO_4)	2.3 kg	2.3 kg
	Manganese sulphate (28% Mn)	54 g	54 g
	Copper sulphate	6 g	6 g
	Zinc sulphate	Nil	Nil
	Borax	31 g	31 g
	Ammonium molybdate	1.4 g	1.4 g
Approximate Dilution Rate		1:150	1:150

APPENDIX 1

b. Soil grown crop

Soil bed will receive standard winter feed programme of 150 N:200 K_2O (166 k)

Stock Tank (100 litres)

Potassium nitrate	8.7 kg
Ammonium nitrate	5.3 kg

Approximate Dilution Rate 1:200

Frequency of application will be adjusted according to system and crop requirements.

APPENDIX II

SHELF-LIFE ASSESSMENTS - TABLES OF RESULTS

APPENDIX II

Table 1. The influence of Aaterra Soil Drenches on Shelf-Life

a. 1992/93

Drench Treatment	No. days to Stage 2	No. days from Stage 2 to Stage 3	Total no. days to Stage 3
Variety: Delta			
None	6.1	21.2	27.3
at 2 days & 2½ weeks	6.5	21.5	28.0
at 2 days, 2½ weeks & 5 weeks	7.0	20.6	27.6
Variety: Snowdon			
None	11.4	12.7	24.1
at 2 days & 2½ weeks	11.3	13.0	24.3
at 2 days, 2½weeks & 5 weeks	10.8	13.8	24.6

Stage 2 = First signs of deterioration
Stage 3 = Advanced deterioration (stems ready to be discarded)

b 1993/94

Drench Treatment	No. days to Stage 2	No. days from Stage 2 to Stage 3	Total no. days to Stage 3
Variety: Delta			
None	17.0	16.8	33.8
at 2 days & 2½ weeks	16.9	17.5	34.4
at 2 days, 2½ weeks & 5 weeks	16.6	17.0	33.6
Variety: Snowdon			
None	17.5	9.7	27.2
at 2 days & 2½ weeks	18.2	7.8	26.0
at 2 days, 2½weeks & 5 weeks	15.4	7.5	22.9

Stage 2 = First signs of deterioration
Stage 3 = Advanced deterioration (stems ready to be discarded)

APPENDIX II

Table 2. The influence of Aaterra/pH in Sand-Based Systems on Shelf-Life

a. 1992/93

pH	Aaterra	No. days to Stage 2	No. days from Stage 2 to Stage 3	Total no. days to Stage 3
Variety: Delta				
Standard	- A	7.0	20.6	27.6
Standard	+ A	11.4	17.3	28.7
Low	- A	7.9	20.3	28.2
Low	+ A	10.7	17.5	28.2
Variety: Snowdon				
Standard	- A	12.2	13.0	25.2
Standard	+ A	13.5	12.8	26.3
Low	- A	12.0	13.7	25.7
Low	+ A	12.8	13.4	26.2

Stage 2 = First signs of deterioration
Stage 3 = Advanced deterioration (stems ready to be discarded)
- A = No Aaterra used in the recirculating solution
+ A = Aaterra added to the recirculating solution

APPENDIX II

b. 1993/94

pH	Aaterra	Propagation	No. days to Stage 2	No. days from Stage 2 to Stage 3	Total no. days to Stage 3
Variety: Delta					
Standard	- A	pb	17.0	16.7	33.7
Standard	+ A	pb	12.4	6.4	18.8
Low	- A	pb	15.1	9.9	25.0
Low	+ A	pb	18.5	13.7	32.2
Standard	- A	ds	16.3	14.5	30.8
Standard	+ A	ds	16.2	14.6	30.8
Low	- A	ds	17.6	15.5	33.1
Low	+ A	ds	18.0	15.5	33.5
Variety: Snowdon					
Standard	- A	pb	12.4	8.3	20.7
Standard	+ A	pb	13.2	7.8	30.0
Low	- A	pb	11.5	7.0	18.5
Low	+ A	pb	14.9	6.8	21.7
Standard	- A	ds	9.5	5.9	15.4
Standard	+ A	ds	7.0	5.0	12.0
Low	- A	ds	16.0	6.4	22.4
Low	+ A	ds	13.5	7.5	21.0

Stage 2 = First signs of deterioration
Stage 3 = Advanced deterioration (stems ready to be discarded)
- A = No Aaterra used in the recirculating solution
+ A = Aaterra added to the recirculating solution
pb = Peat block stuck
ds = Direct stuck in the hydroponic bed

APPENDIX II

Table 3. The Influence of Direct Sticking on Shelf-Life (1993/94 only)

Propagation Method	No. days to Stage 2	No. days from Stage 2 to Stage 3	Total no. days to Stage 3
Variety: Delta			
Peat blocks	15.8	11.7	27.5
Direct Stuck	17.0	15.0	32.0
Variety: Snowdon			
Peat blocks	13.0	7.5	20.5
Direct stuck	11.5	6.2	17.7

Stage 2 = First signs of deterioration
Stage 3 = Advanced deterioration (stems ready to be discarded)

APPENDIX II

Table 4. The Influence of Successive Planting, Sand Depth and Thin Layer Matting on Shelf-Life

a. 1992/93

pH		Sand Depth	No. days to Stage 2	No. days from Stage 2 to Stage 3	Total no. days to Stage 3
Variety: Delta					
I		Half	9.5	18.5	28.0
I		Full	11.4	17.3	28.7
IV		Full	10.1	19.3	29.4
IV	(Probase)	Full	9.1	20.2	29.3
IV	(Soil)	-	7.4	20.4	27.8
Variety: Snowdon					
I		Half	12.6	13.6	26.2
I		Full	13.5	12.8	26.3
IV		Full	12.4	13.0	25.4
IV	(Probase)	Full	12.0	13.6	25.6
IV	(Soil)	-	12.3	12.4	24.7

Stage 2 = First signs of deterioration
Stage 3 = Advanced deterioration (stems ready to be discarded)

b. 1993/94

pH		Sand Depth	No. days to Stage 2	No. days from Stage 2 to Stage 3	Total no. days to Stage 3
Variety: Delta					
IV		Half	17.6	10.1	27.7
IV		Full	12.4	6.4	18.8
VII		Full	16.4	17.6	34.0
VII	(Probase)	Full	16.2	18.6	34.8
I	(Matting)	-	17.0	7.5	24.5
Variety: Snowdon					
IV		Half	14.6	8.5	23.1
IV		Full	13.2	7.8	30.0
VII		Full	16.6	9.3	25.9
VII	(Probase)	Full	16.2	8.5	24.7
I	(Matting)	-	13.6	5.2	18.8

Stage 2 = First signs of deterioration
Stage 3 = Advanced deterioration (stems ready to be discarded)

APPENDIX III

PYTHIUM WORK - 1992/93

(Author - Dr. T. Pettitt)

APPENDIX III

MATERIALS AND METHODS

Assessments

Disease assessment of roots:

Assessments were carried out at the following stages in the crops development:

1. 2 days before the start of short days.

2. At the end of interruption.

3. 10 days after the end of interruption.

4. At maturity (i.e. final harvest).

Samples of root tissue were taken from ten replicate plants of each treatment and examined for the presence of *Pythium* spp. The presence of *Pythium* spp infection was verified by both microscopic observation of root pieces floated in sterilized pond water (5 x 1 cm pieces per root sample, floated for 48 hours at 20^0C) and by isolations onto selective antibiotic agar (v8 agar supplemented with 100 mg/l Pinaricin and 100 mg/l Rifamycin).

RESULTS

Infection of root tissues by *Pythium* spp was widespread and was detected at some stage during the development of the crop in all the beds assessed (Tables A - G, pages 105-111).

There were no apparent differences between the varieties Delta and Snowdon in the incidence of root infection, and despite the presence of infection, even at high levels, all plants apparently established and developed into harvestable stems on all plots.

The incidence of *Pythium* infections was greatest in plants grown on sand beds (Tables C - G, pages 107-111), with the incidence in soil beds being very low (0 - 23.3%; Tables A, B, E and F, pages 105-110). Treatments with Aaterra solution seemed to have little impact on the incidence of infection although they may have reduced the severity of infections.

In virtually all treatments the highest incidence of infection was during the early stages of the crop's development represented by samples 1 and 2. Although not readily explained, this early rise in the incidence of infection followed by a marked decline was also observed during the 1991/92 trials.

Table A. Soil-Grown Crop - Influence of Aaterra on Plant Performance - Root Disease Incidence (1992/93)

Variety: Snowdon

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Soil without Aaterra post - planting	4.3	0.7	2.3	0.7
Soil with Aaterra drenches 2 days and 2.5 weeks post - planting	3.3	0	2.3	0
Soil with Aaterra drenches 2 days, 2.5 weeks and 5 weeks post planting	10	1.3	1.7	0

Sample 1 Two days before the start of short days
Sample 2 At the end of interruption
Sample 3 10 days after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX III

Table B. **Soil-Grown Crop - Influence of Aaterra on Plant Performance - Root Disease Incidence (1992/93)**

Variety: Delta

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Soil without Aaterra post - planting	0.7	1.7	0.7	0.7
Soil with Aaterra drenches 2 days and 2.5 weeks post - planting	23.3	0	0	0
Soil with Aaterra drenches 2 days, 2.5 weeks and 5 weeks post planting	0	0.7	0.3	1.7

Sample 1 Two days before the start of short days
Sample 2 At the end of interruption
Sample 3 10 days after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX III

Table C. **Hydroponic Crop - Influence of Aaterra/pH on Plant Performance - Root Disease Incidence (1992/93)**

Variety: Snowdon

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	60	60	12	5
Sand Low pH with Aaterra	65	28	27	18
Sand Standard pH without Aaterra	52	22	37	7
Sand Standard pH with Aaterra	25	47	33	17

Sample 1 Two days before the start of short days
Sample 2 At the end of interruption
Sample 3 10 days after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX III

Table D. **Hydroponic Crop - Influence of Aaterra/pH on Plant Performance - Root Disease Incidence (1992/93)**

Variety: Delta

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	55	37	37	45
Sand Low pH with Aaterra	53	50	33	50
Sand Standard pH without Aaterra	65	47	37	42
Sand Standard pH with Aaterra	58	48	27	38

Sample 1 Two days before the start of short days
Sample 2 At the end of interruption
Sample 3 10 days after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX III

Table E. **Hydroponic and Soil-Grown Crop - Effects of Successive Planting, Without Sterilization Between Crops, on the Incidence of Root Infection/Disease (1992/93)**

Variety: Snowdon

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Non-sterile soil Planting I	22	0	2	2
Fresh Sand Standard pH Planting I	25	47	33	17
'Old' Sand Standard pH Planting I	54	20	3	0
'Old' Probase Standard pH Planting I	25	2	10	0

Sample 1 Two days before the start of short days
Sample 2 At the end of interruption
Sample 3 10 days after the end of interruption
Sample 4 At maturity (i.e. final harvest)

When direct stuck plants as a whole were compared with peat block stuck plants, the former propagation method apparently favoured early development with both height and fresh weight benefits. Advantages of direct sticking in terms of development would include removal of transplanting shock which would be experienced by peat-block stuck plants, and wider spacing. That is, because cuttings were stuck directly in their final growing positions they were at final spacing (i.e. 54.4 plants/m^2) from sticking onwards. In contrast, peat-block stuck plants were spaced closer together during propagation (i.e. 400 plants/m^2 or block thick) and were not moved to final spacing for 14 days. The obvious disadvantage of this propagation method is the less efficient use of space for two weeks of the cropping period.

The early advantages of direct sticking were less obvious as the crop matured. In this trial all treatments were grown on the same schedule. It is likely however that plants direct stuck in a hydroponic system could be grown with a shorter long-day period since early take-off and development was clearly improved. Hence an advantage in terms of scheduling may result.

The impact of successive planting was very different depending on whether the growing system was soil or sand-based hydroponics. In 1992/93 there was a clear reduction in plant performance from planting IV on soil (i.e. the fourth successive crop with no sterilization treatment between crops) compared with planting I on soil. In contrast, in both 1992/93 and 1993/94, the older sand-based systems produced taller, heavier plants than the newer sand-based systems. As observed through monitoring volumes of water required to top-up the systems, there were probably leaks in the polythene liner of the oldest sand bed and so it was not recirculating all the solution applied which may have influenced this result. It may still be expected however that this repeated cropping on sand would lead to the build up of disease problems and hence declining yield as observed with the soil-grown crop. The fact that this does not appear to be the case is a very positive result for the sand-based hydroponic system. It has not yet been established how many repeat crops may be grown without yield problems but at least three more crops can be grown on the system without problems in comparison with soil-grown crops. Hence there are potential savings in terms of labour, energy and time to turn beds around for the next crop.

There are indications from analysis of the recirculating solution that there may be interactions between the sand growing medium and the nutrient ions in solution which may also have implications in terms of successive planting. Phosphate-phosphorus is a good example of this interaction. PO_4-P levels in recirculation were well below the target range for both the newer and older sand beds in the 1992/93 and 1993/94 trials. Despite this, levels of phosphorus in all foliage samples were well within the satisfactory range for chrysanthemums. The reason for this apparent lack of phosphate in solution has not been identified but may be the result of absorption or precipitation of phosphates within the sand. Calcium from calcium carbonates in the sand for example may have bound to phosphate ions to form calcium phosphate precipitates. Whatever the cause, there was clearly an adequate supply of phosphorus for the nutrition of the plants

APPENDIX III

Table F. **Hydroponic and Soil-Grown Crop - Effects of Successive Planting, without Sterilization Between Crops, on the Incidence of Root Infection/Disease (1992/93)**

Variety: Delta

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Non-sterile soil Planting I	0	2	0	20
Fresh Sand Standard pH Planting I	58	48	27	47
'Old' Sand Standard pH Planting I	37	37	3	87
'Old' Probase Standard pH Planting I	90	10	25	7

Sample 1 Two days before the start of short days
Sample 2 At the end of interruption
Sample 3 10 days after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX III

Table G. **Effect of Reduced depth of Substrate in Hydroponic Sand Beds on Plant Performance - Root Disease Incidence (1992/93)**

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Variety: Snowdon				
'Standard Depth' sand bed	25	47	33	17
'Half Depth' sand bed	55	13	23	35
Variety: Delta				
'Standard Depth' sand bed	58	48	27	38
'Half Depth' sand bed	7	50	38	32

Sample 1 Two days before the start of short days
Sample 2 At the end of interruption
Sample 3 10 days after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

PYTHIUM WORK - 1993/94

(Author - Dr. T. Pettitt)

APPENDIX IV

MATERIALS AND METHODS

Assessments

Disease assessment of roots:

Assessments were carried out at the following stages in the crops development:

1. 2 days before the start of short days.

2. At the start of interruption.

3. 1 week after the end of interruption.

4. At maturity (i.e. final harvest).

The root systems of five replicate plants from each treatment were gently washed free of growing medium under running tapwater. Root systems were laid out on a white background and assessed under daylight for relative root browning using a percentage score. Samples of root tissue were also taken from each plant and examined for the presence of *Pythium* spp. The presence of *Pythium* was confirmed by both microscopic observation of root pieces floated in sterilized pond water (5 x 1 cm pieces per root system sampled; floated for 48 hours at 20^0C) and by isolations onto selective antibiotic agar (v8 agar supplemented with 100 mg/l Pinaricin and 100 mg/l Rifamycin).

RESULTS

Pythium spp infection of roots was present in all of the beds assessed during this season's trial (Tables H - P, pages 114-122). There was a lower incidence of infection in sand beds than in the previous season (92/93) (Tables J, L, C and D, pages 116, 118, 107 and 108) and the amounts of infections seen in soil and sand beds were also more comparable with each other than during the previous season, where much less infection was seen in the soil beds (Tables H, I, J and L, pages 114-118). Again there appeared to be no appreciable variety differences in susceptibility to infection or in the degree of root browning. Direct sticking both Delta and Snowdon into sand beds did increase the incidence of infection by *Pythium* spp (Tables K and M, pages 117 and 119). There also appeared to be a marginal increase in root browning (Tables T and V, pages 126 and 128), although in general, the degree of root browning was not related to the incidence of *Pythium* spp infection. The pattern of infection during the '93/94' season was unlike the previous two seasons, with a more even spread of infection throughout the development of the crop.

Table H. **Soil-Grown Crop - Influence of Successive Planting and Aaterra Treatment on Plant Performance - Root Disease Incidence (1993/94)**

Variety: Snowdon

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Soil without Aaterra post - planting	10	28	25	20
Soil with Aaterra drenches 2 days and 2.5 weeks post - planting	16	48	17	60
Soil with Aaterra drenches 2 days, 2.5 weeks and 5 weeks post - planting	9	22	50	45

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table I. **Soil-Grown Crop - Influence of Successive Planting and Aaterra Treatment on Plant Performance - Root Disease Incidence (1993/94)**

Variety: Delta

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Soil without Aaterra post - planting	16	21	0	50
Soil with Aaterra drenches 2 days and 2.5 weeks post - planting	5	0	12.5	40
Soil with Aaterra drenches 2 days, 2.5 weeks and 5 weeks post planting	0	5	0	10

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table J. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Disease Incidence (1993/94)**

Propagation Technique = Peat Blocks

Variety: Snowdon

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	15	20	0	0
Sand Low pH with Aaterra	56	8	20	0
Sand Standard pH without Aaterra	10	10.5	12.5	0
Sand Standard pH with Aaterra	12	25	12	5

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table K. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Disease Incidence (1993/94)**

Propagation Technique = Direct Sticking

Variety: Snowdon

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	-	24	0	65
Sand Low pH with Aaterra	52	56	0	45
Sand Standard pH without Aaterra	-	39	0	60
Sand Standard pH with Aaterra	31	43	-	25

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table L. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Disease Incidence (1993/94)**

Propagation Technique = Peat Blocks

Variety: Delta

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	20	4	0	45
Sand Low pH with Aaterra	1	4	0	70
Sand Standard pH without Aaterra	25	17	4	70
Sand Standard pH with Aaterra	28	35	4	0

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table M. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Disease Incidence (1993/94)**

Propagation Technique = Direct Sticking

Variety: Delta

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	0	0	8	35
Sand Low pH with Aaterra	44	0	12	45
Sand Standard pH without Aaterra	17	29	8	25
Sand Standard pH with Aaterra	8	21	-	20

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table N. **Hydroponic and Soil-Grown Crop - Continued Examination of the Effects of Successive Planting Without Sterilization Between Crops - Root Disease Incidence (1993/94)**

Variety: Snowdon

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Freshly Sterilized soil	0	32	4	9.5
Sand Standard pH Planting I	12	25	12	5
Sand Standard pH Planting VII	0	8	12.5	65
Probase Standard pH Planting VII	8.7	0	4	80

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table O. **Hydroponic and Soil-Grown Crop - Continued Examination of the Effects of Successive Planting Without Sterilization Between Crops - Root Disease Incidence (1993/94)**

Variety: Delta

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Freshly Sterilized soil	0	8.7	4	50
Sand Standard pH Planting I	28	35	4	0
Sand Standard pH Planting VII	15	13	0	30
Probase Standard pH Planting VII	25	0	4	25

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table P. **Hydroponic Crop - Evaluation of Reduction in Depth of Substrate and Successive Planting on Root Disease Incidence (1993/94)**

Treatment	% Incidence of phycomycete (predominantly *Pythium* spp.) infections in roots			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Variety: Snowdon				
'Standard Depth' sand bed	12	25	12	5
'Half Depth' sand bed	5	0	0	10
Variety: Delta				
'Standard Depth' sand bed	28	35	4	0
'Half Depth' sand bed	0	28	0	5

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table Q. **Soil-Grown Crop - Influence of Successive Planting and Aaterra Treatment on Plant Performance - Root Browning (1993/94)**

Variety: Snowdon

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Soil without Aaterra post - planting	8	11	14	16
Soil with Aaterra drenches 2 days and 2.5 weeks post - planting	4	10	10	18
Soil with Aaterra drenches 2 days, 2.5 weeks and 5 weeks post - planting	10.2	11	17	16

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table R. **Soil-Grown Crop - Influence of Successive Planting and Aaterra Treatment on Plant Performance - Root Browning (1993/94)**

Variety: Delta

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Soil without Aaterra post - planting	1.8	8	42	15
Soil with Aaterra 2 days and 2.5 weeks post - planting	1.8	19	43	24
Soil with Aaterra 2 days, 2.5 weeks and 5 weeks post planting	0.3	13	31	24

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table S. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Browning (1993/94)**

Propagation Technique = Peat Blocks

Variety: Snowdon

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	3.4	2.9	14	30
Sand Low pH with Aaterra	9.5	10	14	19
Sand Standard pH without Aaterra	10.6	12	37	21
Sand Standard pH with Aaterra	15.4	26	13	16

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table T. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Browning (1993/94)**

Propagation Technique = Direct Sticking

Variety: Snowdon

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	5.9	23	21	27
Sand Low pH with Aaterra	1.7	11	19	16
Sand Standard pH without Aaterra	7	18	23	47
Sand Standard pH with Aaterra	3.1	18	12	13

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table U. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Browning (1993/94)**

Propagation Technique = Peat Blocks

Variety: Delta

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	2.3	16	24	20
Sand Low pH with Aaterra	4	40	28	15
Sand Standard pH without Aaterra	12	12	15	14
Sand Standard pH with Aaterra	2.2	62	33	15

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table V. **Hydroponic Crop - Influence of Propagation Method and Aaterra/pH on Plant Performance - Root Browning (1993/94)**

Propagation Technique - Direct Sticking

Variety: Delta

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Sand Low pH without Aaterra	8.5	44	27	28
Sand Low pH with Aaterra	0	35	17	31
Sand Standard pH without Aaterra	1.6	22	28	21
Sand Standard pH with Aaterra	0.6	18	10	23

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table W. **Hydroponic and Soil-Grown Crop - Continued Examination of the Effects of Successive Planting Without Sterilization Between Crops - Root Browning (1993/94)**

Variety: Snowdon

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Freshly Sterilized soil	0.8	11.4	15	14
Sand Standard Feed Planting I	15.4	26	13	16
Sand Standard Feed Planting VII	40	22	27	29
Probase Standard Feed Planting VII	25	18	31	19

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table X. Hydroponic and Soil-Grown Crop - Continued Examination of the Effects of Successive Planting Without Sterilization Between Crops - Root Browning (1993/94)

Variety: Delta

Treatment	Root Browning			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
Freshly Sterilized soil	2.2	13.4	38	16
Sand Standard Feed Planting I	2.2	62	33	15
Sand Standard Feed Planting VII	16	39	38	18
Probase Standard Feed Planting VII	28	64	29	25

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX IV

Table Y. Hydroponic Crop - Evaluation of Reduction in Depth of Substrate and Successive Planting on Root Browning (1993/94)

Treatment	Root Browning			
	Sample 1	Sample 2	Sample 3	Sample 4
Variety: Snowdon				
'Standard Depth' sand bed	15.4	26	13	16
'Half Depth' sand bed	2	20	12	11
Variety: Delta				
'Standard Depth' sand bed	2.2	62	33	15
'Half Depth' sand bed	1.2	49	22	26

Sample 1 Two days before the start of short days
Sample 2 At the start of interruption
Sample 3 One week after the end of interruption
Sample 4 At maturity (i.e. final harvest)

APPENDIX V

FOLIAGE MINERAL ANALYSIS - TABLES OF RESULTS

APPENDIX V

Table 1a. **The Influence of Aaterra Soil Drenches (Planting I - 1992/93)**

Variety: Delta

Drench Treatment	Sample	%DM	%N	%P	%K	%Mg	mg/kg Mn
None	1	7.7	5.67	0.70	*8.07*	0.38	359
at 2 days & 2½ weeks	1	7.8	5.72	0.70	*8.24*	0.35	332
at 2 days, 2½ weeks & 5 weeks	1	8.1	5.46	0.74	*7.88*	0.37	328
None	2	8.3	5.67	0.70	*8.32*	0.37	321
at 2 days & 2½ weeks	2	7.1	5.47	0.73	*8.07*	0.39	345
at 2 days, 2½ weeks & 5 weeks	2	8.1	5.56	0.76	*8.20*	0.40	330
None	3	8.0	5.41	0.52	*8.53*	0.41	*423*
at 2 days & 2½ weeks	3	8.0	5.41	0.54	*8.33*	0.40	*457*
at 2 days, 2½ weeks & 5 weeks	3	7.4	5.32	0.59	*8.27*	0.40	*478*

Sampling Dates:

1 - 06/1/93
2 - 20/1/93
3 - 19/2/93

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 1b. The Influence of Aaterra Soil Drenches (Planting I - 1992/93)

Variety: Snowdon

Drench Treatment	Sample	%DM	%N	%P	%K	%Mg	mg/kg Mn
None	1	8.5	5.73	0.53	*7.06*	0.41	322
at 2 days & 2½ weeks	1	8.2	5.81	0.53	*7.13*	0.38	356
at 2 days, 2½ weeks & 5 weeks	1	8.6	5.67	0.54	*6.77*	0.39	328
None	2	9.9	5.82	0.57	*7.17*	0.44	323
at 2 days & 2½ weeks	2	9.5	5.87	0.59	*7.44*	0.42	298
at 2 days, 2½ weeks & 5 weeks	2	9.2	5.90	0.61	*7.44*	0.41	358
None	3	10.9	5.42	0.48	*7.03*	0.40	339
at 2 days & 2½ weeks	3	10.0	5.40	0.46	*6.76*	0.43	391
at 2 days, 2½ weeks & 5 weeks	3	10.7	5.41	0.46	*6.97*	0.41	395

Sampling Dates:

1 - 06/1/93
2 - 20/1/93
3 - 19/2/93

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 1c. The Influence of Aaterra Soil Drenches (Planting IV - 1993/94)

Variety: Delta

Drench Treatment	Sample	%DM	%N	%P	%K	%Mg	%Ca	Fe mg/kg	Mn mg/kg	B mg/kg	Cu mg/kg
None	1*	94.2	4.77	0.58	5.96	0.36			100		
at 2 days & 2½ weeks	1*	93.4	4.42	0.60	6.21	0.33			112		
at 2 days, 2½ weeks & 5 weeks	1*	93.4	4.81	0.64	6.43	0.35			103		
None	2	8.5	5.07	0.55	*6.87*	0.43	1.64	481	118	27.3	11.30
at 2 days & 2½ weeks	2	7.4	5.04	0.57	*7.74*	0.40	1.52	487	139	28.8	9.90
at 2 days, 2½ weeks & 5 weeks	2	7.4	5.55	0.54	*7.50*	0.38	1.35	355	135	27.1	13.00
None	3	10.5	4.12	*0.29*	5.36	*0.27*	1.66	*1810*	132	21.2	*6.80*
at 2 days & 2½ weeks	3	9.8	4.50	*0.32*	5.70	*0.27*	1.94	*1640*	145	20.6	*7.58*
at 2 days, 2½ weeks & 5 weeks	3	9.9	4.62	*0.30*	5.75	*0.25*	1.83	*1120*	134	21.2	*6.79*

Sampling Dates:

1 - 14/12/93 * sent as oven dried material hence %DM result
2 - 06/01/94
3 - 25/02/94

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 1d. **The Influence of Aaterra Soil Drenches (Planting IV - 1993/94)**

Variety: Snowdon

Drench Treatment	Sample	%DM	%N	%P	%K	%Mg	%Ca	Fe mg/kg	Mn mg/kg	B mg/kg	Cu mg/kg
None	1*	93.5	4.79	0.42	5.57	0.32			62.0		
at 2 days & 2½ weeks	1*	93.3	4.82	0.46	5.58	0.33			72.4		
at 2 days, 2½ weeks & 5 weeks	1*	93.7	4.84	0.44	5.68	0.31			69.5		
None	2	9.2	4.02	0.49	*6.78*	0.40	1.28	382	82.9	*22.9*	*10.50*
at 2 days & 2½ weeks	2	8.7	5.98	0.51	6.50	0.42	1.39	370	82.8	*21.9*	*9.68*
at 2 days, 2½ weeks & 5 weeks	2	9.1	5.53	0.48	5.99	0.37	1.43	434	95.4	*22.8*	*8.45*
None	3	10.0	4.53	*0.27*	4.38	0.24	1.28	*914*	89.8	*17.4*	*5.01*
at 2 days & 2½ weeks	3	9.8	4.76	*0.14*	*2.24*	*0.12*	0.69	209	33.9	*21.9*	*2.85*
at 2 days, 2½ weeks & 5 weeks	3	9.5	4.87	*0.59*	*9.86*	0.58	2.89	*1060*	166.0	*17.3*	*9.86*

Sampling Dates:

1 - 14/12/93 * sent as oven dried material hence %DM result
2 - 06/01/94
3 - 25/02/94

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 2a. The Influence of Aaterra/pH on Sand-Based Systems (Planting I - 1992/93)

Variety: Delta

pH	Aaterra	Sample	%DM	%N	%P	%K	%Mg	mg/kg Mn
Standard	- A	1	6.8	5.93	0.59	*8.05*	0.46	229
Standard	+ A	1	7.5	6.35	0.56	*8.98*	0.42	253
Low	- A	1	6.8	5.84	0.45	*8.21*	0.40	252
Low	+ A	1	7.3	6.11	0.45	*8.75*	0.39	297
Standard	- A	2	7.2	5.73	0.63	*8.67*	0.42	186
Standard	+ A	2	7.3	5.83	0.59	*8.74*	0.46	206
Low	- A	2	4.8	5.54	0.49	*8.33*	0.45	222
Low	+ A	2	7.0	6.04	0.49	*8.76*	0.39	233
Standard	- A	3	6.8	5.52	0.48	*8.89*	0.46	248
Standard	+ A	3	7.6	5.25	0.56	*8.97*	0.43	256
Low	- A	3	7.3	5.42	0.36	*9.60*	0.41	254
Low	+ A	3	7.0	5.68	0.36	*9.62*	0.38	320

Sampling Dates:

1 - 06/1/93
2 - 20/1/93
3 - 19/2/93

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 2b. **The Influence of Aaterra/pH on Sand-Based Systems (Planting I - 1992/93)**

Variety: Snowdon

pH	Aaterra	Sample	%DM	%N	%P	%K	%Mg	mg/kg Mn
Standard	- A	1	8.7	5.75	0.44	*6.84*	0.42	131
Standard	+ A	1	9.2	6.04	0.48	*7.10*	0.39	178
Low	- A	1	8.6	5.83	0.39	*6.66*	0.40	174
Low	+ A	1	8.2	5.96	0.50	*6.25*	0.38	170
Standard	- A	2	9.7	5.82	0.56	*7.18*	0.47	113
Standard	+ A	2	9.1	6.36	0.63	*7.34*	0.48	165
Low	- A	2	11.0	5.91	0.48	*6.61*	0.44	184
Low	+ A	2	9.4	6.33	0.56	*7.24*	0.44	189
Standard	- A	3	11.5	5.43	0.44	*6.94*	0.42	137
Standard	+ A	3	11.2	5.62	0.50	*7.72*	0.41	240
Low	- A	3	9.5	5.55	0.36	*7.34*	0.38	218
Low	+ A	3	9.8	5.54	0.42	*7.10*	0.37	242

Sampling Dates:

1 - 06/1/93
2 - 20/1/93
3 - 19/2/93

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 2c. The Influence of Aaterra/pH and Direct Sticking on Sand-Based Systems (Planting IV - 1993/94)

Variety: Delta

pH	Aaterra		Propagation	Sample	%DM	%N	%P	%K	%Mg	%Ca	Fe mg/g	Mn mg/kg	B mg/kg	Cu mg/kg
Standard	-	A	pb	1*	92.9	4.89	0.56	5.06	0.50			68.6		
Standard	+	A	pb	1*	93.2	4.90	0.66	5.94	0.45			80.1		
Low	-	A	pb	1*	93.1	4.59	0.57	6.36	0.38			96.9		
Low	+	A	pb	1*	91.6	4.93	0.66	5.62	0.49			89.7		
Standard	-	A	ds	1*	92.8	4.41	0.47	5.69	*0.27*			25.7		
Standard	+	A	ds	1*	93.0	4.41	0.48	6.14	*0.21*			41.1		
Low	-	A	ds	1*	92.8	4.49	0.50	6.39	*0.23*			90.3		
Low	+	A	ds	1*	93.1	4.34	0.52	6.29	*0.24*			78.1		
Standard	-	A	pb	2	7.5	4.33	0.55	6.30	0.53	1.72	197	76.0	27.1	12.1
Standard	+	A	pb	2	7.0	6.02	0.59	*7.00*	0.44	1.70	205	80.4	26.1	11.9
Low	-	A	pb	2	6.8	5.65	0.52	6.46	0.38	1.36	228	115.0	29.8	10.3
Low	+	A	pb	2	7.6	5.36	0.62	6.63	0.50	1.60	145	106.0	26.2	13.0
Standard	-	A	ds	2	6.9	5.52	0.55	*7.15*	0.32	1.85	195	37.4	26.1	10.4
Standard	+	A	ds	2	6.7	3.92	0.53	*7.39*	*0.28*	1.56	574	54.1	21.7	12.7
Low	-	A	ds	2	6.0	4.12	0.51	*7.10*	*0.28*	1.35	178	123.0	31.3	13.7
Low	+	A	ds	2	6.5	5.03	0.56	*7.46*	0.31	1.46	206	103.0	24.9	13.2
Standard	-	A	pb	3	8.1	4.78	0.30	5.62	0.31	2.30	625	68.0	*19.7*	*8.0*
Standard	+	A	pb	3	8.4	4.36	0.31	4.92	*0.27*	1.90	*1750*	78.6	*17.2*	11.50
Low	-	A	pb	3	8.3	3.97	*0.24*	4.97	*0.21*	1.36	*1180*	155	23.2	14.40
Low	+	A	pb	3	10.9	*3.29*	*0.18*	*2.87*	*0.24*	1.09	2170	96.5	*15.0*	*9.51*
Standard	-	A	ds	3	8.7	3.95	*0.26*	4.72	*0.18*	1.67	*2060*	36.8	*15.9*	*8.91*
Standard	+	A	ds	3	12.0	*2.94*	*0.17*	*3.28*	*0.12*	1.24	*3770*	42.0	*15.7*	*7.16*
Low	-	A	ds	3	8.6	*3.39*	*0.20*	4.61	*0.13*	0.93	*1160*	128.0	22.4	*6.66*
Low	+	A	ds	3	8.7	4.28	*0.24*	4.52	*0.20*	1.34	*1050*	121.0	22.6	*7.02*

Sampling Dates:

1 - 14/12/93 * sent as oven dried material
2 - 06/01/94
3 - 25/02/94

NOTE:

pb = peat block stuck
ds = direct stuck in sand beds

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 2d. The Influence of Aaterra/pH and Direct Sticking on Sand-Based Systems (Planting IV - 1993/94)

Variety: Snowdon

pH	Aaterra		Propagation	Sample	%DM	%N	%P	%K	%Mg	%Ca	Fe mg/kg	Mn mg/kg	B mg/kg	Cu mg/kg
Standard	-	A	pb	1*	92.8	4.72	0.43	4.43	0.43			52.0		
Standard	+	A	pb	1*	93.6	4.85	0.50	5.54	0.37			57.9		
Low	-	A	pb	1*	92.4	4.58	0.44	5.30	0.35			75.7		
Low	+	A	pb	1*	92.5	4.83	0.50	4.92	0.44			64.8		
Standard	-	A	ds	1*	92.8	4.35	0.40	4.97	0.28			19.3		
Standard	+	A	ds	1*	93.5	4.46	0.43	5.42	0.25			35.3		
Low	-	A	ds	1*	93.4	4.46	0.43	6.04	0.24			89.1		
Low	+	A	ds	1*	93.0	4.52	0.45	5.90	0.27			65.8		
Standard	-	A	pb	2	8.5	5.40	0.49	5.73	0.46	1.66	321	68.3	20.2	7.48
Standard	+	A	pb	2	7.7	-	0.50	6.06	0.40	1.39	154	51.3	21.9	8.73
Low	-	A	pb	2	7.4	5.05	0.45	5.54	0.40	1.23	149	97.9	18.9	7.32
Low	+	A	pb	2	8.9	5.36	0.47	5.80	0.46	1.35	196	88.8	21.2	9.46
Standard	-	A	ds	2	8.6	6.59	0.50	6.27	0.38	1.69	344	21.2	19.6	8.49
Standard	+	A	ds	2	8.2	6.17	0.54	6.33	0.37	1.45	214	39.2	16.5	11.60
Low	-	A	ds	2	7.8	5.76	0.45	6.03	0.32	1.26	169	111.0	17.1	10.70
Low	+	A	ds	2	8.8	5.85	0.49	6.27	0.39	1.47	320	106.0	16.5	11.40
Standard	-	A	pb	3	10.7	4.17	0.26	3.82	0.27	1.58	1400	39.2	15.0	11.20
Standard	+	A	pb	3	10.3	4.20	0.29	4.12	0.28	1.62	877	40.7	15.7	8.47
Low	-	A	pb	3	8.8	4.79	0.26	4.16	0.20	1.07	932	109.0	23.6	8.53
Low	+	A	pb	3	10.5	3.49	0.25	3.16	0.33	1.32	1630	91.7	13.6	8.89
Standard	-	A	ds	3	10.9	3.26	0.25	2.93	0.18	1.19	2180	33.6	13.2	8.14
Standard	+	A	ds	3	11.8	3.47	0.20	3.00	0.16	1.05	2760	32.6	12.1	6.13
Low	-	A	ds	3	8.8	4.73	0.24	3.88	0.16	0.94	858	113.0	18.5	6.28
Low	+	A	ds	3	10.5	4.38	0.20	3.11	0.20	1.02	1800	89.3	13.8	6.73

Sampling Dates:

1 - 14/12/93 * sent as oven dried material
2 - 06/01/94
3 - 25/02/94

NOTE:

pb = peat block stuck
ds = direct stuck in sand beds

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 3. The Effects of 'Direct Sticking' (1993/94)

Variety: Delta

Propagation	Sample	%DM	%N	%P	%K	%Mg	%Ca	%Fe	Mn (mg/kg)	B (mg/kg)	Cu (mg/kg)
Variety: Delta											
peat block	1	92.7	4.83	0.61	5.75	0.46	-	-	83.8	-	-
direct stick	1	92.9	4.41	0.49	6.13	0.24	-	-	58.8	-	-
peat block	2	7.2	5.34	0.57	6.60	0.46	1.60	194	94.4	27.3	11.8
direct stick	2	6.5	4.65	0.54	*7.28*	*0.30*	1.56	288	79.4	26.0	12.5
peat block	3	8.9	4.10	*0.26*	4.60	*0.26*	1.66	*1431*	99.5	*18.8*	10.9
direct stick	3	9.5	3.64	*0.22*	4.28	*0.16*	1.30	*2010*	82.0	*19.2*	*7.4*
Variety: Snowdon											
peat block	1	92.8	4.75	0.47	5.05	0.40	-	-	62.6	-	-
direct stick	1	93.2	4.45	0.43	5.58	*0.26*	-	-	52.4	-	-
peat block	2	8.13	5.27	0.48	5.78	0.43	1.41	205	76.6	*20.6*	*8.24*
direct stick	2	8.35	6.09	0.50	6.23	0.37	1.47	262	69.4	*17.4*	*10.55*
peat block	3	10.1	4.16	*0.27*	3.82	*0.27*	1.40	*1210*	70.2	*17.0*	*9.27*
direct stick	3	10.5	3.96	*0.22*	3.23	*0.18*	1.05	*1900*	67.1	*14.4*	*6.82*

Sampling Dates:

1 - 14/12/93
2 - 06/01/94
3 - 25/02/94

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 4a. The Influence of Successive Planting and Sand Depth (1992/93)

Variety: Delta

Planting		Sand Depth	Sample	%DM	%N	%P	%K	%Mg	mg/kg Mn
I		Half	1	6.2	5.92	0.59	*8.33*	0.44	258
I		Full	1	7.5	6.35	0.56	*8.98*	0.42	253
IV		Full	1	7.7	5.62	0.55	*8.30*	0.37	146
IV	(Probase)	Full	1	7.2	5.37	0.66	*8.05*	0.43	171
IV	(Soil)	-	1	7.9	5.29	0.55	*7.55*	0.38	151
I		Half	2	7.1	5.84	0.62	*8.68*	0.46	209
I		Full	2	7.3	5.83	0.59	*8.74*	0.46	206
IV		Full	2	7.9	5.56	0.58	*7.95*	0.32	140
IV	(Probase)	Full	2	7.7	5.50	0.65	*8.41*	0.45	144
IV	(Soil)	-	2	8.0	5.55	0.60	*8.30*	0.43	124
I		Half	3	6.9	5.57	0.50	*9.06*	0.47	281
I		Full	3	7.6	5.25	0.56	*8.97*	0.43	256
IV		Full	3	6.9	5.14	0.52	*8.66*	0.36	211
IV	(Probase)	Full	3	7.5	5.32	0.56	*8.74*	0.38	254
IV	(Soil)	-	3	7.8	5.18	0.50	*8.54*	0.43	138

Sampling Dates:

1 - 06/1/93
2 - 20/1/93
3 - 19/2/93

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 4b. **The Influence of Successive Planting and Sand Depth (1992/93)**

Variety: Snowdon

Planting		Sand Depth	Sample	%DM	%N	%P	%K	%Mg	mg/kg Mn
I		Half	1	8.5	5.62	0.45	*6.86*	0.43	217
I		Full	1	9.2	6.04	0.48	*7.10*	0.39	178
IV		Full	1	9.1	5.48	0.41	*6.60*	0.32	103
IV	(Probase)	Full	1	8.9	5.72	0.46	*6.84*	0.40	145
IV	(Soil)	-	1	10.3	5.45	0.43	*6.09*	0.42	135
I		Half	2	9.9	6.00	0.57	*7.14*	0.47	199
I		Full	2	9.1	6.36	0.63	*7.34*	0.48	165
IV		Full	2	9.6	5.90	0.55	*7.03*	0.37	94
IV	(Probase)	Full	2	10.3	5.79	0.57	*6.90*	0.44	145
IV	(Soil)	-	2	10.9	5.73	0.51	*7.5*	0.49	120
I		Half	3	11.1	5.75	0.44	*7.50*	0.45	244
I		Full	3	11.2	5.62	0.50	*7.72*	0.41	240
IV		Full	3	10.6	5.66	0.43	*7.43*	0.37	124
IV	(Probase)	Full	3	11.0	5.34	0.43	*6.57*	0.42	198
IV	(Soil)	-	3	15.1	5.26	0.43	*6.27*	0.49	119

Sampling Dates:

1 - 06/1/93
2 - 20/1/93
3 - 19/2/93

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 4c. **The Influence of Successive Planting, Sand Depth and Thin Layer Matting (1993/94)**

Variety: Delta

Planting		Sand Depth	Sample	%DM	%N	%P	%K	%Mg	%Ca	Fe mg/kg	Mn mg/kg	B mg/kg	Cu mg/kg
IV		Half	1*	92.2	5.04	0.76	6.35	0.45			98.0		
IV		Full	1*	93.2	4.90	0.66	5.94	0.45			80.1		
VII		Full	1*	92.5	4.59	0.62	5.95	0.35			79.3		
VII	(Probase)	Full	1*	93.2	4.77	0.67	6.24	0.39			109.0		
I	(Matting)	-	1*	92.2	5.08	0.84	7.39	0.43			146.0		
IV		Half	2	7.1	7.04	0.68	5.82	0.52	1.38	148	93.6	30.1	12.60
IV		Full	2	7.0	6.02	0.59	*7.00*	0.44	1.70	205	80.4	26.1	11.90
VII		Full	2	8.6	4.67	0.43	5.14	0.30	1.06	*950*	70.8	22.4	*9.95*
VII	(Probase)	Full	2	7.7	5.36	0.64	7.56	0.39	1.45	154	136.0	27.7	10.50
I	(Matting)	-	2	6.3	4.58	0.74	6.82	0.41	1.42	131	170.0	31.2	*7.98*
IV		Half	3	7.2	4.77	0.38	6.35	0.39	1.94	573	92.2	*21.8*	10.20
IV		Full	3	8.4	4.36	*0.31*	4.92	*0.27*	1.90	*1750*	78.6	*17.2*	11.50
VII		Full	3	8.1	4.89	0.38	6.00	0.31	1.75	*719*	96.3	23.2	*6.26*
VII	(Probase)	Full	3	9.1	4.01	*0.33*	5.37	*0.28*	1.53	*3080*	184.0	*19.1*	*5.75*
I	(Matting)	-	3	7.6	5.07	0.40	6.82	0.35	1.64	280	199.0	23.4	16.6

Sampling Dates:

1 - 14/12/93 * sent as oven dried material
2 - 06/01/94
3 - 25/2/94

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX V

Table 4d. The Influence of Successive Planting, Sand Depth and Thin Layer Matting (1993/94)

Variety: Snowdon

Planting		Sand Depth	Sample	%DM	%N	%P	%K	%Mg	%Ca	Fe mg/kg	Mn mg/kg	B mg/kg	Cu mg/kg
IV		Half	1*	92.3	5.18	0.54	5.64	0.42			69.7		
IV		Full	1*	93.6	4.85	0.50	5.54	0.37			57.9		
VII		Full	1*	93.5	4.40	0.44	5.16	0.33			57.8		
VII	(Probase)	Full	1*	92.9	4.57	0.48	5.49	0.33			70.7		
I	(Matting)	-	1*	92.2	5.48	0.55	6.00	0.41			96.4		
IV		Half	2	6.8	*3.68*	*0.30*	3.08	*0.25*	0.93	103	47.8	*16.2*	*7.01*
IV		Full	2	7.7	-	0.50	6.06	0.40	1.39	154	51.3	*21.9*	*8.73*
VII		Full	2	7.9	5.33	0.51	6.47	0.38	1.31	172	64.6	*21.0*	*9.52*
VII	(Probase)	Full	2	8.6	6.43	0.58	6.66	0.43	1.28	152	120.0	23.6	*7.83*
I	(Matting)	-	2	7.4	-	0.55	5.94	0.45	1.17	149	138.0	23.2	*5.55*
IV		Half	3	9.3	4.71	0.35	4.76	0.36	1.51	478	58.8	*16.9*	*7.89*
IV		Full	3	10.3	4.20	*0.29*	4.12	0.28	1.62	*877*	40.7	*15.7*	*8.47*
VII		Full	3	12.9	*3.28*	*0.22*	3.30	*0.19*	0.96	*3160*	52.6	*11.6*	*7.11*
VII	(Probase)	Full	3	10.0	4.45	0.33	4.50	0.35	1.38	*1030*	92.9	*16.1*	*5.31*
I	(Matting)	-	3	9.2	4.73	0.39	5.13	0.39	1.39	288	172.0	*18.8*	*4.61*

Sampling Dates:

1 - 14/12/93 * sent as oven dried material
2 - 06/01/94
3 - 25/2/94

NOTE:

Numbers in italics indicate levels above the satisfactory range.
Numbers in italics and underlined indicate levels below the satisfactory range.
Plants were not observed to be exhibiting any deficiency or toxicity symptoms.

APPENDIX VI

PHOTOGRAPHIC RECORDS

APPENDIX VI

Plate 1. General view of the hydroponic sand based system of the type studied throughout PC24b and PC24c.

APPENDIX VI

Plate 2. **Illustration of grading categories used in assessments at harvest.**

Grade One Grade Two Grade Three

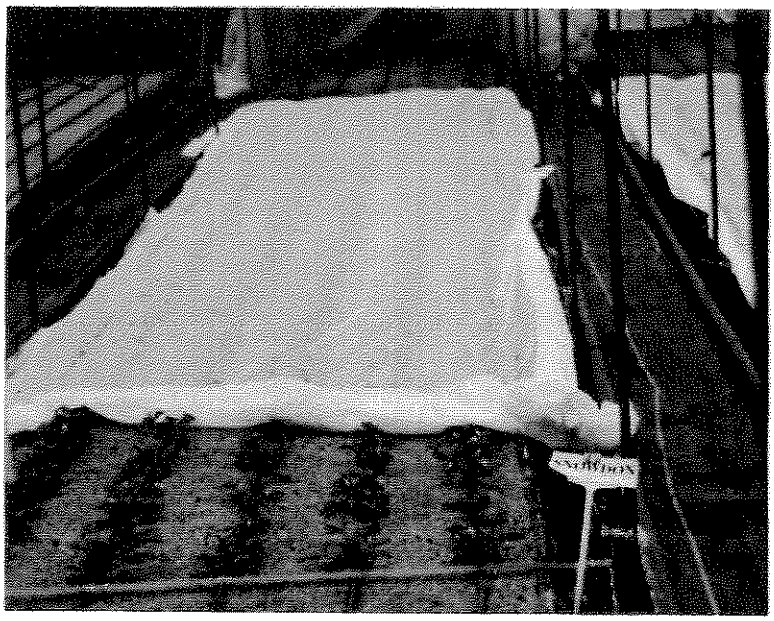
Variety: Delta

Grade One Grade Two Grade Three

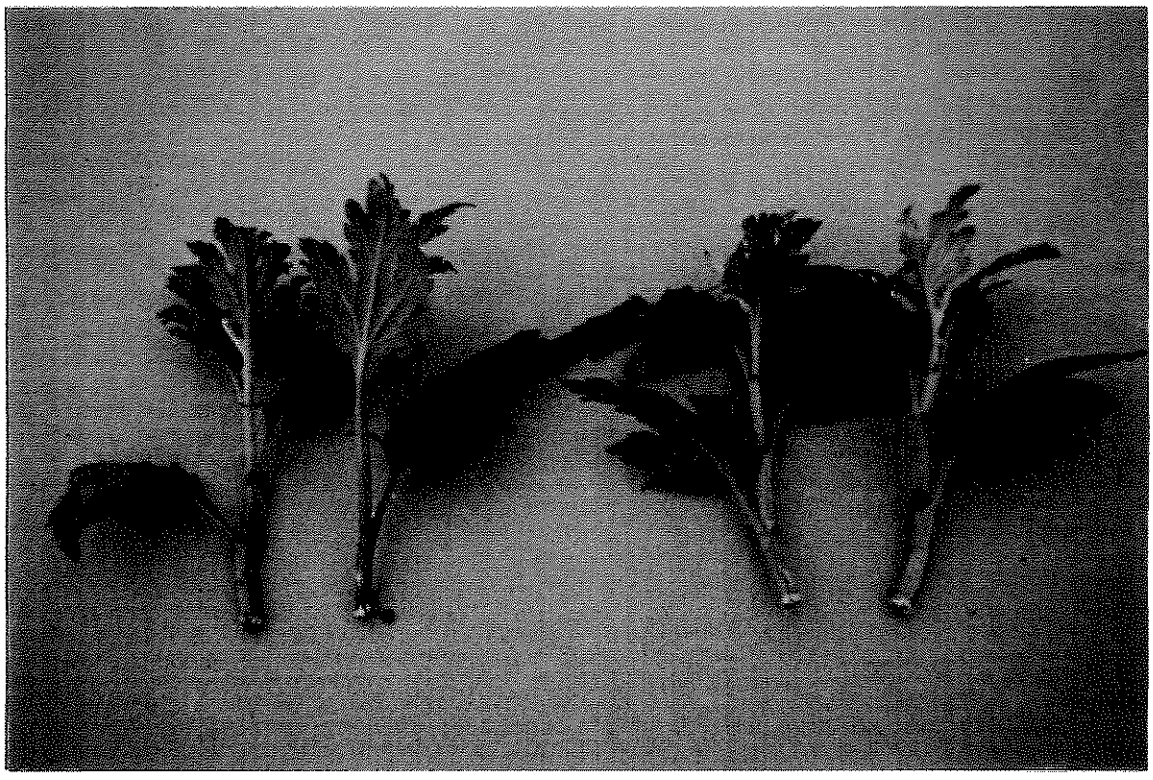
Variety: Snowdon

APPENDIX VI

Plate 3. Illustration of 'direct sticking' propagation.



Cuttings developing in the sand bed with an agryl cover to maintain humidity



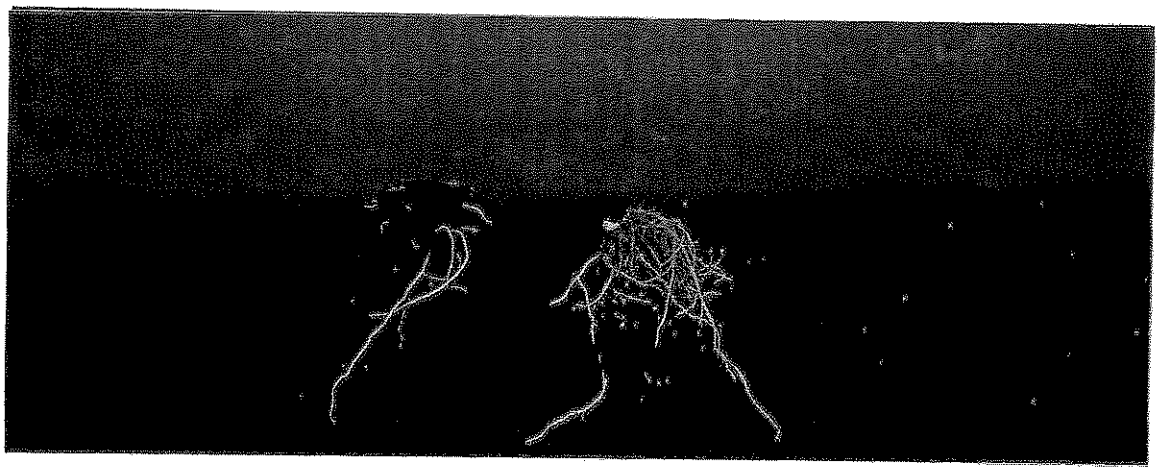
Development of root initials 3-4 days after direct sticking (and stage from which conductivity of the feed solution was gradually increased)

APPENDIX VI

Plate 4. Comparison of direct stuck and peat block stuck plants.

Direct stuck Peat block stuck

Snowdon plants at the end of long days



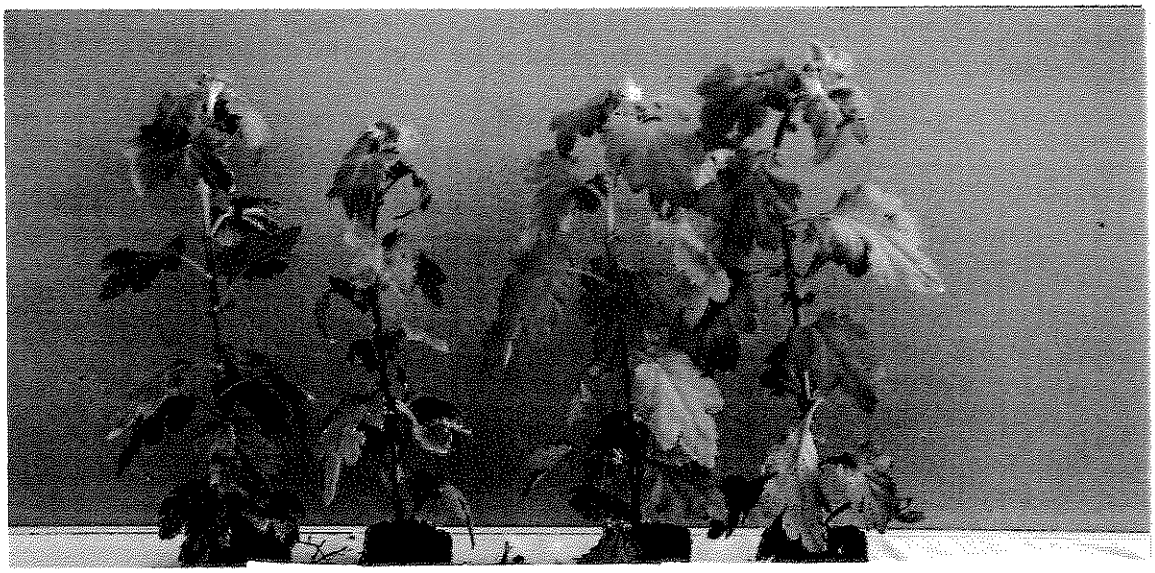
Soil crop
peat block stuck

Hydroponic sand crop
direct stuck

Snowdon root systems at maturity

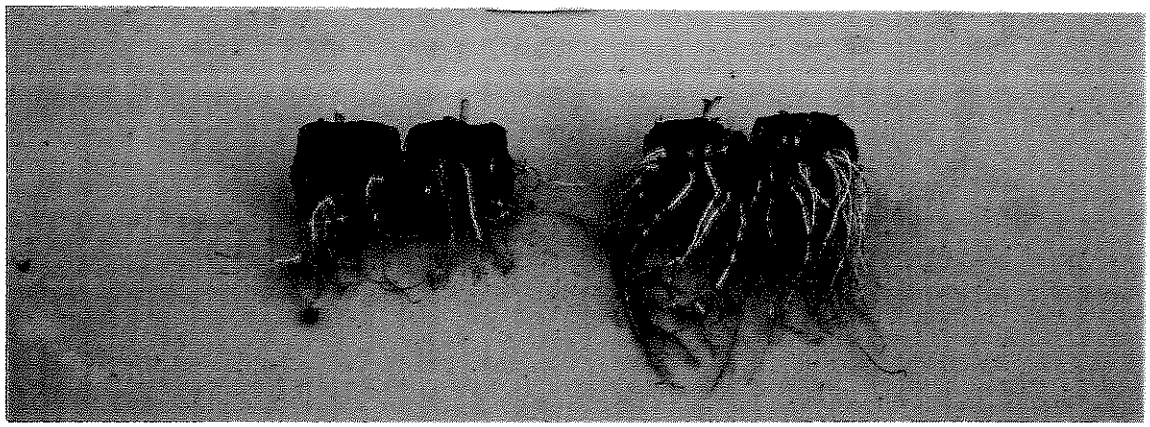
APPENDIX VI

Plate 5. Comparison of plants and root systems from freshly steam-sterilized soil and successive planting IV on soil (with no sterilization treatment between crops).



Planting IV (Soil) Planting I (Soil)

Variety: Delta
Plants sampled one week after the end of interruption



Planting IV (Soil) Planting I (Soil)

Variety: Delta
Roots sampled one week after the end of interruption

APPENDIX VI

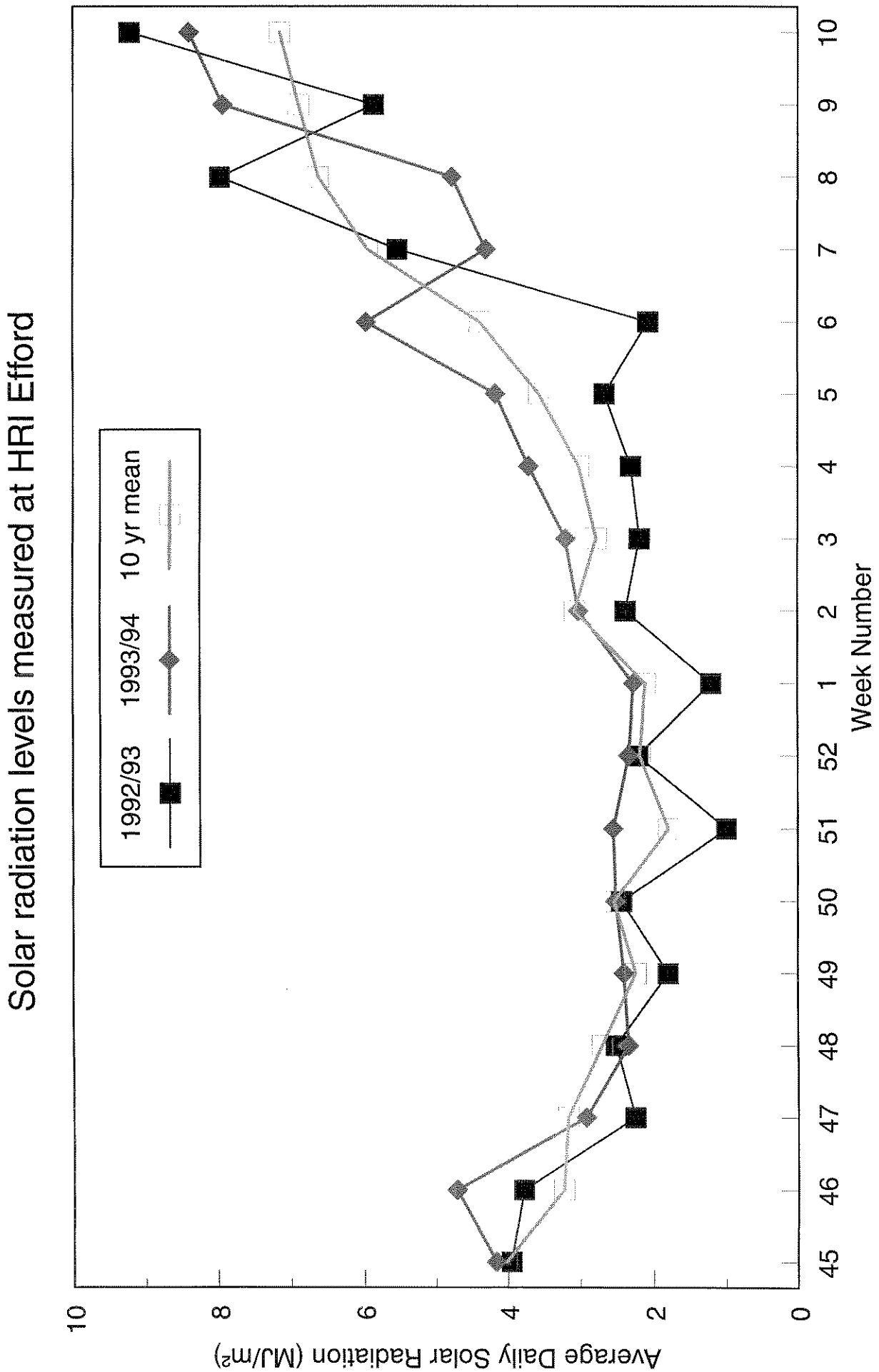
Plate 6. Comparison of successive planting on sand-based hydroponic systems and planting on steam-sterilized soil.

Planting No.	I (Soil)	I (Sand)	VII (Sand)	VII (Probase)

Variety: Snowdon
Sampled one week after the end of interruption

APPENDIX VII

SOLAR RADIATION DATA


Solar radiation levels measured at HRI Efford
1992/93
1993/94
10 yr mean
Average Daily Solar Radiation (MJ/m²)
Week Number
0
2
4
6
8
10
45
46
47
48
49
50
51
52
1
2
3
4
5
6
7
8
9
10

APPENDIX VIII

REFERENCES

Finlay, A.R. 1993 Chrysanthemums: Hydroponic systems for AYR Chrysanthemums. Contract Report HDC PC24.

APPENDIX IX

CONTRACT TERMS AND CONDITIONS, AND SCHEDULE

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

PROPOSAL

1. TITLE OF PROJECT

Contract No: PC/24b
Contract date: 2.11.92

CHRYSANTHEMUMS: FACTORS INFLUENCING QUALITY OF PRODUCTION OF AYR CHRYSANTHEMUMS - HYDROPONIC SYSTEMS AND ASPECTS OF DISEASE CONTROL

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Unlike protected edible crops, AYR chrysanthemums are conventionally grown in glasshouse soil. The potential benefits of hydroponic production of AYR chrysanthemums have yet to be exploited and until recently there has been little interest in this topic. The stimulus to develop systems for soil-less production of AYR chrysanthemums has occurred because of Dutch government concern about emission of nutrients and other chemicals into the sub-soil. Although restrictive legislation in the UK is less imminent, recognition of the potential improvements of growing chrysanthemums in hydroponic systems coupled with general environmental concern resulted in preliminary examination (April 1991) of a range of closed systems at HRI Efford. Using experience gained from this study, further plantings took place in winter 1991 and spring 1992 using sand and Probase as substrates in closed hydroponic systems. Comparisons were made with plants grown in a root-misting system (aeroponic) and those grown conventionally in soil.

Successful production was achieved on both hydroponic systems during the winter and spring trial period. On each occasion hydroponically grown crops outperformed the soil grown crops. This has stimulated interest in elucidating the mechanisms for further improving crop potential both of conventional soil crops and of substrate-based closed systems.

Plant pathogenic organisms present in the substrate could play a major role in influencing crop establishment and productivity. The inclusion of Aaterra in the recirculating solution of the hydroponic systems may have enhanced crop performance beyond that of the conventionally grown soil crop. The influence of Aaterra in this context is unknown. In addition Dutch researchers are investigating the influence of low pH of recirculating solution on suppression of *Pythium* in closed systems.

The implications of closed systems for disease spread is also unknown. Plant pathogenic organisms were isolated during the course of both winter and spring trials, but no detrimental effects were observed. However some post-

establishment problems were encountered in the soil crop following a third (commercial) planting without sterilization. *Rhizoctonia solani* was isolated from affected plants.

Hence further studies are proposed as follows:-

a. Does the application of Aaterra post-planting improve quality of conventionally grown soil crops?

b. What influence does the presence of Aaterra and/or low pH of nutrient solution have on plant performance/disease incidence in a closed hydroponic system?

c. How many successive plantings can be carried out in unsterilized hydroponic substrate and conventional soil before disease problems arise? (Continuation of earlier work)

d. What alternative substrates can be used for closed system - suitability of coconut matting?

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

Evaluation of hydroponic systems and aspects of disease control may be used to maximize returns by the following means:

a. potentially improve production and quality of conventionally grown soil crops,
b. improve quality and uniformity of hydroponically grown crops, particularly during the winter period,
c. reduce use of fungicides through use of alternative disease control methods, hence reduce input costs,
d. maximize returns from water and fertilizer inputs without run-off,
e. minimise cultivation and reduce sterilization costs by successional planting in hydroponic substrates,
f. long-term potential for mechanization of closed systems leading to reduced labour costs.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

a. The qualitative and quantitative influence of fungicide application and/or low pH of recirculating solution on performance of soil grown and hydroponically grown crops at AYR chrysanthemums will be investigated. The effect of treatment on plant height, leaf area, fresh and dry weight and presence of phytopathogenic organisms will be examined at key developmental stages throughout the life of the crops. Production time and post-production longevity will also be examined.

b. Additional monitoring of pathogen population in

unsterilized substrates will assess the risk of disease build-up and spread and examine the potential detrimental effects on plant performance.

c. Evaluation of plant performance on an alternative substrate will further the understanding of mechanisms of chrysanthemum development in closed systems.

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

Extensive research of chrysanthemum production in closed systems and aspects of disease control is being carried out in Holland at:

Proefstatioon voor Tuinbouw Onder Glas, Naaldwijk
Proefstatioon voor de Bloemisterij, Aalsmeer
and Milieudemonstratieproject, Denar Kas B.V.

Additional information and application of technology may be derived from MAFF funded project K111C - which has been established to investigate alternative methods of disease control in greenhouse crops in order to minimize the use of pesticides.

6. DESCRIPTION OF THE WORK

I. Influence if Aaterra/System on plant performance

a. The main component of this study is the evaluation of the influence of Aaterra on plant performance/disease incidence in conventional soil crops and in a closed hydroponic sand based system.

b. In the hydroponic sand based system the influence of pH (+/- Aaterra) on plant quality and disease control will also be examined.

c. An additional system comparison may also be included to evaluate coconut matting as an alternative substrate for hydroponic culture.

Treatments

The following treatments are proposed:

A. **Soil grown crop** - standard feed (blocks containing Aaterra)

1. No Aaterra application post-planting.
2. Drench Aaterra at 4 weeks post-planting (recommended rate).
3. Drench Aaterra at 4 and 8 weeks post-planting (recommended rate).

3 treatments per variety, 2 varieties per bed, 3

replicate beds.

B. **Hydroponic crop - sand base** (blocks containing Aaterra)

4. Aaterra applied, standard nutrient solution.
5. Aaterra applied, low pH nutrient solution.

6. No Aaterra, standard nutrient solution.
7. No Aaterra, low pH nutrient solution.

Aaterra is applied to recirculating solution at planting (treatments 4 and 5) and replenished after 6 weeks (recommended rate).

4 treatments (factorial design comparison), 2 varieties per bed, one bed per treatment.

C. **Hydroponic crop** - half depth sand base

Varietal comparison: Snowdon and Delta

Planting date: Week 45

Planting density: 85%

Sampling/disease assessments

The following assessments will be carried out:-

a. 2 days before start of short days
b. at start of interruption
c. one week after end of interruption
d. at maturity

1. Plant performance per treatment on each of these occasions.

   i. plant height
   ii. fresh weight (individual plants per treatment)
   iii. dry weight (bulk sample per treatment)
   iv. leaf area (sub sample per treatment)

2. Disease assessment of individual plant root systems. (10 samples per treatment on each occasion)

3. At harvesting, assessment of crop duration, grade out and shelf life.

4. Daily check of pH and conductivity and weekly nutrient analysis of recirculating solution.

5. Mid and end of crop leaf mineral analyses.

II. **Effects of successive planting without sterilization between crops.**

The effects on plant quality of successive planting in soil and hydroponic substrate without sterilization between crops may be assessed by monitoring disease levels following the fourth planting of the original hydroponic/soil systems.

Treatments

Planting IV - no sterilization of substrate from October 1991, 3 previous plantings.

1. Conventional soil - unsterilized
2. Hydroponic system - sand base - unsterilized
3. Hydroponic system - Probase base - unsterilized
4. Conventional soil - sterilized
   (Information from treatment 1. Section 1A)

Varietal comparison: Snowdon and Delta

Planting date: Week 45

Planting density: 85%

Sampling/disease assessments

As for I (excluding leaf area measurements).

7. **COMMENCEMENT DATE AND DURATION**

Growing season October 1992 - February 1993. Analysis of results and review for potential extension June 1993. Reporting: September 1993.

8. **STAFF RESPONSIBILITIES**

Project Leader:	Dr Ruth Finlay - HRI Efford
Pathology assessments:	Dr David Jones - ADAS Reading
Industry co-ordinator:	Mr David Abbott - Swallowfield Consultancy

9. **LOCATION**

HRI Efford (C-Block) (Bed dimensions approx. $25m^2$).

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: PC24c
Contract date: 20.12.93

CHRYSANTHEMUMS: EXAMINATION OF THE INFLUENCE OF REPEATED CROPPING IN SOIL AND HYDROPONIC SUBSTRATE-BASED SYSTEMS ON CROP QUALITY AND DISEASE INCIDENCE/CONTROL AND TO INVESTIGATE THE POTENTIAL FOR 'DIRECT-STICKING' OF CUTTINGS IN HYDROPONIC PRODUCTION.

2. BACKGROUND AND COMMERCIAL OBJECTIVE

The stimulus to develop and exploit soil-less production of AYR chrysanthemums has been accentuated not only by recent concern about emission of nutrients and other chemicals into the sub-soil but also by recognition of the improvements in quality and productivity demonstrated in a range of experimental systems at HRI Efford (HDC Projects PC24 and PC24b).

Since all closed systems require relatively high investment, it is imperative that the growers remain competitive and receive an acceptable return for the extra investment. To this end, the potential for re-use of hydroponic substrate without sterilisation between crops may reduce both material and labour costs. It is important, however, to assess the influence of repeated cropping on crop quality, investigate the disease risks and assess the number of crops which can be successfully grown between substrate sterilisations. This, coupled with potential disease control strategies, such as fungicide addition and/or reduced pH of recirculating solutions, may increase the commercial viability of hydroponic production of AYR chrysanthemums.

Additional enhancement of the economics of hydroponic production may be achieved if the cropping time and material costs can be reduced by 'direct-sticking' of cuttings into hydroponic substrates rather than into conventional peat blocks. Preliminary examination of this technique during the summer period has shown promise and should be further investigated, since the potential exists to reduce the length of the crop schedule and thereby increase returns per unit area with time.

Hence, further studies are proposed as follows:

i. To evaluate the influence of repeated cropping and Aaterra drenches on plant performance and disease incidence in a conventional soil grown crop, compared with hydroponically grown crops (Planting IV).

ii To examine the influence of repeated cropping coupled with the effects of pH of nutrient solution (with and without addition of Aaterra) on plant quality and

disease control in hydroponic sand-based systems (Planting IV).

iii Continuation of the examination of the effects on plant quality of successive planting in hydroponic substrates (sand and Probase) without sterilisation between crops (Planting VI).

iv Evaluation of reduction in depth of substrate and repeated cropping on hydroponic culture in sand (Planting IV).

v. Examination of the effects of 'direct-sticking' of cuttings into hydroponic substrate versus planting of peat blocks on crop quality and schedule.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

Evaluation of hydroponic systems, their potential for repeated cropping and for 'direct-sticking' of cuttings, coupled with aspects of disease control, may be used to maximise returns by the following means:-

a. extrapolate from information gained relative to hydroponic systems to improve productivity and quality of conventionally grown soil crops.

b. improve quality and uniformity of hydroponically grown crops, in particular during the winter period.

c. reduce costs by minimising cultivation and sterilisation requirements through successional planting in hydroponic substrates.

d. reduce handling, cropping schedule and potentially improve quality by 'direct sticking' pf cuttings into hydroponic substrate thereby increasing returns per unit area/time.

e. maximise returns from water and fertilizer inputs without run-off.

f. reduce use of fungicides through use of alternative disease control methods, hence reduce input costs.

g. long-term potential for mechanisation of closed systems leading to reduced labour costs.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

a) The qualitative and quantitative influence of successional cropping, influence of fungicide application and/or low pH of recirculating solution on performance of soil grown and hydroponically grown crops of AYR chrysanthemums will be investigated. In addition, the method of propagation relative to

hydroponic production will be evaluated. The effect of treatment on plant height, fresh and dry weight and nutrient status will be examined at key developmental stages throughout the life of the crop.

Production time, product quality, and post-production longevity will also be examined.

b) Evaluation of the disease incidence relative to treatment will be carried out at key developmental stages throughout the life of the crop in order to assess the risk of disease build-up and spread and examine the potential detrimental effects on plant performance.

5. CLOSELY RELATED WORK COMPLETED OR IN PROGRESS

Extensive research of chrysanthemum production in closed systems and aspects of disease control is being carried out in Holland at:

Proefstation voor Tuinbouw Onder Glas, Nalldwijk
Proefstation voor de Bloemisterij, Aalsmeer
and Milieudemonstratieproject, Denar Kas B.V.

Additional information and application of technology may be derived from MAFF-funded project K111C - which has been established to investigate alternative methods of disease control in greenhouse crops in order to minimise the use of pesticides.

A further MAFF-funded study has been proposed to elucidate the mechanisms involved in improving crop potential in hydroponic systems in order to optimise such systems for the production of AYR chrysanthemums.

6. DESCRIPTION OF THE WORK

i. Influence of successive planting and ~~Aaetrra~~ Aaterra treatment on plant performance of soil grown crop.

Comparison of performance of successively planted soil bed (Planting IV) relative to Aaterra drenches post-planting as follows:

A. No Aaterra application post planting
B. Aaterra drench 2 days and 2½ weeks post planting.
C. Aaterra drench 2 days, 2½ weeks and 5 weeks post planting.

3 treatments per variety, 2 varieties per bed, 1 bed only.

Cuttings ~~conveniently~~ confidentially propagated in peat blocks with Aaterra WP (etridiazole) incorporated at 20 g/m^3 at

mixing. Aaterra drench applied at 5 g/m² in 10 litres of water.

ii *Influence of propagation method, successive planting, and influence of Aaterra/pH treatment on plant performance of hydroponically grown crops.*

Comparison of performance of 'direct sticking' versus conventional propagation in peat blocks on successively planted hydroponic beds (Planting IV) with evaluation of disease control relative to Aaterra/pH treatment as follows:

1. Aaterra added, standard pH nutrient solution.
2. Aaterra added, low pH nutrient solution.
3. No Aaterra added, standard pH nutrient solution.
4. No Aaterra added, low pH nutrient solution.

Standard pH = 5.8, Low pH = 4.5

2 propagation treatments per variety x 2 varieties per bed x 2 Aaterra treatments x 2 pH treatments (4 beds).

Aaterra added to recirculating solution at planting (Treatment 1 and 2) and replenished after 6 weeks (60g Aaterra per 1000 litres of solution).

iii *Continued examination of the effects of successive planting without sterilisation between crops.*

Evaluation of the effects on plant performance of the ~~sixth~~ seventh successive planting of the original hydroponic systems relative to that of a freshly steamed soil bed as follows:

1. Conventional soil - steam sterilised, Planting I
2. Hydroponic system -sand-unsterilised, Planting VII
3. Hydroponic system-Probase-unsterilised, Planting VII

All cuttings conventionally propagated in peat blocks with Aaterra WP (etridiazole) incorporated at mixing.

Treatments 2 and 3 to receive standard nutrient solution with Aaterra added.

iv *Evaluation of reduction in depth of substrate and repeated cropping on hydroponic culture in sand.*

Examination of the effects of successionally planting in different depths of hydroponic substrate relative to crop performance and disease risk.

1. 'Standard' depth hydroponic sand bed (15cm approx) - Planting IV
2. 'Half' depth hydroponic sand bed (7.5 cm approx.) - Planting IV

Propagation fungicide addition and nutrient solution

as for iii.

Varietal comparison: Snowdon and Delta on all systems.

Planting date: Week 45

Planting density: 85%

Assessments of plant performance and disease incidence

Assessments will be carried out on 4 occasions:

1. 2 days before start of short days
2. At start of interruption
3. 1 week after end of interruption
4. At maturity

A. Plant performance per treatment on each of these occasions:

   i) Stem length (cm) - 20 plants per treatment per variety
   ii) Fresh weight (g) - 20 plants per treatment per variety
   iii) Dry weight (g) - bulk sample per treatment per variety

B. Disease assessment of individual plant root systems on each of these occasions. 10 samples per treatment per variety on each occasion.

C. At harvesting, assessment of crop duration, grade-out, bunch weight and shelf-life.

D. Daily check of pH and conductivity and fortnightly nutrient analysis of recirculating solution.

E. Leaf mineral analysis on each of 4 occasions

F. Photographic record as appropriate.

7. COMMENCEMENT DATE AND DURATION

Start date 01.10.93; duration 1 year
The experimental work will be completed by Spring 1994 and final report will be produced by September 1994

8. STAFF RESPONSIBILITIES

Debbie Wilson

Project Leader:	Dr ~~Ruth Finlay~~	HRI Efford
Industry Co-ordinator:	Mr David Abbott	Swallowfield Consultancy

9. LOCATION

HRI Efford (C-Block) (Bed dimensions approx. $25m^2$).