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FINAL CONTRACT REPORT

Foliage Plants:
Improving winter production and plant quality with the use of supplementary lighting

HDC/EAT PC112

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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.

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HDC PC112

Foliage Plants: Improving winter production and plant quality with the use of supplementary lighting

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1. RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

1.1 APPLICATION

The aim of this trial was to evaluate the use of different supplementary lighting regimes on a range of foliage species over the winter production period.

The use of supplementary lighting greatly improved plant quality and speed of production in *Begonia rex, Ficus robusta* and *Hedera helix*. *Nephrolepis exaltata* responded well to the higher lighting intensities (5000 lux) as did *Tradescantia zebrina*, although the commercial costs for such regimes may be uneconomic. There was little benefit from the use of supplementary lighting on *Dracaena sanderama*.

The use of higher lighting intensities (5000 lux) during the first weeks of production improved early root development, plant establishment and ensured better uniformity. Plant spacing could potentially be manipulated to increase plant density without a loss in plant quality, thus reducing the costs of supplementary lighting.

Shelf-life of *Begonia rex, Ficus robusta, Hedera helix, Tradescantia zebrina* and *Dracaena sanderama* were all improved, with better foliage colour and variegation.

1.2 SUMMARY

In the UK in recent years the market demand for foliage plants has continued to increase. Foliage plants are becoming an important part of the horticultural industry. Main production is centred in Germany, Denmark and the Netherlands which both have strong home markets and export links. There are, at this time, a limited number of UK growers producing large quantities of foliage plants, but there is a growth in home production for the UK market as well as potential for export.

Problems exist with winter production in that plant growth and habit can suffer and hence overall plant quality is reduced. Erratic crop scheduling, and the overall length of production for some species can become excessive and uneconomic. This trial evaluated the use of two lighting intensities: 2500 lux (6 W/m^2) and 5000 lux (12 W/m^2) in comparison to plants unlit. Plants were grown over the winter period, November-March. In addition, plants were transferred between lighting treatments to produce a series of regimes where plants were lit for different periods of their growth. Plant growth and quality were recorded during production and at marketing for each lighting treatment. Shelf-life assessments were also done over a period of six weeks.

The potential benefits of supplementary lighting may be twofold. Firstly, to improve plant growth with an associated reduction in production time enabling more efficient use of facilities available to the grower. Secondly, the development of robust production techniques which reduce costs due to plant losses through poor quality, unsaleable plants, and improve the plant quality of the final product to achieve better shelf-life for the retailer and consumer.

1.2.1 METHODOLOGY

Plants were supplied as cuttings through Manor Nurseries, Romsey, Hants. Plants were potted in week 46, 1994 and grown on in three compartments of the glasshouse facility, Q-Block at HRI Efford.

Species	**Pot Size**	**Cuttings**
Dracaena sanderama	9 cm	rooted as 5 cm plug plants
Nephrolepis exaltata	13 cm	rooted as natural runners
Hedera helix	9 cm	unrooted
Tradescantia zebrina	9 cm	unrooted
Begonia rex	13 cm	rooted in trays
Ficus robusta	13 cm	rooted as 5 cm plug plant

Treatments

i. 2500 lux (6 W/m^2) supplementary lighting
ii. 5000 lux (12 W/m^2) supplementary lighting
iii. Ambient light - control.

NB: Period of supplementary lighting 12.00 midnight - 7.00 am using sodium SON/T 400W lamps.

Cuttings were stuck in either 9 cm or 13 cm full pots using Roffey Brothers Ltd Professional potting media No. 3. Cuttings of *Tradescantia* and *Hedera* were covered with clear polythene for 7-14 days after being stuck to aid root development and plant establishment.

Plants were grown on the floor in each compartment on capillary matting covered with micro-perforated black polythene. Overhead irrigation was used throughout the course of the trial. Liquid feeding commenced once roots were visible at pot sides for each species. A 300 ppm N and 150 ppm K_2O feed was used at every watering.

Base temperature was maintained at 18°C with an air temperature of 22°C with vents set to open at 24°C. Humidity was maintained by manually damping down the floors around the plants to ensure a minimum humidity of 75% (RH).

There was no carbon dioxide enrichment.

No growth regulants were used and plants were not pinched.

Plant spacing was determined as a function of plant growth, the time and dimensions of the spacing were recorded for each species x treatment combination. Spacing was carried out to best commercial practice; an important economic factor in terms of the costs of lighting treatments.

Plants were transferred between treatments at their estimated mid-crop point:

Begonia rex	12 weeks
Ficus robusta	12 weeks
Nephrolepis exaltata	10 weeks
Hedera helix	6 weeks
Tradescantia zebrina	4 weeks
Dracaena sanderama	6 weeks

Pest and disease control was maintained using an integrated pest/disease management programme.

Plants were recorded at marketing when each treatment block reached marketable size. Six plants were selected for shelf-life assessment.

At marketing, a number of plant growth assessments were made for each species. The time of production (days) and spacing was used to calculate the cost for each lighting treatment. Visual plant quality observations were made during a six-week shelf-life assessment.

1.2.2 RESULTS

BEGONIA REX:

Main Lighting Treatments

- Significant increase in plant growth under lights, measured as increased leaf size, plant spread and both fresh and dry weight.

- Plant growth was more uniform under lights, with all plants reaching marketing stage together.
- Under ambient light, plant establishment and growth was poor, resulting in an erratic cropping time.
- Significant decrease in production time, by up to 31 days at 6 W/m^2 and by 47 days at 12 W/m^2.
- Plants grown under lights were of superior quality at marketing and leaf colour remained good for a prolonged period in shelf-life (new growth in shelf-life was also of better quality, with larger, well coloured leaves).
- *Begonia rex* responds positively to supplementary lighting.

Period of Lighting

- Significant increase in leaf area where supplementary lighting had been applied during the first period of production, but there was little difference in plant response between supplementary lighting at 6 W/m^2 and 12 W/m^2.

***FICUS ROBUSTA*:**

Main Lighting Treatments

- Significant increase in plant growth under lights measured as plant height, leaf number, leaf area and both fresh and dry plant weight.
- Increase in plant growth appeared proportional to applied lighting intensity.
- Decrease in length of production time at 6 W/m^2 and 12 W/m^2, of 9 and 29 days respectively.
- Plants grown at 12 W/m^2 were of better quality at marketing and also held their leaf colour and plant habit well in shelf-life in comparison to unlit plants.

Period of Lighting

- Plant growth was improved with supplementary lighting applied immediately from potting. Similar growth was recorded with plants lit for 12 weeks at 6 W/m^2 as plants grown throughout production with 6 W/m^2.

NEPHROLEPIS EXALTATA:

Main Lighting Treatments

- There was no significant difference in plant growth between plants grown under ambient light conditions and plants grown with supplementary lighting at 6 W/m^2.
- Significant increase in plant growth, in terms of frond size and fresh and dry weight, under 12 W/m^2.
- Foliage appeared paler at the higher light intensities, 12 W/m^2.
- Significant decrease in length of production of 29 days at 12 W/m^2.
- There were no treatment differences apparent in shelf-life. Plants which were paler at marketing darkened in shelf-life.

Period of Lighting

- Significant increase in plant growth at 12 W/m^2 in comparison to 6 W/m^2.
- Trial indicated that Nephrolepis requires higher light threshold for plant response.

HEDERA HELIX:

Main Lighting Treatments

- Significant increase in plant fresh and dry weight under lights, particularly at 12 W/m^2.
- Significant reduction in length of cropping: by 24 days at 6 W/m^2 and by 37 days at 12 W/m^2.
- Improved quality and speed of establishment under lights.
- Improved plant variegation under lights.
- No treatment differences apparent in shelf-life, all plants of good keeping quality.
- *Hedera* responds positively to being lit.

Period of Lighting

- Lighting for the first period of cropping had a greater effect on plant growth than the use of lighting towards the end of cropping, ie once plants had been spaced.

- No significant benefit from increasing light level from 6 W/m^2 to 12 W/m^2 at the end of cropping.

TRADESCANTIA ZEBRINA:

Main Lighting Treatments

- There was an increase in plant quality/growth in terms of number of plant trails, their length, and plant fresh and dry weight with increased lighting levels.

- There was no major commercial benefit from supplementary lighting in terms of production time.

- Foliage variegation was stronger, and plant quality improved under lights.

- *Tradescantia* responded positively to lights, but the improvement in plant quality was not thought to be commercially significant.

Period of Lighting

- Lighting for the duration of the crop produced best results in terms of plant growth and improved plant quality.

- Some evidence that lighting for the first period in production, ie whilst plants are pot thick, has a greater effect on plant growth than lighting at the end of cropping.

DRACAENA SANDERAMA:

Main Lighting Treatments

- Plant growth in terms of height, leaf number, fresh and dry weight was better under 6 W/m^2 and 12 W/m^2, but was not thought to be commercially significant.

- There was a slight decrease in production time with the use of supplementary lighting, but this was not thought to be commercially significant.

- Foliage colour improved under lights with more distinct variegation which held well in shelf-life.

Period of Lighting

- There was no significant commercial benefit from any of the lighting period treatments.

1.3 CONCLUSIONS

- The use of supplementary lighting during the winter months will significantly reduce cropping time and improve final plant quality to the consumer for a number of foliage plant species.

- The use of supplementary lighting for the early phases of production will have a greater effect than its use at the end of cropping. This also has the advantage that plants are pot thick during the early stages and thence cost of lighting per pot is lower.

- Benefits in improved plant 'quality' are difficult to quantify. Higher quality plants should command a higher market price, and stimulated demand increase sales for the grower.

- The main costs of supplementary lighting are related to capital costs with running costs being a smaller component of the overall figure. Specific costs will however, be individual to the treatment x species combination being considered.

2. EXPERIMENTAL SECTION

2.1 Introduction

In the UK in recent years the market demand for foliage plants has continued to increase. Foliage plants are becoming an important part of the horticultural industry. Production is centred in Germany, Denmark and the Netherlands which have both strong home markets and export links. There are at present a limited number of UK growers producing large quantities of foliage plants, but there is a definite growth in home production for the UK market as well as a potential for export. Problems exist with winter production, in that plant growth and habit can suffer and overall plant quality is reduced. Erratic crop scheduling, and the duration of production of some species can become excessively long and hence uneconomic.

There is little published material related directly to winter production of foliage plants in the UK. Research at HRI Efford in 1993 funded by the Electricity Association Technology Ltd (EAT Ltd) established the benefits which can be gained from the use of supplementary lighting during the winter period. Further research is required to evaluate light levels and periods in which to light crops which will be both practical and economically beneficial to growers.

2.2 Objectives

- To evaluate the potential for minimum cropping time and maximum quality through the use of supplementary lighting treatments.

- To establish plant response to a range of supplementary lighting treatments for selected commercial foliage species.

- To examine the influence of supplementary lighting treatments on plant density, and the potential economic advantages of closer pot spacings.

- To evaluate the effect of supplementary lighting treatments applied during production on the shelf-life and post harvest quality of each species.

2.3 MATERIALS AND METHODS

2.3.1 Site

Plants were grown in three compartments of the glasshouse facility, Q-Block at HRI Efford.

2.3.2 Start Material

Plants were supplied as cuttings through Manor Nurseries, Romsey, Hants from the Netherlands. Plants were potted in week 46, 1994.

Species	**Pot Size**	**Cuttings**
Dracaena sanderama	9 cm	rooted as 5 cm plug plants
Nephrolepis exaltata	13 cm	rooted as natural runners
Hedera helix	9 cm	unrooted
Tradescantia zebrina	9 cm	unrooted
Begonia rex	13 cm	rooted in trays
Ficus robusta	13 cm	rooted as 5 cm plug plant

2.3.3 Treatments

i. 2500 lux (6 W/m^2) supplementary lighting
ii. 5000 lux (12 W/m^2) supplementary lighting
iii. Ambient light - control.

NB: Period of supplementary lighting 12.00 midnight - 7.00 am using sodium SON/T 400W lamps.

2.3.4 Experimental Design

3 lighting treatments
x
2 replicates
x
3 transfers

18 plots/species
x
6 species

108 plots in total

Plot size: 25 plants per plot.

3 main compartments with replication of each main treatment, and full block randomisation within treatments to allow statistical analysis.

Transfer experiment, in which each species was moved between treatments at 6-10 weeks post potting, to assess effect of varied lighting periods upon plant growth and quality.

Plants were transferred between treatments at their estimated mid-crop point:

Begonia rex	12 weeks
Ficus robusta	12 weeks
Nephrolepis exaltata	10 weeks
Hedera helix	6 weeks
Tradescantia zebrina	4 weeks
Dracaena sanderama	6 weeks

2.3.5 Cultural Details

Cuttings were stuck in either 9 cm or 13 cm fill pots using Roffey Brothers Ltd Professional potting media No. 3. Once potted plants were positioned in each treatment as shown by the plan layout in Appendix I, page 35. Cuttings of *Tradescantia* and *Hedera* were covered with clear polythene for 7-14 days after being stuck to aid root development and plant establishment.

Plants were grown on the floor in each compartment on capillary matting covered with micro-perforated black polythene. Overhead irrigation was used throughout the course of the trial. Liquid feeding commenced once roots were visible at pot sides for each species. A 300 ppm N and 150 ppm K_2O feed was used at every watering.

Base temperature was maintained at 18°C with an air temperature of 22° with vents set to open at 24°C. Humidity was maintained by manually damping down the floors around the plants to ensure a minimum humidity of 75% (RH).

There was no carbon dioxide enrichment.

No growth regulants were used and plants were not pinched.

Plant spacing was determined as a factor of plant growth, and timing and measurements of spacing was made on a per species x treatment basis. It was carried out to best commercial practice and was an important economic factor in terms of the costs of lighting treatments (see section 3.3, page 22).

Pest and disease control was maintained using an integrated pest/disease management programme. All plants received an Iprodone (Rovral) drench immediately after potting and this was repeated after 14 days for the species *Hedera* only. (Rovral was applied at the rate 0.5 g/l). Routine introductions of the following were made:

on a weekly basis

Aphidius matricariae	for	Aphids
Aphidoletes aphidomyza	for	Aphids
Encarsia formosa	for	Glasshouse Whitefly
Phytoseiulus persimilis	for	Red Spider Mite

every four weeks

Amblyseius cucumeris	for	Western Flower Thrips

No chemical pesticides were applied during the trial.

Plants were recorded at marketing when each treatment block reached marketable size. Six plants were selected for shelf-life assessment. These were sleeved and boxed and underwent a simulated transport run for 3-4 hours. On return, plants were placed directly into simulated shelf-life environment, constant 20°C ± 1°C, 60-65% RH and 1000 lux for 12 hours a day provided by cool white fluorescent tubes.

2.3.6 Assessments

At marketing the following plant growth assessments were made for each species (detailed below).

Marketing Records:

Tradescantia zebrina	***Ficus robusta***
No. of shoots	Plant height
Length of longest shoot and no. of sideshoots	Leaf number
Foliage colour	Leaf area
Plant quality/uniformity	Foliage colour
Rooting assessment	Rooting assessment
Plant fresh weight and dry weight	Plant fresh weight and dry weight

Dracaena sanderama
Plant height
Leaf number
Rooting assessment
Foliage colour
Plant quality/uniformity
Plant fresh weight and dry weight

Begonia rex
Plant height
Plant spread x 2
Leaf area
Foliage colour
Plant quality/uniformity
Rooting assessment
Plant fresh weight and dry weight

Hedera helix
No. of shoots
Length of longest shoot
Foliage colour
Plant spread x 2
Rooting assessment
Plant quality/uniformity
Plant fresh weight and dry weight

Nephrolepis exaltata
Length + width of longest frond
Plant spread x 2
Foliage colour
Plant quality/uniformity
Rooting assessment
Plant fresh weight and dry weight

* **For all species -** Time to marketing stage (in days) for each plot
Water available peat media analysis from unlit and 5000 lux treatments, rep 1 + 2

The time in production (days) and spacing was used to calculate the economic costs for each lighting treatment.

Six plants were selected for assessment in shelf-life. Visual observations were made on a weekly basis for 6 weeks.

2.3.7 Statistical Analysis

Data were analysed using standard Analysis of Variance (ANOVA) or Regression analysis. The degrees of freedom (d.f.), standard error (SED) and probability (P) on which the significance tests were based are presented where appropriate in the table to aid interpretation of the results. Statistical terms referred to are:

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

LSD = The least (minimum) difference when comparing two figures that is required for the means to be statistically different.

P = The likelihood that the result was obtained by chance and hence not a true treatment effect.

P = <0.1 = 1 chance in 10
P = <0.01 = 1 chance in 100
P = <0.001 = 1 chance in 1000

NS = Not significant

3. RESULTS

3.1 Plant Growth Assessments at Marketing

3.1.1 *Begonia rex*

Results are presented graphically in Appendix II, pages 38 to 41.

Plant height was significantly increased under 2500 lux and 5000 lux in comparison to the unlit control, Height was increased where plants had been lit throughout cropping at pot-thick and at final spacing. Increase in plant height under lights was due to the general increase in bulk/vigour of the plants.

Plant spread was similarly increased with the use of supplementary lighting, with a significant increase at 5000 lux in comparison to plants grown without lighting or at 2500 lux. There was no significant difference in plant spread where plants had been transferred between lighting treatments after 12 weeks (post-potting).

Plant fresh weight was considerably higher under both lighting regimes of 2500 lux and 5000 lux in comparison to the control (unlit), and plants grown at 5000 lux were significantly heavier than those at 2500 lux. Where plants had been transferred between treatments there were significant increases in fresh weight where higher intensity lighting had been given to plants before being transferred between treatments (in the first 12 weeks of cropping).

Plant dry weight increased with higher lighting intensity treatments and was significantly greater at 2500 lux and 5000 lux in comparison to unlit plants. The greatest dry weight was recorded where plants had been grown at 5000 lux for the first 12 weeks of cropping and then subsequently at 2500 lux. However, the percentage dry weight did not vary greatly between treatments.

Leaf area of plants was considerably greater when lit, with leaf areas significantly greater at 2500 lux and 5000 lux in comparison to unlit plants. Where plants received higher lighting intensities for the first period before transfer (12 weeks), leaf areas were greater.

Production time in days was reduced by 31 days and 47 days for lighting treatments 2500 lux and 5000 lux respectively, in comparison to plants grown without supplementary lighting which had a total cropping time of 25.7 weeks.

Plant quality was considerably better and more uniform where plants had been grown with supplementary lighting. Unlit plants were very slow to establish in the early stages of growth, and plant growth was uneven from plant to plant.

Visual rooting assessment at marketing revealed greater root development and establishment at the higher light intensity of 5000 lux.

Foliage colour, an important quality factor for *Begonia rex* was greatly improved under lights with more vibrant leaf colour in comparison to unlit plants which had a much duller foliage.

3.1.2 *Ficus robusta*

Results are presented graphically in Appendix II, pages 42 to 44.

Plant height was significantly increased under both 2500 lux and more so at 5000 lux lighting regimes in comparison to unlit plants.

Leaf number was significantly increased where plants were grown continually at 5000 lux. Leaf number was higher under 2500 lux in comparison to unlit plants, but not significantly so. Leaf number increased under the higher light intensity regimes. There was only a very slight increase in leaf number where plants received higher lighting intensities during their first 12 weeks.

Plant fresh weight was significantly increased under both 2500 lux and 5000 lux lighting regimes. There was a slight increase in fresh weight where plants had received higher intensity lighting in the first stages of production as opposed to those provided nearer to marketing.

Plant dry weight was increased in a similar line to fresh weight with dry matter content significantly increased under both lighting regimes of 2500 lux and 5000 lux although the percentage dry matter content of plants did not vary widely at approximately 17%.

Leaf area was significantly increased under 2500 lux and 5000 lux in comparison to unlit plants, although the increase between 2500 lux and 5000 lux was not significant. There was an increase where higher intensity lighting had been given in the final stages of production (12 weeks) but this was not statistically significant.

Production time was reduced from 148 days (unlit) to 139 days and 119 days for 2500 lux and 5000 lux lighting treatments respectively. A comparison of the transfer treatments showed that plants grown at higher light intensities in the earlier stages of growth (5000-unlit and 5000-2500 lux) showed a reduced production time.

Plant quality was perceived to be better under lights due to the general increase in plant vigour, shown as an increase in height, bulk and probably more significantly, leaf area.

There was little difference in **foliage colour** between plants/treatments, although plants grown with the use of supplementary lighting appeared more 'glossy' as opposed to unlit plants which had a duller, darker green colour.

Rooting assessment at marketing found slightly greater rooting at the higher light intensity regimes, although all treatments produced plants with a good root system.

3.1.3 *Nephrolepis exaltata*

Results are presented graphically in Appendix II, pages 45 to 48.

Plant height was significantly increased at 5000 lux (throughout production) but only slightly at 2500 lux, 5 mm greater than the unlit plants. There was no significant difference between any of the transfer treatments.

Plant spread was greatest at 5000 lux (throughout production), at 51.1 cm, and significantly greater than the unlit control at 47.6 cm, although in appearance little difference could be seen between treatments in terms of plant spread.

Frond length and **width** were increased with the use of supplementary lighting, although only 5000 lux throughout production produced a significant increase over unlit plants.

Plant fresh weight was increased under supplementary lighting, with a significant increase at 5000 lux in comparison to unlit plants. There was a greater increase where higher intensity lighting had been given at the start of production (first 10 weeks).

Plant dry weight was almost doubled under the 5000 lux regime in comparison to unlit plants, and both lighting regimes of 2500 lux and 5000 lux were significantly greater than the control, unlit plants. Percentage dry matter was also higher: 20.2% and 22.2% at 2500 lux and 5000 lux respectively in comparison to the control, 18.7%.

Production time was decreased by 26 days and 20 days for 2500 lux and 5000 lux respectively in comparison to unlit plants. Supplementary lighting for the first stages in production had a greater effect than lighting at the end of the crop.

All plants were of good **quality** at marketing, with the only difference between plants seen in their 'bulk'/size.

Foliage colour appeared paler at the higher light intensity, particularly at 5000 lux given throughout production.

Rooting was more vigorous under the higher lighting intensities, although this produced a greater number of aerial roots near to marketing.

3.1.4 *Hedera helix*

Results are presented graphically in Appendix II, pages 49 to 51.

The **total number of trails** was not significantly different between treatments although a slight increase was recorded with the use of supplementary lighting. The number of trails per plant was on average 7.

In contrast the **length of trails** was significantly increased with the use of supplementary lighting, although the difference in growth was not as great between 5000 lux and 2500 lux, as between unlit and 2500 lux where there was a significant increase in length: 121 mm and 106 mm at 5000 lux and 2500 lux respectively in comparison to unlit plants, 88 mm.

Fresh weight at 2500 lux was not too dissimilar to the unlit plants, 4.79 g and 4.18 g respectively. However, there was a considerable and significant increase in fresh weight at 5000 lux, 6.54 g, and generally the higher light intensity had the greatest effect on fresh weight.

Plant dry weight reflected closely the increase seen in fresh weight. Both at 2500 lux and 5000 lux dry weight was significantly higher than the unlit plants, and dry weight was improved where higher lighting intensity had been given in the first stages of production, or throughout growth. The percentage dry weight was increased with the use of supplementary lighting: 24% and 20.6% at 2500 lux and 5000 lux respectively, in comparison to unlit plants, 15.5%.

Plant spread was significantly increased under both 2500 lux and 5000 lux lighting regimes, reflecting the increase in the average length of trails.

Production time was considerably reduced with the use of supplementary lighting; 84 days and 71 days for 2500 lux and 5000 lux respectively in comparison to unlit plants which took at least 108 days to reach a suitable size for marketing.

Plant quality was improved with the use of supplementary lighting through greater plant vigour and earlier establishment of plants.

Foliage colour, variegation was considerably better on plants grown with the use of supplementary lighting, and was best at the higher lighting intensities.

Rooting assessment at marketing did not vary greatly between treatments, although it was evident that supplementary lighting in the early stages of production increased root establishment and uniformity of the plants.

3.1.5 *Tradescantia zebrina*

Results are presented graphically in Appendix II, pages 52 to 54.

It appeared that supplementary lighting increased the **number of internodes**/leaves per plant. Both at 2500 lux and 5000 lux number of internodes was significantly greater than the control, unlit plants, although the increase may not be significant commercially.

Trail length and **number of trails** was significantly increased with the use of supplementary lighting at both 2500 lux and 5000 lux (with the exception of no. of trails between 2500 lux and 5000 lux).

Plant **fresh weight** was significantly increased with the use of supplementary lighting at both 2500 and 5000 lux: 34.15 g and 41.36 g at 2500 lux and 5000 lux respectively in comparison to unlit plants, 26.7 g.

Plant **dry weight** results were similar in their trends to that of fresh weight, with significant increases at 2500 lux and 5000 lux. This afforded increases in percentage dry matter content; 4.8% and 5.1% at 2500 lux and 5000 lux respectively in comparison to unlit plants, 4.4%.

Production time was reduced with the use of supplementary lighting, by 5 days and 7 days for 2500 lux and 5000 lux respectively.

Plant quality was good for plants in all treatments, although those grown with the use of supplementary lighting appeared better as a result of being more compact/harder in their growth/appearance and with much stronger variegation.

Foliage colour and variegation was considerably better under lights, with better pronounced variegation, whilst unlit plants were largely green with little variegation.

There were no differences recorded in **rooting** between any of the lighting regimes.

3.1.6 *Dracaena sanderama*

Results are presented graphically in Appendix II, pages 55 to 57.

Plant height was increased slightly with the use of supplementary lighting, with plant height significantly greater at 5000 lux in comparison to unlit plants, although in commercial terms this difference was thought to be slight.

Leaf number was similar to plant height with a slight increase evident at both 2500 lux and 5000 lux treatments, but the difference was very small and not more than a single leaf.

Plant fresh weight was significantly increased under 2500 lux in comparison to unlit plants. Fresh weight was increased at 5000 lux: 5.6 g and 6.0 g at 2500 lux and 5000 lux respectively, in comparison to unlit plants at 4.9 g.

Plant dry weight was similar to fresh weight, increased under both 2500 lux and 5000 lux lighting treatments. The difference between treatments, although statistically significant, was not great and the percentage dry matter content was not dissimilar between treatments with on average a level of 20%.

Time in production was reduced by 4 and 6 days with 2500 lux and 5000 lux respectively. Plants, although of slightly different size, were all of good quality and variegation was improved under the lighting regimes.

Plant quality was not dissimilar between treatments.

Foliage colour was slightly better where plants had been grown with the use of supplementary lighting, with a ‘stronger’ variegation.

There were no consistent differences in **rooting** between treatments.

3.2 Plant Densities

3.2.1 *Begonia rex*

Closer plant spacing of 30/m^2 at final spacing, caused plants to 'draw' in all lighting treatments. Plant spacing at 25/m^2 was more suitable, allowing better plant habit to develop.

Plant quality was superior at 25/m^2, with the development of larger leaves which were better coloured.

3.2.2 *Nephrolepis exaltata*

Closer plant spacing, 30/m^2, reduced overall plant quality and habit, but plants were still regarded as being of good quality.

3.2.3 *Ficus robusta*

Closer plant spacing, 30/m^2, was possible for all treatments although lower foliage became darker where it was shaded.

Observations suggested that closer plant spacings reduced leaf area.

3.2.4 *Hedera helix*

Closer plant spacing, 90/m^2, was possible under lights, without affecting overall plant quality or time to marketing.

3.2.5 *Tradescantia zebrina*

Dependent upon intended market and hence the final size of plant required.

Closer plant spacing, 90/m^2, caused shading of the lower foliage which reduced the intensity of variegation.

Closer pot spacings and increased plant growth under lights encouraged rooting of plants into neighbouring pots.

3.2.6 *Dracaena sanderama*

No effect of supplementary lighting on final plant spacing.

3.3 Economic Costs

An example of the calculation for costing of supplementary lighting treatments, eg *Ficus robusta*.

Plant spacing

Plants remained pot thick (59 pots/m^2) for the first 12 weeks of production for all treatments before they were spaced (30 pots/m^2) and transferred between lighting treatments. Length of production for each treatment is shown below:

	12 weeks at 59 pots/m^2	(all treatments)
+	5 weeks at 30 pots/m^2	(5000 lux throughout)
	5 weeks at 30 pots/m^2	(5000 lux - 2500 lux)
	5.4 weeks at 30 pots/m^2	(5000 lux - unlit)
	6.3 weeks at 30 pots/m^2	(2500 lux - 5000 lux)
	7.4 weeks at 30 pots/m^2	(unlit - 5000 lux)
	7.8 weeks at 30 pots/m^2	(unlit - 2500 lux)
	7.8 weeks at 30 pots/m^2	(2500 lux throughout)
	9.1 weeks at 30 pots/m^2	(unlit throughout)

Capital costs

Lighting period was for a total of 26 weeks during the winter months.

Capital costs at pot thick (59/m^2) where 1m^2 will service 2.2 crops.

Capital cost - 5000 lux $\frac{720}{2.2 \times 59}$ = 5.5p/pot

Capital cost - 2500 lux $\frac{309}{2.2 \times 59}$ = 2.4p/pot

Capital cost at final spacing (30/m^2)

i. Treatments 5000 lux throughout → 5000 lux (weeks 1-12) and 2500 lux (weeks 13+)
i.e. 5 weeks at final spacing. Therefore, 1m^2 will service 5.2 crops.

Capital cost - 5000 lux $\frac{720}{5.2 \times 30}$ = 4.6p/pot

Capital cost - 2500 lux $\frac{309}{5.2 \times 30}$ = 2.0p/pot

ii. **Treatments 5000 lux - unlit and 2500 lux - unlit** no lighting costs at final spacing.

iii. **Treatments 2500 lux - 5000 lux** i.e. 6.3 weeks at final spacing. Therefore, 1m^2 will service 4.1 crops.

Capital cost - 5000 lux $\frac{720}{4.1 \text{ x } 30}$ = 5.9p/pot

iv. **Treatments unlit - 5000 lux** i.e. 7.4 weeks at final spacing. Therefore, 1m^2 will service 3.5 crops.

Capital cost - 5000 lux $\frac{720}{3.5 \text{ x } 30}$ = 6.9p/pot

v. **Treatment unlit - 2500 lux and 2500 lux throughout production** i.e. 7.8 weeks at final spacing. Therefore, 1m^2 will service 3.3 crops.

Capital cost - 2500 lux $\frac{309}{3.3 \text{ x } 30}$ = 3.1p/pot

Running costs

Running costs at pot thick (59/m^2); all treatments spend 12 weeks pot thick. Therefore, 1m^2 will service 2.2 crops = 2.2 x 59 = 130 pots.

5000 lux for 12 weeks

$$\frac{0.44 \text{ kW x 7 hrs x 84 days x 2.61p/kWhr}}{6\text{m}^2} = 112.5\text{p/m}^2$$

Therefore, running cost per pot = $\frac{112.5}{130}$ = 0.87p/pot

2500 lux for 12 weeks

$$\frac{0.44 \text{ kW x 7 hrs x 84 days x 2.61p/kWhr}}{12\text{m}^2} = 56.3\text{p/m}^2$$

Therefore, running cost per pot = $\frac{56.3}{130}$ = 0.43p/pot

Running costs at final spacing (30/m^2)

The length of time at final spacing varies with each of the treatments. Therefore, costs are calculated on an individual treatment basis.

i. **Treatment 5000 lux throughout production and 5000 lux - 2500 lux**. 1m^2 will service 5.2 crops i.e. 5.2 x 30 = 156 pots.

5000 lux for 5 weeks

$$\frac{0.44\text{ kW} \times 7\text{ hrs} \times 35\text{ days} \times 2.61\text{p/kWhr}}{6\text{m}^2} = 46.91\text{p/m}^2$$

$$\text{Therefore cost per pot} = \frac{46.9}{156} = 0.30\text{p/pot}$$

2500 lux for 5 weeks

$$\frac{0.44\text{ kW} \times 7\text{ hrs} \times 35\text{ days} \times 2.61\text{p/kWhr}}{12\text{m}^2} = 23.4\text{p/m}^2$$

$$\text{Therefore cost per pot} = \frac{23.4}{156} = 0.15\text{p/pot}$$

ii. **Treatment 5000 lux - unlit and 2500 lux - unlit.** No cost of lighting at final spacing.

iii. **Treatment 2500 lux - 5000 lux**. 1m^2 will service 4.1 crops i.e. 4.1 x 30 = 123 pots.

5000 lux for 6.3 weeks

$$\frac{0.44\text{ kW} \times 7\text{ hrs} \times 44\text{ days} \times 2.61\text{p/kWhr}}{6\text{m}^2} = 59\text{p/m}^2$$

$$\text{Therefore cost per pot} = \frac{59}{123} = 0.48\text{p/pot}$$

iv. **Treatment unlit - 5000 lux.** 1m² will service 3.5 crops i.e. 3.5 x 30 = 105 pots.

5000 lux for 7.4 weeks

$$\frac{0.44\text{ kW x 7 hrs x 52 days x 2.61p/kWhr}}{6\text{m}^2} = 69.7\text{p/m}^2$$

$$\text{Therefore cost per pot} = \frac{69.7}{105} = 0.66\text{p/pot}$$

v. **Treatments unlit - 2500 lux and 2500 lux throughout production.** 1m² will service 3.3 crops i.e. 3.3 x 30 = 99 pots.

2500 lux for 3.3 weeks

$$\frac{0.44\text{ kW x 7 hrs x 55 days x 2.61p/kWhr}}{12\text{m}^2} = 36.8\text{p/m}^2$$

$$\text{Therefore cost per pot} = \frac{36.8}{99} = 0.37\text{p/pot}$$

Summary of lighting costs for *Ficus robusta*, table 1.

Table 1

Treatment	**Capital Cost p/pot**	**Running Cost p/pot**	**Total Cost p/pot**	**Prodⁿ days**
5000 lux	5.5 + 4.6	0.87 + 0.30	11.27	119
5000 lux - 2500 lux	5.5 + 2.0	0.87 + 0.15	8.52	128
5000 lux - unlit	5.5 + 0.0	0.87 + 0.0	6.37	119
2500 lux - 5000 lux	2.4 + 5.9	0.43 + 0.48	9.21	136
Unlit - 5000 lux	0.0 + 6.9	0.0 + 0.66	7.56	122
2500 lux - unlit	2.4 + 0.0	0.43 + 0.0	2.83	139
Unlit - 2500 lux	0.0 + 3.1	0.0 + 0.37	3.47	139
2500 lux	2.4 + 3.1	0.43 + 0.37	6.30	137
Unlit	-	-	-	148

Costs were calculated for each combination of lighting treatment for each species, based on lighting intensity and crop duration. Assumptions used for the costings are given in Appendix III, page 58 and reference should be made to HDC reports PC 93b and PC 93c (Pot Chrysanthemum) which contain a full breakdown of the basis and methods for the calculations used.

Economic costing for each species and lighting treatment are given on pages 27-29, tables 2-7.

Quite clearly the capital cost for lighting equipment is by far the greatest contribution to the final cost per pot. In some instances the capital cost can amount to 70% of the total cost per pot.

Lighting treatments obviously influenced the cost. The more expensive treatments being the higher lighting intensity regimes; 5000 lux throughout production.

It should be stressed that all of the costs presented represent the cost of providing the supplementary lighting alone. Individual costs for labour, materials etc. would be constant, regardless of lighting treatment, and should be added onto the appropriate lighting cost (calculated as mentioned above, according to individual circumstances).

Increase in the speed of production (and hence number of pots produced per m^2 annually) through the use of supplementary lighting, improved quality and enhanced shelf-life quality and the maintenance of a position within the market place are other positive aspects to be considered against the increased cost of production. Energy savings on heating will also result from using supplementary lighting since the radiant energy emitted from lamps will reduce the amount of heating required to achieve set point temperatures.

It is important for costs to be calculated according to individual circumstances since costs of equipment and running/maintenance costs will no doubt vary from one grower to another.

Table 2: ***Begonia rex*** **- economic costings for each lighting treatment**

Treatment	Capital Cost p/pot	Running Cost p/pot	Total Cost p/pot	Prod^n days
5000 lux throughout	13.28	4.52	17.80	133
2500 lux - 5000 lux	12.70	4.43	17.13	149
5000 lux - 2500 lux	9.90	3.64	13.54	149
Unlit - 5000 lux	13.10	4.50	17.60	168
5000 lux - unlit	5.50	1.90	7.40	162
2500 lux throughout	6.80	2.69	9.49	149
Unlit - 2500 lux	5.90	2.32	8.22	171
2500 lux - unlit	2.40	0.95	3.25	163
Unlit	-	-	-	180 +

Table 3: ***Ficus robusta*** **- economic costings for each lighting treatment**

Treatment	Capital Cost p/pot	Running Cost p/pot	Total Cost p/pot	Prod^n days
5000 lux throughout	10.10	1.17	11.27	119
2500 lux - 5000 lux	8.3	0.91	9.21	128
5000 lux - 2500 lux	7.5	1.02	8.52	119
Unlit - 5000 lux	6.9	0.66	7.56	136
5000 lux - unlit	5.5	0.87	6.37	122
2500 lux throughout	5.5	0.8	6.3	139
Unlit - 2500 lux	3.1	0.37	3.47	139
2500 lux - unlit	2.4	0.43	2.83	137
Unlit	-	-	-	148

Table 4: *Nephrolepis exaltata* **- economic costings for each lighting treatment**

Treatment	Capital Cost p/pot	Running Cost p/pot	Total Cost p/pot	Prod^n days
5000 lux throughout	7.39	0.55	7.94	79
2500 lux - 5000 lux	7.15	0.55	7.70	91
5000 lux - 2500 lux	5.51	0.50	6.01	82
Unlit - 5000 lux	7.42	0.65	8.07	103
5000 lux - unlit	3.75	0.39	4.14	85
2500 lux throughout	3.70	0.33	3.94	87
Unlit - 2500 lux	3.0	0.29	3.29	100
2500 lux - unlit	1.61	0.19	1.80	89
Unlit	-	-	-	108

Table 5: *Hedera helix* **- economic costings for each lighting treatment**

Treatment	Capital Cost p/pot	Running Cost p/pot	Total Cost p/pot	Prod^n days
5000 lux throughout	3.21	1.10	4.31	71
2500 lux - 5000 lux	2.85	1.00	3.85	77
5000 lux - 2500 lux	2.25	0.81	3.06	74
Unlit - 5000 lux	3.80	1.29	5.09	101
5000 lux - unlit	1.35	0.46	1.81	96
2500 lux throughout	1.76	0.69	2.45	84
Unlit - 2500 lux	1.81	0.72	2.53	108
2500 lux - unlit	0.58	0.23	0.81	93
Unlit	-	-	-	108

Table 6: *Tradescantia zebrina* - economic costings for each lighting treatment

Treatment	Capital Cost p/pot	Running Cost p/pot	Total Cost p/pot	Prod^n days
5000 lux throughout	7.39	0.55	7.94	79
2500 lux - 5000 lux	7.15	0.55	7.70	91
5000 lux - 2500 lux	5.51	0.50	6.01	82
Unlit - 5000 lux	7.42	0.65	8.07	103
5000 lux - unlit	3.75	0.39	4.14	85
2500 lux throughout	3.70	0.33	3.94	87
Unlit - 2500 lux	3.0	0.29	3.29	100
2500 lux - unlit	1.61	0.19	1.80	89
Unlit	-	-	-	108

Table 7: *Dracaena sanderama* - economic costings for each lighting treatment

Treatment	Capital Cost p/pot	Running Cost p/pot	Total Cost p/pot	Prod^n days
5000 lux throughout	7.39	0.55	7.94	79
2500 lux - 5000 lux	7.15	0.55	7.70	91
5000 lux - 2500 lux	5.51	0.50	6.01	82
Unlit - 5000 lux	7.42	0.65	8.07	103
5000 lux - unlit	3.75	0.39	4.14	85
2500 lux throughout	3.70	0.33	3.94	87
Unlit - 2500 lux	3.0	0.29	3.29	100
2500 lux - unlit	1.61	0.19	1.80	89
Unlit	-	-	-	108

3.4 Growing Media Analysis

Samples from each species were taken at marketing from both unlit treatments and 5000 lux (throughout production). The results are presented in tables 8 to 13, Appendix IV, pages 59 to 61.

Typically, it may be expected for media nutrient levels to drop where plants are grown under higher light intensity, and thus plant growth more vigorous. However, only in two species *Nephrolepis exaltata* and *Hedera helix* was a reduction in nutrient levels recorded for plants grown at 5000 lux in comparison to plants unlit. In the majority of species, there was little difference in media nutrition between lighting treatments.

3.5 Shelf-life

A visual assessment of plant quality was made every week for 6 weeks on plants from each treatment held in a simulated shelf-life environment.

The most obvious effect and benefit of supplementary lighting was to increase both leaf colour and variegation, particularly where plants had been grown at the higher light intensities. The improved foliage colour at marketing and variegation was prolonged in shelf-life as a result of the higher lighting intensities provided during production. *Begonia rex, Ficus robusta, Tradescantia zebrina* and *Dracaena sanderama* all responded positively and were perceived to have an improved shelf-life.

4. DISCUSSION

The aim of this trial was to evaluate the use of a range of supplementary lighting regimes for the winter production of foliage plants to improve their quality and speed of production.

The trial followed on from a previous study funded by the Electricity Association Technology (EAT) which investigated the use of supplementary lighting in combination with the use of carbon dioxide to improve the winter plant production of foliage plants. The results from this trial, carried out over the winter 1993/94, showed that supplementary lighting had a greater effect on plant growth, improving plant quality and accelerating growth rate. The use of CO_2 appeared to be of marginal benefit.

In this year's trial six foliage plant species were examined under two main supplementary lighting treatments, 5000 lux (12 W/m^2) and 2500 lux (6 W/m^2). Further lighting regimes were implemented by transferring plants between each lighting regime at a set point after potting (dependent on species type).

The use of supplementary lighting clearly improved plant growth for most species. Only *Dracaena sanderama* failed to respond to supplementary lighting to a degree which would be advantageous commercially. All other foliage species grown had increased growth rate and quality with the use of supplementary lighting. The economic cost of lighting would need to be examined by each grower independently for him/her to appreciate the true costs for their business. However, this trial has demonstrated that significant increase in growth and quality are achievable. Most species responded positively to both lighting regimes of 2500 lux and 5000 lux, although *Nephrolepis exaltata* appeared to require a higher lighting intensity to achieve a significant increase in growth. In addition to the benefits of plant quality, cropping time was considerably reduced for some species, particularly *Begonia rex* and to a lesser extent *Ficus robusta*. The ability to reduce cropping time and increase the productivity of the glasshouse area could have considerable savings for growers. The ability to schedule crops, and to meet the high quality standards of the market would also be of significant benefit with the use of supplementary lighting. The costs incurred as a result would need to be weighed against these expected benefits.

There remains potential for the lighting regimes to be manipulated further to ensure greater efficiency in their use, ie off peak electricity, and also at correct intensities to achieve an effective response in plant growth and quality. The capital costs of providing supplementary lighting remain the major component of total costs. Running costs are a much smaller component of the total cost and potential could exist for lights to be used for extended periods beyond the 7 hrs/day employed for this trial which made use of cheaper off-peak electricity.

5. CONCLUSIONS

- The use of supplementary lighting during the winter months will significantly reduce cropping time and improve final plant quality to the consumer for a number of foliage plant species.

- The use of supplementary lighting for the early phases of production will have a greater effect than its use at the end of cropping. This also has the advantage that plants are pot thick during the early stages and hence cost of lighting per pot is lower.

- Benefits of increased plant 'quality' are difficult to quantify. Higher quality plants should command a higher market price, and their demand increases sales for the grower.

- Main costs of supplementary lighting are related to capital costs. Running costs can be a smaller component of the overall cost attributed to the use of supplementary lighting for the treatments assessed.

6. FUTURE WORK

- It has been seen from this trial that not all species of foliage plant respond favourably to supplementary lighting. Therefore, a greater range of foliage plant species should be examined to determine their response to supplementary lighting.

- As running costs can be only a small percentage of the overall cost of supplementary lighting, further work should examine the use of different lengths of lighting, eg 8, 10, 12, 14, 16 and 18 hours. Therefore, a lighting schedule could be adopted for each plant species to ensure optimum use of supplementary lights.

- This trial was limited to only a single potting date. A series of potting dates should be assessed throughout the winter period to determine the effect of supplementary lighting at different times to ensure effective and efficient use of supplementary lighting.

APPENDICES

APPENDIX I Plant layout for each compartment

Foliage Plants: Improving Winter Production and Plant Quality with the use of Supplementary Lighting (HDC/EAT)

Q-Block Compartment 3

N

2500 Lux 22.00 - 07.00 hrs	**Unlit**
Dracaena	Dracaena
Nephrolepis	Nephrolepis
Ficus Robusta	Ficus Robusta
Tradescantia	Tradescantia
Begonia Rex	Begonia Rex
Hedera	Hedera
Rep. 1	**Rep. 2**

APPENDIX I Plant layout for each compartment

Foliage Plants: Improving Winter Production and Plant Quality with the use of Supplementary Lighting (HDC/EAT)

Q-Block Compartment 2

APPENDIX I   Plant layout for each compartment

Foliage Plants: Improving Winter Production and Plant Quality with the use of Supplementary Lighting (HDC/EAT)

Q-Block Compartment 1

N

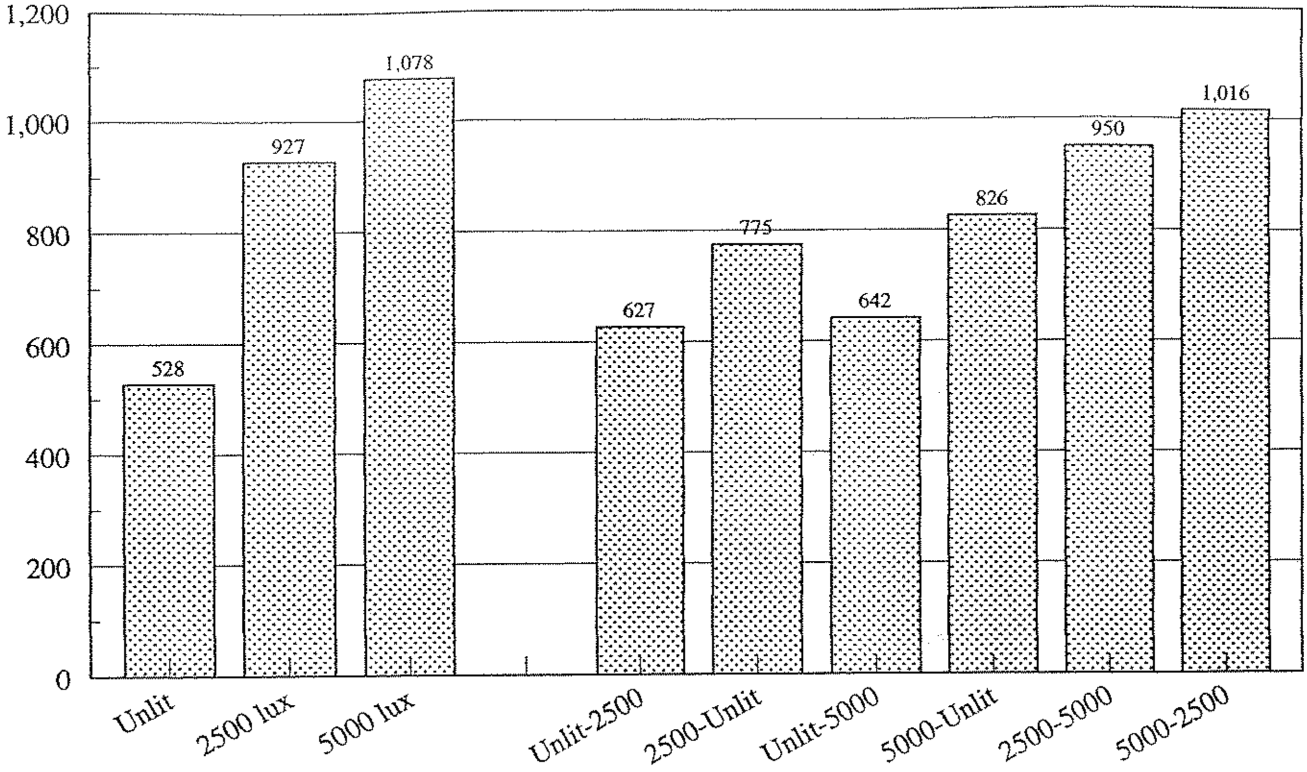
Unlit	5000 Lux 22.00 - 07.00 hrs
Dracaena	Dracaena
Nephrolepis	Nephrolepis
Ficus Robusta	Ficus Robusta
Tradescantia	Tradescantia
Begonia Rex	Begonia Rex
Hedera	Hedera
Rep. 1	Rep. 2

APPENDIX II

Plant growth measurements at marketing - presented graphically

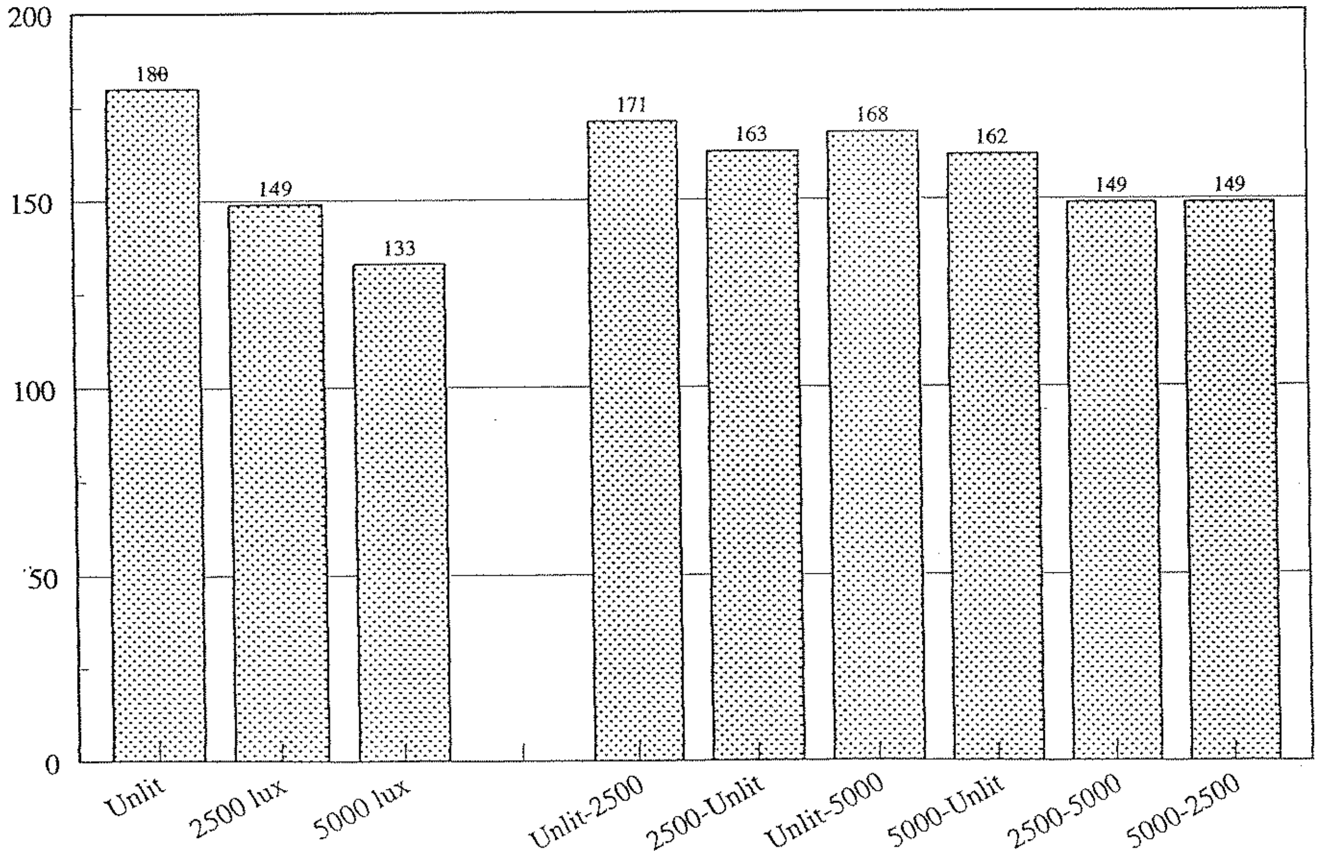
Begonia Rex

Leaf Area (mm²)



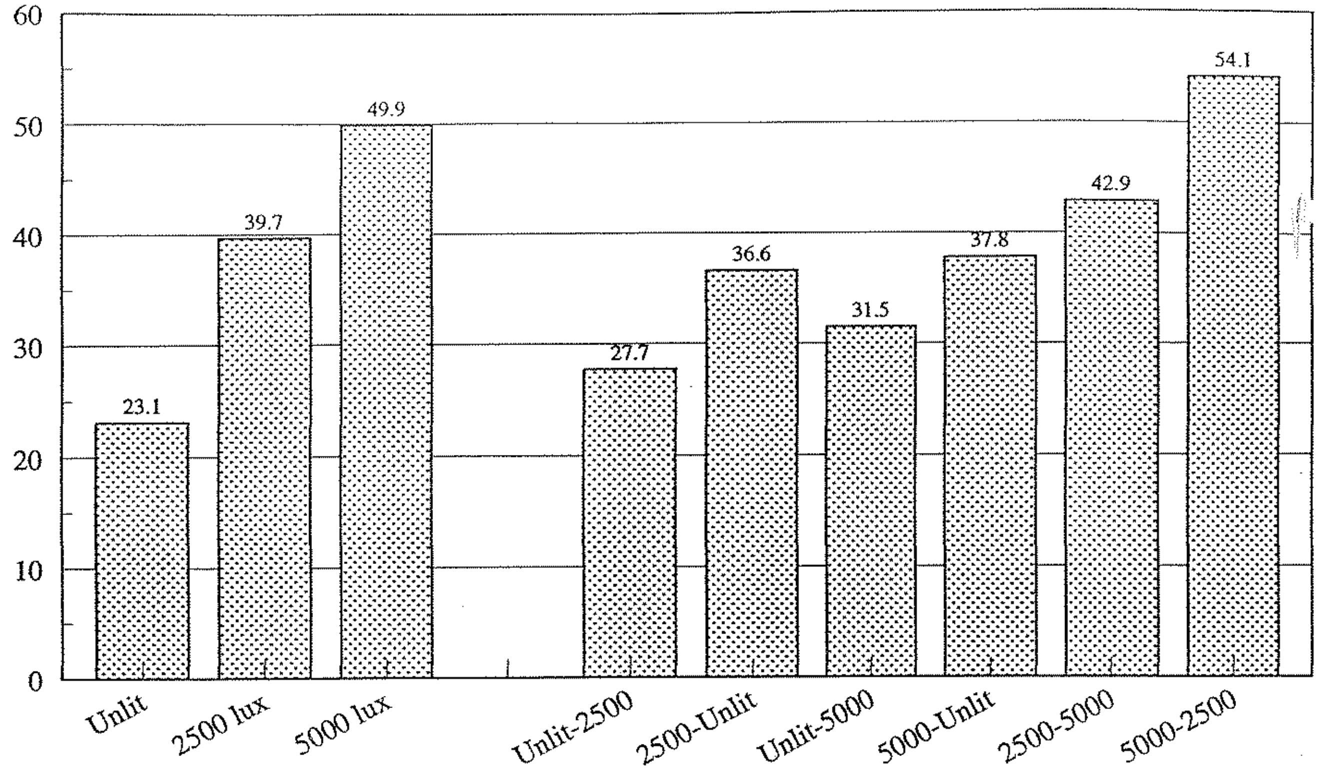
d.f = 8
SED = +/- 71.8
LSD = +/- 165.6

No. of Days to Marketing



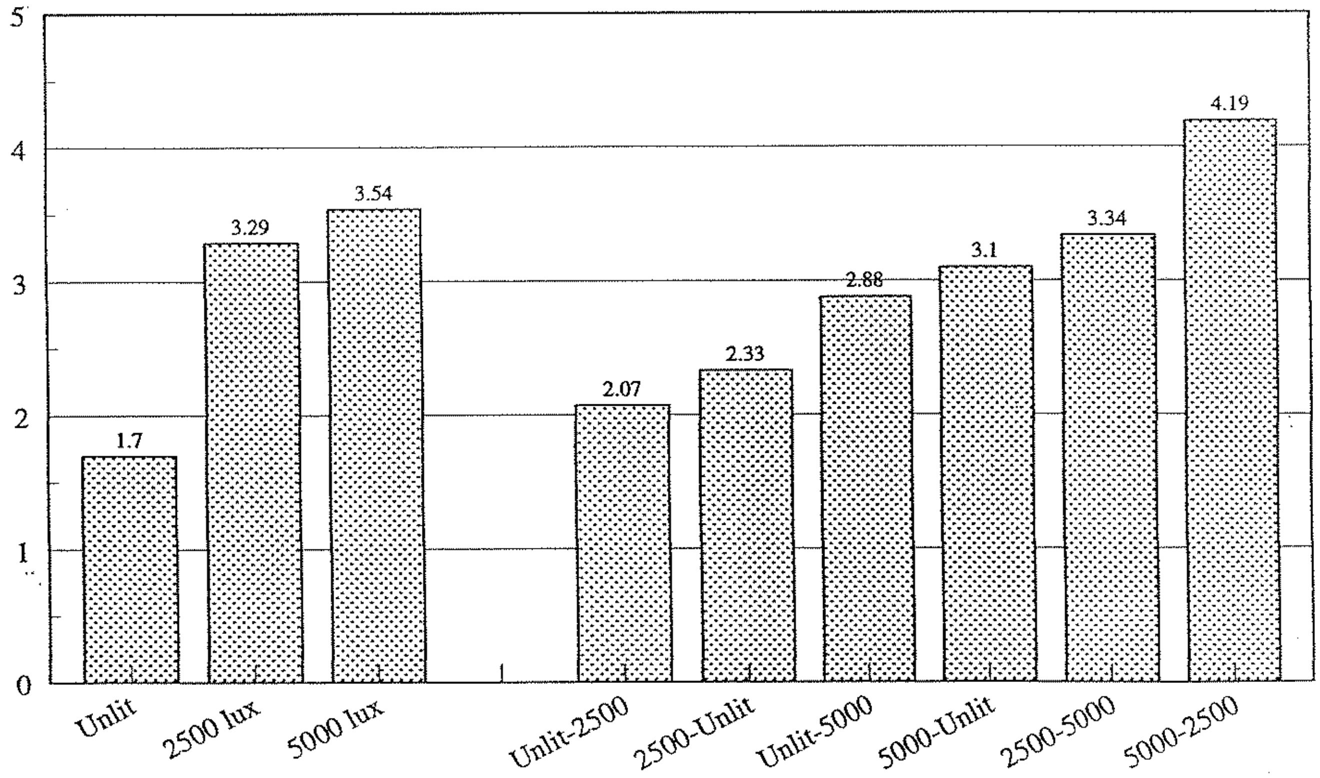
Begonia Rex

Plant Fresh Weight (g)



d.f = 8
SED = +/- 3.65
LSD = +/- 8.41

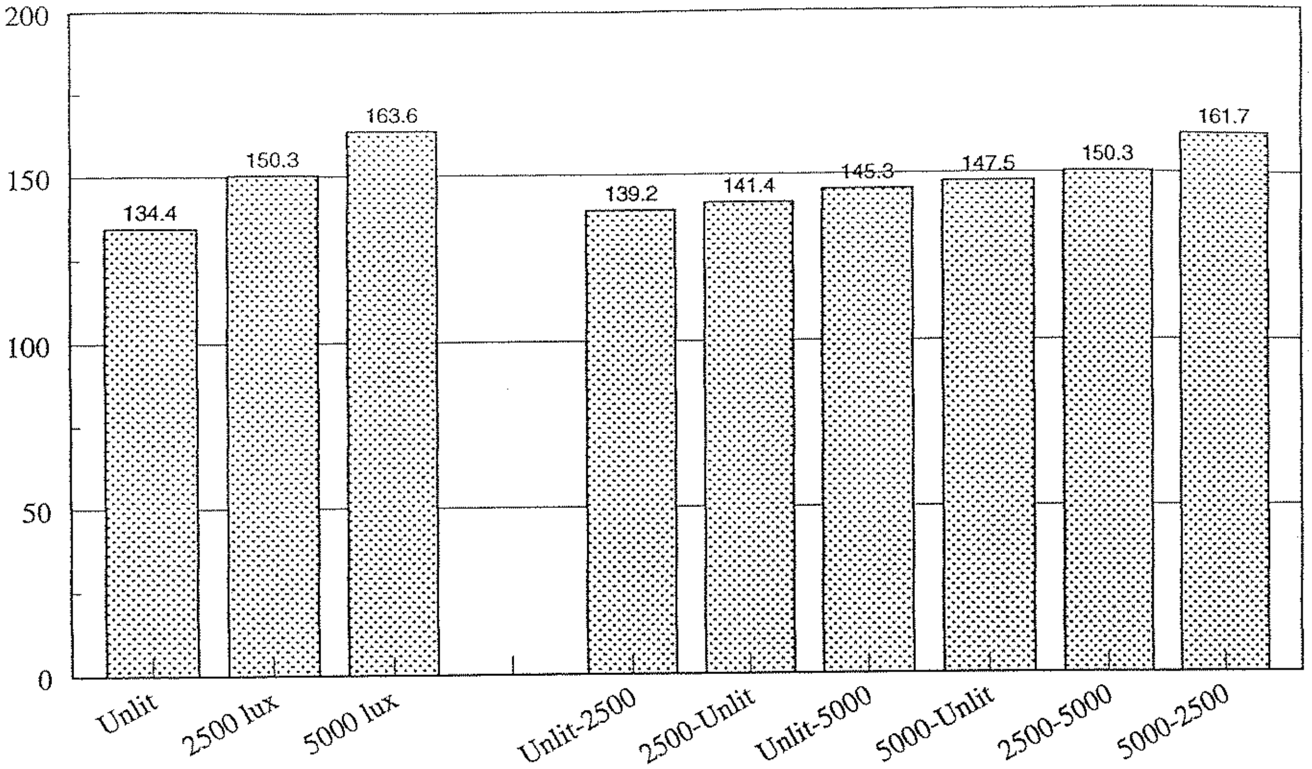
Plant Dry Weight (g)



d.f = 8
SED = +/- 0.23
LSD = +/- 0.53

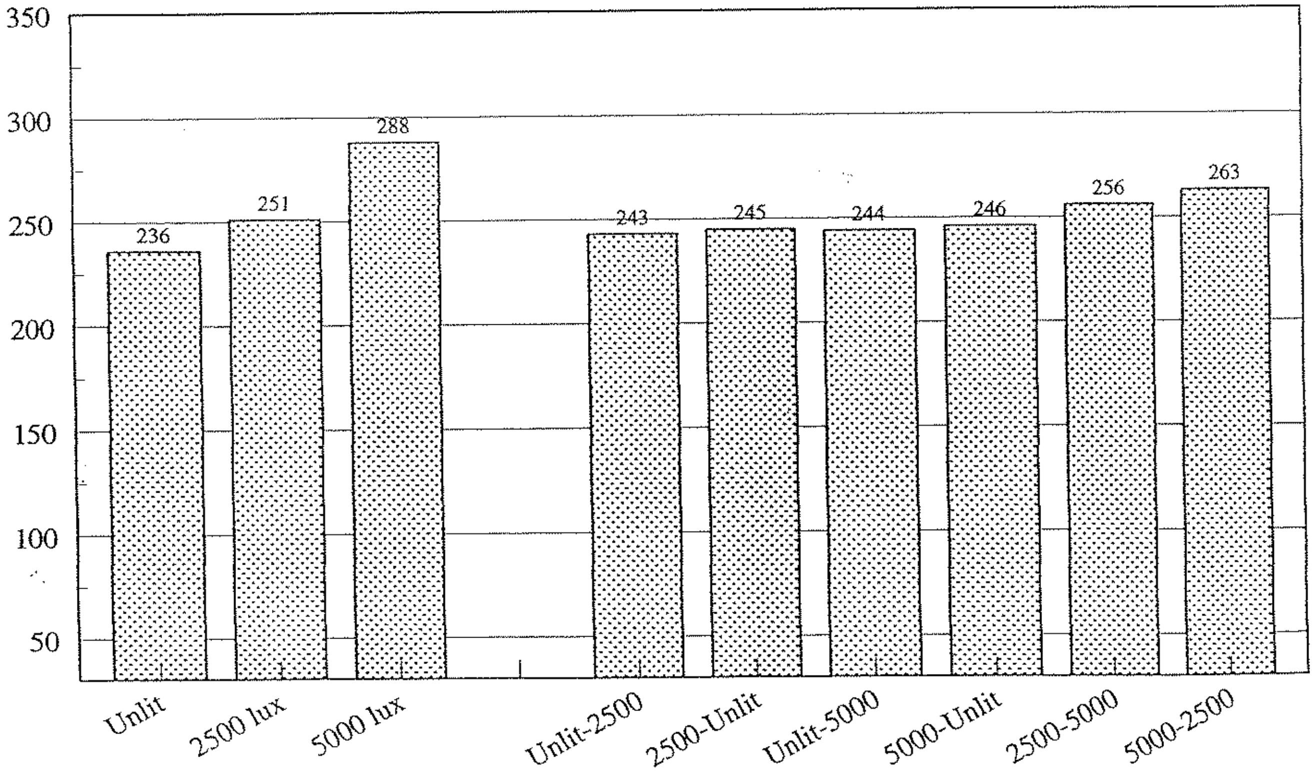
Begonia Rex

Plant Height (mm)



d.f = 8
SED = +/- 3.7
LSD = +/- 8.5

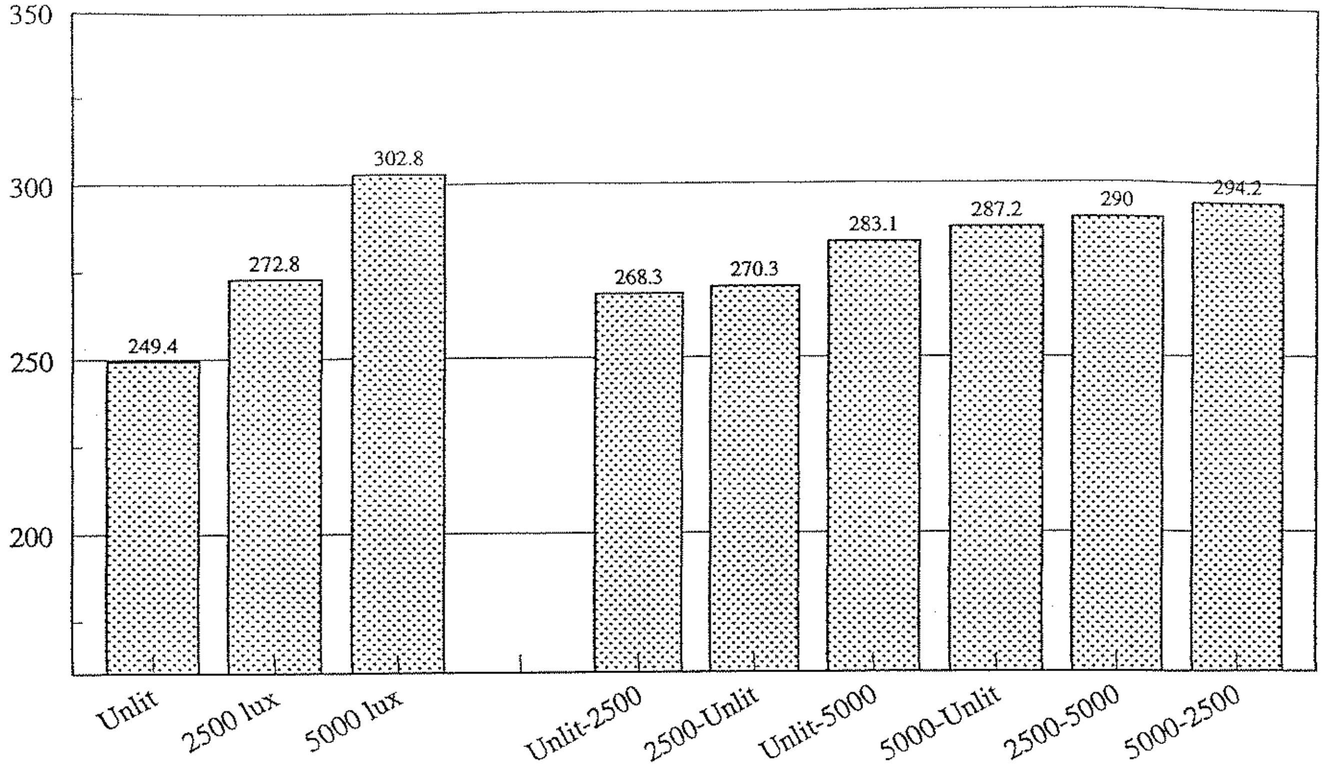
Plant Spread (mm)



d.f = 8
SED = +/- 9.8
LSD = +/- 22.6

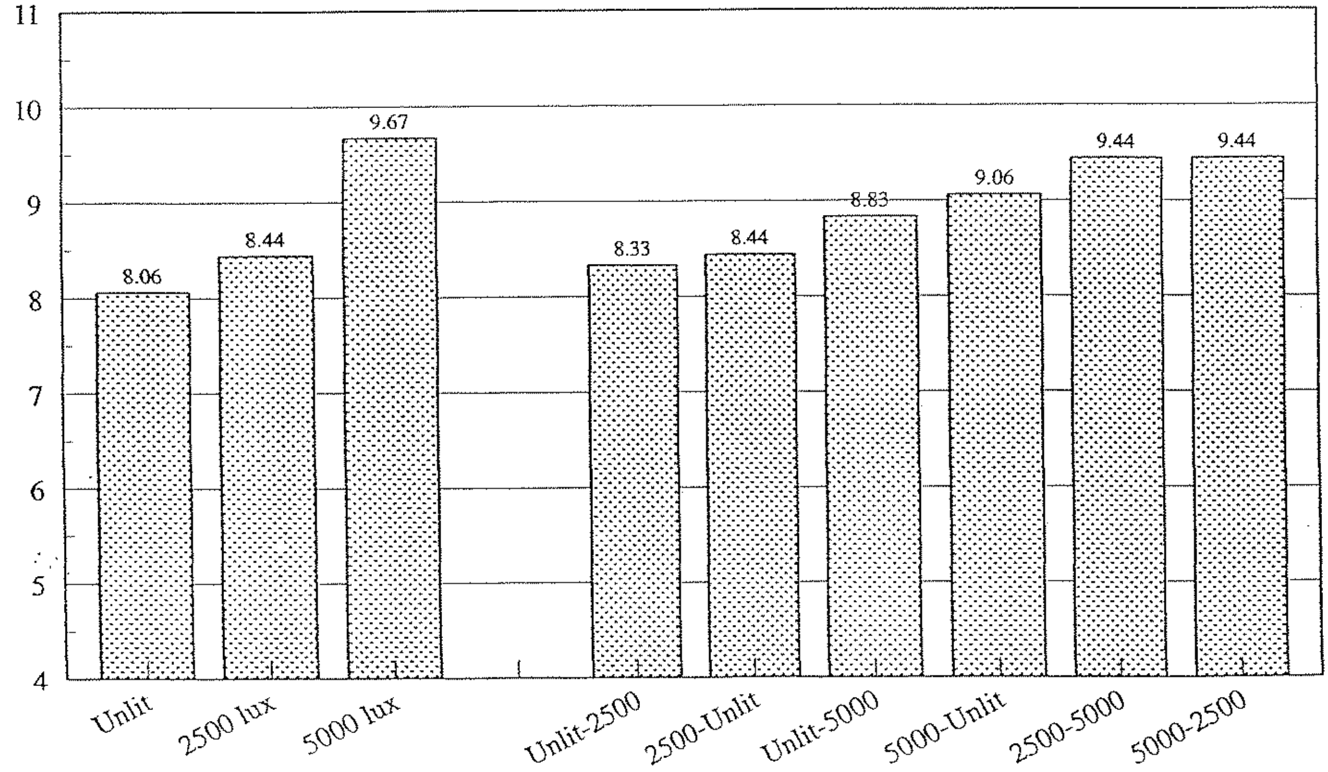
Ficus robusta

Plant Height (mm)



d.f = 8
SED = +/- 8.9
LSD = +/- 20.5

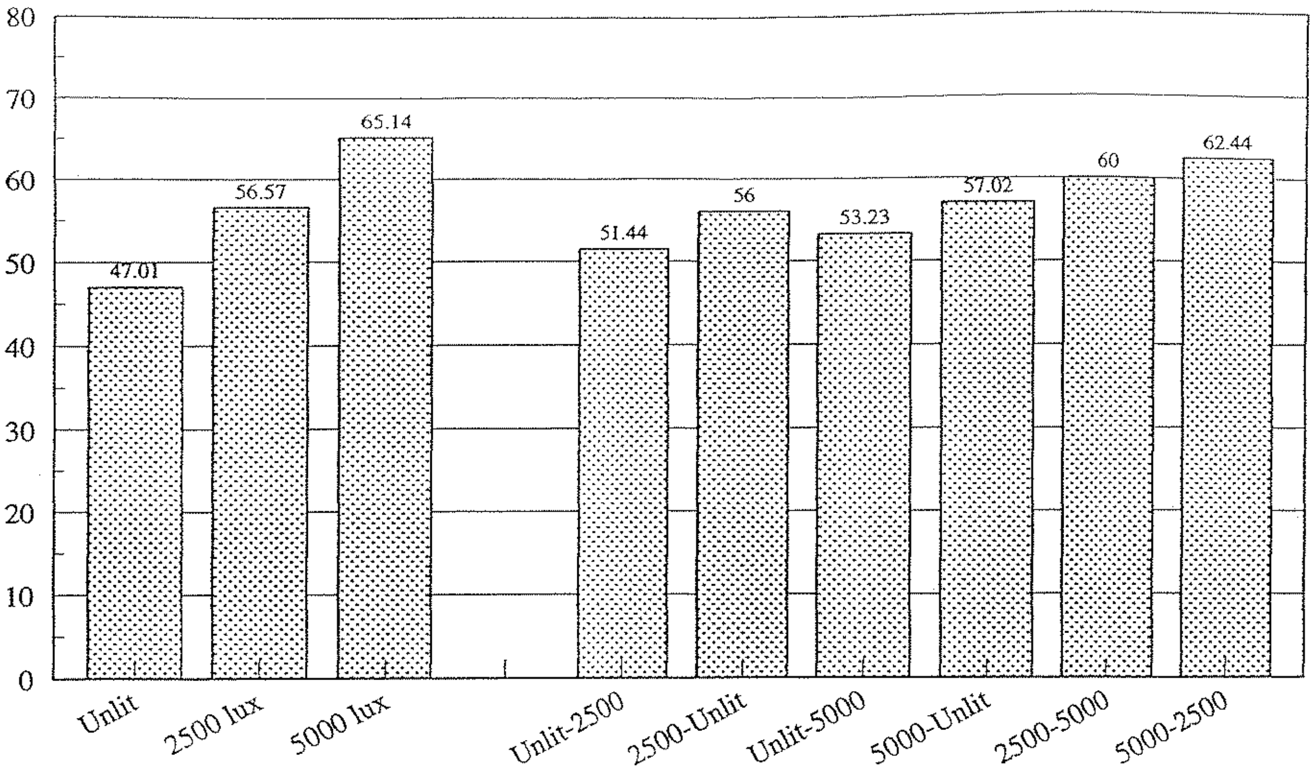
Leaf Number



d.f = 8
SED = +/- 0.25
LSD = +/- 0.57

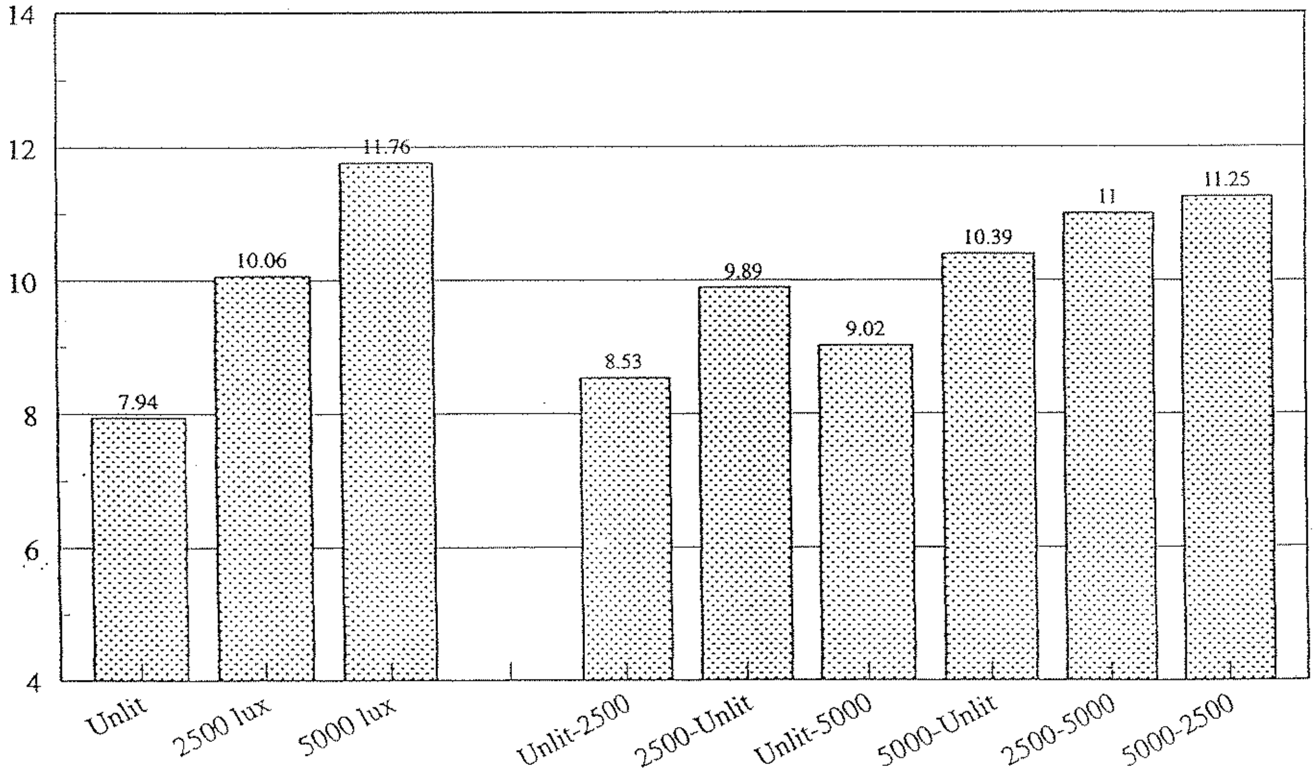
Ficus robusta

Plant Fresh Weight (g)



d.f = 8
SED = +/- 3.3
LSD = +/- 7.6

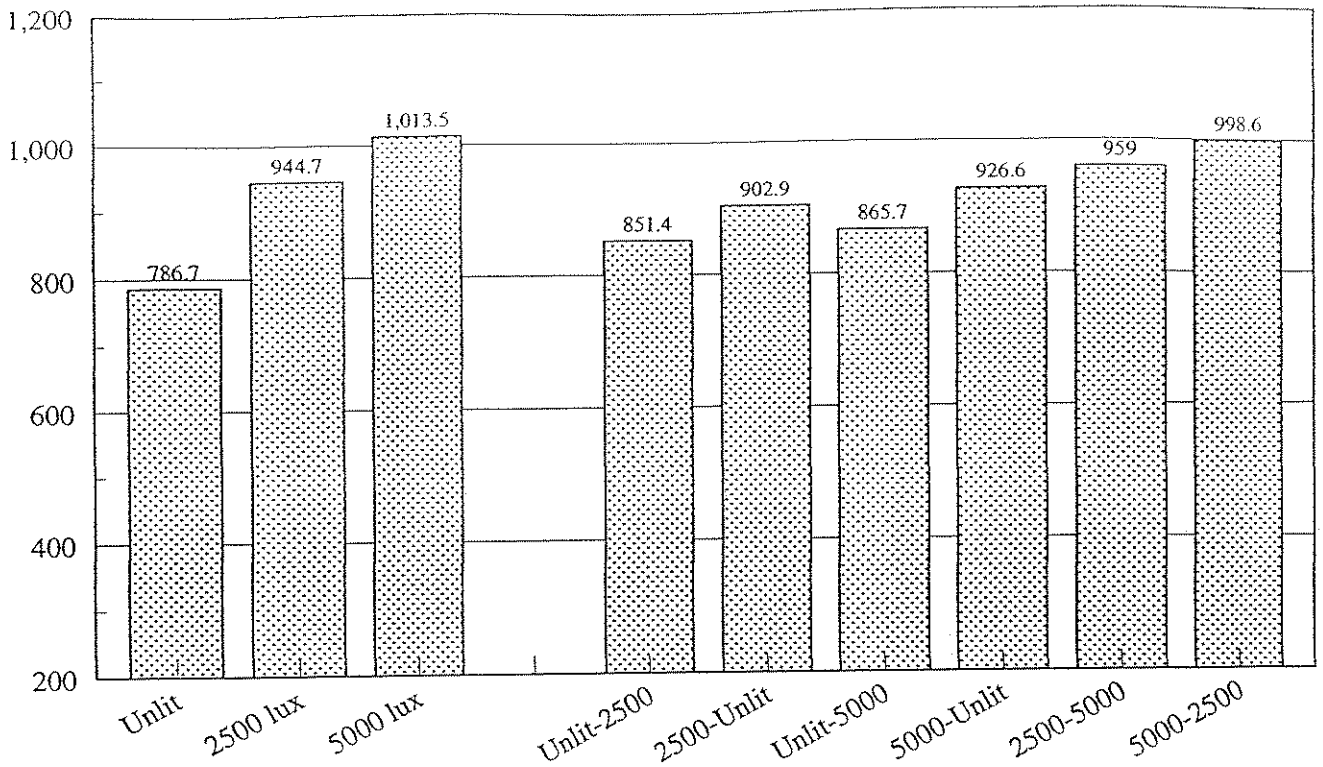
Plant Dry Weight (g)



d.f = 8
SED = +/- 0.6
LSD = +/- 1.4

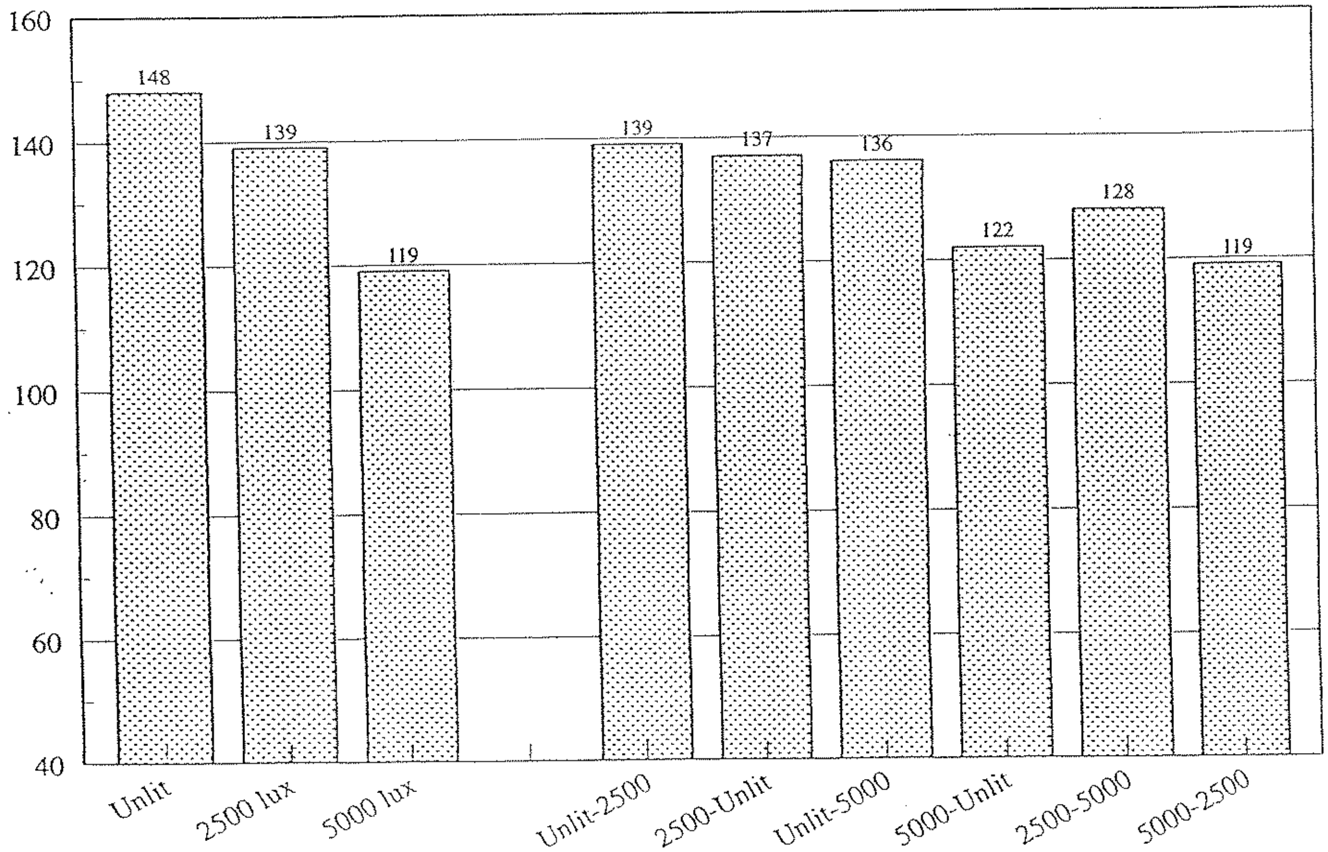
Ficus robusta

Leaf Area (mm^2)



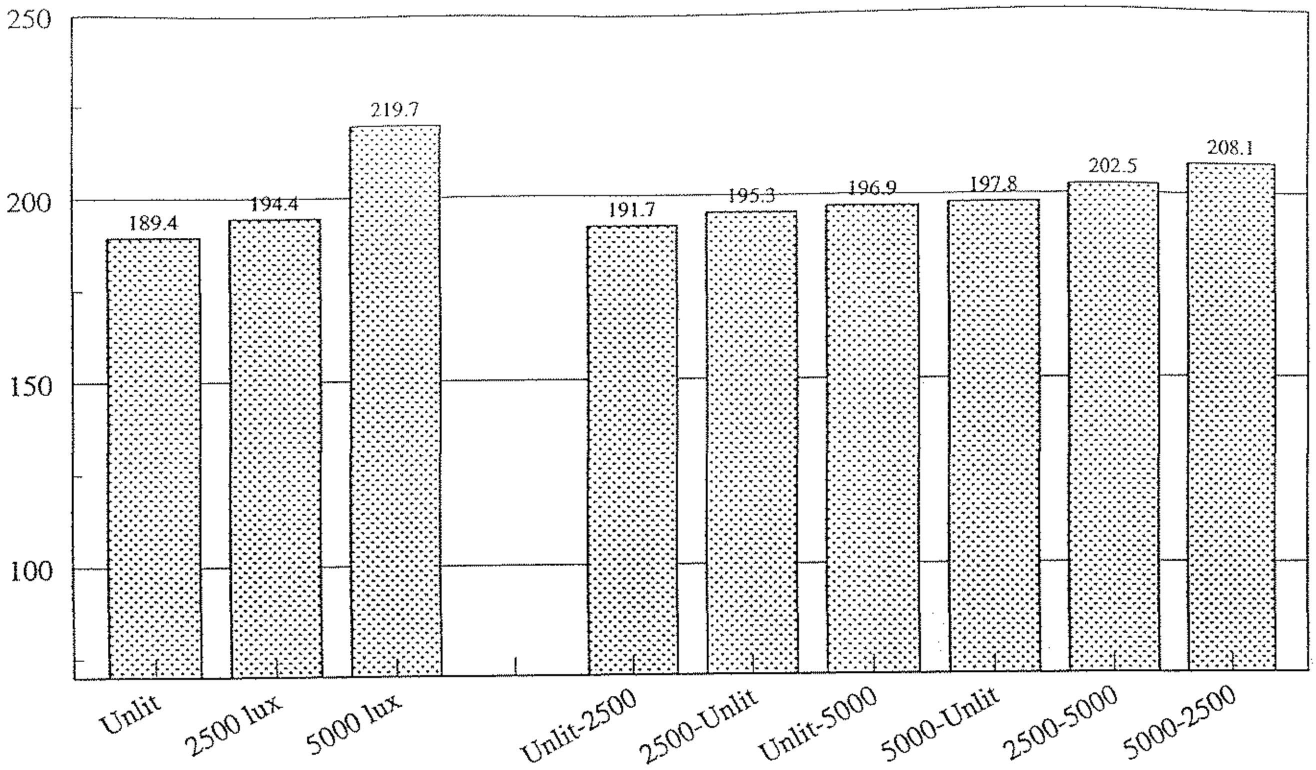
d.f = 8
SED = +/- 46.6
LSD = +/- 107.4

No. of Days to Marketing



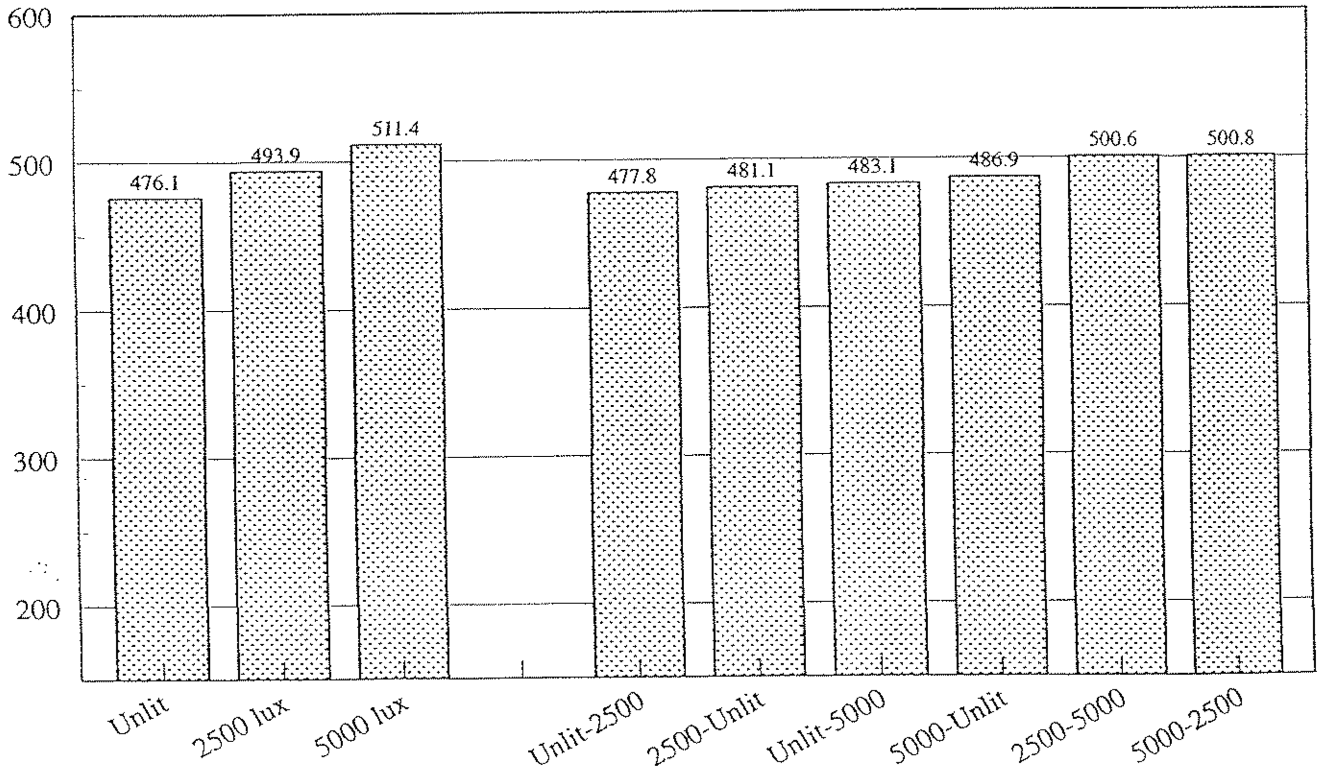
Nephrolepis

Plant Height (mm)



d.f = 8
SED = +/- 8.1
LSD = +/- 18.7

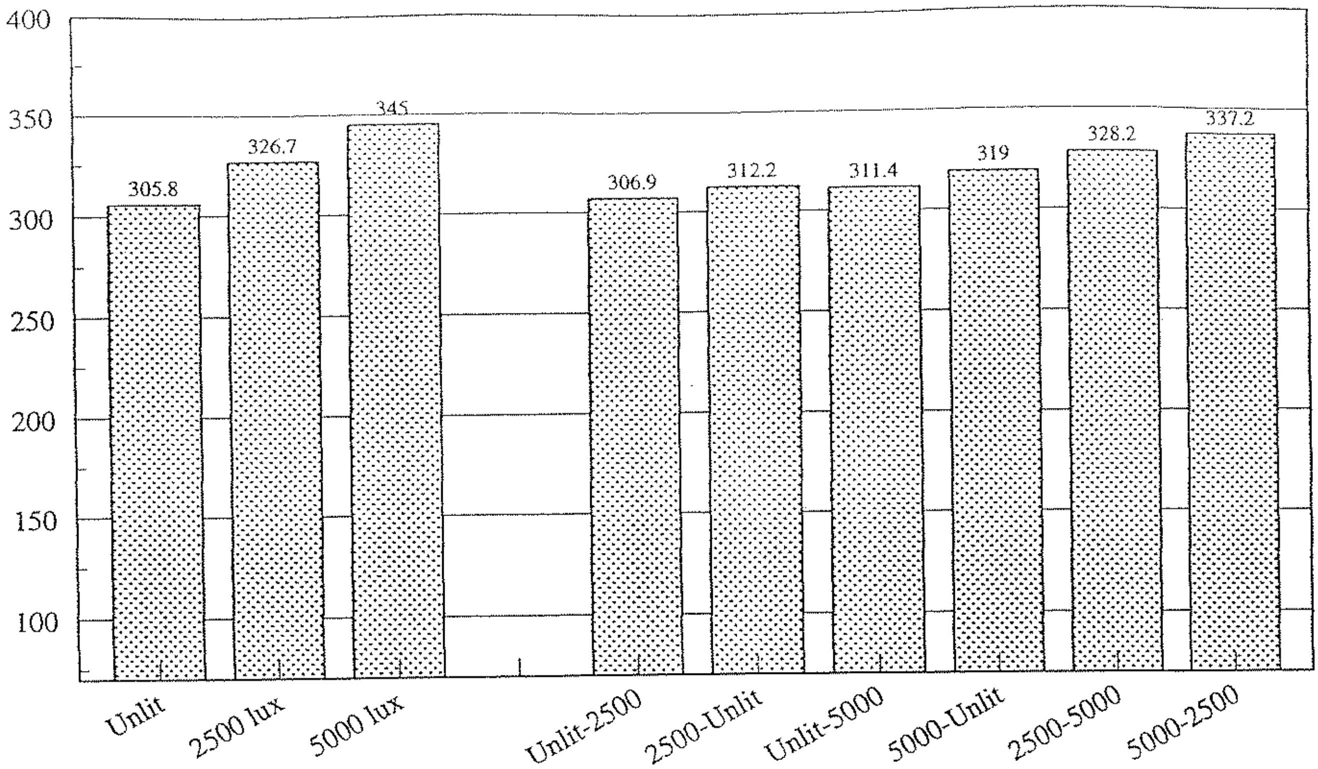
Plant Spread (mm)



d.f = 8
SED = +/- 21.1
LSD = +/- 48.6

Nephrolepis

Frond Length (mm)



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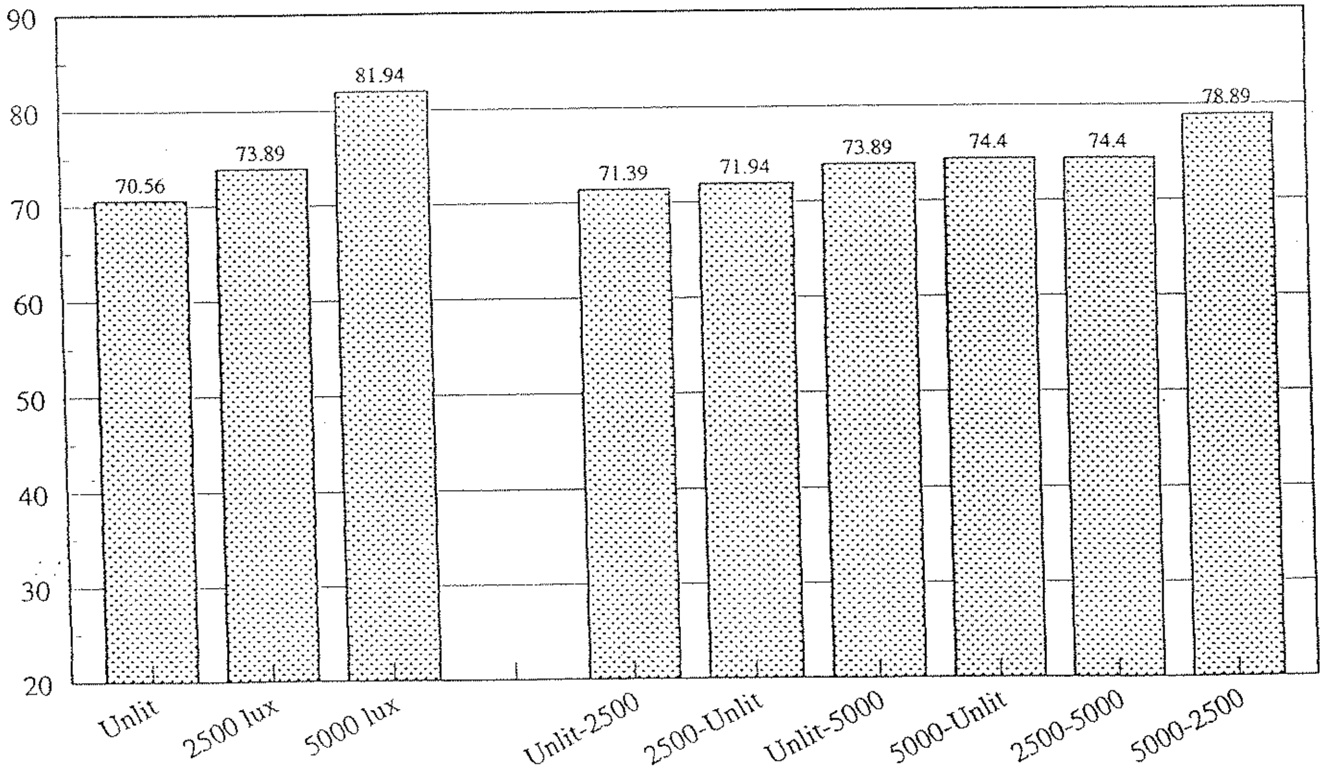
SED = +/- 12.3
LSD = +/- 28.4

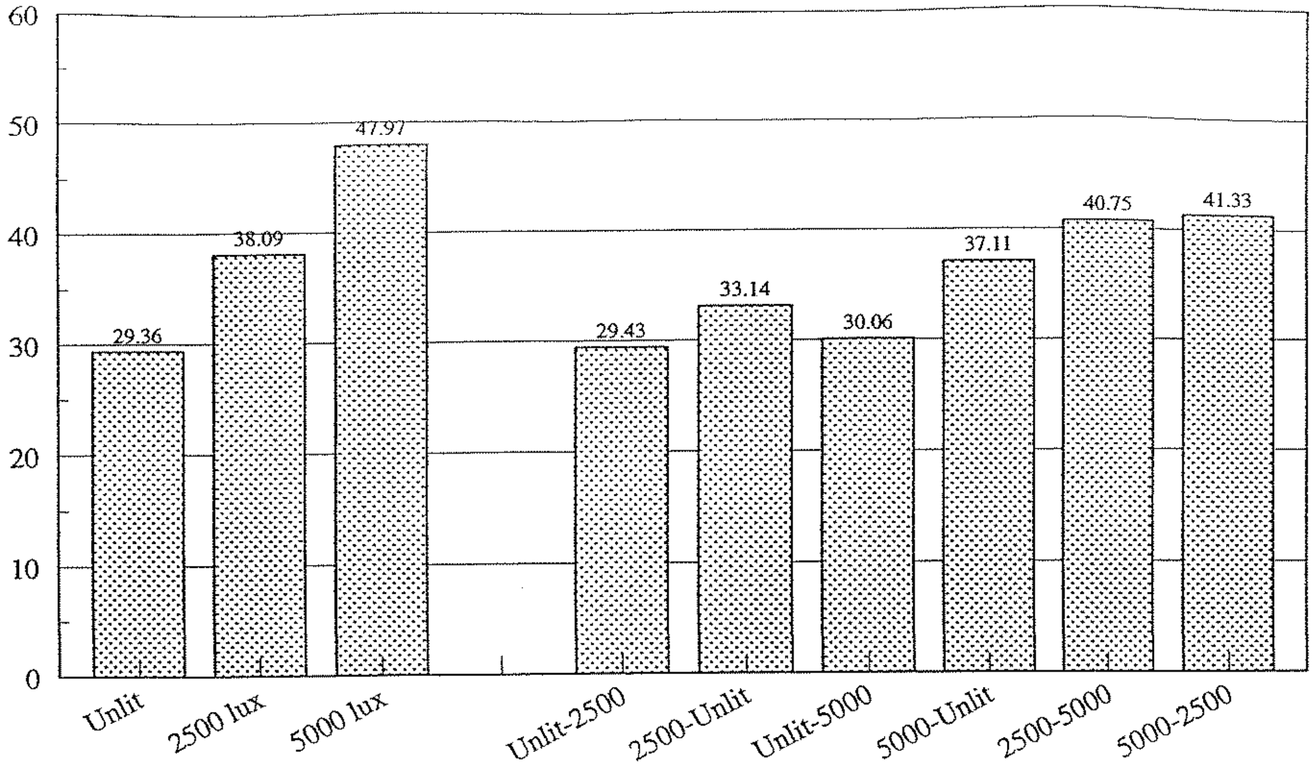
Frond Width (mm)



d.f = 8
SED = +/- 3.3
LSD = +/- 7.7

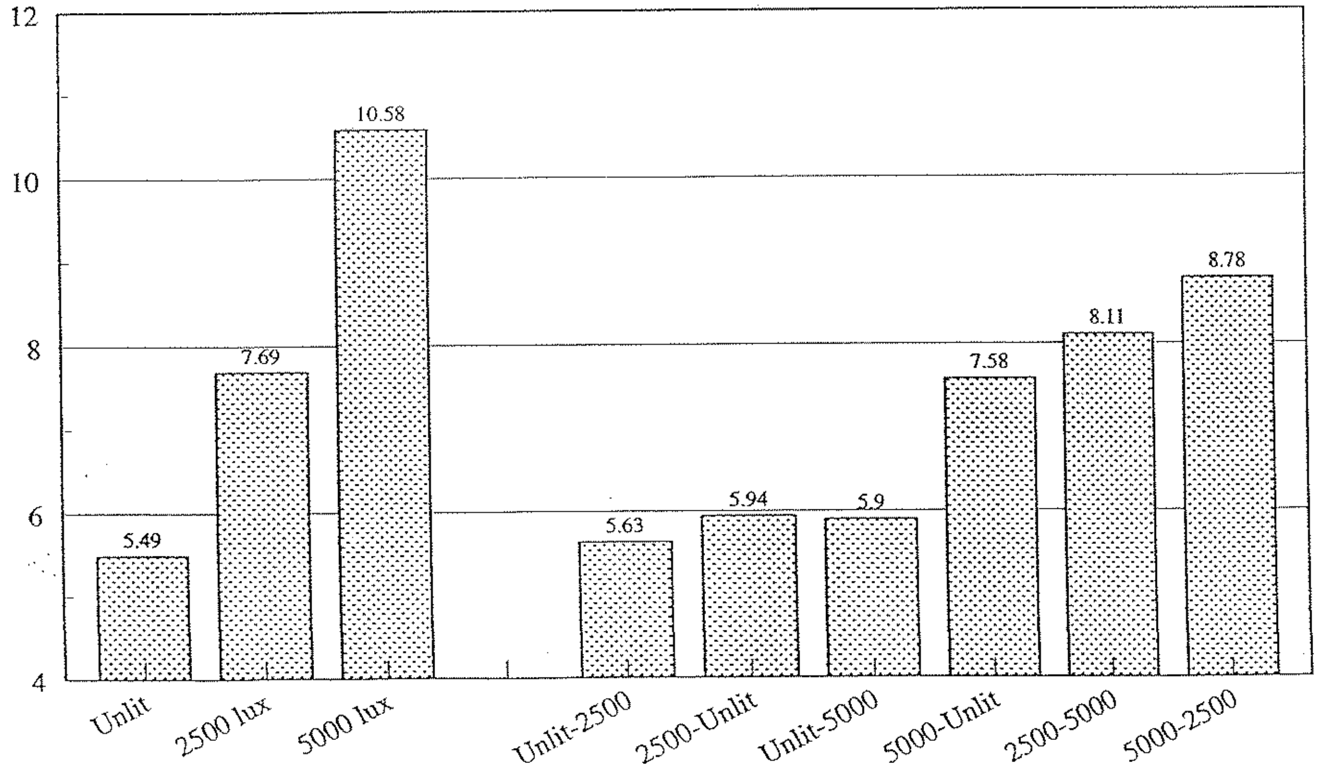
Nephrolepis

Plant Fresh Weight (g)

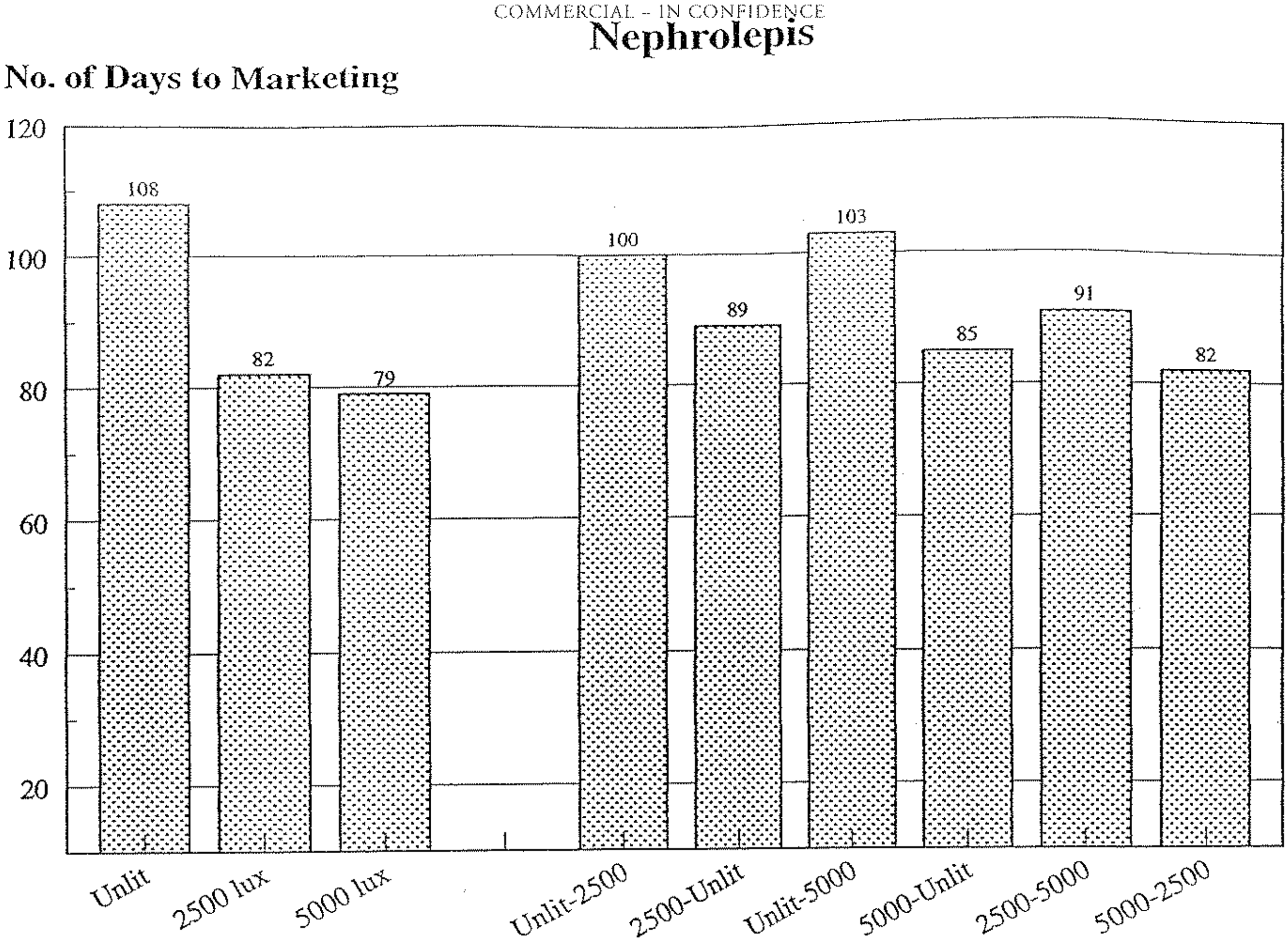


d.f = 8
SED = +/- 4.6
LSD = +/- 10.6

Plant Dry Weight (g)

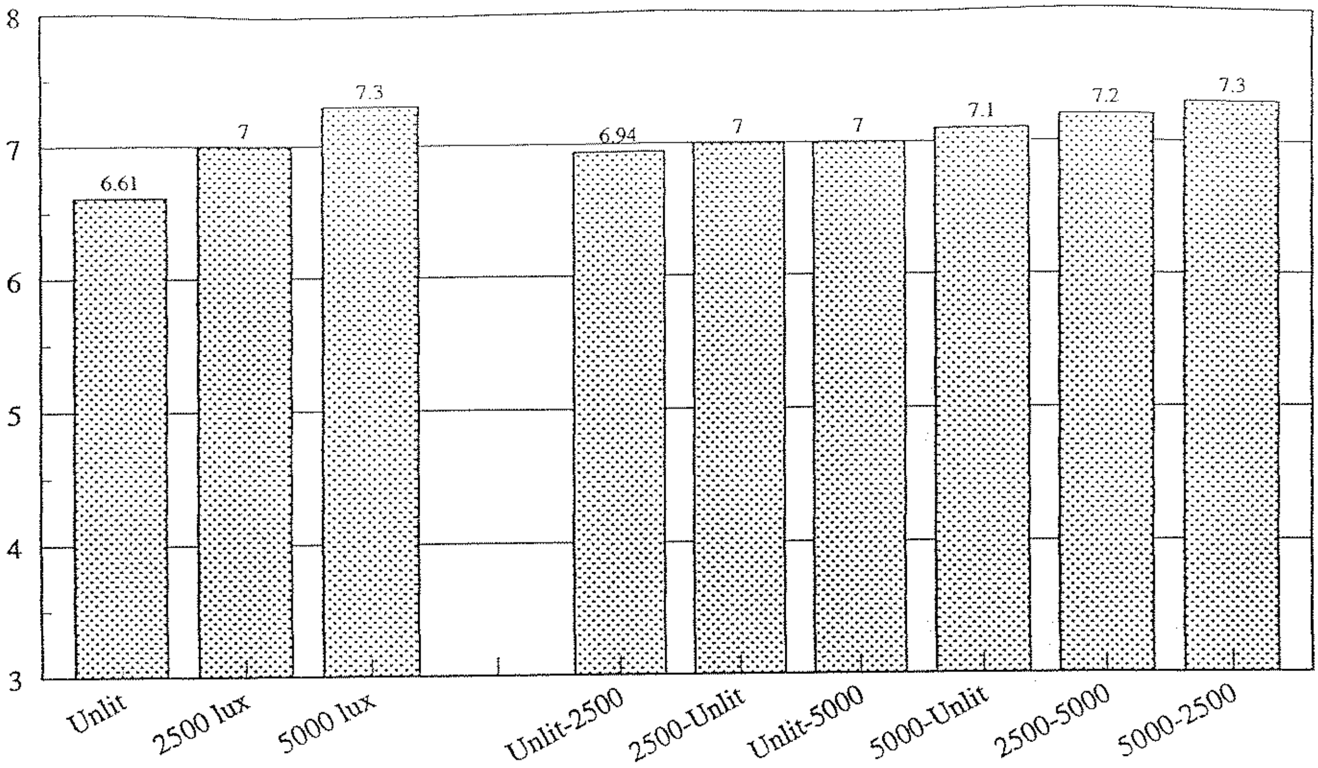


d.f = 8
SED = +/- 0.97
LSD = +/- 2.2


Nephrolepis
No. of Days to Marketing
120
100
80
60
40
20
108
82
79
100
89
103
85
91
82
Unlit
2500 lux
5000 lux
Unlit-2500
2500-Unlit
Unlit-5000
5000-Unlit
2500-5000
5000-2500

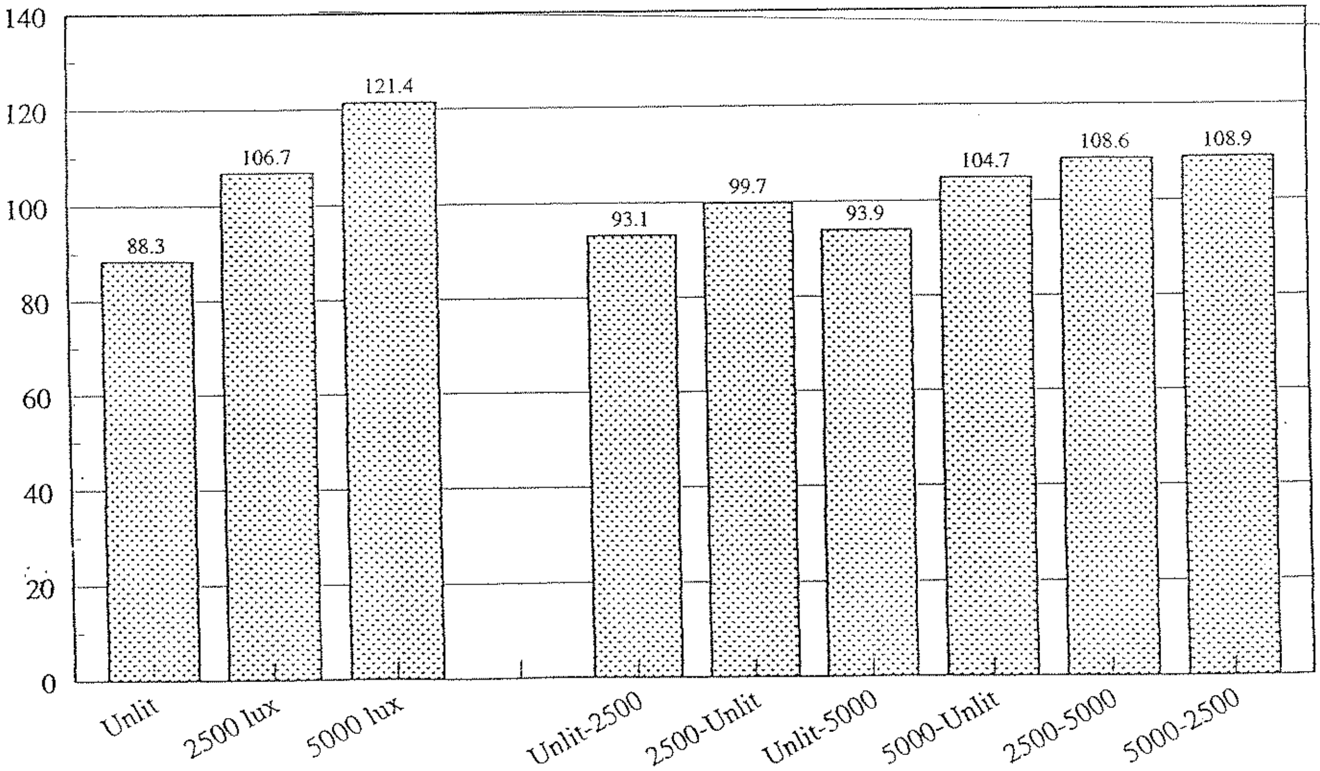
Hedera

Total No. of Trails



d.f = 8
SED = +/- 0.19
LSD = +/- 0.45

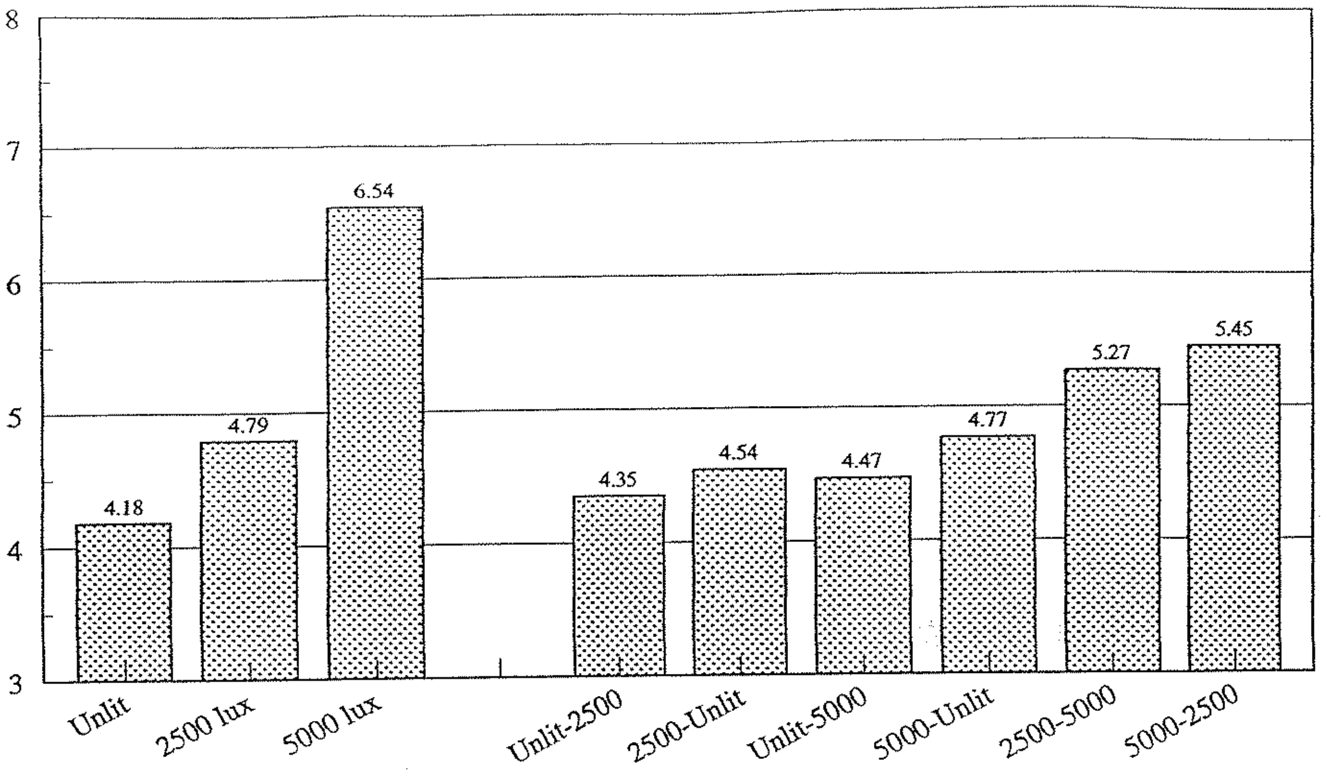
Length of Trails (mm)



d.f = 8
SED = +/- 7.8
LSD = +/- 18.0

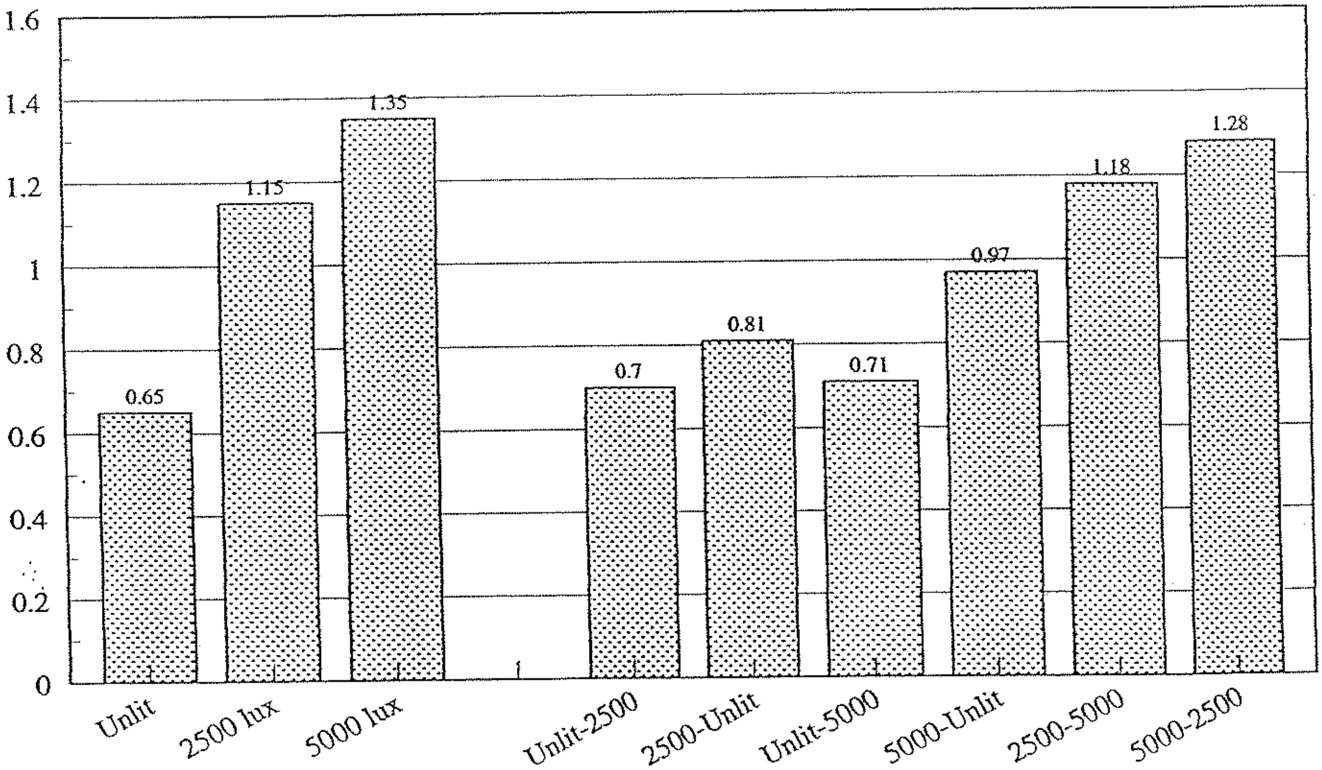
Hedera

Plant Fresh Weight (g)



d.f = 8
SED = +/- 0.53
LSD = +/- 1.23

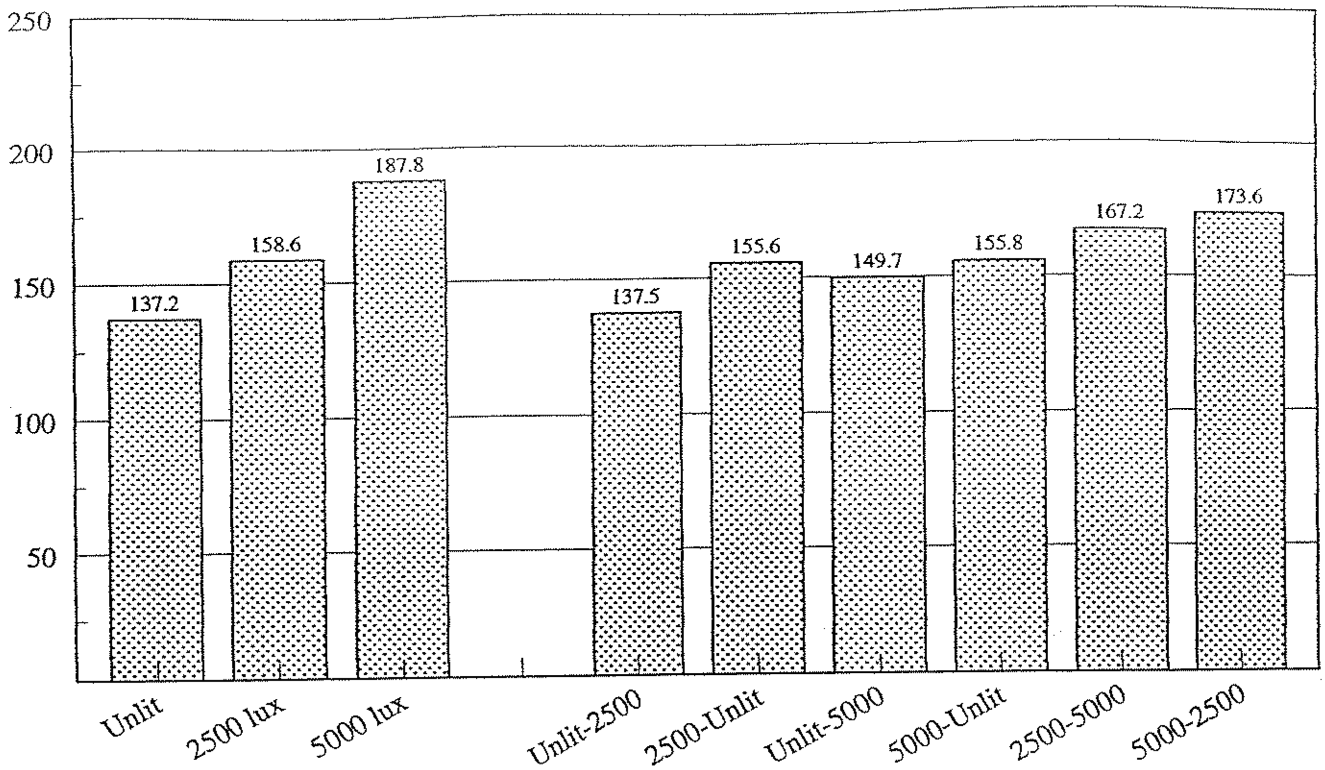
Plant Dry Weight (g)



d.f = 8
SED = +/- 0.18
LSD = +/- 0.39

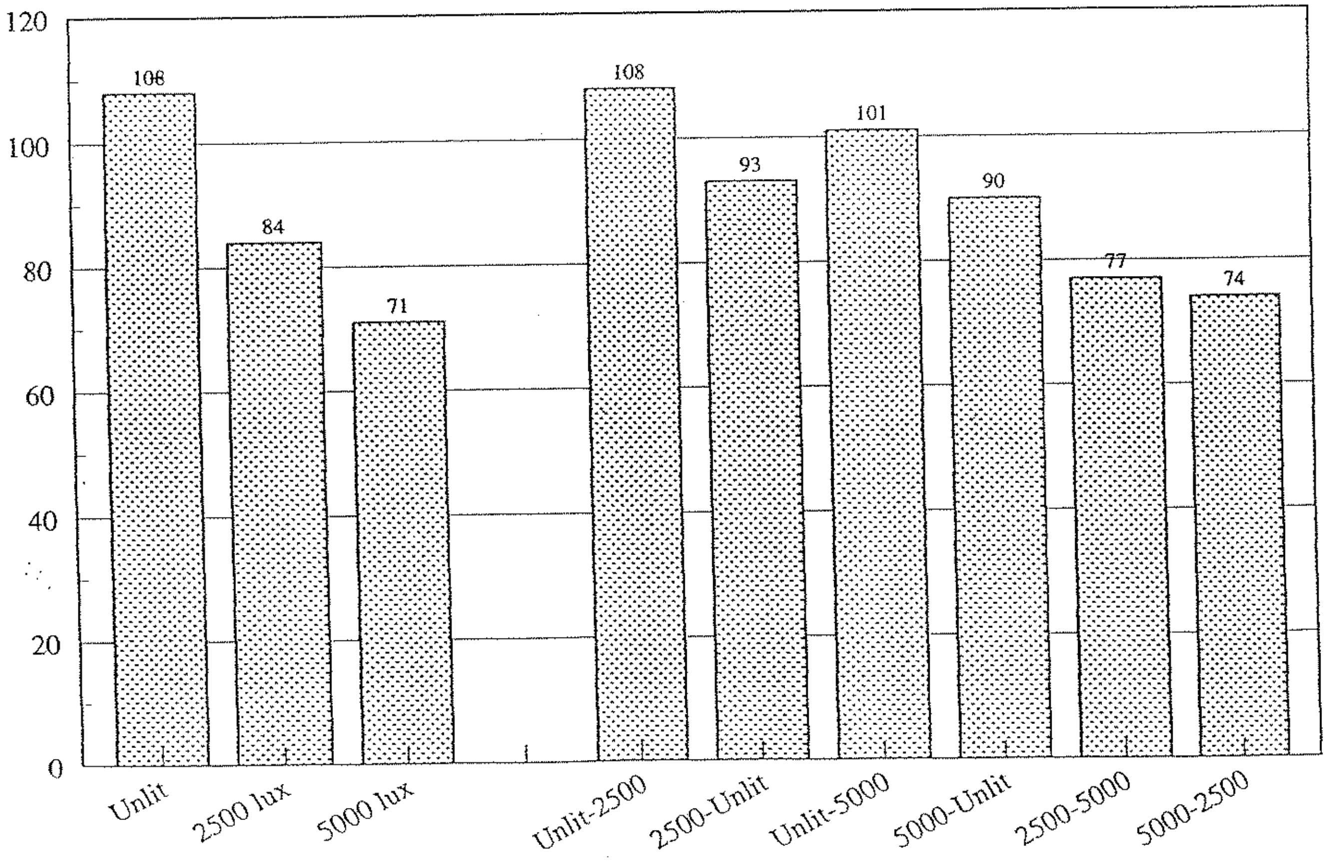
Hedera

Plant Spread (mm)



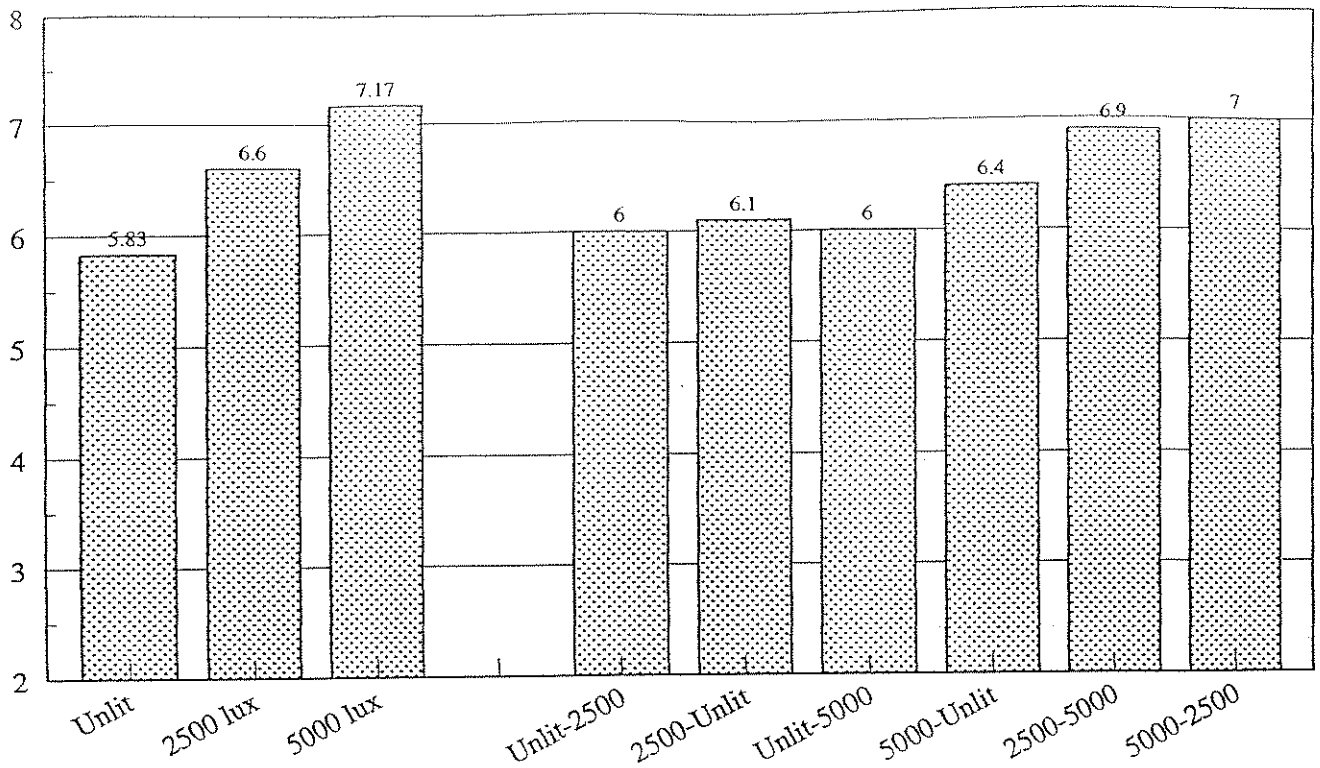
d.f = 8
SED = +/- 7.5
LSD = +/- 17.3

No. of Days to Marketing



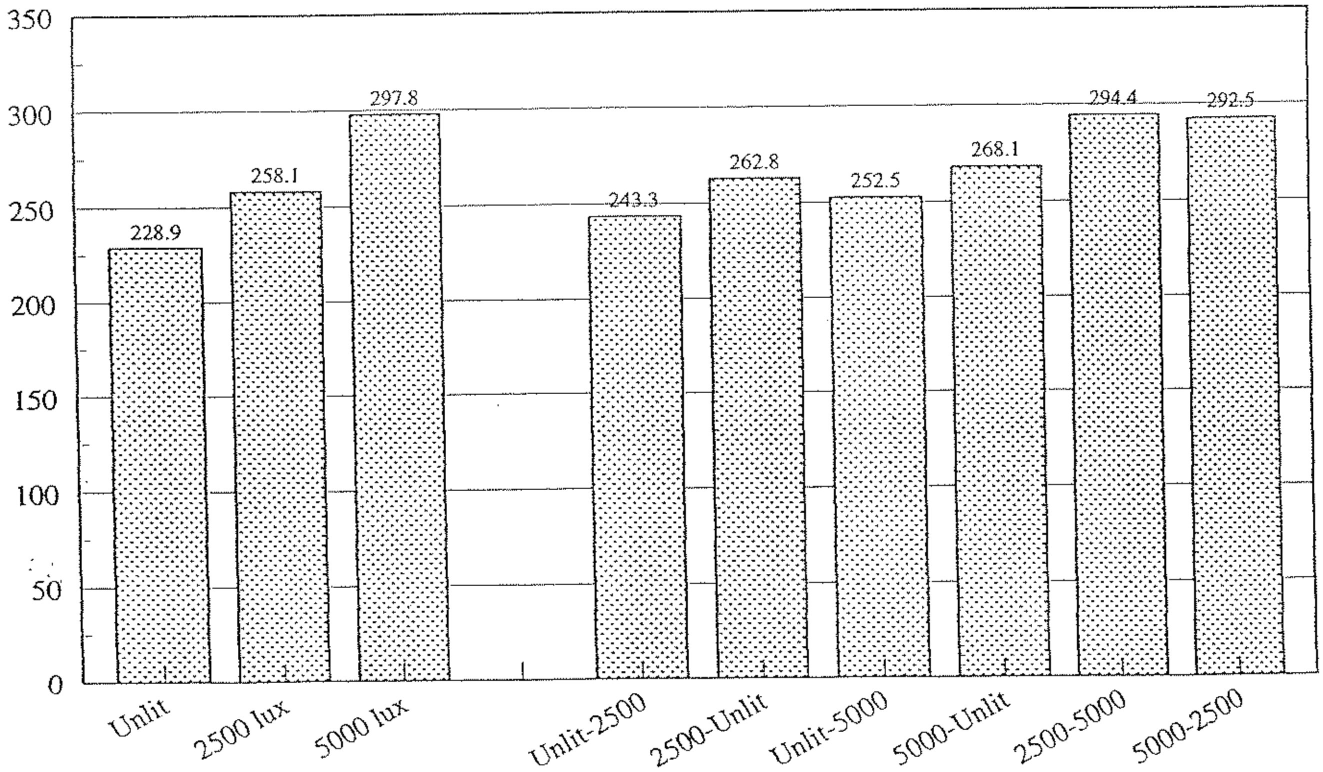
Tradescantia

No. of Internodes



d.f = 8
SED = +/- 0.20
LSD = +/- 0.47

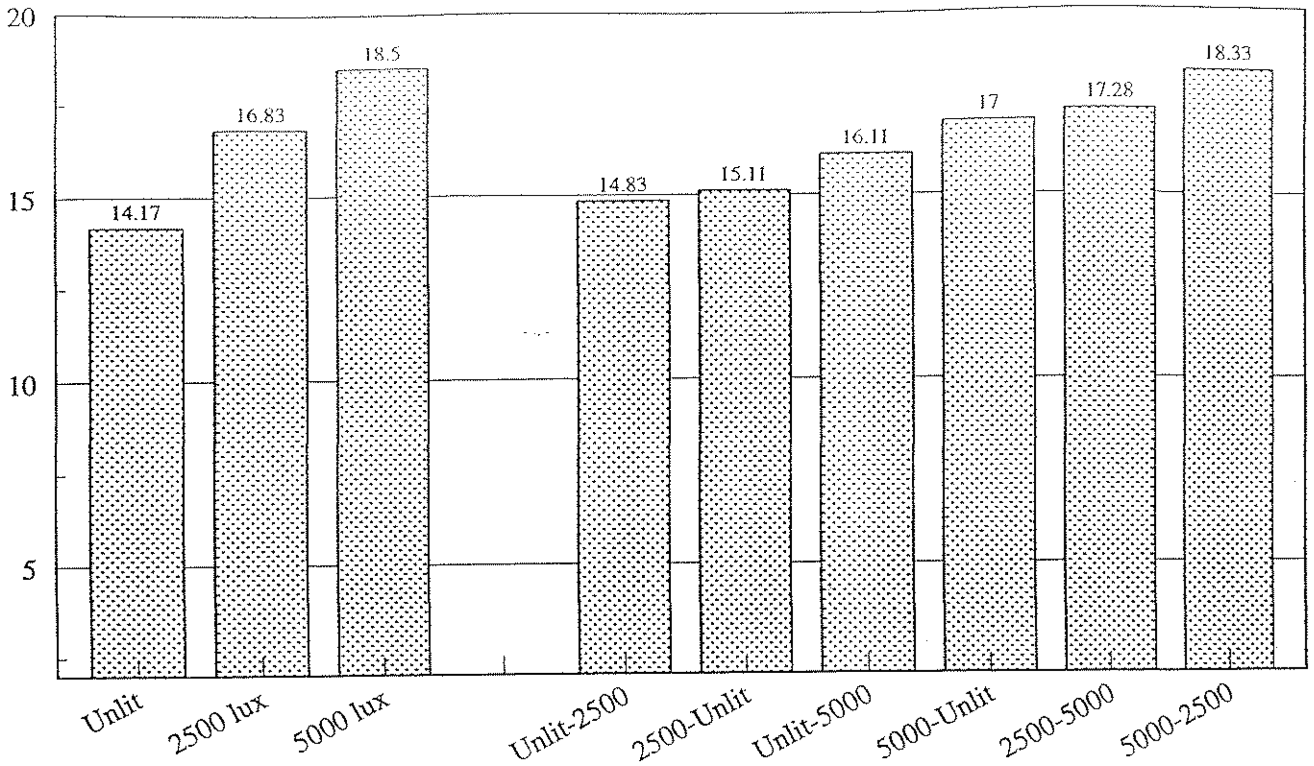
Trail Length (mm)



d.f = 8
SED = +/- 9.5
LSD = +/- 21.8

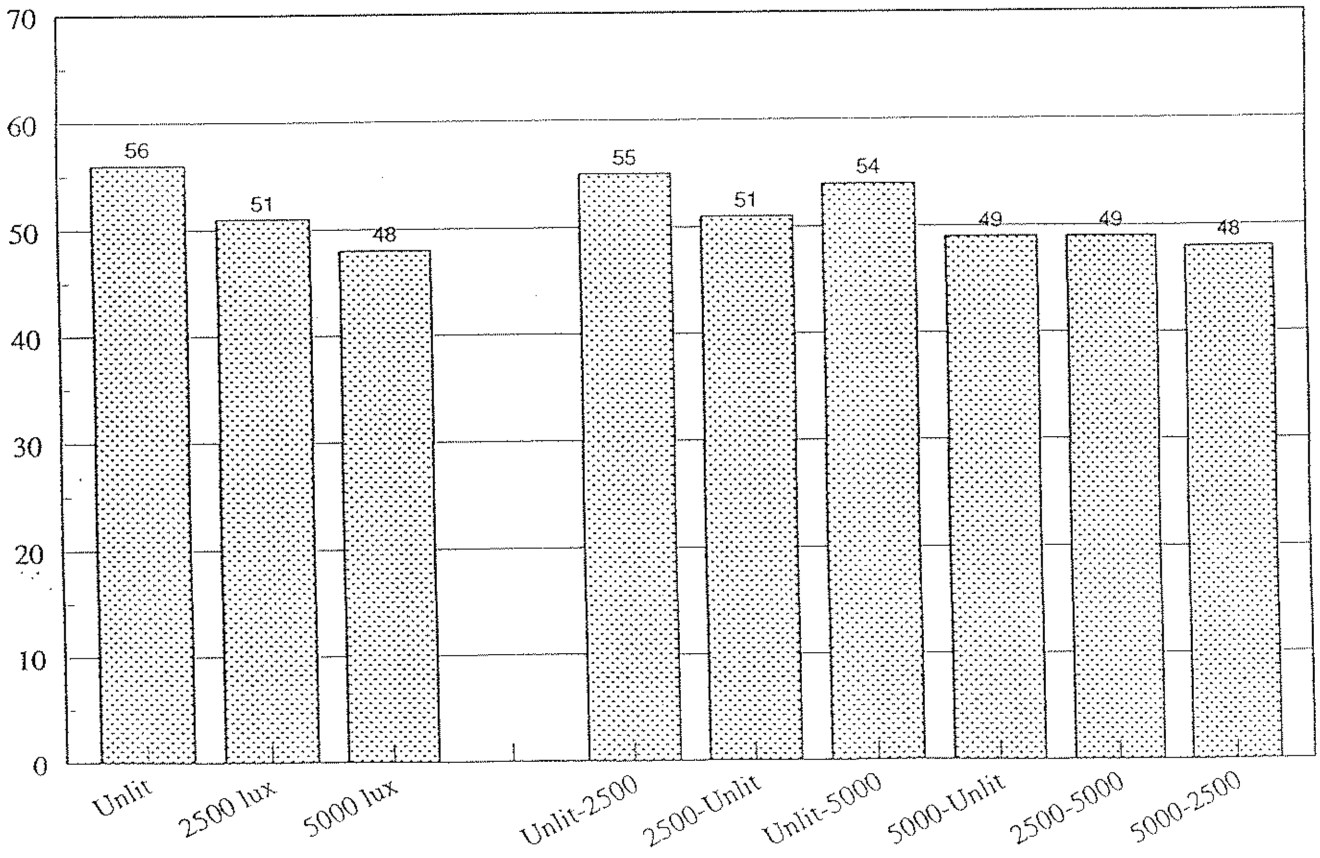
Tradescantia

Total No. of Trails



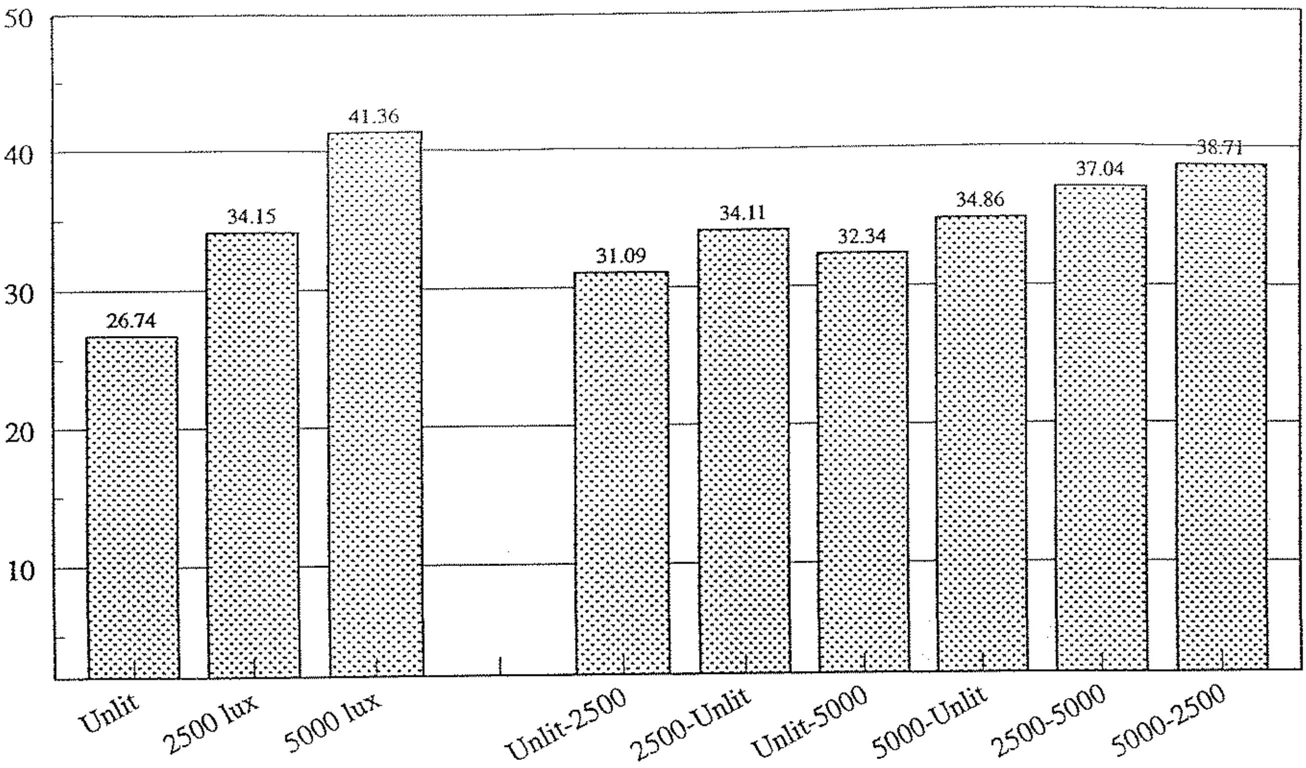
d.f = 8
SED = +/- 1.0
LSD = +/- 2.4

No. of Days to Marketing



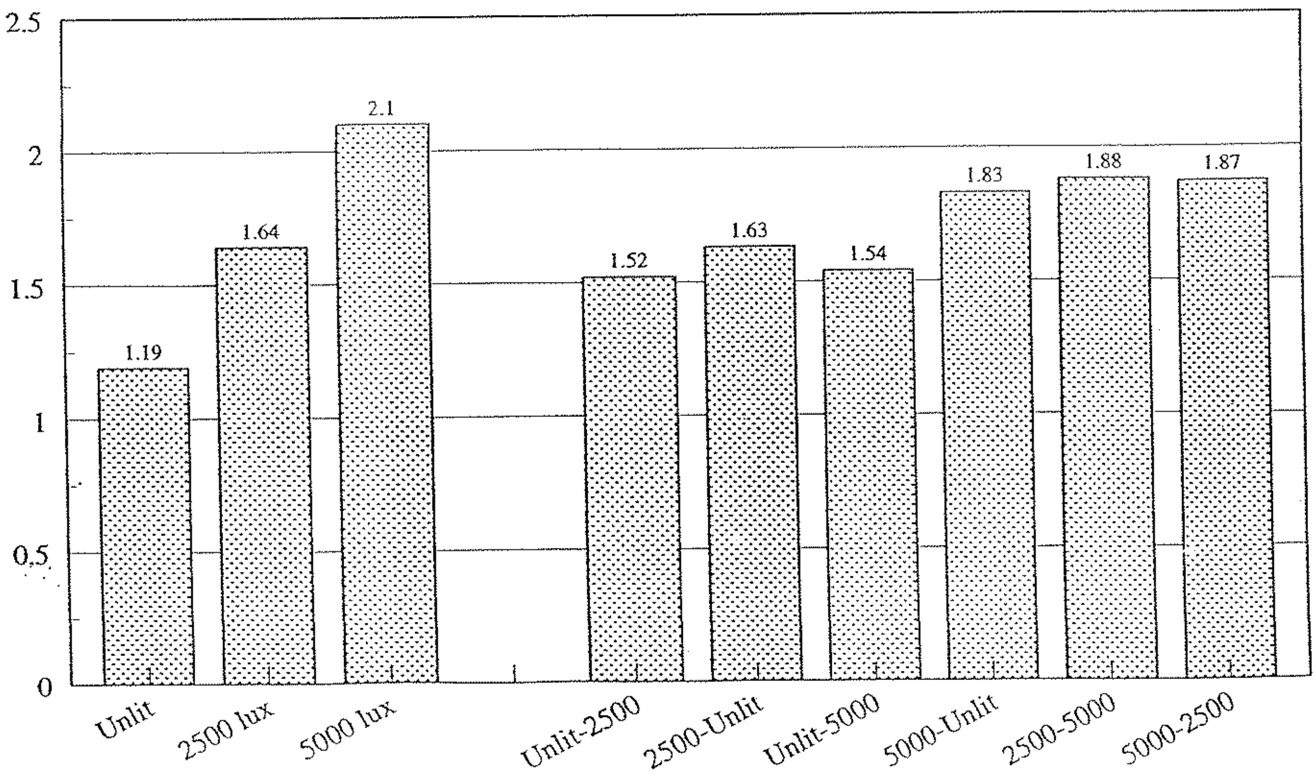
Tradescantia

Plant Fresh Weight (g)



d.f = 8
SED = +/- 1.7
LSD = +/- 3.9

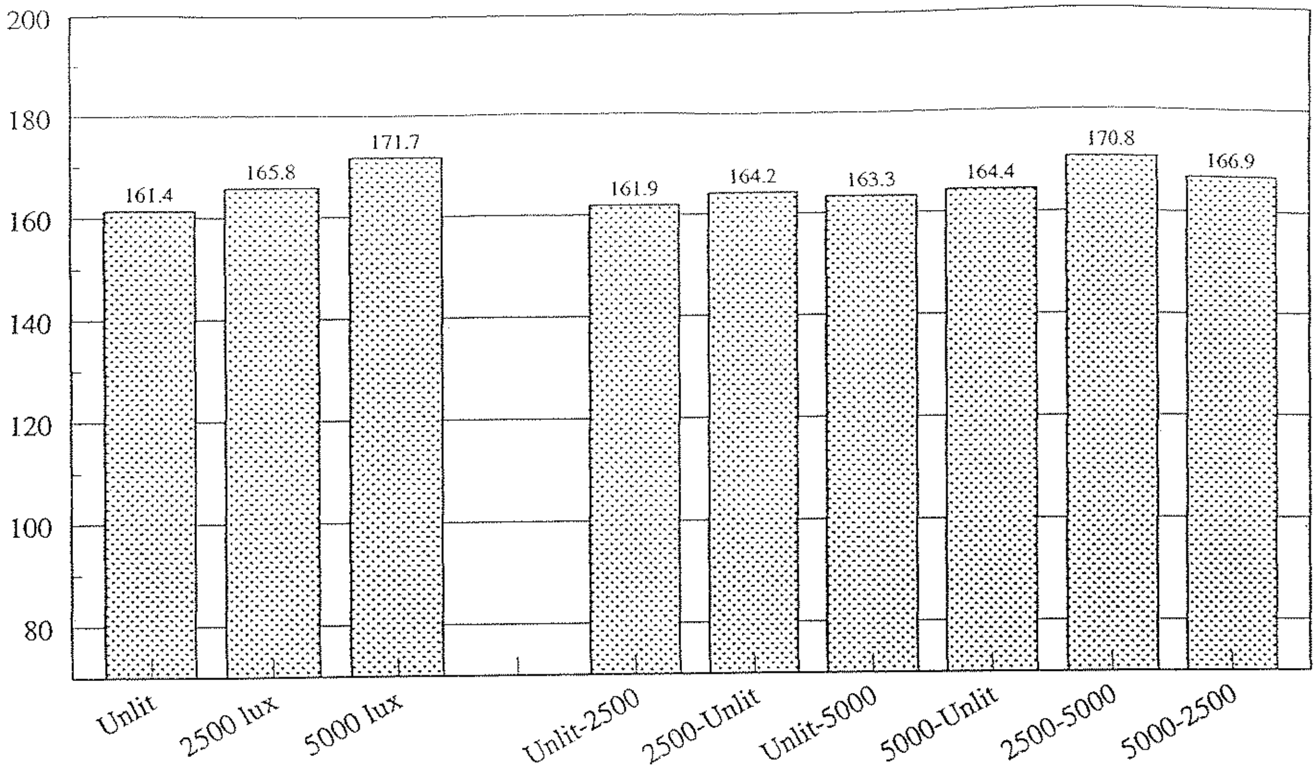
Plant Dry Weight (g)



d.f = 8
SED = +/- 0.1
LSD = +/- 0.2

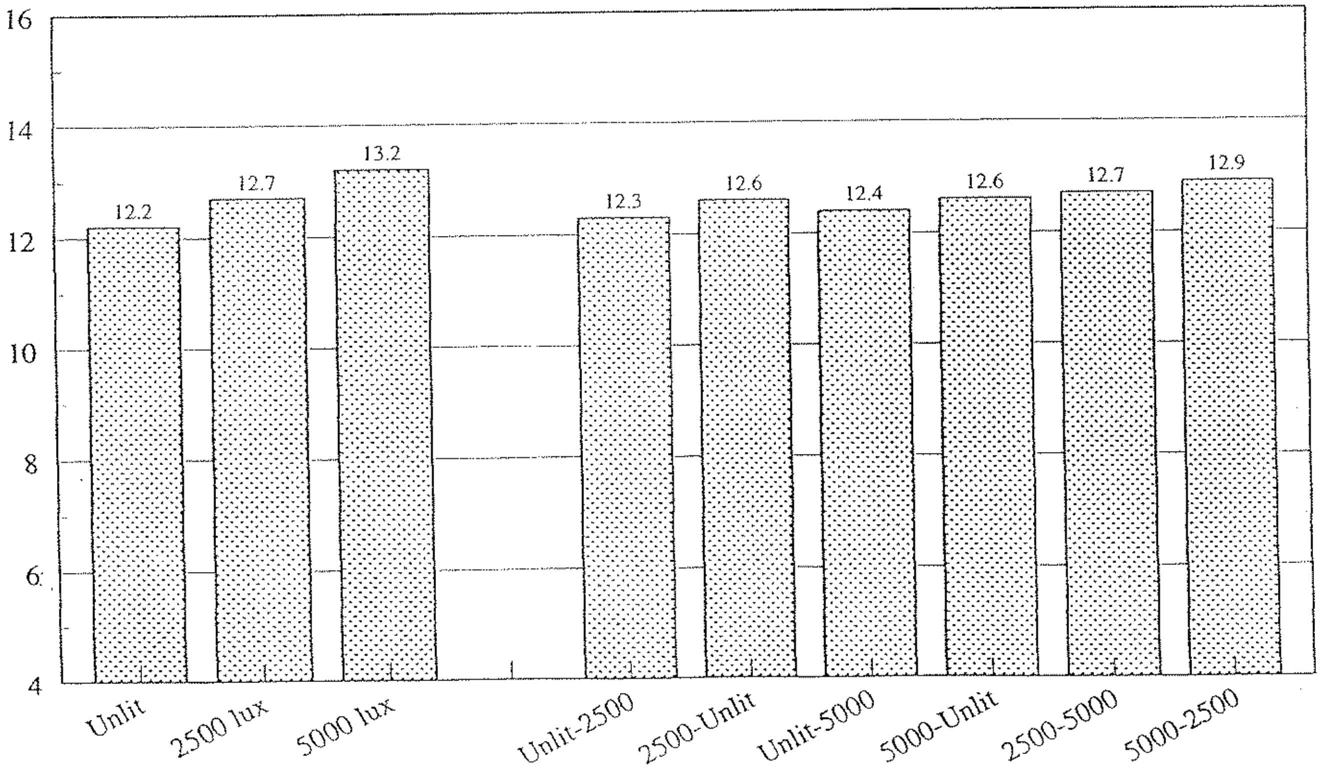
Dracaena

Plant Height (mm)



d.f = 8
SED = +/- 3.1
LSD = +/- 7.1

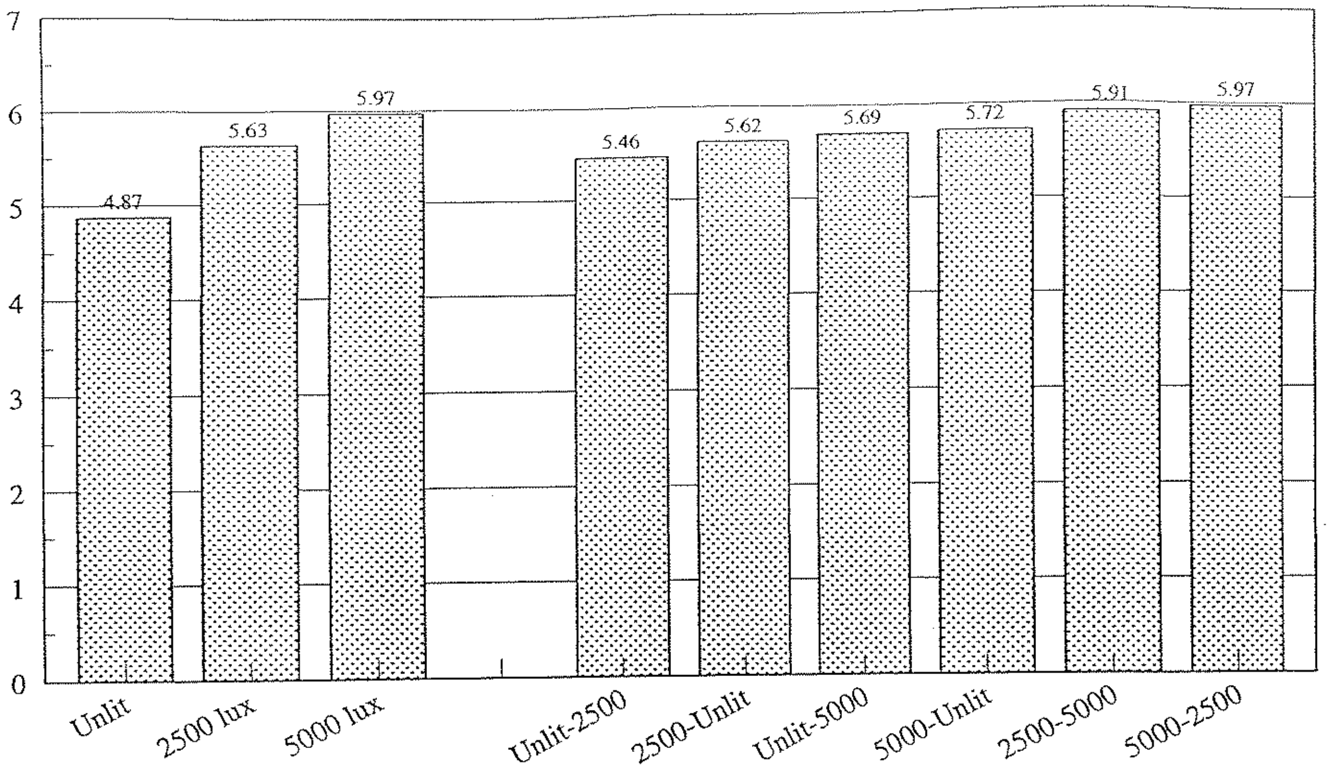
Leaf Number



d.f = 8
SED = +/- 0.23
LSD = +/- 0.53

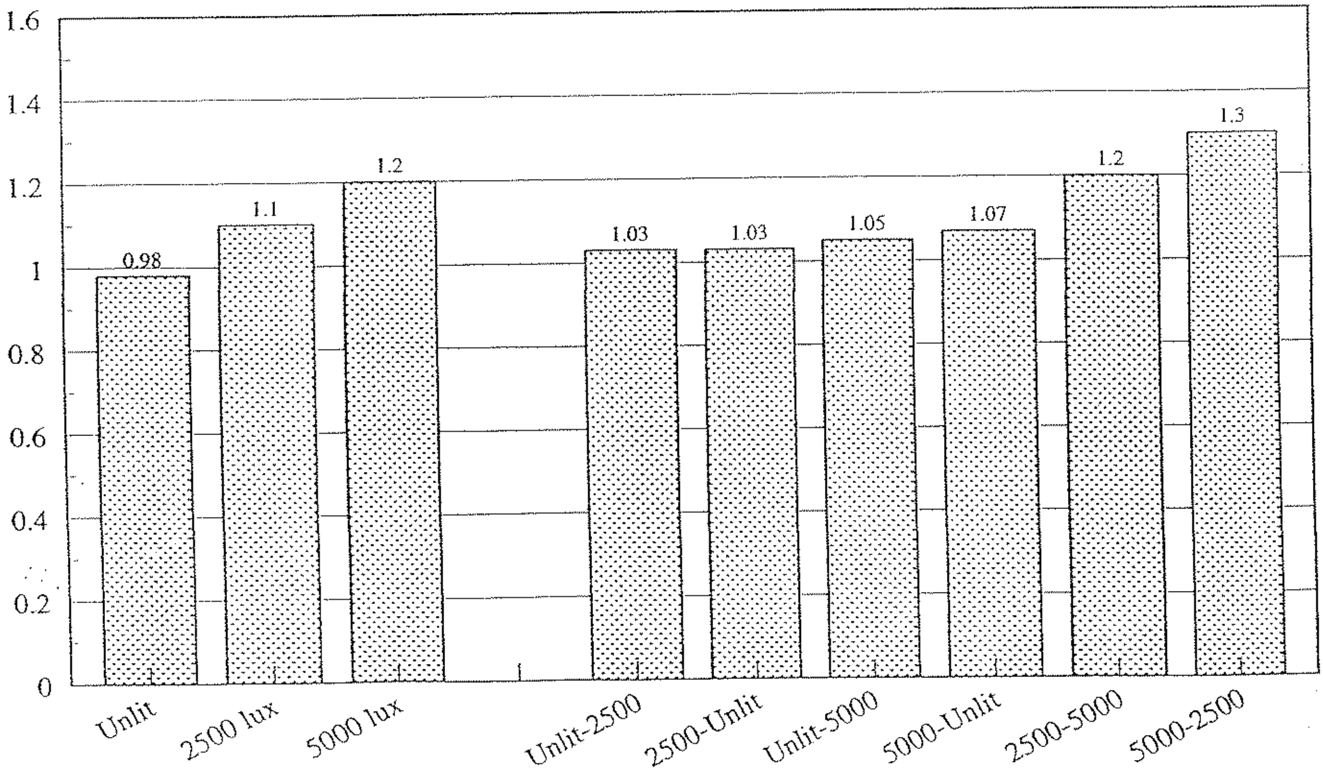
Dracaena

Plant Fresh Weight (g)



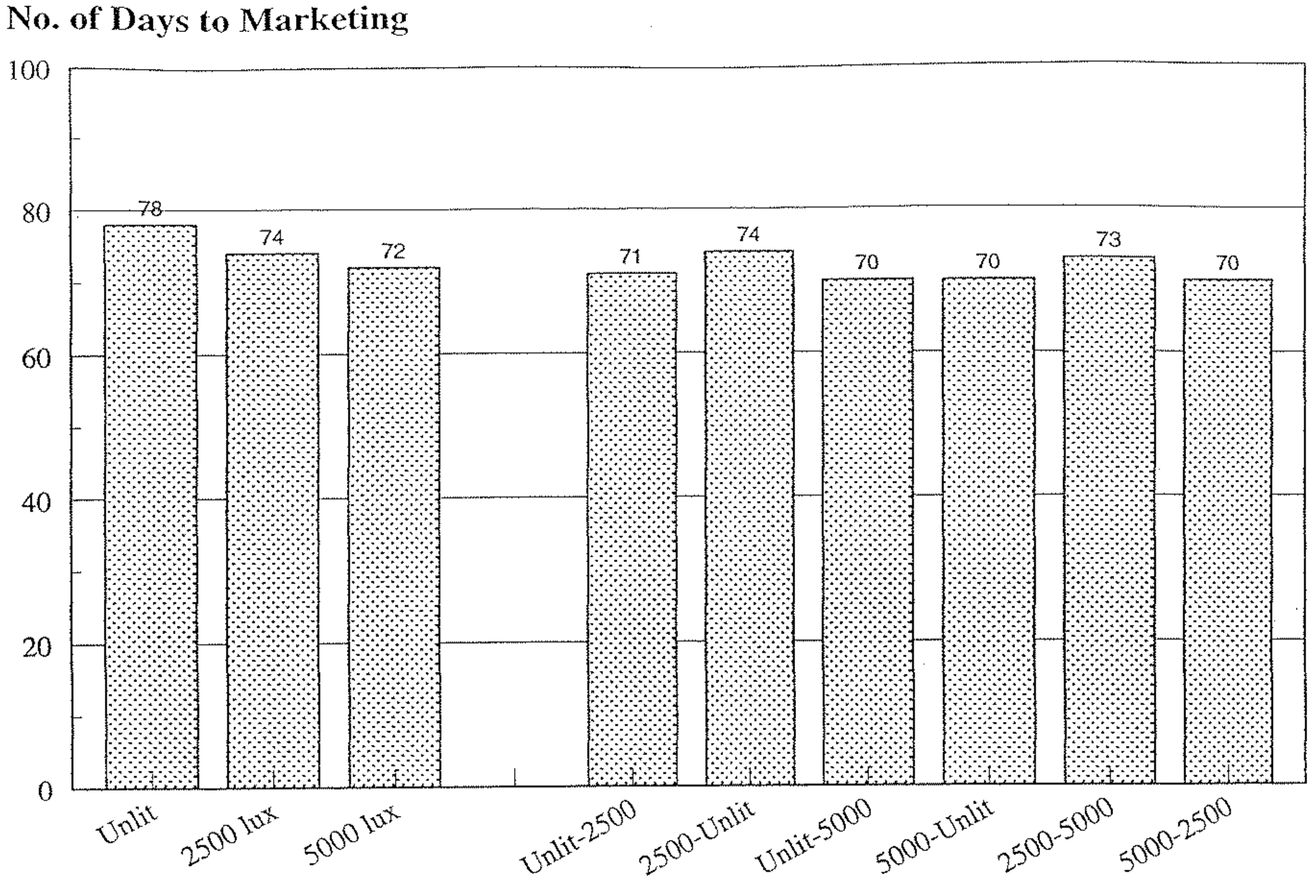
d.f = 8
SED = +/- 0.27
LSD = +/- 0.62

Plant Dry Weight (g)



d.f = 8
SED = +/- 0.05
LSD = +/- 0.11

Dracaena



No statistical analysis

APPENDIX III

Costs of supplementary lighting

(based on figures used in HDC reports PC 13b and PC 13c)

Assumptions

1. Capital cost of 400W SON/T lamp and installation = £160

2. Illuminance 5000 lux 1 lamp covers $6m^2$
   2500 lux 1 lamp covers $12m^2$

3. Annual capital cost per luminaire assuming amortization over 5 years at 14%

$$\frac{£160}{5\text{yrs}} + \frac{(80 \times 14\%)}{100} = £43.20$$

4. Annual capital cost per m^2

$$@\ 5000\text{ lux} = \frac{43.2}{6} = £7.20/m^2/\text{year}$$

$$@\ 2500\text{ lux} = \frac{43.2}{12} = £3.60/m^2/\text{year}$$

5. Lighting for 7 hours/day (midnight - 7 am)

6. Spacings

These reflected typical commercial spacings.

	Pot thick/ m^2	**Final spacing/ m^2**
Begonia rex	59 (12 weeks)	30
Ficus robusta	59 (12 weeks)	30
Nephrolepis exaltata	59 (10 weeks)	30
Hedera helix	123 (6 weeks)	61
Tradescantia zebrina	123 (4 weeks)	61
Dracaena sanderama	123 (6 weeks)	61

All plants remained pot thick for either 4, 6, 10 or 12 weeks (as above), whilst period of final spacing depended on each lighting treatment.

7. Lighting period November-March, but costings based on commercial winter production period of 26 weeks.

8. Electricity running costs. Each luminaire requires 0.44 kW per hour i.e. 400 watts per lamp plus 40 watts for starter equipment. Off peak midnight - 7 am = 2.61p/kWhr.

APPENDIX IV

Table 8: Water Available Peat Media Analysis

Species: *Begonia rex*

		Unlit	5000 lux
Bulk Density	g/ml	0.595	0.569
pH		6.1	6.1
Conductivity	μs/20C	283 (1)	322 (2)
Nitrate (as N)	mg/l	136 (5)	121 (4)
Ammonium (as N)	mg/l	1.5 (0)	1.5 (0)
Potassium	mg/l	124 (3)	116 (3)
Calcium	mg/l	107	137
Magnesium	mg/l	61 (6)	65 (6)
Phosphorus	mg/l	8 (2)	9 (2)
Iron	mg/l	1.82	1.93
Zinc	mg/l	0.29	0.16
Manganese	mg/l	0.19	0.80
Copper	mg/l	0.04	0.04
Boron	mg/l	<0.01	<0.01

Table 9: Water Available Peat Media Analysis

Species: *Ficus robusta*

		Unlit	5000 lux
Bulk Density	g/ml	0.566	N/A
pH		5.8	N/A
Conductivity	μs/20C	332 (2)	N/A
Nitrate (as N)	mg/l	169 (5)	N/A
Ammonium (as N)	mg/l	1.5 (0)	N/A
Potassium	mg/l	109 (3)	N/A
Calcium	mg/l	123	N/A
Magnesium	mg/l	58 (6)	N/A
Phosphorus	mg/l	7 (2)	N/A
Iron	mg/l	2.2	N/A
Zinc	mg/l	1.34	N/A
Manganese	mg/l	1.31	N/A
Copper	mg/l	0.02	N/A
Boron	mg/l	<0.01	N/A

APPENDIX IV

Table 10: Water Available Peat Media Analysis

Species: *Nephrolepis exaltata*

		Unlit	5000 lux
Bulk Density	g/ml	0.636	0.498
pH		6.0	6.4
Conductivity	μs/20C	469 (3)	266 (1)
Nitrate (as N)	mg/l	193 (5)	85 (4)
Ammonium (as N)	mg/l	1.8 (0)	0.4 (0)
Potassium	mg/l	166 (3)	73 (2)
Calcium	mg/l	199	123
Magnesium	mg/l	113 (7)	60 (6)
Phosphorus	mg/l	13 (3)	9 (2)
Iron	mg/l	3.12	5.50
Zinc	mg/l	0.27	0.25
Manganese	mg/l	1.09	1.09
Copper	mg/l	0.07	0.09
Boron	mg/l	<0.01	0.21

Table 11: Water Available Peat Media Analysis

Species: *Hedera helix*

		Unlit	5000 lux
Bulk Density	g/ml	0.595	0.579
pH		5.7	6.1
Conductivity	μs/20C	616 (5)	368 (2)
Nitrate (as N)	mg/l	295 (6)	139 (5)
Ammonium (as N)	mg/l	5.5 (0)	1.8 (0)
Potassium	mg/l	361 (5)	126 (3)
Calcium	mg/l	194	149
Magnesium	mg/l	95 (7)	76 (6)
Phosphorus	mg/l	25 (4)	13 (3)
Iron	mg/l	2.41	8.23
Zinc	mg/l	0.32	0.38
Manganese	mg/l	2.34	1.47
Copper	mg/l	0.08	0.11
Boron	mg/l	<0.01	0.02

APPENDIX IV

Table 12: Water Available Peat Media Analysis

Species: *Tradescantia zebrina*

		Unlit	**5000 lux**
Bulk Density	g/ml	0.481	0.517
pH		6.8	6.6
Conductivity	μs/20C	130 (0)	122 (0)
Nitrate (as N)	mg/l	5 (0)	2 (0)
Ammonium (as N)	mg/l	0.6 (0)	0.6 (0)
Potassium	mg/l	6 (0)	6 (0)
Calcium	mg/l	63	58
Magnesium	mg/l	33 (4)	30 (4)
Phosphorus	mg/l	6 (1)	5 (1)
Iron	mg/l	12.32	15.47
Zinc	mg/l	0.37	0.28
Manganese	mg/l	0.39	0.52
Copper	mg/l	0.04	0.05
Boron	mg/l	<0.01	<0.01

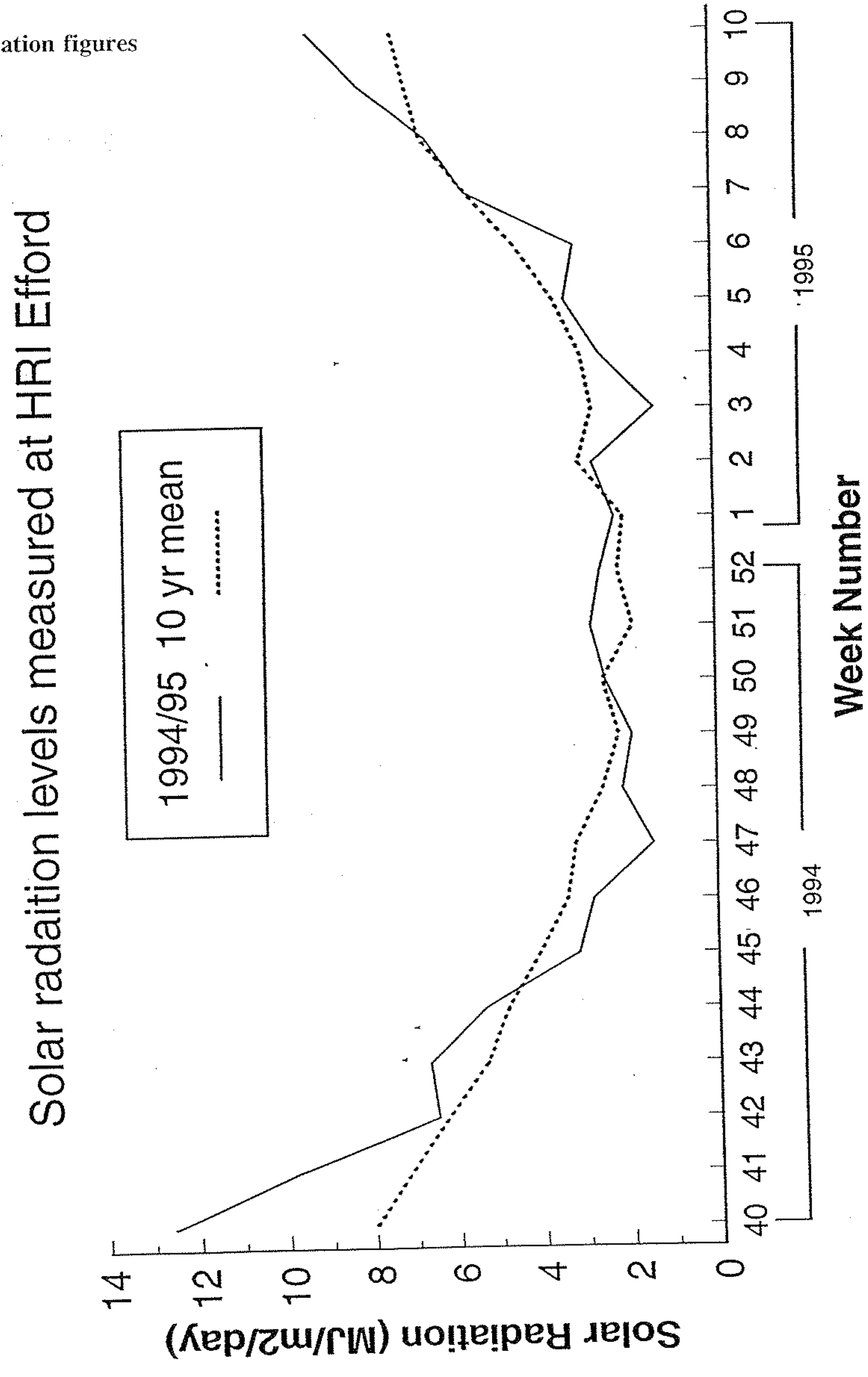
Table 13: Water Available Peat Media Analysis

Species: *Dracaena sanderama*

		Unlit	**5000 lux**
Bulk Density	g/ml	0.510	0.500
pH		6.2	6.3
Conductivity	μs/20C	258 (1)	281 (1)
Nitrate (as N)	mg/l	112 (4)	101 (4)
Ammonium (as N)	mg/l	0.6 (0)	0.7 (0)
Potassium	mg/l	115 (3)	112 (3)
Calcium	mg/l	106	131
Magnesium	mg/l	48 (5)	58 (6)
Phosphorus	mg/l	11 (2)	12 (3)
Iron	mg/l	12.69	7.97
Zinc	mg/l	0.38	1.97
Manganese	mg/l	0.64	0.54
Copper	mg/l	0.04	0.04
Boron	mg/l	<0.01	<0.01

APPENDIX V

Solar radiation figures



Copy of contract, terms and conditions

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

1. TITLE OF PROJECT

Contract No: PC 112
Contract date: 24.4.95

FOLIAGE PLANTS: IMPROVING WINTER PRODUCTION AND PLANT QUALITY WITH THE USE OF SUPPLEMENTARY LIGHTING.

2. BACKGROUND/COMMERCIAL OBJECTIVE

In the UK in recent years the market demand for foliage plants has continued to increase. Foliage plants are becoming an important part of the horticultural industry. Main production is centred in Germany, Denmark and the Netherlands which both have strong home markets and export links. There are a limited number of UK growers at this time producing large quantities of foliage plants, but there is a definite growth in home production for the UK market as well as a potential for export. Problems exist with winter production, in that plant growth and habit can suffer and overall plant quality is reduced. Erratic crop scheduling, and length of production for some species can become excessively long and uneconomic.

There is little published material related directly to winter production of foliage plants in the UK. Research at HRI Efford in 1993 funded by the Electricity Association Technology Ltd (EAT Ltd), established the benefits which can be gained from the use of supplementary lighting during the winter period. Further research is required to elevate light levels and periods in which to light crops which will be both practical and economically beneficial to growers.

3. POTENTIAL FINANCIAL BENEFIT TO INDUSTRY

Improved plant growth with potential reduction in production time enabling more efficient use of facilities available to the grower. Development of good production techniques to reduce costs due to plant losses through poor quality, unsalable plants. Improved plant quality of final product to achieve better shelf-life for retailer and consumer.

4. SCIENTIFIC/TECHNICAL TARGET FOR THE WORK

Assess response of a range of foliage species to lighting during the winter period and their subsequent performance in a 'home'environment. Established 'response group' for species of foliage plan.

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

Electricity Association Technology:	Improving quality of foliage plants using light and carbon dioxide (1993).
Reading University:	Investigating response of foliage plants to different shade and temperature levels (1994).

6. DESCRIPTION OF WORK

Treatments:

i) 2500 lux supplementary lighting
ii) 5000 lux supplementary lighting
iii) Ambient light - control

N B Period of supplementary lighting 12.00 midnight - 7.00 a.m. using sodium SON/T 400W lamps

Plants will be potted and grown as per commercial practice for production from November 1994, to market February 1995.

Species:	Pot size
Dracaena sanderama	9 cm
Nephrolepis exaltata	13 cm
Hedera helix	9 cm
Tradescantia zebrina	9 cm
Begonia rex	13 cm
Ficus robusta	13 cm

Design:

3 lighting treatments
x
2 replicates
x
3 transfers

18 plots/species
x
6 species

108 plots in total

Plot size: 25 plants per plot

3 main compartments with replication of each main treatment, and full block randomisation within treatments to allow comprehensive statistical analysis.

Transfer experiment, in which each species will be moved between treatments at 6-10 weeks post potting, to assess effect of varied lighting periods upon plant growth and quality.

Plant spacing will be closely regulated by each treatment, and each species will be spaced according to their needs. Final plant density will therefore remain flexible, and will be recorded as cost/benefit analysis.

Shelf-life

All plants will be subject to shelf-life assessment for 6 weeks. Environment, 20⁰C, 60% RH and light level 1000 Lux.

Assessments:

(Will be dependant upon species and vary with plant quality specifications)

a. At maturity:
   Plant height
   Foliage colour score
   Overall plant quality
   Leaf area } recorded as a sub-
   Leaf number } sample of the
   Root vigour assessment } main plot.

b. Shelf-life: (Fortnightly for six weeks)
   Foliage colour score
   Quality score

c. Photographs at marketing stage

d. Full environmental records

e. Compost analysis at potting and marketing

f. Costs/benefit analysis

g. Crop diary

7. COMMENCEMENT DATE AND DURATION:

Start date 01.11.94; duration 7 months
The experimental work will be completed by March 1994 and the final report will be produced by 31st May 1995

8. STAFF RESPONSIBILITIES

Project leader: Mr Andrew Fuller, HRI Efford
Grower Co-ordinator: to be appointed

9. LOCATION

HRI Efford, Lymington, Hampshire