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CONTRACT REPORT

Pot Plants: A comparison of light sources for use as supplementary lighting for winter pot plant production

HDC PC42

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I declare that this work was one under my supervision according to the procedures described herein and that this report represent a true and accurate record of the results obtained.

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SUMMARY

The Horticultural Development Council (HDC) through levy funding commissioned trials work at HRI Efford in Winter 1991 to investigate the use of a range of lamp types for pot plant production. Concurrent funding by Electricity Association Technology Ltd enabled an economic appraisal of the lighting treatments to be carried out.

Six cultivars of *Rieger begonia*, 'Annabell', Ilona', 'Kathleen', 'Louise', 'Maiken' and 'Nellie' were grown under supplementary lighting using three lamp types, SON/T, SON/T AGRO and MBI. Lighting treatments were given for 4 weeks post potting followed by appropriate night break lighting (current commercial standard) or throughout the entire production period. The lighting level used was 2500 lux for 16 hours per day.

Assessments were made during growth and at the marketable stage, with plants subsequently transferred to controlled environment facilities for 'shelf life' testing.

All treatments produced marketable plants. Plants that had been lit throughout were of a higher quality and as such may be expected to have commanded a higher market price. Production time was reduced, and flower number, plant form and shelf life improved with the use of this treatment.

The formulative effect of the various lamp types on plant growth, differed between the six cultivars. Overall, the following trends were noted. Lighting for 4 weeks with MBI produced fewer flowers, whilst when lit throughout with MBI the most. No differences in flower number was found between SON/T and SON/T AGRO.

Metal halide (MBI) lamps produced slightly taller plants when lit continuously but this may have been due to the additional radiant heat detected under these lamps.

Economically, taking into account the additional cost of lighting throughout, there would appear to be a financial benefit to this treatment. Assuming a premium price is available for the higher quality product produced from this treatment, lighting throughout with SON/T and SON/T AGRO may be considered economic. The use of MBI lamps is only considered marginally economic and only then in higher price periods (ie. prior to Mothers Day) due to the high capital and running costs of this particular lamp type.

INTRODUCTION

Supplementary lighting is given to *Rieger begonias* during the winter months for two purposes:

1. as a long day treatment to ensure sufficient vegetative growth;

2. as assimilation lighting to improve plant quality and growth, thus leading to potentially reduced production times.

Previous trials work at Lee Valley EHS (Noble 1988) demonstrated some of the potential benefits with regard to improved quality and reduced production periods. The current work investigates the range of lamp types that are presently commercially available for supplementary lighting. These lamps are claimed to have favourable spectral qualities that enhance plant performance. In particular the SON/T AGRO and the MBI lamps have a greater percentage of blue in their emission spectrum. It is claimed that this extra blue (especially where daylight is less than optimum) improves plant performance.

OBJECTIVE

The objectives of the trial were:-

* To compare 3 lamp types for particular pot plant species with regard to quality of product, production period and shelf life.

* To carry out an economic appraisal of the lighting treatments.

MATERIALS AND METHOD

Plants for the trial were supplied by Gasa Odense as rooted top cuttings in 5.5 cm netpots. After potting, plants were transferred to their respective treatment compartments in 'K' block with computerised environmental control using ebb and flow benches.

Treatments

Lamp type

a. High pressure sodium SON/T 400 W.
b. High pressure sodium SON/T AGRO 400 W.
c. Metal halide MBI.

Illuminance level	2500 lux
Lighting period	16 hours
Start/finish	0.00 - 16.00 hours

Duration of supplementary lighting

1. 4 weeks from potting (while plants pot thick) followed by night break lighting after short days. Weeks 1-4.

2. Throughout production (except for 2 weeks short days). Weeks 1-4 and 6-10.

   Night break lighting using tungsten lamps, 200 mW/m^2, 4 hours per night in November and February, 6 hours per night in December and January.

Cultivars

'Annabell'	'Louise'
'Ilona'	'Maiken'
'Kathleen'	'Nellie'

Potting date

Week 48 1991

Design and experimental layout

Weeks 1-4: 18 plots in total

3 lamp types
x
6 cultivars
—
18 plots
—

Week 5 - marketing: 60 plots in total. Replication varied between treatments according to lamp type and duration as follows:

4 weeks supplementary followed by NBL	Lit throughout SON/T and SON/T AGRO	MBI
3 lamp types	2 lamp types	1 lamp type
x	x	x
6 cultivars	6 cultivars	6 cultivars
—	x	–
18 plots	3 replicates	6 plots
—	—	–
	36 plots	
	—	

* It was not possible to fully replicate all treatments due to space limitations and number of metal halide lamps available.

Plot size = initially 120 plants whilst pot thick, and at final spacing, 30 plants.

The six cultivars were placed in blocks down the bench length. Plots of each cultivar were placed in the same relative position in each treatment compartment on each bench, to avoid confounding compartment position with treatment effects.

The trial layout is given in Appendix I, pages 18 and 19.

Cultural details

Cuttings on arrival (30 November) were potted up into 13 cm B range continental pots (2 tier drainage). The media used was Fisons Levington C2. Plants were then transferred to their respective treatment compartments and placed pot thick on the centre benches (59 plants/m^2). Once in position pots were drenched with Fongarid 25 WP (1 g/litre at an application rate of 5 litres/m^2) as a preventative measure against possible root diseases.

The temperature regime was set at 18°C day and night, ventilation at 22°C. CO_2 enrichment was at 800 ppm continuously while supplementary lamps were in use and when vents closed, decreasing to 330 ppm when vents 5% open. For plants nightbreak lit, CO^2 was introduced during daylight hours (08.00-16.00) to match enrichment levels given to lighting throughout treatments.

Liquid feeding at every watering via the sub-irrigation system commenced 2 weeks after potting. The feed given supplied 100 ppm N, 15 ppm P_2O_5 and 100 ppm K_2O. The stock feed was as follows:

Material	**g/litre**
Potassium nitrate	43.5
Ammonium nitrate	37.5
Mono ammonium phosphate	5.0

diluted 1 in 200 E.C. 1160 microsiemens pH 5.8

Growth regulation was achieved using Cycocel (chlormequat 46%) spray at 1.5 ml/litre product to which 0.1 ml/litre Agral wetter was added. Applications made to each cultivar were as follows:

19 December	All cultivars
7 January	All cultivars except 'Maiken'
31 January	'Annabell', 'Louise', 'Nellie'.
	'Ilona', 'Kathleen' and 'Maiken' spot treated only

The short day period (14 days) commenced 4 weeks after potting on 31 December as plants were moved to an intermediate spacing of 40 plants/m^2 and transferred where necessary to the night break lit compartment.

Supplementary lighting was resumed as required on 14 January.

Final spacing (16 plants/m^2) took place on 24 January. Any premature flowers were removed at this point.

During the course of the trial the following pesticides were applied:

11 December	Fungaflor at 0.5 ml/litre	
3 January	Nimrod at 3.8 ml/litre	
13 January	Repulse at 2.2 ml/litre)	tank mix
	Ambush C at 0.62 ml/litre)	

Assessments

During the course of the trial, the following assessments were made:

1. Effect on plant growth/harvest date. (Market date = 5 open flowers).

At marketing

2. Plant height (mm).
3. Spread (2 measurements) (mm).
4. Number of flowers and buds.
5. Number of flowers 50% open at marketing.
6. Quality (scale 1-4, 1 = highest quality) (see Appendix III, page 31).
7. Cost of lighting treatments.

During 'shelf life'

1. Flower and bud drop counts (weekly).
2. Leaf loss (weekly).

Statistical analysis

No formal statistical analysis was possible due to the limited replication of some treatments. All data presented is a mean of plants within plots and across replicates, (minimum of 30 plants where replication limited, up to 90 plants where full replication was available).

RESULTS

Effect of supplementary lighting treatment on marketable date

The use of supplementary lighting throughout production advanced flowering which meant plants were marketable earlier than when supplementary lit for 4 weeks only. The greatest advance was with the cultivar 'Kathleen' which was of 14 days and the least 4 days for 'Nellie' and 'Annabell'.

Effect of supplementary lighting treatment on plant height

The effect of the various supplementary lighting treatments is shown in Figures 1 to 6, Appendix II, pages 20 to 22 and Plates 1 to 12, Appendix V, pages 40 to 45. For all six cultivars plants lit throughout production were markedly taller than those lit for 4 weeks from potting. Differences in plant height for each lamp type within each lighting duration were small, though where lit throughout, the SON/T produced the shortest plants, followed by SON/T AGRO with the MBI lamps producing the tallest plants. This 'stretching' under MBI lamps was most marked earlier in production, the effect having largely evened out by the marketing stage.

Individual cultivar responses were as follows:

Height (mm)	4 weeks lighting			Lit throughout		
Cultivar	SON/T	AGRO	MBI	SON/T	AGRO	MBI
'Annabell'	163	161	165	176	179	184
'Ilona'	142	144	153	170	180	186
'Kathleen'	134	131	133	172	180	187
'Louise'	145	156	148	176	183	197
'Maiken'	147	142	147	176	179	184
'Nellie'	179	174	171	206	203	204
Average	152	151	153	179	184	190

Effect of supplementary lighting treatment on plant spread

Results for mean plant diameter are given in Figures 7 to 12, Appendix II, pages 23 to 25. Lighting throughout production increased plant spread over plants lit for 4 weeks only. Differences between lamp types were small. There was a marginal increase in plant spread under MBI lamps when lit throughout (3-19 mm) depending on cultivar.

Individual cultivar responses were variable and are given below:

Av. diam.(mm)	4 weeks lighting			Lit throughout		
Cultivar	SON/T	AGRO	MBI	SON/T	AGRO	MBI
'Annabell'	229	240	231	251	253	254
'Ilona'	224	223	221	250	251	261
'Kathleen'	224	232	222	285	295	296
'Louise'	219	235	229	265	275	281
'Maiken'	221	222	215	239	237	242
'Nellie'	234	228	231	261	262	282
Average	225	230	225	259	262	269

Effect of supplementary lighting treatment on flower number

Numbers of flowers and buds at the marketing stage are given in Figures 13 to 18, Appendix II, pages 26 to 28 for each cultivar. Lighting throughout production resulted in a marked increase in flower number over plants lit for 4 weeks. Differences between lamp types were small and varied with cultivar.

Effect of supplementary lighting treatment on plant quality

Scores for plant quality are given in Table 1, Appendix II, page 29. The quality criteria used is given in Appendix III, page 31. Overall, plant quality was good from all treatments. Plants lit throughout, however, achieved a higher quality score for each cultivar. When values were averaged across all six cultivars there was a suggestion that slightly higher quality plants were obtained under SON/T AGRO lamps for both lighting durations. Quality from SON/T and MBI lamps was similar overall for both lighting durations.

Effect of supplementary lighting treatment on shelf life

The effect of lighting treatment for 4 weeks and throughout production on the subsequent shelf life in terms of flower numbers and bud abortion is shown in Figure 19, Appendix II, page 30. Six plants of each cultivar from the various lighting treatments were placed in the shelf life rooms at marketing and assessed over a six week period. The shelf life environment used was maintained at 18°-20°C, and lit using fluorescent lamps at 1000 lux for 12 hours per day.

Figure 19 shows that the proportions of flowers (open and buds), and dead flowers plus aborted buds. Results varied with cultivar.

'**Annabell**', produced more flowers during shelf life when lit throughout production, and while this treatment also lost a greater number of flowers during this period, this was compensated for by the higher number of flowers present at marketing. Fewer flowers were recorded during shelf life for plants grown throughout under SON/T AGRO. For the 4 week lighting duration plants produced under MBI had fewer flowers and buds after six weeks of shelf life and had aborted a greater number than the other two lamp types.

'**Ilona**', although initially producing more flowers at the marketing stage when lit throughout, this trend did now follow through into shelf life as with 'Annabell', and little difference between lighting throughout and lighting for 4 weeks was demonstrated in total number of flowers and buds produced. Flower loss and bud abortion were slightly higher for plants lit throughout. Lighting for 4 weeks under MBI once again produced the least number of flowers, but conversely the highest number when lit throughout.

'Kathleen', as with 'Annabell', lighting throughout production improved flowering during shelf life, though bud drop was greater than when lit for 4 weeks. The response to MBI lamps was similar to 'Ilona' with fewer flowers from 4 week treatment and highest number when lit throughout.

'Louise', while this cultivar initially produced more flowers at marketing when lit throughout this trend was not evident by the end of the six weeks shelf life period. By this time plants lit for 4 weeks had produced similar or higher flower counts, and bud drop was less than in plants lit throughout. Effects of lamp type were small.

'Maiken', differences between duration of lighting treatments were small, though as with the other cultivars, there was more bud drop when lit throughout. SON/T AGRO lamps gave the highest flower counts when lit for 4 weeks with very little abortion in direct contrast to plants lit throughout under this lamp which had the lowest flower count. When lit throughout production MBI lamps gave higher numbers. SON/T AGRO gave poorer flower counts when lit throughout than when lit for 4 weeks.

'Nellie', overall, lighting throughout production produced more flowers during shelf life though as with other cultivars bud loss was greater. The use of SON/T AGRO in the 4 weeks duration treatment gave higher flower counts than the other two lamp types but poorer results when lit throughout.

In summary, lighting throughout production improved shelf life of 'Anabell', 'Kathleen' and 'Nellie', for although bud drop was greater from this treatment it was compensated for by the increased flowering at marketing. Results with the other varieties 'Ilona', 'Louise' and 'Maiken' were variable with lighting treatments giving similar results, overall, during shelf life. The effect of lamp type of shelf life was also variable. Where lit for 4 weeks, the SON/T AGRO lamps, produced the best results for 3 cultivars ('Ilona', 'Maiken' and 'Nellie'). When lighting throughout the MBI lamps appeared to produce more flowers during shelf life for 'Ilona', 'Kathleen' and 'Maiken'.

Heating effect of supplementary lighting

During the course of the trial (30 January 1992) measurements were taken of leaf temperature using an infra red sensor (supplied by Electricity Association Ltd). These measurements were taken to ascertain the potential radiant heating effect of the various supplementary lamp types used. The following results were obtained:

Lamp type	**SON/T**	**SON/T AGRO**	**MBI**
Radiant effect*	+ 1°C	+ 0.5 - 1°C	+ 1.5 - 2.0°C

* Sensor - 1 m distance.

The above is supplied for information only and no account of this additional heat element is used in the economic appraisal.

Economics of lighting

Average prices at the wholesale level during the marketing period of the trial (February, March 1992) were £1.22 and £1.31 respectively. For the purposes of the economic appraisal the payment of a premium price (top of price range) is assumed for plants of better quality. (This may not always be the case!). Prices assumed £1.36 and £1.49 for February and March respectively.

The detailed calculations for the economic appraisal of the lighting treatments are given in Appendix IV, pages 32 to 39. The resulting costs of lighting per pot (running + capital charges) are summarised in the following table.

Cost of lighting (pence/pot (running + capital charges)

	SON/T	SON/T AGRO	MBI
Lit 4 weeks	2.08 p	2.08 p	4.35 p
Lit throughout	8.61 p	8.61 p	19.21 p
Difference	6.53 p	6.53 p	14.86 p

The assumption is made that supplementary lighting for 4 weeks post potting is the commercial standard at present used, and that the average price for "standard" plants potted in week 48 is as the average wholesale price above. It is also assumed that the quality of plants lit throughout production would be higher and therefore warrant the "premium" prices given above. The extra value was calculated as 14 p/pot for February sales, and 18 p/pot for March sales, (higher prices in March coinciding with "Mothering Sunday").

This extra value must be sufficient to cover the additional cost of lighting throughout production compared to lighting for 4 weeks only.

For February and March sales this is calculated as shown below.

February

SON/T and SON/T AGRO 14 p - 6.53 p = 7.47 p/pot or £1.19/m^2.

MBI 14 p - 14.86 p = -0.86 p/pot or -£0.13/m^2.

March

SON/T and SON/T AGRO 18 p - 6.53 p = 11.47 p/pot or £1.83/m^2.

MBI 18 p - 14.86 p = 3.14 p/pot or £0.50/m^2.

From the above it can be seen that lighting throughout would appear economic when using SON/T and SON/T AGRO light sources with a reasonable additional return of £1.19 to £1.83 /m^2, especially when the reduction in production time of 1 to 2 weeks resulting from the use of lighting is also considered.

The use of MBI light sources for lighting throughout is more questionable with a negative return in February and only a marginal return of £0.50/m^2 when wholesale prices were higher.

DISCUSSION AND CONCLUSIONS

Results from the trial indicated a wide range of responses to supplementary lighting source and duration of treatment at the individual cultivar level. When lighting was used for 4 weeks only there was little effect on the finished height of plants between the three lamp types. During early growth, however, plants under the metal halide (MBI) lamps appeared to be slightly drawn. Where plants were lit throughout, metal halide grown plants were still slightly taller than plants grown under SON/T AGRO and SON/T. Generally, plants grown under MBI lamps appeared more "robust" than the other two lamp types. With regard to final quality SON/T AGRO gave the best overall performance for both lighting durations, slightly ahead of SON/T and MBI. Differences were however, small.

Overall, plants that had been lit throughout production were of higher quality than those lit for 4 weeks post potting, and on average, reached a marketable stage 1 to 2 weeks earlier. The degree of flowering was greater for plants lit throughout but differences between lamp type were small.

The beneficial effect of lighting throughout on improved flower number meant that although these plants lost more flowers and buds during shelf life there were plentiful "reserves" of flowers being produced to more than compensate for this and flowering quality was maintained. The effect of lamp type varied considerably between cultivars. MBI lamps appeared to improve flowering during shelf life for 'Ilona', 'Kathleen' and 'Nellie' when lit throughout production, in direct contrast to the 4 week lighting period where flowering was poorest. SON/T and SON/T AGRO produced similar results for plants lit throughout, with SON/T AGRO giving a small advantage over SON/T when used for a 4 week period on 'Ilona', 'Maiken' and 'Nellie'.

The economic appraisal of the lighting treatments suggests that as long as a premium price is available for high quality products supplementary lighting throughout could be economically worthwhile, particularly for SON/T and SON/T AGRO lamps. The return with metal halide is less competitive since the lamps are more expensive, with regard to bulb life, installation cost and number of lamps required. Only where a high premium price was available was the metal halide lighting throughout treatment marginally economic.

In summary, of the various lamp types used in the trial results suggest that there would be only small differences in response obtained between SON/T and SON/T AGRO lamps and while there may be some cultural benefits to the use of MBI lamps the practical aspects and the economic viability of lamps currently available would not make their use worthwhile.

It should be noted however, that extrapolation of these results is difficult due to the limited replication of treatments possible and the variable results obtained between cultivars. The 'potential' benefit of the 'blue light' component in the SON/T AGRO and MBI lamps was not clearly demonstrated and more detailed investigations would be required before final conclusions on the formulative effect of these lamp types can be given.

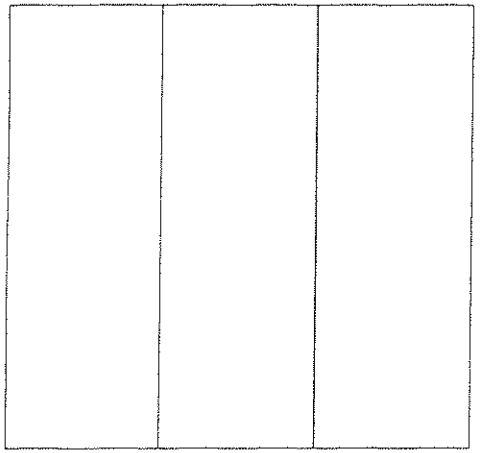
TUNGSTEN

Weeks 1 - 4

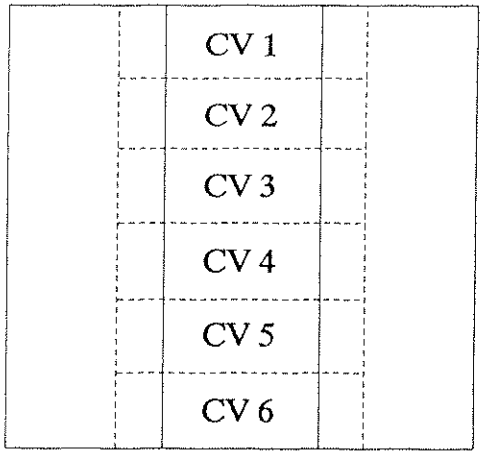
SONT

N ←

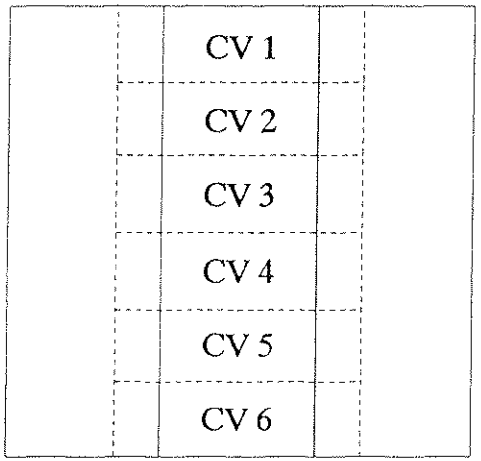
K 14



K 8



K 1



Cultivars

ANNABELL

ILONA

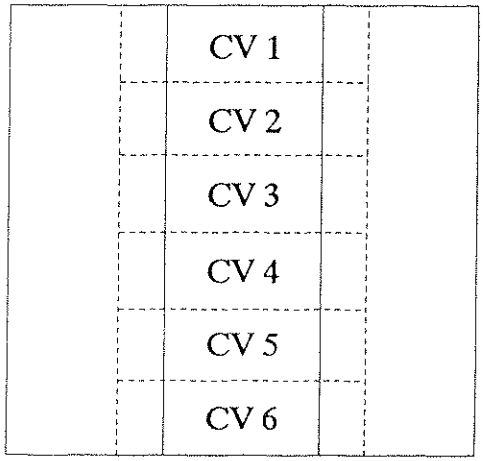
KATHLEEN

LOUISE

MAIKEN

NELLIE

K 11



SONT AGRO

MBI

TUNGSTEN

Weeks 5 - Marketing

SONT

N ←

K 14

43 CV 1	49 CV 1	55 CV 1
44 CV 2	50 CV 2	56 CV 2
45 CV 3	51 CV 3	57 CV 3
46 CV 4	52 CV 4	58 CV 4
47 CV 5	53 CV 5	59 CV 5
48 CV 6	54 CV 6	60 CV 6
(SONT)	(MBI)	(AGRO)

K 8

1 CV 1 ←	7 CV 1 →	13 CV 1
2 CV 2 ←	8 CV 2 →	14 CV 2
3 CV 3 ←	9 CV 3 →	15 CV 3
4 CV 4 ←	10 CV 4 →	16 CV 4
5 CV 5 ←	11 CV 5 →	17 CV 5
6 CV 6 ←	12 CV 6 →	18 CV 6

K 1

19 CV 1 ←	25 CV 1 →	31 CV 1
20 CV 2 ←	26 CV 2 →	32 CV 2
21 CV 3 ←	27 CV 3 →	33 CV 3
22 CV 4 ←	28 CV 4 →	34 CV 4
23 CV 5 ←	29 CV 5 →	35 CV 5
24 CV 6 ←	30 CV 6 →	36 CV 6

Cultivars

ANNABELL

ILONA

KATHLEEN

LOUISE

MAIKEN

NELLIE

K 11

gds	37 CV 1	gds
	38 CV 2	
	39 CV 3	
	40 CV 4	
	41 CV 5	
	42 CV 6	

SONT AGRO

MBI

APPENDIX II

Figure 1

Annabell

Mean Plant Height (mm) at Marketing Stage

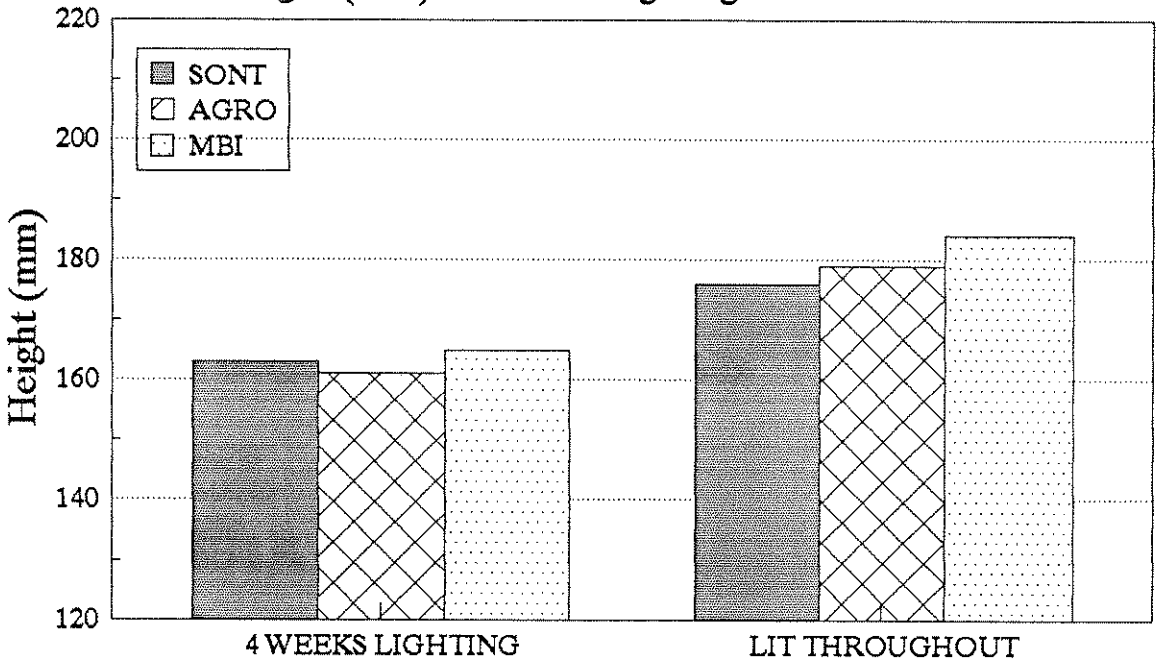


Figure 2

Ilona

Mean Plant Height (mm) at Marketing Stage

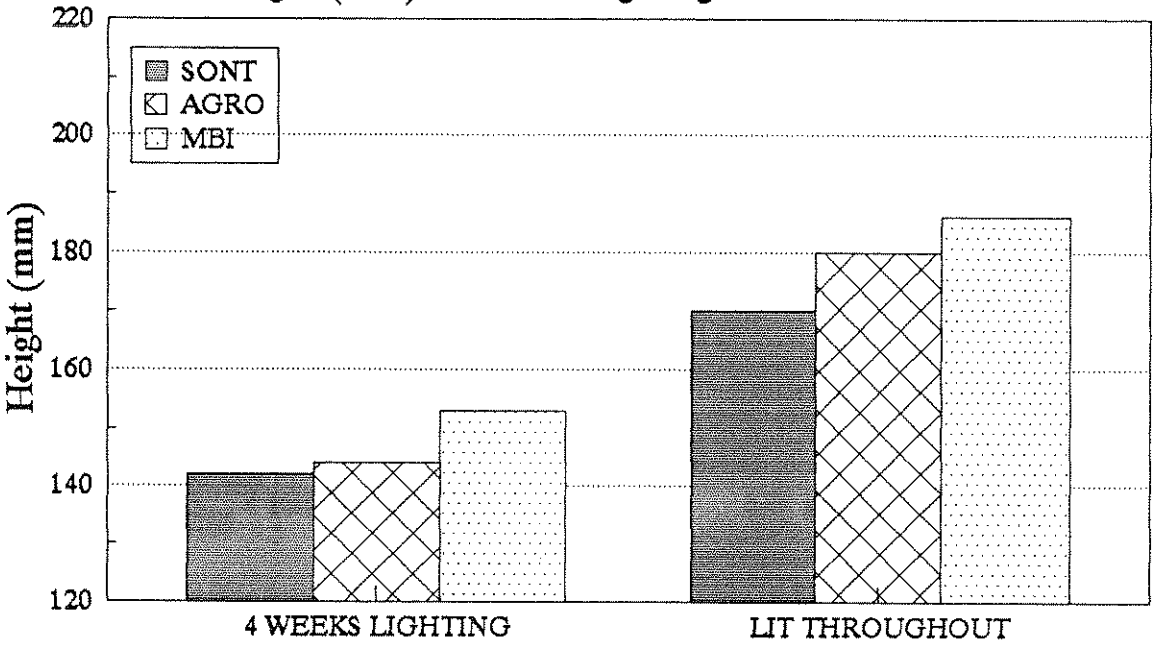


Figure 3

Kathleen

Mean Plant Height (mm) at Marketing Stage

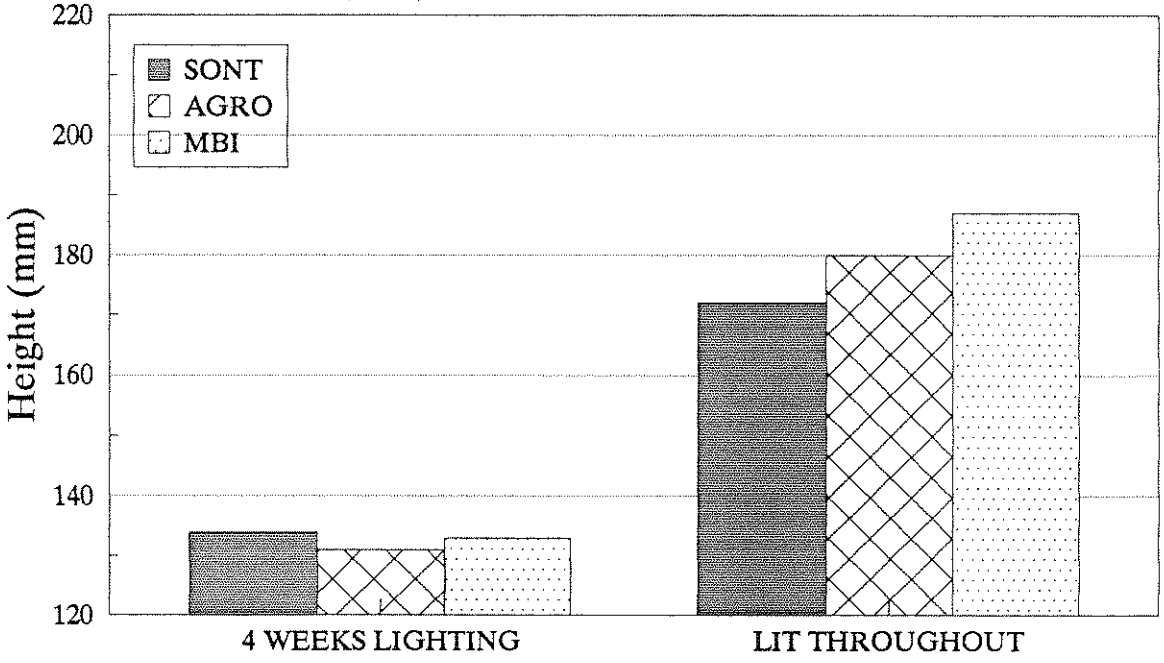


Figure 4

Louise

Mean Plant Height (mm) at Marketing Stage

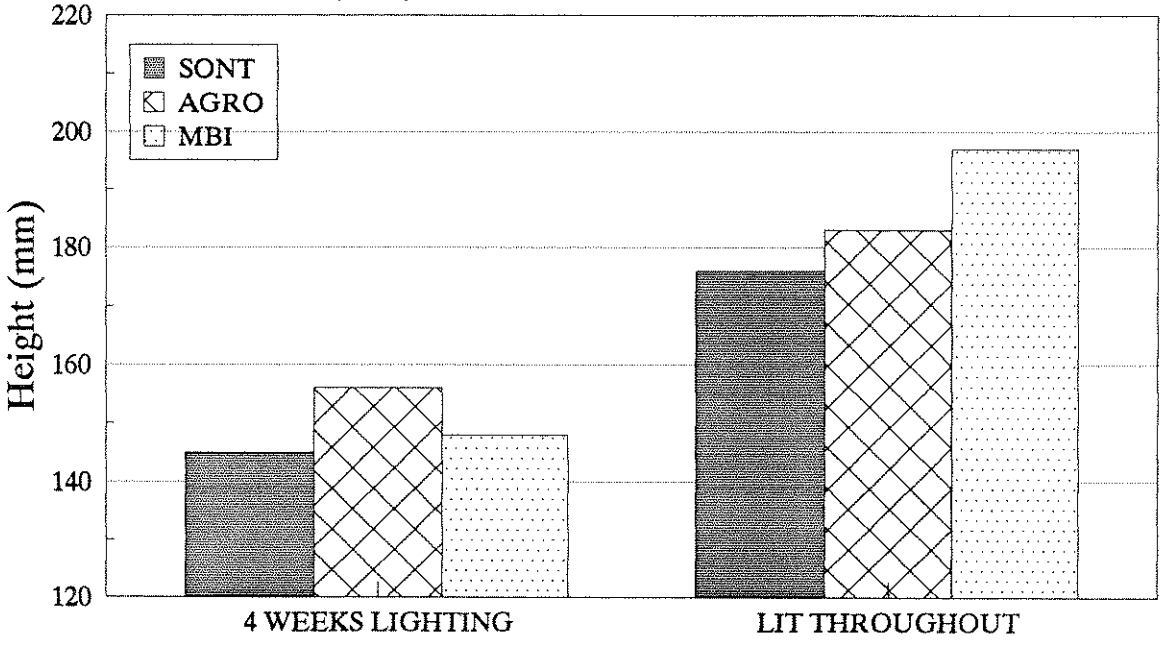


Figure 5

Maiken

Mean Plant Height (mm) at Marketing Stage

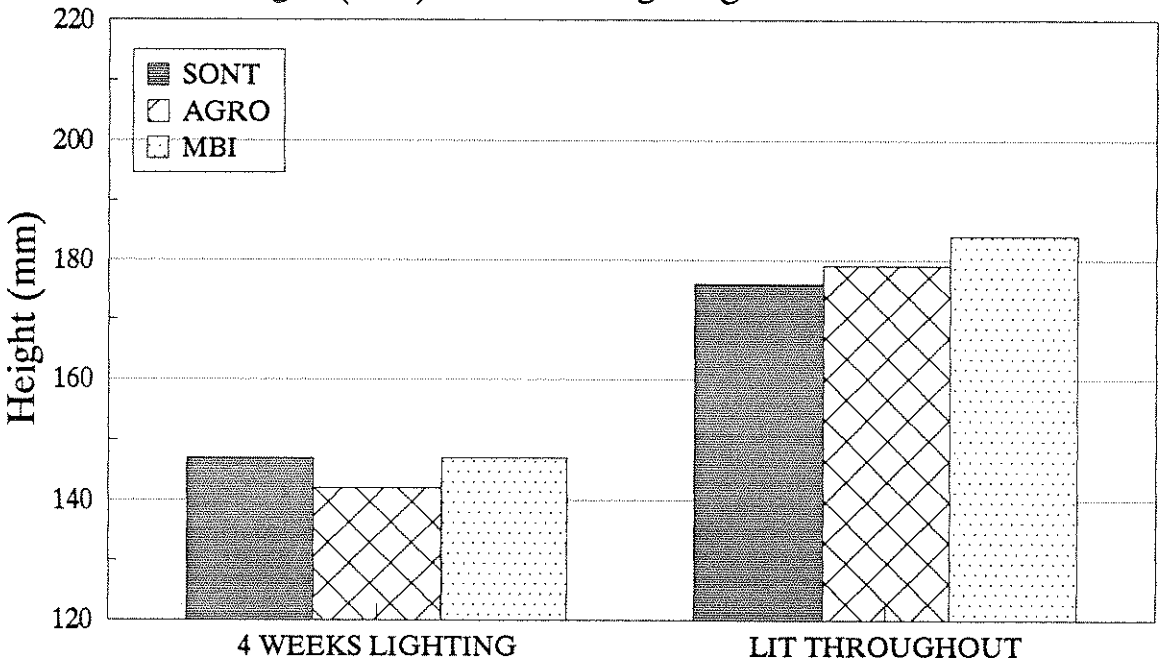


Figure 6

Nellie

Mean Plant Height (mm) at Marketing Stage

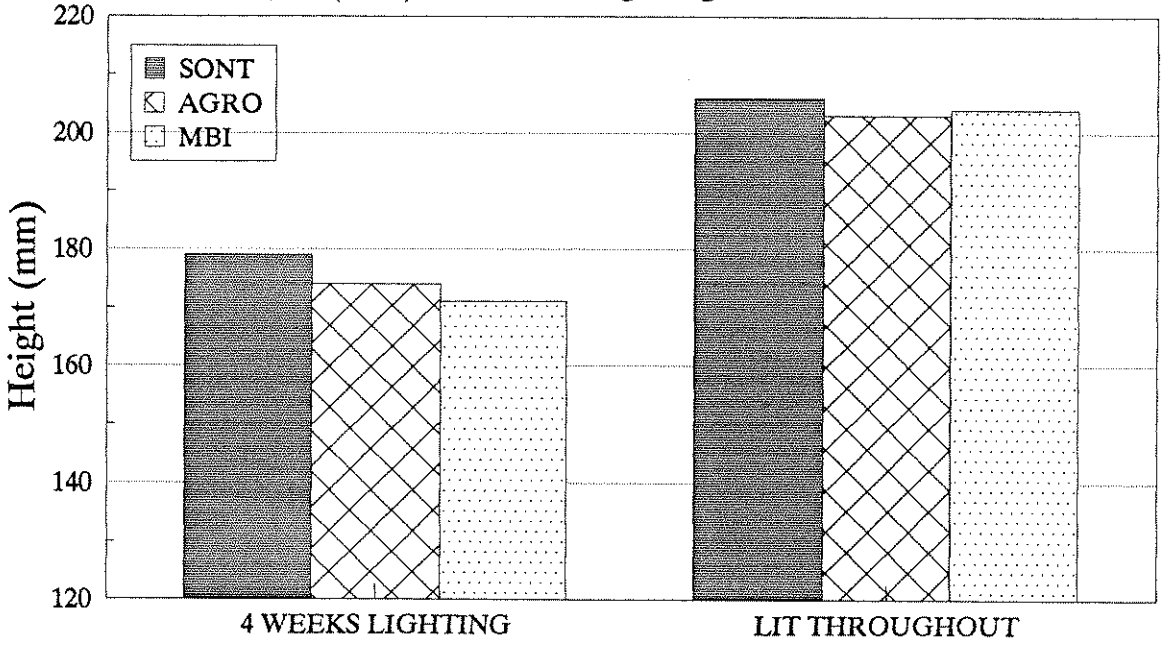


Figure 7

Annabell

Mean Plant Diameter (mm) at Marketing Stage

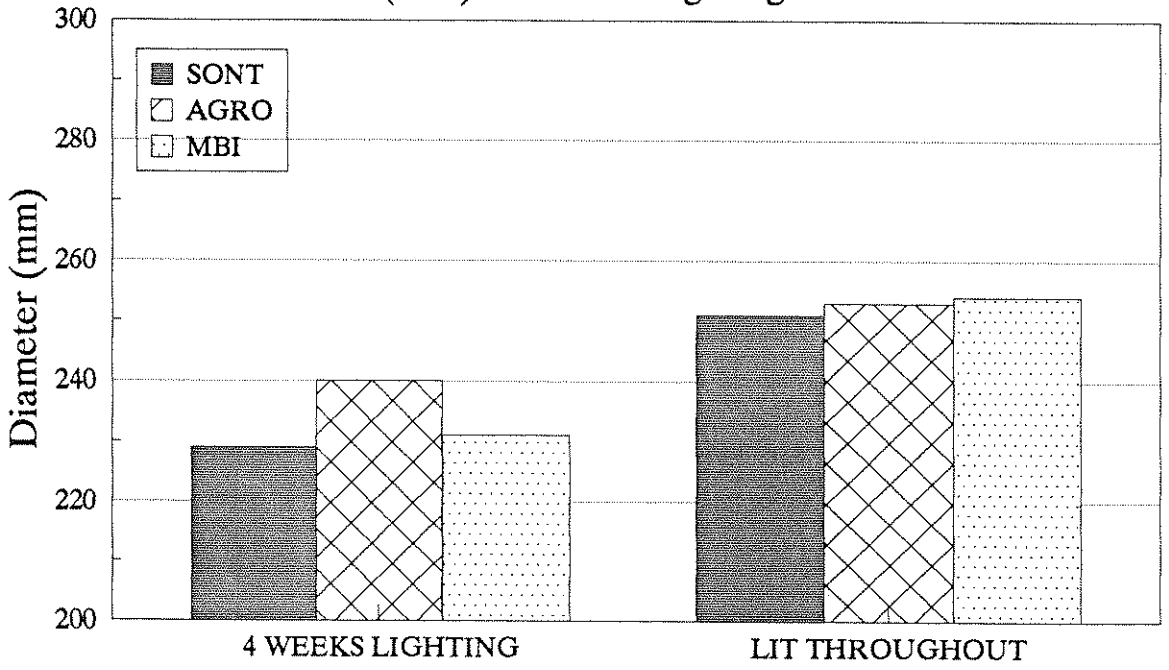


Figure 8

Ilona

Mean Plant Diameter (mm) at Marketing Stage

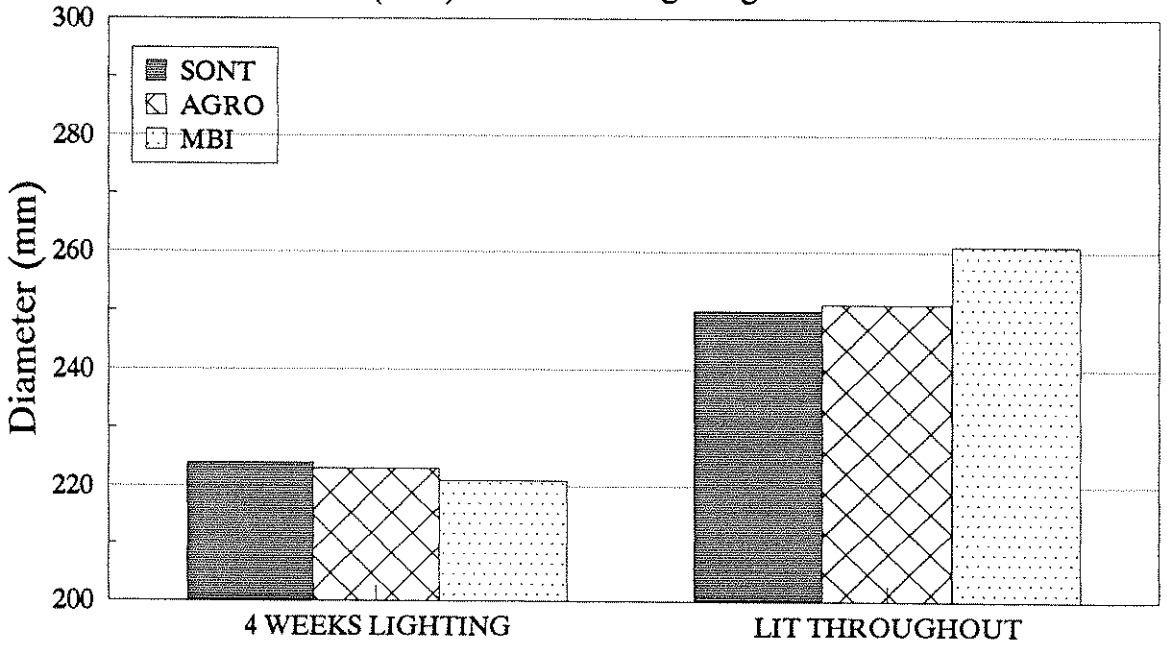


Figure 9

Kathleen

Mean Plant Diameter (mm) at Marketing Stage

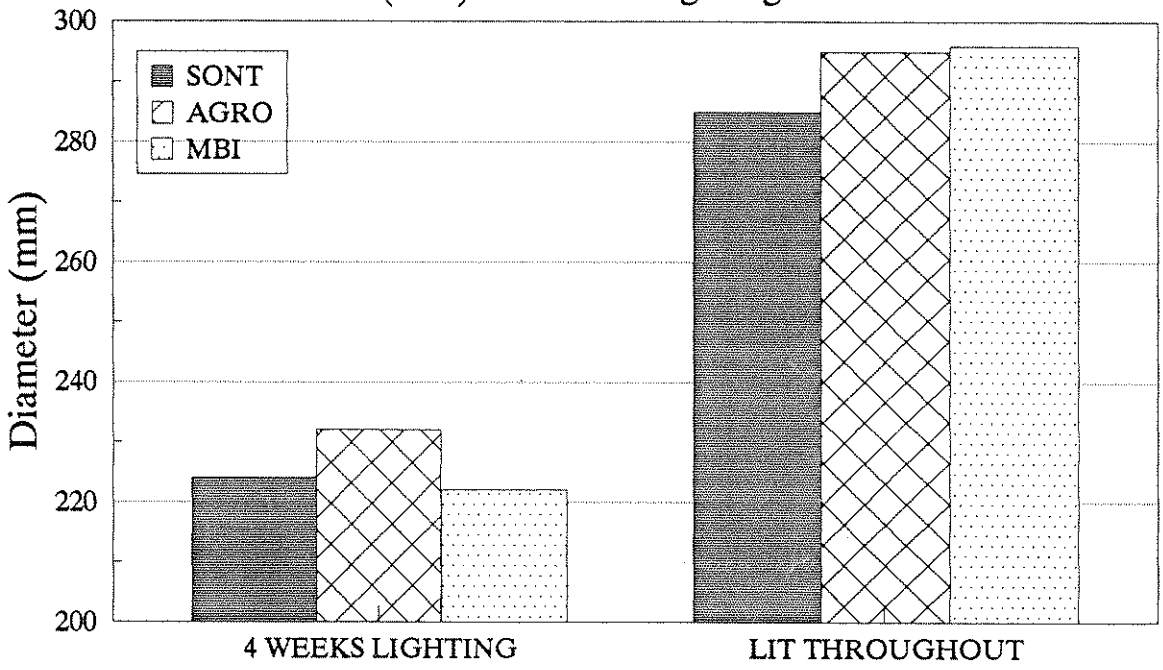


Figure 10

Louise

Mean Plant Diameter (mm) at Marketing Stage

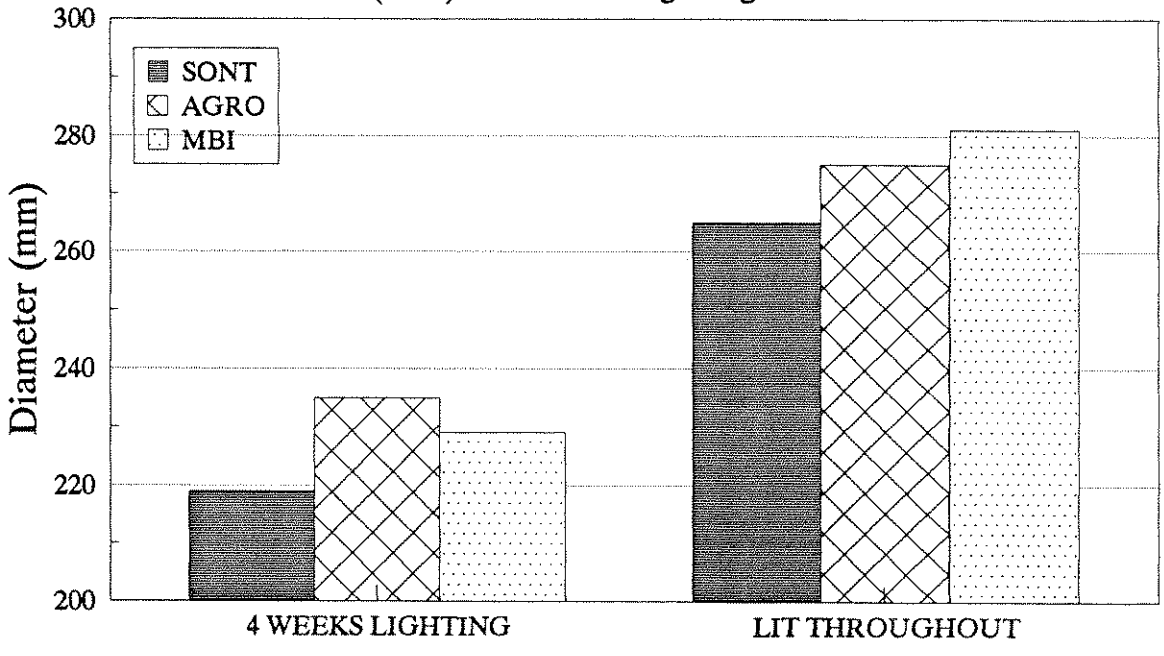


Figure 11

Maiken

Mean Plant Diameter (mm) at Marketing Stage

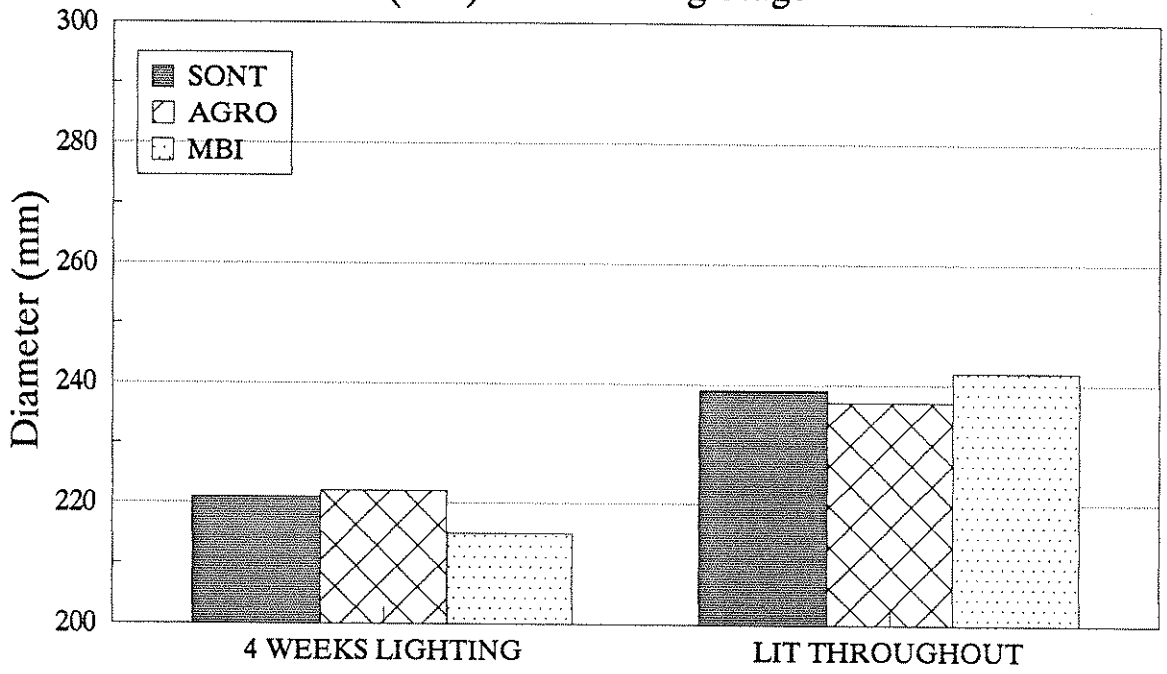


Figure 12

Nellie

Mean Plant Diameter (mm) at Marketing Stage

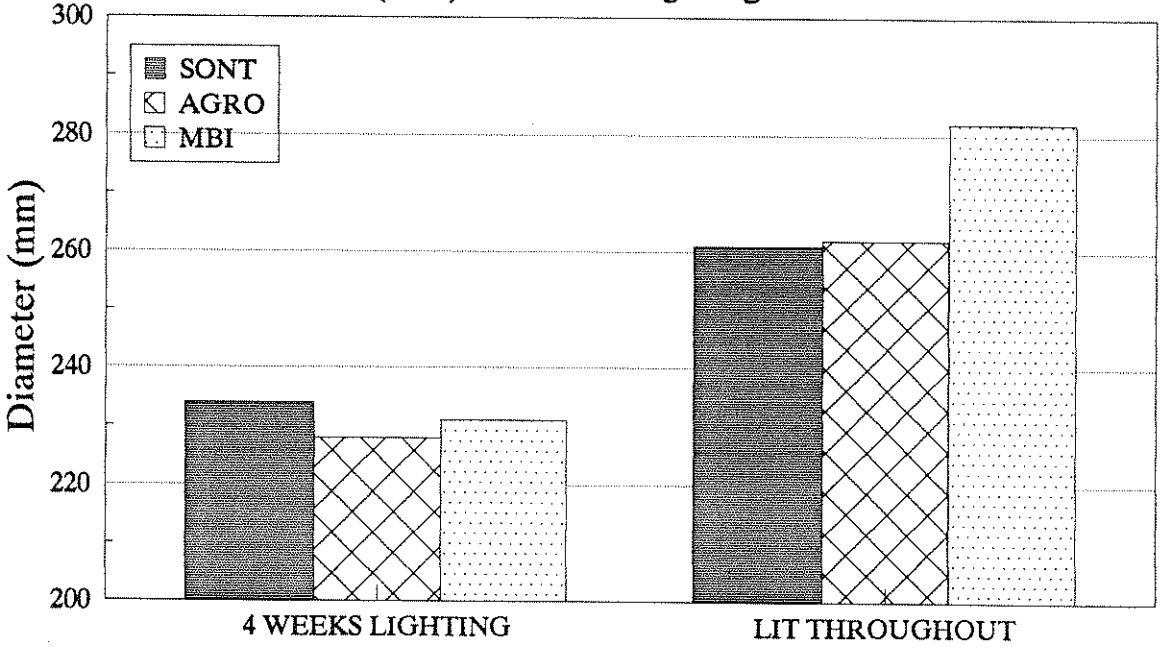


Figure 13

Annabell - Mean Total Number of Flowers and Buds in Colour and Number >50% open at Marketing Stage

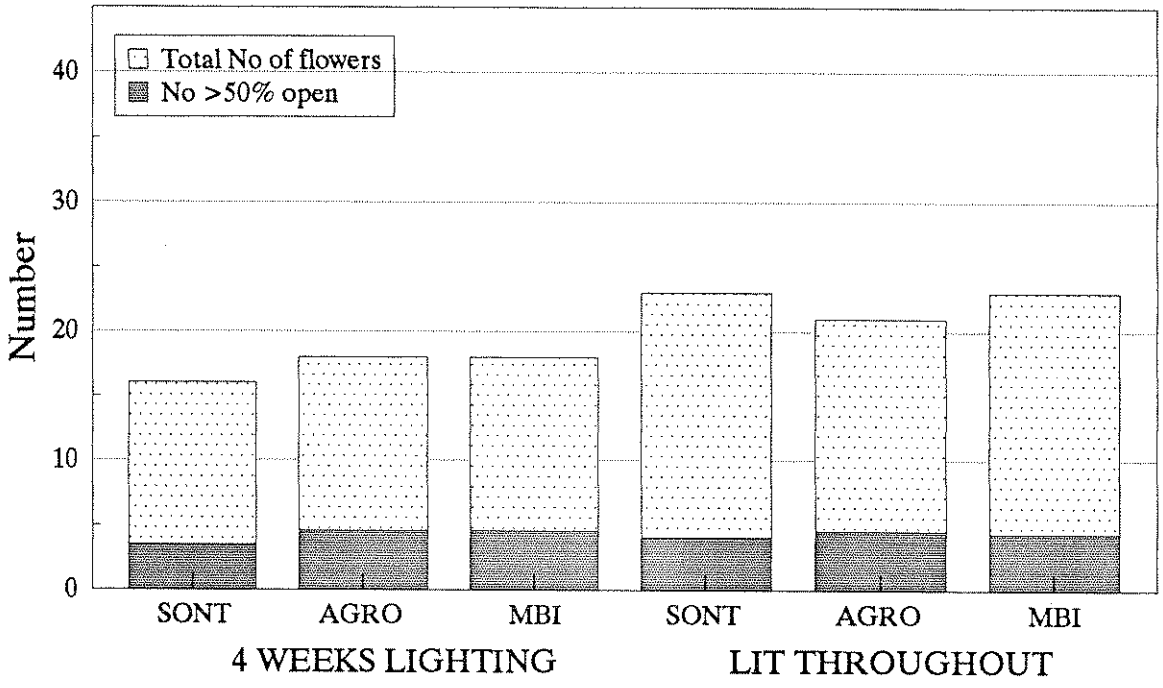


Figure 14

Ilona - Mean Total Number of Flowers and Buds in Colour and Number >50% open at Marketing Stage

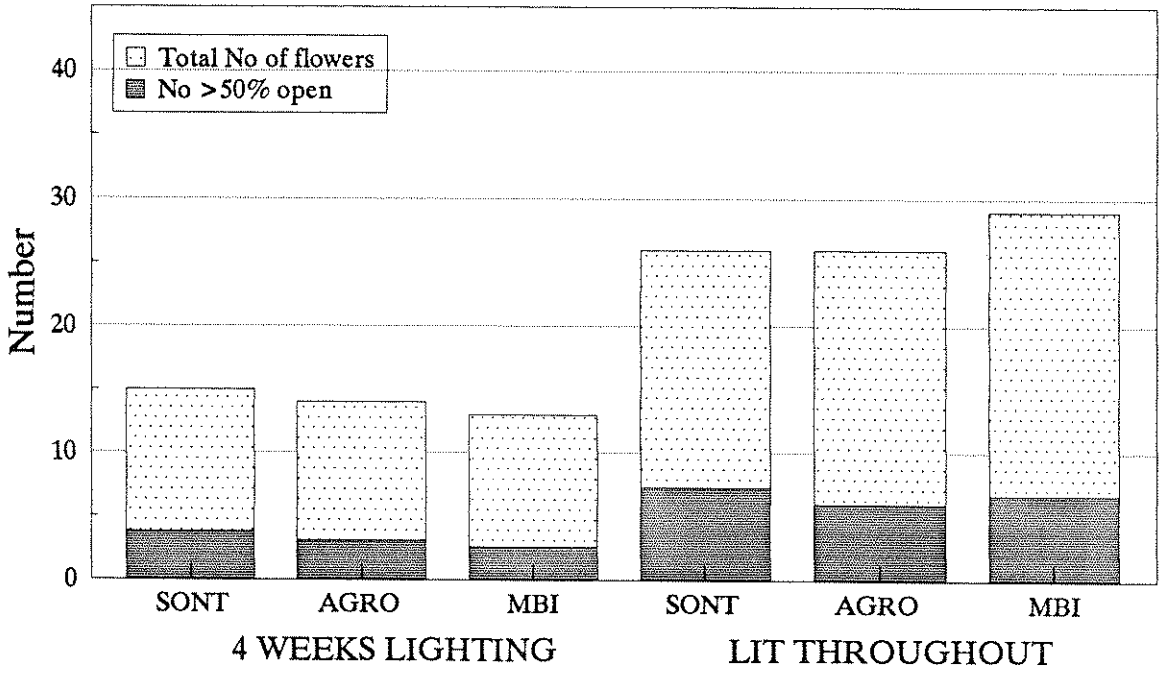


Figure 15

Kathleen - Mean Total Number of Flowers and Buds in Colour and Number >50% open at Marketing Stage

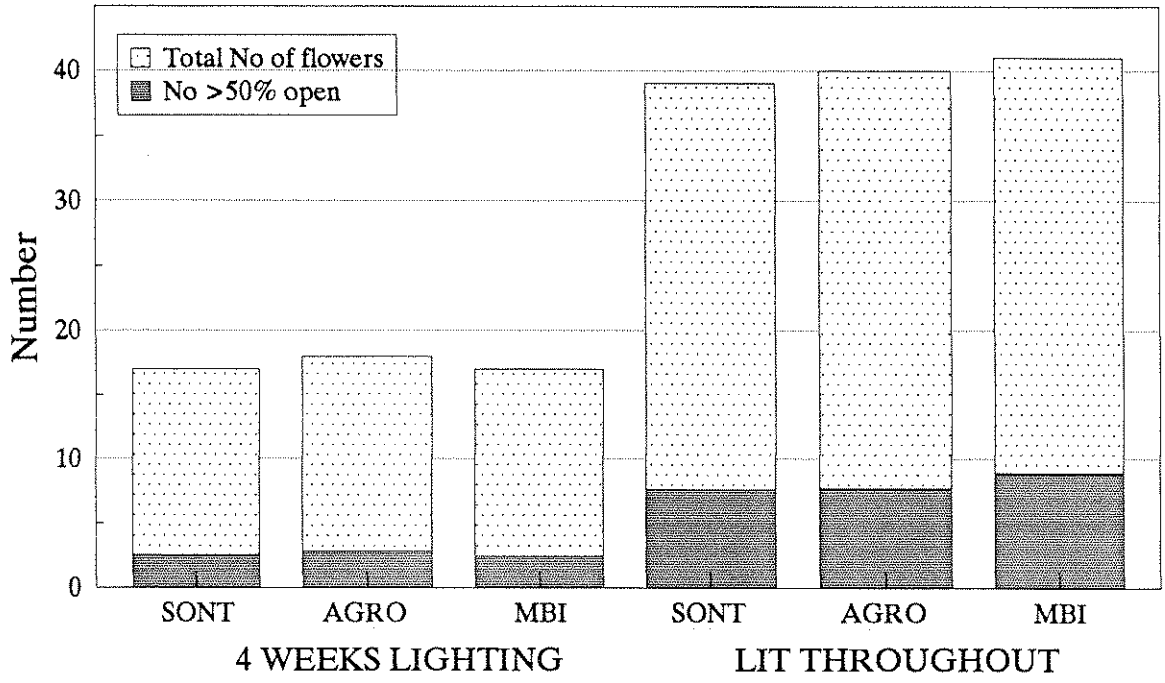


Figure 16

Louise - Mean Total Number of Flowers and Buds in Colour and Number >50% open at Marketing Stage

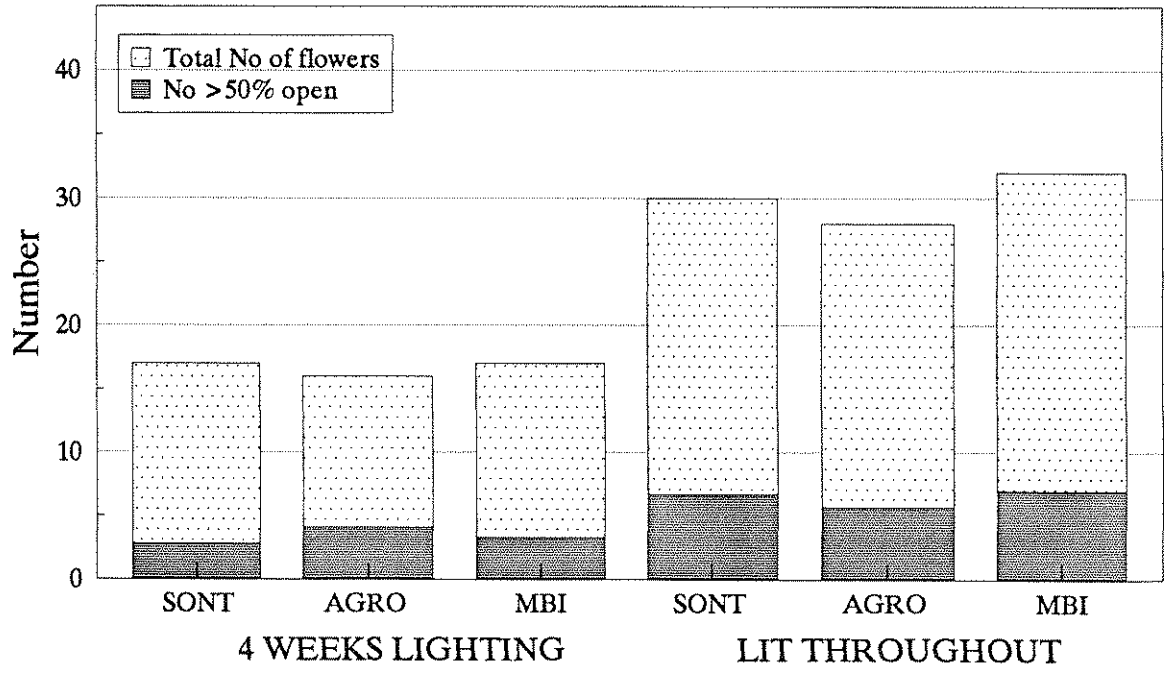


Figure 17

Maiken - Mean Total Number of Flowers and Buds in Colour and Number >50% open at Marketing Stage

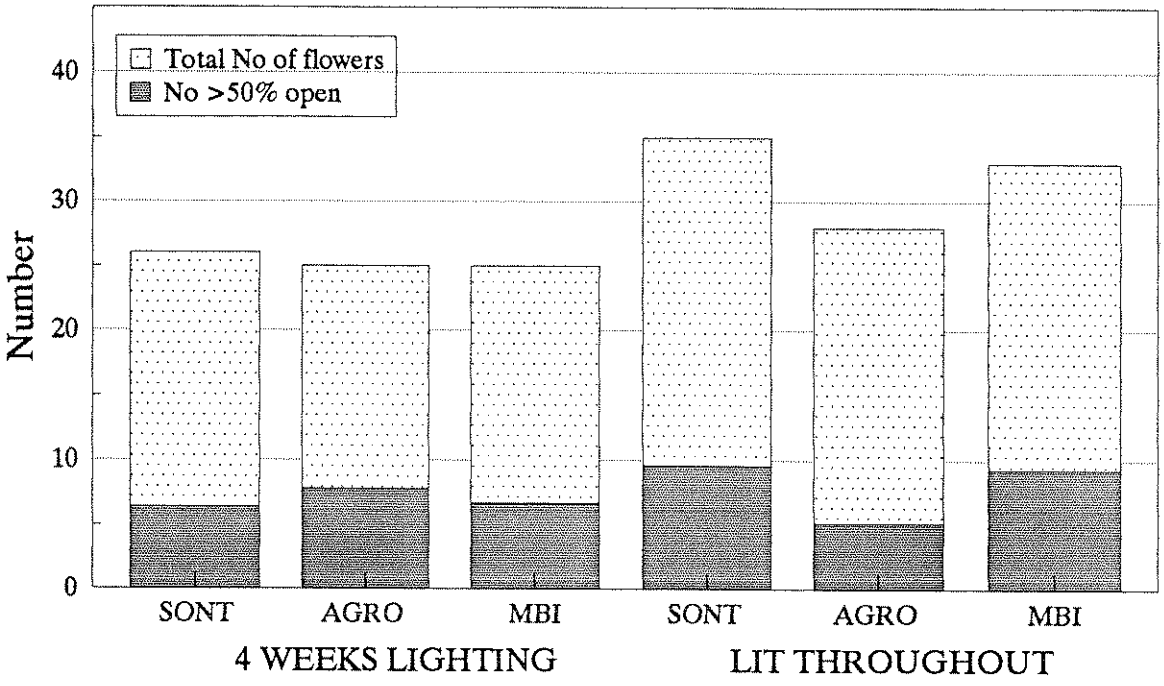


Figure 18

Nellie - Mean Total Number of Flowers and Buds in Colour and Number >50% open at Marketing Stage

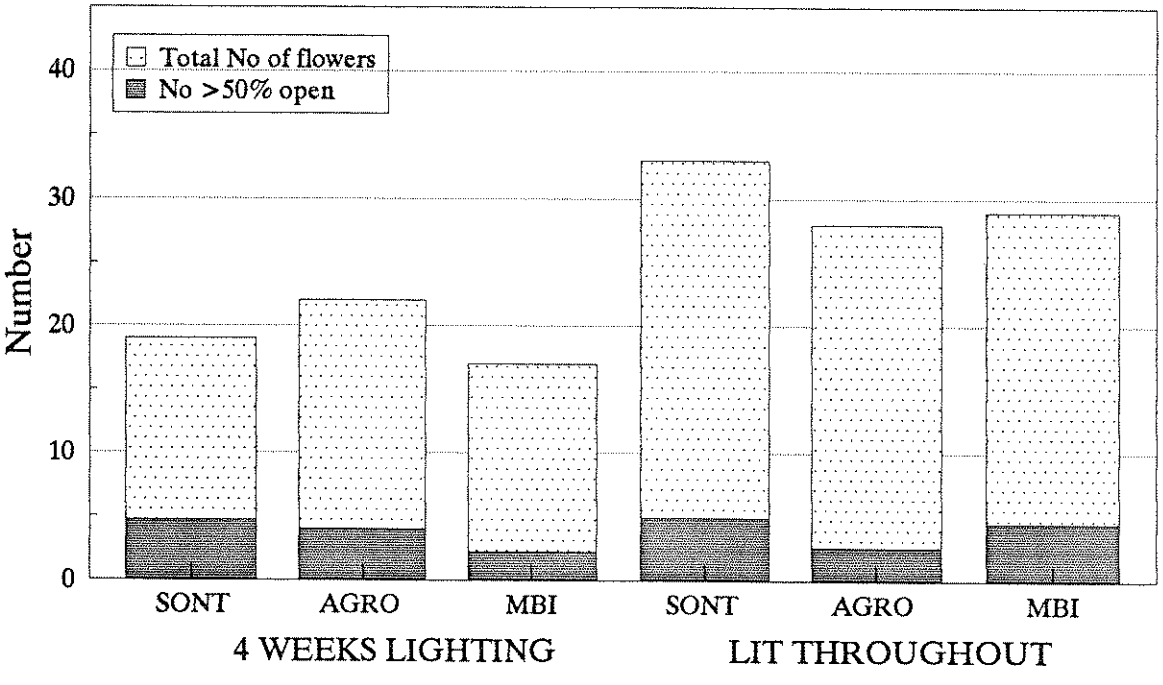
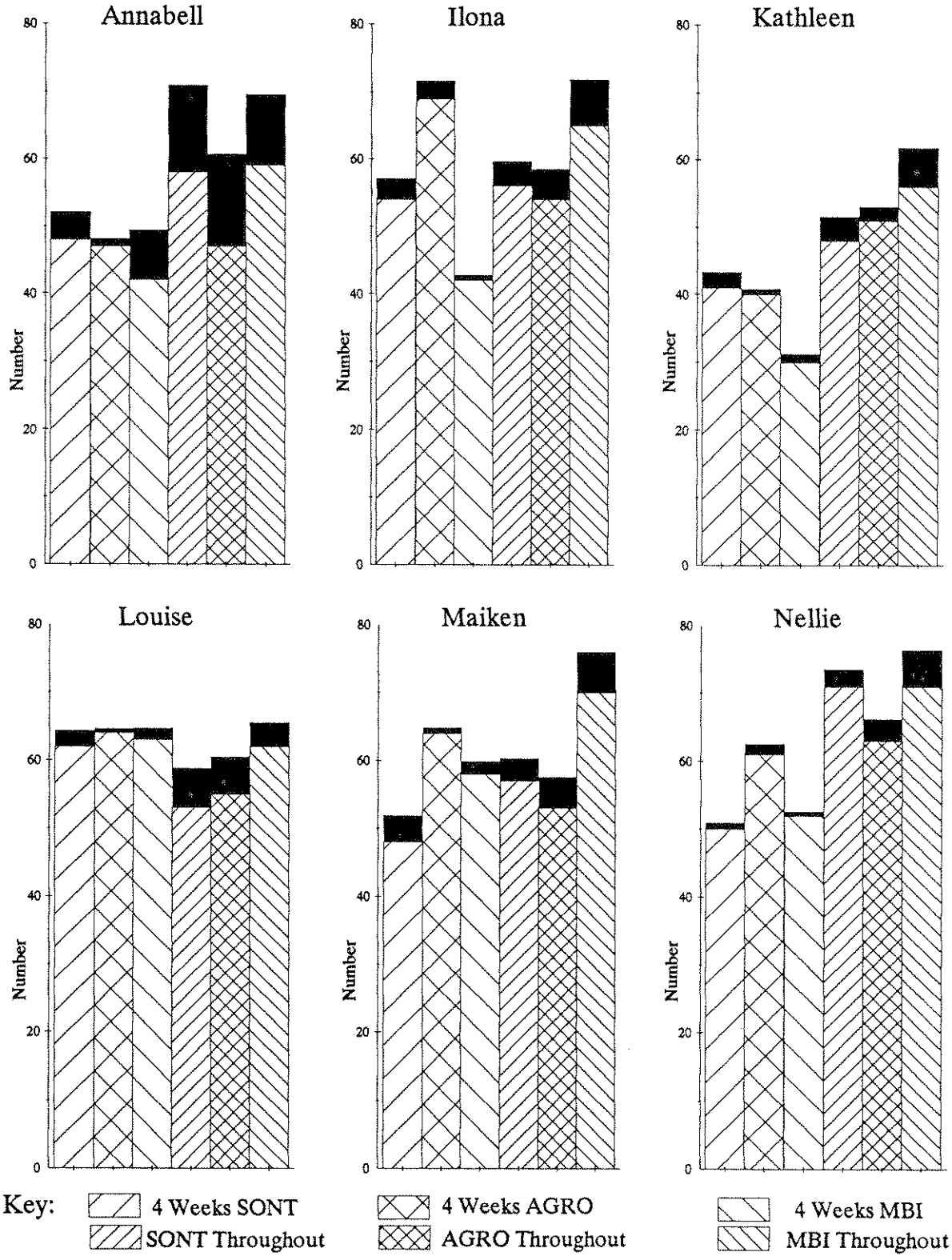


Table 1

Mean Quality Score for Each Variety and Treatment at Marketing Stage. (1 = Highest Quality)

Cultivar / Treatment	Annabell	Ilona	Kathleen	Louise	Maiken	Nellie	Average
4 Weeks SONT	2.1	2.4	2.7	2.1	2.1	1.5	2.15
4 Weeks AGRO	1.9	2.4	2.8	1.7	2.3	1.4	2.08
4 Weeks MBI	2.0	2.4	2.8	2.1	2.2	1.4	2.15
Throughout SONT	2.0	1.2	1.1	1.1	1.2	1.0	1.26
Throughout AGRO	1.8	1.0	1.1	1.1	1.2	1.0	1.20
Throughout MBI	1.9	1.5	1.0	1.0	1.1	1.0	1.25

Figure 19. Mean Number of Flowers after 6 weeks Shelf Life and Mean Number of Flowers and Buds Dead or Fallen Off.



APPENDIX III

RIEGER BEGONIAS

CRITERIA USED FOR QUALITY GRADING

Score

1 = good quality regular shape, height at least 160 mm, average plant spread at least 220 mm, internodes not longer than 30 mm, at least 5 flowers more than 50% open.

2 = slightly irregular shape, less than 5 but more than 2 flowers 50% open, height 140-155 mm, spread 200-215 mm or slight leaf defect.

3 = irregular shape, height 120-135 mm, spread 180-195 mm, obvious leaf defects, less than 3 flowers 50% open.

4 = unmarketable, height less than 120 mm, spread less than 180 mm or a combination of factors in (3).

APPENDIX IV

ECONOMIC APPRAISAL

Notes

1. Capital charges (luninaires, wiring etc.) - this is based on average utilization of 140 days annually depreciated over a 10 year period with interest charges on capital outlay of 14%.

2. Running costs assume that lamps run continuously, although in practice on a large installation this might be reduced by turning off lamps during bright periods.

3. The calculations are based on an average electricity cost of 7.78 p/kWh, and 2.65 p/kWh for Economy 7 usage - figures supplied by Electricity Association. Weighted averages accounting for duration of lighting treatment are listed in the calculations, Economy 7 period Midnight - 07.00 hrs.

4. Average market prices assuming a premium for high quality plants and normal quality.

Wholesale Price per pot	**Average**	**Premium**
February 1992	£1.22	£1.36
March 1992	£1.31	£1.49

5. Spacings

Pot thick for 4 weeks	=	59 plants/m^2
Intermediate for 3 weeks	=	40 plants/m^2
Final spacing for 5 weeks	=	16 plants/m^2

Calculations - running costs (medium grower). (Including lamp replacement cost).

1. **Plants lit for 4 weeks** followed by 2 weeks of short days followed by night break lighting.

   Growth period 12 weeks

   Supplementary lighting 28 days (16 hour/day)

   Night break lighting 42 days (5 hour/night)

2. **Plants lit throughout** with 2 weeks of short days.

   Growth period 10 weeks

   Supplementary lighting 56 days (16 hour/day)

SON/T and SON/T AGRO, 2500 lux, 12 m^2 per lamp

Cost of lighting/pot

1. **Plants lit for 4 weeks (pot thick stage)**

   $\frac{0.44 \times 16 \times 28 \times 3.7}{12}$ = 61 p per m^2 of lit bench during supplementary lighting

   Plants subsequently NBL for 6 weeks. (Full spacing)

   GLS 150 W, 9 m^2 per lamp

   $\frac{0.15 \times 5 \times 42 \times 1.03}{9}$ = 3.6 p/m^2 of lit bench during night break lighting.

   Total running cost of plants SON/T or SON/T AGRO supplementary lit for 4 weeks followed by NBL

   $\text{Cost/m}^2 = \frac{61}{59} = 1.03$ p/pot
   Plants/m^2

   $\frac{\text{Cost/m}^2}{\text{plants/m}^2} = \frac{3.6}{16} = 0.23$ p/pot

   Total = 1.26 p/pot

1. **MBI, 2500 lux, 7.5 m^2 per lamp**

Cost of lighting/pot

Plants lit for 4 weeks (pot thick stage)

$\frac{0.44 \times 16 \times 28 \times 6.0}{7.5} = 158$ p/m^2

Night break lighting period as SON/T and SON/T AGRO = 3.6 p per m^2

Total running cost of MBI supplementary lighting for 4 weeks followed by NBL.

$\frac{\text{Cost/m}^2}{\text{Plants/m}^2} = \frac{158}{59} = 2.68$ p/pot

$\frac{\text{Cost/m}^2}{\text{Plants/m}^2} = \frac{3.6}{16} = 0.23$ p/pot

Total = 2.91 p/pot

SON/T and SON/T AGRO, 2500 lux, 12 m^2 per lamp

Cost of lighting/pot

2. **Plants lit throughout (pot thick stage)**

$\frac{0.44 \times 16 \times 28 \times 3.7}{12} = 61$ p/m^2 of lit bench

Plants lit throughout (full spacing)

$\frac{0.44 \times 16 \times 28 \times 3.7}{12} = 61$ p/m^2 of lit bench

Total running cost of plants supplementary lit throughout SON/T and SON/T AGRO

Pot thick $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{61}{59} = 1.03$ p/pot

Full spacing $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{61}{16} = 3.81$ p/pot

Total = 4.84 p/pot

2. MBI, 2500 lux, 7.5 m^2 per lamp

Cost of lighting/pot

Plants lit throughout (pot thick stage)

$\frac{0.44 \times 16 \times 28 \times 6.0}{7.5}$ = 158 p/m^2 of lit bench

Plants lit throughout (full spacing)

$\frac{0.44 \times 16 \times 28 \times 6.0}{7.5}$ = 158 p/m^2 of lit bench

Total running cost of plants supplementary lit throughout MBI

Pot thick $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{158}{59}$ = 2.67 p/pot

Full spacing $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{158}{16}$ = 9.87 p/pot

Total = 12.54 p/pot

Calculations - capital charges

	pence/m^2/day
SON/T and SON/T AGRO	1.7
MBI	3.0
GLS	0.006

1. **Plants lit for 4 weeks only** (12 week crop)

SON/T and SON/T AGRO, lamps in use for 28 days, capital cost per m^2.

28 x 1.7 = 47.6 p

Pot thick $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{47.6}{59} = 0.80$ p/pot

MBI, lamps in use for 28 days, capital cost per m^2.

28 x 3.0 = 84 p

Pot thick $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{84}{59} = 1.42$ p/pot

GLS, lamps in use for 42 days, capital cost per m^2.

42 x 0.006 = 0.25 p

Full spacing $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{0.25}{16} = 0.02$ p/pot

2. **Plants lit throughout** (10 week crop)

SON/T and SON/T AGRO, lamps in use for 56 days, capital cost per m^2.

During pot thick stage (28 days) = 0.80 p/pot

At full spacing (28 days) $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{47.6}{16} = 2.97$ p/pot

Total = 3.77 p/pot

MBI, lamps in use for 56 days, capital cost per cost per m^2.

During pot thick stage (28 days) = 1.42 p/pot

At full spacing (28 days) $\frac{\text{cost/m}^2}{\text{plants/m}^2} = \frac{84}{16} = 5.25$ p/pot

Total = 6.67 p/pot

Overall cost = running cost + capital cost per pot

4 week lighting period

SON/T and SON/T AGRO = 1.26 p + 0.80 p + 0.02 p = 2.08 p

MBI = 2.91 p + 1.42 p + 0.02 p = 4.35 p

Lit throughout

SON/T and SON/T AGRO = 4.84 p + 3.77 p = 8.61 p

MBI = 12.54 p + 6.67 p = 19.21 p

Calculated returns per m^2

Assume average prices (1992)

Average price 13 cm February	122 p/pot
Assumed premium for extra quality	136 p/pot
Average price 13 cm March	131 p/pot
Assumed premium for extra quality	149 p/pot

Value per m^2

February

For 13 cm crop, average spacing = 16 plants/m^2

Average output value = £19.52/m^2

Extra quality output value = £21.76/m^2

March

Average output value = £20.96/m^2

Extra quality output value = £23.84/m^2

Any extra returns obtained from the lighting throughout treatment over the more standardly used 4 weeks lighting must be adequate to cover the additional lighting costs.

For February sales extra value of high quality crop per m^2 over average quality crop = £21.76 - £19.51 = £2.24/m^2 or **14 p/pot**.

For March sales, extra value of high quality crop per m^2 over average quality crop = £23.84 - £20.96 = £2.88/m^2 or **18 p/pot**.

February sales

Extra value of 14 p/pot must be sufficient to cover additional cost of lighting throughout compared to 4 weeks lighting.

14 p -6.53 p SON/T and SON/T AGRO = 7.47 p/pot or £1.19/m^2
14 p -14.86 p MBI = -0.86 p/pot or -£0.13/m^2

March sales

Extra value of 18p//pot must be sufficient to cover additional cost of lighting throughout compared to 4 weeks lighting.

18 p -6.53 p SON/T and SON/T AGRO = 11.47 p/pot or £1.83/m^2
18 p -14.86 p MBI = 3.14 p/pot or £0.50/m^2

APPENDIX V.

Plate 1. 'Annabell' - comprison of growth under SON/T, SON/T AGRO and MBI lamps lit for 4 weeks.

SON/T SON/T AGRO MBI

Plate 2. 'Annabell' - comparison of growth under SON/T, SON/T AGRO and MBI lamps lit throughout.

SON/T SON/T AGRO MBI

Plate 3. 'Ilona' - comprison of growth under SON/T, SON/T AGRO and MBI lamps lit for 4 weeks.

SON/T SON/T AGRO MBI

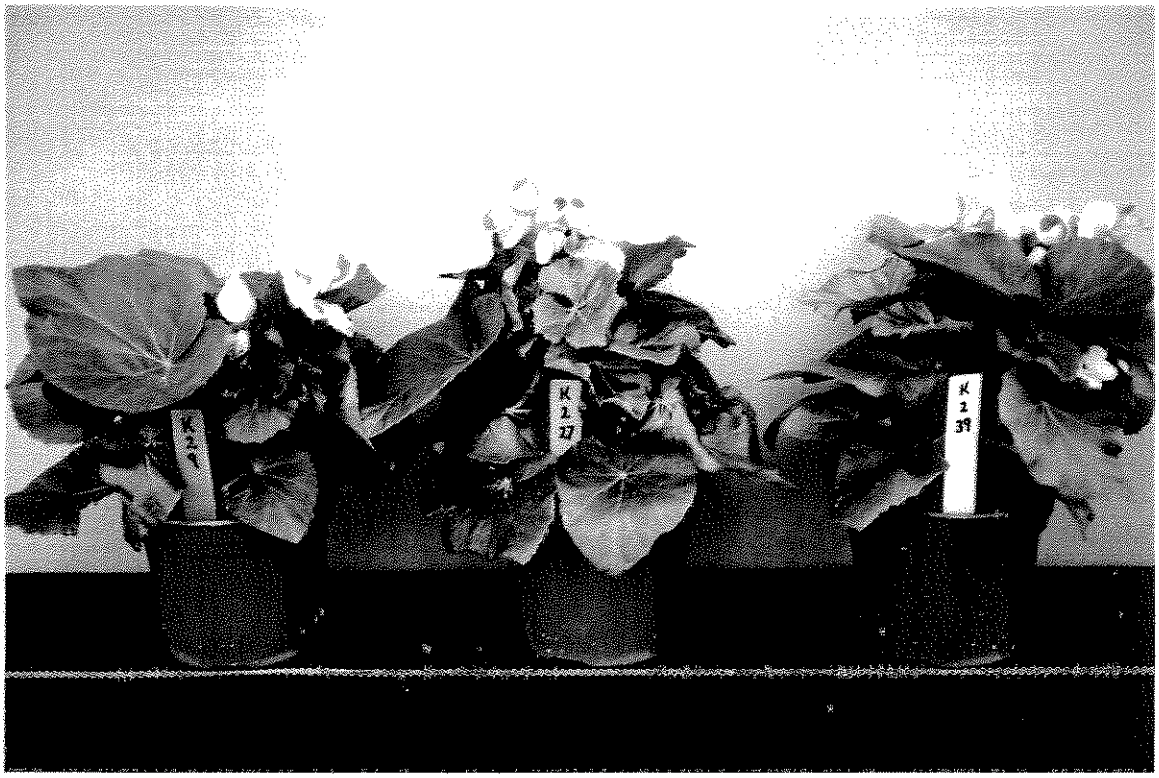
Plate 4. 'Ilona' - comparison of growth under SON/T, SON/T AGRO and MBI lamps lit throughout.

SON/T SON/T AGRO MBI

Plate 5. 'Kathleen' - comprison of growth under SON/T, SON/T AGRO and MBI lamps lit for 4 weeks.

SON/T SON/T AGRO MBI

Plate 6. 'Kathleen' - comparison of growth under SON/T, SON/T AGRO and MBI lamps lit throughout.



SON/T SON/T AGRO MBI

Plate 7. 'Louise' - comprison of growth under SON/T, SON/T AGRO and MBI lamps lit for 4 weeks.

SON/T SON/T AGRO MBI

Plate 8. 'Louise' - comparison of growth under SON/T, SON/T AGRO and MBI lamps lit throughout.

SON/T SON/T AGRO MBI

Plate 9. 'Maiken' - comprison of growth under SON/T, SON/T AGRO and MBI lamps lit for 4 weeks.

SON/T SON/T AGRO MBI

Plate 10. 'Maiken' - comparison of growth under SON/T, SON/T AGRO and MBI lamps lit throughout.

SON/T SON/T AGRO MBI

Plate 11. 'Nellie' - comprison of growth under SON/T, SON/T AGRO and MBI lamps lit for 4 weeks.

SON/T SON/T AGRO MBI

Plate 12. 'Nellie' - comparison of growth under SON/T, SON/T AGRO and MBI lamps l throughout.

SON/T SON/T AGRO MBI