Grower Summary

PC 296

Protected Ornamentals: Assessing the suitability of energy saving bulbs for day extension and night break lighting

Final 2012

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

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Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

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HDC
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

Tel – 0247 669 2051

HDC is a division of the Agriculture and Horticulture Development Board.

Project Number:	PC 296
Project Title:	Protected Ornamentals: Assessing the suitability of energy saving bulbs for day extension and night break lighting
Project Leader:	Professor Brian Thomas
Contractor:	University of Warwick
Industry Representative:	Mr Colin Frampton, First Flora Ltd
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Headline

- Flowering and/or tuber formation in chrysanthemum, poinsettia, begonia and fuchsia was controlled as effectively by compact fluorescent (CF) lighting as it was by tungsten (T) lighting. However, for antirrhinum, Christmas cactus, lisianthus, pansy and petunia the light spectrum from CF lamps did not match that from T lamps well enough to control flowering successfully.
- Deep Red, White and Far-Red (DR/W/FR) LED flowering lamps were able to control flowering and/or tuber formation as effectively as T in chrysanthemum, poinsettia, begonia, antirrhinum, lisianthus, pansy and petunia. However, for Christmas cactus none of the flowering lamps were able to control flowering to the same extent as T lamps.
- Although each species had subtly different optimums, combinations of red (R) and far-red (FR) LED modules were effective at controlling flowering and/or tuber formation for all of the species tested.

Background

Photoperiod lighting can be used to promote flowering in long-day plants (LDP) and to delay or prevent flowering in short-day plants (SDP). Tungsten (T) lamps have traditionally been used for this purpose as they are cheap to purchase and have a suitable light quality. However, Defra have announced that 'inefficient' T lamps will be phased out over the period Jan 2008 to Dec 2011 and higher wattage lamps are already becoming difficult to obtain. Furthermore, there is a desire from some growers to move away from T to minimise stretching which can occur as a consequence of the light spectrum. Consequently, there is a need to assess the suitability of alternative lamps.

The first stage of this project (2009-2010) examined the suitability of replacing inefficient T lamps with compact fluorescent (CF) lamps for daylength control by investigating the flowering responses of a range of horticultural species to CF light quality and quantity. Flowering and/or tuber formation was not controlled as well by CF lighting for over half of the species tested; therefore, CF lamps did not match the light spectrum from T lamps well enough to control flowering effectively for this range of species. As CF lamps lack far-red (FR) light, the solution to achieving better photoperiodic control is likely to require a change in spectral output rather than an increase in the number of lamps and light emitting diodes (LEDs) offered a potentially efficient alternative.

Therefore, the second stage of this project was designed to examine the suitability of LEDs as an energy-saving alternative to T in photoperiod manipulation. A range of important horticultural species have been tested for their response to night-break and day-extension lighting by two LED types;

i) Red (R), FR, mixtures of R and FR, and Blue (B) LED modules and

ii) FR only, Deep Red/White (DR/W), and Deep Red/White/Far-Red (DR/W/FR) LED flowering lamps in order to provide realistic recommendations for growers.

The R LEDs produced light between 600 nm and 700 nm, FR between 700 nm and 800 nm, and B between 400 nm and 500 nm. DR is enriched in the red part of the spectrum but has additional wavelengths.

Summary and Conclusions

In the first stage of the experiment the suitability of replacing T lamps with CF lamps to control the photoperiodic response in nine different species was examined by growing plants in a suite of automated daylength controlled chambers (see photograph) where plants were exposed to 8 hours of daylight (from 08:00 h to 16:00 h) and then automatically transferred into light-tight chambers where the daylength was manipulated using T or CF lamps, or kept dark in the case of the short day (SD) treatment. Different light levels (1, 2.5 and 5 µmol/m^2/s) were used in the chambers. The effect of light level was also examined on fixed benches using light gradients (0.3 to around 9.3 µmol/m^2/s) to extend the natural short daylengths over winter. Both 8-hour day-extension (DE) lighting from 16:00 to 24:00 h, and 4-hour night-breaks (NB) from 22:00 h to 02:00 h were tested.

For the second stage of the project the control of photoperiodic flowering responses to light-emitting diodes (LEDs) was investigated in order to compare the efficacy of replacing tungsten bulbs with LEDs. By using the same suite of automated day length controlled cabinets and the same SD control treatment this experiment provided comparable data for a similar range of horticultural species. In order to provide realistic recommendations for growers, commercially available lamps that have been developed for use in the horticultural industry were tested; i) Philips GreenPower LED modules, developed specifically for applications such as multilayer plant production, plant research and plant production in conditioned environments; ii) Philips GreenPower LED Flowering lamps, which have been specially developed as a replacement for the incandescent lamp to extend day length to control flowering.

NB and DE treatments within the photoperiod compartments consisted of either T lamps or LED modules with R, FR or B LEDs, or mixtures of R and FR at two different ratios (25%R+75%FR and 75%R+25%FR). T lamps were set to 2.5 µmol $m^{-2}s^{-1}$ and the LED modules were set to 2.5±1.5 µmol $m^{-2}s^{-1}$. Due to space restrictions B LEDs were only tested as a DE treatment. DE flowering responses to three types of LED flowering lamp were compared using the fixed benches. The three lamp types and the light levels tested were; FR, 0.8±0.2µmol $m^{-2}s^{-1}$; DR/W, 7.5±1µmol $m^{-2}s^{-1}$; and DR/W/FR, 3±0.9µmol $m^{-2}s^{-1}$.

Compact Fluorescent Lamps

Chrysanthemum (Tampico White) plants grown under an 8-hour daylength (SD) budded and flowered rapidly, while all of the DE and NB treatments remained vegetative until they had produced around 17-20 leaves on the side shoot; then they budded autonomously. Therefore, CF lamps would appear to be safe for chrysanthemum. Interestingly even plants exposed to very low light levels (0.3 to 1 µmol/m^2/s) remained vegetative, suggesting that this cultivar might be more sensitive to light when compared with some of the older cultivars which were tested previously at GCRI.

Poinsettia (Prestige Early Red) was also reasonably sensitive to CF lamps. The plants grown under short days soon went red and had cyathia, while all of the long-day treatments initially remained green. Plants were kept for 26 weeks from pinching and over time some of the DE and NB plants eventually showed some colour, although they did not develop fully red bract stars. There was considerable variability between plants, but colour was seen more frequently in the DE treatment with CF lamps. Plants appeared to be sensitive down to very low (0.3 µmol/m^2/s) light levels.

Non-stop begonia (Illumination Rose) also responded well to CF lamps, which were equally effective at delaying tuber formation and promoting shoot growth as T lamps. Plants appeared to be sensitive to very low (down to 0.3 µmol/m^2/s) light levels.

Christmas cactus (Olga) was the only SD species tested where CF lamps were less effective than T. Flowering of these plants had been delayed by a T DE treatment in commercial production before they were transferred to the experiments and this was also the most effective treatment for delaying flowering. T NB and CF NB and CF DE also all delayed flowering of Christmas cactus compared with the SD treatment.

Fuchsia (Patio Princess) plants grown under a continuous 8-hour daylength had no flower buds even at the end of the experiment (22 weeks after bud appearance in the long-day treatments) whereas the long day treatments budded rapidly. The DE treatment with CF lamps delayed flowering compared with the other long day treatments, but only by around 3 days. Plants appeared to be sensitive to very low (0.3 µmol/m^2/s) light levels.

CF lamps tended to be less effective than T lamps for most of the LDP that were tested. With **antirrhinum** (Bells Red), **lisianthus** (Florida Silver and Forever Blue) and **pansy** (Majestic Giant Purple), DE lighting with CF lamps proved ineffective, irrespective of the light level. NB lighting with CF lamps was more effective, although it did not tend to hasten flowering as much as a T NB. In the case of **antirrhinum** and **lisianthus**, plants budded sooner with an 8-hour T DE than they did with a 4-h T NB. Similar results were found across the light levels tested.

DE lighting with CF lamps hastened flowering of **petunia** (Express Salmon) when compared with the short day treatment. However, once again, these lamps were not as effective as T, especially when used as a DE. Similar results were found across the light levels tested.

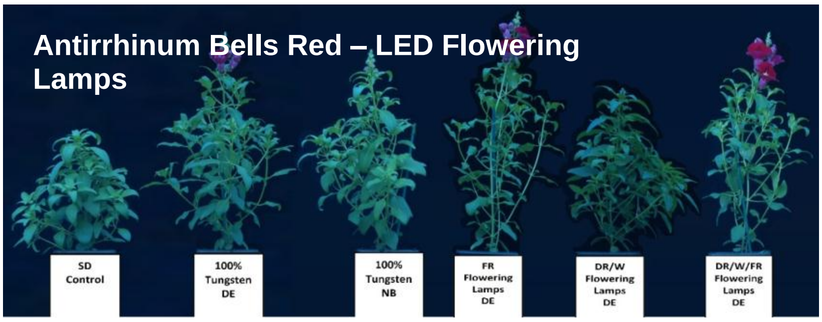
The first stage of this project concluded that there was no single CF solution that would have satisfied the needs of all species when replacing tungsten lighting to manipulate photoperiod. It had not been possible to generalise according to whether the crop had a SD or LD response.

LED Flowering Lamps

In the second stage of the project the DR/W/FR LED flowering lamps were able to control the flowering or tuber development of all of the species tested, with the exception of Christmas cactus (photographs of **chrysanthemum** and **antirrhinum** are shown below as examples of both a SD and a LD plant type and the full results summary is provided in the table below).

As for **chrysanthemum** (Tampico White) plants grown under a T DE or NB, those grown under DR/W/FR LED flowering lamps had not produced visible buds after 91 days in treatment and had produced 10-14 additional leaves on the most developed side shoot compared with those under SD conditions. Similarly, for **poinsettia** (Prestige Early Red), plants grown under T DE, NB or DR/W/FR LED flowering lamps had not developed red bracts 156 days into treatment. The tuber fresh weight of **begonia** (Illumination Rose) was reduced by 5.77g, for plants grown in the T DE treatment, and by 5.85g, for plants grown under DR/W/FR LED flowering lamps.

However, for **Christmas cactus** (olga) plants, all three of the LED flowering lamps tested, FR, DR/W and DR/W/FR, caused a delay in flowering equivalent to T NB but T DE resulted in an even greater delay.



Across the LD species tested, **antirrhinum** (Bells Red), **lisianthus** (Florida Silver), **pansy** (Majestic Giant Purple) and **petunia** (Express Salmon), an 8 hour day extension with DR/W/FR or FR LED flowering lamps provided a level of photoperiodic control equivalent to the 8 hour T DE treatment, which was more effective than the 4 hour T NB treatment for antirrhinum and petunia.

Chrysanthemum was the only species tested where the DR/W LED flowering lamp DE treatment was able to induce the same photoperiodic response as T (DE and NB); plants grown under these treatments had not produced visible buds after 91 days.

GreenPower flowering lamp types tested in eight-hour day-extension treatments

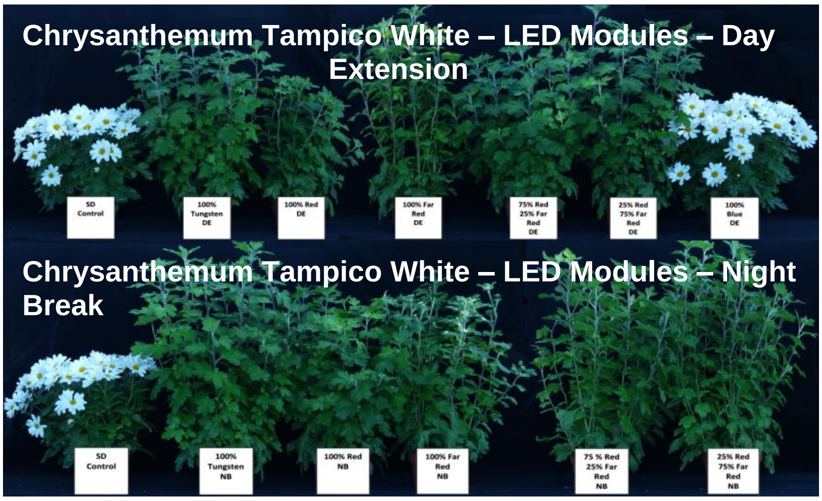
Plant species		Flowering lamp type		
		Far-red only	Red + white	Red + white + far-red
Long-day plants	Antirrhinum	✓	X	✓
	Lisianthus	✓	X	✓
	Pansy	✓	X	✓
	Petunia	✓	X	✓
Short-day plants	Begonia	X	X	✓
	Christmas cactus	X	X	X
	Chrysanthemum	X	✓	✓
	Poinsettia	X	X	✓

✓ = comparable response, X = response is not as good as tungsten

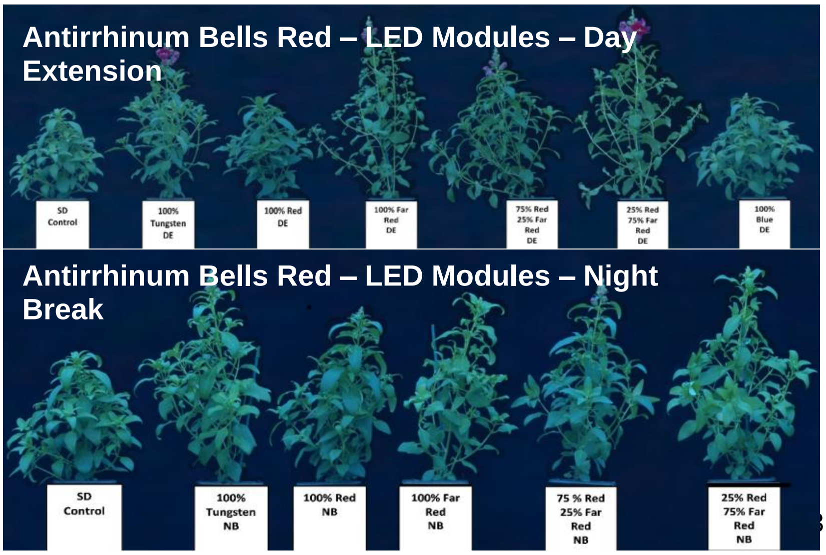
LED Modules

Generally, combinations of R (~660nm) and FR (~730nm) light were the most effective LED module treatments, as long day treatments delayed flowering in SD species and hastened flowering in LD species. However, which light quality and type of LD treatment was most effective varied between species and appears to be species specific (photographs of chrysanthemum and antirrhinum are shown below as examples of both a SD and LD plant type and the full results summary is provided in the table below).

The 100% B LED module DE treatment was generally ineffective across both SD and LD species. All of the SD species, **chrysanthemum**, **poinsettia**, **Christmas cactus** and **begonia**, showed no significant difference in flowering time or tuber development between the 100% B and SD treatments. Of the LD species; **lisianthus** and **petunia** showed no significant difference in flowering time between the 100% B and the SD treatments; for **antirrhinum** and **pansy** although there was a significant difference between the 100% B and the SD treatments, the 100% B LED module was among the least effective treatments for these species.



For **antirrhinum** (Bells Red), **lisianthus** (Florida Silver), **pansy** (Majestic Giant Purple) and **petunia** (Express Salmon) the response to 25%R+75%FR DE was equivalent to the most effective T treatment. Antirrhinum and petunia plants grown under T DE flowered earlier than those grown under T NB, similarly, the LED modules were more effective at hastening flowering as DE rather than NB treatments. Other LED module combinations were effective at hastening flowering for these four species, for example, 75%R+25%FR NB and 25%R+75%FR NB were equally as effective as 25%R+75%FR DE for pansy. Delayed SD responses were observed in **Chrysanthemum** (Tampico White), **begonia** (Illumination Rose) and **poinsettia** (Prestige Early Red) plants grown under 75%R+25%FR DE treatment; flowering or tuber development was equivalent to T DE and T NB treatments.



Although, 75%R+25%FR DE was a significantly effective long day treatment for delaying flowering in

Christmas cactus, 25%R + 75%FR DE was equivalent to T DE (which was more effective than T NB).

A cautious approach should be taken with regards to the replacement of T with CF lamps as just over half of the species tested did not respond effectively to the light spectrum of CF lamps; the results observed applied even when the light level was increased to twice that of the current commercial norm. This is probably because CF lamps lack FR light, which appears to be more important for DE than NB lighting. Although CF lamps would provide a suitable replacement for T for some of the species tested (chrysanthemum, poinsettia, fuchsia and begonias), it would be more beneficial for growers to be able to use a single, more efficient alternative to T.

In considering the replacement of T lighting using LED flowering lamps, the DR/W/FR flowering lamps would be the most appropriate as they illicit the equivalent response to T in all species tested, with the exception of Christmas cactus. In the case of begonia, the fresh weight of the tubers produced was equivalent to that produced under T lighting. The FR flowering lamps provided good flowering control for half of the species tested, but had detrimental effects on plant height; increasing stretching in these species. The DR/W flowering lamp treatment was only able to provide an equivalent level of control for chrysanthemum, due to the lack of FR in the spectrum. For chrysanthemum, however, they would be a preferable choice over the DR/W/FR lamps as they caused less stretching (even in comparison to T).

Ratios of red and far-red LED light which generated a comparable photoperiod response to tungsten bulbs in day-extension (DE) and night-break (NB) treatments

Plant species		0% red + 100% far-red		25% red + 75% far-red		75% red + 25% far-red		100% red + 0% far-red	
		DE	NB	DE	NB	DE	NB	DE	NB
Long-day plants	Antirrhinum	✓	✓	✓	✓	✓	✓	X	x
	Lisianthus	✓	x	✓	✓	x	✓	X	x
	Pansy	x	x	✓	✓	x	✓	X	x
	Petunia	✓	x	✓	✓	✓	✓	X	x
Short-day plants	Begonia	x	x	✓	✓	✓	✓	✓	✓
	Christmas cactus	x	x	✓	✓	✓	✓	X	✓
	Chrysanthemum	x	x	✓	✓	✓	✓	✓	✓
	Poinsettia	x	x	x	✓	✓	✓	X	✓

✓= comparable response to tungsten, X= response is not as good as tungsten

This project has demonstrated the importance of FR light in the control of flowering and considering the very low FR output of CF lamps and their inability to control flowering in over half of the species tested in the first stage of the project, they do not seem to be a dependable alternative to T. In the long term, LED lighting may well be the preferable alternative to T lighting because of the potential to adjust spectral output. LEDs have advanced greatly and are now relatively efficient and robust. They also have a much longer life expectancy than other lamp types, and this is not shortened by repeated cycling. While LEDs offer many advantages, high equipment cost is currently an issue, although this is likely to come down over time. LED lamps can be manufactured to give light of any given wavelength (colour), which is a big advantage for photoperiodic lighting if the plant requirements are known.

Financial benefits

As tungsten lamps are currently being phased out, growers face financial losses if they do not identify suitable alternatives. Implementing new lighting strategies is likely to result in capital costs, this project will assist in identifying strategies that are safe but not over-specified so that they do not incur more set up and running costs than necessary.

Capital costs are high for the installation of LEDs but as a new technology prices are widely expected to reduce with time and benefits include their efficiency coupled with their long operating life. The HDC project *PO 010: LED Lighting for Horticultural Applications – Establishing the Economics of Current Hardware Offerings* provides a current economic appraisal along with a calculator for growers to use for their own situation.   It should also be noted that the Philips LED flowering lamps are able to fit into existing tungsten festoon lighting setups although they are only available in screw fittings. Companies are developing other LED systems, for example, SolarOasis have developed both the GrowStar Pro550 (a broad spectrum solid state LED plant grow light) and monochrome LED clusters (a research and development tool available in 22 wavelengths). As more LED systems become available there are likely to be significant reductions in cost.

Action Points

- Energy-saving compact fluorescent bulbs are only a suitable replacement for the control of flowering in half of the species tested in this project and given the low FR output of CF lamps they are unlikely to provide a dependable alternative to T lighting.
- DR/W/FR LED flowering lamps provided a similar level of flowering control as T day-extension treatments for all species tested, with the exception of Christmas cactus.
- A mixture of R and FR LED modules provided an equivalent level of flowering control to tungsten bulbs in most species tested. From the results obtained here a

75%R+25%FR LED module day-extension treatment would be recommended in order to provide effective photoperiodic control and to minimise stretching.

- It would be sensible for growers to test these and other suggested ratios of R+FR LED modules on a small scale with their own mix of varieties before implementing changes.
- This project has investigated the use of Philips GreenPower LED lighting, however, there are other, commercially available lighting systems that have not been tested here and therefore, may provide varying results.