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S Coutts

FEC Services Ltd

W J Findon & Son Ltd

Horticultural Development Council

Priva (UK) Ltd

Skye Instruments Ltd

The University of Reading

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PRACTICAL SECTION FOR GROWERS

Background and objectives

The bedding plant industry is estimated by DEFRA to have a current farm-gate value of about £120M per annum. It is, however, diverse, and is made up of many thousands of small growers and a smaller number of larger, technologically more advanced companies. Among these latter are companies producing young plants which are increasingly becoming the 'starting material' for smaller growers.

Supplies of bedding plants to the market tend to be erratic and are greatly influenced by climate, particularly light. This problem is exacerbated by the short marketing season for most of the crop (April to June), and early or late maturing crops will be wasted. Consequently, there is an urgent need to develop practices that aid production planning to overcome this supply problem and also ensure the production of high quality plant material. Technology is also required that can increase output during the peak periods of market demand, thereby reducing the need to import product from other EU countries. A possible solution is the application of supplementary light, optimised by the use of quantitative models to predict time to crop maturity and the quality of the resulting plants. However, few growers currently use supplementary lighting, largely because there is a dearth of information on the physiological responses of bedding plants to light, and a lack of confidence on the part of the growers that the high capital costs of installing lights will be financially justified.

The overall objectives of the project are therefore:

- To determine the principle responses of bedding plants to light, especially to supplementary illumination.
- To evaluate methods of quantifying the light environment within greenhouses of varied design as a function of outside solar radiation.
- To construct mathematical models to predict the effects of climatic variables, particularly light, on the time to 'maturity' and quality of bedding plant species.
- To validate these models with and without supplementary illumination under commercial and semi-commercial conditions.

- To construct computer software to enable growers to use the models in conjunction with supplementary lighting to manipulate produce supply in relation to market demand.
- To facilitate technology transfer by producing a booklet directed at growers, which will be concerned with maximising the potential of supplementary light for the production of bedding plants.

Summary of Results and Conclusions

Principle responses of bedding plants to light, especially to supplementary illumination

Geranium and petunia were shown to be the most responsive to supplementary lighting, whilst impatiens and pansy were the least responsive. However, for all species, the use of supplementary lighting during the period of plug production increased the growth (fresh and dry weight, leaf area), thus reducing the plug production time and increasing the quality of the plants.

Carry over effects of supplementary lighting during plug production to final flowering, in terms of increased growth and earlier flowering, were, however, small.

Quality attributes such as plant compactness also increased with increased supplementary lighting whilst reduced hypocotyl length occurred when supplementary lighting coincided with the period of hypocotyl expansion.

Lighting at a lower intensity for longer was more beneficial than lighting at a higher light intensity for a shorter period. Moreover, lighting later in the plug development period when there was a greater leaf area to intercept the additional light was more efficient than lighting earlier.

The response to lighting increased with increasing temperature up to 23°C for impatiens and 25°C for geranium and pansy. Additional benefits could also be achieved when lighting was accompanied by carbon dioxide enrichment. Increased temperature did not affect quality attributes. However, under low light conditions, higher temperatures reduced plant compactness and increased hypocotyl length.

Longer periods of lighting, particularly at lower light intensities increased leaf greenness (chlorophyll content) and it is probable that this effect contributed to the increased growth responses. Longer daylengths, even when provided as nightbreak lighting (approx 2 Watts per m^2), increased leaf greenness and gave benefits in terms of increased plant growth. As the season progressed and background light levels increased the response to lighting decreased progressively.

Supplementary lighting is clearly beneficial in increasing the rate of growth and quality of bedding plants during plug production. The greatest benefits are achieved by applying lighting early in the season, during the night period and later rather than earlier in the production period. It is better to apply lighting for a longer period at lower intensities than for a short period at high intensities. Responses can be improved further through carbon dioxide enrichment and increasing set point temperatures.

Is the response to supplementary light brought about by increased light energy or does increased tissue temperature from the radiant energy emitted by the lamp play a part?

The effect of increased tissue temperature due to the increase in total radiation did not significantly increase growth when applied during the normal daylight hours at light intensities which were two and a half times those used commercially.

The benefits achieved are brought about largely through increased light.

What is the most efficient lamp source for bedding plants?

Eight discharge lamp types were tested on the four bedding plant species. For geranium there were few significant differences between the lighting treatments. Impatiens plants under the mercury and phosphor coated metal halide bulb gained significantly more dry weight when compared to the other bulbs types. This trend was also seen with the other species.

However, it should be noted that all lamps were set to provide 50 µmol per m^2 per second (~ 10 Watts per m^2 PAR) at plant height, and so although the mercury and new metal halides may have the better spectral distributions, due to their efficiency levels (light output per unit energy input) they are not necessarily the best lamps for commercial use.

Note: PAR = Photosynthetic Active Radiation

Bedding plant species show responses to different lamp types but these are probably not great enough to merit choosing lamps other than those which offer the highest PAR output per unit electricity consumption. High Pressure Sodium lamps still offer the best compromise between energy efficiency and cost. For further details on supplementary lighting systems, see HDC Grower Guide on 'Supplementary lighting - equipment selection, installation and maintenance' published in 2001 and available to HDC members.

Methods of quantifying the light environment within greenhouses of varied design as a function of outside solar radiation

A computer based system was developed to enable growers to obtain estimates of outside radiation using long-term historical meteorological measurements. Using this, global radiation data can be provided throughout the UK from information on latitude, time of year and whether the greenhouse is located on the coast or inland. The global radiation at the coast is about 9% more than inland at the same latitude.

However, it is not possible to use indirect methods to measure light transmission in glasshouses, the only accurate method is to measure this directly using one or more light sensors preferable measuring PAR.

Light transmission recorded in range of commercial structures over a six month period highlighted several important factors determining the light environment in a greenhouse. The spatial variation of light transmission tends to follow clear trends i.e. transmission is lowest under the gutters and highest under the ridges. Obstructions within the greenhouse such as boilers, polythene, stacked trays or thermal screens and objects outside of the greenhouse such as hedges or other buildings can significantly reduce light transmission in adjacent areas within the house. Light transmissions for all greenhouse structures showed a marked seasonal trend with a lower transmission during the winter period (October -December) than the summer (July-September). Therefore, greenhouses are least efficient at times when lighting is most limiting to crop growth.

Light transmissions between greenhouses varied from approximately 40% to70%. These differences will result in variations in the yield potential of these houses. A 1% decrease in available light will result in an approximate 1 to 3% decrease in the dry weight of the four bedding plants species studied within this project. Thus, for example, the poly tunnel gave a 20 to 30% higher light transmission than many of the glass structures which is likely to be reflected in equivalent increases in dry weight accumulation and therefore plant throughput. Variations in the light transmission within houses will also result in increased crop variability.

The best estimate of light transmission over a whole house can be obtained by locating the light sensor away from any structural beams and away from the gutter, indeed the best location would appear to be at crop height, between the gutter and ridge avoiding structural beams.

A simple computer package has been constructed which can provide growers with accurate estimates of outside light levels for any location in the UK. The HDC will make this program available to members during 2003.

It is not possible to estimate light transmission accurately without direct measurement using light sensors. It is best to use light meters which measure photosynthetically active radiation (PAR 400-700 *nm) in units of energy (Watts per m^2) or photon flux (µmol per m^2 per second) rather than luminance (lux, lumens). Please see 'HDC Grower Guide on Supplementary Lighting – equipment selection, installation and maintenance' for further information on light units and light measurement.*

Mathematical models to predict the effects of climatic variables, particularly light, on time to 'maturity' and quality of bedding plant species

Plant response algorithms (model) have been constructed to predict the growth and quality of bedding plant plugs of impatiens, petunia, pansy and geranium, to light, photoperiod and temperature. The model is based on light interception and radiation use efficiency. The change in fresh weight for a particular day is estimated by calculating the amount of light intercepted by a plant, and using this value with an estimated measure of the efficiency by which the plant converts light into plant weight, to calculate the production of weight. The increment in leaf area is then predicted using an estimate of leaf area ratio (the ratio of plant weight to leaf area) to convert the increase in weight into leaf area. Finally, these changes in leaf area set the conditions for the next day.

The plant response algorithms generated for petunia and impatiens are scientifically robust. However, the plant response algorithms are incomplete for pansy and geranium and further data needs to be generated to determine these species responses to temperature and CO_2.

The algorithms for petunia, pansy, impatiens and geranium have been incorporated into 'a model' constructed in an Excel spreadsheet format, which has also incorporated global radiation information based upon site location. The user must input:

- ^{O} latitude of the glasshouse location
- Whether the location is coastal or inland
- Average light transmission of the structure
- Day and night temperature
- Light output from the supplementary lighting lamps
- Duration for which the lamps are on
- Target dry weight of the bedding plant plugs
- Plug cell size
- Start date of production or end date of production

The model will then predict the growth rate of the bedding plant plugs with and without supplementary lighting. Some preliminary validation tests of the model using information from commercial nurseries have been undertaken.

A experimental version of a computer 'model' has been developed that has the potential to enable growers to predict the likely benefits of specific supplementary illumination strategies as an aid in the production of bedding plants in the plug phase.

Production of publicity material on the use of lighting in bedding plant production

HDC by 31 March 2003 will:

- produce a grower information sheet on light measurement and light transmission in glasshouses
- make the global solar radiation algorithm available to growers via the HDC web-site
- publish a detailed grower article in HDC News on the response of bedding plants to supplementary lighting.

Action points for growers

<u>Guidance for all growers</u>

1. **Light units**

Measure light either as energy (Watts per m^2) or photon flux (µmol per m^2 per second) in the photosynthetically active range (PAR, 400-700nm). Avoid measuring light in units of illuminance (lumens, lux). Please see 'HDC Grower Guide on Supplementary Lighting – equipment selection, installation and maintenance' for further information on light units and light measurement.

2. **Light measurement**

A wide range of portable light meters are available which measure light in Watts per m^2 or µmol per m^2 per second. Measure light in a greenhouse by locating the sensor at crop height midway between the gutter and ridge avoiding obstructions that will shade the sensor. Measure light transmission by simultaneously measuring glasshouse and outside light levels and expressing glasshouse light level as a percentage of outside light.

3. **Light transmission**

Ensure that light transmission is maximised by cleaning glass regularly. Dirty glass can reduce light transmission by an average of 17%. Avoid shading plants by positioning equipment that could obscure light low in the greenhouse.

4. **Light levels in the UK**

A simple computer-based system (developed by SRI) will be made available by the HDC to enable growers to obtain long term estimates of outside radiation. Global radiation data can be provided throughout the UK from information on latitude, time of year and whether the greenhouse is located on the coast or inland.

5. **What lamps to use?**

High Pressure Sodium lamps still offer the best compromise between energy efficiency and cost.

Actions points for bedding plant plug producers

I. **Key benefits of lighting bedding plants**

Supplementary lighting will increase the rate of growth and quality of bedding plants during plug production. Apply lighting early in the season, during the night period and later rather than earlier in the production period. Apply lighting for a longer period at lower intensities than for a short period at high intensities.

2. **Benefits in terms of improved quality and scheduling**

Supplementary lighting can improve plant compactness. Hypocotyl length can be reduced if supplementary lighting is applied during the period of hypocotyl expansion. Supplementary lighting will reduce plug production times and improve space utilisation. Product supply and quality can be predicted and manipulated using supplementary lighting leading to reduced wastage.

3. Use of CO_2 enrichment

Responses can be improved further through carbon dioxide enrichment.

Action points for finishers of bedding plants

I. **Benefits for plant finishers**

Further use of supplementary will lead to greater growth rates and better quality in finished bedding plants.

2. **Impact on plug quality**

Plugs raised under lights will provide uniform better quality starting material for plant finishers leading to more reliable finished plants.

3. **Scheduling issues ?**

Using supplementary lighting during plug raising can lead to earlier flowering times, particularly when supplementary lighting is used early in the season when outside light levels are low but trials showed that the effects are generally small.

Overall benefits from the Study

Substantial benefits from the study will accrue by the increase in throughput per unit glasshouse space. It estimated, for example, that producing one extra crop per year would yield a return of £60,000 per acre.

Increased productivity from existing greenhouse space will also lessen the need for greenhouse expansion (with glasshouses typically costing £130,000 per acre and imported from other EU countries), which would be attractive to growers and lead to a reduction in imports. Increased productivity will also allow growers to match demand of high quality product, demanded by the consumer, with supply, particularly over the short marketing season for bedding plants. Substantial losses arise from the erratic supply of bedding plants to the markets. These will be substantially reduced as supply and quality can be predicted and manipulated with supplementary lighting. A 1% reduction in wastage over the whole industry, for example, equates to a saving of £1.2M. Wastage levels are currently estimated at 10% per annum.

The main scientific benefit gained from the study is an increased mechanistic understanding of how plants interact with their environment. New modelling strategies have been examined. This study will show how 'scientific' crop models can be applied by growers in decision support systems. Light measuring equipment developed by Skye Instruments will enable growers to measure available light within greenhouses more accurately. Growers will also benefit from information provided to them by HDC and FEC Services Ltd.

Cost Benefit Relationship

A cost benefit relationship has been constructed assuming that, as a result of the work, 20 acres of existing glass will be equipped per year with supplementary lights for bedding plant production, enabling growers to produce one more crop per year. It further assumes that the use of these more productive greenhouses reduces the amount of glass built by 2 acres per year. Furthermore, it is assumed that the project will lead to a 1% reduction in wastage each year through improved scheduling and plant quality , thus;

Extra Production of Crops (20acres @ £60,000 per acre)	£1.20M
Reduction in imports of new glasshouses (2 acres @ £130,000)	£0.26M
Reduction in wastage (1% of£120M)	£1.20M
Total benefits of the project to the UK industry are estimated at	£2.66M per annum

Without quantifying the benefits to the individual industrial partners, and given a project cost of £315,078 (including in kind contributions from industrial partners) a conservative estimate of the gearing ratio of this project would be in the order of 9: 1.