Grower Summary

CP 125

Understanding crop and pest responses to LED lighting to maximise horticultural crop quality and reduce the use of PGRs

Annual *2015*

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

If you would like a copy of the full report, please email the AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

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Project title:	Understanding crop and pest responses to LED lighting to maximise horticultural crop quality and reduce the use of PGRs.
Project number:	CP 125
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Report:	1st Annual report, July, 2015
Previous report:	
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Date project commenced:	01 May 2014
Date project completed (or expected completion date):	30 June 2017

GROWER SUMMARY

Headline

Manipulation of light quality using LEDs can be used to improve all stages of crop production and light spectra designed for plants can be designed to maximise growth, maximise growth regulation and/or to induce flowering. Insect colour perception is also altered under LED light but fluorescent yellow and green sticky traps improved trap effectiveness under red:blue light mixtures.

Summary

Report overview

The experiments reported here are arranged in 3 work packages.

Work package 1 - General agronomy under LED lighting.

This work package will examine the general agronomic practices required for plant production under LED lighting. One of the major benefits of LED lighting is low energy consumption compared to conventional lighting systems. The robust nature and ability to rapidly turn LEDs on and off also provides the possibility of further reducing energy consumption by either creating mobile light rigs that move over the crops at regular intervals or strobing the light to reduce energy consumption. Both these techniques can lower energy consumption, but this comes at the cost of a lower daily light integral (DLI). All plants have an optimal daily light integral at which growth rates are high and plant quality is optimal if no other factors are limiting. While there is some information regarding the optimal DLI for a range of species, these values have been defined under natural light conditions where the solar intensity varies greatly throughout the diurnal cycle. Under the constant conditions that can be achieved in LED light growth systems, there is little information regarding the optimal DLI.

This work package examined the effects of a mobile light system (DLI ~3.5 mol m^{-2} d^{-1}), a slow strobe light system (DLI 6 mol m^{-2} d^{-1}) and four constant-light-intensity treatments with different daily light integrals ranging from 6 mol m^{-2} d^{-1} to 22mol m^{-2} d^{-1}, on the propagation (first three weeks of growth) of two varieties of lettuce. In subsequent years the influence of DLI will be examined in other species.

Work package 2 - Influence of light quality on crops.

The experiments in work package 2 will examine the responses of plants to different light spectra with the aim of improving our understanding of the diversity of plant responses to light and to help commercial implementation of LED technologies. WP2 is divided into subsections examining different aspects of light quality on plant morphology. This report contains results from four subsections of WP2:

WP 2.1a	Comparisons of plant growth under a range of commercially available LED light spectra.
WP 2.1b	Influence of red / blue ratio on plant growth.
WP 2.1c	Influence of red / far-red ratio on plant growth.
WP 2.3	Improving cutting propagation.

Several species were examined (basil, sage, cucumber, petunia, pansy, begonia, pelargonium, lettuce, photinia, elaeagnus, and rhododendron).

Work package 3 - Light quality and its influence on pests.

This report contains results from the first subsection of work package 3 (3a) - monitoring pests under LED light and methods for improving pest monitoring in LED light environments. In subsequent years this work package will examine the influence of light on pest performance of specific host crops, Lettuce, Cucumber and Verbena.

WP 1.2 Energy saving and daily light integral

As noted above daily light integral (DLI) is a useful measure of the light that is available for growth. Optimal daily light integrals are available for many species but these have been determined using natural sunlight, which varies in intensity through the day, and these DLI values may not be accurate / appropriate for the constant light conditions that occur in LED lit systems. Using a range of light treatments with different DLIs created with a mobile light, a strobe light and four constant light treatments with different light intensities, two lettuce varieties, Alega (a winter variety) and Amica (a summer variety) were grown for three weeks to assess the influence of DLI on growth and morphology.

The growth of both lettuce varieties was observed to increase as DLI integral increased (Figure GS1). In the lowest light treatment provided by the mobile light, the plants barely grew, only producing 2 true leaves. Plants grown under a variable light intensity (strobe light turning on and off every 8 seconds) grew more slowly than plants grown under a constant light even when the DLI was the same. The winter lettuce variety grew more rapidly than the summer variety in all treatments. The difference in growth between varieties was at least partially caused by differences in leaf morphology. The curled leaves of the summer variety were able to absorb less light than the flat leaves of the winter variety. Leaf flattening is a blue light response and this difference indicated that the summer variety tested was less sensitive to blue light than the winter variety tested.

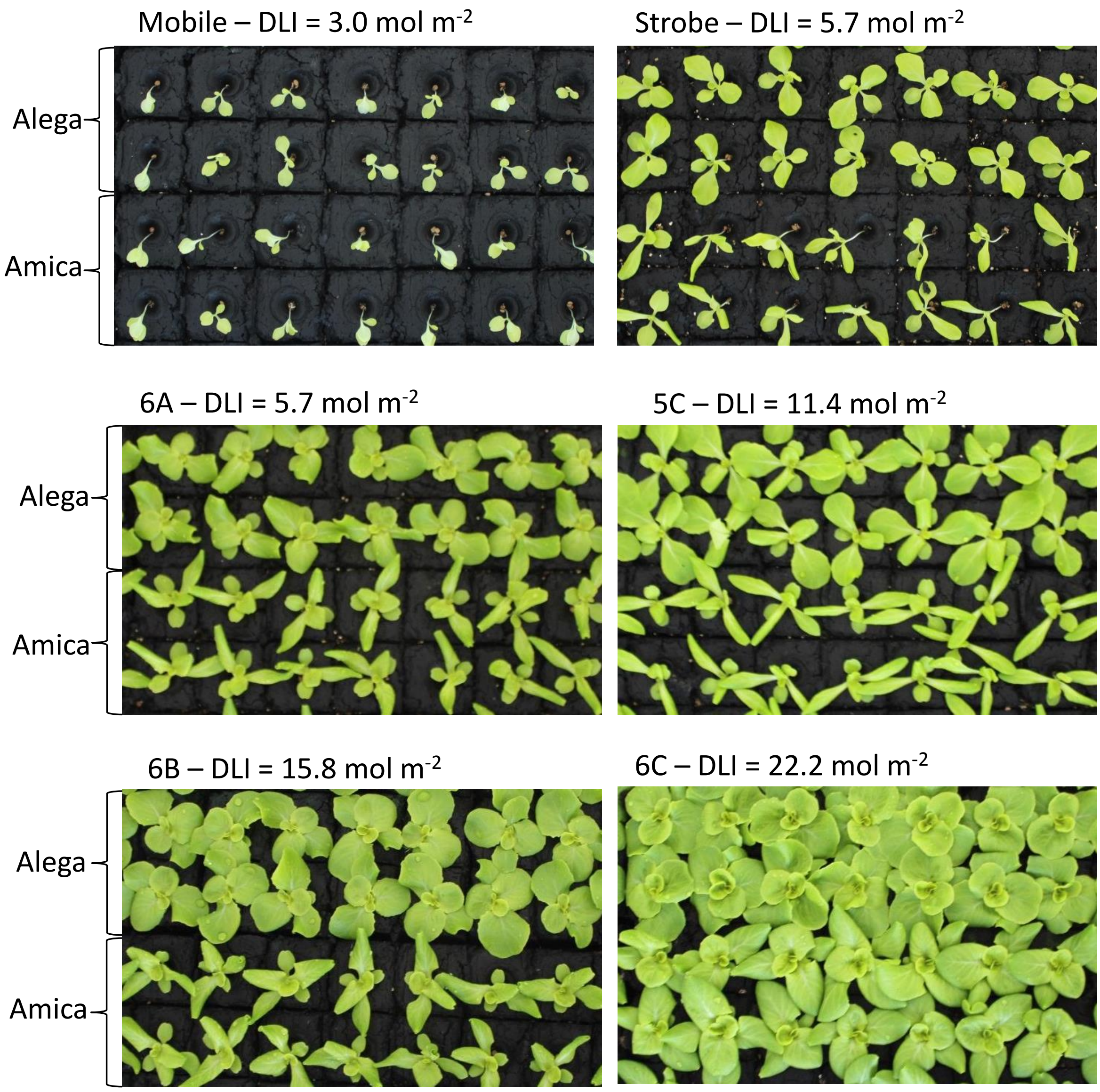

Figure GS1. Images of the two lettuce varieties, Alega (top two rows of plants in each picture) and Amica (bottom two rows of plants in each picture), grown under 6 different light treatments designed to assess the effects of energy saving lighting strategies and different daily light integrals on plant growth and morphology. Plants photographed after 19 days.

WP 2.1a Plant growth under different types of lamp

LEDs provide the ability to alter the spectrum of light and manipulate plant responses. The majority of the experiments in this report have been performed using Philips lamps; however, in this work package we examine plant growth under a range of lamps produced by different manufacturers in order to assess the benefits to plant production from using different regions of the spectrum. Using the same lettuce varieties as for WP 1.2, we examined growth over a three week period under five lamps, each providing a 'white' light that has been tailored for use with plants. The trial contained two Valoya lamps (AP673 and NS2) and three Solidlite lamps. All the lamps produced similar intensity (200µmol m^{-2} s^{-1}) and DLI, but their spectra varied considerably. Each lamp produced a different blue, green, red, and far-red balance. Despite the similarity in the DLI provided by each lamp, biomass varied considerably between the light treatments. Crop biomass accumulation was found to correlate with the proportion of the light provided by the lamps that could be used for photosynthesis. It should be noted that not all plant-specific LEDs are designed to maximise growth rate: some are designed to control plant morphology, as discussed in more detail in sections 2.1b and 2.1c. These results highlight the need to select the correct light source for the plant production system being implemented.

WP 2.1b Influence of red / blue ratio on plant growth.

Many of the LED lamps that are available for horticultural purposes contain both red and blue LEDs. This is because these provide the most energy efficient light source and because plants can use this light most effectively for photosynthesis. Red and blue light are also highly important for controlling plant morphology and selecting the correct balance of red and blue light can allow crop morphology to be controlled. In these experiments eight species (basil, sage, cucumber, lettuce, petunia - Figure GS2, pelargonium, pansy, begonia) were grown under a range of red:blue light treatments to examine how they responded to the different light qualities (for most treatments the intensity was 200µmol m^{-2} s^{-1}). Plants grown under 100% red or 100% blue light were found to be poor quality and were etiolated. Growth rates were greatest in plants grown under red/blue mixtures containing 11-15% blue light. The most compact plants were observed under light containing about 60% blue light. The variation in red:blue light treatment ratios may provide sufficient growth control to replace plant growth regulators. While crop morphology was kept compact in the 60% blue treatments, this treatment was found to delay flowering compared to plants grown under 11-15% blue light. For methods to promote flowering see section 2.1c.

WP 2.1c Influence of red /far-red ratio on plant growth

Many of the issues encountered in horticulture during the winter months are associated with low light conditions. In low light conditions far-red light can cause plants to stretch and may even induce premature flowering. The experiments in WP2.1b examined the use of light treatments without far-red light to control plant morphology, but these treatments were not necessarily suitable for all crops. For example, the cucumber plants remained too compact and flowering was delayed in the ornamental species. The experiments reported in this section examine the use of far-red light in LED lit systems to quantify its effects in eight species (basil, sage, cucumber, lettuce, petunia, pelargonium, pansy, begonia) and identify cases where far-red light is beneficial to crop production systems. The intensity of PAR was 200µmol m^{-2} s^{-1} in all treatments while far-red ranged from 0 to 48 intensity µmol m^{-2} s^{-1}.

Figure GS2. Images of the petunia plants after 42 days growth under the different blue percentage light treatments.

The morphological responses to far-red differed greatly between species, with some showing very weak far-red responses (basil and sage) and others showing pronounced effects (cucumber, pansy and petunia). In far-red sensitive species, the addition of far-red caused stem elongation and reduced plant compactness. Many far-red responses increased progressively as more far-red was added, and inclusion of too much far-red (~40µmol m^{-2} s^{-1} in these experiments) resulted in leggy plants and reduced the number of side branches produced. Far-red light caused flowering to occur earlier and more extensively. Low levels of far red light have the potential to induce flowering while having only a mild impact on crop morphology. If the far-red treatments used in this work package were to be combined with the high blue treatments used in WP2.1b, it may be possible to produce compact plants that produce abundant flowers. These combined treatments will be examined in a later work package.

Figure GS3. The influence of far-red treatments on pansy flowering after 73 days growth.

FR = 0 FR = 18 FR = 24 FR = 40

WP 2.3. Improving HNS Propagation

Many HNS species are propagated via cuttings, which can take months to root. With spectral manipulation it may be possible to induce more rapid rooting and even improve cutting strike rate. In this trial, we examined the influence of red:blue ratio and red:far-red ratio on cutting percentage survival and rooting in three species, elaeagnus, rhododendron, and photinia, with the aim of identifying light treatments that could improve success. Only spectral quality varied between treatments: the light intensity was intensity 70µmol m^{-2} s^{-1} and the day length was 16 hour. In red:blue treatments, the survival of all species decreased as blue light percentage was increased. This was probably a result of blue-light-induced stomatal opening, which would lead to cutting dehydration even in the humid environment created for the trials. Elaeagnus was especially sensitive to blue light, with cuttings wilting, shedding leaves, and dying within the first few weeks of the trial when propagated under 60-100% blue. Interestingly, far-red light was also found to influence cutting survival, with percentage survival decreasing as far-red increased. Overall percentage rooting was generally low in these experiments (less than 40% in most cases) but there were distinctly different responses between the different species. For the red:blue treatments, elaeagnus was found to be unresponsive to changes in blue light percentage, rhododendron rooted most successfully (over 90%) under 33% blue light, and photinia rooting was greatest under 15% blue light. For the red:far-red treatments, the percentage of rooting was lowest in photinia and elaeagnus at 30µmol m^{-2} s^{-1} far-red but highest in rhododendron at 30µmol m^{-2} s^{-1} of far-red. These data suggest that cutting survival and cutting rooting are influenced by different light responses and that rooting in rhododendron has different light requirements to photinia and elaeagnus.

WP3.1 Insect monitoring

Insect populations were monitored in the LED4CROPS facility using standard yellow and blue sticky traps. Sticky traps were found to be a useful tool for monitoring shore fly and fungus gnat populations but were less useful for potentially more serious pests such as aphid and thrips, which were rarely caught on traps. The results indicated that insect colour perception was greatly altered under red:blue light mixtures, with fungus gnat preference for yellow relative to blue sticky traps being greatly reduced under red:blue light mixtures. Use of fluorescent yellow and green traps, which appear yellow and green even under the red:blue light mixtures, was found to restore insect colour preference. Numbers of insects caught on fluorescent traps under red:blue light mixtures were proportional to the amount of green light reflected by the trap.

Financial Benefits

In comparison to HPS lighting the currently available LEDs provide the potential to reduce energy consumption by up to 40%. Advances in LED technology will further reduce LED energy consumption over the coming years. The relatively high cost of LED units has, however, resulted in some uncertainty of the economic benefits of installing LEDs based purely on the energy savings provided by LEDs.

The results in this report demonstrate that the ability to control the light spectrum with LEDs creates the potential to produce better quality plants and reduce the need for plant growth regulators. These benefits have the potential to have a greater impact on business economics than electrical energy savings alone. The results from this trial provide the first steps in defining optimal lighting conditions for a range of crops. This information will help growers, considering investing in LED installations, ensure that light installations have the appropriate spectra for their crops. For certain crops there may not currently be a complete LED solution available. However, these data could help LED manufactures design lighting systems that meet the needs of different crops.

The energy use efficiency experiments (section 1.2) also show how light intensity can strongly influence how effectively plants convert light energy to growth. Providing too little or too much light reduces the return in plant growth from the electrical inputs which has implications regarding the systems running costs. Also the results demonstrate that lighting installations designed to reduce capital expenditure on lights (i.e. strobing and mobile systems) can result in poor growth and, therefore, poor return for the capital and running costs. Equally identifying the light intensity that produces optimal growth can prevent excessive capital and running costs.

Action Points

To make use of the data generated in this report, growers would need to invest in LED lighting systems. Costs of lights and economic analysis of the benefits are beyond the scope of this report and will be unique to each business. If investment in lighting is desired further R&D

will be required to ensure that the lighting systems are appropriate for the crops of interest and the environment where the lights will be installed. Some aspects of this work will performed in latter stages of this project. For example, there is clearly scope to combine the effects high-blue light percentage and far-red induced flowering to produce bedding plants with compact morphology and enhanced early flowering. Experiments designed to examine a range of light treatments with high blue percentage as well as far-red are currently underway as part of the year two experiments.

Even where light recipes have been defined for crops it is recommended that small onsite trials are carried out before large scale investments are made. This is for two responses 1) to ensure the light treatments are appropriate for the specific varieties being grown and 2) to help growers develop the required altered crop management strategies (it is expected that LED lighting systems will result in altered crop water and heating requirements). At latter stages in this project more information will be provided to help growers learn how to manipulate crops with LED lighting.

