TECHNICAL GUIDE

Cross Sector

AHDB Fellowship CP 085
Dr Phillip Davis, Stockbridge Technology Centre
Spence Gunn, Shaddick and Gunn

Lighting: The review

SCAN WITH
LAYAR APP

CONTENTS

Expertise in responses to light

As part of his work in the Horticulture Fellowship Award on crop light responses (CP 085), Phillip Davis (pictured) has been reviewing recently published research on crop responses to light at different wavelengths to help the industry understand more about the potential for using LEDs and the commercial advantages they could offer growers. His findings helped to shape the experiments in CP 125.

This guide reports on some of Davis's research on the growth and development of ornamentals, including results from the first year of CP 125.

OVERVIEW

AHDB Horticulture funded research on managing the light spectrum to manipulate crops is helping the protected crops industry learn about the kinds of responses growers can expect and the underlying biology that governs them.

The dramatic development of light emitting diode, or LED, technology in the last few years has opened up new opportunities for using light to manipulate crop growth. And it's not just yields that can gain – the quality of both edible and ornamental plants can benefit, too, because the light wavelengths of LED 'lamps' can be tailored to elicit specific plant responses.

Crop responses, however, are going to vary widely between species, if not varieties, so AHDB Horticulture research is learning more about the kinds of effects growers can expect and the underlying biology that governs them. The aim is not to supply specific 'recipes' for growers but to provide information that can be built on in more actual R&D avoiding, hopefully, some 'blind alleys'.

The wavelength of an individual diode is fixed, but because an LED lamp consists of several individual LEDs its overall spectrum is derived from the number and the different wavelengths of the LEDs in the unit. It's also possible to alter the amount of light that each LED emits. That means a single lighting source can be adjusted to manipulate crop morphology at different stages of development or to control the habits of different crops with different lighting requirements.

The LED industry is innovating fast. Lamp efficiency has increased by a factor of 20 every 10 years, while the cost for a given output of light is 10 times less. The second generation of Philips GreenPower LED production modules launched in January this year, for example, are reported to have a 25% lower power consumption for the same light output than earlier modules.

It's their energy-saving features, compared with other types of lamp, that have been a major force behind the switch to LED lighting but much of the work undertaken by fellowship researcher Phillip Davis has been about the additional benefits that LEDs offer through spectral manipulation of the crop. Trials that compare LEDs for photosynthetic lighting were not included because others, including growers and manufacturers, are already undertaking these.

PROJECT PROFILES

CP 085 Securing skills and expertise in crop light responses for UK protected horticulture, with specific reference to LEDs

Term: October 2012 to September 2017

Project leader: Martin McPherson

Fellowship researcher: Phillip Davis

Industry representatives: James Bean, Simon Budge, Steve Carter, Colin Frampton, Chris Plackett, Geoffrey Smith, Neal Wright

Location: Stockbridge Technology Centre (STC), North Yorkshire

CP 125 Understanding crop and pest responses to LED lighting to maximise horticultural crop quality and reduce the use of PGRs

Term: May 2014 to June 2017

Project leader: Phillip Davis

Industry representatives: James Bean, Simon Budge, Steve Carter, Colin Frampton, Geoffrey Smith, Russ Woodcock, Neal Wright

Location: STC, North Yorkshire

Figure 1. Growing benches in the Stockbridge Technology Centre (STC) research facility lit by red and blue LEDs. The ratio of red to blue light is adjustable

SECTION ONE
Ornamental crops: mixing wavelengths

Red and blue

As Davis points out in his review, the basic requirement for a crop is light in both red and blue wavelengths. Red drives photosynthesis but plants usually grow best and with the morphology growers are looking for when some blue light is present, one of the main reasons being that the blue light stimulates the stomata to open so carbon dioxide can be absorbed.

What researchers have been unable to agree on is the 'best' ratio of red to blue light. Requirements vary between species and between growth stages, though for ornamentals the grower's aim is a red:blue ratio that produces a compact, floriferous plant. That's why AHDB Horticulture-funded research on LEDs is guided by a large team of industry representatives.

The red:blue balance is one of the questions the experimental work in CP 125, at the LED 4 Crops facility at STC, is addressing (see HDC News December 2014/January 2015, p16). Begonia, pansy, pelargonium and petunia have been grown under various red:blue ratios. Growth was fastest when the light mix included 11–15% blue light. Plants were most compact, however, under light containing about 60% in the blue spectrum. Davis suggests that varying the red:blue ratios between these points may provide enough control of growth to replace chemical growth regulators altogether but points out that the 60% blue treatment also delayed flowering and reduced flower numbers – the key is finding the best balance.

Light quality altered both the timing and extent of flowering. Treatments of blue light alone, in contrast to 60% blue, promoted flowering, resulting in large numbers of flowers, and prompted plants into flower at least a week ahead of other treatments. This is down to the effect that blue light has on the plant's phytochrome pigments, which regulate the transition from vegetative to reproductive growth.

While the flowers were early they were not well-shaped, though, particularly in petunia and pansy.

Plants under the 11–15% blue light treatments were the next to flower and also produced large numbers of flowers. Davis's research review includes reports on work with poinsettias, in which plants grown under 80% red and 20% blue LED supplementary lighting were 20–34% shorter than those grown under standard high-pressure sodium lamps (which emit 5% blue light). In contrast, the height of campanula plants was unaffected by supplementary blue light and was reduced most by the addition of red light.

A combination of red and blue light is enough for the production of high quality plants and, given that red and blue LEDs are the most energy efficient, these are what commercial lighting systems have focused on. There may be additional benefits from introducing additional wavelengths but it makes the development of optimum 'light recipes' even more complicated.

Red and far-red

Far-red light is important for plant development and including it in the light recipe can help control flowering time. Far-red promotes flowering in several long-day species while its absence can prevent flowering. End-of-day red or far-red lighting treatments can also manipulate plant height, making plants more compact.

Trials so far in CP 125 have looked at the effects of far-red light in LED systems on the same ornamental species as in the red:blue lighting trials – begonia, pansy, pelargonium and petunia. Pansy and petunia have shown particularly strong stretching responses to far-red. However, flowering was also brought forward, so including a small proportion of far-red light at low intensity has the potential to induce flowering without causing too much stretching.

There were large differences in sensitivity to far-red, not only between species but between different parts of a plant. In petunia, for example, the number of flowers produced per gram of shoot weight increased with far-red light levels. But the number of side branches and total shoot weight fell as far-red intensity increased. In such a case, the challenge is to find a far-red light level that promotes flowering enough while also keeping stem extension and branch number within specification.

Davis says that if the far-red treatments in these experiments were to be combined with the high blue treatments he has looked at, it may be possible to produce compact plants with more abundant flowers. He plans to test such combined treatments in later stages of the project.

Light mix for propagation

The nursery stock industry's interest in using LEDs includes light recipes that promote rooting and improve strike rates, particularly in those crops that are difficult or slow to root.

One way that LED lighting could help is in the control of transpiration to reduce the risk of cuttings dehydrating, as an alternative to raising humidity through the use of plastic sheeting, misting or fogging.

Blue light stimulates plant stomata to open, so removing blue light from the spectrum will help reduce transpiration. Davis's literature review has also highlighted work that shows how red light treatments can directly promote root development in several species. A number of the published research papers Davis looked at suggest red light can improve rooting in difficult-to-root varieties but may be of no benefit to easier crops.

Few UK nurseries propagate proteas but work on them in South Africa suggests a possible mechanism for the influence of red light that could apply to many other species. The study found that red light during propagation caused cuttings to produce phenolic compounds at concentrations that encouraged rooting, while the inclusion of blue light raised these concentrations to higher levels that inhibited rooting. Davis thinks similar effects may be occurring in other species, though the active compounds are likely to vary.

Mixes of red and blue light in specific ratios have been found to improve rooting most in several species. In published work on climbing gentian, red light was found to promote rooting while blue light inhibited it – but the best rooting was achieved with a combination of 70% red, 30% blue.

In other species, red-only light treatments may be the best for rooting. For these, though, it will be important to move plants to a treatment containing some blue light after roots have initiated, to prevent etiolation of the young plants and help ongoing root development, as blue light enhances both root and shoot growth.

Work so far on propagation in CP 125 has explored the influence of the red:blue and red:far-red ratios on cuttings survival and rooting in elaeagnus, photinia and rhododendron. Only the colour balance varied between the treatments – total daily amounts of light and daylength were the same.

The experiments on red:blue ratios showed that for all three species, cuttings survival improved with increasing proportions of red light (and decreasing blue) in the mix. This was probably a result of the blue light inducing stomatal opening, which would affect tissue hydration even in the humid 'prop unit' environment used in the trials.

Elaeagnus proved especially sensitive to blue light; cuttings wilted, shed leaves and died within the first few weeks of the trial when propagated under regimes with between 60% and 100% blue light. The other two species retained their leaves throughout the trial, but there were other signs of dehydration – browning of leaf tips and stem shrinkage – as the proportion of blue light increased.

It was possible to identify distinctly different responses between the species. Elaeagnus rooting, as opposed to cuttings survival rates, was unresponsive to changes in the red:blue ratio. Rhododendron rooted most successfully (at more than 90%) under 33% blue light, while photinia rooted best under 15% blue.

The presence of far-red light reduced cuttings survival overall but its effects on rooting percentages varied with species. For the red:far-red treatments, rooting percentage was lowest in photinia and elaeagnus when far-red intensity was 30μmol per sq m per second; the same intensity led to the highest percentage in rhododendron.

Clearly, cuttings survival and rooting are influenced by different light responses and different species are going to have their individual requirements There are some general principles that can provide clues on suitable light 'recipes' for different needs and this work is starting to narrow down the options by looking at more specific detail. Pinning down the right light recipes that would work on a nursery will be assisted by the pointers coming out of this work.

The good news is that Davis's trials are beginning to reveal some general principles and, just as importantly, some of the underlying mechanisms behind the responses of different species that will help to narrow down potentially useful light recipes to test.

Figure 2. Pansy (top and middle rows) and petunia (bottom row) grown under (from left) 100% blue; 66% blue and 34% red; 33% blue and 67% red; and, 15% blue and 85% red light

PLUG PLANTS

Davis's experiments on the effects of red:blue ratios and the influence of far-red on begonia, pansy and petunia included observations on the impacts of light treatments on the growth of plug plants, revealing some common responses to all three – and some differences.

Under 60% blue, 40% red light, petunia, pansy and begonia plugs were most compact, a finding that would generally be expected. Reducing the proportion of blue light (to 11–15%) gave a better compromise between speed of growth and quality of all three species.

When grown in 100% blue light, pansy and petunia plugs were etiolated although for petunia this also resulted in the largest leaf size. Begonias were not as strongly influenced by this extreme treatment, with plants growing similarly to those under lower proportions of blue.

Responses to the different red:far-red treatments were less marked but more varied. Pansy plug plants were weaker under the highest proportion of far-red light. Petunia plugs were also more robust and compact where there was no far-red light in the recipe. Begonia plugs were least influenced by far-red light although, as with the petunia, they were more compact when there was less far red-light in the treatment.

SECTION TWO
Edible crops: mixing wavelengths

Figure 3. Lettuce seedlings grown under constant (right), moving (centre) or strobed (left) light. The total daily amount of light in each treatment was the same. In each tray the three rows to the right are the variety Alega, the three rows on the left are Amica

Fixed or intermittent light

LEDs could be used in ways that would cut their capital costs and energy consumption even further, for example on mobile racks passing over the crop or by strobing fixed lights. But both techniques can also reduce the total amount of light a crop receives so, in CP 125, Davis has been testing their commercial viability in trials with two lettuce varieties, Amica, a summer variety, and Alega, for winter cropping.

The mobile treatment consisted of LED units on a rack that passed over seedlings every 56 seconds. The arrangement reduces both energy requirement and capital costs because fewer lamps are needed than if the whole crop is lit continuously. The strobe treatment involved repeatedly turning fixed LEDs on for eight seconds and off for eight seconds. This halves the amount of electricity used but needs the same number of lamps as for a 'conventional' set-up. Both were compared with four constant light treatments at different intensities, the lowest of which was programmed to provide the same total daily amount of light as the strobe treatment.

Seedlings under the mobile or strobe lights grew more slowly than those under a constant light even when the total amount of light was the same each day. But while growth was accelerated by higher light levels, energy use efficiency – measured by dividing crop fresh weight per sq m by kWh of electricity used per sq m – did not increase in line with light intensity. Winter lettuce used light most efficiently at a lower light level than the summer variety.

Davis says these results highlight the need to balance the design of a lighting installation between the capital cost, the running costs, the crop production facility's output – as more light produces plants more quickly – and the efficiency with which the plants use the light.

The work also suggests that the total daily amount of light given could be varied to adjust growth rates to meet changes in market demand.

Davis believes lower light levels were only part of the reason for the poorer growth under the intermittent lighting. It can take up to 30 minutes for photosynthesis to reach its maximum rate after a light is switched on so the period of light in both treatments may simply have been too short. Of course these could be lengthened but this would also have increased the amount of electricity used.

Figure 4. The difference in growth of lettuce seedlings under various types of 'white' light. Growth was fastest under the AP673 modules (above lower) and slowest under the CWW modules (above top) which had the highest proportion of blue light and the greatest red:far-red ratio of those tested. The top three rows in each picture are Alega, the bottom three are Amica

White or white?

Work in CP 125 has also shown how important it is to select the correct light source for the production system and for the crop effect required.

Davis compared the growth of seedlings of the same two lettuce varieties, Amica and Alega, under five lamps each designed to provide 'white' light but achieved through very different colour balances. The trial used two Valoya models emitting different proportions of violet and far-red as part of the overall white mix and three SolidLight models with different proportions of far-red, red, blue and green.

Although the seedlings received similar amounts of photosynthetically active radiation, there were significant differences in their 'final' weight after three weeks of treatment under each type of lamp, indicating that the lamp's spectrum governs how effectively plants can use the light. Growth of these lettuce varieties was greatest under the Valoya AP673 lamp, with an output of 62% red, 24% green, and 14% blue and a red:far-red ratio of 7.38:1.

Just as importantly, differences in growth between the summer and winter varieties highlight the need to choose varieties that are appropriate for the production system, or to select a light treatment to match the species or variety. "For optimal crop production under LED lighting, breeding may in future need to account for the light spectrum plants are likely to be grown under," adds Davis.

Red and blue

A combination of red and blue is enough to grow good quality plants and as LEDs at these wavelengths are also the most energy efficient, these are what several commercial lighting systems have focused on. As part of CP 125, Davis has been looking at lettuce, cucumber and herbs growth under LEDs in mixes with different proportions of red and blue light.

Basil and sage were the herb species in the experiment and both were sensitive to the ratio of red to blue. Basil grew tallest when the mix included 11% blue light but was shortest under 100% blue. Under this mix, the leaves were held horizontally but as the amount of blue was reduced they hung downwards and became more curled. Sage, too, was tallest under the 11% blue mix by the end of the experiment; and the higher the proportion of blue, the smaller and less branched the plants.

Further investigation showed that for basil, photosynthetic potential increased with increasing proportions of blue light in the mix; for sage, photosynthesis peaked under 15% blue – for both species, however, respiration rates fell as the proportion of blue increased and this is what had the bigger impact on growth.

Growth of cucumber plants was strongly influenced by the proportions of red and blue in the light mix. They were shortest under 66% blue and tallest (the internodes were nine times longer) under 100% blue – but as the proportion of blue light increased, the number of leaves decreased.

The two lettuce varieties responded slightly differently to changes in the red:blue ratio. The winter variety Alega was more sensitive to blue light than the summer variety Amica. But in both, growth was greatest under 11% blue.

So the general trend for species studied so far is for best growth in mixes of around 10–15% blue in the mixture with red light. Increasing the proportion of blue beyond this tends to restrict growth, though in some species it leads to stretching.

Red and far-red

Far-red light is important for plant development and including it in the light recipe can affect aspects of crop morphology such as height. In CP 125, Davis looked at the effects of adding varying amounts of far-red into a mix of red and blue light (89% red, 11% blue).

Neither basil nor sage proved particularly sensitive to changes in the amounts of far-red. Cucumber, however, showed a strong response, with plant height and internode length increasing as the percentage of far-red increased.

Davis says the plants that showed the greatest responses to far-red were also the ones that had the most ‘exaggerated’ responses under the 100% blue light treatments, suggesting that the blue light response is a result of signalling by the photoreceptor phytochrome. “These experiments are beginning to show us which photoreceptors are imposing the greatest level of influence,” he says.

“We’re not only getting useful information regarding the scientific basis for differences between plant species but also a better idea of which light treatments are likely to offer the best route for manipulating the responses of the different species. For example, removing far-red light from basil production is unlikely to be as beneficial as supplying additional blue light.

“Fully optimising crop light responses is likely to require treatments that combine the results of red:blue and red:far-red experiments.”

Lighting for colour and flavour

Davis’s review of the research literature in CP 085 revealed many ways in which manipulating the light spectrum could improve aspects of crop quality such as leaf colour of leafy salads and herbs, as well as flavour or aroma.

For example, the red pigmentation of many species can be enhanced by increasing the amount of blue light. Anthocyanin is one of the pigments responsible for red colouration in plants and blue light is an important signal for driving its production.

In lettuce, researchers found that LED lighting of different colours supplied against a background of fluorescent white light led to increases in leaf anthocyanin, xanthophyll and beta-carotene pigments. UVA ultraviolet and blue light both boosted the anthocyanin content, with blue light prompting the largest increase. Far-red and green light reduced anthocyanin concentration, and far-red light also reduced levels of chlorophyll, xanthophyll and beta-carotene. UVB ultraviolet was also shown to stimulate anthocyanin production in lettuce.

Changes in pigment content can alter flavour, too, while light also regulates the production of many of the other compounds that contribute to flavour and aroma. Exposure to UVB, for example, has been linked to higher concentrations of essential oils and volatile compounds in a range of herb species including mint, lemon balm, sage and basil. Blue light has been found to increase the oil content of basil leaves.

Figure 5. Response of Alega lettuce to increasing amounts of far-red light in a red and blue light mix, from none (top) to 40 micro-moles per sq m per second

However, it's not always enough simply to provide more blue light – the plants also need to photosynthesise enough to generate the energy to produce more of such compounds.

More recently, researchers have begun investigating the potential for post-harvest light treatments to improve storage or shelf life. For example, exposure to two hours of low intensity red light delayed senescence of basil leaves kept in the dark for two days at 20°C.

As with other aspects of plant growth under LEDs, some development of light recipes will be needed if crop flavour is the target, because increasing the concentrations of some compounds may well reduce the content of others that also contribute to flavour.

Because we still know so little about how these compounds are influenced by light, and how they in turn affect flavour, Davis says trial and error remains at present the most efficient way to develop light treatments for improved flavour.

Figure 6. Red lettuce: ultraviolet and blue light both boost levels of anthocyanin pigments

SECTION THREE
Colour co-ordinated pest monitoring

We're learning how we may need to change our approach to insect trapping in LED-lit crops thanks to AHDB Horticulture-funded research.

Red, orange, yellow, green, blue, indigo and violet – we're used to a world lit by these seven colours but insects see things rather differently. They're not only more sensitive to some colours than others but to light at wavelengths invisible to us, which could have an impact on the management of crops under modern lighting.

Bees, for example, are able to see very well in blue and green light but not red, though they can also see in UV light. Western flower thrips can see in UV light as well as most of what we regard as the visible spectrum while another thrips species, *Caliothrips phaseoli*, can only see in UV.

LED lighting technology has opened up new opportunities for growers to increase yields or manipulate aspects of crop quality by altering the light spectrum the plants are grown in and AHDB Horticulture has been funding research to learn more about how crops respond to light at different combinations of wavelengths (Section one and two).

But if we are to grow crops in these 'artificial' light environments we also need to know how the behaviour of pests and beneficial insects alike are affected, which could have consequences for how growers manage them. Davis has reviewed published studies on this topic and begun his own experiments in CP 125, initially looking at how changes in the light spectrum could affect insect monitoring using sticky traps.

Sticky traps are commonly either yellow or blue because insect species tend to be attracted preferentially to one colour or the other. "Of course, they're only effective if they can attract pests, enabling growers to identify them before the crop is damaged," says Davis. "But in most cases, the spectral sensitivity of a particular pest species has not been researched – recommendations for which trap colour to use has largely been a result of trial and error."

Davis's work on crop responses has so far concentrated on the benefits of growing in various proportions of red and blue light. "Colour perception, by humans and insects, is greatly altered in structures illuminated with red and blue LEDs," he says. "So, for example, we'd expect any insect species that shows a preference for yellow are less likely to be caught on sticky traps of that colour where crops are grown only under red and blue lighting."

During the crop response trials, described in earlier articles, Davis has been using standard sticky traps to monitor the insects present in the LED 4 Crops research facility at Stockbridge Technology Centre, checking for any differences in their attractiveness to species compared with known performance in daylight or under 'white' artificial lights.

He has begun testing alternative trap colours that might be more effective for insect monitoring in crops where the light spectrum is being manipulated by LEDs.

Standard yellow and blue traps were placed on each bench among the plants lit by various combinations of red and blue LEDs. Catches were counted regularly and the traps replaced after each count. Several pest species were being caught including fungus gnats, shore flies, peach potato aphid, thrips, spider mites and leafhoppers.

In 'white' LED light, fungus gnats were five times more likely to be caught by a yellow than a blue trap, reflecting their colour preference in natural light environments, but in the red/blue treatments they were less attracted to the yellow traps, being only three times more likely to land on them than on a blue trap. Shore flies were 30% more likely to land on blue traps than on yellow under white light but showed no preference for either colour in the red/blue treatments.

The colour preferences of both fungus gnats and shore flies changed as the proportion of blue light in the red/blue mix was altered. Fungus gnats were attracted to yellow more strongly in the 33% blue/67% red light treatment and least under 100% blue light. Shore flies' preference for blue traps increased slightly as the percentage of blue light increased. Low populations of other species – none were deliberately introduced – meant their colour preferences were not clear.

Figure 7. Davis: fluorescent yellow and green traps should attract insects effectively on crops only lit by red and blue LEDs

Lamps by numbers

It’s all very well understanding the principles of lighting and what’s needed to generate a particular plant response, then there comes the choice of what type or model of lamp to invest in.

To help, AHDB Horticulture commissioned consultant Simon Pearson to lead a review of new lighting technology, including LEDs and plasma systems, and to work with the Lighting Industry Association’s (LIA) independent testing laboratory in Telford, Shropshire, to analyse the light output of some of the most commonly used systems for horticulture. The purpose was not to draw up specific product recommendations but to point out to growers which aspects of lamp performance they should be asking questions about when looking for particular types of crop response. Final choice will depend not only on, for instance, energy efficiency and spectral outputs but on costs compared to expected crop benefits, available power supplies and electrical infrastructure on the nursery. Even the weight of the lamp unit can be critical.

Good manufacturers should be able to provide their own independently verified data on light output efficiency and spectral output and to specify the wiring installation and how the lamps should be distributed in the glasshouse to achieve the required responses.

Five example LED lamp models were tested for CP 139, along with a plasma lamp and a typical standard high-pressure sodium lamp, to give an indication of the range of performance between different designs. Plasma lamps differ from high-pressure sodium by generating light using radio frequency power to energise plasma inside a closed transparent burner or bulb.

There are two ways of measuring the spectral output and electrical efficiency of a light source. One is by using an ‘integrating sphere’ in which the lamp is placed inside a sphere that has a highly reflective internal coating. A detector within the sphere records the light reflecting from all points on the internal surface.

The other uses a goniophotometer within which the lamp is steadily rotated at all angles relative to a detector to measure the directional light output, total output and efficiency. In this study spectral performance and energy efficiency were measured in an integrating sphere at the LIA laboratories while light distribution performance was measured for the high-pressure sodium, plasma and one of the LED lamps in a goniophotometer in an accredited French laboratory.

Light output energy efficiency was lowest (1.16μmol/J) from the plasma lamp and highest (2.71) from one of the LED units, with the high-pressure sodium lamp in between at 1.92. The plasma lamp’s spectrum is close to daylight but few studies have compared the growth of plants under these lamps compared to high-pressure sodium or LEDs so we don’t know whether what it can do in terms of plant response outweighs its poorer efficiency.

Efficiency of the LED units is linked to their design output spectrum so any differences between them in efficiency must be judged alongside potential effects on the crop. All of the five LED lamp units tested have peaks in the blue and red region of the spectrum (450nm and 660nm). One included some green LEDs so emitted some light between 500nm and 600nm.

There were striking differences in light distribution patterns between the three lamps tested in the goniophotometer, as each system will have been designed for a particular use and layout in a glasshouse.

The units tested are listed and full test results detailed in the Technical guide, Lighting: in practice, which is available to AHDB Levy payers. It also includes more background information about the technical parameters that should be taken into account when choosing lamps.

Figure 8. Lamp performance measured in an ‘integrating sphere’

PROJECT PROFILE

CP 139 Commercial review of lighting systems for UK horticulture

Term: December 2014 to May 2015

Project leader: Simon Pearson

Location: Lighting industry laboratories in Shropshire and France

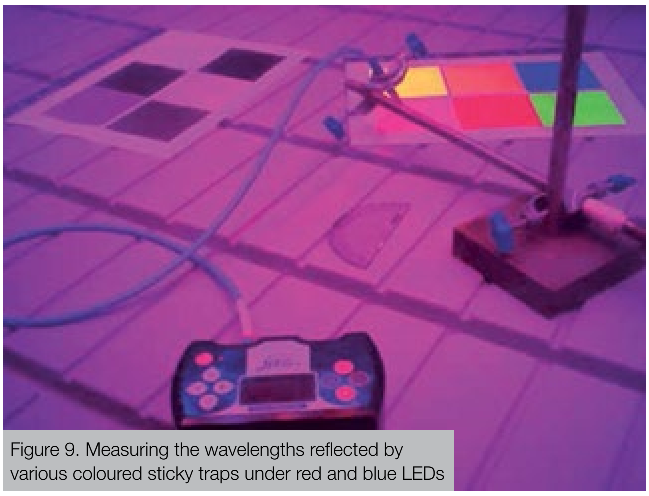

Figure 9. Measuring the wavelengths reflected by various coloured sticky traps under red and blue LEDs

PROJECT PROFILES

CP 085 Securing skills and expertise in crop light responses for UK protected horticulture, with specific reference to LEDs

Term: October 2012 to September 2017

Project leader: Martin McPherson

Fellowship researcher: Phillip Davis

Industry representatives: James Bean, Simon Budge, Steve Carter, Colin Frampton, Chris Plackett, Geoffrey Smith, Neal Wright

Location: STC, North Yorkshire

CP 125 Understanding crop and pest responses to LED lighting to maximise horticultural crop quality and reduce the use of PGRs

Term: May 2014 to June 2017

Project leader: Phillip Davis

Industry representatives: James Bean, Simon Budge, Steve Carter, Colin Frampton, Geoffrey Smith, Russ Woodcock, Neal Wright

Location: STC, North Yorkshire

Fluorescent traps

Many insect species are sensitive to green light, none of which is present under the red and blue light treatments that are generating useful crop growth responses. To see if sticky traps could be made more effective under red and blue LEDs, Davis tested fluorescent card that appears as different colours under these conditions. The fluorescent pigments absorb blue light and re-emit the energy at a longer wavelength, appearing yellow, green or pink.

Davis's measurements showed that under 100% blue light, standard blue traps only reflect blue while standard yellow traps reflect only a small amount of blue light and no other colour.

His fluorescent yellow and green traps reflected some blue light and fluoresced in the green region of the spectrum, with an emission peak near 525nm. The yellow one fluoresced further into the red region than the green trap did. The orange and pink traps fluoresced at a longer wavelength than the yellow and green traps – with the orange emitting more fluorescent red light than the pink trap, while the pink one reflected more blue light.

Figure 10. Lighting layout in the glasshouse roof will depend on the lamps' pattern of light distribution

"These results suggest that the fluorescent yellow and green traps should be able to attract most insects sensitive to green light more effectively on crops only lit by red and blue LEDs," says Davis.

Under red and blue light, shore flies clearly preferred the fluorescent traps, with the yellow, green and orange colours attracting more insects than the standard yellow sticky trap. Fluorescent pink traps attracted fewer shore flies than the standard yellow but more than the standard blue.

The response of fungus gnats was even more pronounced. Yellow and green fluorescent traps were twice as attractive to them than the standard yellow.

"Analysing the statistics showed a definite correlation between the numbers of these insects caught and the amount of green light reflected by the trap," says Davis.

Light colour can affect many aspects of insect behaviour and Davis believes one reason why so few individuals of other species, such as aphids and thrips known to be present in the growing room, were found on traps under the artificial light treatments was because their flight was inhibited.

"We were finding aphids and thrips in high numbers at some points in the facility but the aphids were not spreading into the red/blue-treated benches and the thrips only spread between these benches in low numbers," he says.

"Even though the standard yellow and blue traps caught certain species under the red/blue light treatments, insect colour preferences were altered. If insects are less able to distinguish between colours under the red and blue LEDs, the traps will be less effective for monitoring.

"The fluorescent materials that appear yellow or green under these LEDs were more attractive, because they will appear brighter to insects. We'll be exploring the potential for these trap materials in more detail in the next stages of the project."

While we may need to change the colours of monitoring traps used under LED-modified light regimes, or perhaps even under spectral filter greenhouse claddings, LEDs themselves could also be used to to improve the effectiveness of sticky traps used in crops under natural light.

With so many insect species highly responsive to green light, several researchers have explored the idea of adding green LEDs to traps to make them more attractive – and potentially more selective by tuning the wavelength of the LED to that which the pest target is most responsive to.

Figure 11. A green LED enhances the effectiveness of a yellow sticky trap in attracting glasshouse whitefly

The idea was taken up in a recently completed AHDB-funded studentship in which Kevin McCormack aimed to identify the wavelengths most attractive to a range of protected crop pests and biocontrol agents.

Yellow traps on their own typically catch few diamond-back moths, for example, but he found that clipping green (540nm) or blue (480nm) LEDs to them significantly increased moth catches. And LEDs at either of these same wavelengths were also effective at making sticky traps more attractive to glasshouse whitefly.

The biocontrol agent *Encarsia formosa*, on the other hand, proved no more likely to be caught on traps equipped with green LEDs than on standard yellow traps so using these LEDs to attract whitefly would be unlikely to affect the parasitoid's ability to control the pest.

The impact of light spectrum on crop pests may not end with their ability to navigate around the crop, however, and David George and Jen Banfield-Zanin of STC will be working with Davis in the next stages of CP 125 to look at this. They plan to investigate how pest life-cycles and behaviour change as the plants on which they feed are themselves affected by the light spectrum – such as changes in plant habit or chemical composition – and also the knock-on effects of this on biocontrol predators and parasitoids.

Want to know more?

If you want more information about AHDB Horticulture, or are interested in joining our associate scheme, you can contact us in the following ways...

horticulture.ahdb.org.uk

AHDB Horticulture, Stoneleigh Park,
Kenilworth, Warwickshire CV8 2TL

T: 024 7669 2051 E: hort.info@ahdb.org.uk

@AHDB_Hort

AHDB HORTICULTURE

AHDB Horticulture is a division of the Agriculture and Horticulture Development Board (AHDB).

£8.75 where sold