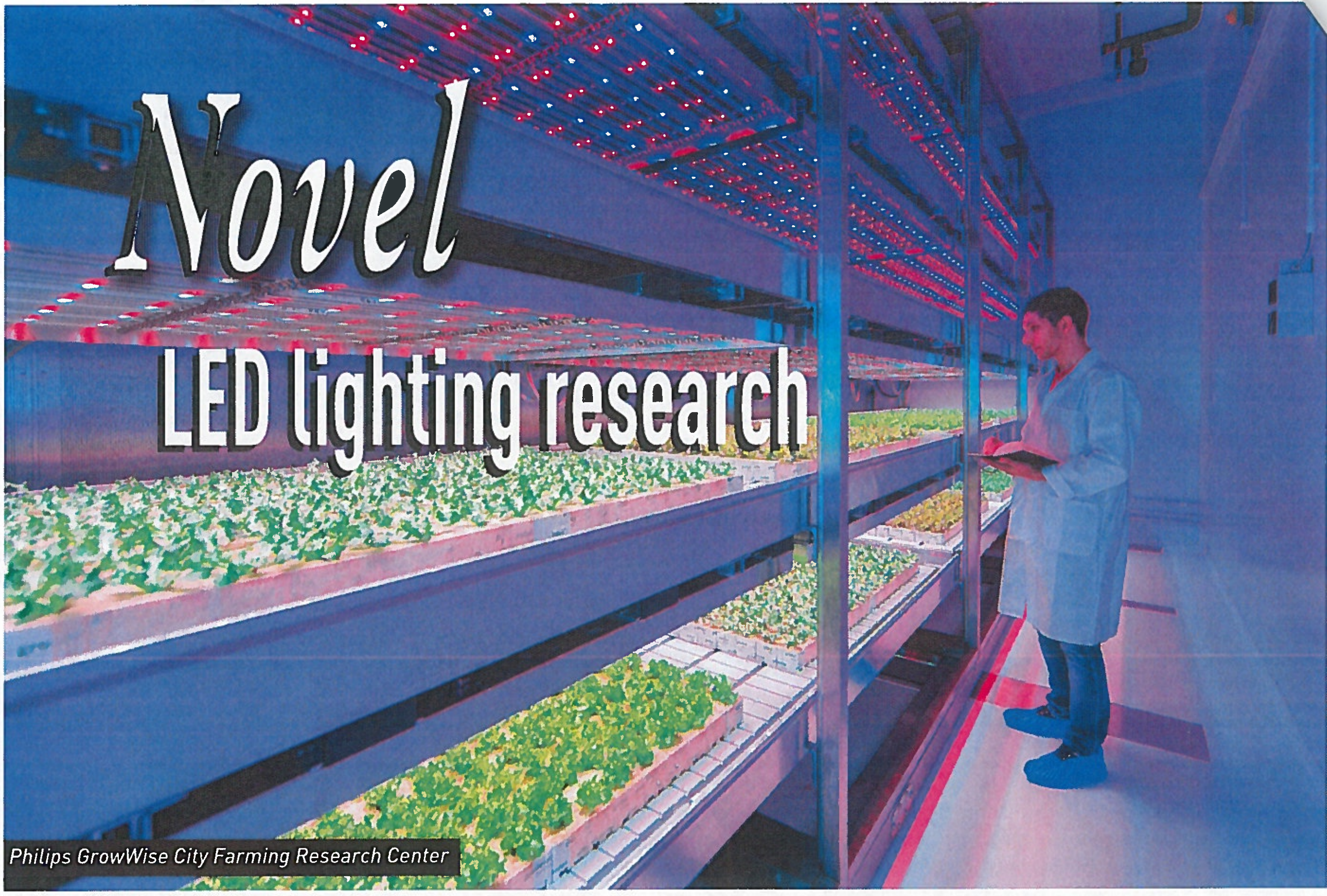
PRACTICAL
HYDROPONICS & GREENHOUSES

The Commercial Growers' Magazine www.hydroponics.com.au

ISSUE 161

NOVEL LED LIGHTING RESEARCH

NOVEMBER 2015



Philips GrowWise City Farming Research Center

Novel LED lighting research

In the space of two decades, the development of LED lighting technology for horticulture applications is displacing traditional High Intensity Discharge (HID) lighting, and opened a pathway for novel new research on the effect of light on plants. In this article, STEVEN CARRUTHERS reports on the latest studies on LED 'light recipes' that improve plant quality and yields.

Since the development of high-brightness blue LEDs in the mid 1990s, LED lighting technology has seen remarkable growth in the horticulture industry. As materials grow more advanced, LEDs are making it possible to improve plant quality and yields with the application of varied light spectra, sometimes referred to as 'growth recipes' or 'light recipes', beyond the ability of traditional lighting installations, particularly High Pressure Sodium (HPS) lighting.

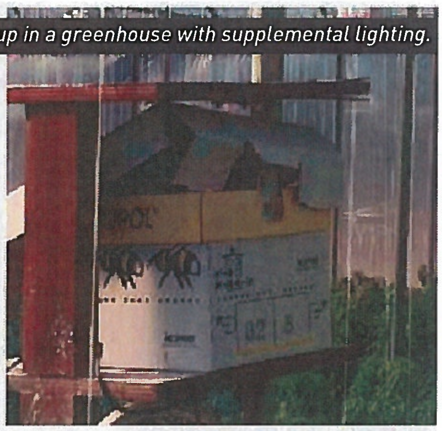
The development of LED lighting technology has opened a new field of science as researchers study the effect of light, a critical growth variable on greenhouse crop production using supplemental lighting and sole-source lighting growing environments. According to the latest studies, it is now possible to improve plant morphology, as well as enhance flavours and nutrition in fruits and vegetables using varied light recipes.

Leading this novel new research is LumiGrow Research, the research division of horticultural LED lighting manufacturer LumiGrow, Inc., which recently released seven new scientific posters that reveal how crop morphology and productivity can be affected through the application of varied light recipes. Conducted in partnership with commercial growers and universities, LumiGrow has announced three key findings from this research.

The first relates to crop height, flowering and bushiness, which can be controlled through the application of varied growth recipes. This is particularly important for the flower industry, where these phenotypes are currently controlled by plant growth regulators (PGRs). A reduction in the use of PGRs is a cost saving to both greenhouse and nursery growers.

The second key finding relates to the control of flavour and nutritional values in the foods tested by researchers, including broccoli, lettuce, tomatoes and basil. It is already known that light and therefore photosynthesis affects the production of sugars and acids, which are important components in determining the flavour of fruits and vegetables. We now know LED light recipes can enhance these values.

The third finding relates to adjustable-spectrum lighting, which has been found to be superior to traditional fixed-



Smart HelioSpectra LED grow lights set up in a greenhouse with supplemental lighting.

spectrum lighting in the production and longevity of flowers suitable for market.

Lumigrow is a leader in spectrum control systems, working with growers and researchers to create individual lighting solutions that improve plant growth, increase crop yields, and achieve cost-saving operational efficiencies. The company offers a range of solutions for use in greenhouses, controlled environment agriculture and research chambers. Headquartered in Novato, California, this privately owned company has more than 3000 installations in 30 countries, and includes the world's top 100 produce and flower growers in more than 200 universities, as well as the US Department Of Agriculture.

"LumiGrow is taking LED research from theoretical to practical use, as demonstrated by the success of our growers, said Melanie Yelton, director of Research at LumiGrow.

Dr Yelton leads research collaborations with scientists at the University of California, Davis, and the University of Guelph and Harrow Research Centre in Canada, among other agencies, along with numerous commercial greenhouse operators.

Winter tomato production

A LumiGrow study on winter tomato production in a central North Carolina greenhouse (34.5^0 latitude) compared 2100 plants grown hydroponically in a 687.5m^2 (7400 ft^2) greenhouse divided into three bays—a non-lit bay; a centre guard bay; and a LED-lit bay. The results of the study by James Byrtus and Dr Melanie Yelton, was presented in a poster at the American Society of Horticultural Science annual conference in 2014.

Solanum lycopersicum var. *Heritage* was planted into grow cubes and grown under sole-source LED at 100 mol m^{-2}s^{-1} for approximately eight weeks. Plants were then transplanted into the greenhouse with the plants that appeared most vigorous being transplanted first in the non-lit bay and guard bays. LED-lit plants were transplanted four days later with lower quality plants. All plants were grown in typical hydroponic cococoir conditions in the greenhouse. Plants were illuminated with 42 lights at a density of one light/5.5m^2 (59 ft^2) for 15 hours/day.

The researchers concluded there was an increase in production of 29.72% for the LED-lit bay over the non-lit bay. Phenotypically, the LED-lit plants had a slight (5%) increase in vine length, an 11% increase in stem diameter, and 50% increase in vine weight at the end of the study. Fruit harvest from the LED-lit plants began nine days earlier than the non-lit plants.

According to these metrics, the LED-lit plants were superior in production and overall plant performance. The LumiGrow researchers report that LED lighting can be beneficial for tomato production even in areas of the country where supplemental lighting is not typically used.

Better tasting basil

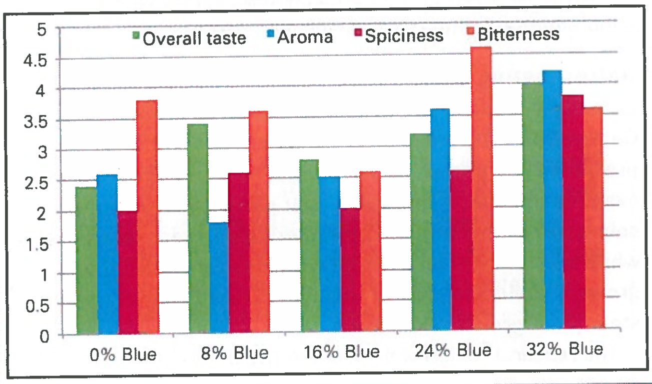
LumiGrow researchers Dr Melanie Yelton, Jimmy Byrtus and George Chan studied basil grown with LEDs with their results presented in a poster. In this study, they used LED fixtures to examine the effects of varying light ratios on basil plants in a sole-source environment. By exploring different ratios of blue, white and red light on basil growth, they concluded that growers could use programmable LED light spectrums to steer plant growth and flavour.

The researchers grew basil under five different light

treatments at 250 mol $m^{-2}s^{-1}$ for a photoperiod of 14 h and analysed the differences in plant morphology, flavour and flowering response. After 63 days of growth, they measured plant height, weight, stem diameter and the number of branches. In all the treatments, there was minimal variation in height.

The light treatment that accumulated the most plant biomass was 16% blue. Biomass peaked at 16% blue, and subsequently dropped as the blue ratio increased to 32% blue. To measure the density of plant mass, the researchers looked at the average plant weight to plant height and found that 16% blue had the highest density.

With regard to stem length and branching, the 8% and 16% blue treatments grew plants with the widest stem diameter. The treatments of 0% and 32% blue had significantly smaller stem diameters. The 0% and 32% blue treatments also had the largest number of branches, while the 16% blue treatment had the low¬est number of branches; other treatments were similar in regards to the number of branches.



The subjective flavour taste testing showed some remarkable results. The 32% blue treatment had the highest rating for taste, aroma, and spiciness. By contrast, the basil described as "most bitter" was grown under the 24% blue treatment.

The researchers concluded that using spectral quality to optimise basil flavour is proven by these taste tests, and that specialty crop growers may benefit from steering their crops for value-added food products (e.g. pesto) and gourmet markets.

This study demonstrates the effects of different light ratios on basil morphology, flavour and aroma. Through the use of adjustable light treatments, the researchers say growers can meet the needs of changing market demands. In the study, 8% or 32% blue grew the best basil for bunched sale. For growers that sell by weight, the 16% blue lighting regime produced plants with the highest average weight. According to the tasting panel, the 32% blue treatment was rated as having the ideal aroma, highest spice and best flavour.

More compact lettuce

BTO Solution (Roseville ,CA) researchers Robert L. Starnes & Chris P. Durand, compared growth of butter leaf lettuce in a growth chamber setting using high output LED lighting (LumiGrow ES 330 Watt) and the industry standard High Pressure Sodium (Xtrasun 600watt HPS ballast, radiant six hoods and Eye Hortilux 600 watt HPS bulb). The experiment was conducted inside a growth chamber at LumiGrow's Treasure Island testing facility (San Francisco Bay, CA).

The NFT Hydroponic system was split in the middle by a light barrier with the HPS light on the left side and LED light on the


Butter Leaf Lettuce growing under HPS (left) and LED (right) in a greenhouse.

Lettuce plants being compared for diameter with HPS on the left and LED on the right.

right side. There were two treatments (LED and HPS), with 15 plants in the LED treatment and 16 plants in the HPS treatment. Plants were kept in the growth chamber with an average temperature of 22°C ± 7.3 °C (72 ± 12 °F) and watered with municipal water blended with nutrients. The NFT nutrient solution ran at all times. All five troughs used water from one main nutrient water reservoir. The EC and pH of the nutrient solution was maintained at 1.0 *u*S and 5.8, respectively, for the first week. The EC and pH of the solution was then maintained at 1.5 *u*S and 5.8 for the remaining cropping cycle. The photoperiod for the lighting was 16 hours per day.

The lettuce plants where planted in 2" Q plugs and placed into the NFT system under their respective treatments. The plants were grown for 32 days, the standard commercial

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cropping cycle. The data recorded for plant growth comparison was: length of roots per plant, weight (grams) per plant, and diameter (inches) per plant.

On average, the plants from the Lumigrow group had longer root lengths (14.21 inches) than that of the HPS group (12.46 inches), and the plants from the HPS group were 10 grams heavier than those from the Lumigrow group. These differences were statistically insignificant. However, the plants from the Lumigrow group produced plants 1.2 inches more compact regarding width than the HPS group, which was statistically significant. The researchers summarised that the LumiGrow group stayed more tight and compact compared to the HPS group

The seven posters released by LumiGrow also include research results for LED lighting on *Phalaenopsis* orchids, which studies the light wavelength on the flowering spike; comparison of LED and HPS lighting for cut gerbera production (see *PH&G* Issue 150) ; and optimum light levels for snapdragon production with LEDs. The posters can be downloaded from the LumiGrow website (www.lumigrow.com/aboutus/case-studies/#research).

Philips GrowWise City Farming Research Centre

In the Netherlands, Philips Lighting recently opened its state-of-the-art GrowWise City Farming Research Center, which will focus on developing light recipes for leafy vegetables, strawberries and herbs, as well as on ways to grow more carbohydrate-rich crops, such as wheat and potatoes, in greenhouses.

"Our aim is to develop the technology that makes it possible to grow tasty, healthy and sustainable food virtually anywhere. The research we are undertaking will enable local food production on a global scale, reducing waste, limiting food miles and using practically no land or water," said Gus van der Feltz, Philips Global Director of City Farming.

"This new GrowWise City Farming Research Center aims to take City Farming to the next level, with Philips scientists leading research into LED light recipes for vegetable and cereal production," he said.

The GrowWise facility is located within the Eindhoven 'High Tech Campus' technology hub, which houses more than 135 companies and some 10,000 researchers, developers and entrepreneurs. With a total growing surface of 234 m^2, the GrowWise centre is the largest research facility of its kind. Potential investors and builders of city farms can visit the facility to see demonstrations of different city farm systems and technologies, while visitors will be able to taste different crops grown under LED.

The success of an urban farm facility depends on how well the lighting, climate control, software controls, sensors and logistics work together. To this end, the GrowWise facility is designed with an integrated system that allows Philips to optimise its light recipes, which specify the ideal growing conditions for vegetables, fruit and herbs to achieve better results. This can range from a higher yield, enhanced taste and stronger plants to increased level of nutrients and vitamins in crops.

The facility has eight climate-controlled rooms, each equipped with four multi-layer systems, and one germination room. No daylight comes into the rooms where plants are grown in substrates such as rockwool. Philips GreenPower LEDs equipped with blue, red, white and far red LEDs are installed above each growing layer to grow crops to find the best light recipe for each crop.

This environment will be used to do research and learn more about the key characteristics and specifications of several city farming building blocks. Trials can be carried out underneath 540 GreenPower LED production modules and 6624 GreenPower LED research modules. Growing conditions can be carefully controlled using tailored growth recipes. They provide everything to grow high quality plants: the right light

Green Sense Farms co-founders Robert Colangelo (left) and Carl Wenz.

recipe, the ideal temperature, amount of water, CO_2 and the best substrates.

Green Sense Farms

Philips has been active in horticultural lighting since 1936 and is using its leadership in LED lighting to develop sustainable food production for the future, which will benefit the planet and improve people's lives.

The company's commitment to developing city farms is evident in a number of projects, such as the Green Sense Farms facility in Chicago, USA (http://greensensefarms.com).

The idea for the indoor urban farm went through many iterations, the business working with Philips as its technology partner on lighting, and conducting research with Purdue University.

Founded by Robert Colangelo and Carl Wenz, Green Sense Farms is the country's largest commercial indoor vertical farm. The facility is located inside a 30,000 square feet (2787 m^2) building, which produces year around, renewing crops every 20 to 30 days.

The facility has two climate-controlled grow rooms, each equipped with seven 12-metre tall grow towers and 7000 Philips GreenPower LED production modules. The cool burning lights require less climate control and use less energy, so they can be placed closer to the plants, allowing for more levels to be stacked. For the operators, this resulted in a cost savings and increased production.

The company markets its vegetables and herbs to five states—Michigan, Ohio, Indiana, Illinois and Wisconsin. Most of its customers are restaurants, grocers and produce sellers. The indoor vertical farm also sells to the general public and advertises produce availability via social media. ꝏ

International lighting conference

The 8th International Symposium on Light in Horticulture will be held at the Kellogg Hotel & Conference Center, Michigan State University, East Lansing, Michigan, USA, from 22-26 May 2016. The conference will focus on all types of sole-source and supplementary lighting technologies, as well as coverings or glazing technologies that manipulate sunlight. Other topics that will be covered include the latest research on:

- *Electrical lighting technologies including light-emitting diodes (LEDs), high-pressure sodium lamps, plasma, induction lighting, etc.*
- *Plant photosynthesis, photoperiodism, and photomorphogenesis*
- *The interaction of light with hormones, plant signaling, and other environmental parameters on plant growth and development of horticultural crops*
- *The commercial production of food and ornamental crops using sole-source or supplemental lighting*
- *Measurement, efficiency, spectral distribution, and economics of lighting*
- *Lighting in greenhouses, growth chambers, plant factories, and vertical farms*
- *Impacts and interactions of light on pests and diseases*
- *Physiological responses of horticultural crops to lighting*
- *Lighting for specialised applications such as plant-made pharmaceuticals and vaccines, and foods with enhanced human health benefits*
- *Opportunities and constraints with future lighting technologies.*

For further information and registration, go to:
Website: www.lightsym16.com

Six tips to maximise LED grow lights

As lighting technology continues to advance, growers are starting to witness the benefits of replacing archaic HPS grow lights with intelligent LED grow lights. Beyond a reduction in energy consumption and utility costs, ambitious cultivators are actively looking to do more than just replace HPS with LED, they're looking towards LED to advance product quality, increase yield and drive efficiencies in their supply chain.

For those growers that have bought already or are interested in taking the next step, HelioSpectra, A world leader in lighting technologies for plant research and greenhouse cultivation, has lined up six tips for maximising LED grow lights:

Keep an eye on water consumption

A common mistake often made when growers switch from HID fixtures to LEDs is overwatering. HID lighting generates heat and contains high levels of Infrared light (IR), which helps dry out the soil and plants. As LED grow lights don't generate the same amount of heat and no IR light, growers need to be observant so they don't overwater plants.

Turn up the heat?

Growers using HIDs often rely on the heat coming from traditional grow lights. After switching to LED grow lights, these growers (if not taken into consideration during installation) often experience a drop in temperature as LEDs don't generate the same amount of heat as HIDs. This means that growers might have to increase the temperature in the growth facility for their crop to thrive. But don't let this discourage you. Thanks to LEDs energy efficiency, the net savings of energy will still be positive.

Mounting height matters

While we're a plug-and-play culture, spending the extra time on mounting LEDs at the precise height can enrich yield and quality. While most environments will have a number of factors that must be accounted for when mounting your LEDs, including the presence or absence of natural light, growers want to make sure that their LEDs can maintain a wide, uniform light distribution concentrated deep into the canopy.

If LEDs are mounted too high, growers may increase their coverage area, but they will also be reducing the light's intensity. If you mount LEDs too low, the intense proximity of the light could stress plants. The best option is to start with the LED manufacturer's mounting recommendation, understand your DLI (Daily Light Integral) and calculate from there.

Install multiple units

Thanks to LED grow lights' ability to create a targeted light output using optics, growers can spotlight one section of their grow with one LED lamp, and repeat the isolation for each cluster in the grow. However, plants are better served when you calculate and implement multiple units in the grow facility. This allows the beams to overlap and maximises light distribution across the canopy. This could save a lot of money in the end, while still obtaining optimal light conditions. HelioSpectra recommend that users ask a qualified lighting company for a light plan before starting the installation—HelioSpectra can help with that.

Define your light cycles

Light cycles set the rhythm for your crop's biological life. Indoor growers can manipulate these light cycles by increasing or decreasing the hours of light and darkness, stimulating a plant's photoperiod whenever desired. For Greenhouse growers, it is also possible to manipulate light and dark cycles by the use of blackout curtains and supplemental lighting. Automated blackout curtains help growers block out unwanted sunlight and ensure needed dark periods during long summer days, while supplemental lighting helps fill the gap of light needed during dark winter months. Make sure plants get all the light it needs.

The most popular light cycle during the vegetative stage is 18 hours of light per day with six hours of darkness for flowers. A 12/12 light cycle will trigger flowering for most flower crops, since the increased amount of uninterrupted darkness signals to the plant that fall (autumn) is approaching. For vegetative crops (such as herbs and salad), 17-18 hours of light per day is often most popular.

Craft light recipes

Just as you can manipulate the photoperiod with LEDs, you can also manipulate exposure to blue, white, red and far-red spectrums at different stages in the growth cycle. While the flowering cycle can be influenced by multiple factors, crafting a custom light recipe that taps into the far-red spectrum has been shown to reduce the flowering cycle of plants, which expedites the time until harvest.

A light recipe also allows you as a grower to set the light intensity throughout the day. For example, in a greenhouse, growers are able to calculate the DLI (Daily Light Integral) for their crop and increase or decrease the output, depending on the need for supplemental lighting throughout the day.

Heliospectra's premier product is its patented, energy-efficient LX60 Series LED system, arguably the most sophisticated, modular LED lamp available for commercial and R&D grow operations worldwide. The LX60 is Wi-Fi enabled, allowing for online monitoring, scheduling and control. Among other features, external sensors and software can be added to the system.

For further information: Email; sales@heliospectra.com, https://www.heliospectra.com/greenhouse_lighting