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Backgrounder
Inside Innovation

LEDs and horticulture
A recipe for success

How do we feed an increasingly urbanized world without damaging the planet? Flexible, controllable and energy-efficient light-emitting diodes (LEDs) have huge potential to help address this challenge. Drawing on fundamental knowledge of the role of light in plant biology, Philips is turning that potential into reality. Its tailor-made horticultural lighting recipes help growers increase yields, cut costs and extend growing seasons. And that's just step one. Philips knowledge of plants and light could help usher in a new era of city farming, where food is grown locally in limited spaces without natural daylight.

Once upon a time, people were content to enjoy the fruit, vegetables and flowers of the season. Now, however, we expect our favorites to be available year round at good quality and an affordable price. And we're increasingly concerned about how that produce is sourced: is it local and fresh, what are the "food miles" and is it sustainably grown to protect our energy and water reserves?

At the same time, there are more of us on the planet and greater proportion of us is living in cities. According to the World Health Organization, by 2030 an estimated 60% of the global population will live in cities compared to 20% a century ago[1]. So we need to grow more food for people in urban areas, but there is less space available for agriculture. Consequently, growers are increasingly turning to technology to help them solve these challenges.

But just how do you guarantee enough perfect red roses for Valentine's Day and poinsettias for Christmas? Or deliver ripe, juicy tomatoes and strawberries in the middle of winter?

A key part of the answer is light. If we want our food sourced locally, that will often mean growing it in places where the length of days varies considerably through the year. We all know plants need light to grow. But the relationship between plants and light goes much further. Besides driving the photosynthesis that gives most plants their food, light also regulates basic biological processes within the plant such as its immune system and the ripening of fruit.

Growing pains

Professional plant growers have long used artificial lighting to supplement natural daylight in greenhouses. In fact, Philips has been offering dedicated horticultural lighting solutions since 1936. By increasing the brightness and duration of light, growers can grow more plants in the same area, and extend the growing season. As a result, we can have more of the fruit, vegetables and flowers we want, when we want them.

[1] See: http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

However, using traditional broad-spectrum light sources such as high-pressure sodium lamps for horticultural lighting has some limitations. For example, they generate waste heat. Not only is this inefficient, it means the lamps have to be carefully positioned at a distance to avoid scorching the plants. They also need to cool down between periods of use, limiting their controllability.

What's more, these lamps were originally developed for general illumination purposes, so they deliver light matched to human eyes. However, academic research stretching back decades has shown that plants' sensitivity to light is very different to our own. Light can have many colors, which are defined by the so-called wavelength of the light – from infrared light with a relatively large wavelength, to ultraviolet with a much smaller wavelength. While we see all the colors (wavelengths) in the visible spectrum, plants only make use of certain wavelengths, also in the non-visible range, and different plants respond to different sets of wavelengths.

This means that much of the light from traditional, broad-spectrum lamps is of no use to plants. However, if the output from a lamp could be limited to just those wavelengths that the plant uses, we could both amplify the benefits of horticultural lighting and reduce energy consumption.

A new light

When this insight into plants' light needs was discovered, none of the lighting technologies available offered the flexibility to exploit it. Today, however, we have LEDs. LEDs are highly efficient, produce light in very pure colors (i.e., with a narrow spread of wavelengths) and are available in varieties across the visible and invisible spectrum from far infrared to ultraviolet.

"LEDs have huge potential for horticulture," explains Udo van Slooten, Director of Philips Horticultural Lighting. "They deliver almost complete freedom of choice which allows us to optimize lighting solutions to bring even greater value for growers – whether that is higher yields, lower running costs or more control over when plants are ready to go to market."

Light recipes

By choosing different types of LEDs, you can very specifically define the spectrum of light plants receive – so there are no wasted wavelengths. Also, LEDs run cool, so they can be placed very close to the plants, ensuring complete illumination of the plant with no shadowing and no danger of scorching. And they are completely controllable – you can turn them on and off, and change the brightness as you wish.

That flexibility is a great opportunity for growers. But it also presents a very big challenge. With so many possible choices, how do you know you are making the best ones? How can you be sure you are getting the maximum value from your lighting?

To help growers answer this challenge, Philips made a truly innovative business decision. Unlike other companies offering LED lighting for horticulture, Philips wouldn't just offer growers a lighting system – it would also help them get the maximum benefit from it by developing tailor-made lighting recipes.

Just like a cooking recipe, a Philips lighting recipe includes an ingredients list and a method, and Philips provides extensive support in both areas to ensure the end result exactly meets the grower's needs. In this case, the ingredients list is the lighting system itself: the type and number of LEDs and where to place them to deliver the optimal lighting conditions and coverage for the plant type and greenhouse

set-up. The method is how to use that system: how bright the lights should be, when they should be switched on and off, etc.

Know your plant

Creating those recipes requires an intimate understanding of plants' relationship with light. This is why Philips recruits plant physiologists such as Esther Hogeveen. Working with leading universities, Esther and her colleagues carry out numerous experiments exposing plants to different lighting conditions to understand basic biological processes. They then translate this fundamental knowledge into ways to use light to create plants that meet growers' and consumers' needs.

"For example, in Japan, older people tend to like their lettuce crispy while the younger generation prefers it softer. We know how to use a mix of colors to determine the development and shape of a plant - in that way we can control exactly how crisp your lettuce is," Esther explains.

In addition, different plant types have different light needs – that's true for different species and for different varieties. So not only does a tomato need different light to a rose bush, but two different types of tomato will also have two different responses. Over time, Philips has built up a database of basic recipes for different plant varieties.

Know your grower

These basic recipes are only the starting point. To really add value for growers, the recipes need to be tailored to their specific needs. So when a grower is thinking about installing an LED lighting system, Esther or one of her colleagues visits them to learn about their specific goals and situation. Is the key concern yield per square meter, running cost or controlling when the plant is ready for market? How much natural light is available and how does that vary through year? How many layers of plants are in the greenhouse?

"From these discussions, we design an optimized lighting system and recipe for that grower and that plant. At Philips, we pay a lot of attention to supporting the grower and exploring what's best for the plant – that's why I joined the company. Our research partners and our own plant specialists provide growers with knowledge about plants, while our application engineers and account managers help them understand the installation. It's great to see my work actually being applied by growers and bringing them benefits," Esther adds.

Seeing the benefits

And these systems are certainly bringing benefits. For example, when Belgian strawberry grower Alain Lutz switched from a standard incandescent lighting system to one based on Philips GreenPower LED Flowering lamps and a tailored light recipe, he made energy savings of around 85%. What's more, he was able to start harvesting strawberries in February and March, rather than May.

Similarly in China, the organic farm Shanghai Xinghui Vegetable Group installed a Philips GreenPower TLED system in the gerbera tissue culture room of its Bio-Technology Center. The system cut energy use by over 50% and, as a bonus, enabled better environmental temperature control.

Improved temperature control is also a big plus for Dutch tomato grower Jami. They are combining overhead high-pressure sodium lamps with LED lamps hung among the crop to illuminate the lower parts of the plants which would otherwise be in shade. The LED lamps operate at 35 °C, so can be placed close to the plants without damaging them but also add a little bit of warmth – which that particular

tomato strain thrives on. And the controllability of the LEDs means more control over the temperature, lengthening the tomato season to all year round. Jami has seen its energy bills fall by 10%, while yields have risen by 35%.

Controlling biology

Looking to the future, Philips is exploring ways to add even more value for growers. One promising area is using light to influence factors beyond growth: things like a plant's disease resistance and the nutritional value of fruit and vegetables.

"Bright light governs how the plant grows. But if you enhance the recipe with low-intensity light of the right wavelengths, you can also regulate all kinds of biological processes deep inside the plant. In this way, you can prime its immune system so the plant is better prepared to fight off disease. Or you can promote the generation of key micronutrients like vitamins." says Eugen Onac, Senior Scientist at Philips Research.

In one startling example of this, researchers from Wageningen University and Research Center and Philips were able to double the vitamin C content of tomatoes by using LEDs to provide extra light.

City farming

It's clear that LEDs and optimization recipes already have a big role to play in modern horticulture: improving yields, cutting energy consumption, letting us enjoy our favorite produce year-round and increasing nutritional value. But they could do much more. In fact, Philips is investigating how they could be used to help the horticulture industry address the biggest food challenges facing the world in the coming years.

The United Nations predicts the world's population will grow by some 2.3 billion people between today (2014) and 2050, and 68% of us will live in cities[2]. Worryingly, 80% of the land that is suitable for growing food is already in use. This is driving the emergence of city farming which involves growing plants indoors in multilayer stacks with no access to natural daylight at all.

With no natural daylight, the right artificial lighting is essential. And LEDs are the best option available. But plants have evolved to grow in daylight that contains a complete spectrum of light. So growing them using purely monochrome LEDs is a brand new challenge. It will be essential to carefully balance the relative intensities of different colors. Finding those balances for different plants and different grower aims will take more research.

Philips has already had some success here. Dutch lettuce grower Deliscious is using a Philips LED lighting solution to grow lettuces from seed to full-grown plant in a closed environment cell. The cell contains seven lettuce growing layers, one on top of another – allowing Deliscious to grow more food in a smaller area. What's more, the LED lighting system reduces water and pesticide usage.

However, if city farming is going to address consumer needs and the challenge to feed more people from less space on a global scale, lighting can only be part of the solution. You also need to consider the climate inside the building, feeding and watering. City farming has great potential to address many different consumer needs. Udo, Esther, Eugen and their colleagues at Philips are already exploring how

[2] Report 'World Urbanization Prospects - The 2011 Revision', United Nations, New York, 2012

lighting technology and building architecture may be integrated to make this revolutionary new approach to horticulture commonplace.

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