FARMING IN THE NEW LIGHT

LED LIGHTING SOLUTIONS FOR HORTICULTURE APPLICATIONS

wpg CREE

Content

LED Lighting in Horticulture

GROWTH, TRENDS & MARKET DRIVERS

Transforming Agriculture with LED Lighting Solutions

"The systems that we are talking about are never going to replace field crops. What we are going to do instead is add another layer of crop production into the current system, which is robust enough to survive climate change and adds security to the food chain."— Dr. Phillip Davis, Former business manager at the Stockbridge Technology Centre, UK (LuxReview)

By 2050, the planet's population is likely to rise from 7.7 billion today to 9.7 billion. This growth, along with rising incomes in developing countries, is set to raise the global demand for food by nearly 70%, according to the Food and Agriculture Organization.

In order to keep up, the agricultural sector and farmers will need to increase food production while finding ways to cope with challenges such as insufficient land, droughts, and climate change.

The use of LED technology in developing horticulture lighting systems for food production is playing an integral role in cutting-edge farming practices that are increasingly seen as potential means to address food production challenges. Today, LED-based horticulture lighting is one of the largest and fastest growing markets, estimated to be worth $690 million annually.

Since plants respond to light in an entirely different way, horticulture lighting is quite distinct from other lighting applications. Light, in the wavelengths useful for horticulture, is called photo-synthetically active radiation (PAR) and falls within the 400-700nm range.

Photosynthetic Photon Flux, or PPF, measures the total amount of PAR photons generated by a luminaire. A higher PPF means the lighting system is more efficient at creating PAR.

THE LED ADVANTAGE

As researchers continue to establish new findings around lights of specific wavelengths and their impact on different plants and stages of growth, broad-spectrum sources such as HPS lamps — popularly used in greenhouses — are being outperformed by horticulture LED lights due to their ability to produce PAR wavelengths. LED-based substitutes for HPS lighting, like Cree's high power grow lights, offer more than 50% PPF efficiency compared to traditional grow lighting.

A host of other compelling benefits of horticulture LED lights makes it a far-superior option for supplemental lighting in green-houses as well as vertical and indoor farms that rely completely on artificial light.

Why LED Horticulture Lights?

Control over spectral output
LED lights allow you to better match spectra to plant's need, plus their luminosity can be tailored to accentuate production depending on plant species and growth stage.

More precise targeting
With LED lights, you have superior control over where the light goes, which increases efficiency, and reduces energy consumption.

Lower radiated heat
LED lights can be placed closer to plants, resulting in more dense farms. This also lowers water consumption.

Greater savings
The long lifetime of luminaires, along with low energy consumption and lower maintenance costs, directly translates to higher ROI for crop producers.

LED ADOPTION AND MARKET GROWTH

While the benefits of using LEDs seem obvious, adoption in the horticulture space was previously slowed by the challenges around the cost of LED-based horticultural lighting systems and the feasibility of cultivating a limited number of crop species using LED grow lights.

Fortunately, the market is changing rapidly as suppliers, manufacturers and product designers are proactively developing and testing new solutions to bring to market. Cree®, for example, released a family of small LEDs optimized for horticulture, aimed at enabling lighting manufacturers to reduce the size of luminaires and lower their system cost.

"The high efficiency and long-term reliability of Cree® LEDs enables us to lower the cost of the food we grow and feed more people better food."— Matt Vail, CEO at Local Roots Farms, Los Angeles, CA

While mainstream adoption may still be years away, we know this market is poised for growth. It represents many opportunities for LED manufacturers, distributors, installers, and the whole host of energy professionals and solution providers to deliver products that are differentiated with new functionalities to help farmers find the ideal light recipe to maximize yield of various types of crop growth.

Most importantly, the focus is on increasing ROI and reducing the Total Cost of Ownership (TCO) of end-users, whose goal is not just to find the lighting system that successfully mimics natural light, but to do so at the lowest possible cost.

The state of the horticulture lighting industry is reflecting these trends and several studies and survey reports point to the growing market span of LED grow lights.

A survey by the Lighting Research Center (LRC) found that:

48% of growers currently use supplemental lighting to grow crops

55% grow crops under HPS lighting, while **25%** grow crops under LED lighting

Cost, **lack of relevant information**, and **skepticism** were listed as major barriers to adopting LED lighting

Yet, they also found that the majority of growers did not know their monthly electrical costs for lighting

64% of growers reported that they pay a flat energy rate or a combination rate (energy rate and demand charges) for their electricity. **20%** of growers did not know how they were billed for electricity.

Source: The Lighting Research Center (LRC) Survey, 2017

A 2016 Navigant Research study estimated the worldwide shipments of luminaires with LED lamps for horticulture applications would see a steadier growth compared to other types, namely incandescent, fluorescent, and high-intensity discharge (HID) lamps *[Figure 1]*.

A recent report by the market research firm estimates the LED-based horticultural lighting market will reach $3.8 billion by 2027.

Another study by Reportlinker predicts the overall horticulture lighting market to grow from USD $2.43 billion in 2018 to USD $6.21 billion by 2023, at a CAGR of 20.61%.

The market growth in horticultural LED applications, according to analysts at Navigant Research, is helping lower installation costs for luminaires, providing a stronger incentive for growers to embrace LED technology.

Another key factor influencing market growth is the tremendous leap in LED efficacies over the past few years. For example, in 2014, the best LED horticulture lighting systems were at par with double-ended HPS fixtures in terms of efficacy. Today, LED-based lighting systems are capable of achieving 45% more photon efficacies compared to double-ended HPS fixtures.

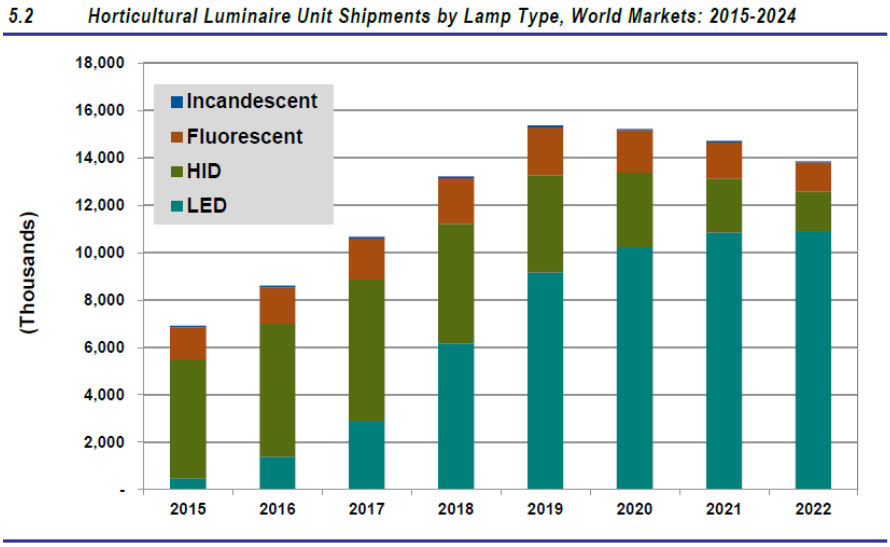


Figure 1. Horticulture Luminaire Shipments

Horticulture lighting market drivers

- Rapid population growth and limited availability of agricultural land
- A steady supply of crops despite unfavorable weather conditions for farming
- Government initiatives to support adoption of energy-efficient LEDs in horticulture
- Increased year-round high-quality yield
- Legalization of cannabis for medicinal purposes

Source: 2018 Horticulture Lighting Report by MarketsandMarkets Research

Farms of the Future

KEY APPLICATION AREAS

LED Horticulture Lighting Applications

With a broad range of different spectra in multiple form factors, LED lights are helping crop producers achieve repeatable, predictable results across a wide array of plant varieties and controlled environments. While greenhouses were the main users of LED-based grow lights, the application area of these lighting systems has radically expanded, and continues to grow.

Greenhouse applications have been the main drivers of the horticulture LED lighting market for many years, but emerging fields and new types of farming are poised to lead the future growth of the industry.

One of these reasons is indoor and vertical farming. The greenhouse use case for LEDs is mainly as a supplementary light source to the sun, whereas indoor farming uses LED fixtures as the primary light source.

More and more growers are embracing these new farming methodologies. Because of this, they are more likely to depend on LED-based horticulture lighting systems for higher crop yields and other benefits that LEDs offer.

While these new farming practices are in the early stages and may be a few years away from taking off, they are poised to provide strong growth potential in the next decade. The 2017 Horticultural LED Lighting report by Yole Développement estimates emerging applications and a horticultural lighting market boom with a 16.4% CAGR between 2018 and 2023 *[figure 2]*.

Cree® and LEDiL® are two of the leading brands supporting and facilitating these changing trends by bringing promising new products to market that meet the needs of the existing and emerging application areas.

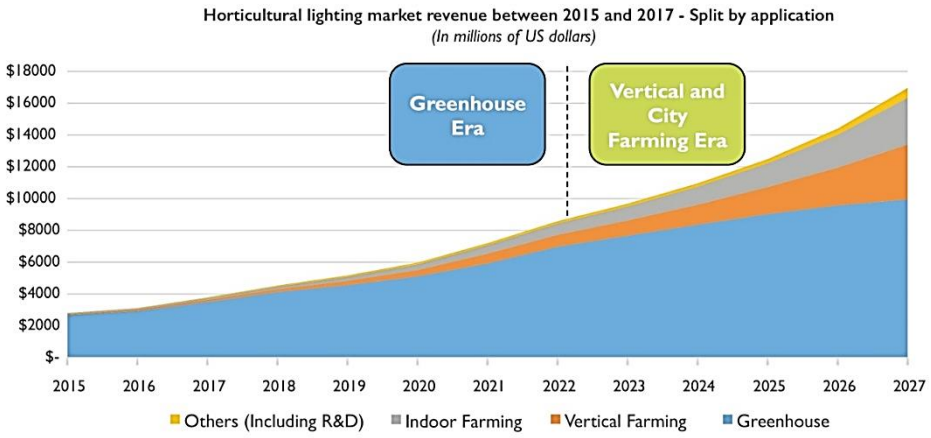


Figure 2. Horticulture Lighting Applications

Breadth of Choice for Lighting Product Designers

Cree®

Pioneering horticultural LED lighting applications from their early days of adoption, Cree® has been at the forefront of research and innovations around developing light recipes for optimal growing in a wide range of controlled environments.

Cree's product portfolio is comprehensive – allowing product designers to find exactly what they need for their unique ideas and requirements.

LEDiL®

LEDiL® offers efficient solutions for all types of horticultural lighting. Their range of optics – from single lenses to multiple lens arrays – are tested and verified to work with the latest LEDs from all the top manufacturers.

LEDiL's light lab and exceptional optical knowledge mean there is no guesswork; their optics hit the target every time with shaped and directed beans that maximize output and minimize cost.

MODERN GROWING TECHNIQUES

While traditional greenhouses have been the most popular means of cultivating in a controlled environment, other techniques such as vertical farming are increasingly heralded as the next-generation of modern agriculture — a future that is not too far away.

Due to factors like decreasing technology costs (LEDs in particular) and rising demand for locally-grown food, alternate growing systems, particularly fully enclosed vertical systems, are being preferred for high density crop production in urban environments.

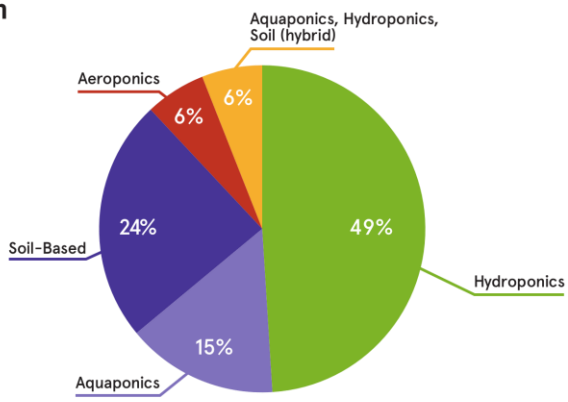
A greenhouse differs from an indoor farming facility by allowing farmers to control growing conditions like temperature and humidity, while they are still able to take advantage of light from the sun. Indoor farming, on the other hand, completely eliminates the need for natural light. Therefore, farmers can produce high density crops in relatively smaller spaces, while being able to precisely control all factors that affect plant harvests.

Then, we have smart farming. The available LED technology, coupled with IoT-based intelligence, will enable future growers with sensor-controlled lighting systems. This technology will not only optimize plant growth and yield, but also automate the growing process by eliminating the need for human intervention.

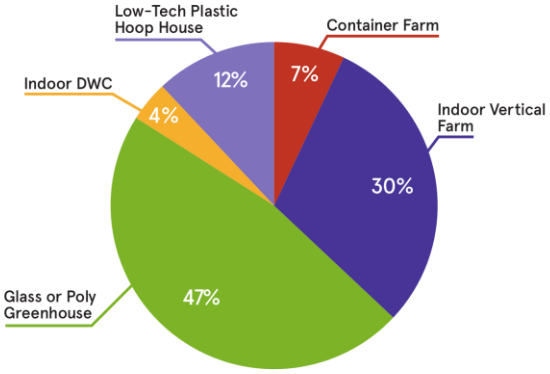
We will discuss more about these growing techniques in the next few sections.

Popular Growing Systems & Facility Types

Growing System



Facility Type



Source: Agrilyst 2017 the State of Indoor Farming report

> *"There is certainly a trend to try and grow more crops and certain types of food indoors for a variety of reasons, such as pest control and environmental control to increase yields."— Paul Scheidt, Product Marketing Manager, Cree*

Greenhouses

"Where solar light is abundant, it should be leveraged for crop growth. However, within 10 years there will be significant integration of LED sources into all kinds of horticultural growing, including closed spaces. As LED costs go down and efficiencies go up it will be more compelling. It's not going to happen overnight, but you'll see differences in five years."— Dr. Cary Mitchell Professor of Plant Physiology Purdue University (GreenhouseGrower)

Greenhouses are currently the most popular and widely practiced method of alternative cultivation across the globe. According to Technavio's market research analysts, the global greenhouse horticulture market will witness a CAGR of more than 11% by 2022. And, it's not hard to see why — greenhouses have been around for the most time and can be set up with a lower investment in artificial lighting since they are not entirely dependent on it. These are encouraging factors for growers wanting to switch from conventional outdoor farming.

Greenhouses can be either soil-based or hydroponic. Either way, they are designed to trap solar light and humidity, creating favorable conditions for growing various types of plants. Greenhouses protect plants from external factors like the extremes of weather and dirt. However, since greenhouse growers heavily rely on sunlight, they give up the opportunity for better production and higher quality yield that can be achieved using artificial lighting.

Compared to greenhouses, a completely enclosed facility like those used in indoor growing gives cultivators more precise control over ventilation, CO_2, light, and other important factors to achieve the highest crop yield and optimal growth. With an increased level of control, challenges to production are easy to overcome.

The greenhouse use case for LEDs is primarily as a supplementary light source to the sun, although artificial lighting is increasingly critical during short days of winter when sunlight isn't available.

According to the Lighting Research Center (LRC) Survey 2017, 37% of growers used greenhouses with supplemental lighting, while the same percentage of growers did not use supplemental lighting in their greenhouse facilities. Even then, the greenhouse applications have been attributed the largest share of the horticulture lighting market.

Greenhouses are more spacious in comparison to other indoor facilities, which is why they are often used for tall crops. In this type of facility, LED grow lights that serve as a supplemental source are installed above the plant canopy.

Cree® Solution for Greenhouses:

Cree's XP-E LEDs targeted at greenhouses where there is more room for larger light emitters.

The XP product lines deliver a higher photosynthetic photon flux density (PPFD) than a traditional high-pressure sodium lamp, while requiring only half the power. PPFD measures the amount of light between 400 nm and 700 nm, which is the band that is useful in plant photosynthesis.

Figure 3. Cree XLamp XP-E

Indoor Farming

"Indoor farms not only address the issue of arable land, but as most of them employ precision agriculture technology, the dependency on natural resources like water and soil is also limited…indoor farming is here to stay." —Indoor Farming: The Doorway to Agriculture 2.0, Technavio Blog

The term 'indoor farming' is often used interchangeably with vertical farming, but its scope goes much beyond that. Indoor farms exist in many different forms — from horizontal flood trays to vertical towers, warehouses to basements, and micro-greens to heirloom tomatoes. Technically, greenhouses can be considered as a form of indoor farming too, but they differ primarily in the way they depend on artificial light — indoor farms utilize lighting systems as sole-source lighting as opposed to supplemental lighting in greenhouses.

Indoor farms are mostly hydroponic, aeroponic, and/or aquaponic, which is one of the reasons why this type of facility uses less resources. Even though it needs to be set up entirely with horticulture light systems, which increases its CAPEX value, operational cost is relatively low thanks to reduced irrigation, chemical and labor expenses. Using LED-based grow lights brings down the cost even further.

Indoor farms produce more per square foot, while providing protection against the risks of weather inconsistencies and pest access. Therefore, farming in indoor facilities enables growers to achieve steady and reliable results, allowing them to produce high quality, pesticide-free crops all year round. These are some of the factors behind the incredible growth of the indoor farming industry.

According to findings in Agrilyst's 2017 the State of Indoor Farming report, indoor vertical farming operations resulted in 2X revenue compared to greenhouses. The report also found that indoor growers yield 10–15 times more than outdoor farms.

Vertical Farming

"Vertical farms, especially developed in cities, is probably the most relevant solution we found to produce fresh food and vegetables." — Pierrick Boulay, technology & market analyst at Yole (ElectronicsWeekly.com)

Vertical farming is a specific kind of indoor growing facility where many racks of plants are stacked vertically, on top of each other — a feature which enables growers to utilize the available space in the best way possible. Stacks of crops can be integrated into structures like a skyscraper, shipping container or warehouse, making this type of facility ideal for urban farming. This is why vertical farms are suitable for growing high density crops in locations that are near to (or even within) a city.

This practice reduces supply chain costs, decreases fuel emissions, and retains the freshness as well as nutritional content of harvested fruits and vegetables till they reach the consumer's plate. These are some of the reasons why vertical farming is being thought of as the gateway into the next-generation of agriculture.

With lucrative business models of producing better, fresher, cheaper produce at a fraction of the cost of organics and with a similar footprint, vertical farms are currently attracting millions of dollars in investments. In fact, notable tech billionaires like Amazon CEO Jeff Bezos and Alphabet Executive Chairman Eric Schmidt have invested in a vertical farming startup, *Plenty*, which aims to grow and sell chemical and pesticide-free fruits and vegetables at costs that are competitive with organic produce.

One of the biggest advantages of vertical farming is that space isn't a constraint, so farmers can grow crops even in a square foot of area, yet benefit from a high yield. Using Controlled Environment Agriculture (CEA) technology, growers are able to have more control over temperature, light, humidity, and other factors that influence plant growth.

Because sunlight is not an option in vertical farms, they receive 100% of the necessary illumination from horticulture lighting and, thus, require fixtures of intensity higher than what is needed for greenhouses. Because of this, vertical farming is poised to become the biggest driver of LED-based grow lights.

Lighting fixtures for these facilities are typically smaller, enabling growers to have fine-tuned control over the light that individual plants receive. Energy efficiency is critical and so is thermal performance as high-intensity lighting produces more heat, which can negatively affect plant growth.

Cree® Solution for Vertical Farming:

Cree's XQ-E line of vertical farming diodes are the industry's smallest high intensity LEDs and about 80% smaller than the horticultural diodes that are designed for the general greenhouse market.

The XLamp® XQ-E LED family enables lighting manufacturers to significantly reduce the size and total cost of their LED luminaires without sacrificing light output, efficacy or reliability.

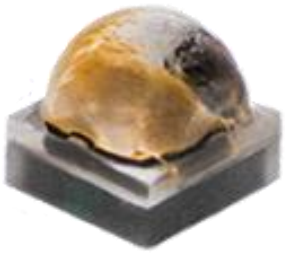


Figure 4. Cree XLamp XQ-E

Smart Farming

"As we demand more and more from our farmers, harnessing IoT technology for smart farming appears to be the only conceivable way they'll be able to succeed. With a world population projected by the United Nations to be 9.8 billion in 2050 and 11.2 billion in 2100, IoT in agriculture is an absolute necessity."— Josh Garrett, president and co-founder at MOBI (TechTarget)

Smart farming refers to tech-driven strategies for crop production, which includes the use of data, high-precision crop-control, and automated farming techniques.

Analytics-driven precision agriculture enables growers to make the best possible production decisions while connected devices and IoT technologies monitor and automate daily operations, helping farmers overcome bottlenecks to production such as droughts and other weather inconsistencies as well as pest management. Having access to real-time data enables growers to quickly identify and address problems, improving their overall yield.

Smart farms monitored using IoT sensors managed by AI-based data platforms could cut down the need for labor, creating cost savings for farmers. Experts have estimated that smart farming could be as much as 50% more energy-efficient than other indoor growing environment.

A report by BIS Research estimates the global smart farming market to reach $23.14 billion by 2022, rising at a CAGR of 19.3% from 2017 to 2022. The market growth is primarily attributed to rising consumer demands, need for higher crop yield, the growing penetration of information and communication technology (ICT) in farming, and the need for growers to become climate-smart.

Growing techniques in highly controlled indoor environments is yet another area that is taking precedence in the smart farming landscape. While indoor cultivation methods help to produce the optimal yield and plant quality, the use of analytics can help growers accurately identify the different factors affecting the harvest.

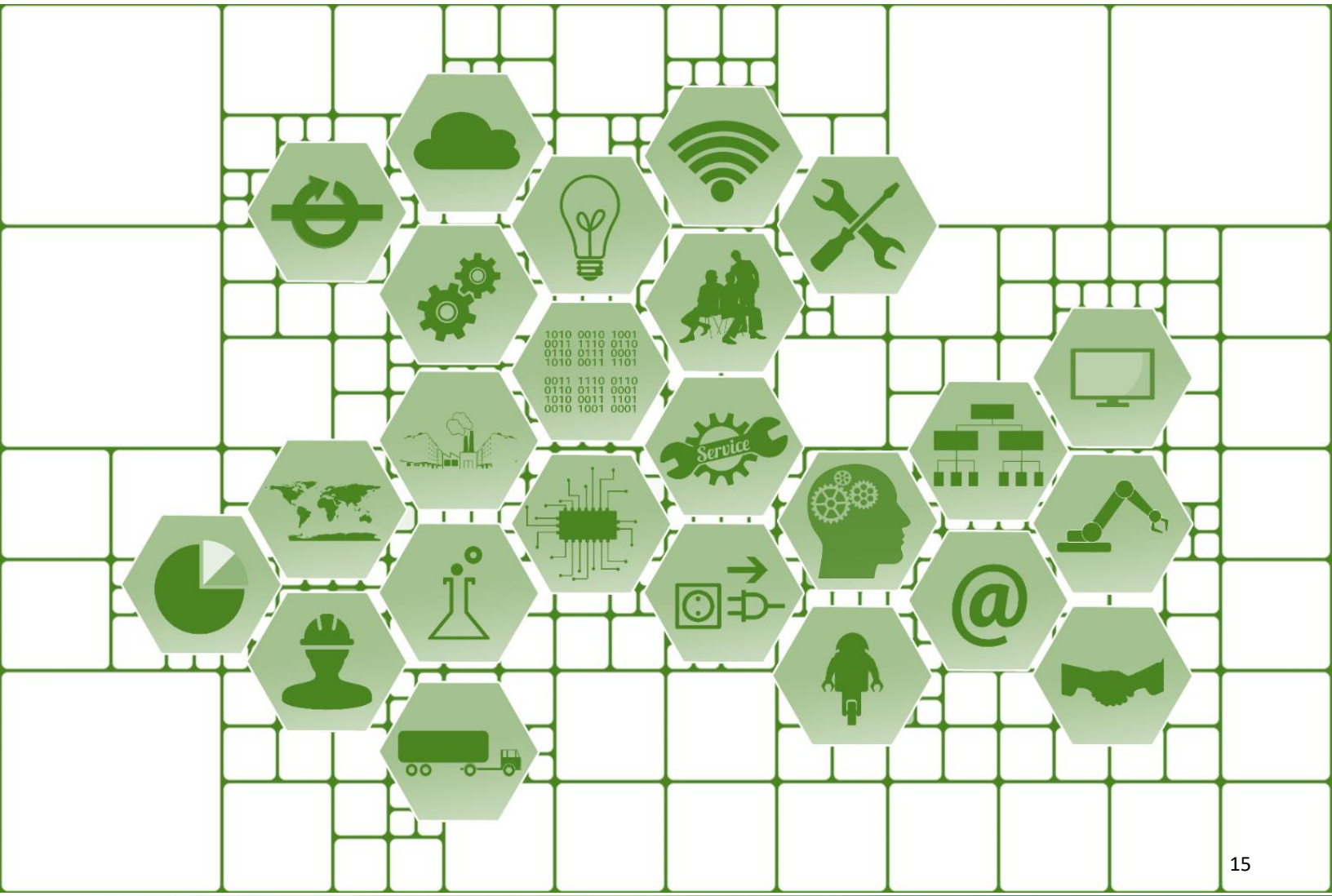
Intelligent LED systems are the ideal lighting partners for smart farming facilities. As such, smart grow lights are being touted as the most value-added internet-connected lighting application in existence. These LED lighting systems go beyond the usual benefits of enhanced produce quality and yield in controlled environments. For example, even the best grow light recipes need to be accurately tweaked according to the stage of the plant's growth. The intelligence and maintenance capabilities of the smart grow lights combined with sensors can efficiently handle such tasks without any human intervention. It will not only make indoor growth facilities more competent to fulfil rising demands, but also create opportunities for unprecedented cost savings. While today, only a fraction of these capabilities have been explored, the possibilities are endless.

Cree® Solution for Smart Farming:

Cree's line of intelligent lighting systems built on its SmartCast® Technology includes luminaires with integrated sensors.

Cree's SmartCast Intelligence Platform™ combines intelligent luminaires, the Internet of Things and innovative apps to deliver actionable insights from day one.

As the most intuitive and easiest to install intelligent light solution on the market, the Cree SmartCast product line delivers up to 70% energy savings for half the cost of other solutions.



Moving Towards Horticulture Lighting

PRODUCT SELECTION GUIDE

Horticulture Lighting Design: Factors to Consider

As more products and brands make their way into the marketplace, the key to success will be in identifying the right products for specific horticultural needs. For product designers, that would mean picking the right components to build more efficient systems; for facility managers, it boils down to finding the right solutions that would allow them to increase profitability at the lowest possible operating cost.

While every horticultural lighting design application is different, there are factors that should always be considered before purchasing and installing LED lighting products. This section is meant to help you understand some of those key considerations in horticultural lighting application design and acquaint you with some of the industry-leading products in the market.

HORTICULTURE TERMS & DEFINITIONS

Photosynthetically Active Radiation (PAR)
- Range, not a unit
- Spectral range in which photosynthesis occurs: 400-700 nm

Photosynthetic Photon Flux (PPF)
- Measured in: µmol·s-1
- Total amount of PAR photons generated by the luminaire

Photosynthetic Photon Flux Efficiency (PPF/W)
- Measured in: µmol·J-1
- Luminaire's efficiency at converting electrical input power into PAR photons

Photosynthetic Photon Flux Density (PPFD)
- Measured in: µmol·m-2·s-1
- Total amount of PAR photons falling on a specified area

Day Light Integral (DLI)
- Measured in: mol·m-2·d-1
- Total amount of PAR photons delivered in a 24 hour day

HORTICULTURE LIGHTING TYPES

Top lighting – Greenhouses:
Illumination of the hall and plants from ceiling level

Retrofitting old HPS, modifying spectral content of light

Challenges: light concentration on plants, uniformity and constant quality of light spectrum, high amount of power needed

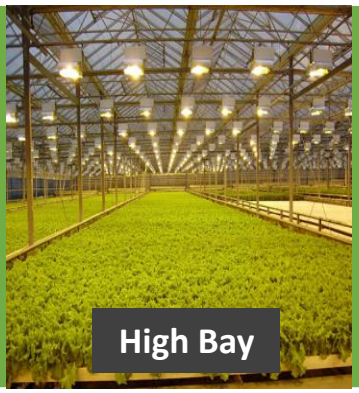
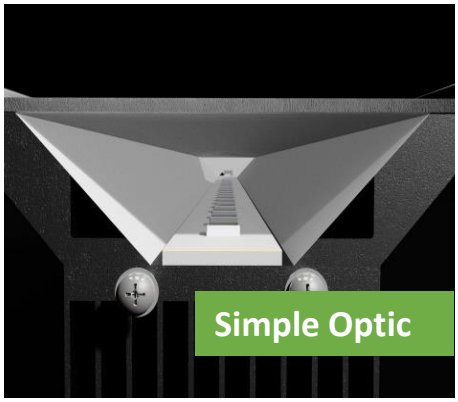
Top lighting – Vertical farming:
Illumination from top of the plants at close distance

Challenges: uniform intensity and spectral distribution, plants shading each other, photosynthetic efficiency (PPF/W), heat

Intra-canopy:
Illumination on the side or in between the plants

Possible with LEDs (HPS too hot)
Challenges: uniform PPFD, good color uniformity (if continuous/wide spectrum), spectrum fit to the rest of lighting, light direction

HORTICULTURE LED LUMINAIRE DESIGN TRADE-OFFS

	 High Bay	 Linear
 No Optics	**Not Recommended** Optics will greatly increase PPFD and are worth the cost	**Lowest Cost** • Worst uniformity, but works for close spacing • No mixing for multi-color systems
 Simple Optic	**Lowest Cost** • Reflector/film improves PPFD and uniformity • Enables wider range of mounting heights	**High Performance** • Good uniformity • Improved mixing for multi-color systems
 Individual Optics	**High Performance** • Good uniformity • Improved mixing for multi-color systems	**Not Recommended** Optics will add unnecessary cost

COMMON SPECTRAL STRATEGIES

	Chlorophyll	Full Spectrum		
	Blue + Red	White + Red	90 CRI White	70 CRI White
Match to Chlorophyll?	●●●●	●●●	●●	●
Match to McCree?	●●●	●●●●	●●●	●●
Match to Sunlight?	●	●●	●●●	●●
Efficiency (PPF/W)	●●●●	●●●	●	●●●
Human Light Quality	●	●●●●	●●●●	●●●
Dynamic Control Ability?	●●●	●●●	●	●
LEDs Used	455 nm Royal Blue + 660 nm Red	4000K, 70 CRI White + 660 nm Red	4000K, 90 CRI White	4000K, 70 CRI White

WHY CHOOSE CREE® AS YOUR HORTICULTURE LIGHTING DESIGN PARTNER?

Cree®, a global leader in LED lighting, defined packaged LEDs and finished SSL products as innovations that will drive the future of LED technology much beyond creating good lights.

With its continuous efforts in exploring new possibilities and ideas through effective LED lighting utilization in varied horticultural environments like photosynthesis process, chlorophyll optimization, and plant morphology, the company aims to improve the efficiency of its LED lighting offerings.

With a portfolio that features a wide array of LEDs optimized for horticulture lighting, Cree® is offering the industry's best lumen density and optical control with excellent L90 and L70 lifetimes, even in extreme conditions. The XLAMP LEDs — its range of horticultural lighting arrangement — includes comprehensive light spectrum strategies like white, royal blue, blue, far red, photo red and green. Cree's color horticulture portfolio provides color wavelengths optimized for horticulture applications.

In addition to the color offering for horticulture, Cree® also offers options for those who prefer "white light" or halogens for these applications. With high CRI (color rendering index) of 90+, their CXA and CXB portfolio push the boundaries of lighting-class performance by combining high quality of light with unmatched light output and efficacy for growers. These products help achieve the full spectrum of light to mimic natural sunlight.

THE CREE EDGE

Broad Portfolio
LEDs that fit your design goals, not the other way around

Best Performance
Industry-best output & efficiency across all color options

Best Reliability
- Extensive
- LM-80 testing to back up lifetime claims
- Superior long-term color / spectrum maintenance

Invested in Your Success
- Access to powerful Cree LEDs brand
- Pure play component supplier
- Strong IP position

TAKE ADVANTAGE OF THE BEST RELIABILITY IN HORTICULTURE LED

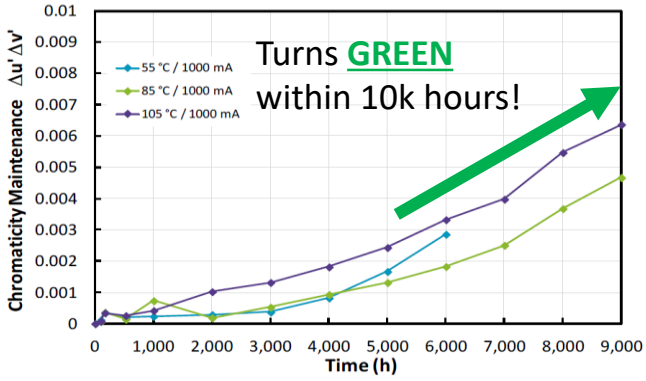
PEACE OF MIND KNOWING THAT YOU'RE TRUSTING THE BEST!

With extensive in-house LM-80 long-term LED testing capability to prove lifetime claims, Cree® can help your vision for horticulture applications turn into a reality.

Cree outperforms the competition, even at high temperatures and high drive currents.

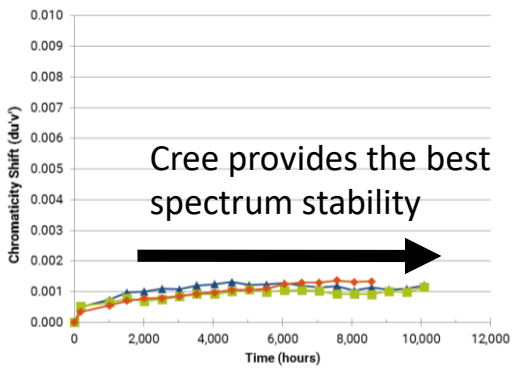
Better LED photon maintenance = Increased crop yields, Stronger TCO sales pitch

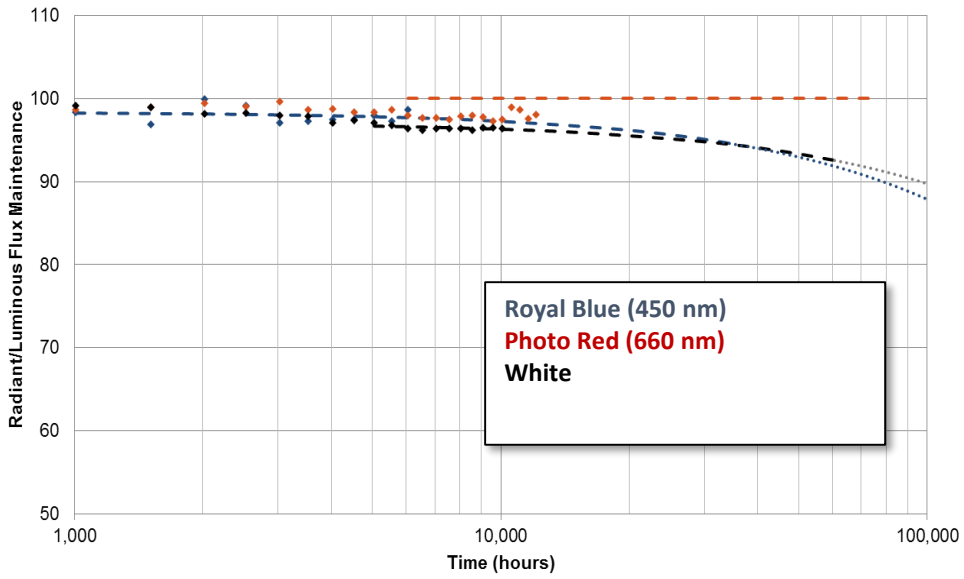
Typical Competitor White LED



vs

Cree White LEDs





FEATURED CREE® HORTICULTURE LED PRODUCTS

XLAMP® MHB-B LED

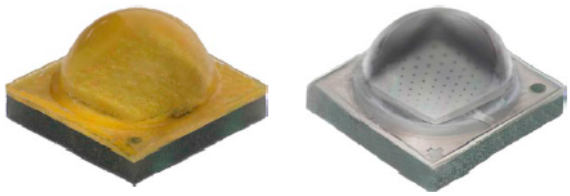
- Best value for high PPF/W, full spectrum light
- 9V, 18V & 36V options provide driver design flexibility
- Can be used in SMD arrays to upgrade the thermal performance of COB designs
- Up to 14k hours of LM-80 test data available

LED & Color	Footprint (mm)	Maximum Current (A)	Test Temperature	Test Current (A)	Minimum PPF * (µmol/s)	PPF/W * (µmol/J)	Min. PPF @ Max. ** (µmol/s)	Order Code
MHB-B 4000 K/ 70 CRI	5.00	0.700 (9 V) 0.350 (18 V) 0.175 (36 V)	85 °C	0.480 (9 V) 0.240 (18 V) 0.120 (36 V)	7.9	1.87	10.8	MHBBWT-0000-000C0BE240E
					7.3	1.75	10.0	MHBBWT-0000-000C0BD440E
MHB-B 4000 K/ 90 CRI					7.3	1.75	10.1	MHBBWT-0000-000C0UC440G
					6.8	1.62	9.3	MHBBWT-0000-000C0UC240G

* Performance for LED with minimum light output & typical voltage at stated test condition.
** Performance for LED with minimum light output & typical voltage at Tj=85 °C, maximum current.

XLAMP® XP-G3 LED

- High PPF & PPF/W full spectrum light in the 3.45 mm XP/XT footprint
- Industry's highest PPF & PPF/W 450 nm LED
- Up to 10k hours of LM-80 test data available



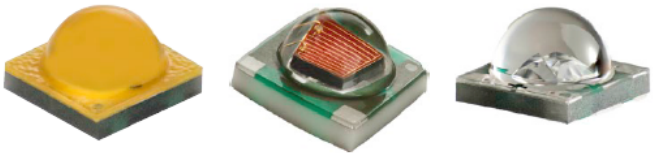
LED & Color	Footprint (mm)	Maximum Current (A)	Test Temperature	Test Current (A)	Minimum PPF * (µmol/s)	PPF/W * (µmol/J)	Min. PPF @ Max. ** (µmol/s)	Order Code
XP-G3 4000 K/ 70 CRI	3.45	2.000	85 °C	0.350	2.2	2.29	9.3	XPGDWT-B1-0000-00L5E
					2.1	2.18	8.9	XPGDWT-B1-0000-00K5E
					2.0	2.07	8.4	XPGDWT-B1-0000-00J5E
XP-G3 4000 K/ 90 CRI					2.0	2.10	8.6	XPGDWT-U1-0000-00G5E
					1.9	1.97	8.1	XPGDWT-U1-0000-00F5E
					1.8	1.85	7.5	XPGDWT-U1-0000-00E5E
XP-G3 Royal Blue 450 nm			25 °C	0.350	2.8	2.80	12.1	XPGDRY-L1-0000-00601
					2.6	2.61	10.8	XPGDRY-L1-0000-00501
					2.4	2.44	10.1	XPGDRY-L1-0000-00401

* Performance for LED with minimum light output & typical voltage at stated test condition.
** Performance for LED with minimum light output & typical voltage at Tj=85 °C, maximum current.

FEATURED CREE® HORTICULTURE LED PRODUCTS

XLAMP® XP-E & XT-E LEDs

- Huge ecosystem of PCB & optics for 3.45 mm XP/XT footprint
- Highest output & efficiency 660 nm LED available
- LM-80 test data available for all colors



LED & Color	Footprint (mm)	Maximum Current (A)	Test Temperature	Test Current (A)	Minimum PPF * (µmol/s)	PPF/W * (µmol/J)	Min. PPF @ Max. ** (µmol/s)	Order Code
XT-E HE 4000 K/ 70 CRI	3.45	1.500	85 °C	0.350	2.1	2.15	6.8	XTEAWT-E0-0000-00000BKE5
					2.0	2.04	6.4	XTEAWT-E0-0000-00000BJE5
XT-E HE 4000 K/ 90 CRI	3.45	1.500	85 °C	0.350	1.9	1.95	6.2	XTEAWT-E0-0000-00000UFE5
					1.8	1.82	5.8	XTEAWT-E0-0000-00000UEE5
XT-E Royal Blue 450 nm	3.45	1.500	85 °C	0.350	2.3	2.28	7.7	XTEARY-00-0000-000000Q01
					2.2	2.18	7.4	XTEARY-00-0000-000000P01
					2.1	2.09	7.0	XTEARY-00-0000-000000N01
XP-E HE Photo Red 660 nm	3.45	1.000	25 °C	0.350	2.3	3.18	5.5	XPEEPR-L1-0000-00C01
					2.2	2.99	5.2	XPEEPR-L1-0000-00B01
					2.1	2.81	4.9	XPEEPR-L1-0000-00A01

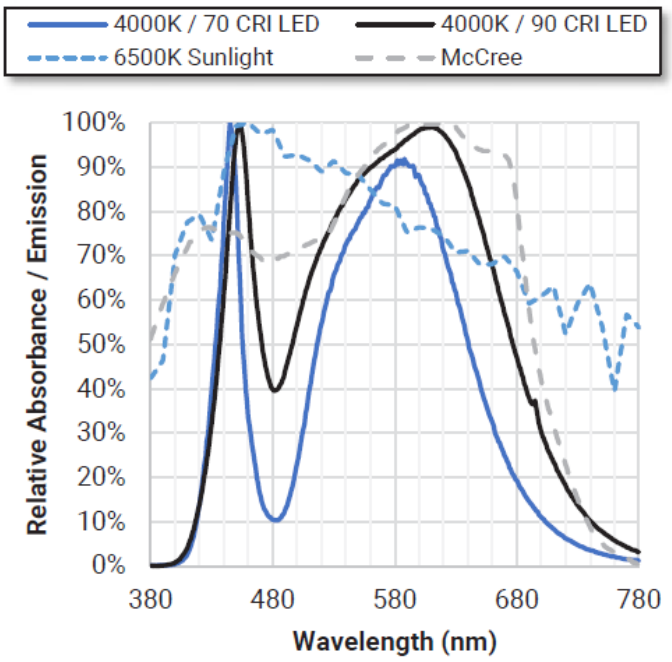
LED & Color	Footprint (mm)	Maximum Current (A)	Test Temperature	Test Current (A)	Minimum Flux * (mW)	WPE * (%)	Min. Flux @ Max. ** (mW)	Order Code
XP-E Far Red 730 nm	3.45	1.000	25 °C	0.350	250	37.6%	589	XPEFAR-L1-0000-00701
					210	31.6%	495	XPEFAR-L1-0000-00601

* Performance for LED with minimum light output & typical voltage at stated test condition.
** Performance for LED with minimum light output & typical voltage at Tj=85 °C, maximum current.

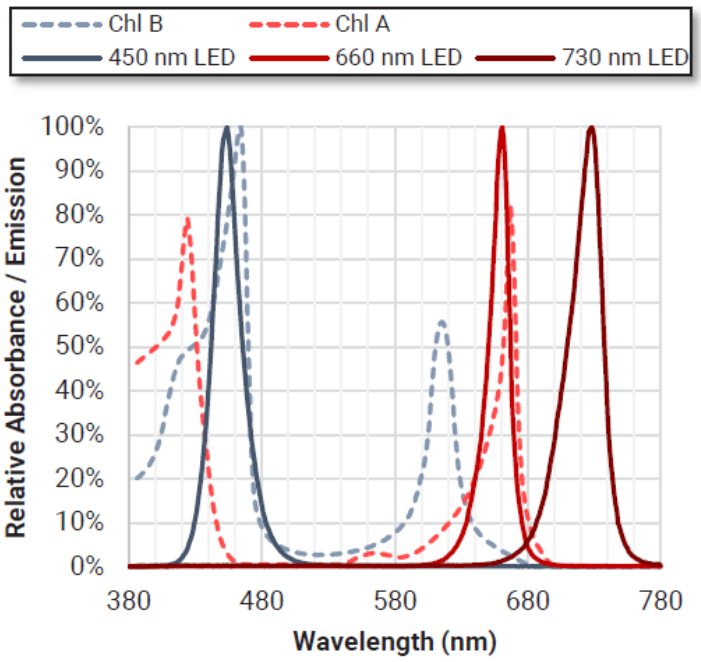
CREE® HORTICULTURE LED PORTFOLIO

Footprint	White		Color			Advantages
	4000 K / 70 CRI	4000 K / 90 CRI	450 nm	660 nm	730 nm	
5.00 mm	MHB-B White	MHB-B White				• Best value for high PPF/W, full spectrum light • 9-V, 18-V & 36-V options • Upgrade the thermal performance of COB designs • Up to 14k hours of LM-80 test data available
3.45 mm	XP-G3 White	XP-G3 White	XP-G3 Royal Blue			• Industry-leading PPF & PPF/W in the 3.45 mm XP/XT footprint • Up to 10k hours of LM-80 test data available
	XT-E High Efficacy White	XT-E High Efficacy White	XT-E Royal Blue	XP-E High Efficiency Photo Red	XP-E Far Red	• Huge ecosystem of PCB & optics for 3.45 mm XP/XT footprint • Highest output & efficiency 660 nm LED available • LM-80 test data available for all colors
1.60 mm	XQ-E White		XQ-E Royal Blue	XQ-E High Efficiency Photo Red		• Highest PPF density: up to 5 µmol/s from 1.6 x 1.6 mm package • 2x-3x PPF density of closest competitors • Enables smallest & highest density luminaires
	XQ-A White		XQ-A Royal Blue			

Spectral Power Distribution (White)



Spectral Power Distribution (Color)



OPTIMIZE YOUR INVESTMENT WITH THE RIGHT OPTICS

Uniform light and spectral distribution are imperative to raise high-quality, healthier, crops with better production. The right optics help focus light energy on the plants resulting in greater photosynthetic photon flux density (PPFD) using less power. Furthermore, optics help growers achieve higher crop yields, while shortening the growing cycles as well as reducing luminaire bill of material costs.

LEDs also have lower radiated heat, which means luminaires can be placed closer to plants, allowing for more dense farms and reduced water consumption. This also offers another vital advantage: sustainability. LED luminaires have a much longer lifetime compared to traditional light sources, resulting lower maintenance costs.

The key questions to ask when designing horticultural lighting are:

- ***Does the light generate enough and the correct ratio of photons?***
- ***Are the valuable photons going where they are needed?***
- ***How efficient is the luminaire at generating photons?***

With the right optics, LED light can be focused on the plants, without waste.

Narrow beam angle:
Gives a higher PPFD (for plants that require deeper penetration of light inside the foliage)

Wider beam angle:
Potentially lower PPFD but can be compensated by lowering the luminaires
Potential cause of shadowing problems
Lower foliage penetration

Asymmetric beam angle:
New possibilities - vertical plane, off-plant installations

LEDiL PRODUCTS AND SOLUTIONS BRING OUT THE BEST IN LIGHTING

A true specialist in the field of secondary optics for high-power and lighting-class LEDs, LEDiL has been producing precision-engineered optics and reflectors since 2002 and now boasts nearly 3,500 standard products optimized for use with LEDs produced by the world's prominent LED manufacturers. Custom solutions are also commonly developed with minimal end-user tooling investment required. With production in Finland and China, new facilities in the US, and a global network of authorized distributors, LEDiL's products are sought and available around the world.

The company's latest optic, DAHLIA, is designed specifically for greenhouse top lighting. DAHLIA is a highly efficient compact linear platform fitting 120 LEDs with up to IP67 ingress protection. The batwing type beam provides extremely uniform lighting in the growth area resulting in shorter growing cycles and even growth of plants, flowers and salad crops.

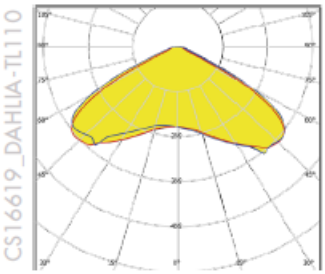
DAHLIA enables you to fully control the light spectrum and intensity to meet the growth phases of individual plants with the support of 1-4 channels and a varying number of LEDs per channel. As DAHLIA fits 120 LEDs, a number divisible by 4, 3 and 2 it covers all the bases regardless of the number of channels you might need. So if you want to get your flowers blooming just turn up the blue light; or zap them with a bit of extra purple light to speed up growth without flowering.

FEATURES

- Comes with a silicone seal for up to IP67
- Made from PMMA (good chemical resistance)
- Sturdy fastening with 14 screws
- Adopts easily into design with 1-4 channels and varying number of LEDs per channel
- PPFD deviation 10 % over the growth area

COMPATIBILITY

- Typical horticultural 3535 HP LEDs (e.g. Osram Oslon SQ Horti, Luxeon SunPlus 35 Line LEDs)



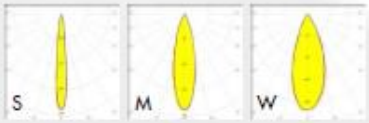
FEATURED LEDIL HORTICULTURAL LIGHTING PRODUCTS

PETUNIA

29.5 x 46.5 mm low profile and dense array with 12 lenses for horticultural lighting and up to 3535 size LED packages.

VIRPI

75 x 75 mm 25-up multi-lenses for spot- and track lighting and up to 3535 size LED packages.

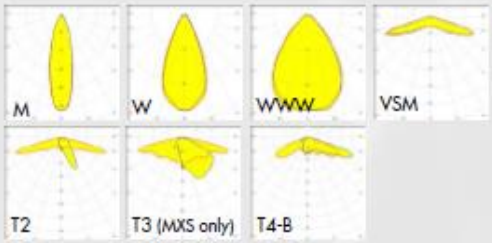


2X2 & IP-2X6 (STRADA & HB)

Standardized modular product families designed for street and industrial lighting, but also suitable for a wide range of other applications.

2X2MX/S (STRADA & HB)

90 x 90 mm up to IP67 2X2 arrays for up to 7070 size LED packages.

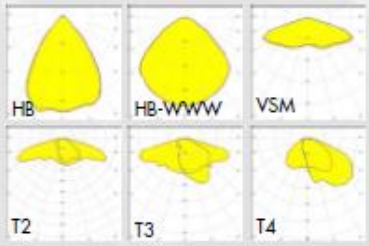


FLORENCE-3R-IP

3-row (Zhaga book 7) up to IP67 linear lenses for humid, wet and dusty environments.

STELLA

Ø90 mm up to IP67 silicone lenses for street, wide area and high bay lighting and up to 30 mm LES size COBs.



POWER YOUR HORTICULTURE LIGHTING SYSTEMS WITH ARTESYN

When designing a horticultural lighting system, the aim is to minimize your power consumption, installation expense and the cost of cooling your facilities. Artesyn Embedded Technologies offers power products that take care of all these factors.

Using a large centralized current source outside the environmentally controlled growth areas and distributing power directly to all the luminaires can help eliminate the need for individual drivers and the associated costs. By offering single conduction and IP rated solutions up to large distributed external systems, Artesyn can help scale power for various power distribution architectures in practically any installation.

Products	Features
LCC600 Series 	• 600 watts from -40 °C to 85 °C baseplate operating temperature • High efficiency design in a 4” x 9” x 1.57” compact IP65 enclosure under 2 kg • Fanless design uses conduction cooling for thermal management – can utilize the same luminaire heatsink for thermal heat transfer • 90-264 Vac or 180-305 Vac operating input • Digital control: Constant voltage (default) or constant current mode of operation; programmable constant current limits through I2C/PMBus® • External voltage or resistance dimming capable • Active share/parallel operation for higher power
LCM Series 	• Fan-cooled alternative to the LCC600, saving typically 50% of cost • Digital control – can be set to operate in constant voltage or constant current • Easily operated in parallel for higher power • Great for controlled environment applications • Conformal coating
iHP Series 	• Can be installed outside growing area so power dissipation does not affect environmental controls • High level of scalability – multiple racks per cabinets can scale up to megawatt levels (in 3 kW increments up to 12 kW in small rack or 24 kW in large rack) • Highly flexible input (180-528 Vac, single or 3-phase) and outputs (12-1000 Vdc) allows high voltage distribution, saving copper wiring costs • Intelligent current and voltage source control (local or via Internet) eliminates the need for individual luminary drivers • Digitally controlled loop compensation eliminates bothersome flickering throughout entire operating range • Cloud-based GUI allows simple user customization of lighting profile dashboards

BEAT THERMAL CHALLENGES IN HORTICULTURE LIGHTING WITH NMB

Effective heat management is critical in indoor farms and controlled growth environments. While LED luminaires generate less heat compared to HPS lamps, cooling fans help to reduce overall heat even further. For horticulture lighting systems in particular, the benefits of active cooling include a decrease in radiant heat directed at the plants, reduction in size of LED fixture, lesser cost, better light output, and longer LED lifetime.

NMB Technologies offers the only series of cooling fans that have achieved IP69K rating, offering the highest proven protection available against closed range, high temperature, high pressure spray-downs. They are available with a new metal casing with high reliability in high temperature, plastic magnet, and if desired, stainless NMB bearings with ceramic balls.

THE NMB ADVANTAGE

Water Resistant - Fan Motor is fully encapsulated by epoxy potting. Protected from total dust ingress and steam-jet cleaning.

High Performance - Air Flow ranging from 12cfm to 346cfm

Durability - Designed for long life, also available in Metal Casing and Ceramic Bearings

Long Life - 100,000 hours at 25°C

Safety Approved - CUL / VDE / RoHS Compliant

Are You Ready for the Future of Your Farm?

Horticulture lighting is a booming industry and, with the integration of LEDs, this is a field poised for massive growth and investment. As a market that is witnessing increased entry of manufacturers, product designers, and innovators, LED horticulture lighting is already a competitive landscape. The competition is only going to get more intense.

WPG Americas can help you take advantage of the revolutionary and more sustainable methods of agriculture. With our vast network of leading lighting solution providers Cree and LEDiL's latest product offerings on our shelf, we are your ideal partner in taking your horticulture lighting projects to the next level. Visit our website to know more information about lighting solutions or contact us anywhere at our nationwide offices with your specific requirements.

Feature Products

Power

Thermal Management

Optics

WPGA Lighting Solution Providers

Production Selection Guide Resources provided be Cree and LEDiL

Downloads of these documents, including datasheets, product guides and additional product documentation are available on our eBook Landing Page.

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To learn more about the latest and best-in-class lighting products, contact WPG Americas at 408-392-8100 or visit www.wpgamericas.com

About WPG Americas
WPG Americas Inc. is a member of WPG Holdings, the largest electronics distributor in Asia. Founded in November 2007, WPG Americas is a franchised partner to technology leaders in the Semiconductor, Passive, Electromechanical, Interconnect, Display and Lighting Solutions markets.

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