SpecGradeLED

Guide to selecting a grow light

by Rick Nathans

CONTENTS

INTRODUCTION

Evaluating grow lights is not a simple process. Even if you're both a botanist and a lighting engineer, selecting a good-quality grow light with the optimal spectrum can be a complex process. Unfortunately, some unscrupulous manufacturers make misleading or false claims to the unsuspecting buyer. In fact, most of them aren't even manufacturers, but resellers. However, if you do your due diligence before investing in a grow system, and vet the manufacturer itself, this research will pay dividends for years to come.

The purpose of this document is to make you aware the issues involved in choosing a grow light. We'll do this by guiding you through the process of selecting a system.

A successful horticulture environment is essentially an ecosystem or a large community of living organisms (plants, animals and microbes) linked together through nutrients and energy flows. Artificial lighting can play a large part in this energy flow, either by supplementing the sun in a setting like a greenhouse, or by replacing the sun in a setting like a warehouse.

HORTICULTURAL LIGHTING CONCEPTS

We'll take you step by step through the selection process, beginning with industry terminology. If your head is spinning with acronyms, metrics, and technical terms — such as PAR, PPF, PPFD, watts, voltages, uniformity ratios, avg/min, max/min, photons, photon efficacies, lux, and lumens — you're not alone. Some of these factors don't even apply horticultural lighting, but they often add to the confusion.

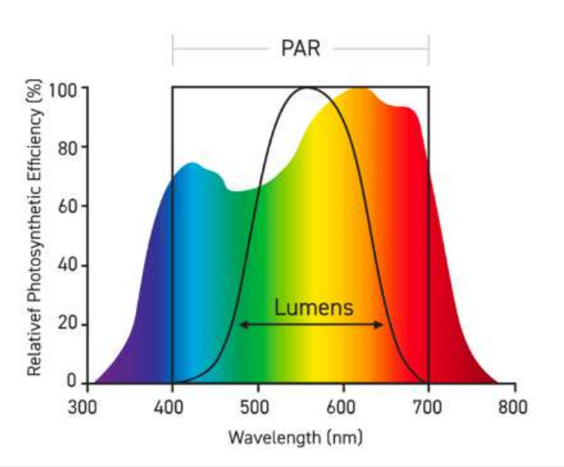
Some of these terms are the building blocks that will help you will make your purchasing decision. Once you understand these concepts, your first step should be to eliminate any companies that don't give you the data you need for the appropriate metrics. However, even if they do make this information available, it's only the beginning of your journey: you need to be able to interpret the information. That's what this section is all about.

PERFORMANCE

PAR VS. LUMENS

The term photosynthetically active radiation (PAR) refers to the spectral range (that is, the wavelengths) of solar radiation that organisms can use in the process of photosynthesis — from about 400 to 700 nanometers.

Lumens, on the other hand, measure the total quantity of light that is visible to the human eye. The spectrum visible to the human eye is about 380 to 740 nanometers, though certain parts of this spectrum are more visible than others. This graphic illustrates the wavelengths perceived by humans verses the one experienced by plants (A good way to remember this: lumens are for humans.)



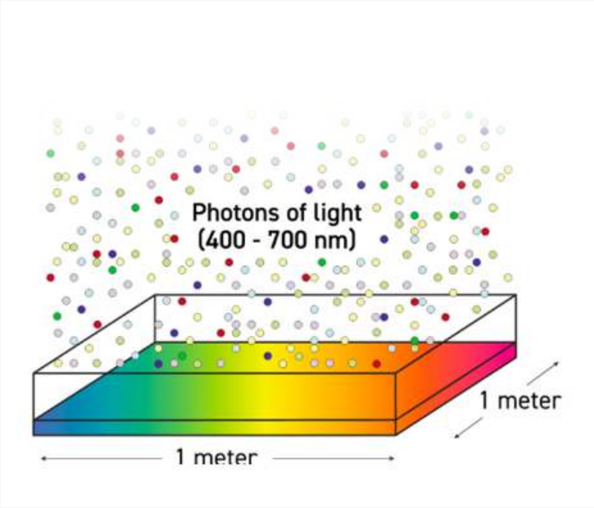
PPF

Photosynthetic photon flux (PPF): This metric indicates the amount of PAR that is produced by a lighting system. It's expressed as micromoles per second (μmol/s).

PPFD

Photosynthetic photon flux density (PPFD) measures the amount of PAR that actually arrives at the plant or the quantity of photosynthetically active photons that fall on a given surface each second. It's measured in micromoles per square meter per second (μmol/m2/s) onto the canopy (see Figure 2). Handheld PAR meters, which are widely available, can be used to measure PPFD.

When evaluating PPFD, the grower should take an average measurement of not only the area below the light, but the entire area, because light from one fixture will spill over into the surrounding areas (more about this on page 22). Also, when evaluating this metric, the distance of the light over the canopy should factor into the equation.



Manufacturers can skew the PPFD they report in a number of ways — for example, simply by raising or lowering the light can significantly affect those levels . The calculations that you should base your decision on are produced using certified independent third party .IES files used to generate the final PPFD calculations (The .IES extension comes from the name Illuminating Engineering Society of North America.)

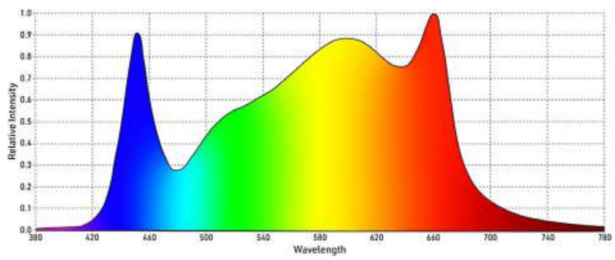
EFFICIENCY

The efficiency of a grow light is calculated by taking the PPF and dividing it by the wattage. This becomes an important factor for larger grows, where inefficiencies can be very costly. Although PPF does not tell you how much of the measured light actually lands on your plants (that's PPFD), it's an important metric if you want to calculate how efficient a lighting system is at creating PAR. This formula is PPF/watts, with the result measured in micromoles per joule of energy (μmol/J). In the case of the SpecGrade Verta-8, for example, the PPF of 1589 is divided by the 649 watts, for an efficiency factor of 2.45 μmol/J.

SPECTRA

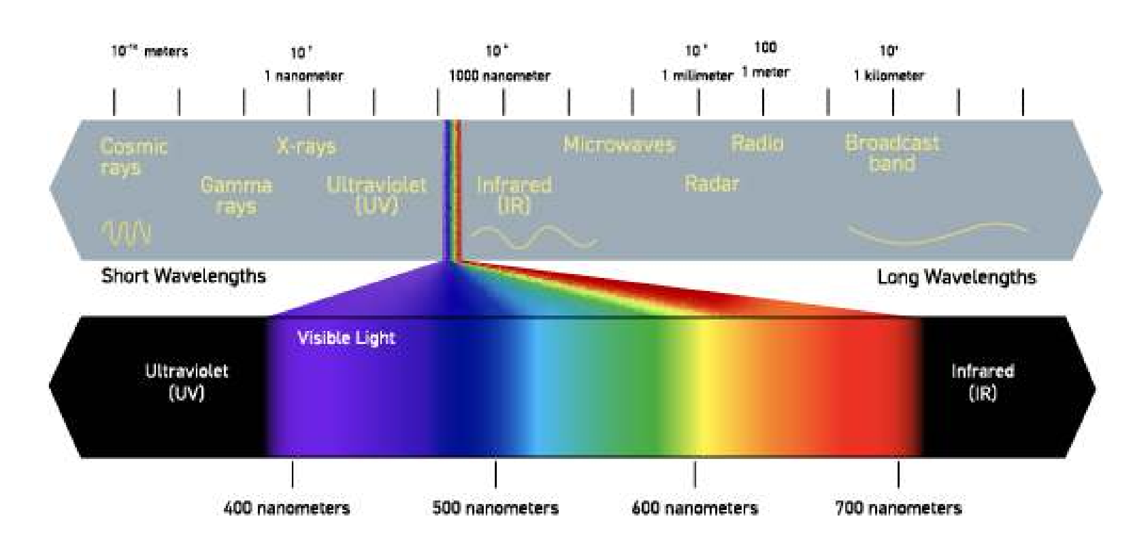
The exact light spectrum that each plant requires continues to be an elusive hypothesis. As yet, there's little agreement on the most effective lighting strategies during various stages of plant growth. What we do know is that blue light lends itself to the vegging portion of a plant's life cycle, while the red portion of the spectrum lends itself to the flowering portion of the cycle (see Figure 3). Although the ratio of spectrum colors is a matter of some argument, and we don't know how much of a role genetics plays, the scientific consensus is leaning toward a balanced approach of reds, blues, and greens, while factoring in the crop and the region — because at the end of the day, we're trying to simulate the sun, and there's much we don't know.

Figure 3



LED technology is gaining the respect of today's professional cultivators, because it enables the grower to finely tune the spectrum to the plant. Older, less efficient technologies such as high pressure sodium, metal halide, and ceramic metal halide bulbs don't have this flexibility (see page 9).

ULTRAVIOLET LIGHT (10–400NM)



Although research indicates that light in this spectrum can be dangerous in larger doses, smaller amounts seem to contribute to the plant's taste and smell. While this spectrum does not affect plant growth, studies indicate that the light in the UVB range can increase the THC content in cannabis. Because this research remains somewhat speculative and the light itself can be dangerous, SpecGrade does not integrate this spectrum into our grow lights. Rather, we encourage our cultivators to cost-effectively add it by incorporating inexpensive PAR38 lamps throughout the grow facility and controlling them on a separate timer.

SPECTRA (CONTINUED)

BLUE LIGHT (430–450NM)

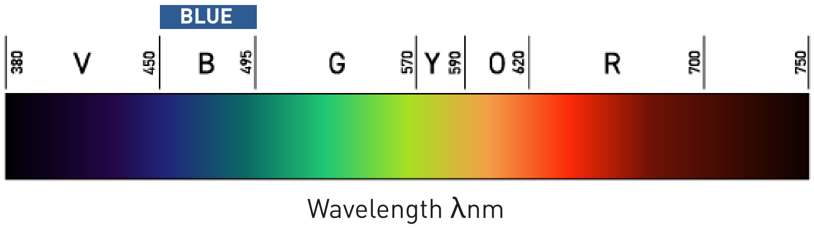


Figure 5

Blue light is typically encountered in nature at midday, when the angle of the sun is directly vertical or close to it. Light in this spectrum is critical to a plant during the vegetative stage of life, when terpenes are developed. In the commercial grow facility, where every cubic foot must be productive, "stretching" must be minimized. 'Stretching' is a term to refer to a plant being tall and not bushy which is produced by not having enough blue light, is a survival mechanism to ensure that the plant gets enough light and nutrients.

Based on millions of years of plant evolution, we can assume that the sun's spectrum is ideal for vegetative growth (Figure 5) in various strains and species — which depends on a combination of red and blue light. Light in the blue spectrum increases photosynthesis rate, thereby increasing yields. Research also indicates that increased amounts of blue light will induce flowering.

However, research also shows that blue light suppresses stem elongation, resulting in plants that are usually shorter and more compact, while having thicker, denser leaves (compared to plants grown without blue light). Growers can maximize ROI by adding more blue to the spectrum.

We designed the A1 (Figure 3) spectrum because botanists widely recommend using a balanced, full-spectrum light source that includes high amounts of blue light, as well as other colors. This means that our A1 spectrum works as a single spectrum for the entire life cycle of a plant.

GREEN LIGHT (500–550NM)

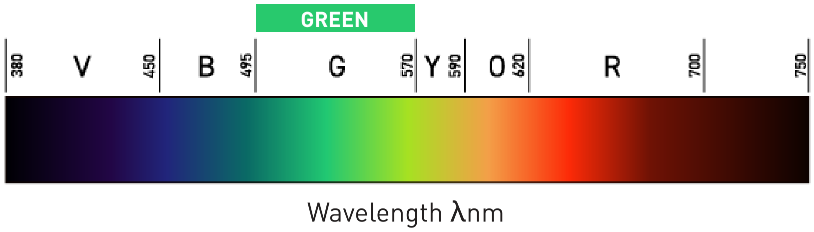


Figure 6

Green light (Figure 5) doesn't often get the attention it deserves when evaluating spectra. Research indicates that this wavelength (500~550nm) drives photosynthesis by penetrating further into the leaf more efficiently than red or blue light. For this reason, many cannabis cultivators have reported growing more secondary buds with green light than they did

SPECTRA (CONTINUED)

RED LIGHT (640–680NM)

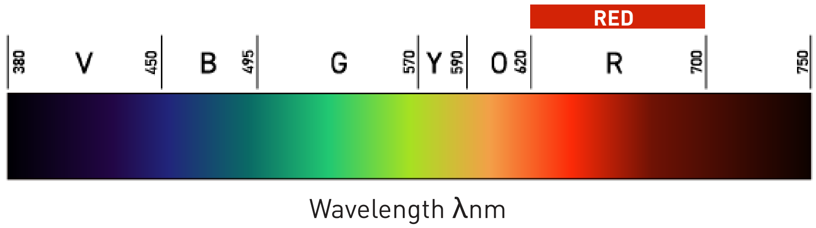


Figure 7

Red light exists most in the morning and evening, when the sun is low in the sky. It delivers high growth to a plant, but without the limiting effect of blue (which obscures the chloroplasts to protect them from the high-blue midday sun). Because of this, red is very efficient at producing fast-growing plants that are tall and strong. Consequently, it promotes some of the most impressive growth rates for height and stem width. The red portion of the spectrum key to the flowering stage in a plant's life cycle (Figure 5). However, if plants are grown under only red-spectrum lights, they can become thin and leggy.

FAR RED LIGHT (730NM)

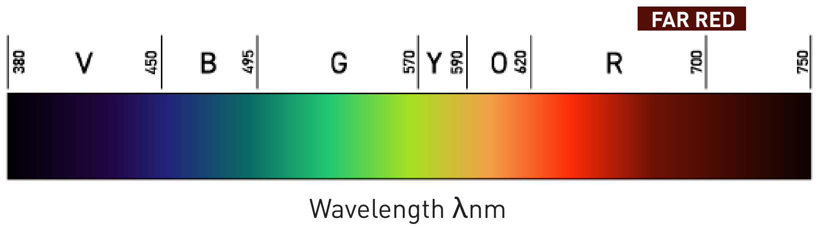


Figure 8

Research shows that far red light can have a significant negative effect on seed germination, leaf size, stem length, and plant height. Because of this, light in this spectrum should not be used in the early stages of a plant's growth.

CONCLUSION

At SpecGrade, we've drawn on the information above to design our products with a balanced spectrum and sustainable, energy-efficient intensity. This proven spectrum is designed to successfully augment the photosynthesis process for optimal growth through each stage of a plant's life, from propagation to flowering.

Figure 9

TECHNOLOGY: LIGHT SOURCES

TYPES

When it comes to types of light sources, there are significant differences between LED, doubleended ceramic metal halide (DE CMH), ceramic metal halide (CMH), metal halide (MH), and high-pressure sodium (HPS) lamps. CMH lamps (bulbs) vary from MH bulbs in that the CMH uses a ceramic tube and the MH uses a quartz tube (the MH, HPS & CMH light sources are all referred to as HID or High Intensity Discharge). This allows the CMH lamp to burn at a higher temperature, which means a better mix of gases, making the CMH tube much closer to natural sunlight than either the MH or HPS options. You can see this by looking at the color rendering index, or CRI (see Figure 12 below). CMH bulbs have a CRI around 92 (closer to full spectrum), whereas MH are around 60, and HPS are only about 25. This makes CMH lamps a superior choice for growing plants in many respects.

An LED in an energy efficient and directionally based light source that generates minimal radiant heat given proper thermal engineering. The LED will consume about 40%~50% less electricity with the same light output than the HID primarily due to the fact that, unlike the HID light sources that depend on a reflector to direct the light (much light loss), the LED throws the light in the direction it is aimed. Also, lower radiant levels of heat directed at the plants are especially important in a grow facility because plants do not thrive with excess heat.

HPS (High Pressure Sodium	MH (Metal Halide)	CMH DE (Double Ended)	CMH (Metal Halide)

Figure 10

FACTORS TO CONSIDER

FLOWERING SPECTRUM VS. VEGGING SPECTRUM

The MH lamps are excellent for flowering, since they contain more cool light in the blue spectrum; however, they lack the warmer reds and oranges in the spectrum. By contrast, HPS lamps are excellent light source for vegging because they contain more red and orange light, but they lack the cooler blues of the spectrum.

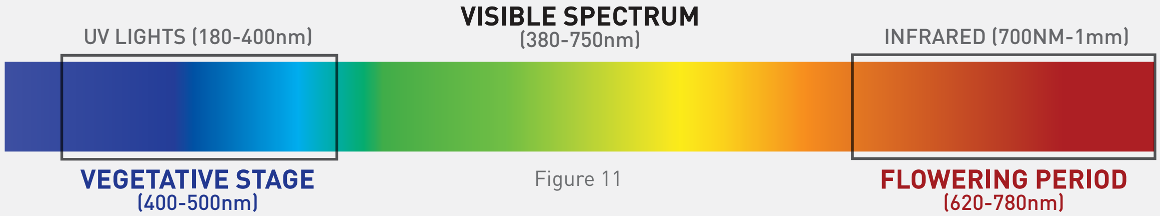


Figure 11

This brings up another advantage of CMH lamps: because of the amount of red light they work well for the flowering portion of the grow cycle. On the other hand, by mixing red and blue LED LED chips we can tweak the overall spectrum to the strain of the plant. The SpecGrade LED has a CRI of 92, making it an excellent full-spectrum light source to grow with.

COLOR RENDERING INDEX (CRI)

The color rendering index (CRI) uses a scale from 0 to 100 (where 100 represents sunlight), to indicate how accurate a given light source is at rendering color when compared to a reference light source. The higher the CRI, the better it simulates the sun. Light sources with a CRI of 85 to 90 are considered good at color rendering. SpecGrade grow lights have a minimum of a 92 CRI.

Figure 12

EFFICIENCY

Perhaps one of the biggest advantages of LED lighting is the massive energy savings. When comparing LEDs one-to-one with high-intensity discharge (HID) technologies (like ceramic metal halide, metal halide, and high-pressure sodium), LEDs offer up to 40 percent savings. This is because LED fixtures have a higher efficiency, since more of the power input goes to light than with HID options, which generate more heat. This efficiency metric can be stated in terms of PPF to watts (see page 12). For example, HPS lights have an efficiency of only about 1.7 μmol/J; LEDs come in at approximately 2.5 μmol/J, depending on the manufacturer. This becomes an important consideration for daily energy costs and HVAC requirements.

Another consideration here is warmup time. MH lamps, for example, tend to have to warm up for 10 to 15 minutes before they can give out full light. They also need a cool-down period of about 5 to 10 minutes before restarting. For this reason, they aren't recommended for locations where the lights will turn on and off frequently, such as in a greenhouse on extremely cloudy days.

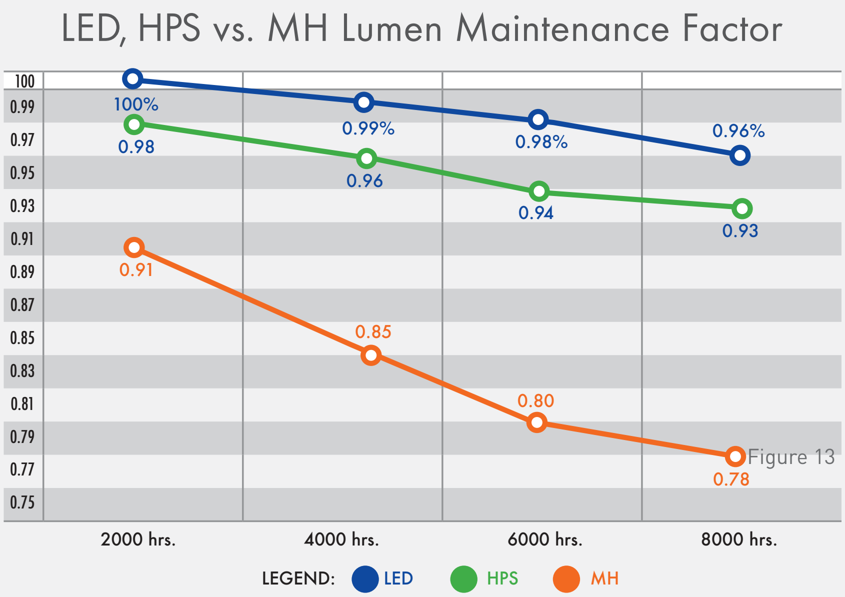
LED fixtures require no warmup time, and they provide superior functionality when they're used as a sole source of lighting, so they're an attractive option for many growers.

FACTORS TO CONSIDER (CONTINUED)

LIFE

One commonly overlooked factor in selecting a grow light is the rate of degradation. Once a light source degrades by more than 10 percent — that is, when it degrades to less than 90 percent of its initial output — it should be replaced. Therefore, you should evaluate your lighting options based on an L90 metric (rather than the L70 standard that commonly gets used in commercial applications). In Figure 13 we see that the CMH, MH, and HPS light sources all degrade relatively quickly, so replacing these options can get expensive quickly.

Independent testing labs will take a chip manufacturer's specifications and extrapolate an estimated life (in hours), based on the L90 standard, for grow light applications. So as you can see from Figure 13 a CMH bulb has an average lifespan of 8,000 to 10,000 hours of 12-12 cycle, which means that each bulb will need changing every six to eight months. On the other hand, an LED will last 36,000 to 50,000 hours before it hits the L90 metric.



DURABILITY

Unlike both MH and HPS light sources, LED has no filament to burn out, which contributes to the longer life of this option. Filaments are also very vulnerable to even minimal power surges, especially as they age.

HAZARDOUS MATERIALS

Unlike MH, CMH and HPS lamps LED grow lights are also free of mercury, making disposal much easier than other bulbs. LEDs are free from any hazardous materials.

FACTORS TO CONSIDER (CONTINUED)

COST

On average, a CMH system will cost twice as much as a MH or HPS system. However, that cost is recoverable because the efficiency is greater, which will result in lower cooling costs. In addition, with lower costs for the lamps and with fewer labor costs for replacing lamps, it's easier to recover the initial added investment.

Although the initial investment for SpecGrade LEDs is higher than for CMH, MH, or HPS systems, these costs are offset over the life of the system, thanks to the longer rated life of the lamps, lower amounts of radiated heat, and greater modularity.

The chart below summarizes the differences between LED and HID technologies.

	LIGHT SOURCES				
	LED	MH (Metal Halide)	MH Ceramic (Metal Halide)	MH Double Ended (Metal Halide)	HPS (High Pressure Sodium)
Operating Temperatures	100°F (38°C)	860°F (430°C)	945°F (38°C)	1202°F (507°C)	1060°F (571°C)
Color Rendering Index (CRI)	92	65	90	92	25
Tunable Spectrum	Yes	No	No	No	No
Average L90 Life (hours)	36,000~50,000	4,000	8.000	9,000	7,000
Utility Rebates	Yes	None	None	None	None
Operating Efficacy (µmol/J)	2.5	1.9	1.9	1.9	1.7
Warmup Time	None	15-20 mins.	15-20 mins.	15-20 mins.	15-20 mins.
UV Spectrum	No	Yes	Yes	Yes	Yes
Hazardous Materials	No	Yes	Yes	Yes	Yes
Est. Ballast/Driver Life	7-years	12,000 hrs.	12,000 hrs.	12,000 hrs.	12,000 hrs.
Good Vegging Spectra	Yes	No	No	No	No

Figure 14

GROWING

SPECTRUM AND INTENSITY

With increased LED efficiencies, high-light intensities are available that mimic the sun, which can be a critical variable for flowering crops such as cannabis or tomatoes. The crop and the region of the seed must be considered in determining the required light intensity. And then there is also the law of diminishing returns: at a certain point, the additional light intensity isn't justifiable when you account for the additional electricity costs and the additional radiant heat that will ultimately impact the HVAC system. So, yes, the yield for certain plants will increase as the light intensity increases. But this can occur with added costs that are out of proportion with the investment.

For example, if you wanted to increase intensity (wattage) to max out the flowering of a cannabis plant at 100 percent, you would need to achieve a PPFD measurement of 1200–1500. This means nearly doubling the light intensity, for a small 15 percent gain from a PPFD of 800. So, just because a manufacturer markets a grow light as having the highest PPFD, that doesn't necessarily mean it's the best.

To complicate things even further, an LED's printed circuit board, when it's placed onto an aluminum substrate, can throw heat either toward the plant or away from it. So the challenge for the cultivator is to determine which manufacturer of grow lights will provide the optimal light spectrum and light intensity to maximize profits.

PPFD GUIDELINES

Each stage of a plant's development requires various levels of light — that is, photons arriving at the plant's surface (PPFD). Every strain of every plant is a little different; however, here are some general guidelines:

FLOWERING PLANTS					LEAFY GREENS (VF)	
Suggested PPFD Levels (μmol/m2/2)					Suggested PPFD Levels (μmol/m2/2)	
Species	Cloning	Propagation	Vegging	Flowering	12-hr. cycle	380
Cannabis	~75~150	~100~300	~300~600	~600~950	16-hr. cycle	260
Tomatoes	~75~150	~150~350	~300~600	~600~950	LEAFY GREENS (GH)	
Peppers		~150~350	~300~600	~600~950	Continuous	~17~25

VF = Vertical Farming GH = Greenhouse Figure 15

GROWING (CONTINUED)

VEGGING

The vegging stage normally requires a PPFD of 300–600 for multilayered plants on a two-week cycle. For larger plants, the PPFD can go up to 600 if they are vegging for more than four weeks.

CLONING

Cloning is very often done at a PPFD of 75–150, though this depends a lot on the time spent and the layer size. Most lighting companies and cultivators use way too much light for cloning; this is likely to stress out the clones. A PPFD level of around 400 for cloning can also be stressful for plants if they aren't really healthy.

It's nice to be able to start clones at a PPFD of around 60–75, and then go up to 100–150 when they start to root, then starting veg around 250 and going up to 400 after a few days. Even with flowering, a starting PPFD level around 300–500 is acceptable, then working up to 800–900 over the course of a couple weeks.

With the right design and dimmers, you can increase the intensity to prep the plants for the next transition. You can also push each stage of growth when the plants can take it, and back off the intensity if the plants react poorly.

FLOWERING

Optimal PPFD levels for flowering plants are generally between 900 and 1000.

THERMAL MANAGEMENT

Like any fixture, as LEDs produce light, they also produce heat. The higher the wattage, the greater the heat, and the more cooling is necessary. For every watt, 3.41 Btu of heat are generated, which will need to be cooled. This is a major variable when it comes to specifying the electrical load in a facility, and it obviously effects your ongoing electrical costs as well.

But heat is also critical in another couple ways that you might not think about: First, the thermal management system in the fixture pulls the heat away from the LEDs and dissipates it, so that the heat-sensitive diodes do not fail prematurely. And second, the substrate, the aluminum board the LED is attached to, can also be engineered to direct heat away from the plants.

A passive technology called a heat sink is typically used to absorb unwanted heat, but there's a tremendous difference in the size and quality of the heat sinks used in grow lighting. If the heat sink is poorly constructed, a motorized fan is often added to the fixture to help cool it down.

Unfortunately, motorized fans are poorly suited to survive the conditions of a grow operation. The accessible vents and whirring blades are vulnerable to the bugs, dirt, water, debris, and chemicals commonly found in the space. Fixtures with motorized fans translate to more potential points of failure. If the motor or fan is damaged or unable to effectively cool the fixture, the LEDs are likely to overheat and fail, exposing an operation to down time that may compromise the crop. You can avoid these potential pitfalls by selecting a grow fixture that uses a fully passive thermal management system.

APPLICATIONS

LEDS FOR HORTICULTURAL GREEHOUSES

Selecting an artificial light source for your greenhouse to supplement the sun can be a confusing decision — one that can have long-reaching economic implications for the commercial grower in terms of crop yields, up-front investment, and ongoing expenses. Although LED technology is relatively new, it has proved to be a viable option for a wide range of crops in greenhouse applications.

Figure 16

In greenhouse applications, commercial LED technology can also be integrated into a wireless mesh that efficiently routes data back to the cultivator, allowing for control over light intensity based on the age of the plant. Daylight-harvesting sensors, which are commonly used in greenhouses, can also be added; these instruments automatically reduce energy consumption by dimming in response to changing daylight due to cloudy days and seasonal variations.

When a grower compares the economics of LED options with other technologies such as HPS, MH, CMH, and fluorescents, then using the proper LED system for greenhouses becomes even more compelling.

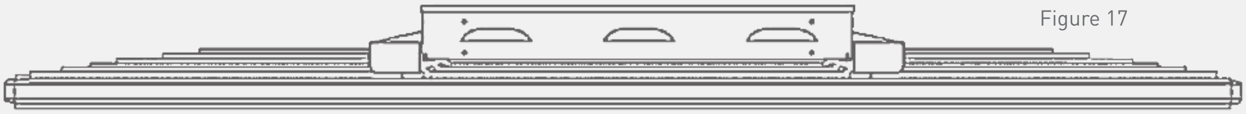
APPLICATIONS (CONTINUED)

LEDS FOR INDOOR APPLICATIONS

No matter what type of crop you are growing, no matter what time of year it is or how much or how little natural sunlight is available, LEDs are likely to be an excellent and cost-effective artificial light source.

LED grow lights can simulate long days or short days. By fine-tuning the light recipe, growers can trigger early flowering or promote delayed flowering without adding additional heat (which will add to HVAC operating costs and water evaporation). This offers more control over the greenhouse climate, which makes year-round production possible. And, depending on the stage in the plant's life cycle and the manufacturer's choice of electronic driver, the light intensity can be varied simply by using an inexpensive 0-to-10-volt dimmer.

Figure 17



Thanks to low-profile designs that combine maximum efficiency and performance, LEDs are an excellent lighting option for optimizing every cubic inch of potential growing space, while reducing water consumption and energy.

LEDS FOR VERTICAL FARMING

Figure 18

Vertical farming applications, which produce plants in vertically stacked layers, require a low-profile grow light that's designed for flexibility and offers high uniformity, so that each plant receives the same amount of photons. In addition, because LEDs generate very little heat it is an excellent light source for distances of as little as 6” from the plant.

SINGLE-LEVEL GROWING

Basic single-level growing from the floor will also require grow lights that are, depending on the crop, powerful enough to deliver high levels of PPFD and precision optics to minimize light spillage into the aisles and onto the walls.

APPLICATIONS (CONTINUED)

SINGLE-LEVEL GROWING

Basic single-level growing from the floor will also require grow lights that are, depending on the crop, powerful enough to deliver high levels of PPFD and precision optics to minimize light spillage into the aisles and onto the walls.

In the SpecGrade's LED Flora series, our engineers have combined a low-profile design (with a height of less than 6 inches) together with flexibility, maximum photon delivery, and uniformity. The more powerful LED Verta series also gives the cultivator exceedingly high levels of focused PPFD that will penetrate the plant's canopy with minimal light spillage.

Figure 19

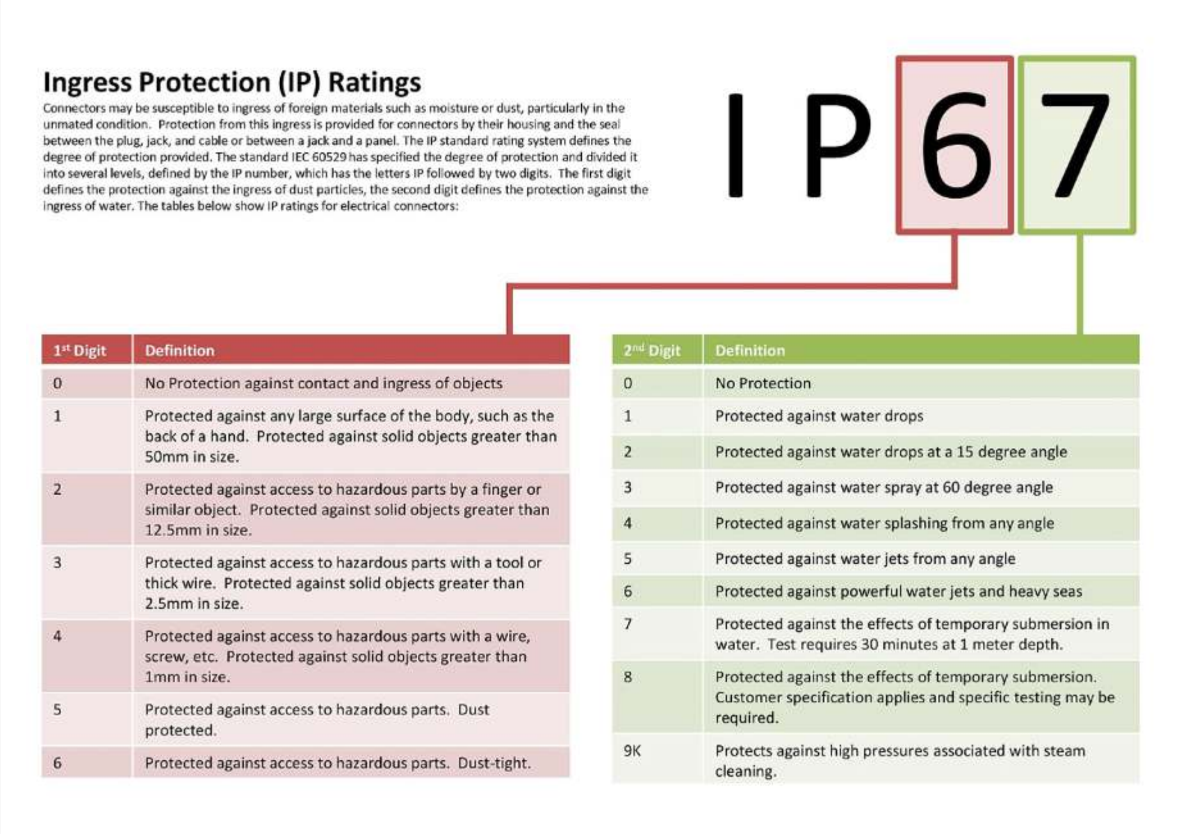
CERTIFICATIONS, RATINGS, REBATES, AND WARRANTIES

IP RATING

If grow lighting is going to last for many years of seamless operation in a horticultural environment, the luminaire must be tough and wellconstructed. The fixture's ingress protection rating, or IP rating, can assist you in finding the correct grow light for your environment.

The IP rating is a two-digit international standard that indicates the level of protection offered by the fixture's construction against intrusions like water, dirt, and dust, and against accidental contact with chemicals. It does not address UV protection standards (outdoor).

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (such as electrical conductors and moving parts) and against the ingress of solid foreign objects. The second digit indicates the level of protection of the equipment inside the enclosure against the harmful ingress of water.



Ingress Protection (IP) Ratings

Connectors may be susceptible to ingress of foreign materials such as moisture or dust, particularly in the unmated condition. Protection from this ingress is provided for connectors by their housing and the seal between the plug, jack, and cable or between a jack and a panel. The IP standard rating system defines the degree of protection provided. The standard IEC 60529 has specified the degree of protection and divided it into several levels, defined by the IP number, which has the letters IP followed by two digits. The first digit defines the protection against the ingress of dust particles, the second digit defines the protection against the ingress of water. The tables below show IP ratings for electrical connectors:

IP67

1st Digit	Definition
0	No Protection against contact and ingress of objects
1	Protected against any large surface of the body, such as the back of a hand. Protected against solid objects greater than 50mm in size.
2	Protected against access to hazardous parts by a finger or similar object. Protected against solid objects greater than 12.5mm in size.
3	Protected against access to hazardous parts with a tool or thick wire. Protected against solid objects greater than 2.5mm in size.
4	Protected against access to hazardous parts with a wire, screw, etc. Protected against solid objects greater than 1mm in size.
5	Protected against access to hazardous parts. Dust protected.
6	Protected against access to hazardous parts. Dust-tight.

2nd Digit	Definition
0	No Protection
1	Protected against water drops
2	Protected against water drops at a 15 degree angle
3	Protected against water spray at 60 degree angle
4	Protected against water splashing from any angle
5	Protected against water jets from any angle
6	Protected against powerful water jets and heavy seas
7	Protected against the effects of temporary submersion in water. Test requires 30 minutes at 1 meter depth.
8	Protected against the effects of temporary submersion. Customer specification applies and specific testing may be required.
9K	Protects against high pressures associated with steam cleaning.

Figure 20

CERTIFICATIONS, RATINGS, REBATES, AND WARRANTIES (CONTINUED)

UL 8800 (SAFETY STANDARDS)

Because horticultural lighting equipment is commonly exposed to water, dust, dirt, humidity, and high ambient temperatures, UL (Underwriters Laboratories) published safety standards for these products in 2017. This set of safety requirements, designated UL 8800, should be used to evaluate lighting equipment, including not only luminaires, but also non-permanent cords and plugs for horticultural applications. Cultivators should look for the UL safety mark before purchasing this type of equipment. You can find a list of products that qualify at www.ul8800.com

DLC (DESIGN LIGHTS CONSORTIUM)

The DLC is an independent third-party certification body that most utilities will look to before considering any rebates to owners of horticultural facilities. Before the DLC puts a manufacturer on its Qualified Products List (QPL), the manufacturer is required to meet a number of performance criteria. A QPL for horticultural lighting can be found at https://www.designlights.org/horticultural-lighting/search/

UL AND ETL (ELECTRICAL SAFETY)

To ensure electrical safety, make sure that the grow light has the mark of an independent thirdparty testing facility like UL or ETL (see Figure 14). The grower needs to request test documents from any manufacturer he or she is considering, and then should match them against the marketing materials and the mark for accuracy. But this is only a partial solution.

Figure 21

CONSTRUCTION

While the certifications above will give you confidence as to safety and performance, nothing will substitute for a thorough examination of a fixture's construction. A grow facility can be a harsh environment, and this can impact the long-term viability of your investment. You should consider many factors as you make your decision, including the effects of the intense heat from the bulbs; interactions with chemicals, water, and high temperatures; and durability as the lights are handled repeatedly over time. And beware: there are a few manufacturers that use plastic components, minimal heat sinking, and underrated drivers, and still qualify for the above-mentioned certifications. Robust construction is essential for ensuring that your investment stands the test of time.

CERTIFICATIONS, RATINGS, REBATES, AND WARRANTIES (CONTINUED)

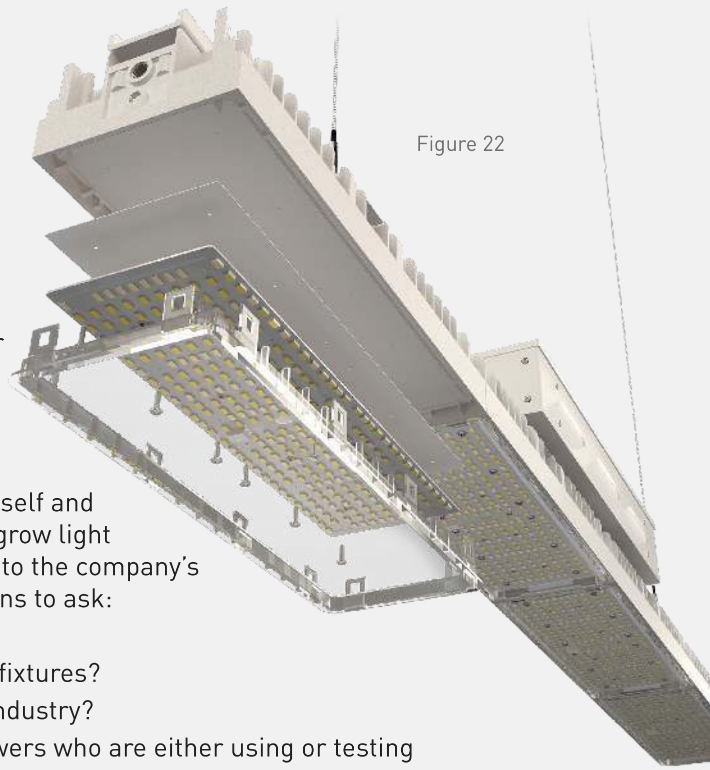


Figure 22

MODULARITY

Modular components will not only allow you the flexibility to update your investment with changes in technology but it will also permit you to replace a single component should it fail without having to replace the entire grow light. Figure 22.

UTILITY REBATE PROGRAMS

You can review the list of policies and incentive criteria for your particular utility company at www.dsireusa.org.

WARRANTIES

Warranties can be a good indicator of both the company itself and the products it is manufacturing. However, with so many grow light companies entering the market, it's smart to dig a little into the company's history and find out what others are saying. Some questions to ask:

- How long have they been in business?
- What experience do they have in manufacturing LED fixtures?
- How does that experience relate to the horticulture industry?
- Can they give you access to or testimonials from growers who are either using or testing their products?
- What is social media saying about the company?
- Are they willing to provide you with test results from independent third parties?
- How quickly do they respond to your inquiries?

SUMMARY

The choice between lighting technologies comes down to the application. Given that these systems are for horticultural applications, instead of more traditional commercial applications, the LED is undoubtedly the optimal choice for growers. Why?

- **LEDs can be tuned for light recipes that create any spectrum.**
- **LEDs can increase light intensity with minimal heat, making year-round production possible**

These two considerations will result in better growth, higher yields, and lower operating costs. However, the advantages of LED technology go even further:

- LEDs have lower heat levels.
- Because of their low profile, LEDs can be used in vertical farming applications to maximize production space.
- LEDs have longer life.
- Modularity makes it easy to change out the circuit boards as technology improves.
- LEDs are the most energy-efficient and robust light sources on the market for horticultural applications.
- LEDs can be controlled via dimming and light harvesting.
- LEDs have no warmup time.
- Because LEDs can be used as a sole light source, they provide superior functionality, making them an attractive option for many greenhouse growers who wish to get an extra cycle of growth at night.

However, it should be noted that not all LED grow systems are the same.

- **Thermal Management:** Some systems employ built-in fans to help with cooling (active thermal management). Should these fans fail, the entire LED system will likely fail as well. Cultivators should look specifically for systems with a thermal management system that is 100 percent passive.
- **Heat:** Although a watt is a watt and a BTU is a BTU, not all LED grow lights are designed to throw the heat away from the plant.
- **Warranty:** Most LED systems come with a warranty of three to five years. SpecGrade comes with a 10-year warranty on the LEDs and a seven-year warranty on the drivers. SpecGrade has been in business since 2010 and has been building LED fixtures since 2003.
- **Modularity:** No other LED system allows for the PCB (printed circuit board) to be switched out in the field if the technology becomes more efficient or the grower wishes to change the spectrum.
- **Utility Rebates:** Available utility rebates are another important consideration. Currently, our Verta-8 and Verta-4 have the Design Lights Consortium (DLC) certification, which typically qualifies them for any available rebates from your local utility.

THE SOLUTION:
INDEPENDENT THIRD-PARTY TESTS (AND BEYOND)

PERFORMANCE TEST RESULTS

When a manufacturer or reseller provides you with grow light performance specifications be cautious. It's important to know that these results can easily be distorted. Obviously, getting test results from an independent third party is the best, and any reputable manufacturer should make this information available to you. If a manufacturer is unwilling to give you independent third-party test results to compare with their published ones, that should send up a red flag.

Independent third-party performance test results of one light are an excellent place to start, but it still doesn't necessarily give you an accurate picture of what you can expect in your actual grow environment.

For example, an independent PPFD test does not factor in the cumulative effect of an area full of grow lights. More specifically, when you have a room full of grow lights, the PAR from one light will inevitably spill over into adjacent areas, increasing your averages. This spillover effect contributes to a more accurate idea of what you can expect in your grow areas. In addition, reflective surfaces also factor into the equation. A room with painted white surfaces will increase the light levels more than a room with gray concrete floors, unpainted block walls, and a ceiling full of aluminum ductwork.

Ultimately, **nothing takes the place of your own test grow**, as long as the variables are the same in each testing areas as long as the variables are the same in each testing areas — that is, the plant strains, the water, the nutrients, and the air circulation must all be the same. As a matter of fact, if you're unsure of which strain to test, then test your light and the spectrum with the strain you're likely to grow with before purchasing them.

If you don't have the luxury of time, or the facility to perform a test grow, then request supporting documentation from the grow light manufacturer. This can be in the form of a simulated computerized test grow. This should be relatively simple or a reputable manufacturer to generate. However, the results can vary greatly depending on the inputed simulation criteria. Here's an example of a grow room using SpecGrade's Verta-8.

"Independent third-party performance test results of one light are an excellent place to start, but it still doesn't necessarily give you an accurate picture of what you can expect in your actual grow environment."

THE SOLUTION:
INDEPENDENT THIRD-PARTY TESTS (AND BEYOND) (CONTINUED)

INTERPRETING PPFD CALCULATIONS CORRECTLY

Although all three PPFD calculations were made by an independent third party testing facility using the same SpecGrade, 652-Watt Verta-8 top light noticed that the actual calculations very significantly.

While Figured 23 and Figured 24 both measure a **4' x 4' area** notice **the average PPFD** level drops by 58% when the light is raised over the canopy from 6" over the canopy to 36" over the canopy.

Note also the **minimum PPFD** drops 283% from a high of 1169 PPFD in Figure 24 it reached that level only in one place because the light was within only 6" of the canopy.

However, when a **whole rooms PPFD** is calculated 36" over the canopy the average using the same Verta-8 goes from 291 and Figure 24 up to 1003 PPFD in Figure 25 or 364%. This is average is directly attributable to the multiple spillage effect of 200 grow lights on simultaneously together with the room's surface's reflectivity properties.

And finally, the important avg./min. metric indicates the PAR uniformity ratio. A ratio of approximately 2.0 or less denotes excellent uniformity, which will result in an even distribution of PAR, which in turn will translated into uniform plant yields

Exhibit A: Test Height 6"

83.7	217.8	262.1	276.8	280.3	269.2	264.6	212.7	97.5	2ft
243.4	654.7	769.8	788.1	790.7	792.8	784.5	693.5	282.3	1.5
314.9	888.7	1055.1	1089.6	1101.5	1087.1	1074.3	944.8	389.2	1
332.1	924.1	1112.4	1145.5	1158.8	1144.5	1126.2	993.9	377.0	0.5
343.7	937.6	1118.4	1161.1	1169.0	1153.9	1133.6	991.9	346.2	0
345.9	949.4	1116.0	1145.0	1150.7	1140.9	1111.3	953.2	367.2	0.5
323.5	910.3	1051.1	1077.1	1084.2	1069.1	1041.3	898.5	338.9	1
241.8	634.0	745.4	759.8	761.7	752.9	734.3	634.0	249.2	1.5
85.7	184.7	219.7	229.5	230.9	233.7	223.2	180.8	83.4	2ft
2ft	1.5	1	0.5	0	0.5	1	1.5	2ft	

Exhibit B: Test Height 36"

166.6	206.2	233.5	251.2	257.9	255.2	236.0	206.1	171.8	2ft
206.2	248.5	283.5	304.9	313.1	304.6	282.2	247.9	207.5	1.5
238.9	288.7	329.8	355.7	366.3	359.2	332.3	289.8	241.1	1
260.6	315.8	362.4	392.6	401.4	389.8	357.7	310.6	260.9	0.5
267.9	323.4	370.3	402.0	413.0	402.8	372.0	321.7	267.3	0
260.3	316.8	362.6	392.7	402.7	390.7	360.1	313.1	260.3	0.5
241.2	289.4	329.2	357.0	366.3	356.9	330.2	287.2	239.5	1
209.5	250.7	286.1	309.0	315.0	306.1	283.0	249.5	209.7	1.5
173.5	206.1	232.7	250.9	256.7	252.4	234.2	205.0	174.3	2ft
2ft	1.5	1	0.5	0	0.5	1	1.5	2ft	

Figure 23	
Maximum PPFD	1169
Minimum PPFD	83.4
Average PPFD	686.9
Power	652.3
Max/Min	14.4

Figure 24	
Maximum PPFD	413
Minimum PPFD	166.6
Average PPFD	291.8
Power	652.9
Max/Min	2.5

THE SOLUTION:
INDEPENDENT THIRD-PARTY TESTS (AND BEYOND) (CONTINUED)

INTERPRETING PPFD CALCULATIONS CORRECTLY

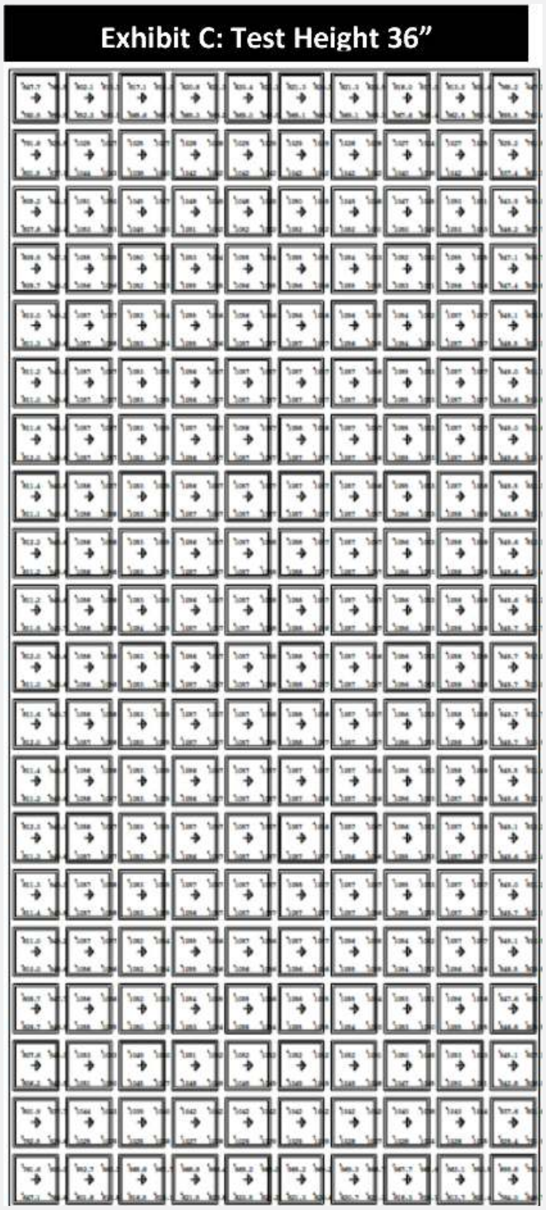


Figure 25	
Maximum PPFD	1058
Minimum PPFD	646.7
Average PPFD	1003
Power	652.9
Max/Min	1.6

CONCLUSION

The conclusion is that before the buyer, or specifier, invests in grow lighting he should run a computerized simulation of the entire grow area indicating the actual hanging height of the light over the canopy, placement of the isles. and reflective surfaces. This exercise, however, needs to be followed up by an accurate interpretation of the results. **In addition to** average PPFD levels the investor should focus on the max/min calculation. This metric is the uniformity ratio which will indicate the uniformity of PAR over the grow area. A target max/min level of a**pproximately** 2.0 or less is optimum which does not happen in our example until the whole room is calculated using 200 grow lights rather than only one grow light covering 16 sq. ft.