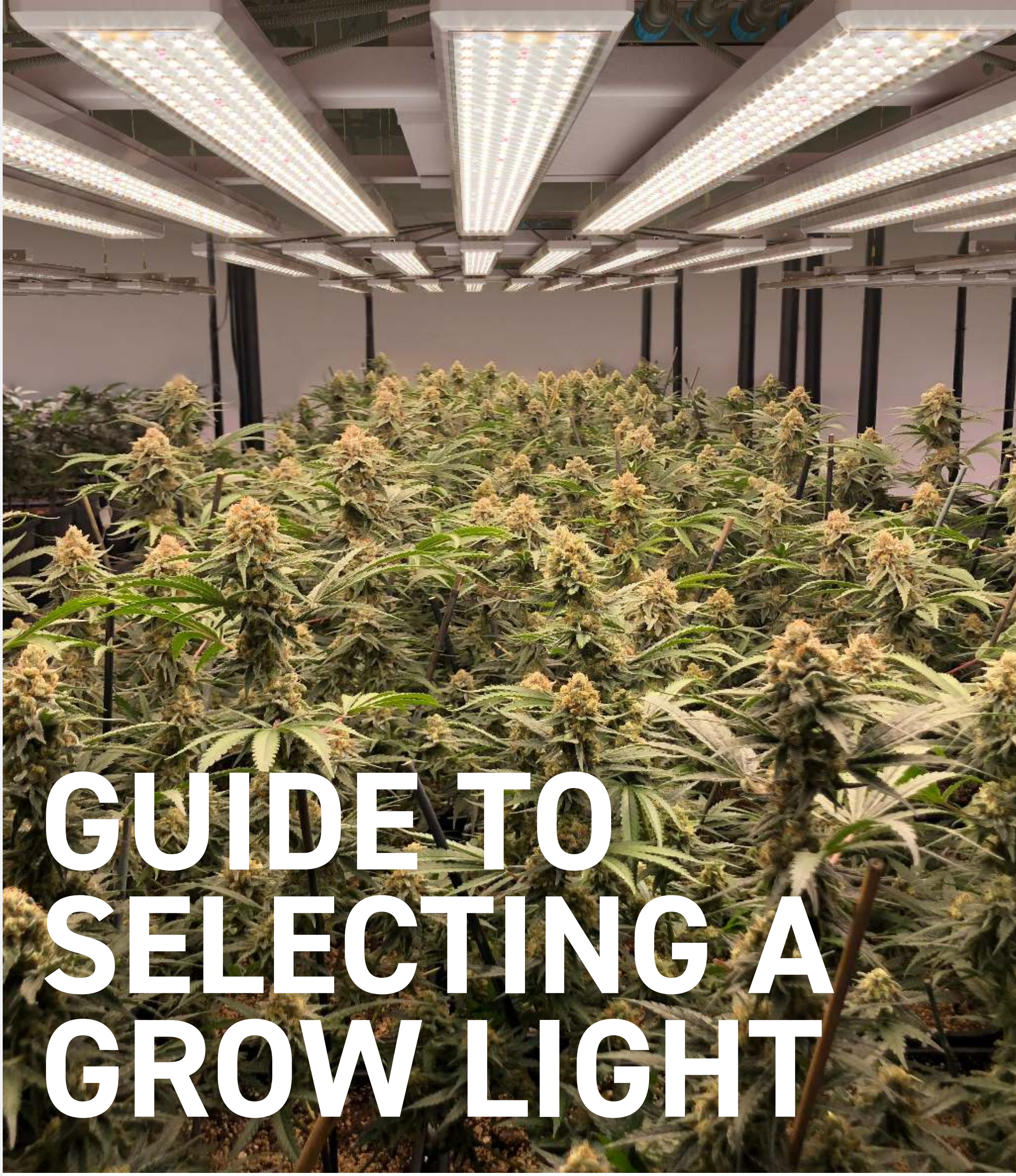
A Reference for the Professional Grower



GUIDE TO SELECTING A GROW LIGHT

An in depth guide on how to select the perfect grow lighting solution for your business.

By Rick Nathans,
Managing Partner

SpecGradeLED
Committed to Increasing Yields

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Guide to Selecting a Grow Light

Introduction

Evaluating grow lights is not a simple process. Even if you are a combination botanist and lighting engineer selecting a quality grow light and optimum spectrum can be a complex process to say the least. Unfortunately, there are unscrupulous manufacturers that make misleading or false claims to the unsuspecting buyer. As a matter of fact most of them are not even manufacturers, but simply resellers. However, doing your due diligence before investing in a grow system as well as vetting the manufacturer itself will pay dividends for years to come.

The Purpose of this Document.

The purpose of this text is to give you an awareness of the issues of choosing a grow light by guiding you through the process selecting a system.

A successful horticulture environment is essentially an eco-system or "a large community of living organisms (plants, animals and microbes) in a particular area. The living and physical components are linked together through nutrient cycles and energy flows." As part of the energy flow, artificial lighting plays a large part by either supplementing the sun in a greenhouse application or replacing the sun in a warehouse application.

Horticultural Lighting Concepts

We will take you step-by-step through this process beginning with industry terminology. If your head is spinning with acronyms and important metrics such as PAR (Photo Active Radiation), PPF (Photosynthetic Photon Flux) , PPFD (Photosynthetic Photon Flux Density), Watts, Voltages, Uniformity Ratios, Avg/Min, Max/Min, Photons, Photon Efficacies, LUX and Lumens you are not alone. Some of them are not even applicable to horticultural lighting but they are being used to add to the confusion.

These acronym's are the building blocks that you will primarily base your purchasing decision on. Once you have an understanding of these concepts your first step should be to eliminate those companies that do not provide for you those metrics these acronyms represent. However, even if they do provide for you this information is only the beginning of your journey by interpreting them.

<u>PAR vs. Lumens</u> (Lumens are for Humans)

Photosynthetically Active Radiation:
designates the spectral range (wave band) of solar radiation from 400 to 700 nanometers that photosynthetic organisms are able to use in the process of photosynthesis. LEDs attempt to tailor the spectrum to the plant that is being cultivated. The spectrum visible to the human eye is about 380 to 740.

Lumens, on the other hand, is a measurement of the total quantity of light that is visible to the human eye.

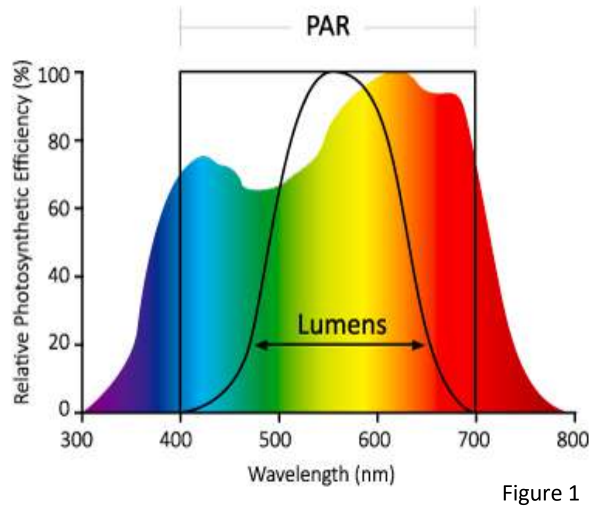


Figure 1

<u>PPF</u>

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

<u>PPFD</u>

Photosynthetic Photon Flux Density measures the amount of PAR that actually arrives at the plant or "the number of photosynthetically active photons that fall on a given surface each second". It is a measurement of micromoles per square meter per second (µmol/m2/s) onto the canopy (see Figure 2). Widely available handheld PAR meters are used to measure PPFD.

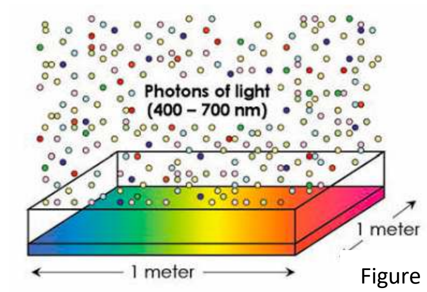


Figure 2

When evaluating the proper amount of PPFD the grower should take an average measurement of not only the area below the light, but then entire area because light from one fixture will spill over into the surrounding areas (See Figure 18, Page 17). Also, when evaluating this metric the distance over the canopy should factor into the equation. A manufacturer can skew the metrics in a number of different ways. For example, one way is simply by raising or lowering the light. The final calculations that you should base your decision on are produced using a quality software package and IES computerized files (illumination engineering society). These IES files are generated when a grow light is mounted in an integrating sphere. All testing should be performed by an independent third party testing laboratory and certified to ensure accuracy.

<u>Grow Light Efficiency</u>

The efficiency of a grow light can be simply calculated by taking the PPF and dividing it by the wattage. This becomes an important metric on larger grows where inefficacies can be very costly. Although PPF does not tell you how much of the measured light actually lands on the plants, it is an important metric if you want to calculate how efficient a lighting system is at creating PAR. This formula is PPF/watts which indicated by micromoles per Joule of energy or µmol/J. In the case of our Verta-8 the PPF of 1589 is divided by the 649-watts or a factor of 2.45 µmol/J.

Spectrums:

The exact light spectrum each plant requires continues to be an elusive construct. Meaning, there is little agreement on lighting strategies during various plant growth stages. What we do know is that the blue light lends itself to the vegging portion of the life cycle of a plant while the red portion of the spectrum lends itself to the flowering portion of the cycle (see chart 1.0).

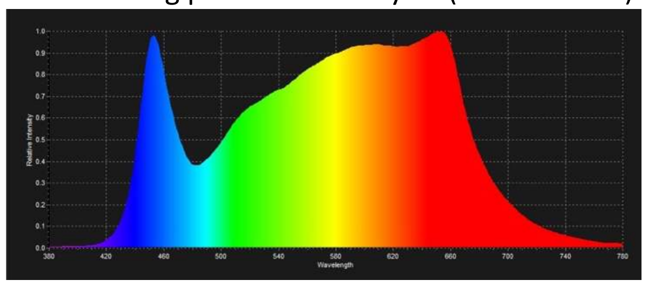


Figure 3

Although the ratio of spectra colors is argumentative, and it's questionable how much genetics factors into the equation, science is leaning towards 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 is much we do not know.

LED technology is gaining the respect of today's professional cultivators. It enables the grower to finely tune the spectrum to the plant while older, more inefficient technologies such as High Pressure Sodium, Metal Halide and Ceramic Metal Halide bulbs don't have that flexibility.

Ultraviolet Light (10nm~400nm): Although research indicates this spectra can be dangerous in larger doses, smaller amounts seem to contribute to the taste and smell. While this spectra does not affect plant growth studies indicate that the UVB spectra can increase the THC content in Cannabis. Because this research remains somewhat speculative and can be dangerous SpecGrade does not integrate this spectrum into our grow lights. Rather, we encourage our cultivators to cost-effectively add it by simply adding low cost PAR38 lamps throughout the grow facility and control them on a separate timer.

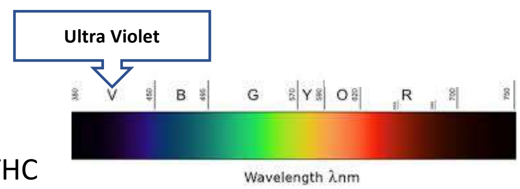


Figure 4

Blue Light (430nm~450nm): Blue light is typically encountered in nature at midday, when the angle of the sun is directly vertical or close to it. This spectra is critical to a plant during the vegetative stage of life where terpene development occurs. The commercial grow facility where every cubic foot must be productive 'stretching' must be minimized. 'Stretching' is a survival mechanism to ensure the plant gets enough light or nutrients.

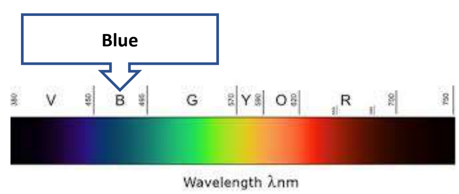


Figure 5

Also, SpecGrade's thermal management design will guarantee that the plant will not be exposed to excessive heat stress at this early stage of life. Millions of years of plant evolution using the sun's spectrum is ideal for vegetative growth is strain and species-dependent on the red-blue light combination. This spectra increases photosynthesis rate thereby increasing yields. Research also indicates increased amounts of blue light will induce flowering.

However, research also indicates that blue light suppresses stem elongation resulting in are usually shorter, more compact while having thicker, and denser leaves compared to plants grown without blue light. So we can maximize ROI by adding more blue to the spectrum is why we designed the A1 spectrum or the single spectrum for the entire life cycle of a plant.

We designed the A1 spectrum because it is widely recommended among botanist to use a balanced "full-spectrum" light source that includes high amounts of blue light, as well as other colors of light.

Green Light (500nm~550nm): Green light often does not get the attention it deserves when evaluating spectra. However, research indicates that green light drive photosynthesis by penetrating further into the leaf more efficiently than red or blue light. Green light gets absorbed by the lower chloroplasts that increase leaf photosynthesis to a greater extent than red or blue light. For this reason, many cultivators have reported growing a greater number of Cannabis secondary buds than they were able to experience with high pressure sodium light source.

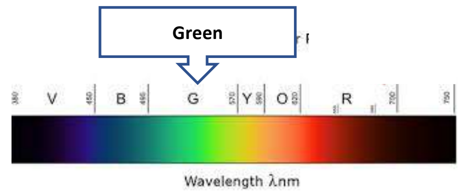


Figure 6

Red Light (640nm~680nm): Red light exists most when the sun is low in the sky, which is in the morning and evening. It delivers high growth to a plant, but without the limiting effect of blue that obscures the chloroplast to protect it from high-blue midday sun. Because of this red stimulates plant growth and is very efficient at producing fast growing tall and strong plants and consequently produces some of the most impressive growth rates of height and stem width in plants. However, if plants are grown under only red spectrum lights, they can become thin and leggy.

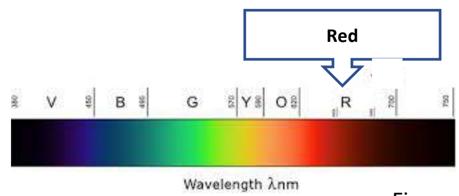


Figure 7

Far Red Light (730nm):
Because Far Red Light has a negative effect on seeds germination and research indicates that it has a significant effect on leaf size, stem length and the height of the plant it should <u>not</u> be used in the early stages of a plant's growth.

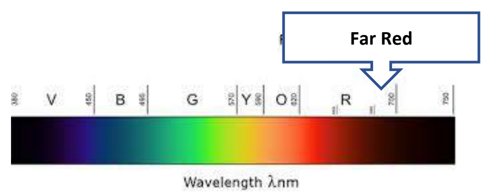


Figure 8

<u>Conclusion</u>

From propagation to flowering our proven spectras, a balanced spectrum with sustainable energy-efficient intensity, is designed to successfully augment the photosynthesis process for optimum plant growth through each stage of its life.

Technology:

Ceramic Metal Halide (CMH) vs. Metal Halide (MH)

vs. High Pressure Sodium (HPS) vs. LED

Types

There is a significant difference between Ceramic Metal Halide (CMH), Ceramic Metal Halide Double DE (CMH DE) & Metal Halide (MH). CMH bulbs are different than MH in that the CMH uses a ceramic tube and the MH uses a quartz tube. This allows a the lamp to burn at a higher temperature which means a better mix of gasses thereby making the CMH tube much closer to natural sunlight than either MH or High Pressure Sodium (HPS) which makes it a superior choice for growing plants but not great because of the heat it puts off. This is indicated by looking at the CRI (Color Rendering Index…see Figure 12). CMH has a CRI of about 92 (closer to full spectrum) verses MH has a CRI of around 60 and HPS has a CRI of only about 25.

Flowering Spectra vs. Veg Spectra

The MH lamps are excellent at flowering due to the fact they contain more cooler blue spectra however they lack the warmer reddish/orangish spectra. HPS lamps are excellent light source for vegging because they contain more of the reddish/orangish spectrum but they lack the cooler blue spectra. The other advantage of the CMH lamps is that they work great for the whole grow cycle because of the ability to mix gases. On the other hand by mixing red and blue spectra LED chips we are able to tweak the overall spectrum to the strain of the plant.

Figure 15

The SpecGrade LED has a CRI of 92 making it an excellent full spectrum light source to grow with.

Color Rendering Index

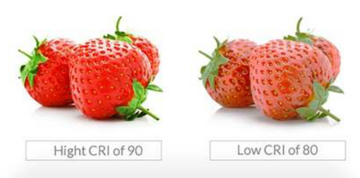


Figure 12

The **Color Rendering Index** (CRI) is a scale from 0 to 100 (100 is the sun) indicating how accurate a "given" light source is at **rendering color** when compared to a "reference" light source. The higher the CRI, the better the **color rendering** ability. Light sources with a CRI of 85 to 90 are considered good at **color rendering.**.

Efficiency
Perhaps one of the biggest advantages of LED lighting is the massive energy savings. When comparing them to high-intensity discharge on a 1:1 level they offer up to 40% savings when compared to high-intensity discharge (HID) lighting technology (ceramic metal halide, metal halide and high pressure sodium). LED lighting fixtures have a higher efficiency because more of the power input goes to light than heat as with HID. This efficacy metric can also be stated in terms of PPF (photosynthetic photon flux) to watts. For example, high pressure sodium is only about 1.7 vs. LED at approximately 2.5 (depending on manufacturer). This becomes an important metric when it comes to daily energy costs and HVAC requirement.

Also, there is no warm-up time required with an LED fixture and they are also free of mercury, making disposal much easier than other bulbs. In addition, LED's provide superior functionality when used as a sole source of lighting, making them an attractive option for many growers.

It is also important to note is that metal halides have to warm up for about 10-15 minutes or less 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 are not recommended for locations where the lights will turn on and off frequently. This can occur in a greenhouse application on extremely cloudy days.

LIFE
One common misconceptions in selecting an grow light is the degree of degradation of the light source. As you can see by the graph the ceramic metal halide, metal halide and high pressure sodium light sources all degrade relatively quickly thereby requiring a costly change-out when a lamp degrades. Any light source that degrades by more than 10% or to a life of less than 90% should be replaced. Therefore, you should evaluate the grow light based on an L90 metric (L70 commonly gets used in commercial applications).

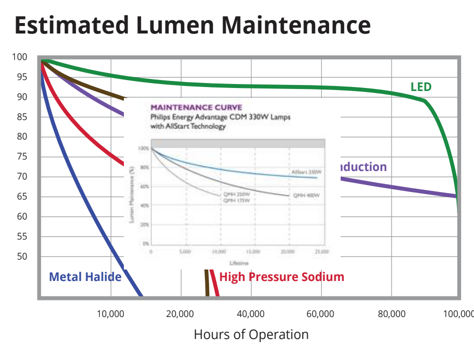


Figure 13

An independent test lab will take the chip manufacturer specifications and will extrapolate an estimated life (in hours) based on it degrading 90% or less (L90) once it is put into a grow light application. So, as you can see from Figure 13, that ceramic metal halide, with an average lifespan of between 8,000 to 10,000 hours of 12-12 cycle, a grower should change out the bulb will need changing every 6-8 months where the LED will last 36,000~50,000 hours before it hits the L90 metric.

UV Light
The CMH spectrum also contains UV-A, UV-B and UV-C. Because UV-C is harmful the glass envelope of a CMH will block that spectra leaving only UV-A and UV-B. MH has no UV spectra.

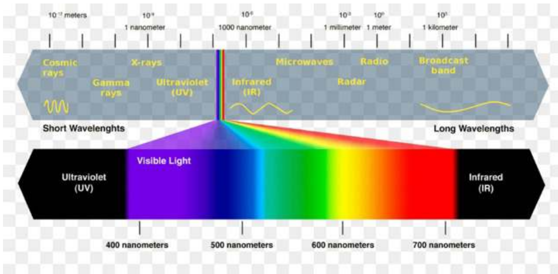


Figure 14

Because this research remains somewhat speculative and can be dangerous SpecGrade does not integrate this spectrum into our grow lights.

Lower Heat

The CMH lamps operate much cooler than both MH and HPS bulbs thereby, reducing the need for additional cooling equipment however CMH bulbs operate much hotter than LEDs.

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, the lamp cost plus the labor costs due to lamp change-outs will also help recover the initial added investment.
Although SpecGrade LED's initial investment costs are higher that CMH, MH and HPS system this cost is offset over the life of the system due to rated life, lower amounts of radiated heat and modularity (which is discussed on page 16.).

Robust

Unlike both metal halide and high pressure sodium light sources LED has no filament to burn out once again resulting in longer life. A filament is also much vulnerable to even the minimal power surges---especially as it ages. The LED does not have a glass envelope that holds in toxic gases or mercury requiring special handling.

Water evaporation

Water evaporation, which is a function of heat and humidity, should absolutely be factored into your evaluation of which grow light system to purchase. Depending on where you live this can be a costly expense. And even if it isn't today, it will be as planet resources become less abundant. On this note, as stewards of the land, it is our responsibility to use the our natural resources very efficiently.

Summary

	Technology				
	Metal Halide	**Ceramic Metal Halide**	**Doube Ended Ceramic Metal**	**High Pressure Sodium**	**LED**
Bulb Temperature	806° F (430°C)	945° F (507°C)	1202° F (650° C)	1060° F (571°C)	100°F (38°C) SpecGrade's Verta-8
Color Rendering Index (CRI)	65	90	92	25	92
Tunable Spectrum	No				Yes
L90 Life (hours)	4000	8000	9000	6000	36000~50000 Hours
Utility Rebates	None				Yes
Cost to Purchase	Moderate Cost: Depends on the Wattage				The Highest
Cost ot Operating: Efficacy (µmol/J)	1.9	1.9	1.9	1.7	2.5
Dimmable	Not Advised				Yes
Warm-Up Time	15-20 Minutes	15-20 Minutes	10-15 Minutes	15-20 Minutes	None
Vegging & Flowering Spectrum	Typically Requires Separate Veg & Flowering Areas				Can Veg & Flower
UV Spectrum	Yes	Yes	Yes	No	No

Growing

Spectrum vs. Intensity

With increased LED efficiencies necessary high light intensities to mimic the sun are available which is a critical variable on flowering crops such as cannabis or tomatoes. Once again, because each species of plant has over 5 billion years of DNA the crop and the region of the seed must be factored into the equation in term of how much light intensity is required. And too there is the 'Law of Diminishing Returns'. Meaning, the additional light intensity will be disproportionate to the electricity costs and to the amount of radiant heat that will ultimately impact the HVAC system. So, the answer is 'yes' that certain plant's yield will increase as the light intensity increases. But, at a disproportionate cost.

For example, by increasing the intensity (wattage) to max-out flowering of a cannabis plant at 100%, you would need to go all the way to ~1200~1500 PPFD thereby nearly doubling the light intensity for a small 15% gain from 800 PPFD. So, just because a manufacture may market his grow light to have the highest levels of PPFD doesn't necessary mean it is the best.

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

PPFD Guidelines

Each stage of a plant's development of life requires various levels of light or photon (PPFD). Every strain of every plant is a little different, however here are some general guidelines:

SUGGESTED PPFD LEVELS (µmol/m2/2)				
FLOWERING PLANTS				
Species	**Cloning**	**Propagation**	**Vegging**	**Flowering**
CANNABIS	~75~150	~100~300	~300~600	~600~950
TOMATOES	~75~150	~150~350	~350~600	~600~950
PEPPERS		~150~350	~300~600	~600~950

SUGGESTED PPFD LEVELS (µmol/m2/2)	
Leafy Greens(Vertical Farming)	
12-hour cycle	380
16-hour cycle	260
Leafy Greens (Greenhouse)	
Continuous	~17~25

Figure 9

Vegging

Veg is normally ~300~600 PPFD for multilayered clients standard size plants 2 week veg.
Veg on larger plants can go up to ~600 PPFD if they are vegging for more than 4 weeks.

Cloning

Cloning is very often ~75~150 PPFD very dependent on time spent and the layer size. Most lighting companies and cultivators use way too much for cloning, and its likely to stress out the clones. ~400 PPFD for veg can also be stressful for plants if they aren't really healthy.

It's nice to be able to start clones at ~60~75 PPFD, then go up to 100~150 PPFD when they start to root, then start veg at ~250 PPFD and go up to ~400 PPFD after a few days. Even with flower, start around ~300~500 PPFD is acceptable and work up to ~800~900 PPFD 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 if the plants have any negative reactions to anything.

Flowering:

Optimal PPFD levels of flowering plants is generally between ~900 and ~1000 PPFD.

LED for Horticultural Greenhouse Applications

Because inside every plant is millions of years of preprogramed DNA selecting an greenhouse's artificial light source to supplement the sun can be a confusing decision that will have long reaching economic implications to the commercial grower in terms of crop yields, up-front investment and on-going expenses. Although LED technology is a relatively new technology it has proven itself in a wide range of crops to be a viable light source for greenhouse horticultural applications on many different levels but the major ones being efficiency and flexibility.

Figure 11

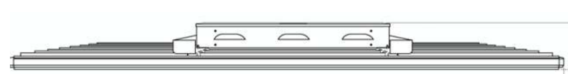
Indoor Applications

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 LED is likely to be a perfect cost-effective artificial light source.

LEDs grow lights can simulate long days or short days. Fine tuning the light recipe will supply spectrums that can trigger early flowering or promoting delayed flowering without adding additional heat (which will add to HVAC operating costs and water evaporation) giving you more control over the greenhouse climate in turn making year-round production possible. And finally, depending on where in the life-cycle a plant finds itself and the manufacturer's choice of electronic driver the light intensity can be simply varied by utilizing a low cost 0-10V dimmer.

Indoor Growing (Less is More)

LEDs, having a low profile designs combined with maximum efficiency and performance, prove to be



an excellent grow light to optimize every cubic inch of potential growing space while reducing water consumption and energy.

Vertical Farming

Vertical Farming applications, or producing plants in vertically stacked layers, requires a low-profile grow light that is designed for flexibility while delivering high levels of uniformity so that each plant gets the same amount of photons.

Single Level Growing

Basic single-level growing from the floor will also require a grow light powerful enough to deliver high levels of PPFD and precision optics to minimize light spillage onto isles and walls.

At a height of less than 6” SpecGrade engineers have combined a low profile design together with flexibility, maximum photon delivery and uniformity in our Flora series. The more powerful Verta series will also provide the cultivator with exceedingly high levels of focused PPFD that will penetrate the plant’s canopy with minimal photon spillage into the isles and onto the walls.

Wireless Controllability

Commercial LED technology in a greenhouse application can be integrated into a wireless mesh that will efficiently route data back to the cultivator enabling him to control light intensity based on the age of the plant. Daylight harvesting sensors, an application commonly found in greenhouses, can be added that will automatically reduce energy consumption by dimming in response to seasonable changing daylight availability as well as cloudy days.

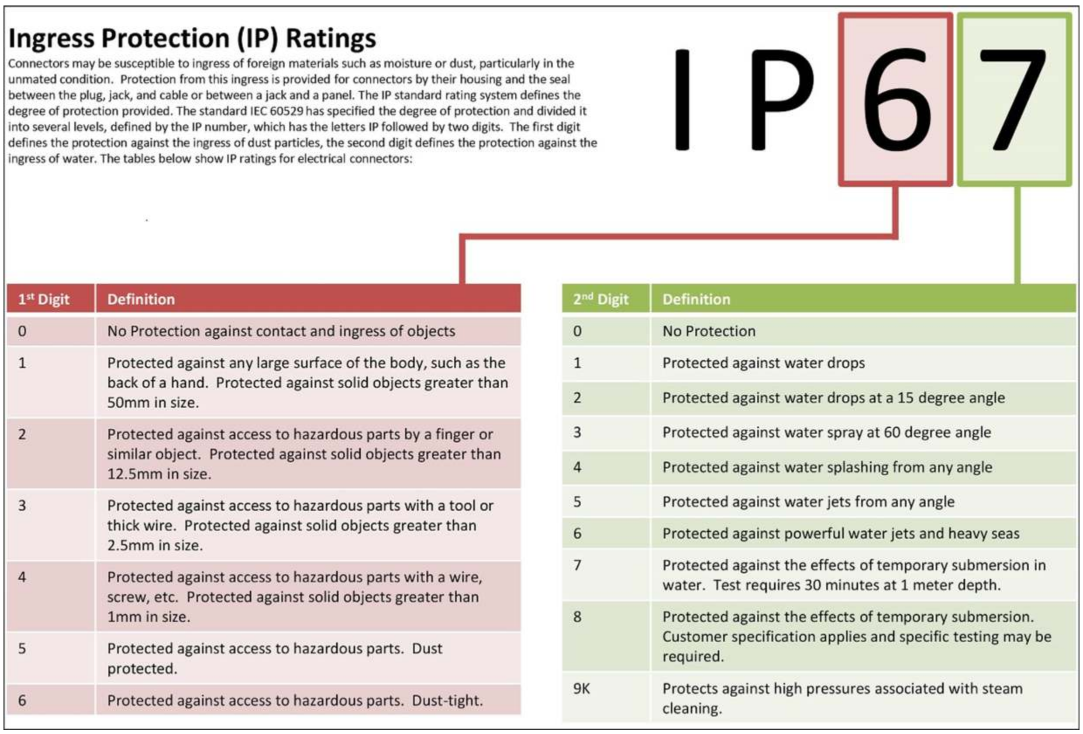
When a horticultural cultivator evaluates the economics of LED to other technologies such as high pressure sodium, metal halide, ceramic metal halide and fluorescents in a greenhouse application then using the proper LED system becomes even more compelling.

Certifications, Ratings, Rebates & Warranties

IP Rating (Ingress Protection Rating)

To help ensure many years of seamless operation of grow lighting in a horticultural environment robust construction of the luminaire is required. An IP rating is available to assist you in the process of evaluating the correct grow light for a grow environment.

An IP rating is a 2 digit international standard used to rate the level of protection against intrusion such as water, dirt, dust, accidental contact with chemicals by using mechanical casings and electrical enclosures. It does not address UV protection standards (outdoor)



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:

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 10

The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects.

And the second digit indicates the level of protection of the equipment inside the enclosure against harmful ingress of water.

MISC:

UL 8800 (Safety Requirements)

Because horticultural lighting equipment is commonly exposed to water, dust, dirt, humidity and high levels of ambient temperatures on May 4, 2017 Underwriters Laboratory (UL) published UL8800, a set of safety requirements to be used when evaluating lighting equipment including not only the luminaire but also non-permanent cords and plugs for horticultural applications. The specifier should look for this 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)

DLC is an independent third party certification body that most utilities will commonly look to before considering any rebates to owners of horticultural facilities. Before putting a manufacturer on their Qualified Products List (QPL) list they are required to meet a number of performance criteria. This horticulture QPL for can be found at https://www.designlights.org/horticultural-lighting/search/

UL & ETL (Electrical Safety)

To ensure electrical safety simply make sure that there the grow light has the 'Mark' of an independent third-party testing facility like UL (Underwriters Laboratory) and ETL. The grower needs to request those test documents from any manufacturer he or she is considering and then match them against the marketing materials and the 'mark' for accuracy. But, is only a partial solution.

Utility Rebates Programs

To review the list of policies and incentive criteria of your utility click on this link: http://www.dsireusa.org/

Warranties

And finally, although warranties are a very good indicator of the indicator of the company itself as well as the products they are manufacturing you should ask yourself the question: 'How long have they been in business?' With so many grow light companies entering the market it would behoove you to dig a little and find out the history of a company as well as what others are saying:

1. How long have they been in business?
2. What experience do they have in manufacturing LED fixtures?
3. How does that experience relate to the horticulture industry.
4. Have them give you a resume of growers or testimonials that are either using or testing your products.
5. What is social media saying about the Company?
6. Are they willing to provide you independent third party test results?

7. How quickly do they respond to your inquiries?

Construction

While the UL8800 certification will ensure safety, and the DLC certification will give you a performance confidence level nothing will substitute for a traditional approach to construction. A grow facility, being is a harsh environment, can impact the long term viability of your investment. The intense heat from the grow light together with chemicals, water, higher temperatures and of course being handled by people should be factored into the decision making. Beware, that a few manufacturers are using plastic components, minimal heat sinking and underrated drivers and still qualify for the above mentioned certifications. Robust construction is essential for your investment to stand the test of time.

Thermal Management

As LED fixtures produce light, they also produce heat. This is a critical issue on 3 different levels.

First, the higher the wattage the greater the heat. And for every watt 3.41 BTUs are required to cool. This is a major variable when it comes to specifying the electrical load on in an facility and it obviously effects the ongoing electrical costs as well.

Secondly, 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 finally, the substrate, the aluminum board the LED is attached to, can also and 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 is a tremendous difference in the size and quality of heat sinks used in grow lighting. If the heat sink is poorly constructed, a motorized fan is often added to the fixture to assist in cooling 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. Avoid these potential pitfalls by selecting a grow fixture that uses a 100% passive thermal management system.

Hazardous Materials

And finally, LED grow lights are also free of mercury, making disposal much easier than other bulbs. LED's provide superior functionality when used as a sole source of lighting, making them an attractive option for many greenhouse growers that wish to get an extra cycle of growth at night.

In summary, the advantages of LED are:

- LEDs have lower heat levels.
- Because of their low profile LEDs can be utilized in vertical farming applications to maximize production space.
- LEDs can be tuned light recipes that create any spectrum
- Enables light intensity increase with minimal heat making year-round production possible.
- LEDs have longer life.
- Modularity enables easy change out of the circuit boards as technology changes.
- LEDs are the most energy efficient and robustness light sources on the market for horticultural applications.
- LEDs have controllability by dimming and light harvesting.
- LEDs have no warm-up time.
- Because LED can be used as a sole light source it provides superior functionality.

Summary:

The choice between these technologies comes down to the application. Given that these systems are for horticultural applications, vs. more traditional commercial applications, the LED's efficient light intensity together with the ability to be optimally tuned for each strain of plant undoubtedly makes it the optimum growers choice over the sun-like spectrum of the CMH system. These two variables will result in better growth, higher yields and lower operating costs.

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

1. **Thermal Management:** Some systems have fans built into them (active thermal management). Should they fail the entire LED system will likely fail as well. The cultivator should look specifically for systems with a 100% passive thermal management system.

2. **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.

3. **Warranty:** Look at the warranty. Most LED systems come with a 3-5 year warranty. SpecGrade comes with a 10-year warranty on the LEDs and 7-years on the drivers. SpecGrade has been in business since 2010 and building LED fixtures since 2003.

4. **Modularity:** No other LED system allows for the PCB (printed circuit board) to be changed out in the field should the technology become more efficient or the grow should wish to change the spectrum.

5. **Utility Rebates:** Look for available utility rebates. As of today our Verta-8 and Verta-4 have the Design Lights Consortium (DLC) certification which will typically qualify them for any available rebates from your local utility.

The Solution: Independent Third Party Test Results---Plus

Performance Test Results

Assuming a manufacturer or reseller provides for you their own internal performance test results they can be easily distorted by:

1. The sample area they are testing
2. An uncalibrated meter
3. Old battery.

Test results from an independent third is obviously the best and should be made available to you.

If a manufacturer is unwilling to provide for you independent third party test results to compare against their published ones that should send up a red flag.

Independent third party performance test results are an excellent place to start but they are good to only when comparing compare apples-to apples. However, they still do not give you an accurate picture of what you can expect in your actual grow environment.

For example, an independent third party PPD test result 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 the adjacent area thereby increasing the averages. Actually, this spill-over effect is a more accurate measurement of what you can expect in your grow area(s). In addition, reflective surfaces will also factor into the equation. Meaning, a room painted with white surfaces will increase the light levels more than a room with concrete gray floors and unpainted block walls with a ceiling full of aluminum ductwork

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

If you don't have the luxury of time or the facility preforming a test grow then request supporting documentation from the grow light manufacturer. This can be in the form of a simp … or a white p …

Exhibit A: Test Height 6"

4' × 4'

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

Maximum PPFD	1169
Minimum PPFD	83.4
Average PPFD	686.9
Power	652.3

Figure 16

Exhibit B: Test Height 36"

4' × 4'

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

Maximum PPFD	413
Minimum PPFD	166.6
Average PPFD	291.8
Power	652.9

Figure 17

Interpreting PPFD Calculations Correctly

Although all 3 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 vary significantly.

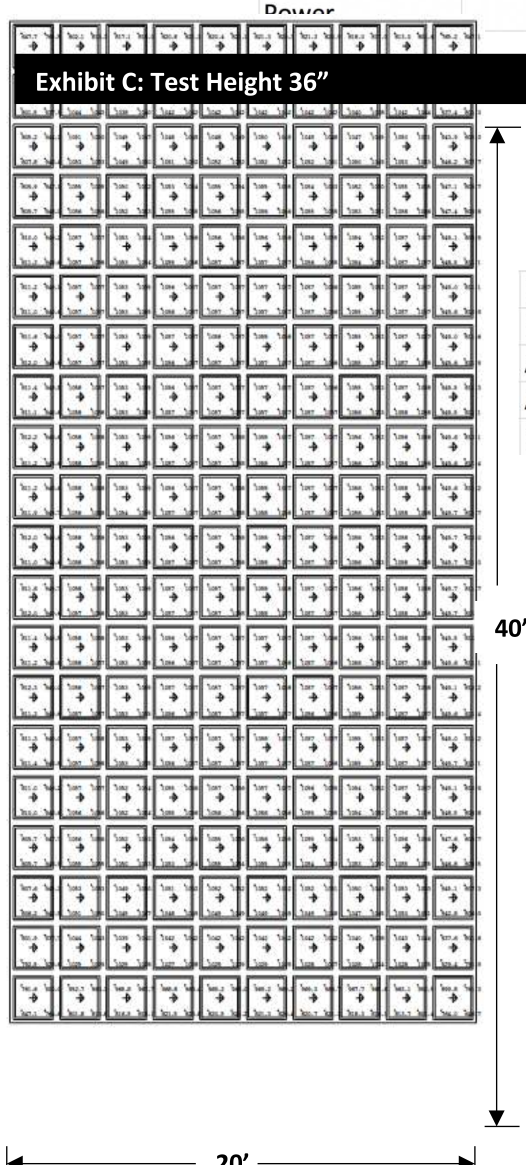
While Exhibit 'A' and Exhibit 'B' both measure a 4'x4' area notice the **average PPFD** level drops by 58% when the light is raised over the canopy from 6" over the canopy to 36".

Note also the **maximum PPFD** drops 283% from a high of 1169 in Exhibit 'A' to 413 in Exhibit 'B'. It reached that level only in one place because the light was within only 6" of the canopy.

However, when a **whole room's PPFD** is calculated at 36" over the canopy the average using the same Verta-8 goes from 291 in Exhibit 'B' up to 1058 in Exhibit 'C' 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 > 2.0 denotes excellent uniformity which will result in an even distribution of PAR which in turn will translated into uniform plant yields.

Exhibit C: Test Height 36"



Maximum PPFD	1058
Minimum PPFD	646.7
Average PPFD	1003
Avg/Min	1.55
Power	652.9

Figure 18

Test Grows
Once you have the field narrowed

Conclusion

Every plant on Earth possesses approximately billions of years of DNA. It would be arrogant of us to think that we have all the horticultural answers after only our handful of years of experience let alone the ability to best artificially simulate the sun. Needless to say that in recent years, and on many different levels, science has made great strides. However, we need to understand that science alone cannot grow plants efficiently. Rather, this is a process that involves all of us working together. SpecGrade is committed to partnering in a collaborative manner with our clients to turn that metaphorical 'screw' a little every day with the clear objective of increasing yields. To do this we need to share our grow knowledge of botany in a precise and meaningful manner. Come collaborate with us.