PAR FORCE Hybrid LED Pro Panels For Cannabis Production

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With the legalization of medical and recreational Cannabis in some states, growers are beginning or expanding operations. Smart Grow Technologies and its phosphor based, tailored spectrum light emitting diode (LED) panels is providing more intense, better quality light that has produced increased yields and higher THC levels.

Introduction

The legal marijuana market in the U.S. is expected to grow 64% in 2014 to $2.34 billion. In five years, it is estimated the market will grow more than 700% to reach $10.2 billion (ArcView, 2014). In recent years, the pace of research being conducted to determine the full extent of the medical benefits from cannabis derived compounds like THC and CBD has accelerated. Organizations like the American Academy of Neurology and the Center For Medicinal Cannabis Research have determined, after comprehensive reviews, that medicinal marijuana has therapeutic benefits in several disorders or diseases including multiple sclerosis spasticity, central pain, neuropathic pain, Parkinson's disease, glaucoma and even shows promising results in early stage research for anti-tumor treatment in certain cancers.

With such opportunity, it is no wonder cannabis growers are seeking state-of-the-art lighting technology to maximize crop yields and quality. This paper discusses the advantages of phosphor blend LEDs in cannabis production and the superiority of PARFORCE Hybrid LED panels. It builds upon a previous paper, *Light Emitting Diodes For Indoor Growing Operations: A Comparison of Traditional Lighting and LEDs,* which presents more detail regarding the benefits of new phosphor blend LEDs compared to traditional HID lighting.

LEDs for Cannabis Production--Why Aren't They An Obvious Choice?

Since the early 1990s, LED technology has improved dramatically via focused research and manufacturing improvements. Modern LEDs provide several advantages over traditional high-intensity discharge (HID) horticultural lighting, including the ability to control spectral composition, the ability to produce very high light levels with low radiant heat output and no long-wave radiation. They also maintain useful light output for years without replacement (Morrow, 2008). LEDs provide spectral composition control permitting lighting recipes whereby wavelengths can be matched to plant photoreceptors for optimal production, plant morphology, pathology and composition. Thus, narrow-band LEDs avoid the inefficient energy burden of broad wavelength light, as a result energy is further saved. LEDs are solid-state devices, as such they can be integrated into digital lighting programs like intra-day, sunrise and sunset simulations as well as inter-day plant life-cycle programs (Yeh & Chung, 2009). They are safer to operate because they do not have glass envelopes or high surface temperatures and they do not contain mercury. (Morrow, 2008)

Despite these recent advantages, earlier LED lighting systems introduced to cannabis growers were based upon older red, green, blue LED (RGB) technology with claims that weren't met. For starters, there was more limited light spectrum which could not be as optimized for plant needs. In addition, these LEDs did not provide sufficient gains in intensity. These two limitations did not overcome the higher costs to acquire early LED systems. Further, existing studies on non-cannabis plants were designed to find ideal LED light spectrums of red, blue, far red and green mixtures, and not comparisons versus HID systems for crop growth rates, yields and quality measures. As a result, growers could not determine if converting to LED lighting was worthwhile.

What has Changed—The Superiority of PARFORCE LED Panels For Cannabis Production

Focused, Tailored Spectrum

An ideal lighting system must convert as much electricity as possible into PAR energy. The spectral output of an LED system can be matched to [Cannabis species' and varieties'] photoreceptors and optimized to provide maximum production within ideal spectrum without wasting energy on nonproductive wavelengths (Dougher and Bugbee, 2001; Sager et al., 1982). The light can be customized for specific plant types or production protocols and even modified over the course of a day or growth cycle (Morrow, 2008).

In addition to the ability to provide narrow-spectrum or colored wavebands specific for desired plant responses, LEDs also cast off heat separately from light-emitting surfaces through active heat sinking (Bourget, 2008). This is significant for high intensity LEDs because it allows growers to place the LED lighting fixtures close to canopies without the risk of overheating and stressing plants (Bourget, 2008). That proximity boosts the intensity and amount of light that reaches plant photoreceptors.

Cannabis plants grown for five days under PAR FORCE Hybrid LEDs in Veg Mode. Check of grow tent temperature (<80 ° Fahrenheit) during trial.

Reduced Operating Costs

Regardless of this encouraging data, the question remains if growers will recoup the upfront cost of new LED lighting systems. Devesh Singh and others at the Hannover Centre for Optical Technologies at the University of Hannover in Germany compared the life-cycle costs of traditional high pressure sodium lamps against those of LEDs and they report that the advantages are clear (Singh et al., 2014). They calculate that the cumulative cost of high pressure sodium lamps surpasses that of LEDs.

Similarly, in the sample return on investment (ROI) analysis presented below, simple payback of the initial investment to purchase and install LED lights to replace traditional lighting can be less than two years.

Comparison of LED and HPS Lighting Systems

For this comparison, intensity and efficiency is expressed in micromole photons per second (µmol/s). Research at universities and applied research stations demonstrated that the rate of photosynthesis is related to the amount of photons emitted between 400 – 700 nm, called 'Photosynthetic Photon Flux' (PPF) which is a way of measuring if a light source is suitable for photosynthesis. This is expressed in micromole photons per second (µmol/s). The higher the PPF value per Watt, the more efficient the light source for plant growth. In the table below, PAR FORCE LED lights are the most efficient, providing the highest PPF per watt.

Lighting System	Power † Total Input Wattage	Lifetime*	Intensity (PPF) *†	Efficiency
LED PAR FORCE Hybrid LED Pro Panel	260w	50,000 hrs	620 µmol/sec	2.38 PPF/w
LED Philips GreenPower LED Toplighting Module DR/B HB 400V	200w	25,000 hrs	440 µmol/sec	2.2 PPF/w
HPS Philips Master GreenPower CG 1000W	1035w	10,000 hrs	1850 µmol/sec	1.79 PPF/w

* Lifetime values are given at an ambient temperature of 25 °C rated life to 90% of initial photon flux = 25 khrs.

† Photon flux and Power consumption values are typical at stable operation at an ambient temperature of 25 ºC.

PAR FORCE LED lighting systems are able to provide higher intensity light at comparable power consumption levels because they are constructed with smaller, more efficient .05 milliamp LEDs that provide the intensity of larger two to three milliamp LEDs commonly used in competing products, and do so at lower, more light-quality stable operating temperatures. In addition, PAR FORCE LEDs use a superior combination of a single blue LED and proprietary phosphor coatings to maximize PAR spectrum. These key differences are why PAR FORCE LEDs are rated to provide the highest intensity by the United States Department of Energy. This higher intensity provides higher PPF which translates to increased efficiency at providing photosynthetically active radiation (PAR). In so doing, PAR FORCE LED fixtures are providing larger yields and growth rates for the same energy consumption.

A New Milestone in LED Technology – Milliamp Sized, Phosphor Blend LEDs

The engineering team that developed the novel technology driving the intensity advantage of PAR FORCE LED panels is Greg Lai, PhD and Jessi Niou of Frequency LED. Together they have 50 years of working experience in the semiconductor industry. Dr. Lai has a PhD in material science from Michigan State University and developed the phosphors used in PAR FORCE LEDs. In addition he is the co-founder of a Taiwan based, indoor vegetable growing operation—VegFab—that has provided Asian markets fresh vegetables since 2010. Mr. Niou, holds a BSEE and MSEE and having co-founded Frequency LED with Dr. Lai, has worked with him since 2010 to develop phosphorous formulations that improve growth rates and yields for vegetables, berries and cannabis.

The Phosphor Blend Difference

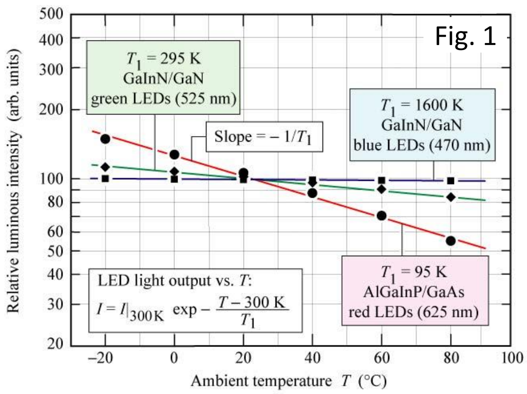


Fig. 5.7. Characteristic temperature T_1 of GaInN/GaN blue, GaInN/GaN green, and AlGaInP/GaAs red LEDs near room temperature (after data from Toyoda Gosei Corp., 2000). More recent data (Toyoda Gosei Corp., 2004) shows the following values for T_1: Blue GaInN LED, 460 nm, T_1 = 1600 K; Cyan GaInN LED, 505 nm, T_1 = 832 K; Green GaInN LED, 525 nm, T_1 = 341 K; Red AlGaInP LED, 625 nm, T_1 = 199 K.

E. F. Schubert
Light-Emitting Diodes (Cambridge Univ. Press)
www.LightEmittingDiodes.org

While it is beyond the scope of this paper to explain all of the technical differences between LED technologies, there are differences that are important to growers and that likely explain the poor performance of earlier LEDs for horticulture applications. Most horticultural LED lighting systems use the common method of mixing red, green and blue (RGB) LEDs to create light. Hence the method is called multi-color white LEDs (often referred to as RGB LEDs). This technology is common to many uses because of the flexibility of mixing different colors and in principle, this mechanism also has high quantum efficiency in producing white light. However, important to horticulture applications that do not need white light, this type of LED's emission power decays exponentially with rising temperature (Schubert, E. and Kim, J.) resulting in a substantial change in color stability. Such problems inhibit its ability to maintain PAR light and likely resulted in disappointing results for growers who trialed this technology. Figure 1, presented by E. Fred Schubert, Department of Electrical, Computer, and Systems Engineering Department of Physics, Applied Physics, and Astronomy Rensselaer Polytechnic Institute supports this assessment of RGB LEDs. It shows the significant fall off of relative luminous intensity at increasing ambient temperatures for typical red LEDs found in RGB LED panels.

The blue diodes used in PAR FORCE LEDs are more stable despite temperature variations compared to RGB LEDs and as such are designed for superior light intensity and color stability. PAR FORCE LEDs use phosphor blends to tailor light spectrum and because of this different approach to creating PAR spectrum, do not suffer a significant fall off in intensity at high operating temperatures. In addition, as mentioned above, they are much smaller than typical horticulture LEDs, which also enables lower operating temperatures providing improved light quality stability. As a result, phosphor blended

LEDs provide more PAR per watt than RGB LEDs and HPS lights. The lower operating temperature and inherent stability advantage enables PAR FORCE LEDs to provide more consistent and intense PAR light throughout an operating day and LED operating lifetime. Add to this that PAR FORCE LEDs have been designed with a larger, 120 degree beam angle and flush mount to permit closer proximity to the plant canopy and it is not surprising that more, and more intense PAR light from PAR FORCE LEDs is providing increased yields per watt and higher THC levels.

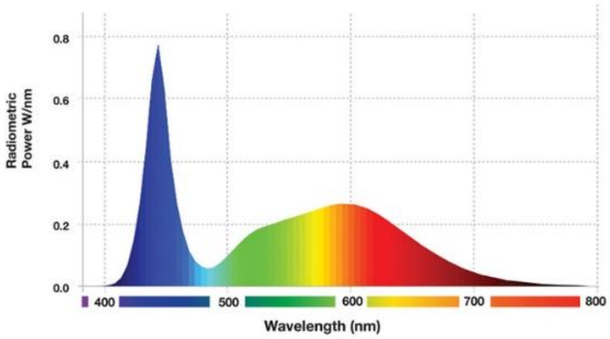
Cannabis plants grown for five days under PAR FORCE Hybrid LEDs in Veg Mode. Check of vegetation and root growth.

Other key attributes of PAR FORCE LED panels are controls for veg and bloom phases and sunrise and sunset controls. Before discussing these features further, a review of what triggers veg and bloom cycles in cannabis plants and the importance of sunrise and sunset like spectrum follows.

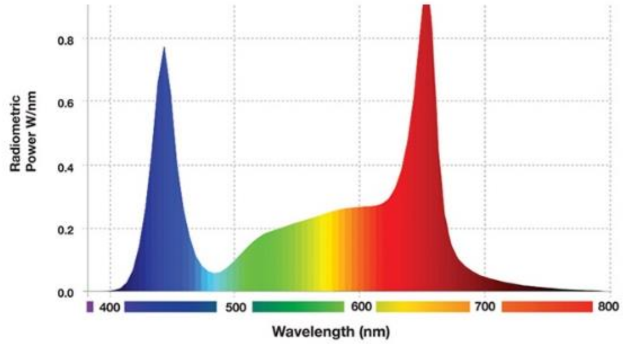
Plants, including cannabis species, monitor day length or photoperiod, that is the duration of light capable of sustaining photosynthesis through photoreceptors. In simple terms, these photoreceptors monitor the duration of red and far red light spectrum to determine when a bloom cycle begins (http://mjgrowers.com/book_what_exper1.htm; http://en.wikipedia.org/wiki/Phytochrome). While the plants need a mix of blue, red and far red light throughout their lifecycle, veg and bloom, it is the shortening of the duration of far red light that most significantly triggers the bloom phase. To trigger blooming in cannabis plants, growers typically reduce lighting to 12 hour on/off cycles. By doing so they are reducing the duration of far red light received to an amount that the plants interpret as the onset of Autumn and so the bloom phase is started.

To accentuate this reaction, PAR FORCE LED panels provide the grower the ability to manipulate light spectrum as presented in the graphs below. To help induce and optimize bloom phases, more red and far red spectrum is provided by the panels automatically but for a shorter duration. This ensures cannabis plants are induced into bloom phase when appropriate.

VEG PHASE



BLOOM PHASE



PAR FORCE LED panels are also equipped with a setting that provides plants a phase of light spectrum that mimics sunset and sunrise. By doing so, it triggers plants to move more optimally from lighted period photosynthesis or energy creation, to dark period respiration, energy use and growth and vice versa.

Initial trials with PAR FORCE Hybrid Pro Panels by Walkin' Happy, a licensed medical marijuana grower in Portland, Oregon produced a comparable yield and higher butane extraction THC levels for the Chemdawg strain (87.54% vs. 83.53%) than HPS lamps at half the electricity consumption. The growers believe the specifically tailored spectrum and precise lighting controls avoid UV and IR spectrum that may cause cannabis to produce natural sun screen in the form of a waxier coating. They have noticed, thinner walled trichomes for LED grown plants which they think have more capacity to produce and store THC and CBD. Trimmings from this grow were analyzed and had approximately 25% THC levels compared to 18% for plants grown under HID lights. Similarly, CBD levels via glycerin extraction were 13 – 19% for PAR FORCE LED grown plants compared to 9 – 12% for HPS grown plants. Walkin' Happy continues to grow with the LED light fixtures and expects even better results as they perfect environmental and other variables.

LED Return on Investment (ROI) Analysis

Despite the many advantages of LEDs compared to traditional lighting, commercial growers are prudently weighing the costs to gain such benefits. In the interest of addressing such concerns, an ROI analysis is presented below which presents the economic benefits of replacing HPS fixtures with PAR FORCE Hybrid Pro Panel LED fixtures. PAR FORCE fixtures are available in three different wattage and corresponding lit areas:

1. 525 watts ideal for 5 foot by 5 foot or 25 square feet of lit area
2. 375 watts ideal for 5 foot by 4 foot or 20 square feet of lit area
3. 260 watts ideal for 4 foot by 4 foot or 16 square feet of lit area

Assumptions

For this analysis it is assumed that PAR FORCE 525 watt Hybrid LED Pro Panels which provide the most yield potential via the largest lit area (25 square feet) and highest concentration of light within that area of the three PAR FORCE options will be installed. These 525 watt LED fixtures will be installed in an indoor growing environment instead of 1000 watt HPS fixtures.

Assumptions include:

Lighting Costs:

- 525watt PAR FORCE Hybrid LED Pro Panel cost is $2000.00 each, complete
- 1000watt HPS fixture cost is $650.00 each including bulb, ballast hood and reflector unit

Plant area:

- A 1000w HPS, and similarly a 525w LED fixture, provide light to 25 square feet of growing space each (5 x 5 feet).

HVAC:

- Electricity costs $0.10 USD per kWH
- Energy Efficiency Ratio (EER) is 14
- HVAC is operated 360 days per year, 13 hours per day
- One 1000w HPS fixture creates 3,412 BTU/kW of heat which requires .28 tons of cooling where one ton of cooling equals 12,000 BTU/hour
- As a result, it takes $114.06 USD per year in HVAC costs to mitigate the excess heat produced by a single 1000w HPS fixture

Growing Area:

- Dimensions are 150 feet long x 5 feet wide x 15 feet high
- 112 crop cycle days; 56 vegetative propagation days; 56 bloom days
- 360 operating days per year
- 13 hours of light per day
- $0.10 USD per kWH electricity cost

Given these assumptions which are based upon actual product specifications and other industry information, 30 525w PAR FORCE Hybrid Pro Panel LED fixtures will replace the existing 30 1000w HPS fixtures. The simple payback of the initial investment of $60,000 USD minus the avoided HPS costs of $19,500 will be 22 months with an internal rate of return (IRR) of 34% calculated based upon a five year cash flow. Labor to replace bulbs and any incentives are not included in this analysis and, if included, will improve the ROI and IRR calculations.

The investment details are as follows:

Initial Investment	1000w HPS Fixtures	525w PAR FORCE HYBRID LED Fixtures	Net Investment
Purchase of Fixtures	$19,500	$60,000	$40,500

Annual Operating Costs	HPS Configuration	PAR FORCE Hybrid Pro Panel LED Configuration	Avg Annual Savings
Electricity	$17,462	$6,950	$10,512
Bulb Replacement	$11,475	-	$11,475
	$28,937	$6,950	$21,987

As mentioned above, PAR FORCE panels are available with different wattage levels. To be most efficient and cost conscious rather than pursue the highest potential crop yield, a grower could install $1800.00, 375 watt PAR FORCE fixtures instead of the 525watt models. If the ROI were to be calculated using 375 watt PAR FORCE fixtures instead of the 525 watt fixtures the simple payback would be approximately 17 months with an IRR of 56% per year.

Amp Load Benefit

PAR FORCE LED panels use approximately one half the wattage of HID lights to illuminate an equivalent growing area. As such, they draw upon one half of the amps (amps = watts/volts). As presented in the table below, if you assume a grower has 220 volts of electricity available via a 20 amp* breaker to power the lights shown in the table, you can see a grower can have twice as many PAR FORCE LED fixtures than HID lights for the same total amp consumption. This means they can have twice the growing area to produce more cannabis.

Lighting Fixture	Wattage	Voltage Available	Amp Load	Available Amps*	Max Number of Lights
1000w HPS Light	1000	220	4.5	15	3
525w PAR FORCE Hybrid Pro Panel	525	220	2.4	15	6
600w HPS Light	600	220	2.7	15	6
260w PAR FORCE Hybrid Pro Panel	260	220	1.2	15	13

* It is generally recommended that lighting systems not use the full amperage available and so for this example it is assumed 75% of the 20 amps available (15 amps) is used.

As discussed, phosphor blend based PAR FORCE LEDs provide cannabis growers flexibility in terms of light recipes specific to cannabis veg and bloom needs. Their controls, light emittance characteristics and operating temperatures make them ideally suited to the marijuana grower industry. Growers can improve the quality of their cannabis grows and yields per watt of electricity. PAR FORCE LEDs provide energy efficiency and other cost saving benefits that translate into reductions in operating costs and substantial returns on investment.

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