AN EVOLUTIONARY APPROACH TO GROWING CANNABIS

Overview – Light plays a critical role in the development of hemp plants and the production of fatty acids associated with resins and THC potency. Empirically, the highest potencies are found among plants grown at higher altitudes close to the equator. This suggests a spectral profile mimicking conditions in these areas should provide the best results when growing under artificial lighting. With the legalization of marijuana in several U.S. states, and a likely nationwide proliferation of relaxed restrictions, substantial research has been directed toward increasing yields and potency as well as promoting varieties based upon genetics and growing conditions. The science demonstrates that light is perhaps the most important influence in determining a holistic product inclusive of potency, texture, aromas, color, consistency, and flavor. Along these lines, hundreds of proprietary strains and growing formulae have emerged, each claiming superiority over their competition. Hemp-Bright™ grow lights are specifically designed to provide the optimal light for maximizing objectives. In fact, Hemp-Bright™ is an *evolutionary* leap forward in grow-light technology based upon advanced magnetic induction lights (MIL) and unique LumenTec® spectral tuning that precisely regulates color output. Not only are Hemp-Bright™ fixtures specifically designed for growing the best marijuana, they are ultra-high efficiency, extraordinarily long-lasting, and environmentally friendly.

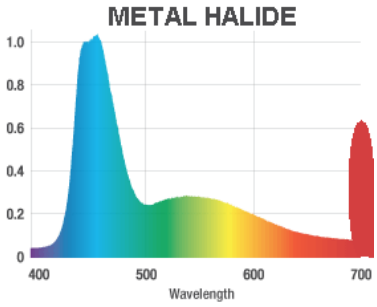
The Ideal Spectrum – Much has been written about ideal lighting conditions for maximizing marijuana yields and quality. Over the past two decades, there has been a growing debate about the advantages of controlled artificial environments compared with traditional outdoor crops. To be sure, there is no perfect substitute for natural sunlight. Moreover, widespread legalization is likely to demand far greater quantities than can be accommodated by indoor production alone. Like tobacco, eventual production will require acreage as opposed to greenhouse cultivation. Nevertheless, precisely controlled environments provide the ability to apply exact science to branded product lines. Outdoor growing forces uniformity. Natural sunlight cannot be altered. This means that the subtle spectral differences known to aid in growth, seed development, budding, and resin production cannot be optimized.

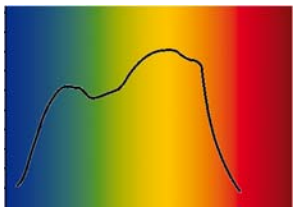
Unfortunately, conventional grow-lights are generic. This means they are designed to fit a wide range of applications with the same bulb. Until recently, grow lights have been based on three technologies:

1) High intensity discharge (HID) lighting that includes metal halide (MH), high pressure sodium (HPS), mercury vapor (MV), and halogen
2) Fluorescent
3) LED
4) Incandescent, including tungsten

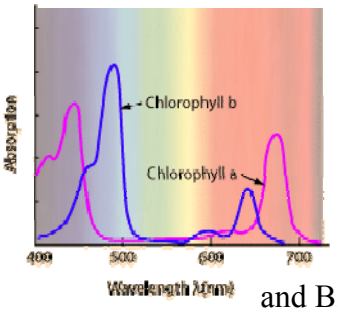
Mercury vapor and incandescent lighting has been phased out due to energy inefficiency and excessive high heat. Sodium lighting is inferior due to its monochromatic output. Halogen is not popular based upon high heat and poor dispersion qualities. This leaves metal halide as the predominant HID player.

Metal halide (MH) is favored for reasonable energy efficiency and higher blue spectral bias. However, MH is extremely hot and suffers from high infrared emission which has very little usefulness. As the graph illustrates, there is a spike in output from approximately 430nm to 470nm (blue) and another spike above 690nm (red). The radiation extends beyond the visible red into infrared which is not shown. There are varying opinions about the usefulness of this spectral profile. According to Phillips the "plant sensitivity" falls within the range between 400nm to 700nm with an emphasis in the blue and yellow range. The Phillips horticultural metal halide and fluorescent lighting follows their own research that asserts the "GrowthLight" peaks in the yellow portion of the spectrum. Thus, Phillips' "Master GreenPower" bulbs emphasize the center of the spectrum as outlined in their sales brochure entitled *Growing Your Profits.* Herein is the debate over which area of the spectrum represents the best for plants. No doubt, Phillips has dedicated considerable research and resources toward developing their





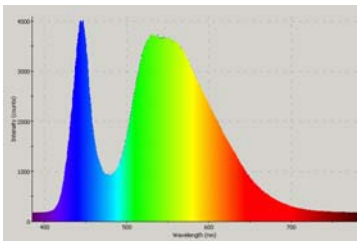
line of horticulture lighting. Yet, the material presented in their literature is contradicted by other technical sources.



Contrary to the Phillips information, botanists have discovered as many as 300 chlorophyll molecules responsible for photosynthesis; the process that converts light into energy through electron transference. In addition, there are 40 or more carotenes and "accessory pigments" responsible for producing long-chain molecules including fatty acids and esters. Research has determined that chlorophyll falls into two main categories; A and B. Both sets of molecules have maximum light absorption in the blue and red range, leaving a void in the middle green/yellow. This suggests that much of the output associated with common grow-lights may be wasted. The debate over plant spectrum goes back to the most obvious question, "Why are leaves predominantly green?" This is to say that leaves reflect green light that is a combination of blue and yellow. The fact that green is reflected rather than absorbed is evidence that plants reject that portion of the spectrum.

By the same measure, hemp leaves are markedly different from other plant species. Cultivators know that some of the most impressive buds display a rainbow of colors inclusive of dark brown hues capable of absorbing more of the middle spectrum. Nitrogen rich soil tends to darken leaves in general, but several highly potent plants have naturally dark leaves. When tested for absorption, a higher amount of yellow is taken in. This aids in producing carotenes and may function as a catalyst for long-chain fatty acids. Still, the research does not support the effectiveness of standard MH grow-lights for enhancing marijuana yields and quality.

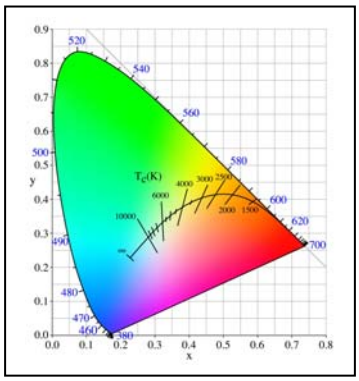
LEDs have gained popularity because of their high UV and blue/violet bias. They can also be lifted in the red range, but with less overall power measured as moles per second. LEDs have the advantage of longevity and cooler operation. This allows the lamps to be moved closer to plants during various critical growth stages. There are some human interface problems with LEDs because direct viewing of an unshielded LED element can actually damage the retina. Greenhouse workers may be subject to this health hazard since glancing at grow-lights is inevitable. Like MH, LEDs have concentrations in the green/yellow range. More problematic is the rapid decline approaching the red spectrum.



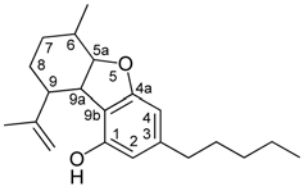
Hemp-Bright™ technology addresses spectral output by fine tuning light output to the known frequencies used by marijuana plants. The fixtures use a 3-part system that provides the maximum amounts of useful light at the highest intensities. Each bulb and ballast set uses LumenTec® spectral tuning and has the ability to *vary the spectrum*

through the growing cycle. This proprietary approach is unique and has the capacity to significantly increase yields and potency through precision growing cycles.

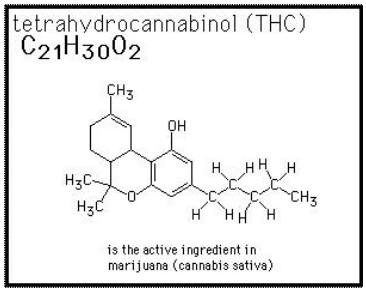
Conventional grow lights that include recently introduced MIL units range between 3,500K and 6,500K. At 3,500K, the color saturation is in the yellow to red range and does not provide the necessary blue and upper red range. The centerpiece of Hemp-Bright™ is a 10,000K color temperature that is balanced to provide the sun's full spectrum on a bright day. With a Color Rendition Index (CRI) exceeding 90, this is the most complete light available for horticulture in general, but includes special tuning that enhances resin production. It is important to note the spectral balance as indicated on the Kelvin color temperature graph (Planckian Locus). Hemp-Bright™ extends the output to include the most absorbed red and blue ranges.



On top of the high Kelvin temperature are two spectral overlays that concentrate the red range beginning at 650nm and extending to 720nm along with intensification from violet/blue at 420nm to 520nm. A third overlay works in the yellow range that is associated with carotenes. Keeping in mind that long-chain carbohydrates (sugars) are the primary resultant of photosynthesis, the objective in creating Hemp-Bright™ was to examine lighting influences on other processes that are linked to resin secretion and active chemistry. Most notably, cannabis possesses a gene for synthesizing hexanoyl CoA synthetase enzyme that acts to build delta-9-tetrahydrocannibinol (THC). Here, we are interested in certain catalytic processes and photonic influences that impact short chain fatty acids as THC building blocks. Just as a dental blue light is used to cure dental preparations through photonic conversion, so does the spectrum act to change molecules within the cannabis plant physiology.

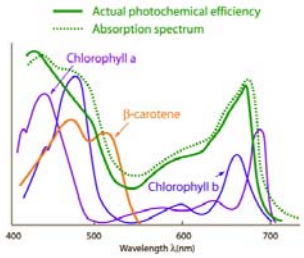


The pharmaceutical industry has dedicated thousands of man hours and millions of dollars researching the intricate chemical properties of cannabinoids. Vast chemical variations exist within the same plants and from plant to plant. This is what makes marijuana experiences so diverse. No doubt, it will take decades to associate even a portion of the chemical variations with definable experiences. Nonetheless, thousands of papers, articles, and informal exchanges have already categorized experiences associated with various breeds and brands.



The THC molecule emerges as an organic chain emphasizing carbon-hydrogen bonds. Unlike sugars where hydrogen-oxygen bonds predominate, we see that the synthesis process must focus on a more sophisticated structure. Hemp-Bright™ pushes the spectrum in ranges that have the greatest absorption for such molecular

production. Rather than apply an approximate spectrum achieved from a generalized generic grow light, the goal is to custom fit the light to the exact chemical process. For generalized horticulture, emphasis is placed upon basic photosynthesis. For THC, the focus is resin production. The chemistry that generates higher resin content is a combination of maximizing plant energy and stimulating molecular response to light. This involves raising energy levels in highly specific spectral ranges… in effect, fine-tuning light to generate precise responses.



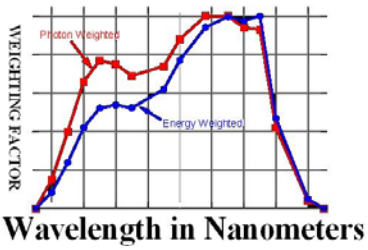
Hemp-Bright™ takes advantage of a particular protein used by plants to protect against sun damage. The UVR8 protein has been called horticulture's "sunscreen" because it responds to UV-B from 280nm to 320nm in the ultraviolet range. Without going into the technical details, UVR8 is responsible for the production of tryptophans that form tt-cation interactions responsible for UV-B protection. In marijuana plants, there is a pronounced reaction in very particular ranges of the ultraviolet range that cause a fierce protective response, generating precursors to THC and other related molecules. Other reactions to the Hemp-Bright™ spectrum serve to finish the molecular process, maximizing the desirable photochemical objectives.

Plants naturally try to protect against threats to the production of seeds. Trichomes help to prevent damage from insects, infections, predators, and UV light. In marijuana, trichome production is linked to cannabinoids and the most specific influence is UV light. The exclusive research used to developed Hemp-Bright™ technology has isolated reactions to UV-A, UV-B, and UV-C spectral ranges. Just as these ranges of light can be damaging to plants, it is dangerous to humans. UV is responsible for sunburn, skin damage including cancers, cataracts, and retinal damage. This makes the use of UV lighting difficult, requiring safety precautions.

Fortunately, the controlled indoor and greenhouse environments facilitate safety precautions when UV light is in play. Rooms and spaces can be isolated during exposure times. There are many growers who employ sun tanning UV lights in their environments. The problem is that the light is concentrated in the spectrum for human skin response; i.e. tanning. This is not necessarily the ideal spectrum for stimulating resin production in marijuana plants.

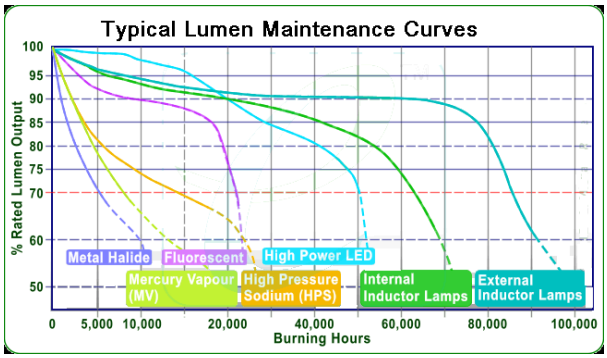
The Ideal Energy Levels – In addition to having the ideal spectrum, Hemp-Bright™ also delivers the maximum light energy for the amount of power. The efficiency of most artificial light sources is usually reported as "lumens per watt." This is a measurement of the total amount of visible light emitted by a source. Even by this standard, Hemp-Bright™ fixtures deliver extraordinarily high performance with more than 95 lumens per watt over more than 90% of the expected lifecycle. In the world of horticulture, the measurement is photosynthetic photon flux density; PPFD. This is the amount of light measured in photons that is generated within the photosynthetic spectral range.

As alluded to in the previous section on the ideal spectrum, Hemp-Bright™ is designed to provide the right amount of energy to generate the most ideal chemistry. PPFD is reported in moles of photonic energy per second (µmol m^{-2} s^{-1}). A metal halide light may report high lumens per watt, but can lack the right energy balance within each spectrum to be effective in growing marijuana. This metric does not necessarily need to be restricted to the photosynthetic range. The measure of energy can apply along the entire photonic range. Hemp-Bright™ delivers remarkable energy within identified wavelengths that fuel the chemical processes for resin generation.



Hemp-Bright™ technology is a lighting system as opposed to simply a fixture. It allows growers to inject the correct light at the right time. From seedling to mature bud, light exposure must be tuned to suit the needs of the plants. Delivering a high response to positive light in the beginning of the growing cycle changes to measured amounts of stimulating light used to nudge chemical processes and pathways.

A 400-watt Hemp-Bright™ bulb delivers the same energy in the required spectral ranges as a 1,200-watt metal halide grow-light. This means that Hemp-Bright™ saves electricity… *lots of electricity!* In fact, Hemp-Bright™ fixtures are 70% more energy efficient than metal halide and 50% better than fluorescent lighting. Given the spectral bias of LED lighting, there is no comparison to the extraordinary effectiveness of Hemp-Bright™ fixtures. The chart illustrates the typical performances of competitive artificial lighting technologies. Since grow-lights represent a substantial capital investment, longevity and performance play important roles in determining overall economics. Hemp-Bright actually *exceeds* the standard for external inductor lamps by yielding up to 95% of their original lumen output over 100,000 hours.



Lowest Maintenance Cost – As the chart demonstrates, metal halide and fluorescent lights rapidly deteriorate from the moment of installation. Within the first 2,000 hours, up to 30% of the original output can be lost. This means your productivity can dramatically decline over the lifecycle of your grow-lighting. Equally important, it becomes extremely difficult to maintain consistent quality when there is such high variability in lumen output.

Growers would have to replace metal halide or fluorescent bulbs ten times, or 1,000% more than Hemp-Bright™ lighting. However, to be as effective as Hemp-Bright™ in maintaining consistency, the replacement cycle would need to be twice as much… once every 2,000 hours. That represents a 2,000% savings on lifecycle performance. When adding labor, disposal costs, and scheduling, Hemp-Bright™ represents the absolute best

buy for marijuana cultivators. Even when using LEDs, Hemp-Bright™ lamps have twice the overall longevity, and more than 300% of the lumen output performance over the lifecycle. A Hemp-Bright™ fixture will last more than eleven years burning 24 hours per day, 365 days per year. In practical terms, it is more than a quarter of a century.

Results – Hemp-Bright™ technology delivers optimum results throughout the growing cycle. From start to finish, growers can control light exposure to assure the right light at the right time. Every stage from seedling to the final bud gains maximum energy to maximize results. Equally intriguing is the potential for selective breeding. Different strains of cannabis will respond differently to light, and Hemp-Bright™ gives growers the ability to customize lighting routines to achieve various objectives.

Flexibility is critical for commercially growing marijuana. When it comes to price/performance, Hemp-Bright™ technology delivers where other grow-lights can't. Commercial scale marijuana production is in its infancy. As more states accept marijuana use for medical application and recreational use, demand for high quality branded products will exponentially increase. Proprietary Hemp-Bright™ applications include tar reduction, shortened production times, consistency, yield, and quality. Consider the Hemp-Bright™ features:

FEATURES	T8/T12	MH	LED	Hemp-Bright™	Other MIL
100,000 hour lifecycle (11 yrs @ 24hrs x 365 days)	No	No	No	YES	Yes
70% energy savings	< 30%	< 30%	Some	YES	Some
Hemp-Bright™Tuned Spectral Technology	No	No	No	YES	No
Proprietary Geometry	No	No	No	YES	No
Instant strike - no warm up or cool down	Yes	No	Yes	YES	Yes
Full Spectrum with CRI > .90	No	Few	No	YES	Some
Color Temperatures up to 10,000K	No	No	No	YES	No
Exceptionally high power factor > .95	No	No	No	YES	Some
Unparalleled Warranty 5 years/50K hrs	No	No	No	YES	Some
Fully recyclable, no special disposal	No	No	No	YES	Yes
Proprietary Nano-Reflector Full Diffusion	No	No	No	YES	No
Multi-Light Design	No	No	No	YES	No

Decades of research have been dedicated to developing artificial lighting for horticulture. Generic grow lights based upon old technologies is readily available. Hemp-Bright™ is truly an ***evolutionary*** approach exclusive to the marijuana industry. There is Hemp-Bright™ and there is compromise. For the best result using any price/performance standard, Hemp-Bright™ lighting delivers the best for less.

Detailed photometric layouts are available to determine the ideal lighting levels for any facility. Since the technical features of Hemp-Bright™ are proprietary, lighting specifications and plans should be obtained through Ultra-Tech™ Lighting, LLC. The

age of commercial marijuana production has arrived. Don't be left behind. Contact your Hemp-Bright™ representative today.

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