IMPORTANCE OF LIGHT MEASUREMENT IN THE CULTIVATION OF CANNABIS

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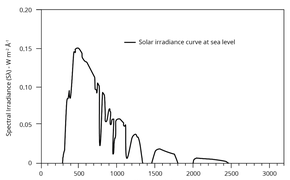
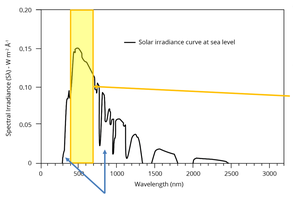
INTRODUCTION

- Light has the most important impact on producing quality *Cannabis sativa*.
- Appropriate **intensities** of light energy in the photosynthetically active radiation (PAR) waveband, ranging from 400-700 nm, are required to drive efficient conversion of carbon dioxide into plant growth and root development.
- The **duration** that *Cannabis* is exposed to light has two significant roles: (1) catalyzing the cannabis plant from a vegetative growth stage to a flowering stage, and (2) establishing a daily light integral (DLI) to efficiently induce the positive effects of increased biomass, flower number and shortened growth cycles.
- The quality, or **spectrum**, of the light source also has important impacts on how plants grow (photosynthetic rates, morphology, production time, and yield), on plant's health (insect, disease, and stress resistance), and the chemical content of the plant (terpenes, cannabinoid (CBD) content, and tetrahydrocannabinol (THC))

BACKGROUND



Solar spectrum of all the sun's energy, W/m^2



This narrow band from 400 to 700 nm is the range of light used by Cannabis for Photosynthesis

Light *not* used for Photosynthesis

This band is called **Photosynthetically Active Radiation (PAR)**. Measurement of 'PAR light' counts the number of photons delivered per unit area per second. This variable is called Photosynthetic Photon Flux Density (PPFD, µmol s^{-1} m^{-2})

Typically the more light supplied in the PAR range, up to the Light Saturation point, the better the growth and yield.

LIGHT (PAR) INTENSITY

Why is it important?

- Varying light sources and efficiencies
  - LED, HPS, MH, Fluorescents, CMH
  - Differing energy costs and heat outputs
- Effect on *Cannabis* growth efficiencies
  - Relationship of Light (PAR)-to-Photosynthesis-to-Yield
  - Total quantity of floral derived THC increases with light intensity
- Different stages, require different **PAR intensities**

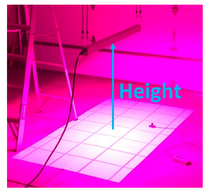
Cannabis Stage	Recommended PPFD range (µmol s^{-1} m^{-2})
Seed Sprouting / Root Cloning	100 to 400
Vegetative Growth	250 to 600
Flowering (Reproductive) Stage	600 to 1000

Materials and Methods

- A typical Greenhouse Bench size of 7 x 3 ft was marked with 1 x 1 ft grids (minimum recommended *Cannabis* plant spacing)
- Two LED light sources were used: (a) VIPARSPECTRA UL Certified Reflector Series V300 300W LED Grow Light Full Spectrum, (b) Philips GreenPower LED toplighting 215W Deep-Red/Low-Blue.

Results

Measuring light intensity of PAR:

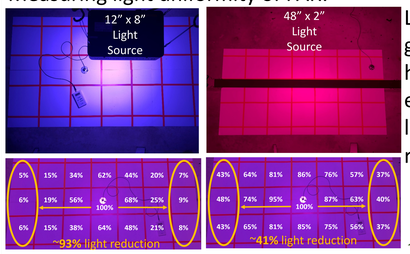


VIPARSPECTRAL	Height 1	Height 2	Change
Height above plants (inches)	80	35	**56%**
PAR Intensity (µmol s^{-1} m^{-2})	29	151	**421%**

Philips GreenPower	Height 1	Height 2	Change
Height above plants (inches)	85	40	**53%**
PAR Intensity (µmol s^{-1} m^{-2})	45	183	**307%**

The inverse square law; intensity is inversely proportional to the square of the distance.

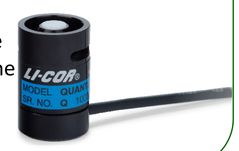
Measuring light uniformity of PAR:



Light uniformity can vary greatly between sources & heights. *Cannabis* at table ends can see 40-90% less light than center of table, resulting in less yield.

Summary

- PAR intensity that is too low or too high will lead to decreased yield, elongation of the stem, limited leaf production, excessive energy costs, photoinhibition, bleaching, leaf burning, accidental inhibition/stimulation of flowering, slower bud maturity, etc.
- To make accurate measurements of PAR, the LI-190R Quantum Sensor is used inside greenhouses and growth chambers with the same precision in sun, artificial lighting, or both, without the need for calibration or correction factors.



DAILY LIGHT INTEGRAL (DLI)

Why is it important?

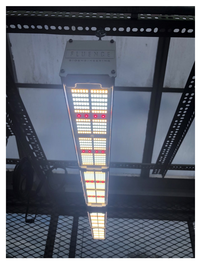
- *Cannabis sativa* is a short day plant that when grown in a greenhouse or grow room, growers can take advantage of this trait, called photoperiodism, to shorten or extend cropping time
- **Daily Light Integral** (DLI) is defined as the total number of photons per square meter in one day (mol m^{-2} d^{-1})
- Factors affecting DLI are geographic location, weather and season
- Dialing in DLI values can lead to increased flower number, larger biomass and decreased growth cycles
- *Cannabis* requires different DLI values during various points in its life cycle

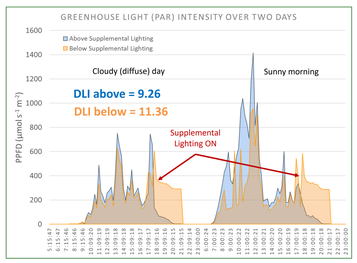
Materials and Methods

- Measurements were made in a Greenhouse in Lincoln, NE
- Supplemental lighting was applied between 6 PM to 9 PM with Fluence Bioengineering VR-P, VR-X Commercial LED Grow Light
- PAR was continuously measured above and below the supplemental light sources throughout two days

Results

Measuring Daily Light Integral (DLI) in mol m^{-2} d^{-1}:





- Supplemental lighting increases DLI to support *Cannabis* growth. Increasing supplemental intensity or duration can be a further benefit. As a point of reference, *Cannabis* requires a much higher DLI of about 65 mol m^{-2} d^{-1} during the flowering stage
- Supplemental lighting increased day length from 12 to 14 hours, which could be used to control vegetative to flowering transitions. If *Cannabis sativa* is exposed to less than 12 hours of light, flowering is triggered. Natural day lengths change during the year.

Summary

- To maximize *Cannabis* growth, accurately measuring the light durations (and DLI's) can control the biomass growth, morphology, chemical content, and harvest time through the feedback of these measurements.
- The LI-1500 DLI package uses a Light Sensor Logger and a PAR Sensor(s) to greatly simplify the complex process of measuring and calculating DLI by automatically taking measurements and performing the appropriate computations.

LIGHT SPECTRUM (QUALITY)

Why is it important?

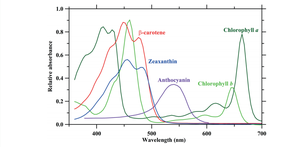
- Changes in light spectrum have been proven to manipulate terpene, cannabinoid, and THC levels
- Knowing and controlling the spectrum of the light source has significant effects on *Cannabis* :
  - Morphology with blue light (400-600 nm)
  - Growth and yield with red light (600-700 nm)
  - Plant heath and chemical content by UV light (<400 nm)
  - Transition from vegetative to flowering by FR light (>700 nm)
- Optimal results in each growth stage requires adaptive application of intensity and **light recipe spectrum**.

Materials and Methods

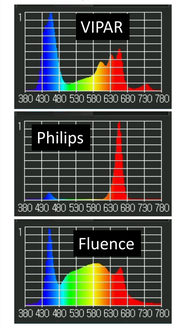
- Spectrums were measured for three different LED light sources:
  - VIPARSPECTRA Reflector Series V300 Full Spectrum
  - Philips GreenPower LED toplighting Deep-Red/Low-Blue
  - Fluence Bioengineering VR-P, VR-X LED Grow Light

Results

Wavelengths where *Cannabis* absorb light used for various functions:



For example, light at 430 and/or 660 nm is absorbed by Chlorophyll and used for Photosynthesis. Far red light promotes stem elongation and stimulates flowering. While blue light can inhibit flowering.



Light source selection should be dependent on stage of *Cannabis* and the goal during that stage.

- During *Cannabis* seed sprouting, blue 450 nm and red 660 nm wavelengths give the best results for elongation and biomass production.
- At vegetative stage, blue 450 nm promotes more compact plants and stomata opening and use of far red 730 nm triggers flowering.
- Ultraviolet light causes the production of resin, and with it increased THC and CBD production

Summary

- Knowing the light source's spectrum, or using an LED 'recipe', can give growers the ability to confidently make decisions on which light sources to use and when to use them.
- The portable LI-180 Spectrometer captures intensity and composition of the five major wavebands at the single-nanometer level. Supplemental lighting can be optimized through the different stages of *Cannabis* growing. Lighting strategies can be monitored against light manufacturer's recommendations. Monitor the intensity and spectrum over time.

CONCLUSION

Light is the most important parameter to understand and measure for effectively and efficiently growing high-quality *Cannabis*. Knowing the light characteristics gives the grower the power to significantly save on energy costs, grow higher yields of cannabis, and reduce time-to-harvest, all while preventing plant stress and disease. Collecting these light measurement sets gives growers the ability to confidently make decisions on which light sources to use, when to use them, and for how long. The minor investment in sensors and instrumentation to measure the quantity and quality of light for *Cannabis* growth pays dividends by both saving costs and producing better *Cannabis*.

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