

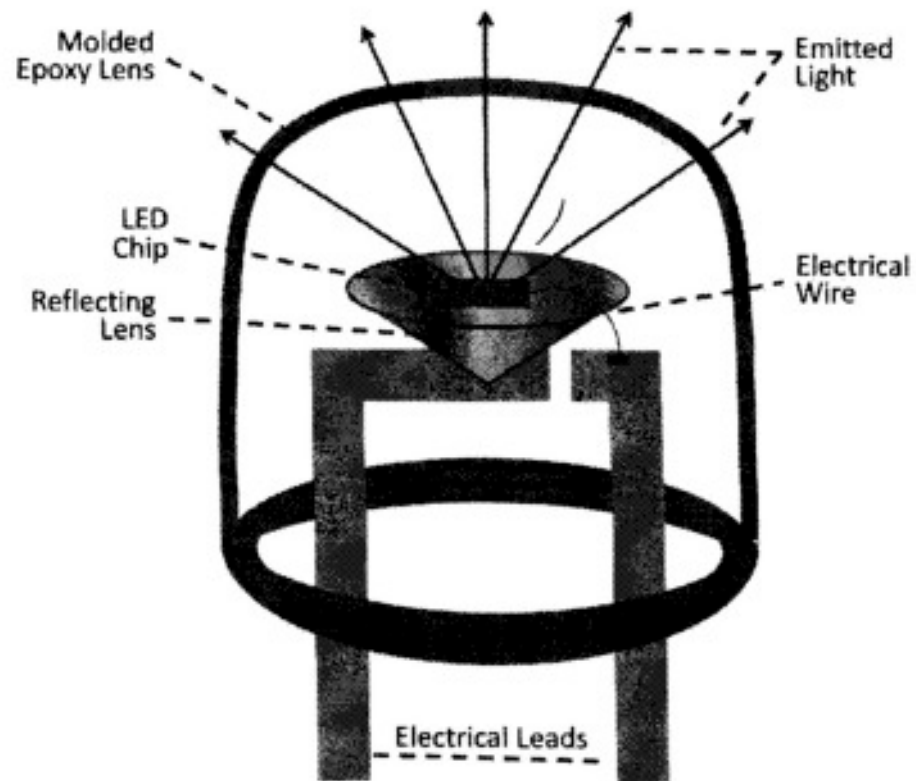
USING LEDS TO GROW BONSAI

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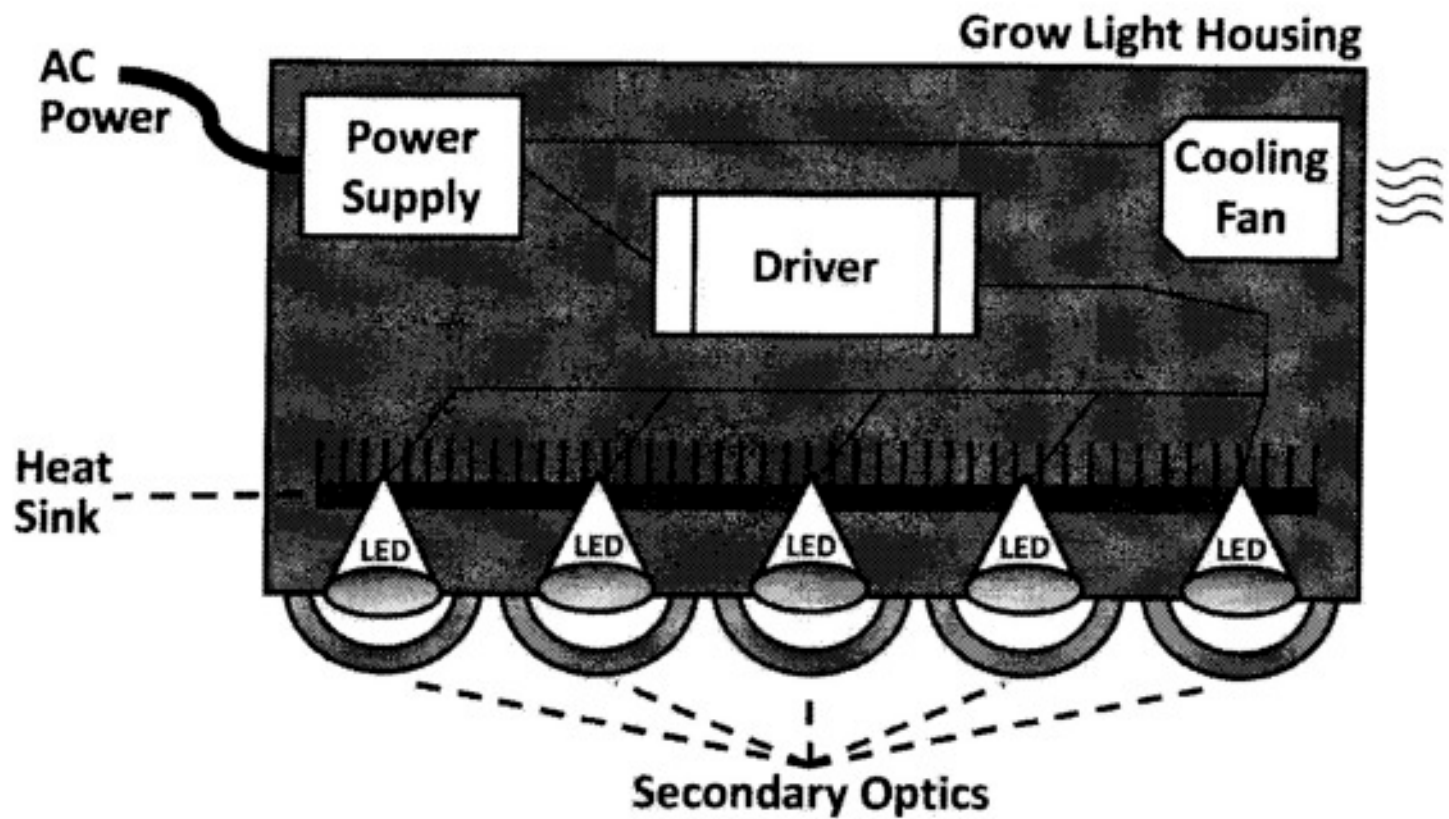
WHAT ARE LEDS?

- LED is short for **light emitting diode**.
- Electric current passing through semi-conductor diodes the “die” glows a color depending on its chemical components. The die sits in a reflective cup to direct the light outward through an epoxy lens. An LED grow light consists of many diode emitters, a heat sink to pull heat away, cooling fans, and a driver that provides power to the LEDs similar to ballasts in fluorescent lights.

What is an LED?



Components of an LED Emitter

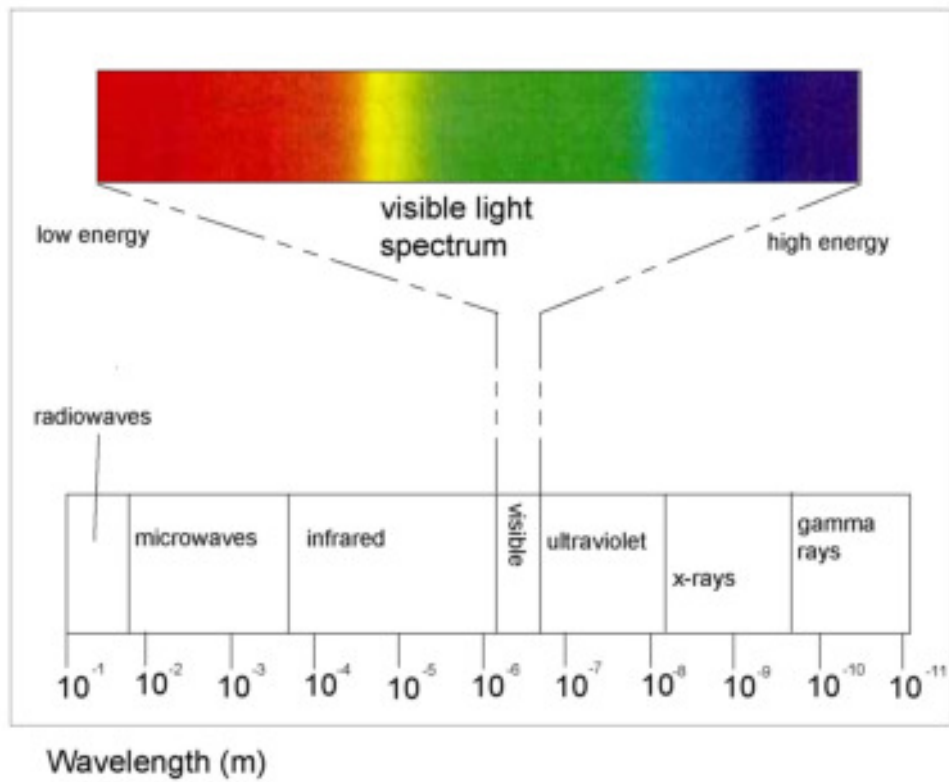


Lighting spectrum delivered is flexible

- Grow lights have multiple LEDs with different configurations of light chips to provide many different ways of providing lighting to the plant below. How do we know what is needed?

Visible light spectrum – 380 nm to 740 nm “reds” are particularly important for plants

Color	Wavelength interval
Red	~ 625-740 nm
Orange	~ 590-625 nm
Yellow	~ 565-590 nm
Green	~ 500-565 nm
Cyan	~ 485-500 nm
Blue	~ 440-485 nm
Violet	~ 380-440 nm



Purpose of light

- Promote photosynthesis in the plant.
 - - light-dependent reactions
 - - light independent reactions
- The light-dependent reactions use light to react with water to create chemicals for the light independent reactions. Carbon dioxide is ultimately converted to sugars in this process.

Chlorophyll's Purpose

- Purpose similar to hemoglobin in blood – absorb energy from the light photos the plant is exposed to. Chlorophyll absorbs in the red and blue regions of the light spectrum. Early on LED manufacturers produced lights with only these spectrum colors. Found this was not enough.

The Importance of Colors to the Plant

- Chlorophyll is green because plants reflect back some of the “green” light but not all. Green Light is absorbed deep within the tissue by Cartenoid compounds Carotenoids cause plant leaves to thicken, increasing their ability to capture more light. Green light can continue to drive photosynthesis when the plant is over exposed to light. Green light can control some diseases and spider mites.

New knowledge improves artificial lighting

Phytochrome – plant growth regulator that functions in the red end of the visible light spectrum – controls internodal elongation and flowering initiation. To develop normal shape, plants must receive specific ratios of red and infrared light on their stems. Without enough infrared, the plant will sense being blocked from light and elongate.

- Cryptochrome – is similar to phytochrome in that it is also a photosensor. It is less understood than phytochrome but it also regulates the physical size and shape of plants. Cryptochrome affects the plant's circadian clock and is responsible for phototropism (turning toward the light). It captures blue, violet and a small amount of UV-A light. UV-A is damaging to the human eye. Most LEDs on the market do not use UV-A light. UV-B is the substitute and is available in some LEDs – check the one you are considering. UV-B is thought to increase flavonoids and terpenoids. Flavonoids (vibrant colors) and terpenoids (aromatic plant smells).

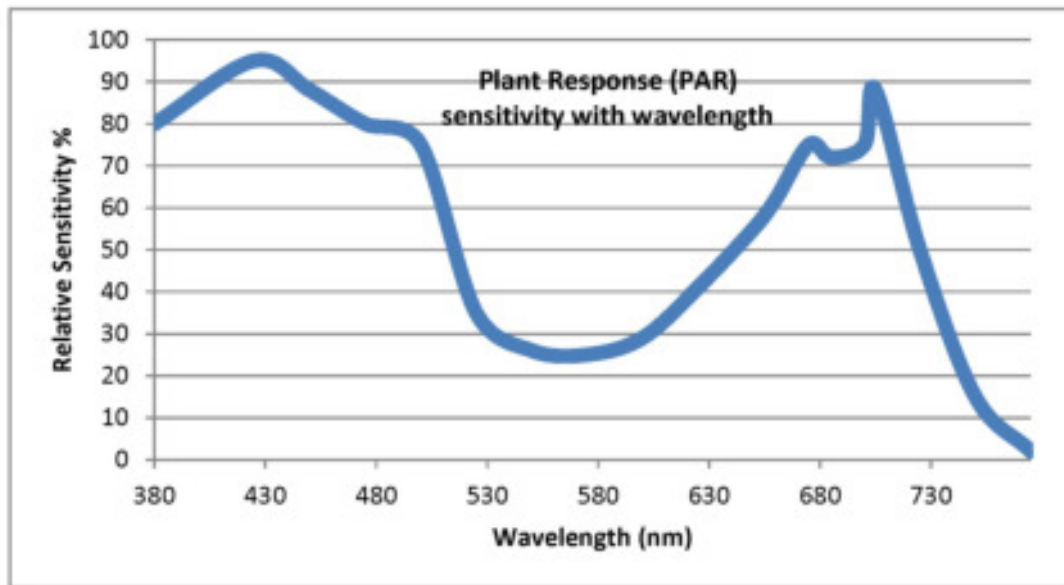
Color Appearance Under LED Lighting

- Green plants appear green under sunlight because of chlorophyll which absorbs most of blue and red regions of visible light. Green light is less absorbed and reflected back hence the green color.
- Green plants illuminated with either monochromatic or dichromatic blue or red LEDs, there is a significant change in plant color under the lights. Mine appear magenta under LEDs. Diseases can be harder to spot under LEDs.

Too Much Light? Effects?

- Too much light produces free radicals in the plant which can be destructive in the plant. This is observed with a leaf “whiteness” and veins being more visible (similar to nitrogen deficiency but in the top instead of the bottom). Also a leaf curl occurs. This is noted in LED literature and experienced myself.

Plant Response (PAR)



Daily Light Integral (DLI)

- A quantitative way to determine if your light is providing too much light is to calculate the daily light interval (DLI). The DLI is the total amount of light molecules received by a plant during a single light period. The maximum DLI that can be achieved outside in full sun is about 60 moles per day. Exceeding a plant's DLI limits can cause your plant to shut down and start protecting themselves. DLI meters that average total DLI for a location over a 24 hour period are commercially available and not terribly expensive.

Choosing an LED light for your growing area

parameter	Peak wavelength	Function	Spectrum Color of Light	Wavelength	Bulb Color	Percent of LED emitters (rounded up)
Beta-carotene	470 nm	Signaling, Carbon fixation	Blue	440 – 450 nm	Dark Blue	10%
Chlorophyll A	465 nm, 665 nm	Carbon fixation	Blue, Red "660"	470 nm	Blue	10%
Chlorophyll B	453 nm, 642 nm	Carbon fixation	Blue, Red	525 – 540 nm	Green	5%
Phycocerythrin	495 & 545/566 nm	Signaling	Aqua/Turquoise, Green	620 nm – 640 nm	Red	20%
Phycocyanin	620 nm	Signaling	Red	660 nm	Red 660	50%
Cryptochrome	450 nm, 370 nm	Signaling, Light quality	Dark Blue, UV	725 – 740 nm	Infrared	10%
Phytochrome	P _r 660 nm P _{fr} 730 nm	Signaling	Infrared, Red "660"	Already present		

Growing with LEDs

- Short-day versus Day-neutral versus Long-Day Plants
- Photo-periodism is the physiological reaction of organisms to the length of day or night. Other than flowering, photo-periodism in plants includes the growth of stems or roots during certain seasons and the loss of leaves. Artificial lighting can and will alter this.
- Not a lot of information on this for bonsai but there are a few rules you can follow when growing different plant species.

- Short-day plants – flower as days grow shorter and nights longer. After June 21st in the northern hemisphere. The shoots are induced to produce floral buds instead of leaves and lateral buds.
- Day-neutral plants – do not initiate flowering based on photoperiodism (roses are an example).
- Long-day plants – flower when the night length falls below their critical photoperiod. These plants typically flower in the northern hemisphere during late spring or early summer as days get longer. Azaleas are an example.
- This is an important element in determining length to keep LED grow lights on.

How do I choose an LED Light?

- *DON'T USE ELECTRICAL WATTS TO COMPARE GROW LIGHTS* – Many manufactures of low cost LEDs use this metric to sell their products. Watch for this!
- *DON'T USE LUMENS TO COMPARE GROW LIGHTS* – this is a measure of brightness. It does not correlate to photosynthetic grow rates.
- *DON'T BE FOOLED BY MAGIC* – Look at what they have to offer. Do not fall for lights that provide only chlorophyll A and B absorption spectrum.
- *DON'T LOOK AT A SINGLE PAR MEASUREMENT DIRECTLY UNDER THE FIXTURE* – you need to know what is being delivered across the whole fixture face.

- *DON'T FOCUS ON THE WATTAGE OF THE LEDS IN THE FIXTURE* – whether you use 1W, 3W, 5W or 10W LEDs does not tell you about performance. You want high quality LEDs in the fixture.

Ranking	Manufacturer/model	Other Information
1	California Lightworks Solarstorm 880	Has a uniform 4'x4' coverage area 2 built in 15 watt UV-B t8 tubes Can switch spectrum from grow to bloom (not inexpensive at around \$1,700)
2	HHE 300	Lots of red and blue spectrum light Four cooling fans (inexpensive at around \$140)
3	G8LED 450	8-band wavelength ratio for optimal flowers, plus IR and UV light (price point is around \$600)
4	KIND K5 XL 1000	A mix of 3 and 5 w diodes Dimmable 8 fully customizable time stages. Top choice for many professional growers because of exceptionally large yields per watt (don't think we are talking bonsai here!) (price point is around \$1,400)
5	Advanced Platinum P600	Change between vegetative or flower options by flipping a switch One of the highest PAR/lumen outputs per watt (price point is around \$660)
6	Apollo Horticulture 1200	Has 240 5W LEDs which draw only 600W while pushing out 1,200W saving on the energy bill. It can be placed very close to the canopy without burn. Has a noisy cooling fan. (this is identified as currently unavailable – other Apollo LEDs are under \$500)
7	MarsHydro 480	Outstanding customer service Affordable for the small grower who wants to experiment with LED (price point is around \$200)
8	BlackStar Chrome 270	Offers a full spectrum range including IR and UV (price point is around \$350)
9	Roleadro Galaxyhydro COB	90 degree high reflective cups for a high light gathering effect. Easily daisy chained together to run multiple lights in sync for large growing areas (price point is around \$400)
10	KingLED King Plus	10W chips, full spectrum grow lights with red, blue, yellow, white, IR and UV. (price point is around \$200 for 1200W light)

Plantzoid.com information on manufacturers

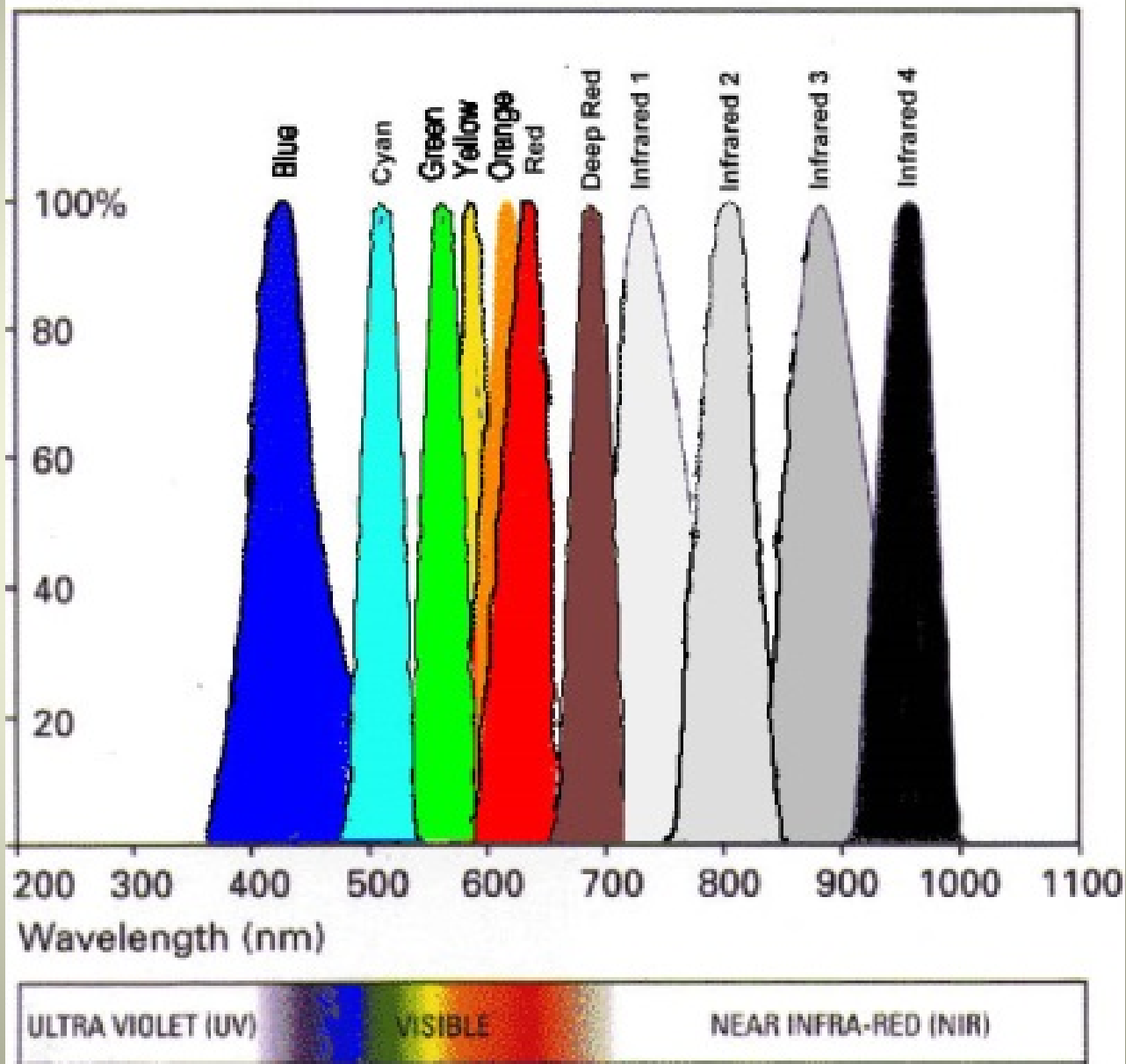
- **ADVANCED LED GROW LIGHTS** – “One of the best LED grow lights manufacturers on the market. Their products perform far above most of the other grow lights you may stumble upon while searching in the internet. They spent many years working in grow lights industry and have been perfecting their products every year.”
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- **CALIFORNIA LEDS** – “it seems that they have finally perfected the art of making the best LED grow lights. Their SolarStorm and SolarFlare lines of products are manufactured in the US and everything else is handled in house.”
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- **KIND LED GROW LIGHTS** – “they spent years working on perfecting the products before they ever opened their virtual doors! ...Kind LED even worked to create a one of a kind heatsink that dramatically reduced the temperature, making them cooler than standard LED panels. ...top notch efficiency and 12 band spectrum”
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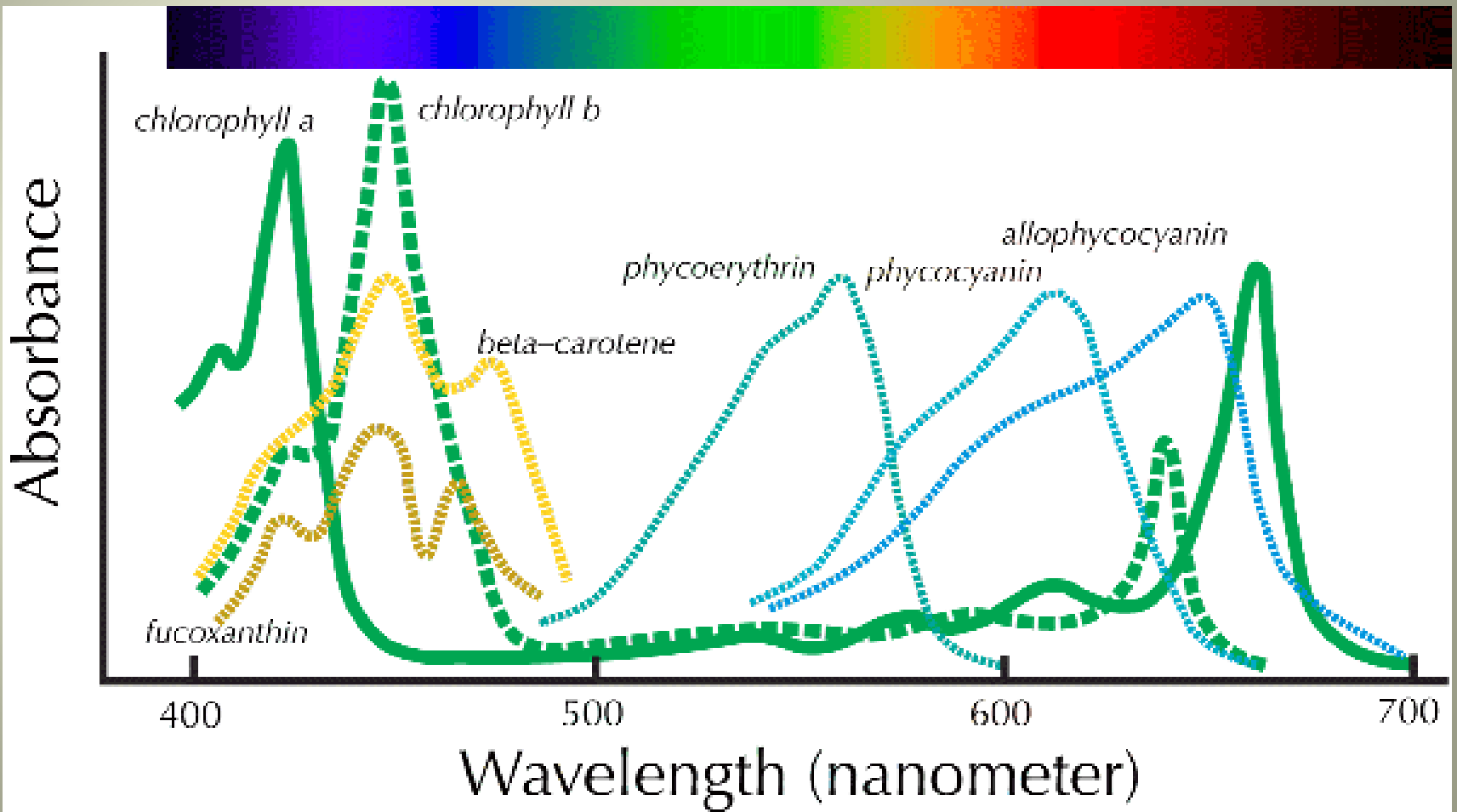
- **SPECTRUM KING GROW LIGHTS** – “have the power to easily increase harvests by 25%, save 50% in electricity bills, and take up less space than many other LEDs. ..some of the most effective if you are looking for larger, more profitable grows”
- **DORM GROW (G8LED)** – “by focusing on the customer, Dorm Grow has learned what people want and what they are unhappy with. They are so sure that you will have better grows that they offer a 90 day no questions asked return as well as a service warranty lasting two years”
- **HYDROGROW** – “pride in being able to convert even the most technologically averse growers to LED innovations....They might not be the cheapest...they work well, and they are some of the most advanced that you will come across”
- **MARS HYDRO** – “been in grow light business since 2009. They have their own testing laboratories and they continue to tune and improve their products every day”
- **TOTALGROW** – “inspired by how plants really absorb and use light. ..these lights produce a broad grow spectrum in the wavelengths plants need most for healthy and quick growth”
- **TAOTRONICS** – “started in 2008...their study of what consumers want has lead them to making some of the top grow lights that are sure to fit any need you have as a grower. The simplified systems they have created let you stress less and grow more”

Height Above Trees

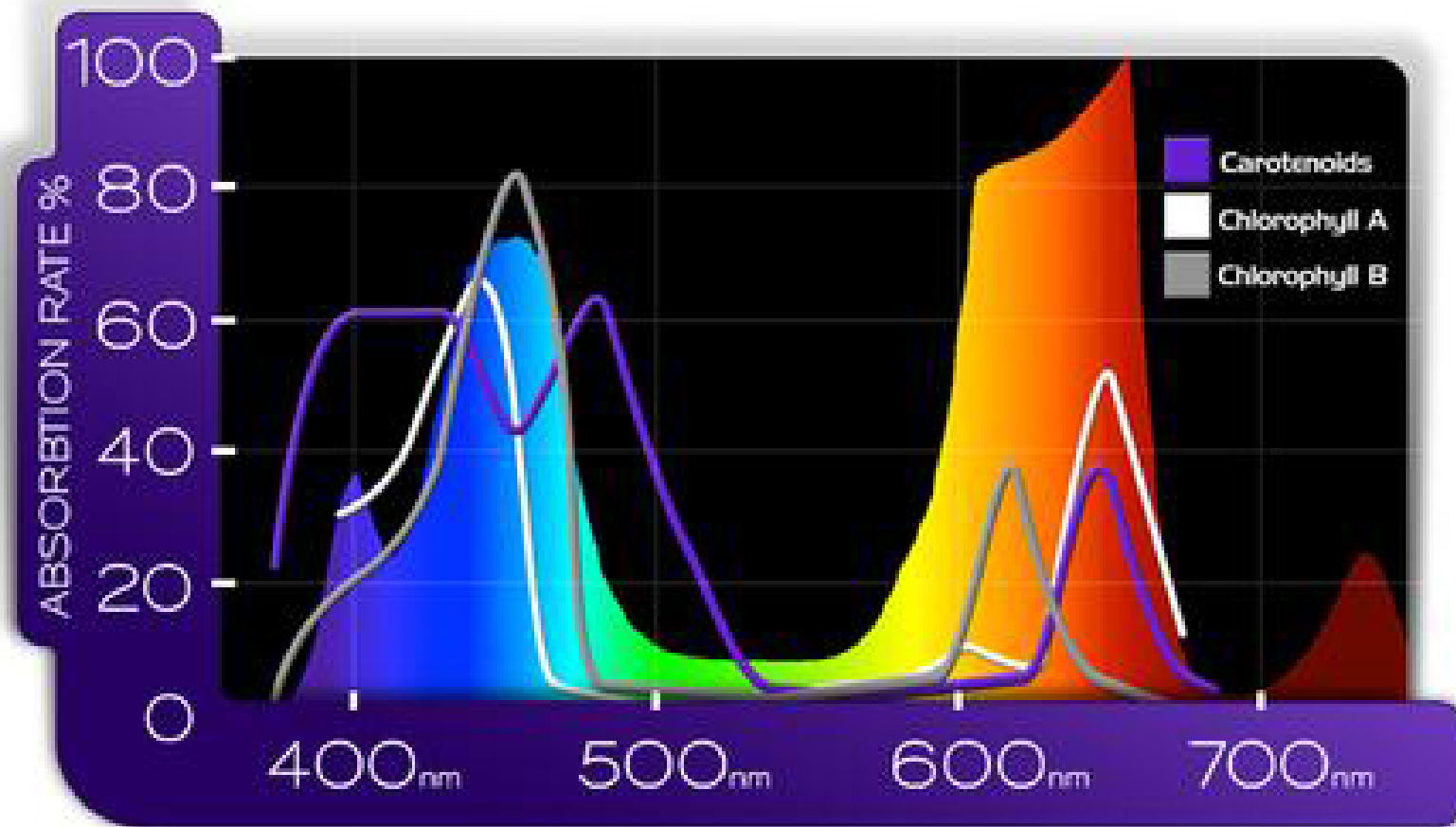
- When first introducing LED light to trees, it is recommended that either
 - A) the intensity turned down to 50% (for adjustable lights) or
 - B) hung at an initial height of 48 inches or more for the first 3 to 4 days
 - Then lowering 4 to 6 inches each day until the desired height is achieved (12 to 24 inches with KIND K3 series and 30 to 36 inches with KIND K5) each manufacturer will be different on this and should be consulted.
- **The signs of too much light will be exhibited with slight curling in the upper youngest leaves and overall slower growth.**

Figure 1. LED Emission Spectra





KIND LED spectrum



Adjustable Intensity Light – KIND K5

- Channel A: 600 nm – 700 nm (Red)
- Channel B: 400 nm – 500 nm (Blue)
- Channel C: 500 nm – 600 nm, <400 nm, >700 nm (other)
- K5 can be adjusted. K3 are not adjustable.
- Vegetative: in this stage, the deeper red spectrums are utilized less by the plant than when it is in flower and uses high levels of blue light that are essential for creating lush, thick plants that have tight internodal spacing and very little stretching. For this stage 30/60/60, 45/80/80, or 60/100/100 are used depending on the plant.

- Flowering – at this stage, the plant has a lot of work to do and is performing many complex biological processes in producing flowers and/or fruits. Because of this, the plant now requires large amounts of light in all categories. For high use plants use 100/100/100. For lower light use plants dial back in the same amount.
- Late Flowering or Maturing of Fruit – during this stage the blues are dialed back to 100/70/100 in order to mimic late summer days.

Trees that benefit from light augmentation

- Any tree originating in the tropics or from a mediterranean climate:
 - Olives
 - Coastal live oak
 - Pomegranates
 - Bougainvilleas
 - All Ficus
 - Quince
 - Brazilian raintrees
- Anything desert or tropical or needs a lot of light