Plant Lighting

Welcome to plant lighting, this file aims to better explain the importance of plant lighting, as well as how to utilize plants within our enclosures. Light is a form of energy and while we are aware of this in regards to animals (e.g. bearded dragons appearing sluggish if they receive insufficient UVB, or ectotherms as a whole becoming sluggish if not receiving enough infrared), plants are commonly overlooked when speaking on the importance of high quality light. We tend to focus on all the little details regarding ultraviolet and infrared light, trying to understand how these provide things such as natural synthesis of D_3 and deep penetrating heat, that we commonly overlook the middle part of the spectrum being visible light. But while we may only utilize visible light for a few functions, such as aiding in a healthy circadian rhythm, it plays a crucial role in plant health and growth. Not only is it an absolute necessity for plants to have visible light to maintain health, but they need to have quality light as well.

Photosynthesis

This is the process in which plants are able to make food for themselves. There are two main types of photosynthesis being **C3 Photosynthesis** and **C4 Photosynthesis**. C3 Photosynthesis is the most commonly used form of photosynthesis by green plants and other organisms, which involves creating a 3-carbon compound (where it gets its name C3) called 3-phosphoglyceric acid during the Calvin Cycle which then goes on to become glucose. C4 Photosynthesis is much rarer and involves creating a 4-carbon intermediate compound (where it gets its name C4) which then splits into carbon dioxide and a 3-carbon compound during the Calvin Cycle. Typically C4 Photosynthesis is used in areas with very limited light and water as it's high carbon yield allows it to maintain certain plants in these less than ideal environments. This file will be focusing on C3 Photosynthesis.

Inside plant cells are small organelles called **chloroplasts** which are responsible for storing light energy. Within the thylakoid membranes of the chloroplast is a green light absorbing pigment called **chlorophyll** (this is where plants get their green color from). During photosynthesis chlorophyll absorbs visible light energy and converts it into chemical energy in the form of molecules called **ATP** (Adenosine Triphosphate) and **NADPH** (Nicotine Adenine Dinucleotide Phosphate). Once this is done then the ATP and NADPH molecules move on to be used in the Calvin Cycle to create glucose for the plant. Of course, there are other factors during this stage of photosynthesis to take into consideration as well, such as water and carbon dioxide, but for the sake of keeping things short we're going to focus primarily on the light aspect.

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The Calvin Cycle is the part of photosynthesis that uses carbon dioxide to create glucose and other sugars. It has three main steps being **Carbon Fixation**, **Reduction Phase**, and **Regeneration Phase**. It takes 6 whole cycles to produce a single molecule of glucose.

Carbon Fixation : a CO_2 molecule (Carbon Dioxide) combines with **RuBP** (ribulose 1,5-bisphosphate) a five-carbon acceptor molecule to create a six-carbon compound that then splits into two molecules of **3-PGA** (3-phosphoglyceric acid).

Reduction Phase : ATP and NADPH are used to convert the 3-PGA molecules into a three-carbon sugar molecule called **G3P** (glyceraldehyde-3-phosphate).

Regeneration Phase : Some G3P molecules are converted into glucose while others are used with ATP and a complex series of reactions to regenerate the RuBP.

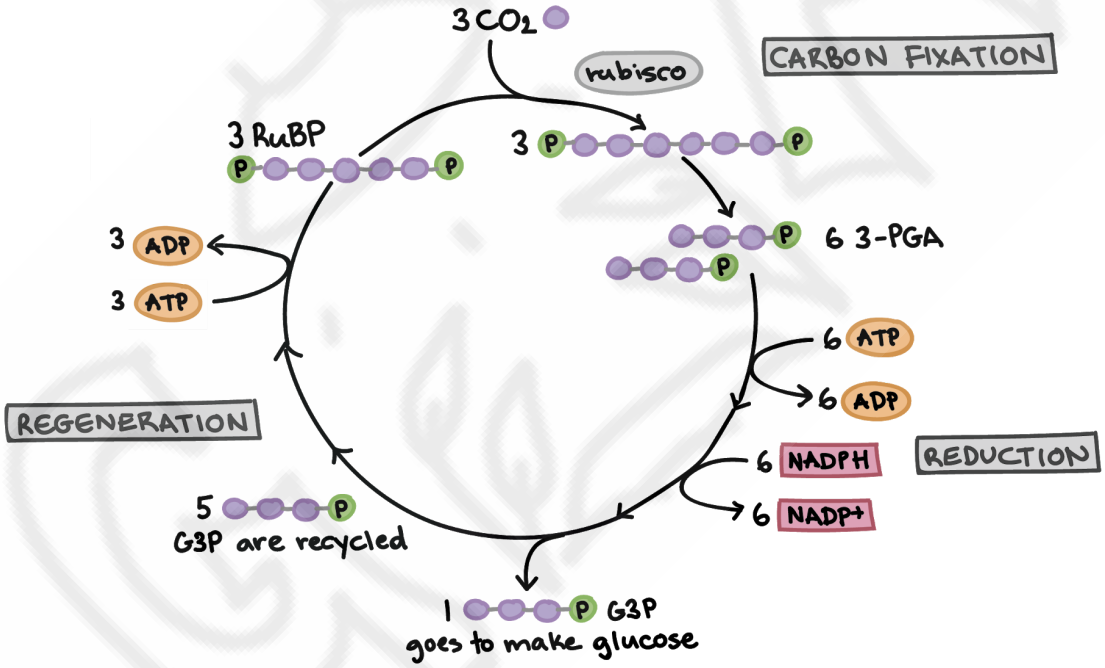

Image source:
https://www.khanacademy.org/science/ap-biology/cellular-energetics/photosynthesis/a/calvin-cycle

Again, this is a very basic explanation of photosynthesis. There are a lot more chemical compounds, reactions, enzymes, and more that go into it. Photosynthesis is such a complex subject that it can be a file in and of itself.

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PAR

PAR when used in reference to horticulture stands for **Photosynthetic Active Radiation** and is the measure of the quantity of usable energy needed for adequate plant photosynthesis. The range in which you are looking for in regards to the electromagnetic spectrum would be 400-700 nanometer (nm) and is the part of light between the ultraviolet (UV) spectrum and infrared (IR) spectrum, commonly referred to as 'visible light' (this being because they are the wavelengths that humans can see as light and color).

PAR is commonly confused with PPFD (read below) and will sometimes be listed as a quantity of usable light, in truth PAR is simply a spectrum and not a measurement. In most cases when PAR is listed as a measurement, the manufacturer is actually referring to PPFD.

PPF

PPF stands for **Photosynthetic Photon Flux** and measures the total amount of light within PAR that is produced each second. This is measured as micromoles per second (µmol/second) and is used to determine how many lamps are needed to cover a specific area in order to provide the desired amount of light.
Example: if you have are trying to provide 400µmol/sm^2 to an area that is 20m large, and you have a lamp that produces a PPF of 2000µmol/s then you will need 4 lamps to cover that area (20m x 400µmol/sm^2 = 8000µmol needed, then we divide the sum of what is needed by the sum of what the lamp provides 8000/2000 = 4 and we are left with the number of units needed to cover that specific area).

This is typically only really needed when creating extra large zoo-like enclosures, but is worth mentioning in case someone is looking for that specific information.

PPFD

This stands for **Photosynthetic Photon Flux Density** and is currently the most accurate measurement of usable energy from a grow light. PPFD measures the amount of light that is actually reaching your plant that is within PAR range of energy. It can also be used with PPF as per the example above to help figure out how many lighting units are needed for a large area. Typically PPFD is measured using a PAR meter (I know, it's confusing when terms get used interchangeably). For lower light plants that enjoy shade you will want a PPFD around 100 whereas high light plants need at least 700 or more, extremely high light plants (such as grasses, and vegetables) will need even higher.

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Temperature

On top of PPFD, many grow lights will be marketed with a specific temperature. Although many believe that temperature correlates with brightness, when in fact it better describes the color of the light. Temperature of light is measured in Kelvin (K) and despite being called 'warm toned' when yellow or red in color and 'cool toned' when more blue in color, the higher the kelvin the more blue the light. This is because blue light is actually much warmer than red or orange light in terms of temperature, think of a gas burner that burns blue when at full heat but will turn more orange when turned down. 5000K is thought to be the midpoint in regards to light temperature, where anything below 5000K is 'warm toned' and anything above 5000K is 'cool toned'. That being said, it would be impossible to accurately replicate light temperature in captivity, as in nature it is not a constant but instead changes depending on a number of variables. Everything from time of day, cloud cover, latitude, time of year, gases within the atmosphere (e.g. rural air vs metropolitan air) how we perceive light based on our surroundings, and so on can greatly affect temperature, however it is generally thought that **terrestrial daylight** (meaning the light that we see and live in on surface level) has a temperature of around 5200-7000K.

PUR

PUR stands for **Photosynthetically Usable Radiation** and is a measure of PPFD against terrestrial daylight in order to determine the accuracy/potency of the spectrum being provided and is displayed as a percentage (%). While PPFD measures the quantity of overall energy, PUR measures whether or not there is a substantial amount of usable energy. This information would be gathered using a PUR meter.

What this means is that there exist bulbs that are marketed as 6500K and high PPFD, but because they are lacking in a balanced or more natural spectrum (heavily skewed towards one side, or both but with nothing much in between) they actually have a very low PUR, a great example of this would be those lights with the red and blue diodes. While red and blue light are the most used parts of the spectrum during photosynthesis, they are not the only parts used and by omitting the middle section of the spectrum you are actually hindering your plants, as they have adapted to use the visible light spectrum in its entirety as they would experience it in nature. In a perfect world we would be able to provide 100% PUR within our enclosures but unfortunately man made lamps are of no comparison to the natural sun, and come with their own limitations. The higher the PUR the better, but you will never truly find 100%.

CRI

CRI stands for **Color Rendering Index** and is used to describe how an object is perceived under a specific light. This is measured from 0-100, the lower the number the

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more unnatural an object will appear. Going back to the previous example of red and blue diodes used in many plant lights, this would create a purplish hue and therefore a very low CRI. When taking CRI into account you will want something that is measured at at least 80, however 90 or above is preferable. Old style UV bulbs used to have a low CRI as they would emit a sort of blue hue, nothing major but enough to be noticeable. This is however in consideration of human light perception. What appears normal to us may not appear normal to our reptiles, as they tend to have much better color vision than humans and are able to see plenty of colors well out of our visible spectrum. This isn't to say CRI is useless during lighting consideration though, as if a light appears unnatural to us then it most certainly appears unnatural to our reptiles. It just isn't as reliable of a scale for them as it is for us.

What To Look For In A Fixture

Quality lights will list all of the above mentioned measurements, not always on their box but at the very least on their website's product page. So look for a PPFD that suits your plants' needs, a temperature between 5200-7000K (typically a cooler light for tropical setups and warmer for arid), a high CRI, and a good PUR (at least above 50%).

You will also want to ensure that you have all white diodes that are closely knit together when using LEDs, preferably in multiple rows. This is because light travels away from the bulb and spreads out as it does. John Courteney-Smith of Arcadia used a great example of trying to use a single dip paintbrush to color in a stamp, and then using the same single dip paintbrush to color in a standard sized piece of paper. The stamp will be saturated with color whereas the standard sheet of paper will be more muted as the same amount of color had to be spread over a larger area, or would simply be incomplete. By providing more diodes, you are providing more light that can then mix with the other beams of light around it to create a much more saturated and effective flood effect. Using lensed diodes or diodes that are spaced farther apart results in dark patches between the beams, and very poor PPFD. Below would be an example of this.

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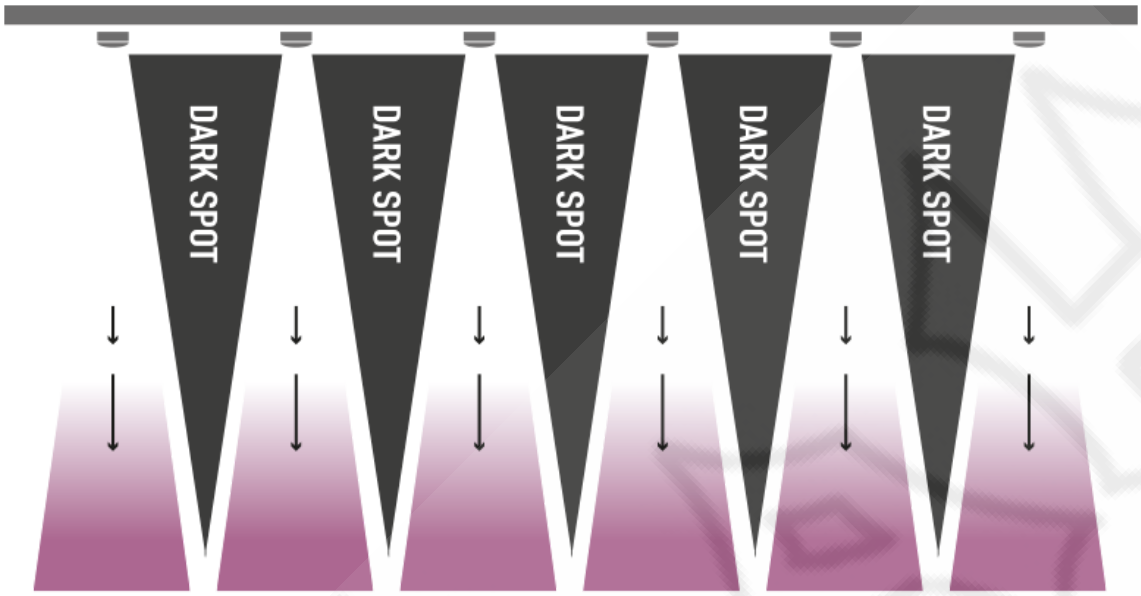

Image created and owned by Arcadia Reptile source:
https://www.arcadiareptile.com/jungledawn-ledbar/

While there are plenty of fluorescent bulbs out there for plant growth, LEDs seem to be the most efficient when all aspects are taken into consideration but this does not mean that they are the only option.

Lastly, you will want your plant light to span the entire length of your planted area. For most this would mean the entire length of the enclosure and this is to ensure that all plants gain the necessary energy needed for adequate photosynthesis, growth, and overall health.

Plant Placement

When deciding on the placement of your plants it is important to take each individual plant's needs into consideration, as well as the animal that will be living with them. Oftentimes we are so preoccupied with making sure the plants themselves are safe to be in the same enclosure as our reptile, we forget to match the plants to the climate that we are trying to create as well.

If you have a tropical setup then you will need plants that thrive in high humidity and low light, as most tropical areas consist of dense plant coverage. On the other hand, if you have a more arid setup then you will require plants that need very minimal watering but most likely need very high levels of light. To take it one step further, you will need to consider

placement within the enclosure even after deciding on which plants will best suit your individual setup's needs. High light plants that can withstand heat and few waterings can go in your warm end by your basking area, whereas your cool end would have high(er) humidity plants that require layering so as to use the leaf coverage of a high light plant to create shade for more shade dwelling plants below.

Summary

All in all, lighting as a whole is one giant balancing act and when you add plants into the equation it becomes that much more complicated. Picking out the right bulb is more than just PPFD, PUR, CRI, or even temperature but is instead a combination of all those things and then some. Then, after you think you've had all your lighting sorted out, you need to sort out the placement of your plants.

It can be overwhelming trying to find good **full spectrum lighting** (this is a term used for any light that emits all wavelengths of visible light), but it is really important to understand just how imperative it is for healthy plants and subsequently a healthy bioactive enclosure. While visible light may not seem like a big deal for us, it's an absolute necessity for plants.

Some recommended plant lights for reptile enclosures would be the **Arcadia Jungle Dawn**, **BioDude Glow and Grow**, and **Reptile Systems New Dawn** for those who do not feel confident enough to search through all the lights on the market on their own quite yet.

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