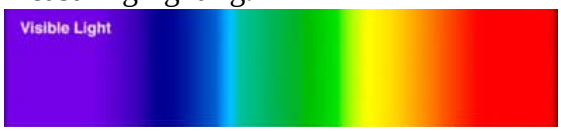
Indoor Lighting for Plant Growth

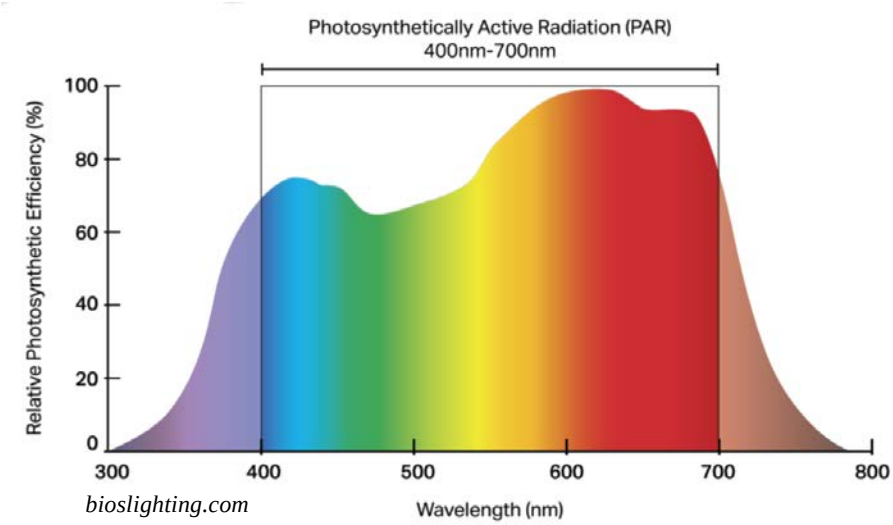
Bill Kealy

Hello winter, goodbye potted annuals! You may have already moved these plants indoors, placing them near a clean window for enough light. An alternative to this is using artificial lighting to keep your annuals growing until springtime. Artificial lighting actually gives you more control of lighting variables than sunlight. For example, the distance between your plants and the light source can be varied, as well as the light's intensity and duration. But how do these different variables affect the growth of different plants and how can they be measured?

If you decide to make use of artificial lighting, there are several things to consider. One such consideration is the type of light to get. In this article I briefly cover the different types of lights and the pros and cons of each. But before I do, I need to present a few lighting terms that, without getting too nerdy, are important for understanding how to use a free smartphone app for measuring lighting.



For the sake of simplicity, white sunlight contains a full spectrum of colors that we see as a uniform rainbow like in the image shown to the left.



Plants, on the other hand, respond to light differently, with some parts of the spectrum more useful than others for photosynthesis. The term for this is *photosynthetically active radiation* or PAR.

You can see from the image to the left that red and blue are especially useful to plants. For this reason, some use lights that emit both colors to produce a purple color (the lights are called "blurples"). The red component of blurples is very efficient for driving photosynthesis, but over the long term these lights can result in plant stretching. The best lights, therefore, are full spectrum lights that can mimic natural sunlight.

Personally, I like using a single blurple bulb, but only for germinating seeds and rooting cuttings. I simply tie the bulb to a rack in my clothes closet (a necessary accommodation for living in a small condo). Besides, I don't need a large operation if all I'm doing is germinating and rooting.

I couldn't find this specific brand of bulb, but I found the equivalent 24-inch bulb at Home Depot:

https://www.homedepot.com/p/Pinegreen-Lighting-2-ft-15-Watt-LED-Grow-Light-Full-Spectrum-Cool-White-Linkable-2-Pack-CL-2PKG2SL-ST/318784279

Only $28.72 for two bulbs.

As I mentioned earlier, red and blue light are great for driving photosynthesis, but other colors also contribute to plant growth as you can see from the table below:

PAR colors	Positive Effect of PAR wavelengths (colors) on Plants
Violet	Stimulates photosynthesis
Blue	Stimulates photosynthesis • Boosts chlorophyll production • Improves biomass • Reduces height • Produces healthier leaves • Prevents stretching
Cyan	Stimulates photosynthesis
Green	Stimulates photosynthesis • Penetrates canopy deeply • Prompts shade avoidance • Prevents stretching
Yellow	Stimulates photosynthesis
Orange	Stimulates photosynthesis • Initiates carotenoid creation
Red	Stimulates photosynthesis • Promotes growth • Induces flowering • Triggers fruiting Manages seed germination • Encourages root propagation
Far-Red	Stimulates photosynthesis • Promotes growth • Induces flowering • Improves total biomass Penetrates canopy deeply • Increases leaf area • Prompts shade avoidance

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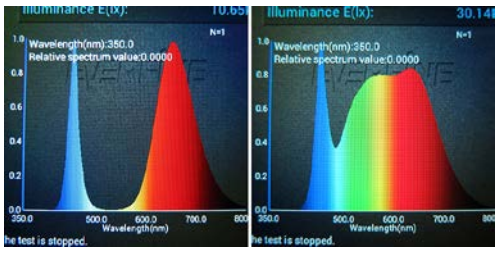
Green light, for example, which some mistakenly believe doesn't aid photosynthesis, is actually pretty useful for plants growing at the forest floor below the tree canopy.

The light from the blurple that I previously mentioned comes from a light-emitting diode or LED, which is one of the best types of light to use since it produces good output without a lot of heat.



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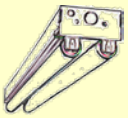
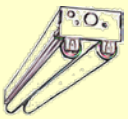
The problem with blurples, however, is that they don't include colors, other than red and blue, that can also contribute to photosynthesis. Compare the PAR spectrum of a blurple on the far left with one for a full-spectrum LED to its right. While blurples provide efficient growth, they also can result in the stretching of plants during the vegetative stage of growth.

As you can guess, I'm a big fan of full-spectrum LED lights which, compared to other sources of light (e.g., incandescent bulbs), produce less heat while supporting all stages of plant growth.

Other types of lights (see below) besides LEDs are used in commercial greenhouses as well as by a few private indoor gardeners. But, in general, LEDs and compact fluorescent lights (CFLs) are most ideal for home use when the lighted space is small. For larger home growing spaces, such as a hothouse, garage, or cellar/attic, T8 and especially T5 fluorescent tubes are best.

Other artificial lights, used primarily in commercial operations, are high-intensity discharge (HID) bulbs, including high-pressure sodium (HPS), metal halide (MH) and ceramic metal halide (CMH) lights. Here are all the lighting options; ones highlighted in yellow are ideal for home use.

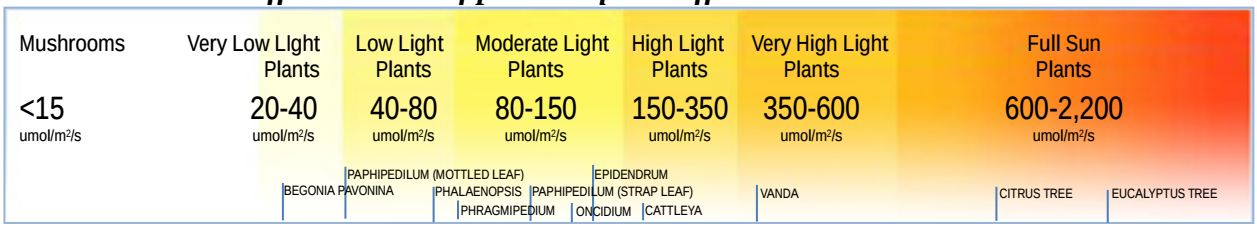
INDOOR ARTIFICIAL GROW-LIGHT OPTIONS							
	FLUORESCENTS			HIGH-INTENSITY DISCHARGE			LEDs
	CFL	**T8**	**T5**	**HPS**	**MH**	**CMH**	**LED**
	compact fluorescent 	linear tube 	linear tube 	high pressure sodium 	metal halide 	ceramic metal halide 	light-emitting diode 
Spectrum	balanced	balanced	well balanced	warm (yellow-red)	cool (blue-green)	well balanced	custom (balanced)
Initial Cost	low	low	medium	medium	medium	medium-high	low-high
Power Draw	low	low	medium	medium-high	medium-high	medium-high	low-high
Efficiency	fair	good	good	better	better	best	good-best
Application	good for short-term use in small spaces to augment a low wattage LED or a bright window	offer better coverage than CFLs for several seeding trays but special full-spectrum tubes are required since standard fluorescents aren't effective for plant growth		yellow-red light typically used for flowering stage by large plant growers vs. for home indoor gardens	used primarily by big growing operations for the vegetative stage vs. for home indoor gardens	lower heat and more costly with broad spectrum for use in all growing stages	wide spectrum allows use for all growing stages; energy efficiency best with high-end models
Uses	seedlings, cuttings, and lettuce	seedlings, cuttings, lettuce and small herbs (T5 = better growth)		flowering and fruiting among mature plants	vegetative stage with large plants	vegetative and flowering stages	vegetative and flowering stages

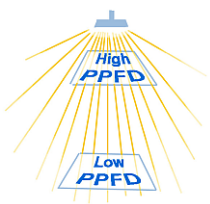
adapted/modified from albopepper.com

After selecting the type of light...

The ***type*** of light that a plant can use (the PAR) is only one thing to consider for indoor growing. Another consideration is the ***amount*** of light hitting a plant,which vary in many ways: (a) the intensity of the light, (b) how close it's placed to a plant, and (c) the size of the planting area. The ***duration*** or amount of time a plant is lighted is also a factor, but I'll get to that later. The standard measure for the amount of light hitting a plant is the number of photons covering a square meter every second—micromoles per square meter per second (µmol/m²/s). This measure is the *Photosynthetic Photon Flux Density* or PPFD. So, **PAR** = the type of light, whereas **PPFD** = the amount of light.

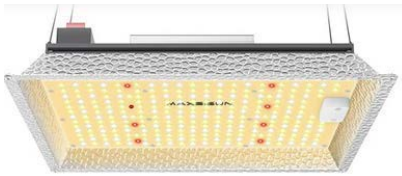
Different kinds of plants require different PPFD levels...





There are clearly several ways to increase or decrease the PPFD of a light. One way is to change the distance between light and plant; moving the light farther away decreases the amount of photons on the plant surface. A plant directly below a light gets more photons (a higher PPFD) than plants on the periphery.

For this reason, most LEDs (the good ones) will include a PAR map in the specifications. For example, here's the PAR map for a Maxsisun MF1000.



MF1000 PPFD MAP
Tested in a 2 x 2 ft Grow Tent

You can see the PPFD for the light 14" from the plant canopy (on the left) is much higher than for the light hung 18" away. Also, PPFD is higher in the middle than along the edges of the lighted area. There are a couple of strategies for addressing this imbalance. One is placing plants requiring lower PPFD (e.g., begonias) along the edge of the lit area and putting plants needing higher PPFD (e.g., vanda orchid) in the center. Another strategy is to reflect the light's illumination to the periphery.

A few years ago I purchased a grow tent (2' x 2' x 4') and, like mine, most of them have sides that use a reflective coating. The reflected light will, to some degree, increase the PPFD along the margins of the growing area. But you can achieve the same result by simply placing aluminum foil around the exterior of the growing area.

DIMMER	-	MAX PPFD
100%	-	100% (1000µmol/m²)
90%	-	95.0% (950µmol/m²)
80%	-	87.3% (873µmol/m²)
70%	-	77.0% (770µmol/m²)
60%	-	67.8% (678µmol/m²)
50%	-	56.9% (569µmol/m²)
40%	-	45.9% (459µmol/m²)
30%	-	34.6% (346µmol/m²)
20%	-	21.5% (215µmol/m²)
10%	-	8.3% (83µmol/m²)

PPFD can also be modified by changing the ***intensity*** of the lighting, and some LED lights, like the Maxsisun, include a remote control (shown to the left) that allows you to vary the light intensity. The better lights will also include a report showing how dimming the light will affect the maximum PPFD possible.

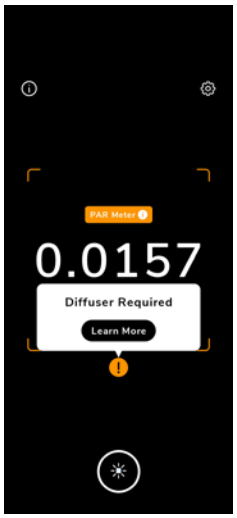
Basil (*Ocimum basilicum*)

PPFDµmol/m²/s
220 – 500

plantlightdb.com

There are useful guides on the internet that will specify the ideal PPFD for a particular plant. One is the Internet's Source of Plant Light Requirements. Here, for instance, is the recommended PPFD for basil.

But with so many variables, how would you know that your light's PPFD is in the ballpark range for a given plant? Fortunately, if you have a smartphone there are a couple of apps—for either iPhone or Android—that let you directly measure PPFD. My favorite is **Photone** (https://growlightmeter.com/), which uses the phone's front-facing camera to measure the light hitting a plant. After installing and starting the app, you'll see this display:



In the middle is a notice that says "Diffuser Required". A diffuser is designed to scatter the incoming light, thereby making the PPFD measurements more accurate. You can purchase a top-of-the-line diffuser from Lightray (https://lightray.io/diffuser) for $26 or build one yourself in a couple of minutes or less. The homemade version is 10-12% less accurate...but good enough.

1. Cut a 1/2 " strip of standard white printer paper long enough to wrap around the top of the phone.
2. Cover the phone's front-facing camera and tape the loop at the back of the phone.
3. The orange icon and notice disappear as the app automatically detects a diffuser and makes adjustments accordingly.

Next, click the star icon at the bottom of the screen (1).

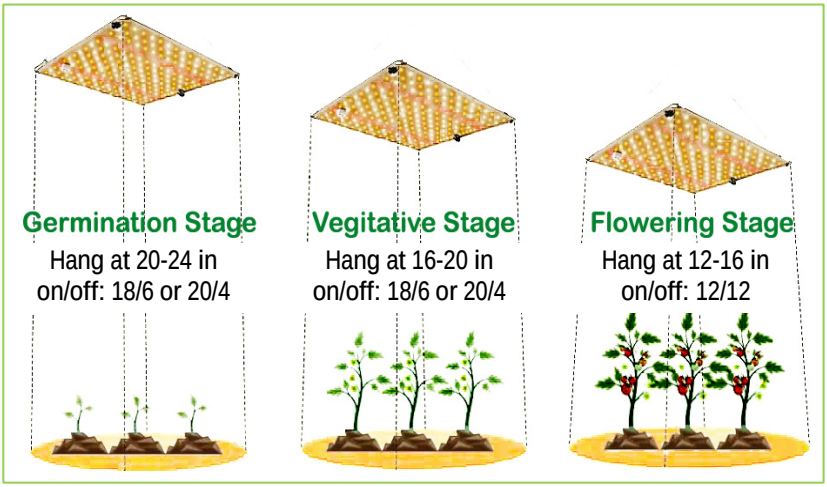
From the horizontal menu, swipe left or right to locate the type of light you're using (2). In this example it's a full-spectrum (i.e., broad) LED light.

Hold the cellphone directly over the top of the plant(s) to see the PPFD reading on Photone.

Pressing your thumb anywhere on the screen (3) will freeze the PPFD reading.

The Daily Light Integral (DLI)

If you light a plant for 12 hours, it will be bombarded with fewer photons than if it's exposed to a light for 18 hours. This introduces a lighting measurement called the *Daily Light Integral* or DLI. DLI equals the PPFD times the number of hours of illumination times 3600 (number of seconds in an hour) all divided by 1,000,000 (to convert moles to micromoles). *Yeow! Sounds complicated!* But fortunately there are tools that make doing math unnecessary.



If the DLI is too great, the plants can experience stress and burn. If the DLI is too small, the plant will suffer reduced growth and vigor. In general, the photoperiod (hours lighted) is longer during a plant's germination and vegetative stages, while it is shorter during the flowering and fruiting stages. The DLI is a product of the distance between light and plant and the photoperiod.

The **Internet's Source of Plant Light Requirements** mentioned earlier not only shows the ideal PPFD for a given plant, but also both the suggested DLI and the photoperiod.

Basil (*Ocimum basilicum*)

PPFD µmol/m²/s	**DLI** mol/m²/d	**Photoperiod** hours
220 – 500	12 – 26	8 – 16

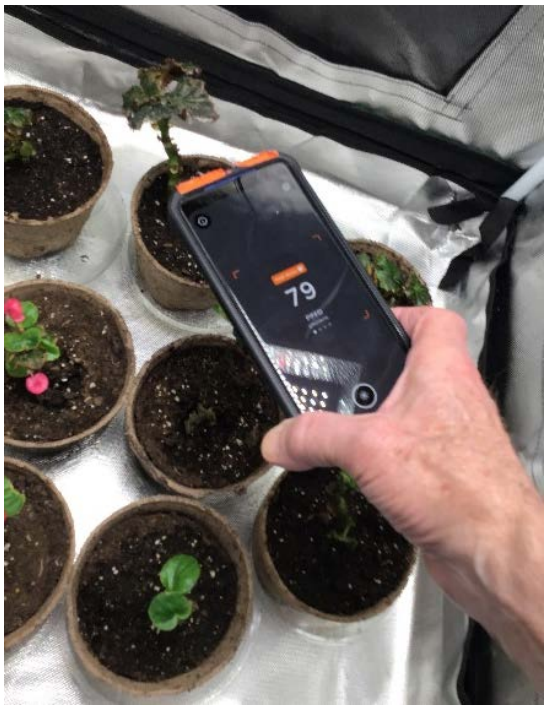
plantlightdb.com

Measuring the DLI with Photone

www.growlightmeter.com

Besides measuring PPFD, the Photone app (see left) also provides the DLI; simply swipe the screen to the left to reveal the DLI interface. The display retains the light type that you specified earlier, so all you have to do is enter the photoperiod (the number of hours the light will be on) by clicking the plus or minus sign to change the value. The photoperiod is based on whether the plant is long-day (e.g., lettuce), short-day (e.g., soybeans), or day-neutral (e.g., tomatoes). Then hold the phone directly above the plant to obtain the DLI measurement. To change DLI, modify the light's distance, duration, or intensity (see https://youtu.be/dQlOJ1zvoPI for the excellent video *Photoperiod Versus Intensity)*.

There are several places on the Internet where you can find suggested DLI values for different kinds of plants, such as the chart above showing high DLI recommended for cacti and low DLI recommended for orchids and peace lilies.

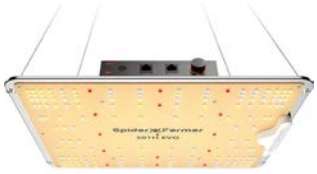


Here I am demonstrating the use of Photone to measure the PPFD of the light striking my young begonias. Notice that I'm not using a diffuser (shame shame!). There are other apps for measuring and adjusting indoor lights for plants. An excellent one—for either iPhone or Android—is called **PPFD Meter** (shown above; get it at https://ppfd.app/). This can show PPFD and DLI simultaneously as well as other lighting measurements such as lux. It has a very good guide on how to calibrate the app to get more accurate readings. I find Photone a bit more straightforward and easier to use, but I have PPFD Meter installed on my smartphone as well.

For $85 you can buy a dedicated PAR meter, which is more accurate than either app. You can get it from Amazon at https://www.amazon.com/Quantum-Spectrum-Precision-Greenhouse-400-700nm/dp/B0C2CH9Q5C?ref_=ast_sto_dp. For my purposes, however, this seems excessive.

Comparison of LED lights: which one is best for you?

After scouring the Internet (endlessly...for days!), I finally settled on the Maxsisun MF1000, which is a full spectrum LED light that is suitable for a 2' x 2' grow tent. I bought it for $77 on Amazon but, alas, the light is currently unavailable. While this is disappointing, there are some very good alternatives. I recently saw an excellent review of three lights: Spider Farmer, Mars Hydro, and Maxsisun (my unit).



The reviewer is Al Gracian III (check out his website: https://albopepper.com/), who is a ***master*** urban gardener. His review at https://youtu.be/g6n8VhVGKDY is somewhat nerdy but, hey, you might like that! Spoiler alert...other than the Maxsisun, your best bet is the Spider Farmer SF1000 (***not*** the SF1000D model) for $90 (www.amazon.com/Spider-Farmer-Dimmable-MeanWell-Spectrum/dp/B07TS82HWB/ref=cm_cr_arp_d_product_top?ie=UTF8). Note that the dimmer, shown to the left, is on the light itself, not on a remote unit as with the Maxsisun MF1000.

In summary, I'll quote the final words of Johann Wolfgang von Goethe and wish you ***"More light!"***