LED iBOND

Vertical Farming White Paper

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7 THINGS TO CONSIDER WHEN BUYING GROWTH LIGHT FOR VERTICAL FARMING

It has become possible to build a cost-efficient vertical farm from scratch based on the right choice of technical solutions. In this paper we discover how to build a successful vertical farm using optimal conditions, such as the right climate, lighting, energy consumption etc.

LED Growth Light - Buyer's Guide and Benchmark

Light emitting diodes (LED lights) were first introduced to the market to replace the traditional incandescent and fluorescent lights for a more sustainable and energy saving solution. With LED becoming a standard for lighting in homes and offices, the horticulture industry is now looking the same way to benefit from this technology.

Highly developed LED growth lights have made a unique niche of its own and have become extremely competitive versus the old traditional growth lights that use HPS (high-pressure sodium) or CMH (ceramic metal-halide).

There are four essential advantages of new and improved LED growth lights:

Energy saving

LEDs use far less energy to produce the same amount of light when compared to HPS or CMH. According to market research, LED lights consume 90 percent less power than HPS growth lights which mean significant savings on electricity bills. LEDs are the most power efficient lighting solution in the world.

Longer Lifespan

In comparison to HPS lights, LED lights have a longer lifespan. With time, HPS bulbs may become dimmer (become black) and lose efficiency, once the issue appeared, need to replace the whole light. LED growth lights can typical last 50,000 hours before its light output is significantly reduced.

Produces Less Heat

Another benefit of LED growth light is that they produce less heat than any other type of lamp. The low heat dissipation means that active cooling in most cases can be eliminated leading to a simpler construction and installation with lower overall cost. The lower temperature of the light panel at which the LED is mounted, the longer the LEDs will last and the higher its energy efficiency will be. In short, it is highly desirable to use a design for the light panel that will keep the temperature of the build-in LEDs as low as possible.

Light Panel Can Hang Closer to Plants

Since LED growth lights produce less heat, they can be placed closer to the plants and thereby more of the emitted light can be captured at the growth area. HPS/CMH growth lights can burn plants if placed too close to the plants due to the large amount of heat they produce.

This means that LED growth light panels are highly suitable for multi-level grow operations enable indoor farms to grow more plants in less space, reducing their expenses.

What to consider when selecting growth light panels

There are several factors to consider when choosing a growth light panel. The following list of seven factors are of very important when benchmarking different LED lights panels:

1. Light Spectrum
2. Light Intensity (Density)
3. Wattage Draw (Power consumption)
4. Coverage Area and Homogeneity
5. Lifespan
6. Maintenance costs and Ease-of-cleaning
7. Price and Installation Cost

1. Light Spectrum

When choosing a spectrum of light for growing plants, the following two main processes in plants must be stimulated with light photons of different colors:

> **Photosynthesis:** a process used by plants to convert light energy into chemical energy that, through cellular respiration, can later be released to fuel the organism's activity
>
> **Photomorphogenesis:** 'Photo' means 'light', 'morpho' means 'shape,' 'genesis' can be translated as 'creation of.' So, it's using light to create a certain plant shape.

Light can do a lot more than just change the growth pattern of a plant, though. It can trigger or delay flowering and fruiting, change chemical composition and taste, among other diverse reactions.

Choosing the right spectrum for specific plant is essential for crop yield but it is also a question of ensuring that the electrical energy used to drive the growth light panel is used optimally by generating light photons with the highest impact on plant growth and thereby crops produced with the right quality. The optimal spectrum will increase the yield.

The optimal spectrum for a specific type of crop can be selected based on knowledge and experience but more accurately by conducting controlled growth experiments using different spectra for comparison of crops produced and its quality. Even small changes in the composition of a spectrum can led to significant changes in yield (as most as 50%). Moreover, most plants and yield will benefit from using different spectra during the life cycle of the plant from nursery phase to full grown plant ready for harvest.

While there is no doubt that growth light spectrum is important, accurate and optimum light intensity is also crucial.

2. Light Intensity (Density)

PPF (Photosynthetic Photon Flux) measures the total amount of light produced by a growth light in terms of micromoles of photons produced per second, µmol/s.

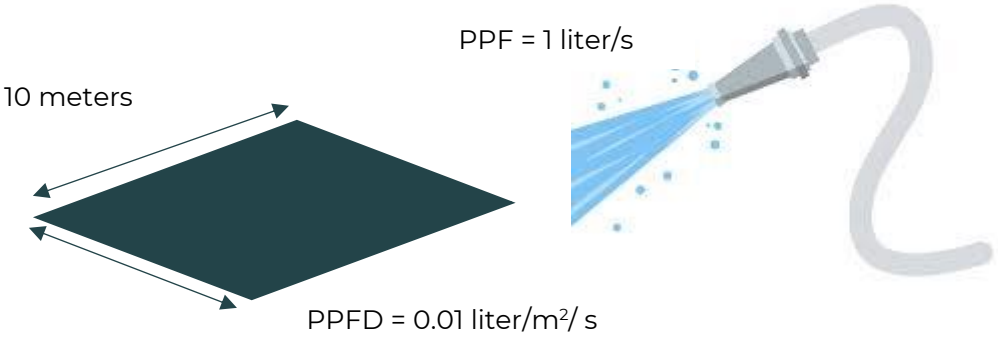
1 µmol/s = 6.022 x 1017 light particles (photons) hitting an area in one second

This is an important number because unlike PPFD (which will be explained below) it can't be manipulated and tells you the full amount of light energy coming from the LED growth light. For comparison you can think of a water hose with water flow: the photon Flux (µmol/s) would then correspond to liters of water per second (liter/second) coming from the hose.

PPFD (Photosynthetic Photon Flux Density) on the other hand measures the amount of micromoles of photons striking a square meter per second, µmol/m2/s.

1 µmol/m2/s = 6.022 x 1017 light particles (photons) hitting a m^2 area in one second

With the example of the water hose, the Flux density becomes 0.01 liter/m^2/s if all the water (1 liter/s) from the hose is distributed equally over a 10x10 meter (100 m2) large lawn.



Full daylight sun at noon in the summer is around 2000 µmol/m^2/s but plants need far less, because the Sun's intensity is only that bright for a small portion of the day and because the angle of that intensity changes throughout the day, providing that much light for an extended period of time would very likely be damaging to plants.

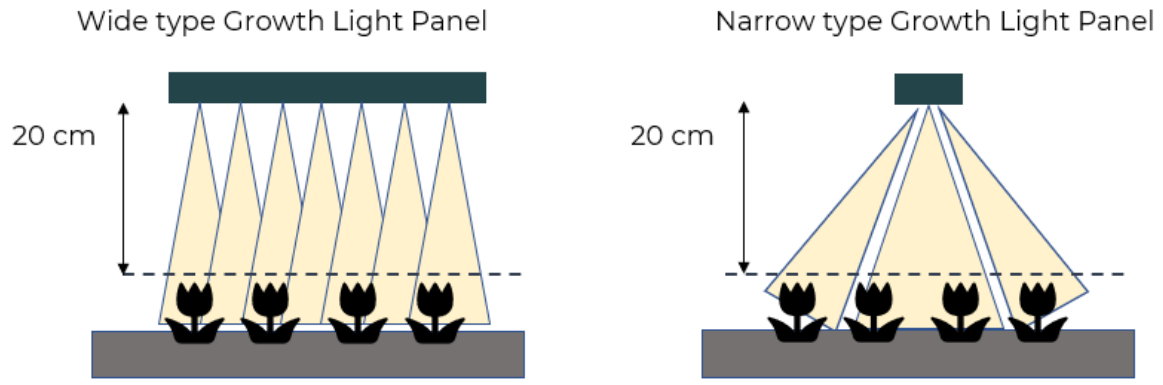
Depending on the type of plant, at levels greater than 800-1000 µmol/m^2/s the plant can't absorb the light anymore and energy is lost. This means that plants can be exposed to more light than this, but it likely not lead toa huge change in outcome (yield). In reality, typical optimal levels for light applied is typically 200 µmol/m^2/s for many plants. There are, however, some type of plants like cannabis that need levels of up to 600-800 µmol/m^2/s.

Measurement of PPFD is highly depended on how close to the growth light panels the measurement is performed.

A growth light manufacturer should therefore always report what distance the PPFD numbers were measured at (e.g., 20 cm) below the growth light and should be an average number measured across the grow area if the homogeny of the light is low.

For indoor farming it is important to ensure that all light from the light panels will reach as much of the plants as possible to increase whole photosynthesis of the plants.

As different growth light panels have different form factors and spreads light differently, it is vital that intensity (PPFD) is determined and benchmarked at the same distance from the panel or the electrical power to the light panel is adjusted so the PPFD becomes identical when measured at the plant's position.



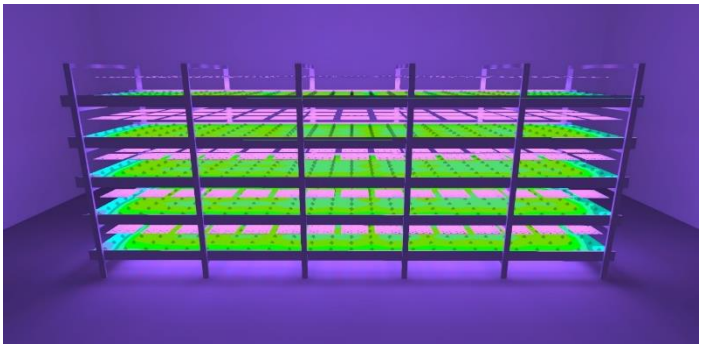
3. Wattage Draw (Power consumption)

The power consumption should be minimized and is very important as a light panel normally are powered on for up to 12-14 hours per day. The power consumption to be considered shall be wall-plug-consumption and shall therefore include any electrical driver (power supply) as the energy loss in a LED driver is typically 7-10%.

In order to compare two different types of growth light panels, the power consumption required to produce the exact same amount of PPFD (Photosynthetic Photon Flux Density) shall be compared. The PPFD must be measured at the location of the plants below the light panels for a benchmark to be valid.

4. Coverage Area and Homogeneity

Each light panel can be used to illuminate a certain grow area. Most light panels are designed to be used together and placed in a row or a matrix to increase the light homogeneity and more efficiently use all the light energy from the panels. An important metric is therefore how many light panels required pr square meter (m2) of growth area. More light panels required will mean more initial cost (capex) and installation cost. The homogeneity is also important to considered as low homogeneity will lead to an uneven growth of the plants across the illuminated growth area.



5. Lifespan

The lifespan of the light panels is an extremely important metric. Typical lifespan is claimed to be several years and is often based on the expected lifespan of the specific light emitting diodes used in the light panel construction.

The lifespan is, however, highly effected by the actual temperature of the light panel (lower temperature leads to longer lifespan) and the harsh environment in an indoor farming facility will lead to lifespan degradation and in some cases compete failures after few years of operation. A long lifespan for a light panel in a harsh environment with high humidity requires a light panel design for which the LED diodes are encapsulated Open structures will not last long in practice as the LED and electronics are exposed to moisture due to high humidity and water from cleaning processes

6. Maintenance costs and Ease-of-cleaning

Most light panels do in general not require any specific maintenance or parts that needs to be replaced over its expected lifespan. Some type of high-power light panels may, however, include active cooling that could need service regularly.

It is necessary to clean the light panels occasionally to keep the grow area facility free from, e.g., fungus. The cleaning process needs to be considered as cost of maintenance. Some growth light panels may have to be demounted for cleaning whereas others can be sprayed using a water hose while the light panels remain in place.

7. Price and Installation Cost

The price and installation cost of a light panel is an initial investment an important metric to consider and shall be included in a total-cost-of-ownership analysis together with all the other 6 factors listed above.

Conclusions and recommendations

Benchmark of different types of growth light panels requires a structed and detailed comparison of several important metrics including light Intensity, power consumption, coverage area (+homogeneity), lifespan, maintenance costs and ease-of-cleaning, price and installation cost, and yield.

It is important that any comparisons are made under the same comparable conditions. If for example power consumption for two different light panels are compared, the consumptions must be determined and calculated pr square meter of grow area with a predefined specific light intensity (PPFD) at the plant's locations below the lamp. Only under such equivalent conditions a benchmark can meaningful be made.

It is also our recommendation that detailed growth experiments are conducted to validate the growth light manufacturers specifications and determine yield under specific and comparable conditions using an optimal spectrum. If not done in a structured way, there is a high risk that any conclusions may be completely wrong.

For more information about vertical farming equipment or advice on lighting options to construct a vertical farm, please visit ledibond.com or send an email to sales@ledibond.com.