Are Your Plants Getting All The Light You Paid For?
Understanding Light Intensity Relative to CO_2 Concentration Levels

Everyone understands that there is a correlation to CO_2, light, and net photosynthesis activity, but rarely are we given easy useable information in respect to the proper balance of CO_2 and light. **Fully understanding this light/CO_2 relation is extremely important to assure the maximum benefit from supplied light as well as finding the optimal cost/profitability point.** Our feeling is that many indoor gardeners and even large greenhouse growers are not optimally taking advantage of the available light and CO_2.

There have been numerous studies performed evaluating photosynthesis rate as a function of light intensity for various fixed CO_2 concentrations as well as various CO_2 concentrations for various fixed light intensities. These studies show how the photosynthesis rate changes, including diminishing returns characteristic and points of saturation. We found a few studies that presented data in a form that we could extract information to formulate a very general formula relating CO_2 concentration and light intensity to assure that the light is being used as optimally as possible. This is particularly important for artificially lit environments where the cost of light is significant.

The formula present should be considered a very general guideline and a good estimate; at this time we have not had the opportunity to provide any serious rigor to the math and analysis. We did look at a few studies and were able to arrive at very similar conclusions independent of each other. We also found this formula to be consistent with some industry rule of thumbs, so it all points to it being a reasonable result. The difference is that this formula can help dial in a more precise applications of light and CO_2. We have also attempted to define a suggested optimal target range for light and CO_2 usage.

Note: ***These values should be very much in the ballpark; this analysis is very cursory and preliminary. Values are shown for high DLI crops over 20 Mole/M^2·Day. Low DLI crops less than 10 Mole/M^2·Day will likely not require CO_2 supplementation above normal atmosphere. Crops requiring 10 to 20 Mole/M^2·Day may benefit from CO_2 supplementation at 500 to 800 ppm depending on actual PPFD.***

For High DLI crops:

< 300 µMole/M^2·S	Ambient CO_2 (~350 ppm)
>300 µMole/M^2·S	Supplement CO_2 to about 1.3 to 1.6 ppm per µMole/M^2·S of light

As a general formula to high DLI crops it would read:
CO_2 supplementation (PPM) = 1.5 x Light PPFD

Noteworthy Values for high DLI crops

750 to 1000 µMole/M^2·S	Approx. Ideal economic point with about 1000 to 1600 ppm CO_2.
500 µMole/M^2·S	Approx. point of significant diminished return at ambient CO_2.
700 µMole/M^2·S	Approx. point of light saturation at ambient CO_2 (~350 ppm).
1000 µMole/M^2·S	Approx. point of significant diminished return with added CO_2.
1500 µMole/M^2·S	Approx. maximum light saturation point with CO_2 supplementation.

Note: While light Intensity values above 1000 µMole/M^2·S with additional CO_2 supplementation will yield a greater rate of photosynthesis, but it will be at a diminishing rate and may not be economically justified depending on crop value and production cost.

Light PPFD (µMole/M^2·S)	CO_2 Concentration (ppm)	
<300	350 (ambient)	350 ppm is approximate normal
300	350 - 500	ambient CO_2 concentration.
400	500 - 600	
500	**600 - 750**	
600	**800 - 1000**	**Typical range of light intensity used for**
700	**900 - 1100**	**indoor grows of a high DLI crop is about**
800	**1000 - 1200**	**500 to 1000 µMole/M^2·S.**
1000	**1300 - 1600**	
1200	1600 - 2000	Extremely high light intensity for
1500	2000 - 2500	indoor application.

Noteworthy comments

1. Artificial light is expensive, be sure to fully utilize the light with an appropriate concentration of CO_2 present.
2. If the grow environment is somewhat closed and CO_2 supplementation is not used be sure that CO_2 drawdown is not an issue. Drawdown is the reduction of CO_2 concentration resulting from the plant's consumption of CO_2. The solution is ventilation with fresh air or to add CO_2 supplementation.
3. If in doubt about the proper CO_2 concentration; error to the high side.

Summary Conclusions

Grow light manufacturers will often advertise their products high intensities as a way of promoting their products superiority over a competing product or technology. But with these intensities, having the proper levels of CO2 is essential as the plants must have adequate levels of CO2 in order to assimilate the light being delivered to them. Inadequate CO2 levels mean that the light being generated may very well be wasted energy as the plant is not capable of processing it without enough CO2 being present.

In high DLI plants the benefits of CO2 supplementation are well known but the proper use may not always be obvious. It is extremely important to use enough CO2 and to maintain those levels to assure the maximum benefit from the supplied light. When evaluating CO2 usage a different perspective comes to light in evaluating overall general efficiencies related to an optimal quantity of lighting used and evenness of light distribution over the grow area. To assure the most benefit from the cost of supplied lighting these factors need to be evaluated in the context of determining absolute profits based on the diminishing returns of increased production costs.