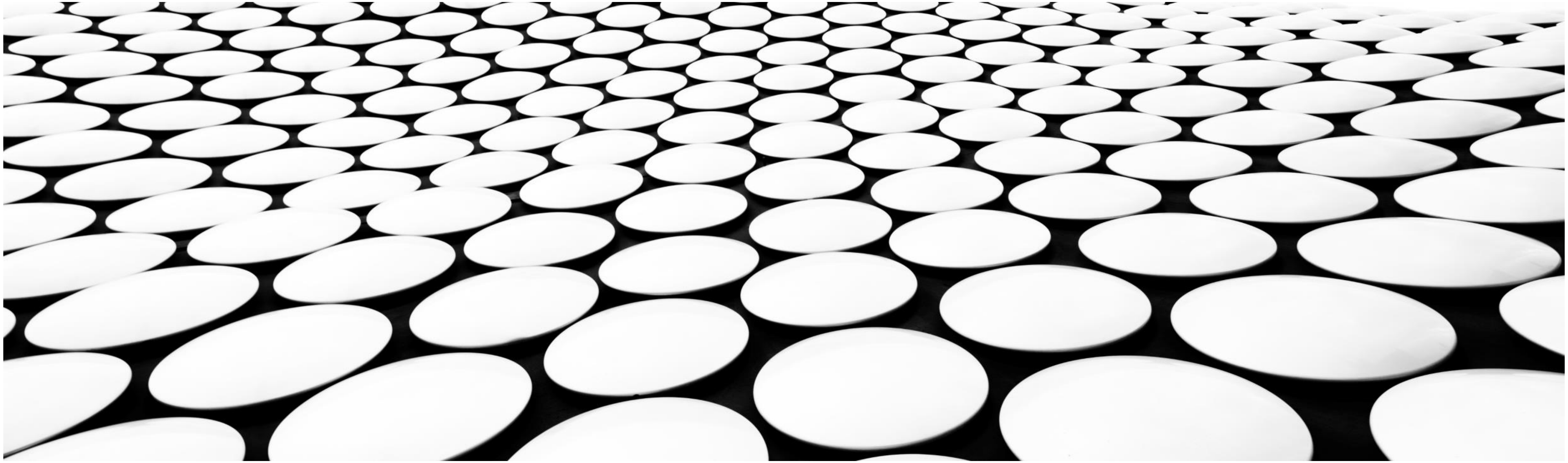
DEFINING PHOTOSYNTHETIC PHOTON FLUX DENSITY (PPFD)

OPTIMIZED LED LIGHTING ARRAY FOR HORTICULTURAL APPLICATIONS

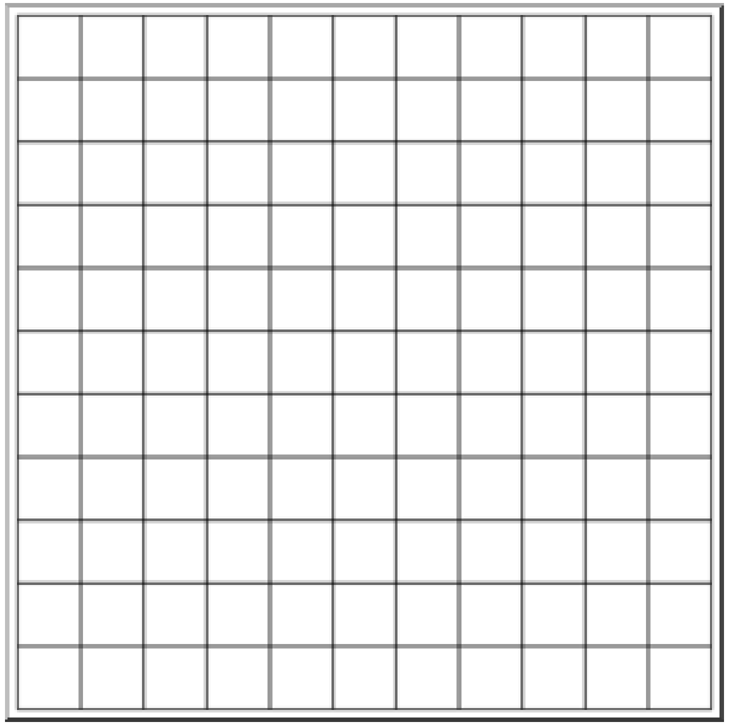


ALGORITHM FOR MEASURING THE EFFICACY OF LIGHTING ARRAYS

We have developed a patented variance measurement algorithm which generates 2D and 3D illustrations that enable you to clearly see the significant improvement our lighting arrays offer over competitors in uniformly saturating a given area with photosynthetically active radiation (PAR).

TESTING MAT

An 5-foot by 5-foot, 11 x 11 grid testing mat is screen printed and a measurement of photosynthetically active radiation (PAR) is collected at each of the 121 points on the mat. These measurements serve to represent “PAR Spikes”.



EQUATIONS FOR GENERATING NEW METRICS

- Generating **APSv** Values
  - (1) Average PAR Spikes to produce Averaged PAR Spikes (**APS**).
  - (2) Deduct each PAR Spike from the **APS** value and use the absolute value of each of those results to generate Deducted PAR Spikes (**|DPS|**), then average these values to generate the Averaged PAR Spike Variance (**APSv**) metric.

  - Equation example for experiment in which 121 points are tested.
    - $$\textbf{APSv} = \frac{1}{121} * \sum_{i=|DPS|}^{121} X_i$$ ➡

Elite **APSv** = 185.419985

HPS **APSv** = 241.867632

Average PAR Spike Variance (**APSv**) Improvement of: 26.4214%

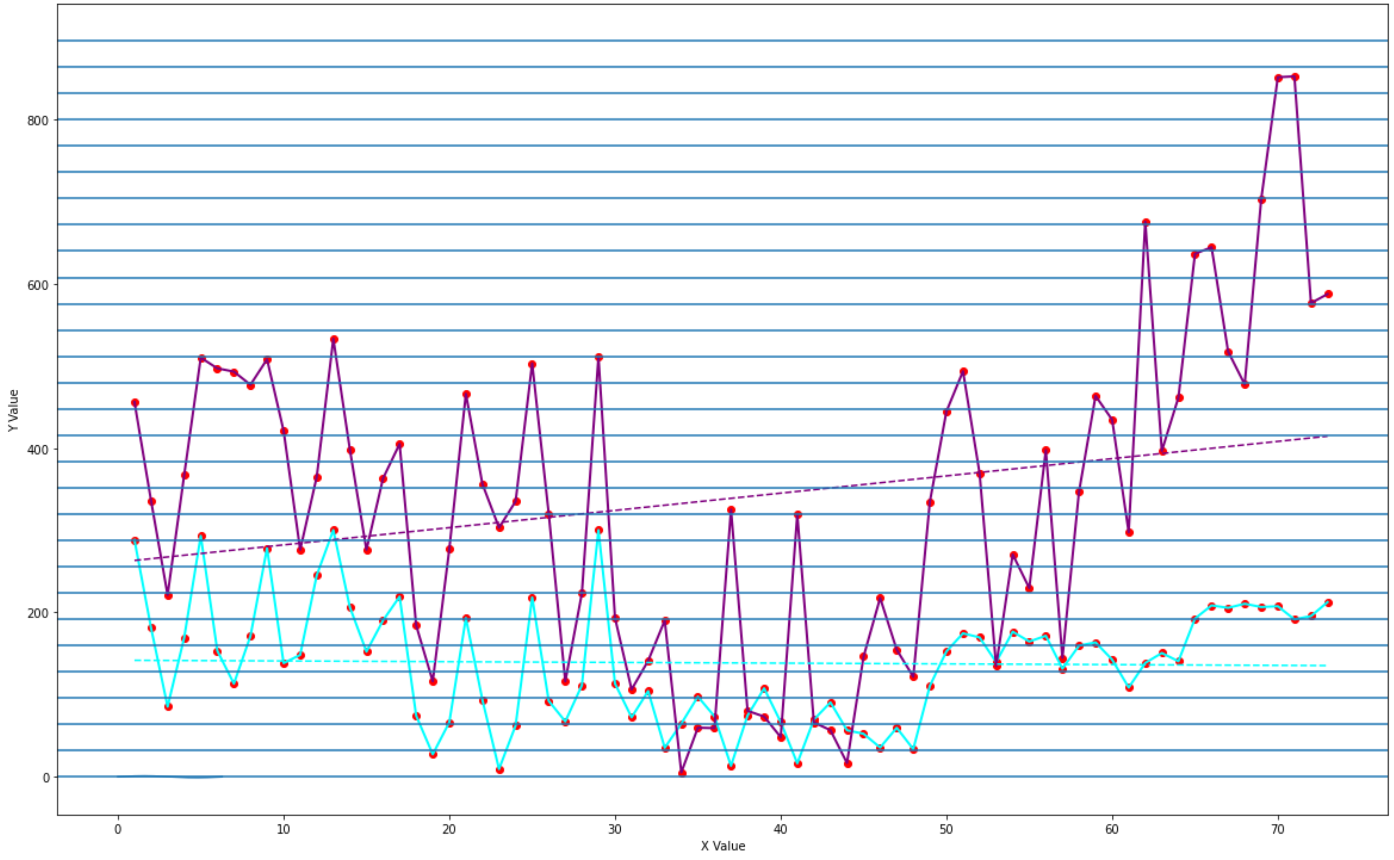
PRODUCING 2-DIMENSIONAL ILLUSTRATIONS USING THE GENERATED METRICS

- We use the |DPS| metric generated by our algorithm to generate our 2-Dimensional illustrations. These illustrations allow us to visualize the difference in radiometric uniformity between our arrays and LED competitors / traditional high-pressure sodium (HPS) lighting systems on a line graph.
- The first plot point for each line on the graph corresponds to the uppermost left point of the 5’ x 5’ square testing mat. The next plot point in each line corresponds to the next point (e.g., to the right of the first point) and the subsequent points follow the outside of the five foot by five-foot square, and then the four foot by four-foot square, and so on, spiraling inward to the center point of the three foot by three-foot square, for a total of 121 plotted points.
- You want to see as stable a line as possible, as well as a line sitting as low on the graph as possible. We can see on the next slide that the differences are clear.
- Note that the 1000w HPS’ trend line (purple) crosses 7 lines on the graph, and our trend line (blue) does not deviate from its starting line. This is very difficult to achieve in a lighting system.

1000w HID:HPS vs. 957w Elite

24" Mounting Distance

No Reflective Walls



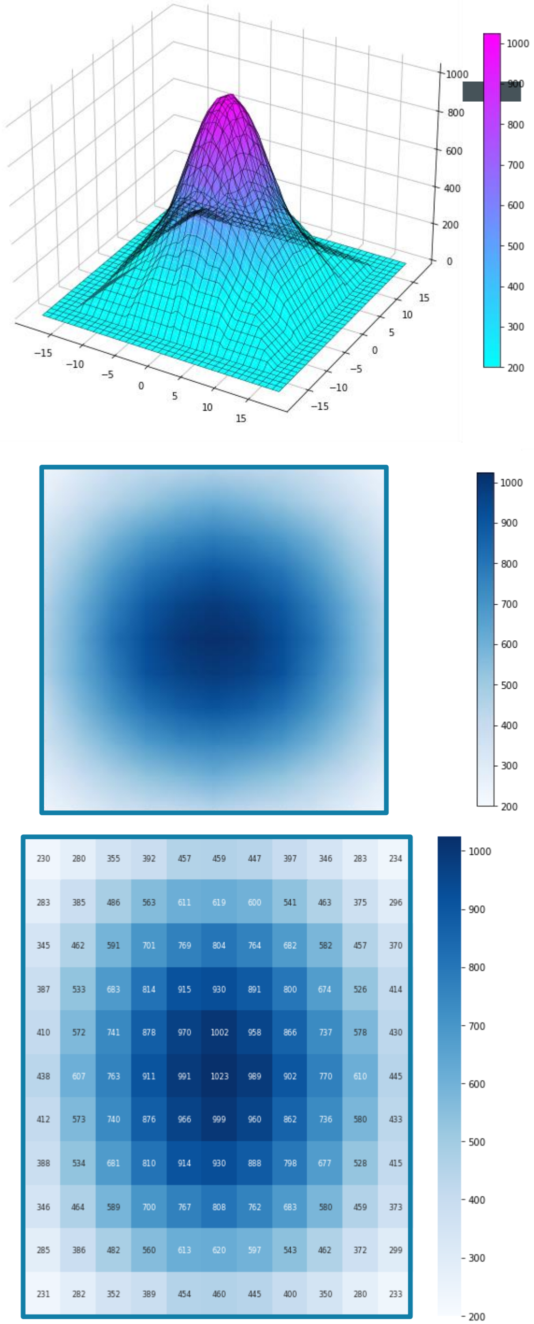
1000w HPS Averaged PAR Spike Variance (**APSv**): 241.867632

957w Elite Averaged PAR Spike Variance (**APSv**): 185.419985

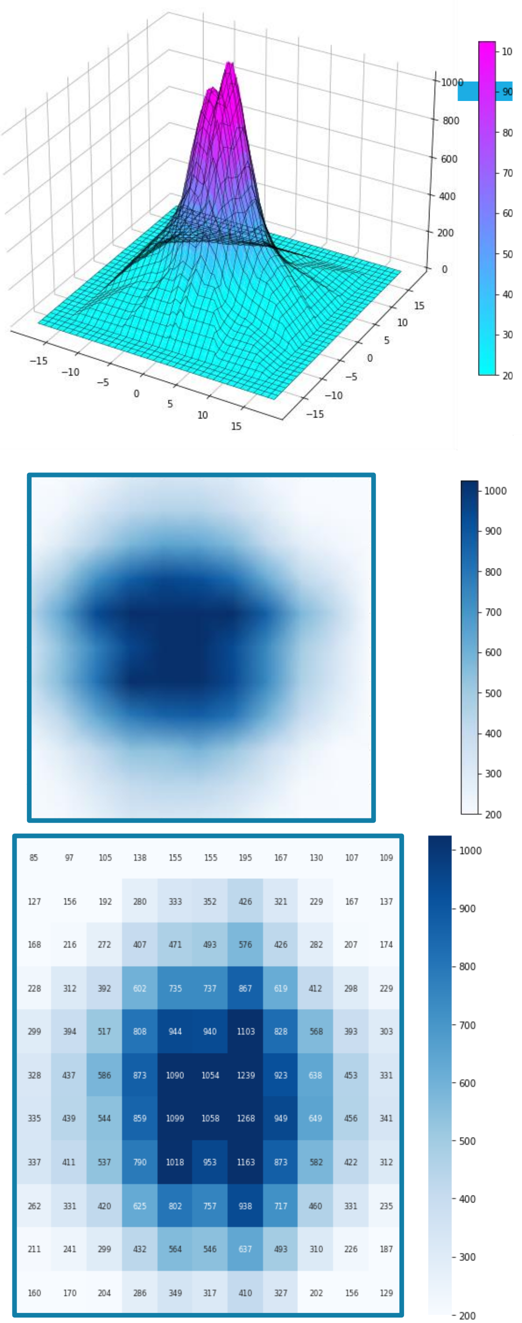
Elite vs. HPS = **26.4214% APSv** Improvement

PRODUCING 3-DIMENSIONAL ILLUSTRATIONS USING THE GENERATED METRICS

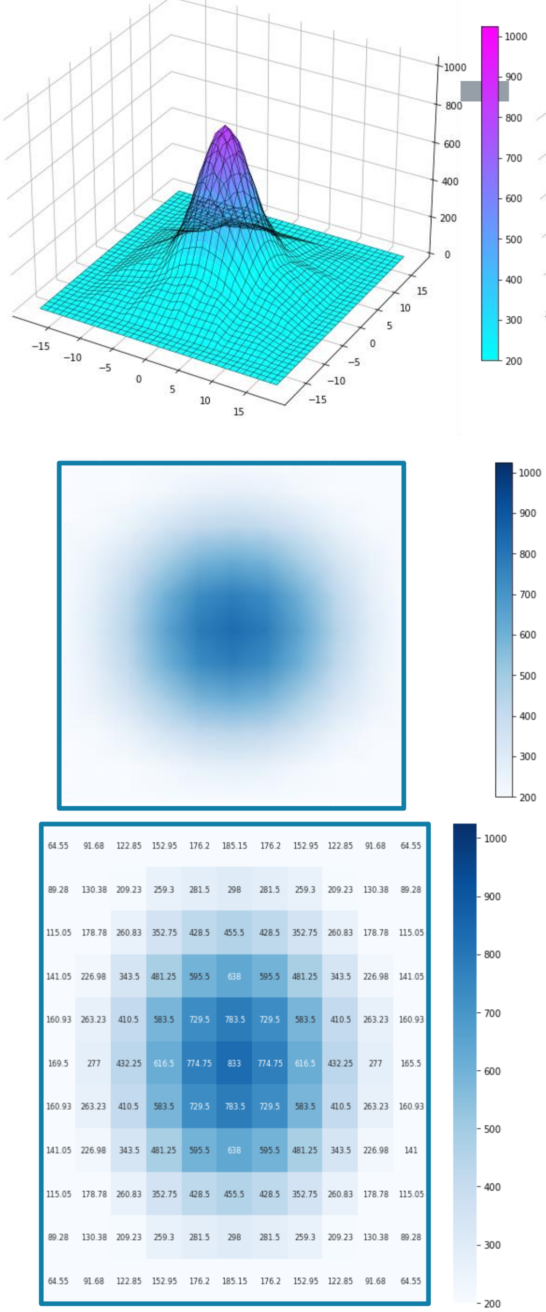
- To generate 3-Dimensional illustrations, we wrote a script in Python that draws 3-Dimensional photosynthetic photon flux density (PPFD) surface graphs. These enable you to truly visualize how the PAR is behaving in the testing environment.
- The script simulates our 5-foot by 5-foot, 11 x 11 grid testing mat and raises each PAR spike along the Z-axis relative to the amount of PAR collected at each point.
- Imagine your canopy is in the middle of the plot; you want that area to be *encapsulated* with light. As you can see in the next slides, there are some significant differences in how well the photons produced by different lighting systems behave.
- Also included in the following slide are PAR heat maps for our LED solution versus HID:HPS and LED competitors.



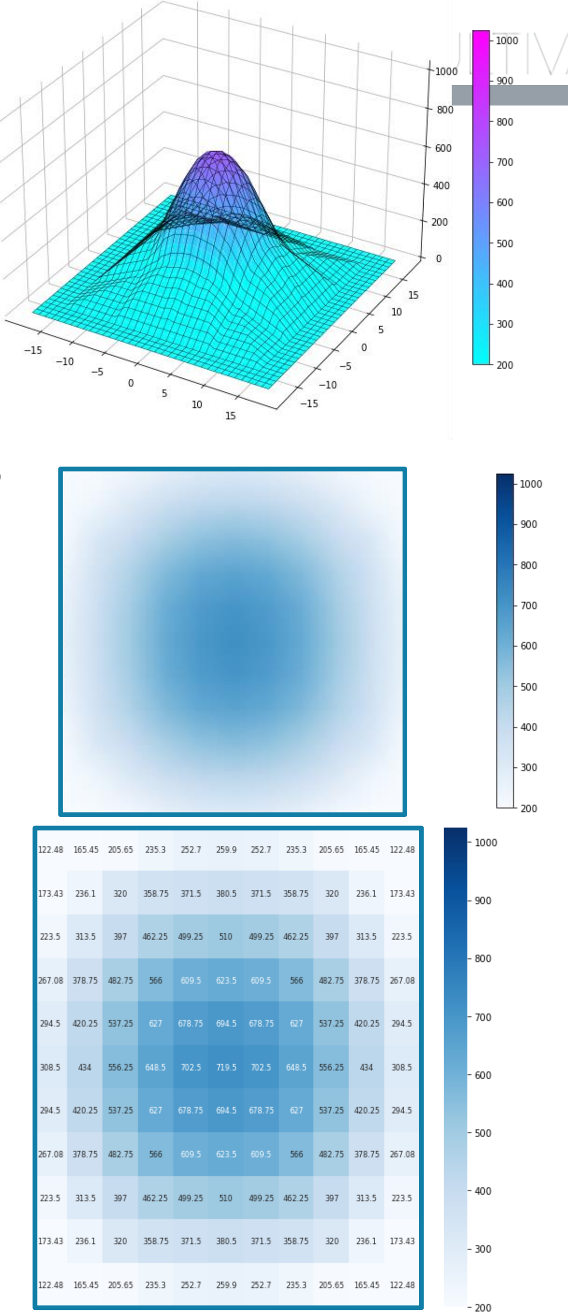
LED Cultivation “Elite”



1000w HID:HPS



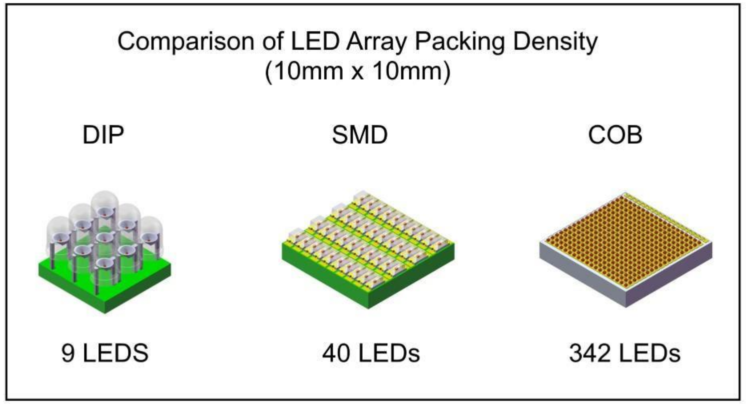
HLG 550 V2 R-Spec



Gavita Pro 1700e

WHAT ARE SOME DIFFERENCES BETWEEN US AND OTHER LED COMPETITORS?

- The principal issue we have solved is in uniformly saturating a given area with photosynthetically active radiation (PAR). This results in the highest yield per square foot on the market.
- Our lighting arrays' photon output is primarily sourced from Chip On Board (COB) technology and supplemented with Surface Mount Technology (SMT), whereas competing technologies' photon output is sourced solely from SMT. COBs are the most cutting-edge LED technology available on the market. Improvements over SMT include a higher chip packing density, resulting in a higher quality beam of light; higher photon production efficiency, resulting in less heat produced / more usable light per watt; and 360-degree multi-directional photon emission, which enables more areas of your canopy to receive PAR.
- With 25 separate LED modules consisting of precisely 5,000 LEDs, our arrays are comprised of more LED modules and LED chips than anything else on the market.



CONCLUSION

If the PPFD is spatially uniform at an appropriate level in a plant canopy regardless of the canopy's depth, the net photosynthetic rate of the whole plant canopy increases significantly, and the decrease in net photosynthetic capacity of lower leaves due to their senescence is prevented. (Zhang et al., 2015; Joshi et al., 2017)

Even distributions of photosynthetic photons and air currents to all parts of all leaves maximize photosynthesis and thus plant growth. A uniform light environment in a plant canopy has the following effects:

(1) Geometrical relationships between the source (photosynthesizing parts) and sink (accumulating parts of translocated carbohydrates) of plants are changed; (2) All leaves of a plant canopy relatively equally act as producers of carbohydrates; (3) Senescence of lower leaves due to low PPFD is suppressed; and (4) Phytohormone balances in individual plants are changed.

References:

Joshi, J., Zhang, G., Shen, S., Supaibulwatana, K., Watanabe, C., Yamori, W., 2017. A combination of downward lighting and supplemental upward lighting improves plant growth in a closed plant factory with artificial lighting.

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