GROWRAY
LIGHTING TECHNOLOGIES

WHITE PAPER 2018

Controlled Indoor Head-to-Head Comparative Yield Study:

Grow Ray LED vs. Double Ended High Pressure Sodium System

Cultivation Partner: Gud Gardens, Grants Pass, Oregon

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Introduction

Grow Ray Technologies, in partnership with commercial cultivators Gud Gardens in Grants Pass Oregon, performed and concluded a comprehensive comparative LED yield study between two identical grow rooms: One containing all Grow Ray LED fixtures, the other containing all Double Ended High Pressure Sodium fixtures. No supplemental or intra-canopy lighting was used.

Each 30-light flowering room was designed to 'mirror' the other and contained duplicate strains for a true head-to-head test. Both the Grow Ray LED and the Double Ended HPS fixtures were identical in number, with each fixture covering sixteen square feet.

Nutrient recipe was identical for each room, as was all associated cultivation infrastructure. Both rooms shared a single environmental controls system.

The yield study hypothesis and primary goal was to prove that Grow Ray Technologies' LED fixtures, when specifically paired with the Company's LED Whole-Systems Yield Optimization Protocols (SOP's), would:

- Out-perform and out-produce DE HPS in a head-to-head, strain-to-strain controlled grow
- Reduce overall kW consumption by greater than 40% per square foot of cultivation space
- Increase plant health, visual and physical quality (including trichome production and density)
- Provide an economic case study demonstrating the superiority of Grow Ray LED from an ROI/IRR perspective vs. DE HPS
- Validate the material benefits of the specific parameters and protocols outlined in Grow Ray's LED Optimization Protocols
- Provide Gud Gardens with a fantastic crop and exceed expectations

The test concluded in July 2018, with results that did exceed expectations: The Grow Ray LED room produced substantially more dry-weight yield than the DE HPS room. Details are outlined below.

The Problem & Opportunity

Since 2016, LED lighting has begun to 'cross the chasm' between limited early adoption and mainstream acceptance as a viable primary lighting technology for commercial cannabis. The adoption rate of LED's in the cannabis space is increasing for the following reasons:

- Increases in efficiency of LED diodes and drivers that now out-perform DE HPS in PAR-per-Watt
- Advances in form factor by LED manufacturers: Bar-based systems delivering a more uniform distribution of PPFD
- Spectrum advances: Full spectrum solutions currently available vs. incomplete "Red & Blue Only" spectra of early LED solutions
- Shared, documented experiences with LED resulting in successful usage protocols
- Prices of LED solutions coming down
- Price & Regulatory pressures driving growers to use more efficient productions methods and technologies

However, the adoption rate of LED lighting solutions in the cannabis space is still well below forecasts, and High Pressure Sodium lamps are still the dominant choice among most commercial growers. This is true for the following reasons:

- Viable LED solutions (efficiency, price, performance) have only been available for about two years
- HPS systems are low cost and have years of proven results despite their inefficiencies, high OP-EX requirements and other shortcomings
- The cannabis industry is fragmented, disintegrated and many growers still use 'pre-legal', inefficient growing methods and are hesitant to change
- LED still has a higher CAP-EX requirement
- Results from early-stage LED grows were poor, and the resulting bad reputation has been difficult to overcome

- Most LED manufacturers do not have robust, science-focused teams capable of delivering next-gen LED solutions
- LED optimization has been poorly understood; successful LED use requires a 'paradigm shift' is certain cultivation methods that few growers and manufactures understand

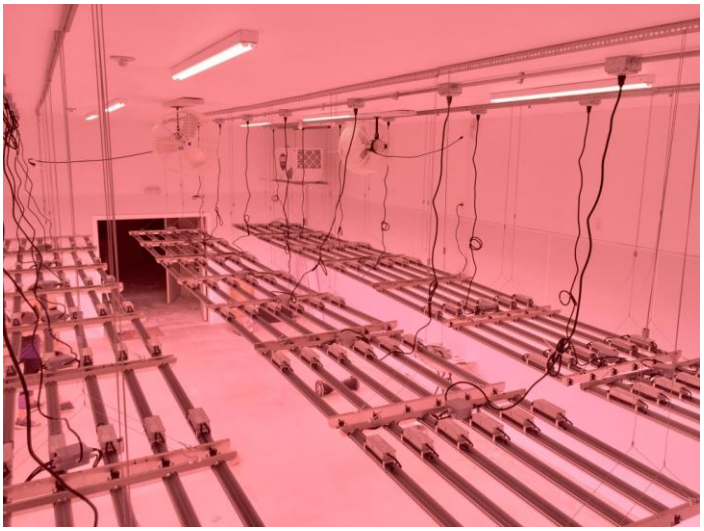
Grow Ray Technologies' PhD-driven team of engineers and bio-scientists have not only developed the first viable, industrial-grade cannabis LED solution, but have also created a data-backed series of LED Optimization Protocols (SOP's) that "unlock" the vast potential for this technology to increase yields and save energy. This White Paper serves as a case study for the effectiveness of both.

The Set Up

The test was performed in a way that was designed to be a true "apples to apples" comparison between DE HPS and Grow Ray LED fixtures. The only difference between the DE HPS room and Grow Ray LED room were the controlled environmental conditions in each. The Grow Ray LED SOP's require very specific, fluid set-points for temperature, humidity and CO2. These parameters were scheduled into the Gud Gardens controls system and monitored via a cloud-based app.

Each room contained thirty lights, with each light covering sixteen square feet of canopy above 4' X 8' rolling trays. All strains were introduced to both LED and HPS rooms at the same time and flowered for the same duration of 8 weeks.

Installation & Cultivation:



The Results

Main Takeaway #1:

The dry weight yield results significantly favored the Grow Ray LED room, with an aggregate increase of 11.29% when compared to the DE HPS room. Only one of the eight strains performed better under DE HPS lights than LED.

Main Takeaway #2:

The LED room could have performed even better. Although very successful in proving out Grow Ray's technology and SOP's, several factors contributed to limiting the yield potential from hitting peak numbers:

1. Environmental controls system did not perform to standard. There were several instances when the set points were not achieved, and temperatures/CO2 were sub-optimal over a 24 hour cycle. Specifically, 'lights off' temperatures remained above the targeted, optimal levels throughout the test.

2. The Dehumidification system had a hard time tracking to the correct Vapor Pressure Deficit targets.

3. The plants were not Veg'd under LED and entered the flowering room with sub-optimal root mass and nodal spacing. The Veg rooms suffered from low PAR values.

Despite these hiccups, the test numbers fully achieved the intended results. Additionally, the issues that contributed to limiting the yields are easy fixes and do not constitute any sort of barriers to future improvement and continued success.