SPECIAL REPORT

STATE OF THE CANNABIS LIGHTING MARKET

7 YEARS OF RESEARCH

IN PARTNERSHIP WITH

FLUENCE

CANNABIS BUSINESS TIMES

A COMMITMENT TO INNOVATION

We are all acutely aware of the complex set of headwinds the cannabis industry is facing. Supply chain shortages continue to drive up capital improvement costs, cannabis surplus in the U.S. is forcing retailers to sell their products at deep discounts and inflation hangs over consumers worldwide. It's tough out there. But, since Fluence's inception, we have experienced the resilience of this industry. Cannabis professionals by nature are adaptive and creative. In spite of today's obstacles, their forward-looking ingenuity has never shone brighter.

The industry's resilience and innovation are clear in this year's "State of the Cannabis Lighting Market" report. For the first time ever, at least 70% or more of study participants from commercial indoor or greenhouse operations with supplemental lighting used LEDs in propagation, vegetation and/or flowering. Moreover, LED usage has increased by more than 50 percentage points since the study's first year in 2016. These numbers are not only massively impressive, but also demonstrate a deeply inspiring shift being driven by a collective grower commitment to instill innovation into the craft of cultivation and deliver top-tier products to consumers.

Cultivators are looking for technological advancements for greater control over factors such as light intensity, spectra and energy costs. They're interested in fostering sustainability throughout their supply chains. They have pushed lighting companies to produce realistic, usable fixtures for facility retrofits and are continuously exploring optimal lighting strategies through solutions such as side, intercanopy and sub-canopy lighting.

The pioneering spirit and relentless pursuit of excellence that cannabis growers have always brought to the industry has never been more apparent. At Fluence, we are committed to meeting their ambition, purpose and vision with best-in-class tools and technology to realize success. We work closely with growers to increase average yields and advance their scientific understanding of light's impact on plant genetics and quality.

This year's report and the industry-leading research performed by our global team of horticulture experts continue to affirm the important role of lighting in achieving even more efficient and productive economies of scale. Being led by science means we're dedicated to delivering technology that improves the interaction between light and life and to helping our cultivation partners drive operational efficiencies at every stage of their grows.

To helping the world grow smarter, together,

DAVID COHEN
CEO, Fluence

PHOTO COURTESY OF FLUENCE

> **THE PIONEERING SPIRIT AND RELENTLESS PURSUIT OF EXCELLENCE** THAT CANNABIS GROWERS HAVE ALWAYS BROUGHT TO THE INDUSTRY HAS NEVER BEEN MORE APPARENT.

ILLUMINATED GROWTH

BY **JOLENE HANSEN**

THIS YEAR MARKS the seventh annual *Cannabis Business Times* "State of the Cannabis Lighting Market" report. This research serves as a reminder of how far commercial cannabis cultivation has advanced in the intervening years. Since this exclusive cannabis lighting research first published in 2016, the industry has collectively benefited from a growing body of scientifically rigorous cannabis research that was impossible a few short years ago.

While the increasing wealth of cannabis knowledge impacts all aspects of cultivation, perhaps no area has proved more exciting and surprising than the relationship between cannabis and light. From hands-on, in-house lighting trials to university and manufacturer research, growers are pushing genetics to potentials yet unknown. What's been discovered is changing the lighting market and the ways cultivators grow. Yet, there's still much to learn.

This 2022 "State of the Cannabis Lighting Market" report was made possible with support from Fluence and conducted by third-party research organization Readex Research. These results and comparisons to previous *CBT* reports reveal valuable insights into cannabis lighting trends and practices. They also reinforce the importance of the benchmarks established by this significant *Cannabis Business Times* research.

Jolene Hansen is a freelance writer specializing in the cannabis, hemp and horticulture industries.

ABOUT THE RESEARCH & PARTICIPANTS

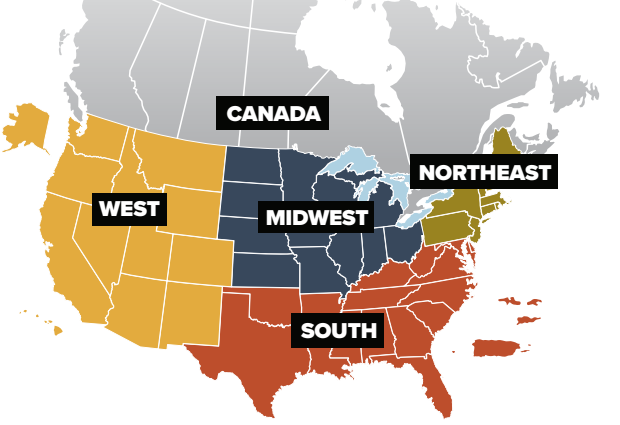
Readex Research conducted the study and compiled the data for the 2022 "State of the Cannabis Lighting Market" report. The questionnaire was sent to all emailable, active, qualified subscribers of *Cannabis Business Times* magazine located in the United States, Canada or other (unknown) North American locations in July and August 2022.

To examine lighting trends among cultivators specifically, most results were based on the 137 participants who grow cannabis in an indoor facility or a greenhouse, with or without supplemental lighting. Data was further refined to exclude non-commercial operations. Unless otherwise indicated, results reflect research participants who cultivate cannabis commercially indoors and/or in greenhouses, with or without supplemental lights.

The margin of error for percentages based on the 137 respondents who indicated they own or work for a cultivation operation that grows cannabis in an indoor facility and/or greenhouse with or without supplemental lighting is approximately ±7.8 percentage points at the 95% confidence level.

GEOGRAPHIC DISTRIBUTION OF RESEARCH PARTICIPANTS

(Participants could select multiple regions for operations with more than one location.)



In what regions does your cannabis cultivation business currently operate?

45% **22%** **6%** **24%** **26%** Other: 1%

LIGHT-EMITTING DIODE DOMINATION

When *CBT*'s first "State of the Cannabis Lighting Market" research published in 2016, 21% of participants used light-emitting diodes (LEDs) in propagation, 17% in vegetation and 15% in flowering, while other lighting types such as T5 (high output/HO lights) or other HO flourescents and high-pressure sodium (HPS) were more widely adopted across all growth stages. This year, LEDs dominate the study results.

For the first time in this report's history, 70% or more of research participants from commercial indoor or greenhouse operations with supplemental lighting used "light emitting diodes (LEDs)" in every growth stage. Across propagation, vegetation and flowering, LEDs were used by more than double the number of growers using any other lighting type.

Propagation: About three-fourths (74%) of study participants reported using "light-emitting diodes (LEDs)" in propagation, up 53 percentage points from this study's first year. "Fluorescent lights (compact, T5, other HO fluorescents)"—2016's top propagation lighting choice—were cited by 30% of participants. At 9%, "high-pressure sodium (HPS) lights" ranked third for propagation lighting this year.

Vegetation: 70% of participants reported using "light emitting diodes (LEDs)" for vegetation—another 53 percentage-point increase from 2016. "Fluorescent lights (compact, T5, other HO fluorescents)" were used by 17%. 2016's top-ranked veg lighting—"metal halide (MH)"—was used by 12% of participants, down 31 percentage points from 2016.

Flowering: 71% of 2022 participants used "light emitting diodes (LEDs)" for flowering, an increase of 56 percentage points from 2016. "High-pressure sodium (HPS) lights," used by 30% of participants, dropped 32 percentage points from their top-ranked flowering spot in this study's first year. "Fluorescent lights (compact, T5, other HO fluorescents)" were used by 7% of 2022 participants.

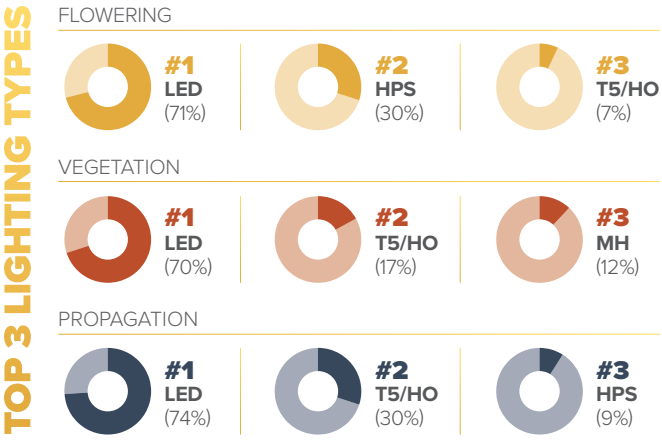
As LED technology has become the standard for cannabis lighting, reservations about LEDs have faded. Among study participants representing non-LED-powered operations, 30% plan to add LEDs for flowering within the next 12 months. Another 30% are considering LEDs for flowering within the coming year.

TYPES OF LIGHTING USED

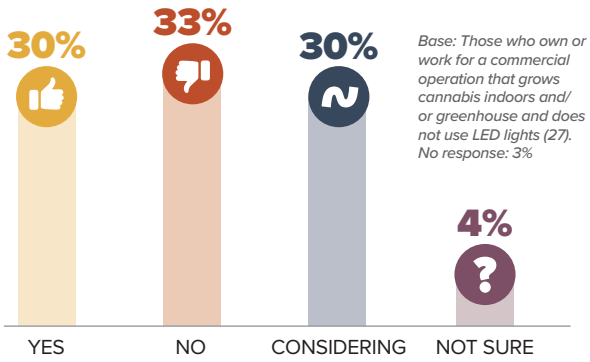
	PROPAGATION			VEGETATION			FLOWER		
	2016	2022	% pt. change	2016	2022	% pt. change	2016	2022	% pt. change
light emitting diodes (LEDs)	21%	74%	↑53% pts.	17%	70%	↑53% pts.	15%	71%	↑56% pts.
fluorescent lights (compact, T5, other HO fluorescents)*	74%	30%	↓44% pts.	37%	17%	↓20% pts.	8%	7%	↓1% pts.
high-pressure sodium (HPS) lights (including double-ended)	16%	9%	↓7% pts.	31%	11%	↓20% pts.	62%	30%	↓32% pts.
metal halide (MH) lights**	16%	3%	↓13% pts.	43%	12%	↓31% pts.	12%	2%	↓10% pts.
other	6%	1%	↓5% pts.	8%	5%	↓3% pts.	5%	4%	↓1% pt.

*Total may exceed 100% because respondents could select all that apply. Base: Participants who indicated they work for a commercial operation that grows cannabis indoors or in greenhouses: 89; *2022 data includes compact fluorescents; 2016 data combined but was separate in initial survey **In 2016, questionnaire requested specific metal halide (MH) lighting type, and participants indicated ceramic vs. quartz MH. In 2022, participants noted all MH lighting types and did not differentiate. Responses from 2016 have been combined.*

TOP 3 LIGHTING TYPES



Is your operation planning to use LED lights in the cannabis flower cycle within the next 12 months?



Base: Those who own or work for a commercial operation that grows cannabis indoors and/or greenhouse and does not use LED lights (27). No response: 3%

FACTORS INFLUENCING **LIGHTING PURCHASES**

Historically, price has been a leading factor influencing lighting purchasing decisions for flowering. That remains true with the 2022 "State of the Cannabis Lighting Market" report, but a new leader edged into the top spot this year.

Aligned with the dramatic results reported by growers and researchers experimenting with higher light intensities in this study's 2021 report, 53% of participants named "light intensity" a top-five factor driving their light purchasing decisions for flowering—up 13 percentage points from last year.

More than half of study participants named "price" (52%) and "light spectrum" (51%) as leading factors in purchasing lights for flowering. "Energy efficiency" (48%) and "must be LED" (43%) rounded out the top five.

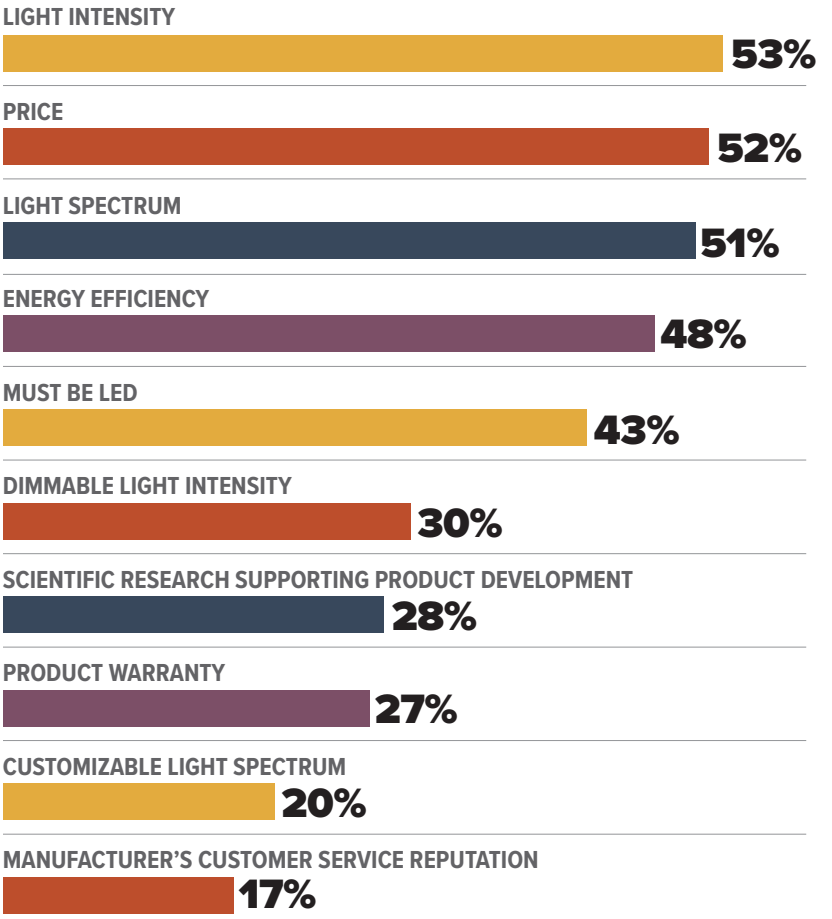
Dimmable light intensity was cited as a purchasing factor by 30% of participants. And data indicate that dimming, with regard to controlling light intensity and enhancing lighting flexibility, is becoming more important to growers.

Nearly half (47%) of research participants described lighting fixture dimming capabilities as "very important" for their cultivation operation—an increase of 11 percentage points from 2021. Only 8% indicated dimmable capabilities were "not at all important," down 9 percentage points from last year.

53%

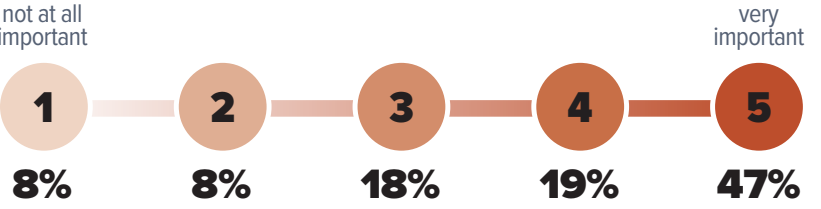
Portion of research participants who indicated **LIGHT INTENSITY IS IMPORTANT** when purchasing a lighting fixture for cannabis flowering phase

When purchasing a lighting fixture for the cannabis flowering phase, which factors are among the top five most important to you? *(Top 10 in order below)*



**Base: Participants who grow cannabis commercially in an indoor facility or a greenhouse, with or without supplemental lighting: 89*

How important to your operation is dimming with regard to controlling light intensity and allowing for greater lighting flexibility in your garden?



LIGHTING CHALLENGES MEET LED BENEFITS

As cannabis cultivation advances, lighting-based challenges faced by commercial indoor and greenhouse growers using supplemental lighting grow more complex. The interconnectedness between growing environment components is evident in the top lighting-related challenges cited in this 2022 "State of the Cannabis Lighting Market" report.

For 22% of this year's research participants, "managing energy costs" was their cultivation operation's single greatest challenge when it comes to lighting–up 7 percentage points from its top-ranked spot last year. "Managing heat load" was named by 15% of participants, compared to 10% in 2021. "Ensuring consistent/even lighting across the crops" (13%), "adjusting light distance to the canopy" (10%) and "lighting's impact on plant growth (yield, internodal spacing, etc.)" (10%) rounded out 2022's top five greatest lighting-related cultivation challenges.

This year's study reveals that perceptions about LED benefits correlate with cultivator concerns. When asked about the top three benefits to using LEDs, 83% of participants specified "energy efficiency." More than half (55%) named "low heat." Nearly one-third (31%) cited "dimming" to round out the top three benefits of using LEDs.

TOP LIGHTING CHALLENGE

2022
MANAGING ENERGY COSTS

2021
MANAGING ENERGY COSTS

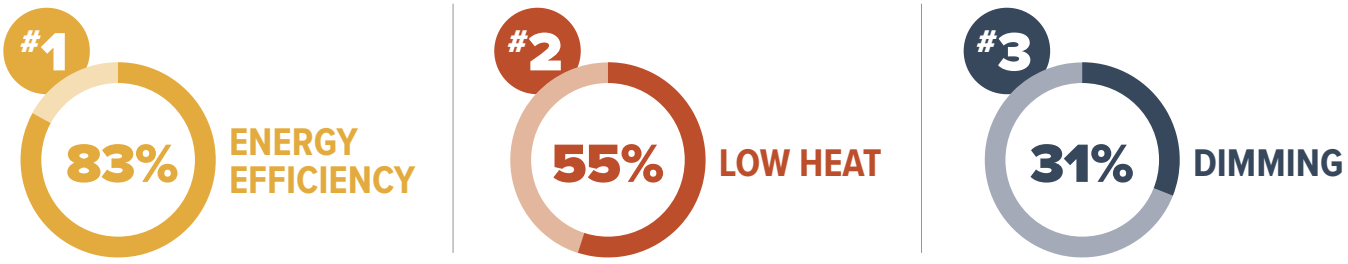
2020
ENSURING CONSISTENT/EVEN LIGHTING ACROSS THE CROPS

What is your cannabis cultivation operation's ***greatest challenge*** when it comes to lighting?

TOP CHALLENGES IN 2021		TOP CHALLENGES IN 2022	
managing energy costs	15%	managing energy costs	22%
ensuring consistent/even lighting across the crops	14%	managing heat load	15%
lighting's impact on terpene/cannabinoid content	13%	ensuring consistent/even lighting across the crops	13%
managing heat load	10%*	adjusting light distance to canopy	10%
automation	10%*	lighting's impact on plant growth (yield, internodal spacing, etc.)	10%
lighting's impact on plant growth (yield, internodal spacing, etc.)	10%*		

Base: Participants who grow cannabis for a commercial operation in an indoor facility or greenhouse with supplemental lighting: 87 Note: Percentages are rounded to nearest integer.

What are the top three benefits of using LED lighting?
(Participants could select up to three answers; top three answers out of 10 options listed below.)



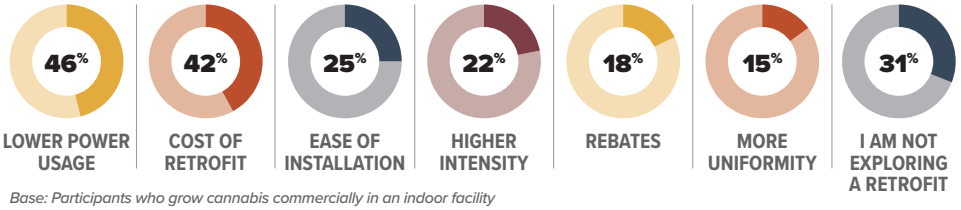
Base: Participants who grow cannabis commercially who use LED lighting for at least one growing stage: 89.

RETROFITS AND REBATE AWARENESS

For growers using non-LED lighting, many obstacles to implementing LEDs or retrofitting facilities are being overcome. New lighting technologies are making 1:1 retrofits a reality, while fixture costs and solid ROI put change within reach. Still, nearly one-third (31%) of commercial indoor and greenhouse growers using non-LED lighting aren't exploring retrofits.

For those considering a switch to LEDs, factors driving purchasing decisions provide added insights. "Lower power usage" (46%) and "cost of retrofit" (42%) were the two most common purchasing drivers for participants considering retrofits. One-fourth of participants named "ease of installation" as a top driver, while 22% noted "higher intensity." "Rebates" were a top decision driver for 18% of participants considering LEDS.

If you are considering implementing LED lighting/retrofitting your facility but are currently using a different technology, what are your top three purchasing drivers? *(Participants could select all that apply; Other: 3%; No answer: 1%)*



Base: Participants who grow cannabis commercially in an indoor facility or a greenhouse with or without supplemental lighting: 89.

AVERAGE YIELDS AND LIGHTING TYPES

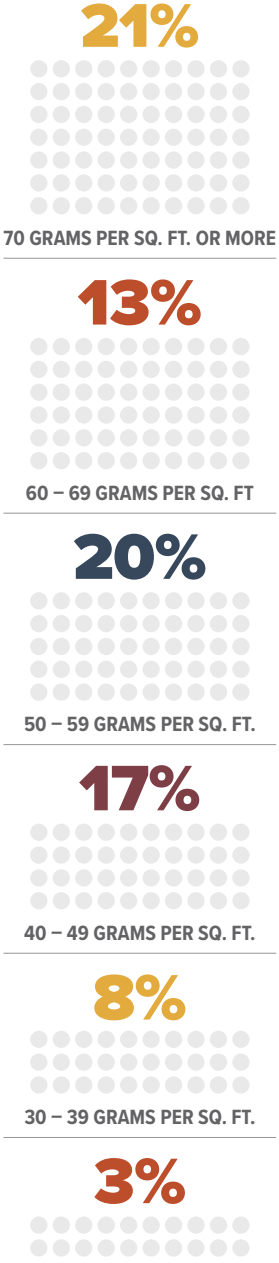
In any discussion about lighting and cannabis, maximizing yield is a primary goal. Recent research around spectra, light intensities and lighting technologies has intensified interest in where cultivation yields are currently and where they'll soon be.

When examining average yields per square foot across all genetics, two segments held the greatest percentages of research participants: 21% reported achieving "70 grams per square foot or more," while 20% averaged "50 to 59 grams per square foot." Meanwhile, 17% of participants reported average yields of "40 to 49 grams per square foot."

As lighting technologies advance and manufacturers respond to growers' needs, more cultivators are moving beyond top lighting to explore other lighting types. More than half (51%) of participants currently using supplemental lighting or considering adding it within the next 12 months expressed interest in exploring at least one alternative lighting type.

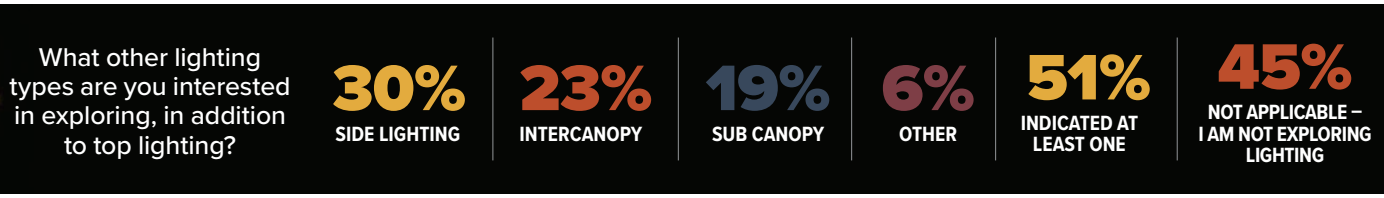
In moves closely tied to yields, 30% of participants say they're interested in exploring "side lighting" in addition to top lighting. "Intercanopy" lighting has the attention of nearly one-fourth (23%) of participants. And 19% of participants are interested in exploring "sub canopy" fixtures this year.

On average, how many grams per square foot does your operation achieve across all genetics?



Base: Participants who grow cannabis commercially in an indoor facility or a greenhouse, with or without supplemental lighting: 89 No answer: 1%

What other lighting types are you interested in exploring, in addition to top lighting?



Base: Those who grow cannabis for a commercial operation in an indoor facility or greenhouse with supplemental lighting, or those without lighting that are considering lighting in the next 12 months: 88

FACILITY SIZES, TYPES AND TIERS

As in past years, canopy footprints varied significantly for cultivation operations in the 2022 "State of the Cannabis Lighting Market" research. Last year's study reported an average canopy size of 34,500 square feet. But averages prove tricky when extremes are involved—and cannabis facility size is a case of extremes. This year's study highlights median canopy size instead, reflecting a middle value of 10,000 square feet of canopy.

This year, 88% of participants cultivate indoors under artificial lighting—up 9 percentage points from 2021. More than one-fourth (28%) cultivate in greenhouses under natural and supplemental lighting. One in five (22%) grow in facilities 50,000 square feet or more, while 13% cultivate canopies less than 1,000 square feet. One-third (33%) of commercial-grower participants also have hobby or personal-use grows.

Vertical farming comprises a significant segment of commercial indoor and greenhouse operations. For 2022, 37% of participants who use supplemental lighting reported using vertical rack systems for cannabis vegetation (not including propagation). That figure echoes 2021 and represents a 6 percentage-point increase from 2017, the first year this research addressed vertical systems. One-fifth (20%) of participants use two tiers for vegetation.

For flowering, 26% of research participants who cultivate with supplemental lighting use vertical racks—up 5 percentage points from last year and 13 percentage points from 2017. The largest segment (22%) grow in two tiers.

What is the area of your operation's cannabis crop production (total plant canopy)?

250,000 sq. ft. or more	4%	50,000 - 79,999 sq. ft.	6%	2,500 - 4,999 sq. ft.	11%
150,000 - 249,999 sq. ft.	4%	25,000 - 49,999 sq. ft.	10%	1,000 - 2,499 sq. ft.	13%
100,000 - 149,999 sq. ft.	6%	10,000 - 24,999 sq. ft.	18%	500 - 999 sq. ft.	9%
80,000 - 99,999 sq. ft.	2%	5,000 - 9,999 sq. ft.	11%	less than 500 sq. ft.	4%

CULTIVATION FACILITY TYPES

In what **type of facility** does your operation grow cannabis?*

88% INDOOR FACILITY**

21% OUTDOORS***

28% GREENHOUSE WITH SUPPLEMENTAL LIGHTING**

11% GREENHOUSE WITHOUT SUPPLEMENTAL LIGHTING

*Total may exceed 100% because participants could select all that apply. **To examine lighting trends among cultivators specifically, CBT's research looked at the responses of the 89 participants who grow commercially indoors and/or in greenhouses. ***Responses from participants who grow outdoors only were excluded from the final report.

10,000 SQ. FT.

MEDIAN CANOPY SIZE FOR COMMERCIAL GROWERS*

WORK AND PLAY:

33%

OF COMMERCIAL GROWERS ALSO GROW AS A HOBBY OR FOR PERSONAL USE.*

*Base: Participants who grow cannabis commercially in an indoor facility or a greenhouse, with or without supplemental lighting: 89

VERTICAL FARMING – VEGETATION & FLOWERING

2017 2022

Does your operation **use vertical rack systems** for cannabis *vegetation*?

YES – 5 TIERS	YES – 4 TIERS	YES – 3 TIERS	YES – 2 TIERS	NET: YES	NO, BUT CONSIDERING DOING SO IN THE NEXT 12 MONTHS	NO, AND NOT CONSIDERING DOING SO IN THE NEXT 12 MONTHS
2% 2%	4% 1%	8% 14%	17% 20%	2022: 37% 2017: 31% % point change: ↑6 pts.	2022: 26% 2017: 35% % point change: ↓9 pts.	2022: 37% 2017: 33% % point change: ↑4 pts.
% point change: 0 pts.	% point change: ↓3 pts.	% point change: ↑6 pts.	% point change: ↑3 pts.	NET: NO 2022: 63% 2017: 68% % point change: ↓5 pts.		

*Base: Participants who grow cannabis for a commercial operation in an indoor facility or greenhouse with supplemental lighting: 87

Does your operation **use vertical rack systems** for cannabis *flowering*?

YES – 5 TIERS	YES – 4 TIERS	YES – 3 TIERS	YES – 2 TIERS	NET: YES	NO, BUT CONSIDERING DOING SO IN THE NEXT 12 MONTHS	NO, AND NOT CONSIDERING DOING SO IN THE NEXT 12 MONTHS
2% 2%	2% 0%	4% 2%	5% 22%	2022: 26% 2017: 13% % point change: ↑13 pts.	2022: 18% 2017: 27% % point change: ↓9 pts.	2022: 52% 2017: 59% % point change: ↓7 pts.
% point change: 0 pt.	% point change: ↓2 pts.	% point change: ↓2 pts.	% point change: ↑17 pts.	NET: NO 2022: 70% 2017: 85% % point change: ↓15 pts.		

*Base: Participants who grow cannabis for a commercial operation in an indoor facility or greenhouse with supplemental lighting: 87; No answer: 3%

Leyla Bustamante, BioLumic R&D science manager

PHOTO COURTESY OF BIOLUMIC

CRACKING THE LIGHTING CODE

Using light to increase cannabinoid and terpene production is complex, but researchers are advancing their knowledge on how light spectrum could come into play.

BY **THERESA BENNETT**

When it comes to cannabis lighting, research in the area generally revolves around two goals: increasing yield and maximizing cannabinoid and terpene content.

As the industry has matured, growers and researchers have seen success with using higher light intensities to increase yield. But manipulating cannabinoid development with lighting remains more of an enigma.

Numerous researchers and lighting companies are studying if and how light spectrum can optimize cannabis's chemical content. And while results have been mixed, it's an area of research that shows glimmers of potential.

ADJUSTING THE LIGHT SPECTRUM

While many studies have demonstrated that higher light intensities proportionally produce higher yields (up to a certain threshold), cannabinoid levels do not respond in the same way, according to Dr. Youbin Zheng, a professor in the school of environmental sciences at University of Guelph. So far, researchers have yet to see cannabinoid concentration increase in proportion to yield as light intensity increases, he says.

Based on research he's seen, lighting below a certain threshold–roughly 200 micromoles per square meter

per second–could *reduce* the potency of cannabinoids. However, he has not seen higher light intensities increase cannabinoid content.

Researchers have instead turned to spectral quality–i.e., the "color" of the light or, more specifically, the wavelength of the photons hitting the plant–to increase cannabinoid content. But so far, many researchers have yet to see significant effects.

Mitch Westmoreland, a Ph.D. candidate and graduate research assistant at Utah State University in the Department of Plant, Soils and Climate, has two possible explanations for the lack of findings.

"One possible explanation you see very often is there are genetic differences between high-THC cannabis and low-THC cannabis [hemp] in response to spectral quality. … We have been studying low-THC cannabis," Westmoreland says.

And while they "only differ in a few genes related to cannabinoid synthesis," and there is little evidence to indicate high-THC and low-THC cannabis respond differently to spectral quality, Westmoreland says, "it's possible" the higher-THC plants could show different results.

"Everybody who's worked with this plant knows there's so much variability from cultivar to cultivar and even within seeds in the same seed lot," Westmoreland says. "Because there's so much variability possible, there is the potential for genetic differences in response to spectral quality and light intensity."

Another possible explanation: many studies so far have been conducted at high light intensities, Westmoreland says, which is good for yield but may inhibit demonstrating what changes in spectrum can actually do.

"Once you reach certain light intensities, the effects of spectral quality [are] much less significant," Westmoreland says.

He adds that other studies, including one conducted in 2018 and published in the journal "Medical Cannabis and Cannabinoids," have shown spectral quality can affect cannabinoid production when paired with lower light intensity–around 500 micromoles per meter squared per second.

Therefore, Westmoreland and Zheng agree it is still possible that spectrum can affect cannabinoid content. "However, currently we don't have enough research to demonstrate what spectrum could be used at what stage," Zheng says.

THE POTENTIAL OF UVB

For photosynthesis, Westmoreland says plants use light wavelengths from around 400 to 750 nanometers (a range that represents the color spectrum from violet to red).

But plants can detect wavelengths above and below that range, too. And while they cannot use light with wavelengths beyond that range for photosynthesis, they can still capture that light, which could lead to downstream effects as the plant grows.

One particular wavelength that has caught researchers' attention is UVB (ultraviolet B), which measures around 300 nanometers.

The fascination with UVB likely dates back to research conducted in 1987, which involved exposing both high-THC and low-THC cannabis to UVB light for 40 days, Westmoreland says. The results showed that THC concentration increased in the high-THC variety.

Since then, researchers have attempted to replicate those results with mixed success.

PHOTO COURTESY OF BIOLUMIC

The BioLumic cannabis science team at the company's R&D facility in New Zealand.

"We did a study where we grew plants at increasing levels of UVB radiation and did not see any effect on cannabinoid concentration, but we did see a really powerful effect of UVB radiation on plant growth and health in general," Westmoreland says. "UV causes sunburn in humans, and it causes the same thing in plants. UV radiation in our study reduced yield and didn't significantly affect cannabinoid concentration."

Zheng and his team had similar results when working with UVB. He offers two theories for the discrepancies between modern findings and the study from 1987.

First, the high-THC cannabis in the original study contained 3% THC. "Nowadays, cannabis has THC content [that ranges from] 20-30%. ... You're looking at different things," Zheng says. "Probably at that time, UV increased THC because it was so low. I hypothesize that THC can't increase any more in new cultivars."

Zheng also theorized that the timing of UV application played a role in cannabinoid development. He and his team tested that theory by applying UVB to plants in the last 45 days before harvest and in the last 20 days before harvest. While they did not see different results, Zheng still doesn't discount that theory.

"For UV, there is probably more research needed to look at different combos in the future," Zheng says.

Westmoreland agrees: "I think the next big path that we take in our research is understanding how we can change the light intensity and spectral quality at strategic points in the lifecycle to optimize yield morphology and chemical quality," Westmoreland says.

GETTING THE RECIPE RIGHT

Timing, varied genetics, different light spectrums and intensities are all factors that could play into increasing cannabinoids and terpenes, making the endeavor a moving target.

But one company that has spent years researching how light affects plants says it has cracked the code.

BioLumic is a company based in the U.S. and New

INTERCANOPY LIGHTING: ILLUMINATING THE WHOLE PLANT

One potential method researchers are exploring to increase both yield *and* cannabinoid content in cannabis is with intercanopy lighting. This lighting method involves distributing lights among plants instead of just overhead.

While this may not necessarily push the limits of a certain cultivars' chemical content, it could help produce more buds that reach their full potential.

"Generally, with just overhead lighting, you tend to get sort of a gradient along the plant, and cannabinoid concentration tends to be higher at the top, where the flowers are receiving a lot of light, and then it decreases as you move down the plant where the light intensity is significantly lower," says Mitch Westmoreland, a Ph.D. candidate at Utah State University in the Department of Plant, Soils and Climate.

Westmoreland points out that while higher light intensities haven't been shown to increase cannabinoid production, low light intensities—such as the intensity the lower portion of the plant would receive with overhead lighting—can result in decreased cannabinoid production.

"With intercanopy lighting, you can uniformly illuminate the entire plant and potentially increase overall light, as well as increasing the uniformity within the plant," he adds.

Little research has been published on intercanopy lighting within cannabis, but it's a method used by cultivators of other plants with tall canopies, such as tomatoes and cucumbers.

"We can get the light to where we need it instead of providing all the light from above. We can move some of the light from the top into the canopy, allowing for a much more uniform vertical light distribution," says Dr. Jason Lanoue, a postdoctoral researcher at Agriculture and Agri-Food Canada's Harrow Research and Development Centre. Although he has not studied cannabis specifically, he says he has seen the potential of intercanopy lighting in other plants.

Intercanopy lighting is only possible through the use of light-emitting diode (LED) fixtures, as high-pressure sodium (HPS) lights are too hot to position so close to the plants.

While this method could be potentially beneficial for cannabis growers, Lanoue says the economics of integrating new lighting are still unknown.

"A lot of times, for growers, it's an economical decision over [a decision about] plant growth. Is the additional capital investment for the added fixtures going to be worth it?" Lanoue says.

Cultivators across industries also have mixed feelings about its efficacy.

"Some growers aren't convinced that intercanopy lights are worth it, while other have seen great benefits," Lanoue says.

A major way he's seeing it used is by growers who use HPS. Instead of converting their entire facility to LED lighting, they keep HPS lights overhead and integrate LED fixtures for intercanopy lighting. This can reduce the capital investment while still achieving a more uniform vertical light distribution.

> **Once you reach certain light intensities, the effects of spectral quality [are] much less significant."**
>
> – MITCH WESTMORELAND, PH.D. CANDIDATE, UTAH STATE UNIVERSITY

Victoria Rodriguez-Morrison measures light intensity levels within a cannabis canopy grown under different light intensities at University of Guelph.

Zealand that uses light to change the genetic expression of crops, including cannabis, to produce specific results. This could include increased yield, drought or pest and disease resistance, and optimized cannabinoid and terpene content.

BioLumic is focused on photomorphogenesis, or light-mediated regulation of plants, rather than photosynthesis. The company's technology uses one-time, short-duration light signals that activate specific signaling pathways and impact the plant throughout its growth cycle. BioLumic CEO Steve Sibulkin says the technology is all about applying "the right energy at the right time in the right patterns and sequences."

"We're basically changing genetic expression with light," Sibulkin says, adding that BioLumic's technology is not modifying plants' DNA. "We're simply unlocking the natural genetic potential of the plant."

The technology uses UVB–which, at specific levels, triggers certain responses in plants–along with a mix of other lighting spectrums and intensities to produce certain outcomes, Sibulkin says. The company calls this mixture its "recipes."

There are trillions of potential recipes that could be applied depending on the cannabis variety and desired outcome, Sibulkin says. One way BioLumic's technology determines the right recipe is by measuring a plant's certain proprietary genetic markers. Instead of applying the treatment later on in the lifecycle, Sibulkin says UVB "has the ability early on to influence the direction of how plants will grow."

For cannabis, BioLumic applies its light treatment to cultivators' clones in the beginning of their growth cycle for six days during the regular propagation cycle. This is enough to produce significant downstream effects, Sibulkin says. After the application, BioLumic continues to track the results throughout the plants' lifecycles and alters its recipe for subsequent grow cycles if needed.

According to BioLumic Chief Science Officer Dr. Jason Wargent, results when aiming to increase cannabinoid content were promising: When BioLumic treatment was applied to the cultivar White Cheese (which contains around 15% THC and 2% CBD, according to Wikileaf), THC yield per plant increased by 94% and THCA yield per unit of dry flower mass increased by 27%. When the treatment was applied to the cultivar Charlotte's Angel (which contains around 1% THC and 15% CBD, according to Leafly), CBD increased by 25%, while other minor cannabinoids experienced a significant increase as well.

SETTING GOALS

Even with gene-detecting technology, "plants are unbelievably multilayered and complex," Sibulkin says. Using light to produce multiple desired outcomes–i.e. increased yield *and* cannabinoid content–is even more complicated.

A more realistic target, at least in the short term, is to focus on achieving one specific outcome with lighting.

"There's sort of this trade-off of, do you want to be able to manipulate cannabinoid and terpene concentration and optimize the chemical quality of the flower, or are you really interested in getting the most yield?" Westmoreland says. "Over the past few years, we've found there are differences in how you're going to light your plant depending on what your goal is."

THERESA BENNETT is editor for *Cannabis Business Times*.

PHOTO BY DAVID LLEWELLYN

A GUIDING LIGHT

CULTA nurtures its cannabis with different lighting types in a variety of environments, taking note of the plants' preferences to maximize the genetic potential of each cultivar.

BY **MICHELLE SIMAKIS**

At CULTA, cannabis genetics are at the heart of every decision the company makes.

The Maryland-based, vertically integrated cannabis company operates cultivation, extraction and processing in Cambridge, in addition to distributing and selling its products at retailers throughout the medical-only state and at its own dispensary in Baltimore.

Research and development are constants at CULTA and, through experimentation, growers have learned that the more than 50 individual cultivars in its genetic library have environmental preferences and require specific conditions to thrive. Plants are carefully preserved in the company's in-house tissue culture lab, which was launched in 2021 to nurture its cannabis cultivars and protect them from pathogens and genetic drift, says Jay Bouton, CULTA's senior director of cultivation.

"We spend a lot of time and energy finding specific phenotypes that we keep in our library, and this gives us the ability to keep them safe for longer than your typical mother plant's lifecycle," Bouton says.

Once the plants leave the tissue culture lab and move to propagation, vegetation and flowering, their journeys vary. CULTA has a mix of growing environments, growing both indoors and tending to 3 acres outdoors, monitoring the plants' performances in the various spaces, Bouton says.

"Over the course of four years of growing indoors, and four seasons of outdoor cultivation, we have found

Tom Moylan, CULTA's director of cultivation, examines cannabis in one of the facility's flower rooms equipped with LED lights in two tiers.

Young cannabis in CULTA's propagation room.

PHOTOS COURTESY OF FLUENCE

that genetics play a large role in how successful the crop will be depending on its environment," Bouton says. "For outdoor, pest and pathogen resistance are key, especially for us here in Cambridge, Maryland, where humidity is routinely above 70% in the peak summer months."

Indoors, CULTA maximizes space in its 20,000-square-foot facility using three-tier vertical growing systems in vegetative rooms and two tiers in some flowering rooms that are equipped with light-emitting diode (LED) lights. The company is intentional about where plants are placed within the tiers.

"We have found that certain strains like the top tiers of our racking system because they handle slightly warmer temperatures and don't require quite as much water throughout the day," Bouton says.

Temperature also comes into play when working with different lighting systems. CULTA's original grow rooms had high-pressure sodium (HPS) lighting but, over the years, the facility has added more LED capability to its cultivation facility, Bouton says. Both lighting systems play an important role in CULTA's cultivation strategy.

"We have found certain strains do prefer different [spectra] of light …. Every room we have brought online since 2020 has had LED lighting," Bouton says. "We find that some strains show their unique expressions better under HPS lighting, and we choose to keep them growing under that spectrum to continue to see those differences. We run our LED rooms slightly warmer than our HPS rooms to account for the loss of heat load from the HPS lights and to keep the leaf temperatures at optimal levels."

Optimizing the conditions at various growth stages and watching for plant preferences have helped the company better dial in the various cultivars' growth habits and yields, Bouton says. Cultivars under LED lights tend to produce denser flower, for example, while plants illuminated with HPS have varied habits.

"Strains that have unique traits, like more bulbous calyxes, tend to fill out differently under the HPS spectrum, so the structure of some strains' flowers can be more visually appealing in those rooms," Bouton says. "We

Every cultivation room that CULTA has brought online since 2020 has been outfitted with LED lighting.

have also seen that strains that have more sativa-based genetics, especially ones that like to stretch, like Poochie Love, don't mature in the same way under the LED lights, so we keep them under the HPS spectrum."

Cannabis cultivars also have specific lighting needs in the in-house tissue culture lab, where low-intensity LEDs are critical in plants' infancy stage, Bouton says.

"The lighting needed for the tissue culture lab is still very important but doesn't need to be as intense," he says. "We use single bar LEDs to light our tissue culture explants with a maximum of 100 PPFD."

The LED lights also help the team maximize space and operate more efficiently, says Michelle Sprawls, CULTA's director of science.

"In micropropagation, plants are cultivated aseptically in culture vessels, typically in a multi-tier culture room that is outfitted with LED lights. Arranging the LED lights on tiers allows large numbers of cuttings to be maintained in a very small space, thereby reducing the amount of floor space required ...," Sprawls says. "Lighting is an important part of the tissue culture process as it drives the reaction of photosynthesis. LED is becoming more common in the application of tissue culture because it features high efficiency, low energy, safety, reliability, and intensity flexibility."

While overhead lighting is the norm in cannabis cultivation, using LED technology, CULTA is also experimenting with side lighting and monitoring the results. Bouton is hopeful this can help the company increase yield and overall efficiency.

"We just began a new trial with a company that is introducing side lighting with LEDs in combination with the existing overhead lighting in hopes of increasing yields of usable biomass under the canopy," Bouton says. He could not share details about the trial parameters, he said, including if they are installing lighting in flowering rooms exclusively or how long they are trialing this strategy, until after data is available. "Many companies have introduced under-canopy lighting recently, but most are installed on the tables looking directly up at the plants. We are hoping the light penetrates the canopy better than under lighting, and hits the top of the leaves, rather than under, where the stomata are."

Bouton says this approach of carefully monitoring the grow rooms and outdoor cultivation has helped drive CULTA's success in Maryland's medical cannabis market.

"[The] advice I would give to other growers is to pay as much attention to your environment as possible," he says. "If you can get your environment dialed in to fit your situation, your rooms will be much happier over time."

> **"... WE HAVE FOUND THAT GENETICS PLAY A LARGE ROLE IN HOW SUCCESSFUL THE CROP WILL BE DEPENDING ON ITS ENVIRONMENT."**
>
> – JAY BOUTON, SENIOR DIRECTOR OF CULTIVATION, CULTA

MICHELLE SIMAKIS is editor-in-chief for *Cannabis Business Times*.

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