CANNABIS BUSINESS TIMES

IN PARTNERSHIP WITH QUEST

SPECIAL REPORT:

CANNABIS POST-HARVEST

An exclusive research report examining trends and practices in cannabis drying, curing and other post-harvest processes.

A NOTE FROM QUEST PRESIDENT **CLIFTON TOMASINI**

> "WHILE PASSION AND WILL MAY BE ESSENTIAL, SO TOO ARE INSIGHTS THAT HELP ADVANCE CULTIVATION PROCESSES."

Having been active in the cannabis market for more than 10 years, I continue to be impressed by the passion and perseverance among cultivators. The still federally illegal cannabis industry is not one for the faint of heart. As many have said, if you're not passionate about this industry, you might not have the will to survive the many challenges that cannabis businesses face every day.

But while passion and will may be essential, so too are insights that help advance cultivation processes. That is why Quest is pleased to support *Cannabis Business Times*' efforts to conduct the first-ever research on post-harvest production and trends. I hope that the information in this special report helps you in your efforts to consistently produce the highest-quality cannabis products possible to serve the ever-increasing market of patients and consumers.

CLIFTON TOMASINI, PRESIDENT, QUEST

HEADSHOT COURTESY OF QUEST; COVER PHOTOS MITCH; BILLY; FUKUME; JUST.B PHOTOGRAPHY | ADOBE STOCK

POST-HARVEST BENCHMARKS, WITH ROOM TO EXPERIMENT

For the past five years, *Cannabis Business Times*' exclusive research reports have focused on investigating and benchmarking various aspects of cultivation, from overall industry trends to lighting, nutrients and odor control. This year, for the first time, *CBT* conducted a study about what happens after harvest, examining cultivators' drying, curing, trimming and other practices.

This research, conducted by third-party company Readex Research and made possible thanks to the generous support of Quest, provides a glimpse into how indoor, greenhouse and outdoor cultivators manage the post-harvest process. The "Special Report: Cannabis Post-Harvest" features data on temperatures and humidity levels growers like to maintain in drying and curing rooms and how long they dry and cure cannabis—benchmarks cultivators can compare to their own processes. Research participants also noted their top post-harvest challenges, the top three being hand trimming, curing and drying. Getting the environmental conditions, especially humidity, just right was another aspect cultivators said they struggle with.

Dr. Markus Roggen, Ph.D., founder and CEO of Complex Biotech Discovery Ventures, likens the cannabis drying process to roasting a Thanksgiving turkey—there are myriad options for dressings and a range of cooking times, but the goals are the same: Cook the turkey long enough so that it is safe while preserving moisture and flavor.

"Everyone makes their turkey differently, but there's a rule—you need to get over 165 degrees F to not get salmonella," says Roggen, who conducted research to determine drying and curing best practices while he was vice president of extraction for cannabis cultivation and extraction/formulation company OutCo. Like cannabis, "there are some hard numbers around which you will play."

Cannabis moisture can and must be measured to prevent mold, Roggen says, and certain drying temperature and humidity ranges stymie bacterial growth while preserving terpenes.

"For drying room conditions, we found the optimal window is 60 to 74 degrees F and 40% to 60% humidity," he says. "We found 10 to 14 days worked well for us to preserve terpenes but to free the room for the next harvest."

Looking at the research from the *CBT* study, cultivators appear to be in those optimal ranges—the average reported temperature in drying is 65 degrees F, while the average humidity level is 53%. Some cultivators said, as Roggen suggested, they like to "play," preferring "variable" conditions for both temperature (7%) and humidity (11%).

Curing parameters can be more difficult to pinpoint, he says. He likens that stage to wine aging, and there are still many compounds that are important to cannabis flavor that the industry does not yet consider or fully understand, Roggen says.

"How do you define a good cure? Right now, a good cured cannabis bud is defined by the guy who smokes it and likes it," he says. "The end product is still at the mercy of the consumer. Some people like red wine, some people like white. … There is still the sensory aspect that we have to consider."

Although there are certain benchmarks and safe ranges to stay within, Roggen says it's important to continue to explore variables in the post-harvest process and how best to optimize it for safety, efficiency and product quality.

"We should not be fearful to experiment, and we should not be content with the current status."

As you navigate the research included in this report, perhaps it will spark opportunities to trial and explore in your own facility.

53%

THE AVERAGE HUMIDITY LEVEL PARTICIPANTS SAID THEY PREFER IN THE DRYING STAGE

MICHAEL; CENDECED | ADOBE STOCK

WHAT HAPPENS AFTER HARVEST?

DRYING METHODS

What methods does your cannabis operation use to dry its plants?

52% PARTIAL PLANT HUNG

42% WHOLE PLANT HUNG

23% FLOWER ONLY ON MESH SCREENS OR TRAYS

8% NOT DRIED, PROCESSED WET

8% FLOWER AND STEM ON MESH SCREENS OR TRAYS

8% FREEZE DRIED

2% OVEN/INFRARED DRIED

4% OTHER

Note: Total exceeds 100% because participants could select all that apply.

WHILE MUCH TIME, EFFORT AND MONEY ARE SPENT to create optimal growing conditions to produce the highest-quality cannabis during cultivation, as growers know, what happens after harvest is just as crucial. The drying and curing stages are perhaps the most challenging to get right, as the timing of various processes can depend on flower size and density, and vary by cultivar, too. Preserving terpenes and cannabinoids while also preventing mold and pests requires a delicate balance, and 30% of participants in *Cannabis Business Times'* first-ever post-harvest study said they struggle with "maintaining cannabinoid/terpene levels."

In *CBT*'s "Special Report: Cannabis Post-Harvest" research, most cultivators indicated they either dry by hanging partial plants (52%) or whole plants (42%). About a quarter of cultivators reported drying flower only on mesh screens or trays (23%), while few reported employing other methods such as processing wet, laying flower and stems on mesh screens or trays, and freeze drying (each 8%).

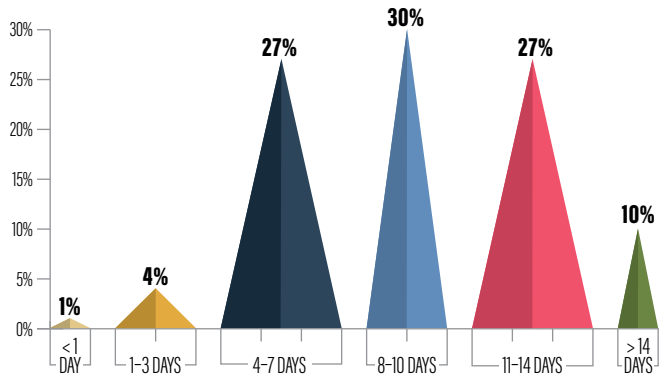
On average, participants said they dry cannabis for about 10 days. However, their optimal drying times range from more than two weeks (10% of cultivators) down to 4 to 7 days (27%). Of note, 71% said drying is one of the most challenging aspects of the post-harvest process.

Curing also is a challenge for many, according to the data. Nearly three-fourths (73%) of research participants said it is one of the most significant post-harvest challenges. The reason? More than 43% of those respondents cited humidity control.

It's been said that producing quality cannabis is both an art and a science, and curing is perhaps the greatest example of that, a step that requires a careful balance of both. Cultivation teams need to carefully monitor and burp flower to be sure moisture is retained but that mold and mildew don't develop. Perhaps because of this art-science mixture, typical cure times vary widely among participants, ranging from more than 30 days (21% of cultivators) down to 4 to 10 days (22%).

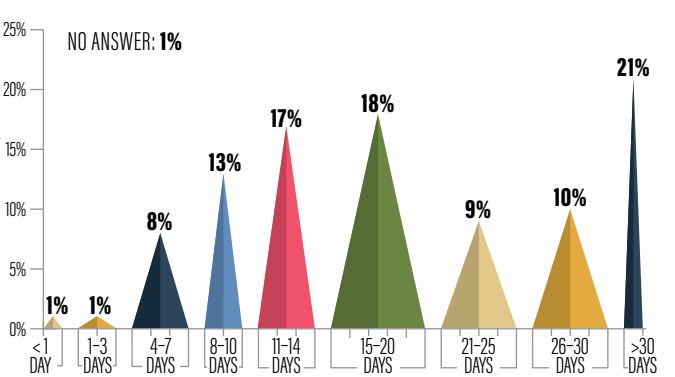
DRYING TIME

How long does your cannabis operation typically dry its plants?



CURING TIME

How long does your cannabis operation typically cure its plants?



WOLLERTZ | ADOBE STOCK

Note: The numbers in charts throughout this report may not add up to 100% due to rounding.

A CHALLENGING **ENDEAVOR**

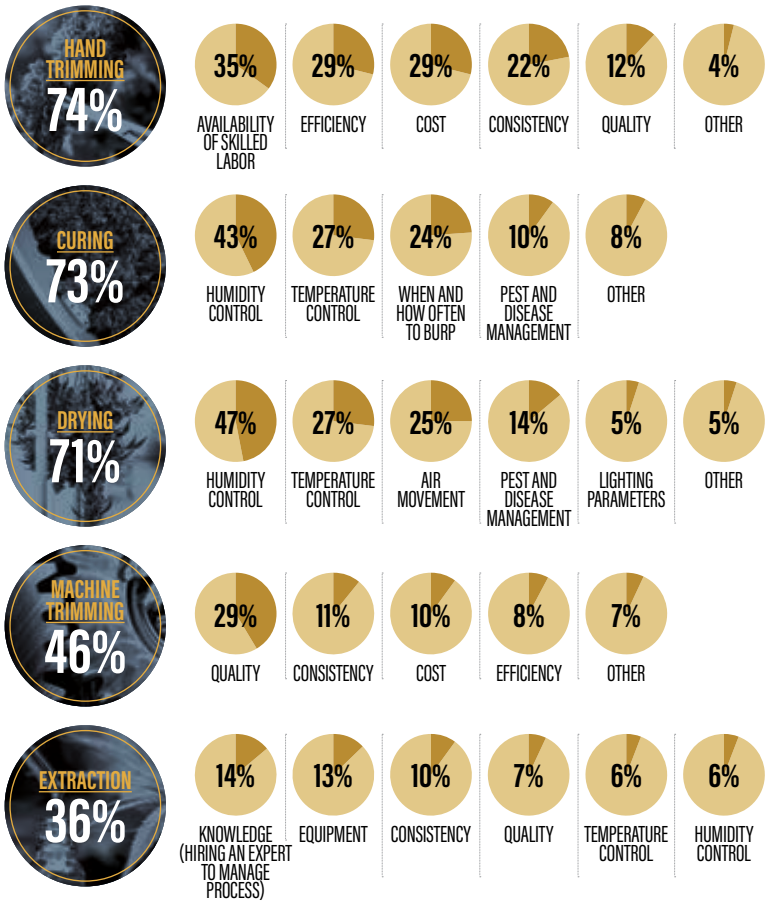
AS MENTIONED EARLIER IN THE REPORT, drying and curing, and specifically targeting humidity for those processes, are among the top three post-harvest challenges, according to study participants. However, 74% of cultivators said hand-trimming is the most difficult step and the top challenge noted. The reasons why participants reported hand trimming is so complicated is because of the availability of skilled labor (35%), efficiency (29%), cost (also 29%), consistency (22%) and quality (12%).

Other than utilities, labor is one of the biggest costs of operating a cultivation facility. When looking at the monthly cost of post-harvest labor alone, 34% of participants reported spending less than $10,000, the most common range selected, while 10% said they spend $50,000 or more, the highest range.

On average, cultivators hire nine employees to run the post-harvest process, according to the research. More than a third (38%) of participants hire two to four people to run their post-harvest operations, while 26% have a team of five to nine people manage drying, curing, trimming and more.

POST-HARVEST CHALLENGES

What are your cannabis operation's greatest post-harvest challenges?



OTHER

Note: Total exceeds 100% because participants could select all that apply.

POST-HARVEST LABOR

On average, how much does your cannabis operation spend on labor in post-harvest processes per month?

$50,000 or more	10%
$40,000 - $49,999	1%
$30,000 - $39,999	8%
$20,000 - $29,999	14%
$10,000 - $19,999	15%
less than $10,000	34%
don't know	16%

NO ANSWER: **2%**

NUMBER OF EMPLOYEES

How many employees does your cannabis operation have dedicated to the post-harvest process?

30 or more	9%
20 to 29	4%
10 to 19	15%
5 to 9	26%
2 to 4	38%
1	6%

NO ANSWER: **2%** | AVERAGE: **9**

CENDECED; FUKUME; XHICO; OPENRANGESTOCK; LOTUS_STUDIO; TINNAKORN | ADOBESTOCK

THE RIGHT ENVIRONMENT

WHEN PLANTS ARE ALIVE, ensuring they have the best environment to thrive is key to maximizing growth, quality and yield as well as to mitigate pests and disease. Once cannabis is harvested and moves to the drying and curing phase, the environment still can affect product quality, and maintaining appropriate levels is just as important to preventing disease as it is during cultivation. In *CBT*'s post-harvest research, participants noted that maintaining ideal environmental conditions, especially humidity, is among top challenges.

When asked about *overall post-harvest challenges*, humidity control is one of the areas participants struggle with most: 47% reported humidity control challenges in drying and 43% in curing.

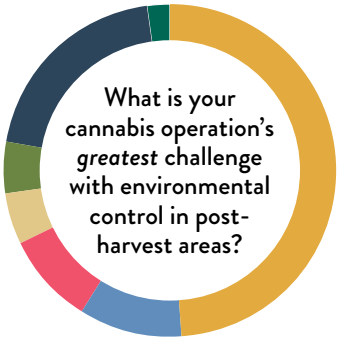
Focusing specifically on *environmental control challenges in post-harvest*, cultivators listed humidity control as the *greatest* challenge, as nearly half (49%) selected this factor as the one they grapple with most. The next most reported challenge with post-harvest environmental control was filtered fresh air intake (10%). According to *CBT*'s research, cultivators do not have as much difficulty with targeting temperature as they do humidity, as only 9% said temperature control is their greatest post-harvest environmental control challenge. Notably, 20% responded "none" to this question.

49%
THE PORTION OF CULTIVATORS WHO SAID **HUMIDITY CONTROL** IS THEIR **GREATEST** POST-HARVEST ENVIRONMENTAL **CONTROL CHALLENGE**

HUMIDITY IN DRYING

The average *humidity* level cultivators like to maintain when *drying* cannabis plants is about 53%. The most common ranges cultivators selected for preferred humidity ranges during

POST-HARVEST ENVIRONMENTAL CONTROL CHALLENGES

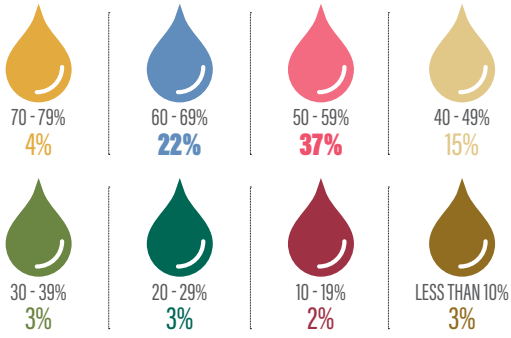


49% | 10% | 9% | 5% | 5% | 20% | 2%

HUMIDITY CONTROL | FILTERED FRESH AIR INTAKE | TEMPERATURE CONTROL | AIR MOVEMENT | OTHER | NONE | NO ANSWER

HUMIDITY IN DRYING ROOM

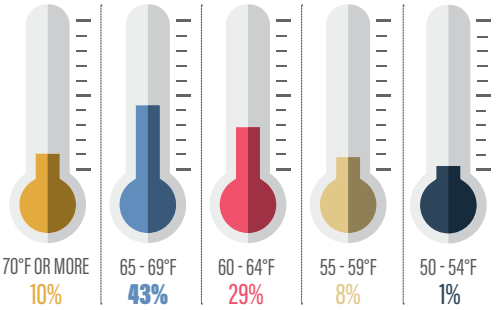
What humidity level does your cannabis operation like to maintain in its drying room(s)?



VARIABLE: **11%** | NO ANSWER: **1%** | AVERAGE: **53%**

TEMPERATURE IN DRYING ROOM

What temperature level does your cannabis operation like to maintain in its drying room(s)?



VARIABLE: **7%** | NO ANSWER: **2%** | AVERAGE: **65°**

SOUTH_AGENCY | ISTOCKPHOTO

drying were 50% to 59% (noted by 37% of research participants) and 60% to 69% (noted by 22%). Fewer participants (15%) reported preferred humidity levels of 40% to 49%, while 11% said they have no optimal humidity level/goal, but instead prefer variable ranges.

TEMPERATURE IN DRYING

The average *temperature* cultivators like to maintain when *drying* cannabis plants is about 65 degrees F. There was more consensus among participants when looking at preferred *temperature* ranges in *drying* rooms compared with humidity, as nearly half (43%) said they keep the dials to 65 to 69 degrees F in drying rooms, while another 29% indicated they like conditions just a bit cooler, at 60 to 64 degrees F.

METHODS OF CONTROL

To achieve desired temperature and humidity ranges in drying rooms, most cultivators reported they use dehumidifiers (71%), fans (63%), HVAC systems separate from cultivation (43%) and combined HVAC-dehumidification systems (33%).

Spending on HVAC equipment for post-harvest varied greatly, with 15% spending $50,000 or more and 22% spending less than $10,000. Another 11% said they do not have HVAC equipment for post-harvest, and 17% said they don't know how much it cost.

QUALITY

With all the emphasis growers placed on the post-harvest environment throughout the study, it's not surprising that when asked, "What do you consider the *most important* aspect of producing quality cannabis flower in post-harvest production," most participants (59%) selected "all aspects of the environment." The next most selected answers were "length of curing time" and "a properly cultivated plant," both noted by 7% of participants.

CONTROL METHODS

How does your cannabis operation control humidity and temperature levels in its drying room(s)?

71% DEHUMIDIFIER

63% FANS

43% HVAC SYSTEM (SEPARATE FROM CULTIVATION)

33% COMBINED HVAC-DEHUMIDIFICATION SYSTEM

24% HEAT

14% HVAC SYSTEM (SAME AS CULTIVATION)

OTHER: 5%

Note: Total exceeds 100% because participants could select all that apply.

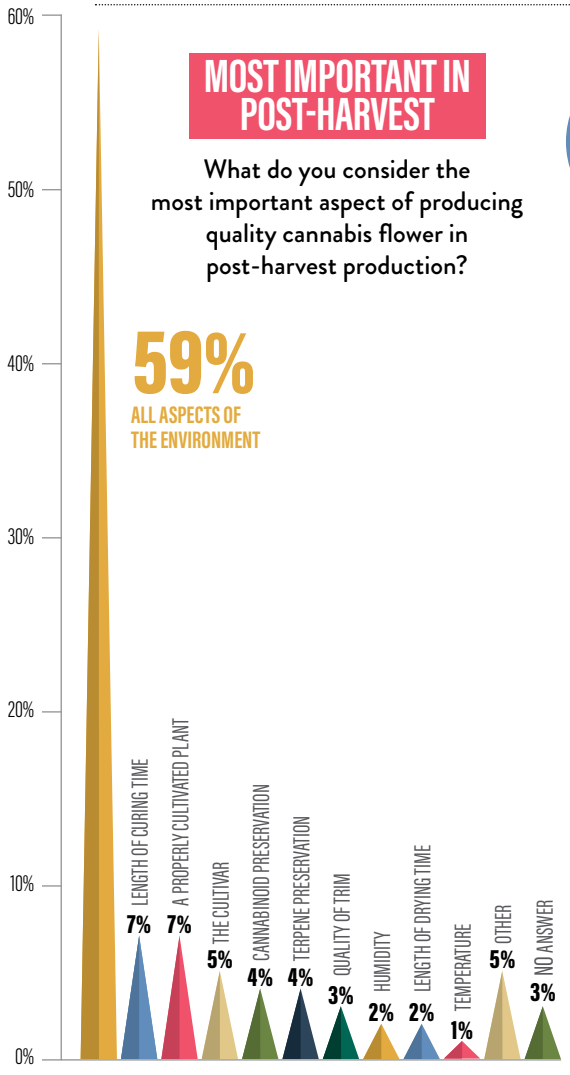
COST OF HVAC EQUIPMENT

What was the cost of your cannabis operation's current HVAC equipment when it was purchased for *post-harvest* processes?

$50,000 or more	15%
$40,000 - $49,999	6%
$30,000 - $39,999	4%
$20,000 - $29,999	5%
$10,000 - $19,999	18%
less than $10,000	22%
do not have HVAC equipment	11%
don't know	17%
no answer	3%

MOST IMPORTANT IN POST-HARVEST

What do you consider the most important aspect of producing quality cannabis flower in post-harvest production?



65°F

THE AVERAGE TEMPERATURE LEVEL CULTIVATORS LIKE TO MAINTAIN IN DRYING ROOMS

MARIUSZ BLACH | ADOBE STOCK

FACILITY SIZE AND POST-HARVEST SPACES

TOTAL FACILITY SIZE

Approximately what is the total area of your cannabis operation's facilities, including active crop production areas, post-harvest cultivation spaces, and administrative/office spaces?

250,000 sq. ft. or more	9%
150,000 - 249,999 sq. ft.	3%
100,000 - 149,999 sq. ft.	5%
80,000 - 99,999 sq. ft.	8%
50,000 - 79,999 sq. ft.	10%
25,000 - 49,999 sq. ft.	8%
10,000 - 24,999 sq. ft.	20%
5,000 - 9,999 sq. ft.	16%
2,500 - 4,999 sq. ft.	8%
1,000 - 2,499 sq. ft.	8%
less than 1,000 sq. ft.	5%

TOTAL POST-HARVEST SPACE

What is the total area of your cannabis operation's *post-harvest* cannabis production space (including trimming, drying/curing, extraction, etc.)?

100,000 sq. ft. or more	4%
80,000 - 99,999 sq. ft.	7%
50,000 - 79,999 sq. ft.	3%
25,000 - 49,999 sq. ft.	4%
10,000 - 24,999 sq. ft.	8%
5,000 - 9,999 sq. ft.	18%
2,500 - 4,999 sq. ft.	10%
1,000 - 2,499 sq. ft.	25%
500 - 999 sq. ft.	14%
less than 500 sq. ft.	8%

18,400 SQ. FT.
AVERAGE POST-HARVEST AREA SIZE

57,500 SQ. FT.
AVERAGE TOTAL FACILITY SIZE

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HARVESTS AND YIELDS

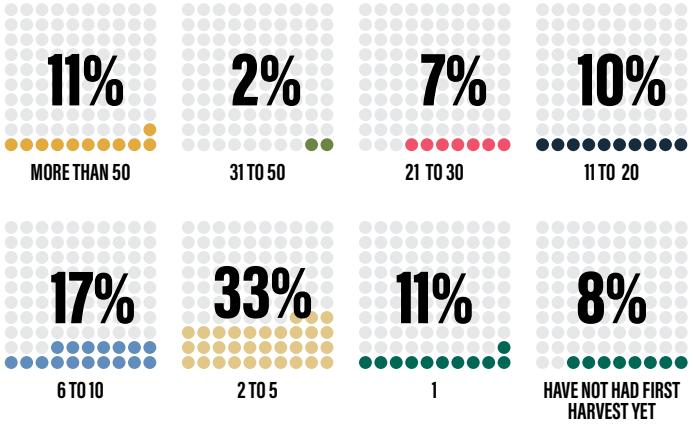
THE NUMBER OF HARVESTS a cultivation company produces in a year depends on many factors, including if cannabis is grown outside or indoors, the facility size, and whether growers are running perpetual harvest systems. Because of that, it's no surprise that participants indicated a wide range of figures when asked how many harvests their operations produced in the past 12 months. The vastness of that range, however, may surprise some: At the very top of the spectrum, 11% said they had more than 50 harvests in the past 12 months; the same percentage (11%) said they had one harvest in the past year. (Though we cannot assume these are outdoor growers, note that 12% of study participants operate outdoors only.) A third of participants reported two to five harvests, the most of any range provided.

As number of harvests per year is an indicator of yield potential, so is the grams per square foot of flower produced in each room or zone. Participants reported a wide range for this metric, with 15% averaging 80 or more grams/square foot (g/sq. ft.) at the high end, and 9% averaging less than 30 g/sq. ft. foot on the lower end. On average, cultivators said their yields are 55 g/sq. ft., with the largest number (22%) reported achieving 50 to 59 g/sq. ft.

14 AVERAGE NUMBER OF HARVESTS FOR THE PAST 12 MONTHS

TOTAL HARVESTS

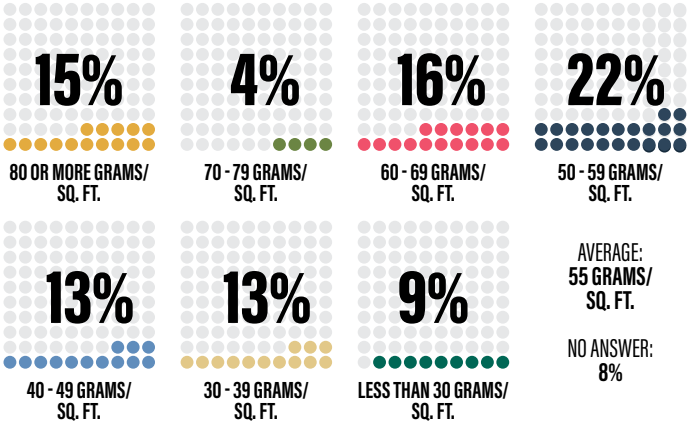
How many total harvests did your cannabis operation have during the past 12 months?



NO ANSWER: 1%

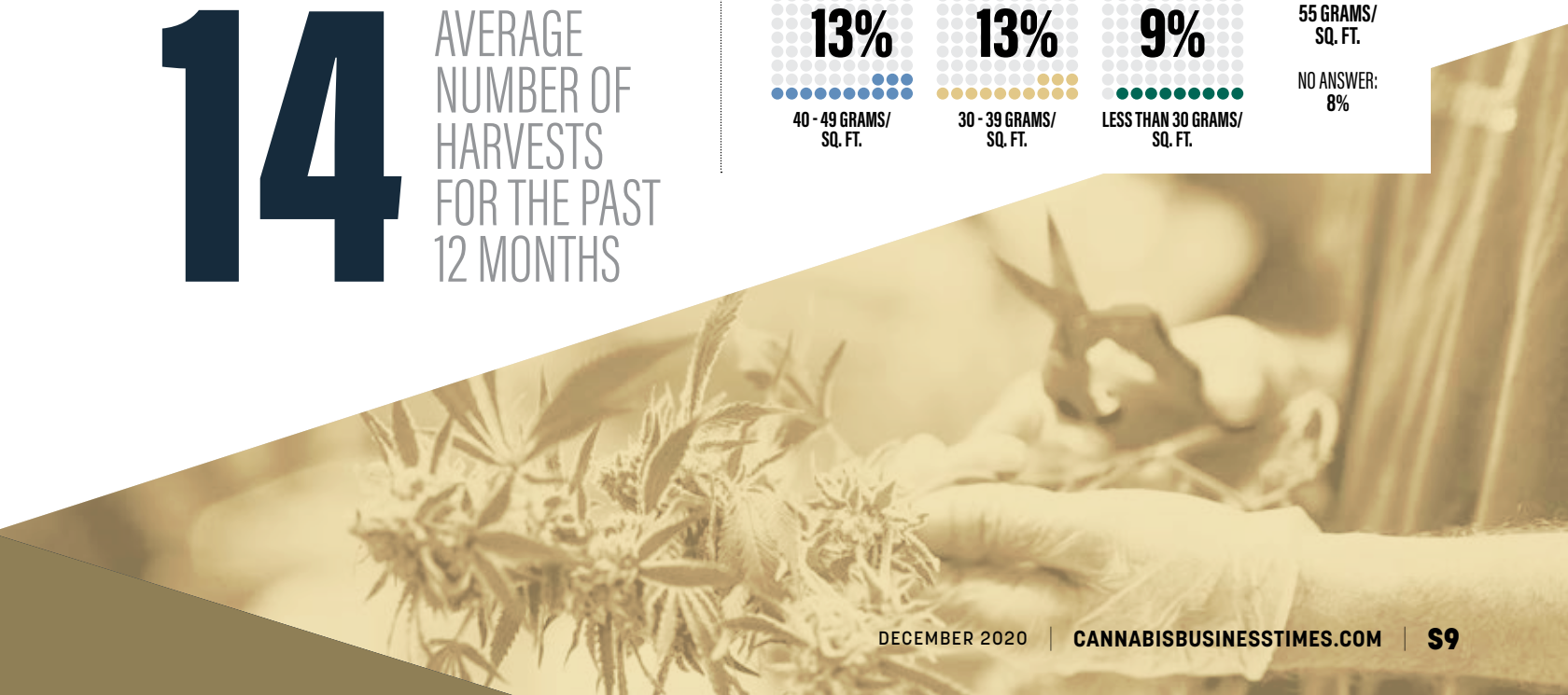
AVERAGE YIELD PER ROOM PER HARVEST

What is the average yield in grams per square foot for each cannabis room/zone per harvest?



AVERAGE: 55 GRAMS/ SQ. FT.

NO ANSWER: 8%



DO CULTIVATORS PACKAGE THEIR OWN PRODUCTS?

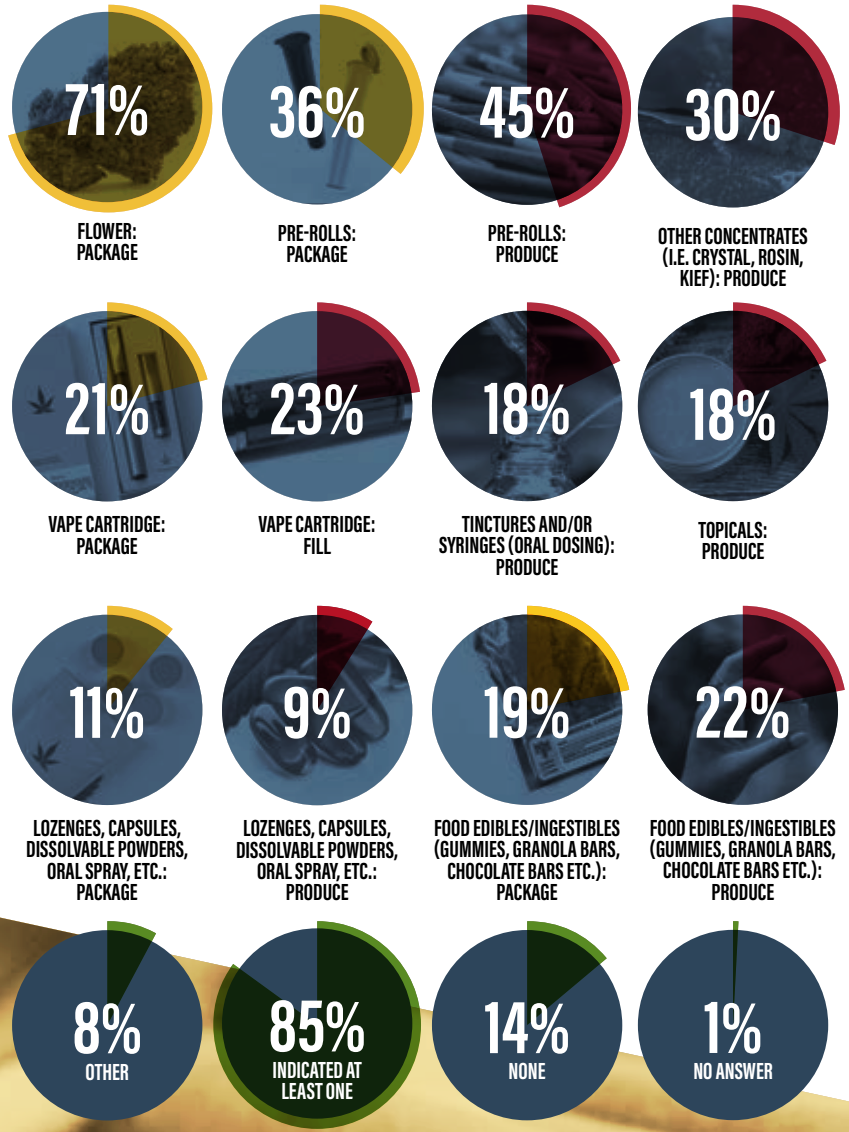
The final step in the post-harvest process is either sending product off to be packaged, distributed and sold, or packaging products in house. As part of the "Special Report: Cannabis Post-Harvest," *CBT* explored how many growers are packaging their own products for sale. Most participants (85%) package and/or produce some or all of their own products. The chart below details which products cultivators are producing and which they fulfill with packaging. Other than flower and pre-rolls, "other concentrates (i.e., crystal, rosin, kief)" is the top product category cultivators reported producing, with 30% of research participants indicating they make those in-house.

PRODUCTS PRODUCED & PACKAGED

● PACKAGE | ● PRODUCE | ● OTHER INFORMATION

Which of your cannabis operation's own products does it produce/package?

Note: Total exceeds 100% because participants could select all that apply.



FACILITY TYPE

Which of the following best describes your cannabis cultivation operations?

40% INDOOR FACILITY ONLY

12% OUTDOORS ONLY

5% GREENHOUSE ONLY

43% COMBINATION OF TWO OR MORE

NEW OR RENOVATED

For your indoor and/or greenhouse cannabis cultivation space, are you operating out of a facility and/or greenhouse planned and built to specifications, or a retrofitted/renovated facility and/or greenhouse?

45% RETROFITTED/ RENOVATED

29% PLANNED/BUILT TO SPECIFICATIONS

24% BOTH

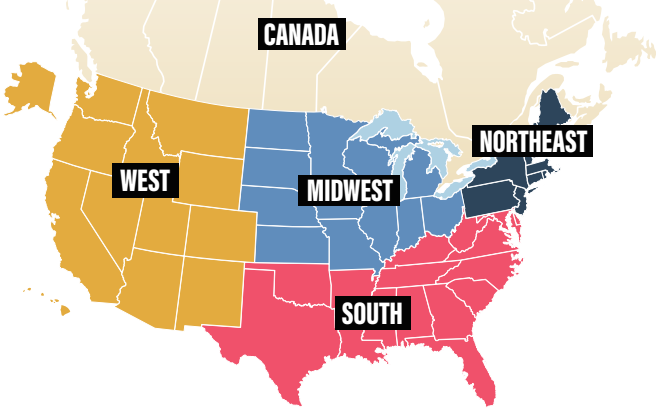
DON'T KNOW: 1%
NO ANSWER: 1%

ABOUT THE RESEARCH PARTICIPANTS

MANY PARTICIPANTS (43%) said they operate two or more types of cannabis cultivation operations (p. S10). However, more said they operate an indoor facility only (40%) than outdoor only (12%) or greenhouse only (5%). Also, more said they operate retrofitted facilities (45%) than those planned/built to specifications (29%), and 24% said they operate both retrofitted and spec-built. More participants have headquarters and are operating in the West or South than other U.S. regions.

HEADQUARTERS

In which region is your cannabis cultivation business currently headquartered?

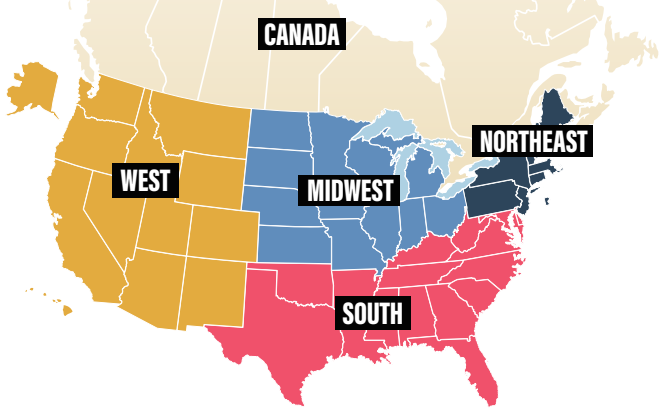


40% 14% 5% 27% 12%

OTHER: 3%

ALL LOCATIONS

In which region(s) does your cannabis cultivation business currently operate?



42% 19% 7% 30% 13%

OTHER: 2%

Note: Total exceeds 100% because participants could select all that apply.

INDEPENDENT, THIRD-PARTY RESEARCHER READEX RESEARCH conducted the study on behalf of *Cannabis Business Times* and compiled the data for the "Special Report: Cannabis Post-Harvest." The study was sent to *CBT* magazine subscribers with known email addresses and/or e-newsletter subscribers located in the United States, Canada, or other (unknown) North American locations in October 2020. Results are based on 106 participants who own or work for a licensed operation that cultivates cannabis for sale. The margin of error for percentages based on the 106 participants who indicated they own or work for a cultivation operation that grows cannabis for sale is approximately ±9.5 percentage points at the 95% confidence level.

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