Far-Red Research

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Jolene Hansen | January 2023

Portrait by Caroline Wilkins

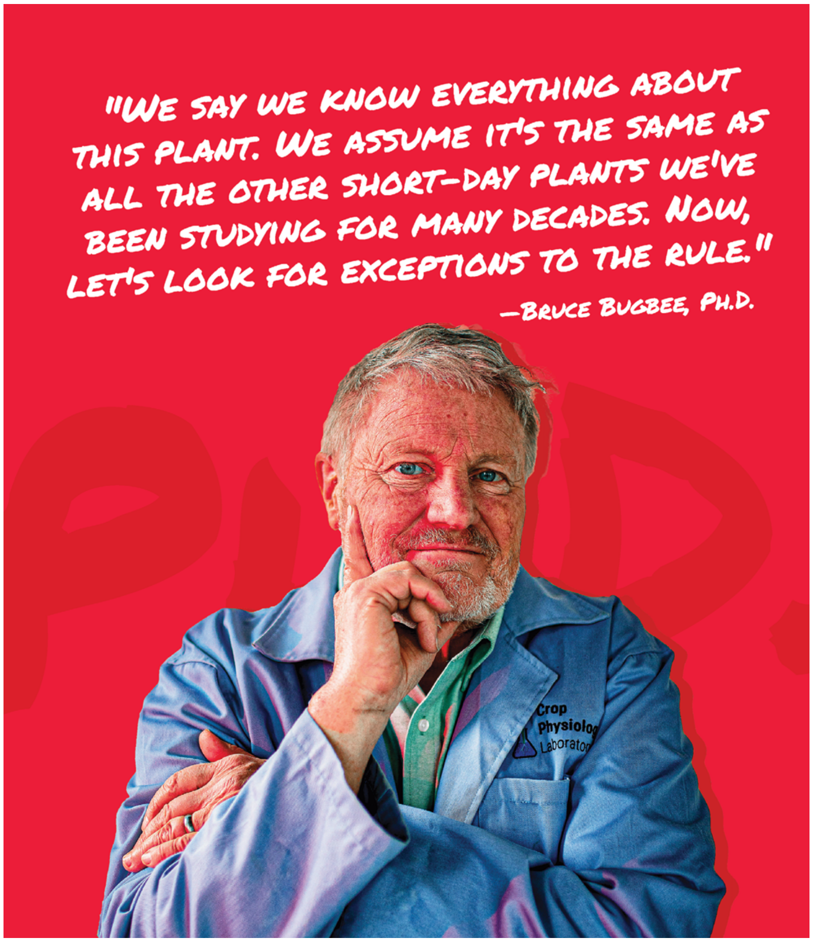
Before the 2018 Farm Bill legalized hemp and opened the gates for broad land-grant university research of *Cannabis sativa*—albeit using cultivars with THC levels not exceeding 0.3%— scientific studies on the plant were limited. Due to federal illegality, university research programs dependent on federal funding for survival shied away from the plant. Research fell to growers who, by necessity and choice, largely kept their findings to themselves.

When that changed in 2018, knowledge gleaned from decades of hands-on studies by legacy growers provided a springboard for scientific research, yet a cultural wall still existed between cannabis cultivators and researchers.

Recent years have seen dramatic growth in university programs focused on rigorous *Cannabis* research, from North Carolina State University cannabis nutrition studies to Utah State University research yielding a new definition of photosynthetically active radiation (PAR) that Bruce Bugbee, Ph.D., calls the most significant finding of his career to date.

But that's not the only shift. Growers, from legacy enterprises to new legal-market entries, are welcoming university research that may yield a competitive edge.

As a new year dawns, researchers and growers are finding common ground to advance the cannabis industry for the benefit of all. In that spirit, *Cannabis Business Times* checked in with four leading U.S. university research programs for the latest in *Cannabis sativa* research.



Portrait by Caroline Wilkins

Bruce Bugbee, Ph.D. Utah State University

With Professor Bruce Bugbee at the helm, the Utah State University (USU) Crop Physiology Lab is often associated with refining the relationships between plants and light. But while light is a focus, the lab's research ranges widely.

"Because cannabis is a new crop [for researchers] and a unique crop in how it grows and flowers, there are multiple things we've learned in the last few years," Bugbee says.

But the USU lab's approach to cannabis differs from many. Rather than researchers saying they know nothing about the plant, they take the opposite approach, Bugbee says. "We say we know everything about this plant. We assume it's the same as all the other short-day plants we've been studying for many decades. Now, let's look for the exceptions to the rule."

Extended PAR: The most groundbreaking news out of Bugbee's lab involves far-red photons and photosynthesis. For the last half-century, the accepted definition of photosynthetically active radiation (PAR)—known as the McCree curve—has been the range of 400 to 700 nanometers.

But research by Bugbee and team, as reported in *Cannabis Business Times* in 2019 and more recently published by *New Phytologist* in 2022, suggests a new definition of PAR, known as ePAR or extended PAR. Already accepted by some researchers, ePAR extends the upper range of photons involved in photosynthesis to 750 nanometers, including far-red photons at the fringe of visible light.

The discovery that far-red photons—already known to impact plant shape—also cause photosynthesis applies to all plant life and has implications for all growing environments, including outdoors. But Bugbee cautions that growers in controlled environments apply far-red photons with care.

Bruce Bugbee demonstrates where far-red photons fall in terms of wavelength.
Portrait by Caroline Wilkins

The good news is far-red photons increase leaf expansion, so light is captured more quickly. But they simultaneously increase stem elongation, which is bad news when compact plants are the goal.

In controlled environments, Bugbee suggests applying far-red photons early in the lifecycle to help close the canopy and capture all available photons, then minimizing far-red during stem elongation early in flowering to keep plants short. With that phase finished, Bugbee says, the last four weeks before harvest open the door to apply far-red photons again.

Light intensity: Bugbee says cannabis is remarkable in its ability to benefit from extremely high photon flux, aka light intensity. Leafy greens, in comparison, saturate around 500 micromoles per square meter per second (µmol/m2/s). Tomatoes saturate around 1,000 µmol/m2/s. But cannabis doesn't saturate until much higher levels.

"In our studies, it keeps going all the way up to 2,000 µmol/m2/s, which is equivalent to full sunlight at noon in the summer," he says. The lab's research has confirmed a linear relationship between increased light intensity and increased cannabis yields up to that 2,000 PPFD ceiling—significantly higher than growers in controlled environments traditionally have used.

But Bugbee stresses cannabis only benefits from high intensity lighting if nothing else is limiting in the growing environment, noting irrigation, fertilization, CO_2 enrichment and more: "You've got to have everything else optimized in order to take advantage of the high light."

He adds, however, that increased light intensity isn't always cost-effective. Electric bills increase along with yields, so every grower should consider both the physiological and economic optimums for their grow.

Fertilization: Several lines of USU research involve nutrients. Bugbee says many cannabis growers use "extraordinarily high" levels of phosphorus, up to 100 parts per million (ppm) or more. Research confirms cannabis benefits from higher phosphorus than typical crops for flower production, but Bugbee puts optimal levels around 30 ppm. Higher rates waste fertilizer and money and introduce environmental risks.

One fascinating study—which Bugbee characterizes as "the kind of thing that gets you out of bed every morning"—focuses on the micronutrient copper and the role that elevated copper fertilizations may play in disease control. Though needed only in small quantities for plant nutrition, copper is widely used as a potent fungicide.

"We're looking at elevating copper to inhibit fungal diseases, like Pythium and Fusarium in the root zone. We're finding that cannabis can tolerate these high copper levels with no reduction in growth or yield. And, therefore, we're anticipating that the higher copper will reduce disease. This is early research, but it's looking really promising so far," Bugbee explains.

Crop steering: Researchers may call it "phasic environmental control," but most growers call it crop steering, or guiding plant growth with specific lighting, nutrients, humidity and other parameters. With crop steering, there's particular interest in root zone manipulation to optimize growth and yield. Bugbee's lab studies areas such as precision water stress and restricted nutrients during early flowering—refining the fine line between keeping plants short and yields high.

Mitch Westmoreland, a Ph.D. candidate and research associate in Bugbee's lab, is focused on optimizing temperature at different lifecycle stages.

"That's a powerful tool, and it's very underappreciated because it's hard to study," Bugbee says. "… As a general principle, we recommend starting warm and then reducing the temperature at the end of the lifecycle."

Photo courtesy of Michael Gutensohn

Michael Gutensohn, Ph.D. West Virginia University

As lead scientist in a USDA-funded project, West Virginia University (WVU) associate professor Michael Gutensohn studies factors that cause increased secondary metabolites, including CBD, THC and terpenes. Drawing on his background as a biochemist and geneticist, his lab-based research focuses on the biochemistry of these specialized metabolites.

THC spikes: For growers cultivating hemp, staying under the federal 0.3% THC limit is critical to bringing crops to market. Gutensohn's team studies factors that trigger THC spikes, from insects to environmental conditions, to help growers avoid "hot" hemp.

He suggests plants have developed strategies of producing specialized metabolites—chemicals—in response to threats. "Simply spoken, you can say chemicals do chemical warfare. That sounds a little drastic, but that's essentially what it is," he explains.

Gutensohn's lab studies how these specialized metabolites may accumulate in response to environmental factors and stress conditions in highly controlled environments.

"One of the things we found already is that certain types of [pest problems] definitely cause increased cannabinoid levels," he says, noting pest management is critical. "Not just because it may be limiting your yield or the quality of your product, but it might cause spikes in THC levels."

His lab is also studying how interactions between mycorrhizal fungi and plant roots impact cannabinoid production or accumulation.

"We have some indications this interaction affects cannabinoid accumulation," Gutensohn says, noting fertilizer use or overuse may also trigger hot hemp. He expects to be able to offer growers specific recommendations in one or two years.

Expanded uses for hemp: Gutensohn's interests extend beyond hemp's traditional uses to areas like terpenes as a biofuel additive. "You can fly an airplane on terpenes," he says. He hopes WVU research will help enable breeders to produce cultivars for completely new purposes that are unattainable through classic breeding.

A medium-term goal is to understand the underlying genetics of the process by which hemp's formation of compounds such as cannabinoids and terpenes occurs. But a long-term goal is understanding how to turn the "light switches" on or off. "We are trying to find out, what is the regulation of all this? Because if you have an understanding of that, then you can modify it," Gutensohn says.

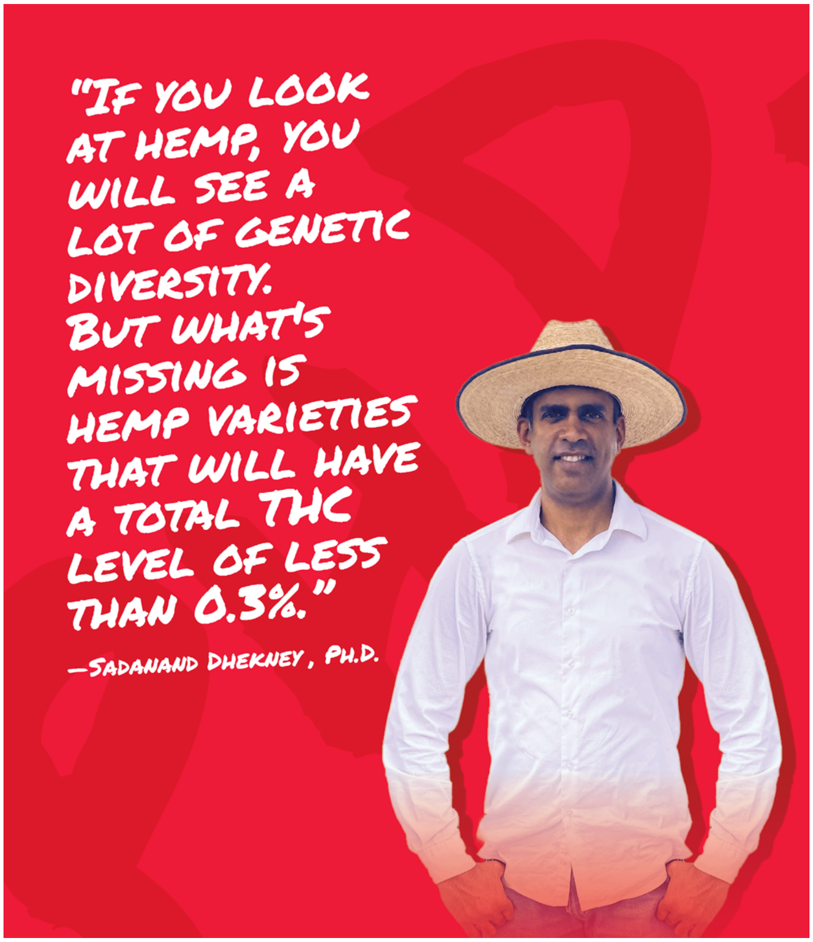


Photo courtesy of Sadanand Dhekney

Sadanand Dhekney , Ph.D. University of Maryland Eastern Shore

Professor Sadanand Dhekney and his team at University of Maryland Eastern Shore (UMES) work with cultivars meeting the legal requirements for industrial hemp. But he's vocal about broader applications of their findings.

"Botanically, hemp and marijuana are the same species. The way I look at them, they are different varieties or different cultivars of the *Cannabis* genus," he says. "Any research that we do with hemp is directly applicable to cannabis for that reason."

Genetics for cannabinoid production: Identifying hemp genetics that can produce their full potential of cannabinoids and stay under federal THC limits at harvest is a priority for land-grant researchers and the growers they serve. A UMES field trial with 50 hemp varieties yielded only four that could meet both criteria.

"If you look at hemp, you will see a lot of genetic diversity. But what's missing is hemp varieties that will have a total THC level of less than 0.3%," Dhekney says. The balancing act for farmers is either to harvest early, when CBD levels are less than optimal, or risk hot hemp at full maturity.

The WVU research team will identify parents to develop new varieties that restrict THC but fully express CBD potential in a process that takes six to seven years outdoors—or half that indoors.

Diseases in cannabis: Dhekney says that viral pathogens—viruses and viroids—are currently the biggest disease problem in cannabis. With no control strategies available, a grower's only option is destroying infected plants.

Bruce Bugbee in a controlled environment chamber, where researchers measure canopy photosynthesis, at Utah State University.
Photo by Dennis Hinkamp USU

To complicate matters, viral pathogens may be latent for generations. Symptoms such as stunting, leaf curl and low trichome production are easily misdiagnosed. Plus, insect vectors such as thrips and aphids contribute to pathogen spread.

With many growers focused on Hop Latent Viroid Disease (HpLVD), Dhekney stresses that more than 15 different viral pathogens are already infecting cannabis and causing problems—growers just aren't testing for them yet.

The UMES team is focusing on tissue culture techniques to clean the virus from plants during micropropagation and produce healthy, disease-free plant material for growers.

Optimized seed feminization: Dhekney explains that seed feminization in cannabis, a plant that naturally has male and female flowers occur on separate plants, involves chemically inducing male flowers alongside female flowers on the same plant. That leads to self-pollination and, in turn, feminized seed.

But when chemical concentrations are too low, feminization may be incomplete. If too high, on the other hand, seed isn't viable. Either way, growers lose.

Dhekney's lab is identifying optimal parameters for chemical treatment to achieve reliable, economical feminized seed. He hopes to have recommendations on timing, duration and concentration of sprays within two years.

> "WE HAVE MOLECULAR MARKERS NOW THAT WE CAN USE TO IDENTIFY THAT [AUTO-FLOWERING] GENE IN THE PLANT."
>
> – LARRY SMART, PH.D.

Larry Smart, Ph.D., and Cornell University's Hemp Research Team's work includes studying hemp production and cannabinoid development.
Photo Courtesy of Larry Smart

Larry Smart, Ph.D. Cornell University

With plant geneticist and breeder Larry Smart as its lead, Cornell's Hemp Research Team is focused on identifying genes that control key traits important for hemp production, profitability and yields—and breeding new cultivars for the industry.

Cannabinoid production timelines: Cornell research on timelines of CBD and THC production has focused on identifying optimal times for growers to do regulatory testing relative to maximum CBD production and the impact of environmental stress during flowering.

While cannabinoid levels change as they accumulate, the team found the CBD:THC ratio in the shoot tip of high- cannabinoid varieties during flowering does not change in response to environmental stress. Smart says results have shown “pretty conclusively” the ratio of CBD:THC is fixed. This suggests the ratio—and hot hemp—is driven by genetics.

Cannabinoids and plant structure: How cannabinoid production relates to overall plant form, plant architecture and canopy structure is another area of study. Field trials show that cannabinoid allocation, from a plant’s top to bottom, varies based on its architecture.

Some varieties produce a gradient of CBD concentration, meaning it’s highest at the top of the plant and lowest at the bottom, but other varieties do not. “That definitely varies depending on the cultivar, and it’s related to the overall architecture of the plant,” Smart says.

Flowering time and disease resistance: The Cornell team has been able to map a single recessive gene responsible for auto-flowering.

“We have molecular markers now that we can use to identify that gene in the plant,” Smart says. “We can actually use it now in our breeding program to intentionally select for plants that are auto-flowering.” This opens the door to new varieties tailored to different latitudes.

Similar work in the lab of Cornell professor and plant pathologist Christine Smart, Larry’s wife, has identified a single major gene that confers resistance to powdery mildew. Molecular tools like these mean that breeders will be able to make selections of auto-flowering or powdery-mildew resistant cultivars within weeks of germination instead of waiting until plants fully mature.

Like all the researchers in this research roundup, Smart is excited about working with *Cannabis sativa* and hearing from growers that benefit from his work.

“If we can help to bring tools to the industry that will accelerate the breeding of new cultivars and improve overall profitability across the industry, I think that’s the most gratifying and exciting thing we can do,” he says.

Jolene Hansen is a freelance writer specializing in the horticulture, specialty ag and cannabis industries. Reach her at jolene@jolenehansen.com.