UbiGro

SPECTRUM CONTROL FOR GREENHOUSES

Luminescent Greenhouse Films Improve Crop Yields

UbiQD

UBIQUITOUS QUANTUM DOTS

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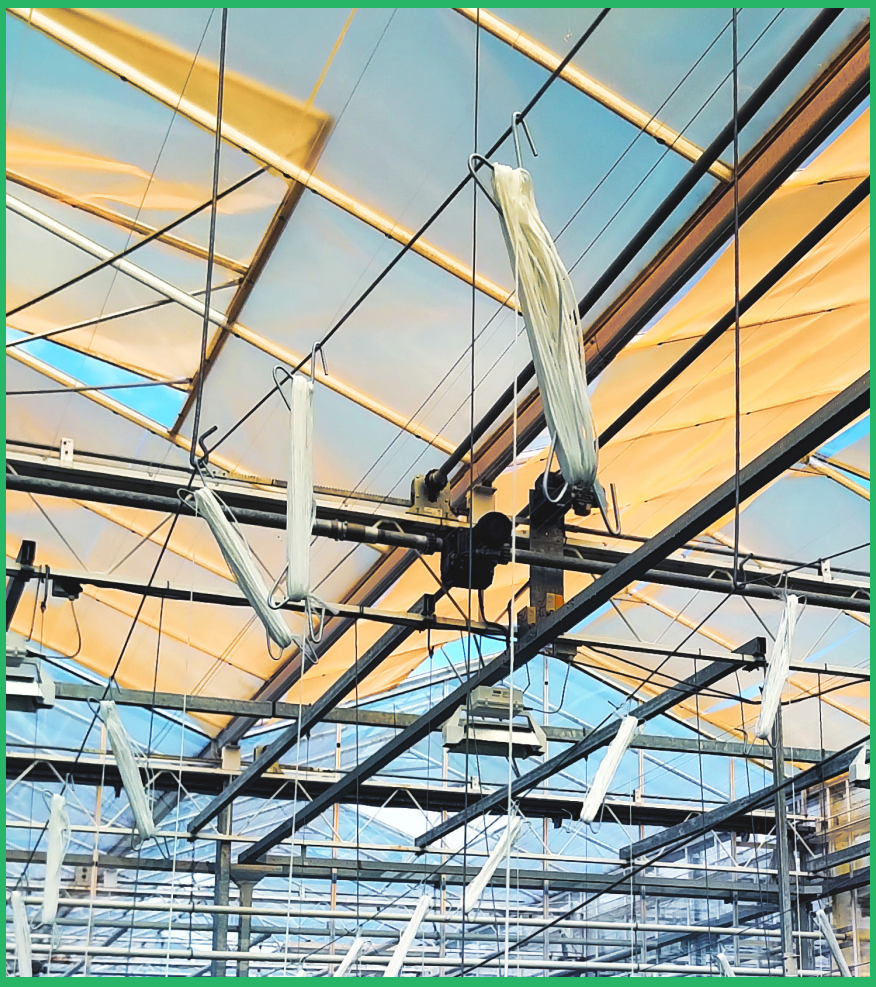


UbiGro luminescent greenhouse film can be installed in any greenhouse construction. Quantum dots embedded in the retrofit film provide an orange glow, bringing in better quality light for crops and improving their production.

Introduction

UBIGRO GREENHOUSE FILM IS HERE

How do you control the light environment in your greenhouse?

For many years, greenhouse growers would only consider technologies that add or subtract light from their greenhouses, trying to maintain the ideal light intensity and photoperiod to achieve optimal production for their crops. Now that LEDs are available with customized spectra, growers are beginning to consider how the spectrum of the light can improve their annual production. Unfortunately, LED supplemental lighting is expensive to install and operate. Growers need a better option for improving their spectrum.

A new, innovative product that lets growers take control over their light spectrum without breaking the bank is now available. UbiGro luminescent greenhouse films modify the sun's spectrum without requiring wires or electricity and provide crops with ideal light conditions. The patented quantum dot technology efficiently shifts UV and blue light to the red portion of the spectrum, which enhances the photosynthetic efficiency of the plants as well as improves fruit and flower production. This ultimately leads to improved crop yields for the grower, which means more revenue for the farm. This low-cost solution can be used in both low-tech greenhouses and large operations that have all the bells and whistles. The end result is the same: more production!

The UbiGro retrofit film has now been tested in various types of greenhouse construction, in a variety of different climates, and for growing different crops. In all cases, the film has shown a benefit to the farmer through improved crop yields due to the enhanced light spectrum.

Take control of your light environment. Join our growing community and use the power of nanotechnology to enhance crop production in your greenhouse!

Matt Bergren, PhD
Chief Product Officer, UbiQD

01 Light Quantity

LIGHT ENVIRONMENT IN A GREENHOUSE

Light is the most important growing parameter needed for plants. There are three major attributes that should be considered:

- The **quantity** of light (intensity)
- The **quality** of light (color)
- The **duration** of light (photoperiod)

The Impact of Light on Plants

LIGHT INTENSITY AFFECTS PHOTOSYNTHESIS

The intensity of light provided to a plant will directly affect its production. For horticulture applications, light intensity is measured over the wavelength range from 400-700nm, which is referred to as Photosynthetically Active Radiation (PAR). Growers measure the instantaneous PAR intensity in their greenhouse in micromoles per square meter per second ($\mu mol\ m^{-2}\ s^{-1}$), or the number of photons useful for photosynthesis that hit a square meter area every second.

While an instantaneous PAR measurement can be useful in understanding the light environment in a greenhouse, it alone will not necessarily correlate with crop production. The Daily Light Integral (DLI) is a better metric to predict production in a greenhouse. DLI is simply the amount of PAR received by plants over the course of a single day, calculated by adding up the instantaneous PAR measurements over a 24-hour period. The units of DLI measurements are in moles of photons (1 mol = $6.02x10^{23}$) per square meter per day. In general, a 1% increase in DLI results in a 1% improvement in crop yield for most plants. Although DLI requirements for crops differ depending on the type of plant, in general, maintaining a high DLI in your greenhouse will result in higher crop production.

PHOTOPERIOD

The photoperiod refers to the amount of time plants receive light during a 24-hour period. The photoperiod is important because it not only factors into DLI calculations, but it also determines the number of hours of interrupted darkness perceived by the plant. Darkness also influences plant reactions, such as flowering, fruiting, and stem elongation. In this way, the photoperiod plays a role in the plant's circadian rhythm and helps trigger plant responses depending on what "season" the plant perceives it is in. This takes into account the photoperiod, day/night temperatures, and spectrum.

Supplemental lighting can be used to extend the photoperiod in a greenhouse, by providing light after sundown.

Most plants require a minimum number of hours of darkness in a 24-hour period in order to maintain regular plant growth. While plants utilize photosynthesis to convert CO_2, water, and light into sugars and oxygen, plants do most of their growing in the dark. They rely on a process called respiration, where sugars made by photosynthesis and oxygen absorbed from the environment are converted into energy. Respiration occurs during the day and night, but photosynthesis only occurs when there is light available during the day. In the evening, respiration is the only way for the plants to create energy for growth.

Did you know?

Different plants require different quantities of light.

Some common DLI values (in mol/m^2 day) for optimal growth of different plants are listed below.

Crop	DLI
Cannabis	35-40
Tomatoes	22-35
Cucumbers	22-35
Peppers	16-35
Strawberries	22-30
Lettuce	14-16

02 Light Quality

PHOTOSYNTHESIS & PHOTOMORPHOGENESIS

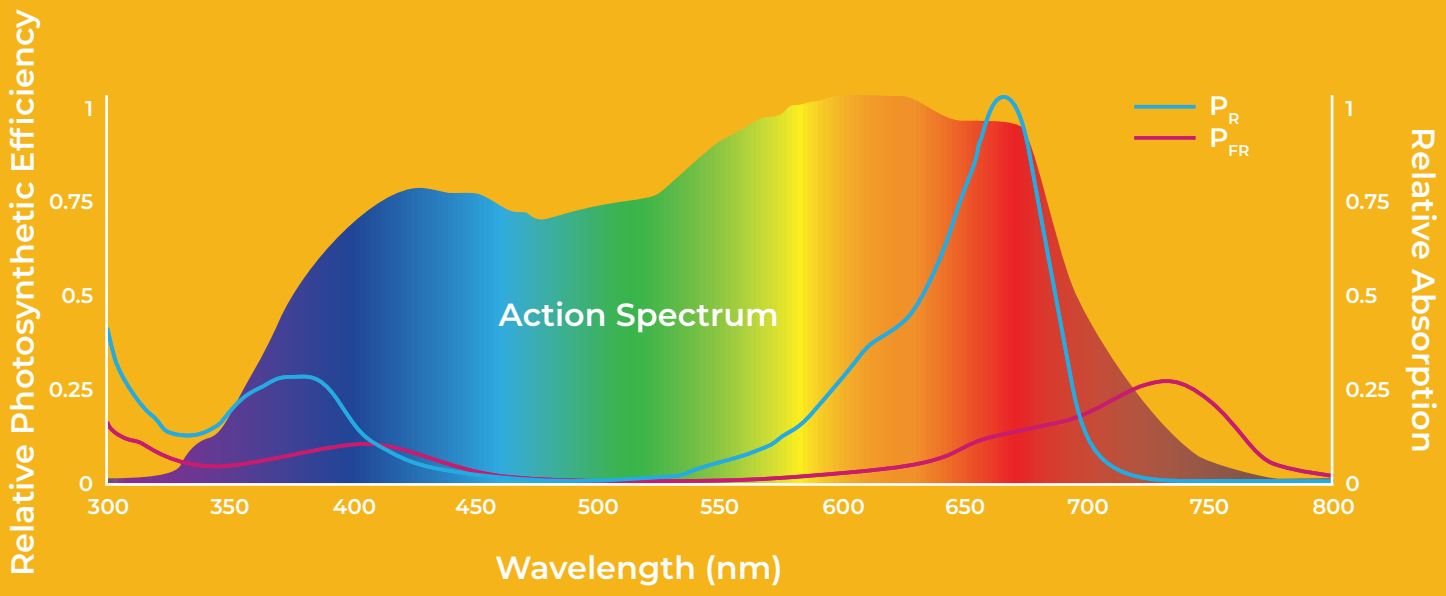
Light outside the PAR range is generally not used directly for photosynthesis. However, the spectrum, including colors outside of PAR, can modify the architecture and growth rates of plants, with significant consequences on the value of the crop. How light affects the development of the plant is called photomorphogenesis.

Numerous plant responses, including growth and fruit production rates, plant stretching, the color and flavor of food crops, and the duration of crop cycles can be regulated by controlling the color spectrum.

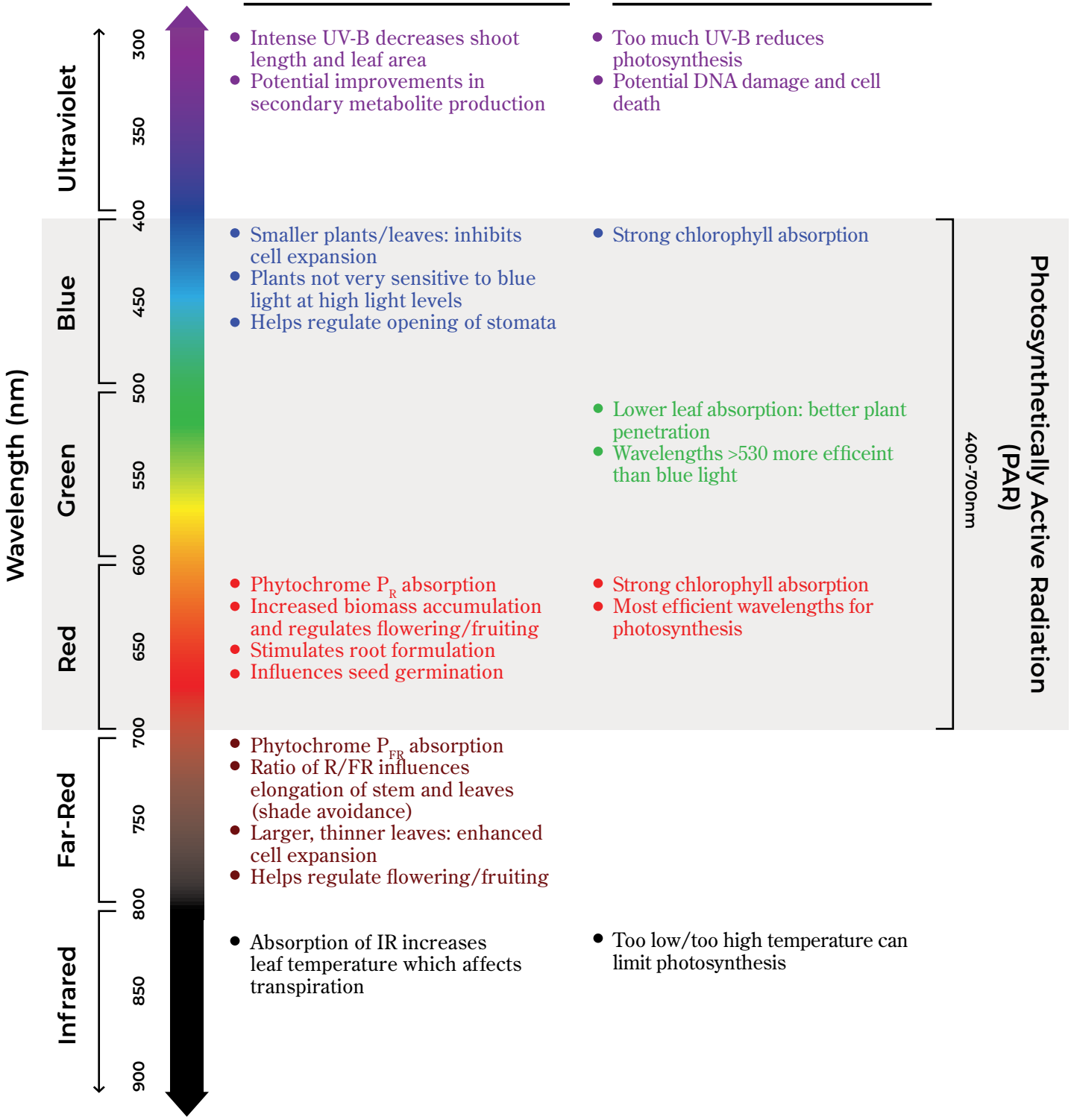
COLOR AFFECTS PLANT GROWTH

The relative photosynthetic efficiency is dependent on the wavelength of light. Wavelengths between 600-650nm are most efficient for photosynthesis. The action spectrum (shown below) illustrates the differences in relative photosynthetic efficiency for various wavelengths.

Phytochromes play an important part in plant development. The ratio between the red-absorbing form (P_R, blue curve) and far-red-absorbing form (P_{FR}, red curve) inform the plant of the light environment and induce different plant responses.

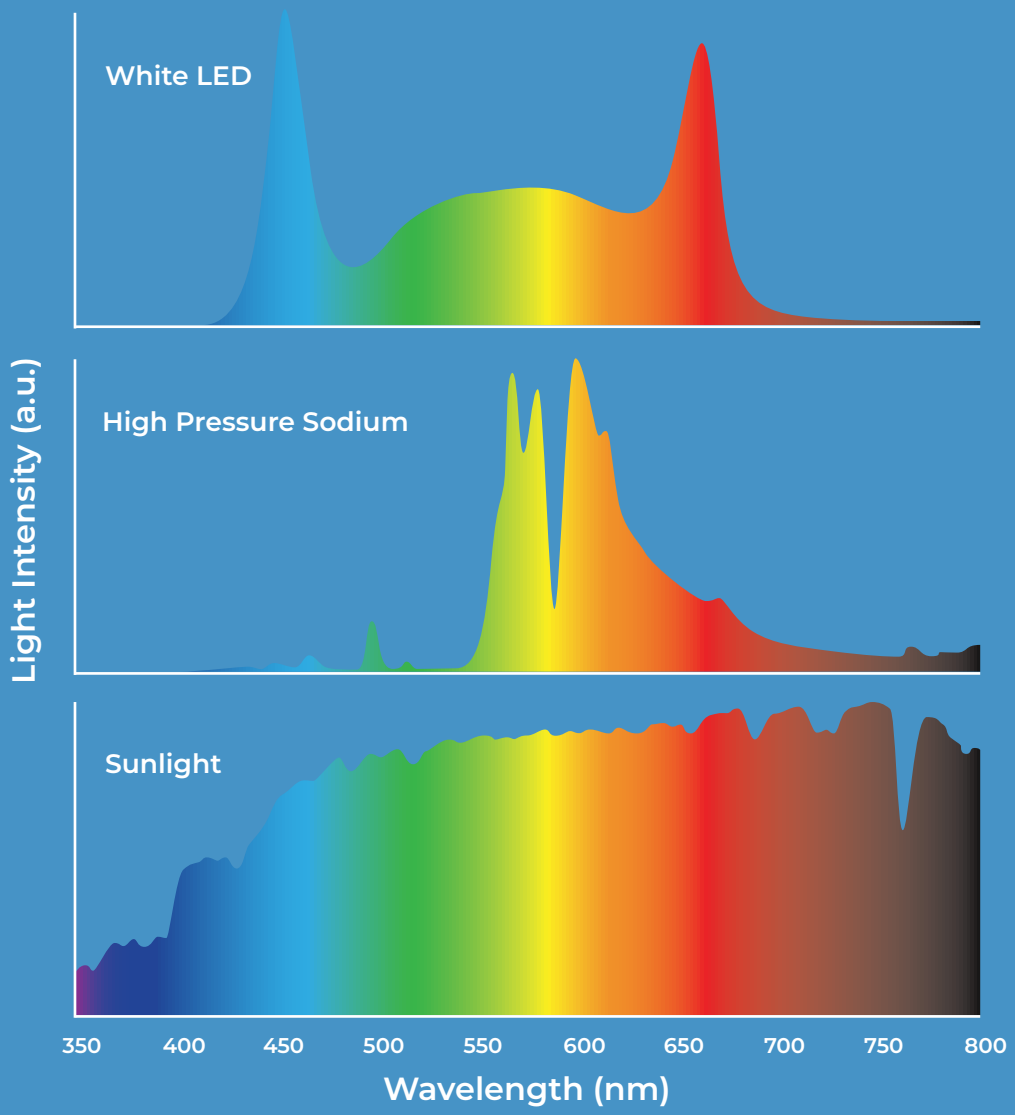


The Impact of Color on Plants



03 Technologies

HOW DO DIFFERENT SUPPLEMENTAL LIGHTING TECHNOLOGIES COMPARE TO THE SUN'S SPECTRUM?



HOW IS LIGHT CONTROLLED IN A GREENHOUSE?

There are multiple ways to control the light environment in a greenhouse, ranging from supplemental lighting to shade nets. Here we discuss the benefits and drawbacks from different technologies that can be employed in greenhouses. We also introduce a new technology, luminescent greenhouse films, which solves some of the issues with previous technologies.

LED HORTICULTURE LIGHTING

Artificial lighting has been used in greenhouses for years to extend photoperiods in the winter and to maintain PAR levels during cloudy days. In the past, the light fixtures of choice were generally high-intensity discharge (HID) lights, where a mixture of metal halide and high-pressure sodium (HPS) bulbs are installed. Today, more growers are turning towards LED luminaires for horticulture lighting as they provide a more electricity-efficient solution to providing similar light levels, allow for control of the spectrum (better quality light), last longer, and the fixtures produce less heat than HID lights, which can reduce the cooling requirements for a greenhouse.

Supplemental lighting (HPS and LED) used in a glass greenhouse.

Supplemental lighting can **extend photoperiods**, provide additional light on cloudy days, and alter the **quality of light** in a greenhouse environment.

While LED horticultural lighting can be beneficial for greenhouse growers, especially in northern climates, the technology does have drawbacks. The biggest drawback is the cost of implementing supplemental, overhead or inter-canopy, lighting. There are two costs associated with artificial lighting, 1) the upfront cost of purchasing and installing the fixtures (CapEx) and 2) the cost of electricity needed to operate the lights (OpEx). The number of fixtures required for a given greenhouse depends on the type of system you are purchasing, the construction of the greenhouse, where the greenhouse is located, and the type of crop(s) that are being grown in the controlled environment. Another drawback of LED horticulture lights are they generally provide direct light, instead of diffuse light, and thus don't penetrate into the lower canopy as well. This sacrifices potential yield benefits from illuminating lower leaves. Finally, in contrast to sunlight, LED lighting typically does not contain any far-red light, which helps enhance cell expansion.

SHADE NETS & COATINGS

Shade nets and spray coatings (applied to the roof and walls of a greenhouse) are generally used to reduce light intensities and overall greenhouse temperature during sunny days and warm seasons. This can help prevent damage to the plants and maintain optimal DLI levels. In some cases, the shade nets convert direct light into diffuse light, which benefits crop production. Recently, some light intensity-reducing products have been developed to also modify the light spectrum inside the greenhouse. This is done by absorbing certain portions of the solar spectrum and transmitting wavelengths that are desirable for plant growth.

Retractable shade nets can be deployed inside a greenhouse to reduce light intensity.

Spray coatings can be applied and removed depending on greenhouse requirements.

Spray coatings are generally applied and removed depending on season and light level. They are low-cost and provide different levels of shading and diffusion, depending on the requirements for a specific greenhouse.

Shade nets are commonly installed so that they can be deployed or retracted in real time depending on the light levels measured inside the controlled growing environment. When coupled with an automation system, the shade nets can be deployed and retracted as the light intensity changes throughout the day.

While these technologies are typically low-cost solutions to managing light levels, they always are reducing PAR intensity when in use. In locations like the southwest of the United States, this may be a desired quality, due to the high light levels in this area during summer. In northern latitudes where you are typically trying to maximize PAR, these technologies are less useful.

These typical **low-cost** solutions for managing light levels in a greenhouse **reduce PAR** when in use.

LUMINESCENT FILMS

A new technology that is beginning to attract attention among growers are luminescent greenhouse films that glow when illuminated with sunlight. Unlike shade cloths, or spray coatings that filter light, this technology has the unique property of converting short wavelength photons to longer wavelength photons. This shifting of the sunlight spectrum provides growers a low-cost solution to modify the light spectrum in their greenhouse, without sacrificing PAR. Luminescent films also provide diffuse light for the wavelengths that are radiated by the film, since light is emitted in all directions.

Traditionally, luminescent films are composed of organic dyes, which have a specific absorption and emission spectra. This has limited which wavelengths of light can be shifted, with most products absorbing green light and emitting photons in the red. Previously it was believed that green light was not useful to plants since it is not strongly absorbed, and is reflected more than other colors (hence the green appearance of leaves and stems). Recently, it has been proposed that green light actually plays an important role in photosynthesis. Not only are most green wavelengths equal to, or more photosynthetically efficient than blue light, but the higher transmission of green light through leaves means these wavelengths can penetrate deeper into plant tissues and into the plant canopy and drive photosynthesis for the entire plant.[i,ii]

Ideally, luminescent films would be customizeable to provide different light recipes for greenhouse growers that could be specific to their crop and geographical location. A new luminescent film, called UbiGro, has been developed that finally provides growers the ability to fully control the light environment in their greenhouse.

Luminescent films absorb certain light colors and convert them to other light colors through a process called photoluminescence. This differs from filtering colored films, which block certain colors while letting others pass through.

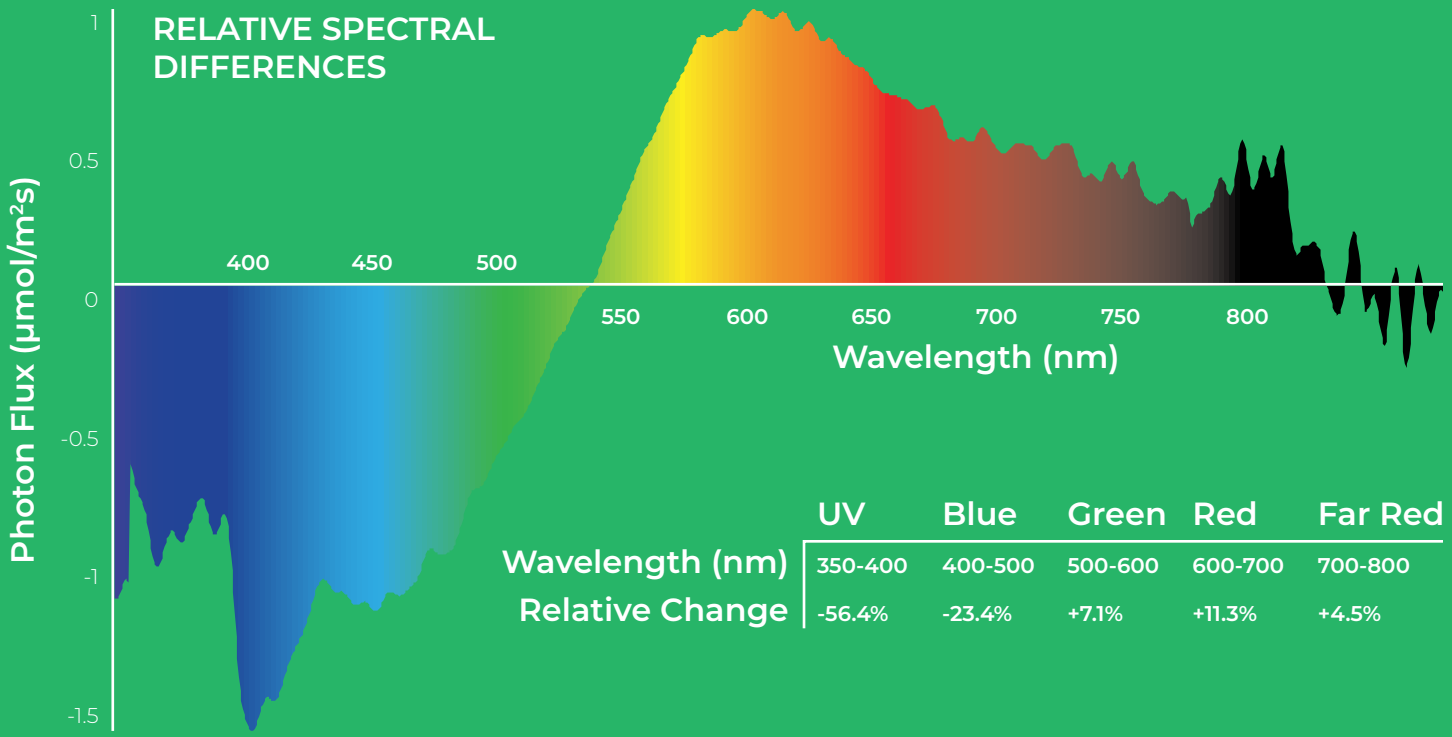
Luminescent films **convert** short wavelength photons to longer wavelengths, providing a low-cost solution to light modification **without sacrificing PAR.**

04 UbiGro Luminescent Greenhouse Film

COLOR OPTIMIZATION WITH NANOTECHNOLOGY

UbiGro films convert UV and blue photons to longer wavelength photons, such as orange or red, by using novel nanomaterials called quantum dots (QDs). The absorption and emission spectra of QDs can be altered by simply changing the size of the manufactured QDs. The emitted light can be selected for a specific crop or certain stage of growth to realize optimum crop yields.

The current UbiGro film emits light centered in the orange (600nm). The graph and table below demonstrate how the film modifies the solar spectrum by absorbing shorter wavelengths of light and converting them to longer wavelengths.



	UV	Blue	Green	Red	Far Red
Wavelength (nm)	350-400	400-500	500-600	600-700	700-800
Relative Change	-56.4%	-23.4%	+7.1%	+11.3%	+4.5%

SPECTRAL SHIFT

The UbiGro film has been manufactured to provide an optimized spectrum to realize higher production yields in a greenhouse. The film improves production in three ways. First, the film converts UV and blue light to orange and red wavelengths, which is more efficient for photosynthesis. Second, the emitted light has an effect on the plant structure, where the plant can focus more energy into the fruit or flowers. Finally, the quantum dots in the UbiGro film emit light in all directions, providing the greenhouse with diffuse light and allowing the light to reach deeper into the plant canopy.

PHOTOSYNTHESIS SPECTRAL RESPONSE DIFFUSE LIGHT

UbiGro film can be installed under any type of greenhouse construction.

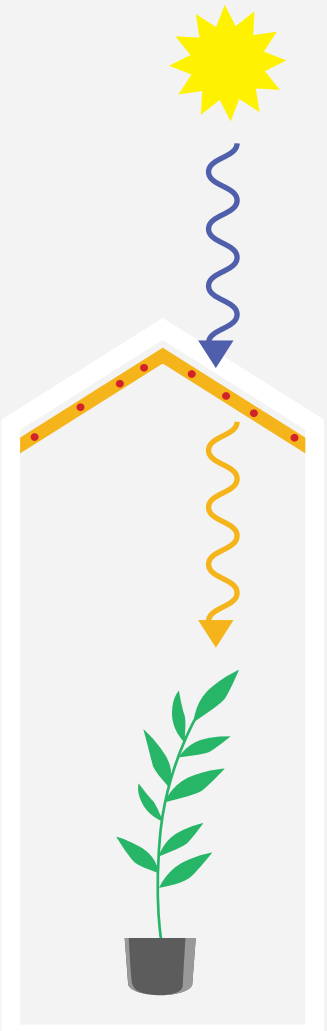
COMPARISON OF DIFFERENT LIGHTING TECHNOLOGIES

Technology	CapEx	OpEx	Lifetime (yrs)	Light Quality	Light Quantity	Photo-period	Diffuse Light	Yield Boost	ROI (yrs)*
LED Top Lighting	$$$$$	$$$$$	10	Yes	++	Yes	No	++	5.9
LED Inter-Canopy Lighting	$$$$	$$$$	5	Yes	++	No	No	+	10.9
UbiGro Luminescent Films	$$	0	4-6	Yes	neutral	No	Yes	+	0.9
Spectral Conversion Netting	$	0	4	Yes	---	No	Maybe	+**	N/A
Shade Netting	$	0	4	No	---	No	Yes	No	N/A

* ROI for greenhouse-grown tomatoes
** Under high light intensities

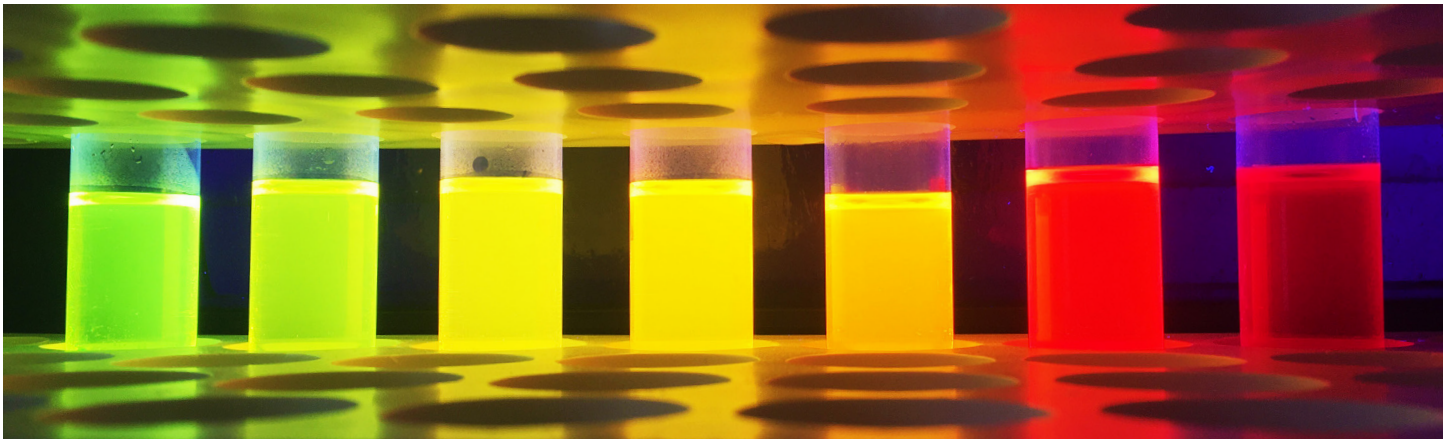
How it works

UbiGro luminescent greenhouse films provide the highest **production yield benefit** for a variety of crops. Light from the sun is absorbed by quantum dots in the UbiGro film. The **quantum dots shift** some of the shorter wavelength colors, like UV and blue, **towards the red**.



The **optimized light** is absorbed by plants, improving overall crop yields.

What are Quantum Dots?

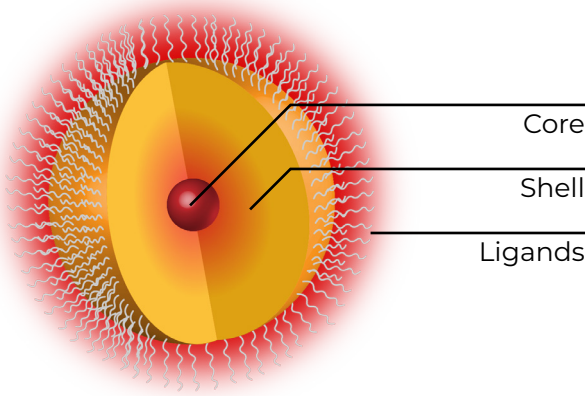


Quantum dots convert light very efficiently. Different sized QDs emit different colors.

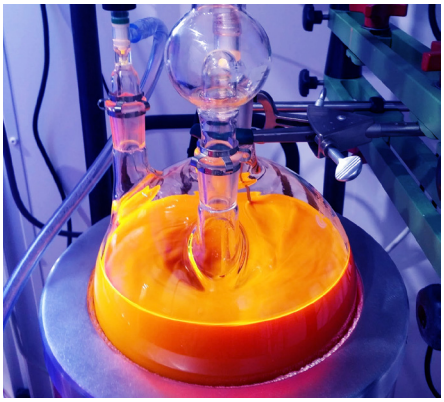
OUR NANOTECHNOLOGY

Colloidal semiconductor nanocrystals, or quantum dots, are nanoparticles so tiny that it would take roughly 10,000 of them to span the width of a human hair. Quantum dots have remarkably high light conversion efficiency and exhibit size-tunable photoluminescence over a wide range of colors.

Quantum dots typically consist of a central core, a protective shell, and hair-like features called ligands.



MANUFACTURING PROCESS



Quantum dots are manufactured at the UbiQD headquarters in Los Alamos, New Mexico.

Solutions of quantum dots are prepared to make the UbiGro film.

UbiGro film is rolled out, cut to size, and deployed at greenhouse locations around the world.

Case Study

Tomatoes: New Mexico

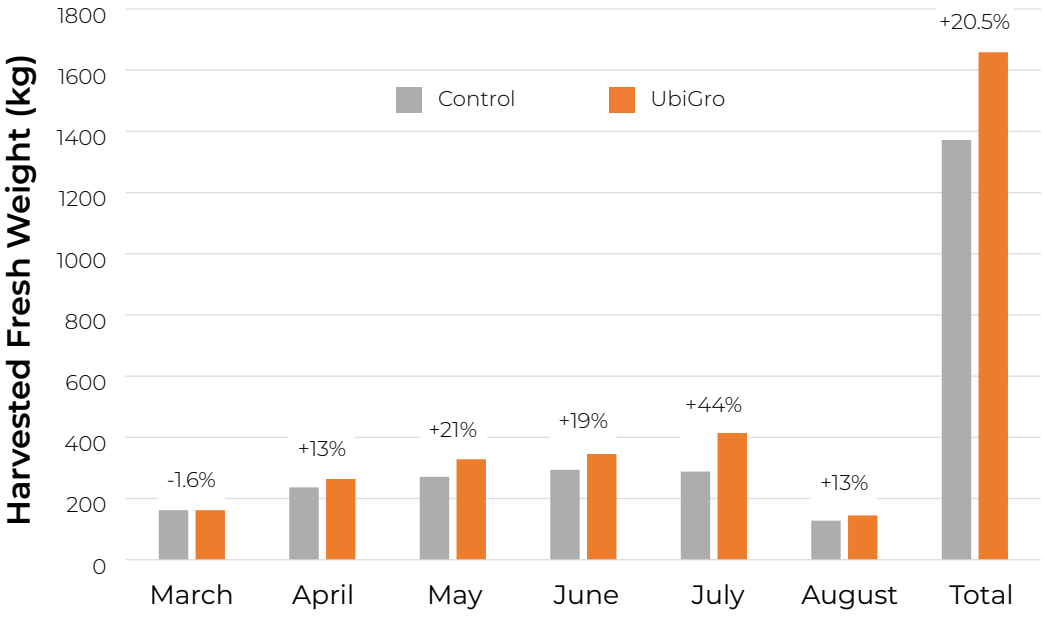
+20.5%
yield increase

GROWING OPPORTUNITIES

UbiGro films were installed and tested in a hydroponic greenhouse located at Growing Opportunities Farm in Alcalde, NM. In this five-month plant trial, two sections of UbiGro films were suspended over a row of 126 beefsteak tomato plants. The tomato production under these films was compared to a control row located in the same greenhouse that was only exposed to un-modified sunlight. There were three rows of tomatoes in between the two test rows, which served as barrier rows, ensuring the light conditions for the film and control row were distinct. The 30'x90' greenhouse had a double-polyethylene cover that was whitewashed to lower light intensity during the summer.

The films were installed on March 8th, 2019, 76 days after harvesting had begun on the crops. The plant trial continued for five months and completed after their final harvest on August 9th, 2019. All growing conditions besides the light environment were kept identical for both sides of the trial including: watering and nutrient regimen, humidity and temperature, harvesting and pruning regimen, integrated pest management regimen, etc. The farm harvested ripe tomatoes twice a week and the fresh weights for both rows were reported after each harvest.

BEEFSTEAK TOMATO PRODUCTION

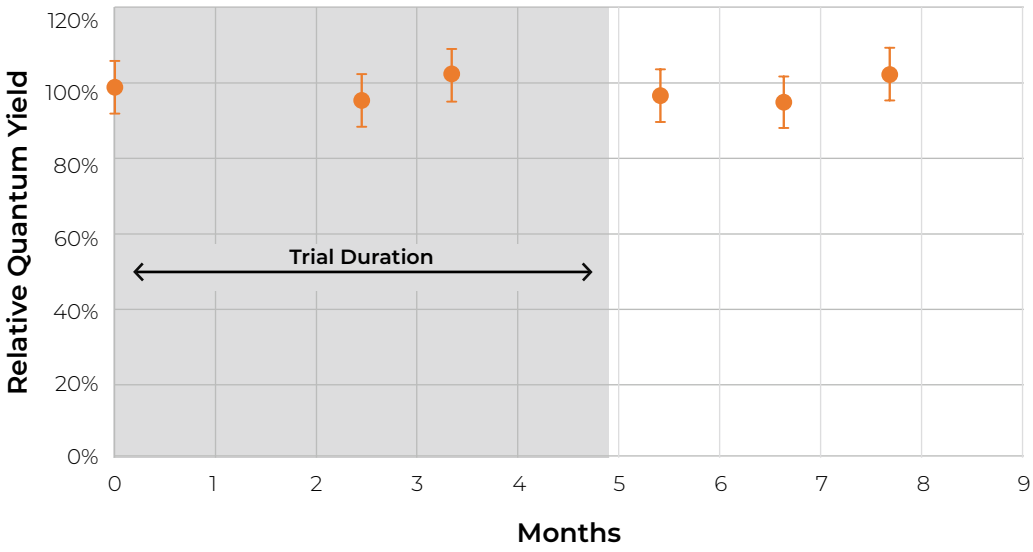


The UbiGro film enhanced tomato production in 4 of 5 months of the trial, with a total yield enhancement of +20.5%.

Trial Summary

Farm	**Growing Opportunities**
Location	Alcalde, NM
Crop	Hydroponic Tomatoes
Total Plants	252
Yield Boost	+20.5%

UBIGRO: STABILITY IN GREENHOUSE



The data for this tomato plant trial is shown on page 15, where a yield enhancement was consistently observed throughout the duration of the trial. This resulted in a +20.5% overall increase in fresh weight harvested under the UbiGro films relative to the control. The benefit was most pronounced in high-light level months, June and July. There were no observed differences in color, flavor, or overall quality of the fruit harvested from the two separate rows of tomatoes.

Films were tested for stability regularly throughout the plant trial and the relative luminescent quantum yield, or photon conversion efficiency, was compared (above). The quantum yield of the film correlates with the brightness of the emission, and therefore indicates the performance of the film over time. Over the course of the five-month summer trial, the UbiGro films showed no degradation in quantum yield, indicating no change in the optical properties of the film. The films have remained installed in the greenhouse for an additional 77 days and the film has maintained its original optical performance.

UbiGro film installed over hydroponically grown tomatoes at Growing Opportunities.

Did you know?

UbiGro films are designed to maintain their **optical performance for 4 years** and have an expected **usable life of 6 years**.

ECONOMICS

An improvement in crop yield will benefit the economics of a farm, but what is that yield enhancement worth to the farmer? Taking this plant trial as a case study, we can calculate the value that the yield-boosting UbiGro film brings to the economics of the farm. Based on historical production data, this 2880 ft^2 greenhouse produces on average 29,750 lbs/yr. The farm sells beefsteak tomatoes for $2.50/lb (wholesale price), and the tomatoes retail for $4.99/lb. This equates to $74,375 in wholesale revenue from this single greenhouse. A +20.5% increase in yield, as shown in this study, translates to $15,247 in increased revenues per year.

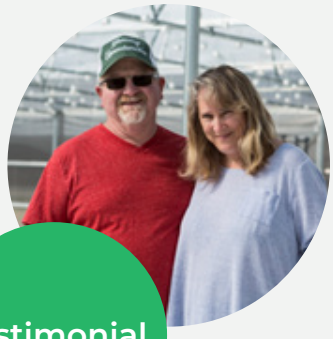
In order to quantify the value of the increase in revenue, we must calculate the increased profit. There are variable costs associated with producing and selling this extra produce, including harvesting, packaging, and transportation. However, fixed costs are not increased with the additional yield. These costs include real estate (rent/mortgage), heating/cooling, electricity, marketing, and labor (such as cleaning, seeding, vegetative labor, etc.). Given that the gross margin on the baseline production of beefsteak tomatoes at Growing Opportunities farm is 68% (32% COGS), we can estimate an 84% gross margin on any extra production (16% COGS) realized as a result of the superior UbiGro spectrum.

In this example, that translates to $12,807 additional profit per year from this greenhouse. Over the projected 4-yr life of the installed UbiGro film, the farm would take in over $51,000 in extra profit from this greenhouse alone.

A Growing Opportunities' Hydroponic Greenhouse.

"When light passes through the quantum dots, the **light spectrum is altered** in a manner that is more **beneficial to the plant**."

- Owner, Growing Opportunities



Testimonial

Case Study

Cannabis: California

LITTLE HILL CULTIVATORS

+5.4%
yield increase

UbiGro films were installed at Little Hill Cultivators farm in Trinity County, California. The films were mounted flush against the inside polyethylene cover of half of a 20'x108' greenhouse. The UbiGro film covered 133 cannabis plants while the other half of the greenhouse had no UbiGro film and served as the control for the trial. The number of control plants matched the number under the UbiGro film for a total of 266 plants that were monitored during the trial. The strain for the plant trial was the Indica-dominant Ice Cream Cake (Gelato x Wedding Cake).

All conditions were kept identical for both sides of the experiment: watering and nutrient regimen, humidity and temperature, harvesting and pruning regimen, integrated pest management regimen, etc. The cultivation team at Little Hill Cultivators made qualitative observations of the crop during the growth cycle. They noted that the plants under the UbiGro film showed an obvious enhanced vegetative growth rate, exemplified by an increase in height, width and overall foliage, filling more aisle space than their control counterparts. After three months under the films, dry, trimmed harvest weights were reported in September of 2019. Dry yield showed an extra 2.5 lbs harvested from under the film, equivalent to a +5.4% increase in total dry yield. No differences in trichome color, finishing time, bud color, bud odor/flavor, or overall quality were observed.

Specimens from both sides of the plant trial were sent to CW Analytical Laboratories (Oakland, CA) for cannabinoid and terpene testing. Total terpene content for flowers grown under the UbiGro films came back slightly increased compared to flowers grown under the control side, by +7.7% (relative). Total cannabinoid content was slightly reduced for flowers grown under the UbiGro film, by -3.5% (relative). Both of these small variations are well within the error bars of the testing accuracy, which falls about ±10% (relative). Therefore, we conclude that the UbiGro film had a negligible effect on terpene and cannabinoid content of this strain.

TRIAL SUMMARY

Farm	**Little Hill Cultivators**
Location	Trinity Co., CA
Crop	Cannabis (Ice Cream Cake)
Total Plants	266
Yield Boost	+5.4%

POTENCY SUMMARY

Terpenes

UbiGro	**1.4%**
Control	**1.3%**
Rel. Change	**+7.7%**

Total Cannabinoids

UbiGro	**21.25%**
Control	**22.02%**
Rel. Change	**-3.5%**

ECONOMICS

A yield enhancement improves the economics of a farm, but what is that yield enhancement worth to the farmer? Taking this experiment as a case study, we can calculate the value that the yield-boosting UbiGro film brings to the economics of the farm. During this trial, the full greenhouse produced 93.1 lbs of dried, trimmed cannabis, excluding the 2.5-lb boost realized by the half covered by UbiGro. The greenhouse will produce double that amount given two rounds of harvests per year. The farm wholesales trimmed cannabis for $1250/lb. This equates to $233,000 in wholesale revenue from this single greenhouse per year. A +5.4% increase in yield translates to $12,600 increased revenues per year.

To quantify the value of the increase in revenue, we must calculate the increased profit. There are variable costs associated with producing and selling this extra cannabis, including harvesting, drying/curing, trimming, packaging, and transportation. However, fixed costs are not increased with additional yield. These costs include real estate (rent/mortgage), heating/cooling, electricity, marketing, labor tied to square footage such as cleaning, seeding, vegetative labor, etc. Given that the gross margin on the baseline production of cannabis at Little Hill Cultivators is 50% (50% COGS), then we estimate a 65% gross margin on the extra production (35% COGS) realized as a result of the UbiGro spectrum. In this example, that translates to $8,170 additional profit per year from this greenhouse. Over the 4-yr life of the installed UbiGro film, the farm would benefit from $32,700 in additional profit from this greenhouse alone. If the farm adopted the UbiGro technology across all six greenhouses on site and this yield improvement was consistently realized, it could profit an additional $49,000 per year, or an additional $196,000 over the 4-yr lifetime of the films.

GREENHOUSE DETAILS

Greenhouse Size	**20ft x 108ft**
Increased Revenue/Year	**$12,600**
Increased Profit/Year	**$8,170**
Increased Profit over Film Life	**$32,700**
Increased Profit over Film Life, Farm	**$196,000**

Cannabis growing under UbiGro film at Little Hill Cultivators.

"After two weeks of growth we are noticing a **clear increase in overall foliage, height, and width** of plants under the film.

It's night and day in there."

- Owner, Little Hill Cultivators

Testimonial

Case Study

Cannabis: Oregon

FRONTIER FARMS

UbiGro films were installed in one of 40 greenhouses at Frontier Farms, a licensed recreational cannabis farm in Hood River, Oregon. The films were mounted flush against the inside polyethylene cover of half of a 25'x90' greenhouse. The UbiGro film covered 96 cannabis plants while the other half of the greenhouse had no UbiGro film and served as the control for the experiment. With 98 control plants, a total of 194 plants were monitored during the trial. The strain for the plant trial was the Indica-dominant Cherry Chem (Cherry Pie x Chem 4).

All conditions were kept identical for both sides of the experiment: watering and nutrient regimen, humidity and temperature, harvesting and pruning regimen, integrated pest management regimen, etc. The cultivation team at Frontier Farms made qualitative observations of the crop during the growth cycle. They noted that the plants under the UbiGro film were taller, with a little tighter buds, and overall grew with more vigor. After three months under the films, whole plant wet weights were reported in October of 2019.

Excluding edge and border rows that were particularly inhomogeneous in plant size on both sides of the trial, wet yields were increased by +7.7% on the film side of the trial. While final dry yields have not been reported as of this writing, we estimate this to be equivalent to a +3.1 lbs of dry, trimmed bud off the film side, based on an assumption of a 15% whole-wet-plant/dry-trimmed-bud ratio. No differences in trichome color, finishing time, bud color, bud odor/flavor or overall quality were observed.

+7.7%
yield increase

TRIAL SUMMARY

Farm	**Frontier Farms**
Location	Hood River, OR
Crop	Cannabis (Cherry Chem)
Total Plants	194
Yield Boost	+7.7%

ECONOMICS

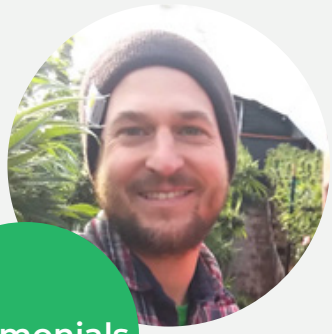
A yield enhancement improves the economics of a farm, but what is that yield enhancement worth to the farmer? Taking this experiment as a case study, we can calculate the value that the yield-boosting UbiGro film brings to the economics of the farm. During this trial, the full greenhouse will produce an estimated 80 lbs of dried, trimmed cannabis, excluding the 3-lb boost realized by the half covered by UbiGro. The greenhouse will produce double that amount given two rounds of harvests per year. The farm currently wholesales trimmed cannabis for $1000/lb. This equates to $160,000 in wholesale revenue from this single greenhouse per year. A +7.7% increase in yield translates to $12,320 increased revenues per year.

To quantify the value of the increase in revenue, we must calculate the increased profit. There are variable costs associated with producing and selling this extra cannabis, including harvesting, drying/curing, trimming, packaging, and transportation. However, fixed costs are not increased with additional yield. These costs include real estate (rent/mortgage), heating/cooling, electricity, marketing, labor tied to square footage such as cleaning, seeding, vegetative labor, etc. Given that the gross margin on the baseline production of cannabis at Frontier Farms is 50% (50% COGS), then we estimate a 65% gross margin on the extra production (35% COGS) realized as a result of the UbiGro spectrum. In this example, that translates to $8,000 additional profit per year from this greenhouse. Over the 4-yr life of the installed UbiGro film, the farm would benefit from $32,000 in additional profit from this greenhouse alone. If the farm adopted the UbiGro technology across all 40 greenhouses on site and this yield improvement was consistently realized, it could profit an additional $320,000 per year, or an additional $1.28M over the 4-yr lifetime of the films.

GREENHOUSE DETAILS

Greenhouse Size	**25ft x 90ft**
Increased Revenue/Year	**$12,320**
Increased Profit/Year	**$8,000**
Increased Profit over Film Life	**$32,000**
Increased Profit over Film Life, Farm	**$1.28 million**

Cannabis growing under UbiGro film at Frontier Farms.



Testimonials

"It seemed like they were growing **better and bushier** on the orange side."

- Owner, Head Grower
Frontier Farms

"I'm excited about being on **the front lines** with you guys. I think it's gonna **do us well**."

- Grower,
Frontier Farms

UbiGro vs LED Inter-Canopy Lighting

UbiGro films represent an alternative to inter-canopy lighting, which typically results in similar yield improvements. Inter-canopy lighting generally uses LEDs bar-lights mounted under or within a plant canopy, and is especially useful in greenhouses with high plant density and low PAR levels at the lower canopy. One study on single-truss tomato plants reported a 27% yield enhancement in winter, and no enhancement in summer while another study on single-truss tomato cultivation, inter-canopy lighting increased yield by 20% in winter and 14% in autumn. [iii,iv] Lighting from underneath the canopy has also shown to increase the photosynthetic rate, leading to improvement of total plant growth in lettuce.[v] Finally, a case study with Philips Lighting at Glenwood Valley Farms in British Colombia showed intercanopy lighting improved cucumber production by 18%.[vi] A 2018 study out of the University of Guelph showed that supplemental sub-canopy lighting can increase dry bud yield (+13 to +22%), increase the bud/non-bud (stem and leaf) tissue ratio and modify cannabinoid and terpene profiles; the yield improvement was ascribed to an increase in PPFD compared to production with overhead lighting alone.[vii]

Turning to the economics of inter-canopy lighting, these products claim yield improvements of 10-30% with a 3-5 year warranty. Typical operating costs are about $5/month/fixture and a single fixture runs about $450, covering approximately 30 square feet of greenhouse space. [viii,ix] With a capital expenditure of $15/ft^2 and an operating cost of another $2/ft^2 per year, over four years the total cost to the grower would be $17/ft^2. With a price point nearly six times lower while realizing similar crop yield improvements and the added benefit of not having to pay for additional electricity consumption, UbiGro is the more economical choice for greenhouse growers.

About UbiGro

UbiGro™ is the agriculture brand of UbiQD, Inc., a nanotechnology company spun out of Los Alamos National Lab in 2014. We have ongoing or completed over 25 trials at 12 different locations, including five states (NM, CO, AZ, CA, and OR) and four international greenhouses. UbiGro was recognized by Frost & Sullivan for product excellence. In the recognition, Frost & Sullivan recognized that our advancement represents a "huge disruption to traditional grow lighting solutions, such as LED fixtures." UbiQD was named winner in the hyper-connected communities technology category in the 2019 SXSW Pitch Competition for their UbiGro technology. UbiGro was also named one of "Ten Killer Technologies" by MJBizMag and made the cover of Sungrower & Greenhouse Magazine in the Spring 2019 issue.

For more information, visit www.ubigro.com, www.ubiqd.com, or follow us on social media @ubigro and @ubiqd.

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SPECTRUM CONTROL FOR GREENHOUSES

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UBIQUITOUS QUANTUM DOTS