Introduction

The CoolGrow® Linear LED grow light offers a unique platform for single- and multi-layer crop cultivation plant factories.
In traditional light setups, often a big part of the produced light isn't used in an effective way. With the CoolGrow® Linear everything becomes just that little more effective, which makes the difference in the end.

By positioning the LED grow light bars as close as possible to the crops, all the produced light is steered towards the crop in the most effective way.
Also, the generated heat, although less prominent than in other grow light technologies, will thus make a positive contribution to the stomatal opening and plant activation.

The light intensity on the plant canopy can be determined by the distance to the crop, the number of light bars on the surface as well as by light output controls on the lamps themselves.
This way, you can optimise the PPFD needed light level on the crop for each of the plant's growth stages.

The CoolGrow® Linear can be installed in a horizontal setup with each lamp parallel to each other and bridged by a cable as in most traditional grow light setups, but can also be directly interconnected to each other to generate a long line of light in the grow rack installations. This last method saves a lot of cabling and delivers an overall neater installation over the canopy.

Because we can't explain all potential cultivars and crop stages in this brochure, we limit ourselves here on potential setups for leafy greens and salads, medicinal cannabis, vegetative growth, flowering and multi-layer strawberry cultivation techniques.
Of course the potential of the CoolGrow® Linear goes much beyond these, in case you have specific cultivation requests, let us know and our plant lighting experts will be happy to advise you.

Grow rack example with 3 layers of 8 feet by 4 feet – total growth canopy surface 96 square feet – layer height 2 feet

With horizontal lamp setup interconnected with a loop cable 8 lamps per unit – 24 lamps per grow rack

With linear daisy-chained lamp setup – 4 lines of 2 lamps in length – 24 lamps per grow rack

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The unique grow light system for multi-layer plant cultivation

Plant factory system for Salads & Microgreens

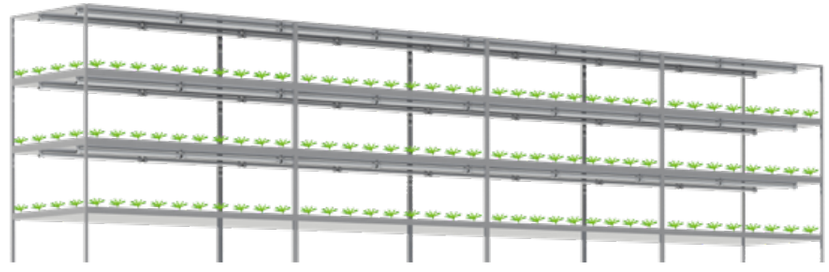
Given the compact plant structure with limited height, the overall moderately needed light level and the relatively short growth cycles, most leafy greens and microgreens are ideal for multi-layer cultivation methods. Thus, thousands of large and medium scale plant factories specialising in leafy greens have emerged in the last decade based on a good commercial crop model.

The key for grow light installations for leafy greens is an as low-as-possible initial capital investment without compromising on lamp quality and crop growth results.
In addition, the operational running cost, which is highly impacted by the energy consumption of the grow light system, is an absolute point of attention. The light efficacy system (expressed in µmol/J or µmol/W/s) determines, given the long photoperiod, a big part of the financial efficiency of a plant factory, and can show serious variations between manufacturers and models.

- As an example a typical plant factory grow light setup for butterhead lettuce with high light level PPFD 280µmol/sm².
  A plant factory setup with 12 grow units of 8 by 4 feet each (32 square feet per unit, 384 square feet total) needs a total of 48pcs of CoolGrow® Linear lamps, on each shelve placed in a linear setup with 2 rows. Each lamp consumes 60 watts so the total hourly power consumption is 2.88kWh.

In this example our setup runs 280 days per year at photoperiod of 16 hours per day, 4480 hours per year, so good for a daily light dose DLI of 16.13mol/d.
The total annual power consumption is 12.9MW.
The investment cost with a depreciation on 7 years would come around 1250USD per year while the energy cost calculated at 77USD per MW would result in 993USD per year.
As a result the total cost per square foot is 5.84USD during the depreciation period, and drops to 2.59USD after the depreciation.
The major reason of the moderate operation cost comes from the high efficacy of the CoolGrow® Linear LED grow light, with an efficiency of 3.5 µmol/J with this spectrum for leafy greens.

To demonstrate the importance of light and spectrum efficacy, a similar system with a light efficiency of 2.3 µmol/J would have a major impact on both capex and opex.
To reach a light level of 280µmol/sm² you would need 40% more lamps and capital, while the energy cost would raise with the same 40% overall.



Plant Factory setup butterhead lettuce 3 layers – 384 square feet cultivation area – 16.000 crops per year – light level PPFD 280µmol/sm²

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Plant Factory system Medicinal Cannabis Vegetative and Flowering

While witnessing new licenses being released and new global regions being legalized in both medicinal and recreational cannabis cultivation, the need for system efficacy in growing repeatable high-end crops also grows exponentially.
Classic cultivation methods are replaced by advanced multi-layer plant factories.
Shorter compact morphology, more plants per square foot, with a higher overall yield, perfect control on the plant quality and composition, prevention of pests, shorter growing cycles and more optimal use of the resources all plead for controlled, multi-layer cultivation methods.

For an optimal plant balance at higher artificial light levels, we recommend a rather broad growth spectrum, with a good balance between system efficacy, plant health and yield.
The use of far-red photons is in this case not recommended (typical wavelength 730nm) as these mainly lead to stretched and longer internodes while our aim here is to steer towards a more compact morphology and controlled growth.
The use of supplemental UV-A or UV-B photons can be considered if it fits with the growth goal, but we recommend using this more towards the end of the cycle and separate from the photoperiod with the basic growth spectrum, as the high rate of blue photons in the basic spectrum will decrease the efficacy of the UV-A and UV-B photons on the crop.

Rooting and vegetative stage in the same grow rack setup

Both in the rooting and vegetative stages, the crops need a relatively high dose of blue photons in the light spectrum.
The light intensity and photoperiod needs to be adapted to the growth phase and increasingly be augmented towards the end of the vegetative phase.
This way, a stronger rooting base, thicker stems and a healthy compact crop which is ready to go, flowering can be obtained.
To enable this, the CoolGrow® Linear can be equipped with the CoolControls® digital BLE controls.
Both, the light intensity and the photoperiod can be set in a calendar scheme running on a cloud application, without extra cabling for the lamps.

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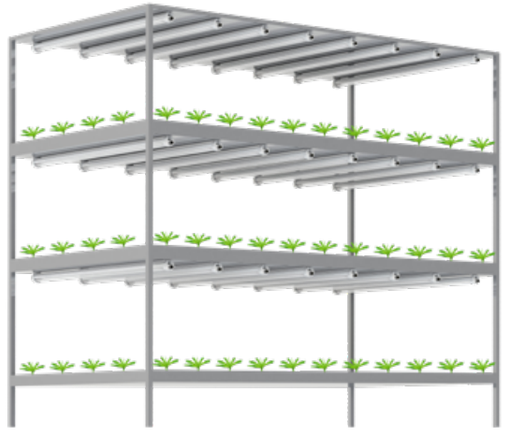
The unique grow light system for multi-layer plant cultivation

Plant Factory setup for vegetative cannabis growth

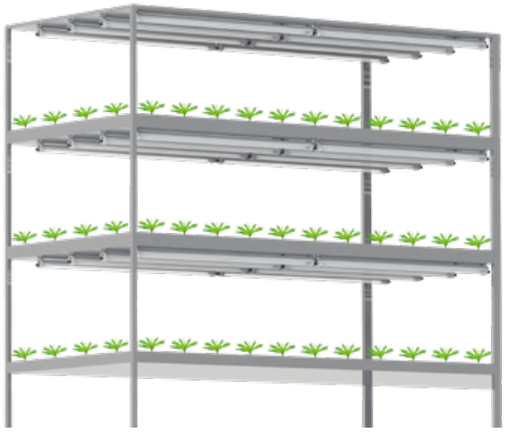
In the vegetative growth phase, we aim for a short growth cycle with uniform crops and a strong rooting, a high biomass with thick stems which will later lead to a higher overall yield.
The photoperiod can be built up from 18 hours to 24 hours but can also be maintained in the long-day period of 18 hours over the whole cycle.

- For example a 3 layer setup with a canopy on each layer of 8 feet by 4 feet = 32 square feet per layer, 96 square feet in total.

  Light level PPFD 435µmol/sm².
  Light spectrum high blue broad spectrum – concentration on root development – short vegetative cycle with compact plants.
  8 lamps CoolGrow® Linear per layer – 60 watts per lamps – 15 watt per square foot
  Photoperiod 18 hours – DLI 27 mols/day.
  The lamps can either be placed with 8 bars in parallel next to each other, or in 4 rows of 2 lamps in the length.
  By use of the CoolGrow® Linear 100 watts the rows can be reduced to 3 lines.



Grow rack setup vegetative growth
8 lamps per canopy layer
PPFD 435µmol/sm²



Grow rack setup vegetative growth
8 lamps per canopy layer in 4 daisy-chain lines with reduced cabling
PPFD 435µmol/sm²

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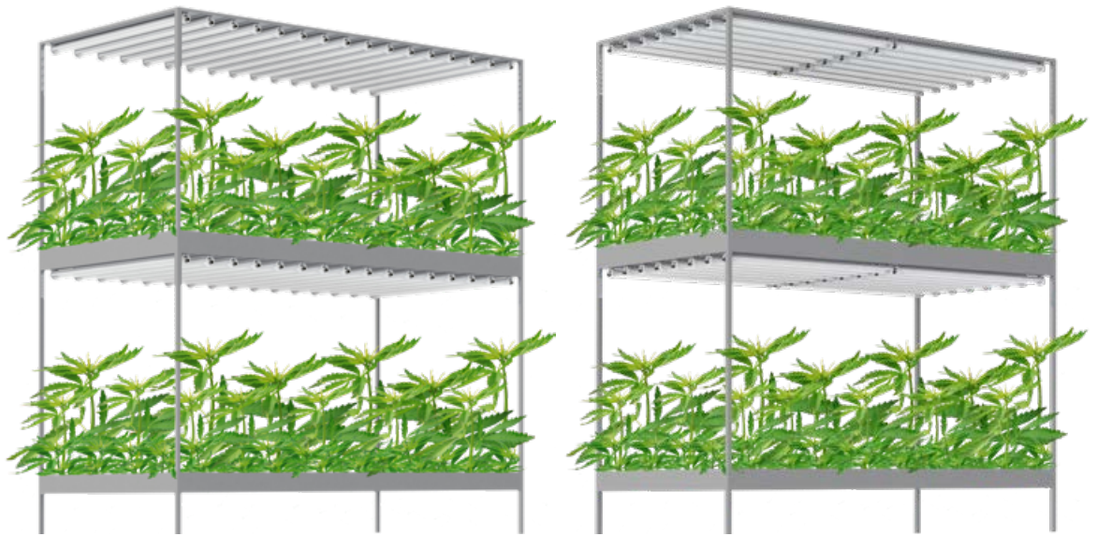
Plant Factory setup for flowering cannabis

- 2 layer plant factory setup with per layer a cultivation area of 8 feet by 4 feet = 32 square feet, 64 square feet in total.

Light level PPFD 900µmol/sm².
Light spectrum broad generative – concentration on flowering and homogeneous crop development.
16 CoolGrow® Linear LED grow lamps of 60 watts per layer, either parallel next to each other or in 8 rows over the length daisy-chained or 5 rows of 100 watts.
60 watts per lamp – 30 watts per square foot.
Photoperiod 12 hours – DLI 39 mols/day.
The light intensity and photoperiod can easily be controlled either by a simple dimmer (0-10 volt or PWM) or by the CoolControls® BLE digital controls option. The CoolControls® offers calendar control, so the cultivation can be planned in up front.



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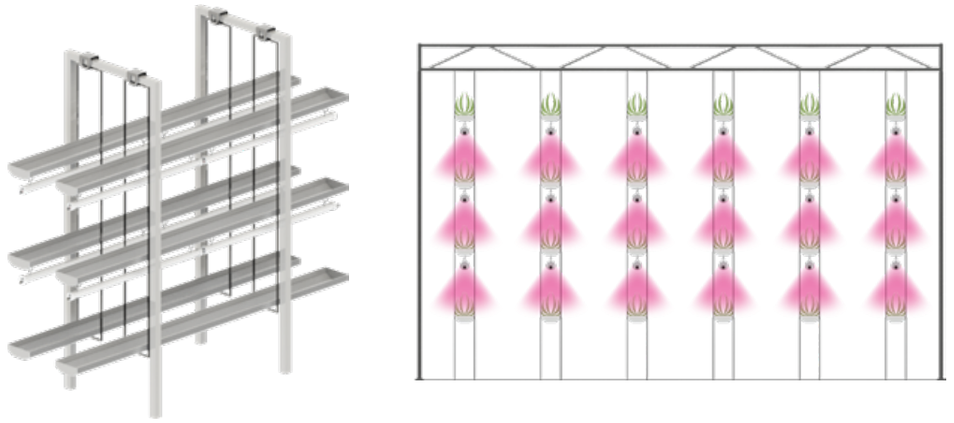
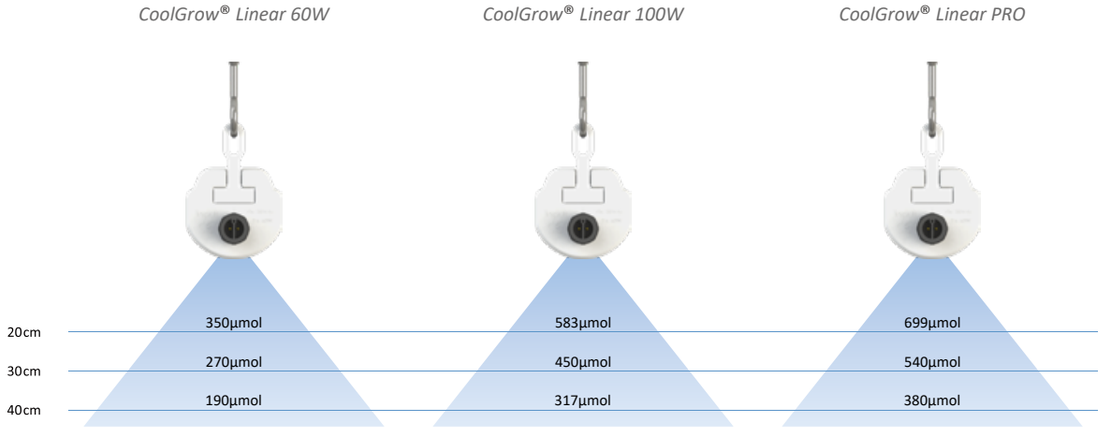
Multi-layer strawberry cultivation in a greenhouse or plant factory

Extension with new greenhouses, building permits, staff management on multi-locations, split processing halls,… all aspects with which we would rather not be confronted.
Strawberry growers have already been through a major evolution over the past decades, from open field to modern gutter systems with swing systems for space optimization in the greenhouse cap even up to alternating lifting gutter methods.
With CoolGrow® Linear we aim even higher and work on a bright future for strawberry growers with multi-layer cultivation in greenhouses and plant factories, with normal seasonable plantings as well as early, late and real winter growth.



Multi-layer strawberry gutter system for optimal use of space in a greenhouse

On various locations in Belgium and the Netherlands, we are conducting multi-layer greenhouse strawberry growth trials, together with our customers and under the supervision of professional researchers and plant consultants.
In the first phase we focus on classic seasonable plantings in December or January, where we add an extra gutter above the existing gutter lines – this means we go from the classic 8-gutter per cap setup to 16 gutters per cap.
The light deficit that arises on the lower rows caused by the plants in the gutter above is compensated with CoolGrow® Linear bars that are daisy-chained and placed directly under the upper gutter.
The plant trials are mainly conducted on Juneberry cultivars like Sonata, Elsanta, Sonsation, Clery and Malling Centenary.
Together with the market leaders in plant gutter systems and greenhouse automation, we are already investigating to enable 3-layer or 4-layer strawberry cultivation systems.



The CoolGrow® Linear is available in 60, 100 and 120 watt execution – the lamps need to be placed 8 to 12 inch above the canopy height of the mature grown plants.
For classic seasonal plantings, including early and late seasons as well as true winter cultivation, we recommend the 120-watt CoolGrow Linear Pro version. With full dynamic spectrum controls, this lamp provides the optimal balance between plant steering and energy efficiency.

- Separate far-red controls for end-of-day treatment and crop length adjustments.
- Tunable green and blue settings for energy savings.

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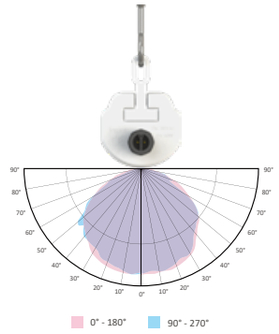
Crop-Specific light distribution

Intensive research and development, in collaboration with industry leaders in cultivation systems, has resulted in a wide range of available beam patterns.

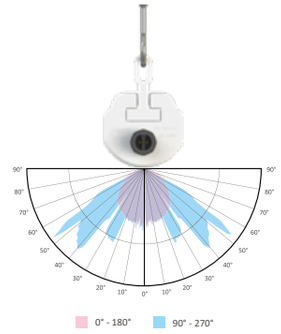
For an optimal balance between required lamps and a perfect light distribution, we offer three different light beams:

▸ Narrow Beam



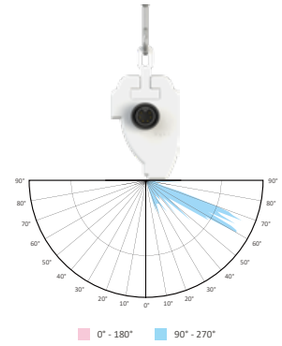
120 degrees deep plant penetration, larger distances lamp to crop

▸ Wide batwing Beam



150 degrees batwing short distance lamp to crop high light uniformity strawberry multi-gutter cultivation

▸ Canopy Edge Beam



Unique light beam for edge of canopy 40% less light spill Optimal use of canopy width with stable light level

Crop-specific light beams lead to major improvements in specific cultivation systems. As an example, the wide batwing beam placed over a gutter of strawberries immediately leads to a more homogeneous photon spread over the leaves resulting in a higher net photosynthesis and a notable increase of brix level in the berries.

Plant-balanced heat management

The limited heat generation of LED grow lights fits perfectly with the cultivation of colder cultivars like microgreens and leafy greens, but also creates major climate advantages for high level lighted crops like medicinal cannabis.

LEDs definitely also produce heat, but the major differentiator compared to other lighting technologies comes from the type and the amount of heat which is generated.
An HPS SON-T lamp of the latest generation has an efficacy around 40%, Which means that a 1000 watts HPS SON-T produces 40% of light and 60% of heat or 600 watts of heat.
Since a HPS SON-T lamp becomes extremely hot, the majority of this heat loss (90%) goes to radiated heat or IR radiation. As a result, this technology doesn't allow the lamps to hang too close to the crops, which would lead to tip burn and damage of the stomata.
At higher light levels, the excess radiation and general heat loss leads to bigger challenges concerning climate control.

Radiated heat does not only have disadvantages – the long wavelength of the IR radiated heat facilitates the penetration into the canopy, which on many cultivars leads to extra activation and stomatal opening. The radiated heat also raises the leaf and plant temperature when it penetrates the tissue.
When transitioning from HPS SON-T lamps to LED technology, adjustments to climate settings and light strategies are essential for achieving optimal results.

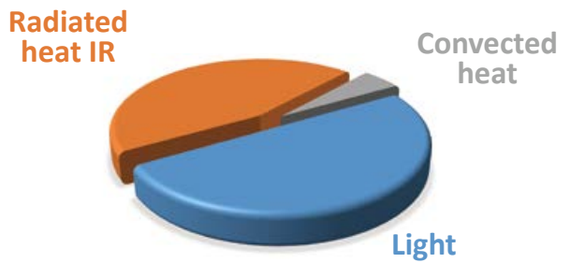
CFLs or fluorescence lamps (often in the format of a linear TL) are frequently used for micropropagnation and for crops with limited light needs, but have a very low efficiency of only 20%, which means that just 20% of the energy goes to light and 80% goes to heat.

A LED grow light has an average efficacy of 70% and the other 30% goes to heat.
Thermal design to obtain a low temperature is an absolute must in LED grow lights, this ensures a longer lifetime. The heat goes mainly to free air convection, so heat that goes up in the air.

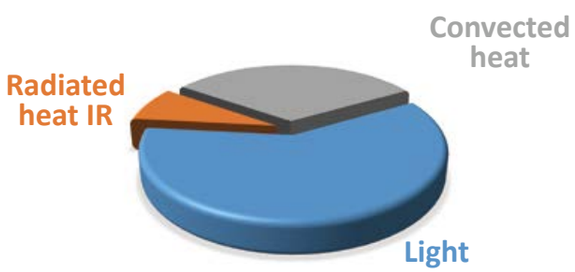
This makes LED grow lights ideal for plant factories and vertical farms, where the lights are placed close to the crops to obtain optimal use of the available height of the room.

As we still want to use the heat loss in the most optimal way, we have designed the CoolGrow® Linear in such way that the chassis of the lamp will stabilize at 40°C at an ambient temperature of 23°C.
In this way, we have created an artificial grow tube where the energy loss is used in a positive way.

HPS SON-T



LED



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The unique grow light system for multi-layer plant cultivation

Growth Spectra for Yield and advanced Morphology

To understand how your crops are going to react to different wavelengths and colors, you have to keep in mind that every crop and every growth stage requires an individual approach.

The amount of light affects the photosynthesis process in the plant.

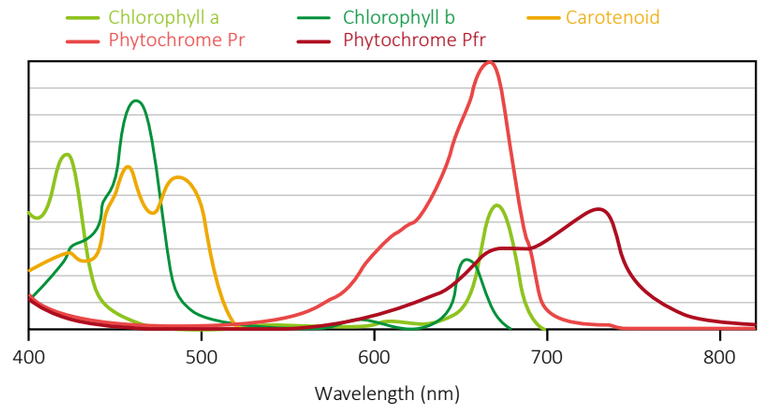
This process is a photochemical reaction within the chloroplasts of the plant cells, in which CO_2 is converted into carbohydrate under the influence of light energy.

The spectral composition of the different wavelength regions (blue, green, yellow, red, far-red or invisible e.g. UV or IR) is important for the growth, shape, development and flowering (photomorphogenesis) of the plant.

For photosynthesis, the blue and red regions are most important.

The timing / light duration which is also called the photoperiod, is mainly affecting the flowering of the plants. The flowering time can be influenced by controlling the photoperiod.

Absorption curves of plants



Photosynthetic efficiency is mainly driven by chlorophyll a and b.

Chlorophyll a and b are the primary pigments responsible for absorbing light energy during photosynthesis. These chlorophyll pigments primarily absorb light in the blue (400–500 nm) and red (600–700 nm) regions of the spectrum, which defines the Photosynthetically Active Radiation (PAR) range.

The Photosynthetically Active Radiation (PAR) shows further photosynthetic pigments, also known as antenna pigments, like carotenoids (carotene, zeaxanthin, lycopene, lutein, etc.).

The Phytochromes Pr (red) and Pfr (far-red) are mainly influencing germination, plant growth, leaf building and flowering.

The phytomorphogenic effects are controlled by applying a spectrum with a certain mix of 660nm and 730nm in order to stimulate the Pr and Pfr phytochromes.

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Fixed light spectrum or dynamic spectrum – advanced morphology and energy saving

While all MechaTronix LED grow lights are dimmable and controllable by the climate computer since 2018, a lot of research has been conducted over the last few years with a strong focus on the potential of controllable light spectra in vertical farms.

A key benefit of a full dynamic light spectrum in vertical farming is the potential for significant energy savings. Previously, fixed spectra were a compromise, providing an excessive amount of light just to maintain plant balance. Dynamic spectrum controls, used during both the photoperiod and various growth stages, result in substantial and economically necessary energy savings.

Additionally, spectral control offers considerable potential for morphological steering. End-of-day treatments with a balance of far-red to red light can induce plant elongation, as demonstrated in chrysanthemum and strawberry cultivation.

Improved morphology and higher yields

The best examples of morphologic advantages can be seen in the research results for chrysanthemums and everbearing strawberries.

Wageningen University & Research (WUR) conducted deep research in collaboration with Plant Lighting on the ideal light strategy for cut chrysanthemums. They discovered that an end-of-day treatment with only far-red light while the base spectrum was turned off, resulted in clearly longer flowering shoots with very little extra energy.

The spectral research of Proefcentrum Hoogstraten (PCH) on strawberry varieties clearly proved that extra far-red during the day resulted in average bigger size berries and a higher yield, while end-of-day treatment with far-red led to longer fruit trusses and a larger LAI of the crop.

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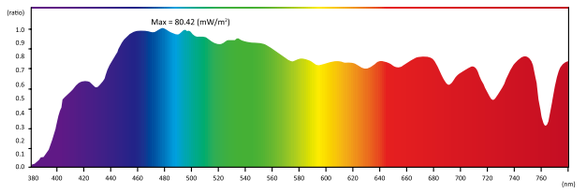
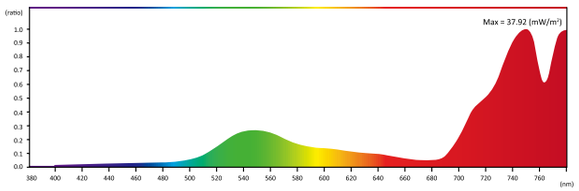
These effects are mainly triggered by the Phytochrome balance in the crop: Red to Far-Red ratio R:FR and Phytochrome Photostationary State PSS are both methods to trigger and control the elongation of crops.

While the Phytochrome Pfr antennas are in the far-red bandwidth (730nm peak) and the Phytochrome Pr in the Red zone (660nm peak), the change in relation between these two tells the plant that it is in the shadow, which triggers the shade escape effect and leads to elongation.

Natural shade plants like anthuriums react in the opposite way. Absence of Far-Red leads to stretch while a high dose of far-red will avoid this.

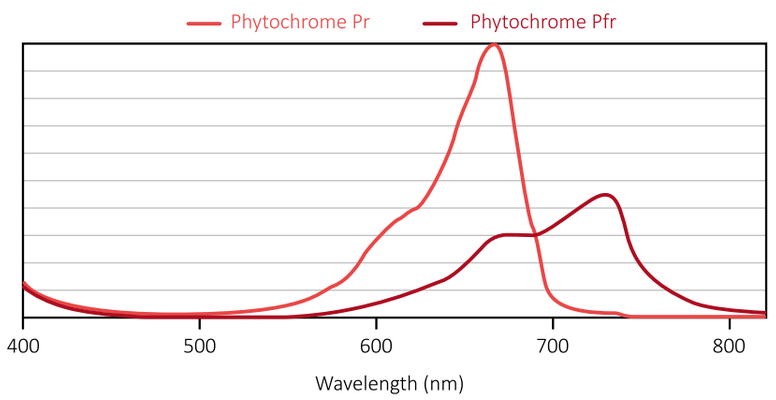


Open sun spectrum



Crop under one leaf spectrum

Phytochrome sensitivity curve



Besides morphologic effects, far-red has other effects on most plants.

As the energy of far-red travels deep into the crop it leads to local higher energy, stomatal opening and in general a more generative growth.

A higher portion of the photosynthetic energy goes to the fruit and a lower portion to the leaf.

This leads, for example, in cucumbers to a faster production of the fruit and in strawberries to an average higher sorting and an improved yield.

CoolGrow® Linear

The unique grow light system for multi-layer plant cultivation

LINEAR 60

Photon Flux up to 210µmol/s per bar

For medium light levels on crop <250µmol
Daisy chain up to 10 bars
Hight light efficacy

LINEAR 100

Photon Flux up to 350µmol/s per bar

For high light levels on crop 250-450µmol
Daisy chain up to 10 bars
Hight light efficacy

LINEAR PRO

Photon Flux up to 425µmol/s per bar

Dynamic spectrum controls 4 channels
Optimal plant steering through photo-period
End-of-day treatments with Far Red

SPECIFICATIONS				
		Linear 60	Linear 100	Linear PRO
PPF Photon Flux		up to 210µmol/s	up to 350µmol/s	up to 425µmol/s
Power		60 watt	100 watt	120 watt
Efficacy		3.2 µmol/J – 3.5 µmol/J		3.32 µmol/J – 3.54 µmol/J
Input voltage		110-230 Vac or 400-480 Vac		249-528 Vac
Fixture Dimensions	Standard	L1160 x W55 x H50 (mm) - L 3.8' x W2.17" x H1.97"		
	Pathway	L1160 x W55 x H87.5 (mm) - L 3.8' x W2.17" x H3.45"		
Weight		2250 gr		
Light Distribution		120° deep beam - 150° wide batwing beam - Asymmetric pathways beam		
Lifetime		50.000 hours – L90B10		
Power Factor		> 95%		
Warranty		5 years		

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