SEOUL

Let's Grow Together

Highest Efficacy in Horticulture

SunLike
Powered by TRI-R

5050-6V
3.3 umol/J

3030 C
3.1 umol/J

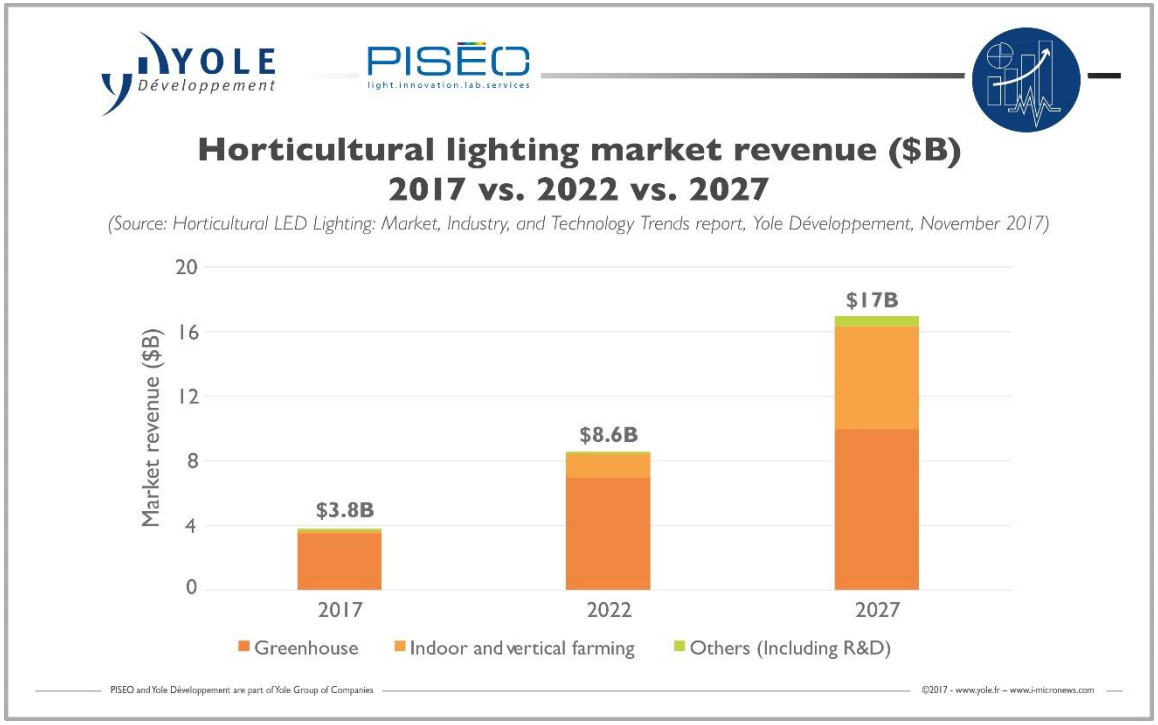
3528-E2
2.9 umol/J

Summary

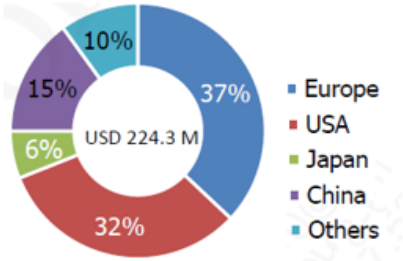
- ***Market situation***
- ***Trends in the market***
- ***Effects of light in plants***
- ***SSC Solutions***
- ***Scientific Reports***

Worldwide market

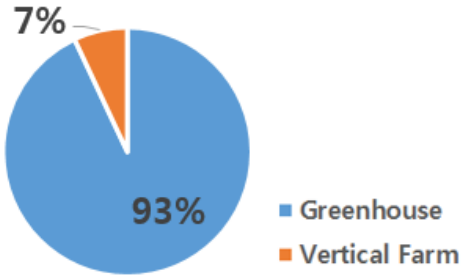
- The market is still dominated by HPS luminaires for supplementary light
- In 2018, US and Japan remained the main markets for plant lighting.
- Legalization of Cannabis made the market explode in US
- Expected that China and Europe will be the next emerging markets



Worldwide market



< By Region >



< By Application >

Expansion of Horticultural LED Market Depends on Lighting Efficacy

Customers need to **replace HPS (2.0 µmol/J)** with LEDs with better ROI

LED Efficacy	ROI
2.6 µmol/J	3-5 yrs
3.0 µmol/J	2-3 yrs
3.2 µmol/J	< 2 yrs

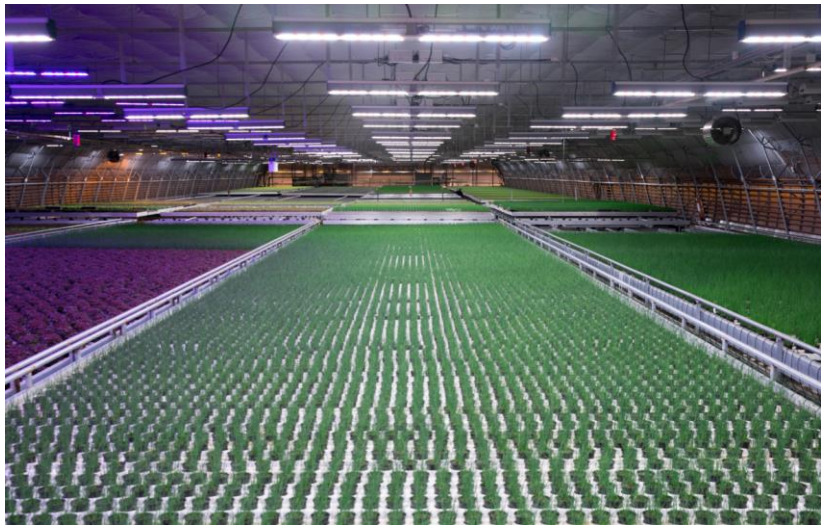
→ Most LEDs

When horticultural LED market explodes → BEST ROI

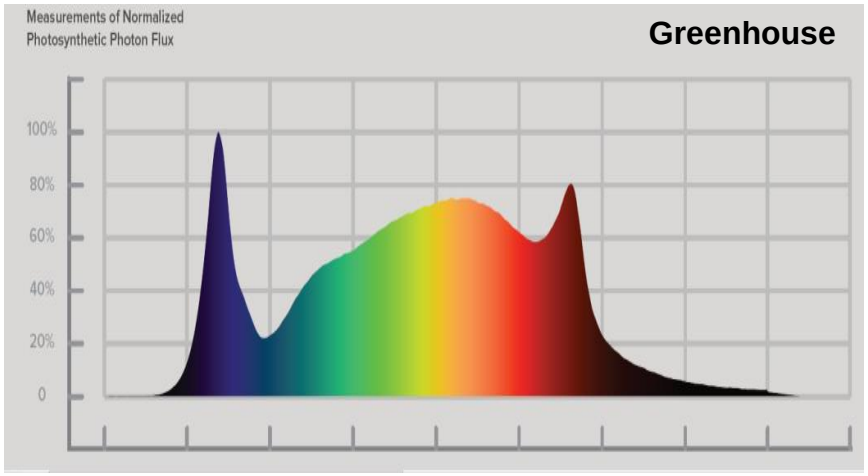
LED Horticulture until 2018

Main trend was **RED** - **BLUE** solution

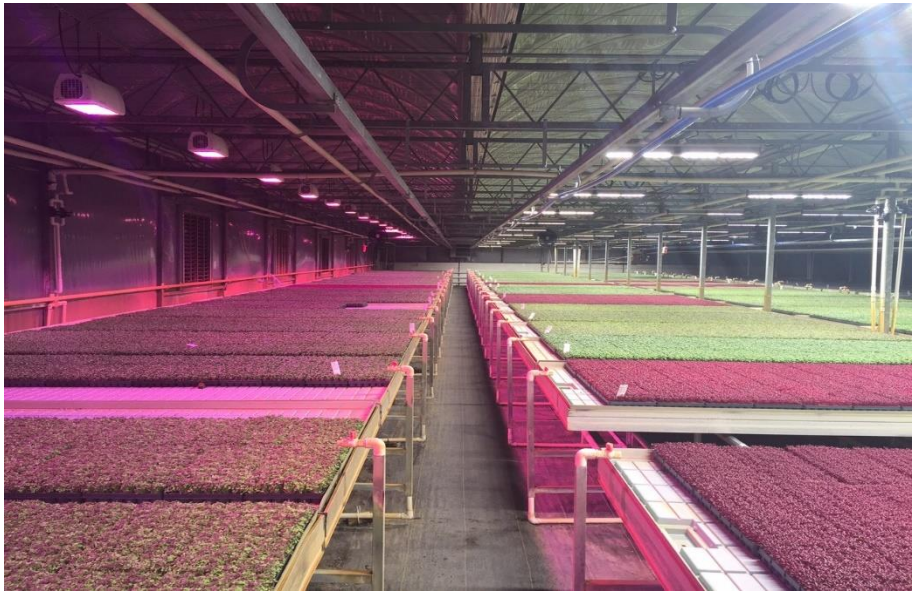
Things started to change in 2019



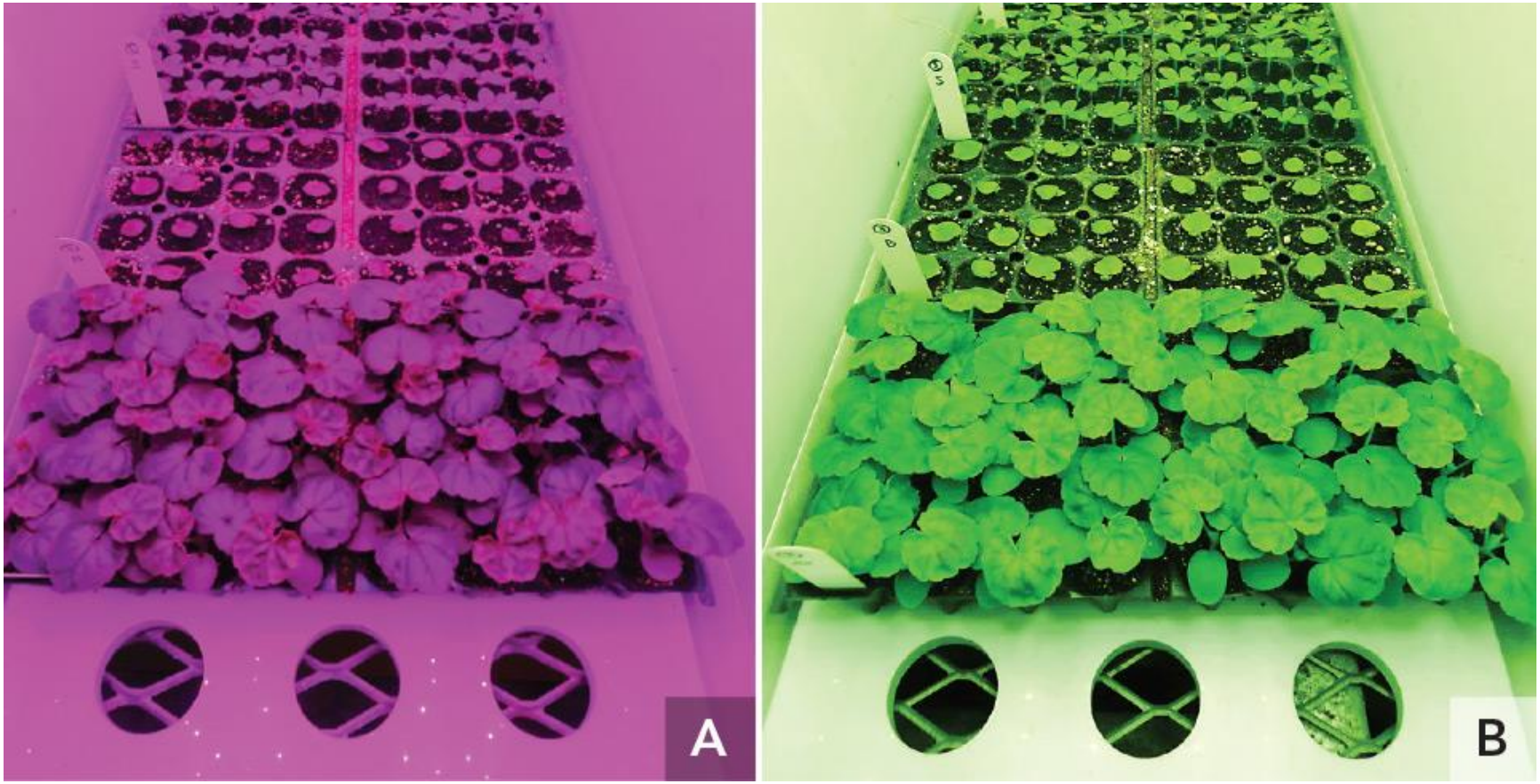
TOP players in Horticulture moved ALL portfolio to **White LED solutions**



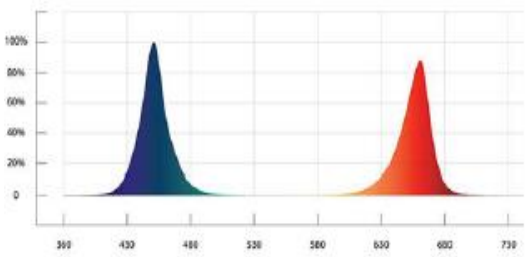
The White trend is replacing Blue-Red & HPS



The White trend is replacing Blue-Red & HPS



Future Market trend for Horti Luminaires



Blue + Red

- Efficiency ~ 3.0 µmol/J
- Need a recipe
  (can have issue with patents)
- Single crop growth
- Not healthy for workers
- Cannot identify plant diseases
- Usually high power LEDs
- High cost solution
- Use fans → maintenance issue

- Efficiency ~ 3.1 umol/J
- Need a recipe
- More crops than blue-red
- Use of mid-power LEDs
- Many different White LED options from SSC

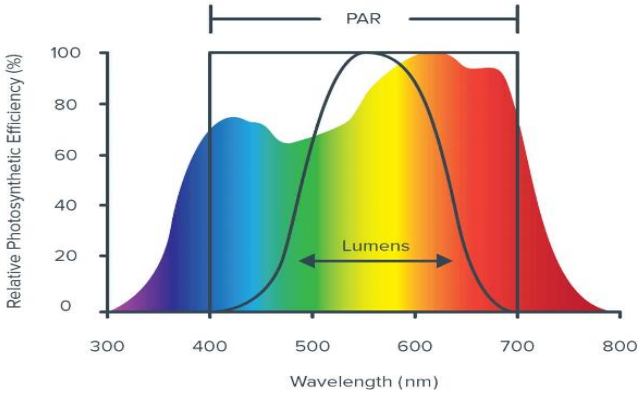
- Efficiency around 2.4 umol/J
- No need for recipe
- Grow all crops more efficient
- Can grow special plants
  - Cannabis THC&CBD ↑
  - Orchids, Algae,…
  - Special Paprika, tomatoes,…
- Use of mid-power LEDs

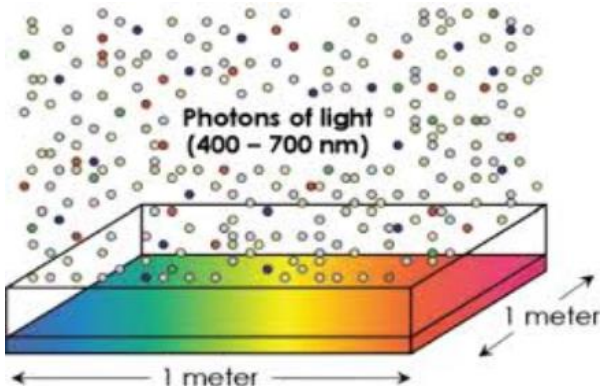
SEOUL SEMICONDUCTOR

Effects of light on plants

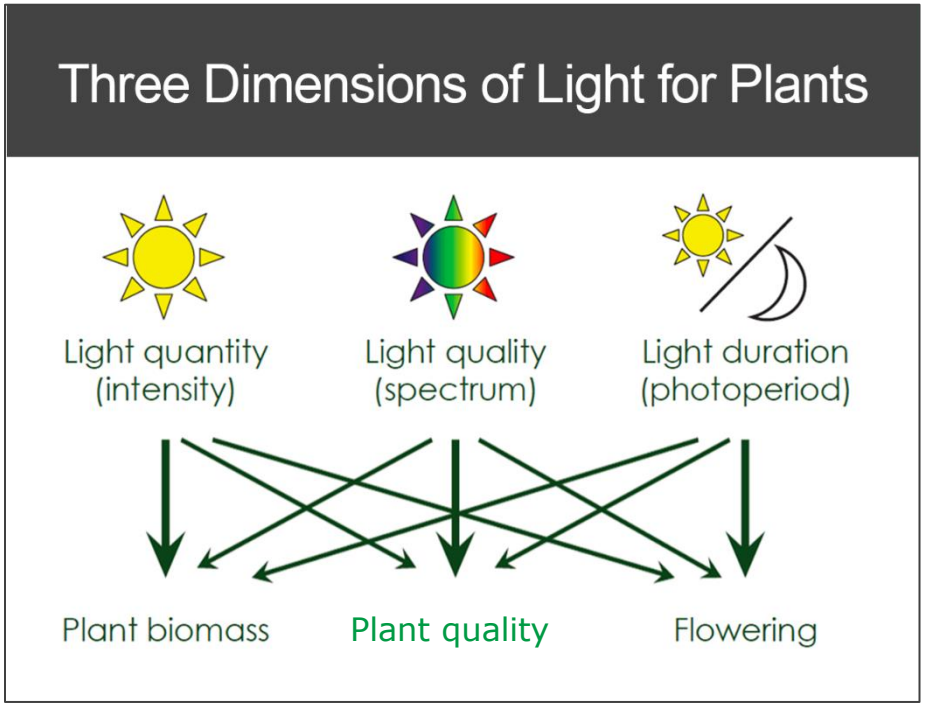
Terminology

Terms	Descriptions	Units	Comparable Lighting terms
PAR	Photosynthetically Active Radiation The range of light plants use for photosynthesis **400-700nm**	NA	Human: 380-700nm
PPF	Photosynthetic Photon Flux The number of photons coming out of a light source per second	**μmol/s**	Luminous flux **(Lumens)**
PPE	Photosynthetic Photon Efficacy = PPF/W The number of photons coming out of a light source per second per watt How much should we pay for electricity to create an amount of light?	**μmol/J**	Luminous efficacy **(Lm/W)**
PPFD	Photosynthetic Photon Flux Density = PPF per m^2 How much light reaches plants?	$\mu mol/m^2s$	Illuminance (Lux)
DLI	Day Light Integral How much light does your plant need for proper growth per day?	mol/m^2d	None





What is really important for plants ?



Dr. Erik Runkle, MSU (HLC US, 2018)

Light Quantity

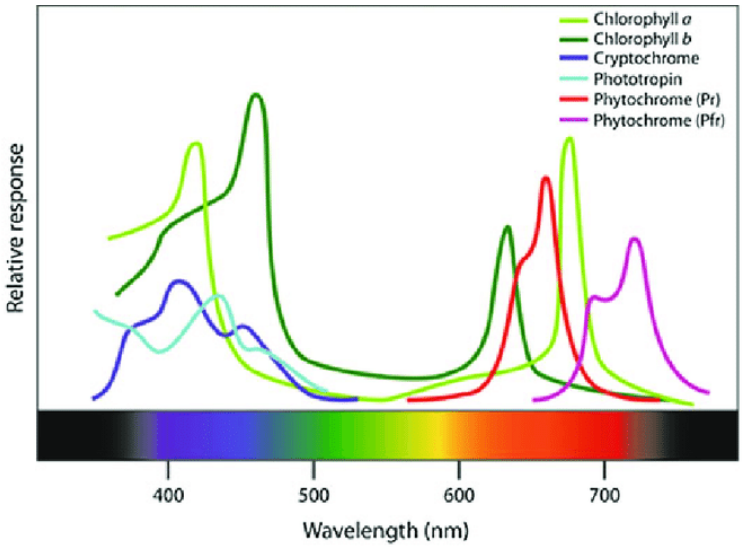
- Most important for yield
- The more light, the more Kilograms collected

Light Quality

- More important when light is limited

Color area	Effect on Plants
Blue (450nm)	Structure robustness ↑
Deep Red (660nm)	Leaf area ↑ Plant mass ↑
Far Red (730nm)	Sprouting, Blooming ↑ Stem elongation ↑
Green (530nm)	Photosynthesis below top canopy ↑

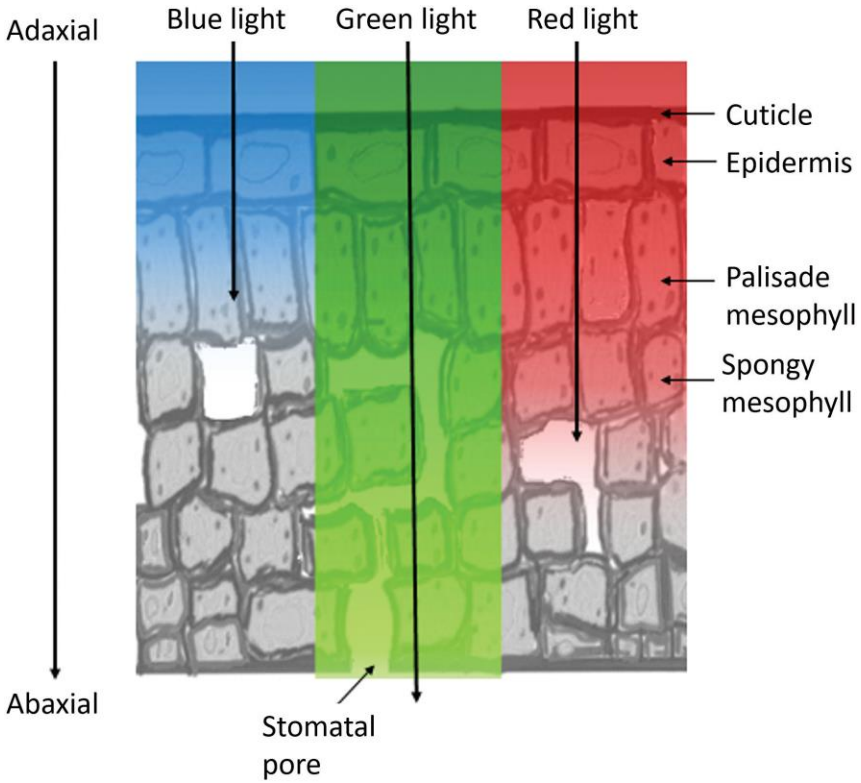
Absorption of light by plants



Blue and Red are the most important ….Until recent discoveries

Pigments	Roles
Chlorophylls	• Chlorophyll a, Chlorophyll b • Light harvesting – Red & Blue • Photosynthesis for organismal operation
Phytochromes	• Reactive to and transformed by **red** and **far-red** lights between Pr and Pfr • Floral stimulation, stem elongation, circadian rhythm and shade avoidance
Cryptochromes	• **Blue**-sensing pigments controlling **plant heights** and **fruit size**
Phototropins	• **Blue** sensing pigments responsible for **phototropism**

Green and Full spectrum are the key



Smith *et al*., *J. Exp. Bot*. (**2017**)

Green is more important for photosynthesis below the top canopy...

Green goes through leaf tissue, enhancing photosynthesis in shaded leaves under the top canopy while red and blue stops in first leafs

And, more benefits of other wavelengths are continuously being revealed including product quality with latest studies…

The Lighting Trend is changing from combination of single colors to full spectrum regime like the Sun

Green and Full spectrum are the key

ELSEVIER

Scientia Horticulturae

Volume 268, 27 June 2020, 109371

Physiological responses of pepper seedlings to various ratios of blue, green, and red light using LED lamps

NB Claypool [a, b], JH Lieth [a]

Show more

https://doi.org/10.1016/j.scienta.2020.109371

Highlights

- Green light stimulated growth, increasing dry weight and leaf area.
- Dry weight increased under monochromatic green compared to monochromatic blue.
- Blue light reduced plant height, increasing compactness.
- Spectra with blue light increased stomatal density and photosynthetic capacity.

Green and Full spectrum are the key

Working under white light is much more pleasant

White light boosts tomato and cucumber yields

There are still many unanswered questions about what the optimum light spectrum is for different crops. Remarkably, very little international scientific research has so far been done into white light. Unique trials by Wageningen University & Research with tomato and cucumber under white LEDs show that it is easy to grow under and that it may even produce better results.

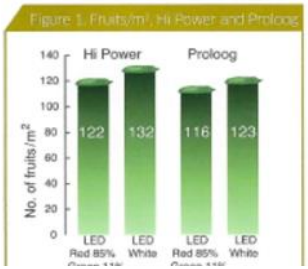
Now that LEDs are becoming more and more widespread in greenhouses, teething problems are also coming to light. The widely used solution with 95% red light and 5% blue (sometimes including some far-red) was dictated by cost, not by what the crop needs. Tomato growers are not unhappy. But rose growers have had problems in winter, and at the recent "Meer met licht" [More with Light] study day at Sint-Katelijne-Waver in Belgium, voices critical of this colour combination in cucumber could be heard.

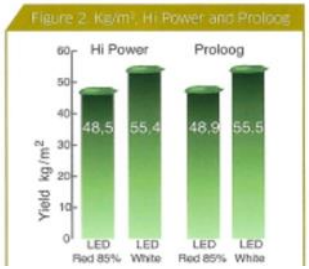
Cucumbers grown under white light produced more biomass, resulting in more ki more fruits. Very clear with Proloog but not statistically significant with Hi Powe

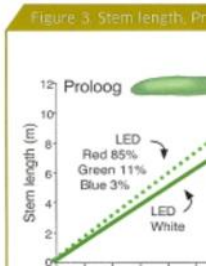
White LEDs

"In climate chambers, various plants grow and develop better under plasma lamps that have a spectrum similar to sunlight than under red/blue LEDs or HPS lamps," says researcher Ep Heuvelink. However, plasma lamps are very expensive and there has been no research on their use in greenhouses. The researcher: "But you can find hardly any research on white LEDs in the literature, although some practical experience has been gained by medicinal cannabis growers in the USA."

Heuvelink has been overseeing tomato and cucumber in the g at Wageningen since Decemb research is funded by Fluence is being carried out with LEDs







Article from Wageningen University

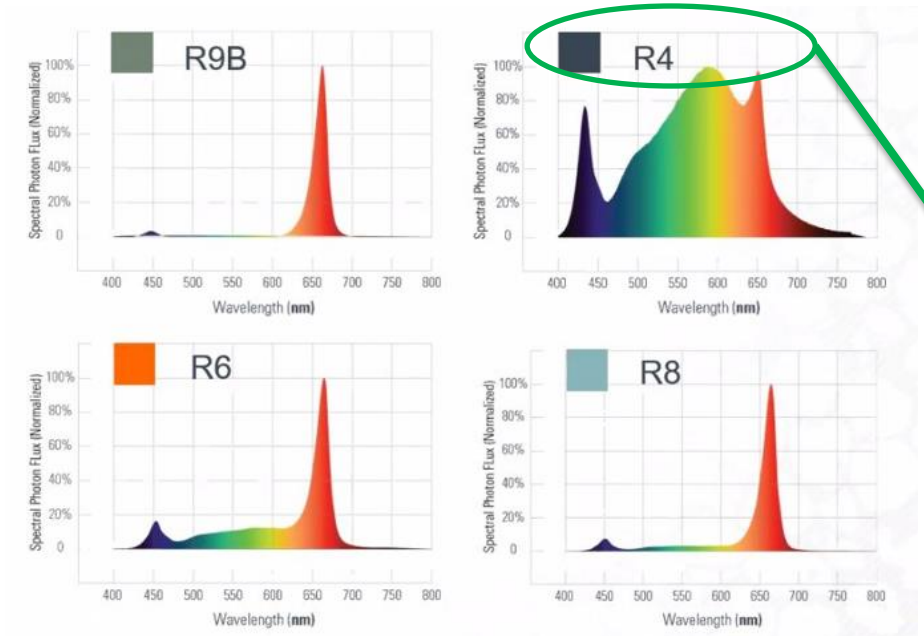
WAGENINGEN UNIVERSITY & RESEARCH

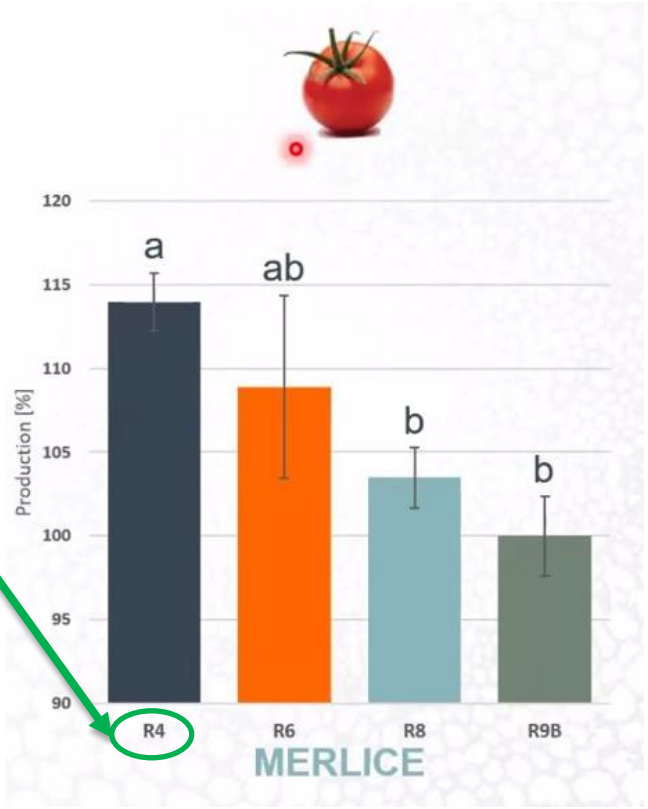
Green and Full spectrum are the key

Increased RED light 660nm drives to LOWER yields in Tomatoes

** Information from Fluence Webinar August 2020 about Tomatoes production

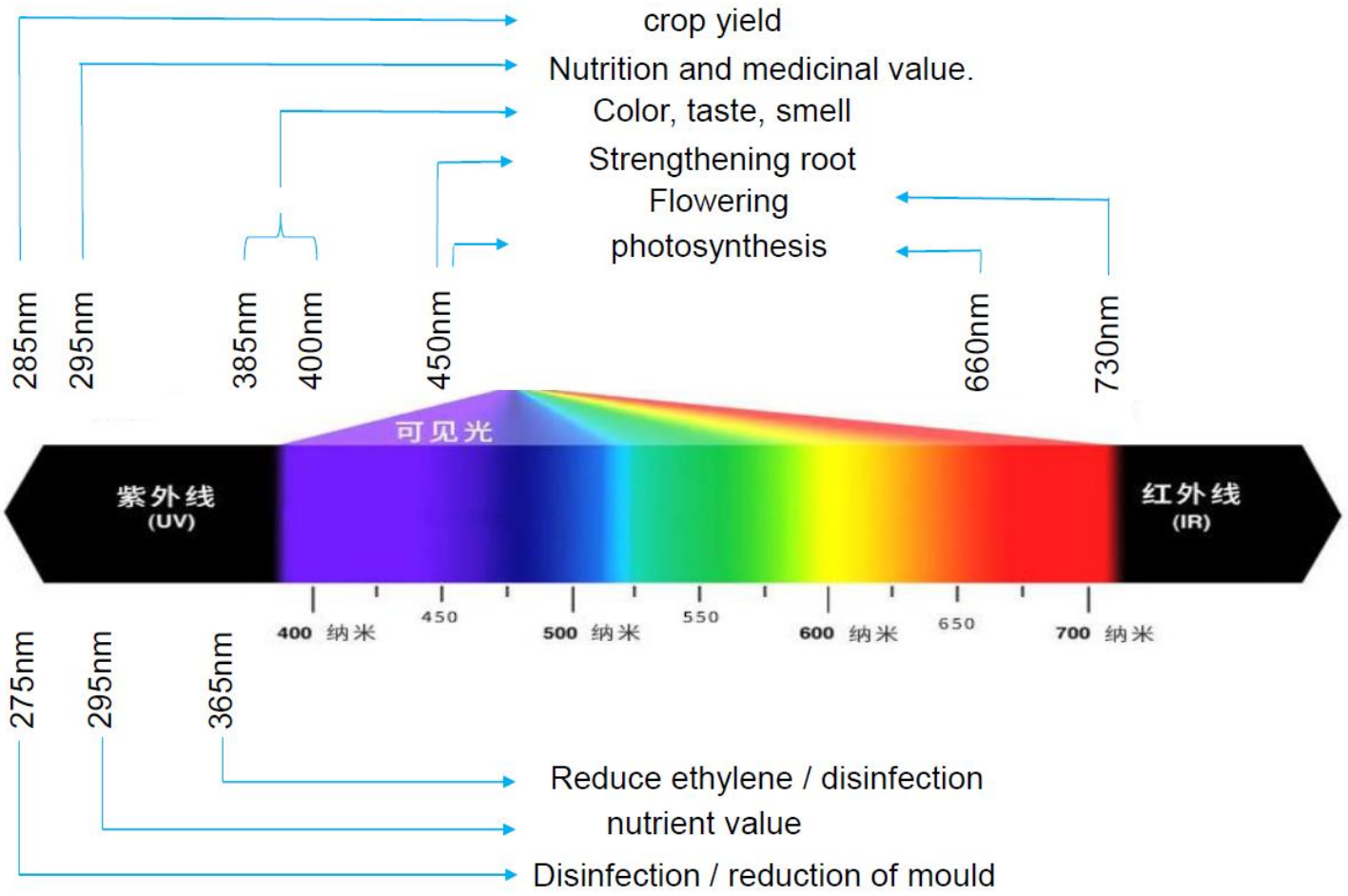
We can see that excessive 660nm RED and low spectra balance → lower outputs



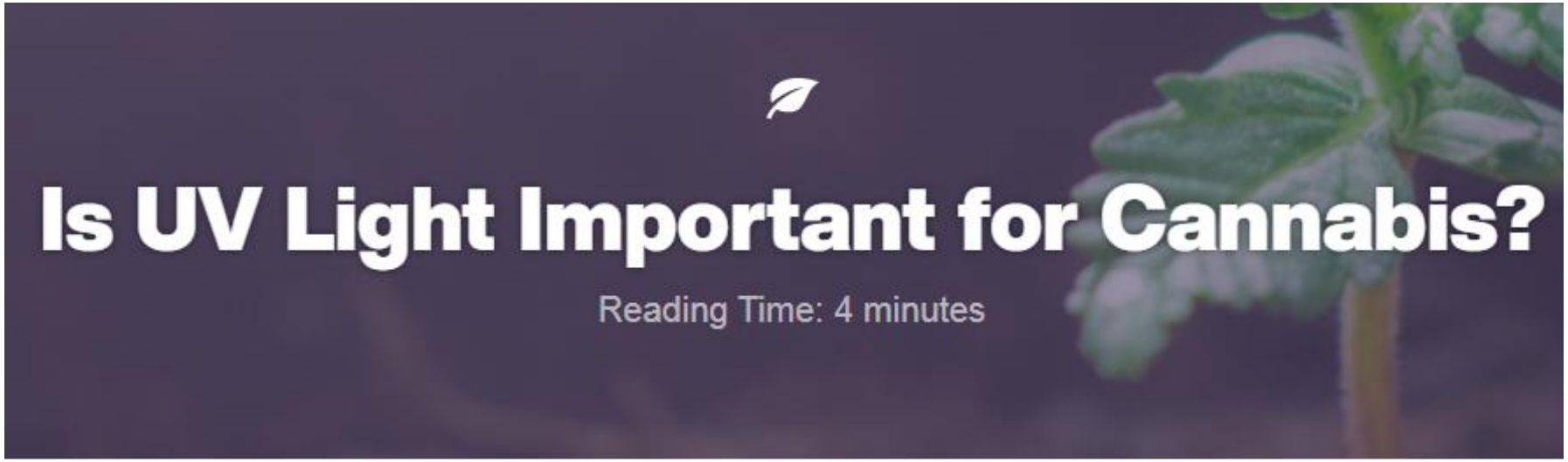


Plants use Full Spectrum light

From UV to IR. Plants developed their internal structures under the Sun for millions of years with interactivities in their development by all the wavelengths.



Plants use Full Spectrum light



UVA light has been shown to increase secondary metabolite activity in many plants, and this is also the case with cannabis. The most important secondary metabolites from a cannabis grower's perspective are cannabinoids such as THC and CBD, as well as terpenes which give cannabis its distinctive aroma. Short wavelength irradiation, such as UVA and blue light, trigger the plant's stress response system and the plant starts to protect itself from the abiotic stress i.e. short wavelength irradiation. Increased stress level results in increased metabolite activity and therefore higher THC accumulation in flowers, when compared to light sources lacking UVA or blue light (Magagnini et al. 2018).

Plants use Full Spectrum light

- **20% increase in Δ^{9}-THC** when greenhouse-grown Nepalese cannabis was given UV 4hrs/day [1]
- "The potency of high quality marijuana increases in direct ratio to the amount of UVB light it receives." [2]
- Concentration of Δ^{9}-THC increased in leaf and flower of UV-B-dosed plants.

1 Fairbairn, JW. and J A. Liebmann. 1974. The cannabinoid content of *Cannabis sativa* L. grown in England. J Pharm. Pharmacal. 26: 413-419
2 Pate, D.W., 1994. Chemical Ecology of Cannaibs. Journal of the International Hemp Ssoc 2:29, 32-37
3 Lydon, John, Alan H. Teramura, and C. Benjamin Coffman. 1987. UV-B Radiation Effects on Photosynthesis, Growth, and Cannabinoid Production of Two Cannabis sativa Chemotypes. Photochemistry and Photobiology, 46:2 pp. 201-206

SEOUL SEMICONDUCTOR

LED Solutions

DLC (USA) Tech requirements for Horticulture

Table 1: DLC Horticultural Lighting Technical Requirements

Parameter/Attribute/Metric	Requirement	Requirement Type	Method of Measurement/Evaluation
Photosynthetic Photon Flux (PPF) (µmol/s)	n/a	Reported	(LM-79-08) 400-700nm range, with 400-500nm, 500-600nm, and 600-700nm bins reported alongside the total
Far-Red Photon Flux (PF_{FR}) (µmol/s)	n/a	Reported	(LM-79-08) 700-800nm range
Spectral Quantum Distribution (SQD) (µmol/s/nm)	n/a	Reported	(LM-79-08) 400-800nm range
Photosynthetic Photon Intensity Distribution (PPID) (µmol/s/sr)	n/a	Reported	(LM-79-08) 400-700nm range
Photosynthetic Photon Efficacy (PPE) (µmol/J)	≥1.9 µmol/J, with -5% tolerance	Required/Threshold	(LM-79-08) 400-700nm range
Photon Flux Maintenance, Photosynthetic (PFM_P)	Q_{90} ≥36,000 hours	Required/Threshold	(LM-80-15 / TM-21 or LM-84 / TM-28) 400-700nm range
Photon Flux Maintenance, Far-Red (PFM_{FR})	Report time to Q_{90}	Reported	(LM-80-15 / TM-21 or LM-84 / TM-28) 700-800nm range

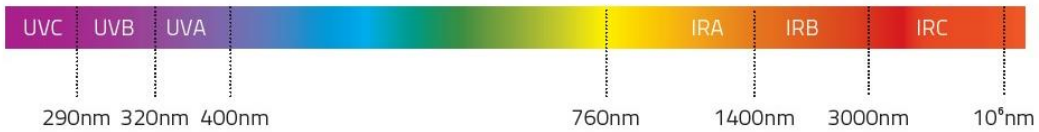
Parameter/Attribute/Metric	Requirement	Requirement Type	Method of Measurement/Evaluation
Driver Lifetime	≥50,000 hours	Required/Threshold	Driver Technical Specification Sheet, Fixture Technical Specification Sheet, and *In-Situ Temperature Measurement Test* (ISTMT)
Fan Lifetime	≥50,000 hours	Required/Threshold	Fan Technical Specification Sheet, Fixture Technical Specification Sheet
Warranty	5 years	Required/Threshold	Legal Warranty Terms & Conditions
Power Factor	≥0.9	Required/Threshold	Electrical testing per LM-79-08
Total Harmonic Distortion, Current (THDi)	≤20%	Required/Threshold	Electrical testing per LM-79-08
Safety Certification	Appropriate Horticultural Lighting designation by OSHA NRTL or SCC-recognized body	Required/Threshold	Per safety certification body (see below)

Key points for LED selection:

- Efficacy of the luminaire PPE >1.9 umol/J, minus 5% tolerance minimum 1.8 umol/J
  - Means the LED should be around + 30% losses (cover, driver, heat) = **2.34 umol/J minimum at LED level**
- Lifetime PPF Q90 > 36000 hours

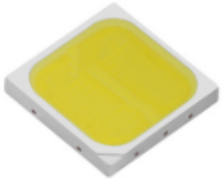
Horticulture Portfolio

- Portfolio of Horticulture solutions
  - Full range of the spectrum covered from UV to IR
    - LEDs available from 275nm to 800nm
    - Different packages available like 3528, 3030, 5050, 5630, 3535
    - Products targeting:
      - Highest ***umol/J*** *(5050* ***> 3.3 umol/J*** *+ 3030C* ***> 3.1 umol/J****)*
      - Highest ***umol/second*** (5050, Z5M4)
      - Best Spectrum ***SunLike***
      - UV LEDs (UVA, UVB, UVC)



Horticulture Portfolio

- Main Focus on White LED solutions with Highest Efficacy

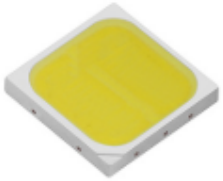


5050 6V – STW0L8PA

3.45 umol/J at 1.25 umol/s @0.35W

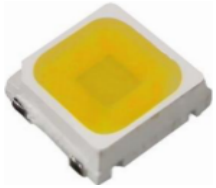
Horticulture Portfolio

- Main Focus on White LED solutions with Highest Efficacy



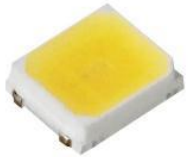
5050 6V – STW0L8PA

3.45 umol/J at 1.25 umol/s @0.35W @750



3030C 3V – STW7C12C-E0

3.1 umol/J at 0.53 umol/s @0.2W

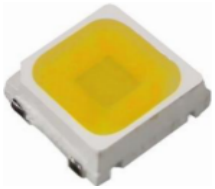


3528 3V – STW8A2PD-E2

2.90 umol/J at 0.50umol/s @0.2W

Horticulture Portfolio

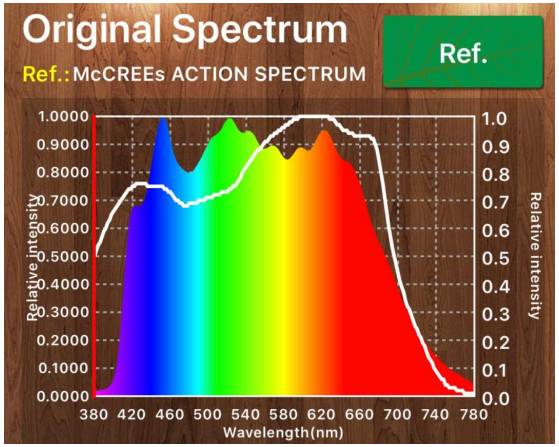
- Main Focus on White LED solutions with Highest Efficacy



SunLike 3030 3V 2chips – STWSC2PB-E0

2.35 umol/J at 0.39 umol/s @0.18W

With unique Full Spectrum to simulate Sun

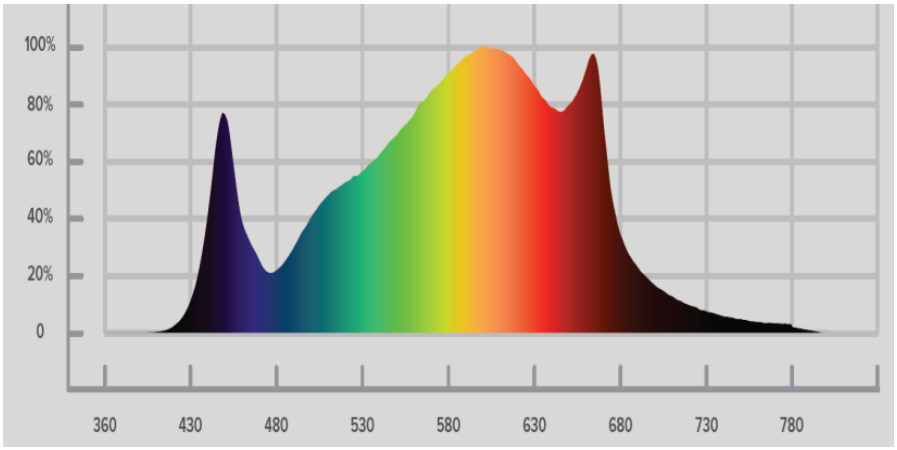


SEOUL SEMICONDUCTOR

Spectrum Solutions

Existing spectrums in the market

Combination of White LED + Extra Red



Target specifications on Luminaire level

Light Output PPF
1700 µmol/s

Efficacy
2.2-2.6umol/J

Power
300-630W

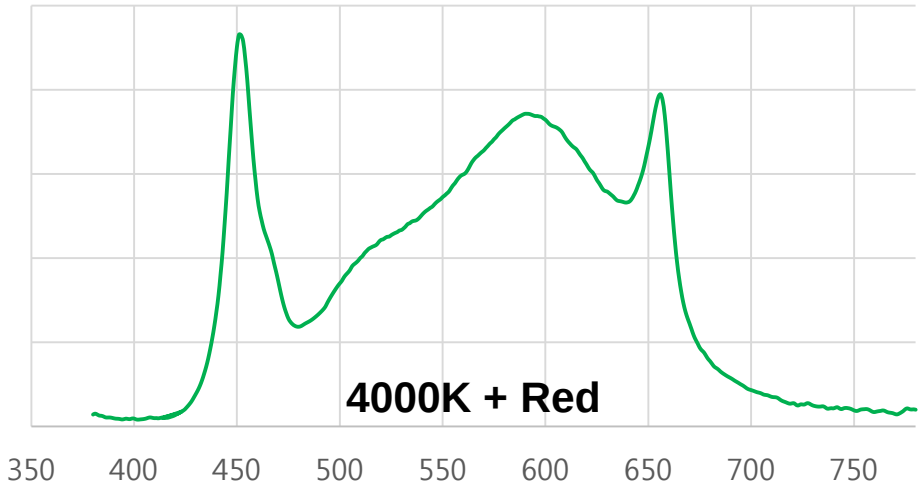
Target at LED level

2.6 umol/J

+ 10% loss heat
+ 6% diffuser
+ 10% driver

3.30 umol/J

SSC solutions



TOP Efficacy solutions

5050 + Z5C (660nm) = 4.0 umol/J

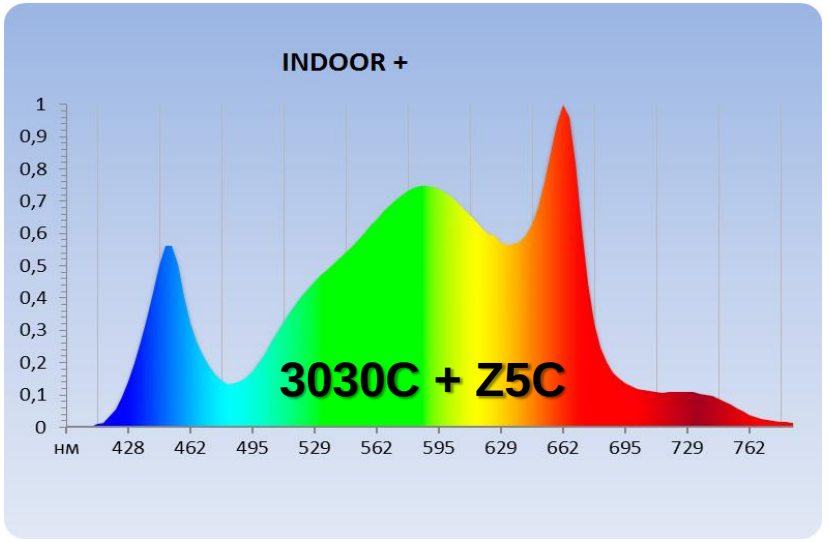
3030C + Z5C = 3.5 umol/J

3528-E2 + Z5C = 3.4 umol/J

Best Cost/Efficacy solution

3528-E1H + Z5C = 3.1 umol/J

SSC solutions



SSC solutions

HORTIONE (GERMANY) → 3030C + 660nm RED

hortiOne 592

Datasheet, 2019

pic:hortiONE 592

Full-Spectrum **LED grow light** for horticultural applications. Suitable for vegetative and generative phase. h1 592 is designed to be a cost-efficient, cutting-edge Solution in indoor growing environments. High light output for asmall budget. Neutral-white -bright-light for a real color rendering of your plants. Low heat-generation (no cooling required) and no active heat radiation (IR, 800nm) towards your plants.

Cardbox - packaging

LED Board and Drriver are delivered in a separate cardbox

100cm 14.5cm 31 cm 23cm 14cm 14.5cm

Measurement

Sepcification

Consumption	Real consumption	190W
LEDs	576x STW8C12C CRI80 Seoul 16x HR OSLON CSSRM3.24 Osram	592 PCS
PPF (380-800nm)*		500 µmol/s
Efficacy**		2.7 µmol/J
Lifetime		50.000 h
CRI	Real color rendering	80
CCT***	Neutral White	3500 K
Input Voltage	Universal Input 110/230V	90-305 Vac
Operating Current		108 mA/216 mA
Ambient temperature		0 - 35 C°
Power Factor		>94%
Warranty		2Years

* Photosynthethic Photon Flux - Biologial Photon Flux
** Module-Efficacy
*** Correlated Color Temperature is derived from CIE 1931 Chromaticity diagram.

AC-Plug Type C Shuko Type J CH

SSC solutions

New Players using massive LEDs

SSC solutions

New Players using massive LEDs – Specially medical cannabis farmers

- **Use of around 300 to 600Watts LEDs / square meter**

SSC solutions

New Players using massive LEDs – Specially medical cannabis farmers

SSC solutions

New Players using massive LEDs

SSC solutions

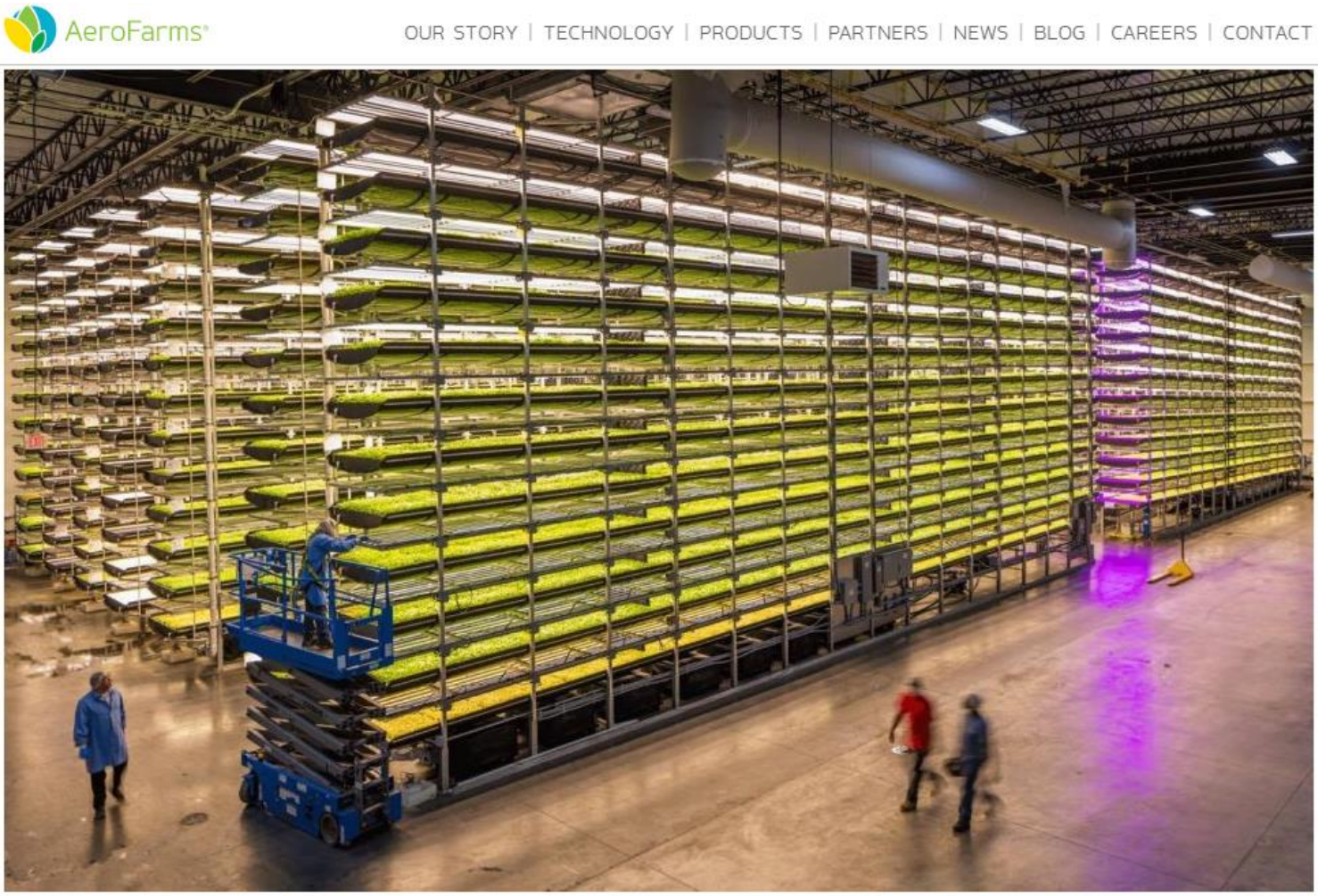
New Players using massive LEDs

SSC solutions

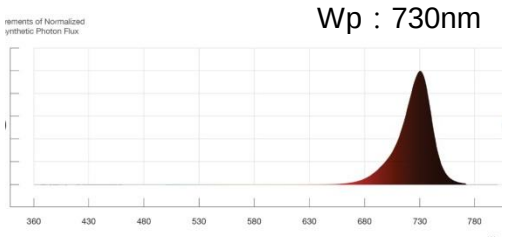
New Players using massive LEDs

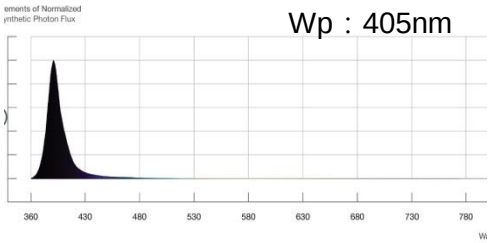
SSC solutions

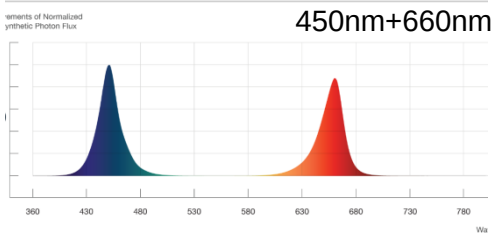
New Players using massive LEDs



Existing products in the market







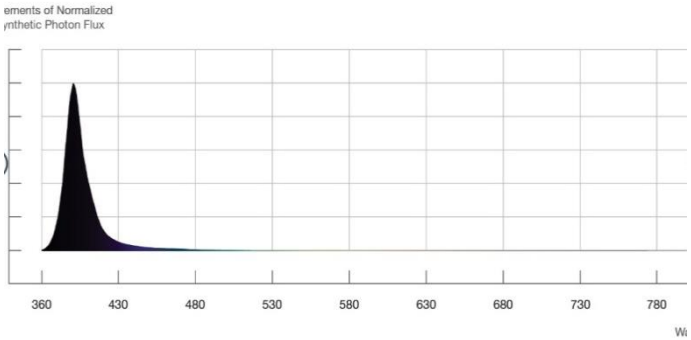
Light Output PPF
1700 µmol/s

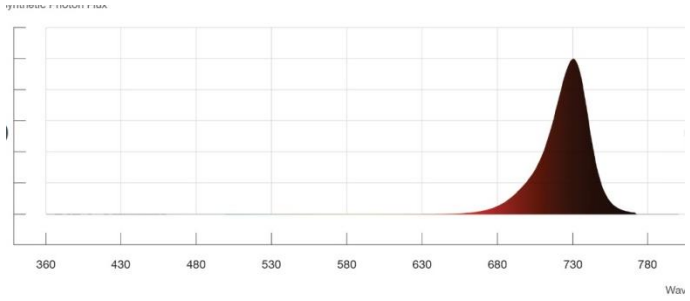
Efficacy
1.4-2.6umol/J

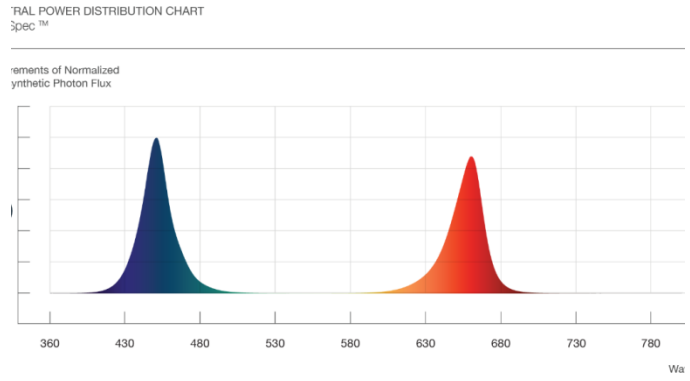
Power
45-630W

LOW Cost Solution
Multiple spectra for different demands

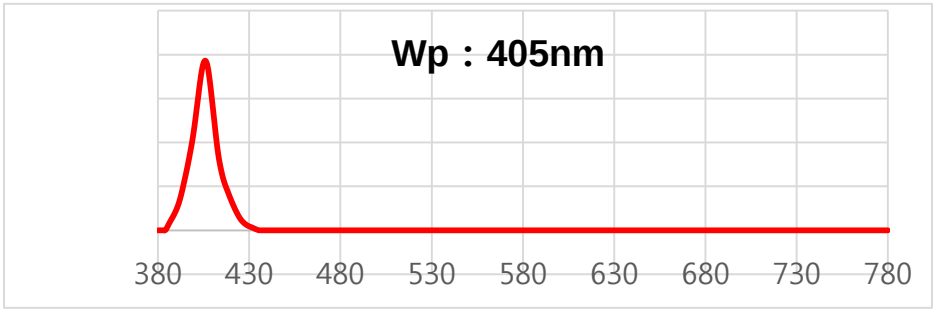
SSC Solutions

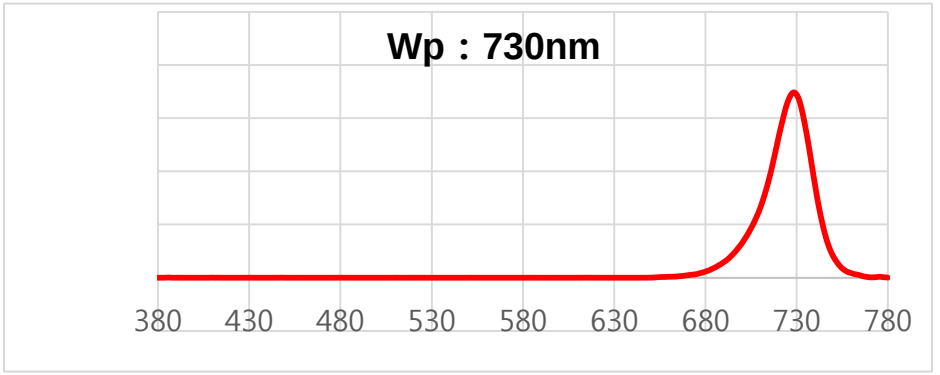


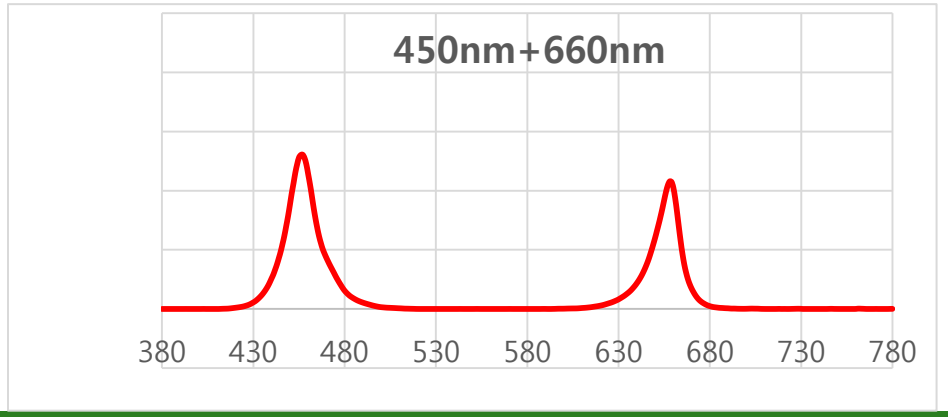




SSC solutions

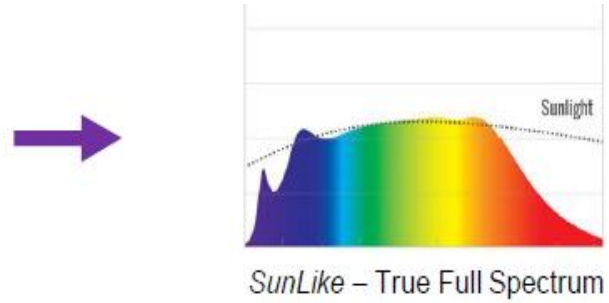


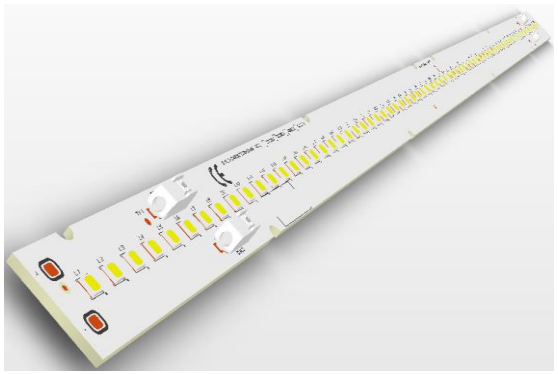


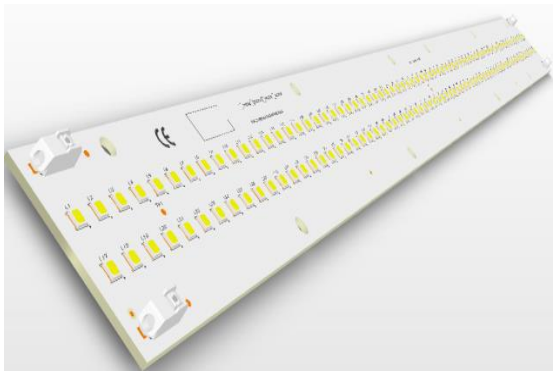


SSC SunLike solutions

Full spectrum solution modules：Sunlike 3030

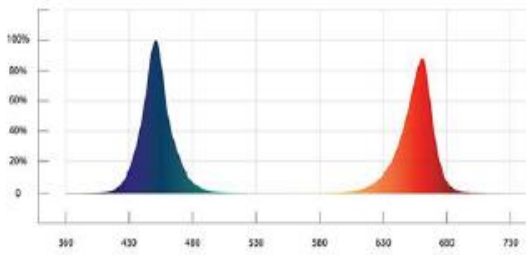




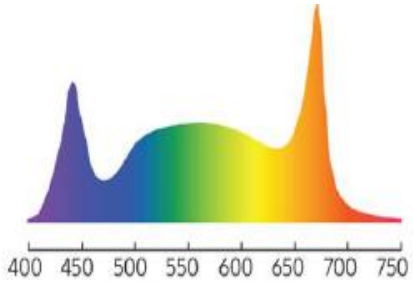


Item	Number	I(A)	U(V)	P(W)	PPF(umol/s)	PPE(umol/J)
1	SMJD-4846144G-XXN1	1.35	52	46	92	2.00
2	SMJD-2423072G-XXN1	1.35	26	23	46	2.00

Technology comparisons

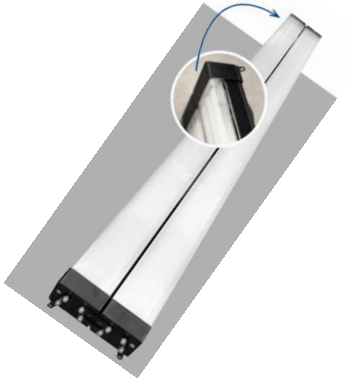


Blue + Red



White + Red

SunLike – True Full Spectrum

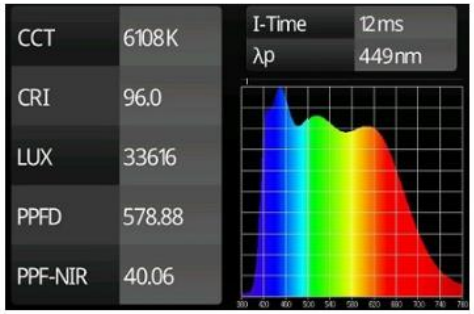


Toplighting compact

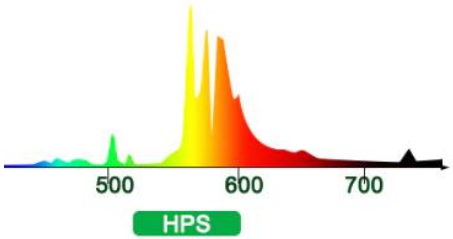
The easy 1-to-1 HPS replacement. Switch to LED lighting as a way to improve crop results or reduce energy costs.

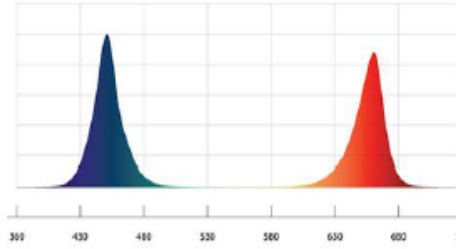
Specs	
Voltage input	277 – 400 V
Power consumption	49-635 (inc. dimmable vers.)
Light output	1800 µmol/s
Efficiency	2.9 – 3.0 µmol/J

Light Output PPF	1700 µmol/s
Efficacy	2.7 µmol/J @ 230V AC
AC Input Power	632W @ 230V AC
AC Input Voltage	120-277V AC, 347-480V AC, 50/60Hz
Light Distribution	120°
Mounting Height	6" - 12" (15.2-30.5cm) Above Canopy
Thermal Management	Passive

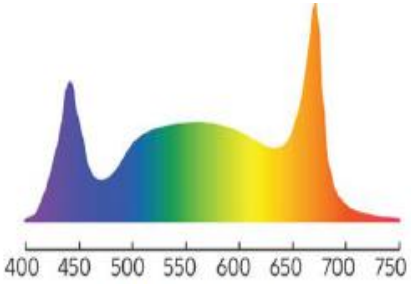


Technology / Cost comparisons

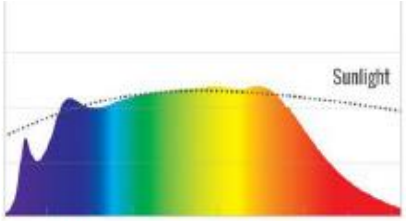




Blue + Red



White + Red



SunLike – True Full Spectrum

High Pressure Sodium

Input power = 1000W
PPF = 1900 µmol/s
Efficacy = 1.9 µmol/J

Blue + Red LED

Input power = 600W
PPF = 1800 µmol/s
Efficacy = 3.0 µmol/J

LED estimation units

Blue LED = 21 units
Red LED = 372 units
Estimated cost = 150 ~ 180 € (LED only)

White + Red LED

Input power = 630W
PPF = 1700 µmol/s
Efficacy = 2.7 µmol/J

LED estimation units

White CRI80 = 1584 units
Red LED = 48 units
Estimated cost = 90 ~ 110 € (LED only)

SunLike LED

Input power = 800W
PPF = 1440 µmol/s
Efficacy = 1.8 µmol/J

LED estimation units

SunLike 3030 = 1600 units
Estimated cost = 120-150 € (LED only)

What People says about SunLike ?

“SunLike is the best artificial light to reproduce the real Sunlight indoors”

SunLike success stories

Rofianda
Light Solutions

full-spectrum sunlight installed at From Boer

"We want to grow every lettuce variety without having to think about the light recipe"

SunLike success stories

Rofianda
Light Solutions

SunLike success stories

Rofianda
Light Solutions

SunLike success stories

ekonoke
eat as you are

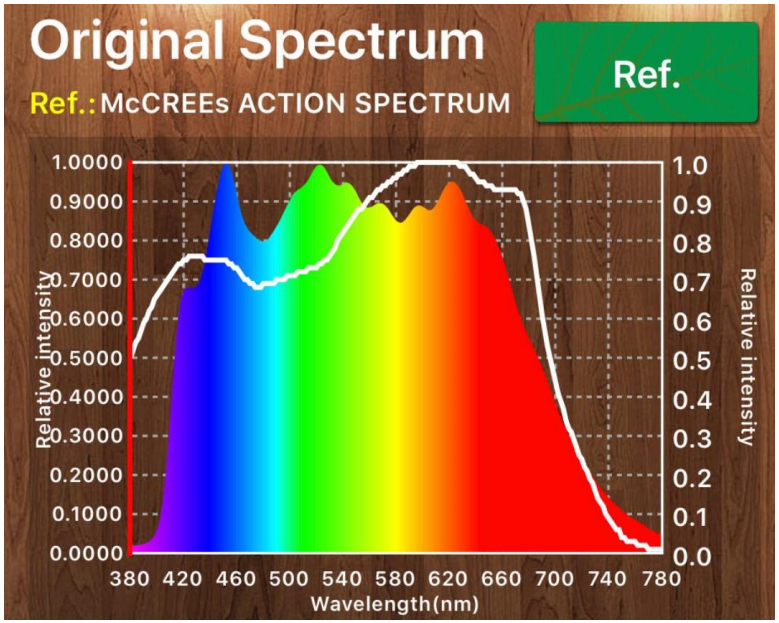
“We are an organic farm and we don’t want to modify the nature, we use the closest light to the Sunlight”

SunLike success stories

GROW LIGHT

Fiberli

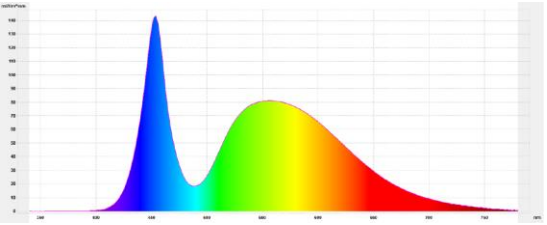
“We have the Best spectrum for growing healthy plants”



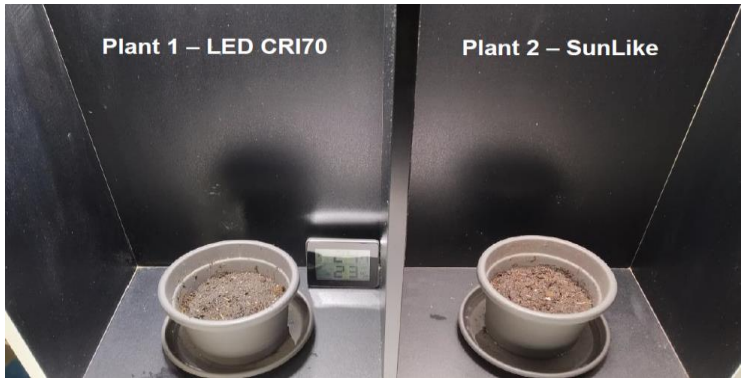
SunLike success stories

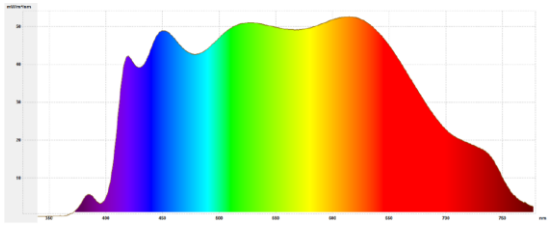
“We want to grow plants by simulating the Sun with LED SunLike Quality”

SunLike success stories



300 μmol/m^{2}s





300 μmol/m^{2}s

SunLike

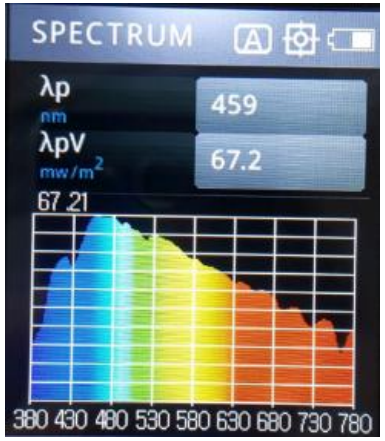
Growing Faster

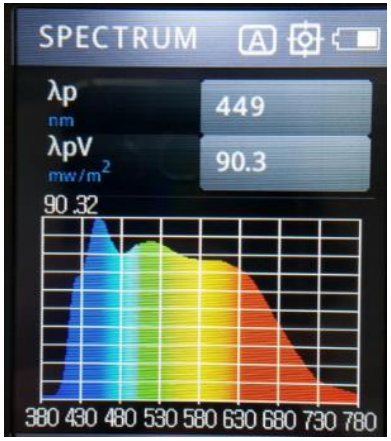
Research articles

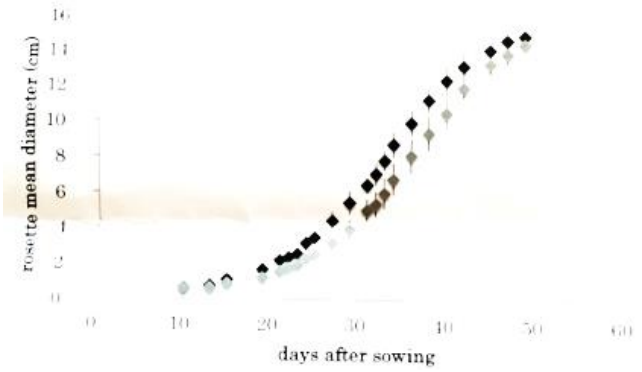
- **Growing *Arabidopsis thaliana***

Summary of the test:

1. Test conditions: Day/Night 8h/16h at temperatures 24ºC / 18ºC , relative humidity 65%, constant 300 µmol/m^2·s
2. 49 days growth test
3. Conclusions: **SunLike 5000K is the best single LED source ever tested** in this research facilities. Makes it perfect for research in new genetic plants in the lab.
4. All new Horti labs in Cadarache (France) will be equipped with SunLike







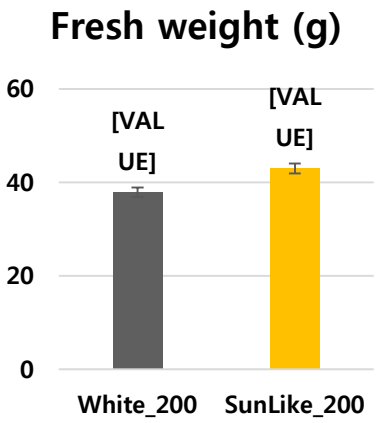
Research articles

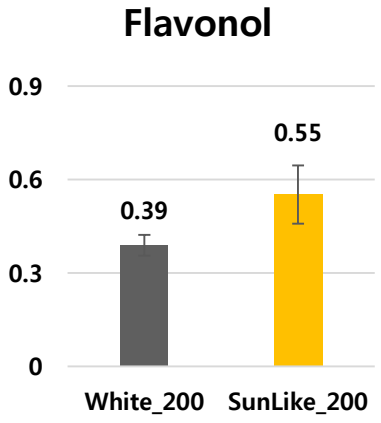
- **Growing Lettuce under LEDs**

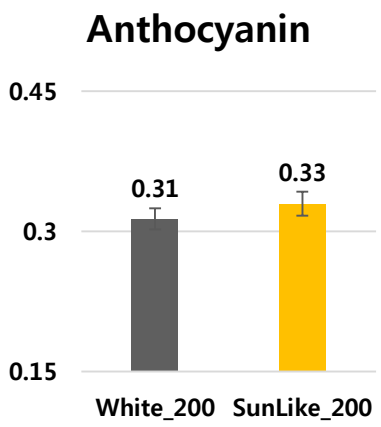
By Dr. Jinwon Kim - Korea

Summary of the test:

1. Lettuce growing under 3030 SunLike LED and 3030 CRI80 LEDs
2. Conditions → Inside of test lab / 16h (ON) + 8h (Off) / 20 °C / 60% Humidity
3. Results show:
   - **13.5% extra Weight with SunLike (faster growth)**
   - **41% extra Flavonol with SunLike (better nutrition)**







Research articles

Growth, nutritional quality, and energy use efficiency in two lettuce cultivars as influenced by white plus red versus red plus blue LEDs

Zhengnan Yan[1], Dongxian He[1*], Genhua Niu[2], Qing Zhou[1], Yinghua Qu[1]

(1. *Key Laboratory of Agricultural Engineering in Structure and Environment of Ministry of Agriculture and Rural Affairs, China Agricultural University, Beijing 100083, China*;
2. *Texas A&M AgriLife Research Center at Dallas, Texas A&M University System, Dallas, TX 75252, USA*)

4 Conclusions

Growth, nutritional quality, and energy use efficiency of hydroponic lettuce could be strategically changed by supplemental selected lights in red plus blue LEDs or white LEDs. Moreover, lighting environment management for hydroponic lettuce production is also associated with different leaf color. Fresh weight, light and electrical energy use efficiencies of hydroponic lettuces grown under white plus red LEDs were higher or no significant differences compared with those grown under red plus blue LEDs. In conclusion, white plus red LEDs was suggested to substitute for red plus blue LEDs in hydroponic lettuce (cv. Lvdie and Ziya) production in plant factory with artificial lighting.

nutrition and energy-use efficiency. Acta Horticulturae, 2018; 1227: 491–498.

[14] Agarwal A, Gupta S D, Barman M, Mitra A. Photosynthetic apparatus plays a central role in photosensitive physiological acclimations affecting spinach (*Spinacia oleracea* L.) growth in response to blue and red photon flux ratios. Environmental and Experimental Botany, 2018; 156: 170–182.

[15] Mitchell C A, Dzakovich M P, Gomez C, Lopez R, Burr J F, Hernández R, et al. Light-emitting diodes in horticulture. In: Janick J (Ed.). Horticultural Reviews. John Wiley & Sons, Inc., 2015; pp. 6–8.

[16] Li Q, Kubota C. Effects of supplemental light quality on growth and phytochemicals of baby leaf lettuce. Environmental and Experimental Botany, 2009; 67(1): 59–64.

[17] Zhang X, He D X, Niu G, Yan Z N, Song J X. Effects of environment lighting on the growth, photosynthesis, and quality of hydroponic lettuce in a plant factory. Inter J Agric & Biol Eng, 2018; 11(2): 33–40.

Research articles

MICHIGAN STATE UNIVERSITY

- **Michigan State University**

  Use of SunLike luminaires to simulate the Sunlight when testing covering materials for greenhouses that change the light transmission to crops grown below

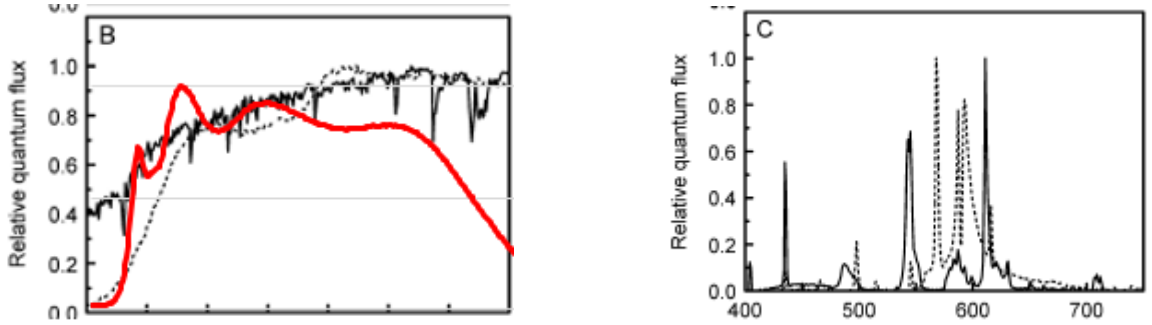
By Professor Erik Runkle

Research articles

WAGENINGEN UNIVERSITY & RESEARCH

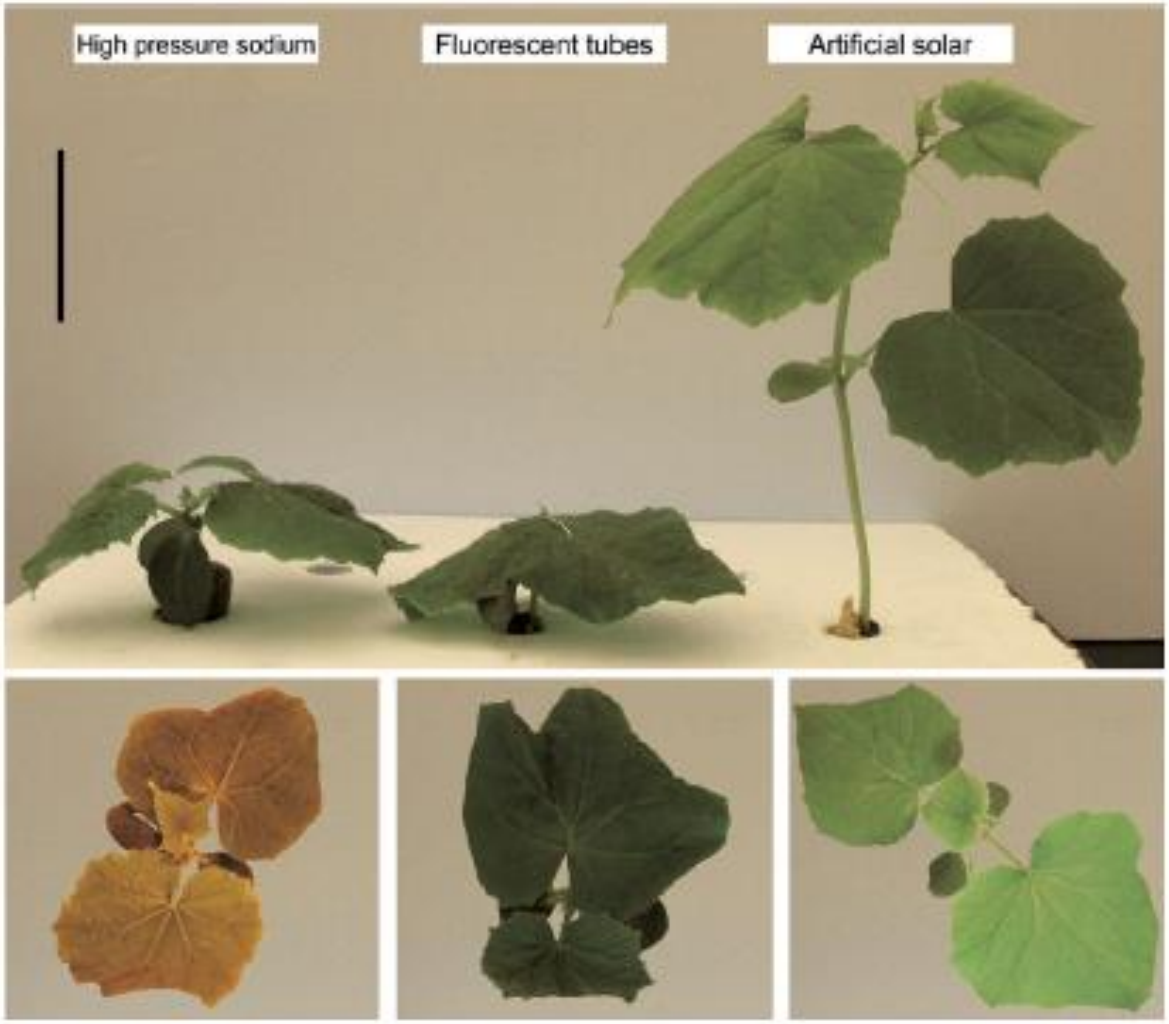
- **Artificial solar spectrum for plant development**

control or, if a natural daylight control is used, it will fluctuate in intensity and spectrum. An artificial solar (AS) spectrum which closely resembles a sunlight spectrum has been engineered, and growth, morphogenesis, and photosynthetic characteristics of cucumber plants grown for 13 d under this spectrum have been compared with their performance under fluorescent tubes (FTs) and a high pressure sodium lamp (HPS). The total dry weight of the AS-grown plants was 2.3 and 1.6 times greater than that of the FT and HPS plants, respectively, and the height of the AS plants was 4–5 times greater. This striking difference appeared to be related to a more efficient light interception by the AS plants, characterized by longer petioles, a greater leaf unfolding rate, and a lower investment in leaf mass relative to leaf area. Photosynthesis per leaf area was not greater for the AS plants. The extreme differences in plant response to the AS spectrum compared with the widely used protected cultivation light sources tested highlights the importance of a more natural spectrum, such as the AS spectrum, if the aim is to produce plants representative of field conditions.



SunLike in RED color very close to the AS (Artificial Solar) used for test

Research articles



THANK YOU!

www.seoulsemicon.com