UV LED Applications in Horticulture Lighting

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Agenda

1. What are the wavelengths used in horticulture?

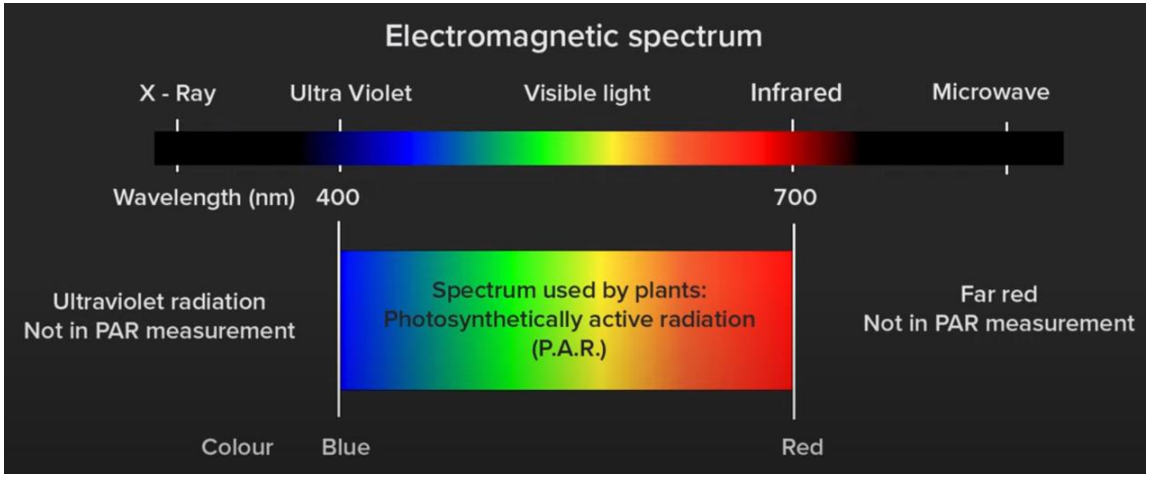
2. State of UV LED technology

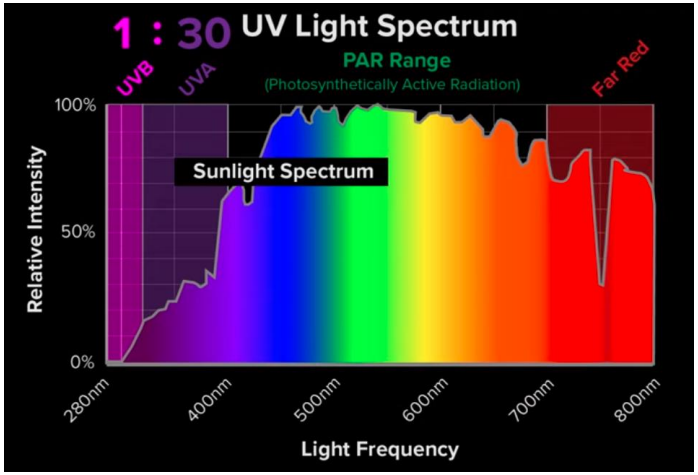
3. Luminus UV LED Product Portfolio

4. Plant Photoresponse to UV light

5. Selective applications of UV LEDs in horticulture:
   - Boost THC & cannabinoid content
   - Fight pathogens
   - Change color and texture in leafy greens
   - Extend shelf life
   - Improve chicken behavior

What are the wavelengths used in horticulture?



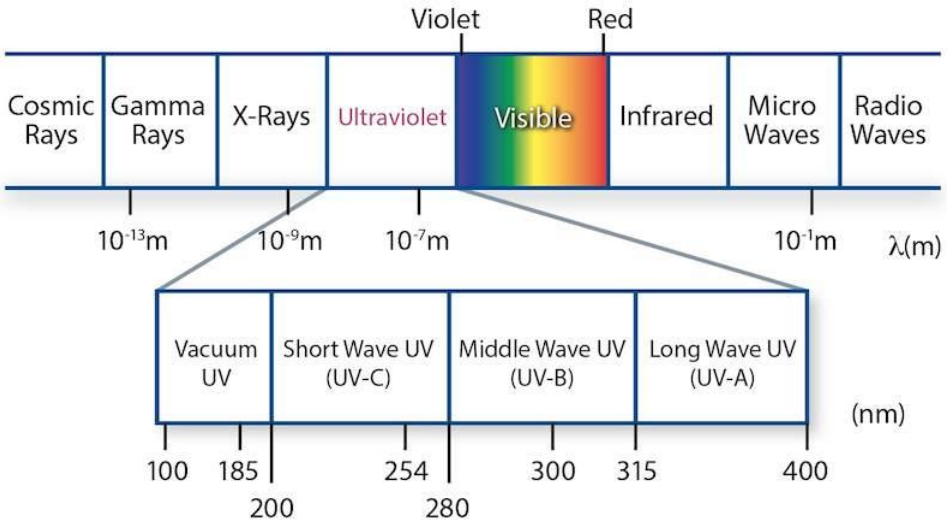


- UV light falls outside the **P**hotosynthetically **A**ctive **R**adiation (PAR) range (400-700nm) but is still very useful in horticulture
- Only 3% of sunlight is UV radiation
- UVC and part of UVB is blocked out by the atmosphere

What are the wavelengths used in horticulture?

Wavelength (nm)	Effect on Plant Growth	State-of-the-art WPE (%)
280	Significantly reduces quantum yield rate of photosynthesis. UVR8 photoreceptor pathway	3-4%
315-400	Promotes pigmentation, thickens plant leaves. Eco-friendly way for pest control	60%
440-470	**Chlorophyll absorption peaks at 439 and 469 nm**. The blue spectrum is the most efficiently absorbed spectrum, promoting mainly vegetative growth.	>70%
510	Quantum absorption in the green spectrum. Little absorption in the yellow spectrum	25%
610	No chlorophyll benefit, but efficiently absorbed by phycocyanin receptors which initiate light signaling mechanisms for photoperiodism (onset of flowering)	45%
640-660	**Chlorophyll absorption peaks at 642 and 667 nm**. Speeds up germination and flower/bud onset. 660nm is the most vital wavelength for flowering.	>70%
690	Some research papers seem to indicate plant benefit at this wavelength – unclear.	40%
720-740	**Emerson Enhancement Effect**—quantum yield of red light and far red light, when shone simultaneously on a plant, increases the rate of photosynthesis.	55-60%
1000-1400	No plant activity detected in this wavelength range. Heat generated.	-

State of UV LED technology



3 distinct regions:

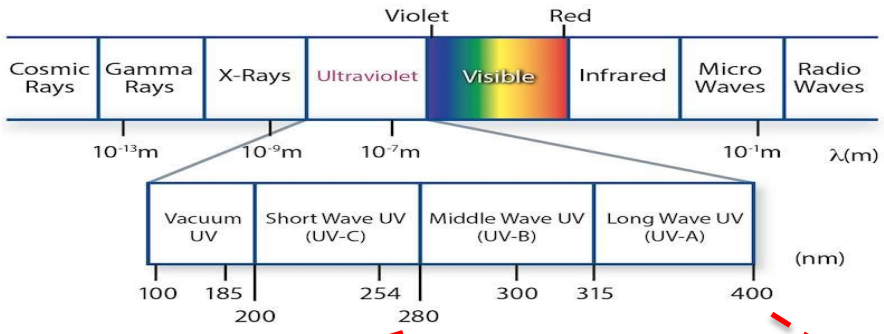
- **UVA radiation (from 315 to 420 nm)** - Barely visible to the human eye, UV-A has the longest wavelength, is the least harmful to the human eye and is the most efficient.
- **UVB radiation (from 280nm to 315nm)** - Primarily used within water sterilization and decontamination, ensuring that mold and spores do not grow on plants.
- **UVC radiation (typically below 280nm)** - These wavelengths are usually filtered out through the ozone layer.

- UVA LEDs have become mainstream thanks to:
  - **Excellent WPE (up to 60%)**
  - **Low price**
  - **Good reliability and lifetime**

- UVC LEDs **have still yet to gain traction in horticulture** but:
  - They gradually become more efficient and cheaper at current wavelengths (above 270nm)
  - UVC LEDs will increasingly replace Hg and Xe lamps for high power, high irradiance applications

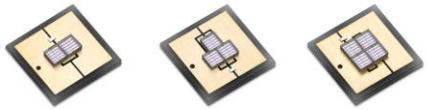
- UV LEDs provide **digital control** compared to legacy UV solutions (narrow band spectrum)

Luminus UV Horticulture Portfolio



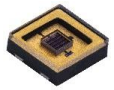
UVC LEDS

XFM-5050



XST-3535

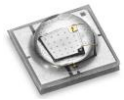
XBT- 3535



XBT-1313

- *UVC/UVB portfolio ranges from 5 mW- 250 mW*
- *Wavelength: 270 nm-285 nm*
- *Different package sizes available: 1313, 3535 and 5050*

UVA LEDS



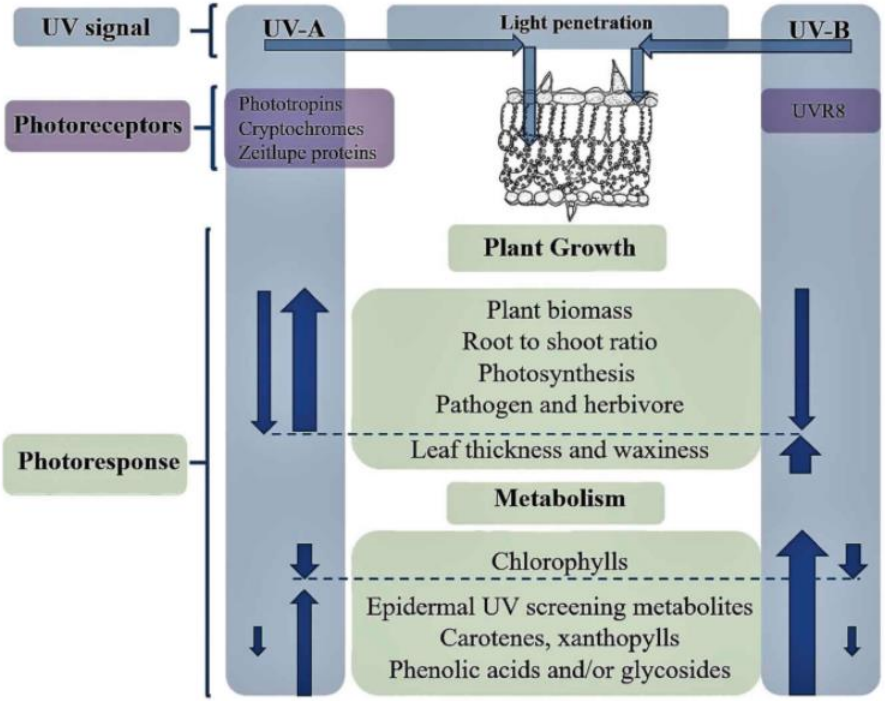
SST-10 Series

- *3535 package, silicone encapsulation*
- *700 mW- 1 W @ 500 mA*
- *365 nm-405 nm*
- *Available in solder footprints compatible with Cree and Osram.*

Plant photoresponse to UV light

- UVB radiation has the potential to damage plants and its negative impact on plant growth is well documented:
  - ↓ Smaller but thicker leaves
  - ↓ Lower biomass, shorter height
  - ↑ More phenolic compounds

- UVA radiation role is less understood and research results are contradictory. Some results may be species specific.
  - ↓ Reduction of leaf area
  - ↑↓ Biomass and net photosynthesis



Source: "Ultraviolet LED technology for food applications – from farms to kitchen", T. Koutchma et al.

Selective Applications

Selective Applications where UV is used in Horticulture and adjacent markets:

Pre Harvest

- Boost THC content in cannabis
- Eco-friendly way to control powdery mildew or other pathogens
- Change color, texture and vitamin content in leafy greens & mushrooms

Post Harvest

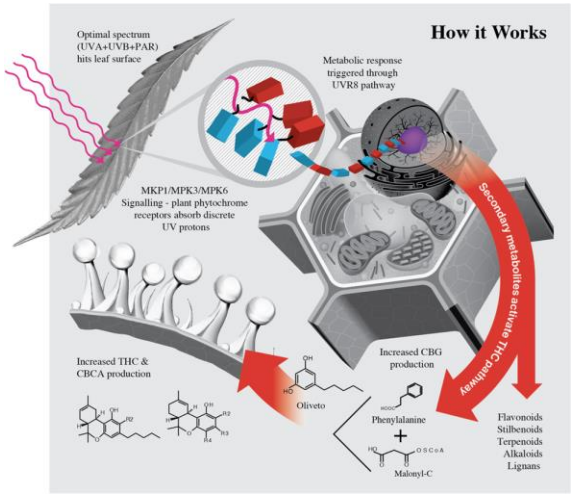
- Extend shelf life post harvest by several days

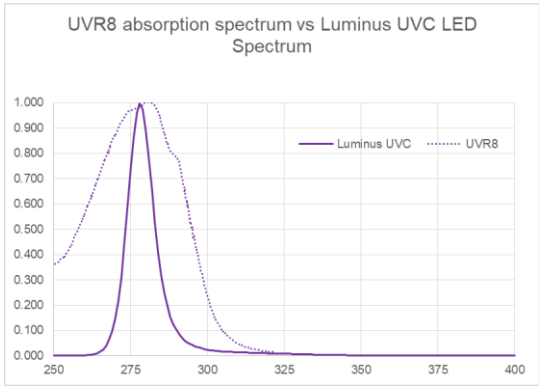
Adjacent Markets

- Improve chicken behavior

Application 1: Boost THC/CBD content in Cannabis

- Mechanism relies on **UVR8** which is a protein found in many plants and animals, including cannabis:
  - Acts as a messenger that send information to the host plant, when exposed to **UV radiation that peaks at 285nm**.
  - In all plants, this causes a plant stress message to be sent to the plant, which can react according to its own DNA.
  - In the case of cannabis, the plant reacts by producing more trichomes and more THC.
- Recent studies challenge previous studies dating as far back as 1987 (J. Lydon et al.) and more research is needed to better understand the mechanisms involved and the potential for THC increase.
- **Several horticulture fixtures companies integrate UVA LEDs in their fixtures but UVC LED penetration for this market has yet to become mainstream.**





UVC LEDs provide digital control to match the absorption spectrum of UVR8 where UVC lamps don't

Application 2: UVC to fight pathogens & pests

- **Pathogen protection mechanism (similar to a flu shot):**
  1. UVC exposure triggers a defense mechanism in the plants which results in the production of a natural hormone: **salicylic acid**
  2. This hormone activates natural defenses even before the pathogen attacks.
  3. After treatment, plants become more resistant to future attacks

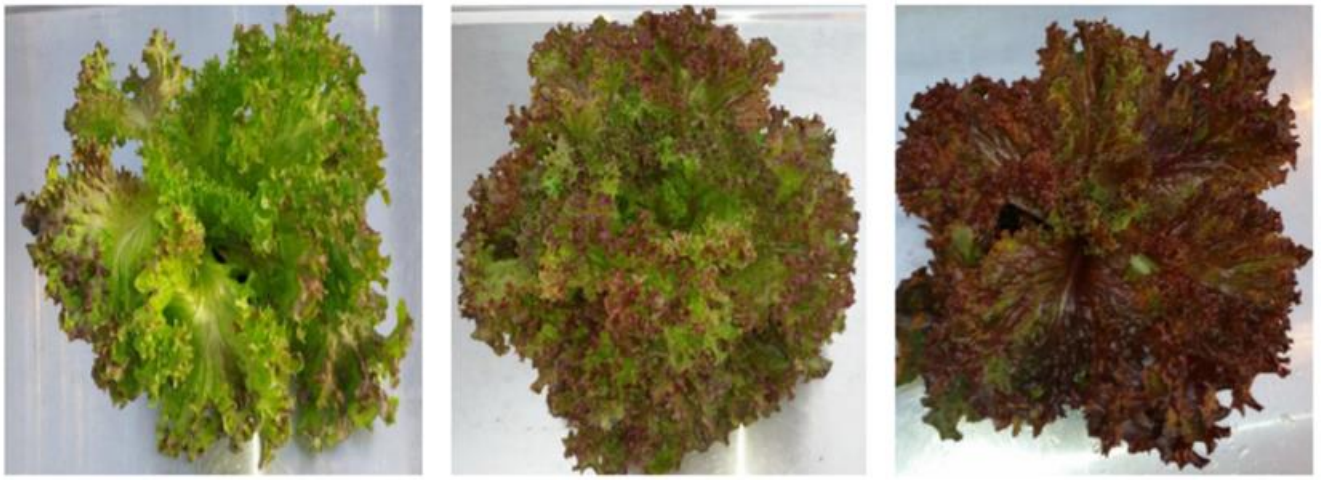
Credit: UV Boosting

- **Field trial** to treat vines, strawberries & basil in several countries

Credit: Saga Robotics / Cornell University

- **Initial tests with UVC LEDs** but UVC lamps are currently widely used.

Application 3: Change color & texture of leafy greens



Red lettuce 'Lollo Rosso' after 7 days under the UV treatments.

Source: "The Effects of UV Radiation on the Content of Phenolic acid and Flavonoid, Stomatal Conductance and Taste in Red Lettuce 'Lollo Rosso", Dinalva Almeida De Oliveira, Master's Thesis - 2016

- UVA/UVB LED is added to standard LED lighting to change the color (and texture) of leafy greens
- Other characteristics such as texture, taste and vitamin content are also affected by UV LEDs

Application 4: Extend Shelf Life of Fresh Produce

- UVC LEDs can reduce risks associated with food poisoning, extend produce storability and minimize losses
  - USDA studies show that fresh fruits and vegetables exposed to UVC LEDs in the range of 285-305nm exhibit a **shelf increase of 2x** using 20mW/m^2 of UVB LED power

Dark Control: before test (left) and at end of test (right)

Illuminated with UVC: before test (left) and at end of test (right)

Illuminated with UVB: before test (left) and at end of test (right)

Source: "Deep Ultraviolet (DUV) Light-Emitting Diodes (LEDs) to Maintain Freshness and Phytochemical Composition During Postharvest Storage"

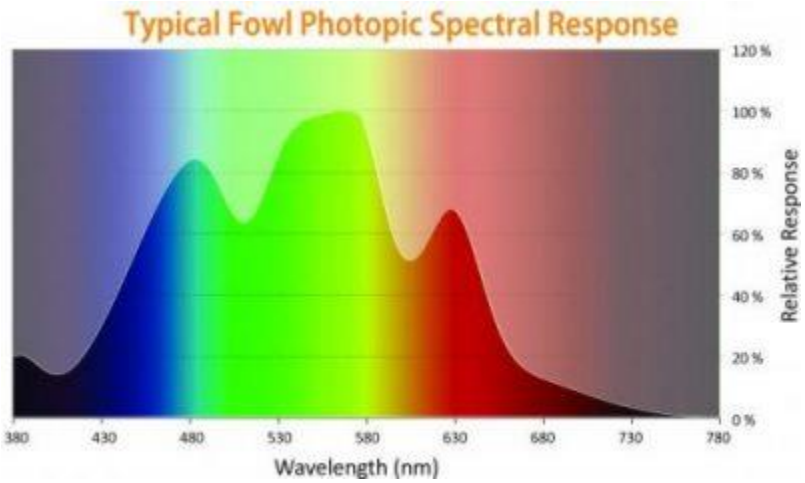
  - Research at Agriculture and Agri-Food Canada (AAFC) showed that 277nm UVC LEDs can reduce mold spores on the skin of apples by 2.8 log (compared to 2 log for low-pressure mercury lamp)

Application 5: Use of UV in Poultry Farming

- Poultry, unlike humans, have a **fourth retinal cone** that allows them to see UVA light

- Research has shown that UVA and UVB light provides the following benefits in chicken farming:
  - Reduce stress and fearfulness
  - Improve mobility
  - Improve feather condition
  - UVB may promote vitamin D synthesis

- Scientists believe widespread use UVA LED light might be **economically advantageous** in chicken broiler



Source: "The effect of supplementary ultraviolet wavelengths on broiler chicken welfare indicators", Charlotte James et al., Applied Animal Behaviour Science 209 (2018)

Luminus UV Horticulture Portfolio

1 W+

500 mW

200 mW

50 mW

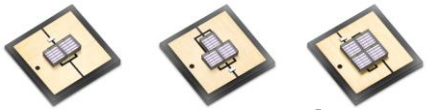
5 mW

280 nm

315 nm

- *3535 package, silicone encapsulation*
- *700 mW- 1 W @ 500 mA*
- *365 nm, 385, 395, 405 nm options*
- *Available in solder footprints compatible with Cree and Osram.*

XFM-5050 Series



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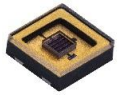

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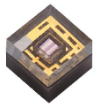

UVC UVB UVA

LUMINUS

Summary

- UV light is used more and more in horticulture today with several benefits clearly identified
- Additional research is needed to optimize light recipe - including exact wavelength and fluence (or μmol/s/m^2) - for each application and crop
- UVA LEDs are gaining traction in horticulture markets thanks to their relatively low cost and long lifetime
- However, penetration of UV LEDs in horticulture market is still limited to UVA LEDs
- As UVC LEDs become more efficient and less costly, gradual penetration is expected

Questions?

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