Horticulture Application: Grow Lights

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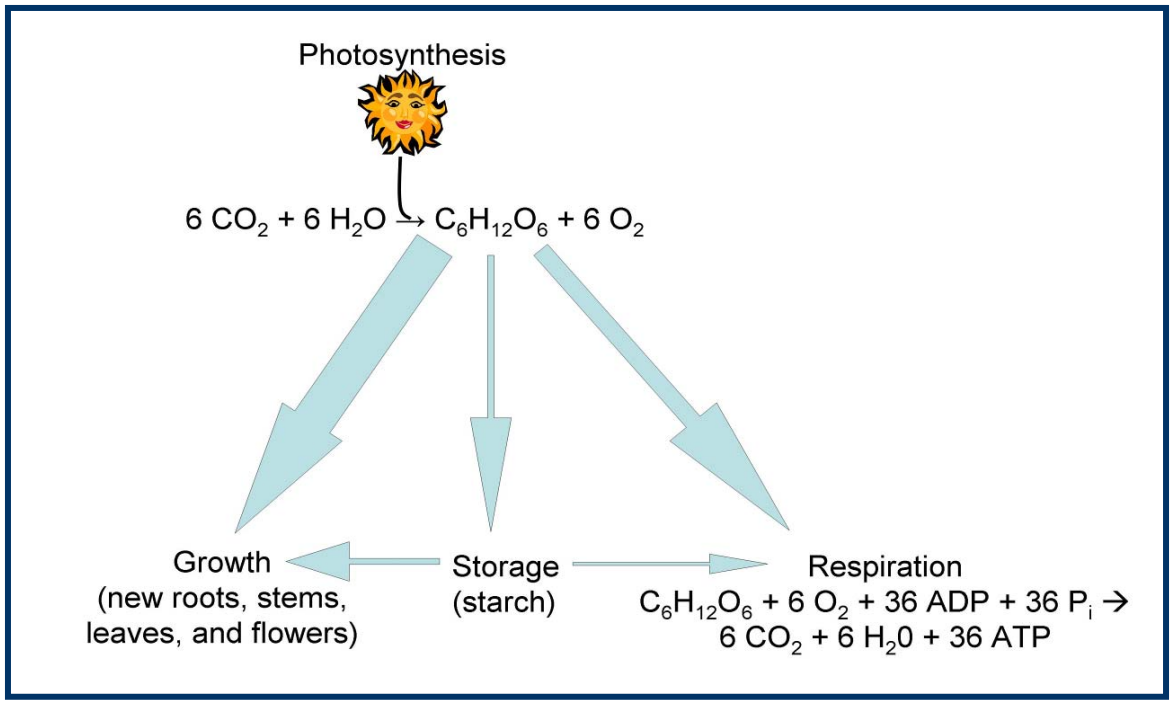
Agenda

- Photosynthesis
- Light Measurement in Horticulture Environment
- Factors that effect Photosynthesis
- Photoperiod and significance of Phytochrome
- LED Advantage

Photosynthesis

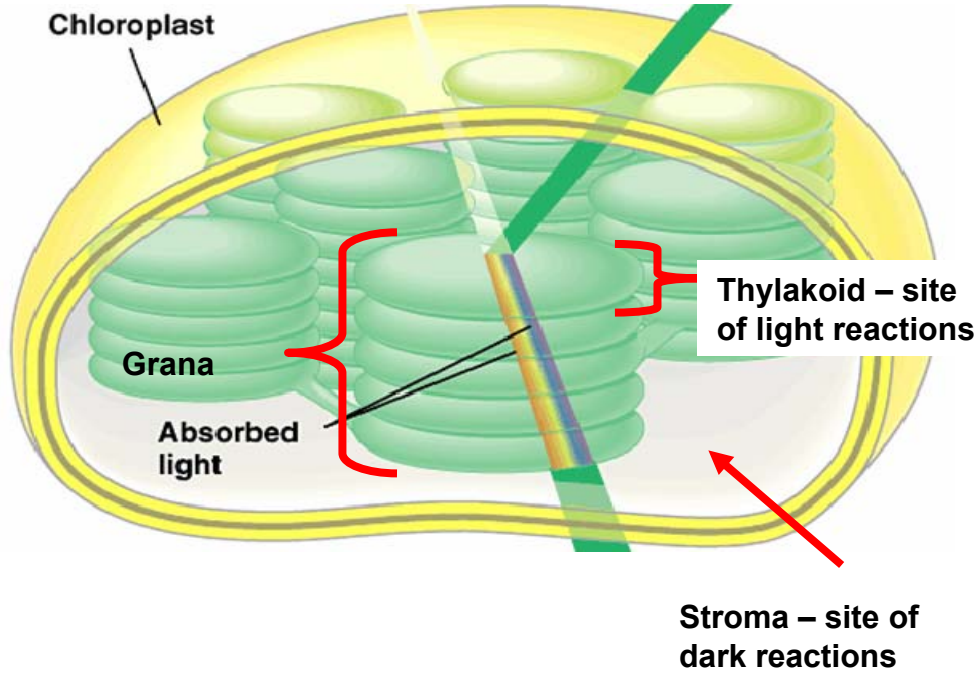
Photosynthesis converts energy from the sun, plus carbon dioxide (CO_2) and water (H_2O) into carbohydrates (such as glucose, $C_6H_{12}O_6$) and oxygen (O_2).

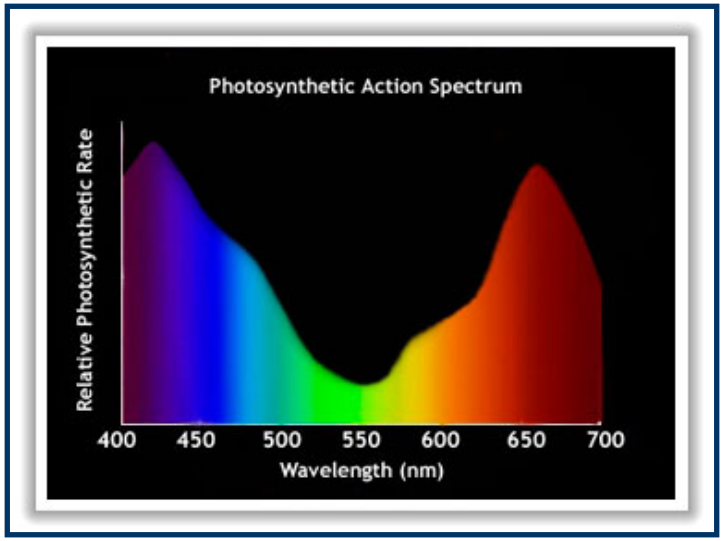


In respiration (the opposite of photosynthesis),

carbohydrates are converted back into carbon dioxide, water, and energy (ATP).

Chloroplast





- Photosynthesis occurs in the chloroplasts using chlorophyll the green pigment, specifically in the thylakoid membrane
- Stomates are holes which occur mainly in the lower epidermis and are for air exchange
- Chlorophyll production is the primary for compact vegetative growth. Beta-carotene and Cartenoids are also pigments absorbing different spectral content and converting it to ener

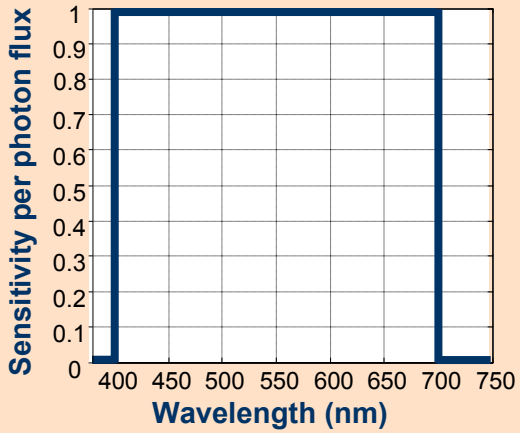
Background Knowledge – Photon counting

Today's method of weighing the spectrum is inadequate

Situation today

- The whole spectrum is weighed equally by counting the photons in the photosynthetically active region (PAR)

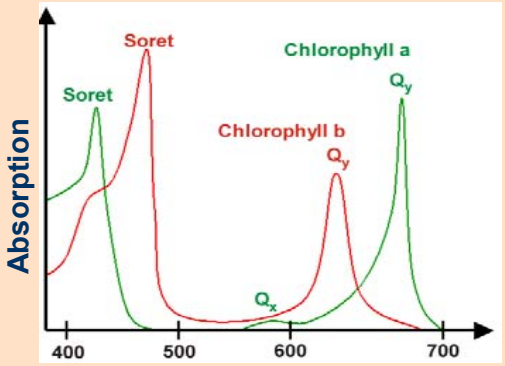
PAR sensitivity curve



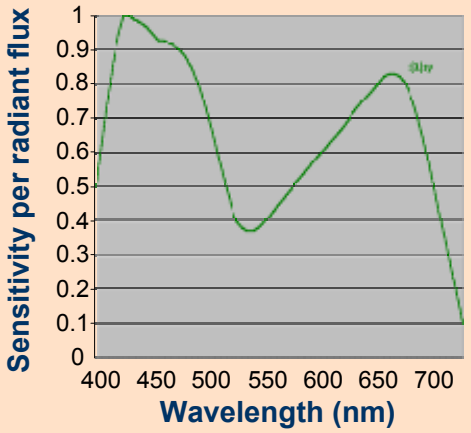
More realistic approach

- Weighing the emission spectrum of the light source with plants' spectral sensitivity curve ("plm/W")
- This curve is derived from the chlorophyll absorption spectrum taking into account internal energy transfer processes of the plant / leaves

Chlorophyll absorption spectrum



Plant sensitivity curve (DIN)*



* DIN 5031-10

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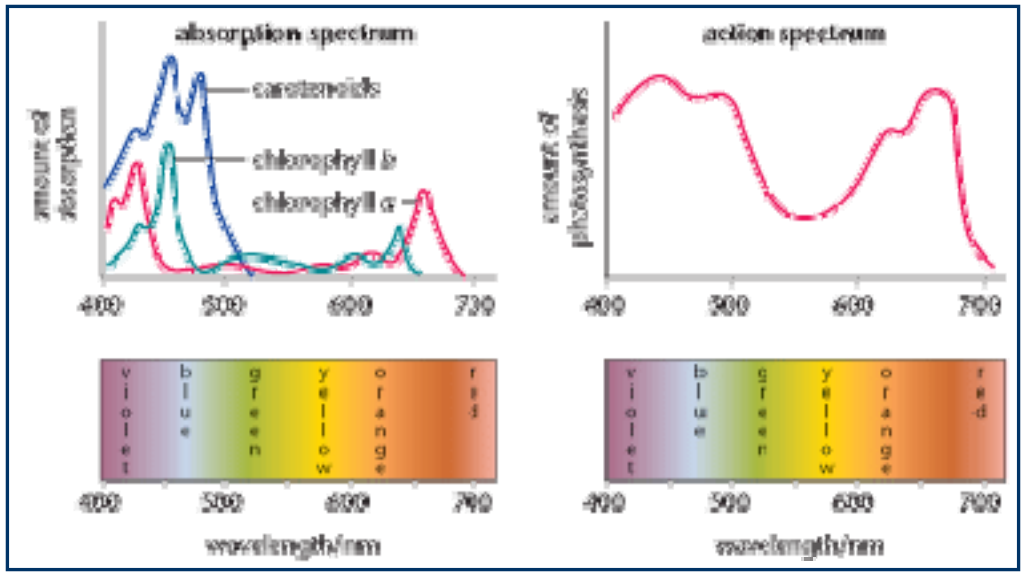
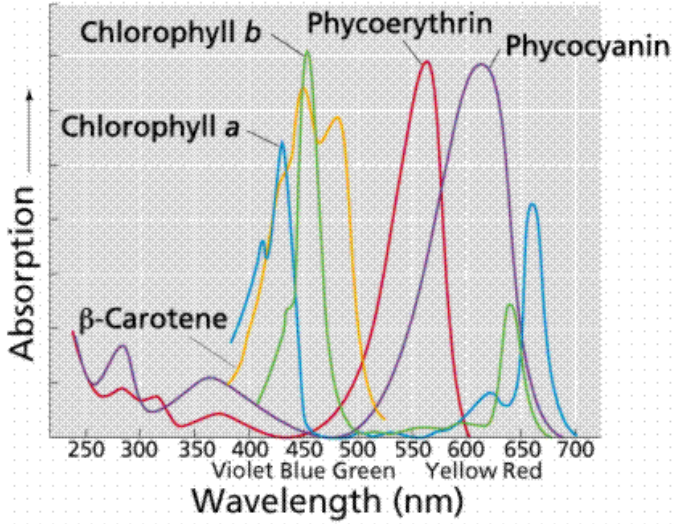
Chlorophyll and Accessory Pigments





- Photosynthesis takes place in the chloroplasts, specifically using pigments such chlorophyll and carotenoids.
- Light is mostly absorbed by the chlorophyll in the blue (400nm -500nm) and red (600nm- 700nm) regions of light spectrum and by carotenoids in the blue region.
- Providing plants with equal amount of monochromatic light at different wavelengths and measuring the photosynthesis rate.

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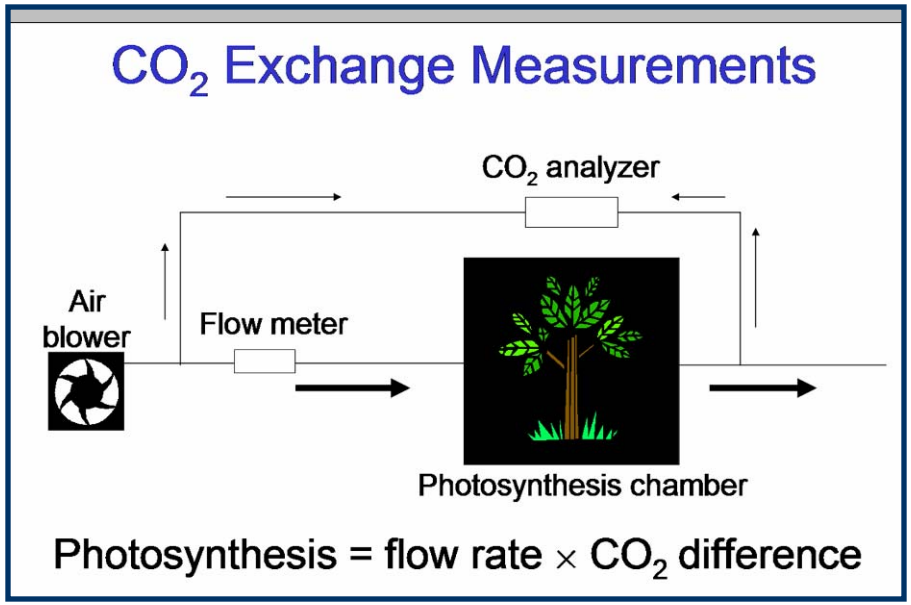
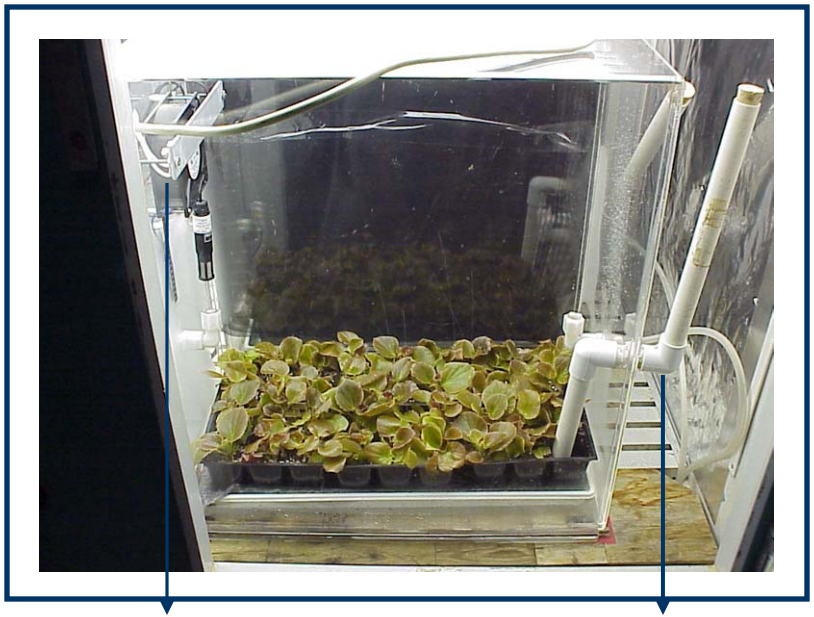
Autumn Foliage

- Chloroplasts also contain carotenoids. These are also pigments with colors ranging from red to yellow.
- Carotenoids absorb light most strongly in the blue portion of the spectrum.
- They thus enable the chloroplast to trap a larger fraction of the radiant energy falling on it.

Measuring photosynthesis

Setup for measuring Photosynthesis





FAN

TUBE for
sub irrigating tray without
opening chamber.

Light in chamber – combination of different saturated wavelengths of light to stimulate growth of the plant at various stages.

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Measuring light

Unit	Type of measurement	Mainly used by	Sunlight	Incandescent 100W	Cool-white Fluorescent
Footcandles	Visible (human eye)	Industry (US)	1	1	1
Lux	Visible (human eye)	Industry (Europe)	10.76	10.76	10.76
$\mu mol \cdot m^{-2} s^{-1}$ of PAR	Quanta of light in PAR range	Horticulture Research	0.20	0.22	0.15
$\mu mol \cdot m^{-2} d^{-1}$ of PAR	Daily light integral accumulated PAR during an entire day	Horticulture Research	Footcandles x 0.000718 x hours of light	Footcandles x 0.000775 x hours of light	Footcandles x 0.000524 x hours of light
$W.m^{-2}$	Energy in PAR range	Engineers, research	0.044	0.043	0.032
$W.m^{-2}$	Total Energy	Engineers, research	0.101	0.567	0.081

1 **$\mu mol \cdot m^{-2} s^{-1}$** PAR = 5 footcandles (visible) sunlight

Types of Sensors

Sensor	Spectrum	Units
Pyranometer	250nm - 2800nm	Wm^{-2}
Quantum	400nm -700nm	$\mu mol \cdot m^{-2}s^{-1}$ or Wm-2
Photometric	380nm - 730nm	ft-cd or lux
Spectroradiometer	Measure individual wavelengths	$\mu mol.m^{-2}s^{-1}nm^{-1}$ or $Wm^{-2}nm^{-1}$
Datalogger		$mol \cdot m^{-2}d^{-1}$

Datalogger

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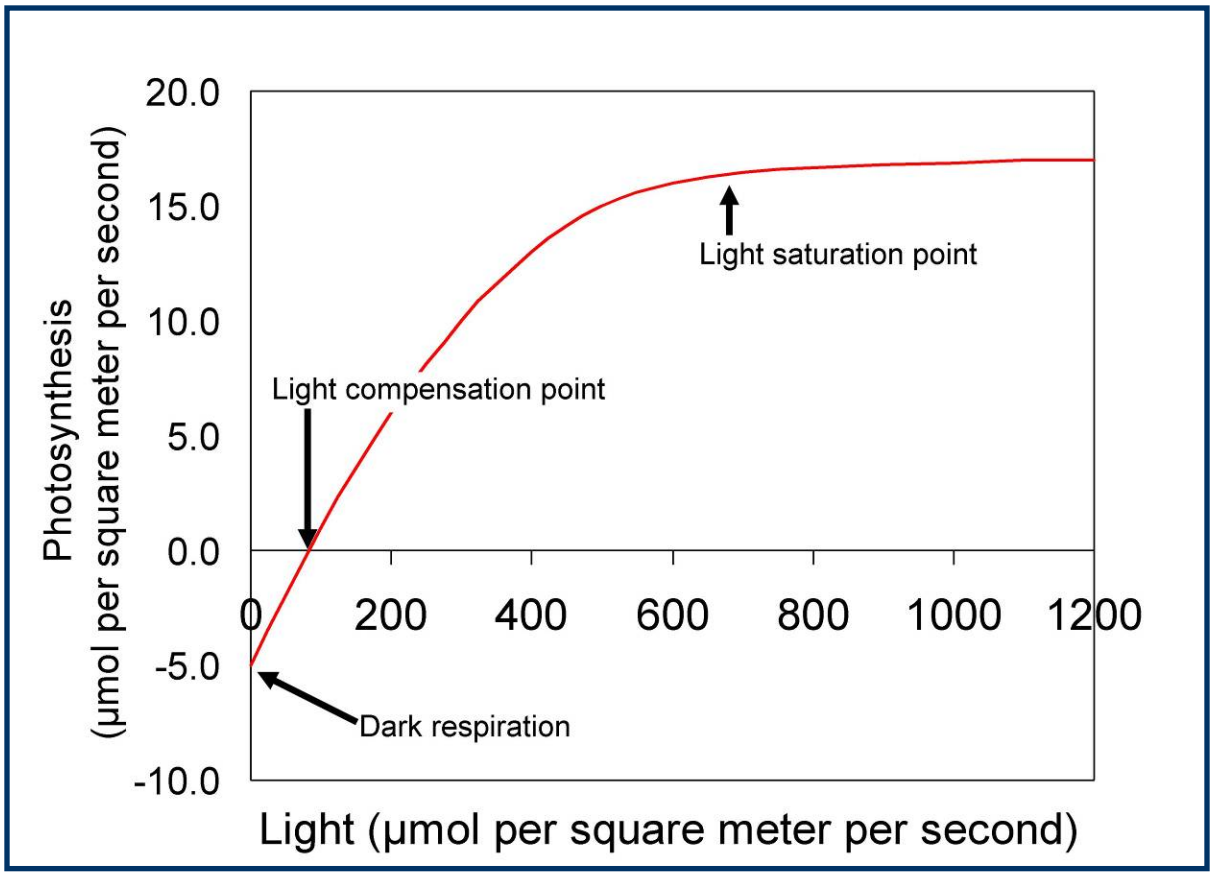
Effect of light on Photosynthesis



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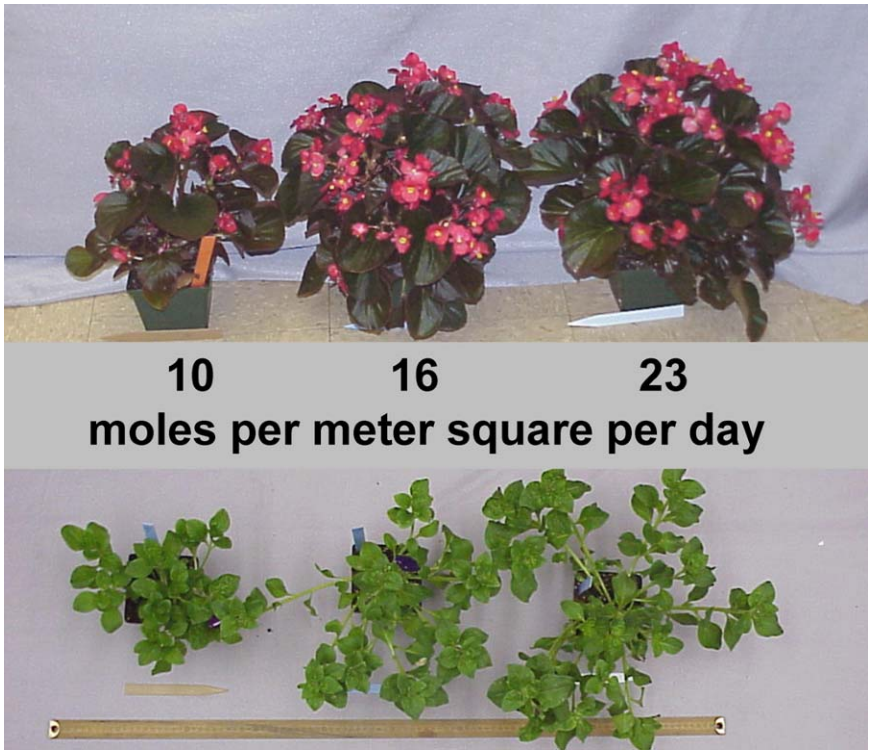
Effect of light on Photosynthesis



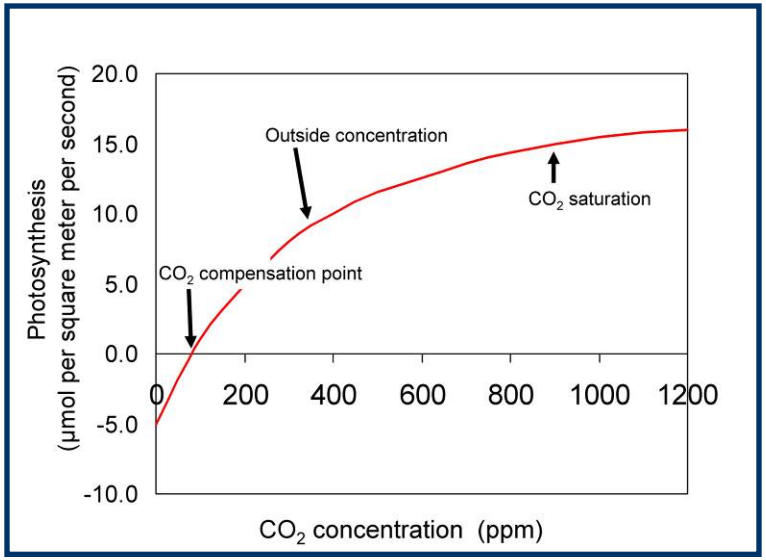
- Increasing light increases photosynthesis and thus growth.
- These begonias (top) and petunias (bottom) received three light levels.

(picture courtesy of Krishna Nemali)

CO_2 and Temperature Effects

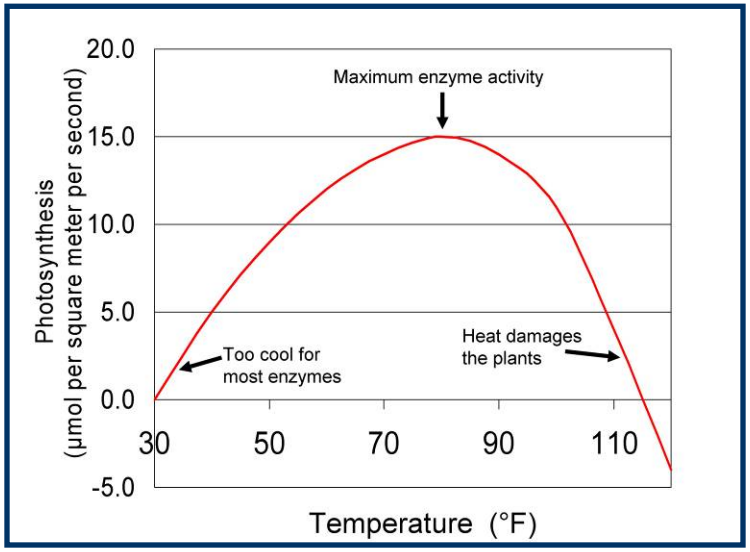
CO_2 Effects

- CO_2 outdoors is ≈370 ppm (parts per million).
- CO_2 inside a greenhouse can drop as low as 200 ppm with a lot of plant material, high light, and low ventilation.
- CO_2 can therefore be supplemented as a gas or through combustion.
- As CO_2 increases to ≈ 900 ppm, photosynthesis rate increases.



Temperature Effects

- Metabolic processes, including photosynthesis, increase to some optimum temperature.
- At low temperature, enzymes are not active.
- At high temperature, plant damage may occur.



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Environmental Factors

Nutrition

- Nutrient deficiencies, toxicities, or other plant stresses can reduce photosynthesis.
- For example, iron deficiency leads to chlorosis (lack of chlorophyll) which results in less photosynthesis.

Irrigation

- When plants have lack of water, they close their stomata (pores) to reduce water loss.
- Closing the stomata also cuts off air exchange and fresh supply of the carbon dioxide needed for photosynthesis.
- Lack of water also reduces cell elongation.
- That is why mild drought stress leads to more compact bedding plants.

Photoperiod and Flowering

Photoperiod is defined as number of hours of light in one day

Most floriculture crops have one of three flowering responses to photoperiod

- **Short-Day Plants** (SDP) only flower, or flower earlier, when the photoperiod is less than some duration.
- **Day-Neutral Plants** are relatively insensitive to photoperiod, and flower in approximately the same time under the short days of winter or the long days of summer.
- **Long-Day Plants** (LDP) only flower, or flower more rapidly, when exposed to a photoperiod of at least some critical duration.

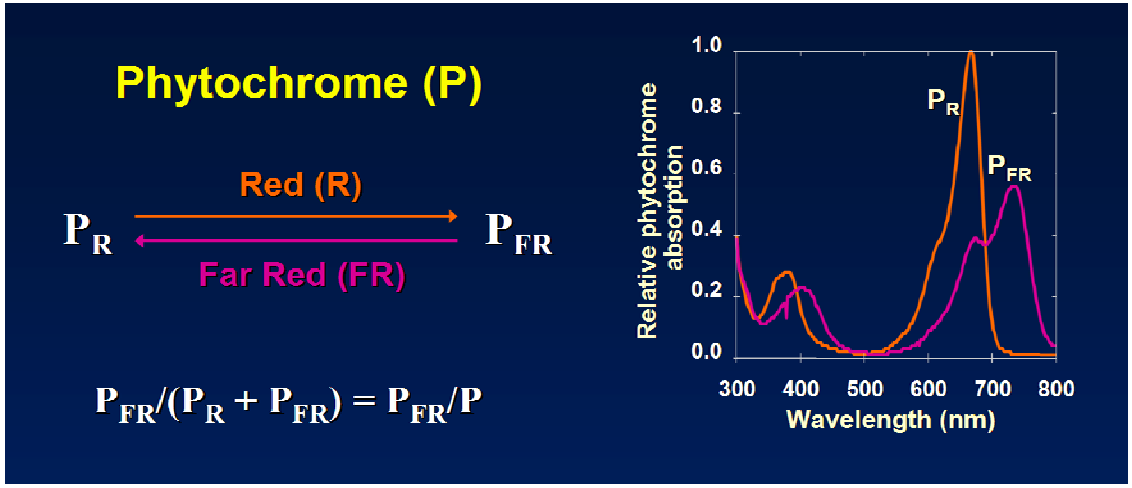
Qualitative or Obligate Response: Plants only flower under a particular photoperiod. For example, a plant that only flowers under short photoperiods is an obligate short-day plant.

Quantitative or Facultative Response: Plants flower under any photoperiod, but flower faster under some particular photoperiod. For example, a plant that flowers under all daylengths, but flowers earlier under long days, is a facultative long-day plant.

Phytochrome

- Leaves perceive and measure the duration of darkness and light through proteins found in all plants called phytochrome.

- Phytochrome exists in two inter-convertible forms. Under red light, phytochrome is primarily in the far-red absorbing form (P_{FR}). Under far-red light, phytochrome converts primarily to the red-absorbing form, P_R.



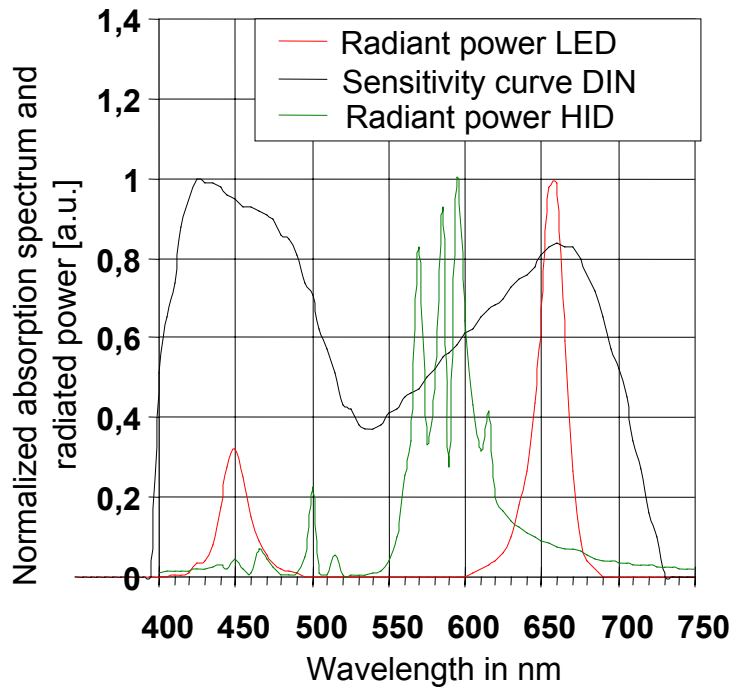
P_R peak absorption 660nm

P_{FR} peak absorption 730nm

LED vs HID

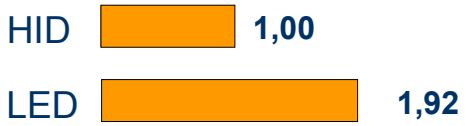
Luminous efficacy of HID lamps is overweighed

Emission (LED, HID) and sensitivity curve



- Red (~660mnm) & blue (~450 nm) are the most appropriate wavelengths from a technical point of view
- Much of the HID spectrum takes place in the yellow and orange range

→Theoretical calculation leads to a factor of 1.9 higher efficacy using LED*



→ High energy saving potential

→ Best ratio of blue and red needs to be determined under realistic conditions

* Impact of heat generated by HID not taken into consideration for comparison

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Important segments for horticultural LED lighting

Multilayer Cultivation

Interlighting

Ceiling lighting

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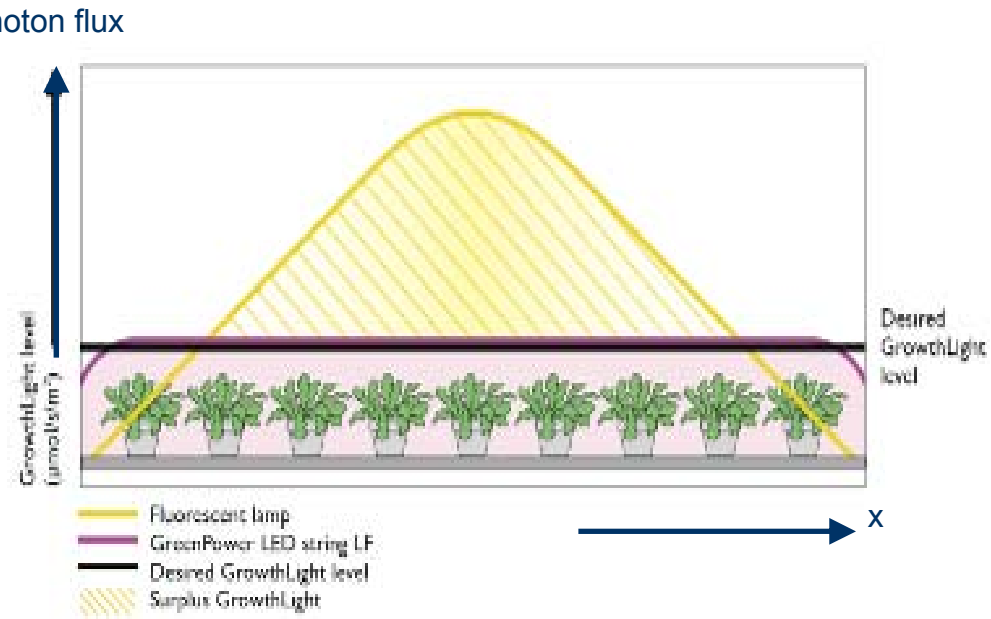
LED Advantage

Advantages with LEDs

- More Compact Luminare
- Homogenous Illumination.
- Optimized usage of light.



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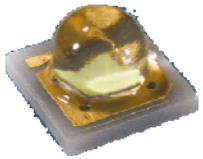
Key Data LH W5AM (660nm)

Golden DRAGON Plus and OSLON SSL LEDs with their efficiency of 37% are among the most efficient light sources on the market in the deep red range (660 nm wavelength).

- Golden Dragon Plus HyperRed
- Peak wavelength: 650-670 nm
- Typ. output power: ~320 mW @ 400 mA
- Performance increase planned shortly to 400mW

- Alternative package: Oslon SSL 80° (LH CP7P)
- → no secondary lens required
- → compact design
- → higher robustness



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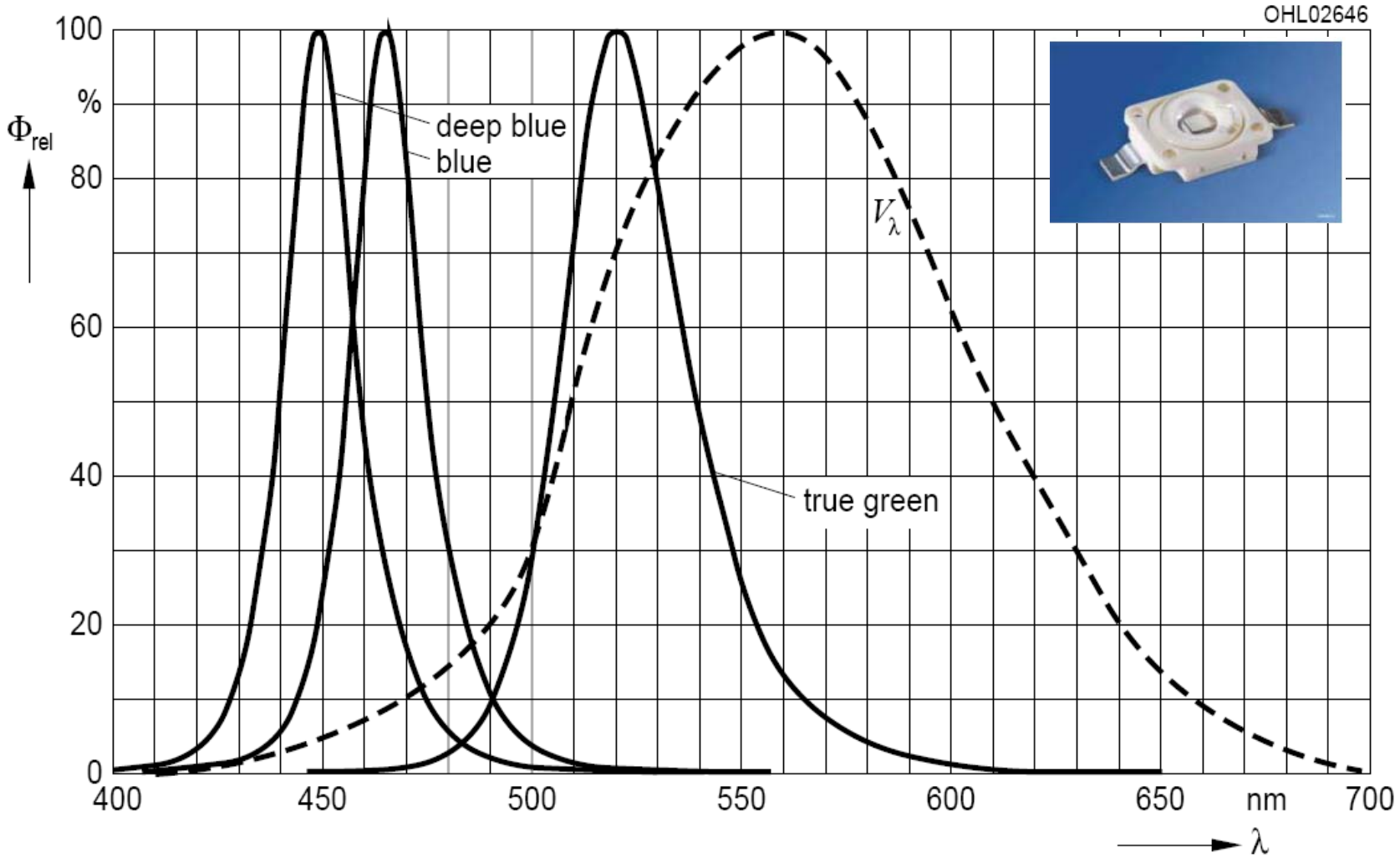
Spectrum LD W5AM (455nm)



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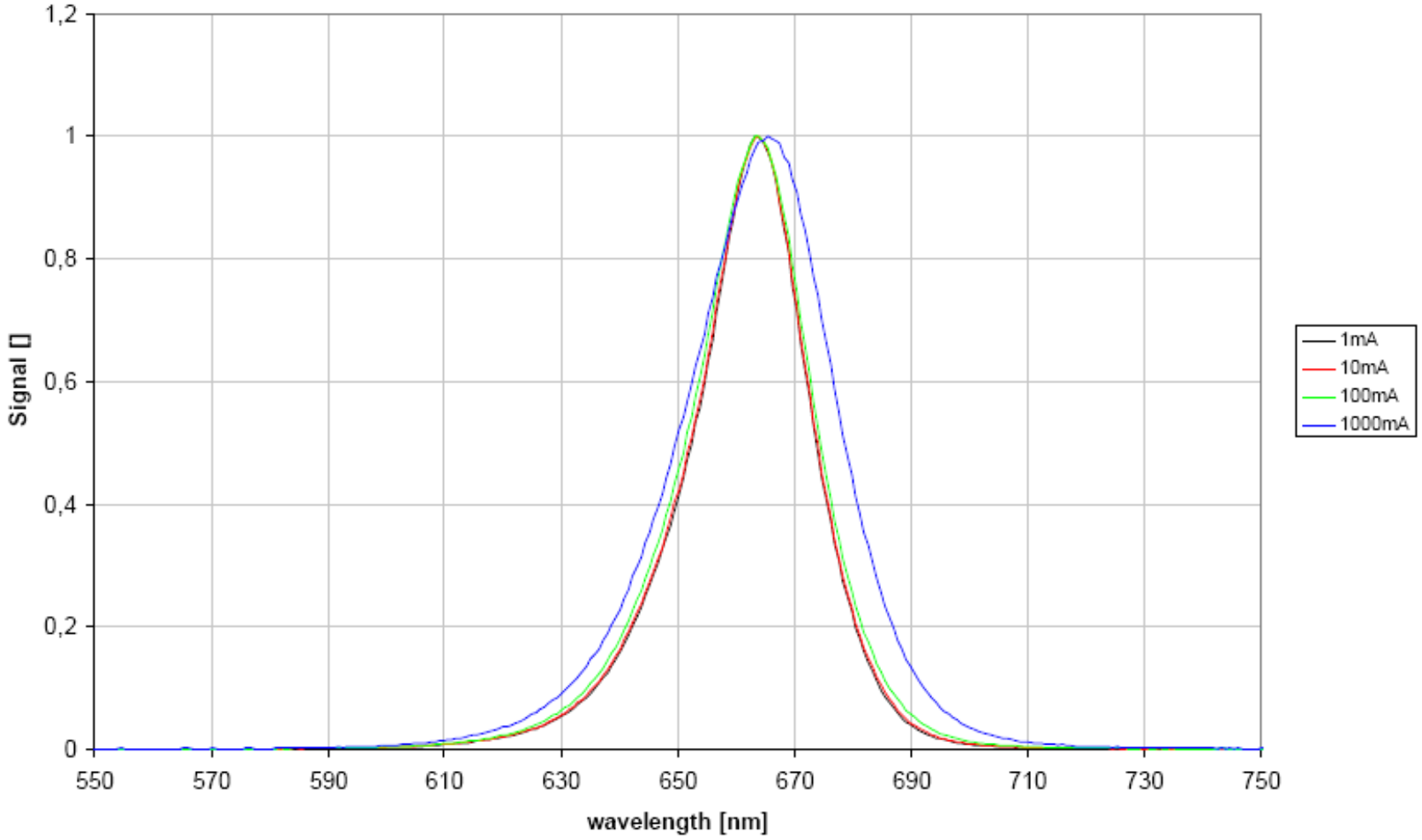

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First Pilot Project

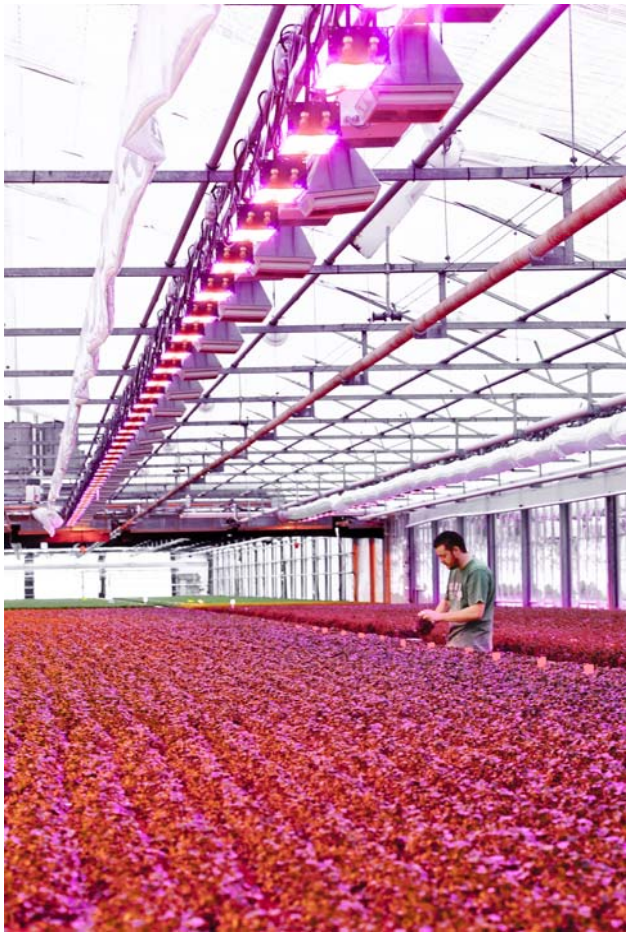
Cooperation with FioniaLighting A/S in Denmark.

Pilot project covered several thousand square meters of planting.

Around 50,000 Golden DRAGON Plus LEDs were used.

Results:

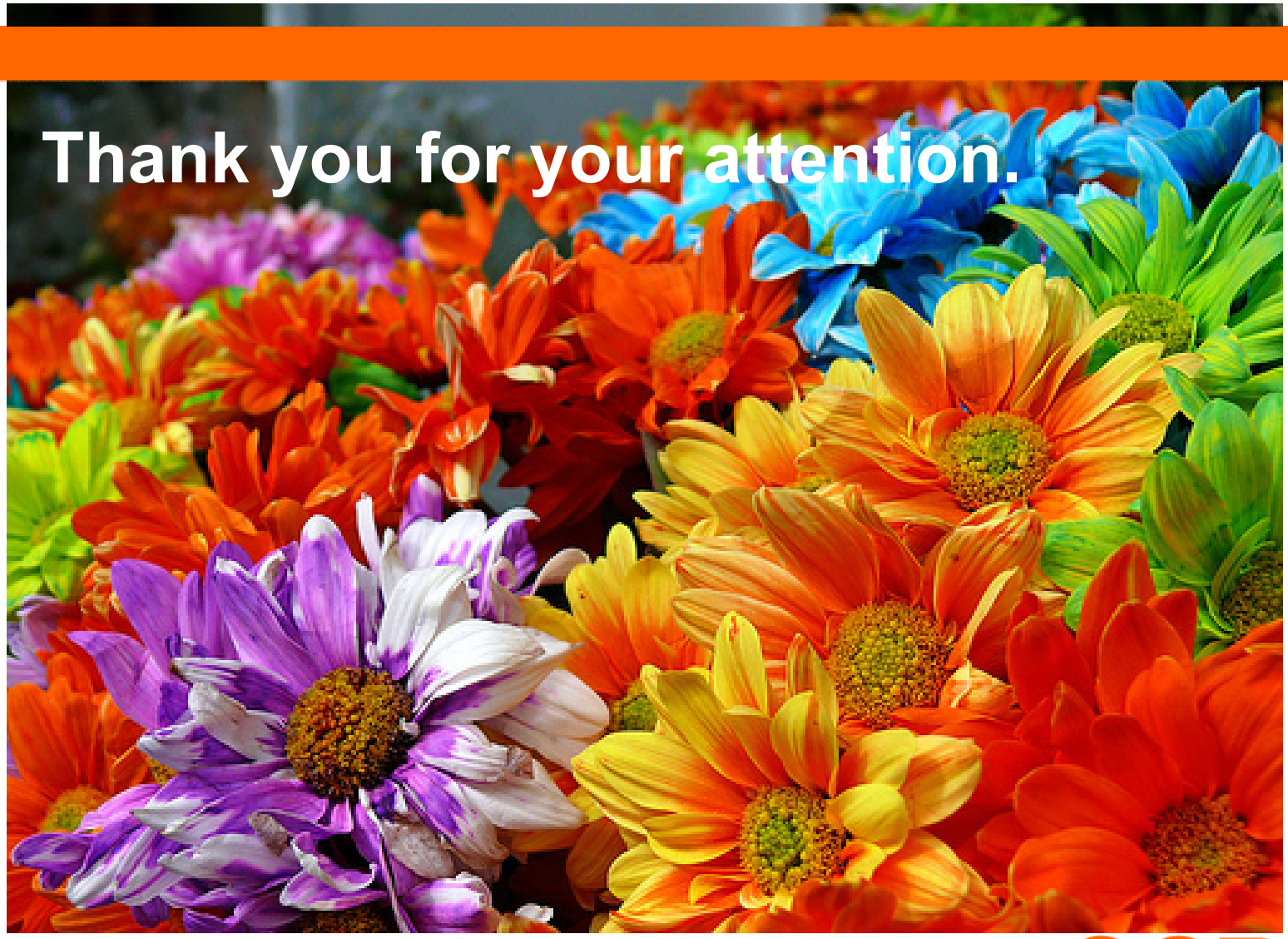
- 40% energy savings
- Reduction of chemicals such as growth regulators
- Flowers had more buds



Source : Fionia Lighting A/S

Summary

- Light is the key element that stimulates the process of photosynthesis in plants.
- Different wavelengths in light contribute to the varies stages in photosynthesis process.
- Most traditional lighting sources (incandescent, Fluorescent, high pressure sodium) produce a lot of “waste” light. By using LEDs, we can tailor growth lamps to the specific spectrum needs of plants
- Duration and intensity of light play a significant role in different plants for photosynthesis.



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