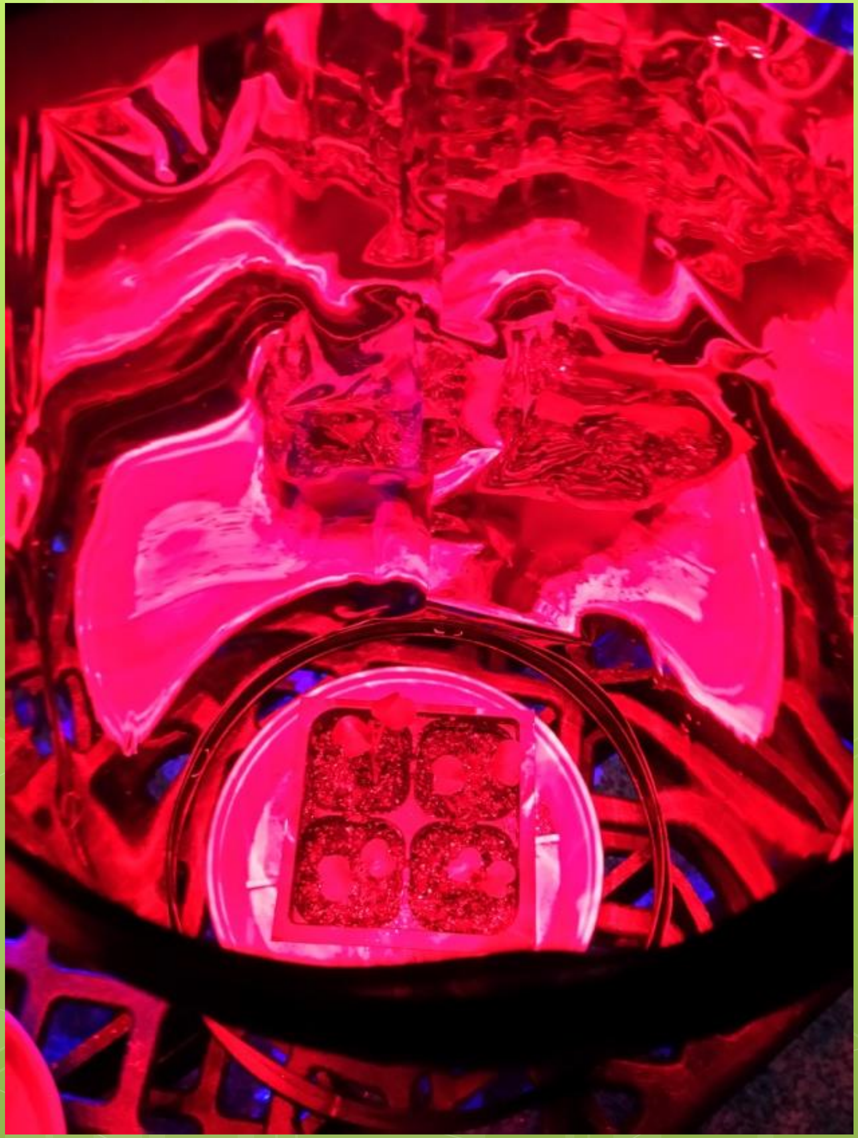


The Effect of Light and Temperature on Plant Growth

Björn Karlsson and
Jacob Schoville
UW-Biotron

The Biotron

- Completed in 1970, Greenhouse built 1996.
- Provides climate controlled research environments for animal, plant and materials research
- Offers control of temperature, light, humidity, CO_2, automatic watering

Why Temperature and Light?

- Greenhouses subject to climate: Latitude and time of year
- Expected and unexpected events, concisely described can help determine factors affecting reproducibility.
- May need to identify the reason for conflicting results.
- High costs of running experiments.

Temperature

- Measured with a simple thermometer, an infrared heat gun or via thermocouple
- Temperature regulation in a greenhouse is a constant battle throughout the year
- Heat and high light of summer can cause indoor temperatures to soar
- Cold and low light of winter can cause indoor temperatures to plummet

Sensor

- Sensor placement: Top of canopy
- SHADED

Media and Temperature

http://upload.wikimedia.org/wikipedia/commons/2/29/Exposed_mango_tree_roots.jpg

- Temperature can impact germination rates
- Vernalization
- Pot can absorb radiant energy→paint pot white.

Shoots, Leaves and Temperature

- Flowers, seeds and new growth most susceptible to temperature fluxuation
- Temperature directly affects transpiration
- To an extent, growth will increase with increased temperatures
- Plants can regulate their own temperature via stomata opening/closing to control transpiration
- Much heat comes from light; leaves may reorient to lessen exposed surface area

Control of Temperature

- **How can we?**
  - Shade cloth/whitewashing
  - Vents
  - Fans
  - Evaporative cooling

Control of Temperature

- **What are our limits?**
  - Supplemental lighting
  - Evaporative cooling limited by relative humidity
  - Nature always wins

Heat Stress

- **What happens when plants get too hot?**
  - Wilting
  - Browning
  - Increased growth rate problems
  - Weakened plants more susceptible to pests

Cold Stress

- **What happens when plants get too cold?**
  - Chilling vs. freezing
  - Hardening
  - Symptoms not always immediate
  - Cell damage -> wilting
  - Chloroplast damage -> bleaching

Avoiding Temperature Stress

- Grow plants in spring or fall to mitigate temperature extremes
- Grow plants that are naturally heat or cold tolerant
- Grow plants that have been selectively bred or genetically modified for temperature tolerance
- Use temperature to your advantage: conduct heat stress experiments in summer, cold stress in winter

Heat load on leaves

- 300 um thickness of water in a leaf would heat up to **100°C every minute** without heat loss.

- Heat loss occurs by:
    1. long wavelength radiation,
    2. sensible heatloss,
    3. evaporative (latent) heat loss.

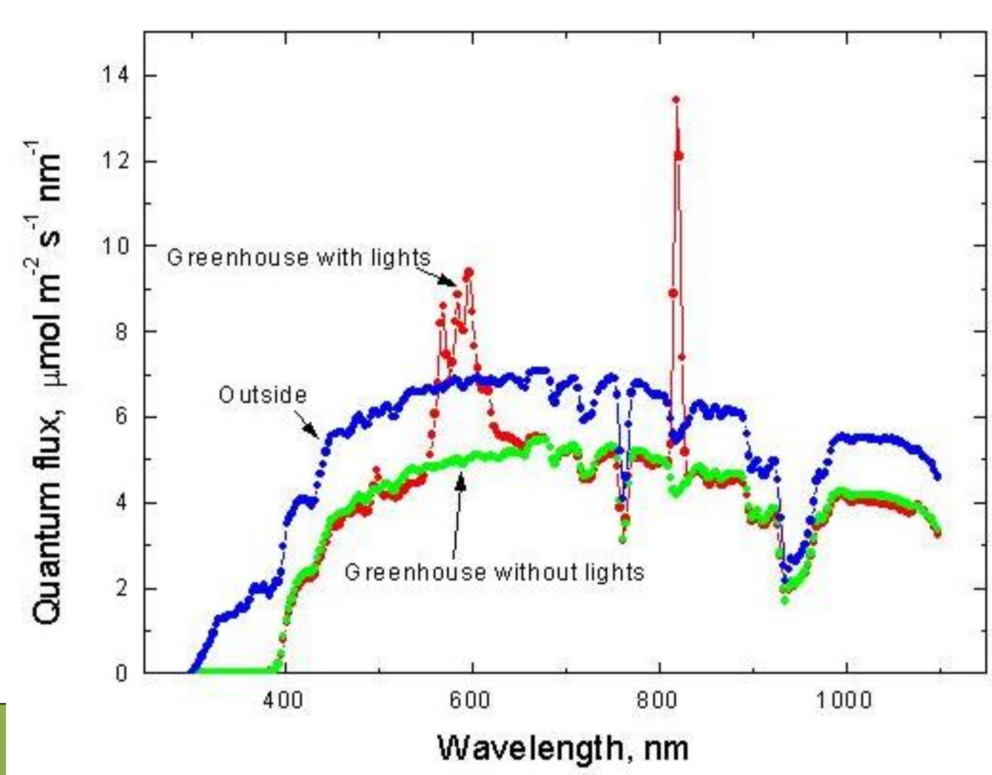
- AIR CIRCULATION AROUND LEAF removes by sensible heat

Plants and Light

- What is most important?
  - Light intensity: µmol photons/m^2/sec. Measured with a **quantum sensor**
  - Light quality: photosynthetically active radiation (PAR). Measured with a **spectrophotoradiometer**
  - Red/Far Red Ratio
  - ENERGY FROM ALL PAR wavelengths (400-700 nm) peaks of efficiency in blue (440 nm) and red (620 and 670 nm) regions.
  - Where to measure: Top of Canopy
  - When to measure: Start, end and every 2 weeks of experiment.

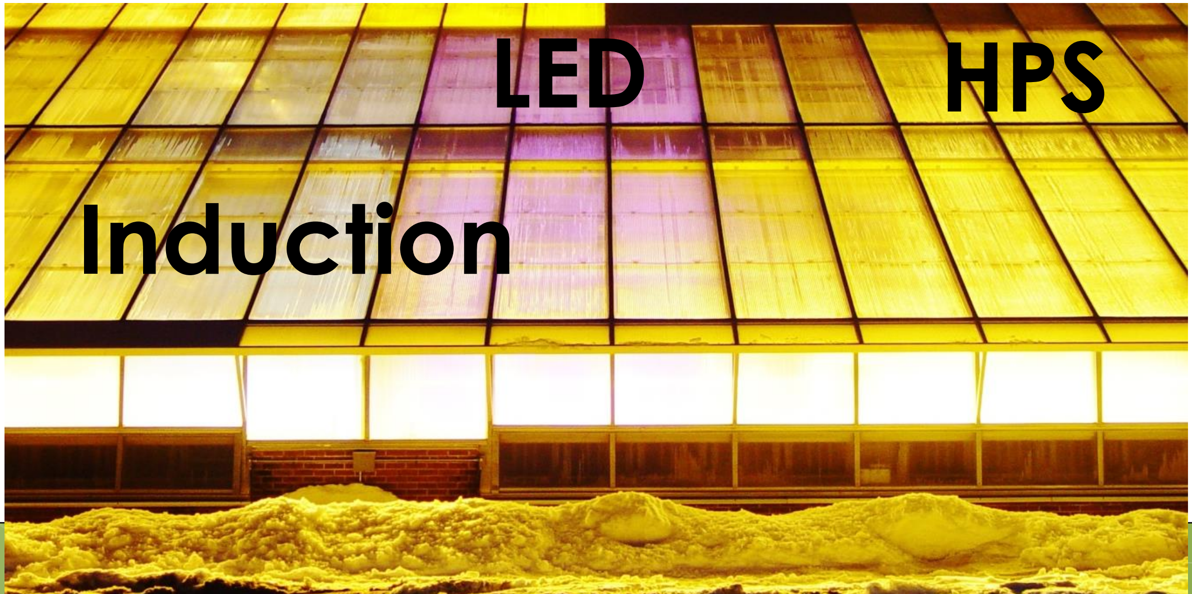
Greenhouse Lighting

- Difficult to control light levels due to other buildings, greenhouse structure (~30% lost), sunlight incidence (2000 umol)
- *Supplemental* lighting (100-500 umol)
- Edge effects



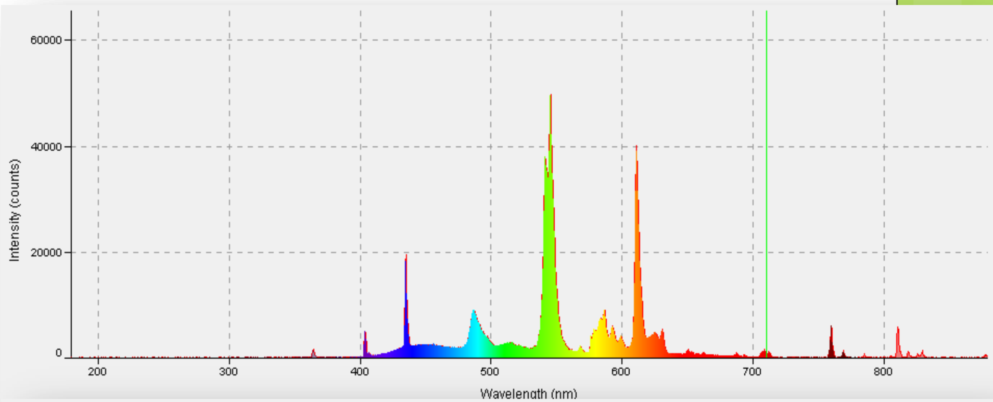
Supplemental Light Trial

- Jackson Hetue* , Jacob Schoville and Björn Karlsson *Rapid-cycling *Brassica* Collection
  - *Brassica rapa:* 3 AC rooms, 18°C, 16 hr Supplement
  - Comparision of 3 supplemental lighting sources:
  - Bumblebees pollinated Cross => F1 seed

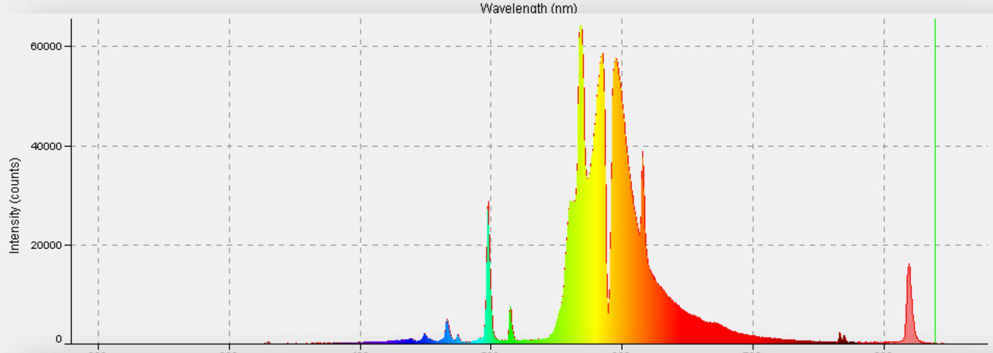


Supplemental Light Sources

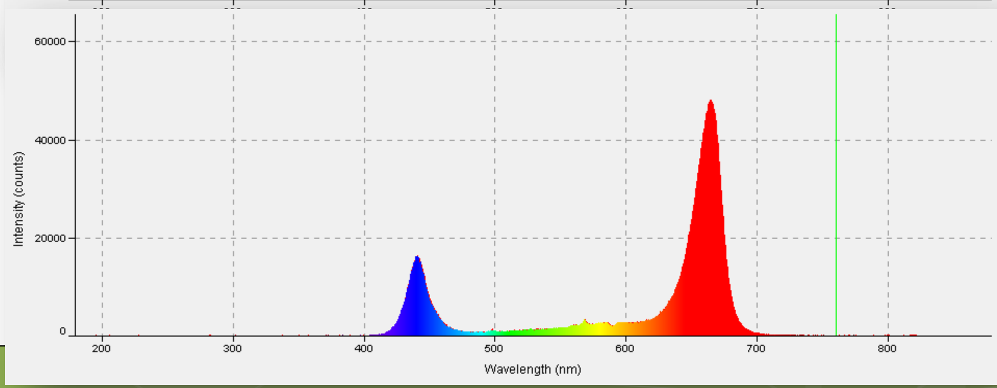
- Induction



- High Pressure Sodium



- LED



Supplemental Light Source Considerations

	Bulb Life **hours**	Irradiance **umol/m²/s**
HPS	20,000	**213**
LED	50,000	108
Induction	**100,000**	149

Seed Yield and Power Consumption

Round 1 - Summer (Jun-Aug) 2013	LED	HPS	IND
Relative yield (%)	93.5%	100.0%	76.6%
Power consumption (W)	1840	4600	2190
Electrical cost	$ 152.79	$ 362.88	$ 184.89

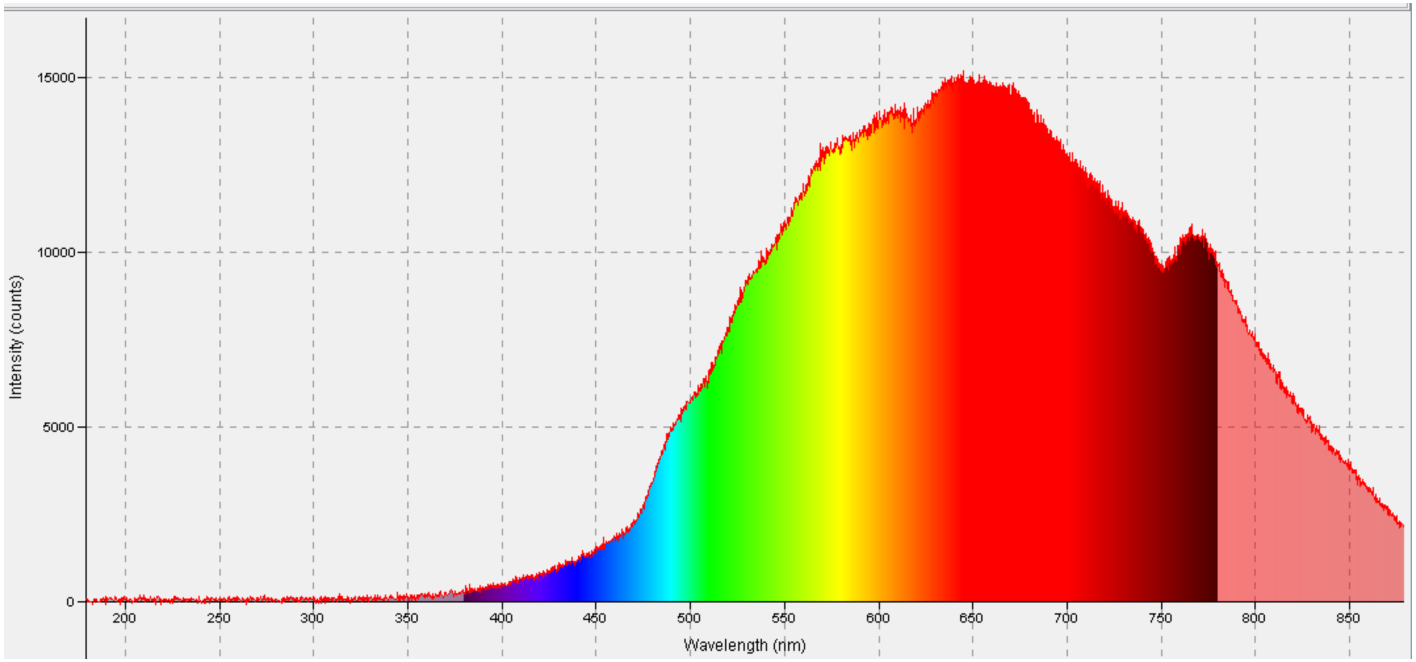
Round 2 - Fall (Oct-Dec) 2013	LED	HPS	IND
Relative yield (%)	100.0%	98.2%	90.2%
Power consumption (W)	1840	4600	2190
Electrical cost	$ 152.79	$ 318.32	$ 169.73

Color Scale			
	Best	Median	Worst

Light/Temperature Interaction

- **How do these interact?**
  - Lights can add a large heat load to the room that must be dissipated
  - Light bulb temperature important to achieve proper output
  - How does plant density affect temperature and light distribution?

Photomorphogenesis of **Wisconsin Fast Plant Seedlings**: Effect of monochromatic LED lights.

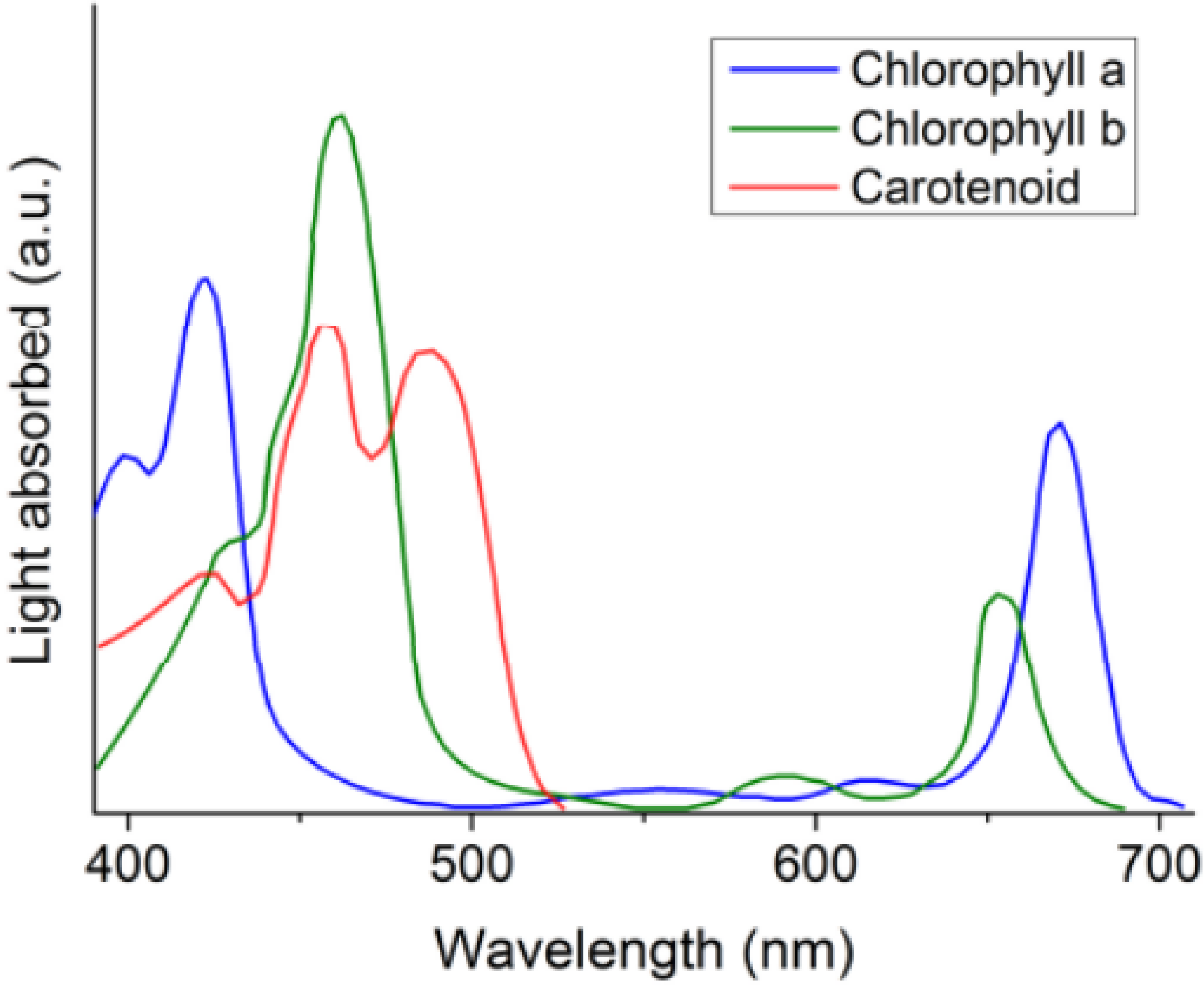


Eye Sensitivity Function and Luminous Efficacy

- Human eyes sensitive in range 390 to 720 nm.
- Green LEDs are the brightest to our eyes: We are most sensitive at 555 nm.
- Lumen = green light at 550 nm with a power of 1 watt has a luminous flux of 683 lumen.

Demonstration

How is plant growth affected by different colors of light?



The Set-Up

Seed: Wisconsin Fast Plants **Rapid Cycling *Brassica Rapa***

Standard 1-033 lot: 1-2311 95% germ rate

Controlled Environment Room: Biotron

22 °C, **60%** Relative Humidity, **24** hour lights

Light Treatments: **2 replications per light source**; **~ 150 µmol/m^{-2}/s^{-1}**

Compact Fluorescent (white light): 9 watt

Dark Grown: ~ 1 µmol/m^{-2}/s^{-1}

Yellow LED: 3 watt, Feit Electric

Orange LED: 3 ", " "

Green LED: 3 ", " "

Blue LED: Variable wattage, Lumigrow Strip Light

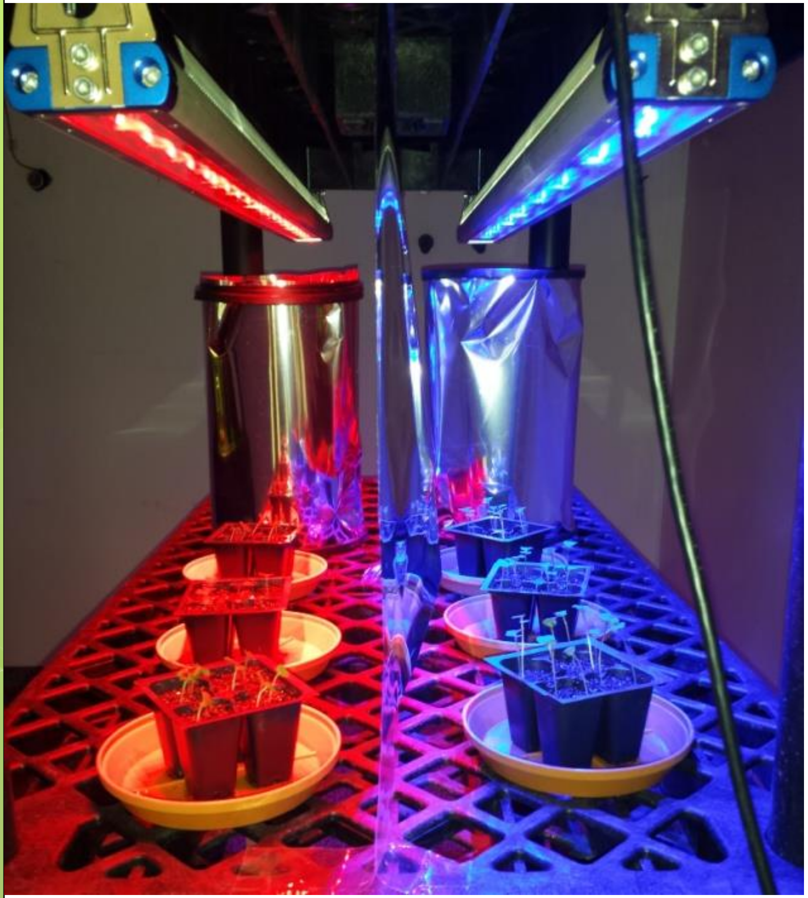
Red LED: Variable wattage, Lumigrow Strip Light

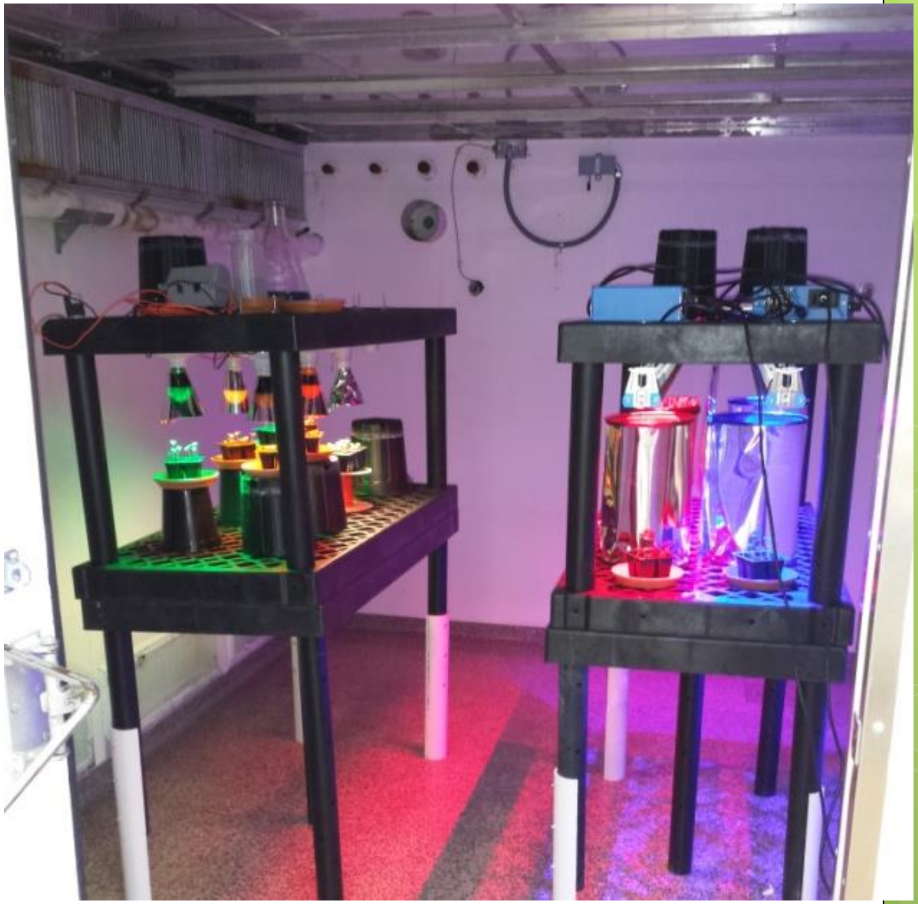
Different Treatments: **Red** and **Blue** LED plants:

Light Tube concentrated light => **~ 150 µmol/m^{-2}/s^{-1}**

Without Light Tube => **~ 50 µmol/m^{-2}/s^{-1}**

The Room





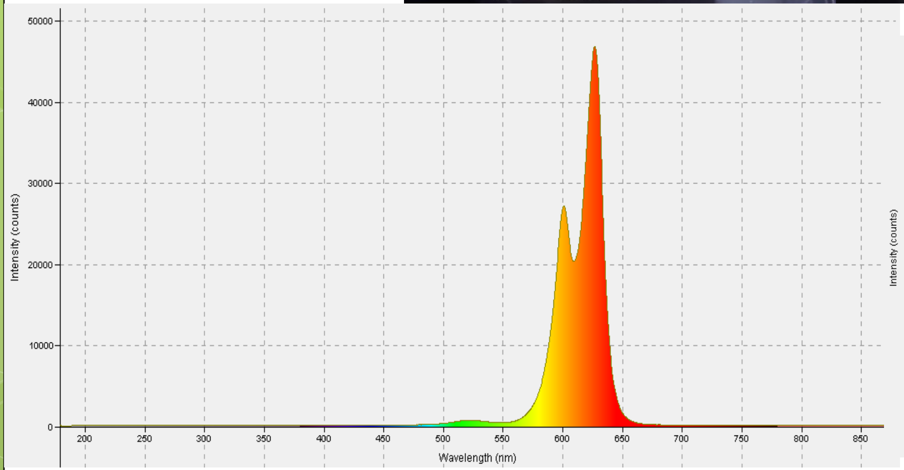
Results

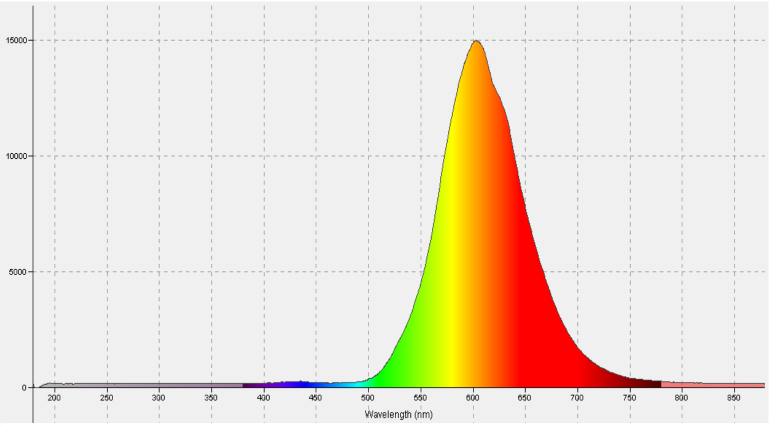

Yellow LED
3 watt ~150 umol/m2/s
Orange LED
3 watt ~150 umol/m2/s
Feit Electric
Red LED
Mylar Tube ~150 umol/m2/s
Lumigrow
Green LED
3 watt ~150 umol/m2/s
Blue LED
Mylar Tube ~150 umol/m2/s
Lumigrow
Compact Fluorescent
9 watt ~150 umol/m2/sec


Green LED
3 watt ~150 umol/m2/s


~Dark Grown
1 umol/m2/sec

Results

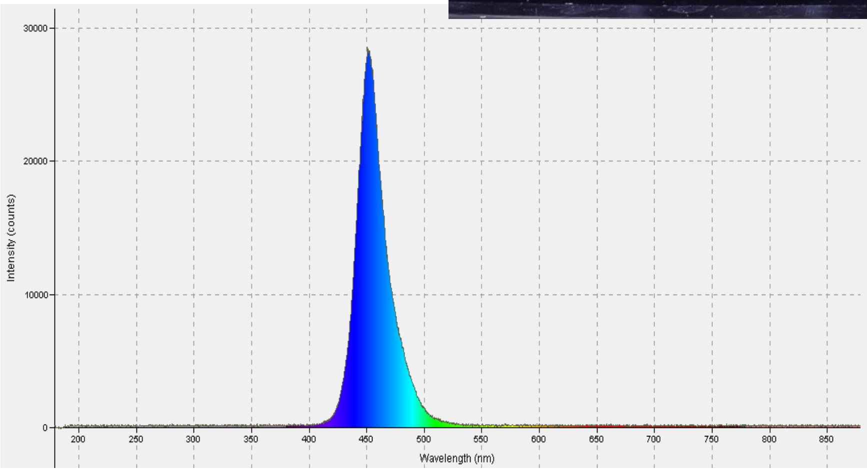




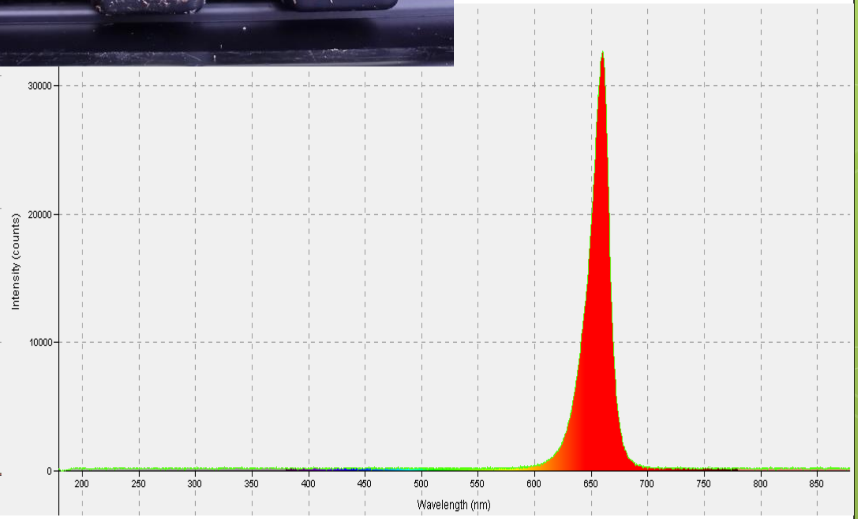
Orange: 590 – 620 nm

Yellow: 570 – 590 nm

Results



Blue: 450 – 495 nm



Red: 620 – 750 nm

Blue light responses

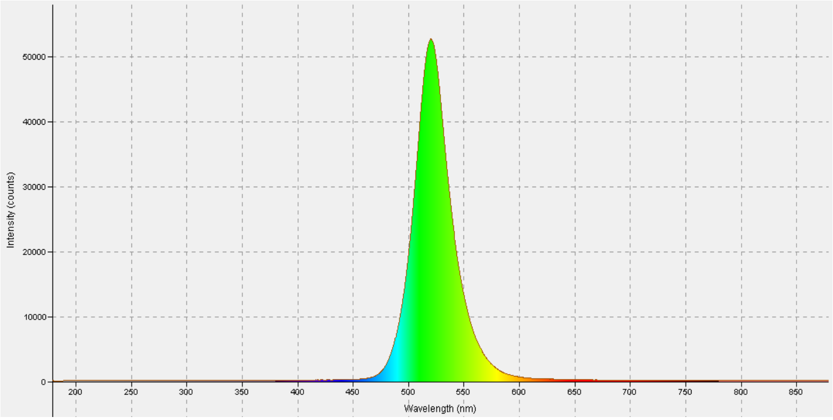
- Most important pigments absorb red and blue light.
- Bending of shoots toward light (phototropism), solar tracking, chloroplast movement within photosynthetic cells.
- Blue-Light perception in coleoptile tip: Peaks at 425, 45 and 472 nm.

Phytochrome: red-light

- Mustard (Sinapis) promotes formation of leaf primordia; development of primary leaves.

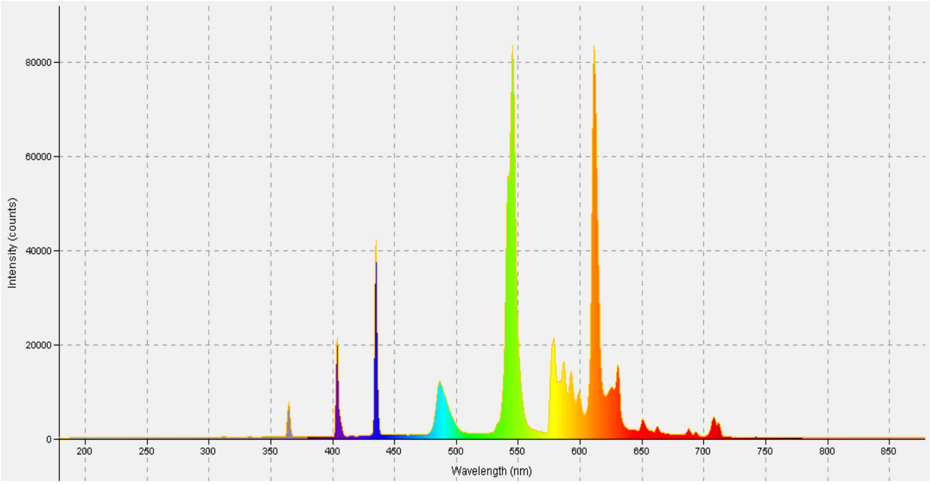
- Pea (Pisum) it inhibits elongation.

Results



Green: 495 – 570 nm

Results



Compact Fluor: 450 – 495 nm

LED lighting

- Environmentally benign
- Semiconductor approaches to solid-state light will give highest luminous efficacy.

Semiconductors as converters

- Most common white LED is basically a blue LED with a yellow phosphor. Some of the light from the blue semiconductor exits as blue and some is absorbed by the phosphor and distributed as yellow phosphorescence.

Trichromatic LED white light

- Created 6500 Kelvin, which is natural daylight.
- Example of luminous efficiency:
- Incandescent light source = about 16-17 lumens per watt
- LEDs are technically capable of 300 lumens per watt.
- High color rendering.

Thank You!

Jacob will now lead you in a challenge!