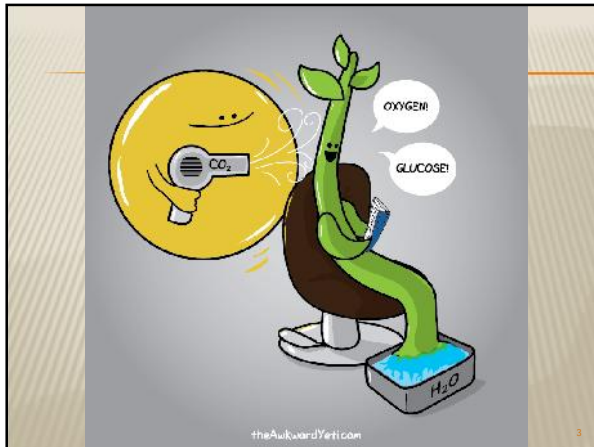


WHAT IS LIGHT?

- ✗ Electromagnetic radiation
 - + Energy emitted by a light source
 - + Measured in watts
- ✗ Visible light
 - + Wavelengths of 380-750nm

The diagram shows electromagnetic radiation with frequency scales in Hz (0.0001, 0.01, 10, 100, 1000, 10,000, 100,000, 1,000,000) and wavelength scales in m (1000, 100, 10, 1, 0.1, 0.01, 0.001). A visible light spectrum is shown below with wavelengths from 400 nm to 700 nm.



PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR)

Spectral range of solar light from 400 to 700 nm most useful to terrestrial plants in the process of photosynthesis

The graph shows absorbance peaks for chlorophyll a (around 680 nm) and chlorophyll b (around 470 nm). The chemical structure of chlorophyll is shown to the right.

Chlorophyll

- most abundant plant pigment
- most efficient in presence of red and blue light

(noon on a sunny, summer day ~10,000 fc) (office ~ 40fc)

METHODS OF MEASUREMENT

Illumination intensity –illumination received; units are **lux (lumens/m²)**, or **footcandles (lumens/ft²)**

- ✗ Most common method
- ✗ Use it because it's convenient and meters are inexpensive
- ✗ A light meter measures intensity according to **human eye sensitivity**, primarily yellow and green light (450-650nm)

(noon on a sunny, summer day ~ 2000 μmol/m²/s¹) (office ~ 20 μmol/m²/s¹)

METHODS OF MEASUREMENT

Irradiance –energy received; units are **watts per square meter (watts/m²)** or **(μmol/m²/s¹)**

- ✗ A quantum meter measures **PAR**: the most photosynthetically active radiation 400-700nm
- ✗ A more accurate measure of light energy as used by plants

“Lumens are for looking at, watts are energy.”

ATTRIBUTES OF LIGHT AFFECTING PLANT GROWTH IN THE GREENHOUSE

Light Quantity (Irradiance)

- + Affects photosynthesis and growth

Light Quality (Spectrum)

- + Wavelength provides developmental triggers

Light Duration (Photoperiod)

- + Length of exposure provides developmental triggers

All attributes interact in their effects.

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LIGHT QUANTITY

Irradiance – the amount of light energy received by the plant ($\mu\text{mol}/\text{m}^2/\text{s}$)

- ✗ Affects rate of photosynthesis and plant growth.
- ✗ Plant growth response is species and cultivar specific.

The daily light integral (DLI) is a measure of light accumulation in greenhouse crops.

Goal in greenhouse production is to optimize light levels in order to maximize photosynthesis.

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LIGHT QUANTITY

Optimal Quantity (DLI)

Plant	Irradiance* $\mu\text{mol}/\text{m}^2/\text{s}$	DLI* $\text{mol}/\text{m}^2/\text{d}$
African violet	150 – 250	5-10
Foliage plants	150 – 250	7-15
Chrysanthemum	250 – 450	10-20
Easter lily	250 – 450	10-20
Geranium	250 – 450	10-20
Poinsettia	250 – 450	10-20
Lettuce	250 – 450	12-15
Carnation	250 – 450	12-20
Cucumber	250 – 450	20-30
Strawberry	250 – 450	20-30
Roses	450 – 750	25-30
Tomato	450 – 750	25-30



Saintpaulia ionantha
African Violet



Lycopersicon
Tomato

*Adapted from:
Plant Growth Chamber Handbook, Iowa Agriculture and Home Economics Experiment Station
Special Report No. 99.
Light Management in Greenhouses, I. Daily Light Integral: A useful tool for the U.S. Floriculture Industry, James E. Faust

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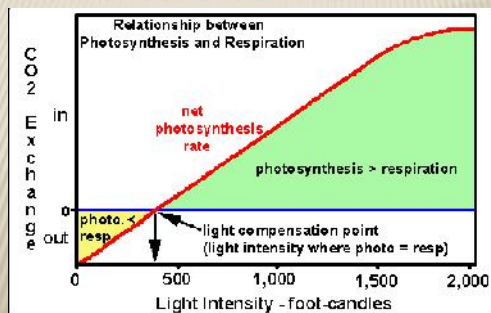
LIGHT QUANTITY

Light compensation point

- ✗ Lowest level of light to sustain a plant
- ✗ When the amount of CO_2 being incorporated into sugars during photosynthesis equals amount released when sugars are burned during respiration

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LIGHT COMPENSATION POINT



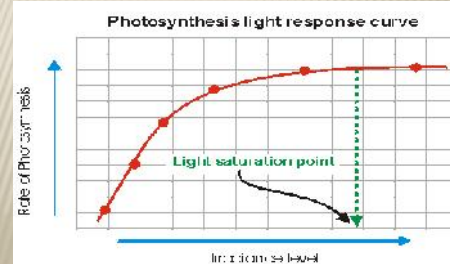
From: TAMU General Horticulture: Properties of Light

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LIGHT QUANTITY

Light saturation point

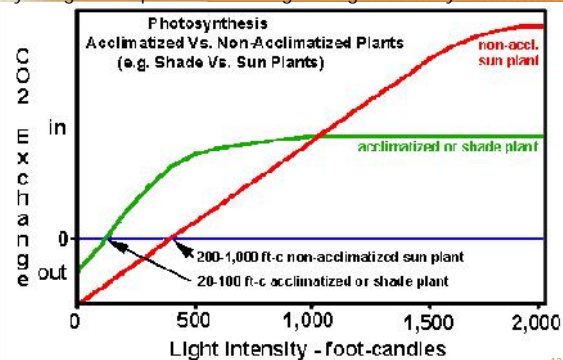
- ✗ Point at which light is no longer the factor limiting the overall rate of photosynthesis



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LIGHT ACCLIMATIZATION

Physiological adaptations to changes in light intensity



From: TAMU General Horticulture - Properties of Light

LIGHT QUANTITY: GROWTH RESPONSE

Too High

- ✗ Photo oxidation
 - + Bleaching
- ✗ Sunburn
- ✗ Excessive transpiration
 - + Water loss
- ✗ Leaf Drop

Too Low

- ✗ Flower bud abortion
- ✗ Reduced growth rates
- ✗ Elongation
 - + Stretched plants with spindly stems
- ✗ Increased disease
- ✗ Leaf drop

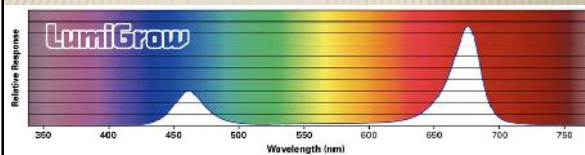
Just Right

- ✗ Thick, strong stems
- ✗ Healthy foliage
- ✗ Flowers (in season)

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LIGHT QUALITY

Wavelength provides a developmental trigger for a **photomorphogenic** response.



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LIGHT QUALITY

Developmental Cues

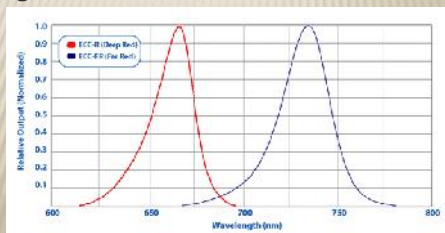
- ✗ Blue light
 - + leaf development
 - + height control
- ✗ Red light
 - + germination
 - + Phytochromes and flowering
 - ✗ Red absorbing 650 - 670 nm
 - ✗ Far-red absorbing 705 - 740 nm



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PHOTOPERIOD

- ✗ Flowering response controlled by the ratio of red and far-red absorbing pigments (phytochromes).
- ✗ This ratio is affected by the duration of the dark period in a given 24 hours.



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PHOTOPERIOD

Short-day plant (long night) - requires a night longer than a critical dark period. Usually 12 hours or more of continuous darkness to flower

- ✗ chrysanthemum, kalanchoe, azalea, begonia

Long day plant (short night) - requires a night shorter than a critical dark period usually 12 hours or less of continuous darkness to flower.

- ✗ petunia, viola, fuschia, lobelia

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LIGHT QUANTITY CONTROL

Reasons to increase light levels

- ✘ Increase photosynthesis rates (and growth)
- ✘ Hasten flowering (facultative irradiation response)

Ways to increase light levels

- ✘ Incandescent fixtures
- ✘ Fluorescent Fixtures
- ✘ HID Fixtures
- ✘ LED Fixtures




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WAYS TO INCREASE LIGHT QUANTITY

Incandescent lamps

- ✘ Cost
 - + Fixture <\$10
 - + Lamp <\$1
- ✘ Efficiency 7%
- ✘ Spectrum
 - + radiation is mostly red and infrared (heat)
- ✘ Life 750 to 1000 hours





Only recommended use is for photoperiod control

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WAYS TO INCREASE LIGHT QUANTITY

Fluorescent lamps

- ✘ Cost
 - + Fixture \$20-200
 - + Lamp \$10-15
- ✘ Efficiency 20%
- ✘ Spectrum high in blues and greens, may lack reds
- ✘ Life 12,000 hours
- ✘ Require ballasts
- ✘ Used in growth chambers, seed germination, indoor farms and by hobbyists






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WAYS TO INCREASE LIGHT QUANTITY

High Intensity Discharge (HID)

- ✘ Cost
 - + Fixture - \$250-400
 - + Lamp - \$25-40
- ✘ Efficiency 20-30%
- ✘ Life 24,000 hours
- ✘ Spectrum: broad
 - + Metal Halide (MH) similar to daylight
 - + High pressure sodium (HPS) High in yellow to red, lack blues
- ✘ Type of reflector affects spacing
- ✘ Most commonly used supplemental light





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WAYS TO INCREASE LIGHT QUANTITY

Reflectors

- ✘ Focus light output
 - + Shape
 - + Direct
 - + Distribute
- ✘ Output should match bench or bed width
- ✘ Light plan designed to maximize efficiency
- ✘ Typical styles
 - Parabolic (dish or mirror)
 - Ellipsoidal (cone)



Source: P.L. Light Systems


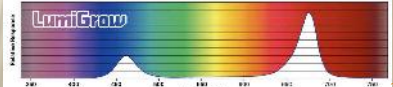



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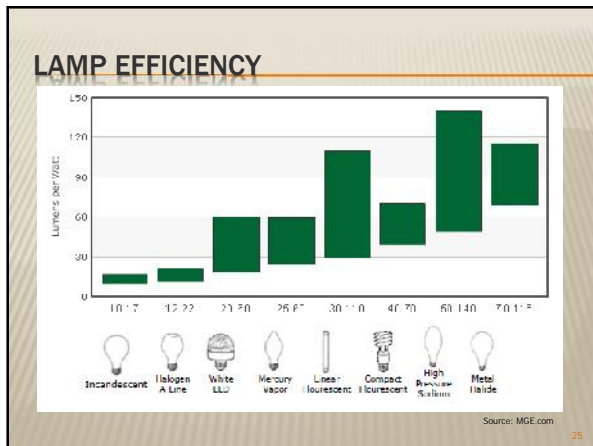
WAYS TO INCREASE LIGHT QUANTITY

Light Emitting Diode (LED) Fixtures

- ✘ Cost
 - + Fixture - \$700-1,500
 - + Lamp - not replaceable
- ✘ Efficiency 20-30%
- ✘ Spectrum
 - + Variable 20-40nm spectra
- ✘ Life 50,000 hours
- ✘ Use in crop production is promising, but still under study

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MANAGING THE DAILY LIGHT INTEGRAL (DLI)

- ✗ How much supplemental light are my fixtures providing for my crop?
- ✗ How long should I run my lights to achieve the recommended DLI for my crop?

<http://extension.unh.edu/Agric/AGGHFL/dlicalc/index.cfm>

SCENARIOS: GERMINATION

- ✗ Response in red wavelengths
- ✗ Typical fixtures
 - + Fluorescent
 - + HID
 - ✗ Metal Halide
 - + LED
 - ✗ Red/blue mix

SCENARIOS: GREENHOUSE PRODUCTION

- ✗ Filling in when natural light is low
- ✗ Typical fixtures
 - + HID
 - + LED

SCENARIOS: INDOOR PRODUCTION

- ✗ Balanced spectrum
- ✗ Typical fixtures
 - + Fluorescent
 - + HID
 - + LED
 - ✗ Mixed Red and Blue

SCENARIOS: HOUSEPLANTS

- ✗ Incandescent
 - + Reds for flowering
- ✗ Fluorescent
 - + Blues for foliage color and compact growth
- ✗ LED
 - + Red/Blue mix
 - + Still an expensive option

SCENARIOS: CONTROL OF FLOWERING

- ✘ Red wavelengths
- ✘ Typical fixtures
 - + Incandescent
 - ✘ Recommended use
 - + HID
 - ✘ High Pressure Sodium
 - + LED
 - ✘ Red



SCENARIOS: VEGETATIVE GROWTH

- ✘ Stock plants
 - ✘ Early stage short-day flowering plants
- Flowering in long-day crops
- ✘ Insurance Lighting in Easter Lily

