2002

Three Challenges of Controlled Environment Research

USU - Crop Physiology Lab

Three Challenges of Controlled Environment Research

- 1st Grow healthy plants
- 2nd Grow plants that represent field grown plants
- 3rd Grow stressed plants

Cardinal parameters

Shoot environment	Root environment
humidity	H_2O
temperature	temperature
CO_2	O_2
radiation	nutrients
wind	

Four components of radiation in controlled environments

- Intensity
- Duration
- Quality
- Timing

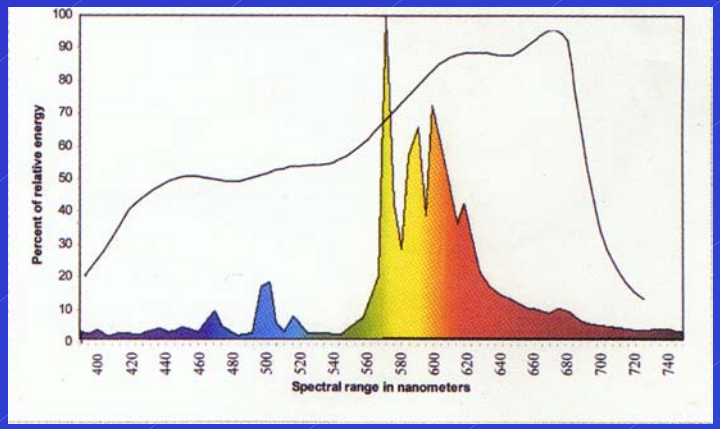
Myth Number One

- Broad spectrum light is better than narrow spectrum light

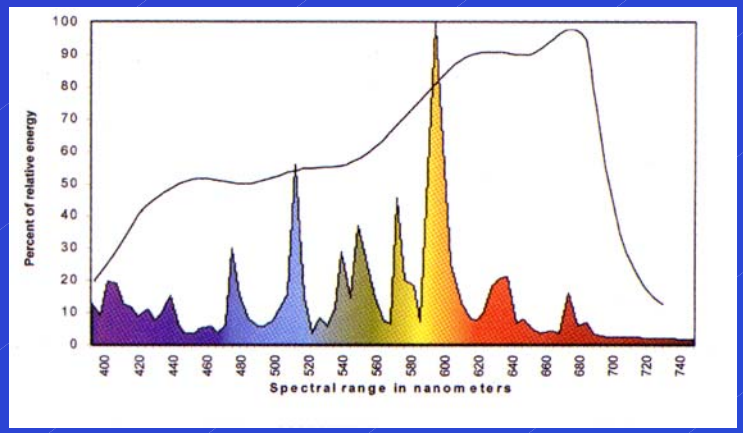
Example: Gro-Lux fluorescent lamps
vs. Cool White fluorescent lamps

Myth Number One

- Broad spectrum light is better than narrow spectrum light

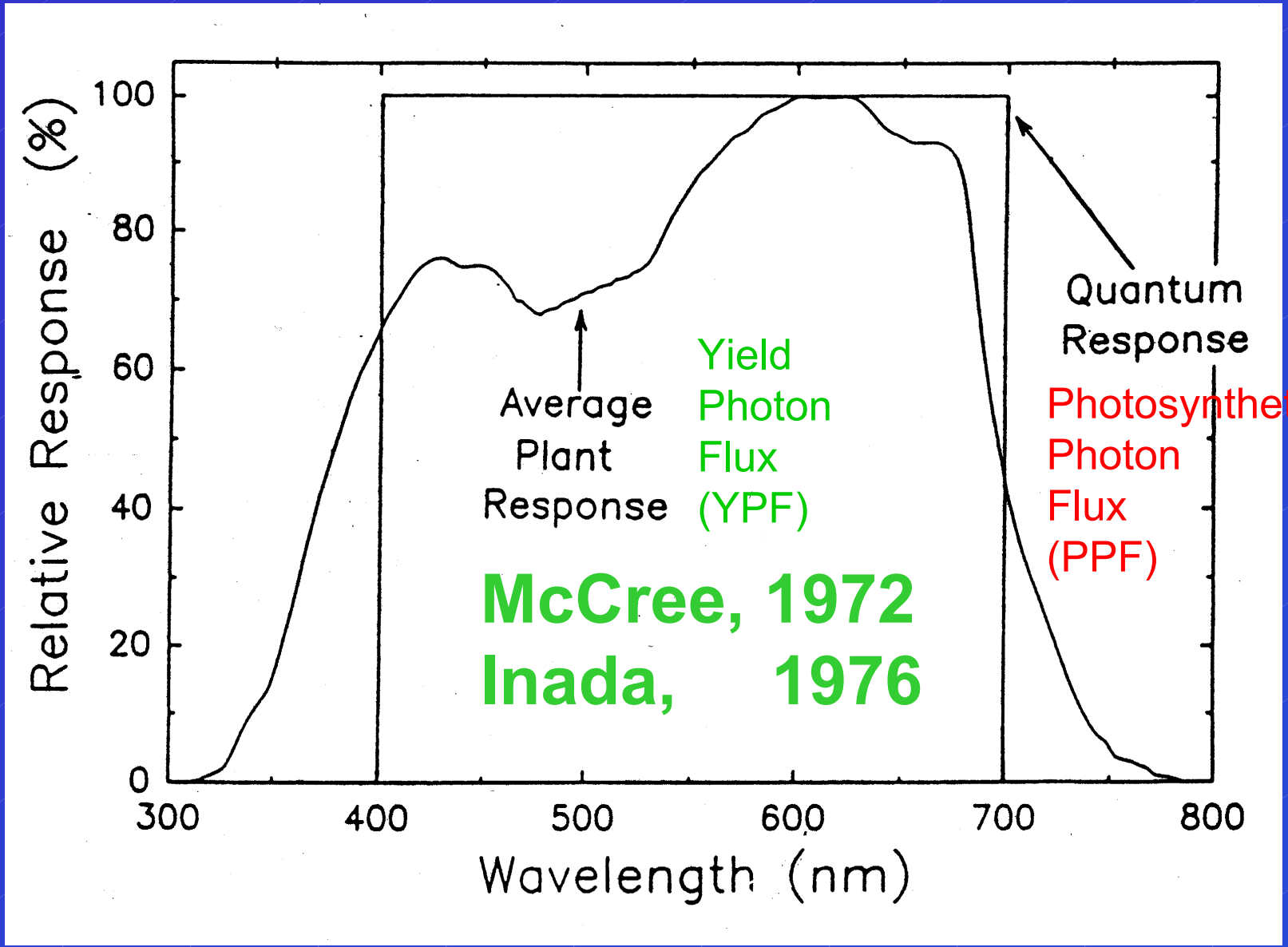


High pressure Sodium (HPS)

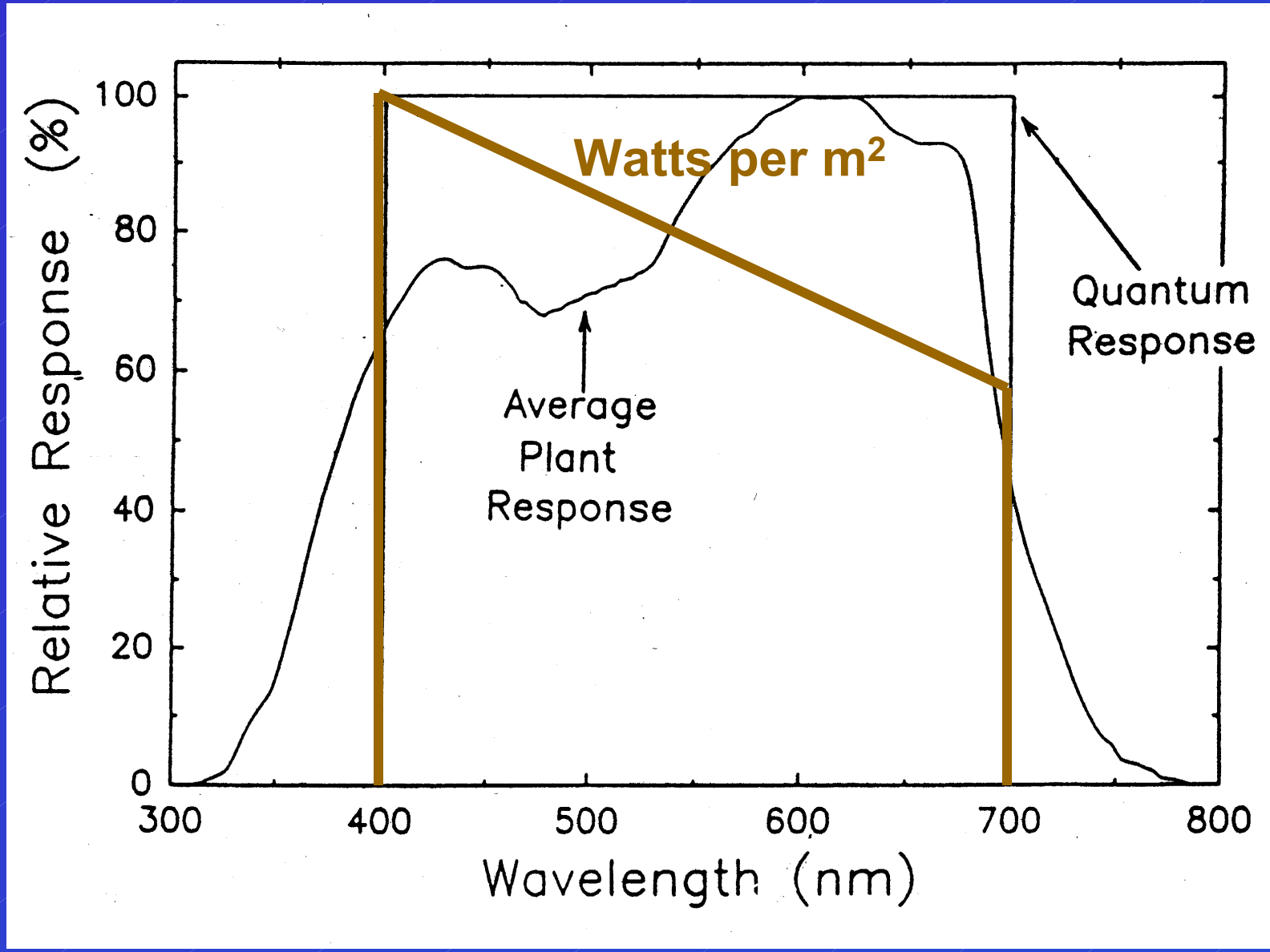


Metal Halide (MH)

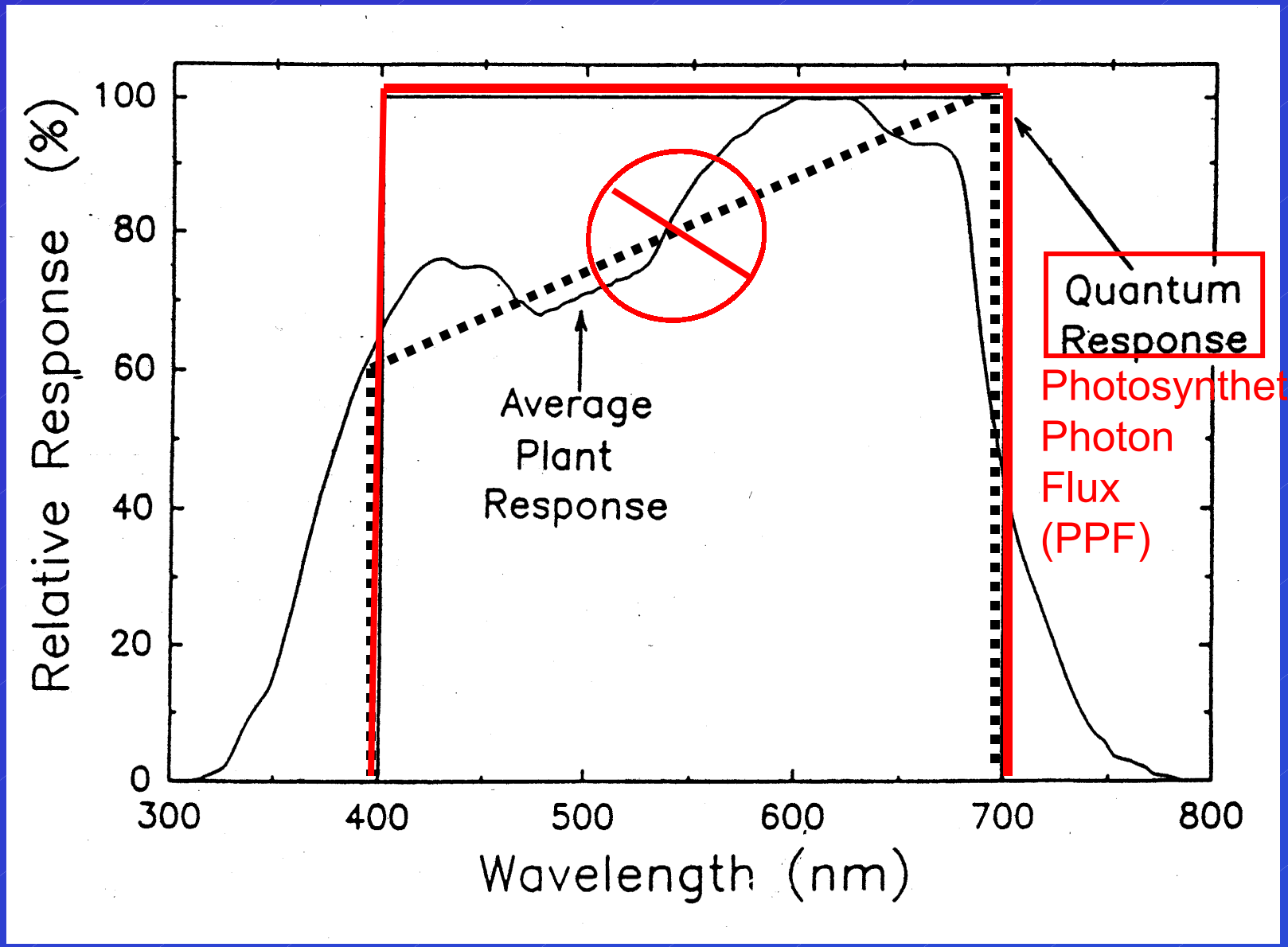
A review of spectral quality and photosynthesis



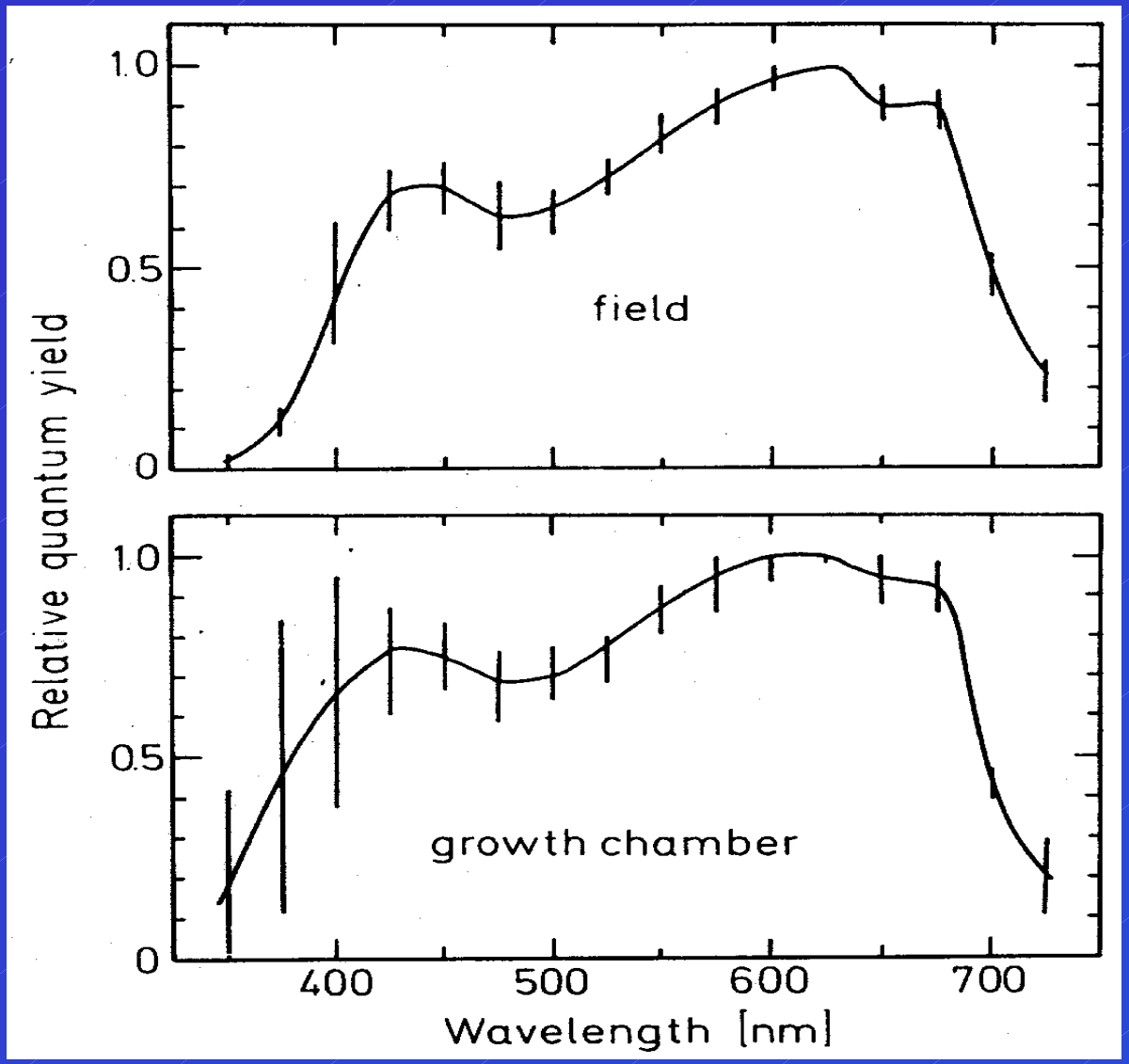
A review of spectral quality and photosynthesis

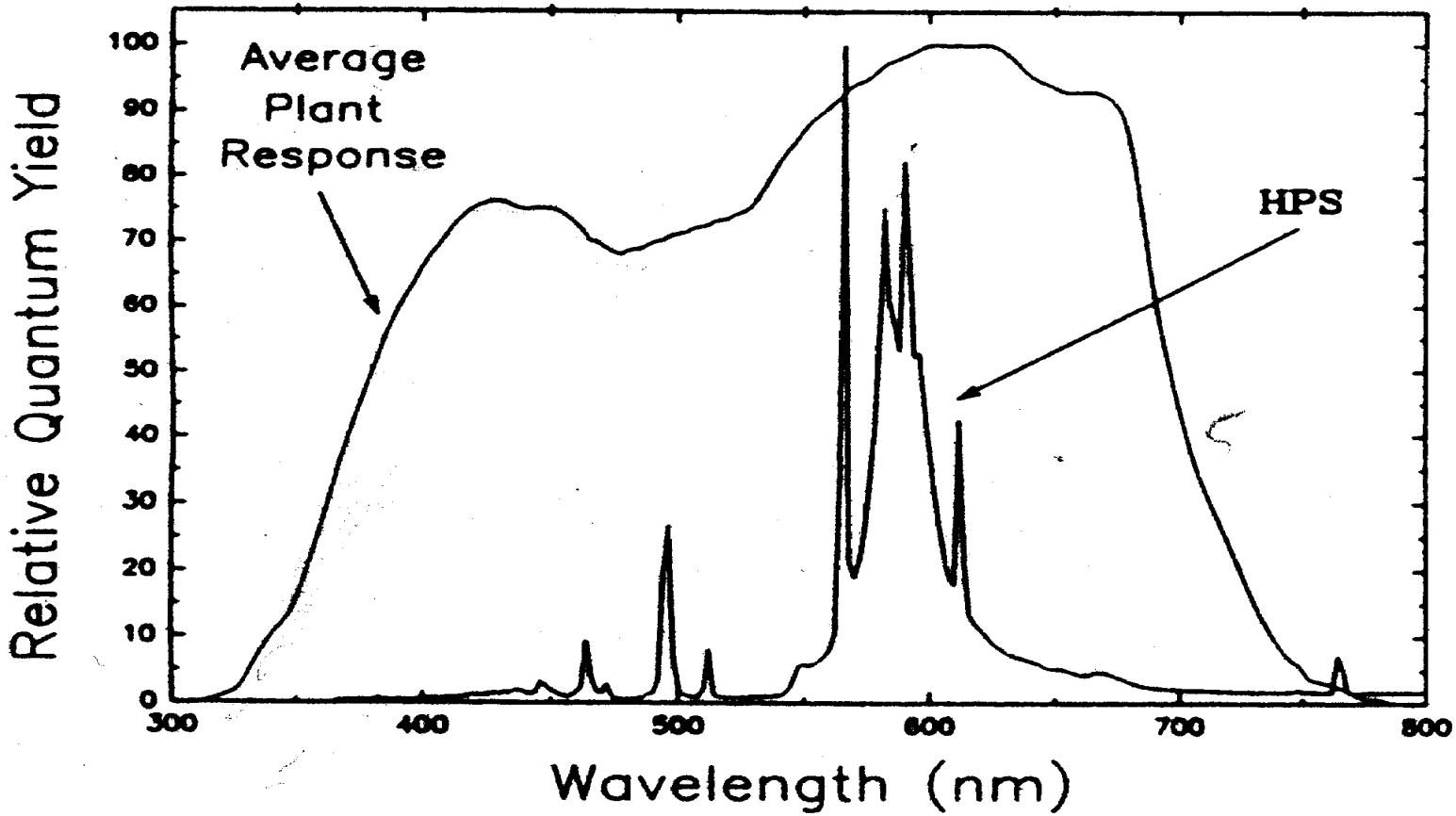


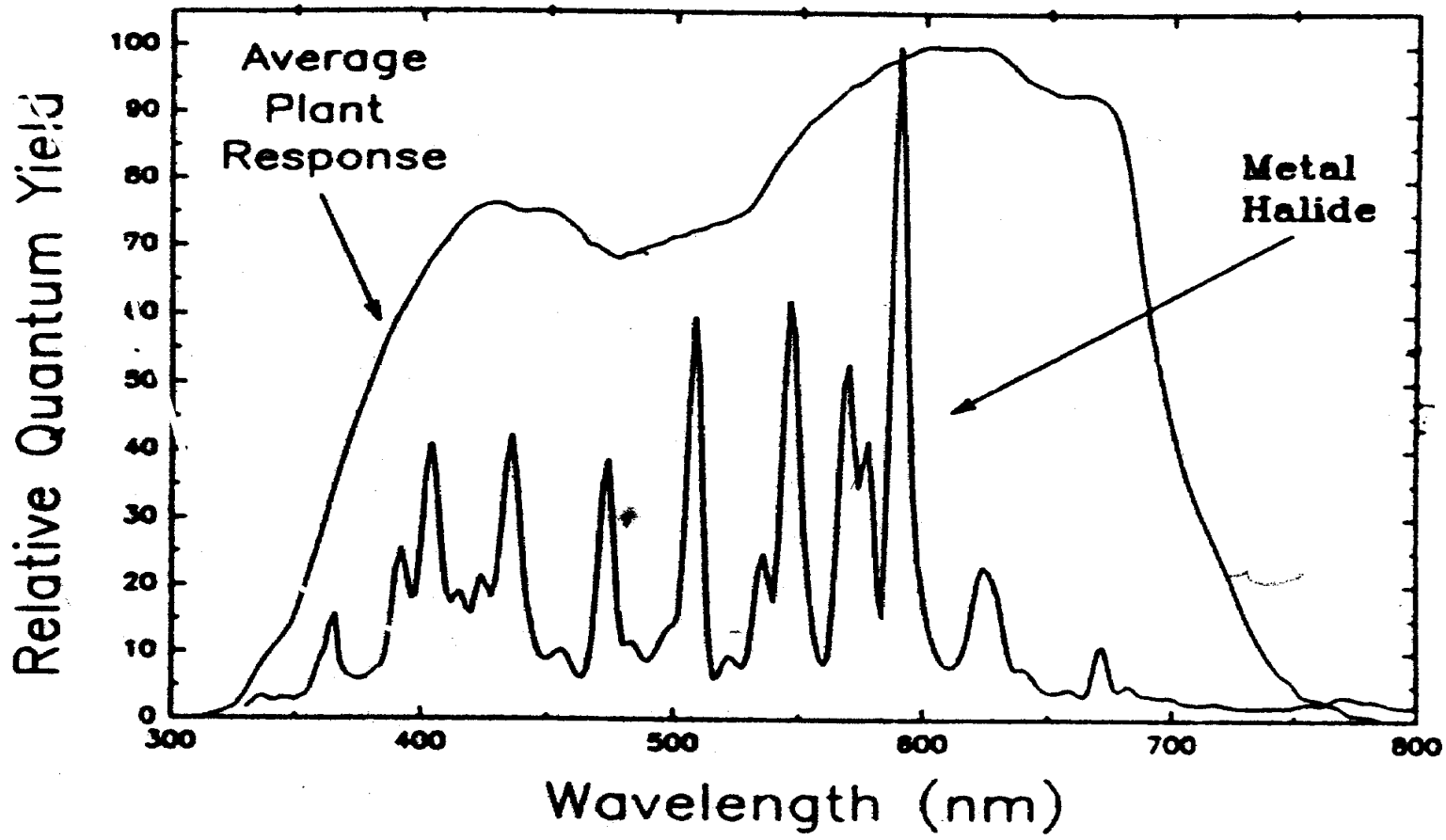
A review of spectral quality and photosynthesis



Photosynthetic spectral efficiency is remarkably similar among species

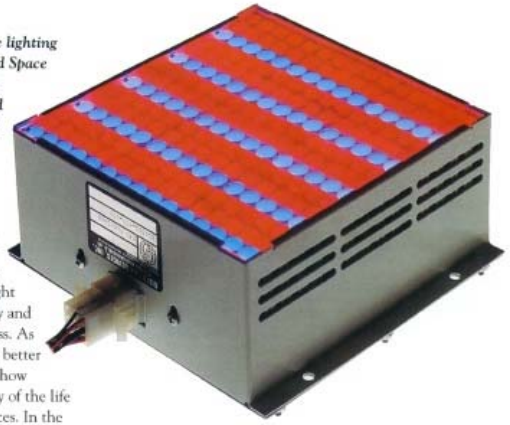



Relative Quantum Yield
100
90
80
70
60
50
40
30
20
10
0
Average
Plant
Response
HPS
300
400
500
600
700
800
Wavelength (nm)

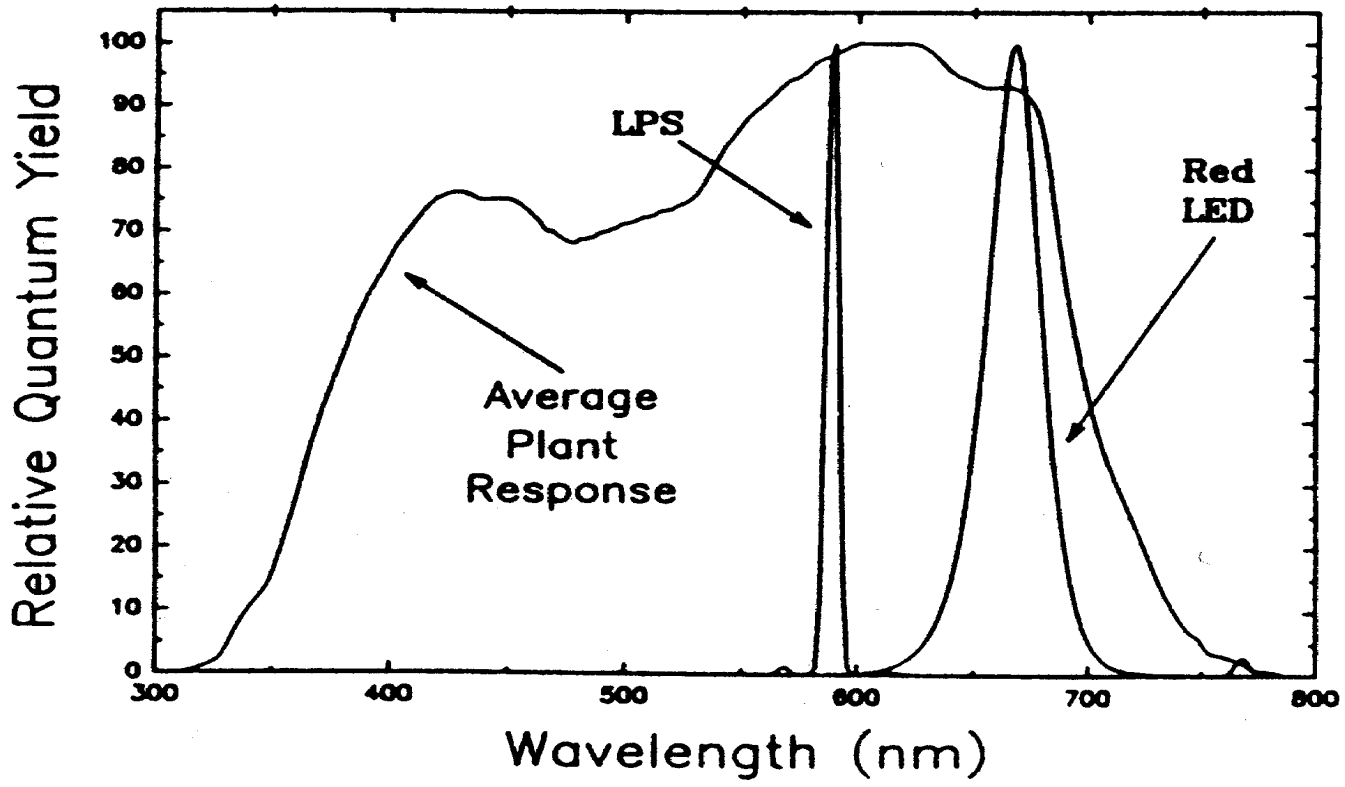

Relative Quantum Yield
100
90
80
70
60
50
40
30
20
10
0
Average
Plant
Response
Metal
Halide
300
400
500
600
700
800
Wavelength (nm)

SNAP-LITE™

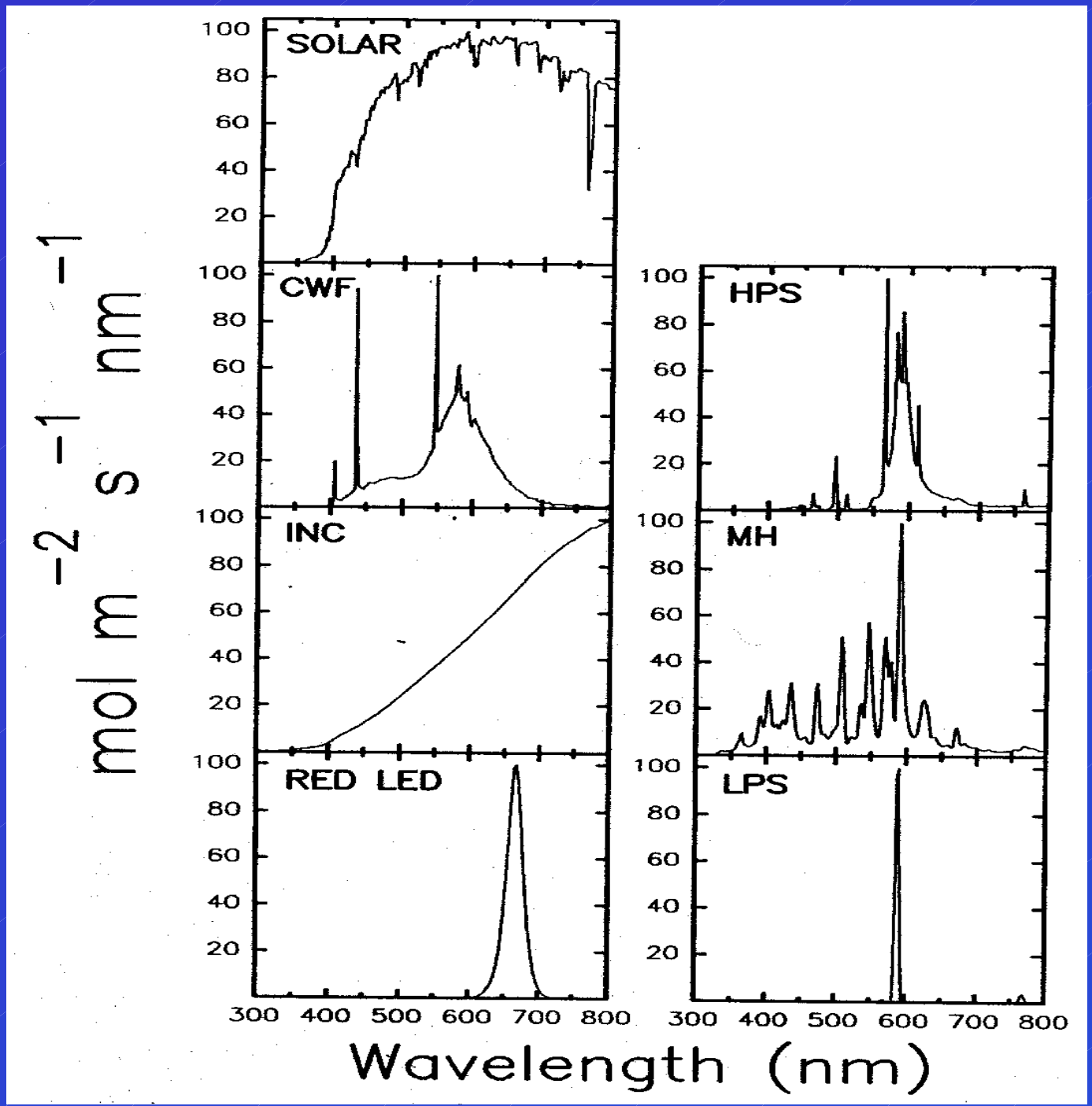
SNAP-LITES™ – a new innovative solid state lighting system developed for the United States Manned Space Program – is now available to replace the high thermal profile conventional lamp systems used by the environmental chamber industry for life science research.



Since the dawn of time, man has worshipped the sun for its inexhaustible energy, and sunlight as the driving force for all life on earth. In the 20th century man had tried to develop light sources that would reproduce the spectral quality and power of the solar spectrum but with little success. As we approach the 21st century, man has begun to better define the solar spectrum and the interaction of how photons of a specific wavelength can effect many of the life cycle processes within the study of the life sciences. In the



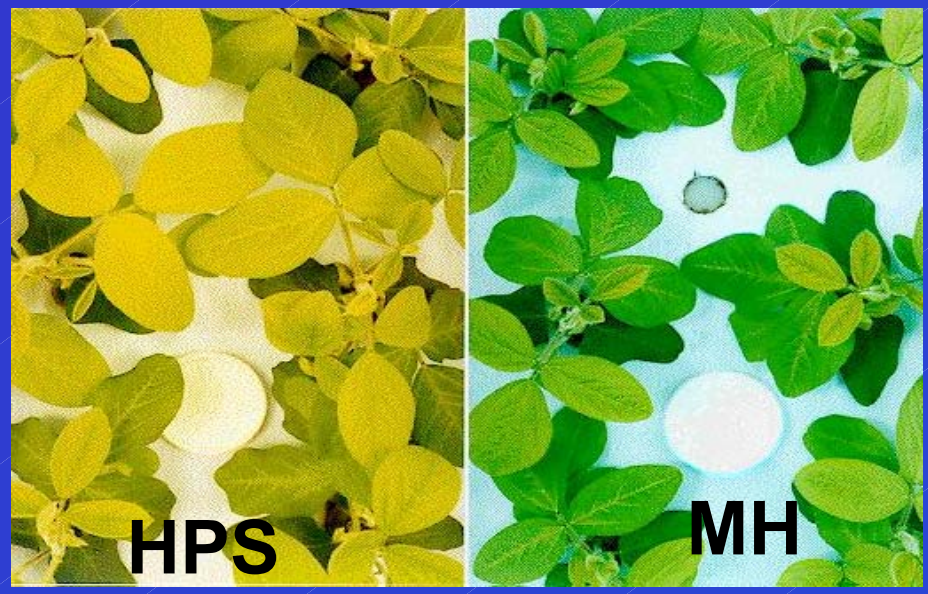
Spectral Distribution of sunlight and the 6 most common electric lamps



The ratio of YPF to PPF of six electric lamps compared to sunlight

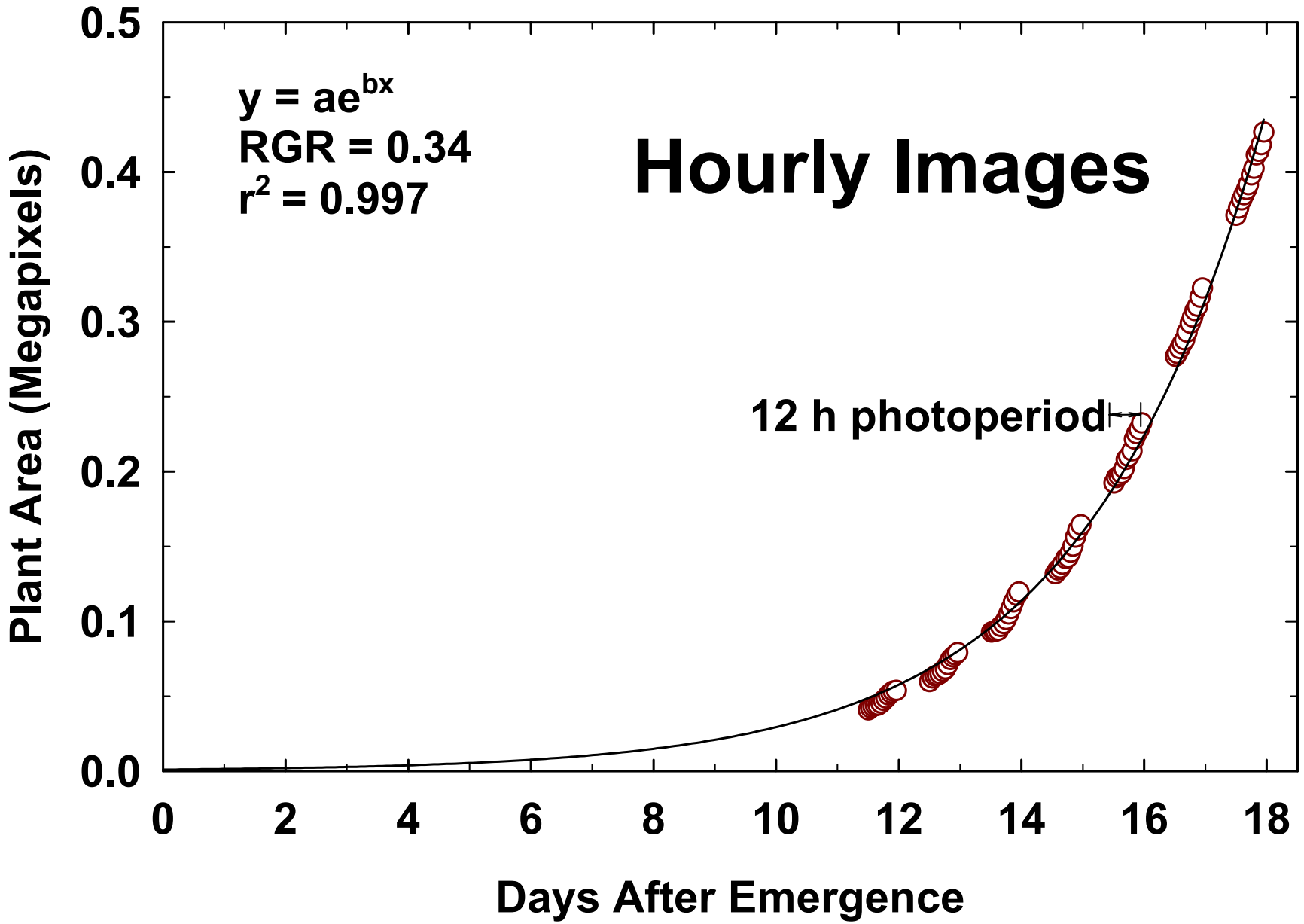
Lamp type	Ratio
Low Pressure Sodium	.99
High Pressure Sodium	.95
Incandescent	.95
Metal Halide	.90
Cool White Fluorescent	.89
Red LED	.89
Solar on clear day	.88

The effect of lamp type on the growth of soybeans



Lamp Type	Growth
High Pressure Sodium	100
Metal Halide	90

Photosynthetic effect = +5%
Photomorphogenic effect = +5%


y = ae^bx
RGR = 0.34
r^2 = 0.997
Hourly Images
12 h photoperiod
Plant Area (Megapixels)
Days After Emergence
0.0
0.1
0.2
0.3
0.4
0.5
0
2
4
6
8
10
12
14
16
18

Myth Number One

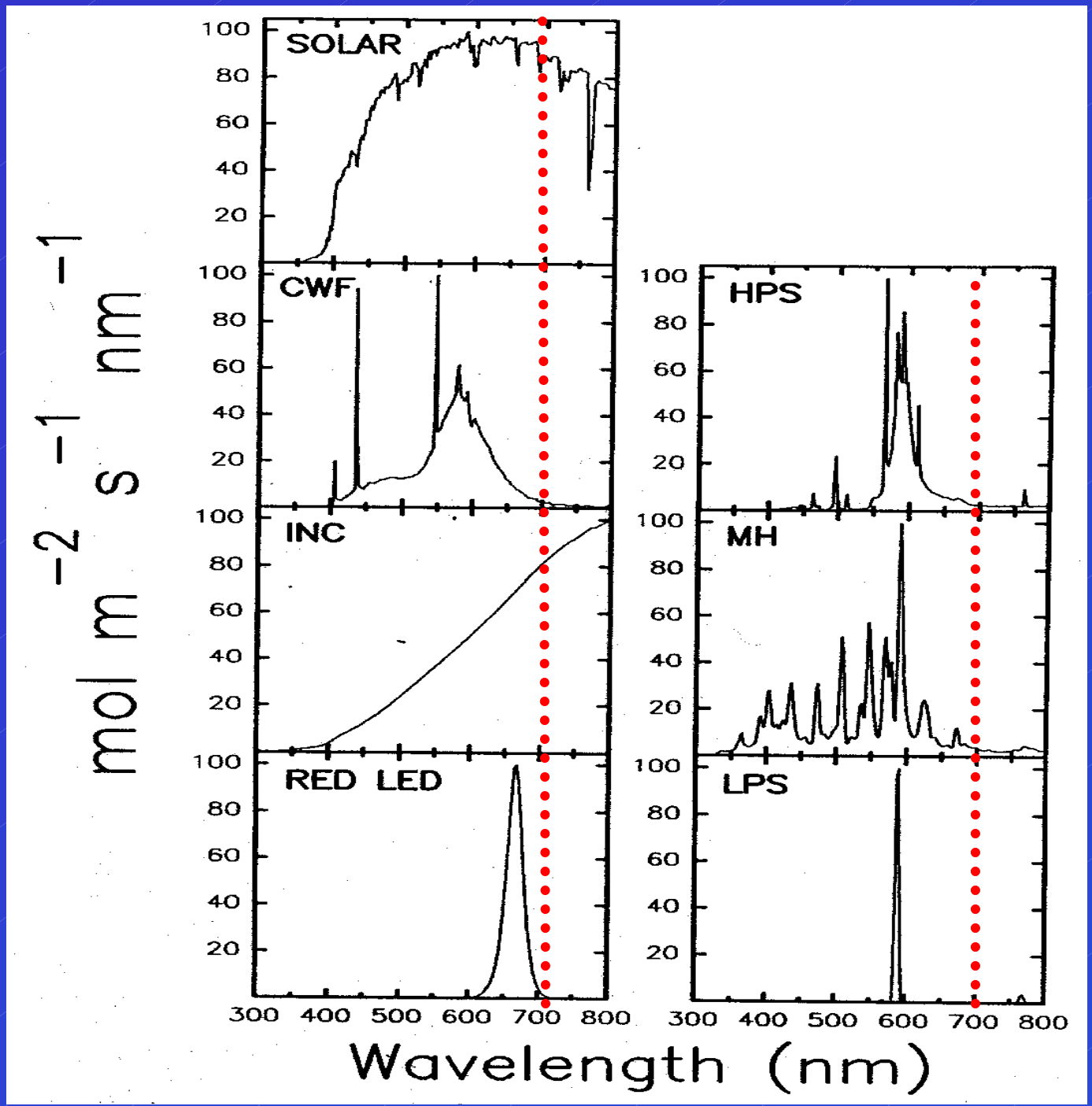
- Broad spectrum light is better than narrow spectrum light

Reality: Unusual electric lamps (HPS) can provide excellent plant growth.

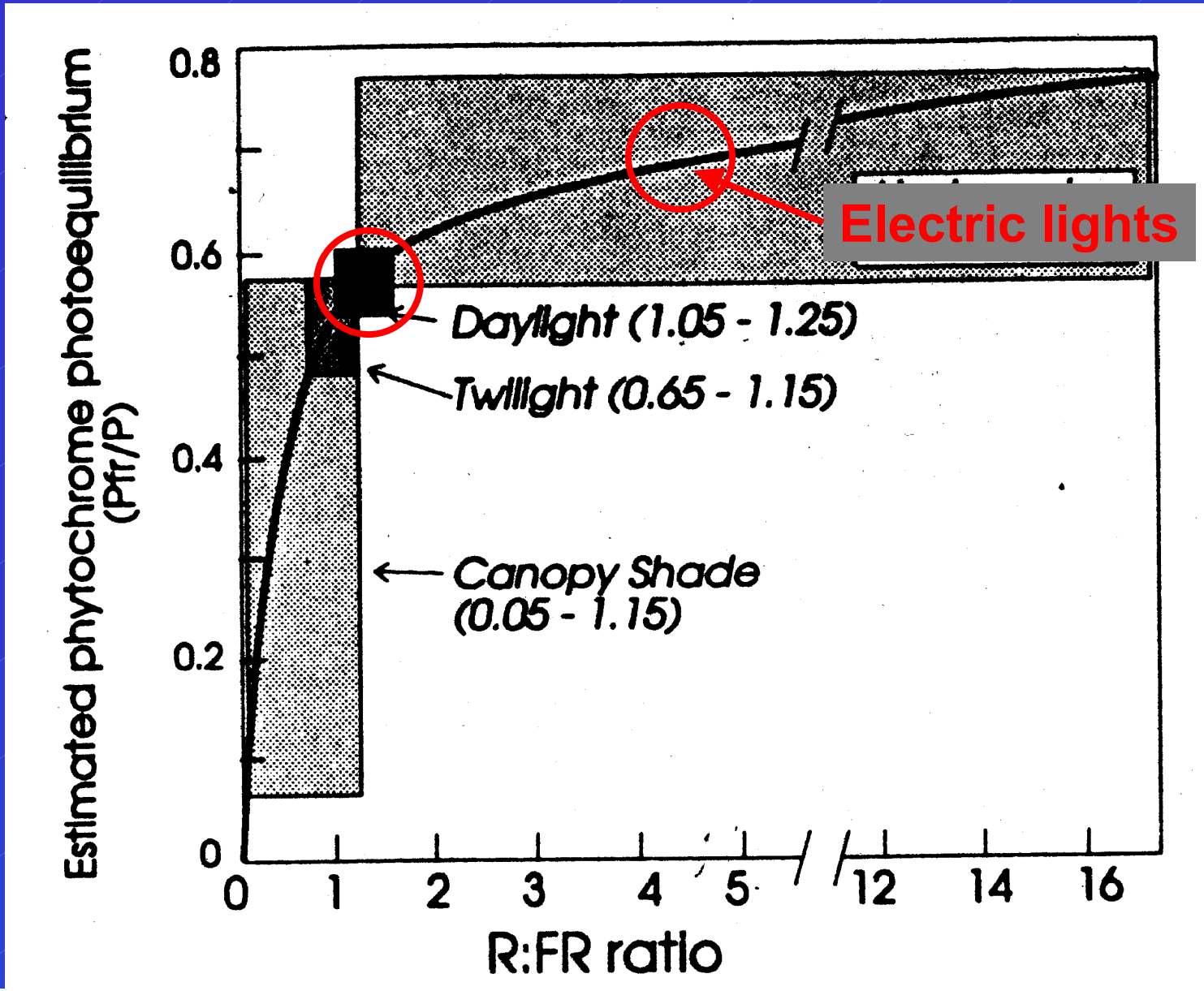
In many cases growth under unusual lamps is better than broad spectrum light

Myth number two

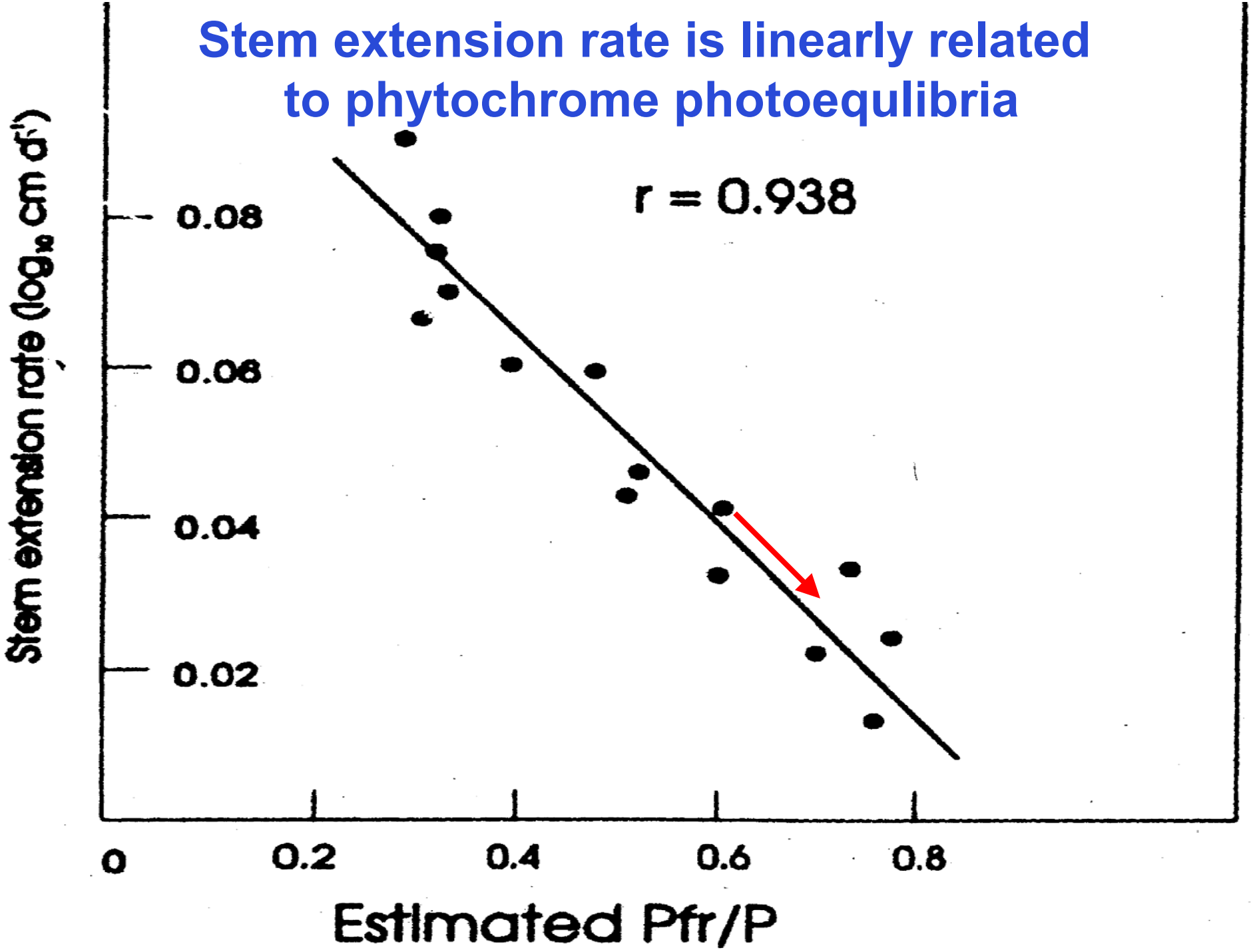
- Incandescent lights are required in growth chambers

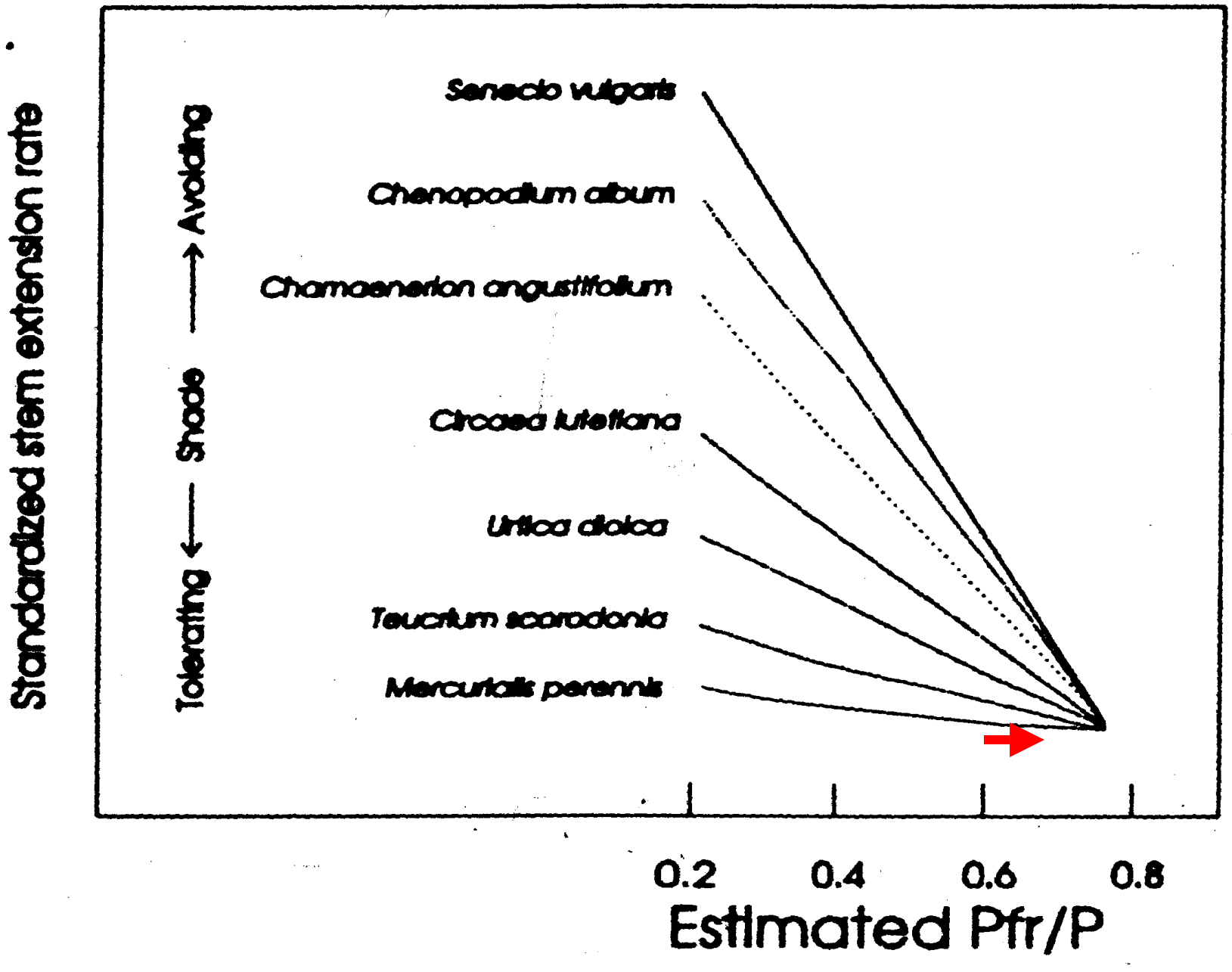

SOLAR
CWF
INC
RED LED
HPS
MH
LPS
100
80
60
40
20
300
400
500
600
700
800
mol m -2 s -1 nm -1
Wavelength (nm)

The relationship between phytochrome photoequlibria and Red: Far-red ratio

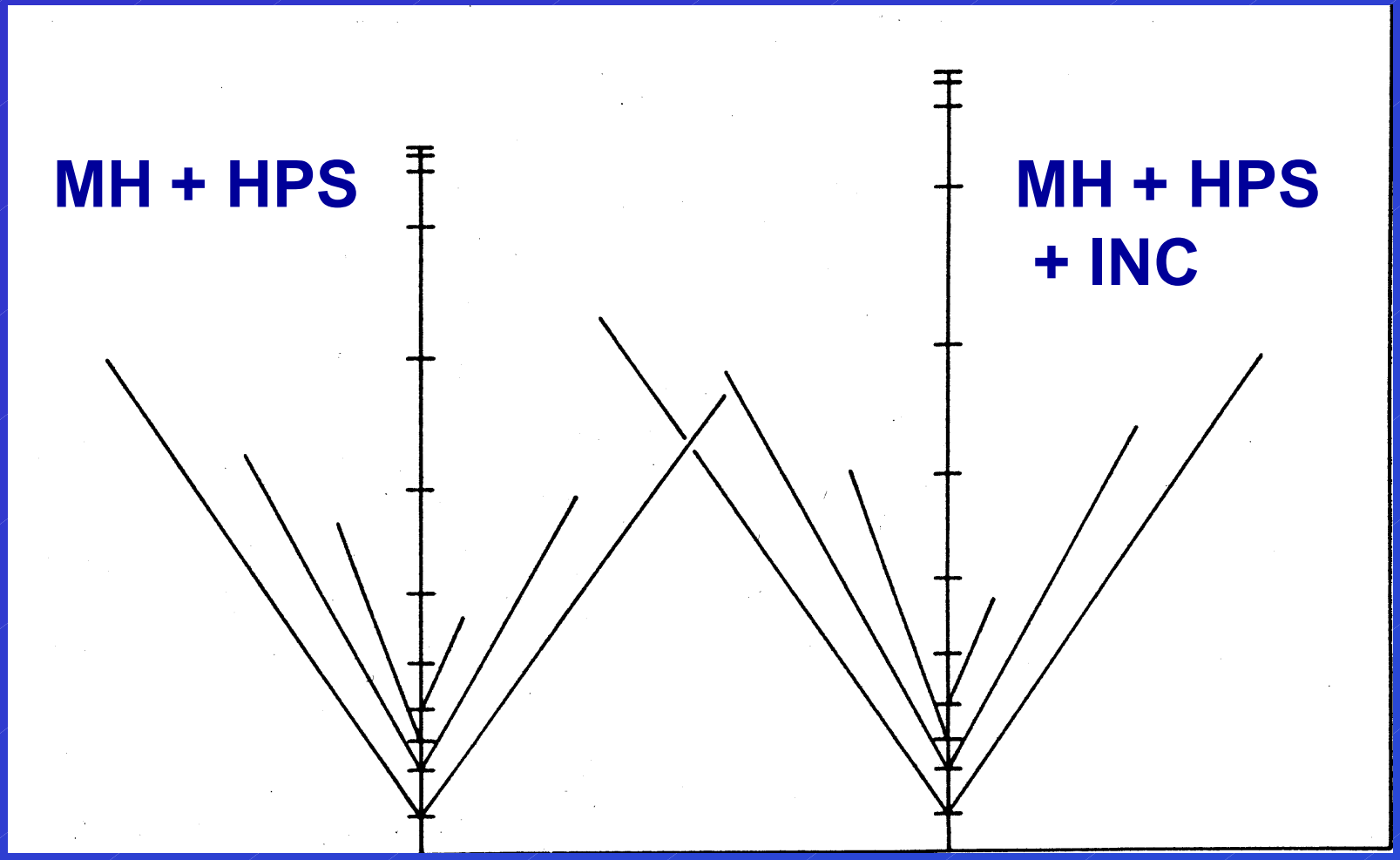


Stem extension rate is linearly related to phytochrome photoequlibria




Standardized stem extension rate
Tolerating ← Shade → Avoiding
Senecio vulgaris
Chenopodium album
Chamaenerion angustifolium
Circaea lutetiana
Urtica dioica
Teucrium scorodonia
Mercurialis perennis
0.2
0.4
0.6
0.8
Estimated Pfr/P

Far-red light effects on photomorphogenesis In soybeans



From: Jack Downs, 1994,
Intl. Lighting in Controlled Environments Workshop

Myth number two

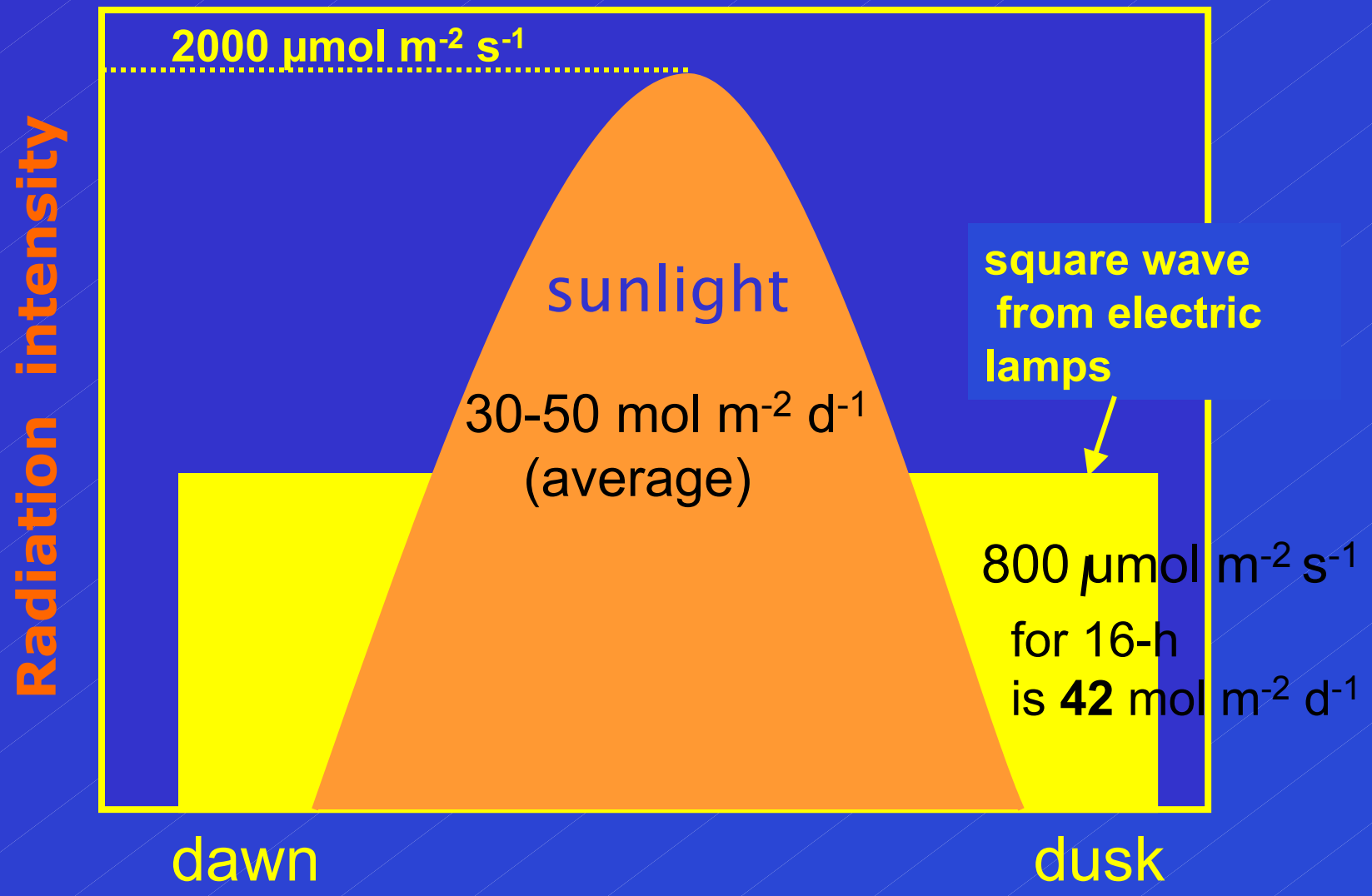
- Incandescent lights are essential in growth chambers

Reality: Incandescent lamps are not necessairly essential and sometimes result in unusually elongated growth

Myth number three

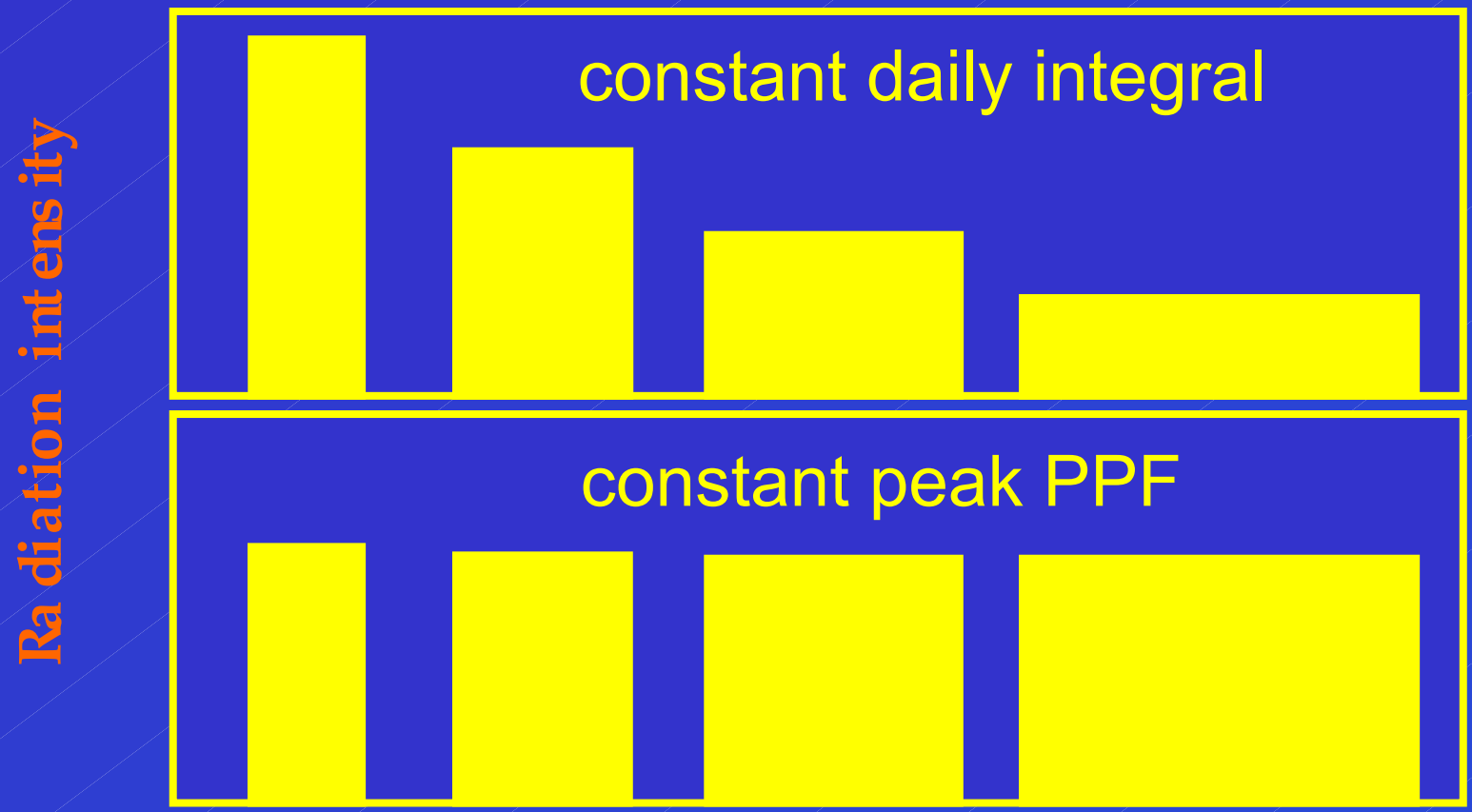
- High light is necessary in growth chamber research

Reality: A long photoperiod can be substituted for high PPF intensity



Answer: NO!

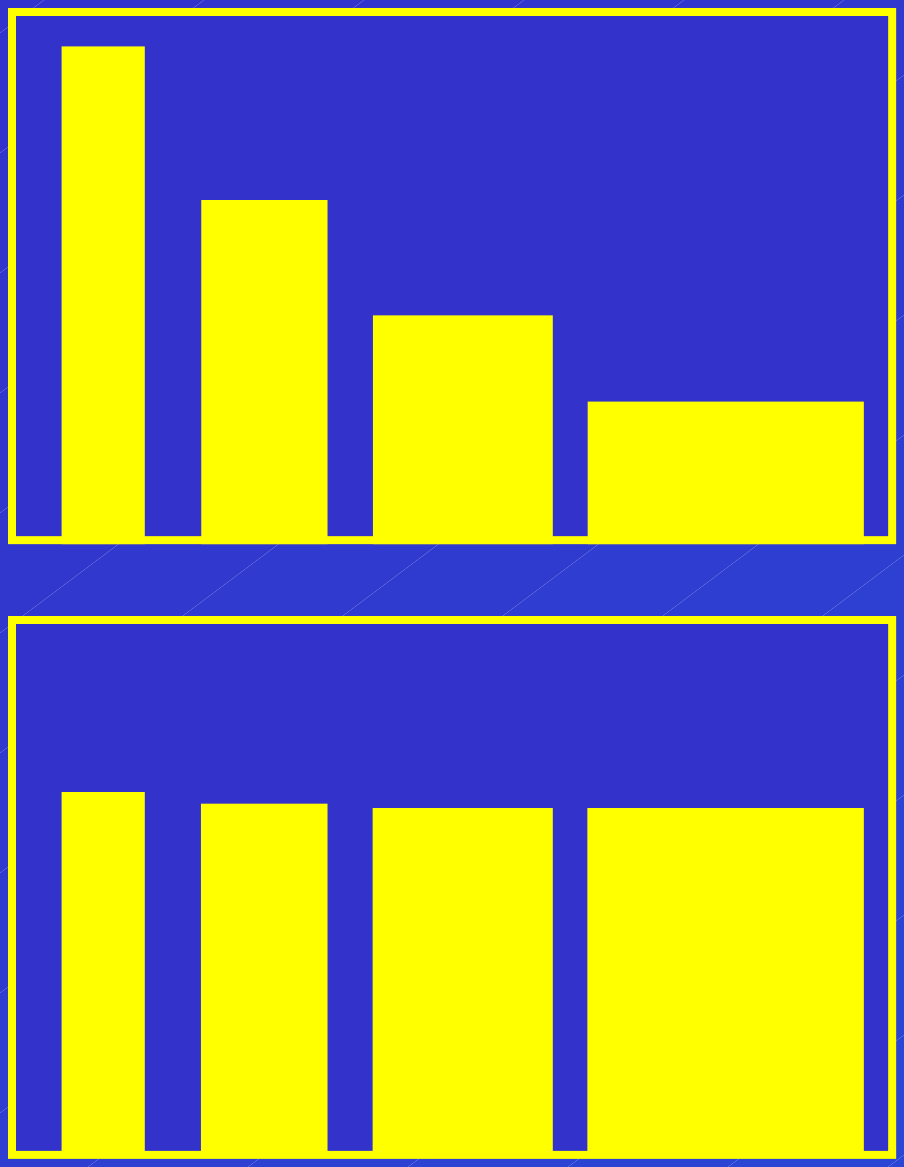
Plant growth is determined by the daily light total, not the peak light level.

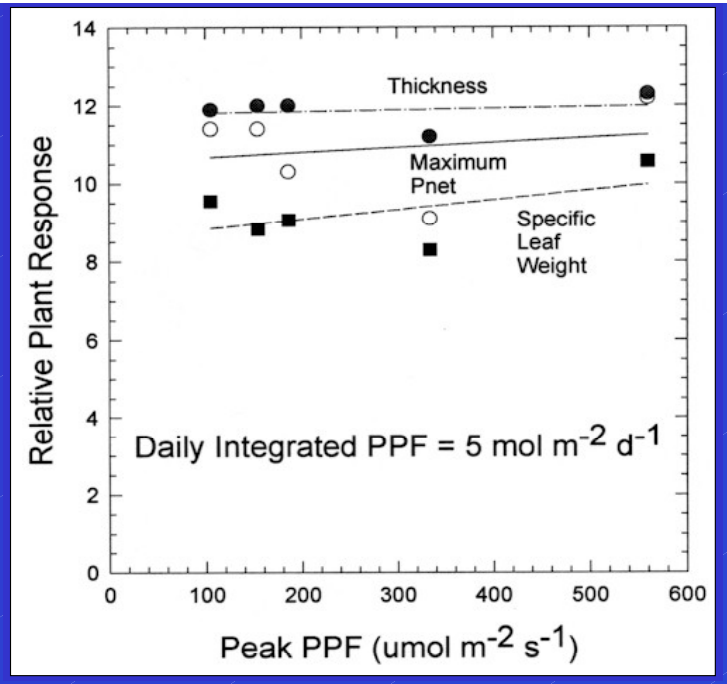


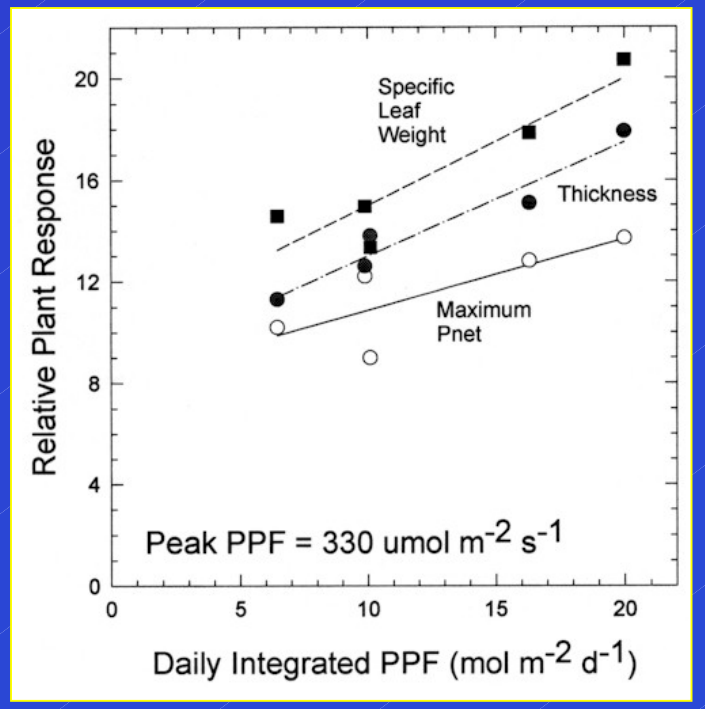
Chabot, et. al. 1979. Influence of Instantaneous and Integrated Light-Flux Density on Leaf Anatomy and Photosynthesis. Amer. J. Bot. 66: 940-945.

Chabot, et. al. 1979.

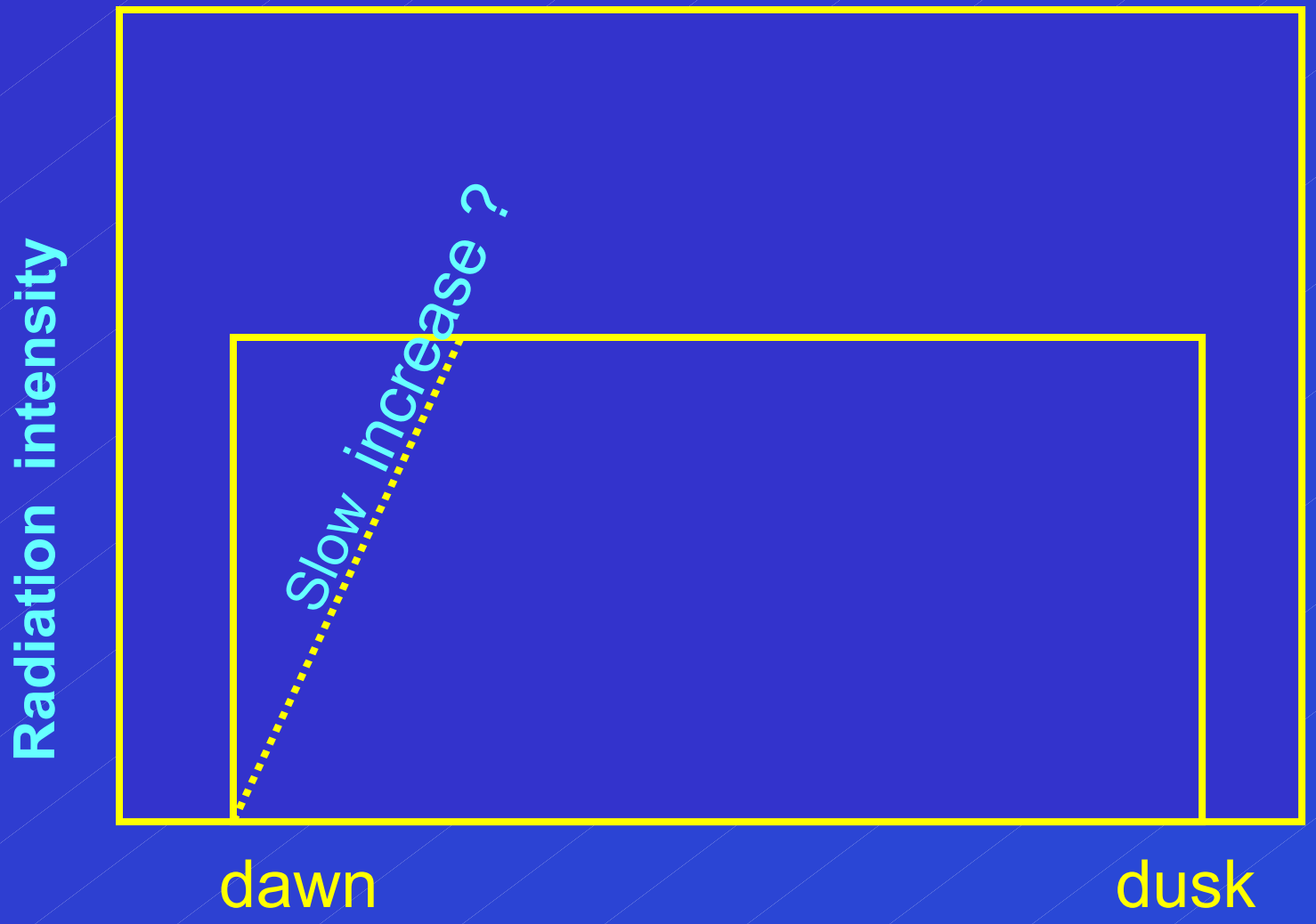
Amer. J. Bot. 66: 940-945.





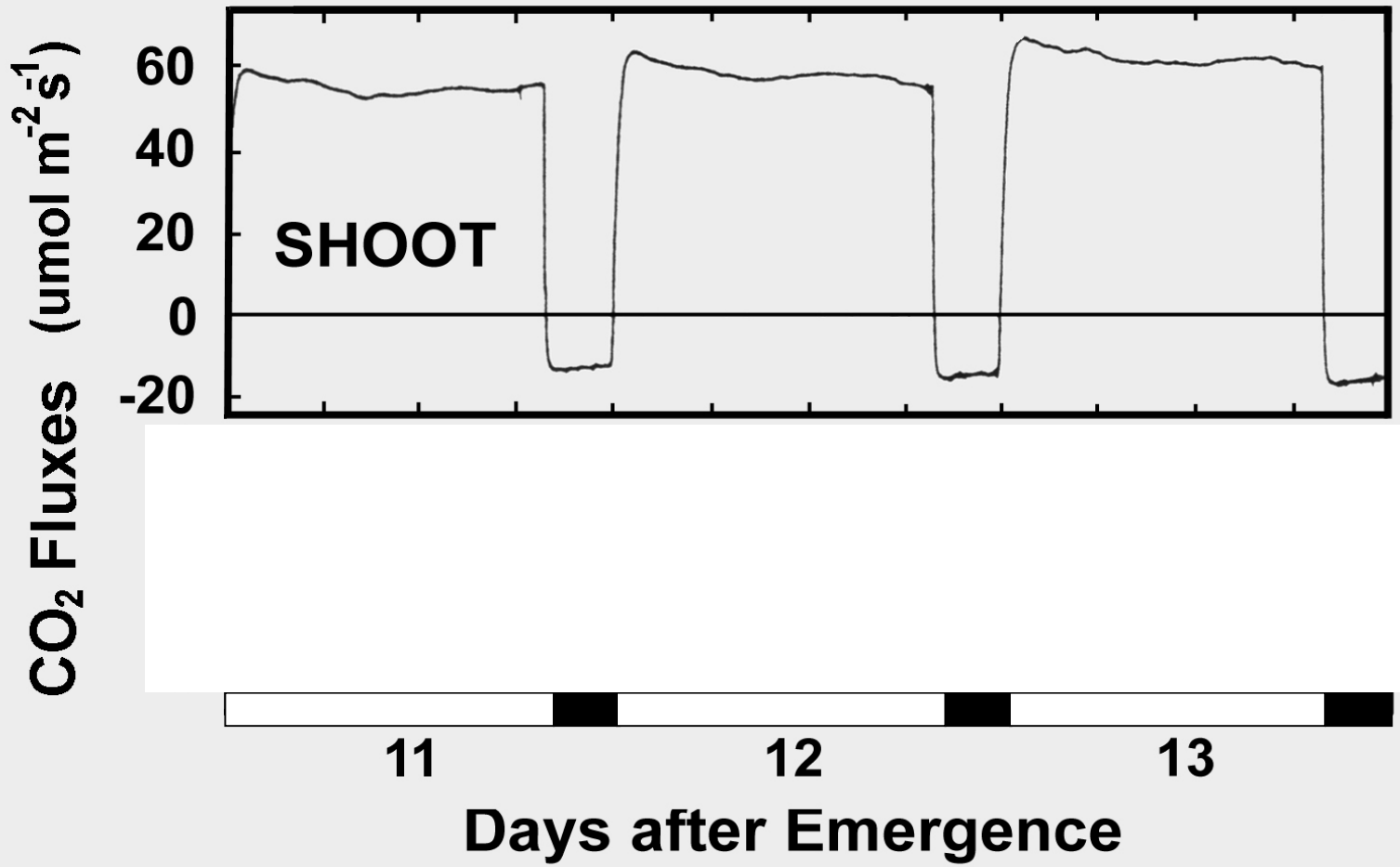


Is it important to slowly increase the radiation in the morning, like the field?



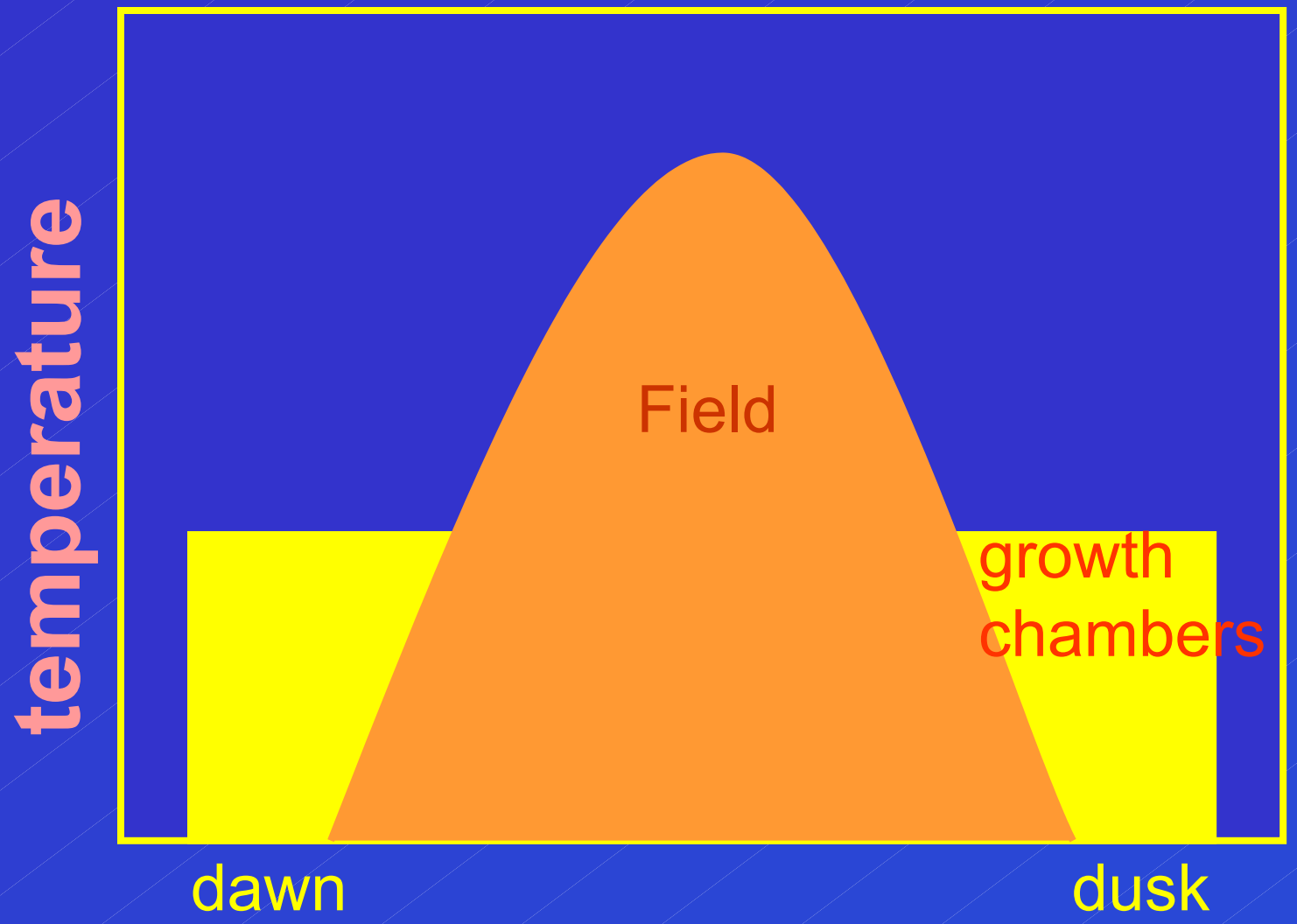
Photosynthetic rate increases rapidly in the morning as the light reaches full output.

There is no evidence of the need to ramp the lights up gradually



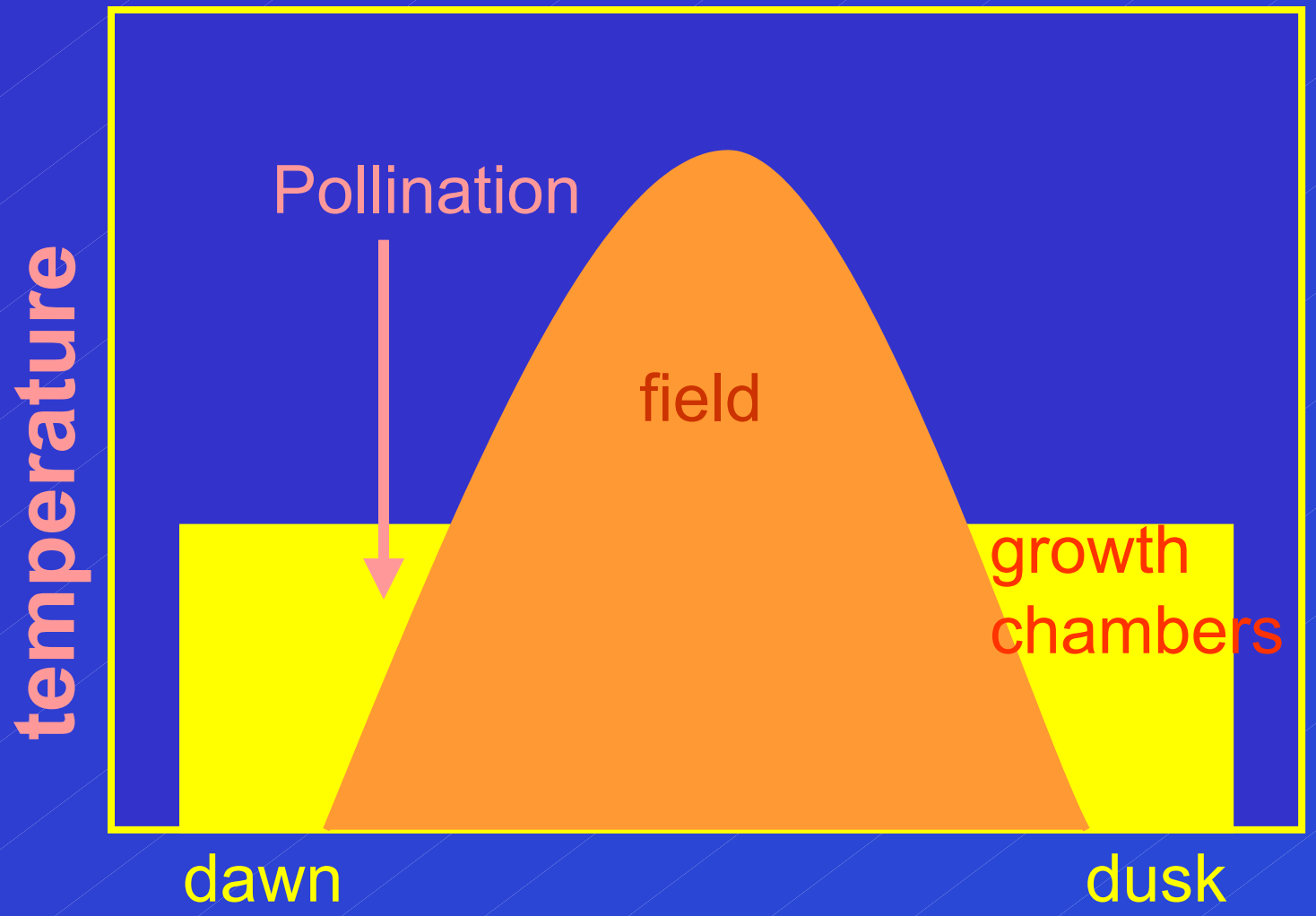
Monje and Bugbee, 1996. Acta Hort. 440:123-126.

Should we gradually increase the temperature
in growth chambers,
like the slow increase after dawn in the field?



Answer: yes, in some unique cases.

Pollination in most crops occurs a few hours after dawn, when the temperature is still cool. Pollination, fertilization, and seed set can be reduced if the temperature increases too high, too fast.
This is mostly a problem in high temperature stress studies.



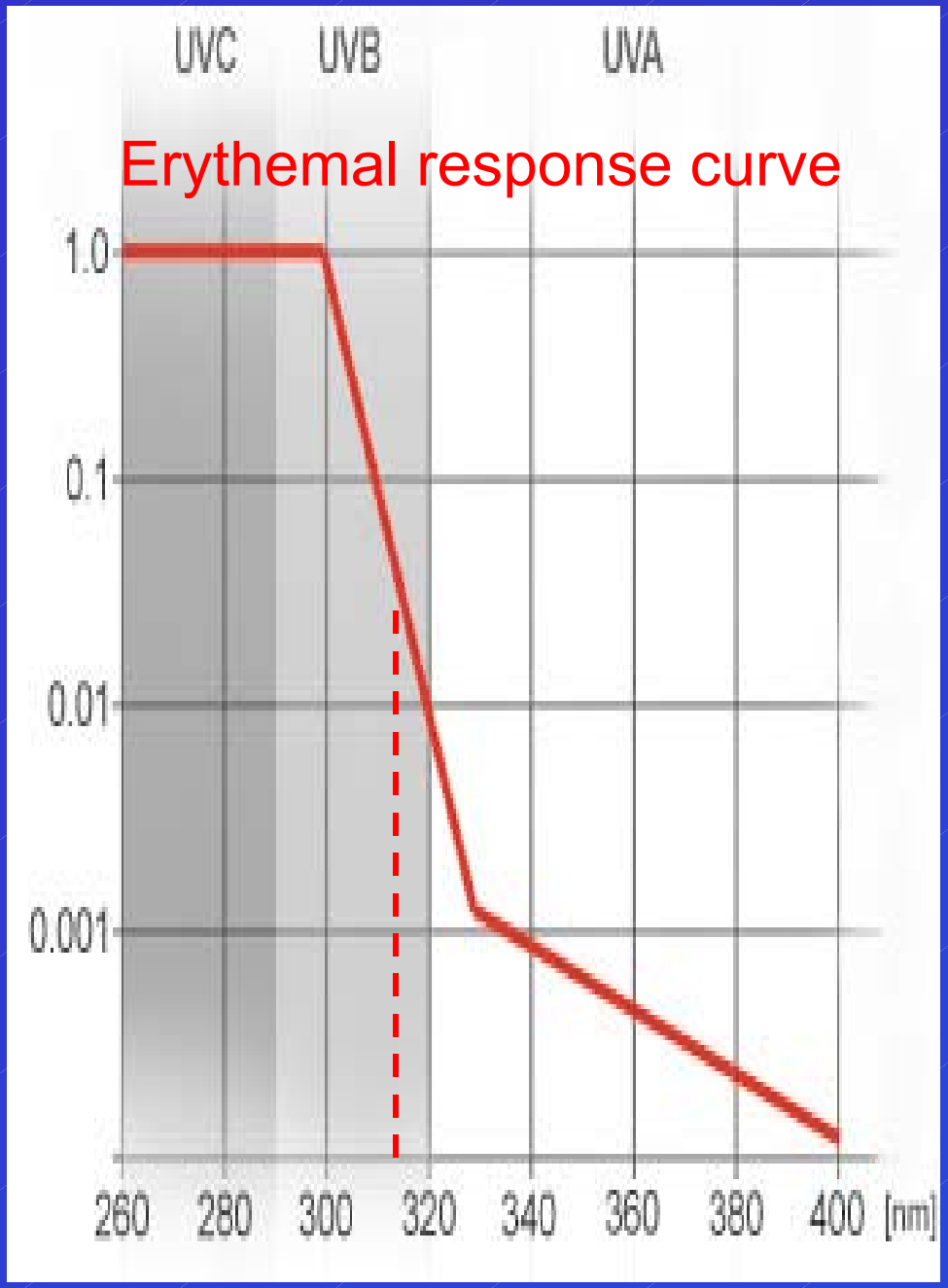
Tipburn

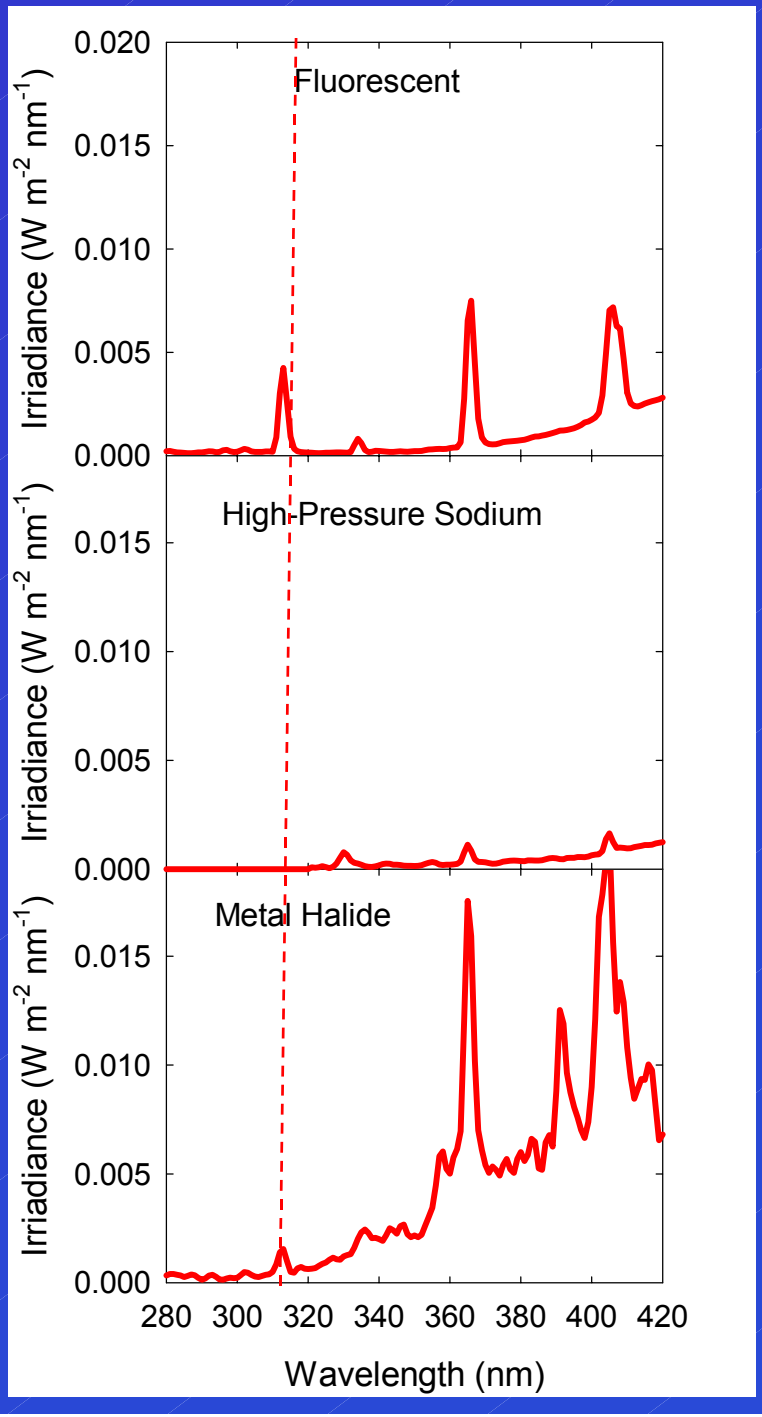
May be increased by the abrupt dark to light transition

Substituting for sunlight: UV effects

% of photon flux below 400 nm

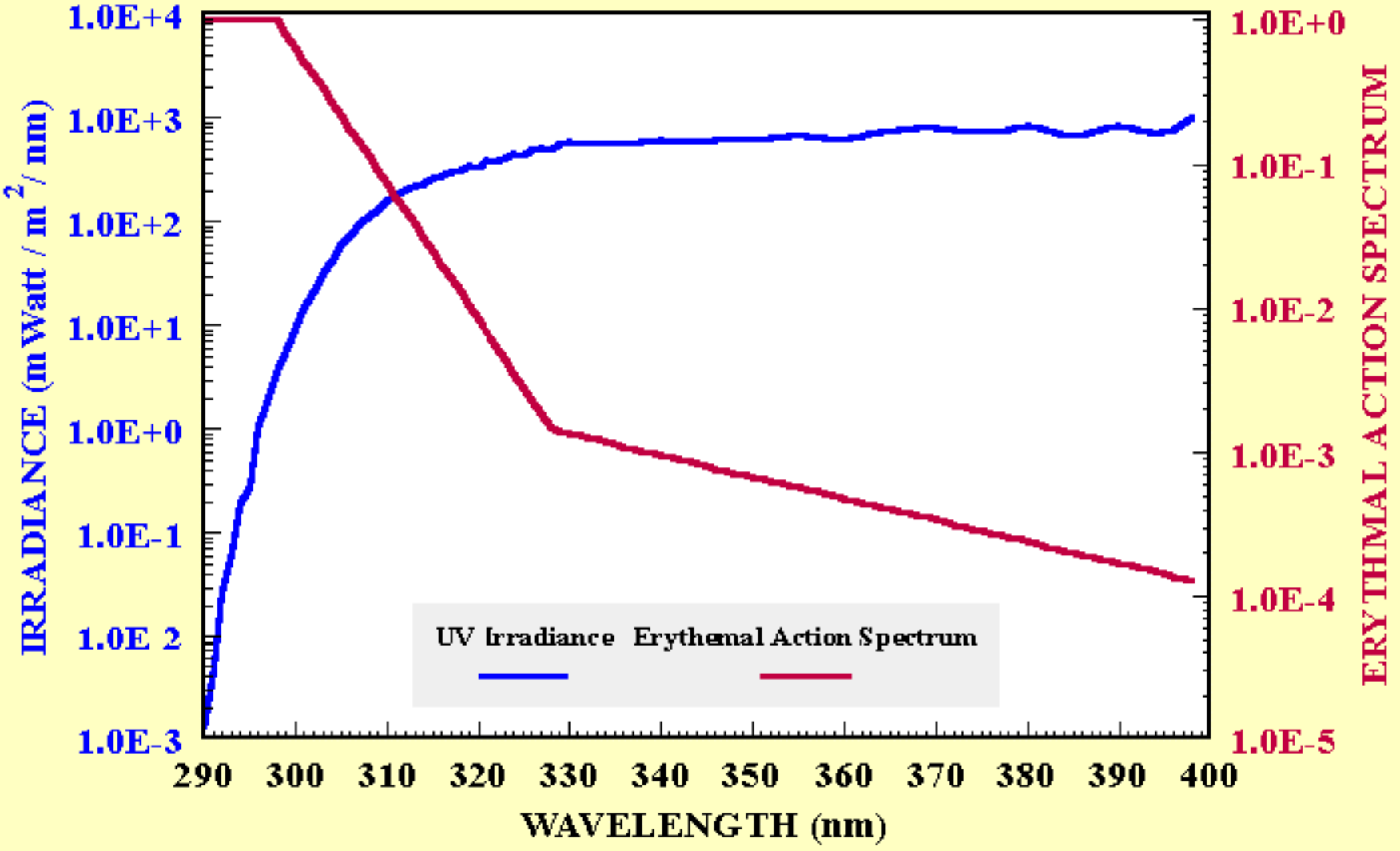
- Sunlight 8.5 %
- Metal halide: 7.7 %
- Cool white fluorescent 3.2 %
- High pressure sodium 0.7 %


UVC
UVB
UVA
Erythemal response curve
1.0
0.1
0.01
0.001
260
280
300
320
340
360
380
400
[nm]


Fluorescent
High-Pressure Sodium
Metal Halide
Irriadiance (W m-2 nm-1)
0.020
0.015
0.010
0.005
0.000
280
300
320
340
360
380
400
420
Wavelength (nm)

UV SPECTRAL IRRADIANCES & ERYTHEMAL ACTION SPECTRUM

Lat = 40N Ozone = 300DU Day of Year = June 22 Time = 12noon

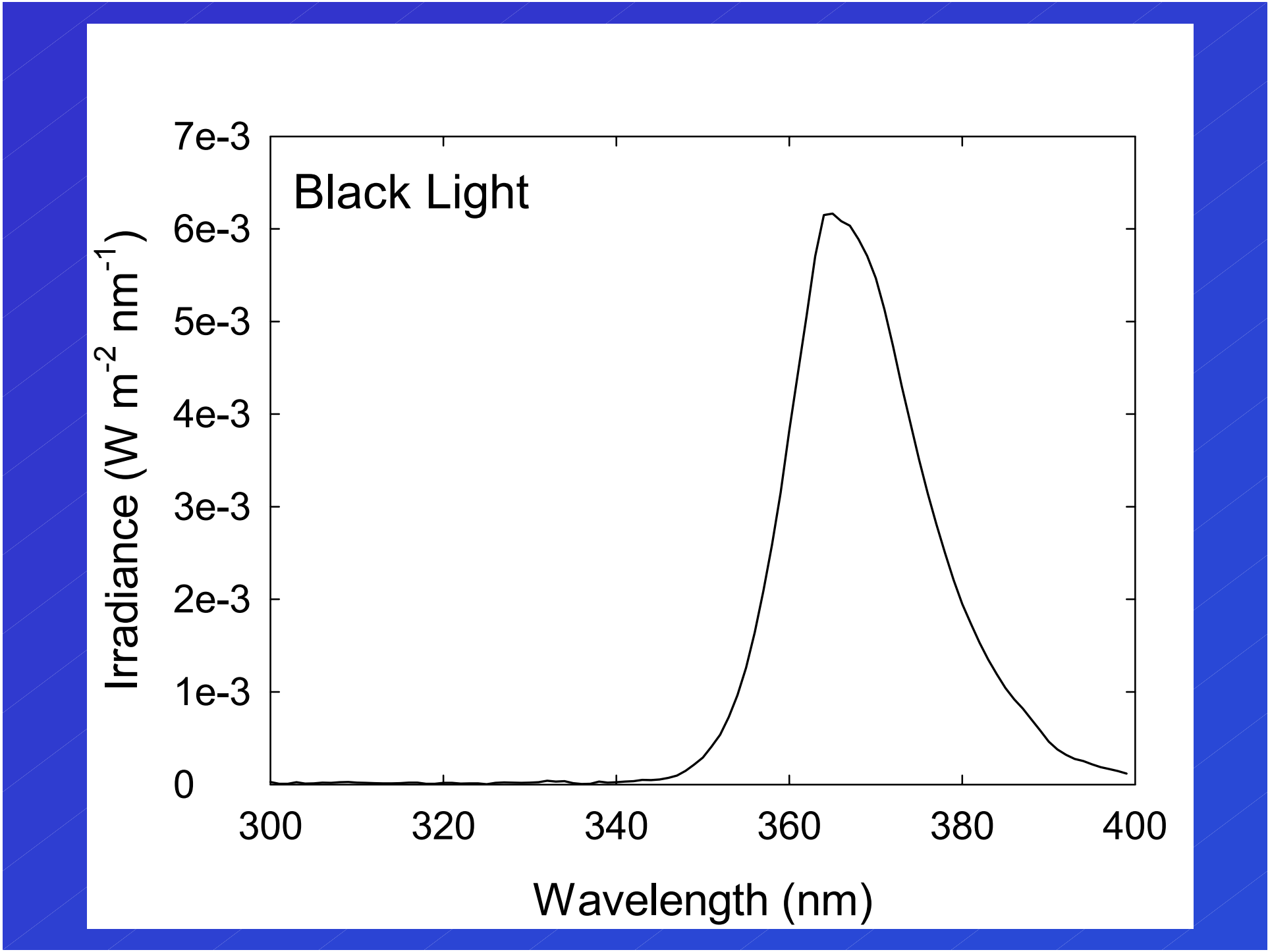


Substituting for sunlight: UV effects

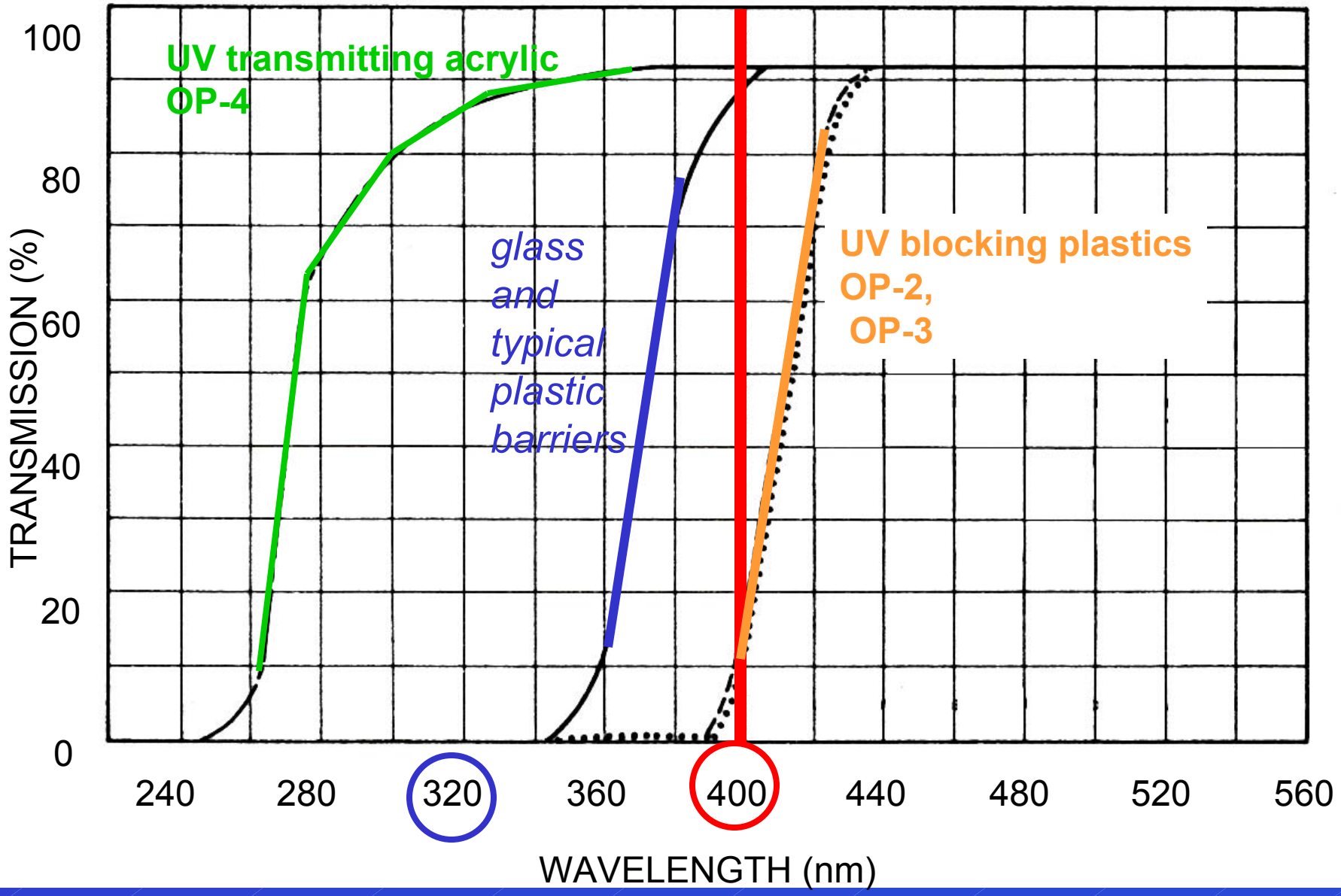
	250-350	350-400	Total
– Sunlight	2.5	6.0	8.5 %
– Metal halide:	0.7	7.0	7.7 %
– Cool white fluorescent	0.7	2.5	3.2 %
– High pressure sodium	0.2	0.5	0.7 %

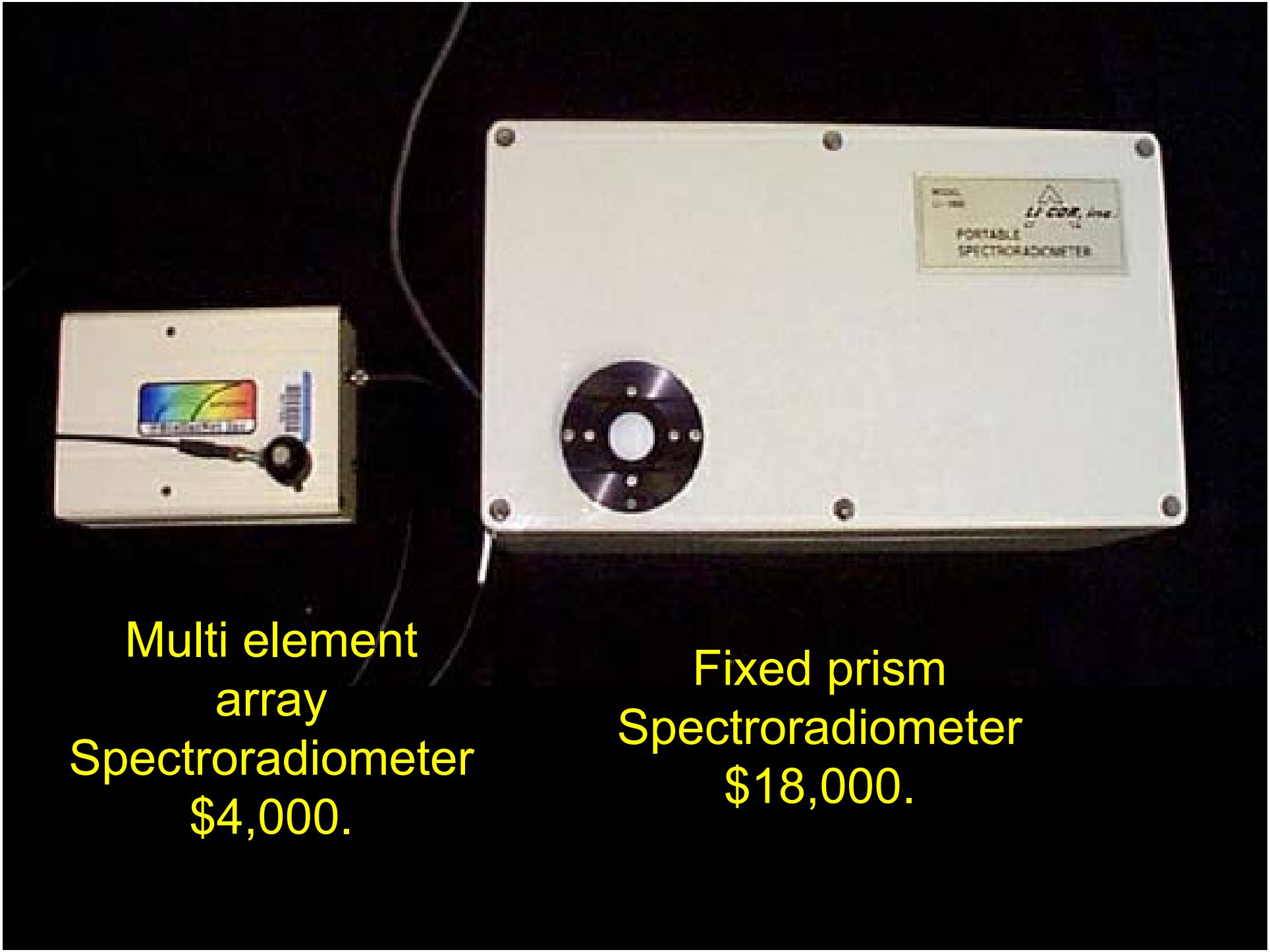

intumescence
Small galls on the surface of leaves and stems

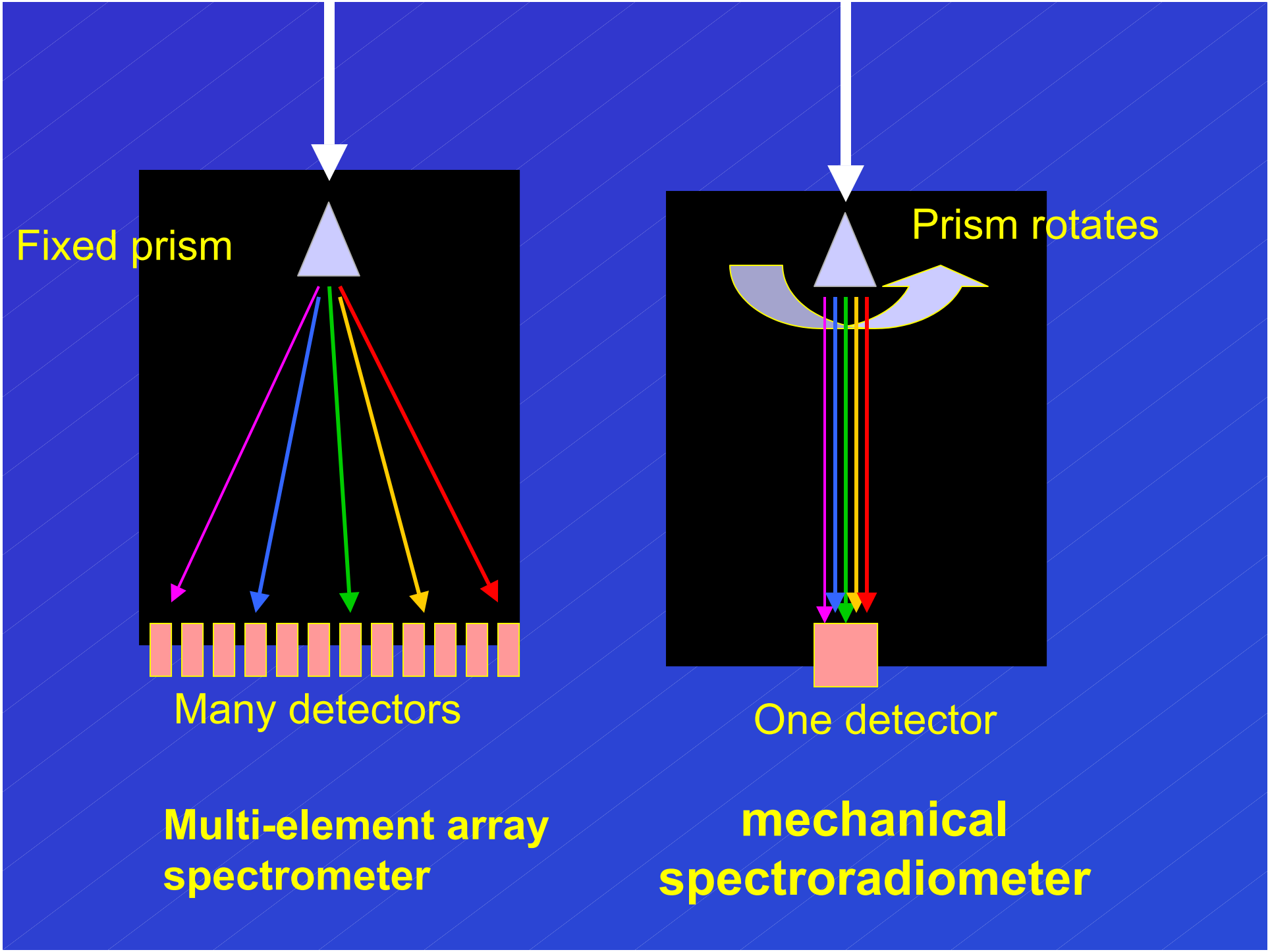
UV “black lights” for fluorescent fixtures

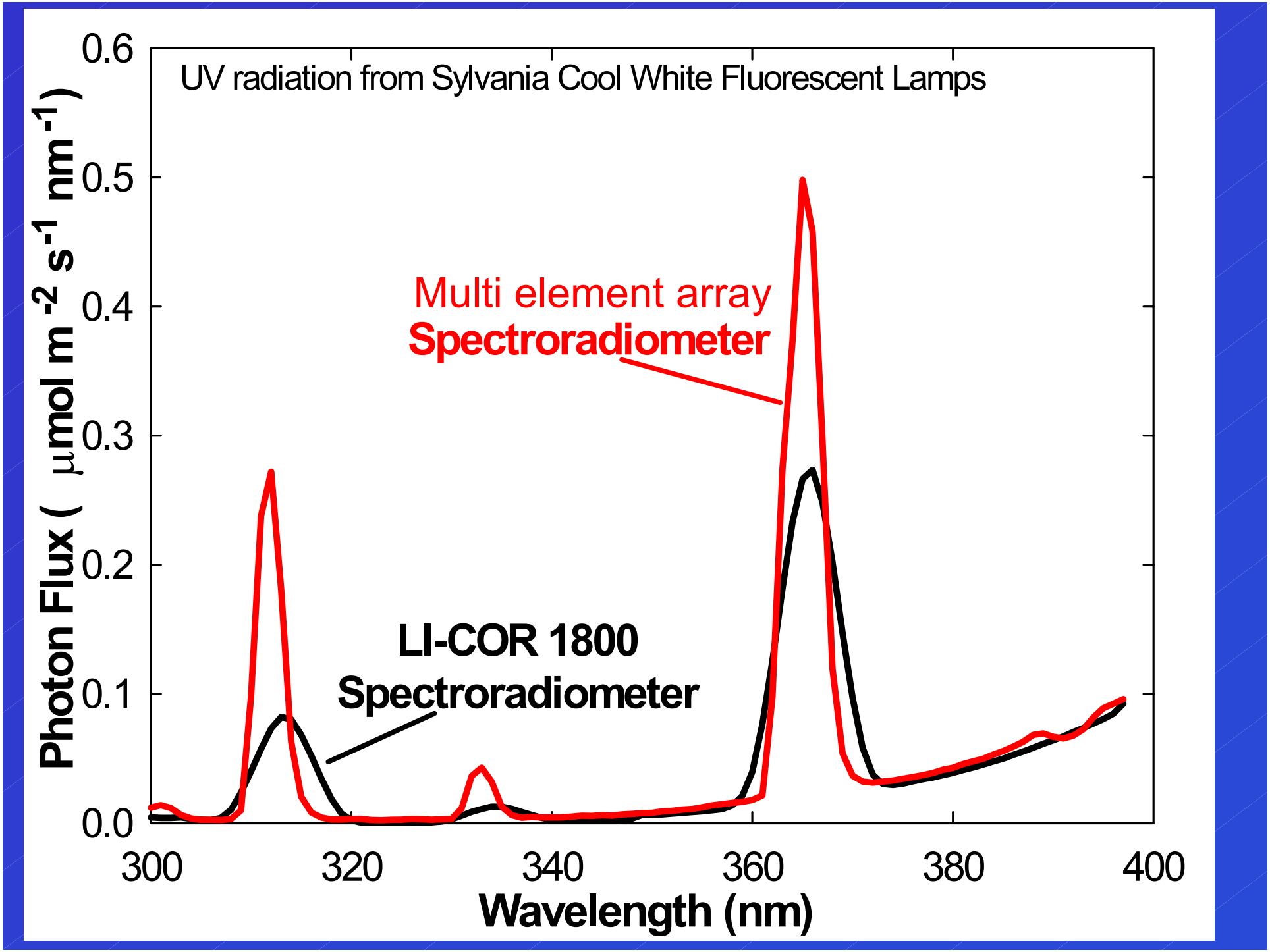

Black Light
Irradiance (W m-2 nm-1)
7e-3
6e-3
5e-3
4e-3
3e-3
2e-3
1e-3
0
300
320
340
360
380
400
Wavelength (nm)

Cyro industries “Acrylite” acrylic plastics




LI-COR, Inc.
PORTABLE
SPECTRORADIOMETER
Multi element
array
Spectroradiometer
$4,000.
Fixed prism
Spectroradiometer
$18,000.


Fixed prism
Many detectors
Prism rotates
One detector
Multi-element array spectrometer
mechanical spectroradiometer


UV radiation from Sylvania Cool White Fluorescent Lamps
Multi element array
Spectroradiometer
LI-COR 1800
Spectroradiometer
Photon Flux (μmol m-2 s-1 nm-1)
Wavelength (nm)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
300
320
340
360
380
400

Multi-element array spectrometers

- ASD hand held $10,000.
- PP systems $10,000.
- Ocean optics $4,500.
- Apogee/Stellarnet $3,700.

Thermal radiation from electric lamps is more than sunlight

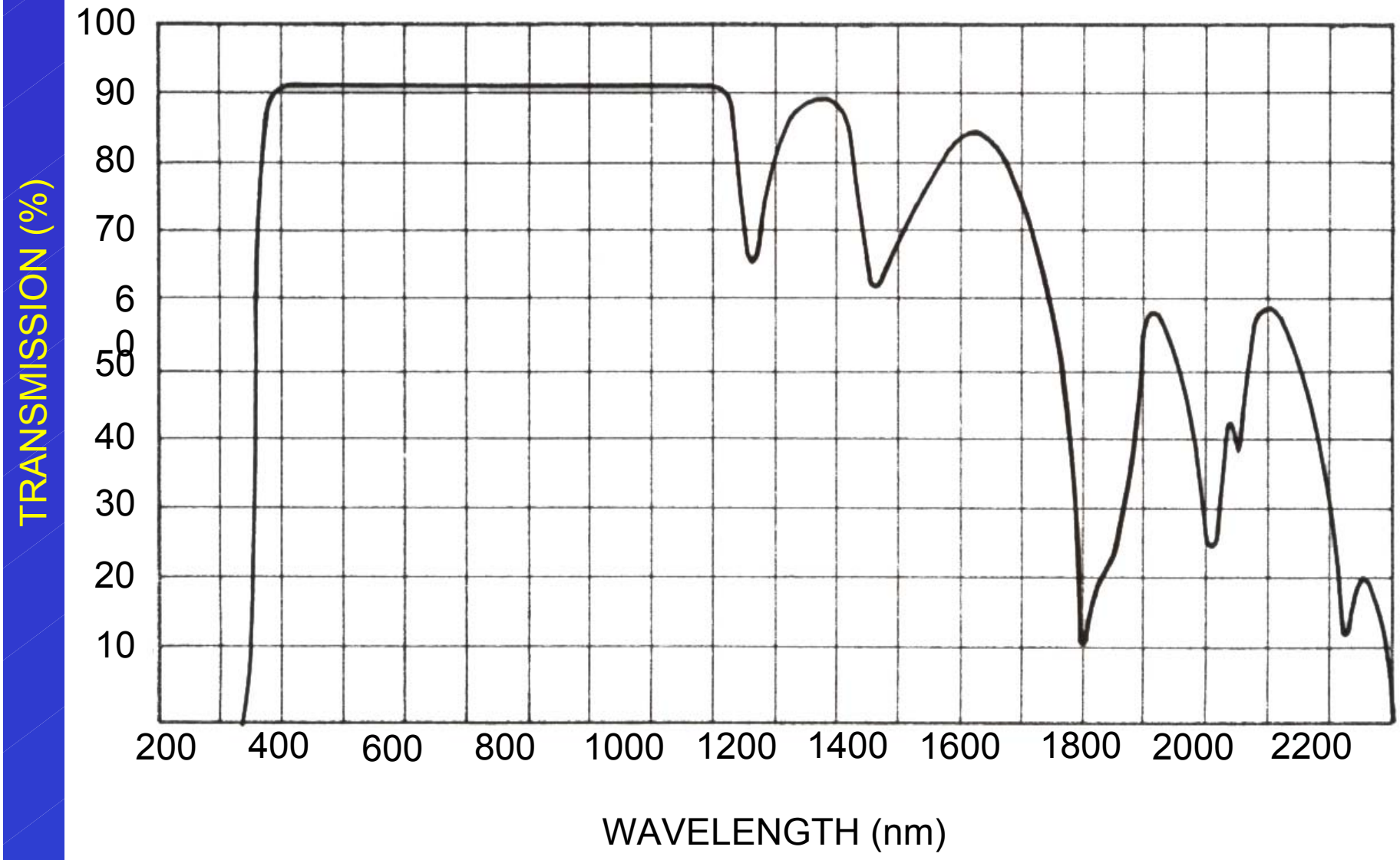
	PAR shortwave	PAR total net radiation
• Sunlight	.44	.50
• Fluorescent	.57	.32
• H P Sodium	.48	.35

Effect of filters on PAR/thermal ratio

	no filter	acrylic plastic	4 cm water filter
• Sunlight	.50	--	--
• Fluorescent	.32	.42	.69
• H P Sodium	.35	.46	.82

Bubenheim, Salisbury and Bugbee, 1988, J. Am.Soc. Hort. Sci

Transmission of Acrylic plastic filter



Higher plant sensitivity to light

What is reagent grade darkness?

	PPF ($umol/m^2$ s
Full moonlight	0.05
Potato tuberization	0.6
Poinsettia color	0.1