Lighting the future of horticulture:
Energy saving and spectral manipulation

Dr Phillip Davis

Horticulture Technologies Event. Dublin 4th May 2017

Energy efficiency of different lighting systems

HPS treatment

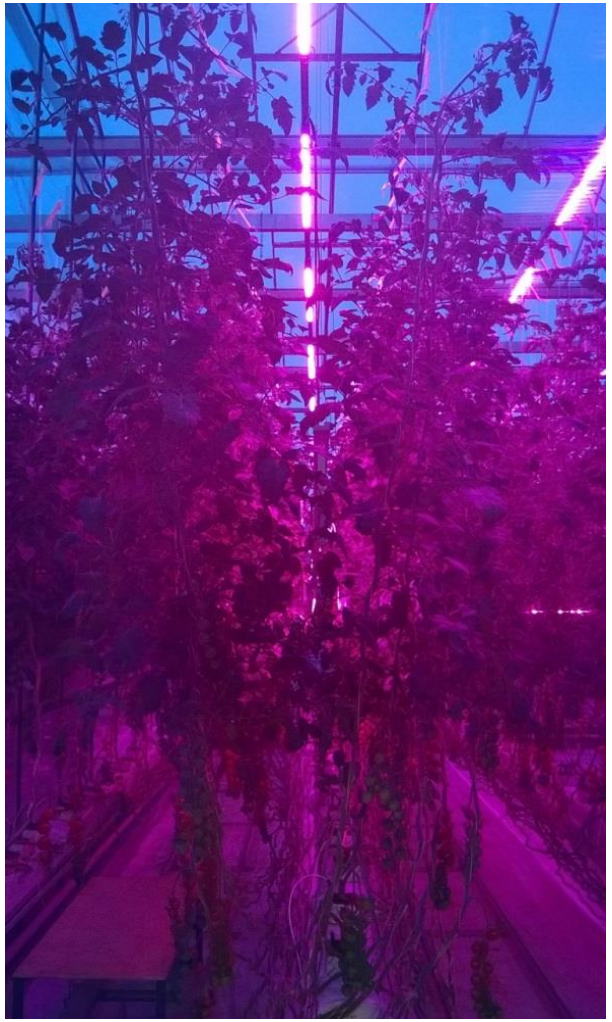
600W
Efficacy 1.92 µmol /J

Assuming 200 µmol m^{-2} s^{-1} is required to grow a crop over a 10m^2 area.

Number of light required
=200/(600*1.92)*10
= 1.73 lamps per 10m^2

Total power of **1041W**

Philips LED top light



190W
Efficacy 2.71 µmol /J

Assuming 200 µmol m^{-2} s^{-1} is required to grow a crop over a 10m^2 area.

Number of light required
=200/(190*2.73)*10
= 3.86 lamps per 10m^2

Total power **733W**

30% Electrical energy saving

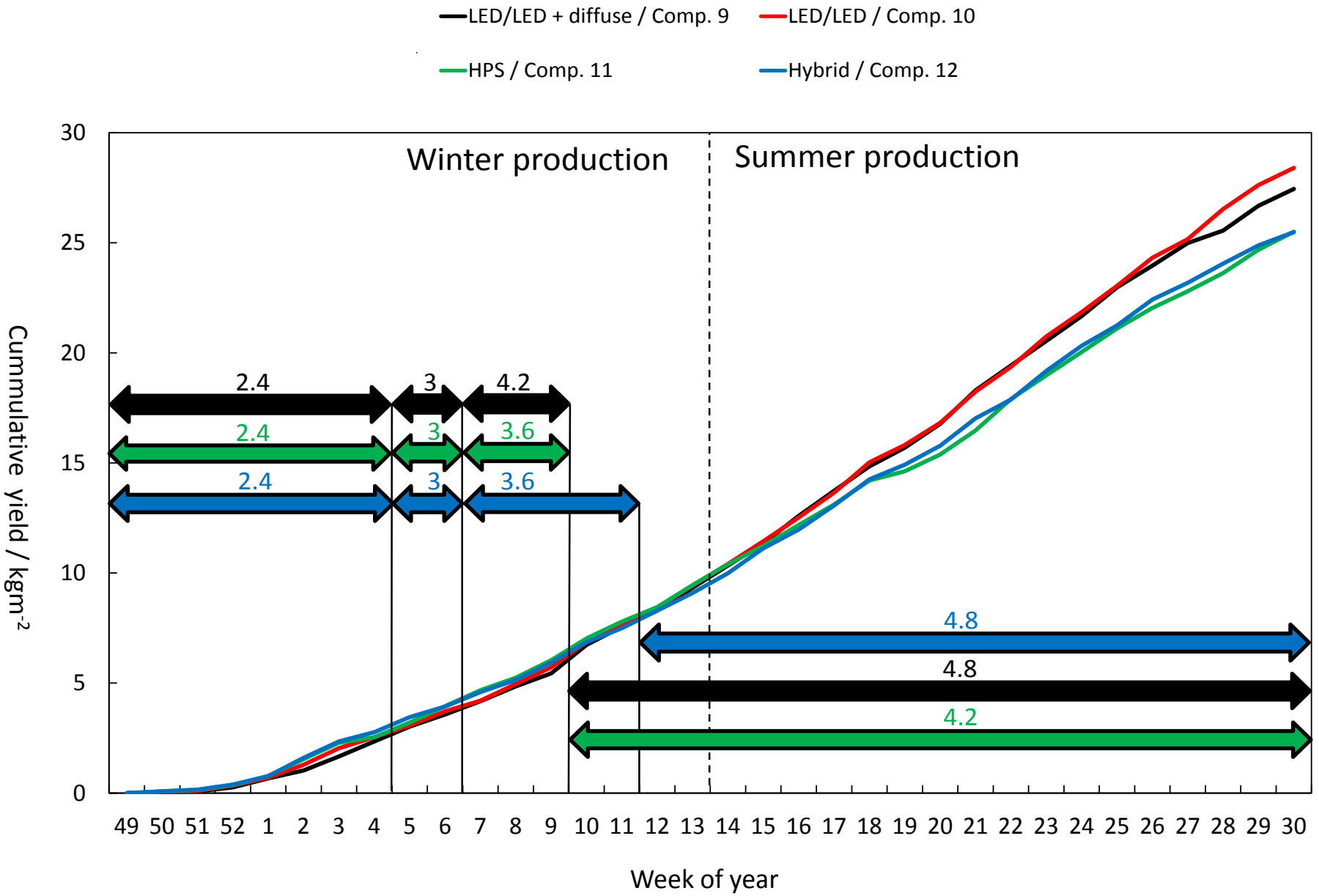
Efficacy data from AHDB CP139 project and Philips data sheets

Not all LEDs are equal

Lamp	Efficacy / µmol m^{-2} s^{-1}
HPS	1.92
LED 1	1.44
LED 2	1.27
LED 3	2.43
LED 4	2.71
LED 5	2.56
Plasma	1.16

Efficacy data from AHDB CP139 project

Tomato yields



More light - more growth

Petunia 35 days after sowing

100 µmol m^{-2} s^{-1} | 200 µmol m^{-2} s^{-1} | 280 µmol m^{-2} s^{-1} | 360 µmol m^{-2} s^{-1}

But also more cost!

…but not always a better result

Pepper plants grow shorter as the light intensity increases

100 µmol m^{-2} s^{-1}

200 µmol m^{-2} s^{-1}

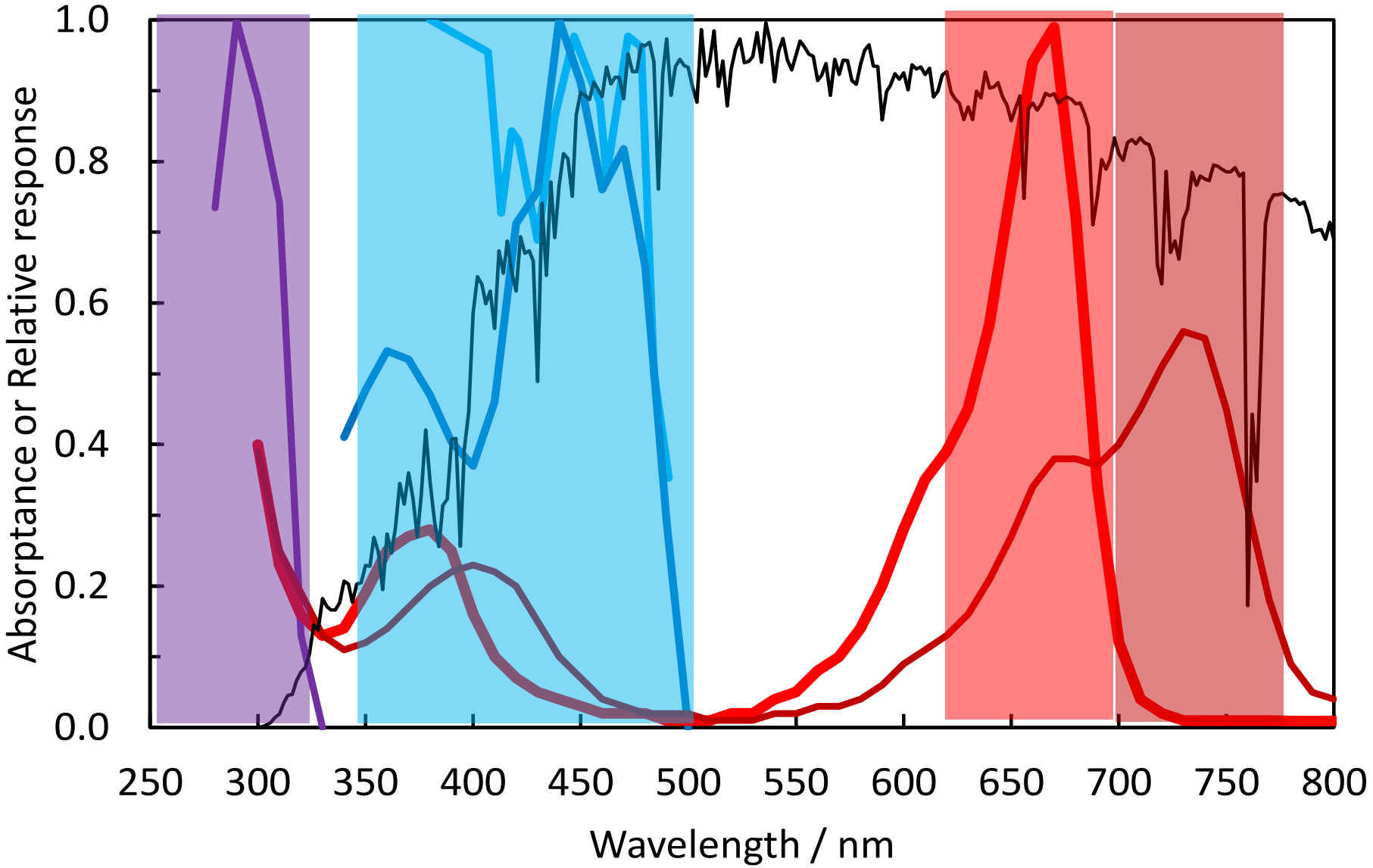
360 µmol m^{-2} s^{-1}

Light controls more than just photosynthesis

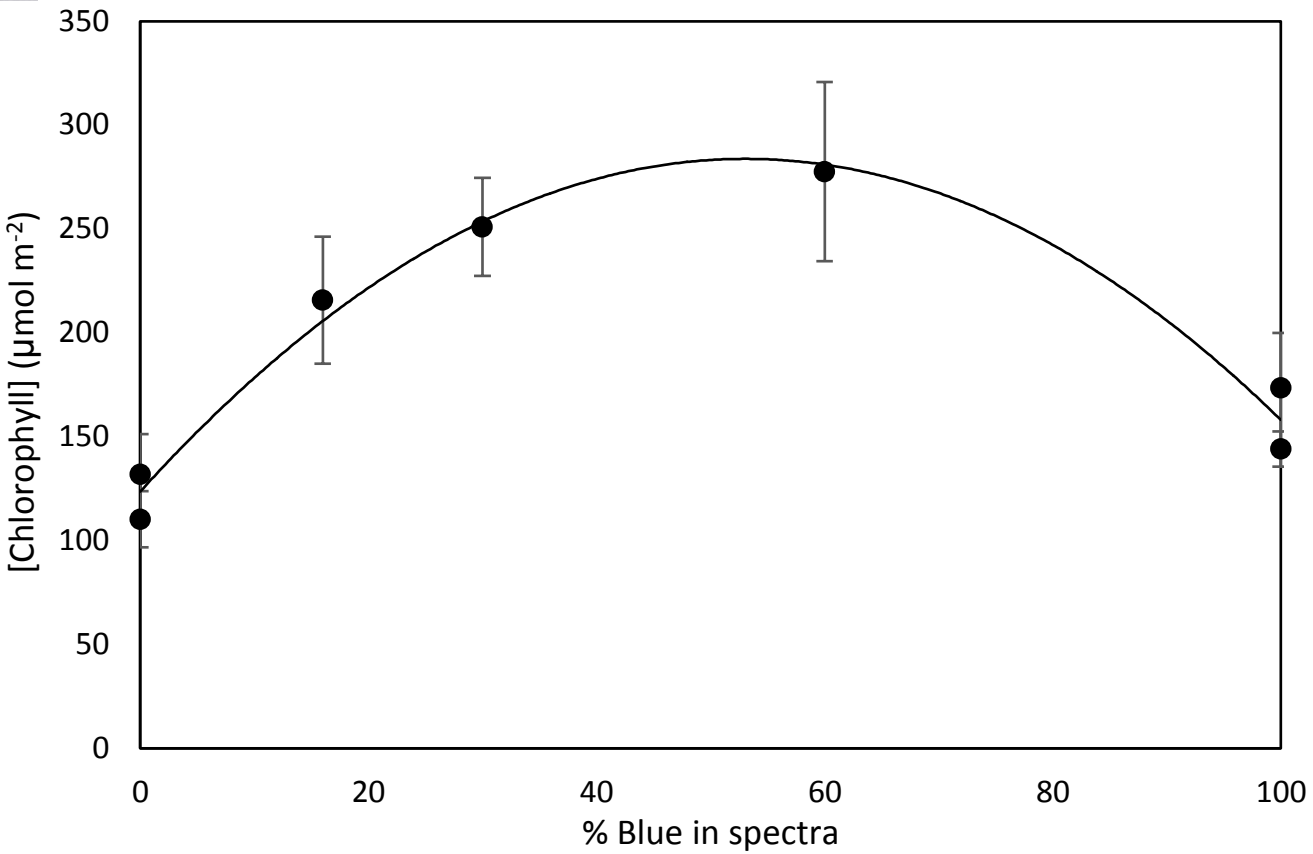
Movie by Prof. R Hangarter
http://plantsinmotion.bio.indiana.edu/plantmotion/earlygrowth/photomorph/photomorph.html

How plants sense light quality

UVB light responses



Secondary metabolism



Leaf morphology

100% RED

60% BLUE

Red: blue effects on leaf morphology

100% red | 11% blue | 30% blue | 60% blue | 100% blue

Increasing blue percentage

Red: blue effects on plant height

Increasing blue percentage

Far-red effects on plant height

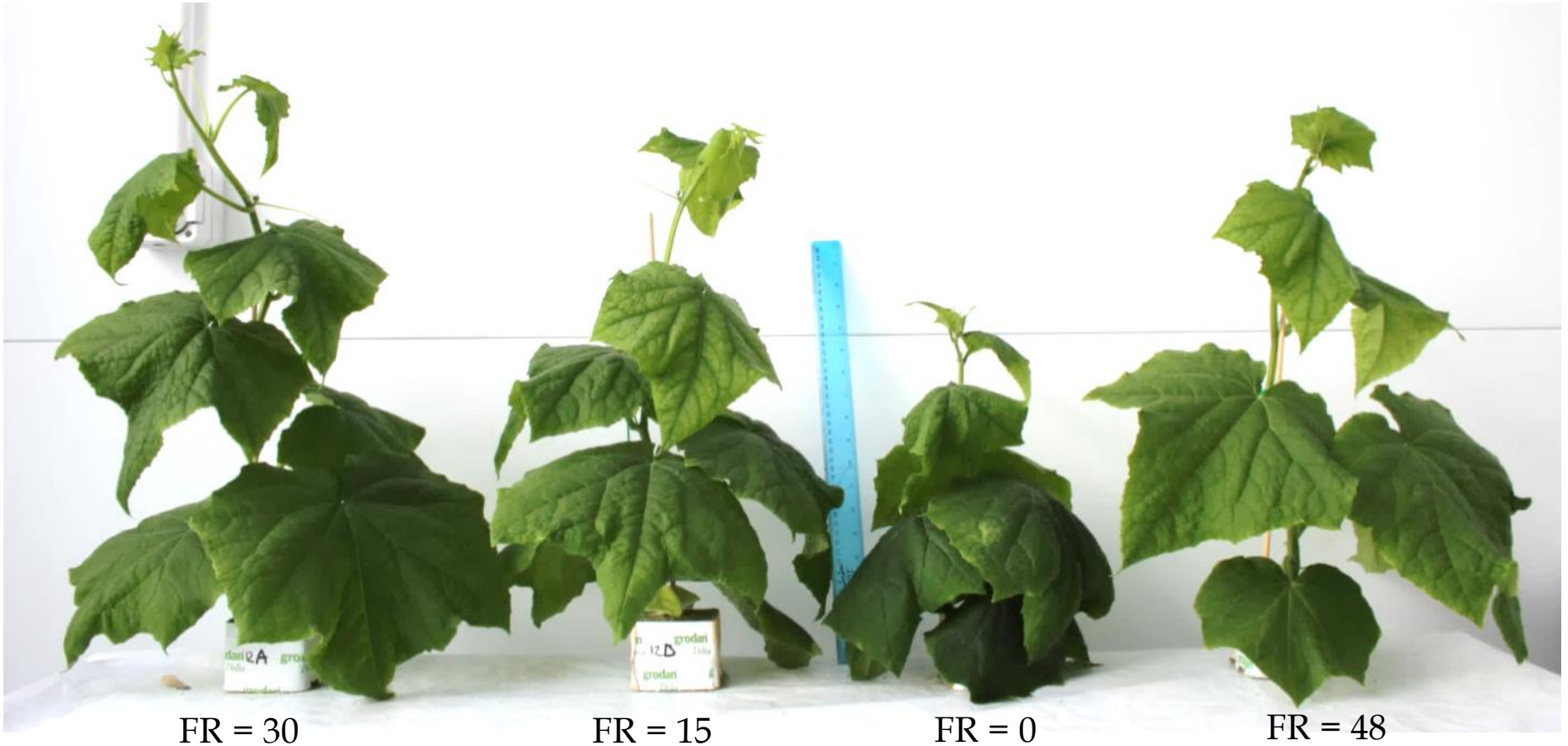
FR = 0
µmol m^{-2} s^{-1}

FR = 15
µmol m^{-2} s^{-1}

FR = 30
µmol m^{-2} s^{-1}

Increasing far-red intensity

Far-red effects on plant height



FR = 30
µmol m^{-2} s^{-1}

FR = 15
µmol m^{-2} s^{-1}

FR = 0
µmol m^{-2} s^{-1}

FR = 48
µmol m^{-2} s^{-1}

Far-red effects on leaf morphology

How do we make use of this information?

FR = 0 µmol m^{-2} s^{-1} | FR = 18 µmol m^{-2} s^{-1} | FR = 24 µmol m^{-2} s^{-1} | FR = 40 µmol m^{-2} s^{-1}

Increasing far-red intensity

Modelling plant light responses

$$L = L_D - (R_B - R_G + R_R - R_{FR}) \quad (1)$$

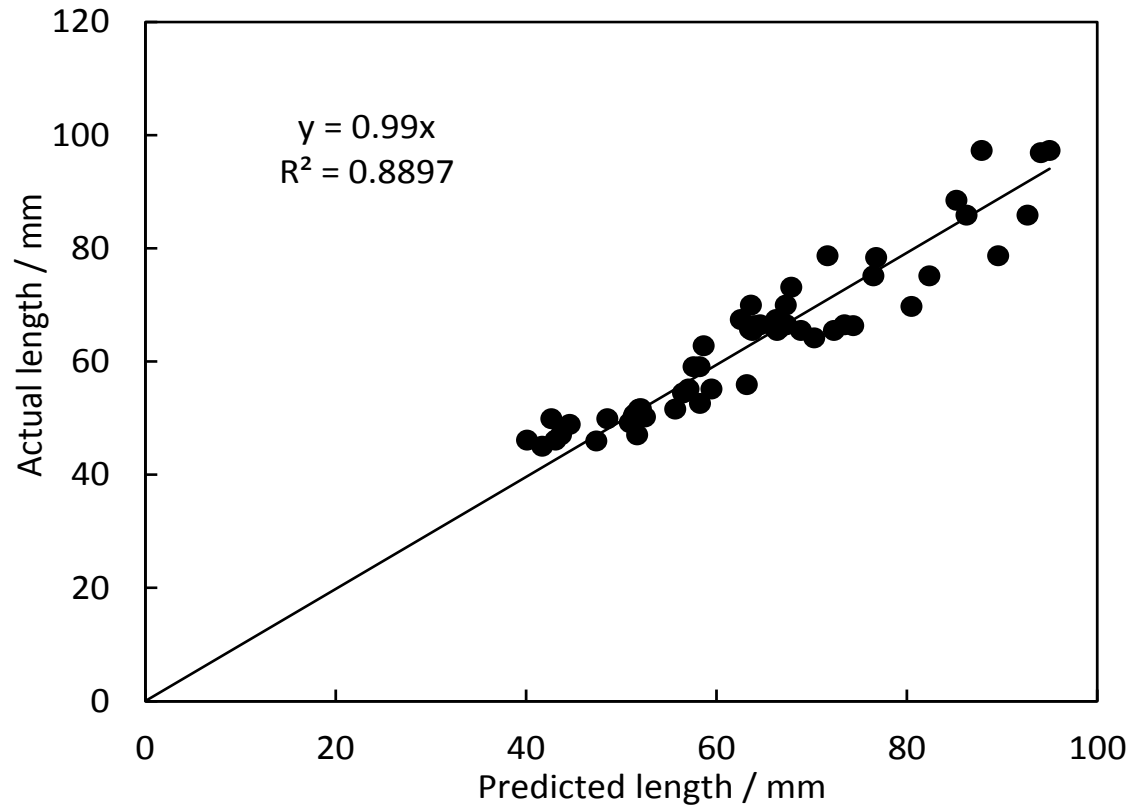
where

$$R_B = a * 1 - e^{(-\alpha\frac{b}{a})} \quad (2)$$

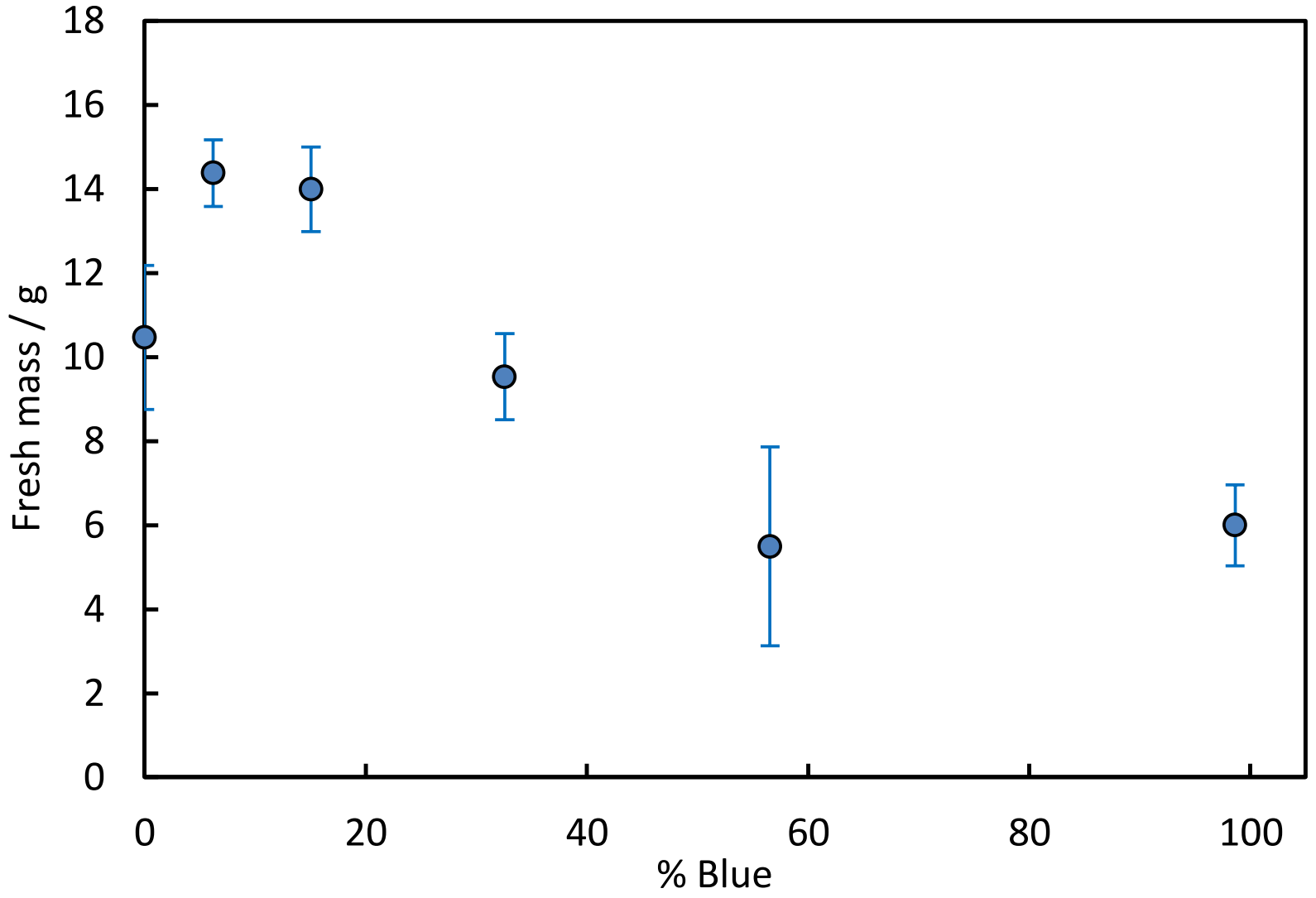
$$R_R = b * 1 - e^{(-\beta\frac{r}{b})} \quad (3)$$

$$R_{FR} = c * FR$$

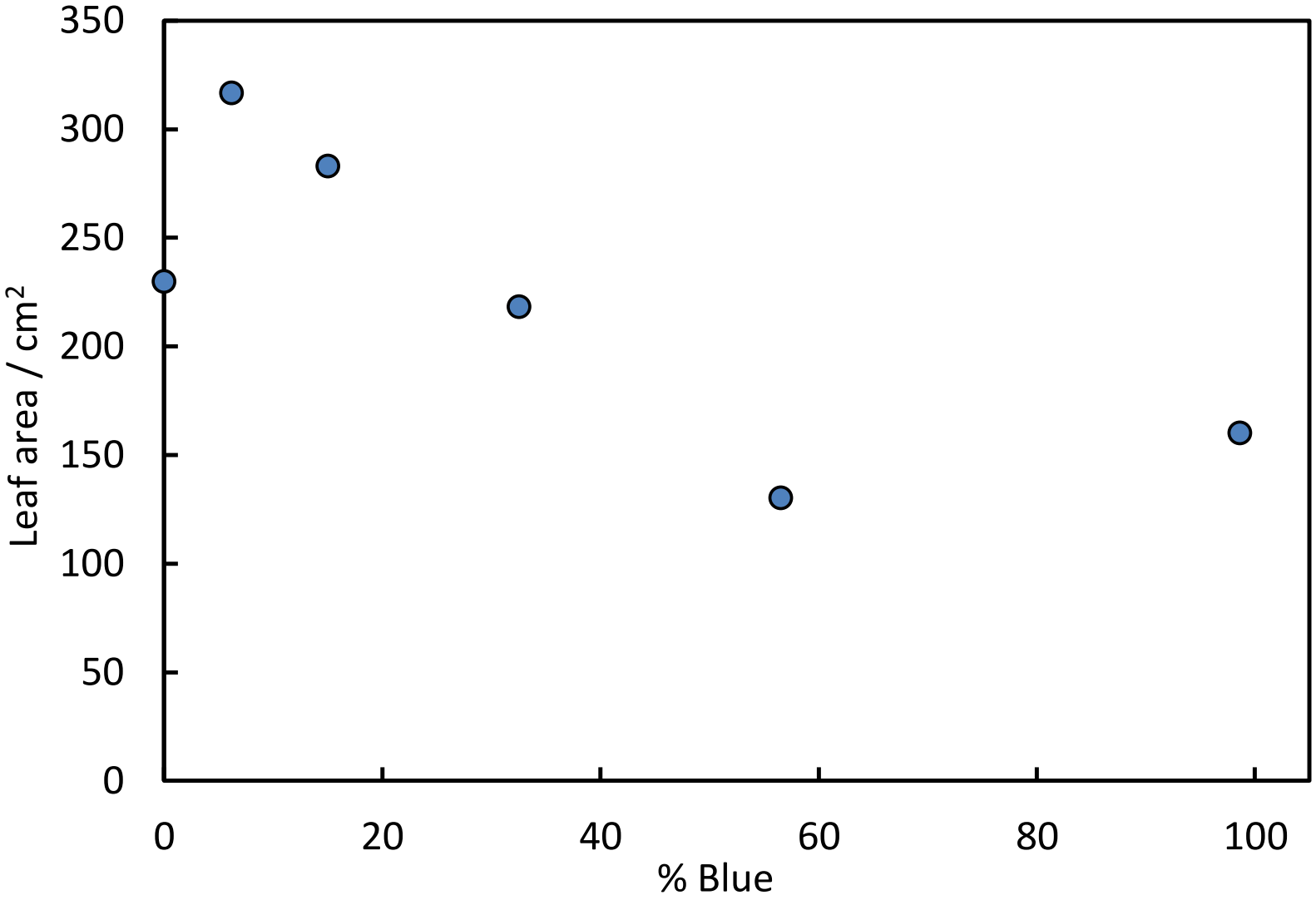
$$R_G = d * G$$



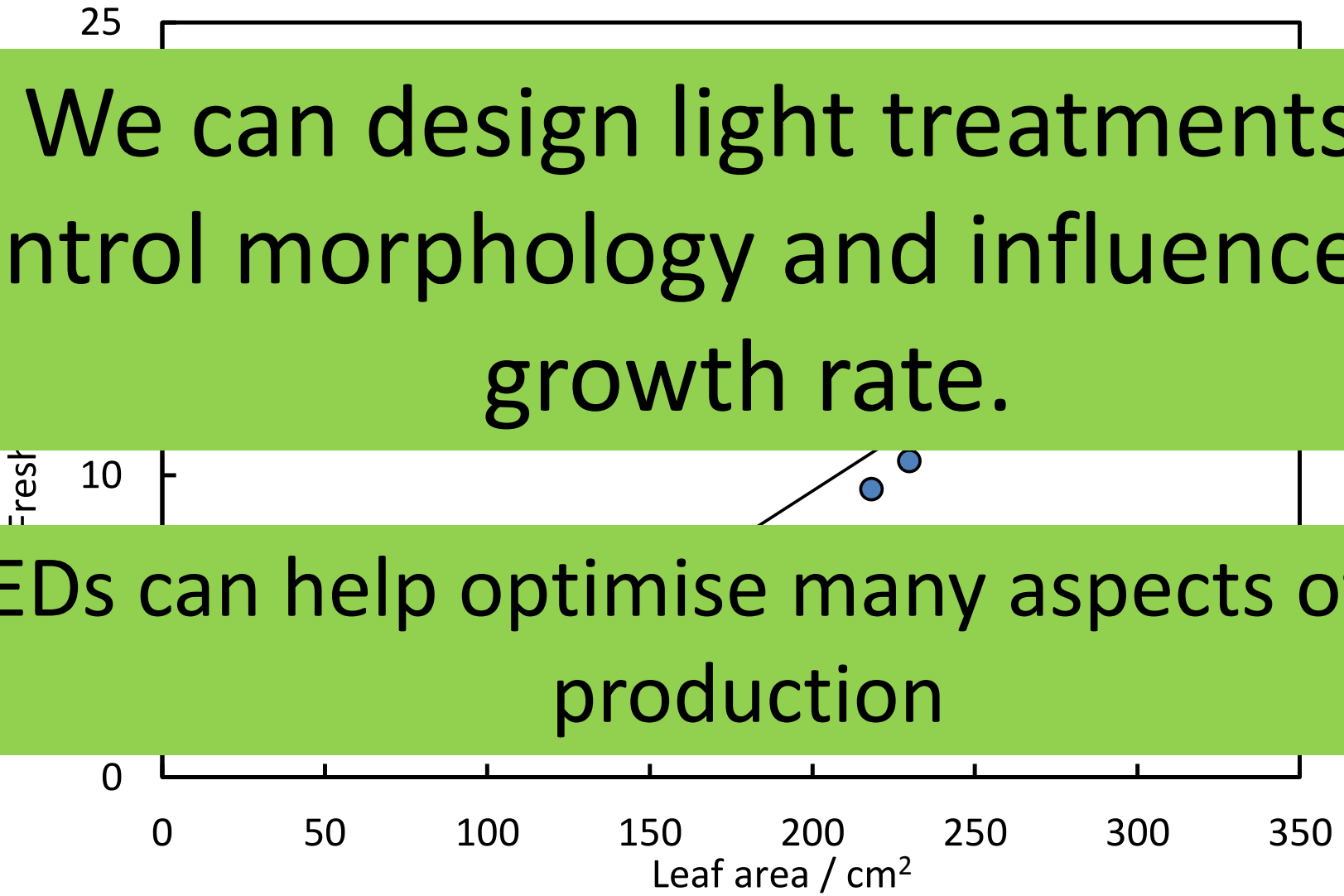
Effect of blue light on Tomato fresh mass



Effect of blue light on Tomato leaf area



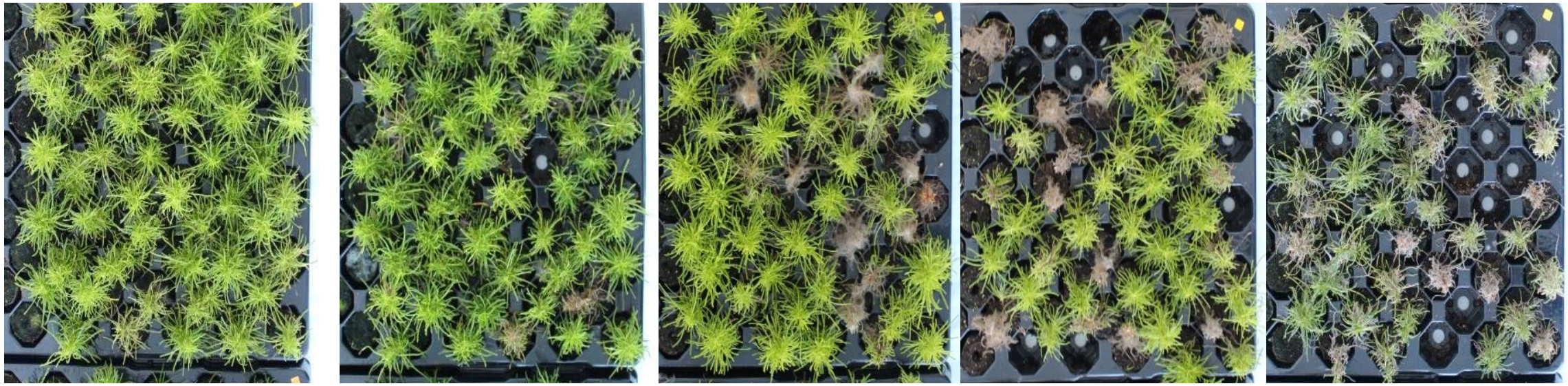
Leaf area strongly influences growth rate



We can design light treatments to control morphology and influence their growth rate.

LEDs can help optimise many aspects of crop production

Improving propagation



0% BLUE
(100% RED)

9% BLUE

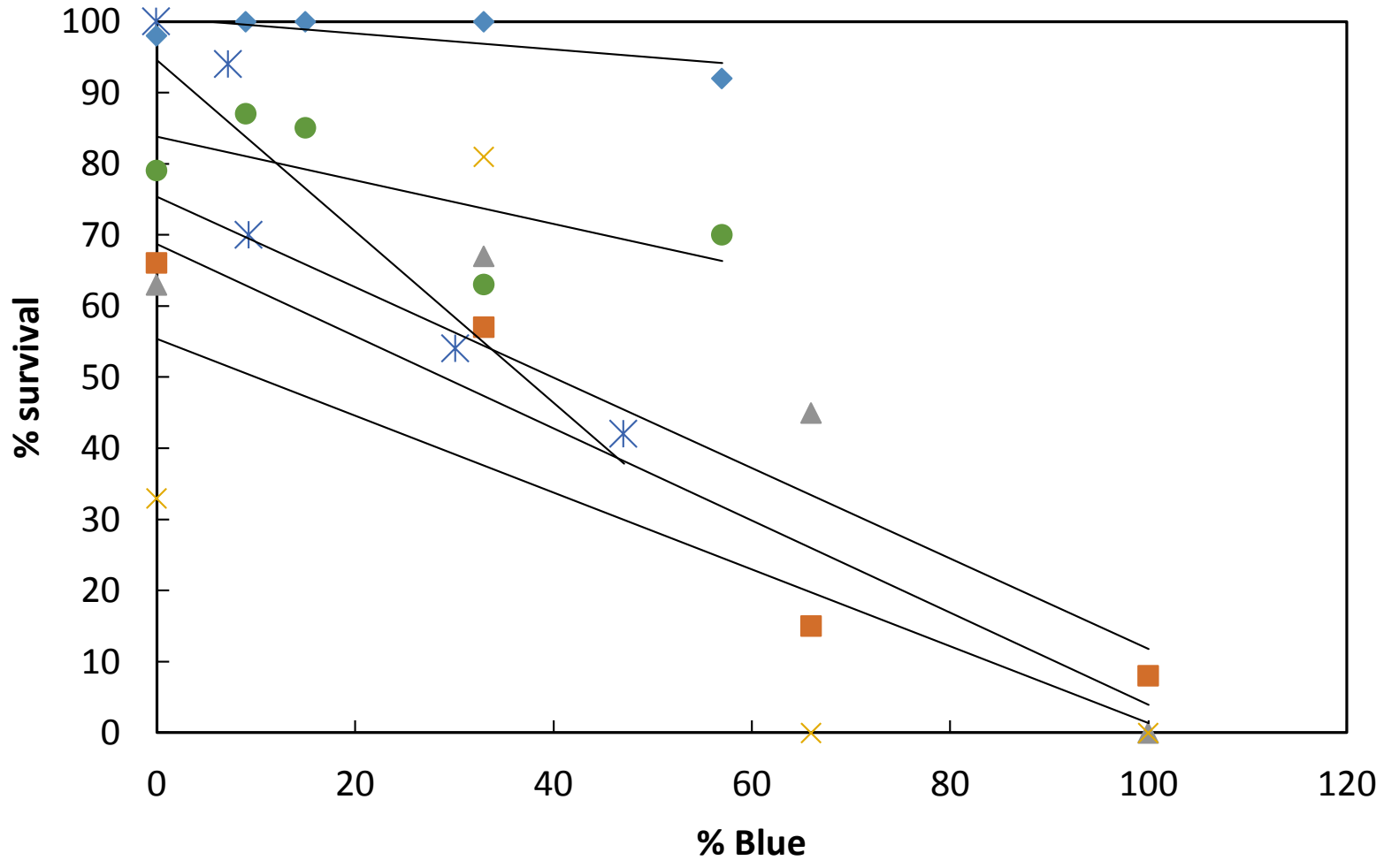
11% BLUE

30% BLUE

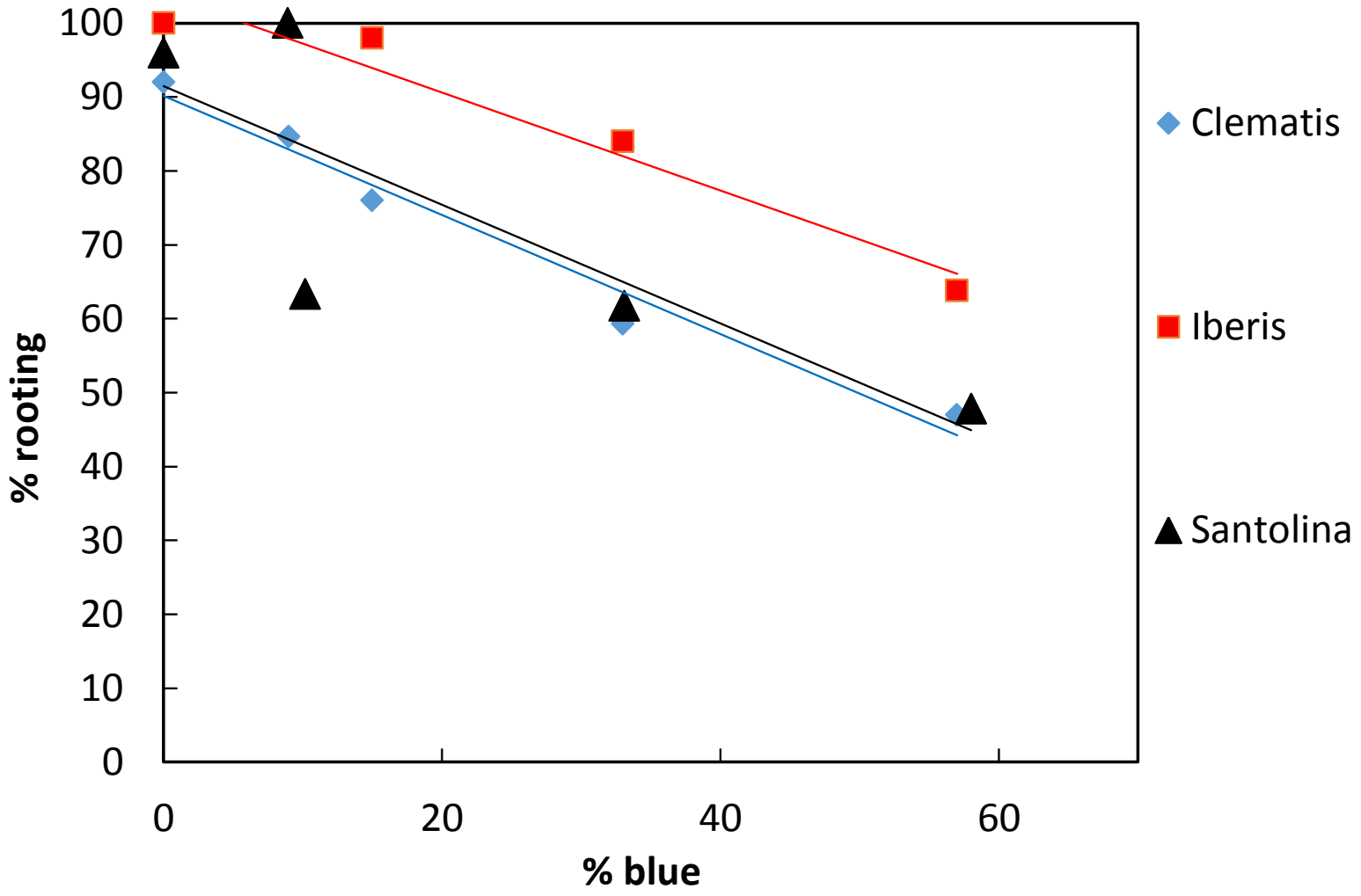
60% BLUE

Blue light stresses cuttings

Blue light reduces cutting survival



But survival does not mean cuttings will root.

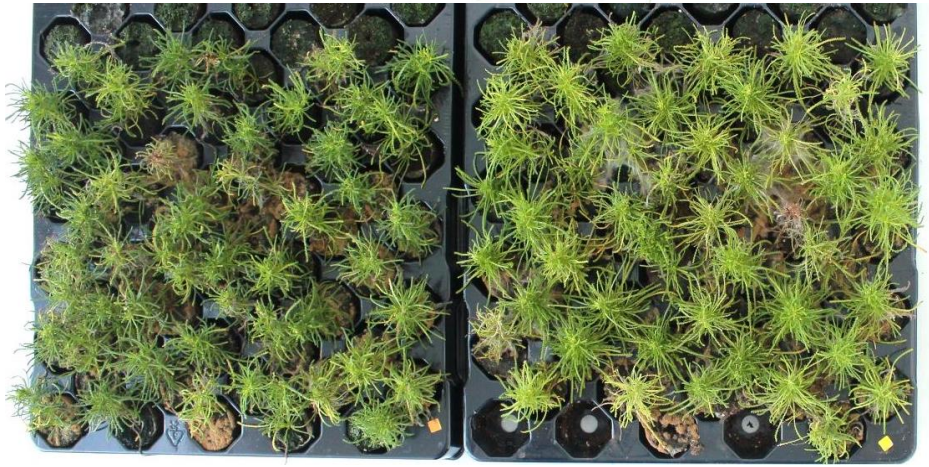


Influence of far:red on rooting

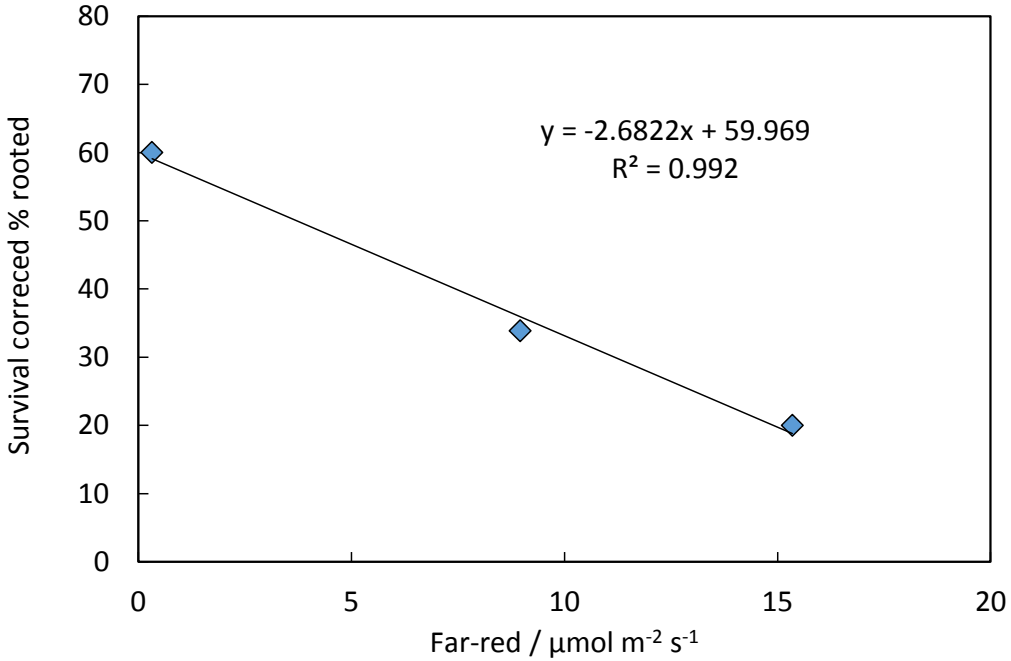
Santolina

T4
15%B

R3
15%B
+FR



Clematis data



Chrysanthemums showed no negative responses to far-red so again there are differences in sensitivity between species.

Benefits of lighting mother stock

Supplemental lighting

No light

Day length extension lighting

Cuttings lit with 0% BLUE (100% RED) Low stress

Survival and rooting poor if pre-excision lighting inappropriate

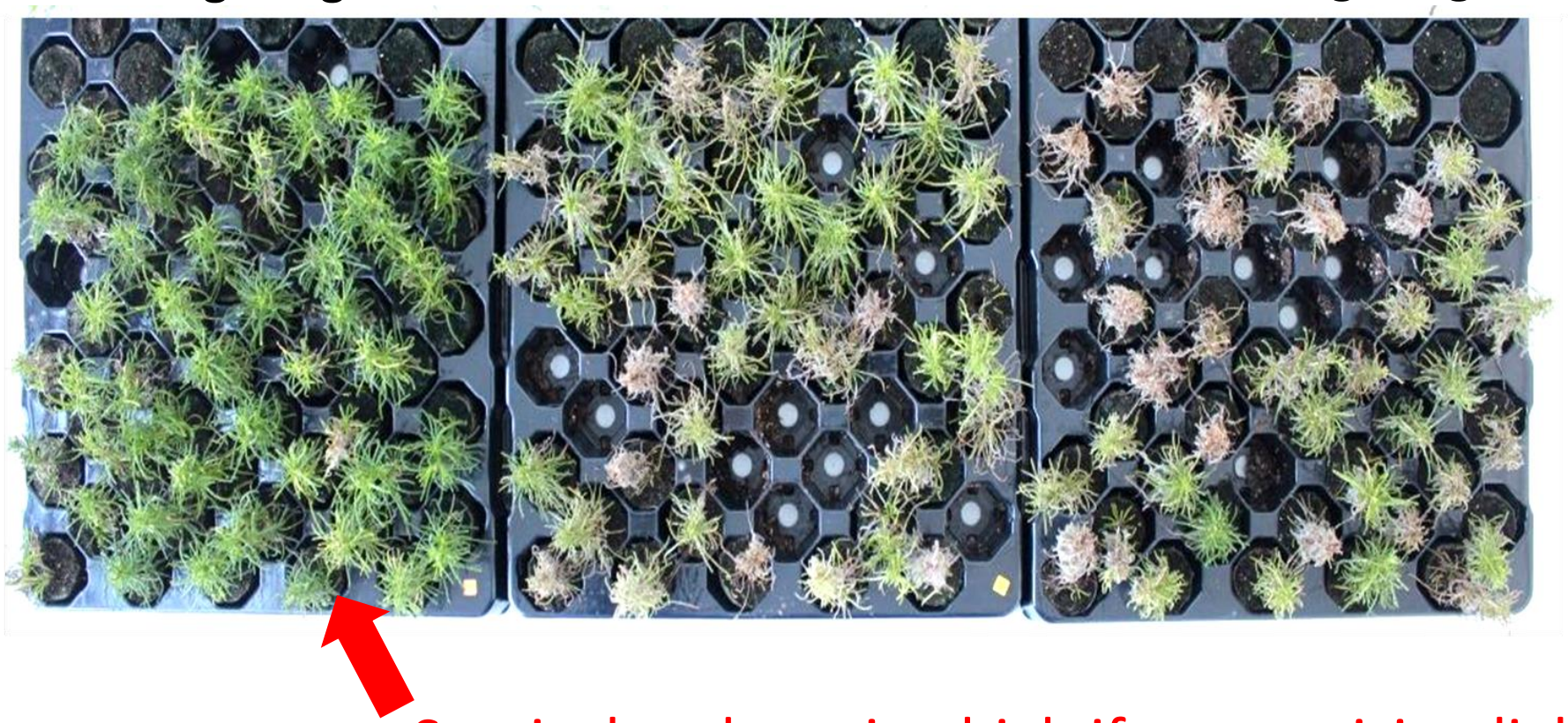
Benefits of lighting mother stock

Supplemental lighting

No light

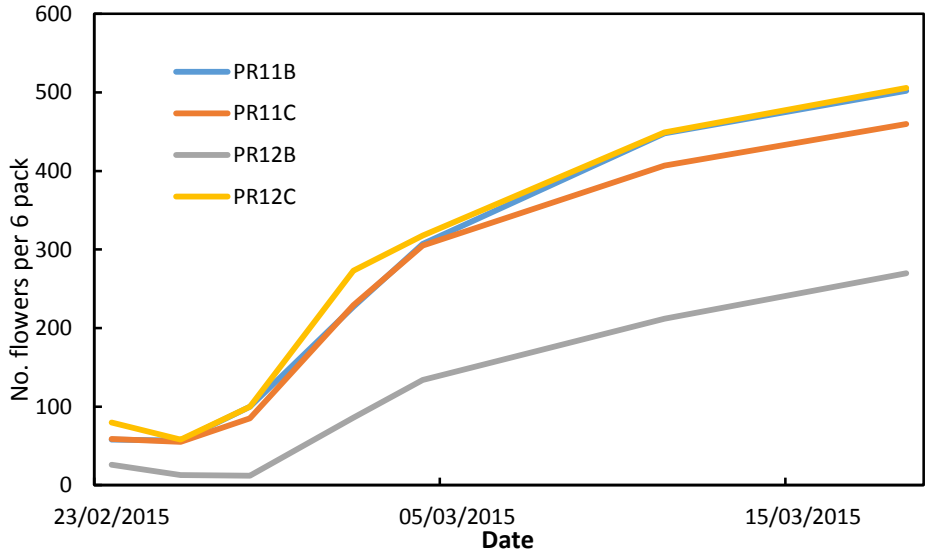
Day length extension lighting

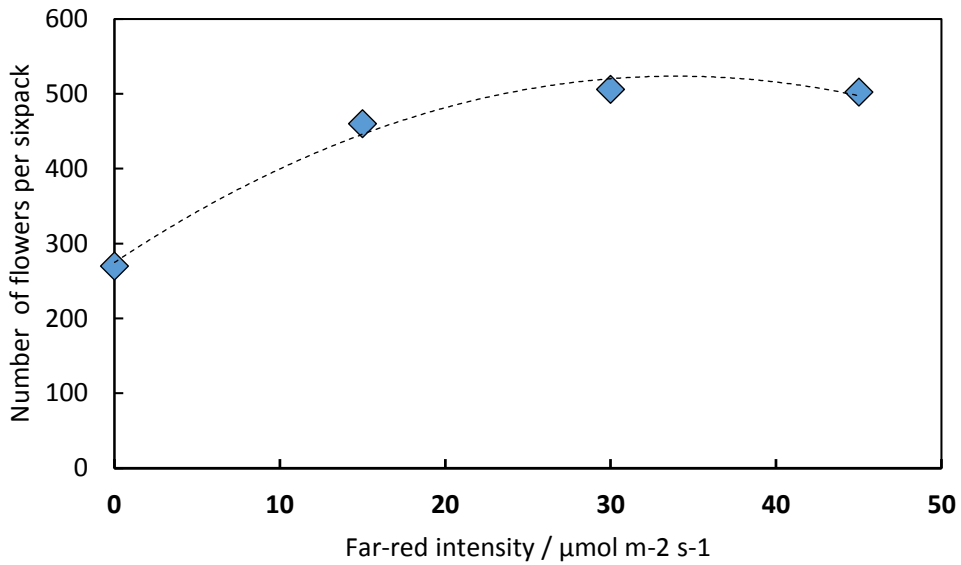
Cutting lit with 60% BLUE High stress



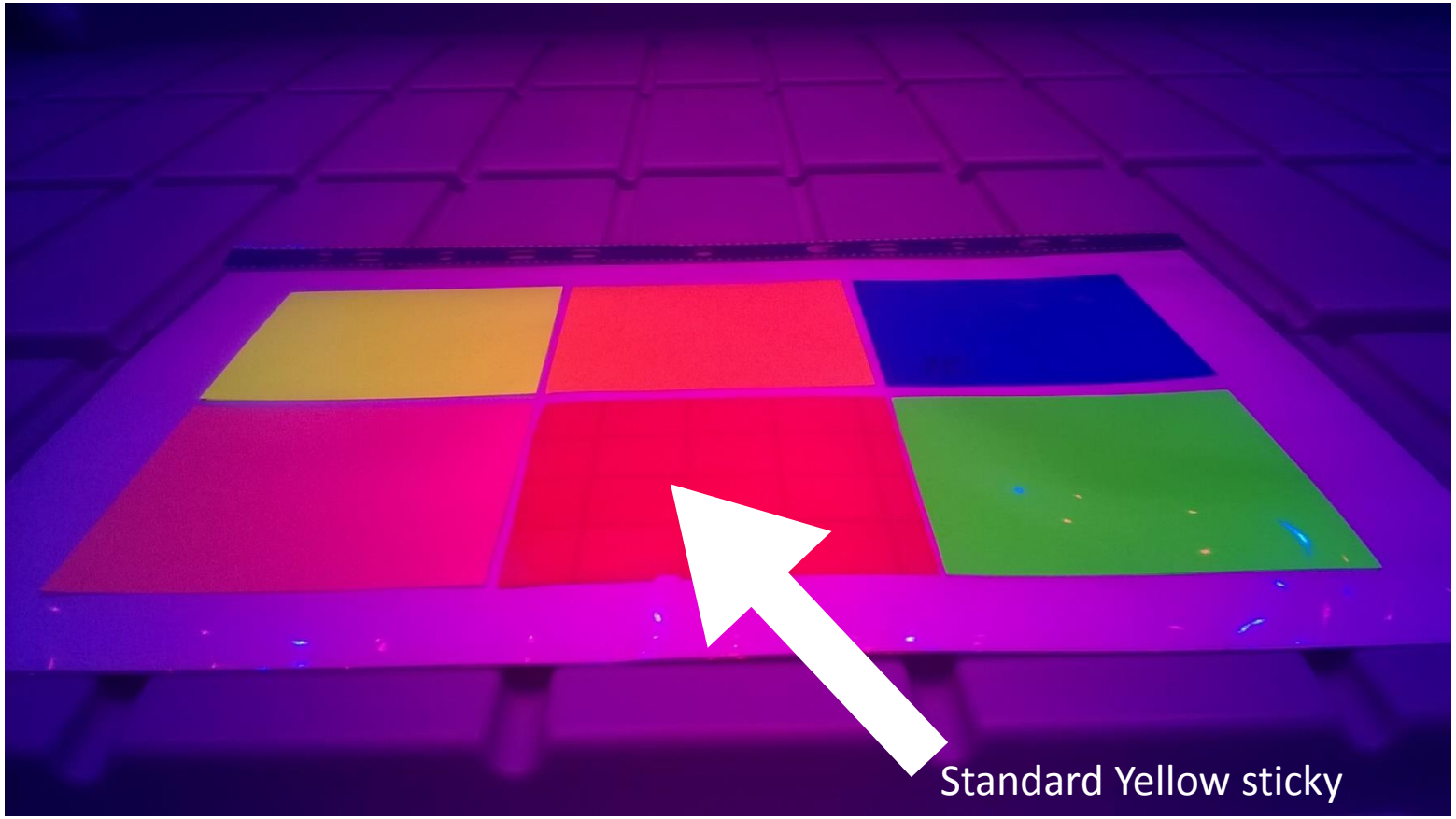
Survival and rooting high if pre- excision lighting appropriate even under stressed conditions

Flowering time

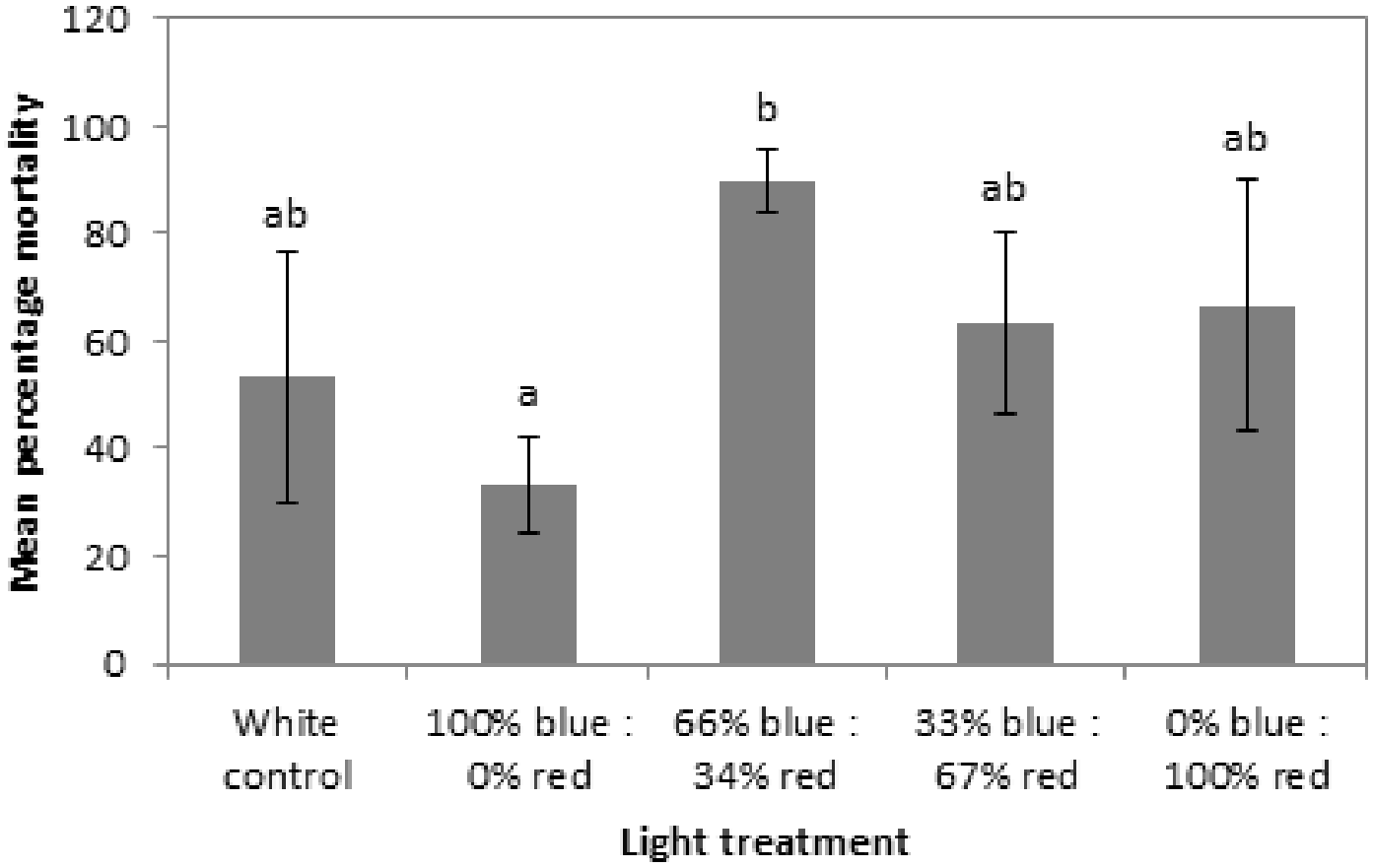




Pest monitoring under LED ligths



Pest performance under LED lights



Further information

- CP125 reports available at the following link https://horticulture.ahdb.org.uk/project/understanding-crop-and-pest-responses-led-lighting-maximise-horticultural-crop-quality-and
- CP139 report available at the following link https://horticulture.ahdb.org.uk/project/knowledge-transfer-commercial-review-lighting-systems-uk-horticulture
- AHDB Technical Guides are available at the following link https://horticulture.ahdb.org.uk/led-principles-and-practice
- LED4CROPS website - http://www.led4crops.co.uk/

Thanks to…

- Dr Rhydian Beynon-Davies
- Mr Adam Omerod
- Dr Martin McPherson

STC

LED4CROPS
Stockbridge Technology Centre
Lighting the future for horticulture

AHDB
HORTICULTURE

THE HORTICULTURAL TRADES ASSOCIATION
HTA
Est'd 1899

emt
east malling trust