

Exploring & exploiting the physiology for a full control of plants in vertical farms

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General trends

- Citizens: no environmental impact
(licence to produce)
- Consumers:
health, safe, quality, sustainable
Supermarkets are leading (licence to deliver)
- Legislation (world, national, regional)
- Urbanisation (50% in cities -> 70%)
- globalisation
- Growing population (7→ 9 billion) →
60% increase in food/feed demand by 2050
- Natural resources are scarce
(water, energy, minerals)

History: wall glasshouses and frames



First half of 20st century



cucumbers

grapes



Modern greenhouses



Ever increasing control of production



LEDs opens opportunities for vertical farming

- Full control production process
- Limited area
- Anywhere
- Independent of environment
- Sustainable, but needs lot of electricity
- Guarantee on quantity and quality
- 2-3 times higher costs



Many new possibilities with LED

- Energy efficient:
 - HPS: $1.8 \mu\text{mol}/\text{J}$
 - LED: up to $\pm 3 \mu\text{mol}/\text{J}$
- Spectrum
- Direction (position)
- Timing
- No NIR
- Hardly heat radiation



It is not just about the lights

- All climatic conditions (temperature, CO₂, air humidity, air flow)
- Water and nutrients

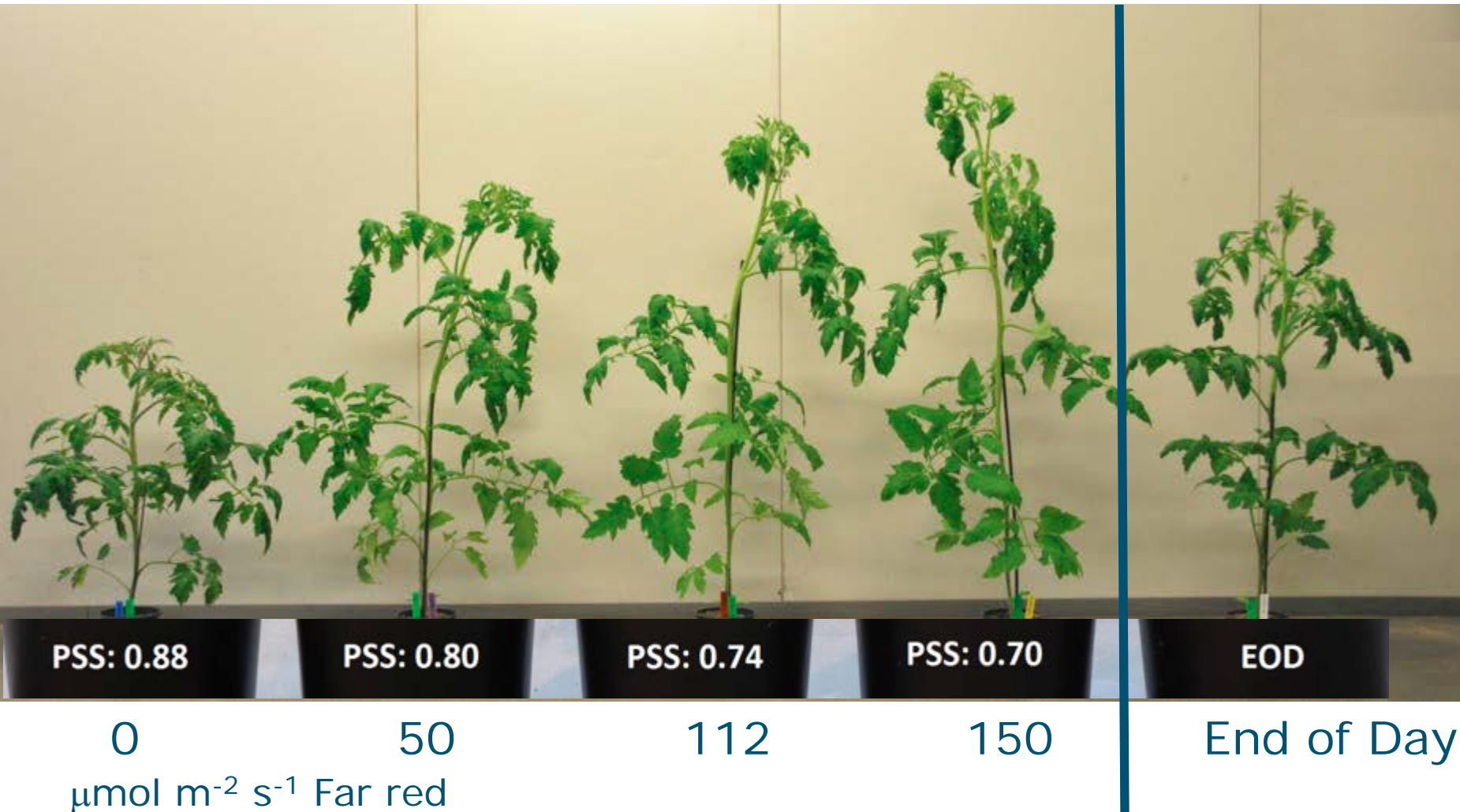


How sustainable is vertical a farm?

- No pesticides (ultimate hygiene, disinfection)
- Very little nutrient use
- Extreme limited water use
 - E.g. tomato
 - Open field: 60liter / kg
 - Modern greenhouse 17 liter /kg
 - Vertical farm: few liters / kg
- Extreme limited land use
- Less transport
- Less food waste
- Energy use needs tremendous effort

Example of controlling growth

Effect of adding Far red to Red+Blue LEDs



Example of controlling growth

Effect of blue light

- Solar spectrum (plasma lamp)
- Total intensity ($100 \mu\text{mol m}^{-2} \text{s}^{-1}$)
- Blue LED 0-50% and 100-50% solar spectrum
- High blue fraction \rightarrow low light interception
 \rightarrow high leaf photosynthesis rate

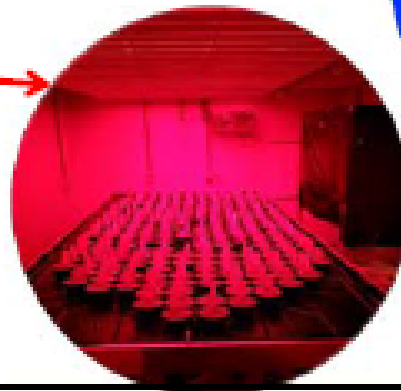
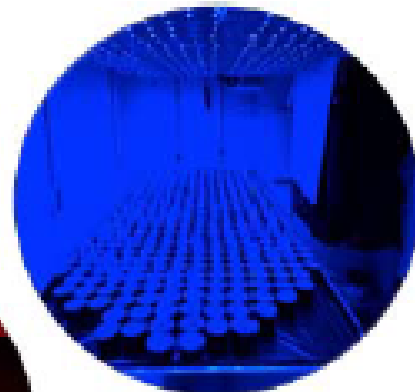


Comparing 40 tomato genotypes under different light environments

Light environments

Climate room; LED lights
 $16 \text{ h } 150 \mu\text{mol m}^{-2} \text{ s}^{-1}$

- Control: UV-B, White, FR
- 88% RED / 12% Blue
- 100% Blue
- 100% Red
- Control + extra FR



Light spectrum affects growth and morphology (pictures from 1 genotype)



Control

100%R

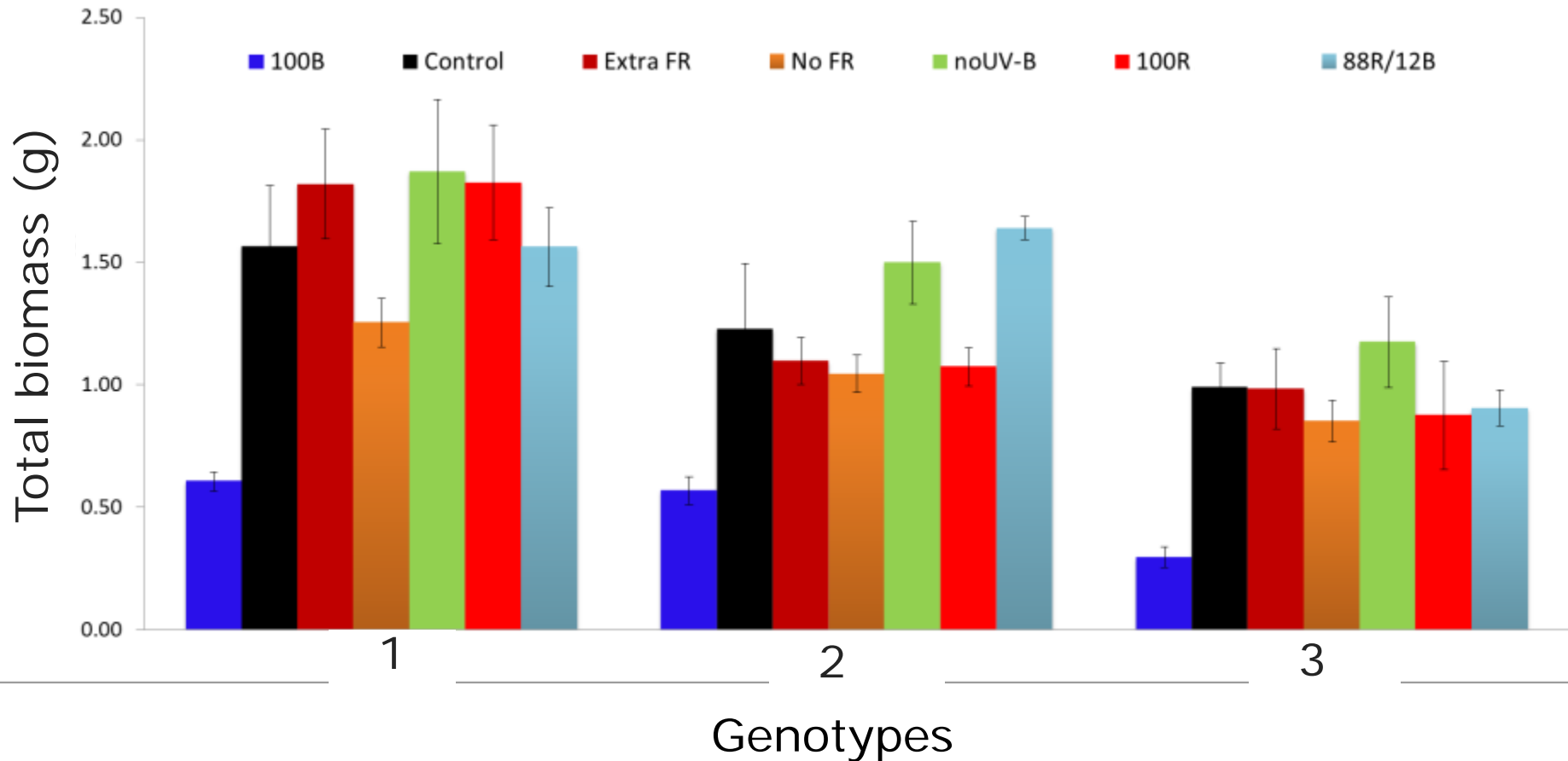
88R/12B

100%B

Control
Extra FR

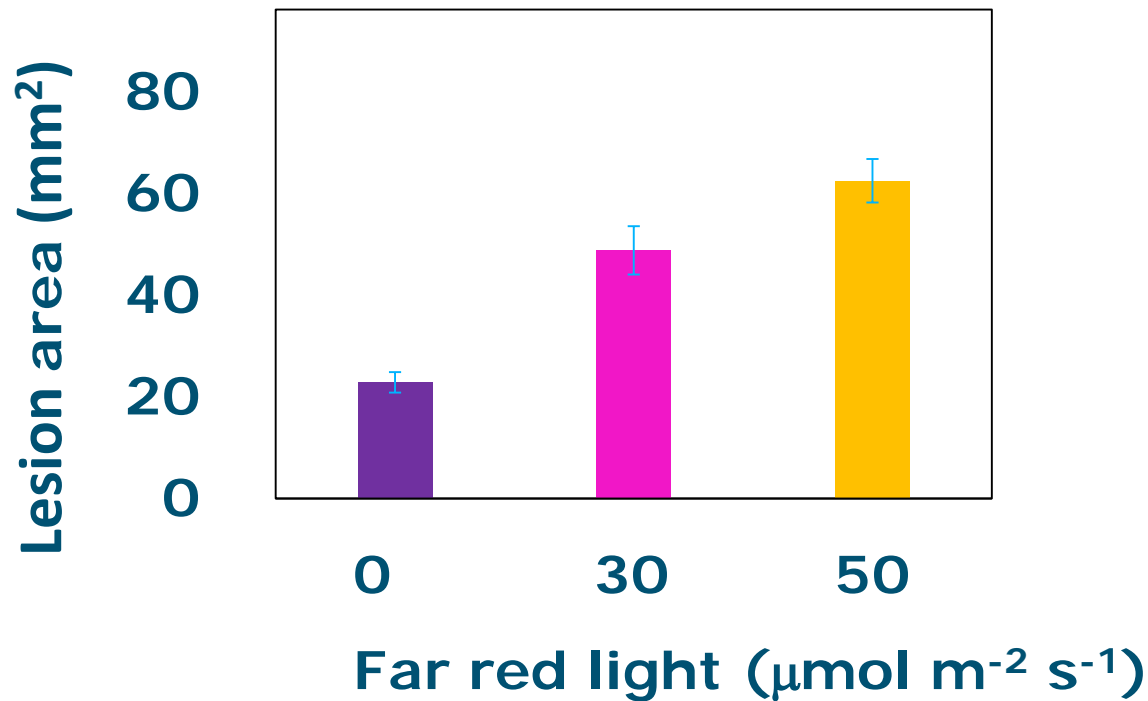
Total biomass

Response of some genotypes



Besides growth we can control diseases.

Ratio red to far red light may affect susceptibility for botrytis (tomato)



By light we can control quality



By light we can control quality

**High
(500)**

**Medium
(240)**

**Low
(50)**

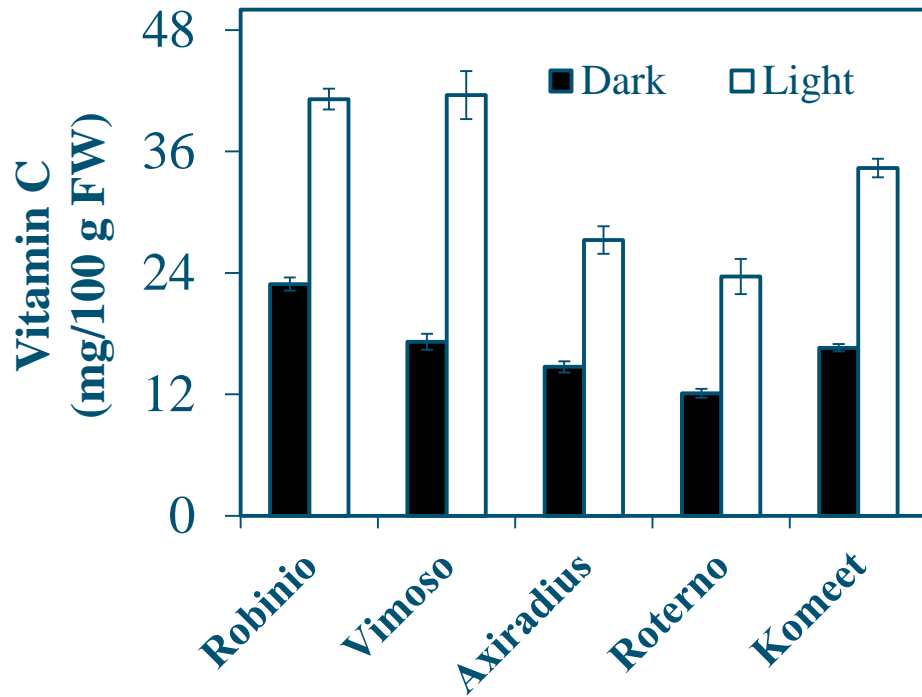


**13 days after
harvest**

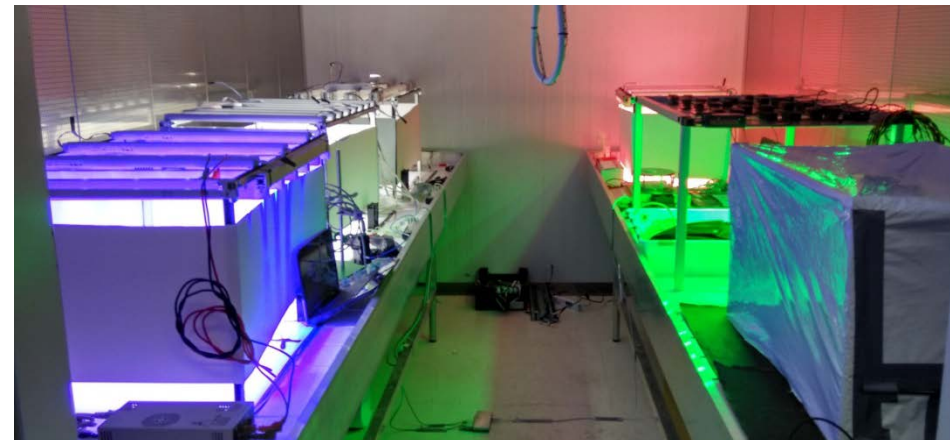


**21 days after
harvest**

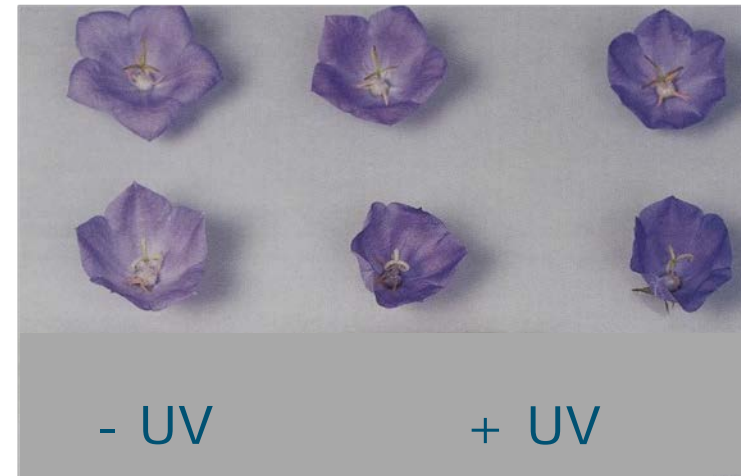
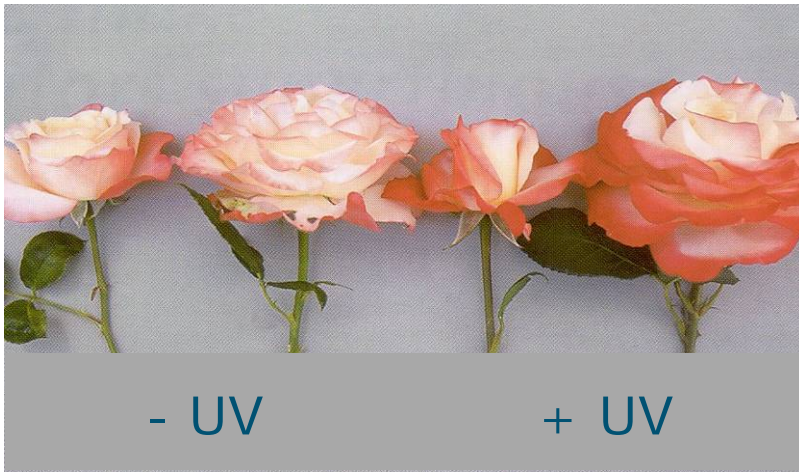
Light on tomato fruit → more vitamin C



Light ($300 \mu\text{mol m}^{-2} \text{s}^{-1}$) compared to darkness
From: Ntagkas et al, unpublished



Light spectrum (UV) for control of flower or leaf colour



Picture from Beßler, LVG Ahlem



Pre- and Post-harvest lighting for quality of fruits, vegetables, ornamentals

Cut lettuce, after 5 days

In darkness



In light



Conclusions on vertical farming

- Full control of production and quality possible
- We are still exploring, while exploiting

Thank you for your attention !



Course on lighting:
7- 9 Feb 2018
12-14 Feb 2018

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