The photosynthetic effects of different light colours on tomato growth and production

A model study

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Light in horticultural: 2 main functions

Photosynthesis and growth:
ASSIMILATION LIGHT

- PAR light (400 - 700 nm)
- Interacts with CO_2 and temperature

Quality (plant morphology, flowering):
STEERING LIGHT

- UV, purple, blue (300- 450 nm)
- Red (600 – 700 nm)
- Far red (700 – 800 nm)

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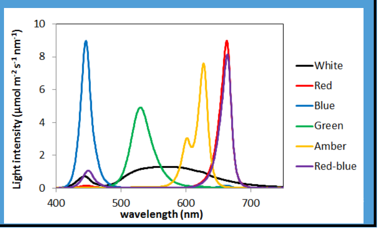
Advantages LEDs

- More efficient conversion of electricity to light than HPS (reduction of energy use)
- Rapid change in intensity and spectral light composition
- Can be placed close or within the crop
- Spectral composition on the basis of the needs of the crop
- Long life-time



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Effect of LEDs on photosynthesis

- Young plants
- Cultivation
  - blue, green, red, white
- Measurements
  - Cultivation colour, or red/blue
  - Effect on initial light use efficiency ε
  - Effect on maximum carboxylation capacity VC_{max}

light intensity (µmol m^{-2} s^{-1})	blue, green, red, white	red/blue
200	ε	ε
1500	-	VC_{max}

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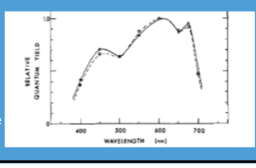
Relative gross photosynthesis rate

Light colour of cultivation	200 µmol m^{-2} s^{-1} under the same colour	200 µmol m^{-2} s^{-1} under red/blue	1500 µmol m^{-2} s^{-1} under the same colour	1500 µmol m^{-2} s^{-1} under red/blue
blue	0.81	1.05	n.a.	1.28
green	0.89	0.95	n.a.	0.92
red	0.95	0.96	n.a.	0.98
white	1.00	1.00	n.a.	1.00

- Under the same colour: short-term
- Under red/blue: long-term



McCree 1972

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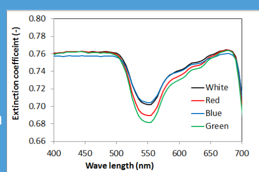
Scenario studies

- Blue light can have an effect on stomatal opening and chlorophyll content
- Green influences morphology
- Red is most efficient for photosynthesis

- Potential effects
- Only assimilation (light)
- Carry-over effects assumed
- Intkam model
  - LED wavelength distribution
  - Light extinction
  - Effect on ε and VC_{max}



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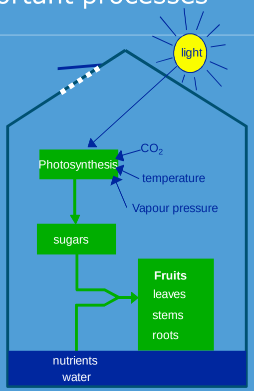
Intkam: the most important processes

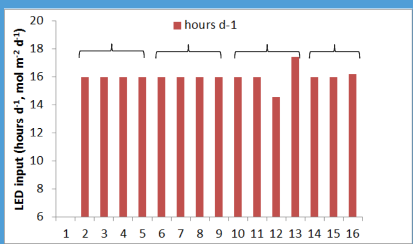
- Photosynthesis
- Maintenance
- Crop growth
- Sink strengths
- Organ growth
- Development
- Transpiration



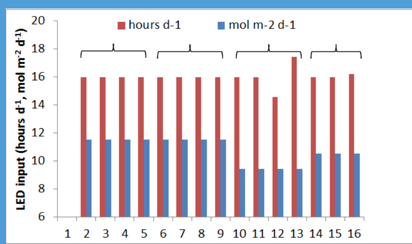
Scenarios

#	lighting strategy (intensity in µmol m^{-2} s^{-1})	remark
1	None	actual solar radiation
2-5	16 hrs blue, green, red, white (200)	no solar radiation
6-9	16 hrs blue, green, red, white (200)	10 µmol m^{-2} s^{-1} solar radiation during daytime
10	2 hrs blue (50) + 14 hrs red (180)	
11	2 hrs green (50) + 14 hrs red (180)	
12	14.56 hrs red LED (180)	
13	2 hrs blue (50) + 13.45 hrs red (180) + 2 hrs green (50)	a) actual solar radiation b) LED during Oct - April if outdoor global radiation < 350 W m^{-2}
14	2 hrs blue (200) + 14 hrs red (180)	
15	2 hrs green (200) + 14 hrs red (180)	
16	16.22 hrs red (180)	

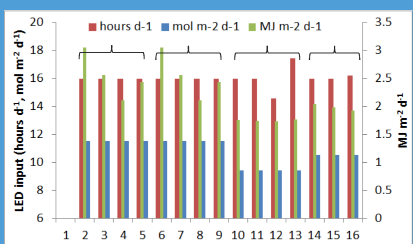
Scenario studies: LED hours



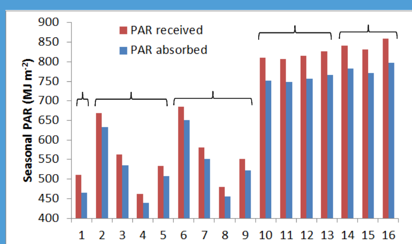
Scenario studies: LED moles



Scenario studies: LED MJ

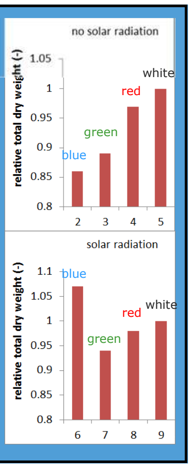


Scenario studies: PAR



Scenario studies

- LED lead on average to 12% increase compared to only solar radiation
- Total dry matter production is related to initial light use efficiency ε
- Effects of ε dominate effects of PAR_{abs}
- Low light conditions!
- Results for fruit production almost similar to total dry matter production



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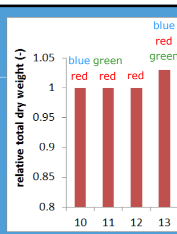
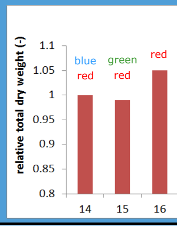
Scenario studies

- Duration of LED matters
- Intensity of LED matters
- Effect of VC_{max} very limited (2-4%)





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Summary

- Differences in the initial light use efficiency for different light colours caused different simulated total dry matter productions.
- The effects of differences in maximum carboxylation capacity proved small during the winter season with low light levels.
- Results concern potential effects; effects on leaf morphology and crop architecture were not incorporated

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Thanks

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HI-LED

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