Smart Materials for greenhouses

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Long term goal

New greenhouse production systems will utilize **sunlight** in a very efficient way since they will be covered with **smart and adaptable** materials. Solar light at any climate zone in the world is converted in a form (**quantity**, **quality**, **geometrical distribution**) exactly needed by the crop to produce fresh products with **high yield**, **good taste**, **high healthy components** with a minimum input of natural resources.

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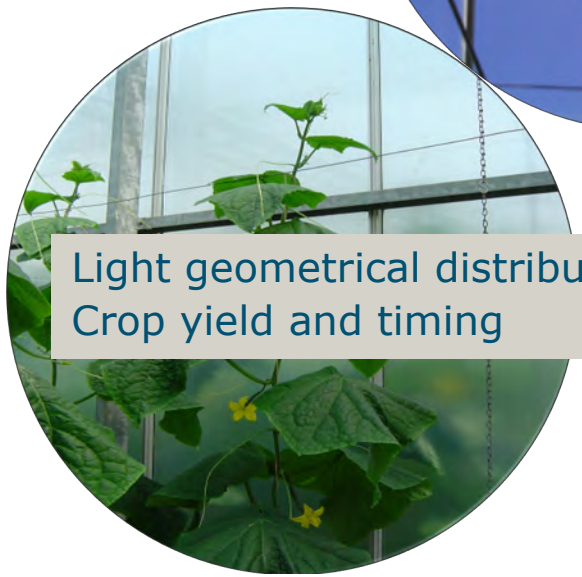
High-value fresh food production

High value crops
High nutritional value

Light quality as "signalling effect"
Crop development and morphology
Nutraceutical content

Light quantity
Driving force for photosynthesis
Crop yield and quality

Greenhouse=solar collector
Free energy for crop



Light geometrical distribution
Crop yield and timing

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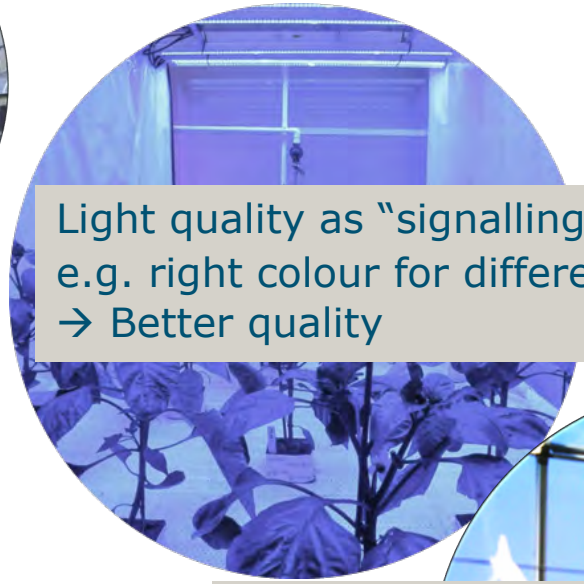
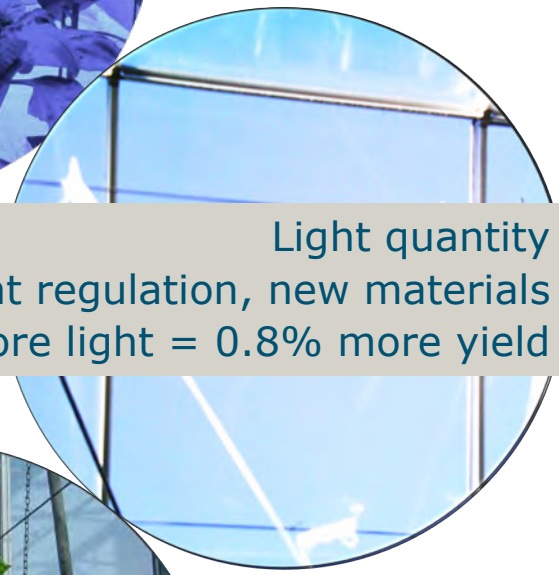
High value crops
High nutritional value

Smart humidity control

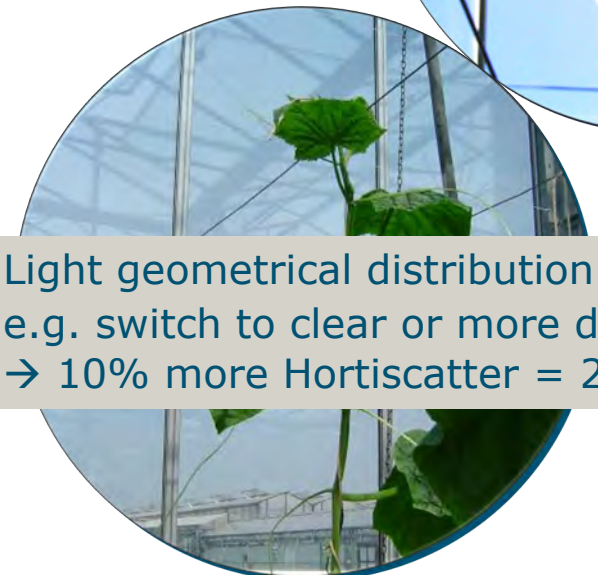


Light quality as “signalling effect”
e.g. right colour for different crop stage
→ Better quality



Light quantity
e.g. light regulation, new materials
→ 1% more light = 0.8% more yield

Greenhouse=solar collector
e.g. high insulation for heat capturing
→ Energy saving



Light geometrical distribution
e.g. switch to clear or more diffusion
→ 10% more Hortiscatter = 2-3% more yield

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Coordinator

Academic partners

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Supported by:

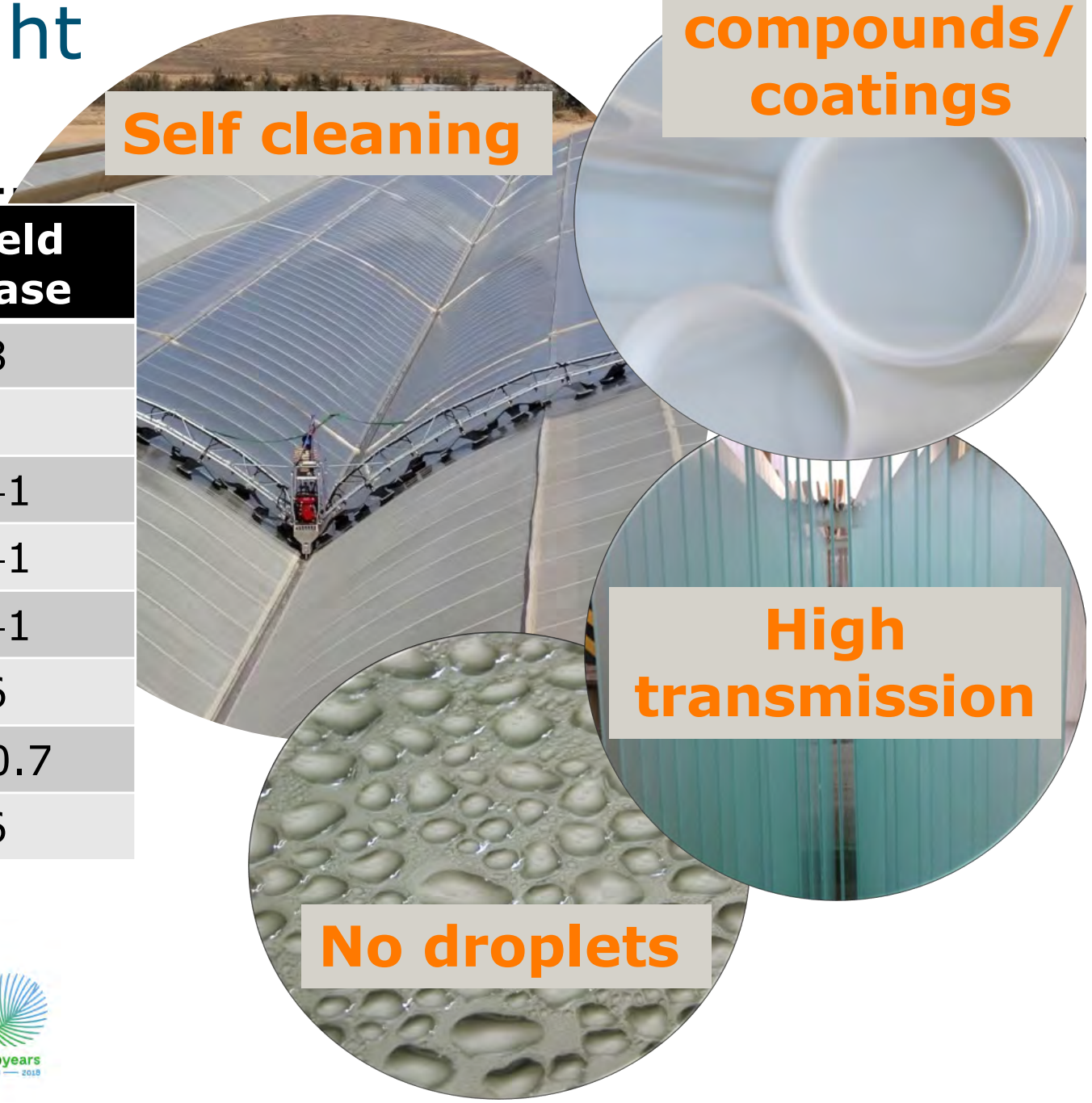
Ministerie van Economische Zaken

Light intensity
Plants 'eat' light

1 % light increase..

Crop	% Yield increase
Lettuce	0.8
Radish	1
Cucumber	0.7–1
Tomato	0.7–1
Rose	0.8–1
Chrysanthemum	0.6
Pointsettia	0.5–0.7
Ficus benjamina	0.6

Marcelis et al., 2006



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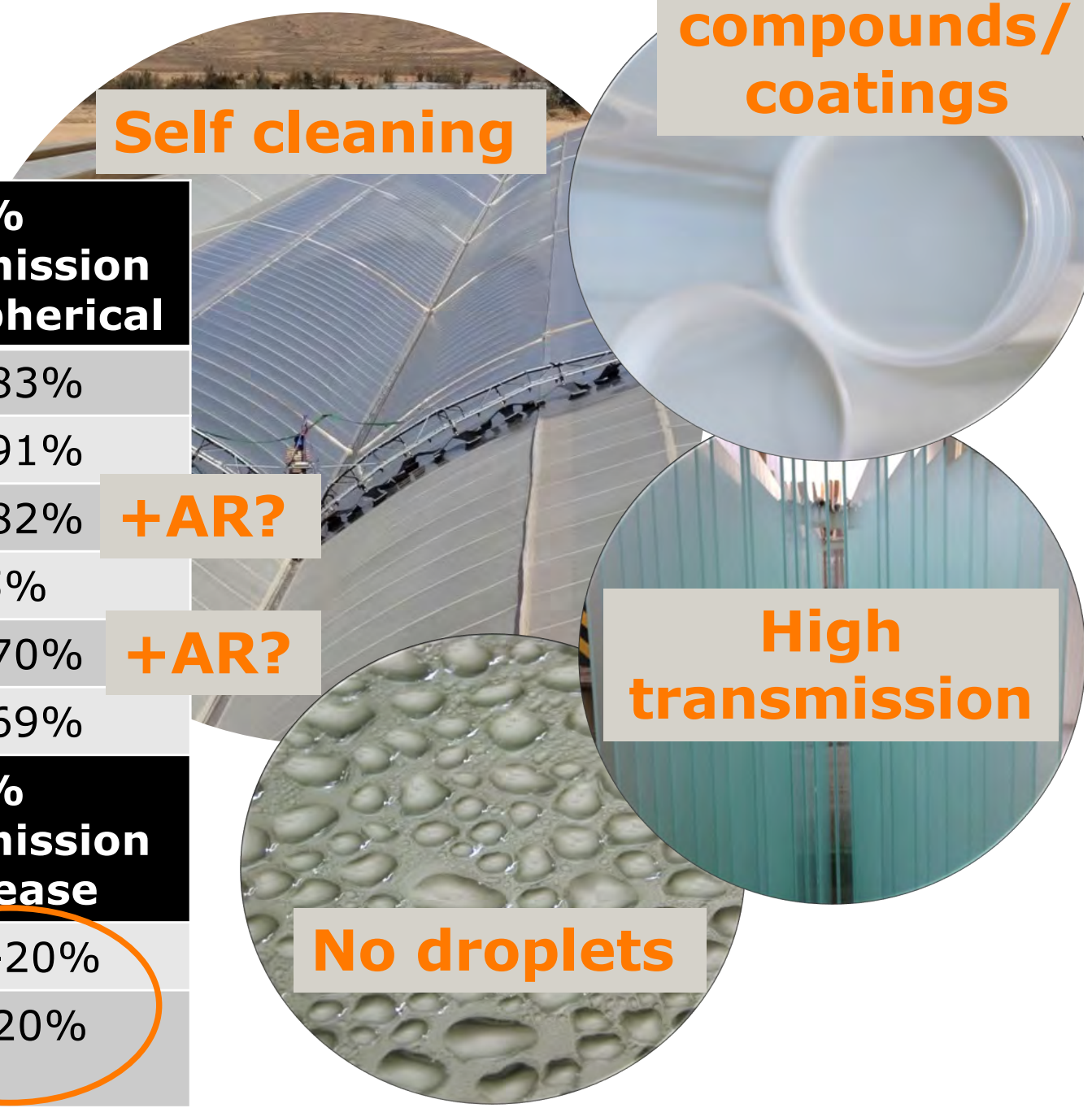
Light intensity

	% transmission hemispherical
Glass	82-83%
Glass & AR	89-91%
PE / EVA films	78-82%
PVDF	85%
PC double sheet	60-70%
Bubble film	67-69%

	% transmission increase
Cleaning	+10-20%
No-drop condensation	+4-20%

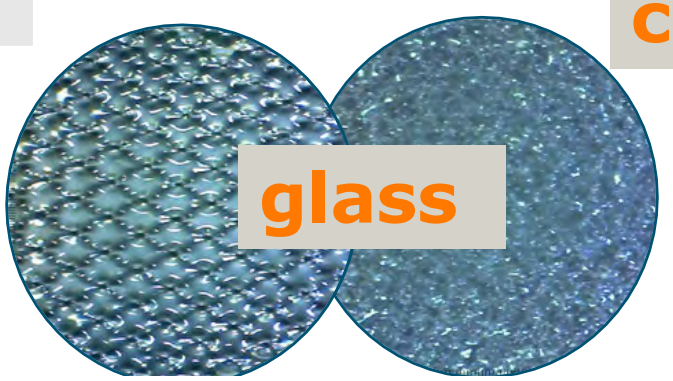



Permanent anti-drop
Self-cleaning

Plants like diffuse light

10% Hortiscatter increase

Crop	% Yield increase
Tomato	2.5-3.5
Tomato winter artificial light	1.1
Cucumber	2.7-4.8
Cucumber winter	2.5
Rose	1.7
Diverse potplants Increased growth and development	7-9



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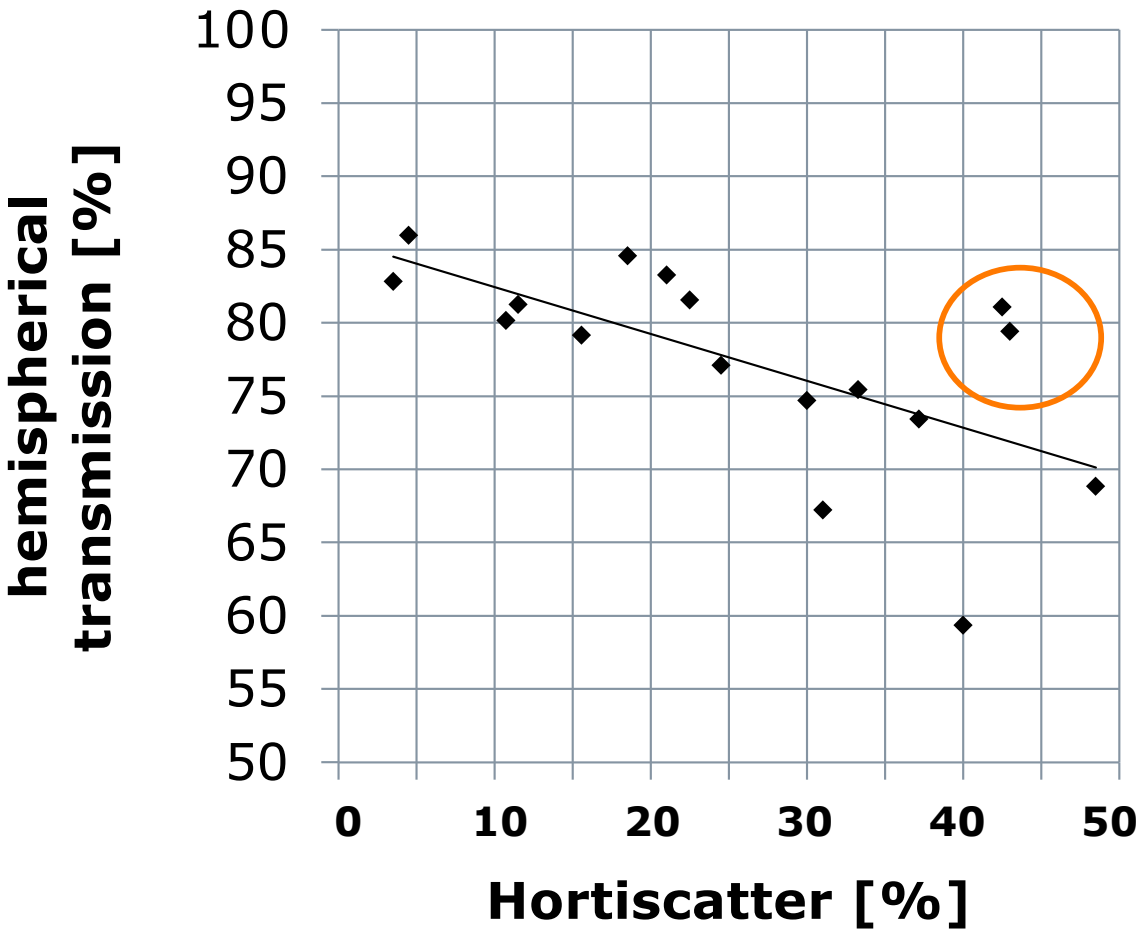
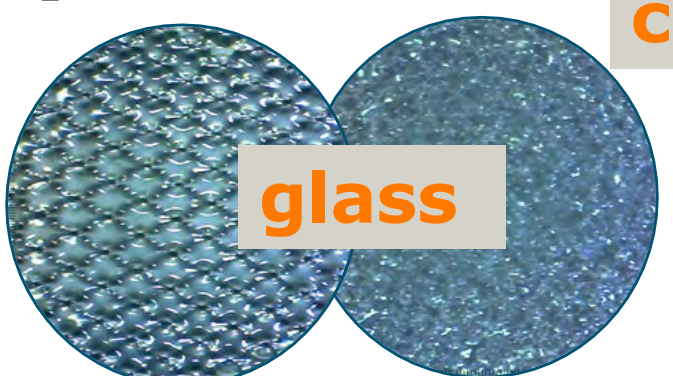
Light diffusion



Combine high diffusion with high light transmission



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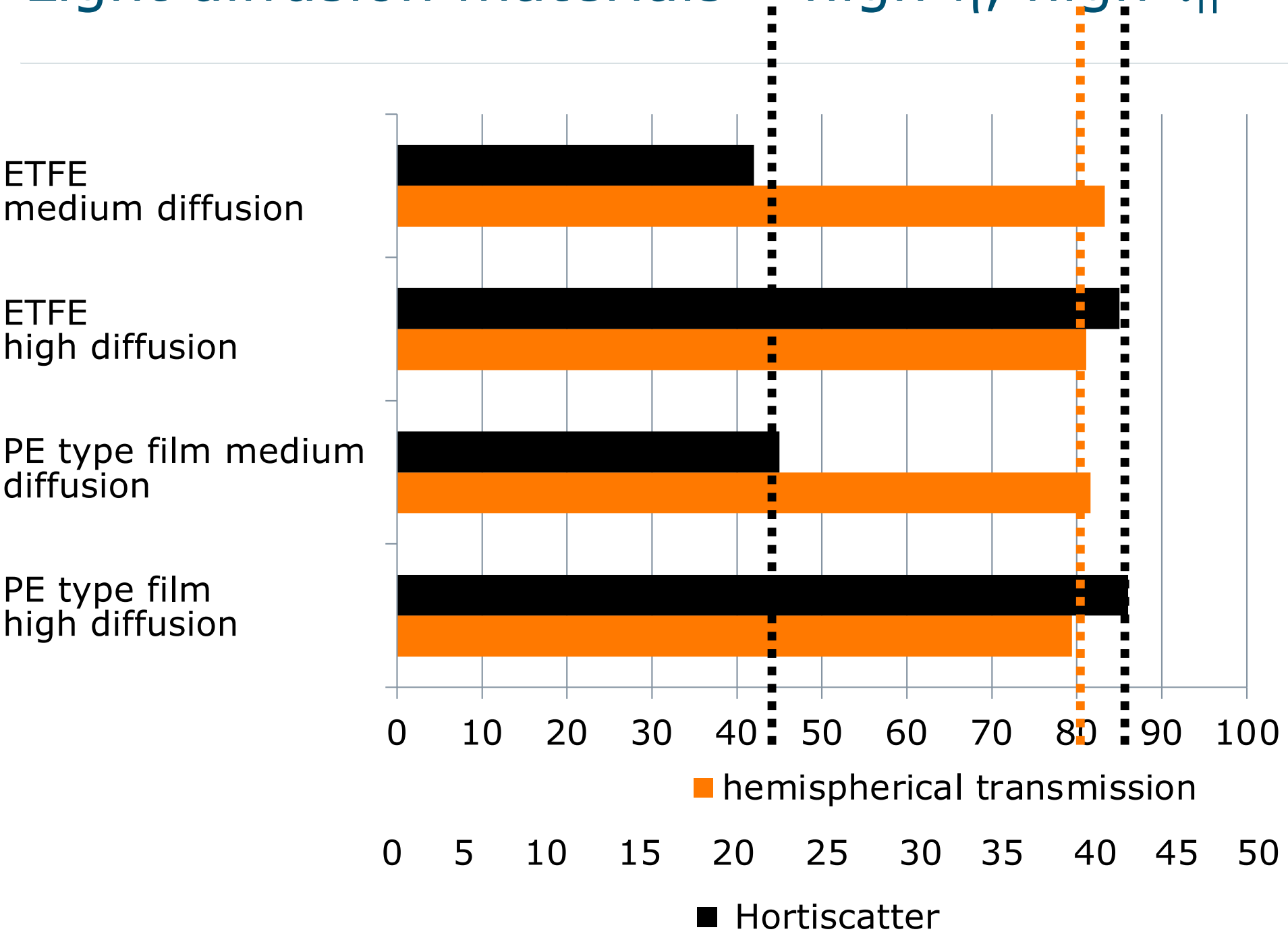
Light diffusion materials – high η, high τ_h



Experiment *young tomato plants* under highly diffusing material

Question:

Do highly diffusing materials (Hortiscatter ca. 95%) have additional value above commercially available diffuse materials (Hortiscatter ca. 45%)

- Climate chamber
- Short duration
- Small scale
- Young plants

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Experiment young tomato plants

Energy saving

→ FIR transmissivity
→ FIR emissivity
→ Thermal conductance

	u-value
Glass	7.6
Glass low-ε	5.7
PE films	10.1
EVA films	8.5
ETFE	8.2
PC double sheet	3.6
Bubble film	3.3

Hemming et al., 2011, Acta Horticulturae 893
Hemming et al., 2004, WUR report A&F 100
Tantau, Landtechniek 68(1), 2013

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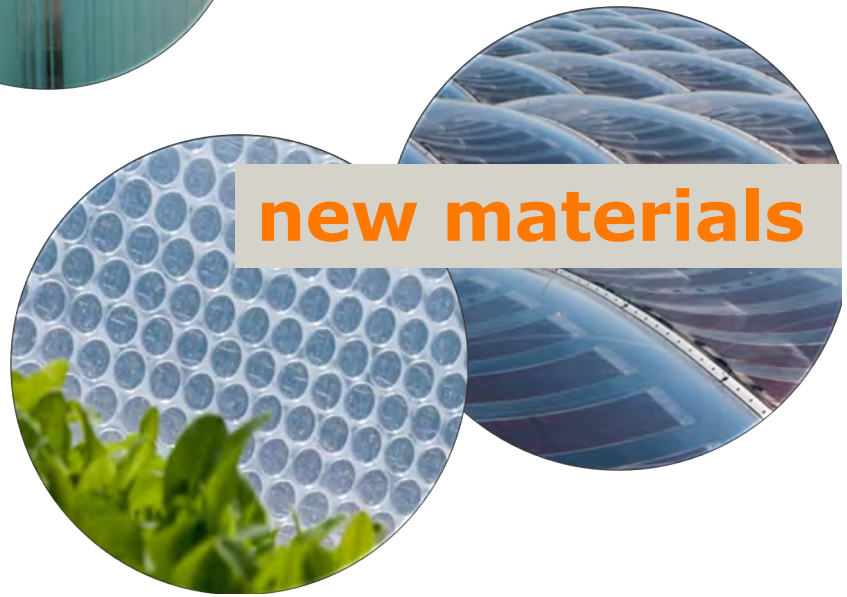

FIR transmissivity materials

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B(ubble) E(nergy) S(aving) T(echnology) greenhouse

GENSON
Soft Fruit Plants

BerryWorld
EUROPE

HYPLAST
a World of Plastics

rkw
WHEN EXCELLENCE MATTERS

svensson

Modiform®

rovero

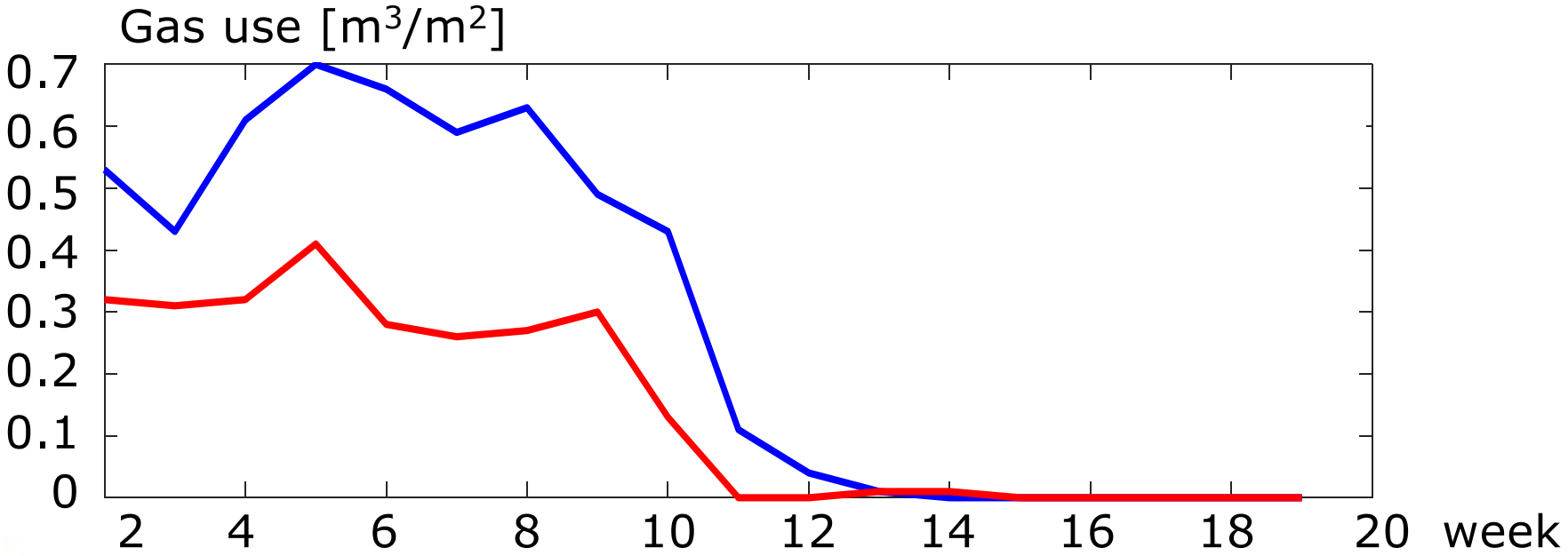
METAZET

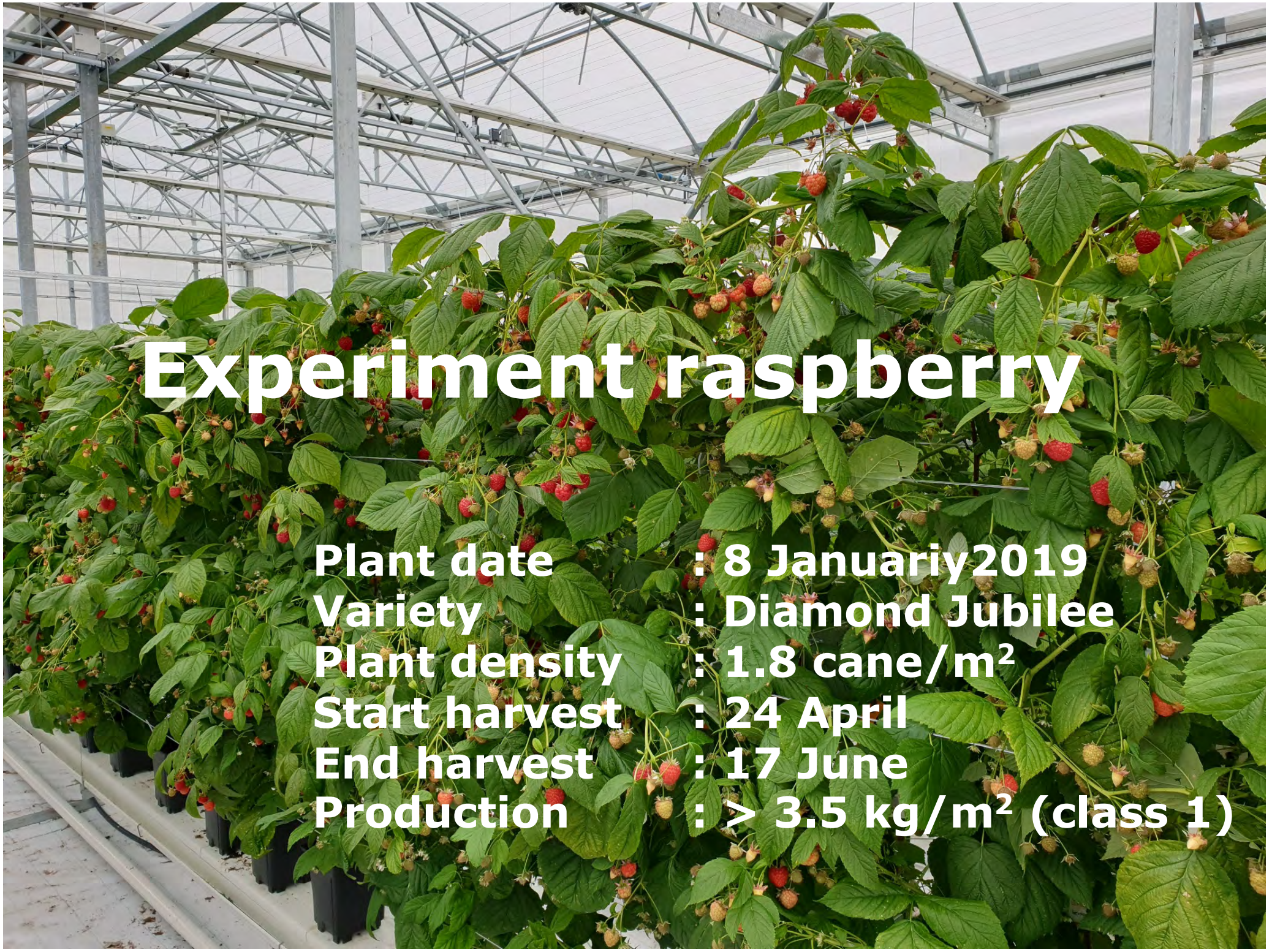
FormFlex

Greenhouse energy use

- BEST =5.7 m^3/m^2
- Practice = 9.1 m^3/m^2

➔ 37% reduction energy use



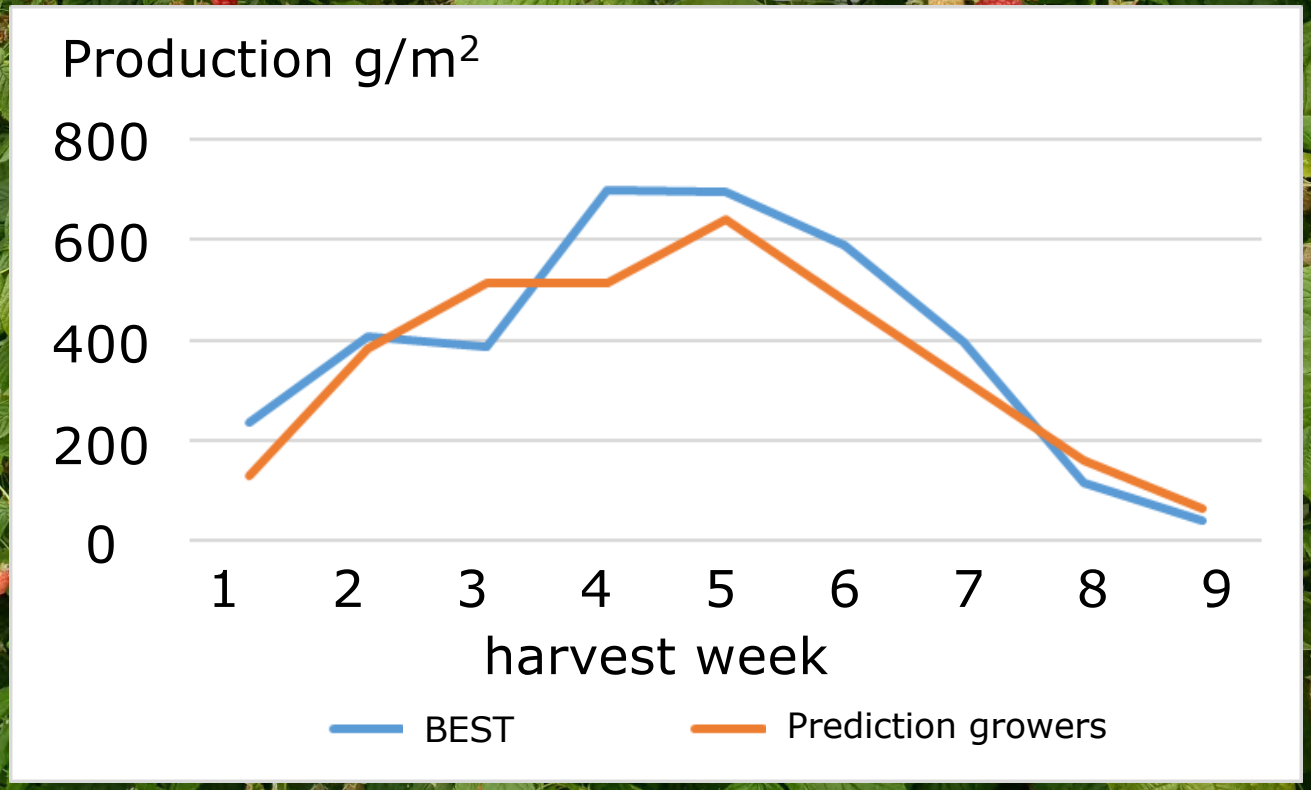


Experiment raspberry

Plant date : 8 Januariy2019
Variety : Diamond Jubilee
Plant density : 1.8 cane/m^2
Start harvest : 24 April
End harvest : 17 June
Production : > 3.5 kg/m^2 (class 1)

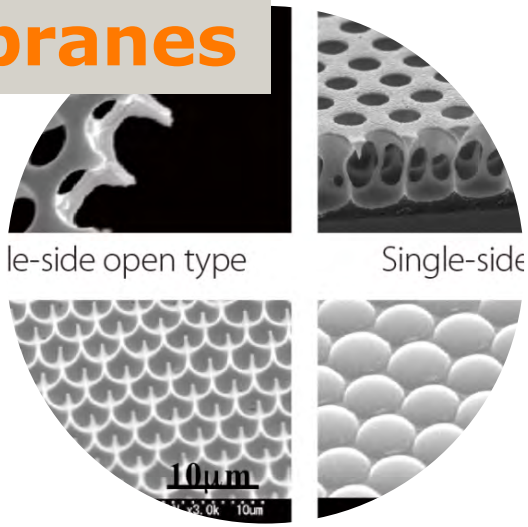
Raspberry production

Production class 1 >3.5 kg/m²

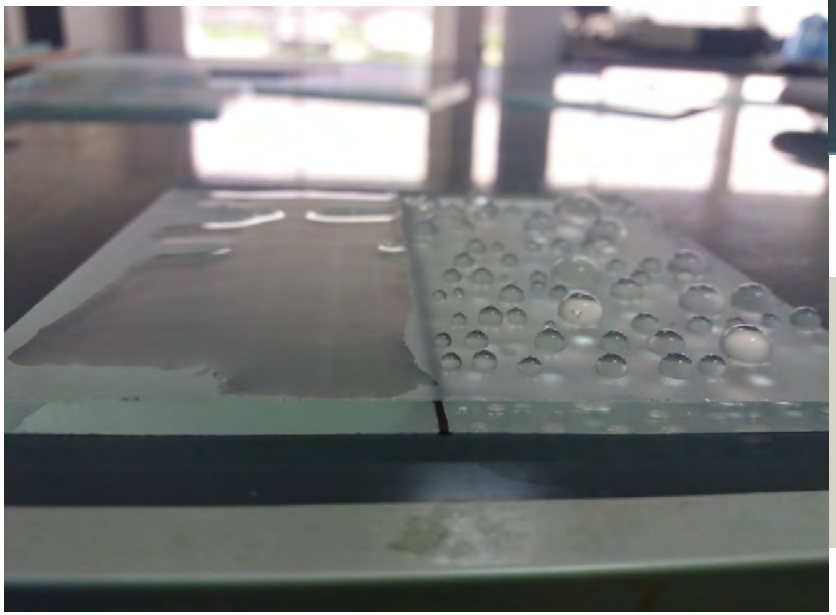


Humidity control

Ultra porous membranes



Humidity transparent films



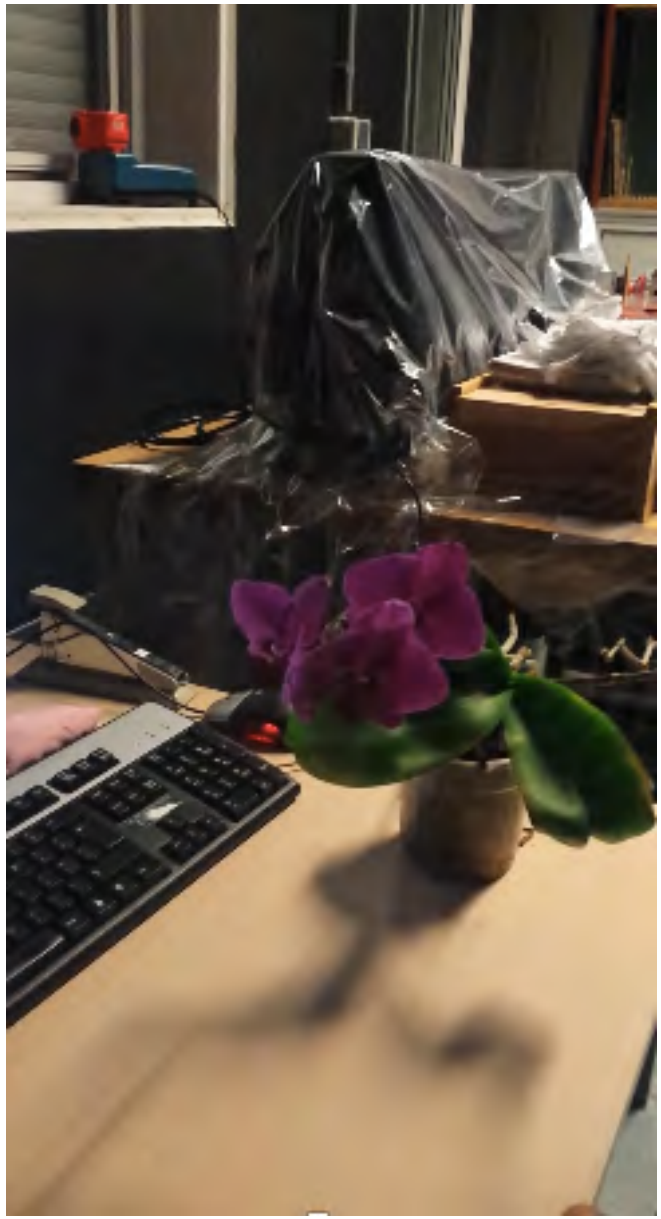
Super hydrophylic/phobic coatings

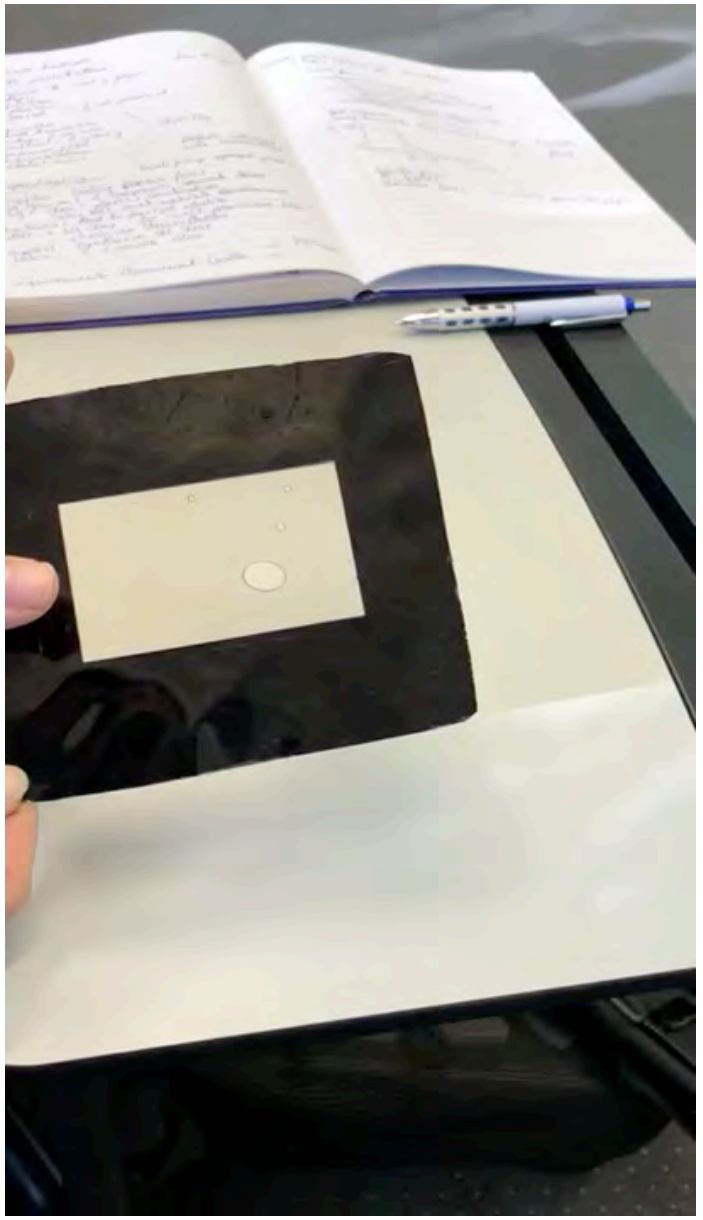
Switchable Materials

Light intensity

Light diffusion

Light colour





Electrical switch

Thermal switch

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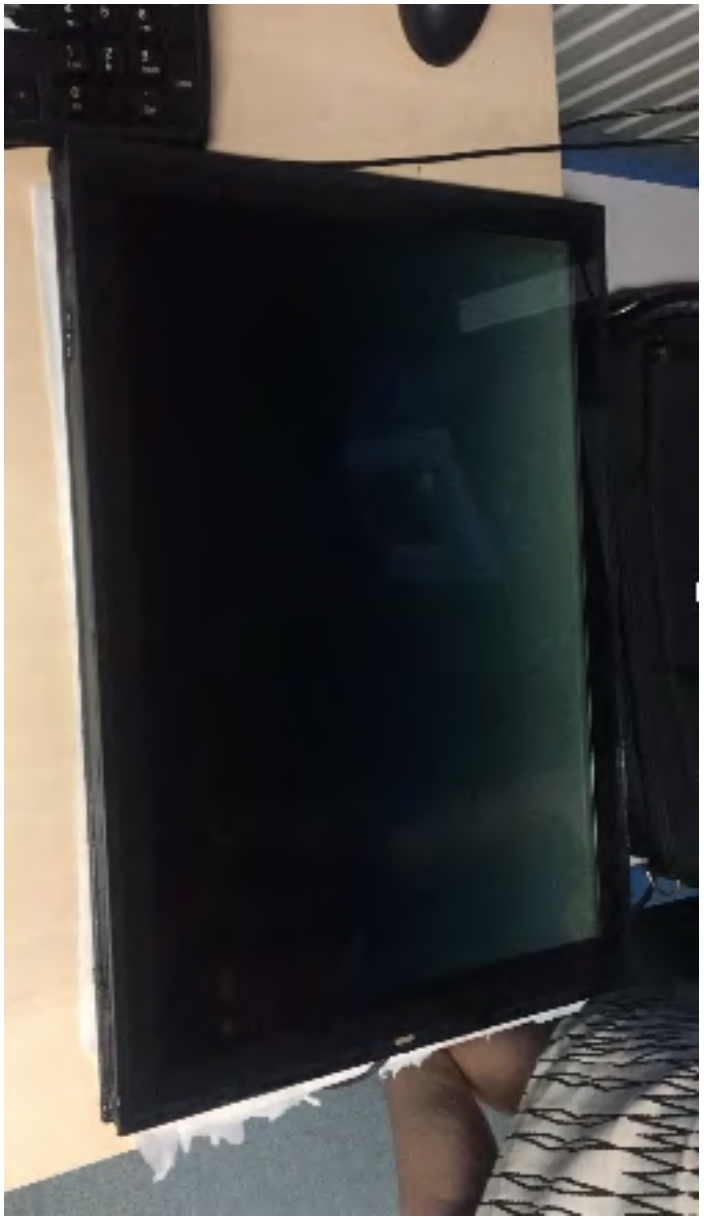

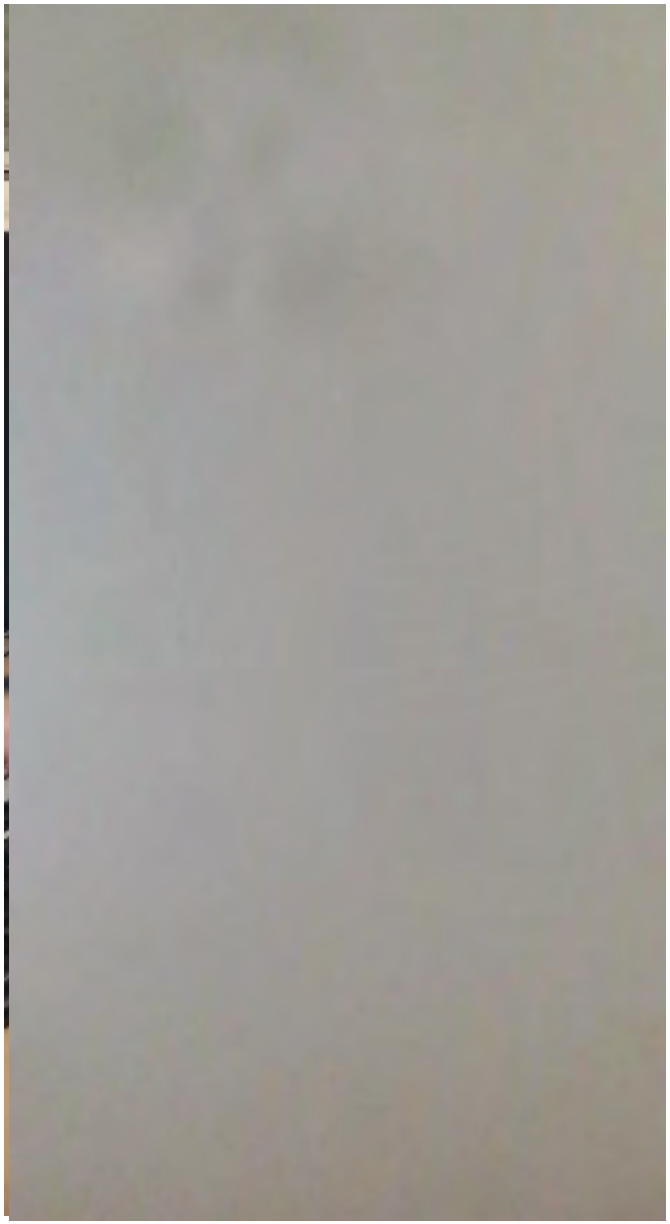

Electrical switch

Thermal switch

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Experiment *Anthurium* under light intensity switching materials

Electrochromic materials:

- Possibility to regulate light smoothly → shade crops
- Fast reaction to changing light conditions → crop quality?
- Allow higher light sums → crop growth (time to market)?

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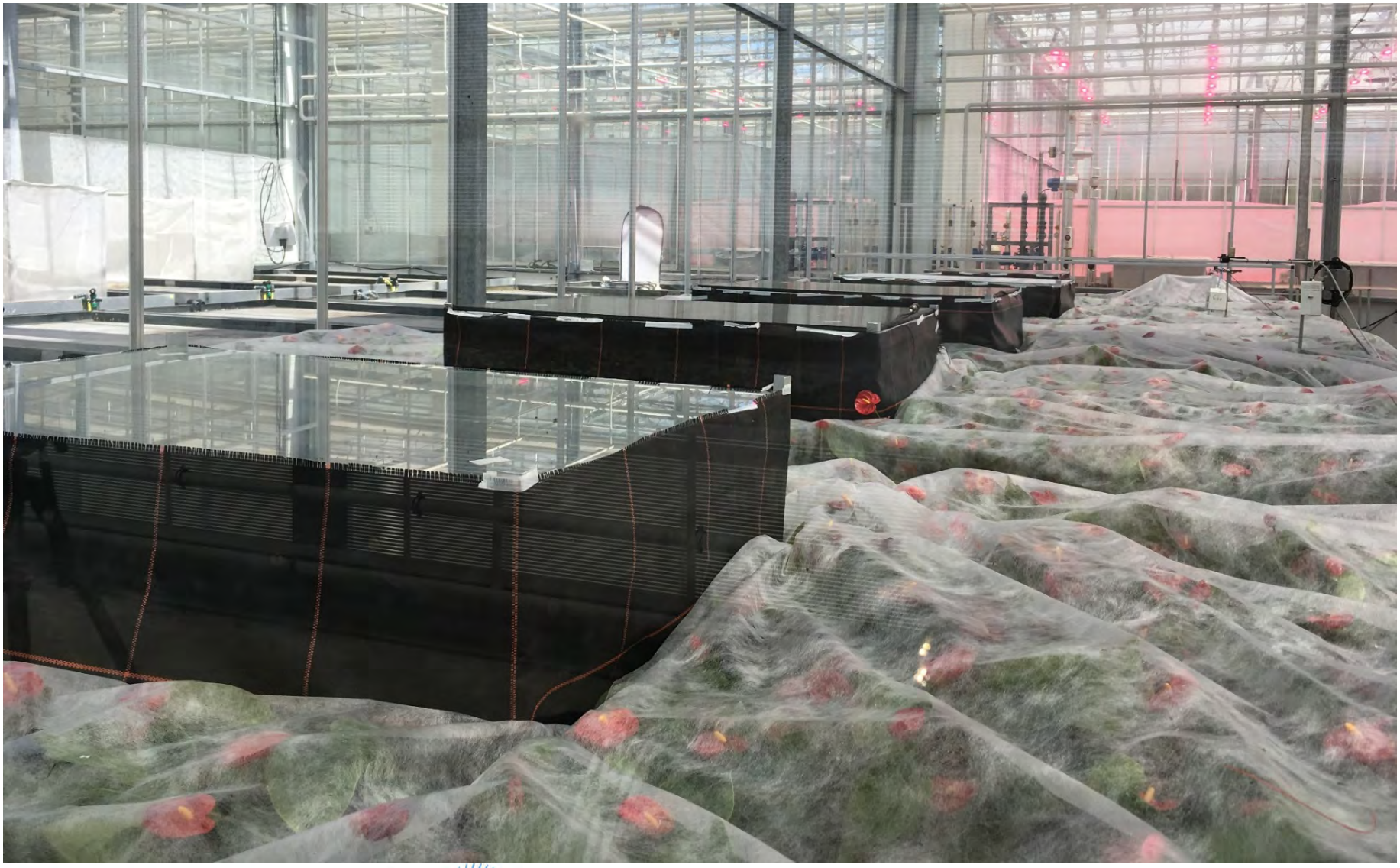
Set up Greenhouse experiments



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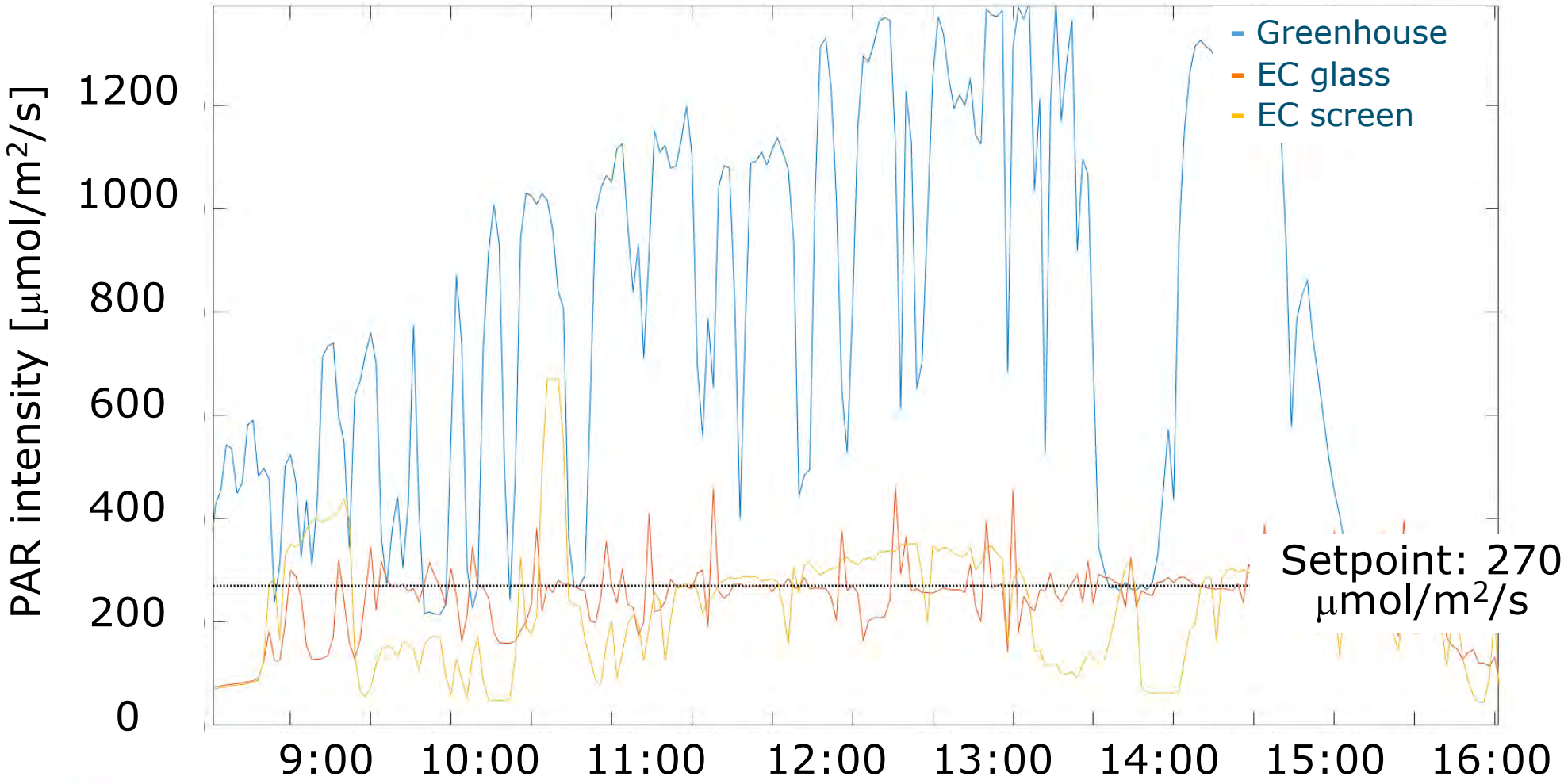
Results: light level in greenhouse

- Light control on a sunny day (30 July 2019)



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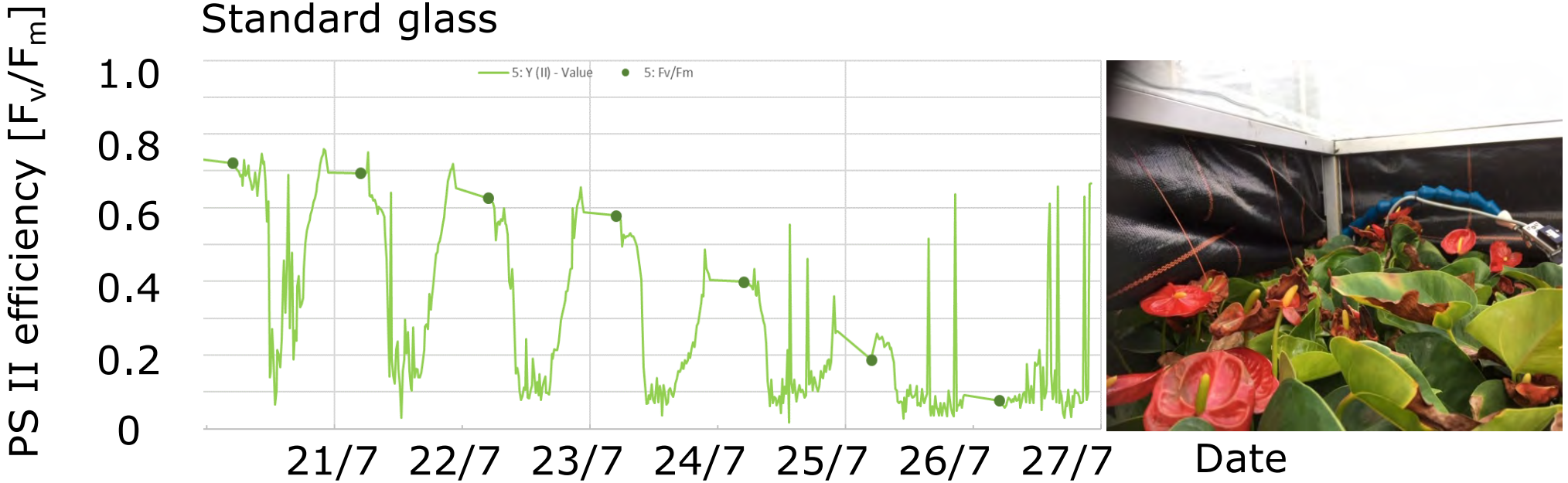
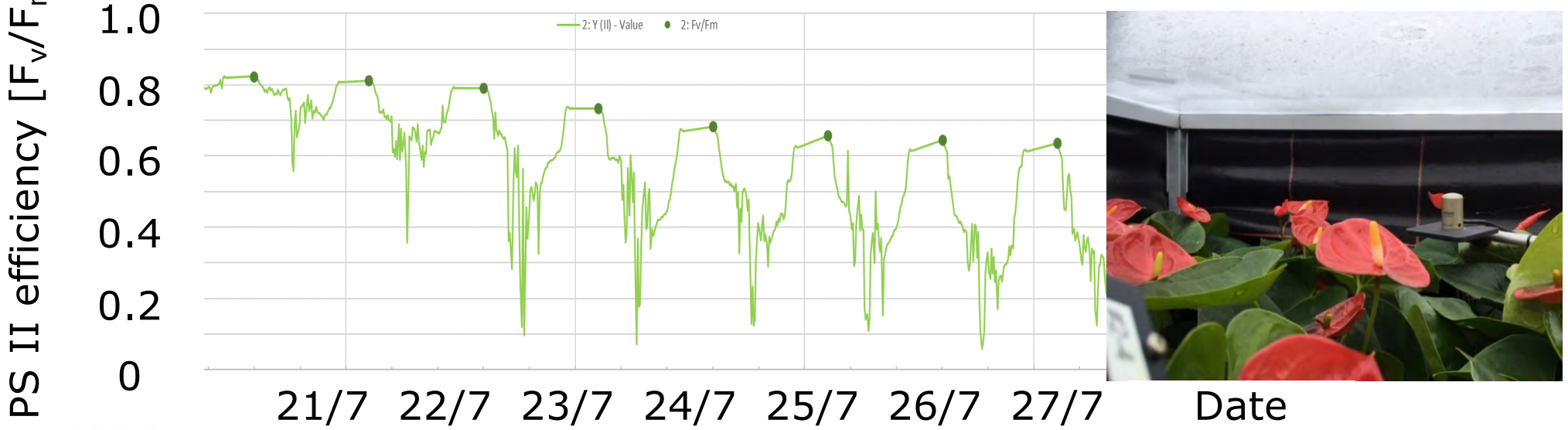
Results: Efficiency of crop photosynthesis

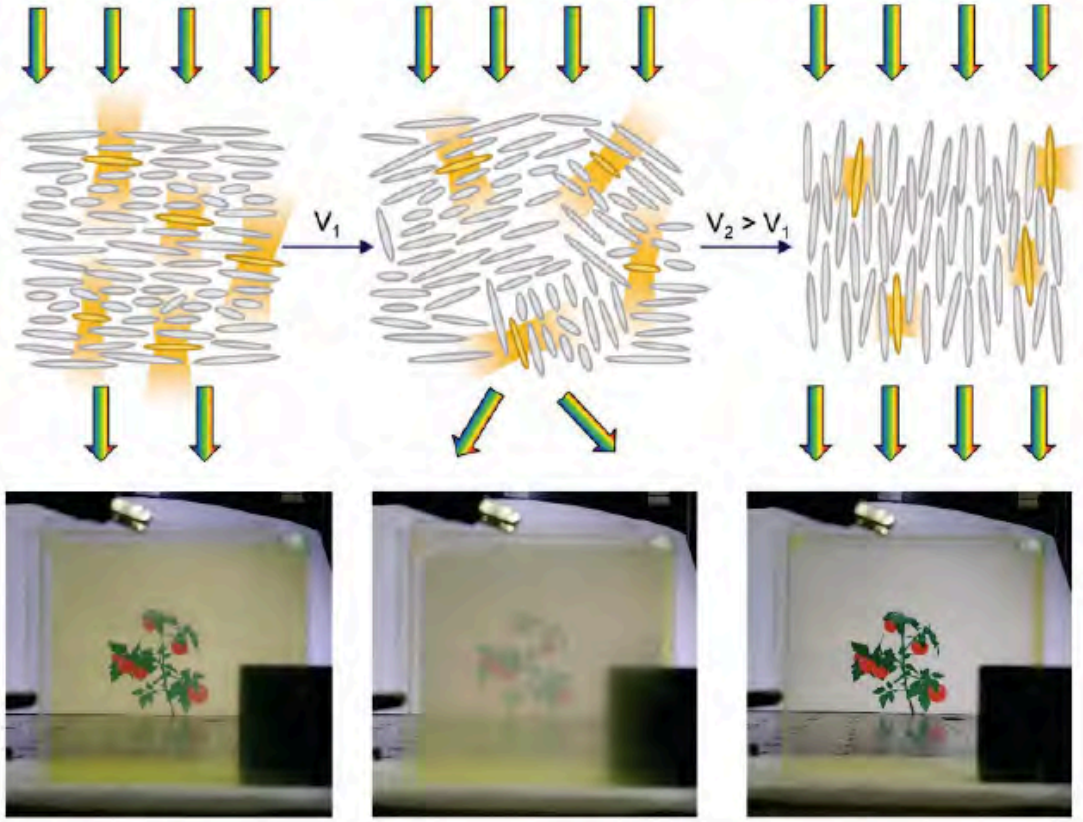
Standard glass

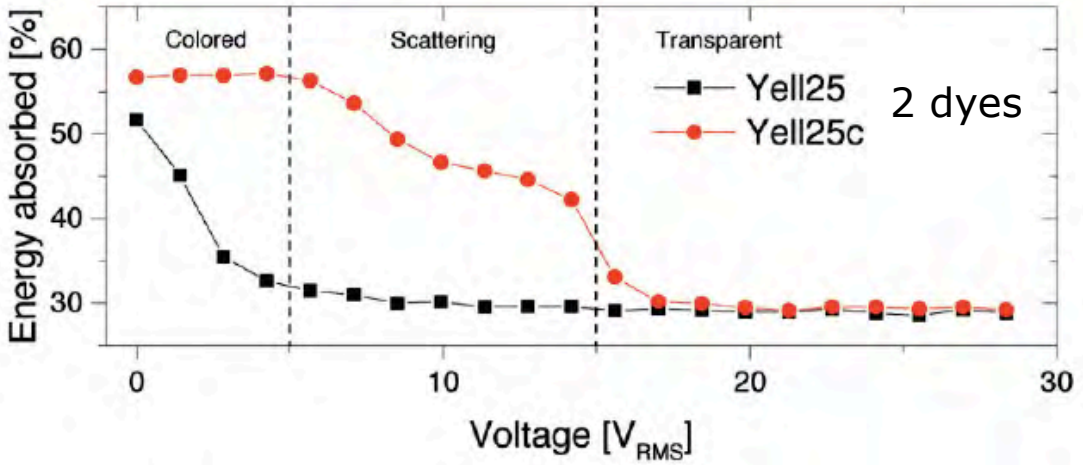


EC glass



Luminescent solar concentrators (LSC)





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J. A. H. P. Sol, G. H. Timmermans, A. J. van Breugel, A. P. H. J. Schenning, M. G. Debije, "Multistate Luminescent Solar Concentrator "Smart" Windows", Adv. Energy Mater. ***2018****, 1702922.*

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Questions?

Thanks to my collegaues: Bram van Breugel, Esteban Baeza, Cecilia Stanghellini, Nieves Garcia, Geert Franken, Vida Mohammadkhani, Bas Briarie etc. etc.