

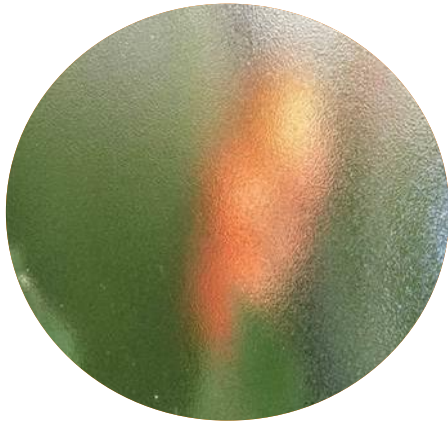
# Diffuse light in tomato: a clear story

And still so many questions!

Hungarian tomato growers association

31-05-2024

Nieves García Victoria



# Outline



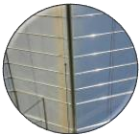
Introduction to Wageningen Greenhouse Horticulture



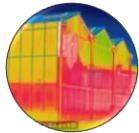
Background: The importance of light for crop growth & yield



Opportunity: Diffuse light and its benefits for crop production

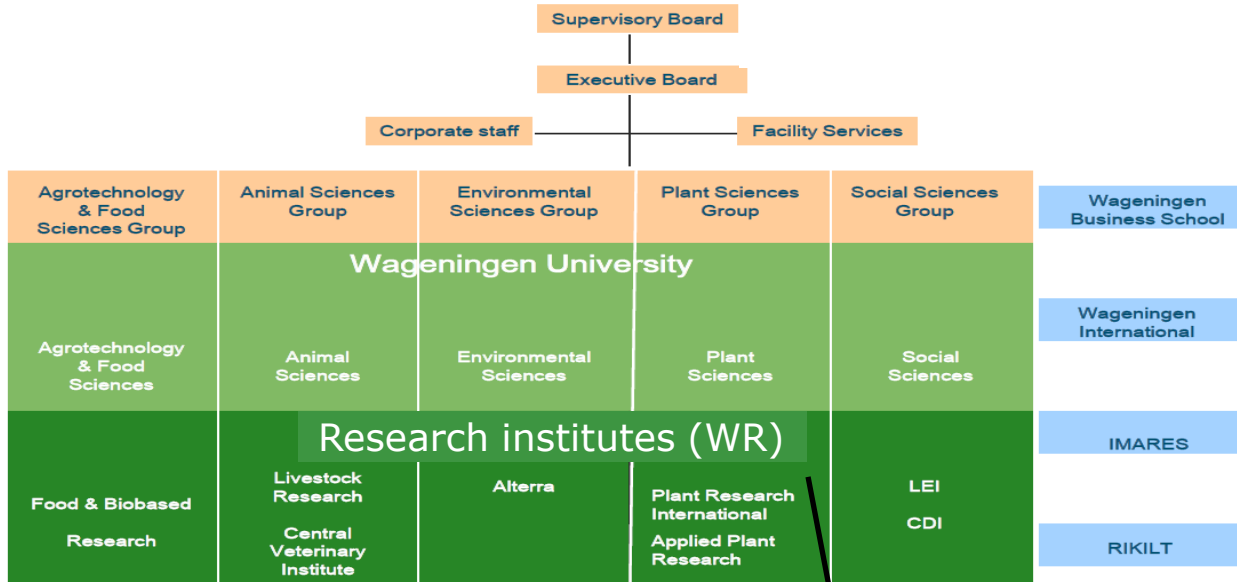


New measurement methods: From Haze to Hortiscatter



Questions and discussion

# Wageningen University & Research



WUR Greenhouse  
Horticulture & Flower  
bulbs

# WUR Greenhouse Horticulture

- 165 scientists work on all aspects of greenhouse horticulture & flower bulbs production
- **High & low tech cultivation GH, VF**
- Flavour testing facilities
- Facilities for post-harvest research
- **Innovation and Demonstration Centres: Energy, Water, LED, Taste**
- Robotica labs
- Light lab

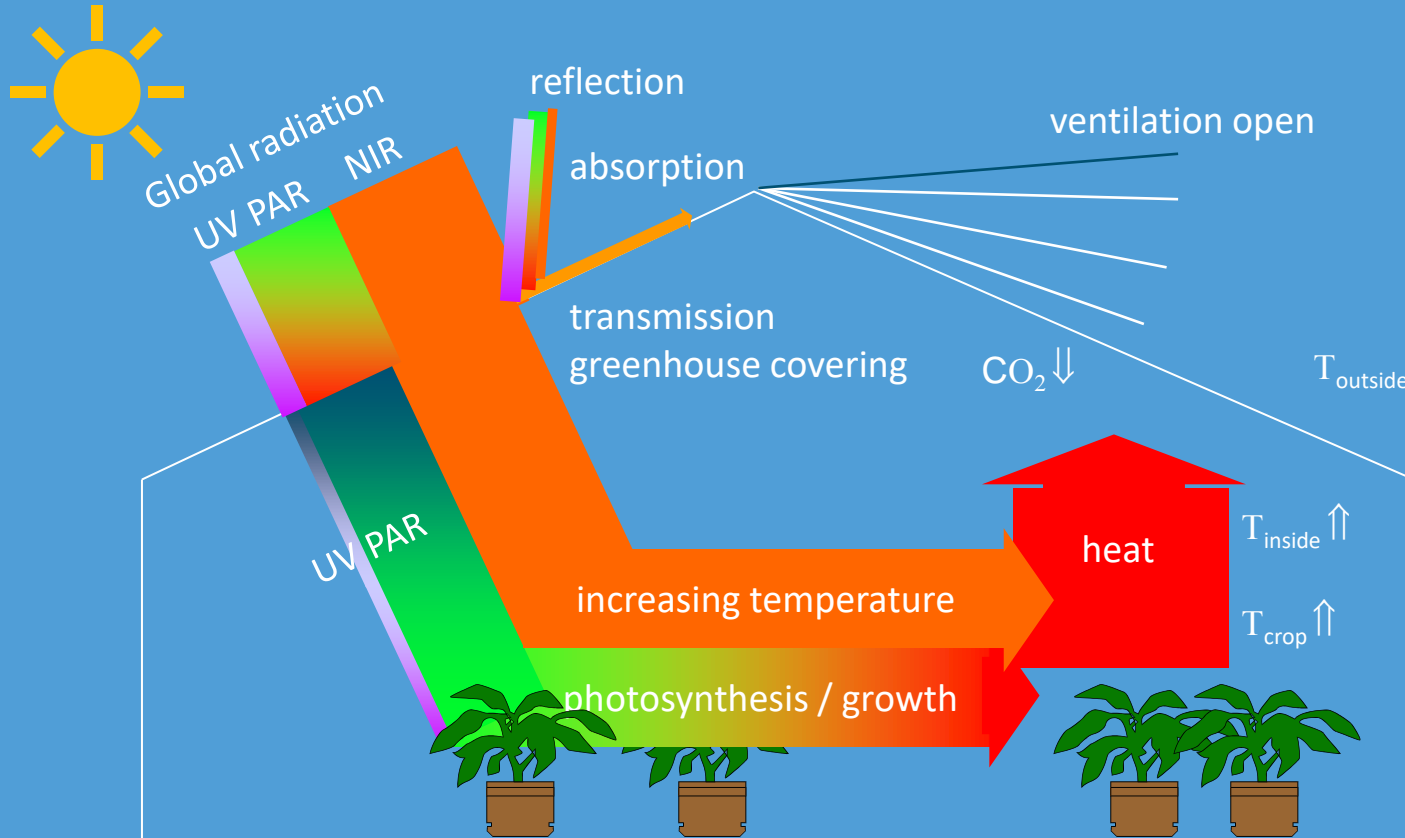


# WUR LightLab

- Optical / Thermal properties of greenhouse cover materials and screens
- R&D new materials with suppliers
- Developing new measurement protocols
- Certified NEN2675, standardize measurements according to scientific principles
- Modern equipment
- From theory to application



# Importance of light for crop growth and yield (I)



# Importance of light for crop growth and yield (II)

Extra production per 1% more light

| crop           | % increased production |
|----------------|------------------------|
| lettuce        | 0.8                    |
| radish         | 1                      |
| cucomber       | 0.7–1                  |
| tomato         | 0.7–1                  |
| rose           | 0.8–1                  |
| chrysanthemum  | 0.6                    |
| poinsettia     | 0.5–0.7                |
| figus benamina | 0.6                    |

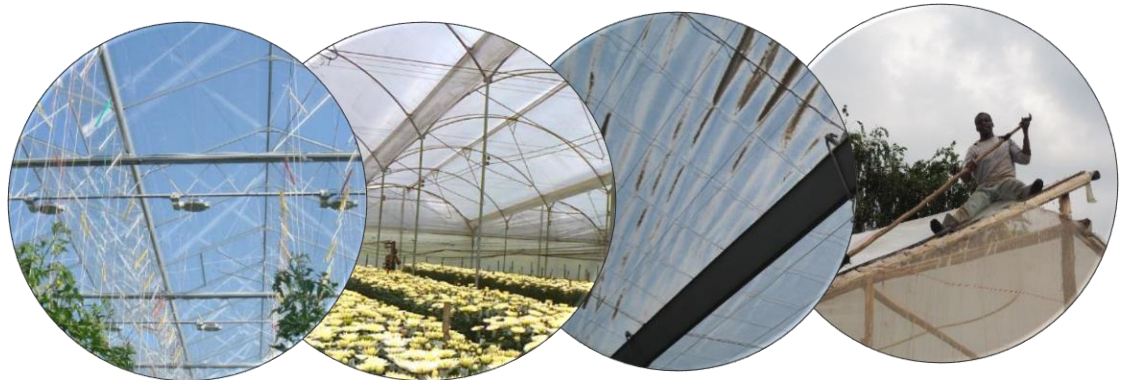
from: Marcelis et al., 2006



**Light transmission matters!**

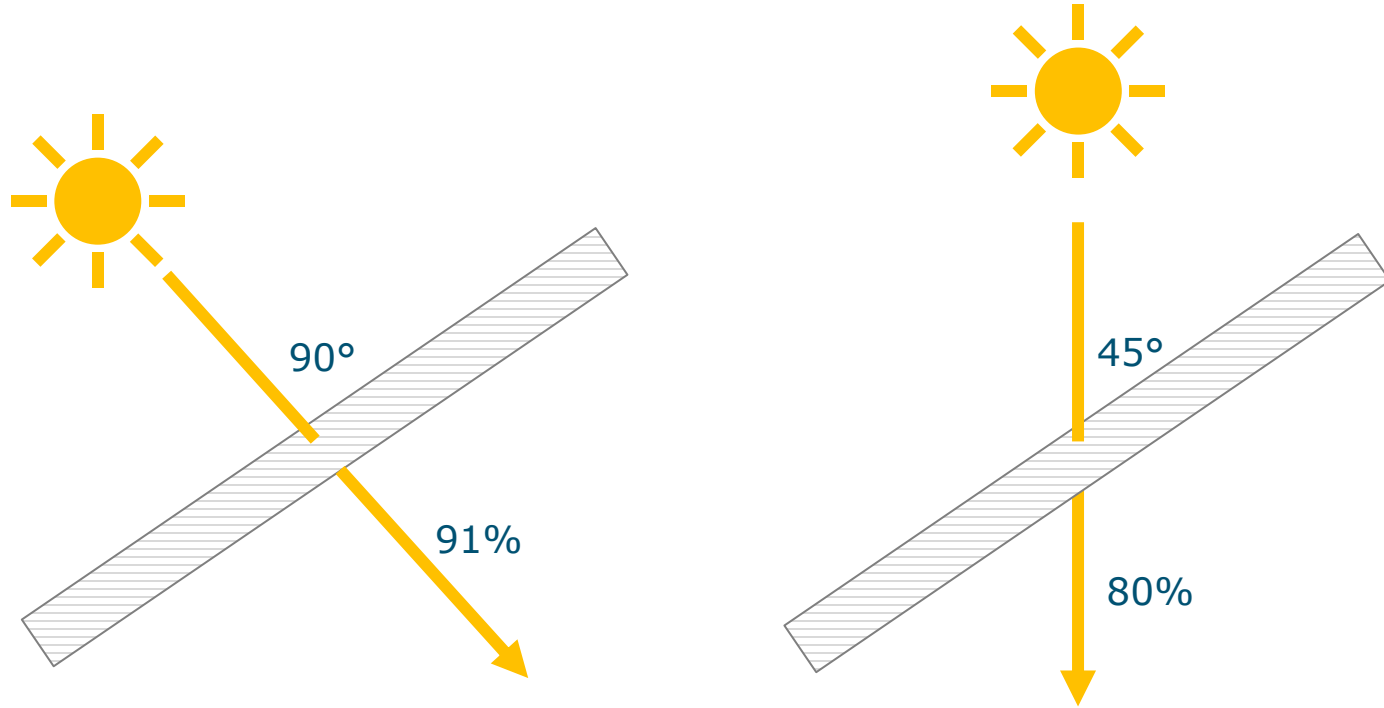
# More light in the greenhouse with...

- High transparent cover (low iron glass, plastic films ETFE) 3-8%
- Reduce reflection (Anti Reflection Coatings AR)
- Lighter construction (5-10%)
- Replacing (plastic) cover on time (5-10%)
- Cleaning the cover (10-15%)

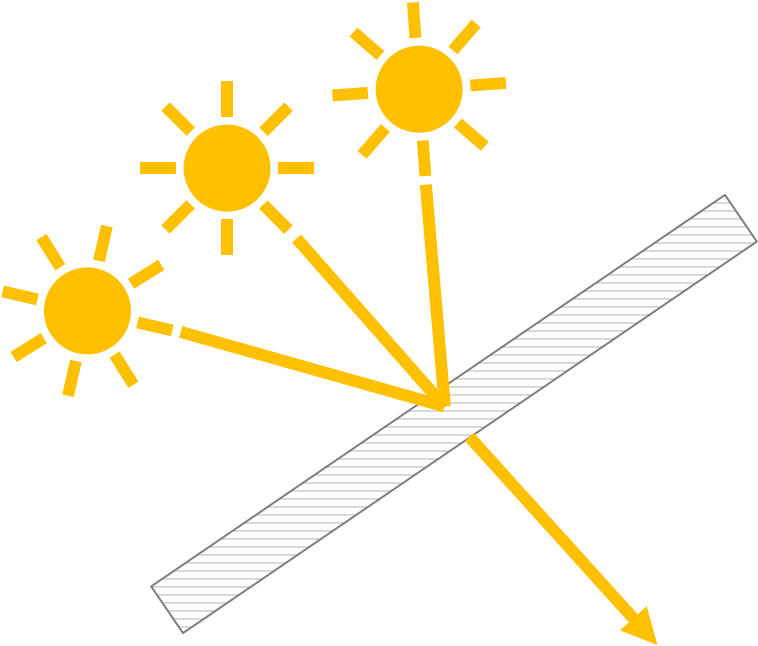




# Perpendicular & hemispherical light transmission



# Hemispherical transmission



# Direct or diffuse light in the greenhouse/

## **Direct light:**

light rays and shadows, top of plant too much light, lower parts too little.



## **Diffuse light:**

homogeneously spread through the crop layers, all layers receive some of the light.



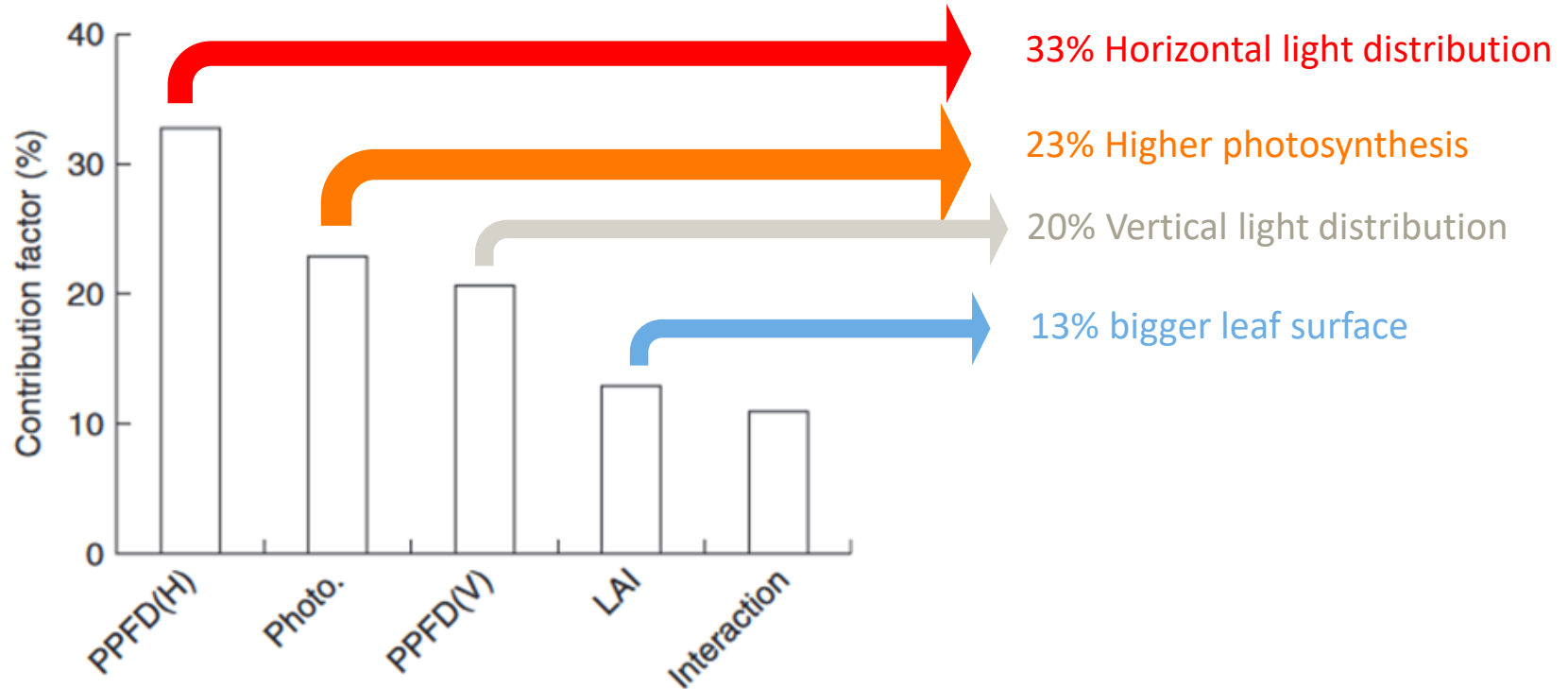
# Diffuse light increased tomato yield in trials

| Glass                                | % Haze (diffuse-veness) | % light transmission (hemispheric) | Production (kg/m <sup>2</sup> ) | Production increase (%) (reference 100) |
|--------------------------------------|-------------------------|------------------------------------|---------------------------------|---|
| Reference (Float)                    | 0                       | 82                                 | 62                              | 100                                     |
| Etched glass AR                      | 45                      | 82                                 | 67                              | 108                                     |
| Structure AR                         | 62                      | 85                                 | 68                              | 109                                     |
| Prismatic AR                         | 71                      | 83                                 | 69                              | 111                                     |
| ReduFuse 1:8 (non-permanent coating) | 50                      | 78                                 | 65                              | 105                                     |

Diffuse light 5 to 11% more production

# Contributing factors to higher yield

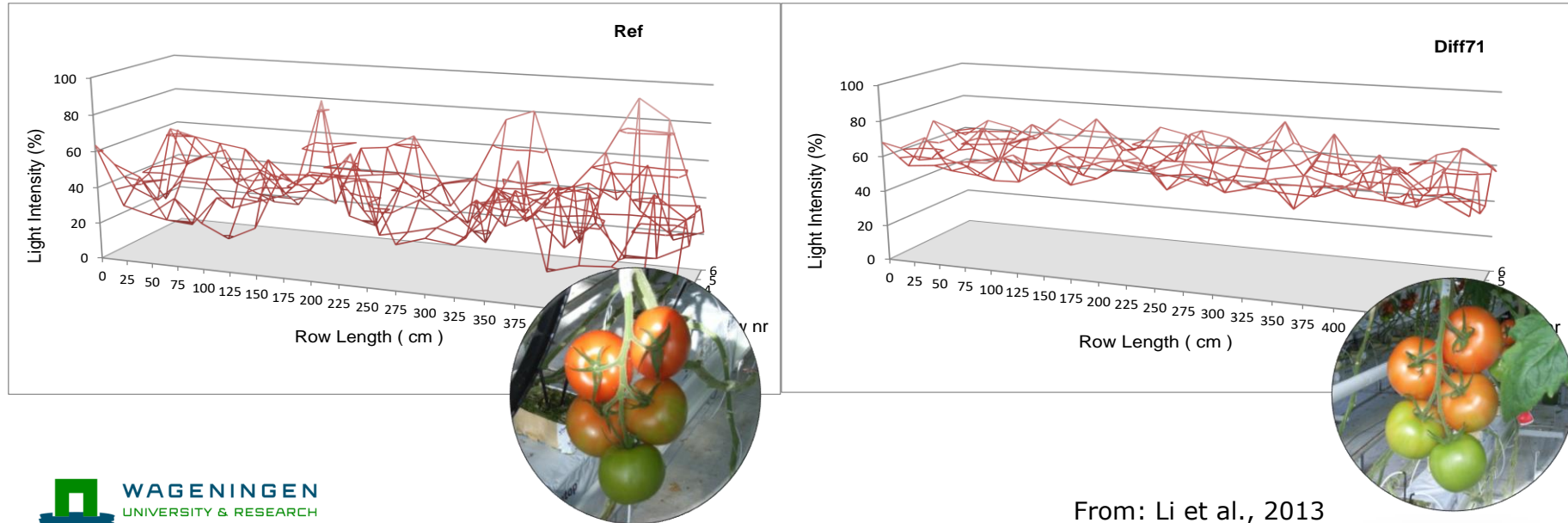
(Li et al., 2014, 2015)



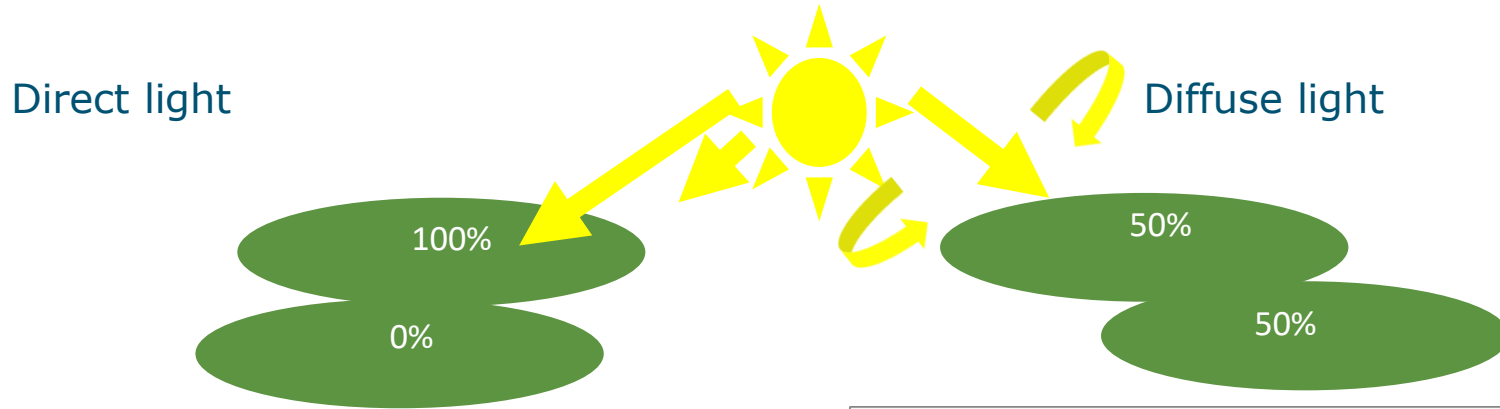
# Diffuse vs. direct light in the greenhouse

(horizontal distribution)

- The light in the greenhouse (PAR measured at many different spots in the greenhouse, at half height of the crop)



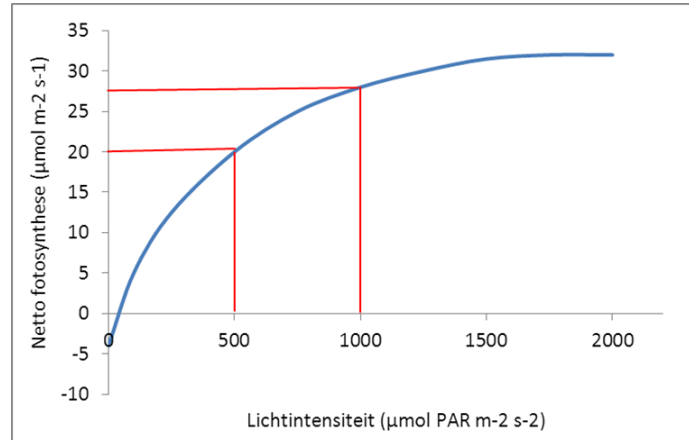
# Diffuse vs direct light (photosynthesis)



Light reaches 2 leaf layers

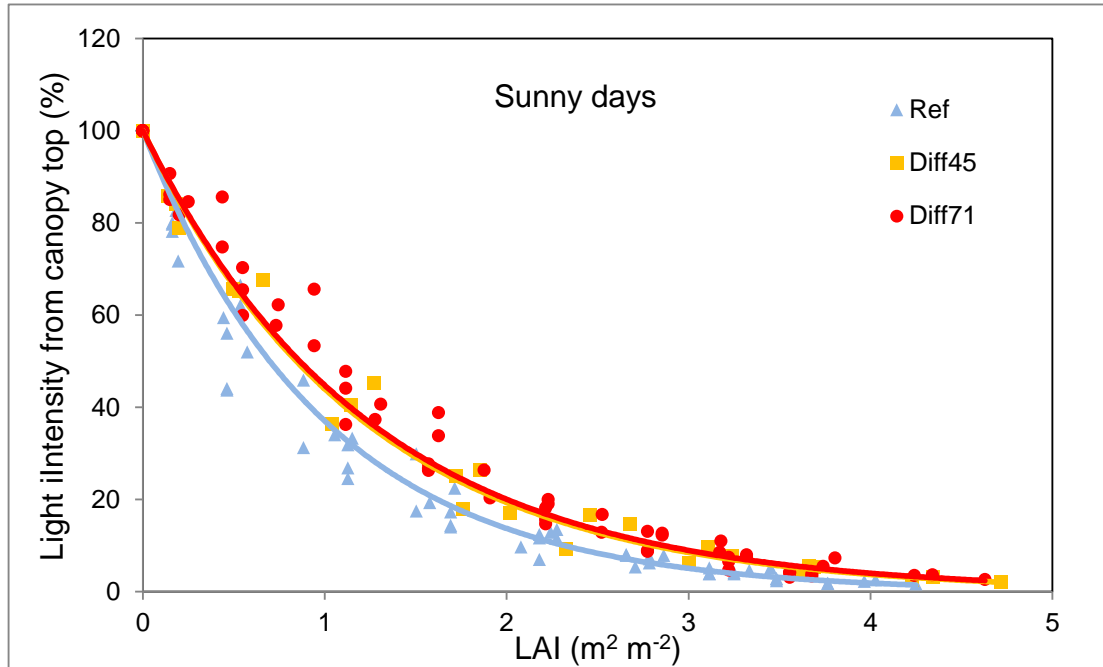
Direct ( $1 \times 1000 \mu\text{mol} + 1 \times 0 \mu\text{mol}$ )  
Photosynthesis =  $28 \mu\text{mol CO}_2$

Diffuse ( $1 \times 500 \mu\text{mol} + 1 \times 500 \mu\text{mol}$ )  
Photosynthesis =  $40 \mu\text{mol CO}_2$



# Diffuse vs. direct light in the greenhouse

(vertical penetration in the tomato crop)



From: Li et al., 2013



# Light diffusion, formerly measured as “haze”

Diffusivity used to be expressed by means of the “haze” factors. At equal light transmission, the higher the haze factor, the bigger the light dispersion in the greenhouse



**Normal**

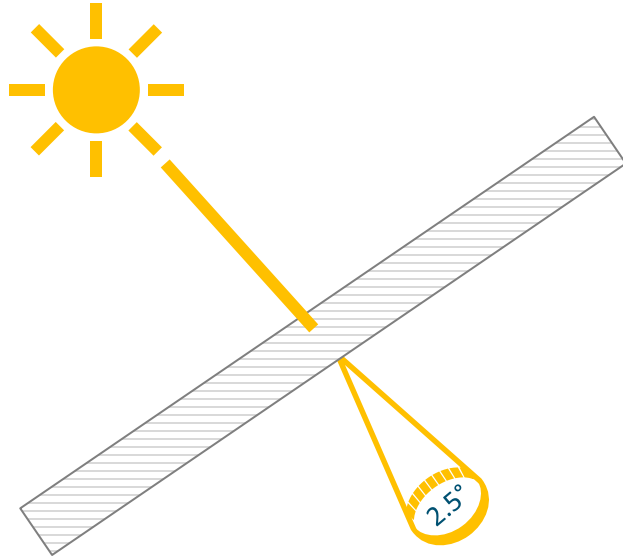


**Low “Haze”**



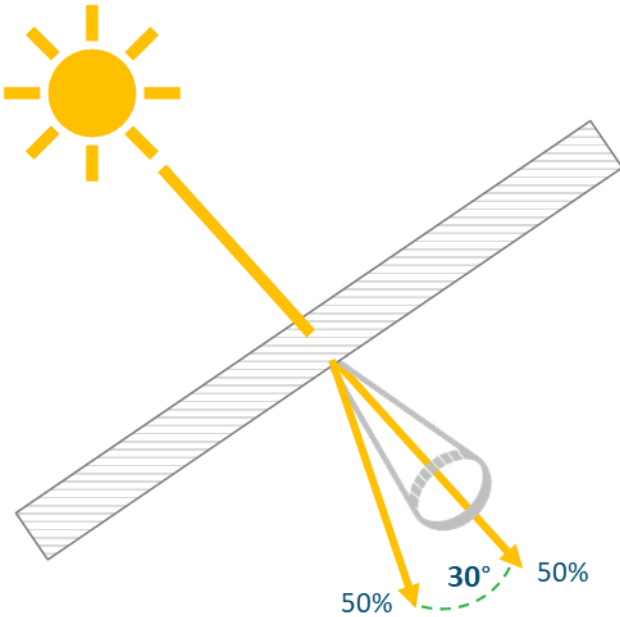
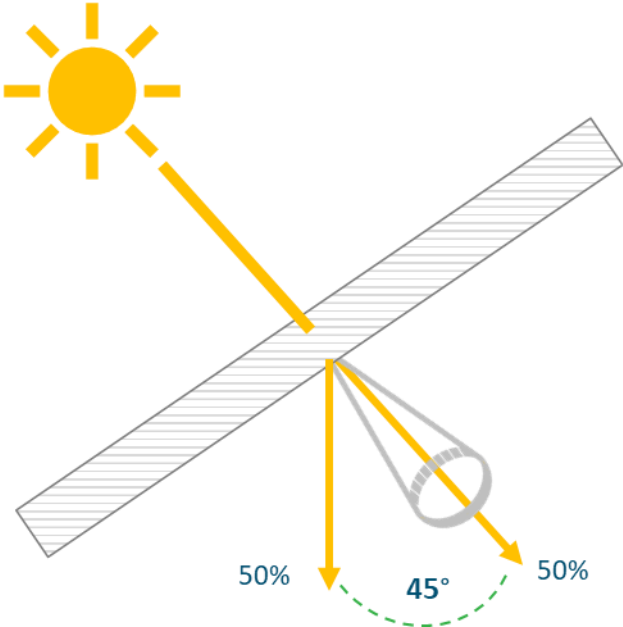
**High “Haze”**

# Haze vs Hortiscatter



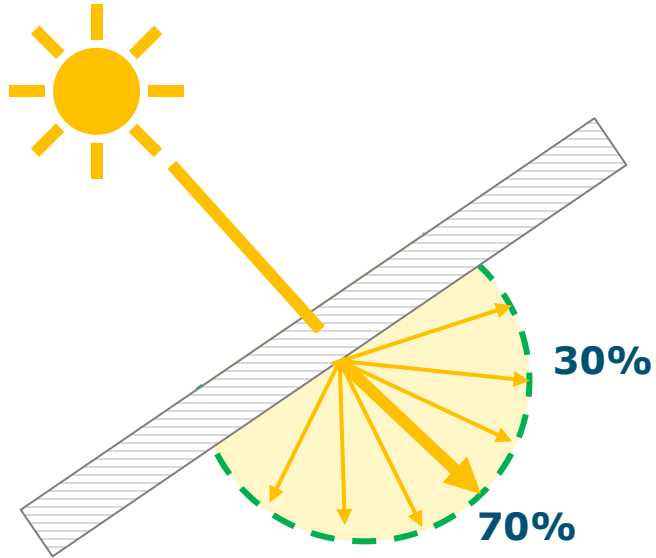
The percentage of the radiant flux that is transmitted through the glass at any direction with an angle larger than  $2.5^\circ$  from the outgoing perpendicular

# Haze vs Hortiscatter



# Haze vs Hortiscatter

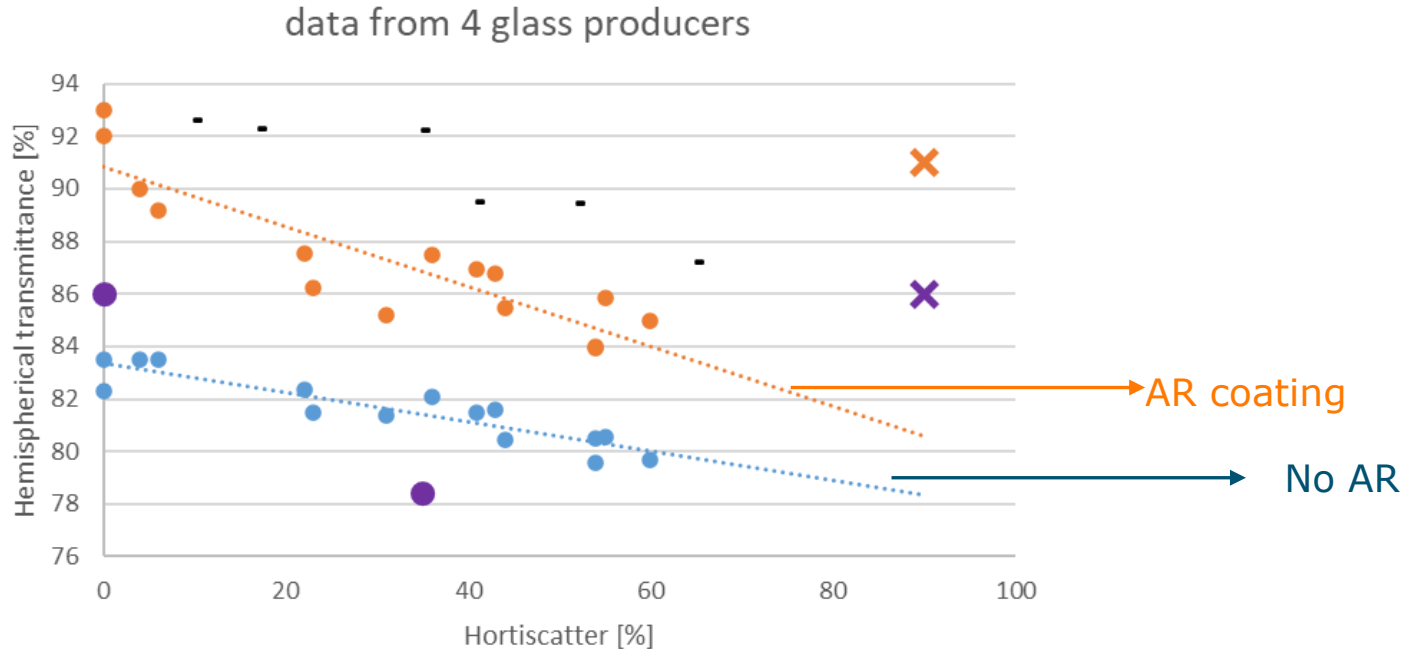
- HS measures light dispersion through the material



**HS is based on a measurement of all radiant fluxes transmitted through the glass under all outgoing angles**

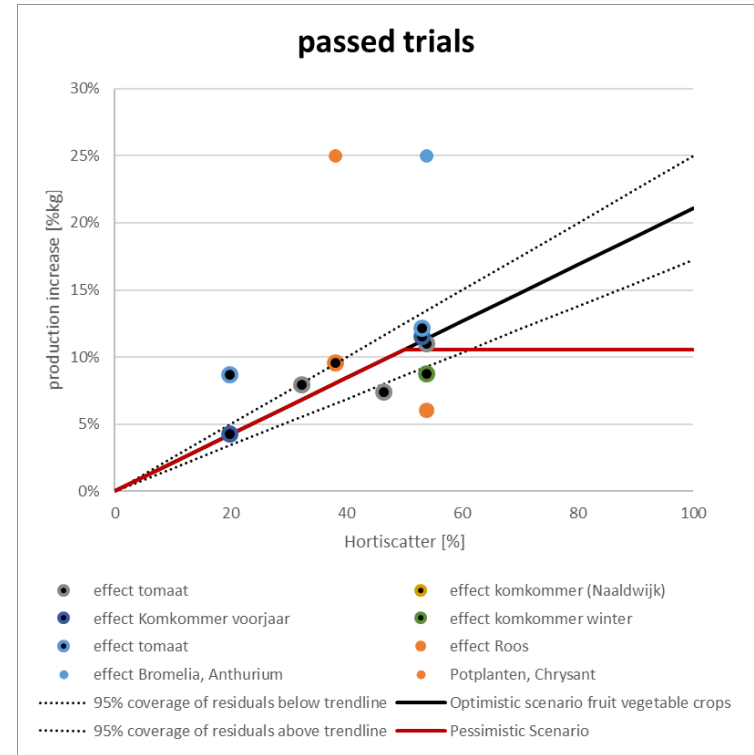
# HS and light transmission

- Increasing HS, usually results in reduced light transmission...



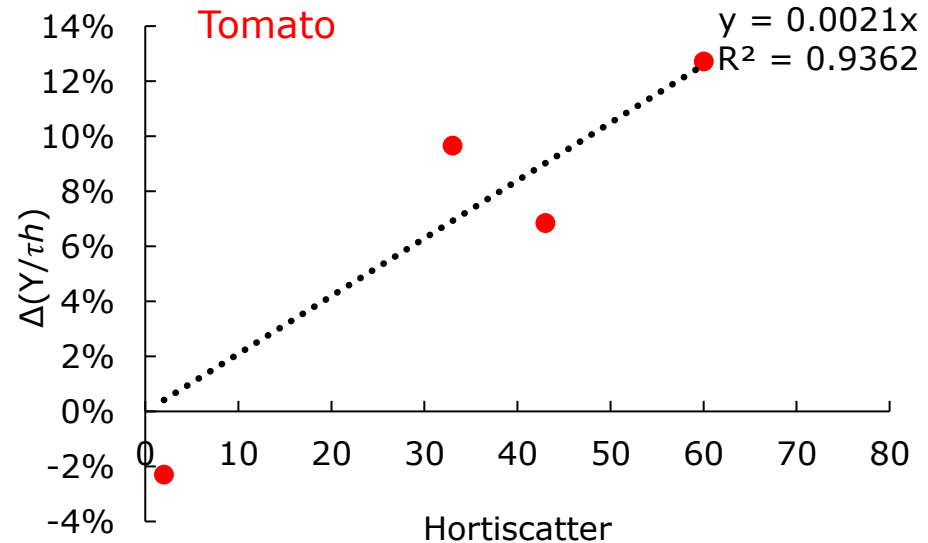
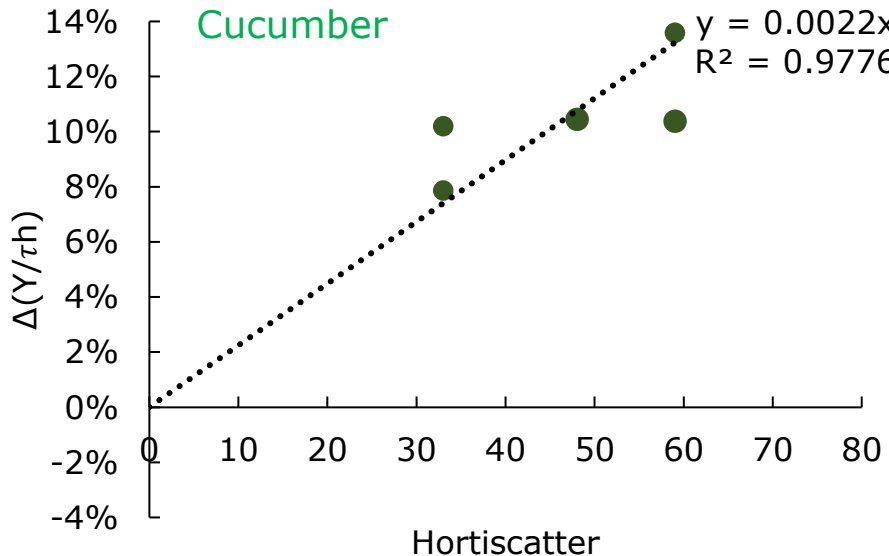
# Previous experiments – HS of used materials

- In general, higher HS leads to higher yield (improved light distribution & photosynthesis)
- Diffuse light research has been conducted with Hortiscatter lower than 60%
- In practice, most of the growers have HS around 20%
- Much “noise” due to different crops and light transmission differences

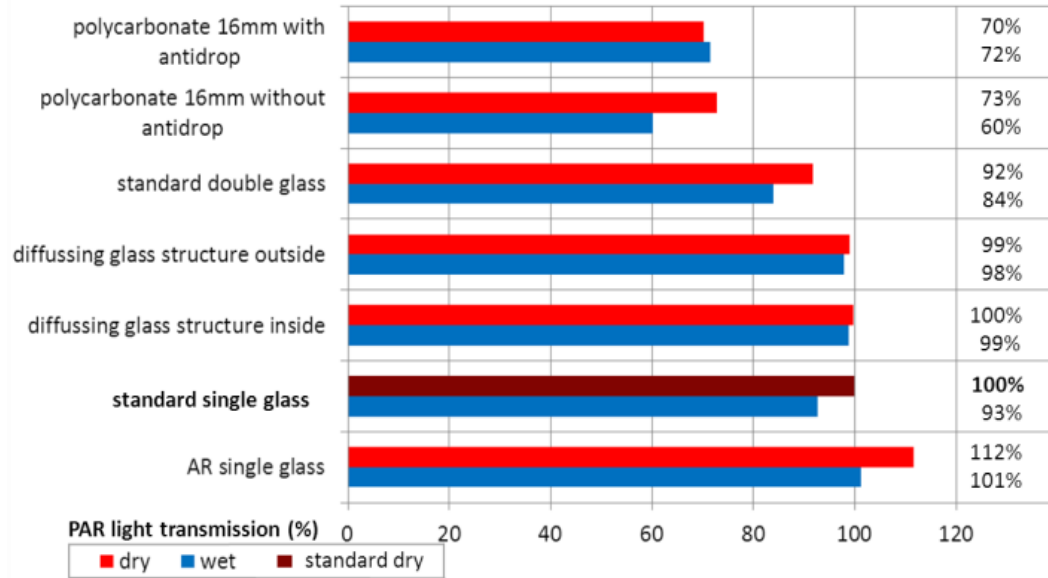


# Results cucumber and tomato revised

- For cucumber and tomato respectively 2.2 and 2.1% potential yield increase per 10% Hortiscatter (assuming no loss of transmission)



# Other effects: Condensation + transmission



- Most materials loose transmission when wet (condensation).  
But not the hydrophobic / structure materials.
  - => more light in greenhouse especially in winter



# Summary (diffuse) light

- Hemispheric light transmission of the greenhouse cover is important for production
- Diffuse glass improves light distribution in the greenhouse
- This is positive for photosynthesis, crop growth (LAI) and production
- “Hortiscatter” (HS) defines the cover diffusive properties better than “Haze”
- Increasing HS leads to higher yield (when no transmission is lost)
- Loss of transmissivity by increasing HS (partially solved by AR)
- Structured glass panels do not lose transmission when wet

# Questions / discussion

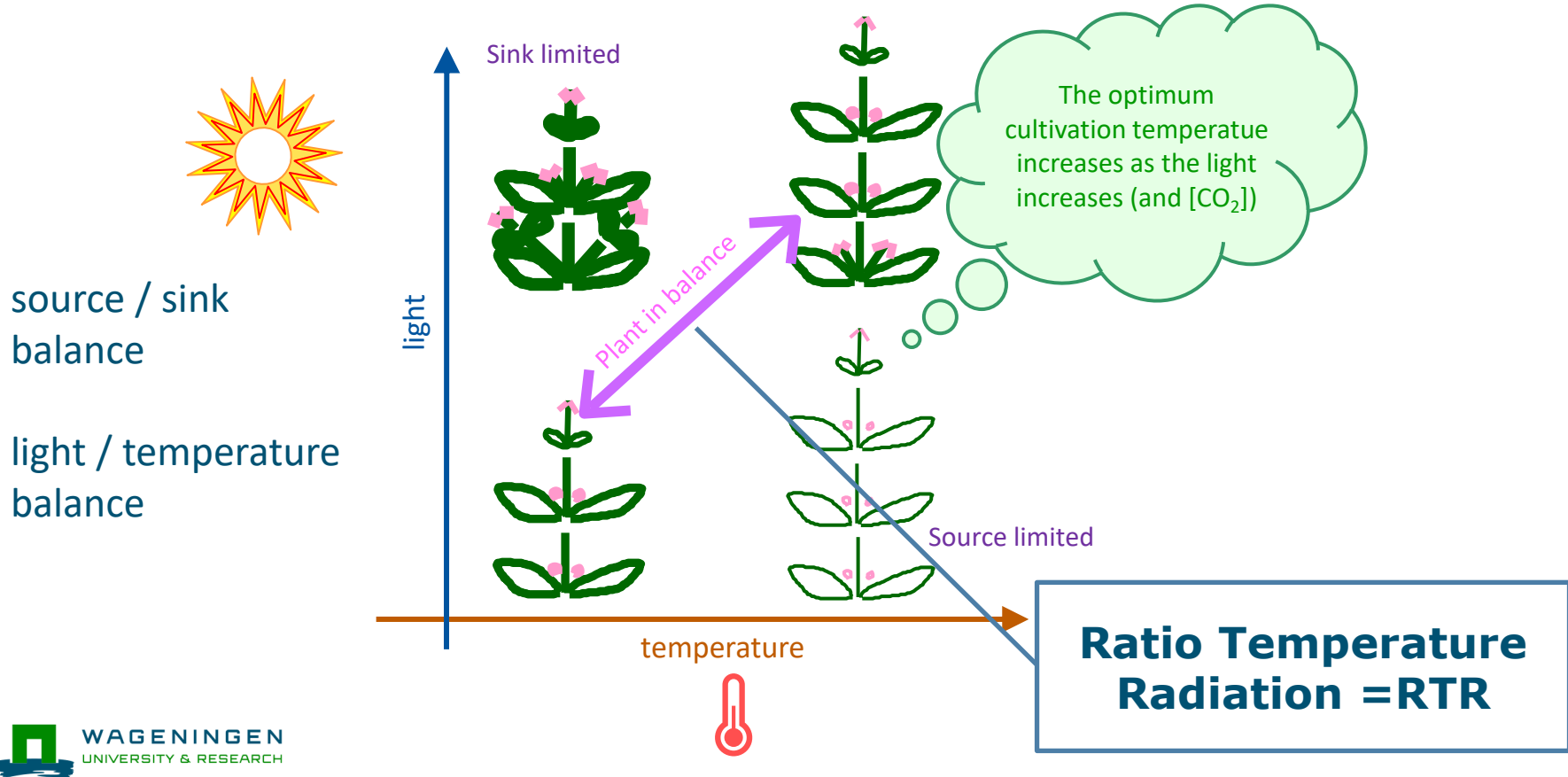
Thanks!

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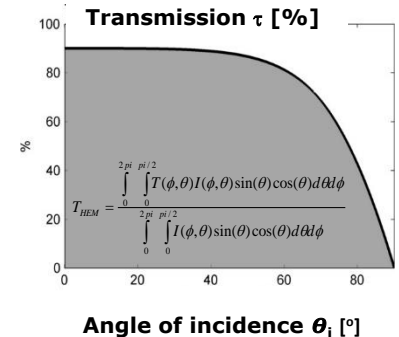
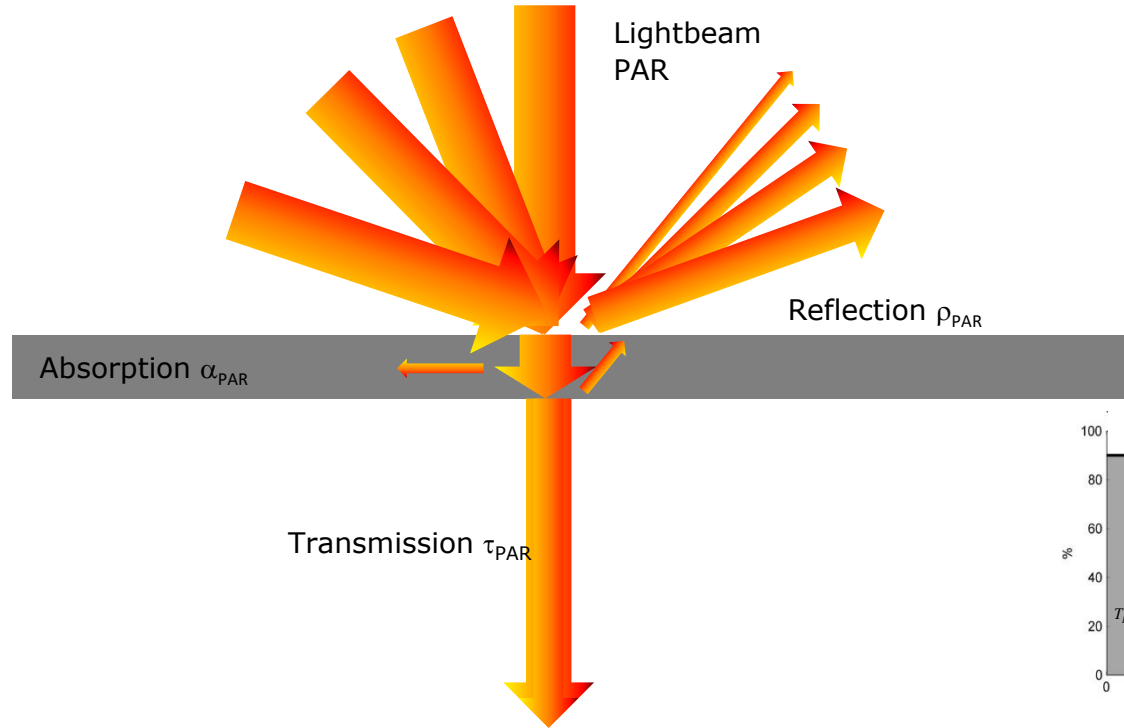


# Concepts "Plant balance" and RTR



# Natural light in the greenhouse

hemispherical transmission  $\tau$ , reflection  $\rho$ , absorption  $\alpha$



# Natural light in the Greenhouse

## Light distribution: Hortiscatter $\Phi$

