Ongoing developments in greenhouse climate control

J.I. Montero, P. Muñoz, E. Baeza, C. Stanghellini

IRTA
RESEARCH & TECHNOLOGY FOOD & AGRICULTURE
Generalitat de Catalunya
Government of Catalonia

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GREENHOUSE AGROSYSTEMS OPTIONS

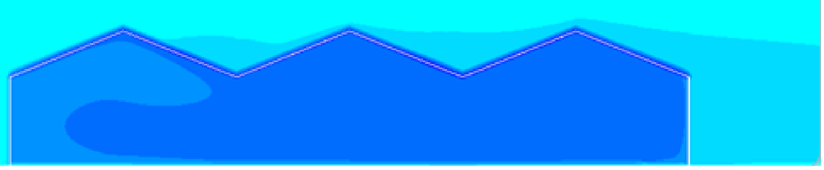
OPTION 1 PASSIVE CLIMATE CONTROL	OPTION 2 ACTIVE CLIMATE CONTROL
LIMITED YIELDS GOOD QUALITY IN LIMITED PERIODS UNEVEN PRODUCTION LOW COSTS	HIGH YIELDS GOOD QUALITY ALMOST YEAR-ROUND UNIFORM PRODUCTION HIGH COSTS

Developments in Passive Greenhouses

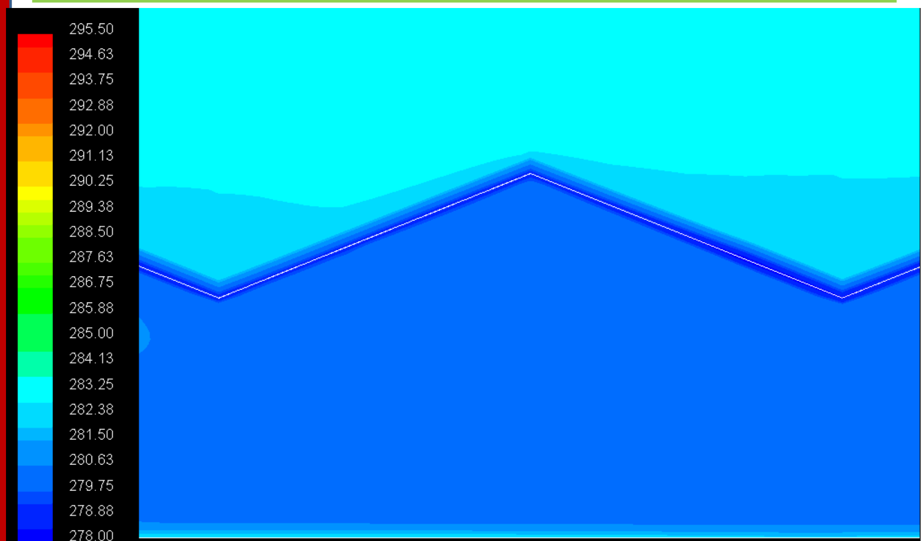
- Significant improvements in recent years: light transmission, natural ventilation, new greenhouse structures, etc.
- Yield Improvement by a factor of three, but innovations not always put in practice.
- Less attention has been paid to make progress on night time conditions.

Night time climate in Passive Greenhouses

- Internal and external screens
- Radiative properties of covering materials
- Semi-closed passive greenhouses.
- Increasing greenhouse thermal inertia

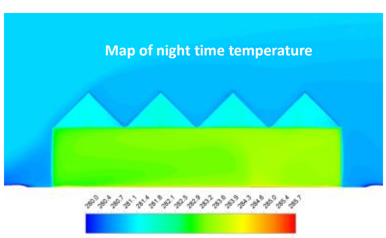


At night FIR exchange controls the passive greenhouse climate

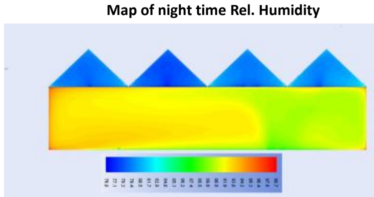


Clear skies (T exterior 10 º C, T sky-10 ºC)

Internal screens in passive greenhouses



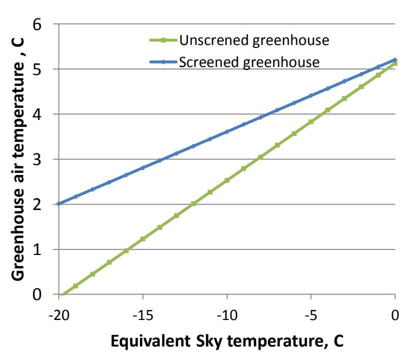
Map of night time Rel. Humidity



Polyethylene thermal screen

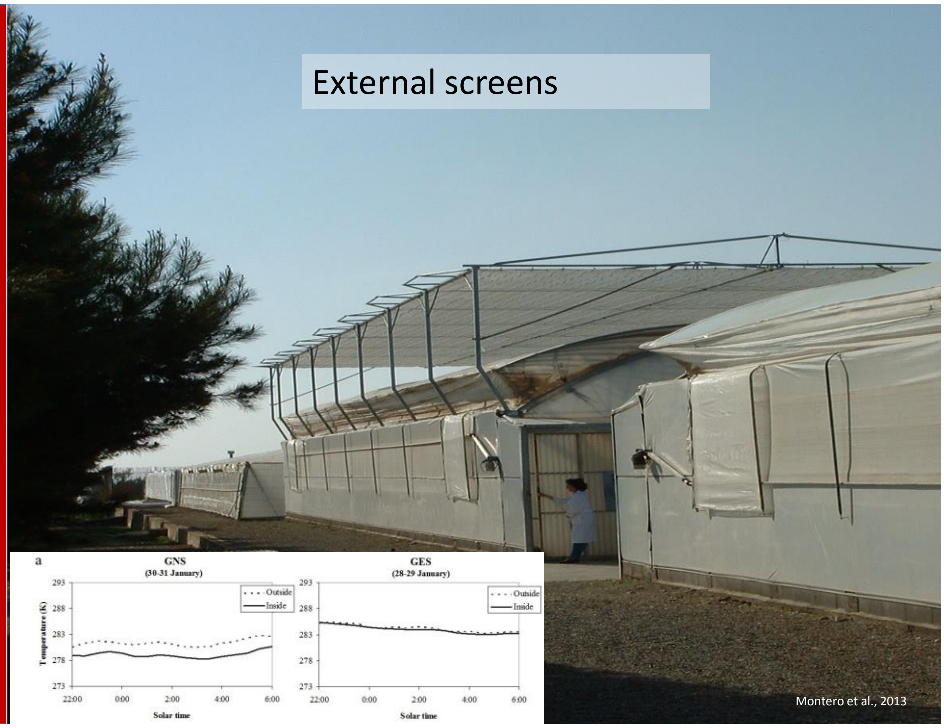
T SCREENED = 3.13 + T SKY*0.26 + SHF * 0.10

T UNSCREENED = 2.41 + T SKY*0.16 + SHF * 0.14



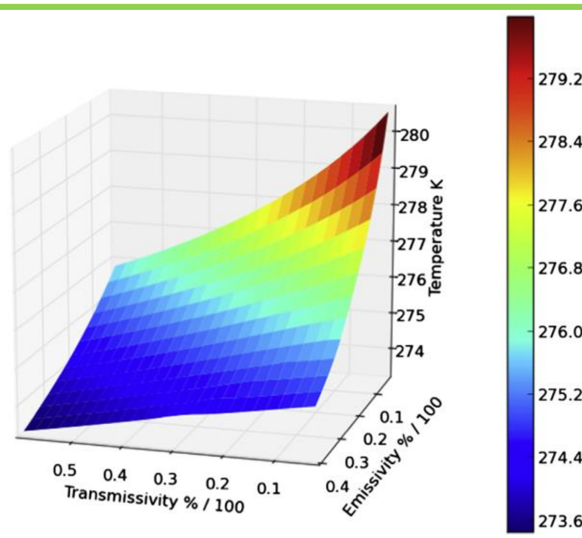
Piscia, 2012

External screens



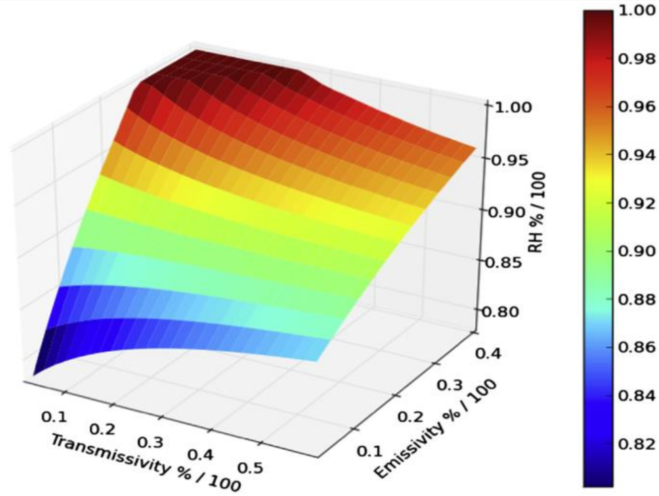
Montero et al., 2013

Radiative cover properties and greenhouse temperature



Piscia et al., 2013

Radiative cover properties and greenhouse Relative humidity



Piscia et al., 2013

Closed and semi-closed greenhouses

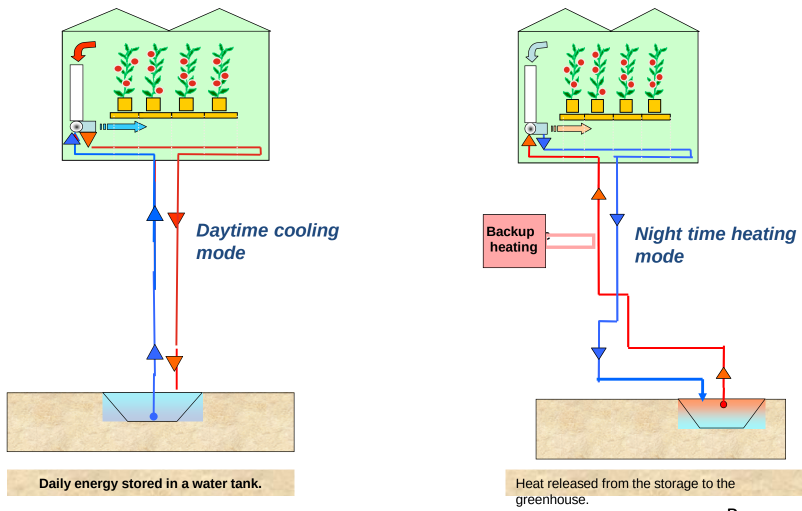
State of the art reviewed by Vadiee, and Martin(2012).

Energy saving up to 30% and increase in yield of 20% (Marcelis et al., 2009)

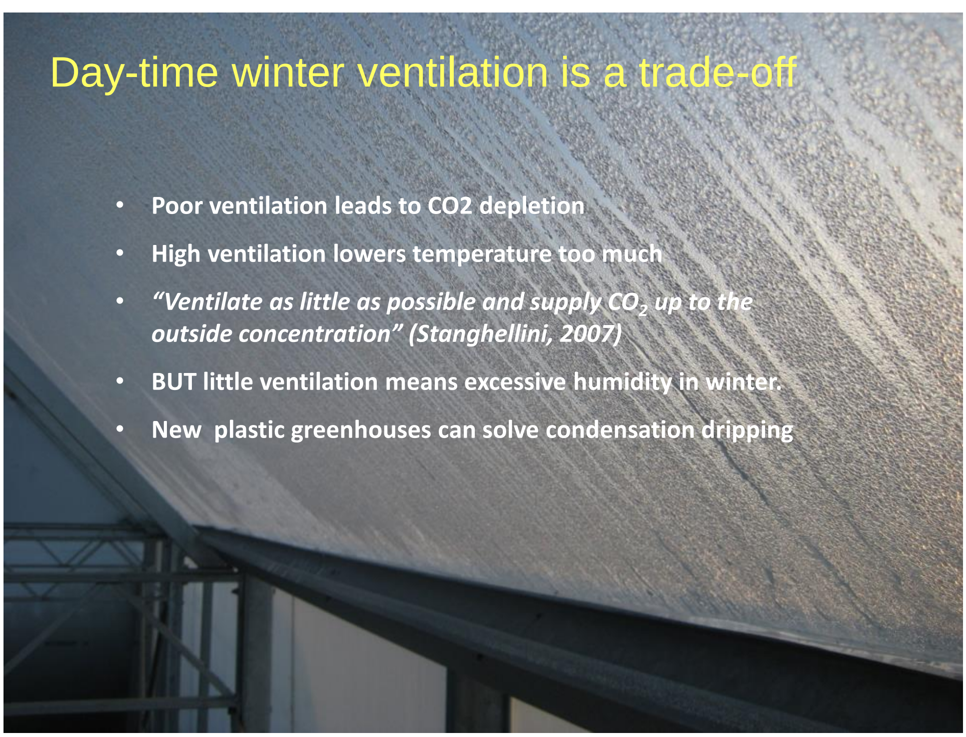
Important increase in water use efficiency (Katsoulas et al. (2015)

Closed and Semi-closed greenhouses

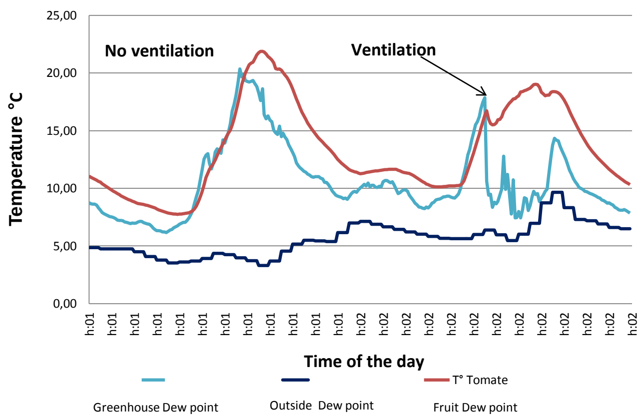
Operational scheme in cold periods.



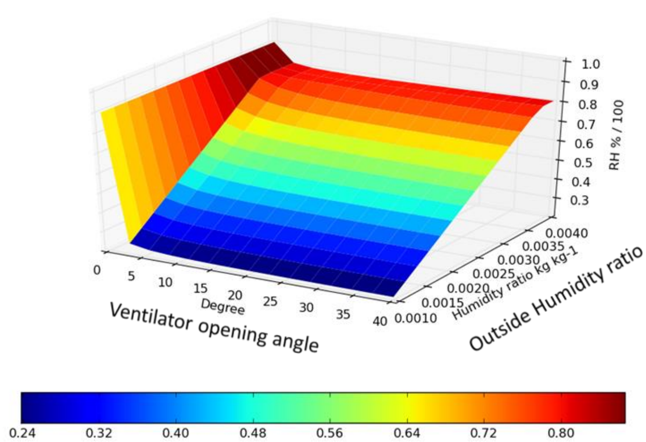
Baeza et al, 2012



Condensation on fruits in semi-closed unheated greenhouses

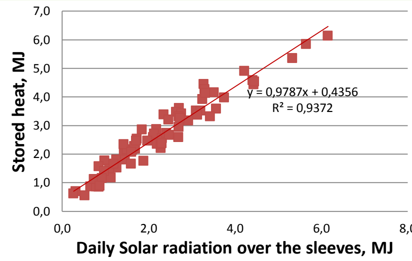


How much ventilation?



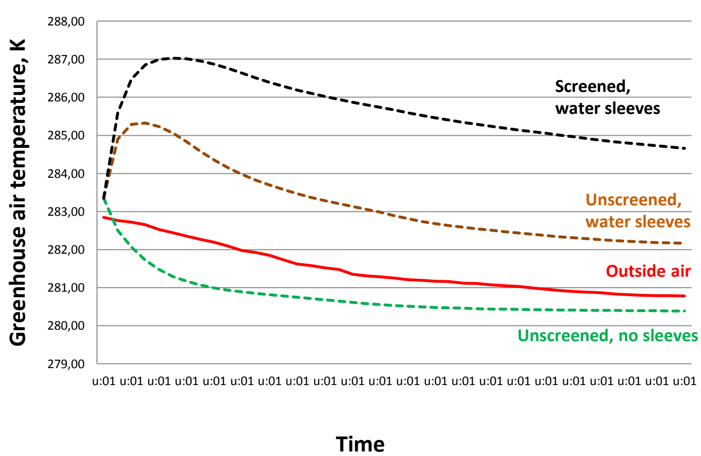
Greenhouse relative humidity

Passive methods: water sleeves



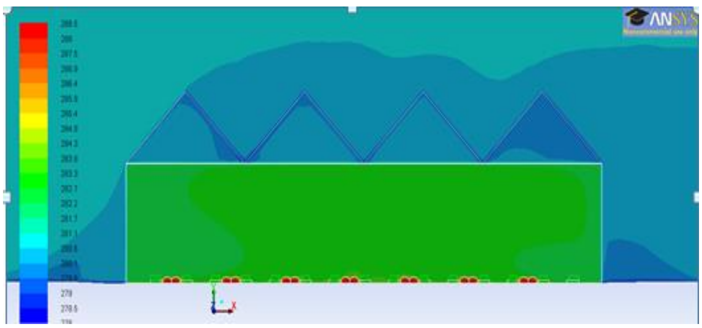
Ntinas et al., 2015: 10.8% higher marketable yield, 18.4 % more antioxidant capacity

Preheating water sleeves, 300 K



Conclusions: Passive greenhouses

- Day time: application of existing knowledge on ventilation and light transmission
- Night time: Integration of solutions (screening, semi-closed greenhouse, water sleeves, use of waste/solar heat)
- Specific climate controllers for passive greenhouses are needed, particularly concerning humidity control.



Active greenhouses

- Most common type of greenhouses in regions with cold winter climate.
- Highly technical, aim is to achieve optimal microclimate during the whole cycle to maximize yield and quality.
- This is achieved at the expense of high fossil energy input and labour intensive cultivation
- Therefore much of the research and innovation for active greenhouses is focussed on:
  - **Energy saving**
  - **Automation and robotization.**

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Strategies for fossil energy saving

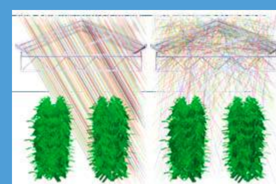
1. MAXIMIZING USE OF SUNLIGHT.

Group of crops	Crop	Yield reduction at 1% less light	Remarks
Soilgrown vegetables	Lettuce	0.8%	Equal effects on fresh and dry weight
	Radish	1%	Effects on tuber stronger than on shoot. Shoot/tuber ratio increases at low light
Fruit vegetables	Cucumber	0.7-1%	Dry-matter percentage of fruit decreased at low light. Effect of light on fruit fresh weight is smaller than on fruit dry weight
	Tomato	0.7-1%	Effect on fruit fresh weight stronger than on plant dry weight
	Sweet pepper	0.8-1%	
Cut flowers	Rose	0.8-1%	Light affects number of shoots as well as shoot weight. Effects in summer smaller than in winter
	Chrysanthemum	0.6%	

Marcelis et al., 2006

Diffuse light – crop effects

Up to 10% higher yield by diffuse light (e.g. Hemming et al., 2006; 2008; Dueck et al;,2012; Li, 2014)



Swinkels, 2016

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New prototype of glasshouse with optimum light transmission: the "Winterlight greenhouse"

▪Goals: >10% more natural sunlight in greenhouse during winter months (October-March) and >10% higher light use efficiency by the crop

▪ Innovation elements:
● Greenhouse roof construction – roof shape, angle, orientation, materials
●Glass- basic glass with diffuse structure, AR coating, condensation behaviour
● Screen – basic material, installation
● Crop – high-wire cucumber, cultivars, cropping system, crop management

Kempkes, 2016

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Strategies for fossil energy saving

2. MINIMIZING HEAT LOSSES

New glasshouse concepts have been developed with double roof covers to minimize radiative and convective heat losses while maintaining excellent optical properties.

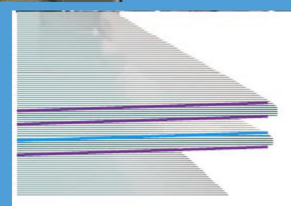
VenLowEnergykas

Goal: Greenhouse concept with **highest** energy saving and **good** production

- Double glass with low u-value and high light transmission

Glass	Coating	T	U-value
Single	-	82	6.7
Single	AR-AR	91	
Single	AR-Low-ε	81	
Double	AR-AR-Low-ε-AR	79	1.2

- low u-value due to low-ε coating
- high light transmission due to AR coatings



Hemming et al. 2012

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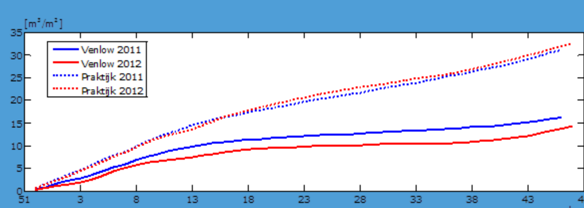
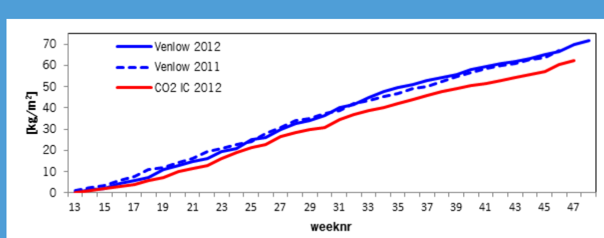


	2011 (m^3 gas/m^2)	2012 (m^3 gas/m^2)
Venlow	16.3	14.4
Commercial grower	31.2	32.6

The lower use of energy for heating is at the expense of more electricity use for mechanical dehumidification and use of CO_2 from other sources other than from the combustion gases from the boiler.



The Venlow concept has already been upgraded to a tomato commercial grower in The Netherlands (1 ha)

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Kempkes, 2016

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2SAVEENERGYKAS®

Goal: Greenhouse concept with high energy saving and high production at limited level of investment

- New Venlo-greenhouse with insulated covering
- Glass with AR coating and diffuse F-CLEAN® inside for insulation and high light level
- Small ventilation windows: mechanical dehumidification

Hemispherical transmission τ_h and the haze η of different combination of materials for PAR light 400- 700 nm

Material	Haze η	Hemispherical light transmission τ_h
glass clear + Fclean diffuse	77	72.6
glass clear + AR coating + Fclean diffuse	77	75.9
glass diffuse high haze + Fclean clear	68	75.3
glass high haze + AR coating + Fclean clear	68	80.7

Kempkes et al., 2015

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VAN DER VALK SYSTEMEN BOAL SYSTEMEN AGC

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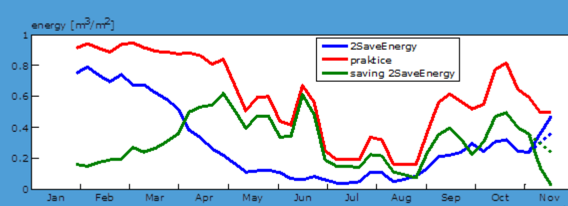

	Cultivation 2015 27/01 to 18/11
Heat consumption (m³/m²)	**12.6**
Electricity consumption AHU b) (kWh/m²)	0.8
Heat consumption standard practice (m³/m²)	**25.7**
Heat consumption RZ practice (m³/m²)	28.0
Saving 2SaveEnergy compared with standard practice (m³/m²)	**14.3**
CO_2 purchase (kg/m²)	**12.7**

Final yield of 67 kg/m²

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Kempkes et al., 2015

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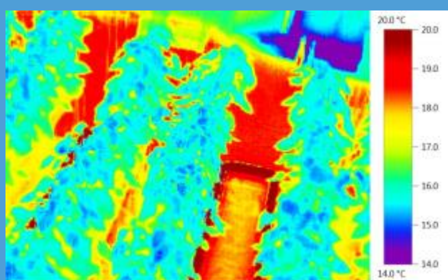
3. THE NEXT GENERATION OF CULTIVATION TECHNIQUES

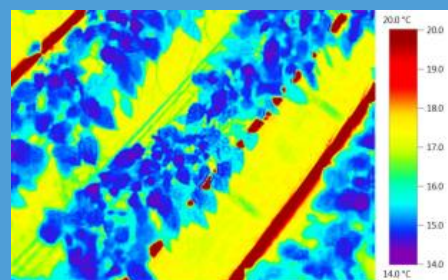
A) Maximizing the use of screens, even during daytime!

Ongoing projects with screen manufacturers to characterize better energy saving of screens: thermal properties, air permeability and water permeability

Developing experiments and simulation tools to understand the effect of multiple screens on radiative losses and crop profile temperature



Screen deployed:
Much smaller differences



Screen stowed:
clear temperature differences in the crop

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3. THE NEXT GENERATION OF CULTIVATION TECHNIQUES

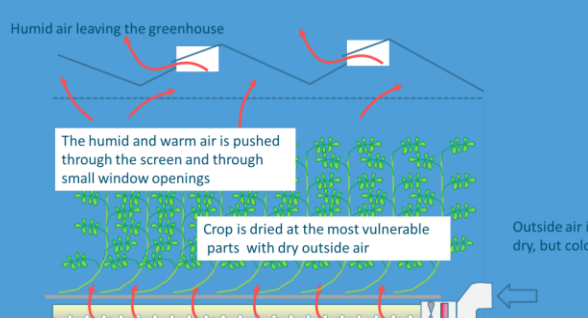
B) MECHANICAL DEHUMIDIFICATION

How to reduce losses

Reducing the transpiration rate during heating periods
Reduce the Sensible/Latent ratio of the ventilation air
Both measures imply growing at higher humidity

OR

Make use of the cold roof top (condensation)
Energy efficient system



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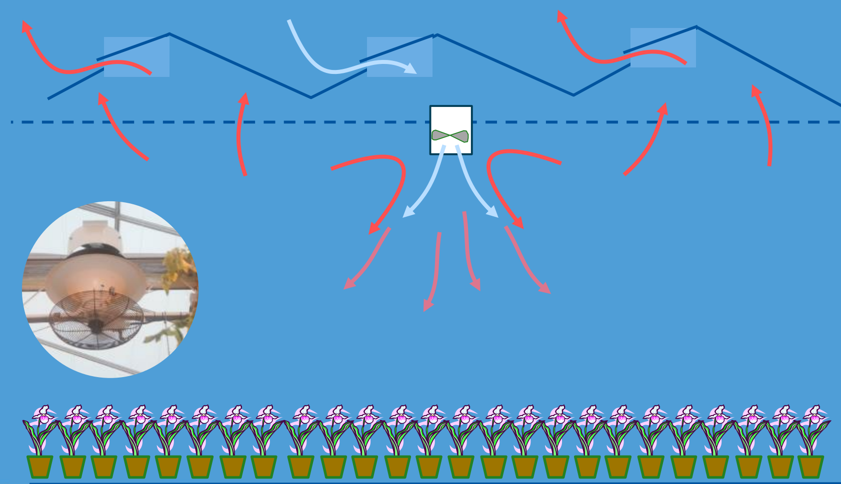
Kempkes et al., 2015

Air exchange from above the screen

- Vents can be opened to reduce dew point temp. cover



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Kempkes et al., 2015

Conclusions Active greenhouses.

- Active research is under way, mainly combining higher light transmission and energy saving.
- Multiple screens are being installed in new greenhouse prototypes as well as commercial greenhouses for additional energy saving.
- Temperature integration depending on available solar radiation; higher humidity set points and mechanical dehumidification are part of the Next Generation Cultivation Concept.

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