Modeling the vertical profile of transpiration in greenhouse

Cecilia Stanghellini, Anja Dieleman, Steven Driever, Leo Marcelis
Wageningen UR Greenhouse Horticulture

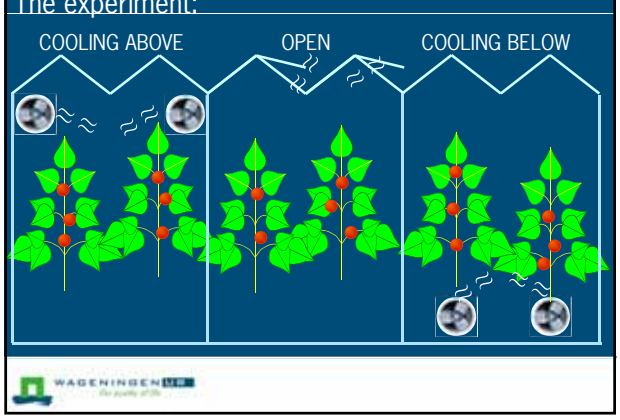
GreenSys 2011

Background

- Reducing ventilation in greenhouses has advantages
  - Ability to maintain a higher [CO_2]
  - Increased water use efficiency
  - Reduced pest pressure
- Less ventilation = need for cooling
  - Dimensioning of cooling
  - Design
  - ➢ trade-off between air mixing and light interception

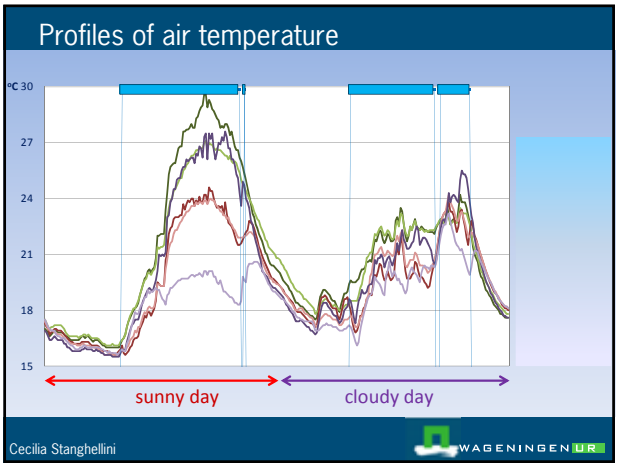
Cecilia Stanghellini GreenSys 2011

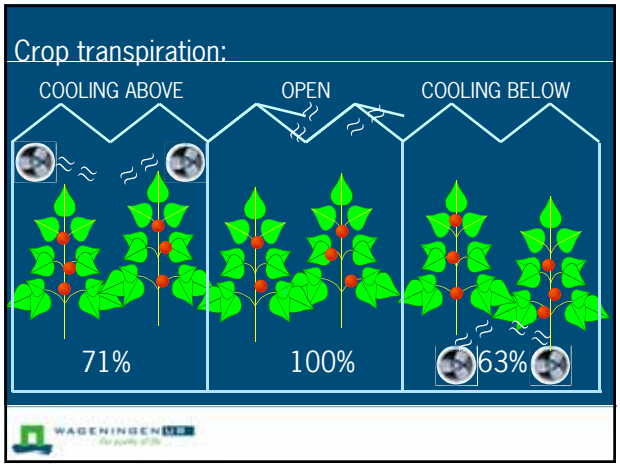
The experiment:

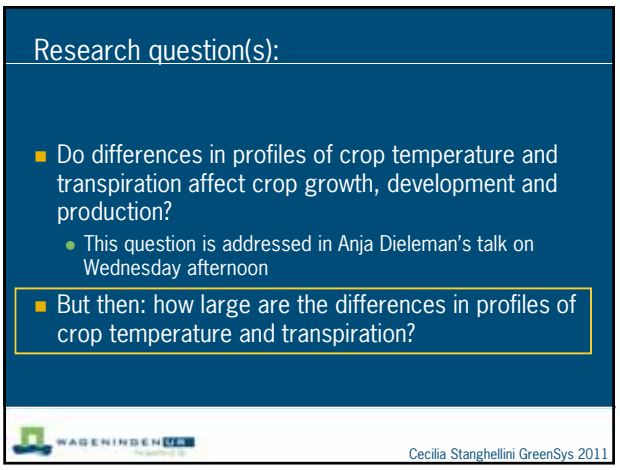


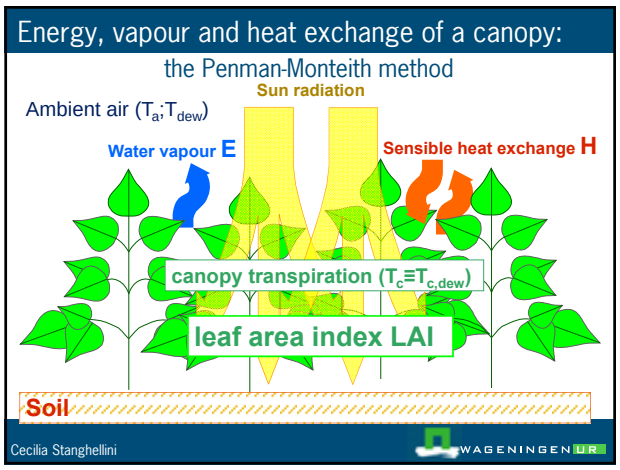

COOLING ABOVE


COOLING BELOW

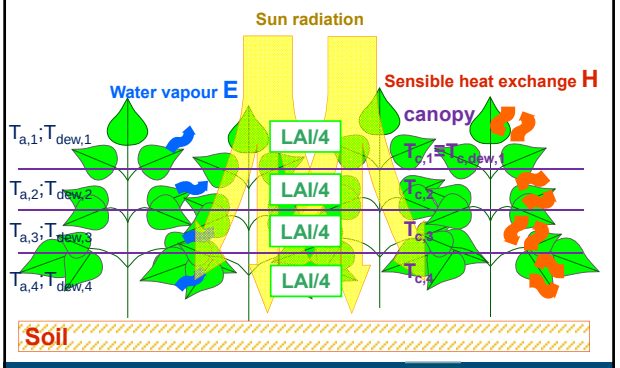

Profiles of air temperature
°C 30
27
24
21
18
15
sunny day
cloudy day
Cecilia Stanghellini
WAGENINGEN UR


Crop transpiration:
COOLING ABOVE
OPEN
COOLING BELOW
71%
100%
63%


Research question(s):
Do differences in profiles of crop temperature and transpiration affect crop growth, development and production?
This question is addressed in Anja Dieleman's talk on Wednesday afternoon
But then: how large are the differences in profiles of crop temperature and transpiration?
Cecilia Stanghellini GreenSys 2011

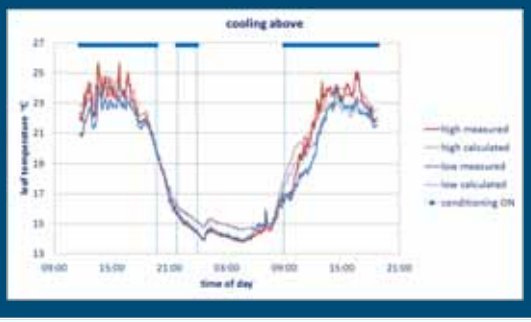

Energy, vapour and heat exchange of a canopy:
the Penman-Monteith method
Sun radiation
Ambient air (Ta;Tdew)
Water vapour E
Sensible heat exchange H
canopy transpiration (Tc≡Tc,dew)
leaf area index LAI
Soil
Cecilia Stanghellini
WAGENINGEN UR

And now on four layers:



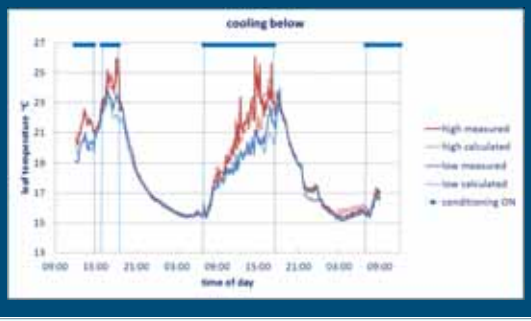
Cecilia Stanghellini

Measured and calculated leaf temperature



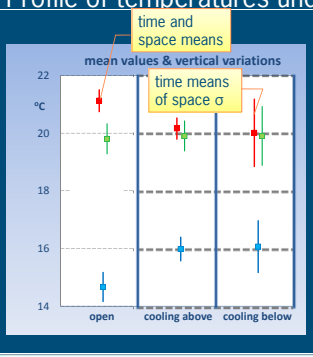
Cecilia Stanghellini GreenSys 2011

Measured and calculated leaf temperature



Cecilia Stanghellini GreenSys 2011

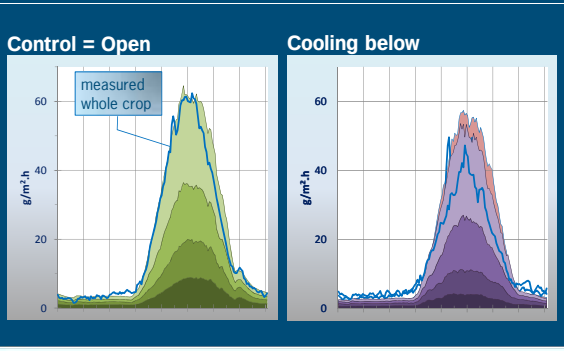
Profile of temperatures under cooling operation



- The cooled compartments were more (and equally) humid
- Calculated crop temperature was the same in all compartments
- Cooling above gives the most uniform vertical profiles, and cooling below the least
- The vertical profile of plant temperature is less than of climate

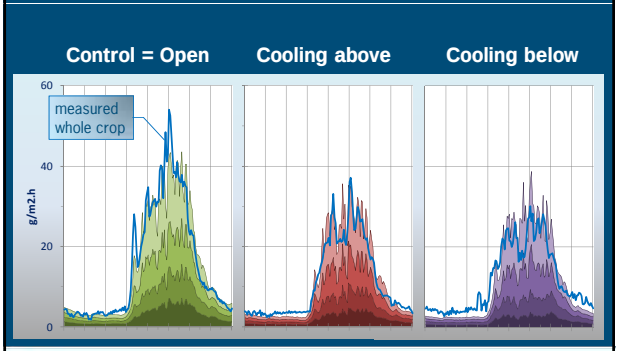
Cecilia Stanghellini GreenSys 2011

Calculated profile of transpiration (sunny day)

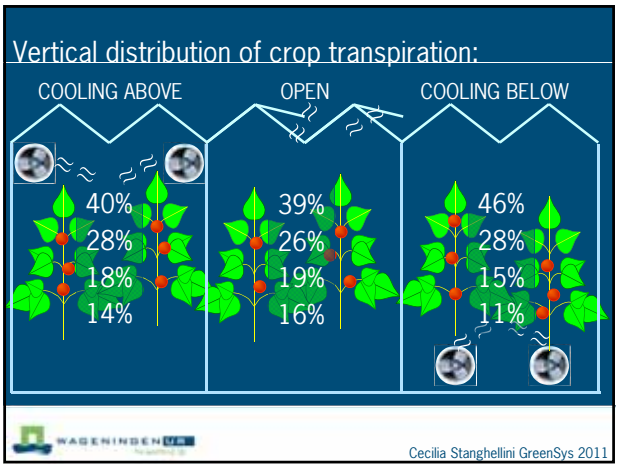


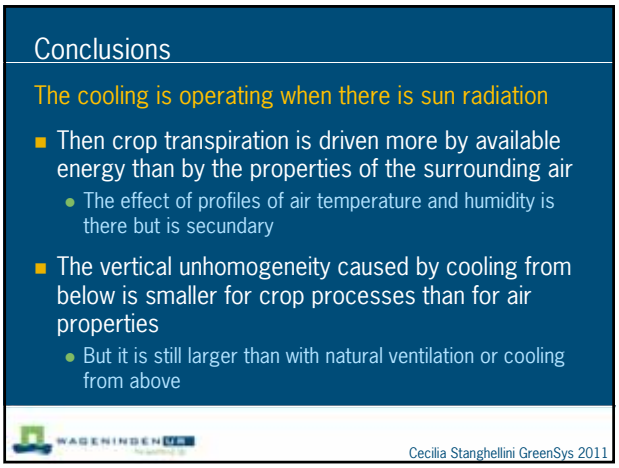
Cecilia Stanghellini GreenSys 2011

Calculated profile of transpiration (cloudy day)



Cecilia Stanghellini GreenSys 2011


Vertical distribution of crop transpiration:
COOLING ABOVE
OPEN
COOLING BELOW
40%
28%
18%
14%
39%
26%
19%
16%
46%
28%
15%
11%
Cecilia Stanghellini GreenSys 2011


Conclusions
The cooling is operating when there is sun radiation
Then crop transpiration is driven more by available energy than by the properties of the surrounding air
The effect of profiles of air temperature and humidity is there but is secundary
The vertical unhomogeneity caused by cooling from below is smaller for crop processes than for air properties
But it is still larger than with natural ventilation or cooling from above
Cecilia Stanghellini GreenSys 2011


Thanks to:
THANK YOU !
Questions?
for your attention
Kang-mo Lee for the leaf temperature data
The Dutch Ministry of EL&I and the Dutch Horticultural Board for sponsoring the project