Requirements of Plastic Films for greenhouse application – Latest Development in Research

6th European Additives & Colors Conference, 11/12 March 2009, Antwerpen

Silke Hemming,
Wageningen UR Greenhouse Horticulture

Requirements

- Covering materials for horticultural applications:
  - High light transmission
  - Optimum light spectrum
  - Optimum heat input - low heat losses
  - Optimum condensation behaviour
  - High mechanical resistance
  - Low sensitivity to ageing (UV, temperatures, chemicals)
  - Fabrication sizes
  - Costs

General

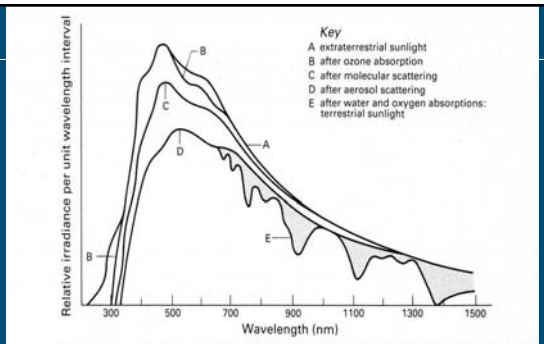


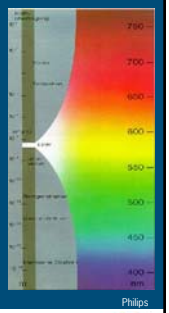
Figure 3.1 The spectrum of sunlight, progressively modified by various processes as it penetrates the atmosphere.

General

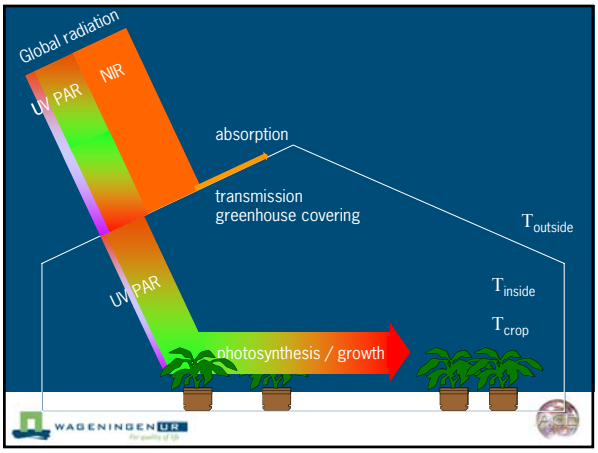
Solar radiation (300-2500nm), energy input greenhouse

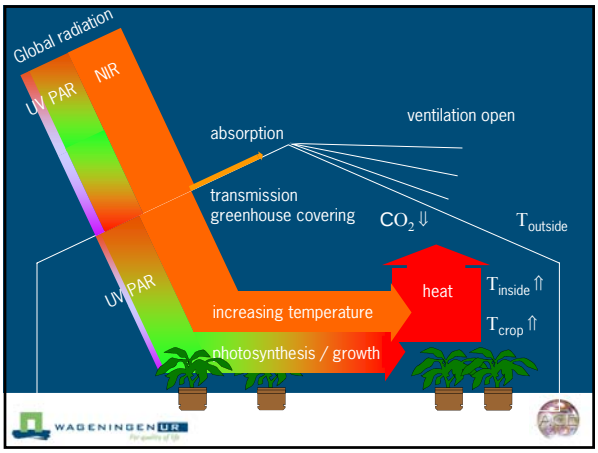
Relevant for horitcultural applications

UV	300-400 nm	morphogenesis
PAR	400-700 nm	photosynthesis, morphogensis
FR	700-800 nm	morphogenesis
NIR	800-2500 nm	*increasing greenhouse temperature*
FIR	2.5-100 µm	*heat radiation*



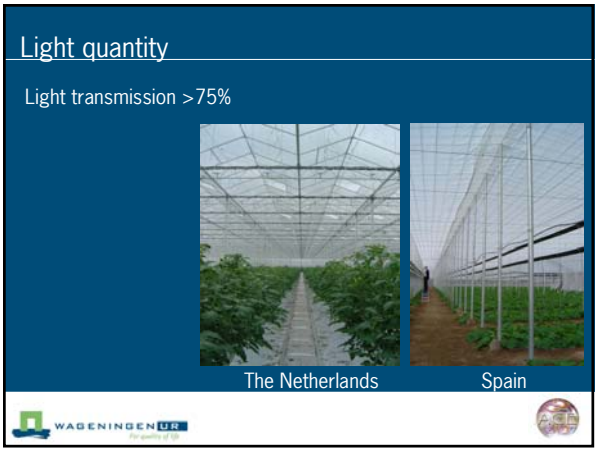
Heat radiation, energy loss greenhouse

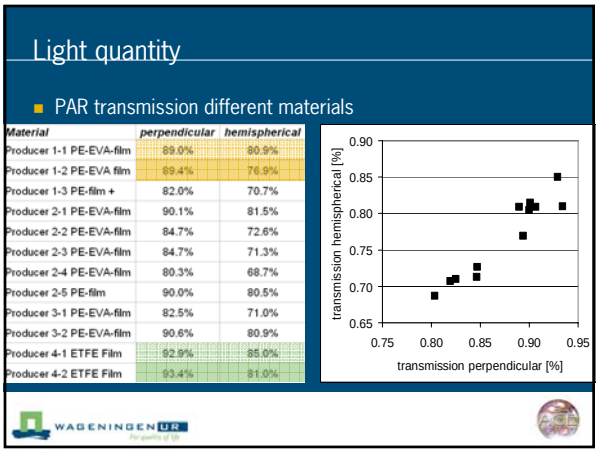


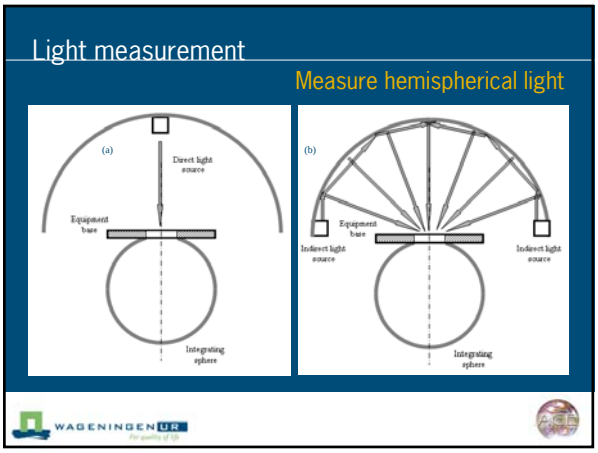

Global radiation
UV PAR
NIR
absorption
ventilation open
transmission
greenhouse covering
$CO_2 \Downarrow$
$T_{outside}$
UV PAR
heat
$T_{inside} \Uparrow$
$T_{crop} \Uparrow$
increasing temperature
photosynthesis / growth


Light quantity


Light quantity
Light transmission <<50%
Tropics
Spain


Light quantity
Light transmission >75%
The Netherlands
Spain


Light quantity
PAR transmission different materials
Material | perpendicular | hemispherical
Producer 1-1 PE-EVA-film | 89.0% | 80.9%
Producer 1-2 PE-EVA film | 89.4% | 76.9%
Producer 1-3 PE-film + | 82.0% | 70.7%
Producer 2-1 PE-EVA-film | 90.1% | 81.5%
Producer 2-2 PE-EVA-film | 84.7% | 72.6%
Producer 2-3 PE-EVA-film | 84.7% | 71.3%
Producer 2-4 PE-EVA-film | 80.3% | 68.7%
Producer 2-5 PE-film | 90.0% | 80.5%
Producer 3-1 PE-EVA-film | 82.5% | 71.0%
Producer 3-2 PE-EVA-film | 90.6% | 80.9%
Producer 4-1 ETFE Film | 92.9% | 85.0%
Producer 4-2 ETFE Film | 93.4% | 81.0%
transmission hemispherical [%]
0.90
0.85
0.80
0.75
0.70
0.65
0.75 0.80 0.85 0.90 0.95
transmission perpendicular [%]

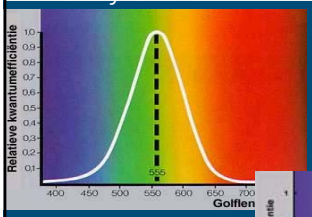

Light measurement
Measure hemispherical light
(a)
Direct light source
Equipment base
Integrating sphere
(b)
Equipment base
Indirect light source
Indirect light source
Integrating sphere

Light quality

Photosynthesis

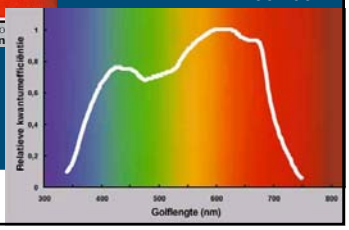
- 400-700nm photosynthetic active radiation
- Lightreceptors: chlorophyl, carotinoids
  - Plants use theoretically all colours for photosynthesis
  - Most plants use red light (≈650nm) and blue light (≈ 450nm) more efficiently
  - Plants adapt to colours during growth

Photosynthesis



Sensitivity of 'all' plants = PAR 400-700nm

Sensitivity of human eye = visible light 380-780nm



Morphogenesis

- 300-800nm
- Specific lightreceptors for UVB, UVA, Blue and Red:Far-red
  - Elongation
  - Side shoots
  - Leaf area and leaf thickness
  - Flowering
  - Colour of flowers and leaves
  - Germination

Light quality

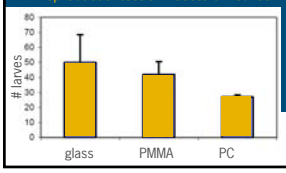
- UV-transparent films influence:
  - Hardening of crops;
  - Leaf and flower colour (lettuce "lollo rosso", aubergines, some flowers or flowering potplants);
  - Compact growth (bedding plants, some potplants)
  - Behaviour of insects (white fly, trips, louse, (bumble-) bee)

Light quality – UV influence on insects

- Population growth of insects on *chrysanthemum* under different UV-transparant covers

after 6 weeks		louse			white fly			trips		
		#	mean	s.d	#	mean	s.d	#	mean	s.d.
Glas	A	19320	24420.5	7213.2	341	376.5	50.2	303	219.5	118.1
	D	29521			412			136		
PMMA	B	17528	21163.5	5141.4	481	429.0	73.5	164	201.0	52.3
	E	24799			377			238		
PC	C	11421	13007.0	2242.9	173	242.0	97.6	128	163.0	49.5
	F	14593			311			198		

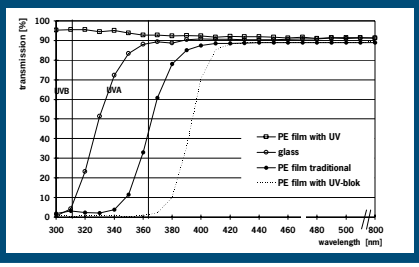
- Reproductiontest of insects on leaves → indirect influence of UV (plant as food source)



Many other influence factors:
- temperature / humidity / light
- sanitation
- plant vitality

Light quality

- UV transmission of different materials



Light diffusion

Light diffusion

Greenhouse covering materials are able to scatter light rays, transforming direct light into diffuse light

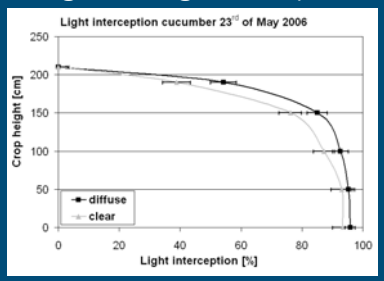
50% 0%

Haze

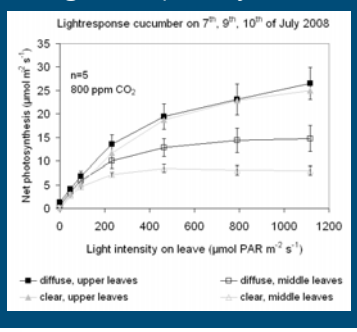
Light diffusion

- Vertical light distribution
  - Most light intercepted by upper leaves
  - Lower leaves grow little and lose photosynthesis

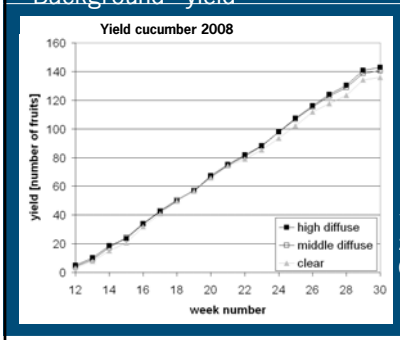
Background – light interception



Background - photosynthesis

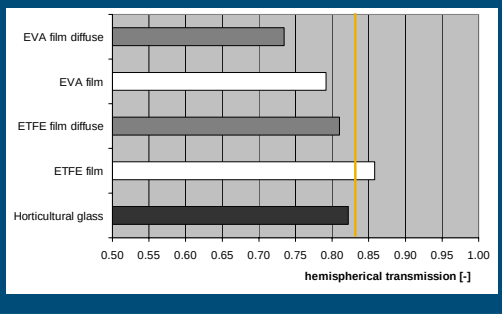


Background - yield

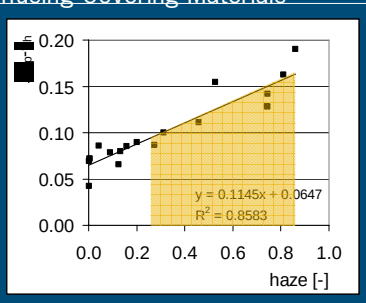


	more fruits
74% haze	9.2%
27% haze	6.5%
0% haze	-

Materials – haze and light transmission

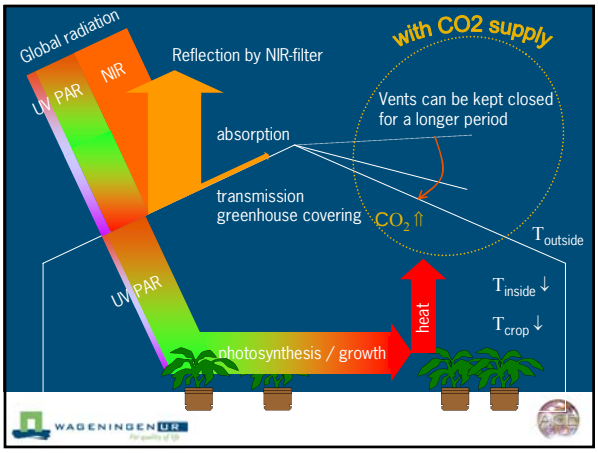


Light Diffusing Covering Materials



Be careful with light losses at high haze factors

Heat input

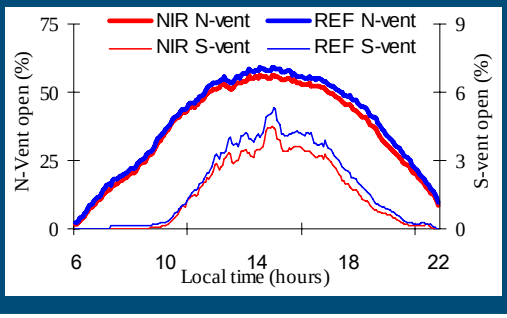


Experiment: inside NIR reflecting screen

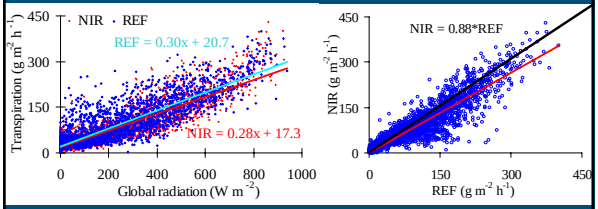
NIR-reflecting inside screen (800-1100 nm)
- Screen: 40% reflection of NIR energy
- Crop: 45% reflectio of NIR radiation
- Installation parallel to roof

Greenhouse climate control:
- Temperature
- Artificial lighting (100 micro mol m^{-2} s^{-1})
- CO_2 injection (1000ppm)

Results: ventilation opening



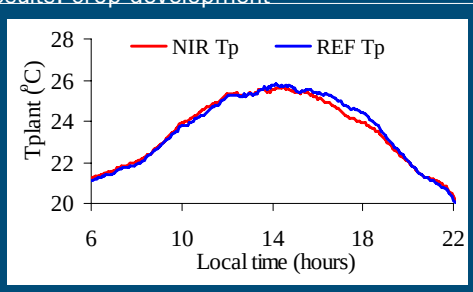
Results: crop ranspiration



Transpiration VS global radiation outside

NIR VS REF transpiration

Results: crop development



Slower crop development in NIR due to lower temperature in NIR

NIR-filtering

- Northern Europe:
- Adaptable NIR-filtering screen outside (!) with high light transmission
- In "closed greenhouse" NIR-filtering reduces cooling capacity up to 30%

NIR-filtering

- Mediterranean Countries:
  In (unheated) greenhouses use of an (adaptable) NIR-filtering outside screen only in hot periods
- Tropical regions:
  NIR-filtering coverings reduce air and crop temperatures permanently

Questions?