Covering Materials for sustainable greenhouse ecosystems

ISHS Greensys2011, Greece

Silke Hemming,
Wageningen UR Greenhouse Horticulture

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Trends world-wide

- Decrease of availability natural sources (water, gas/oil, fertilizers)
- World population is growing
- Open field production moves to more protected systems
- Low tech and mid tech growing systems have biggest areas
- High tech greenhouse industry increases and moves to year round production with high quality and predictability

Challenge world-wide

- Sustainable greenhouse ecosystems:
- Design greenhouse systems which combine (economic) production efficiency with minimal input of energy, water and nutrients
- High production, product quality, predictability
- High energy efficiency
- Low pesticide use, high food safety
- High water use efficiency, low nutrient losses
- Economic feasible production

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Covering materials

- Goal:
- Protect the crop from harmful events (extreme temperatures, extreme rainfall or drought, irradiation, pest and diseases).
- Create favourable micro-climate for crop (temperature, humidity, light)
- Save natural resources (water, nutrients, pesticides, energy)

Requirements of covering materials

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

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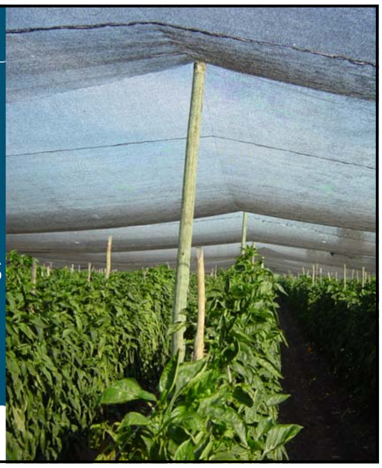
- Nettings & screens



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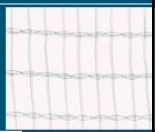
Pest and disease control

- Nets are a barrier against insects
  - Mechanically: mesh size/porosity
  - Optical: colour



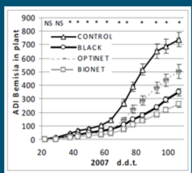


Figure 3. Evolution of the accumulated day incidence of *Bemisia* in plant (2007).

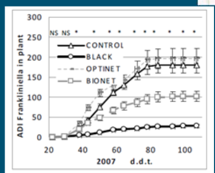


Figure 5. Evolution of accumulated day incidence of *Frankliniella* in plant (2007).

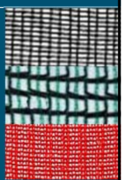
Gázquez et al., 2009

Pest and disease control

- Coverings (nets and plastics) affect
  - Movement / mobility of insects
  - Reproduction of insects
  - Crop nutrition value for insects
  - →UV
- PHOTOSELECTIVE FILMS IN PEST AND DISEASE CONTROL
- **D. Skirvin, J. Clarkson, Laura Pirondini, R. Napier, Sacha White , 2011**

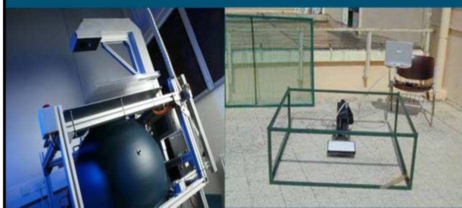
Optical properties of nettings

- **Nets create the right light environment**
  - **Shading effect – reduce high irradiation**
  - **Photoselective effect – modify spectrum for crop growth and development**



- **GLOBAL, PAR AND DIFFUSIVE RADIATION TRANSMISSION OF AGRICULTURAL SCREENS: PRELIMINARY REPORT.**
- M. Romero-Gamez, E.M. Suarez-Rey, T. Soriano, **N. Castilla**(*), 2011

Optical properties of nettings



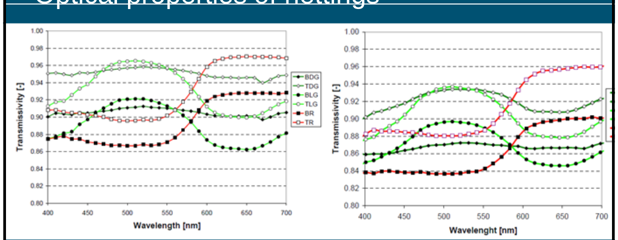
Light trans-mission and light spectrum measurements

under defined conditions

under field conditions

Castellano et al., 2008

Optical properties of nettings



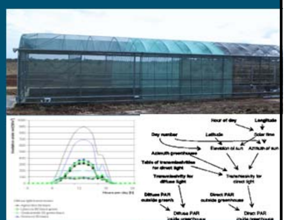
Laboratory (The Netherlands) **Field-test (Southern Italy)**

→ Good correlation +/- 2%

Castellano et al., 2008

Optical properties of nettings (models)

- Quantification of radiometric properties of agricultural nets
- Develop a numerical model to estimate radiometric performance of net covered structures
- Validate model with greenhouse measurements

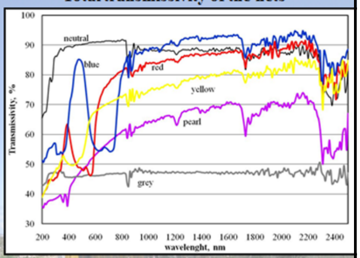


Hemming et al., 2008

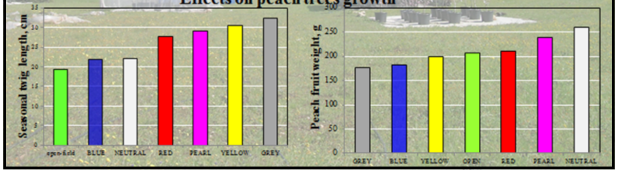
Peach trees covered with photoselective coloured nets

Schettini et al., 2011

Total transmissivity of the nets

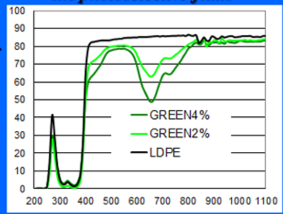


Effects on peach trees growth



Peach and cherry trees covered with photoselective and photoluminescent films

Total transmissivity of the photoselective films



Photoluminescent effect of the RED, BLUE and RED-BLUE films

	absorbed radiation	emitted radiation
RED	290-350 nm	600-650 nm
BLUE	280-380 nm	420-490 nm
RED-BLUE	290-400 nm	420-490 nm and 610-620 nm

Schettini et al., 2011

Seasonal increase in peach and cherry shoot length (cm)

	Open-field	LPDE	RED	BLUE	RED-BLUE	GREEN2%	GREEN4 %
Peach	13.5 a	18.3 b	27.2 c	22.4 b	20.8 b	31.0 c	46.1 d
Cherry	39.3 a	49.8 b	55.8 c	48.9 b	45.1 b	47.6 b	68.7 c

Photoselective plastic films

- **Poster**: The effect of coloured plastic films on the growth and yield formation of tomatoes
- **G. Gmizo, I. Alsina, L. Dubova**

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Light control and water use by screens

- **Screens reduce crop transpiration**
  - **Reduce solar energy – reduce transpiration – save water**

shading fraction	water consumption [m³/(m² yr)]	production
No shading	1.217	100%
30% shading	1.090	94%
40% shading	1.067	93%
50% shading	1.034	90%

+control light intensity
+ increase water use efficiency
- decrease production

Optimum?

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Hemming et al., 2010

- Diffuse coverings

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Diffuse light effects

- Diffuse light is positive because…
  - Changed light penetration in crop
  - Diffuse light is absorbed more by middle leaf layers of cucumber
  - Higher photosynthesis in those leaf layers
  - Higher yield
  - Milder greenhouse climate on sunny days
  - Lower head temperature during high irradiation
- 1% light = 1% growth rule has to be re-defined
- Optimum diffusing properties have to be found for crops/locations

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Hemming et al., 2007
Dueck et al., 2009

Diffuse light on roses

- GREENHOUSE CLIMATE AS AFFECTED BY A DIFFUSE GLASS COVER: FIRST RESULTS FROM A ROSE EXPERIMENT
- **Kempkes et al. , 2011**

- **Poster:** EFFECT ON ROSE PRODUCTION AND QUALITY OF A DIFFUSE GLASS GREENHOUSE COVER
- **Garcia et al., 2011**

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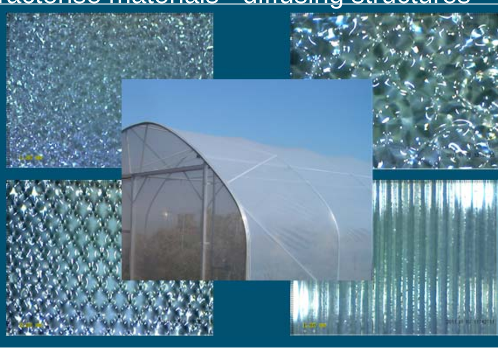
Characterise materials - diffusing structures



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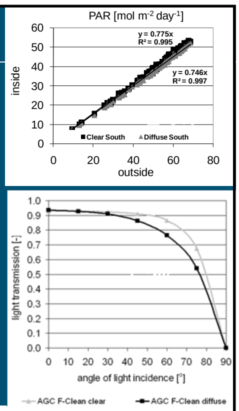
Characterise materiales

→ Transmission for hemispherical light τ_h and haze η to characterise diffuse materials



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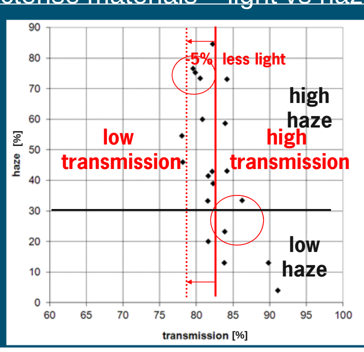
Hemming et al., 2008

Characterise materials – light vs haze



Still tolerable?

What is better?

Price?

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Diffuse light materials

- Measure transmission hemispherical & haze
- Plastic films with high haze show lower light transmission
- Additional coatings improve light transmission of glass with high haze, spectrum can be changed
- Chose right material for crop and location
- → high light losses are negative during periods with low solar irradiation for some crops

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- NIR blocking coverings

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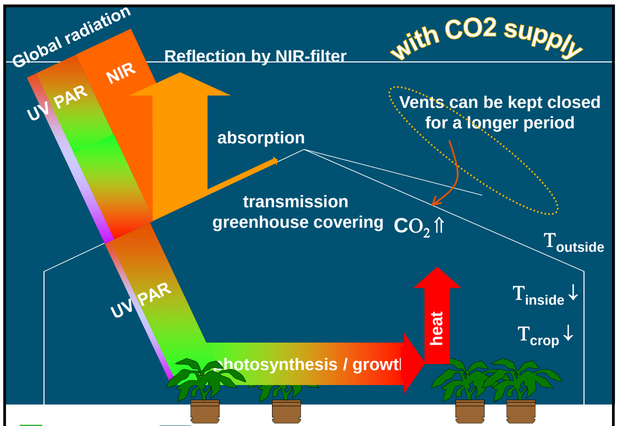

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Experiment: inside NIR reflecting screen

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

Greenhouse fully climate controlled:
- Temperature, humidity
- Artificial lighting (100 µmol m^{-2} s^{-1})
- CO_2 injection (1000ppm)

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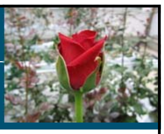
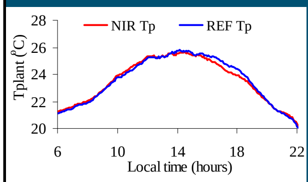
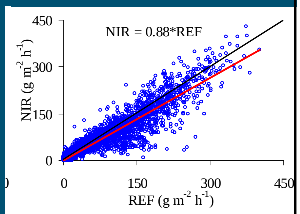
Kempkes et al., 2008

Inside NIR reflecting screen





Crop temperature lower during high irradiation



Crop transpiration ca. 12% reduced by NIR reflecting screen

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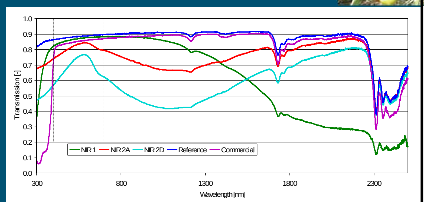
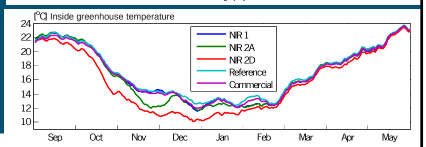
Kempkes et al., 2008

NIR absorbing plastic films

- Model study using KASPRO:
- NIR absorbing plastic films
- Tomato, Southern Spain
- Light transmission and spectrum important
- Temperature reduction in winter, important in passive greenhouses





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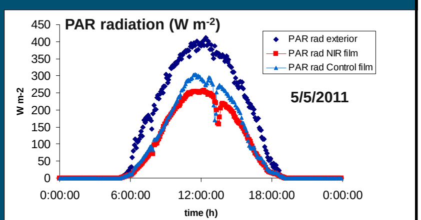
Kempkes et al., 2010

NIR absorbing plastic films

- Experiments for validation of earlier KASPRO model studies:
- NIR absorbing plastic films
- Passive greenhouse in Almeria, Spain
- Tomato



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Baeza et al., 2011

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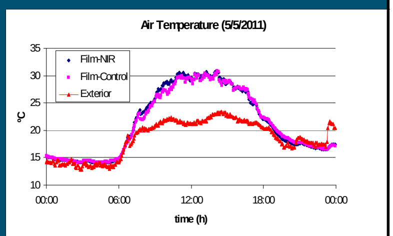

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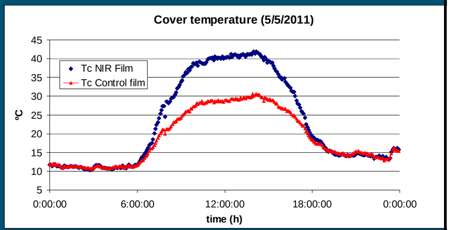

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Baeza et al., 2011

NIR blocking materials

- **Poster:** Influence of two new greenhouse covering materials on greenhouse microclimate and cooling load
- **E. Kitta, T. Bartzanas, N. Katsoulas**

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Modern double coverings

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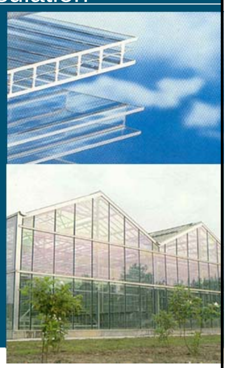
Reduction of energy losses: insulation

- Decreasing u-value:
  - Double cover
  - Screens
- Reduction of radiation loss:
  - IR absorbers
  - Low emission coatings
- Maintain light transmission:
  - Anti-reflection coating
  - Micro/Nanostructures



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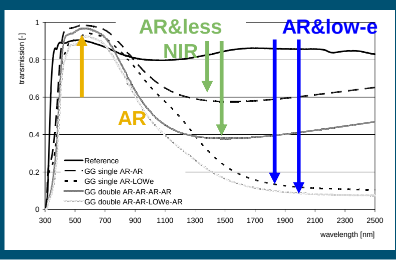
Bakker et al., 2007

Glass coverings with modern coatings

- Spectral transmission of glass with coatings (anti-reflection and low-emission) for perpendicular global radiation (300-2500nm)
- Single and double glasses



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Hemming & Kempkes, 2009

Glass coverings with modern coatings

- Transmission measurements and model study with KASPRO:
- New double coverings with anti-reflection and low-emission coatings
  → higher energy saving, high light transmission

	Ref	Single AR-AR	Single AR-lowe	Double AR-AR-AR-AR	Double AR-AR-lowe -AR
Gas use [$m^3.m^{-2}$]	33.8	34.9	28.2	25.4	23.0
Gas use [%]		3.4	-16.5	-24.6	-32.0
Dry weight production [$kg.m^{-2}$]	8.3	9.0	8.0	8.3	7.6
Light transmission hemispherical $t_{PAR\ h}$ [-]	0.822	0.905	0.838	0.850	0.785

- Need for dehumidification
- Need for external CO_2

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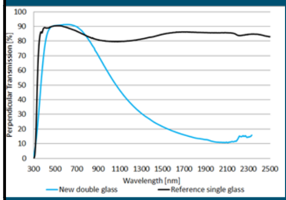
Hemming & Kempkes, 2009

Glass coverings with modern co…

- New greenhouse concept and experiments
- Improved double glass with AR-AR & AR-low e
- 60% energy saving possible?!?



	Trans-mission τ_p [%]	Trans-mission τ_h [%]	U-value [$Wm^{-2}K^{-1}$]
New double glass	88.9	79.6	1.2
Reference single glass	89.5	82.3	6.7

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Hemming et al., 2011

Condensation

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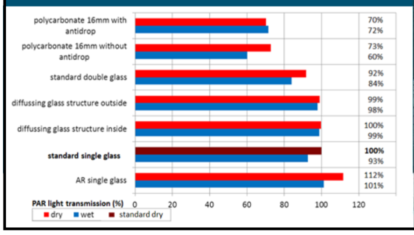
Light loss due to condensation

- Characterisation of material properties – light transmission under defined conditions
- Poster: EFFECT OF CONDENSATION ON LIGHT TRANSMISSION AND ENERGY BUDGET OF EIGHT GREENHOUSE COVER MATERIALS
- **Stanghellini et al, 2011**



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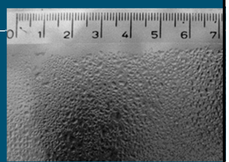
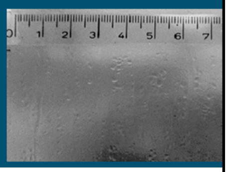
Anti-drip films

- EFFECTS OF ANTI-DRIP POLYETHYLENE COVERING FILMS ON MICROCLIMATE AND PRODUCTION OF A GREENHOUSE
- **Evagelini Kitta, Thomas Bartzanas, Nikolaos Katsoulas**





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Future challenge

- Challenge for research remains the same since several years:
- Finding the right covering material combing
  - a high light transmission,
  - low energy and water consumption,
  - creating the ideal microclimate for a high quality crop production &
  - which is economically interesting for growers.
- Develop smart materials which are able to adapt to seasonal changes in outside conditions?

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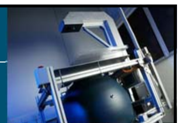
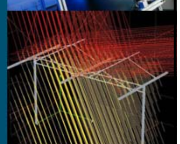
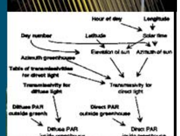
Future research needed

- Characterise materials under standard conditions
- ...and under special conditions
- Link physical properties with crop physiology (and pest and disease physiology)
- Develop and validate models, generic models considering local conditions
- Explain, understand and predict processes instead of try and error practical research







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Developing the right covering material for a given local climate condition and crop requirement is the first step towards sustainable greenhouse ecosystems!

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