Options for design and management of greenhouse production systems in the tropics

Anne Elings & Silke Hemming
Wageningen UR Greenhouse Horticulture

Priorities to increase food supply

1: Increase primary production
2: Decrease losses in supply chain

Why a greenhouse? Tomatoes in Indonesia

Benefits of protected horticulture

- Increased production and resource efficiency (e.g. water and nutrients)
- Less diseases/better opportunities for biological control
- High product quality and food safety

Protected systems

Enable increase of the production period and productivity of the crop.

Complete controlled environment greenhouse

Open field
Passive greenhouses

Protected Horticulture: 15 times better resource efficiency

Water Use Efficiency sweet pepper
Kg fresh produced per m² stub

<table>
<thead>
<tr>
<th></th>
<th>Open Field</th>
<th>Passive greenhouse</th>
<th>Modern greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1m²</td>
<td>3 kg</td>
<td>13 kg</td>
<td>43 kg</td>
</tr>
</tbody>
</table>

(Images and figures shown in the slides are not transcribed here.)
Horticulture

Production value: €22 billion
Added value: €10.3 billion
Employment opportunities: 400,000 labour forces


The Netherlands 2nd largest export country in the world

Production value: €80.7 billion export agricultural products

Companies in agriculture and horticulture: 65,505
9% g.n.p. generated by agriculture and horticulture
77% Export to other EU countries
8.8% Employment in agriculture and horticulture

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Greenhouses in The Netherlands


Innovations in greenhouse horticulture over the last 50 years (primary production)

Focus: to become independent of...

- Soil (substrates)
- Environmental conditions (greenhouses, climate control)
- (Fossil) energy (energy saving, sustainable sources)
- Chemicals (IPM, biological control)
- Labour (Logistics and robotics)
- Water saving (closed cycles, rainwater)

Innovations in...

- Breeding
- Marketing and trade

Greenhouse inside

- Light
- CO₂
- Temperature
- Air humidity
- Nutrients
- Water
- Pests & Diseases

Situation in the tropics

- Growing demand for high-quality produce
- Tropical climate:
  - high temperature and air humidity
  - high wind speeds
- A variety of suppliers of greenhouses & installation
- Variation in technology level
- Need / willingness to innovate
- Natural ventilation
- High insect and disease pressure
Design criteria for a greenhouse in the tropics

Covering material:
- Nets/plastic/glass; screens
- Good light transmission
- Protection against sun
- Good insulation against pests

Construction:
- Good light transmission
- Ventilation for temperature and humidity management
- High volume
- Wind proof

Installation
- Clean water
- Substrate
- Good and efficient cooling
- Automation

Sustainability:
- Water
- Nutrients
- Economics

Knowledge:
- Sanitation
- Crop, water, nutrient management
- Delegate!

Market:
- Crop
- Variety

Don not do this:
- Free entry for pests
- Insufficient water
- A jungle
- No sanitation

Covering material
- High light transmission, optimum spectrum
- Spectral reflectance → block UV and NIR radiation
- Haze properties → Making direct radiation diffuse
- Cleaning methods
- Durability (mechanical resistance, UV, temperatures, chemicals)
- Optimum condensation behaviour
- Fabrication sizes
- Costs
Covering material

- Make use of natural sunlight: it is for free!!!
- Light -> yield
- Solar energy -> energy saving

Clear glass

Glass with modern coatings

Diffuse glass

Greenhouse coverings

- **Glass**
  - **Floatglass** – Greenhouse glass
  - **White glass** – Low-iron, Crystal Clear, Extra Clear, Ultra Clear, Vetraclear, Diamantglass, Optiwhite, Albarino Zero Crystal...
  - **AR glass** – Coating or surface treatment, HGI 91+AR, DA Glass 101-103, Albarino Zero Crystal+AR...
  - **Diffuse glass** – surface treatment with different structures, Vetrasol, Terrasol, Smart glass, Velglass, Brisa, Albarino...

- **Plastic sheets**

- **Plastic films**
  - PE-UV polyethylene with UV-stabilisation
  - PE-IR polyethylene with IR-absorption
  - EVA ethylenvinylactetate
  - ETFE ethenetetrafluourethene
  - PVC, PVDF

- **Plastic sheets**
  - PMMA polymethylmethacrylate (double)
  - PC polycarbonate (double)
  - PVC polyvinylacetate
  - GRP glass-reinforced polyester (fibre glass)

Greenhouse coverings

PAR light entering the greenhouse

Transmission $\tau$, reflection $\rho$, absorption $\alpha$

$$\tau + \rho + \alpha = 1$$

Light quantity

Light transmission $<<50\%$

Light transmission $>75\%$

(Spain)

Light transmission coverings

<table>
<thead>
<tr>
<th>Material</th>
<th>light transmission perpendicular</th>
<th>light transmission hemispherical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional glass</td>
<td>89-90%</td>
<td>83-84%</td>
</tr>
<tr>
<td>Low iron glass</td>
<td>90-91%</td>
<td>84-85%</td>
</tr>
<tr>
<td>AR glass</td>
<td>95-97%</td>
<td>89-91%</td>
</tr>
<tr>
<td>Diffuse glass</td>
<td>90-91%</td>
<td>76-82%</td>
</tr>
<tr>
<td>AR Diffuse glass</td>
<td>95-97%</td>
<td>85-91%</td>
</tr>
<tr>
<td>PE / EVA films</td>
<td>85-90%</td>
<td>76-82%</td>
</tr>
<tr>
<td>PE / EVA films diffuse</td>
<td>85-90%</td>
<td>73-80%</td>
</tr>
<tr>
<td>ETFE (F-Clean)</td>
<td>93%</td>
<td>86%</td>
</tr>
<tr>
<td>ETFE (F-Clean) diffuse</td>
<td>93%</td>
<td>81%</td>
</tr>
<tr>
<td>PC sheet</td>
<td>76-80%</td>
<td>60-70%</td>
</tr>
<tr>
<td>PMMA sheet</td>
<td>89-92%</td>
<td>ca. 76%</td>
</tr>
</tbody>
</table>

Hemming et al., 2005
Direct and diffuse light

Diffuse light gives higher yield

Diffuse coverings

Light spectrum – crop effects

Heat IR loss from greenhouse

IR transmission and emission coverings

<table>
<thead>
<tr>
<th>Material</th>
<th>IR transmission</th>
<th>IR emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>0%</td>
<td>0.83</td>
</tr>
<tr>
<td>Glass low-ε</td>
<td>0%</td>
<td>0.3</td>
</tr>
<tr>
<td>PE film</td>
<td>40-60%</td>
<td>-0.4</td>
</tr>
<tr>
<td>PE film thermic</td>
<td>20-40%</td>
<td>-0.7</td>
</tr>
<tr>
<td>EVA film</td>
<td>20-40%</td>
<td>-0.6</td>
</tr>
<tr>
<td>ETFE film</td>
<td>15-20%</td>
<td>0.78</td>
</tr>
<tr>
<td>PC double sheet</td>
<td>0%</td>
<td>0.83</td>
</tr>
<tr>
<td>PMMA double sheet</td>
<td>0%</td>
<td>0.84</td>
</tr>
</tbody>
</table>
Shading and screens

Reduces
Radiation temperature
transpiration rate
photosynthesis, but less than transpiration
Improves light distribution and light use efficiency
Can improve quality
Preferably outside
Some crops prefer shade

Greenhouse construction

Make use of natural ventilation, it is for free!!!
Air exchange for temperature/humidity control
Air exchange for natural CO₂ supply

Greenhouse construction: light

Daily temperature in tropical climate

Risk Diseases

High ventilation rates needed

Natural ventilation

Mechanical ventilation

Wind effect: lee side
Wind effect: wind side
Buoyancy effect
Cooling

The adaptive greenhouse method:

Indonesian design

Width & temperature

Greenhouse construction

Malaysia

Indian design

Greenhouse model

Crop model

Active means

Needed resources

Best possible passive structure

Climate

Heating

CO₂ supply

Cooling

Lighting

Temperature

Humidity

Sun radiation

Wind

Heating

CO₂ supply

Introduction

Forced cooling

Natural ventilation

Fogging

Wind

Radiative properties of the cover

Insulation (including screens)

Temperature

Humidity

Sun radiation

Wind

Heating

CO₂ supply

Lighting

Needed resources

Best possible passive structure

Climate

Greenhouse structure

Ventilation capacity

Ventilation management

Active means

Best possible passive structure

Production

Fuel

Electricity

CO₂

Water

Indonesia

Factory demo Malaysia

Construction with local materials

Three-span greenhouses with Dutch installation

Average air temperature

Maximum air temperature

Average air temperature

Average of AirTemp out

Average of AirTemp GH1

Average of AirTemp GH2

Average of AirTemp GH3
Demonstration results

Local materials  Dutch computers  Monitoring

Crop growth  Fruit ripening  Harvest

Also in Thailand

Realised demo greenhouse in Tainan, Taiwan

Goal: Introduce a medium-tech greenhouse concept with environmental control, soilless cultivation for safe tomato production

Taiwan climate – global radiation

Typical:
- Year-round daily radiation sum of 10-20 MJ/m²
- Large difference in cloudiness per region

Hemming et al., 2013

Crop and cultivar

- Strategic choice
- Depends on:
  - market demand and price
  - climate
  - skills and knowledge of staff and management
  - availability of resources and technology.
Energy
- Geothermal energy
- Oil, diesel
- Solar
- Wind
- Biomass

Growing systems and substrates
- Soil
- Substrates

Water and nutrient supply
- Water and nutrient supply
- pH
- EC
- Nutrients
- Pathogens
- Polluted water

Pest and disease management
- Chemicals
- Biological control
- IPM = integrated pest management

THE LAST STEP PESTICIDE USE

<table>
<thead>
<tr>
<th>Mesh size</th>
<th>Hole size (mm)</th>
<th>Hole length (mm)</th>
<th>Thread diameter (mm)</th>
<th>Light transmission</th>
<th>Permeability (%)</th>
<th>Source</th>
<th>Insects</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>0.74</td>
<td>1.17</td>
<td>0.26</td>
<td>0.43</td>
<td>5</td>
<td>Tutia absoluta</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.64</td>
<td>0.44</td>
<td>0.39</td>
<td>0.25</td>
<td>87</td>
<td>Leaf miner (lygnaeys trifolii)</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>0.462</td>
<td>0.80</td>
<td>0.25</td>
<td>0.31</td>
<td>70</td>
<td>Sweet potato whitefly (dendroica nataly) (Melon) Aphi (aphis gossypii) Greenhouse whitefly (Trialeurodes vaporiorum) Silverleaf whitefly (dendroica argentifolia)</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>0.34</td>
<td>0.29</td>
<td>0.18</td>
<td>0.19</td>
<td>86</td>
<td>Leaf miner (lygnaeys trifolii)</td>
<td></td>
</tr>
<tr>
<td>123</td>
<td>0.192</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td>Silverleaf whitefly (dendroica argentifolia)</td>
<td></td>
</tr>
<tr>
<td>132</td>
<td>0.192</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>Western flower thrips (Frankliniella occidentalis)</td>
<td></td>
</tr>
</tbody>
</table>
Pay-back period (Mexico example)

Other remaining issues
- Training, and more training
- Maintenance industry
- IT structure; sensor technology
- Market intelligence
- Rules and legislation

Thank you

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