Possibilities of modern greenhouse concepts and equipment for sustainable and high quality orchid production in Taiwan

Horticulture Forum: "The High Efficiency and Energy Saving Production in Agriculture Greenhouse"
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Trends world-wide – greenhouse production

- New production areas are coming up
- From open field production to more protected systems
- Low tech and mid tech growing systems have biggest areas, but move to high tech
- Modern greenhouse industry in Western Europe and US develops more and more to year round production with high quality

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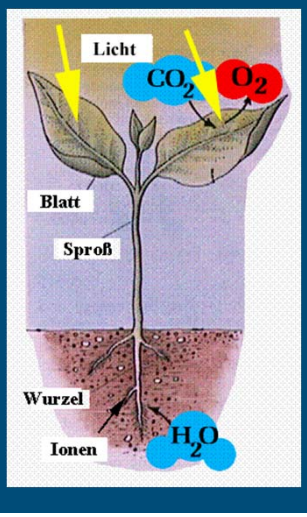
source: GREEN Q

Technology for sustainable crop production



- CO_2 + water + light → sugar + O_2
- Sugars and nutrients are used for growth
- Growth ➔ yield
- Reactions are temperature dependent

➔ control all growth factors
➔ technology needed

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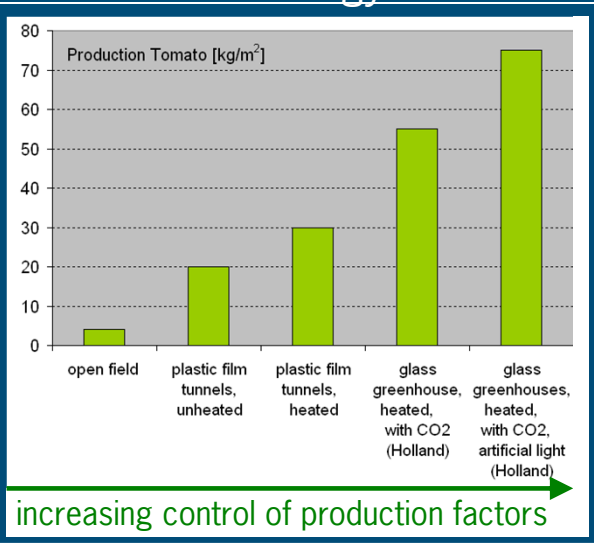
Trends world-wide - technology



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Sustainable greenhouse production in Taiwan

- Design greenhouse systems which combine (economic) production efficiency with minimal input of energy, water and nutrients

- High production, product quality, predictability
- High energy efficiency and use of sustainble energy
- Low pesticide use, high food safety
- High water use efficiency, low nutrient losses
- High ratio benefit – costs of the production system

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Methodology to improve greenhouse production

- Dynamic greenhouse climate and crop models
  - → input: local outside climate, crop parameters
  - → variables: greenhouse design, climate equipment, set points
  - → result: year-round inside greenhouse climate (temperature / humidity / CO_2) and crop performance at every hour of year
- CFD model
- Economic model
  - → input: local prices for products, materials and investments, local interest rates
  - → output: return of investment, yearly net benefit
- Expert view
  - Industrial partners with long year experiences in different countries

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Greenhouse Technology

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- Orchid production: phalaenopsis

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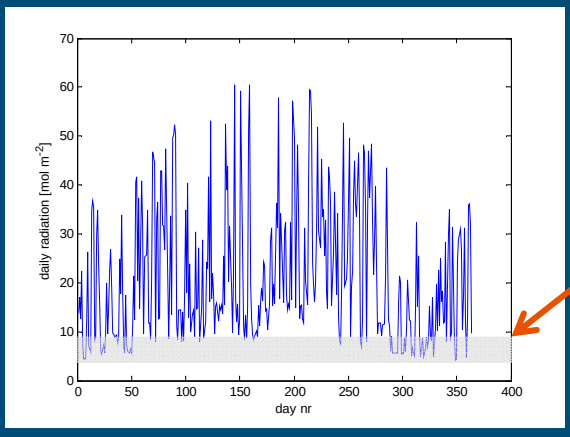
Outside climate Taiwan - global radiation



Phalaenopsis in NL

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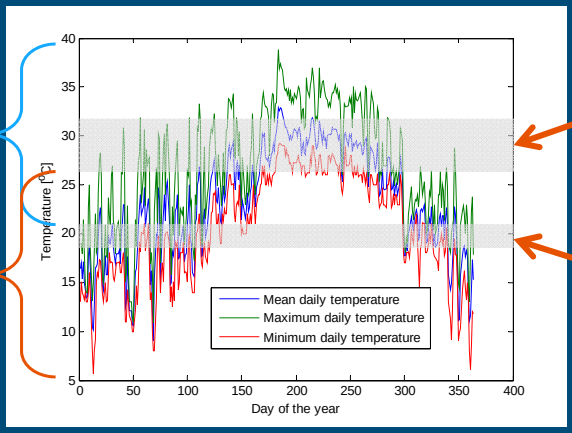
Outside climate Taiwan - temperatures

efficient cooling needed

heating needed for phase 1



Phalaenopsis young plants

Phalaenopsis flowering

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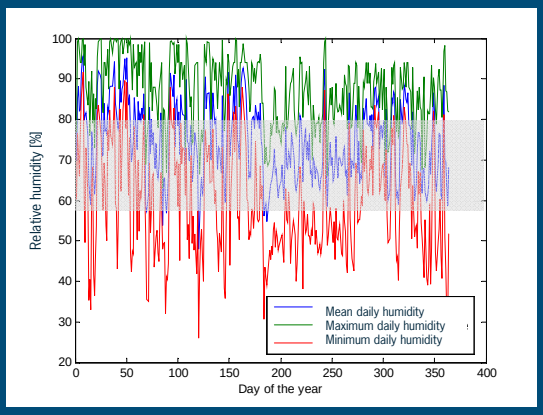
Outside climate Taiwan - humidity



Humidity levels are very high

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Growing phases phalaenopsis

Fase	Young plants Phase 1a	Phase 1b	Flowering stage Phase 2a	Phase 2b
PAR sum (mol PAR/m² day)	3-3.5 →	4-4.5	6-7	5.5-6.5
Temperature (°C)	27-29	27-29	18-19 →	19-21
Period (weeks)	12-14	12-14	6 - 8	8 – 12
Plants per area (pots/m²)	80	60-45	45-37	37

Optimum light levels can be different in Taiwan from NL
Maximum tolerable temperatures can be different in Taiwan from NL
Production period could be different in Taiwan from NL

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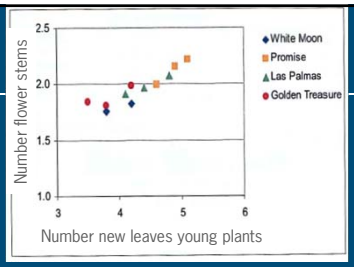
Light and growth



Fresh weight leaves [g]

Light level	White Moon	Promise	Las Palmas	Golden Treasure
3 mol m⁻² dag	685 a*	662 a	631 a	522 a
4 mol m⁻² dag	747 b	723 b	634 a	531 a
5 mol m⁻² dag	872 c	789 c	689 b	539 a

Good correlation between new leaves developed during phase 1 and flower stems at end

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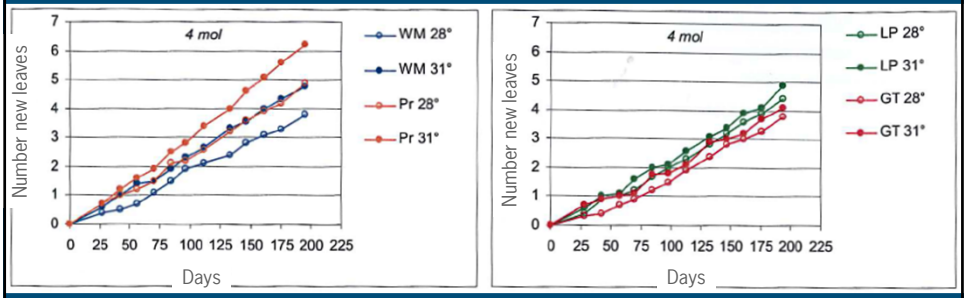
Ministerie van Economische Zaken, Landbouw en Innovatie

Uw sector investeert in dit onderzoek via het Productschap Tuinbouw

Dueck et al. 2011

Temperature and growth



Cultivars:	Temperature:
White Moon Promise Las Palmas Golden Treasure	28°C 31°C

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Dueck et al. 2011

Challenges warm section / young plant stage

- Let crop develop as much new leaves as possible!
- Keep light level low (3.5-4.5 mol/m²/day?) → risk for leave damage
- Avoid too high humidity (<80%) → risk for diseases
- Keep temperatures around 28°C-32°C

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Controlling light level

- Goal: keep light level low
- To be reached by:
  - Covering with lower transmission
  - Moveable summer screen to be closed at high light levels
  - Moveable second screen?
  - Adding chalk?

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Controlling light level

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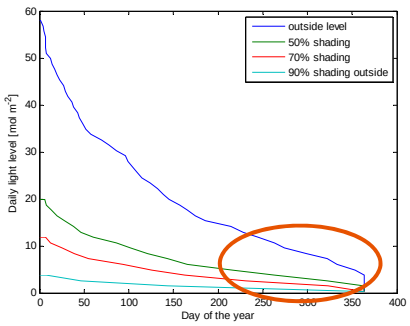
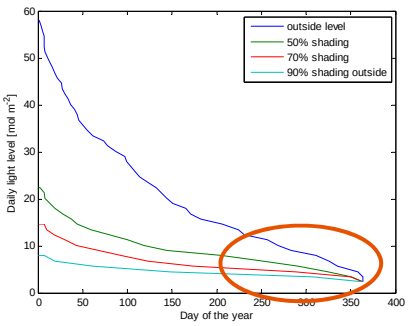
Controlling light level – warm section





Reducing light transmission by
covering only
→ too low light levels

Reducing light transmission by
moveable screen
→ homogeneous light levels possible

→ choose right screen transmission

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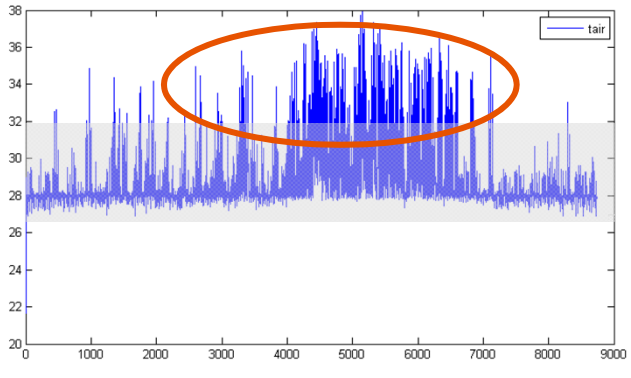
Controlling temperature

Temperatures too high?



- Temperature control by using different screens and lowering covering transmission
- No cooling
- Heating necessary to maintain minimum temperature

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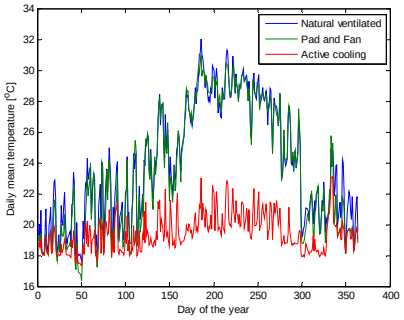
Controlling temperature – cooling systems

pad & fan have low effectiveness



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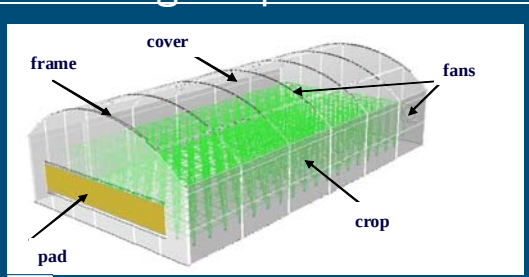
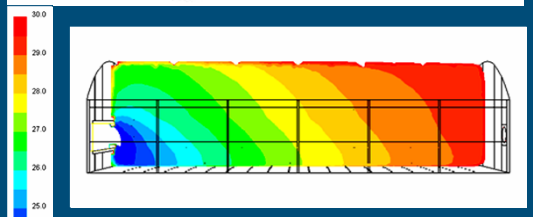
Controlling temperature – cooling techniques





Adiabatic cooling: pad & fan result in temperature differences

Sapounas, 2008

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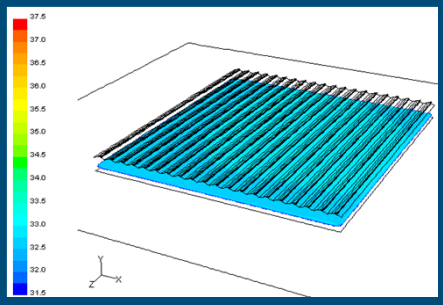
Controlling temperature - fogging



Adiabatic cooling: fogging gives homogeneous temperatures

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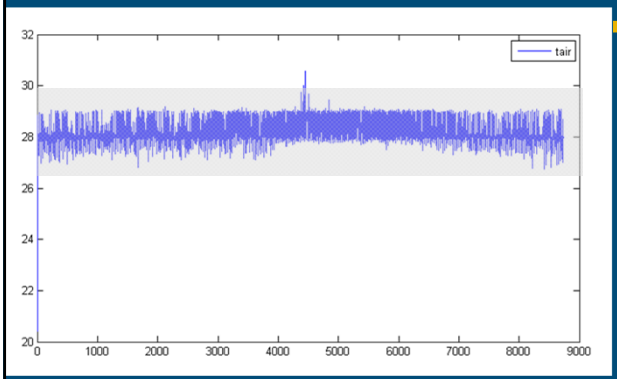
Controlling temperature



- Temperature control by active cooling → ca. 28°C

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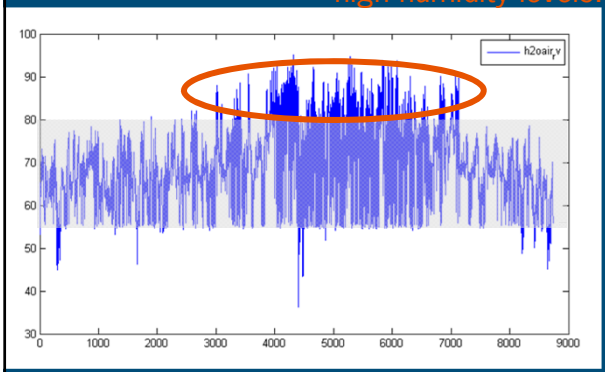
Humidity – natural ventilation

Diseases caused by high humidity levels?



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Energy consumption determined by humidity level

- Active cooling system can be used for dehumidification

Maximum relative humidity (%)	Energy for dehumidication (GJ)	Heating demand (GJ)	Cooling demand (GJ)	Total energy demand (GJ)
65	1.02	1.66	0.15	2.8
70	0.67	1.33	0.20	2.2
75	0.39	1.07	0.23	1.7
80	0.20	0.91	0.26	1.4

- Active dehumidification if $\Delta\Theta$ inside-outside < 5 g m^{-3}
- Active cooling if ΔT inside-outside < 3 K
- Otherwise: control by natural ventilation !

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Challenges cold section

- Keep temperatures low to induce predictable flowering (18-21°C)
- Keep humidity low to decrease risk of diseases (<70%)
- Control light level (6-8 mol/m^2/day?)

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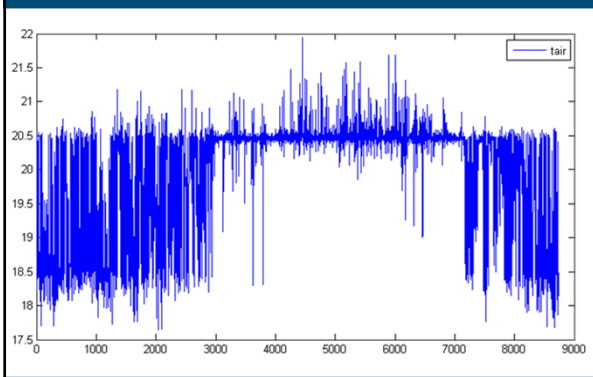
Controlling temperature – cooling



- Goal: 18-21°C
- Temperature control by active cooling system necessary

- Humidity control necessary by active cooling system (max. 70%)

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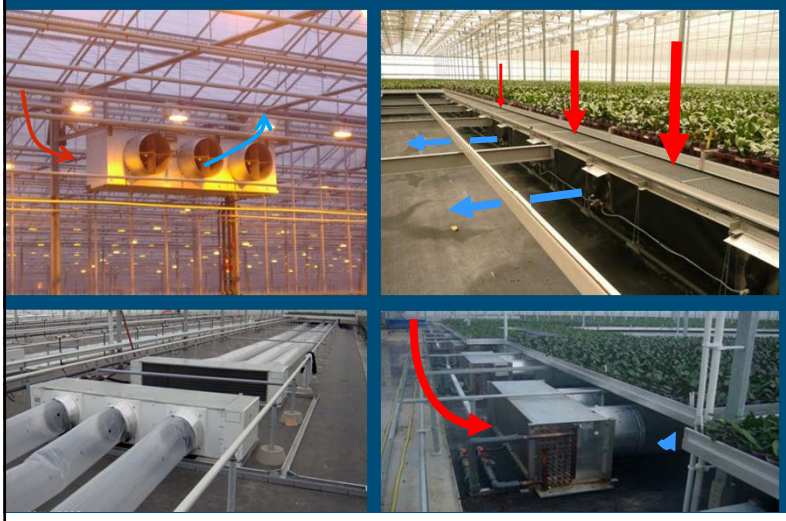
Controlling temperature – cooling systems



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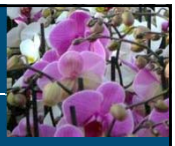
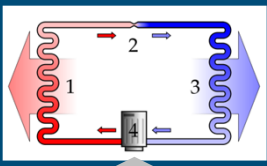
Total energy consumption



- Phalaenopsis greenhouse has heating and cooling requirement in order to have high quality and predictable production
- Use of heat pump useful
  e.g. COP=4

4 MJ heating energy



3 MJ cooling energy

1 MJ electrical energy

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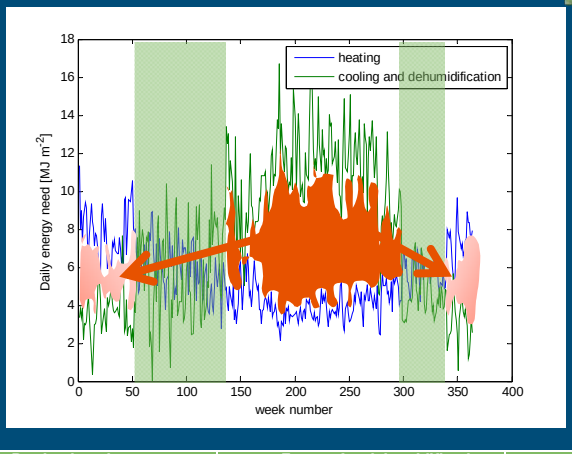
Total energy consumption



Since cooling demand is much larger than heating demand → surplus of heat → Other processes? Clustering? Storage in lake/river?

Production phase	Energy for dehumidification and cooling (GJ/m²/year)	Heating demand (GJ/m²/year)	Total
Young plants (warm section)	0.5	0.9	**1.4**
Flowering (cold section)	1.8	0.6	**2.4**
Total	**2.3**	**1.5**	

Water use efficiency

- Save water with right greenhouse design and climate equipment
- Collect rain water (rainfall in Taiwan ca. 1700 mm, consumption 800-1300 mm depending on system and crop)
- Recirculate irrigation water
- Use water saving irrigation system

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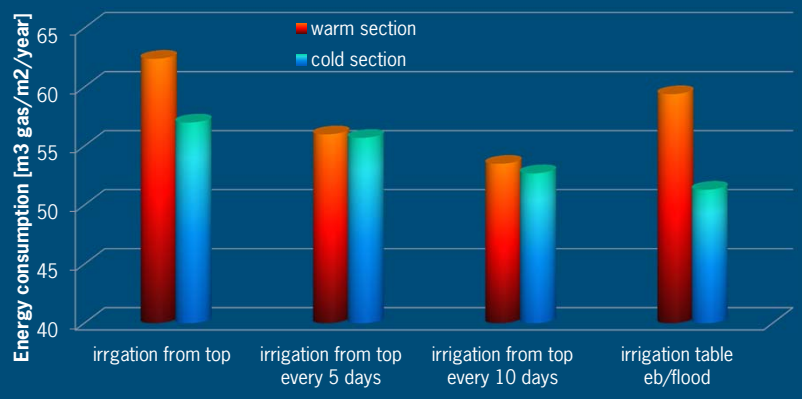
Irrigation system



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Conclusions

- Controllable greenhouse necessary for orchid production for high quality and predictability
- Technology needed:
  - Active cooling for at least cold section
  - Heat pump useful
  - Climate computer essential
  - (Phyto)Monitoring essential
  - Light control by optimum choice of covering and moveable screens (outside and inside)
  - Adapt irrigation system and strategy
  - CO_2 for faster growth in young plants can be useful

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