Growth of tomatoes under hybrid LED and HPS lighting systems

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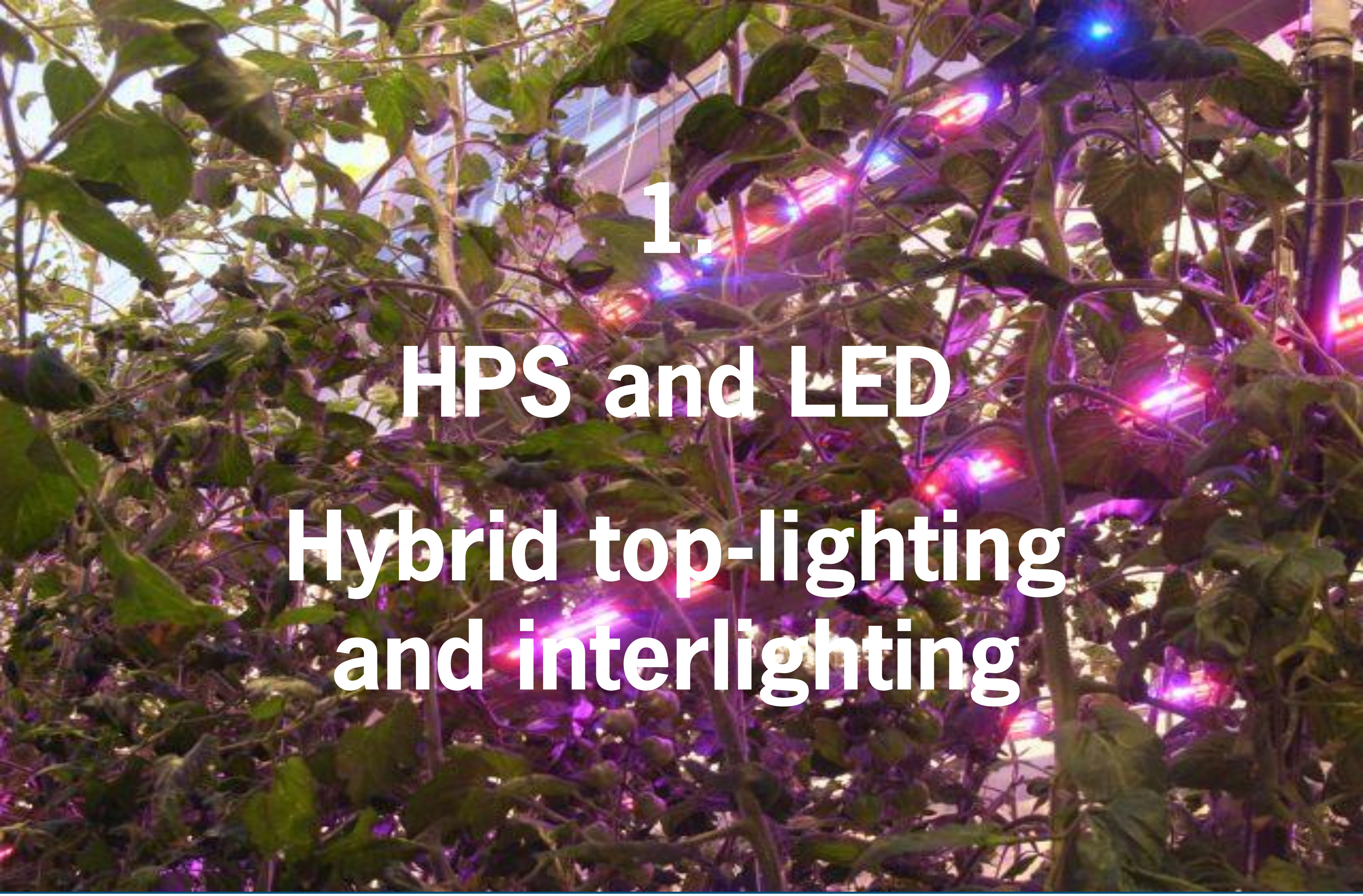

1.

HPS and LED

Hybrid top-lighting and interlighting

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Aims of the experiment

- Investigate effects of lighting systems on tomato
- Examine energy use and efficiency of lighting systems
- Learn to grow tomatoes under LED's

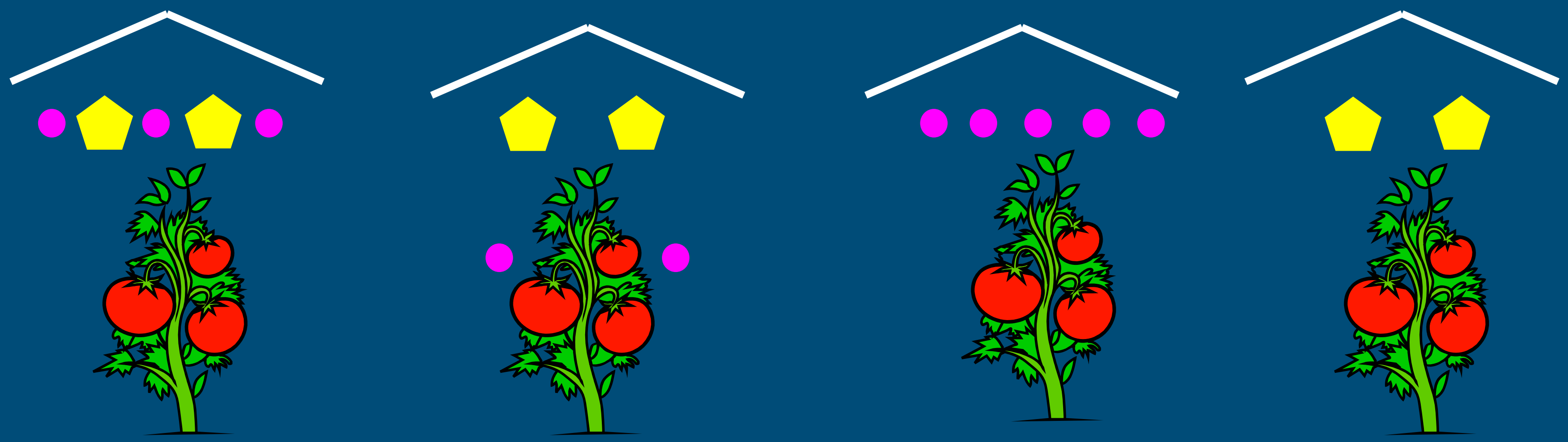
Experimental design

- Cultivar: Sunstream
- Oct. 15, 2009 – July 1, 2010

- 4 treatments: equal light intensities (170 μmol/m^2/s) and light duration
  - HPS-top
  - LED-top
  - Hybrid-top (50% HPS, 50% LED-top),
  - Hybrid-interlight (50% HPS, 50% LED-interlighting)

- Management focussed on optimal crop

Hybrid-top | Interlighting | LED-top | HPS



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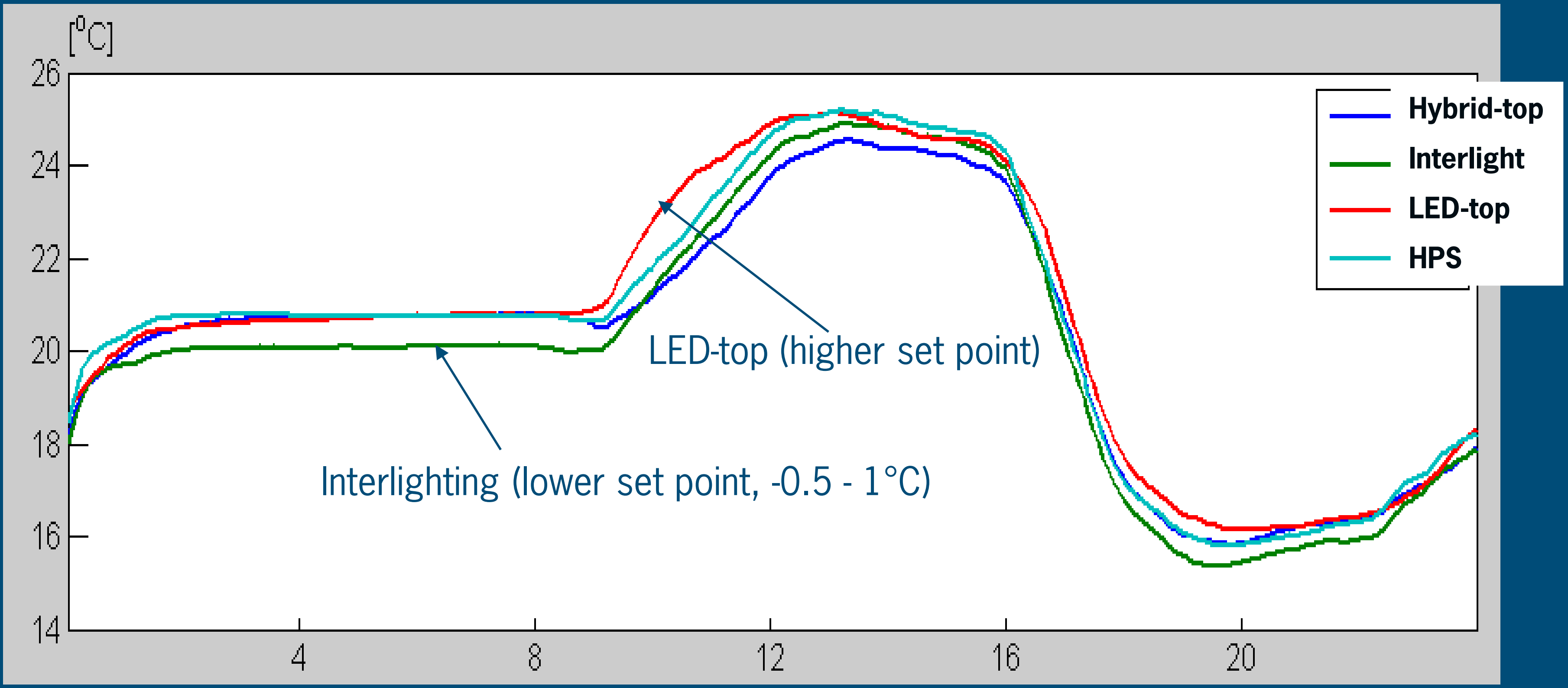
Crop treatments optimized:

- Climate set points
- Truss pruning (sink)
- Removal of a top leaf
- Varying stem density: ending at 4.7 (Hybrid-top, HPS) or 5.2 (Interlight, LED-top) stems/m^2

Greenhouse temperature set points



Daily mean temperature Oct - May in hybrid-top (20.2), interlight (20.1), LED-top (20.5 ↑) and HPS (20.2°C)

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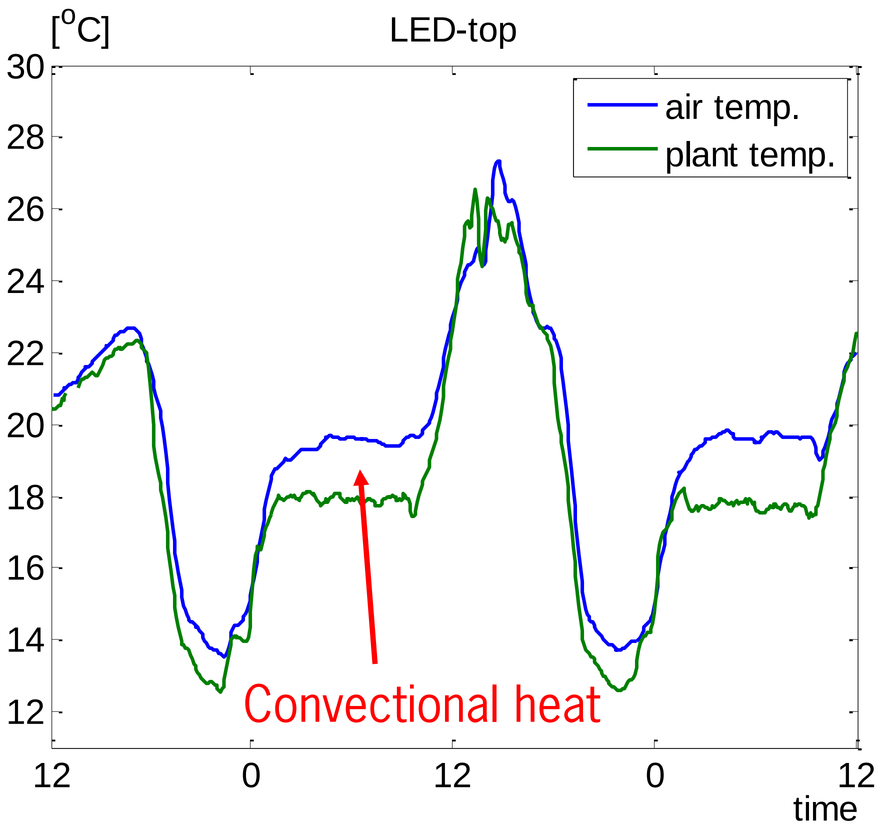
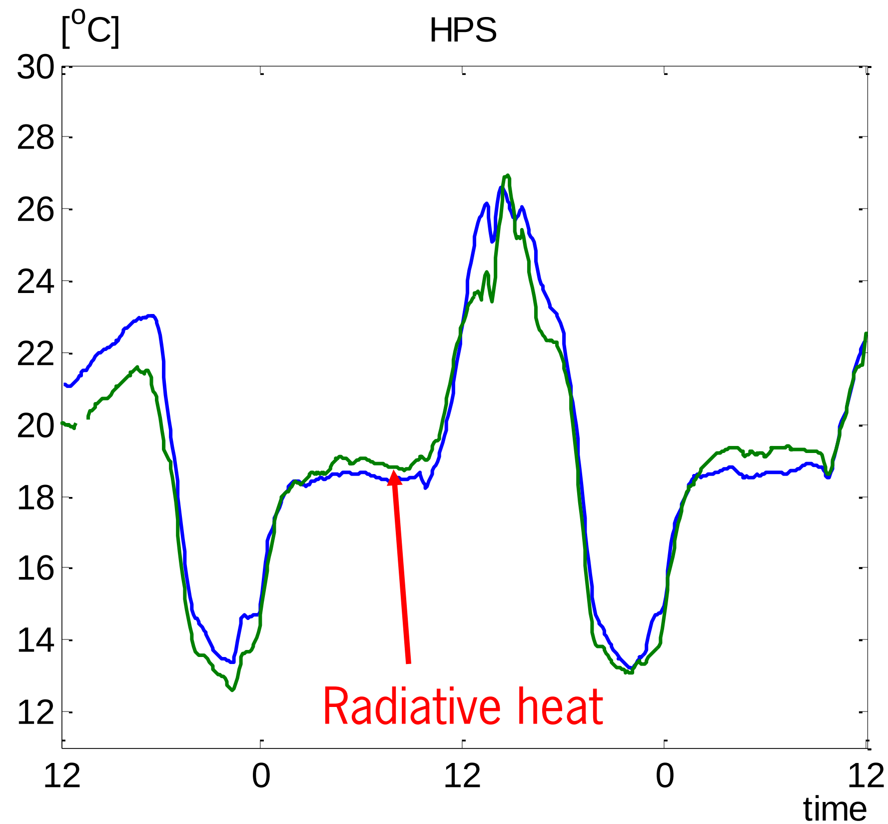
Plant temperature vs air temperature

LED-top



HPS



Leaf temp LED-top < air temp

Leaf temp HPS > air temp

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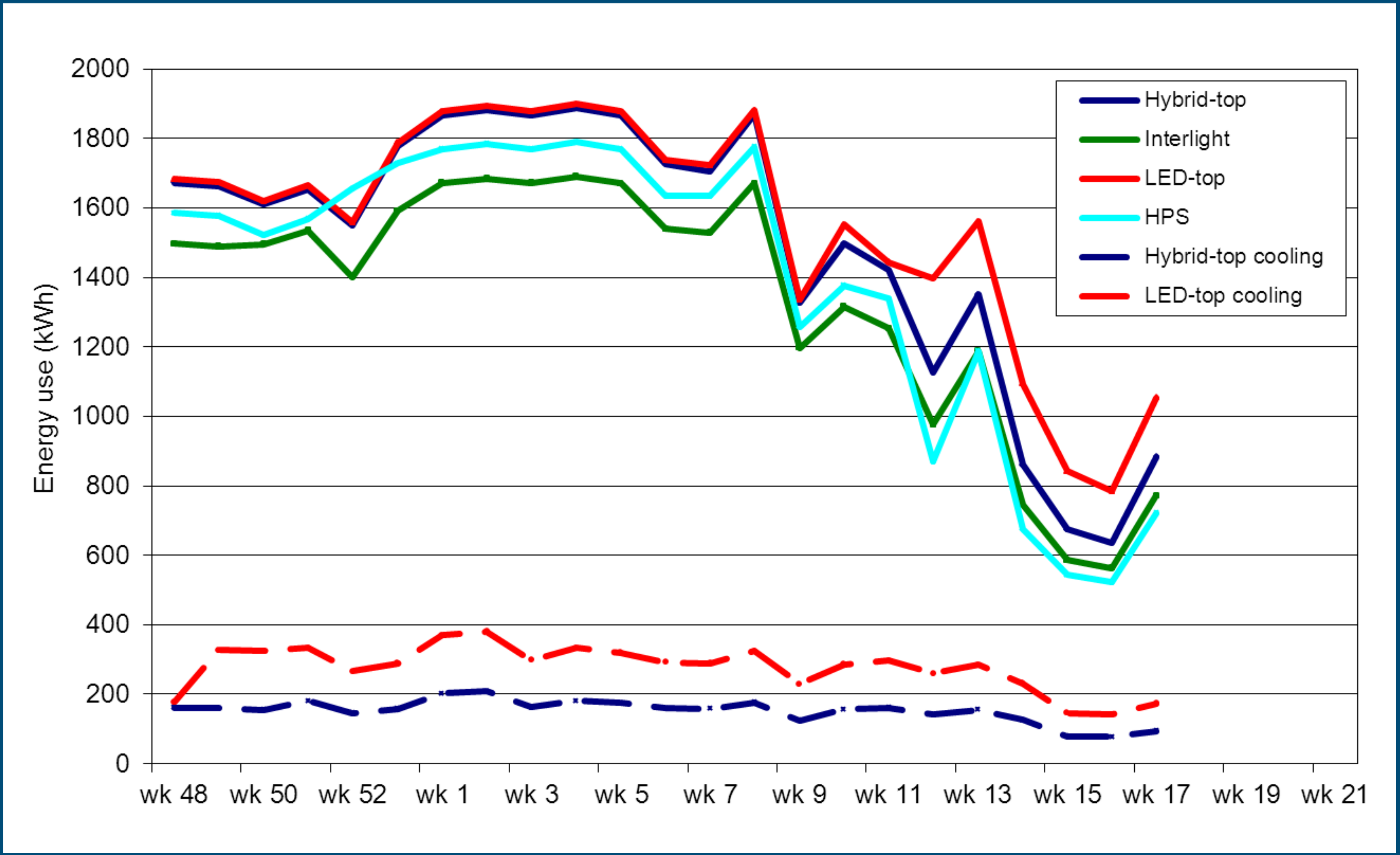
Production up to June 10

	Flowering truss	Total set trusses	Prod. kg/m²	Prod. %
Hybrid-top	35.4	1466	25.2	- 3%
Interlight	35.3	1433	24.3	- 6%
LED-top	34.9	1472	24.5	- 5%
HPS	36.1	1498	25.9	-

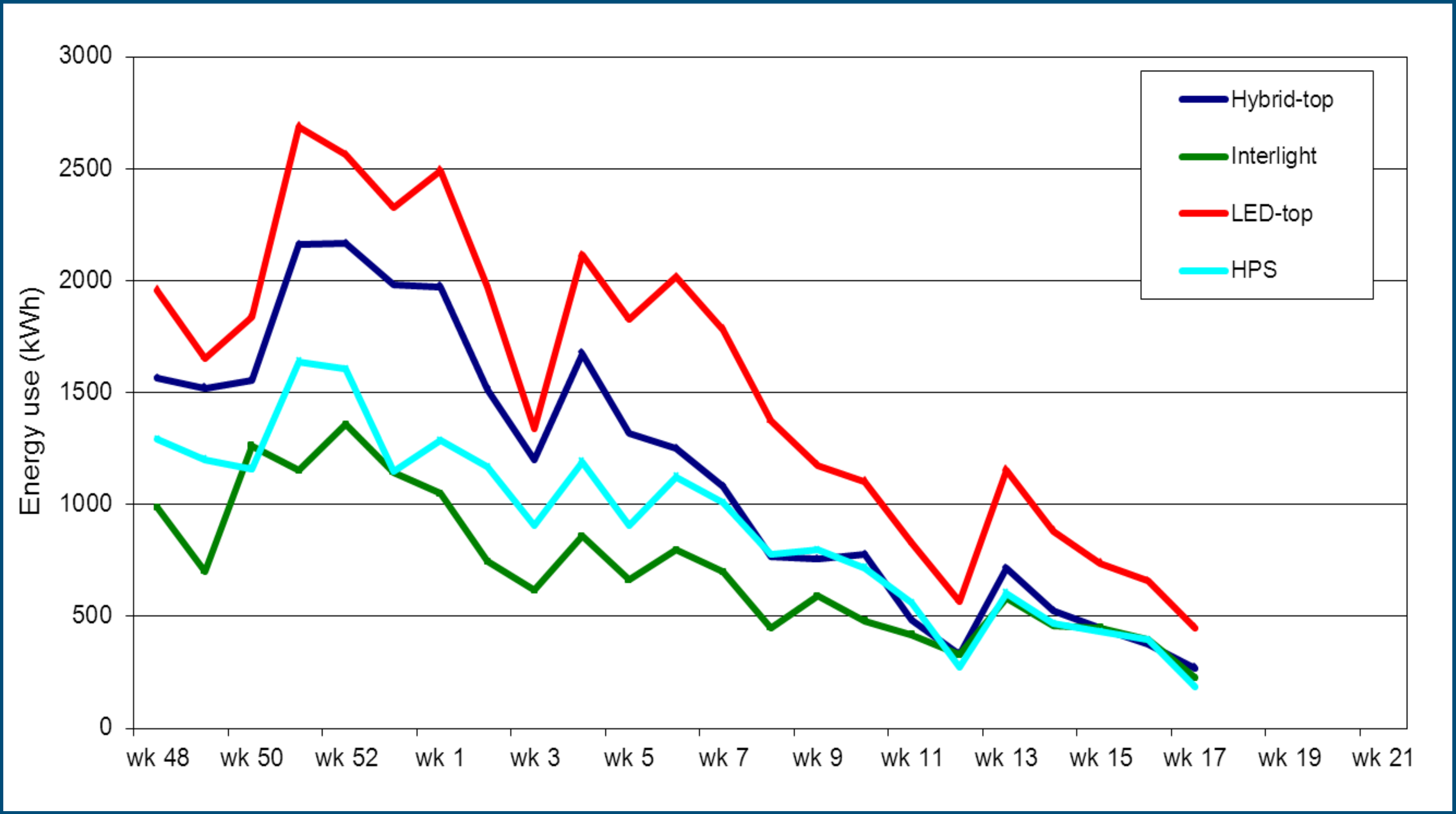
Energy use of both lighting systems

- LED-top light system (water-cooled)
  - Energy costs: electricity for LEDs and water pump
  - Energy exchange: heat from LEDs out of greenhouse, production of cool water
- LED-interlighting system (air-cooled)
  - Energy costs: electricity for LEDs
  - Energy exchange: heat from LEDs into greenhouse

Electrical energy for lighting, production of cool water



Thermal energy input for heating



Energy differences between lighting systems with LEDs

- Water-cooled light system
  - Used more electrical energy for light
  - Used extra energy for production of cool water (= loss of energy from greenhouse)
  - Used most energy for thermal heating (absence of radiative heat in top of crop)

- Air-cooled light system
  - Used least electrical energy for light
  - Used least energy for thermal heating

Energy efficiency (Nov. 18 – May 3)

Energy use in natural gas equivalents per kg tomato

Hybrid-top	3.87 g.e.
Interlight	3.56 g.e.
LED-top	4.26 g.e.
HPS	3.62 g.e.

Lessons learned from LEDs (1)

- LED-top
  - Crop misses radiative heat, more thermal heat is necessary (more use of screens to maintain top plant temp)
  - Crop can take a higher plant load (higher stem density, more fruits/truss)
- LED-interlight
  - Crop needs more top lighting for top plant temp (higher top light:interlight ratio by hybrid?),
  - Less thermal heat required (works as heating tube)

Lessons learned from LEDs (2)

- HPS vs. LEDs
  - HPS was pushed to its limit (more experience)
  - LEDs were grown more carefully (limitations unknown?)
  - Cold winter was advantageous for HPS system
  - Each lighting system requires its own climate set points for optimum crop growth
  - The energy costs of LEDs for light do not differ greatly between air-cooled and water-cooled systems, but the costs of cooling (energy + equipment) make a large difference in energy costs between the two systems


2.
Hybrid interlighting
with less energy

Aims of the experiment

- Optimize light distribution
  - Placing of (height) interlighting
  - Ratio toplighting/interlighting

- 30% less energy (with same production)
- More production?

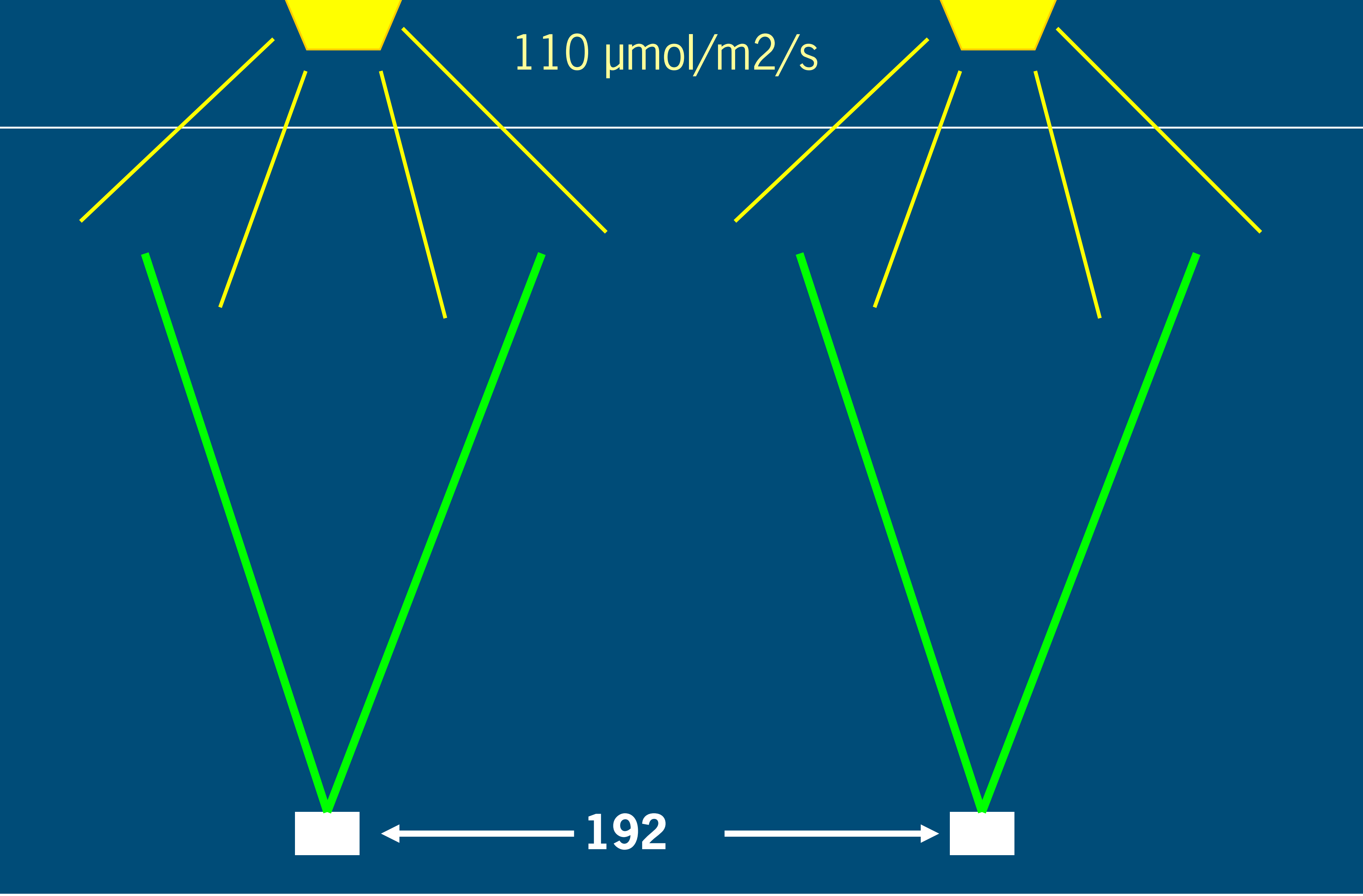
- 1 (!) greenhouse 1000m2 (virtual reference only)
- cultivar Komeet

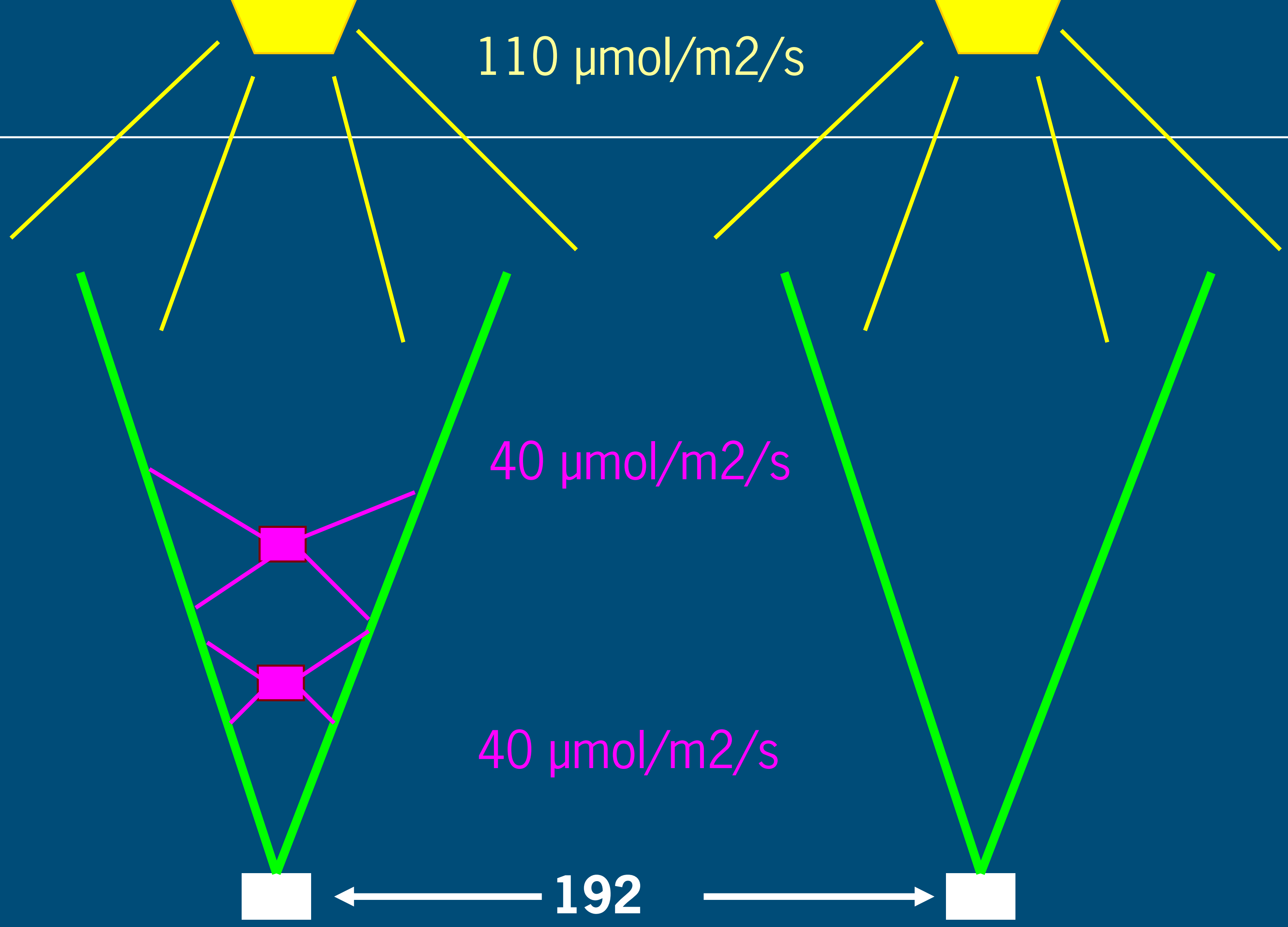
How to realise same crop with less energy

- Lichtintensity: 190 μmol/m^2/s (not 210); 110 top and 80 interlighting
- Less light 16 hours/day (not 18)
- More efficient LEDs (Production LEDs, 12% blue vs. Interlighting LEDs, 5% blue)

Next generation greenhouse cultivation

- Temperature integration
- Dehumidification and use of 2^{nd} screen


110 µmol/m2/s
192


110 µmol/m2/s
40 µmol/m2/s
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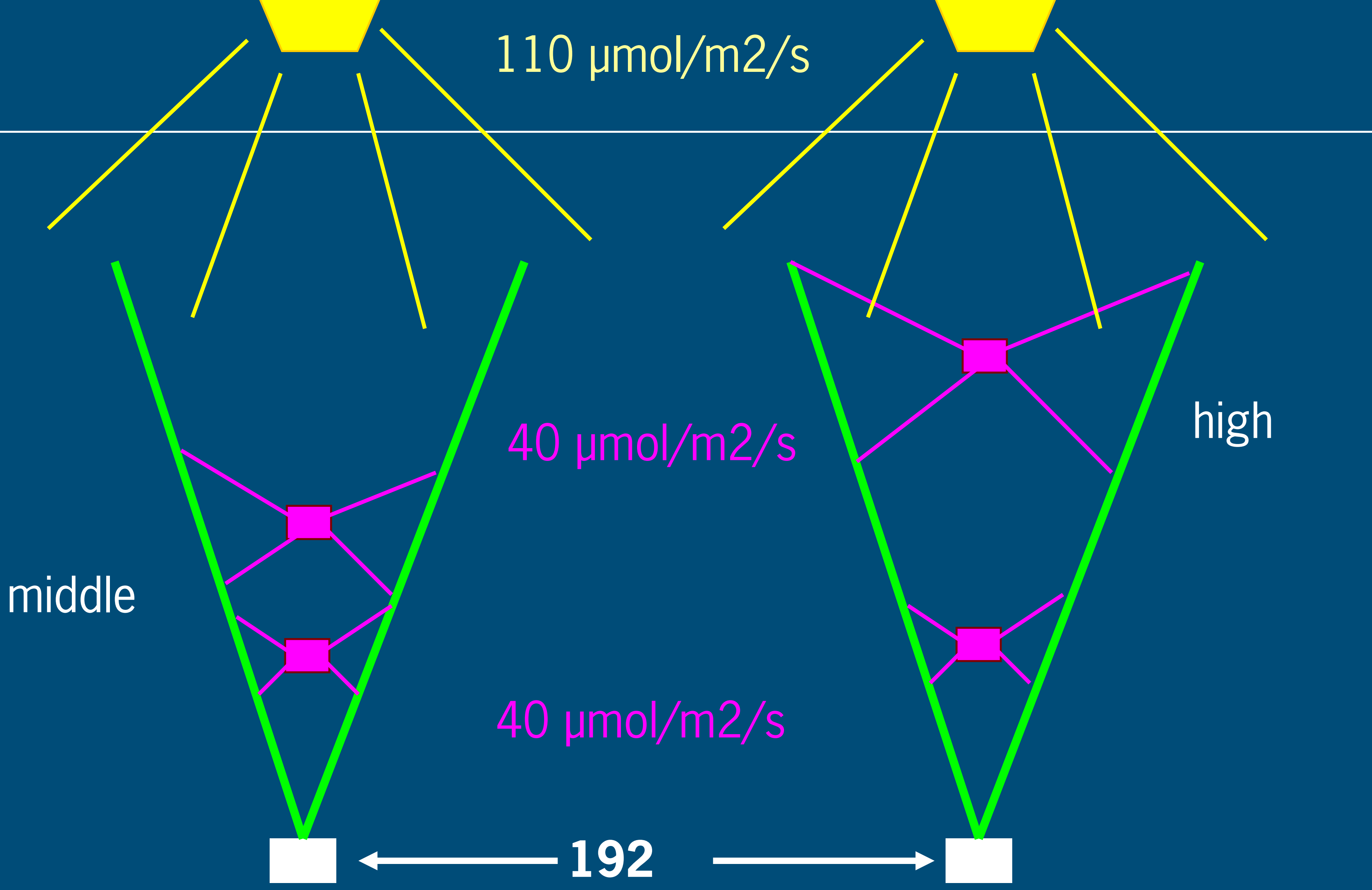

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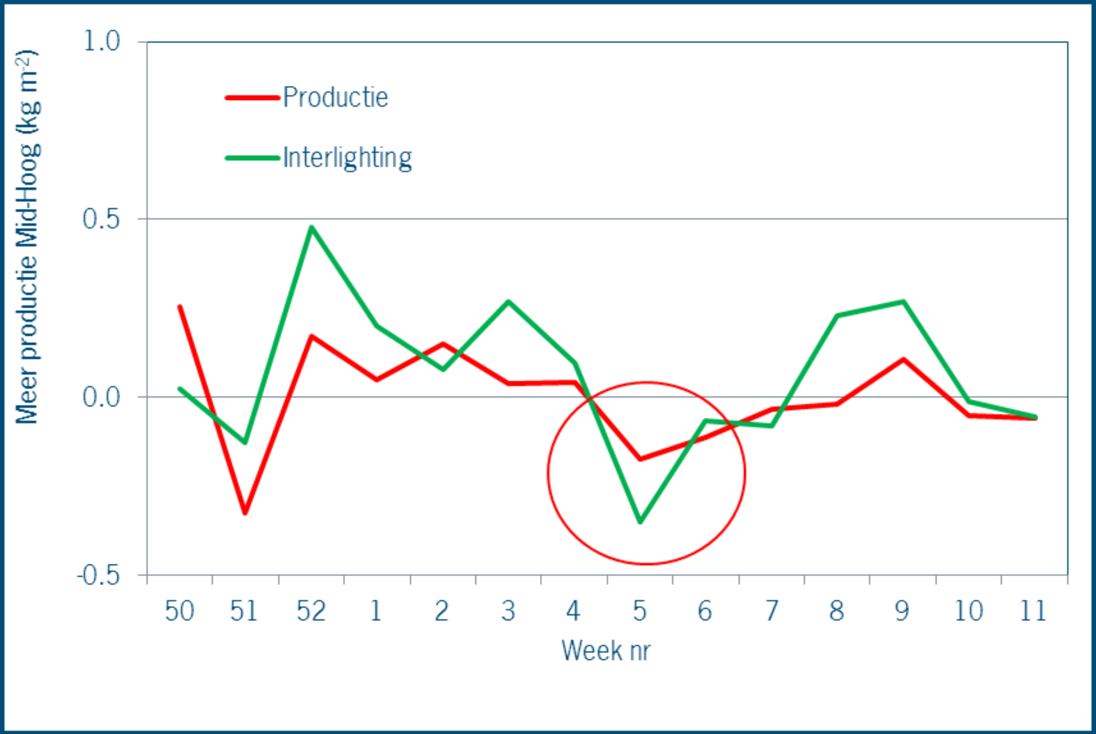
What did we see? production i.r.t. position of LEDs

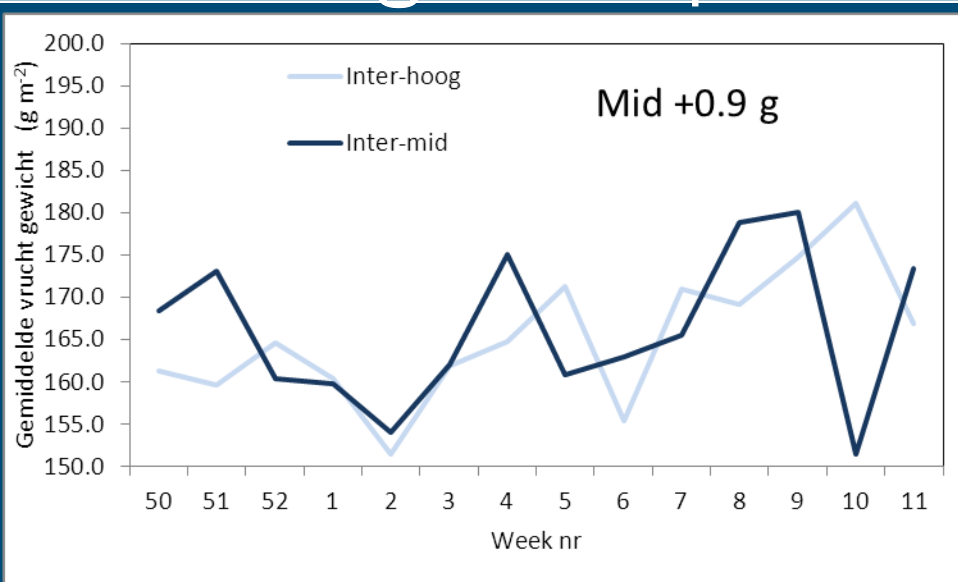


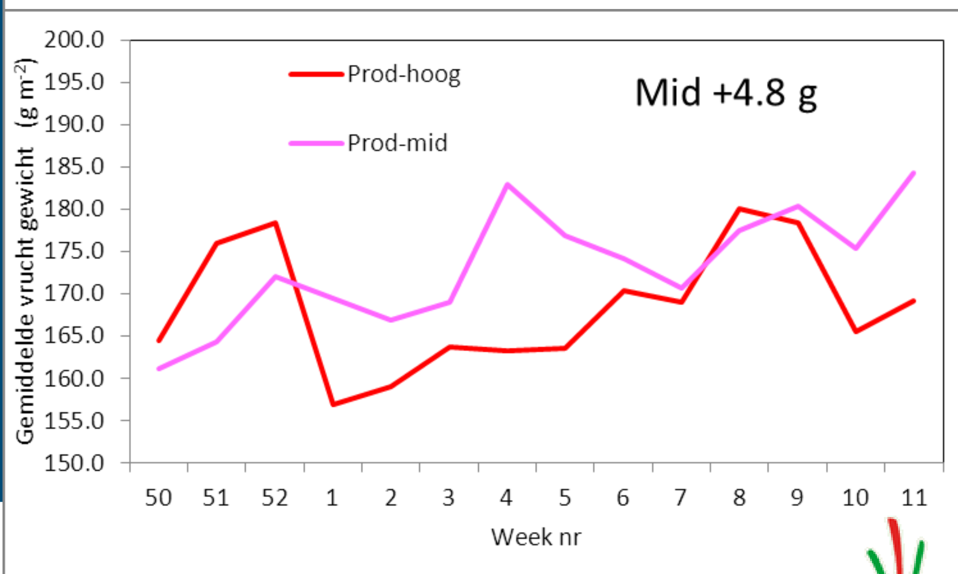
Prod. LEDs middle i.r.t high: 50 g/m2 more

Inter. LEDs middle t.o.v. high: 960 g/m2 more !

General dip in production wk 4-6: 6-8 weeks earlier -> microelements -> poor flowers -> poor bee visiting -> less setting (2-3 poor trusses)

Fruit weight i.r.t. position of LEDs





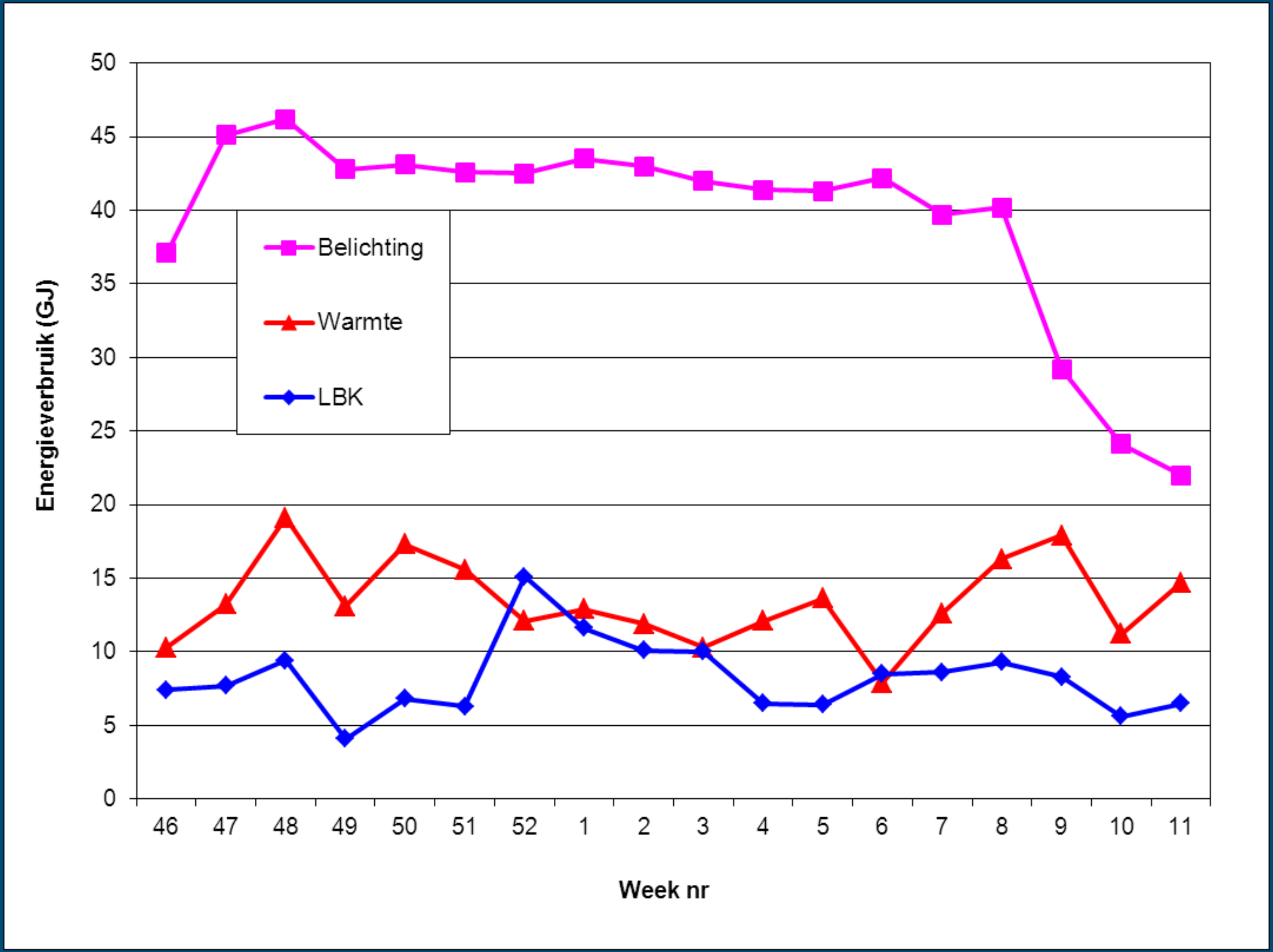
Interlighting LEDs:

LED middle 1 g/m2 heavier fruits

Production LEDs:

LED middle 5 g/m2 heavier fruits

Energy use: overview November - April



Less energy use: predicted vs realised

- Predicted energy saving: 30% less than reference

- Febr. 10.: 22% energy saving
- March 31: 27% energy saving
- May 19: 28% energy saving

- "Profit" due to less light (sunny weather), and due to better use of dehumidifyer

What have we learned: evaluation April 29, 2011

- Botrytis
- Crop recovery
- Light distribution
- Climate

What dit we learn i.r.t. Botrytis?

- Crop was pushed too fast in the beginning
- We couldn’t cope with humidity in a crop under artificial light (insufficient knowledge)
- Consequences: problems light a too heavy plant load, uneven crop, necrotic leaf edges, Botrytis

- Don’t push the crop too hard at the start, dehumidy faster, even if it means forced ventilation

What dit we learn i.r.t. crop management?

- Crop was pushed too fast in the beginning
- Too much unevenness between plants in crop
- Weaker plants came into the shadow, recovery was slowed down

- Be more careful with plant density i.r.t. light interception
- Number of stems/m2 is limiting factor

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What dit we learn i.r.t. light distribution?

- Was 110 µmol/m2 on the top of the crop sufficient in the (dark) winter period?
- Stem density was increased too early (before Jan. 1st with increasingly less sunlight per day) – crop was pushed too hard

- Find a better balance between light and crop development in autumn/winter as sunlight decreases each day

What dit we learn i.r.t. climate?

- We do not know enough about the interaction between screens i.r.t. dehumidication, and dehumidication in a crop with artificial lighting
- Crop with lighting transpires much more than a crop without lighting. We started in a wrong (too slow) rate of dehumidification, later it became better

- The climate was sub-optimal (otherwise there would have been less Botrytis)
- Dehumidify faster, more research on use of screens

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