Growth of tomatoes under hybrid LED and HPS lighting systems

Tom Dueck, Jan Janse, Barbara Eveleens, Frank Kempkes & Leo Marcelis

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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)

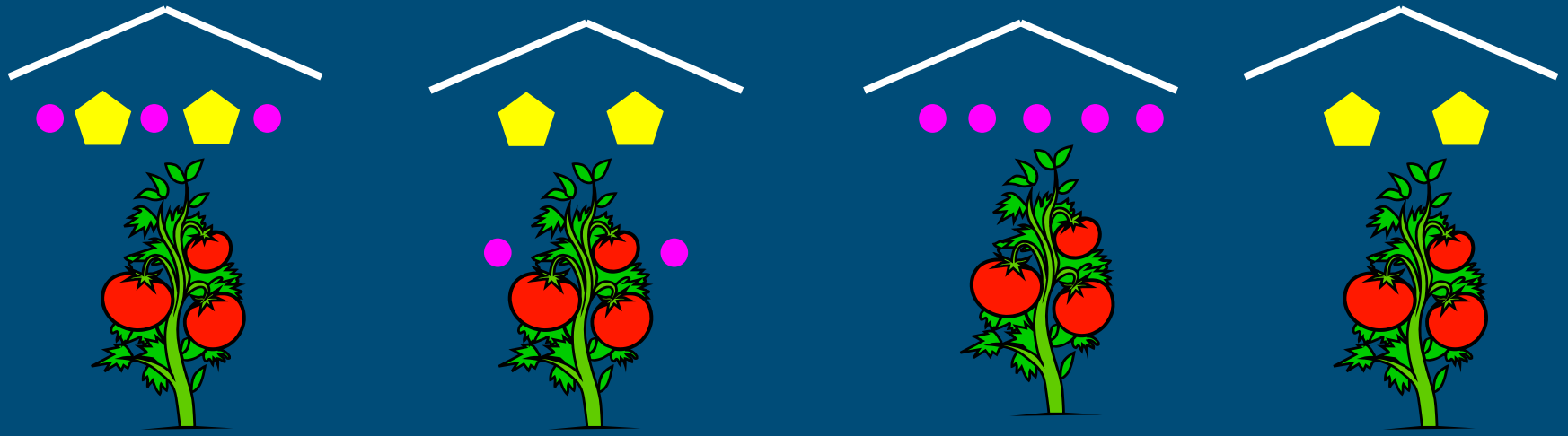
- Management focussed on optimal crop

Hybrid-top

Interlighting

LED-top

HPS



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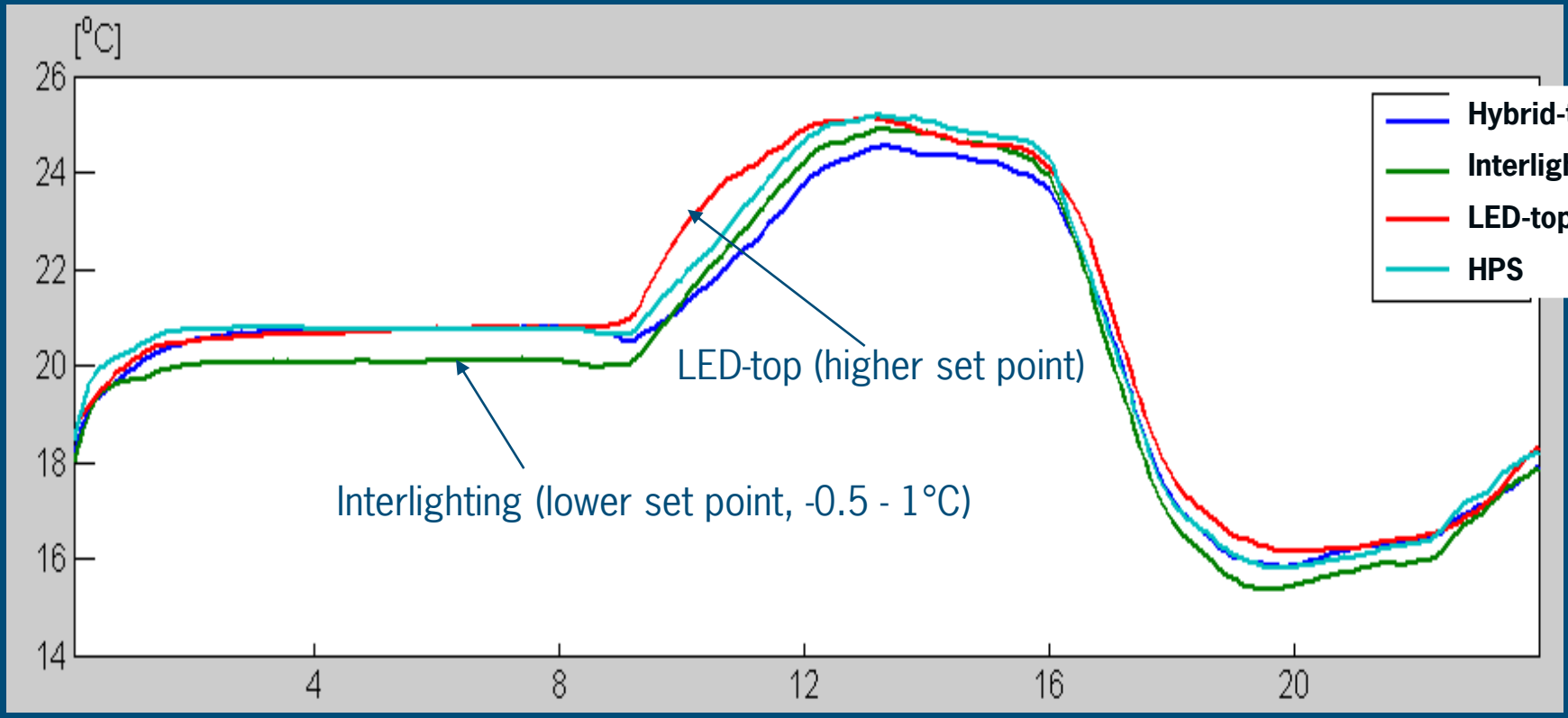
Crop treatments optimized:

- 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

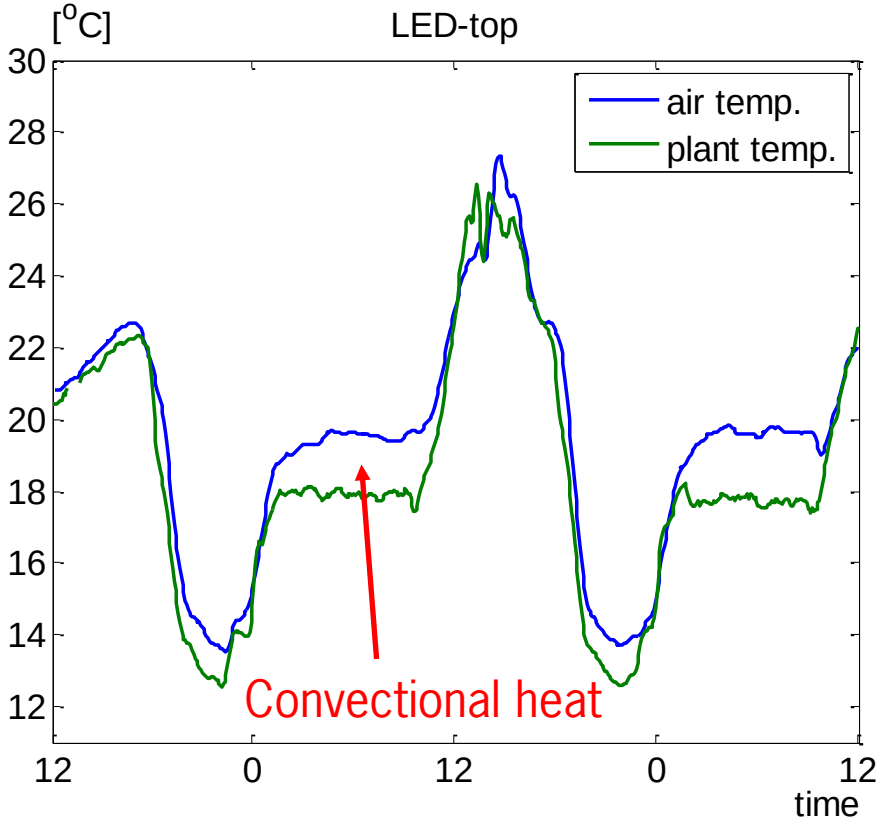
Greenhouse temperature set points



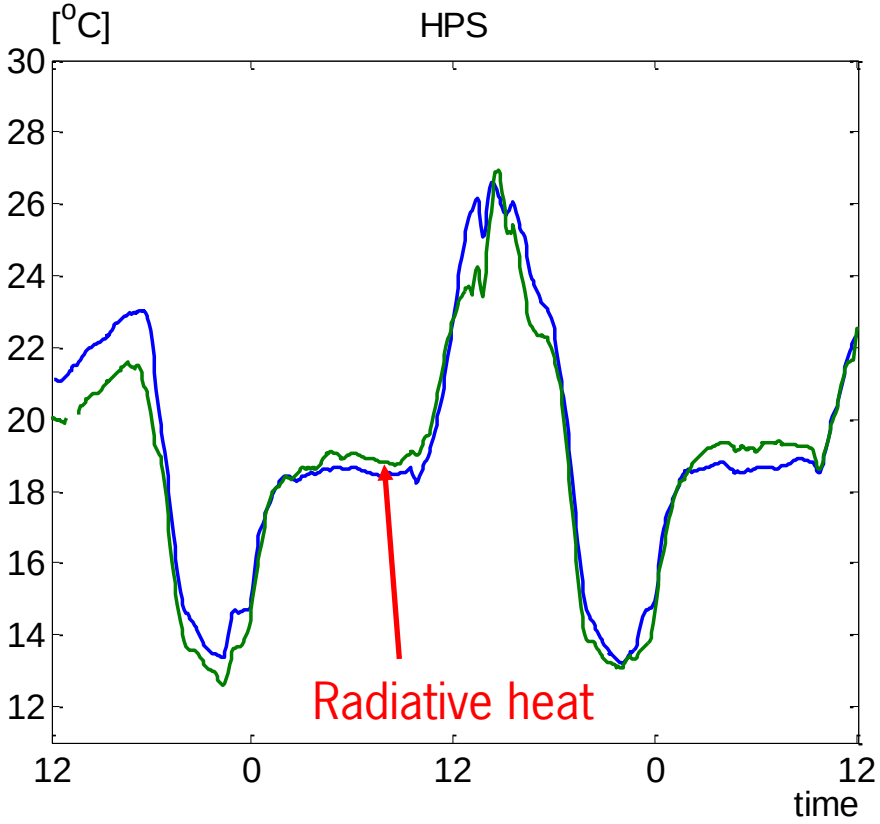
Daily mean temperature Oct - May in hybrid-top (20.2), interlight (20.1), LED-top (20.5 ↑) and HPS (20.2°C)

Plant temperature vs air temperature

LED-top



HPS

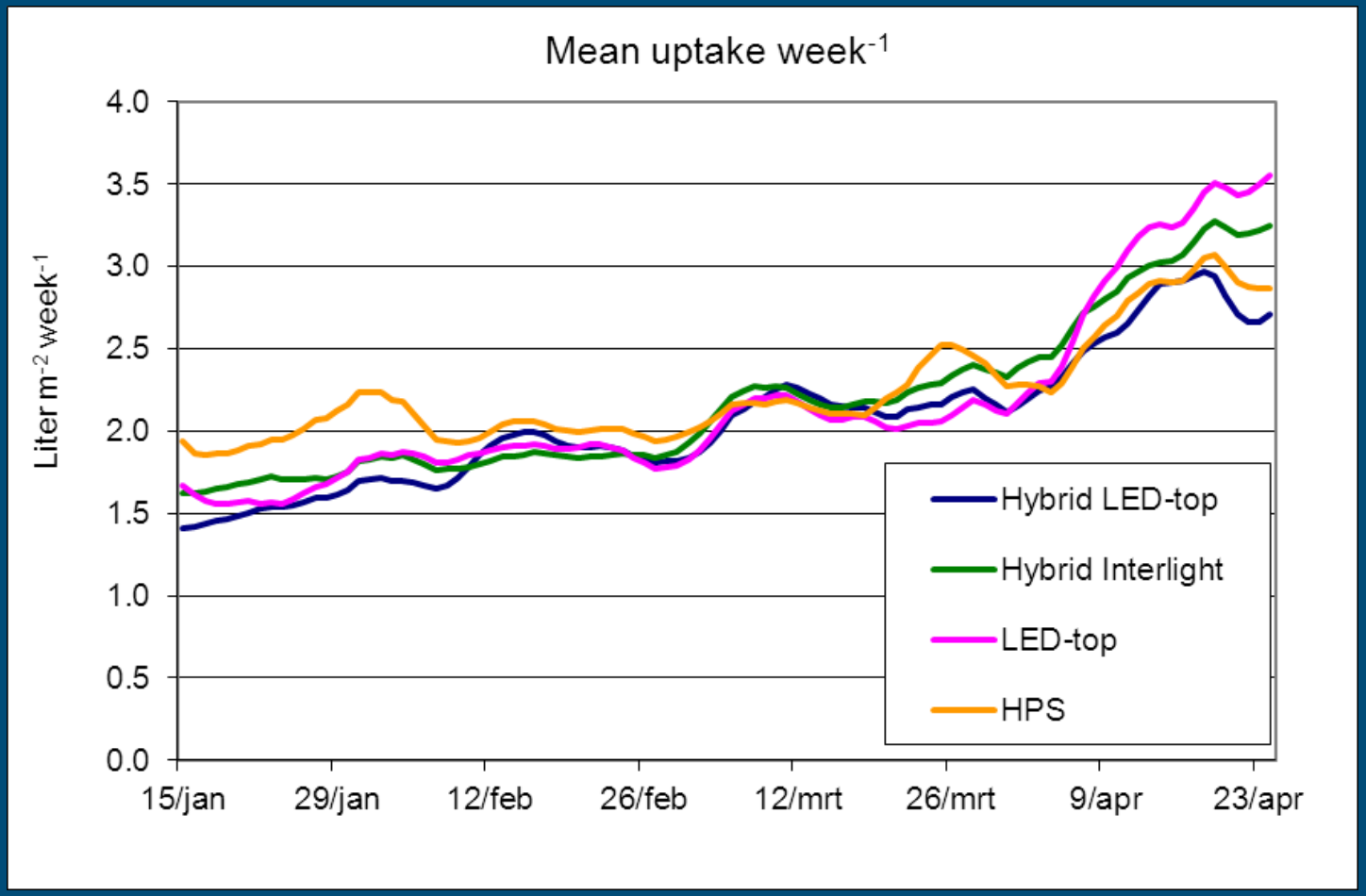


Leaf temp LED-top < air temp

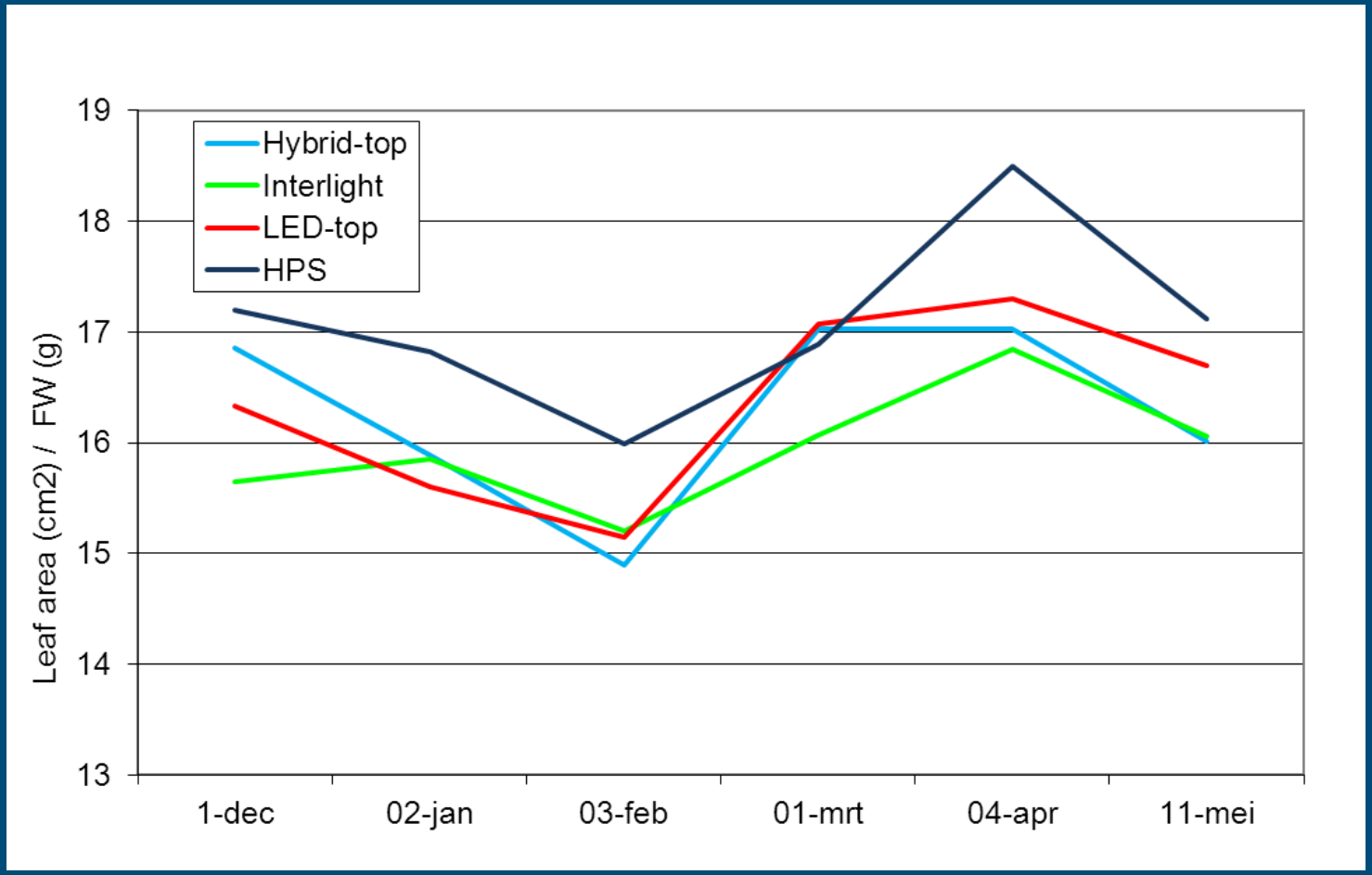
Leaf temp HPS > air temp

Consequences for water uptake

More radiation in winter from HPS -> more transpiration

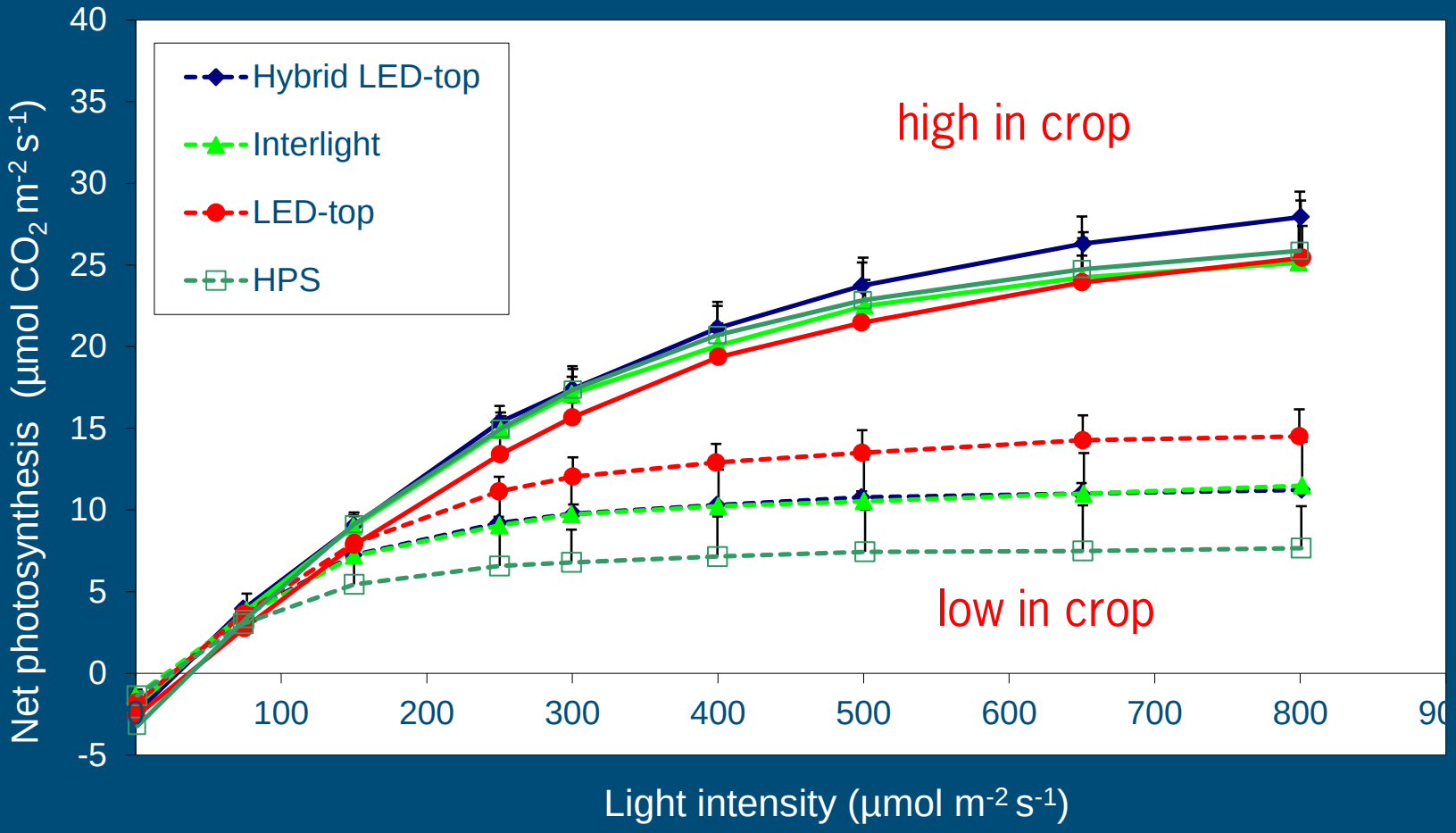


Specific leaf area (leaf area/g FW)



Under HPS higher leaf area per unit fresh weight

Photosynthesis capacity - winter



With more sunlight in March, no differences between treatments

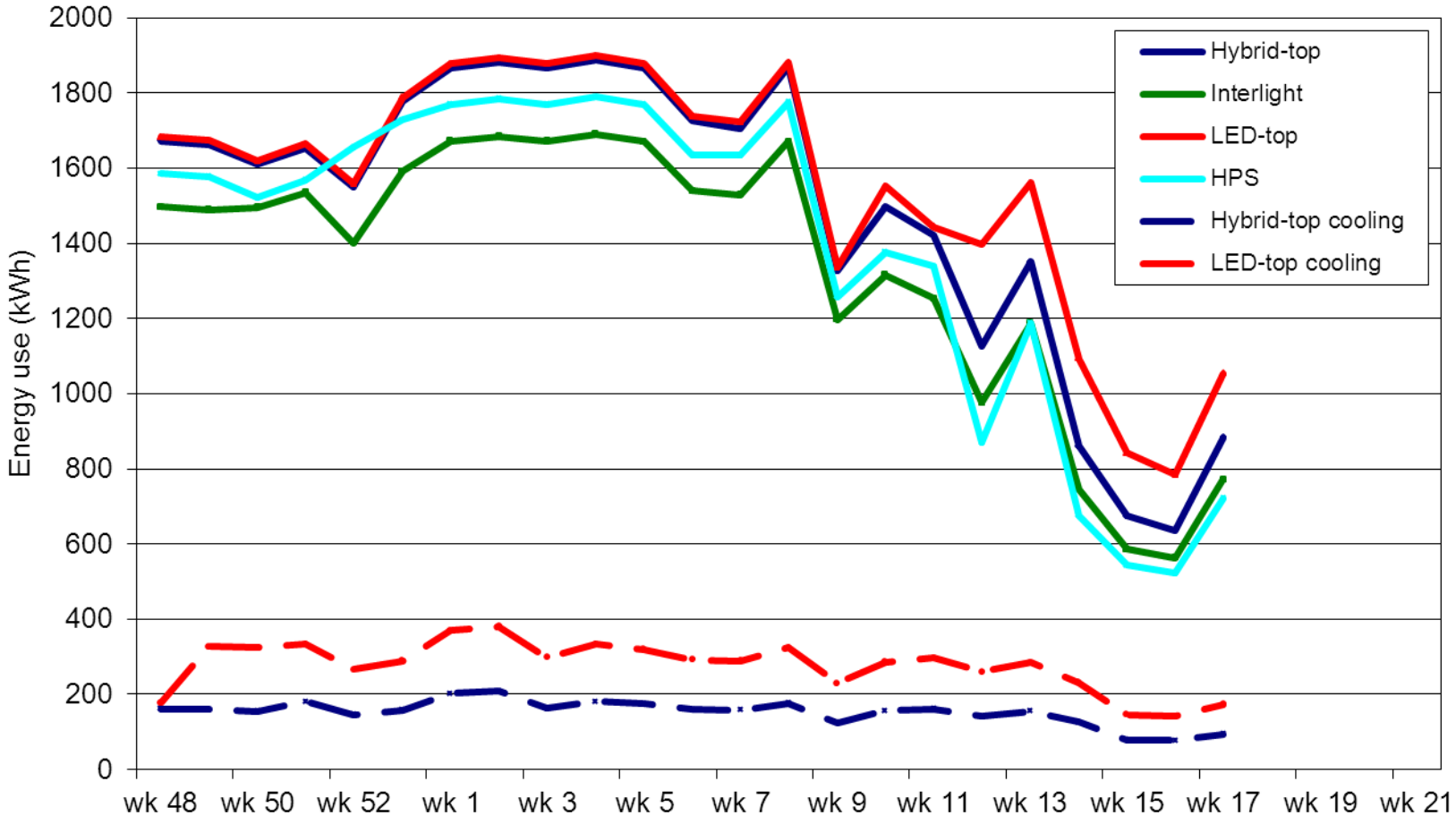
Production up to June 10

	Flowering truss	Total set trusses	Prod. kg/m^2	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	-

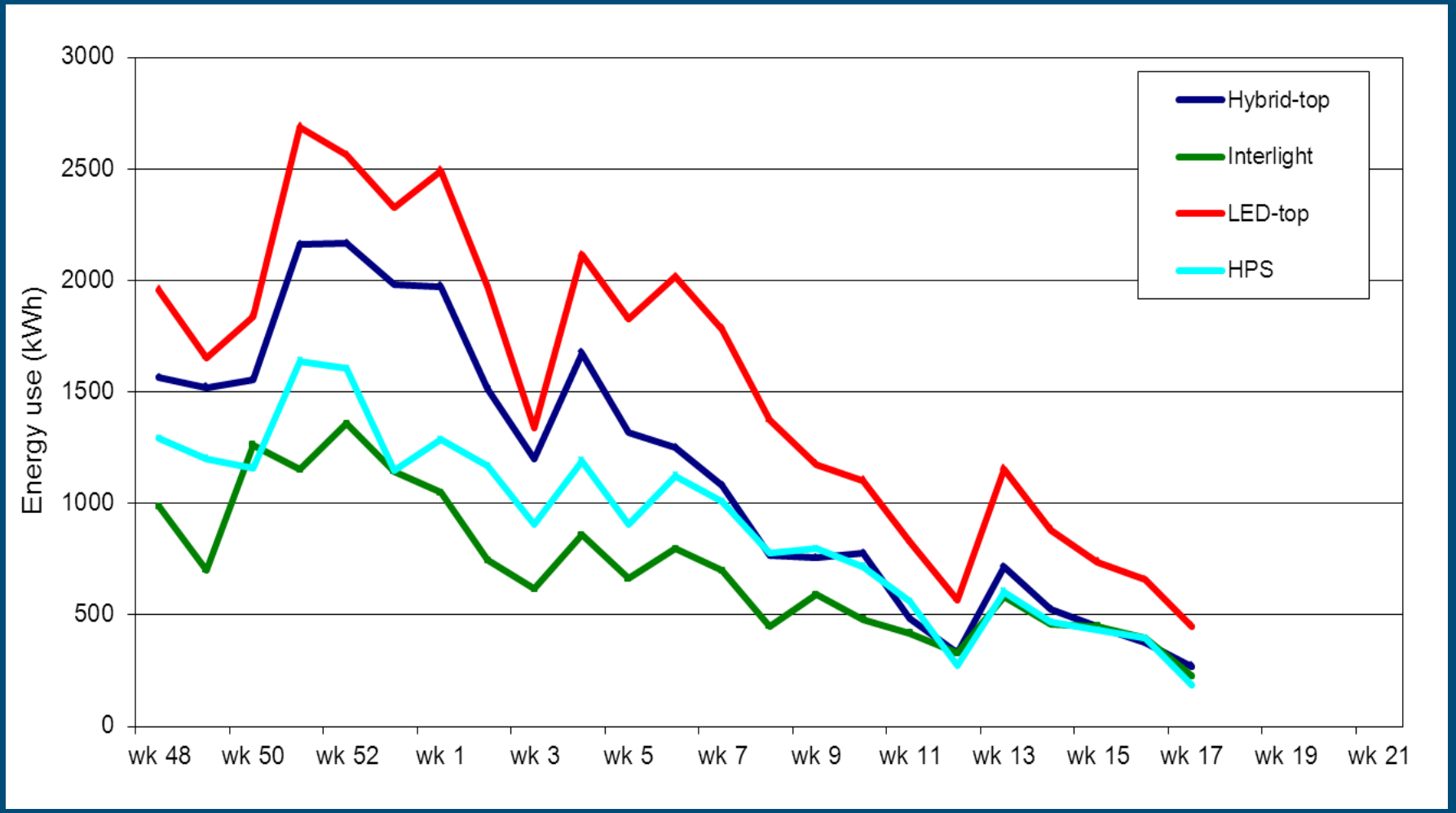
Energy use of both lighting systems

- 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

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