



Temperature Integration in Greenhouses

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Outline of the presentation

- Brief description of temperature integration (TI)
 - Background
 - What is TI?
 - How it work?
 - Our experience with TI at GPCRC
 - Extension of the TI concept
 - Results
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Background of temperature integration (TI)

- Average temperature is more important than the instantaneous temperature for crop development.
 - Strong correlation between average daily temperature (ADT) and net plant growth
 - Save heating energy while ensuring a desired average temperature for crop production.
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What is (TI)?

Use high temperature when the cost is lower and to use low temperature when the heat loss is high, while achieving the desired **average temperature or heat unit** over an integration period.

The basic principle of TI is to use average temperature over a certain period, instead of instantaneous temperature, for temperature control because the average is decisive for crop growth and development.

(Van den Burg et al., 2001)

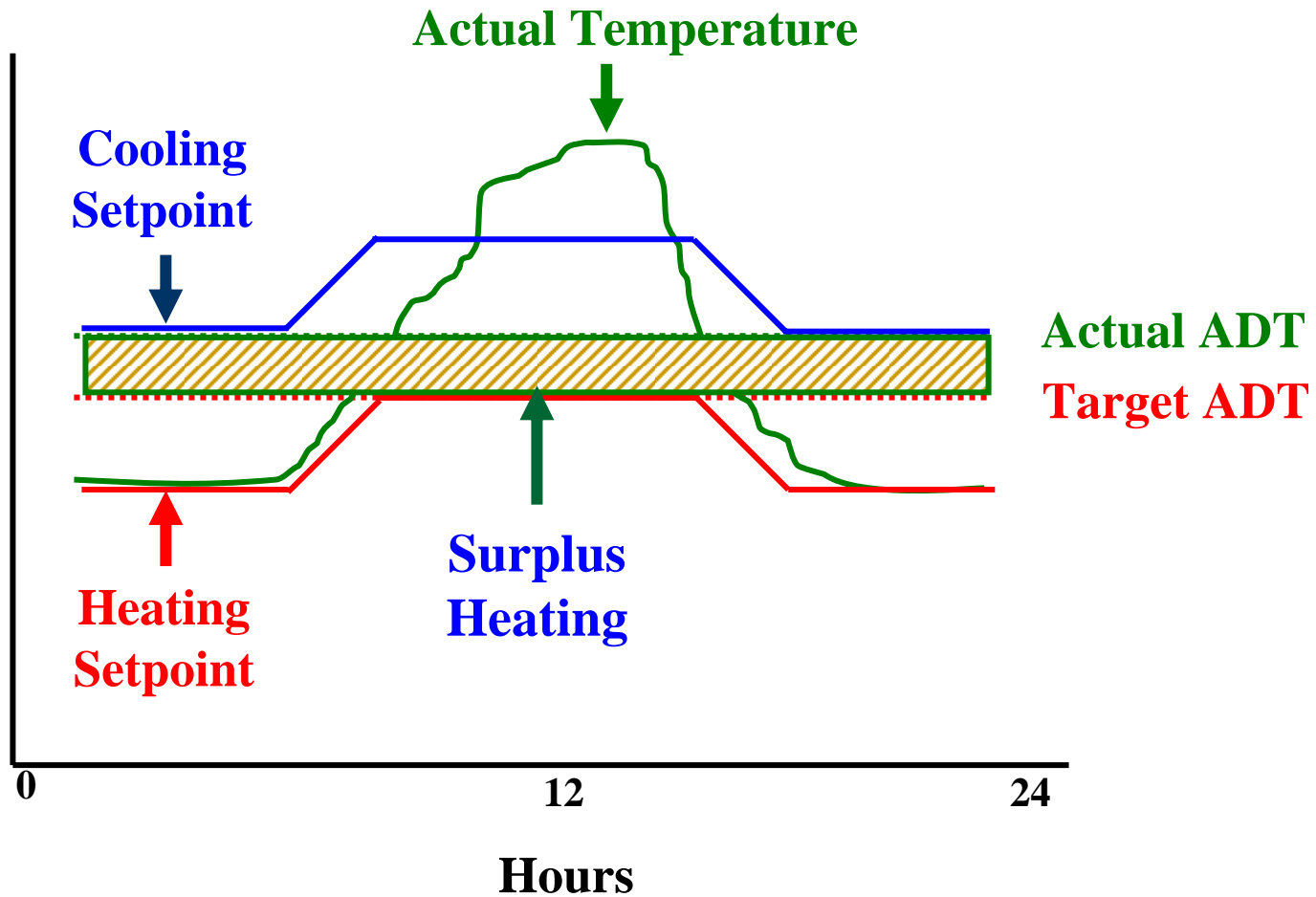
Exception to basic principle

- Distribution of the temperature over day and night
 - Consistent day-night temperature difference (DIF) over a long time has consequences on crops.
 - The **+DIF** elongates internodes. The **+DIF** promotes leaf development and early production.
 - The **-DIF** shortens the internodes but is not recommended for first week after planting.
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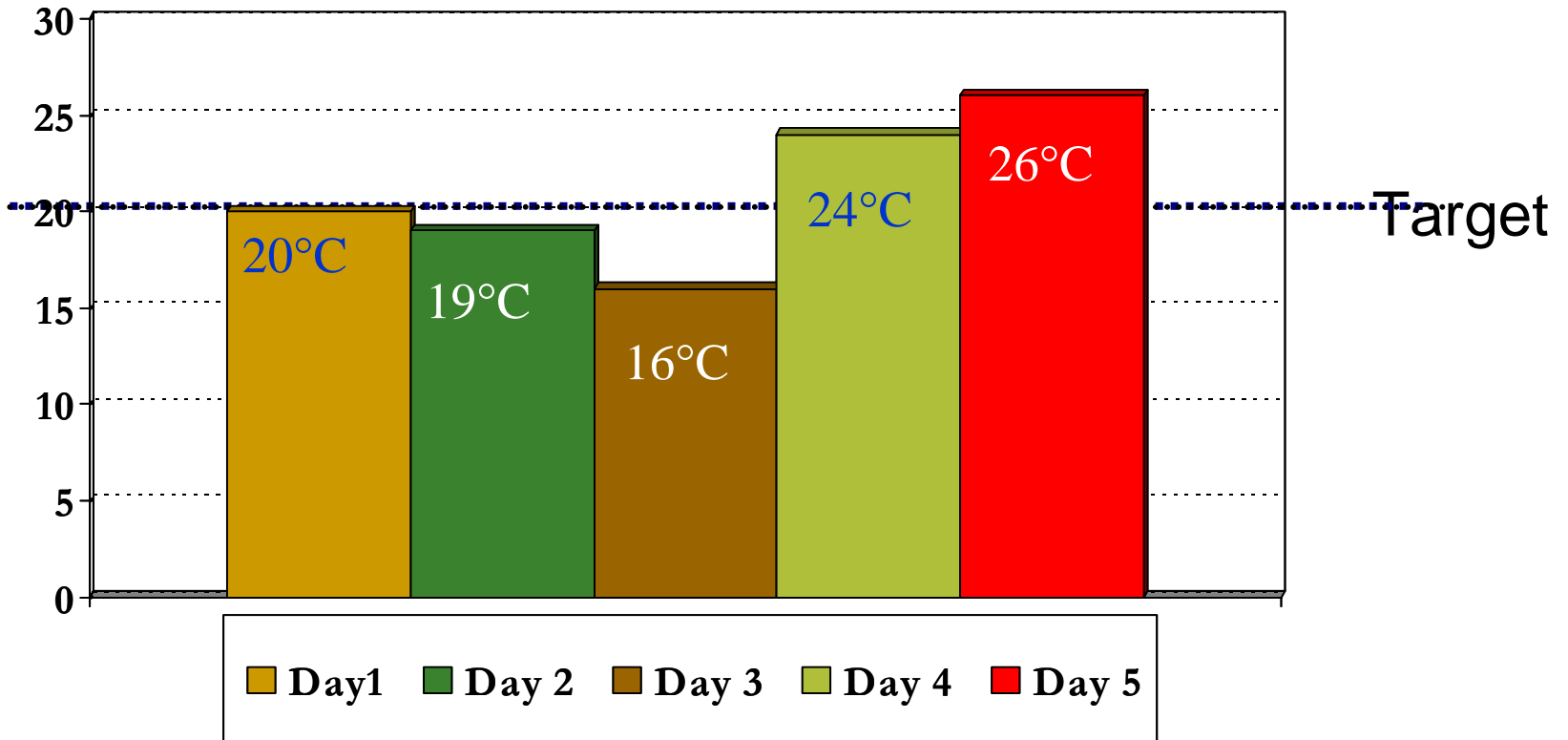
How TI work?

- TI duration may be one day (24-hrs period) or multi-days; on actual climate of previous days or weather forecast.
 - **24-hour period:** no change in average temperature compared to conventional control; only the distribution of the temperature over the 24-hr period changes.
 - **Multi-day TI:** average daily temperature (ADT) generally used to calculate accumulated heat gain and loss.
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Heating surplus and deficit

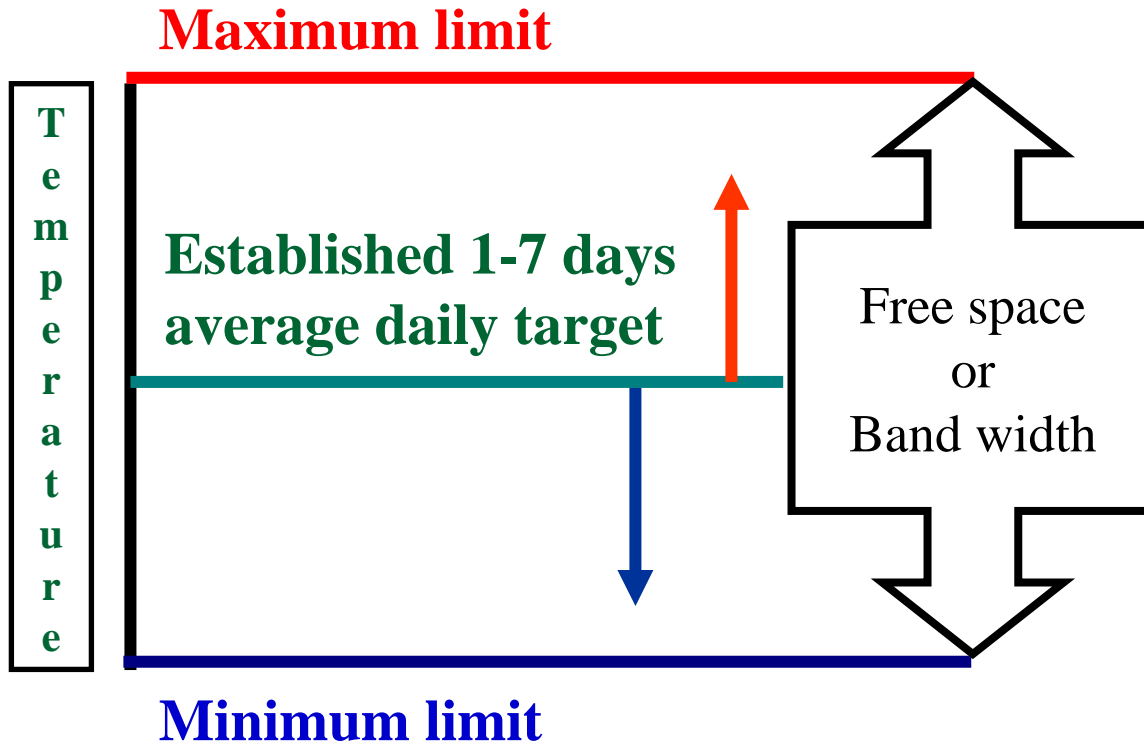


Example calculation for 5 days



Normal	Colder	Coldest	Warmer	Warmest
480	456	384	576	624 deg_hrs

What is operator limits



A control program based on TI generates flexible set-points between two fixed limits

How TI work?

- **Heating take place if:**
 - The minimum temperature limit is reached or
 - Heat surplus is exhausted.
 - **The temperature is increased** if raising temperature is relatively cheap (sunny weather, less wind etc).
 - **The temperature is decreased** if raising temperature is relatively expensive (cloudy weather, high wind etc.)
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Our experience with TI

- 3-days temperature integration (TI)
 - We extended TI concept further by incorporating two **pre-night low temperature regimes to increase early production and save energy**
 - Big-Dina, Macarena, and Clarence
 - Previous 3-days actual climate temperature was used to calculate heat surplus and deficit.
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- Argus **Smartheat** Climate Control Strategy

Our experience with TI

Two pre-night low temperature regimes are:

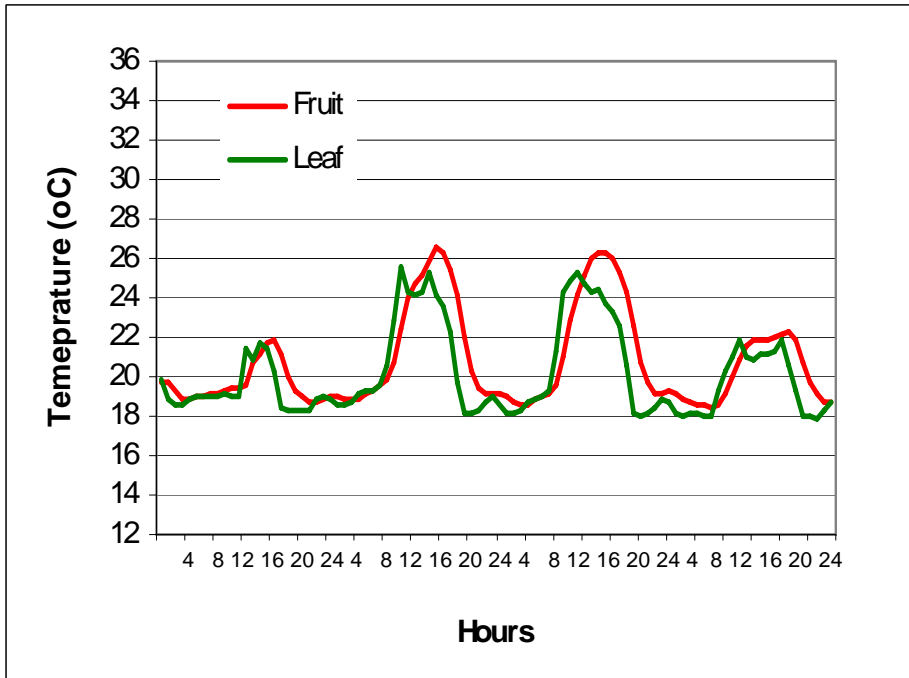
- **New TI**: a pre-night low air temperature of 13°C (PNT13°C) was applied for three hours (18:00-21:00) with a target daily average temperature of 18.25°C
 - **Control TI**: a pre-night low temperature of 17°C (PNT17°C) was applied with an exact target daily average temperature of 18.25°C.
 - Implemented in 6 greenhouse compartments with 3 replications
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Effect of TI methods on microclimate

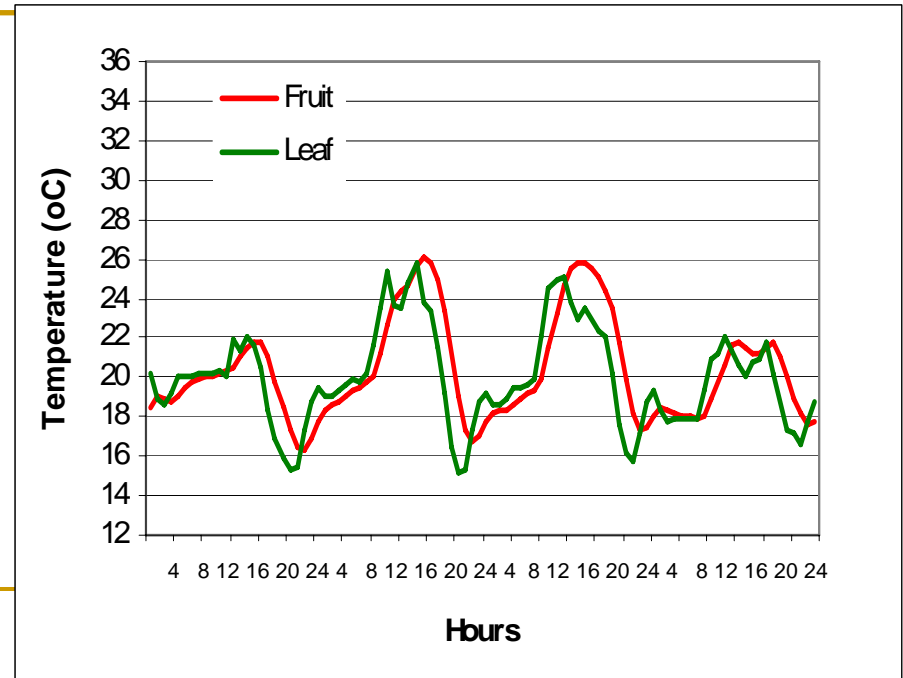
Microclimate measured at three canopy heights

Canopy	Relative humidity (%)		Air temp (°C)		Leaf temp (°C)		Fruit temp (°C)		Dew point temp (°C)	
	Control	New	Control	New	Control	New	Control	New	Control	New
Bottom	80.42	79.75	21.27	21.13	21.00	20.36	21.02	20.75	17.67	17.37
Medium	80.94	83.70	21.15	20.74	20.56	20.32	-	-	17.68	17.79
Top	82.82	85.88	21.03	20.26	20.16	19.84	-	-	17.89	17.71
Average	81.39	83.11	21.15	20.71	20.57	20.17	-	-	17.74	17.63

Control TI - PNT17°C



New TI - PNT13°C



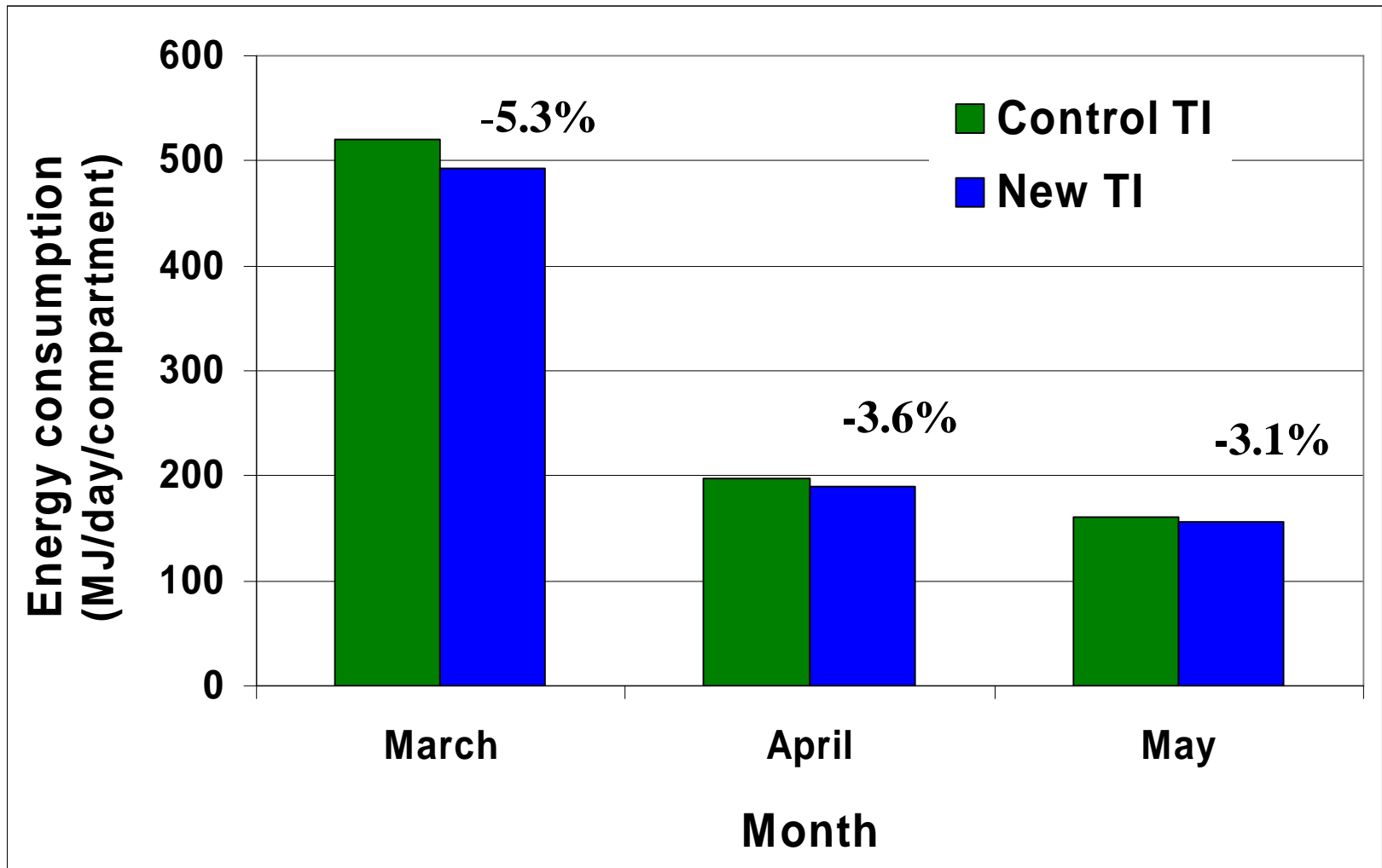
With control TI: Lowest temperature and long term average temperature between fruits and leaves were similar

With new TI: Lowest fruit temperature during pre-night was about 1-2°C higher than leaf temperature

Effect of pre-night temperature TI regimes on marketable fruit yield

Cultivars	Early fruit yield (April 13-30) (g plant ⁻¹)		Total fruit yield (April 13-May 31) (g plant ⁻¹)	
	Control TI	New TI	Control TI	New TI
Big-Dina	662b	1160a	4114b	4679a
Macarena	929a	1226a	4217a	4102a
Clarence	1089b	1512a	4618a	4688a

Effect of pre-night temperature TI regimes on energy consumption



Conclusions

- With the New TI method, average vertical air temperature was 0.40-0.50°C lower, leaf temperature (0.26-0.46°C) lower, and relative humidity was 2-3% higher.
 - A low air temperature (0.5°C) above the canopy might lead to lower heating energy consumption in the New TI method.
 - The new TI used 3-5% lower energy than the control TI.
 - There was no significant difference in growth and quality parameters between two TI methods in all three cultivars.
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Conclusions

- New TI method increased fruit temperature in comparison to leaf temperature which prompted fruit growth.
 - Early yields were about 75%, 32%, and 39% higher for Big-Dina, Macarena, and Clarence, respectively.
 - Total marketable yield over whole period was increased 13% by new TI method for Big Dena only, while it was similar for Clarence and Macarena
 - The new TI method did show a potential for higher yield, earlier production, and increased energy use efficiency for Big-Dina.
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Thank you for your attention

