Protected crops: microclimate, evapotranspiration and water use efficiency

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Outline of presentation

-- Review of common screens and structures
-- Microclimate
-- Crop water use
-- Water Use Efficiency

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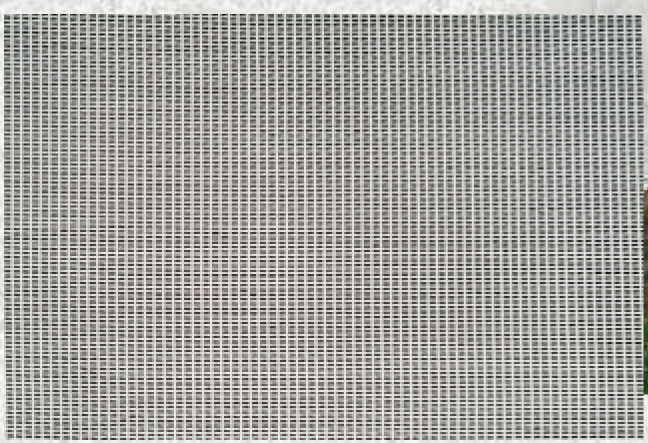
Current uses of screens in agriculture

1. Insect proof screens – exclude insects: 17-75 mesh
Reduce pesticide application – environmental friendly production.
Better access to world markets.

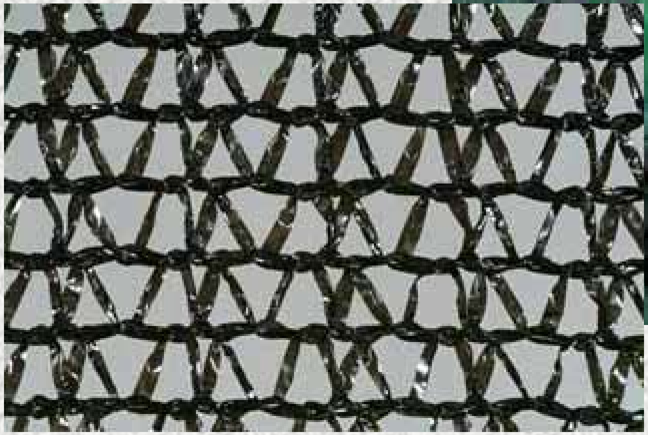


Polysack Inc., Israel

Josef Tanny
ARO, Volcani Center, Israel

Current uses of screens in agriculture

2. Shading screens (black) – reduce radiation load – save irrigation water – avoid sun damage.



Polysack Inc., Israel

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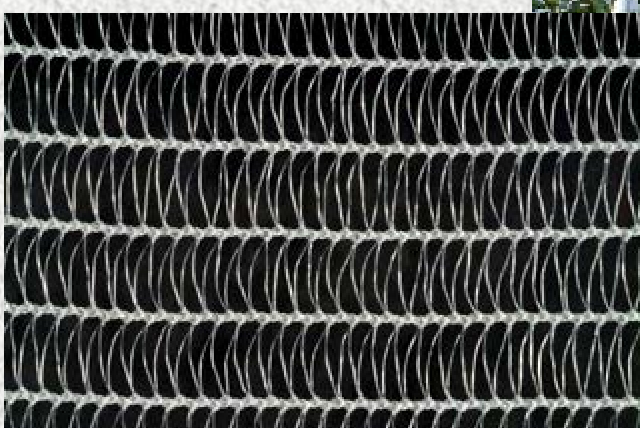
Current uses of screens in agriculture

3. Shading screens (transparent) – reduce radiation load – reduce crop water use – avoid sun damage – increase diffuse radiation.



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Types of Greenhouses and Screenhouses

A naturally ventilated greenhouse:
Screened sidewalls and roof vents

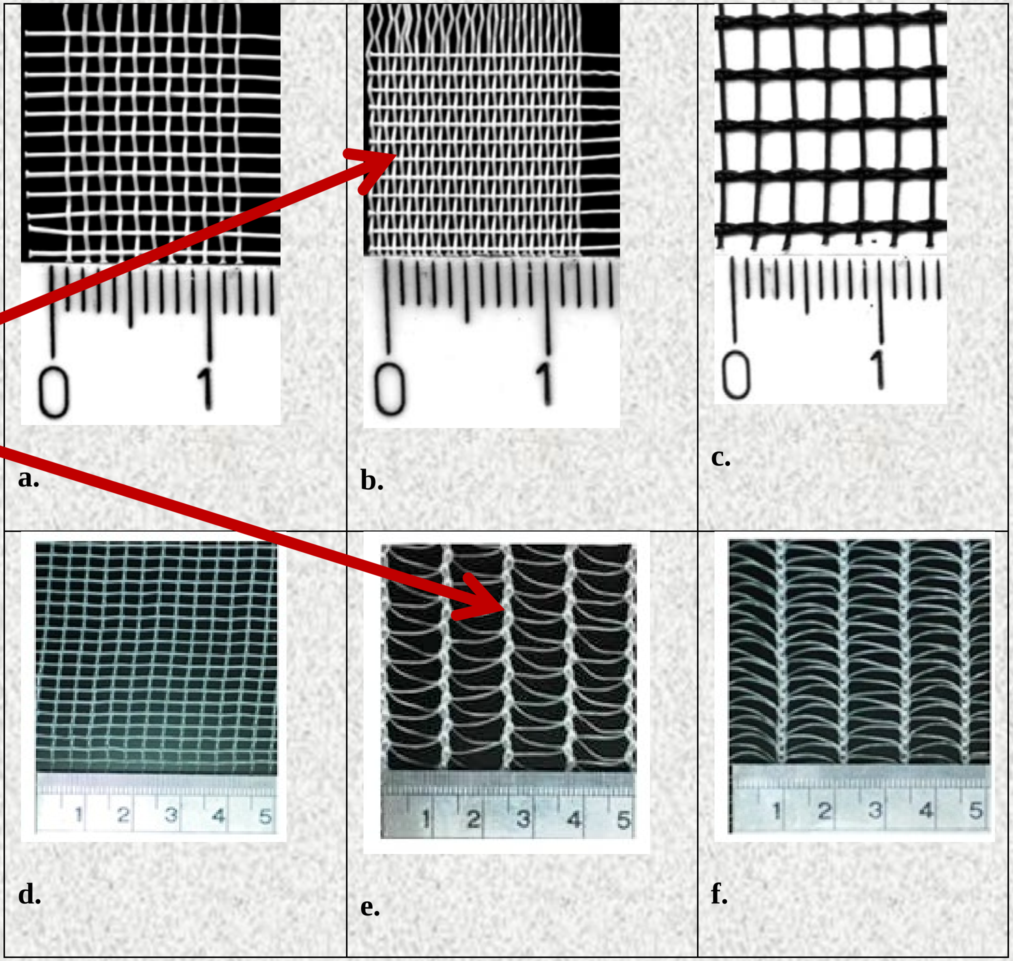
A shade screen cover

A screenhouse with sidewalls

Strong interaction between inside and outside -
No active climate control

Scanned images of screens (ruler in cm)

Notice the rectangular holes – the screen is not symmetrical



Analysis of the scanned image (eg. with NIH IMAGEJ software) gives the coverage (or solidity) of the screen (Möller et al., 2010).

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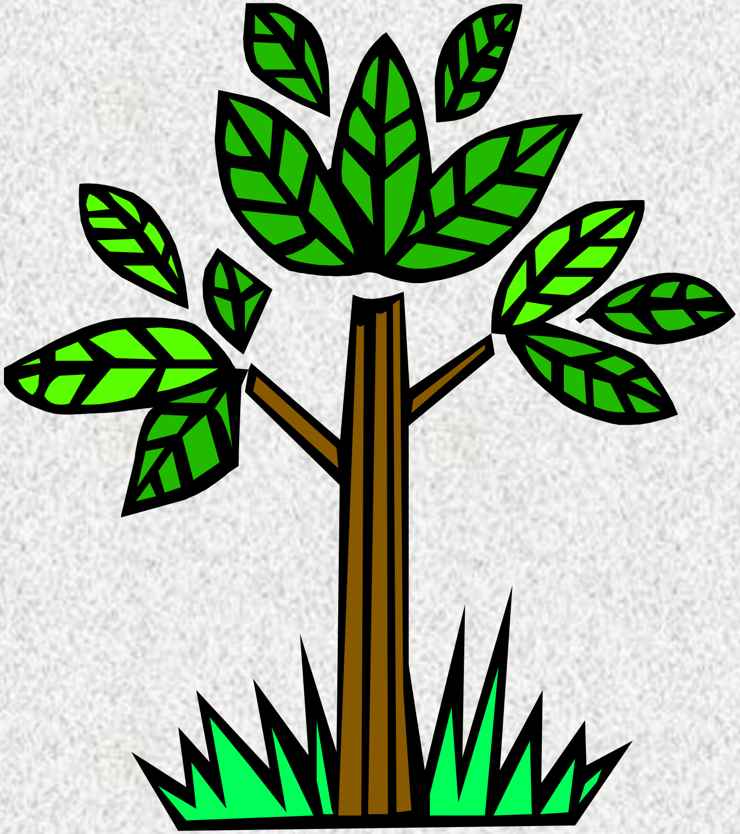
Effects of screens on crop microclimate

<u>Examples from our studies:</u>

Temperature
Humidity
Radiation
Wind



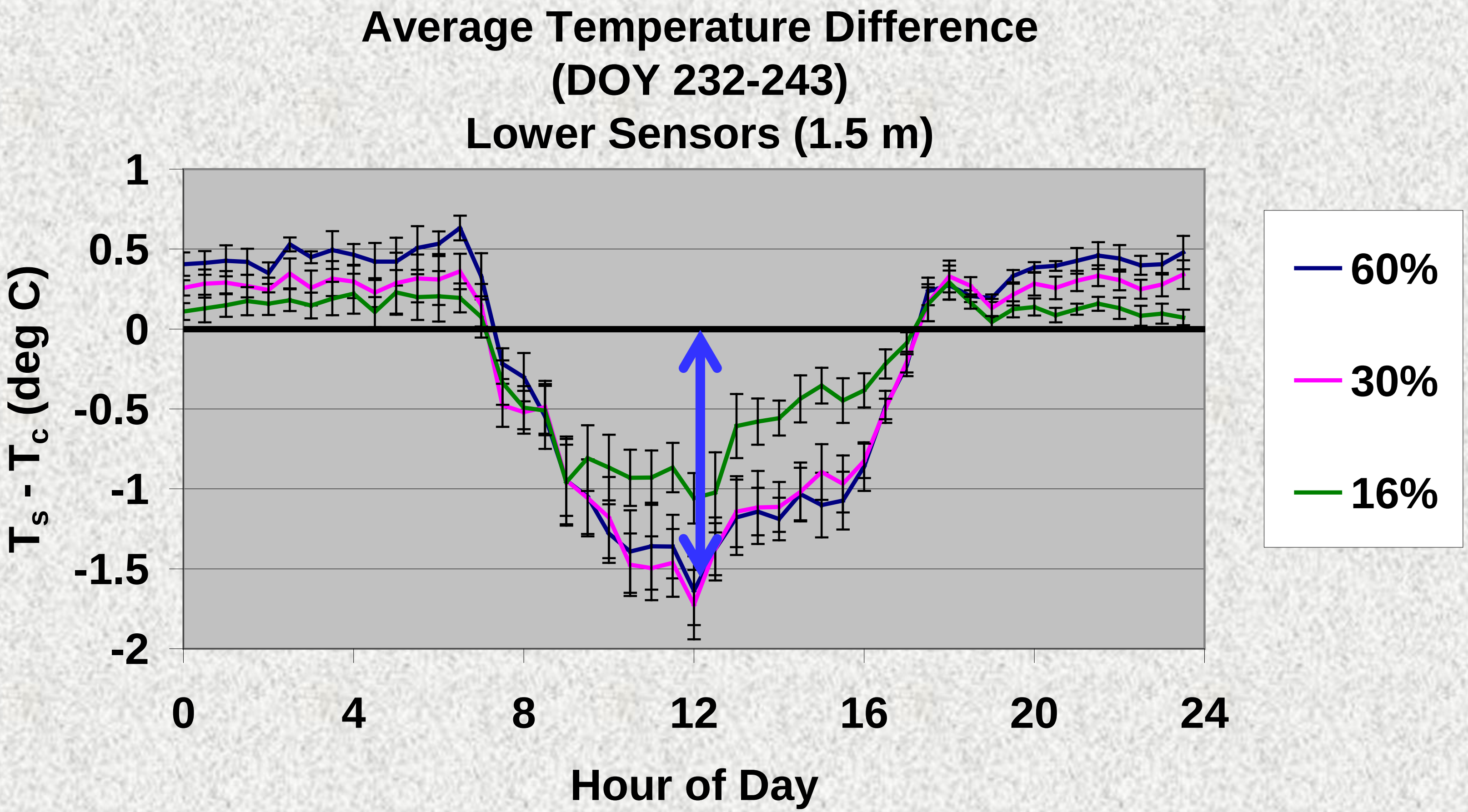
Effect of shading screens on apple orchards

south

east	west
60%	16%
0%	60%
30%	30%
16%	16%
0%	30%
16%	0%
30%	60%
60%	60%
16%	0%
60%	16%
30%	30%
0%	

north

Effect of shading screens on air temperature



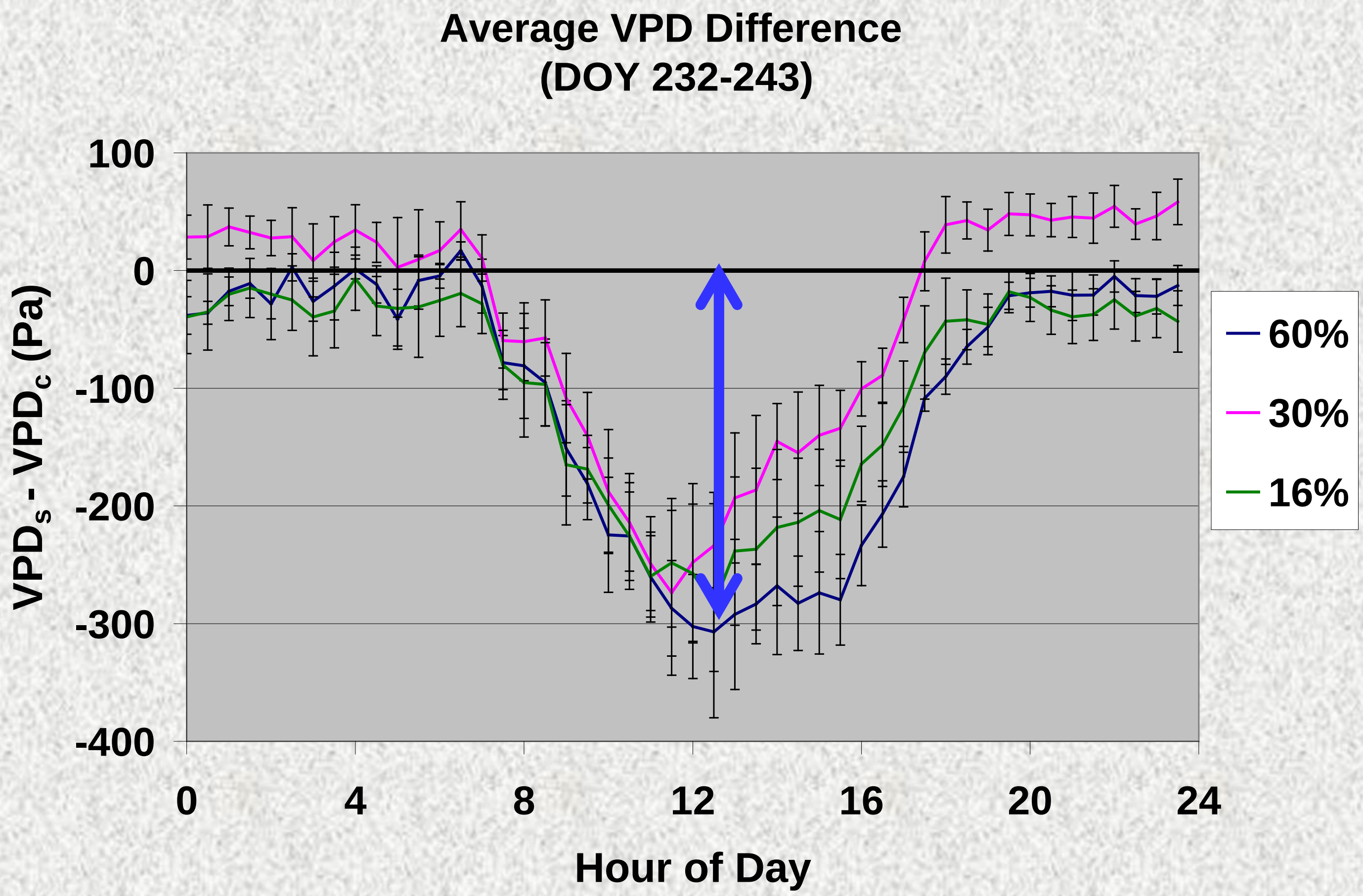
Temperature reduction ~ 1.5°C

Under the screens:

Cooler during the day.

Warmer during the night.

Effect of shading screens on VPD



Air is more humid

Under the screens:

Smaller VPD means the air is closer to saturation - a more “humid” air.

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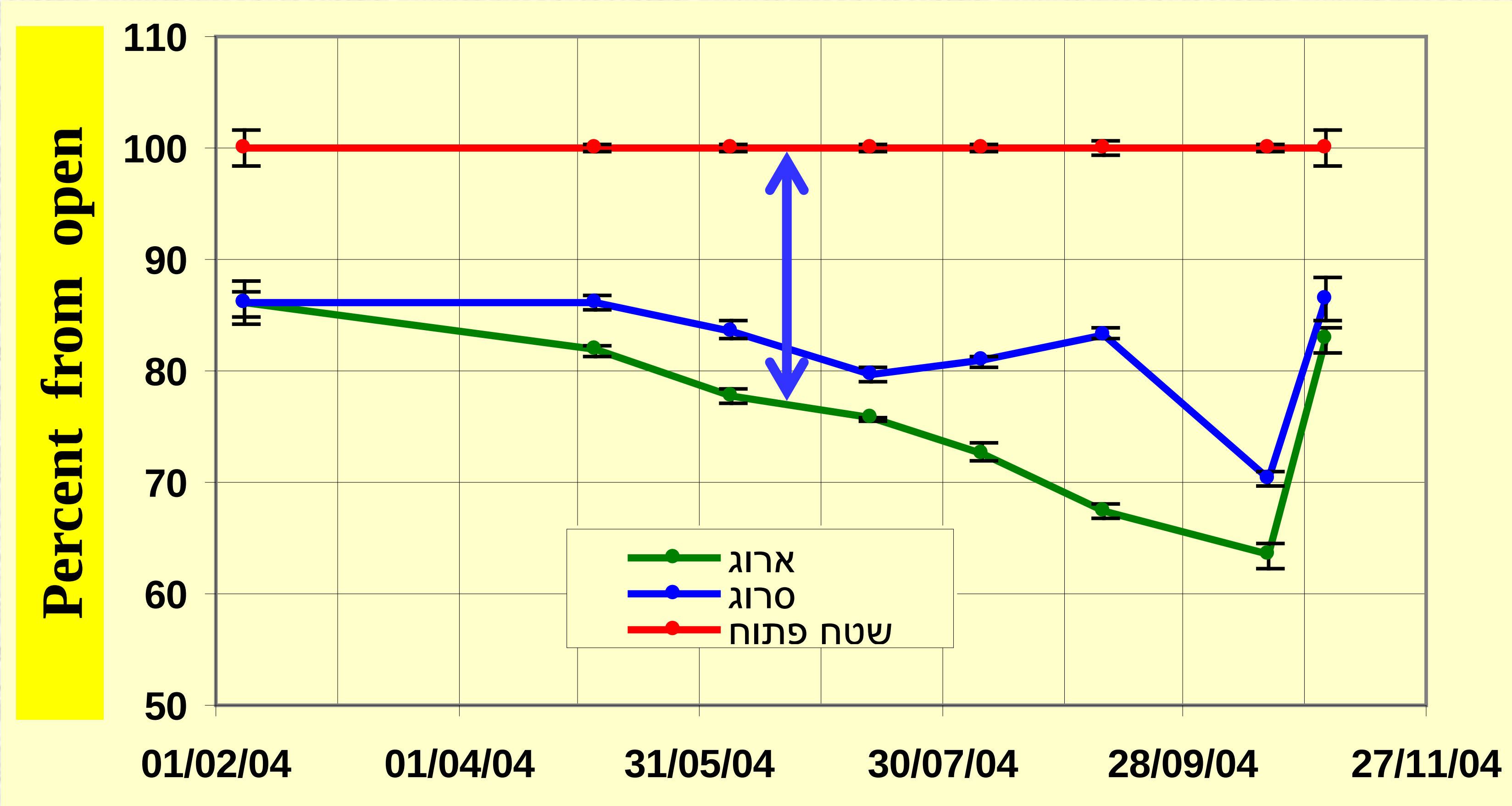
Banana plantations grown inside shading screenhouses – a common practice in Israel


Woven screen
Knitted screen

Radiation under the screen as percent of an uncovered orchard



Radiation reduced by 15-35%

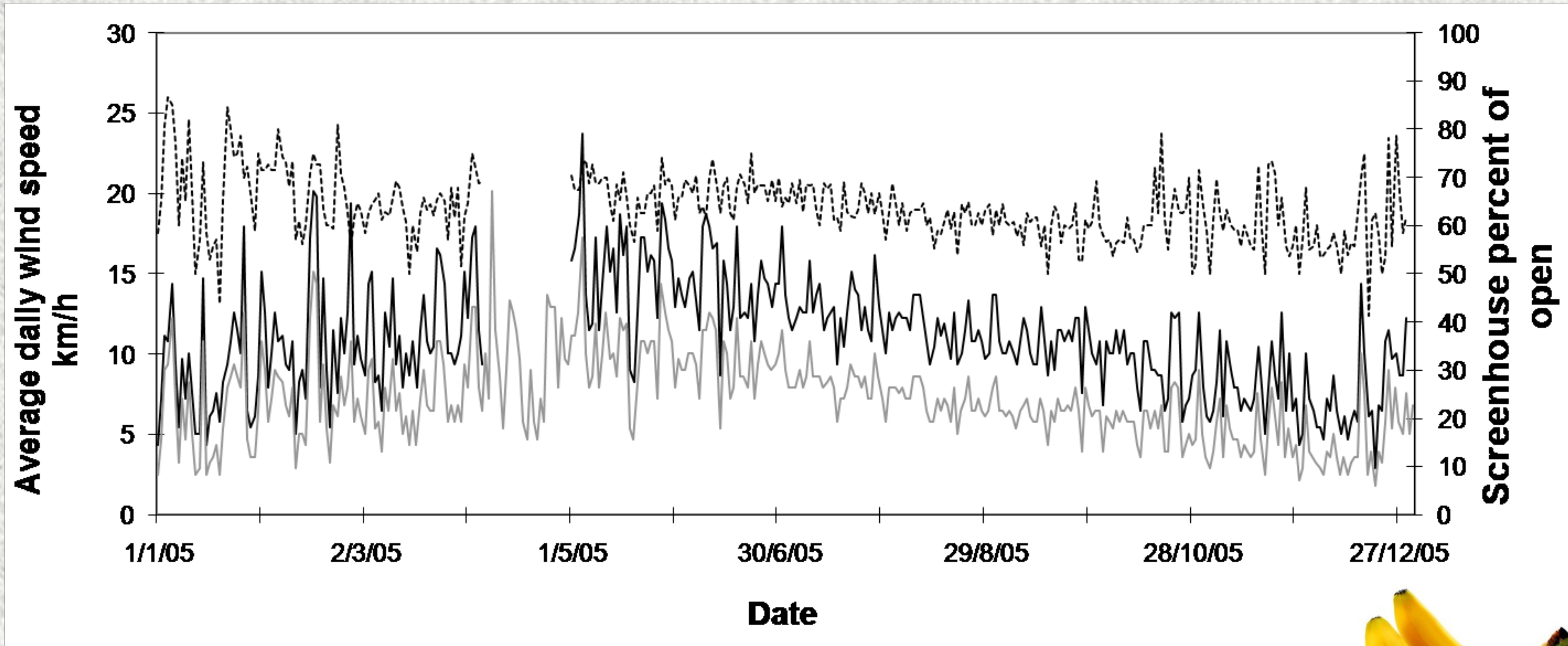
Open
Knitted
Woven

Y. Isaeli, Pers. Comm.

The effects of screens on wind speed

A 3-axis ultrasonic anemometer in a large banana screenhouse

Air speed at 5 m height in **covered** and **uncovered** banana plantations



Wind speed reduction ~ 35%

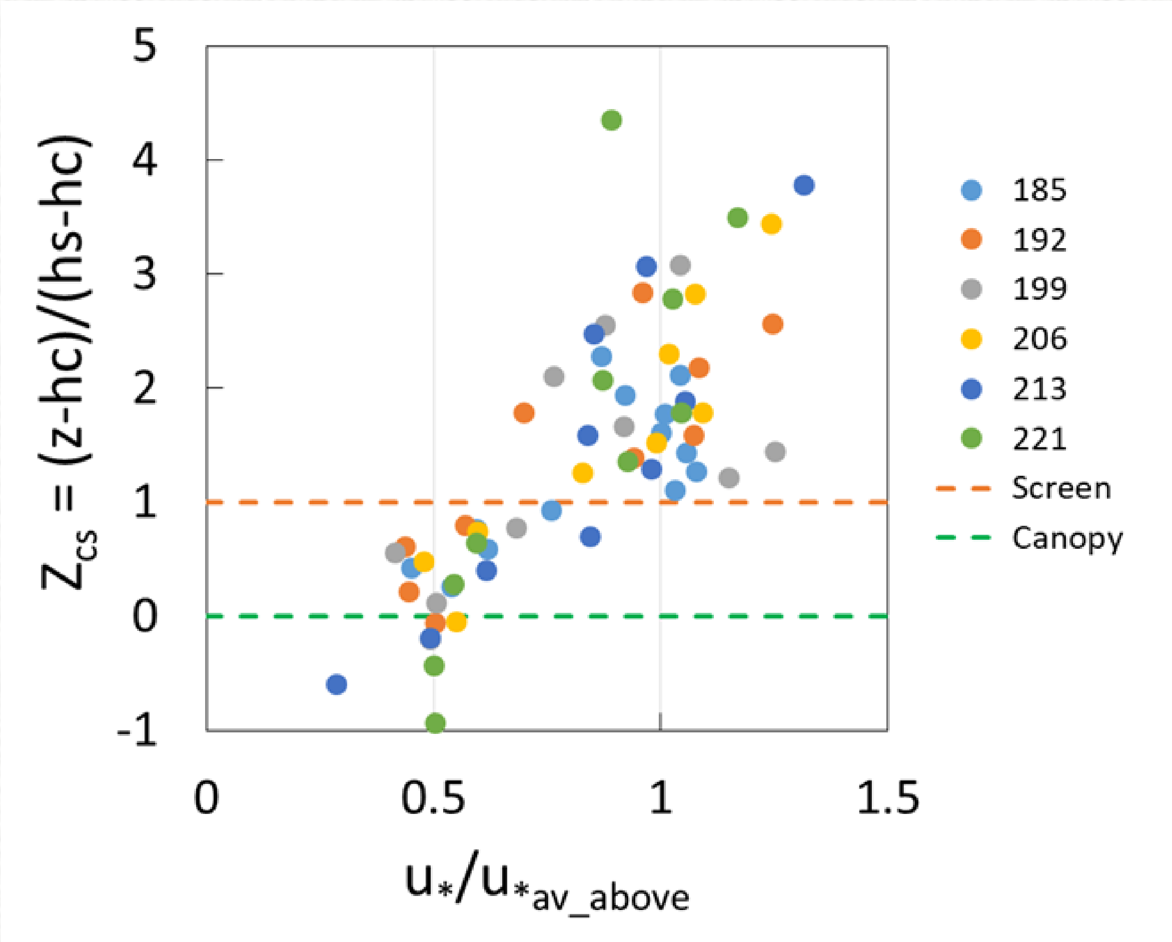
Open plantation
Screenhouse
Screenhouse percent

Y. Isaeli, Pers. Comm.

Torn leaves in an open banana plantation


The lower wind speed inside the screenhouse avoids tearing the leaves
4. 7. 2001

Momentum absorption by the screen



Vertical profiles of the friction velocity, normalized by the mean friction velocity above the screen.
The vertical axis is the normalized height.
Each symbol color represents a profile measured on a different day as indicated in the legend.

The screen is at Zcs = 1 (orange dashed line) and canopy top is at Zcs = 0 (green dashed line).

$$\frac{u_{*BELOW}}{u_{*ABOVE}} = 0.54 \pm 0.035$$

Tanny et al., 2018, AFM

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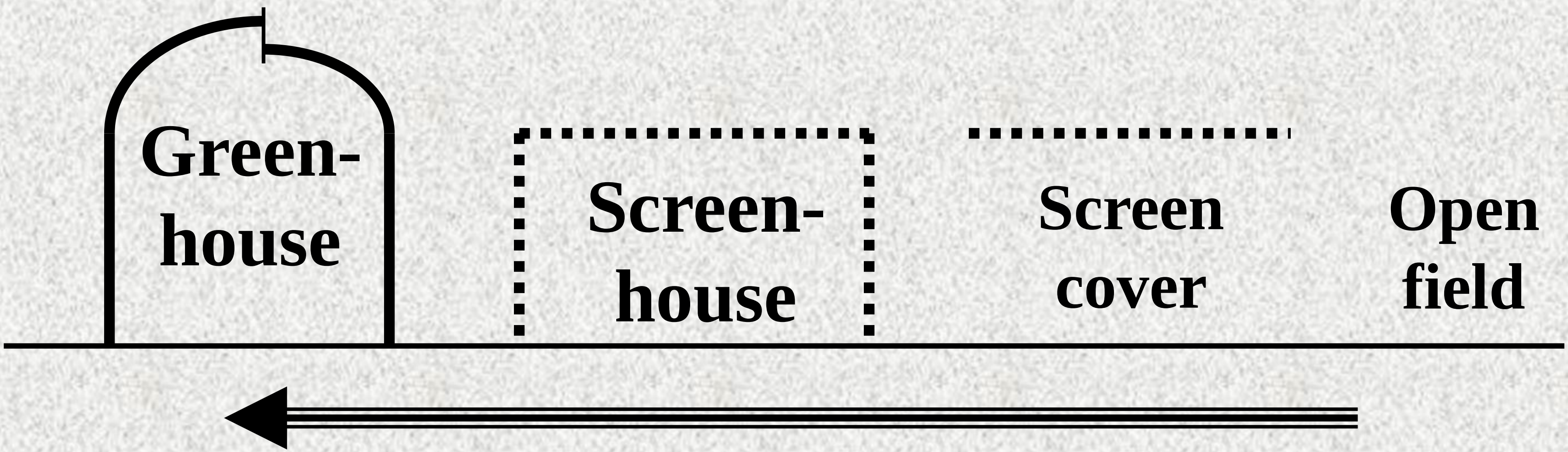
The effect of a screenhouse on crop water use – evapotranspiration

A challenge: measuring and predicting crop water use in modified climates



Can we use the same models?

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Pepper grown in a 50-mesh insect-proof screenhouse

Sap flow sensor in the stem

An eddy covariance system – evapotranspiration

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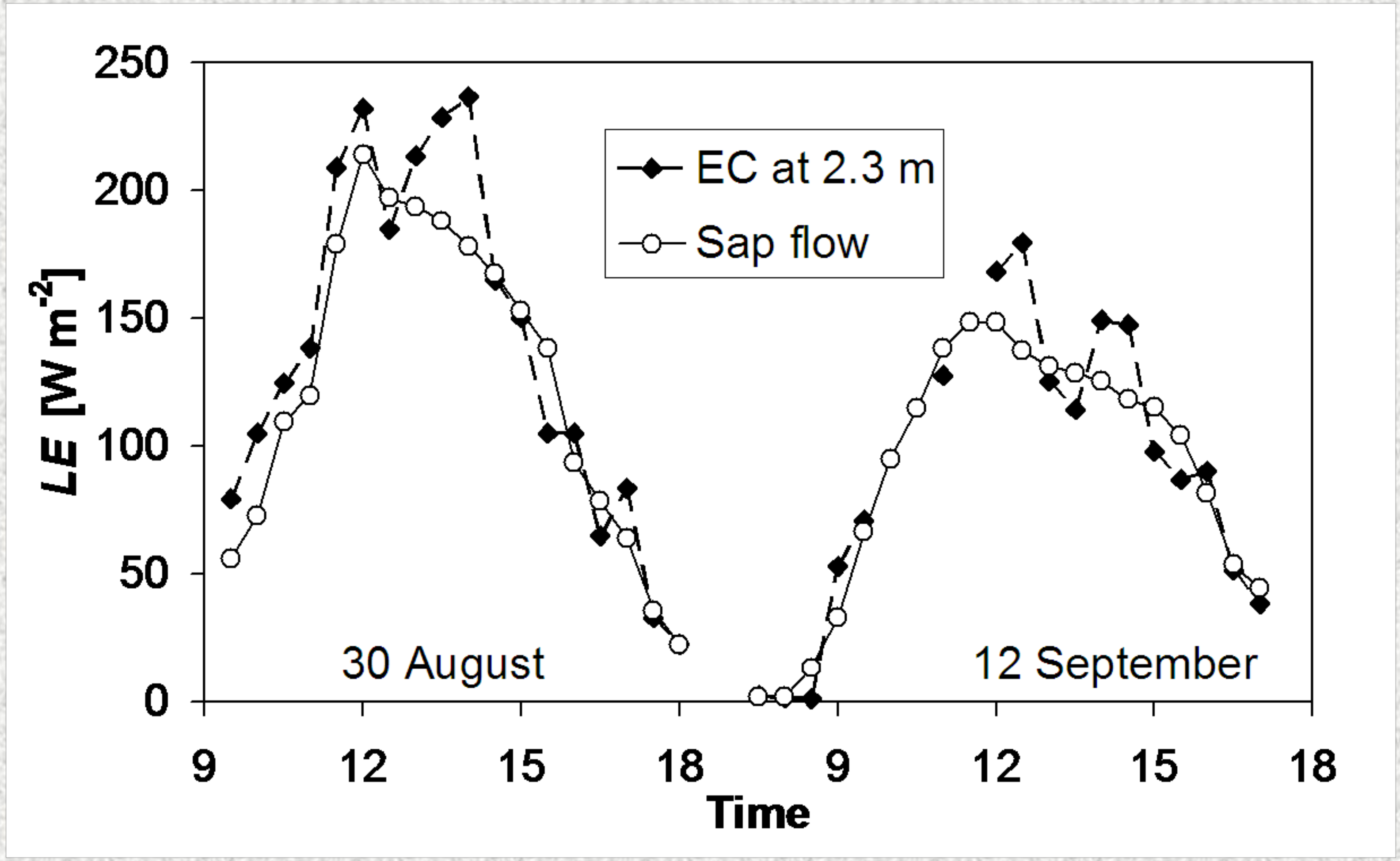
Comparison between diurnal courses of sap flow and evapotranspiration in a pepper screenhouse



LE is latent heat flux in Wm^{-2}

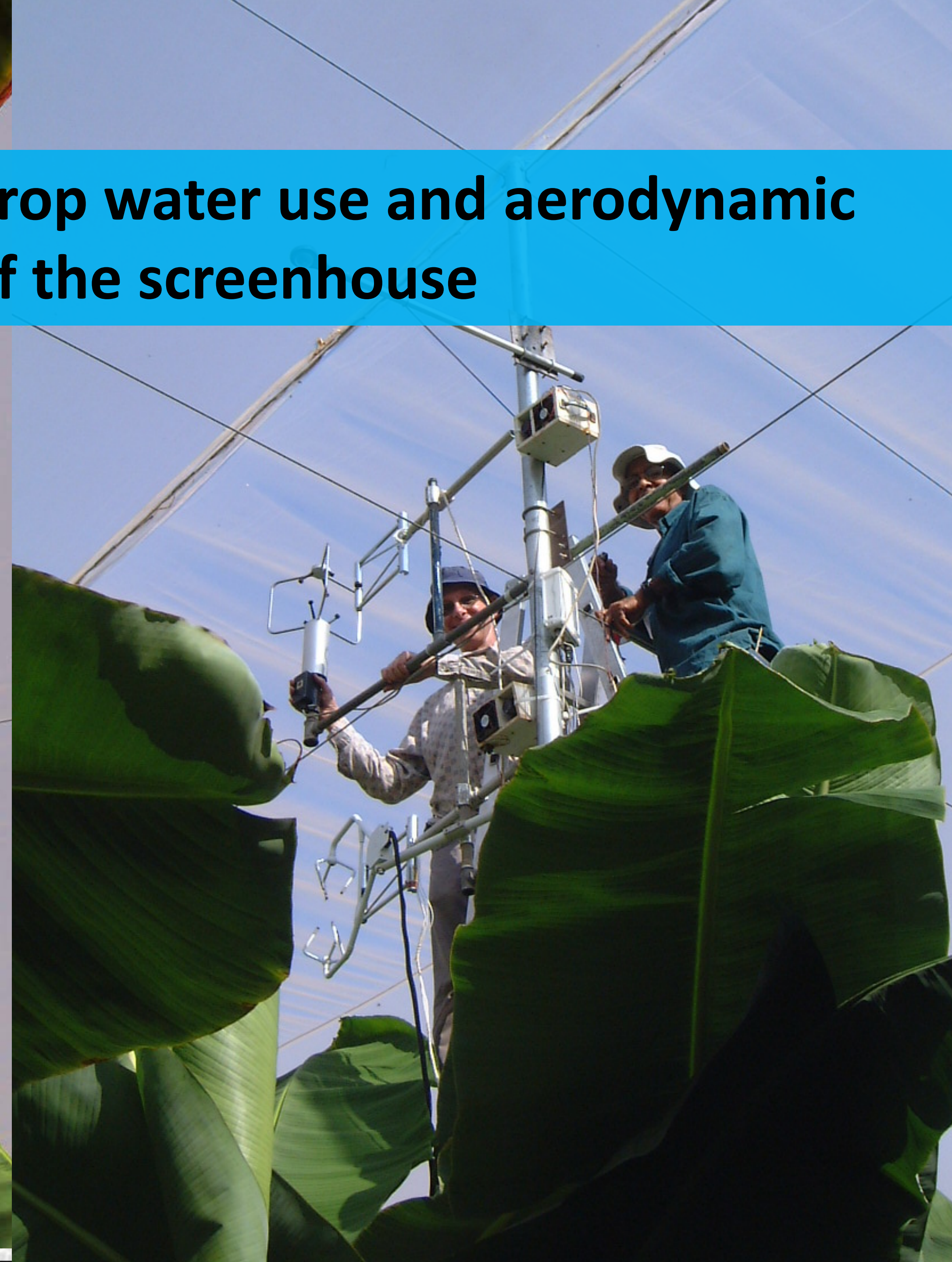
A Modified Penman-Monteith Equation for Screenhouses

$$\lambda E = \frac{\Delta}{\gamma^* + \Delta^*}\left(R_n - G\right) + \frac{\rho c_p}{r_a(\gamma^* + \Delta^*)}\left[e_s(T_a) - e_a\right]$$

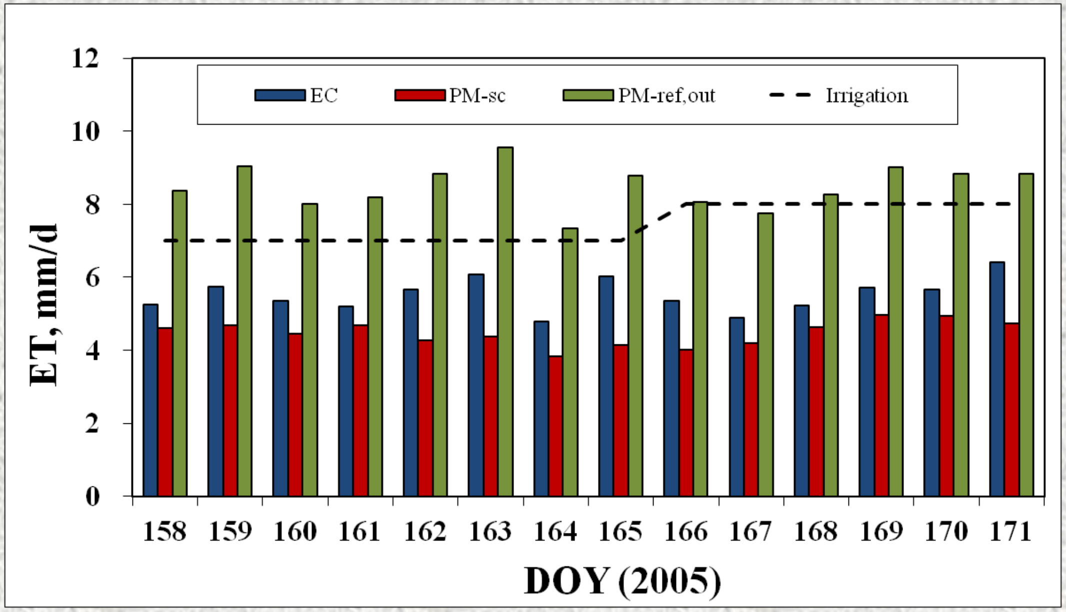
$$\Delta^* = \Delta\left(1 + \frac{r_b}{r_a}\right) \qquad \gamma^* = \gamma\left(1 + \frac{r_c + r_b}{r_a}\right)$$

R_n – Net radiation (Wm^{-2})
G – Soil heat flux (Wm^{-2})
e – Vapor pressure (Pa)
T – Air temperature (K)
r_a – Aerodynamic resistance ($s\ m^{-1}$)
r_b – Boundary-layer resistance ($s\ m^{-1}$)

Measuring crop water use and aerodynamic properties of the screenhouse



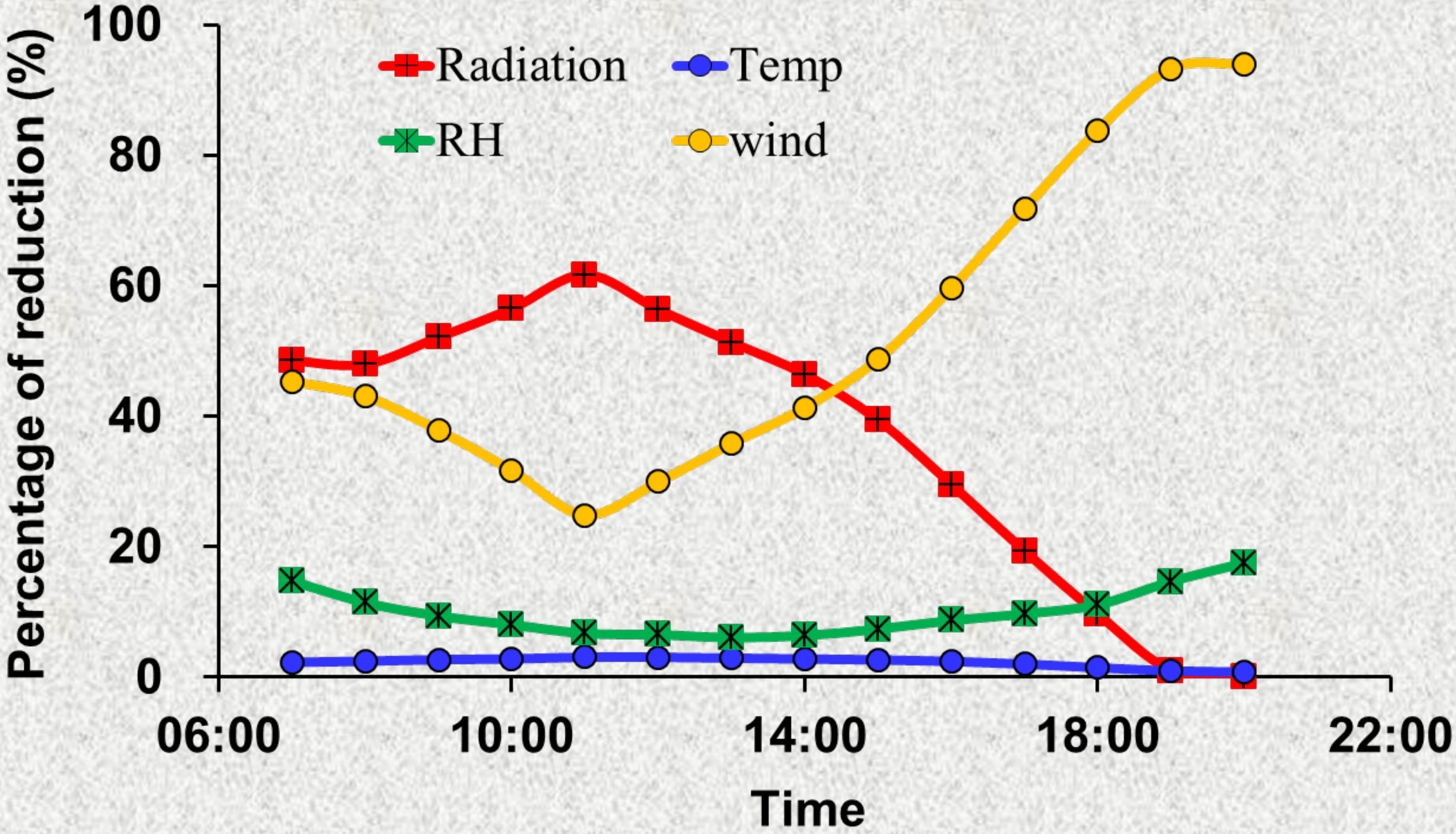
Measured and modeled evapotranspiration in a banana screenhouse



Blue- measured inside
Red – modeled inside
Green – modeled outside

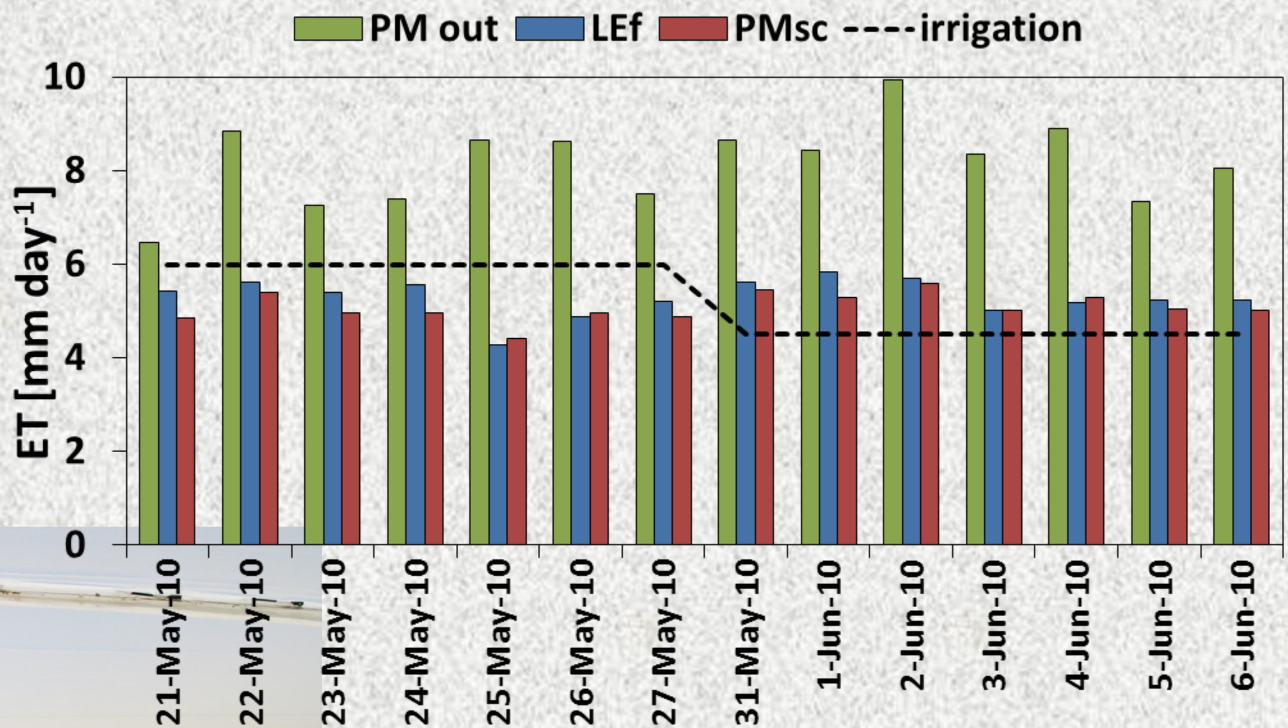
$$\frac{\textbf{Measured } ET \textbf{ inside}}{\textbf{Modeled } ET \textbf{ outside}} = 0.65 \pm 0.014$$

ET reduction by screen compared to open field



Haijun et al., AFM, 2015

Measured and modeled evapotranspiration in a covered vineyard

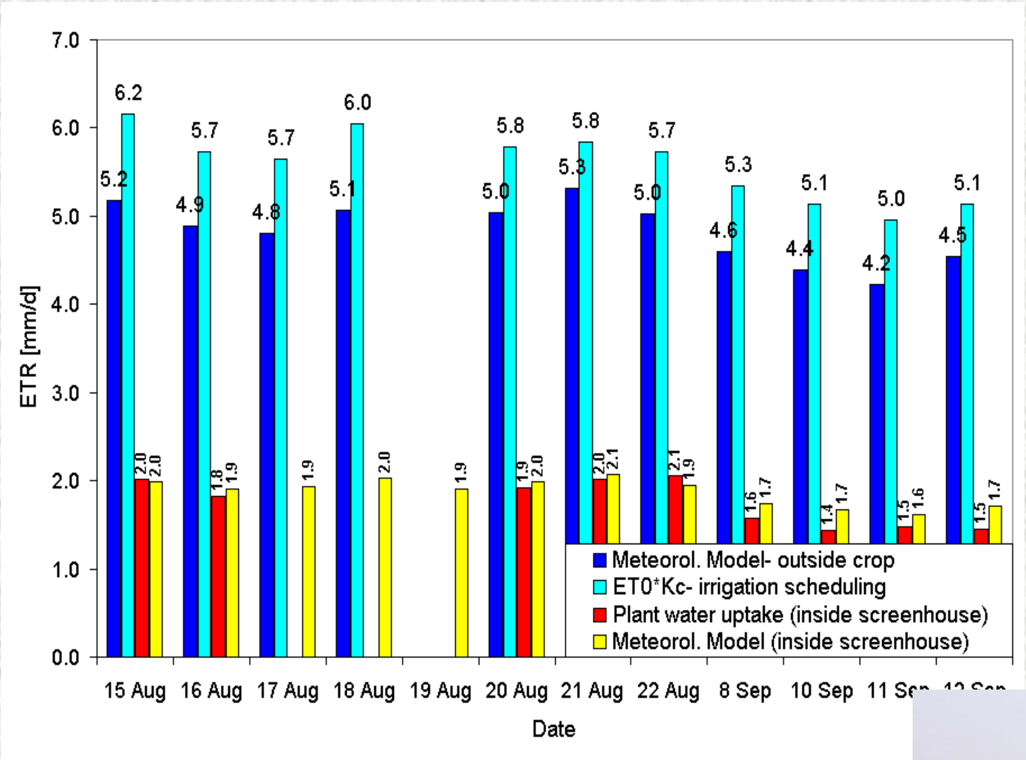


Blue- measured inside
Red – modeled inside
Green – modeled outside

$$\frac{\textbf{Measured } \; ET \textbf{ inside}}{\textbf{Modeled } \; ET \textbf{ outside}} = 0.66 \pm 0.09$$

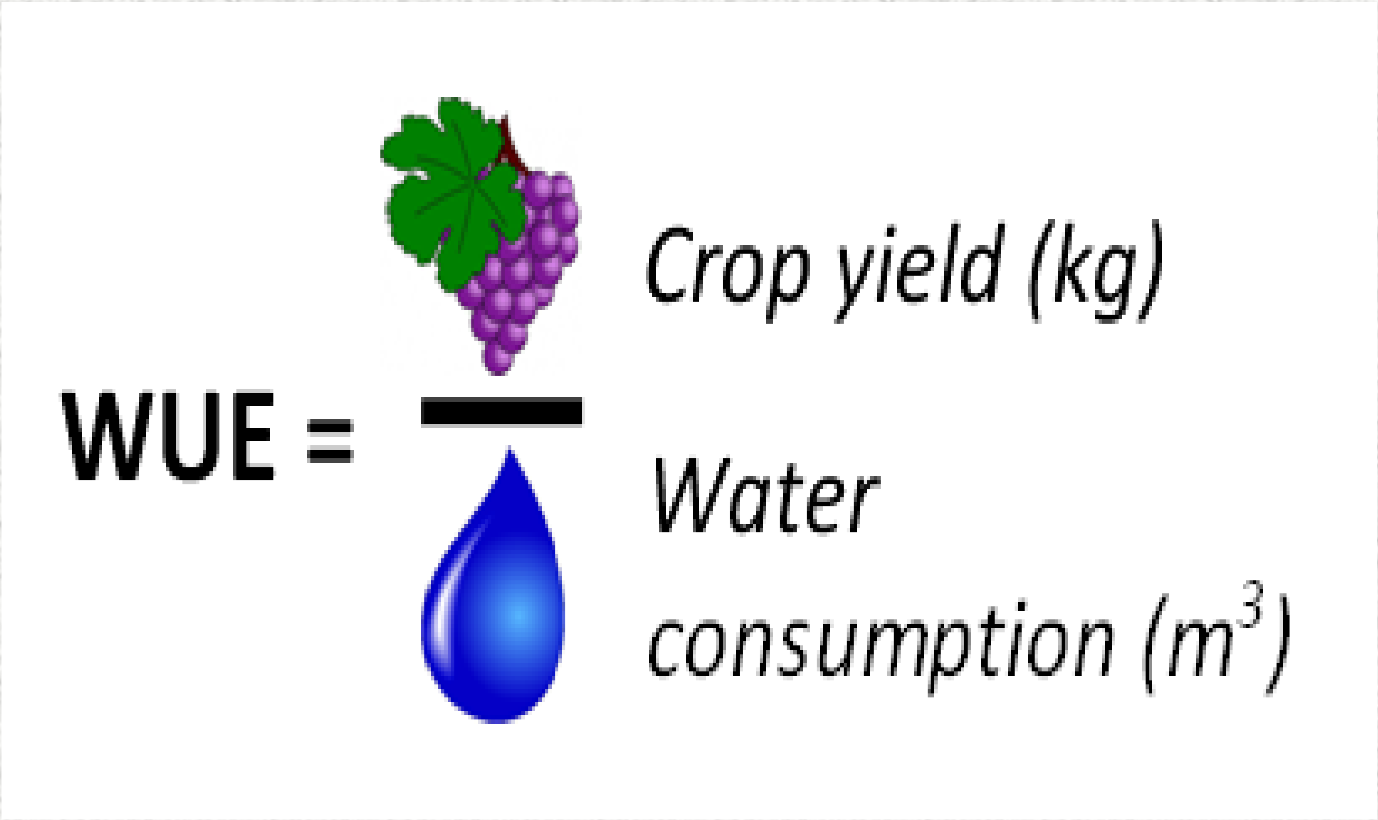
Pirkner et al., IJB, 2015

Evapotranspiration of a pepper plantation: inside the screenhouse and outside



$$\frac{\text{Measured } ET \text{ inside}}{\text{Modeled } ET \text{ outside}} \approx 0.4$$

Saving water means: Increasing the Water Use Efficiency (WUE)



Irrigation experiment
in a banana screenhouse

Four irrigation levels:

100% of outside (~2200mm/year)
85%
70%
55%

Yield (Ton/ha) vs. Irrigation (m^3/ha)
Plantation WUE

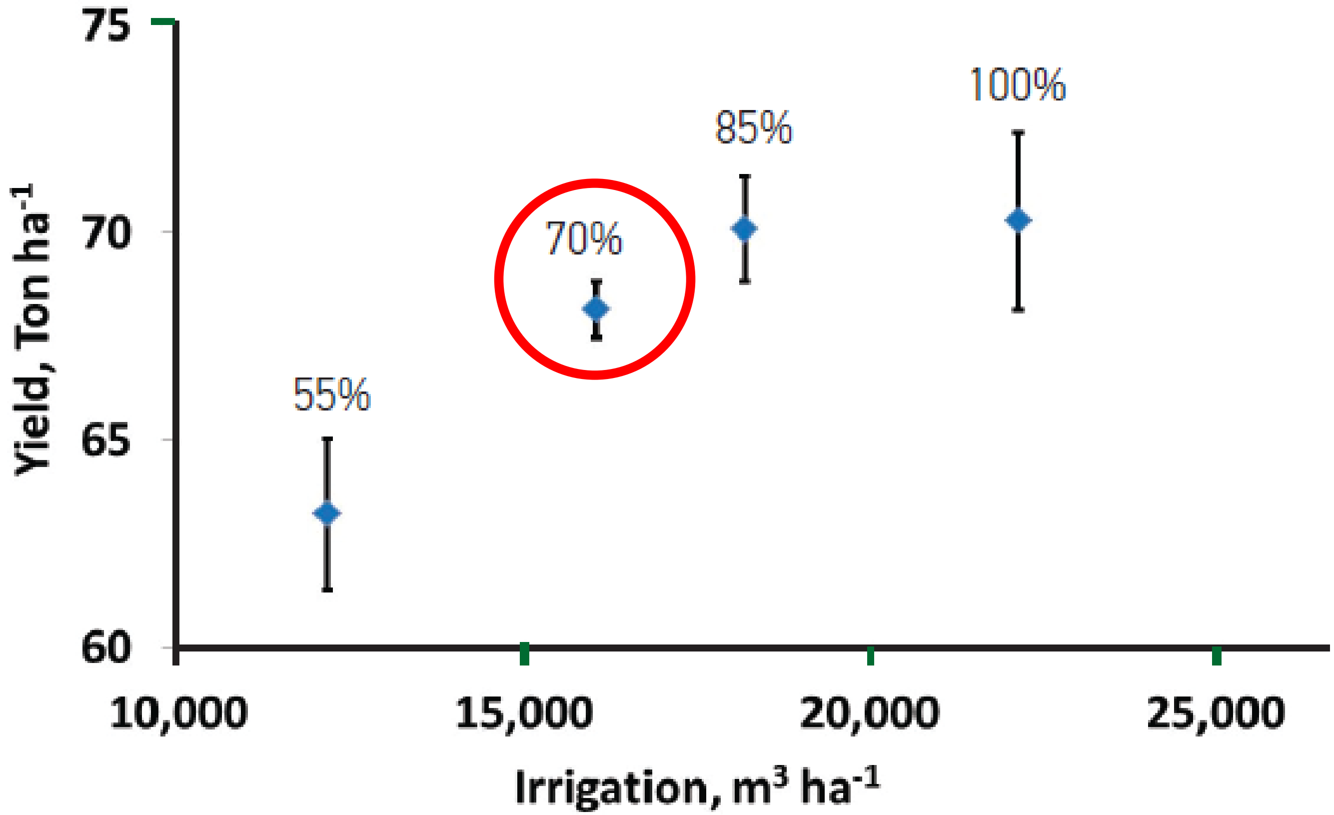


Fig. 4: Mean annual banana yield as a function of the mean annual irrigation, for the years 2004-2007. Percentage indicates the irrigation amount relative to open banana plantations in this region.

Tanny et al., Israel Agriculture, 2015

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Heat pulse technique - installation

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Comparisons between measurements and models (2015-2016)

	mm/day					
	Greenhouse			**Screenhouse**		
	mm/day		STDEV	mm/day		STDEV
Actually measured	2.54	±	0.78	2.43	±	0.90
ET_{FAO56} out Daily	2.12	±	0.46	2.12	±	0.46
ET_{FAO56} out Hourly	2.41	±	0.66	2.41	±	0.66
ET_{FAO56} in Hourly	2.34	±	0.73	1.70	±	0.49
ET scr	2.74	±	0.90	2.13	±	0.72
PM in (for Pepper)	2.28	±	0.76	2.24	±	0.68
ET gr	2.59	±	0.87	N/A		N/A
ET pt	2.59	±	1.00	1.66	±	0.59
ET rb	2.38	±	0.78	2.28	±	0.66
Ratio: Model/HP	**Ratio**		**NSC**	**Ratio**		**NSC**
ET_{FAO56} Daily out	0.90		0.34	1.07		0.59
ET_{FAO56} Hourly out	0.98		0.88	1.14		0.83
ET_{FAO56} Hourly in	0.93		0.79	0.74		-0.03
ET scr	1.06		0.94	0.96		0.62
PM in (for Pepper)	0.89		0.81	0.98		0.63
ET gr	1.01		0.89	N/A		N/A
ET pt	1.00		0.62	0.71		-0.11
ET rb	0.93		0.88	0.99		0.79

Ratio: Periodic

NSC: Daily

Protected cultivation of pepper

Actual irrigation by internal microclimate

	Irrigation (m^3/dunam) 15/8/16-15/5/17	
Treatment	**Greenhouse**	**Screenhouse***
Penman (external hour)	778	762
Penman (internal)	596	692
Penman (external recommended)	830	841
60% of recommended	635	643

Greenhouse – reduction of 28%
Screenhouse – reduction of 18%

*Add 100 mm rain to the screenhouse

Yield

Greenhouse	Export (Kg/m^2)	Total (Kg/m^2)
Penman (external hour)	a 9.4	a 10.4
Penman (internal)	a 9.4	a 10.3
Penman (external recommended)	a 9.3	a 10.4
60% of recommended	b 7.8	b 8.8

No significant difference between 2 and 3

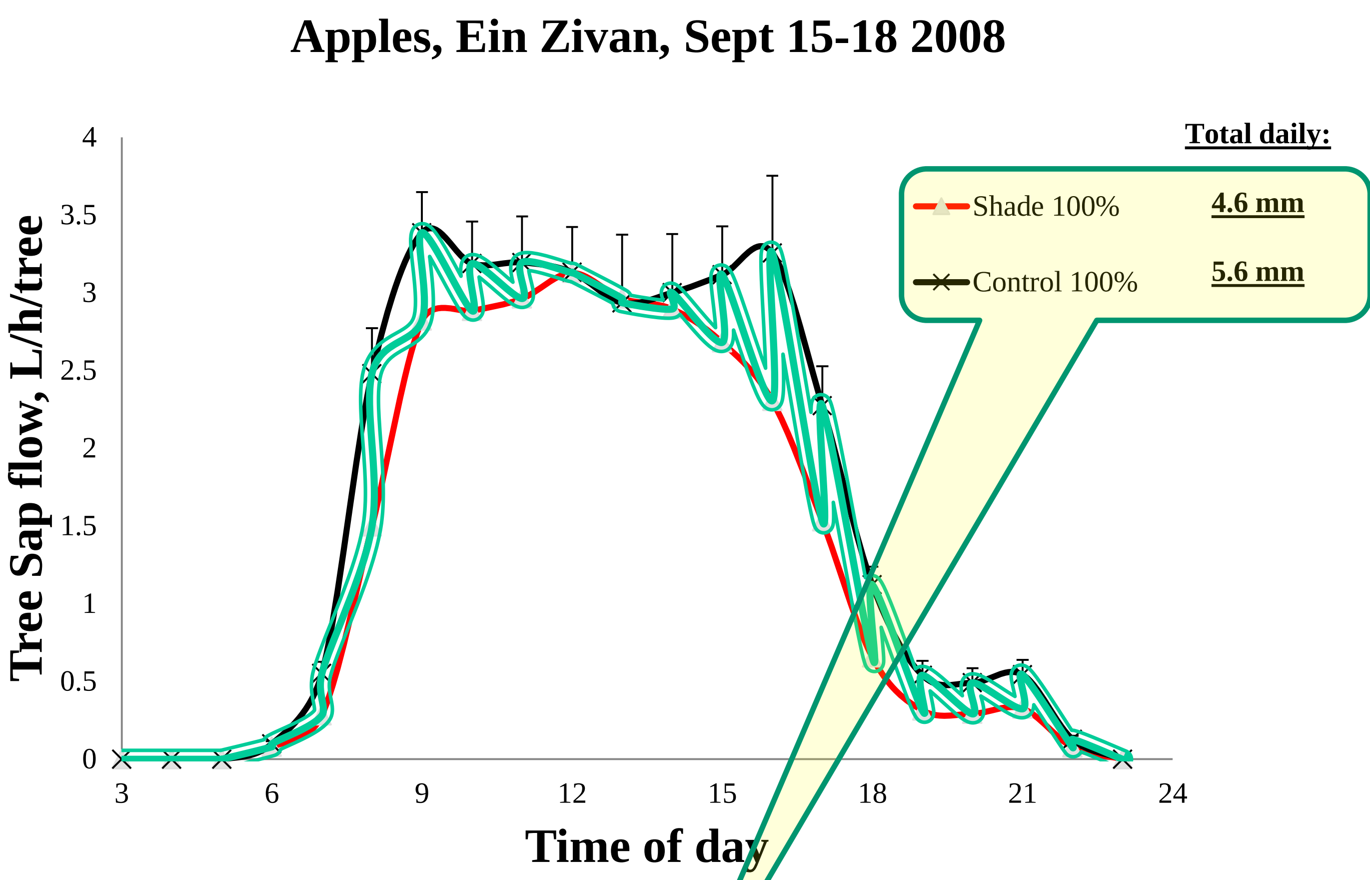
Screenhouse	Export (Kg/m^2)	Total (Kg/m^2)
Penman (external hour)	a 9.78	a 11.7
Penman (internal)	ab 8.87	a 11.1
Penman (external recommended)	b 8.1	b 10.1
60% of recommended	b 8.16	b 10.1

Treatment 4 (60%) – fertilization problem

Cover increased water use efficiency ~ 20 - 35%

Screen covered apple orchard

Tree sap flow sensors. 36 trees were measured continuously



Screens increased water use efficiency ~ 20%

Major conclusions

- Reductions of between 35-60% in evapotranspiration were realized under the screens, depending on screen and crop type.

- Increase in water use efficiency:
  Banana 20-30%.
  Apple 10-20%.
  Pepper 20-35%.

- Future research –
  - Optimization of the use of screens.
  - Improve the water use efficiency.
  - Study other crops.

Thank you!
Questions?

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