TURNING INFORMATION INTO PROFITS.

Pessl INSTRUMENTS

Frost Protection

JAN 2018

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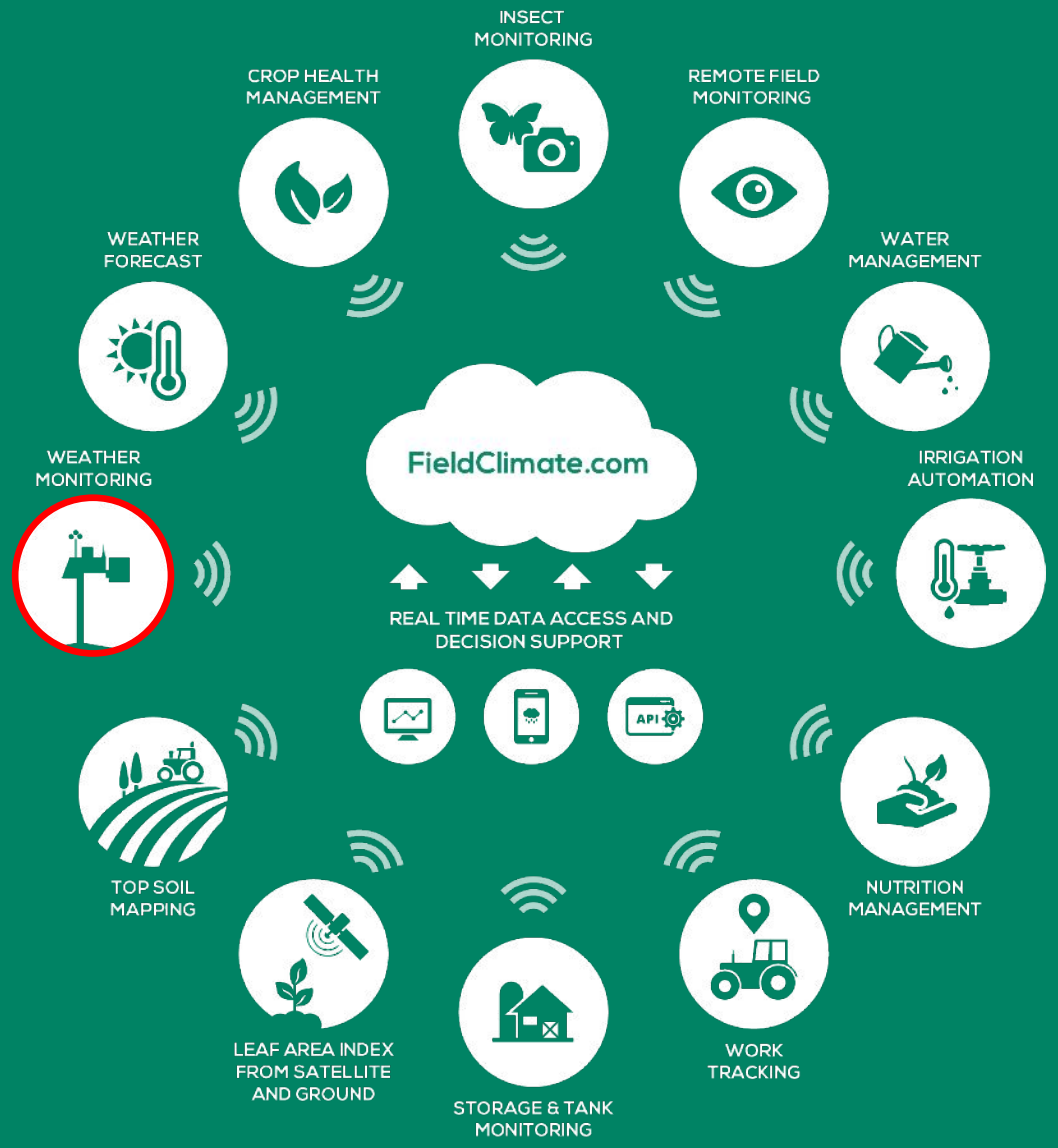
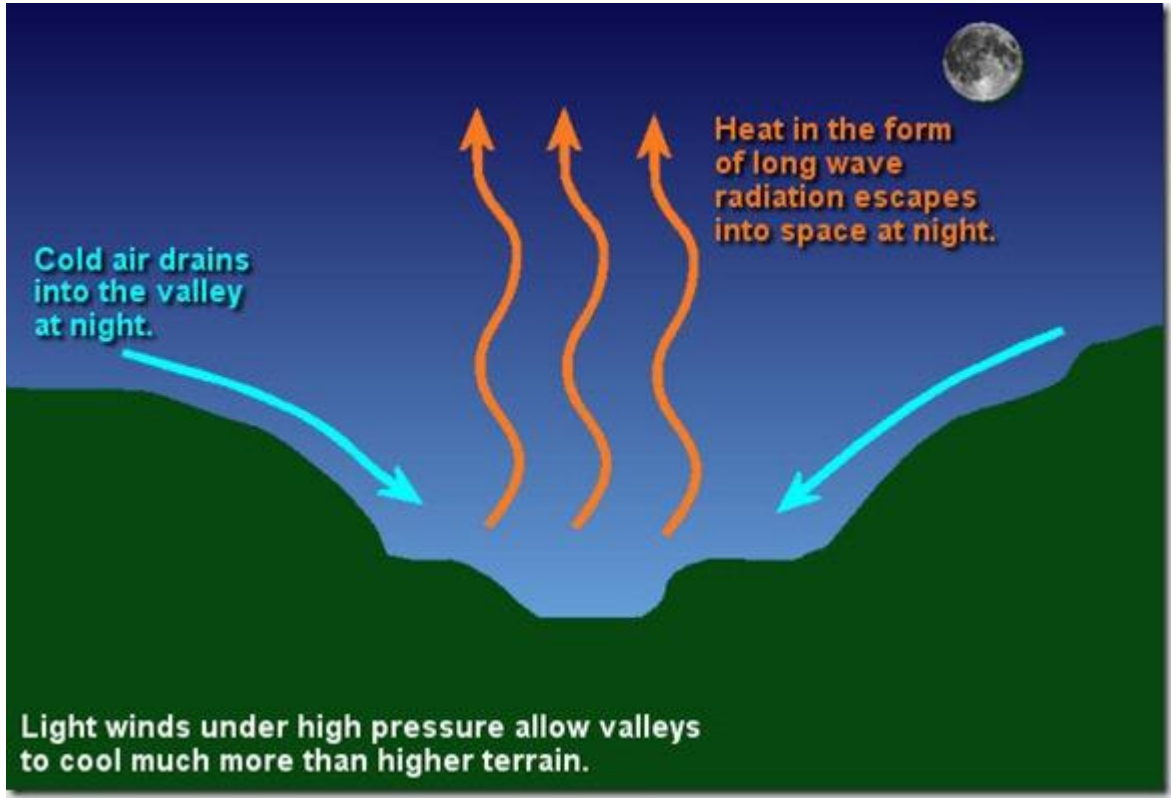
Holistic Solutions for Smart Agriculture



Frost Development

- Ideal conditions for Temperature inversion:
  - Long nights, outgoing radiation is greater than the incoming one.
  - A stable/static atmosphere with no cloud cover.
  - Light wind (<2m/s) or katabatic flows.



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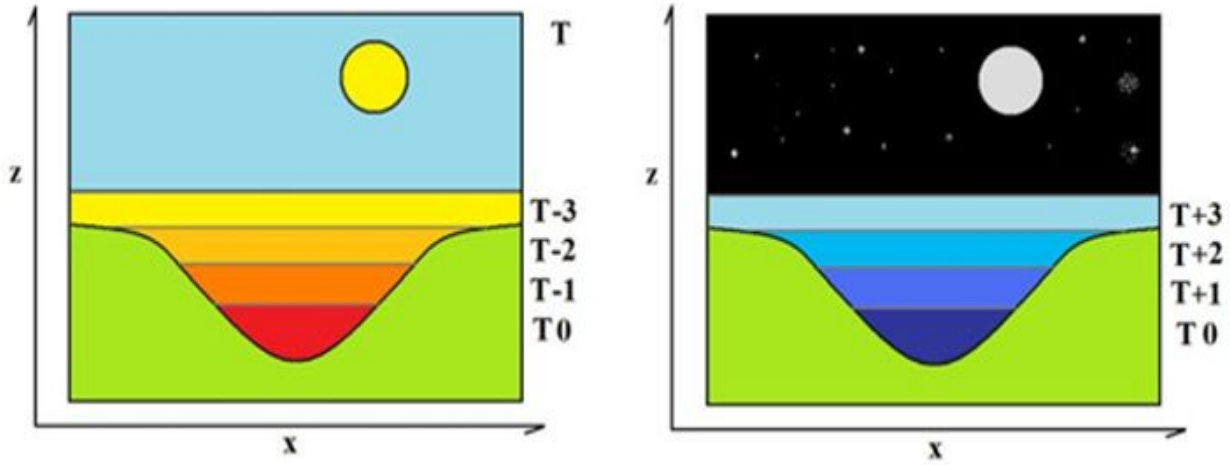

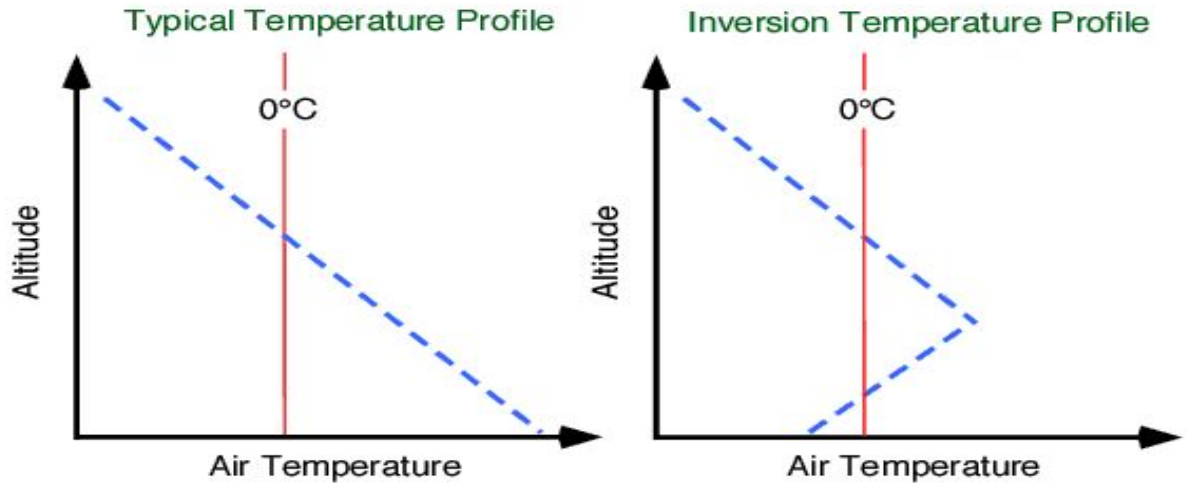

Frost Development

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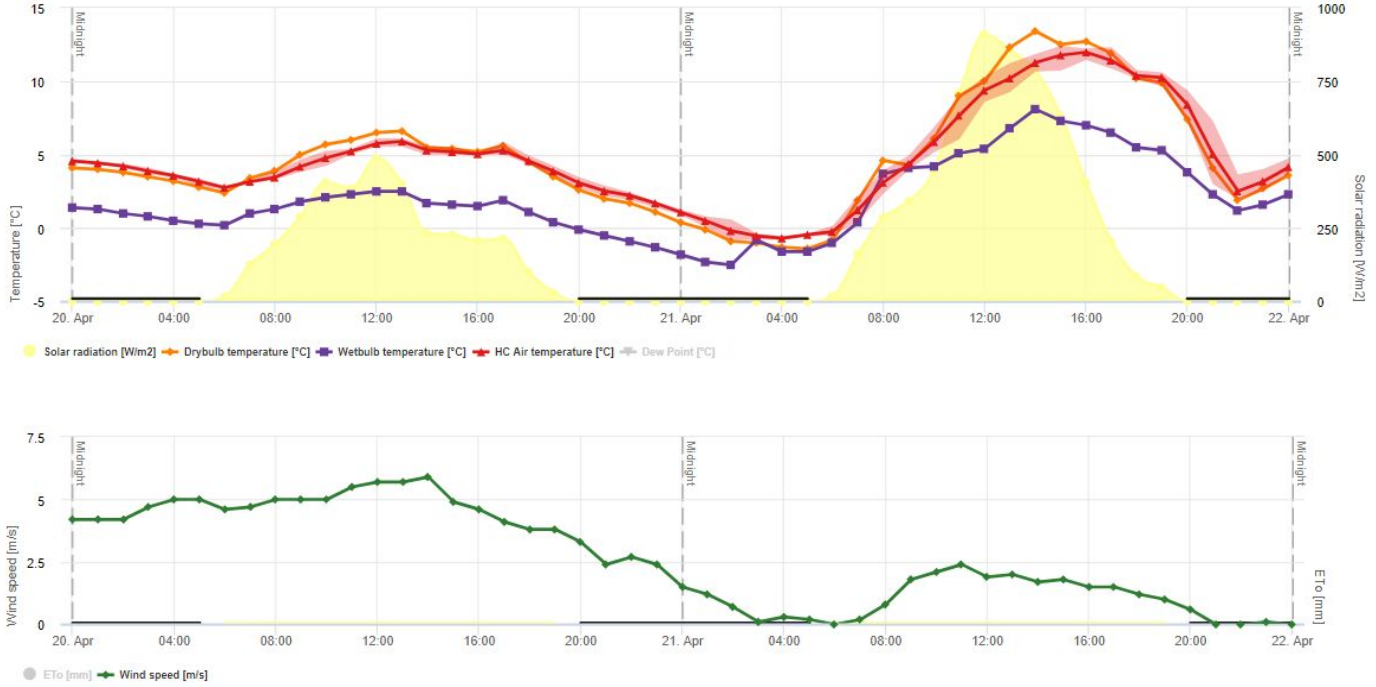
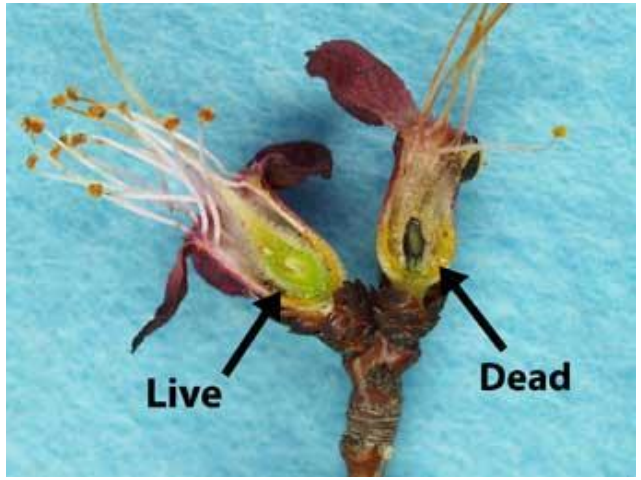
- **Advection frost**: cold air mass moves into an area. Temperature can be suzero during day. Possible protection is very limited.



***21.04.2017**. Cold air mass moves into Weiz (AT).*

About Frost

- When temperature falls below 0°C our crop can be injured – significant effects on production.
- Intracellular ice formation inside plant tissue which draws water out of cells and dehydrates them.



iMETOS solution

iMetos ECO D3 ICE

- Ideal solution for frost monitoring with Wet & Dry Bulb temperature sensor.
- Powered by a solar panel with internal battery.
- Weather data transmitted in real time.
- Make sure the bottle is full of water.
- SMS warnings.
- Site specific weather forecast – additional specific sensors needed.

WET & DRY BULB TEMPERATURE SENSOR

You can connect it also to your existing IMT station.

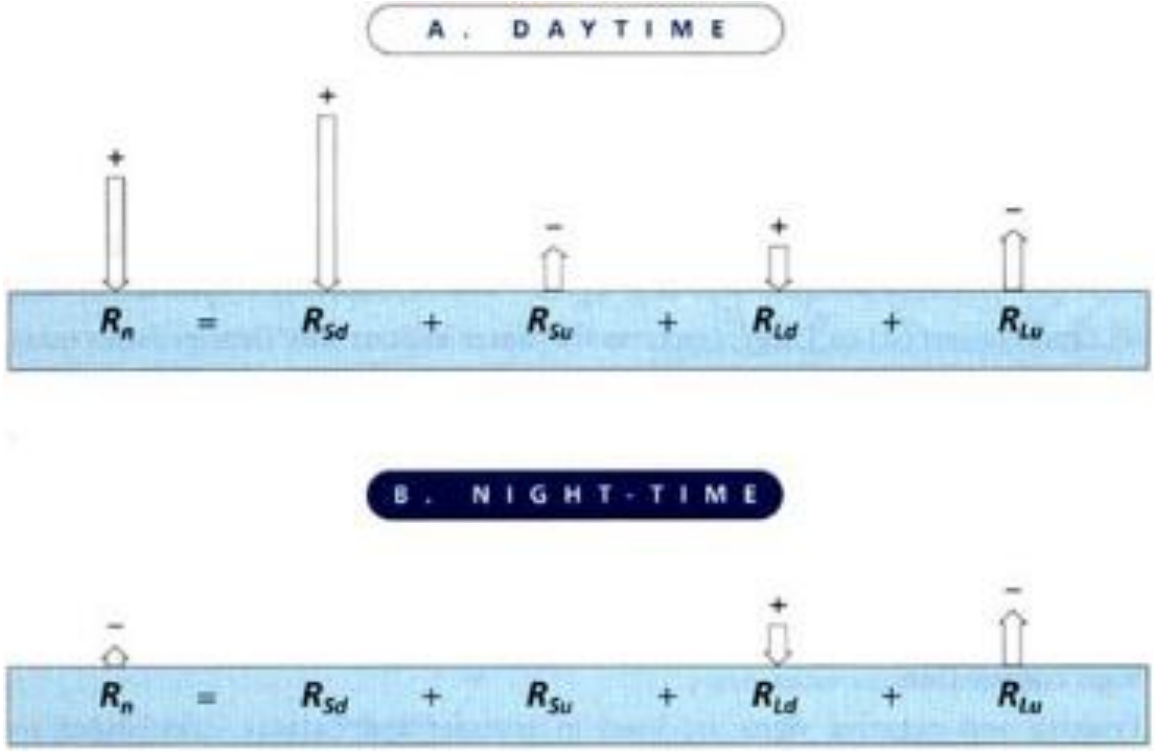
Wet & Dry Bulb Temperature sensor

Keep monitoring Wet & Dry Bulb temperature during frost conditions:

- Dry temperature **unshielded** sensor follows more accurately the plant tissue's temperature during clear nights:
  - $T_{unshielded}$ reached is lower than $T_{shielded}$.
  - More radiation energy is lost than gained.
  - Faster reaction to temperature changes.

…WHY WET BULB TEMPERATURE?

- It better represents the temperature of the leaf during frost conditions.
- To know when turning irrigation systems on and off.



Sign convention for radiation during daytime and night-time. Note that during night-time net radiation is negative due to loss long-wave radiation.
Source: FAO.

Frost protection

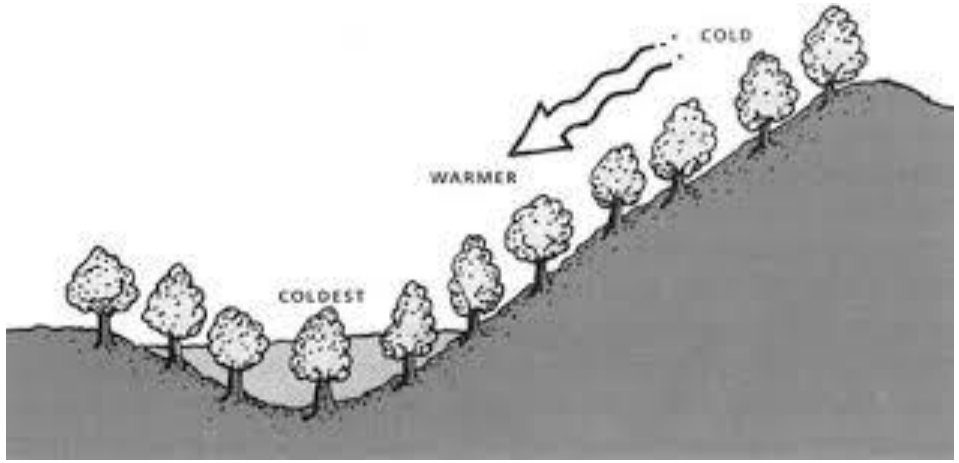
INSTALLATION OF STATION

- Place the station in the **coldest** spot of orchard: lower sites have colder temperature. (Rely on your experience for previous seasons)

- Wet & Dry bulb temperature sensor installed at the **height** of the **lowest** flowers or fruits.

Passive methods

- Site selection and management.
- Soil water management: keep soil water content near Field Capacity
- Plant selection.
- Plant and soil covers.

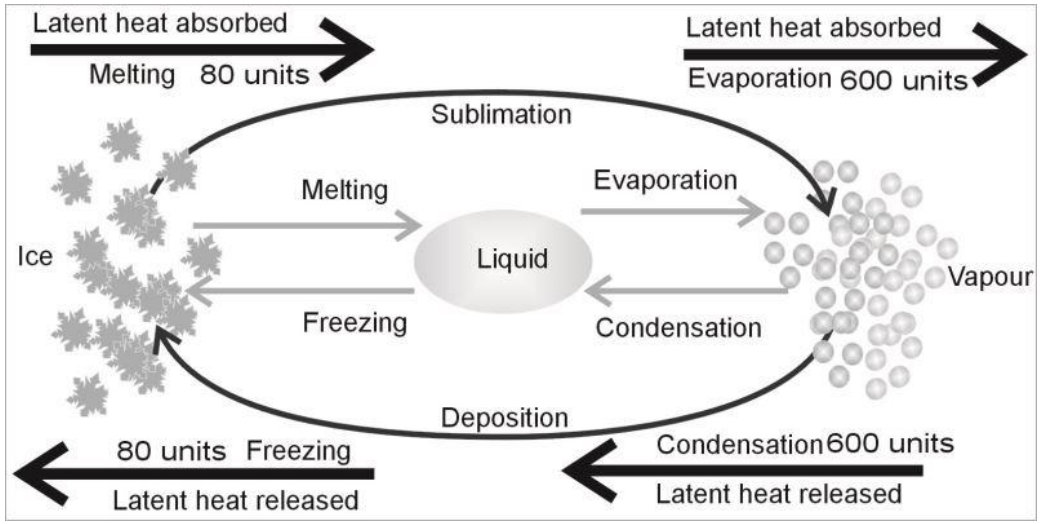


Cold air drains downhill and settles in low spots, where frost damage is most likely (source: FAO).

Frost protection

Active methods

Sprinkler system - Frost protection



Phase changes of water and the latent heat absorbed and released by the change of state (Source: Fundamentals of Aviation Meteorology).

- Be aware that sprinklers can cause more harm than good: apply enough water at the right time.
- Sprinklers should be started before wet temperature drops below 0°C - set the minimum threshold of wet temperature in FieldClimate at +0.5°C or +1°C - depending on the crop's different phenological phases and critical damage temperature.
- When water droplets strike a flower, bud or small fruit, the water will freeze and release latent heat, which temporarily raises the plant temperature.

Apple phenological phases - Wet temperatures when turning sprinkler system on (Iasma Notizie, 18.03.2005).

When to turn ON and OFF sprinklers

TURN ON

- When Wet bulb is above critical temperature. All sprinklers should be operating before the wet bulb temperature drops down to the critical temperature upwind from the crop.

TURN OFF

- When the sun is shining on the crop and the wet bulb wet bulb temperature upwind of the crop is higher than the critical temperature. In practice, wait until 0°C. But if it is windy or if dew point dew point is low, don't turn off just because the air temp is > 0°C. Wait until at least 1°C.

Turn sprinklers on and off when wet temperature is above the crop's critical damage temperature.

When water is applied, temperature falls then rises

GIVEN: When a sprinkler system is first started, the plant temperature might drop to the WET BULB temperature.

GOOD: Temperature then increases as water freezes.

BAD: If the DEW POINT temperature is low, then the WET BULB is much lower then the air temperature and damage can occur if insufficient water is applied.

If the wet bulb temperature is AT or BELOW AT or BELOW the critical temperature, then the air temperature can drop below the critical temperature and cause damage.

Beware of a Low Dew Point!
BASIC CONCEPT: Temperatures will drop lower when the air is dry. Turning on the sprinklers may initially bring the surface temperatures of the vines below the freezing point due to evaporative cooling.

WHAT TO DO: The drier the air, the sooner you must turn on the sprinklers

Sprinkler system - Frost protection

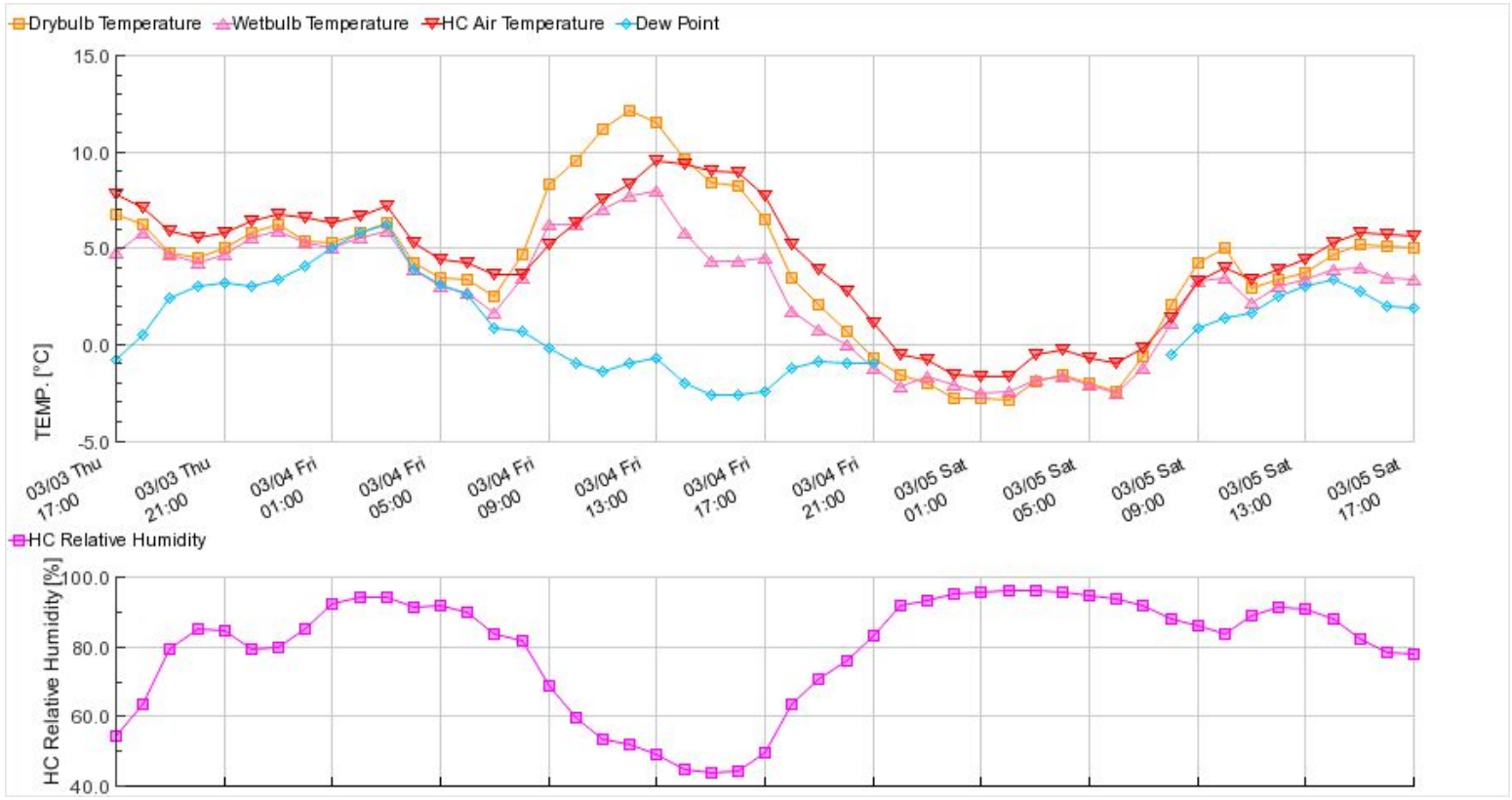
Technical features:

- A minimum of **3 mm/h** is required to provide protection in temperatures as low as **- 3°C**.
- Another **0.5 mm/h** (5 m^3/ha/hour) is required for every **additional degree** (*Irrigazette, n°163*).
- Not in windy conditions.
- Pay more attention to that varieties sensible to frost (e.g. for apple - *Red Delicious, Braeburn*).

Frost protection

DEW POINT

- *The rule of thumb*: the T_{min} on a given morning will approach the T_d taken the prior evening.
- This "rule" has some scientific merit for **only** the most common frost scenarios.



Dew point trend (blue line) during clear night, calm conditions with cold air drainage and vertical temperature stratification.

Frost protection

Critical temperatures for several fruit tree crops

CROP	STAGE	10% KILL	90% KILL
Apples	Silver tip	-11.9	-17.6
	Green tip	-7.5	-15.7
	1/2" green	-5.6	-11.7
	Tight cluster	-3.9	-7.9
	First pink	-2.8	-5.9
	Full pink	-2.7	-4.6
	First bloom	-2.3	-3.9
	Full bloom	-2.9	-4.7
	Post bloom	-1.9	-3.0
Apricots	Tip separates	-4.3	-14.1
	Red calyx	-6.2	-13.8
	First white	-4.9	-10.3
	First bloom	-4.3	-10.1
	Full bloom	-2.9	-6.4
	In shuck	-2.6	-4.7
	Green fruit	-2.3	-3.3
Cherries (Bing)	First swell	-11.1	-17.2
	Side green	-5.8	-13.4
	Green tip	-3.7	-10.3
	Tight cluster	-3.1	-7.9
	Open cluster	-2.7	-6.2
	First white	-2.7	-4.9
	First bloom	-2.8	-4.1
	Full bloom	-2.4	-3.9
	Post bloom	-2.2	-3.6

CROP	STAGE	10% KILL	90% KILL
Peaches (Elberta)	First swell	-7.4	-17.9
	Caylx green	-6.1	-15.7
	Caylx red	-4.8	-14.2
	First pink	-4.1	-9.2
	First bloom	-3.3	-5.9
	Late bloom	-2.7	-4.9
	Post bloom	-2.5	-3.9
Pears (Bartlett)	Scales separate	-8.6	-17.7
	Blossom buds exposed	-7.3	-15.4
	Tight cluster	-5.1	-12.6
	First white	-4.3	-9.4
	Full white	-3.1	-6.4
	First bloom	-3.2	-6.9
	Full bloom	-2.7	-4.9
	Post bloom	-2.7	-4.0
Prunes (Italian)	First swell	-11.1	-17.2
	Side white	-8.9	-16.9
	Tip green	-8.1	-14.8
	Tight cluster	-5.4	-11.7
	First white	-4.0	-7.9
	First bloom	-4.3	-8.2
	Full bloom	-3.1	-6.0
	Post bloom	-2.6	-4.3

10 % and 90 % kill imply that 30 minutes at the indicated temperature is expected to cause 10 % or 90 % kill of the plant part.

Frost protection

Critical temperatures for several fruit tree crops

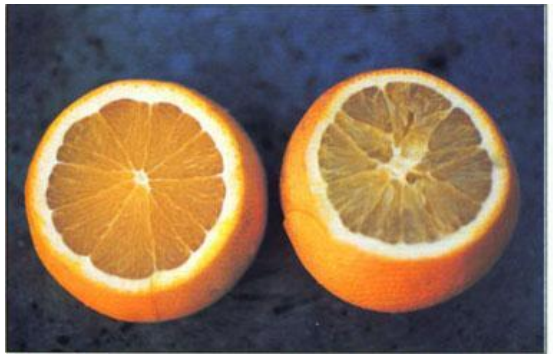
Critical temperature (T_c) values (°C) for grapevines			
		?	?
Grape [1]	New growth:		-1.1
	Woody vine:	-20.6	–
	French hybrids	-22.2	-23.3
	American		-27.8
		10% kill	90% kill
Grapes (cv. Concord)[2]	First swell	-10.6	-19.4
	Late swell	-6.1	-12.2
	Bud burst	-3.9	-8.9
	First leaf	-2.8	-6.1
	Second leaf	-2.2	-5.6
	Third leaf	-2.2	-3.3
	Fourth leaf	-2.2	-2.8

10 % and 90 % kill imply that 30 minutes at the indicated temperature is expected to cause 10 % or 90 % kill of the plant part.

Frost protection

Critical temperatures for several fruit tree crops

CITRUS SPECIES	CRITICAL TEMPERATURE (°C)
Green oranges	-1.9 to -1.4
Half ripe oranges, grapefruit and mandarins	-2.2 to -1.7
Ripe oranges, grapefruit and mandarins	-2.8 to -2.2
Button lemons	-1.4 to -0.8
Tree ripe lemons	-1.4 to -0.8
Green lemons (diameter >12 mm)	-1.9 to -1.4
Lemon buds and blossoms	-2.8



METOS®

PESSL Instruments GmbH

Werksweg 107

8160 Weiz

Tel.: +43 (0) 3172 5521

Fax: +43 (0) 3172 5521 23

email: sales@metos.at

www.metos.at

www.pesslinstruments.com