

2.2 Temperature monitoring

Fact sheet objectives

- To describe temperature measurement
- To discuss screens for air temperature probes
- To illustrate use of temperature data in heat unit calculations.

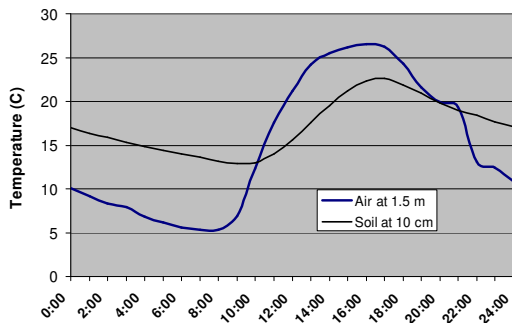


Figure 1. A 24 hour comparison of screened air temperatures versus soil temperatures at 10cm in the summer

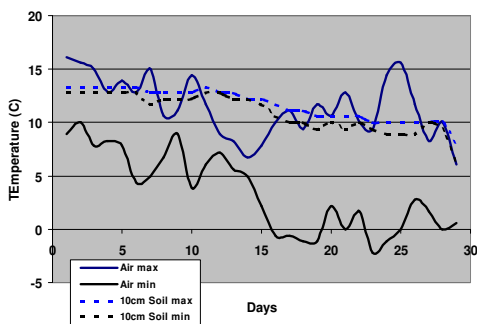


Figure 2. A 30 day comparison of daily maximum and minimum air and 10 cm soil temperatures in the winter

Heat and temperature

Growers are well aware that temperature is one of the two most important weather factors affecting plant growth and development.

Temperature represents heat pressure - heat flows from higher temperature to lower temperature.

The amount of heat energy in a solid object or a fluid depends on more than temperature - mass and other factors are involved.

Soil temperatures

Soil temperatures are typically recorded at depths from 10cm and provide a good indication of conditions experienced in the crop root zone and of the thermal mass in the soil. Soil temperatures show a smaller range and slower rate of change than air temperatures

Air temperature

Influenced by temperature of ground and surrounding objects, which are in turn heated by the sun during the day and cooled by radiation at night

Varies in a cyclic fashion over 24 hours

Taken to represent crop temperature, even though parts of the crop will differ

Sensors

The simplest sensor is the liquid-in-glass thermometer

More usefully, a maximum/minimum thermometer has a mechanical system for marking extremes experienced, but requires resetting daily

At a more sophisticated level an electronic sensor such as a thermistor or thermocouple connected to a data logger gives an automatic temperature reading at regular time intervals

Thermistors

A thermistor is a "thermal resistor". The electrical resistance of this semiconductor device changes with temperature. Many commercial temperature sensors supplied with data loggers incorporate thermistors.

The temperature/resistance curve for a thermistor is non-linear. Data loggers use a combination of circuitry and internal calculation to convert resistance to temperature,

but this calibration is usually limited to a specified temperature range. Outside the specified range large errors occur. For example an air temperature probe with a specified range of -5°C to 35°C would not be suitable for measuring shallow soil temperatures in summer.

Thermocouples

A thermocouple is a pair of wires of different metal, joined at "junctions" at each end. A temperature difference between the junctions produces a small voltage, so one of the junctions must be at a known reference temperature.

There are different thermocouple types, denoted by letters such as J, K, S, and T, depending on the material. For example the T type is a copper / constantan pair.

Traditionally, thermocouples have been used in industrial rather than horticultural applications because they are less sensitive than thermistors and typically operate over ranges of hundreds of degrees.

One advantage is that several thermocouples can be combined into a single "thermopile". A number of probes throughout a pallet of fruit, for example, could be used to record a single representative temperature.

Point measurements

Sometimes it is useful to make point measurements of temperatures, for example to record fruit temperatures in a cool store or to find cold patches in a field. It is important to give the temperature sensor time to equilibrate with the surrounding temperatures. To speed this process, when not in use it is best to store the sensor under conditions as close as possible to those to be recorded.

Calibration

All temperature recording equipment should be calibrated at the icepoint temperature (0°C). A mixture of crushed ice (2-5mm diameter) should be packed into a thermos flask and water added to fill the gaps between the ice crystals. Stir the mixture and leave for 5 minutes to reach equilibrium. Immerse the temperature probe in the ice mixture and leave until a stable reading is achieved. It should give a reading of $0 \pm 0.1^\circ\text{C}$. If the temperature reading is not 0°C, make any adjustments necessary. If you cannot make the adjustments yourself, contact the manufacturer or buy a new one!

The ice point is the temperature at which equilibrium between ice and saturated water is reached. To create this you should ideally have just enough water to fill the gaps between the crushed ice. If you are using this flask over a period of time, then as the ice melts, excess water needs to be drained off, ice replaced to the top of the flask, and the mixture left to reach equilibrium again.

Different temperature sensors can deviate from actual temperatures to different degrees across their recording range.



Small stacked plate screen designed for a single temperature logger.



Wooden Stevenson screen



Screened and unshielded temperature sensors - grass minimum temperature probe shown below



It always pays to check at least two sensors together across a range of temperatures.

Temperature screens

Air temperature sensors must be housed in a ventilated screen to avoid solar heating during the day and radiative cooling at night

The standard is the wooden louvered Stevenson screen, used in meteorological stations throughout the world. The Stevenson screen relies on natural air movement for ventilation and is suitable for housing both manual reading glass thermometers and electronic sensors

Increasingly electronic sensors are housed in smaller stacked plate screens made of metal or plastic, again relying on natural ventilation

Where high accuracy is required a mechanically aspirated screen is best, in which air is forced over the sensors.

For general orchard measurements, screens should be located over short grass with the sensors 1.5m above ground

Screen errors

Temperatures measured in naturally ventilated screens, the most common situation, can vary by several degrees from temperatures measured in an aspirated screen

The errors are due largely to solar heating and tend to be greatest at low sun angles and at low wind speeds, conditions typical of the first hour or so of a calm sunny day

Maximum and minimum temperatures are more consistent between screen types, compared with hourly spot readings

The smaller, lighter 'stacked' screens follow changes in air temperature more closely than the bulkier wooden Stevenson screens

Heat and chilling accumulations

The accumulated effect of temperature strongly influences the development of plants, and also affects the population growth of insect pests and disease organisms

Daily mean temperature is best calculated as a mean of hourly temperatures, but if hourly temperatures are not available the daily mean is taken as the average of the maximum and minimum temperatures.

Heat units or growing degree days (GDD) are calculated as the daily mean temperature excess above a base temperature. For example a mean temperature of 12°C gives 2 GDD with a 10°C base, 16°C gives 6 GDD with the same base.

Heat units can be summed from a fixed calendar date or from some observable event such as the first appearance of a particular pest in an insect trap.

Cold temperatures during winter also affect plant development, particularly flowering the following spring.

Chill hours are calculated by summing the temperature deficits below 7°C for each hour temperatures dip below this threshold. A temperature of 8°C for one hour adds 0 chill hours, a temperature of 5°C for one hour adds 2 chill hours.

Richardson units are a more complex calculation, covering a wider temperature range and giving more weight to temperatures known to be more effective from a winter chilling perspective.

Both Richardson units and the more simplistic chill hours are less than ideal under New Zealand's mild winter conditions. The Hortplus and Fencepost websites listed below provide a fuller discussion of winter chilling.



Summary Information

- Temperature is a key weather variable driving crop and pest and disease development, and occasionally crop damage.
- Most interpretations of temperature effects are based on measurements of air temperature in screens that reduce the effects of direct radiation on or from exposed surfaces.
- Soil temperatures show smaller ranges and rates of change than air temperatures due to the stabilising thermal mass of the soil.
- Soil or screened temperatures provide a consistent benchmark from which to estimate effects on the crop or pests and diseases. Readings from unscreened or uncalibrated sensors provide little or no useful information.

Useful Websites

Fencepost www.fencepost.com

Hortplus www.hortplus.com

Ibutton temperature micro logger manual
www.hortplus.com/Brochure/TempLog/qmtmpman.pdf

Glossary of terms <http://k12.ocs.ou.edu/teachers/glossary/>

A MAF Sustainable Farming Fund Project:



Materials developed by Hort Research and NIWA

