3.2 TEMPERATURE MEASUREMENT

Fact Sheet Objectives

- Describe temperature measurement.
- Discuss screens for air temperature probes.
- Illustrate the use of temperature data in heat unit calculations.

Heat and Temperature

Horticulturalists 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 temperature

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 due to the stabilising thermal mass of the soil.

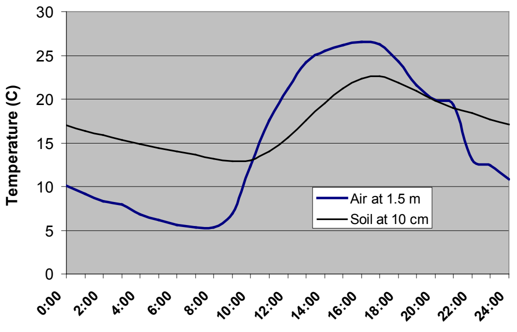

Figure 1. A 24 hour comparison of screened air temperatures versus soil temperatures at 10cm in the summer.

Air temperature

Air temperature is influenced by the temperature of the ground and surrounding objects, which are in turn heated by the sun during the day and cooled by radiation at night. Air temperature varies in a cyclic fashion over 24 hours. Air temperature represents crop temperature, even though parts of the crop will differ.

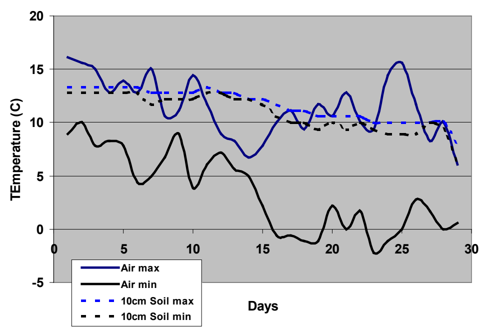

Figure 2. A 30 day comparison of daily maximum and minimum air and 10 cm soil temperatures in the winter.

Measuring Temperature

Sensors

The simplest sensor is the liquid-in-glass thermometer. More usefully, a maximum/minimum thermometer has a mechanical system for marking temperature extremes, 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.

Screened and unscreened temperature sensors – grass minimum temperature probe shown below.

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 coolstore or to find cold patches in a block. 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 ice point temperature (0ºC). A mixture of crushed ice 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 $\pm$ 0.1ºC. If the temperature reading is not 0ºC, make any adjustments necessary. If you cannot make the adjustments yourself, contact the manufacturer or buy a new one!

Different temperature sensors can deviate from actual temperatures to different degrees across their recording range. It always pays to check at least two sensors together across a range of temperatures.

Ice Point

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 (2-5mm diameter ice). If you are using this mix 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.

Small stacked plate screen designed for a single temperature logger.

Wooden Stevenson screen.

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 louvred 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, typical conditions of the first hour or so of a calm sunny day. The smaller, lighter ‘stacked’ screens follow changes in air temperature more closely than the bulkier wooden Stevenson screens.

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

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 website listed below provide a fuller discussion of winter chilling.

Summary

- Temperature is a key weather variable driving crop and pest and disease development, and occasionally crop damage.
- Soil temperatures show smaller ranges and rates of change than air temperatures due to the stabilising thermal mass of the soil.
- 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 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.

Further information

Hortplus www.hortplus.com
Temperature micro loggers, Hortplus
http://www.hortplus.com/product/temperature-and-humidity-microloggers.htm

A MAF Sustainable Farming Fund extension initiative for Pipfruit and Winegrapes
Weather Monitoring: March 2006 Updated June 2010