Factsheet

September 2010

Arming against frost

Joanna Jones, Tasmanian Institute of Agricultural Research (TIA); Steve Wilson, Consultant

Introduction

This fact sheet is designed to give some directions and assistance in dealing with the, often confusing, information and advice available both before and after a serious frost event. It is not intended to provide the technical detail required to make a significant investment in any particular site or frost protection system. Looking to the future, although climate change models suggest reduced spring frost frequency in all regions, the danger is unlikely to diminish as warmer winter temperatures lead to earlier spring bud burst. Furthermore, in some regions climate change may lead to the advent of more clear sky spring days coupled with drier soils increasing the incidence and severity of frosts. Paradoxically the warmest decade in recorded history has seen some of the most widespread and serious frost damage to commercial crops in both Australia and North America.

Frost and climate

Southern Australia is not prone to the disastrous large-scale freeze events that occasionally occur in North America and parts of Europe. Damaging frosts in the southern Australian wine regions, typically occur with a weather pattern resulting in a cold cloudy day followed by a still and cloudless night (Figure 1). Under these conditions, soil cools quickly after sunset and the air is coldest near the ground increasing in temperature with increasing elevation up to a height that can vary from a few centimetres to a hundred meters or more. Above this 'inversion' layer the air begins to cool again, so that under frost conditions, there is typically a layer of air, some meters above ground level, warmer than the air below or above it. Understanding this atmospheric structure above the vineyard, and the role played by the land surface with its soil and vegetation is critical for good decision making on frost protection measures.

Cold air is denser (heavier) than warmer air and in hilly or undulating terrain the cold air near the ground flows down hill, pooling in hollows and depressions, or creating larger scale valley flows of freezing air. These topographic influences are characteristic of a region, change little from frost to frost and are often enshrined in local folklore. Frost 'pockets' are reasonably predictable, are usually well known to local residents and site selection to avoid them is the first and most basic step in frost management. Flows of cold air are a little less constant from frost to frost and moving air tends to more turbulent with a smaller change in temperature with elevation compared with still air collected in a frost pocket.

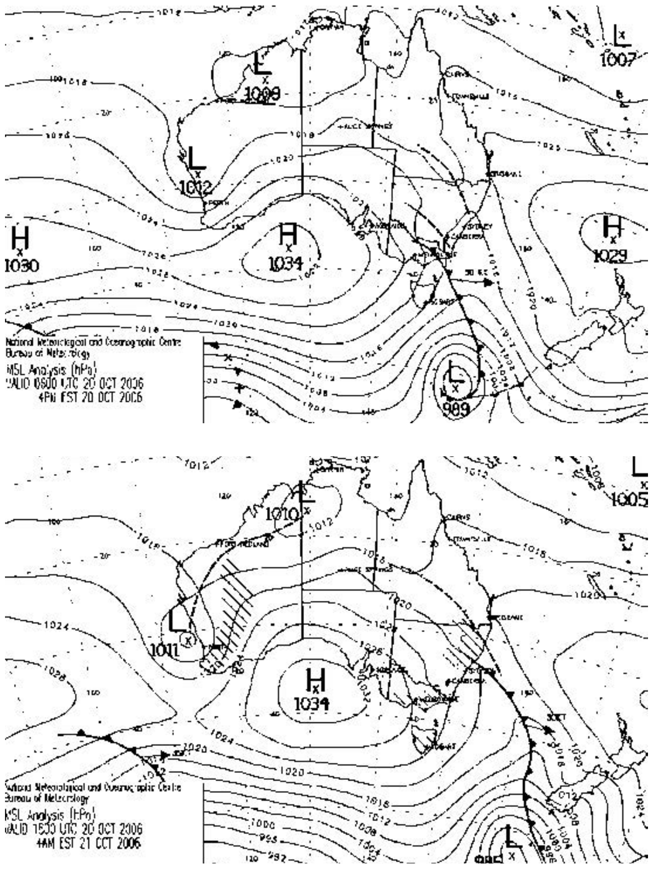

Figure 1: Synoptic charts showing the serious frost event of october 2006. An active front with clouds is moving away at end of day (top) to leave clear sky under the high pressure zone over night and early morning the next day (bottom).

Frost damage

Technically a frost occurs when the temperature at ground level falls below 0°C. Most temperate plant species, including vines, tolerate this temperature, even though surface ice may have formed. At about –2°C, water from within the cells in leaves, buds or flowers begins to move out into the ice layer that has been forming on the surface, resulting in desiccation and death of all or part of the exposed tissue. The lower the temperature and longer the duration, the more severe this desiccation and consequent damage becomes. To plant cells, frost damage is much like a sudden and severe drought.

Control methods

Most control methods work by introducing some form of heat into the sensitive area around fruiting height of the vine. The physics may get a little complicated, so let us divide the options into three groups.

(1)

Adding heat from off-site – when water freezes it releases heat, so that ice with surface water that is continuing to freeze stays at about 0˚C, a safe temperature for any plant tissue it encases. This is the basis for irrigation protection and it remains the most reliable of all methods, being effective to around –5°C, or lower for some systems. Application rate is critical, and the rule of thumb is that systems that apply less than about 3.5 mm/hr are ineffective. Specially designed sprinklers that target the vines only (sold as 'Flippers') will apply a much lower overall (per ha) rate. Application needs to be continuous over the whole protected area from when air temperature is above 0°C in the evening until it has risen well above freezing the next morning. Consequently, water supply, pumping capacity and soil drainage may all limit the use of irrigation as the primary protection system.

Other, more direct, methods of introducing heat include fire pots and, for small areas, heating cables along the arms of the vines. Fire pots, used alone, are surprisingly inefficient with most of the heat lost directly upwards and the use of heating cables is still in an 'experimental phase'.

(2)

Using the heat in the atmosphere – because there is usually a layer of warmer air above the coldest air near the ground, any mixing of the atmosphere in the first 20 or so meters of elevation results in a small increase in temperature in the lowest and coldest layer. Fixed vertical (Figure 2) and horizontal (Figure 3) fan systems operate as air mixing machines and helicopters can also be used as efficient mobile mixers. Access to night flying helicopters can be difficult, and it is important to have a signed service agreement well before the frost season. Regardless of the method of mixing, effectiveness is critically dependent on being able to access warm air from higher levels. If the inversion is weak, i.e. there is only a small increase in temperature with increasing height, and/or the temperature of the mixed air near the vines remains below –2°C, there will be no useful protection. For growers planning to use such systems, measurement of a vertical temperature profile during a frost is essential. The guide, for a vertical fan machine, is that the maximum temperature gain is about half of the temperature difference between the top and bottom of the tower.

Figure 2: Fixed vertical fan system.

Figure 3: Horizontal fan system.

Fans are used throughout the world and are most successful in continental climates, where there is a strong inversion, near flat land and little lateral air flow. In these areas, they remain the most cost effective method of management, but operating noise for the larger vertical types has become an issue in some areas. Measurements in Tasmania's maritime climate have shown that there are few locations where there is sufficient temperature difference in the inversion for the machine to give temperature gains needed justify the investment. Their effectiveness is also unpredictable in hilly terrain. Consequently, DO NOT ASSUME that a fan system will work in all situations. Because the atmospheric structure is relatively constant from frost to frost, it may pay to try a helicopter first, as the pilot will be able to find and record the temperature and elevation of the warmest air. Otherwise measure the temperature in the lowest 5–6m of air using a lightweight pole and several readily available electronic thermometers.

(3)

Getting maximum value from the natural system – in a natural day/night cycle, the soil captures and stores radiation from the sun, radiating heat back to the atmosphere. Thus, the more energy the soil is able to intercept and store over daylight hours, the higher the night-time temperature. Managing this radiation exchange offers a cheap and effective approach to minimising damage in marginal frosts. Bare, compact, dark coloured and moist soil works best as a heat storage bank, and also provides the best conditions for release of heat into the lower atmosphere at night. A layer of vegetation, or mulch, lowers air temperature because it acts as an insulator, reducing intercepted energy from the sun during the day and slowing movement of heat out of the soil at night. Shallow cultivation or herbicides, close mowing and, where necessary, early season irrigation are valuable frost mitigation strategies. All of these need, of course, to be balanced against negative impacts of soil compaction and excessive cultivation.

These three approaches are often effectively combined. Good vineyard floor management is an obvious way of getting maximum benefit from one of the more expensive 'active' approaches (1 and 2 above). Indeed, under-crop irrigation using minisprinklers can be successfully used and utilises the heat introduced by irrigation to modify the inversion structure and (after the first frost of the season) enhance the heat bank effect of the soil. Under-crop sprinklers may however present difficulties with inter-row management.

Under some circumstances it is possible to modify the site to improve air drainage and minimise the formation of frost pockets. Conversely it is also possible to increase frost hazard with inappropriate tree planting or earth works. On a frost prone site any barrier to airflow down the slope (shelterbelt, woodlot etc) will cause cold air to pool and removal or at least opening up suitable air drainage channels will reduce the risk of damaging frosts. Modifying the vine may also have some benefits. Simply pruning so that the head of the vine is as high as is practicable, to place the sensitive buds higher in the inversion, captures the natural increase in temperature with height above the ground.

What about spray on protection?

Products claimed to improve frost tolerance in exposed plants contain active ingredients including seaweed extracts, natural and synthetic glycols, oils, resins, sugars, mineral salts and even a common fungicide. Laboratory studies have demonstrated that some can influence the water balance of stressed cells and should therefore offer a few degrees of frost protection. To date, there is little evidence that these laboratory results have been translated into practical and reliable protection from field frosts. While there is anecdotal evidence that spray products have worked in some situations, their use should be regarded as experimental, not as a first line of defence. Any trial should leave a few untreated vines to confirm whether treatment has been effective.

Maintenance and timing

Protection systems operate at night and infrequently. Routine maintenance is easily forgotten and a flat battery can render the best designed system useless on the one night of the season when it is needed. Spray on controls usually need to be applied a day or two before a frost and soil management for passive control needs to start weeks before the vines become prone to damage.

Dealing with damage

If protection fails and damage occurs, it can severely reduce the current crop, as well as reduce the crop of following seasons. Direct impacts on flowering and vegetative growth in both the current and subsequent year may influence longer-term vine balance, with the indirect effects of a single frost damage event potentially continuing into a third year.

Although -2°C is generally taken as the critical temperature for damage to non-dormant tissue across a wide range of temperate crop species, tissues vary in susceptibility and the potential damage in any season depends on the time of the frost and the phenological stage.

There are three management strategies for reducing the damage;

- Taking no action
- Removing only the visibly frost damaged material and
- Removing all green shoots (effectively re-pruning)

Studies in Tasmania as well as in Victoria and New Zealand have consistently shown that post-frost pruning results in an open and more manageable canopy, which allows for more efficient pruning the following winter. Pruning decreases bunch number in the frost year, but can increase bunch number in the following year. In all cases post frost management did not affect ripening or fruit quality other than reducing the amount of fruit. From a practical point of view and considering the labour costs of approximately $1500 per hectare, doing nothing may be the best option. However, as frost damaged material rots over time, in years when disease pressure is high, removing the damaged tissue may be warranted. If growers do decide to prune after a damaging frost, severity needs to be matched against the amount of damage on each vine rather than a prescribed pruning guideline. With variable damage across a block, there is a risk that a prescribed pruning may limit both quantity and quality of an otherwise salvageable crop.

Getting serious

For anyone seriously contemplating installation of a frost protection system it is important to realise that frost control is an exercise in risk management. A well designed system costing around $10,000/ha can legitimately claim to provide 100% protection, but only within limits and once the limit is exceeded there is nil return on this investment. If your vineyard is on a frost prone site there is only one course of action for totally effective frost control and that is to move to an area naturally free of frost. Maintaining clear moist soil (or at least short grass) in the inter-row spaces and providing for good air-drainage are low cost strategies used by prudent managers. To take the next step to active protection demands significant investment. Managing the risk, by financially offsetting the losses in some way, may be better than managing it physically using some installation that is inevitably limited by local conditions. The core message of this paper is that every type of frost protection system protects to a defined temperature (which itself is often hard to quantify and varies from place to place and time to time) and if the weather throws up an unusually cold frost then the system will not work. There may be just fractions of a degree between total control and total loss.

This applies to all systems, but the tower mounted wind machine provides a good example. Such machines generally increase air temperature by about 50% of the difference between the top of the tower and the fruiting wire. Thus, if it is –0.8˚C at the top of the tower and at fruiting height it is –3˚C, the difference is 2.2 and the available temperature gain is thus 2.2/2 or 1.1. Add this to the –3 at the wire and we get –1.9˚C, and the crop is saved. If the ambient temperature drops by just 0.2 at both top of the tower and the fruiting wire, the difference is still 2.2 with a possible gain of 1.1. add this to the –3.2 at the wire and we get –2.1˚C. Damage occurs and the crop is lost.

Frost Fast Facts

- Consider frost dynamics when selecting sites for vineyard plantings and protection systems in frost prone regions.
- Recognise frost forecast weather patterns.
- Understand which frost protection systems are appropriate for your vineyard.
- Base your decision to prune after a damaging frost on economics and level of damage.
- Good planning, preparation and maintenance of equipment are keys to getting the best out of any system.

References

Creasy, G.L., M.C.T. Trought, G. Wells, 2002, Moderate to severe frost recovery options for grapevines. Proceedings of the 11th Australian Wine Industry Technical Conference. Adelaide, Australia, July 2002.

Jones, J.E., S.J. Wilson, G. Lee, and A.M. Smith, 2010, Effect of frost damage and pruning on current crop and return crop of Pinot Noir. *New Zealand Journal of crop and Horticultural Science*, 38 (3): 1-8.

Kalma, J.D., G.P. Laughlin, J.M. Caprio and P.J.C. Hamer, 1992, Direct active methods of frost protection. *The bioclimatology of frost, Advances in Bioclimatology* 2, 83-91

Needs, S., G. Dunn, M.C.T. Trought, E.W.R. Barlow, 2010, Managing Spring Frosted Grapevines in Australia. Proceedings from the 14th Australian Wine Industry Technical Conference, Adelaide, Australia, July 2010.

Trought, M.C.T., D. Stewart, B. Arnst, G. Bartleet, S. Mccartney, S. Friend, 2003, Romeo Bragato frost workshop. Workshop proceedings. Wellington, New Zealand.

Wilson, S, 2001, Frost management in cool climate vineyards. Final report to Wine Australia project number: UT 99/1.

Wine Australia for Australian Wine

Wine Australia
Industry House, Cnr Botanic and Hackney Roads, Adelaide SA 5000
PO Box 2733, Kent Town SA 5071
Telephone: (08) 8228 2000
Facsimile: (08) 8228 2066
Email: research@wineaustralia.com
Website: www.wineaustralia.com

This factsheet was first published in September 2010.