



Frost management in vineyards



Summary

Frost is a significant hazard to grape production in Australia, and research suggests that the frost season may be becoming longer in many grapegrowing regions. There are two types of frost: radiation frosts which generally occur on clear nights; and advection frosts where a cold air mass moves into a vineyard. Management options mainly apply to radiation frosts and include ensuring that the inter-row area is closely mown, and the soil is moist and firm. A radiation frost can be predicted based on the temperature and humidity during the late afternoon when the

sky is clear, and this knowledge used to arrange control measures including frost sprinkler systems. Understanding the impact of inversion layer height and 'strength' is critical for the effective use of wind machines and helicopters. The management choices for advection frosts are far fewer, with overhead sprinkler systems the only proven option. Another way to reduce the likelihood of frost damage is pruning in late spring (after budburst) to delay bud break into a period when frosts are less likely to occur (Friend et al. 2011).



What is the impact of frost?

Frosts during the growing season can cause serious damage, reducing or eliminating the crop. The yield potential in the following season may also be reduced (Jones et al. 2010). Frost injury is caused by the freezing of plant cells, with ice forming either within or outside the cell. Young or immature tissues are most prone to damage. Air temperatures of -3.4°C or less will damage 50% of vine buds at the woolly bud stage (Gardea 1987). Flowers are more sensitive than leaves or stems to low temperatures hence frosts can sometimes lead to little or no fruit on shoots that show no signs of damage.

How does frost occur?

There are two types of frost: advective and radiation. An advection frost occurs when a large mass of cold air moves into a region. These are less common than radiation frosts in Australia and mainly occur at high altitudes.

Radiation frost risk is greatest on clear nights, when both ambient temperature and relative humidity are low. As the sky is colder than the ground the heat is transferred (radiated) to the sky above.

Under calm conditions the less dense warm air will rise and cold air settles close to the ground and especially into hollows. This leads to stratification, with a layer of warmer air sitting above a layer of very cold air close to the ground. The height of the inversion layer can vary from approximately 5 metres up to several hundred metres above the ground, but the normal range is from 10 to 30 metres. Another characteristic of radiation frosts is katabatic winds; these light winds carry cold air downhill under the force of gravity. Low

soil moisture exacerbates the risk because moisture increases the soil's ability to absorb and store heat during the day and radiate heat at night.

A grower can predict radiation frost for their vineyard based on the temperature and humidity during the late afternoon or evening (Ireland 2005). This information can be used to ensure staff are on standby or arrange control measures such as helicopters.

Frost damage may not be immediately noticeable and the symptoms appear more clearly after a period of sunny days. Young succulent shoots will wilt once the frost thaws but older more hardened shoots will take a few days to show symptoms. Frosting of inflorescences may not be immediately apparent but after several days they begin to dry out and individual flowers start to fall off, particularly when handled (Figure 1).



Figure 1. Frost damage to inflorescences; note the brown appearance that occurs a few days after the frost event and that the basal leaves are undamaged, while the inflorescences at the same height have been killed.



Seasonal changes in frost risk?

The risk of spring frost is significantly higher under El Niño conditions as cloudless days are more common. In some parts of Australia such as southern NSW and northern Victoria, the risk is 15 to 30% higher than the historical average (Alexander and Hayman 2008).

Climate change is also increasing frost risk due to an increase in the number of high pressure systems (and associated still and clear nights) occurring over the winegrowing regions in south-eastern Australia during spring (Crimp et al. 2014). Warm winters may result in an earlier spring budburst and this can lead to a higher risk of frost damage to vines (Crimp et al. 2013).

What can I do to reduce the risk of frost damage?

When considering frost minimisation or control measures it is important to consider both the risk at your site and the cost of such measures. Investment in expensive control options such as wind machines or sprinklers may only be justified if risk is high.

Frost control can employ both passive and active methods. Passive methods rely on enhancement of solar energy input and retention of heat by soil, reduction of longwave radiation loss and reducing the period of this that vines are exposed to low temperature. These include site selection, soil management, trellis design, variety choice and pruning method/timing. Active methods require energy to reduce longwave radiation loss to the sky, or to directly warm the air near to the soil. These include sprinklers, air mixing, heating and foliar sprays.

Site selection: Frost damage (particularly with radiation frosts) commonly occurs in low-lying areas where cold air 'pools' and in areas where cold air drainage is impeded by obstructions. Therefore, planting on slopes with vine row orientation that facilitates air flow is desirable. Be aware of the likely frost pockets on your property and avoid planting them. On frost-prone sites remove any barriers which may impede airflow e.g. shelterbelts, long grass along fence lines etc. (McCarthy et al. 1992).

Soil management: Strategies that maximise radiation interception and heat storage during the day and minimise loss of long-wave radiation at night will increase air temperature (Figure 2, McCarthy et al. 1992). A moist, compact, vegetation-free surface is therefore the key. Rolling may be beneficial to help compact the soil but it must be moist as there will be little benefit of compaction if it is too dry. Irrigation prior to a predicted frost event may be useful—but only if it is able to wet most of the soil surface. Cultivation of cover crops into the soil prior to budburst has been recommended in the past, but this can cause soil moisture to evaporate and create air spaces that reduce the soil's capacity to store heat (McCarthy et al. 1992). Mowing close to the soil may be just as effective as cultivation; but maintaining a clear under-vine area using herbicide was found to result in higher vineyard minimum temperatures (Donaldson et al. 1993).

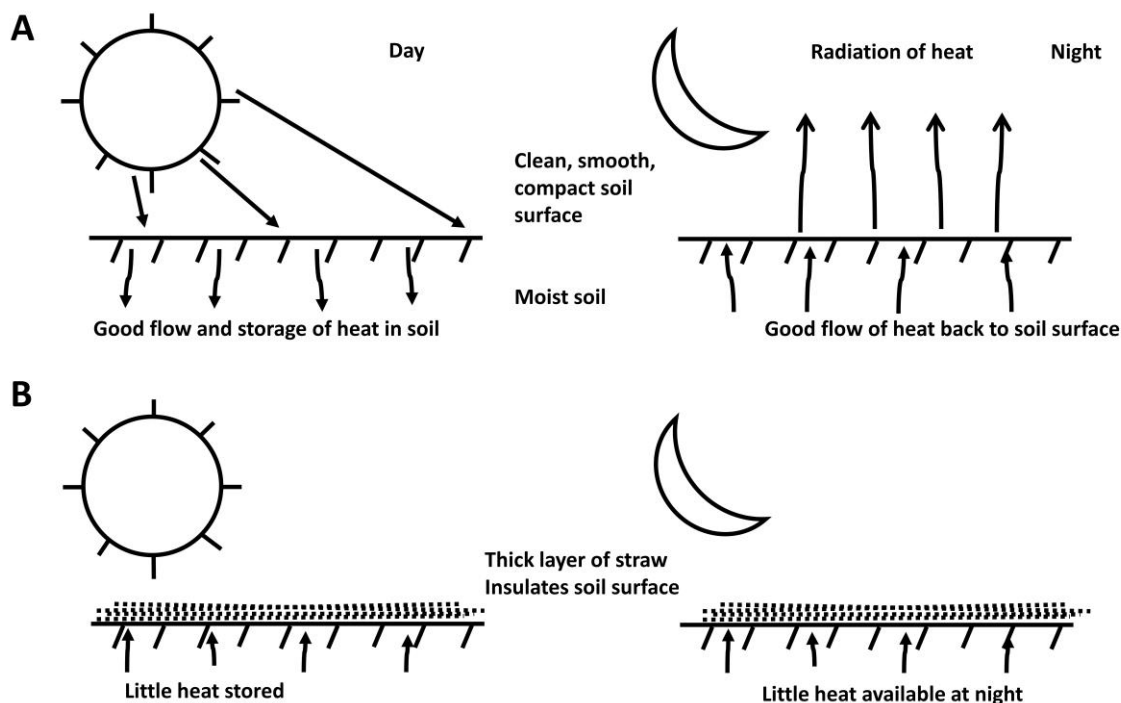


Figure 2. Energy balance during a radiation frost. Image A where the soil is bare and image B where is insulated by a layer of straw. The straw prevents the adsorbing heat during the day and radiating it at night. (Figure adapted from one previously included on the Agriculture Victoria website)

Trellis height: The closer that shoots or buds are to the ground, the greater the risk of frost damage; for example, a cordon at 1.4 m above ground level may be 0.5°C warmer than one at 0.9 m (McCarthy et al. 1992). Trellis systems with low fruiting wires such as Scott Henry should be avoided in frost-prone sites.

Variety choice: Varieties with late budburst may avoid frost because the risk of frost declines as the season progresses. For example, in the Barossa Valley, Mataro was traditionally planted on low-lying frost-prone sites in preference to Shiraz. Also, some varieties recover better after a frost event because their secondary buds (the buds that

will burst if primary shoots are killed by frost) are more fruitful than those of other varieties.

Pruning method and timing: Freeze sensitivity of shoots increases as shoots develop; therefore, delaying their development may reduce the risk of damage. For example, shoots at budburst will suffer 50% loss at -2.2°C but those at 4th leaf stage only need -1.1°C (Gardea 1987) to suffer the same extent of damage. In frost-prone vineyards it is best to prune late-bursting varieties first and early-bursting varieties last. Some growers may delay pruning until several weeks after normal budburst to delay budburst (and this may also delay harvest slightly) (Friend et al. 2011). Mechanically hedge-pruned vines have a larger number of 'reserve' buds than hand-pruned vines, and



thus may recover much better in the event of frost damage.

Overhead sprinklers: Water applied by sprinklers provides protection because latent heat is released when water freezes. Sprinklers should be turned on when the temperature drops to 0.5 to 1.0°C and they must operate until all ice has melted (Loder 2008).

Air mixing: The presence of an inversion layer containing air that is warmer than that next to the soil surface offers an opportunity to increase the air temperature near to the surface. Mixing air typically increases the temperature at cordon height by 1-2°C. The effectiveness of mixing air will vary with the height and strength of the inversion layer. It is recommended that growers confirm that inversion layers are present at a height where they can be accessed by fans before investing in this technology. Fans also produce noise pollution that can cause problems near dwellings.

Air warming: Oil/gas heaters not only warm air close to the ground, they also create convection currents that break up the inversion layer. The high density of heaters that is required (80-100 per hectare) make this technique impractical for all but small vineyards. In addition, fuel costs and potential air pollution issues mean they are rarely used in Australia.

Foliar sprays: Copper products (that reduce the number of ice-nucleating bacteria), vegetable oils and anti-freeze are not generally effective (and may not be registered for use on vineyards). Growers should check

with their winery or grape purchaser before applying any of these products.

What can you do if your vineyard is frost-damaged?

Depending on the timing and severity of the frost, growers may wish to consider management options to improve yield in the current and subsequent season, as well as providing good quality canes and spur positions for pruning in the following winter. Several studies have compared 'no management' with options such as removal of frost-damaged tissue back to healthy green tissue, pruning the original spurs back to one bud or pruning damaged shoots back to one bud. In most cases the researchers concluded that the 'no management' option was most economically viable because there was no significant yield advantage and all treatments incurred a cost (Jones et al. 2010). The 'no management' option will result in lower quality pruning wood in the following winter and potentially lower bud fruitfulness in the following season, but this can be compensated for by retention of extra buds at pruning.

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