



**VINEYARD COOLING**  
**- *A Literature Review* -**

**Prepared for** : **Victorian & Murray Valley Winegrape Growers Council**

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## **INTRODUCTION**

Scholefield Horticultural Services (SRHS) was engaged by the Victorian and Murray Valley Winegrape Growers' Council (VMVWGC) to conduct a literature review of both published and unpublished scientific articles and other relevant articles on methods of reducing ambient temperature in horticulture crops.

The review would consider the techniques used in vineyards and orchards and detail the effectiveness in reducing crop temperatures, the positive effects on the horticulture crop, any negative aspects of the practice including sustainability and the resources need to implement these practices in a commercial enterprise.

## **METHODOLOGY**

Published research papers were sought through the Waite Library data base at the University of Adelaide and the CSIRO Library at Merbein. These papers provided the scientific basis for work undertaken in the cooling of vineyards and orchards to test the impact of cooling mechanisms and the improvement of fruit quality.

Published articles in industry journals and magazines were reviewed for commercial application of cooling systems being trialled or currently used in horticulture.

Personal communications were made with local and overseas researchers and extension personnel to garner anecdotal experiences and additional industry references.

The focus of the literature searches was on the cooling of vineyards for the improvement of fruit composition, however information was also gathered on other crops, particularly apples, to demonstrate the wide range of applications of cooling practices in horticulture.

## **OUTLINE OF TOPIC**

The purpose of this review is to ascertain the potential for reducing temperatures in vineyards during the growing season to improve fruit quality, as described by the accumulation of soluble solids (sugars), anthocyanins (colour) and secondary metabolites (flavour compounds) and the levels of acid and pH in the grape juice.

Techniques that moderate temperatures during the hot months of December to February, reduce the disruptions to metabolic processes during grape maturity and result in more desirable berry composition at harvest.

There are many methods that can contribute to the moderation of daily maximum temperatures in vineyards. A combination of strategies and practices will maximize the cumulative effect of temperature reduction, however the extent to which maximum temperatures can be reduced in the field is limited.

Below, is a list of factors that can be used separately or combined together that could assist in the cooling of a vineyard.

### **Vineyard design**

- Row orientation
- Trellising
- Shelter belts

### **Canopy management**

- Pruning

- Irrigation
- Nutrition

Vineyard floor management

- Grassing down
- Mulching under vines

Cooling the canopy with water

Cooling the canopy with air (wind)

Spraying physical barriers onto canopy and fruit (kaolin)

Vine covers, netting, cloth

The focus of this literature review will be on the cooling effects using overhead sprinklers, however other approaches to cooling will also be considered.

## **BACKGROUND TO COOLING**

### **The mechanism of cooling**

Ambient and crop temperatures can be reduced by using water as a coolant. There are 3 mechanisms.

1. Convective cooling: Water evaporating in the air, cools the air then cools the crop by convection. For example fogging and misting. This is not a very efficient method to lower crop temperature.
2. Hydro cooling: The application of water onto the plant or crop using overhead sprinklers with a fairly high output. The water directly cools the leaves and fruit by absorbing the heat. Not that practical as the volume of water required is high.
3. Evaporative cooling: This is when the water on the fruit and leaves evaporates from the surface. The rate of evaporation depends on the weather conditions such as wind, temperature and humidity.

All of these mechanisms act together but the application method, rate of water and climatic conditions will determine the relative contribution of each mechanism.

The most effective method for cooling fruit in a vineyard or orchard using applied technology will rely on evaporative cooling and will be most effective in a low humidity/windy climate.

We must not forget that plants have their own method of keeping cool, the process is called transpiration. Water taken up by the roots is translocated through the vascular system and vaporized at the leaf's surface through openings called stomata.

Provided the vine is well supplied with water, leaves facing the sun will be only 2-3°C higher than air temperature. However, if water is limited then this figure can exceed 10°C (*Robinson 1997*). As the vine becomes stressed with lack of soil water, it closes its stomatal openings thus reducing the rate of photosynthesis, or sugar producing mechanism.

Also remember that applying water for cooling increases the humidity of the air around the leaves, so the evaporative demand of the air decreases. Less water is transpired by the plant, which can under certain circumstances result in an increase in leaf temperature.

The message here is that we must make sure soil moisture levels are adequate and the climatic conditions are suitable before we try to impose artificial cooling on the canopy.

### The technology used for water cooling

Greenhouses use fogging and misting units that produce droplets of 5-10 microns for fog and 50-100 microns for mist. Ambient temperatures are reduced by 12-15°C, however this has limited effect on lowering the temperature of the crop.

Outdoor applications include overhead sprinklers especially designed for quite low output (1-2mm/hour) and smaller droplet size (depending on pressure) than regular overheads.

Undertree/vine sprinklers are less effective than overheads but their benefit is still positive. Being below the canopy they rely more on convective cooling rather than evaporative cooling.

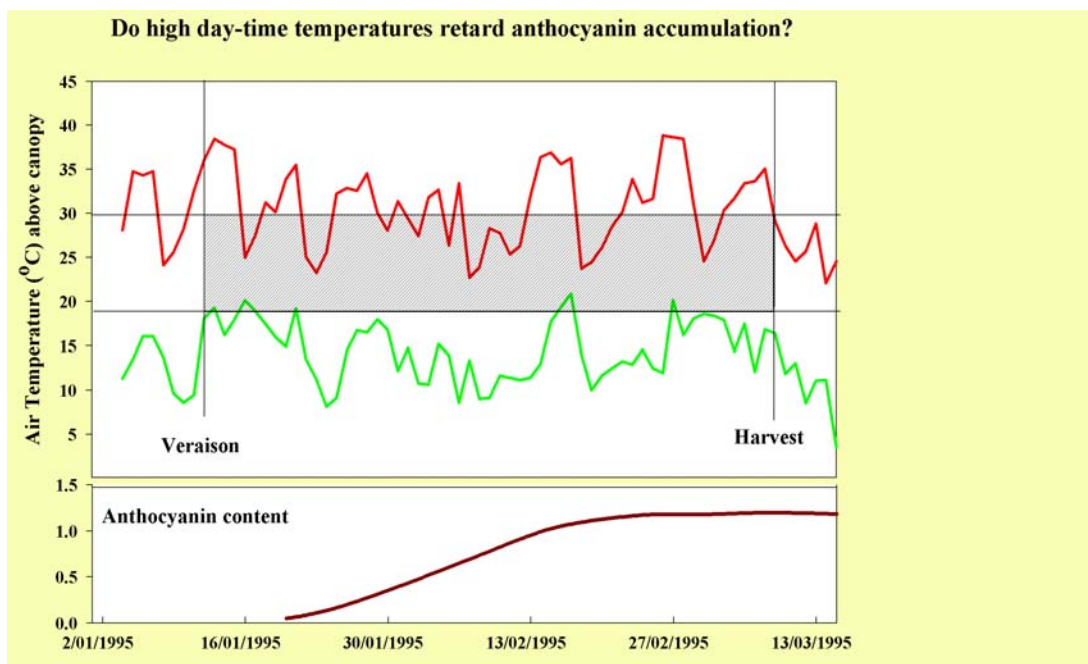
### The need for cooling in vineyards

We grow produce in regions where the growing seasons have high heat accumulation and often excessive daily temperatures during ripening.

Although high heat is good for some aspects of maturation it is often detrimental to other metabolic processes.

The need for cooling is therefore to reduce the peaks and moderate daily temperatures.

Below is a graph depicting the maximum and minimum temperatures experienced during the véraison to harvest period for Shiraz grapes in the Riverland region. The accumulation of anthocyanins is shown as is the ideal temperature range for the accumulation of anthocyanins.



McCarthy (PIRSA)

The broad literature states and accepts that high temperatures in wine grape production affect the metabolism of anthocyanins (colour in red varieties), flavours (especially aromas such as terpenes), sugar (through photosynthesis) and acid degradation.

Although there are limitations to the degree to which temperatures in a vineyard can be reduced during a hot summer's day, there is merit in investigating cultural practices that may mitigate the adverse effects on fruit composition.

## **LITERATURE REVIEWS - Vineyards**

Extensive research has been carried out over the past 35 years to examine the changes in wine grape berry composition with different temperature/light regimes. Four papers are summarized below in chronological order:

### **Effect of Temperature on the Composition of Cabernet Sauvignon Berries**

Buttrose, Hale and Kliewer - CSIRO Australia, (published in California 1971)

**Aim:** To determine the effect of temperature or changes in temperature on various aspects of berry development.

**Procedure:** Potted Cabernet vines were held at different temperatures regimes (day and night) in a green house environment. Temperature regimes of 20°C day and 15°C night were compared to 30°C day and 15°C night. Berry volume, colour, sugars, malic and tartaric acid and nitrogen compounds were measured in the fruit.

**Results:** There was no difference in berry volume.

Colour levels were higher at 20°C than 30°C

There was no difference in the sugar concentration (not expected, could be varietal)

Acid levels were sustained at the lower temperatures.

### **Effect of Night Cooling at High Temperature Season on Vine Growth and Berry Ripening of Grape Kyoho.**

Fukushima, Iwasaki, Gemma, Oogaki – Japan 1990

**Aim:** To explore the effects of night cooling on large black table grapes.

**Procedure:** Night temperatures were held at 15°C, 20°C and 25°C for the growing season. Growth rate, brix and fruit colour were measured.

**Results:** Both brix and colour were the highest for the 20°C treatment, followed by the 15°C treatment and then the 25°C treatment. Night cooling was seen to promote the translocation of photosynthetic products and decrease the respiration consumption of assimilates.

### **Sunlight Exposure and Temperature Effects on Berry Growth and Composition of Cabernet Sauvignon and Grenache in Central San Joaquin Valley of California.**

Bergqvist, Dokoozlian, Ebisuda – California 2001

**Aim:** To determine the optimum sunlight exposure for Cabernet and Grenache.

Previous studies showed that sunlight exposed fruits are generally greater in TSS, anthocyanin and phenolics and lower in TA, malate, pH and berry weight compared to shaded fruit.

Past research with light has been done in greenhouses where an increase in light does not necessarily mean an increase in temperature. The outcomes of this past research have suggested that we need to expose fruit more to capture the benefits of light, however in the field there could be some implications with the associated temperatures.

**Procedure:** Clusters within a canopy were tagged as:

- Fully exposed
- Moderate to high exposure

- Moderate to low exposure
- Shaded

Measurements undertaken:

- PAR (photosynthetically active radiation)
- Temperature of berries
- Berry composition (colour, phenolics, pH, TA, TSS)

Results:

- ❑ The temperature of fully exposed berries was 9-10°C higher than shaded fruit, so when accumulated over the ripening period this attributed to a marked difference in berry composition.
- ❑ The colour of the fruit on the shaded side of the canopy had a linear increase in berry colour with exposure.
- ❑ The colour of the fruit on the exposed side of the canopy decreased in the fully exposed bunches due effects of high temperature accumulation. Phenolics were also lower.

Conclusion: Row orientation, trellising and canopy management practices should be considered to avoid prolonged fruit exposure to direct sunlight in these warm regions.

### **Separation of Sunlight and Temperature Effects on the Composition of Merlot Berries.**

Spayd, Tarara, Mee, Ferguson – Washington State USA 2002

Aim: To examine the composition of Merlot grapes under different light exposure and to separate the effects of temperature and solar radiation on colour and phenolics compounds within the fruit.

Procedure: Field trial with N-S rows, bunches within the canopy selected as exposed or shaded. A device was fitted over the bunches to allow control of fruit temperature. For example, some shaded fruit was heated up to temperatures experienced by exposed fruit and some exposed bunches were cooled down to temperatures experienced by shaded fruit.

Measurements undertaken:

- Colour
- Phenolics
- TSS
- Total acidity
- pH.

Results:

- ❑ East and west-side bunches were both elevated above ambient temperature to the same degree, ie 12-13°C above ambient temperature, however . .
- ❑ Actual berry temperatures on the exposed (west side) fruit were higher than the east side due to heat accumulation.
- ❑ Shaded berries were at ambient temperature
- ❑ The looser the bunch the cooler it was during the hot periods of the day.
- ❑ Colour in the west side bunches was lower due to degradation of anthocyanin and inhibition of anthocyanin synthesis, however . . .

- ❑ The west side exposed chilled bunches did not show this degradation in colour, in fact they registered the highest colour and brix but lower pH and TA as expected.
- ❑ The number of hours above 35°C was associated with a net loss of colour.

Conclusions: Excessive absolute temperatures rather than the difference between fruit and ambient temperatures reduce berry colour. West exposed fruit gets hotter and should be avoided.

Some early work was done on the effects of water cooling of vineyards, using overhead sprinkler systems. Very little published work of recent research has been found on the application of cooling in vineyards however cooling methods in other crops appears to be more common. Below are summaries of research papers and references on the subject of using sprinkler systems to deliver water to fruit crops to cool the plant, fruit and ambient temperatures.

### **Evaporation Cooling of Vineyards**

Gilbert, Meyer and Kissler – California 1971

Aim: To evaluate the atmospheric stress reduction at different sprinkler application rates in wine grapes.

Procedure: Field trial of 50 year old Tokay vines. Overhead sprinkler with 0.75-1.5mm/hour output, activated when air temperature exceeded 32°C. Sprinklers operated for 3 minutes on and 15 minutes off.

Plant parts were measured using sensors on the canopy and fruit composition was assessed along with yields and harvest dates.

Results:

- ❑ Air temperatures were reduced by 4-5.6°C (down from 32°C to around 26.4°C)
- ❑ Humidity increased by 10-20%
- ❑ Plant temperatures were reduced by 8.3-14°C (down from around 40°C)
- ❑ Berry temperatures rarely exceeded 32°C
- ❑ Positive aspects:
  - Colour was increased, yield increased through lack of fruit dehydration.
  - Acid was higher and pH lower
- ❑ Negative effects
  - Sugar accumulation was delayed in sprinkler cooled canopies (could be variety specific)
  - Serious *Botrytis* problems

No evaluation of wine was made.

### **Effect of Sprinkler Cooling of Grapevines on Fruit Growth and Composition.**

Kliewer & Schultz – California 1973

Aim: To determine how sprinkler cooling of grapevines during various periods from bloom to maturity affects growth and composition of grapes.

Based on the above research that the temperatures of plant and fruit are decreased by up to 15°C with sprinkler application.

Procedure: Field trial with potted vines of White Riesling, Carignane and Cardinal varieties pruned to one cluster/shoot. Trial over 2 seasons.

## Treatments:

A - No sprinklers (control)

B - On 2 minutes, off 7 ½ minutes

C - On 4 minutes, off 15 minutes

D - Continuous, controlled by hemp switch, therefore time varied depending on humidity, temperature, air movement (wick technique)

E - Continuous, switch set at 30°C

Started at véraison (10-13 Brix) and finished at harvest with approximately 33 (year 1) and 58 (year 2) days of application.

Measurements: Berry weight, TSS, colour, pH, TA and malate.

## Results:

Temperature drops using sprinklers were in line with previous research.

When air temperatures were 38°C+, then moist leaves were cooler than unsprinkled leaves by 17-22°C.

When air temperatures were 32-38°C, then moist leaves were 11-17°C lower.

When air temperatures were 30-32°C, then moist leaves were less than 11°C lower.

Table 1: Summary of results

	A no sprinkler	B 2 + 7 ½	C 4 + 15	D wick	E continuous
<b>Water used (mm)</b>					
Year 1 Véraison – harvest	0	102	102	204	735
Year 2 Set - harvest	0	195	195	393	735
<b>Fruit composition</b>					
Sugar accumulation	Generally no significant difference however continuous sprinkling on red varieties showed lower brix at the end of the maturity phase.				
Colour (Cardinal)	low (v.low early)	low-med	med-high	med	high
pH	up	inbetween			down
TA	down	inbetween			up
Malate	down	inbetween			up
Berry weight	low	med	med	med-high	high

## Other observations:

- Optimum temperature for photosynthesis and sugar accumulation is around 32 °C, however fruit ripening around 20°C had better acid and colour for dry table wines.
- Apparently in order to maintain low pH and high acid, the vines must be sprinkled until the fruit is fully mature.
- Water suitable for sprinkler cooling must be low in salt - less than 750EC
- Some negative aspects of overhead sprinkler for vineyards cooling include excessive vegetative growth during fruit maturation, bunch rot and susceptibility of wines to early oxidation.

## **LITERATURE REVIEWS – Apples**

Much of the published research on canopy cooling pertains to apple production in USA.

### **The Evaporative Cooling Effects of Overtree Sprinkler Irrigation on Red Delicious Apples**

Unrath – Nth Carolina (33° Lat) 1972

Aim: To measure the extent of cooling by sprinklers and assess any adverse effects.

Procedure: Sprinklers with output of 1.4mm/hr activated at 30°C.

Results: Fruit temperatures in sprinkled canopies using overhead sprays were on average 5.6°C lower than unsprinkled trees, from around 34°C down to 28°C. Air temperature was 2°C different.

When undertree sprinklers were used for cooling, the fruit temperatures only differed by 1.7°C.

Quality measurements:

- Early harvesting with cooling (increase by 1%)
- Higher yields (+20%) fruit weight and size increased.
- More uniform colouring (+8%) allowing a more compacted harvest period.
- Fruit was initially softer with overtree sprinklers but after storage there was little difference.
- No problem with disease, in fact cork spot and bitter pit were reduced (-8%).
- Some loss of effectiveness with herbicides during sprinkler periods.
- Generally undertree sprinkler results were between non-sprinkled and overheads.

### **Evaporative Cooling of Delicious Apples. The Economic Feasibility of Reducing Environmental Stress.**

Unrath & Sneed – Nth Carolina 1974

Aim: Assess the economic feasibility of previous work.

Results:

- Sprinklers ran 127 hours per season
- Quality increased
- Yields and packouts increased
- Overhead sprinklers returned \$1457/ha more than non-sprinkled at an extra cost of \$207/ha.
- Undertree sprinklers returned \$835/ha more than non-sprinkled at an extra cost of \$207/ha.

### **Orchard Cooling With Pulsed Overtree Irrigation to Prevent Solar Injury and Improve Fruit Quality of Jonagold Apples.**

Parchomchuk and Meheriuk – BC Canada (50°+ Lat) 1996

Aim: To reduce SI and compare fruit quality.

Procedure: Field trial with 2mm/hr sprinkler output, 2 minutes on and 4 minutes off, activated at 30°C.

Results: No improvement to fruit quality in this climate.

- Colour – no difference
- TSS – reduced

- Size – no difference
- Acid – increased
- Firmness – no difference
- Storage disorders – no difference
- Solar injury – reduced by 15.8% and 9.1% following year.

### **Orchard Cooling with Overtree Sprinkler Irrigation to Improve Fruit Colour of Delicious Apples.**

Iglesias, Graell, Echeverria, Vendrall – NE Spain (42° Lat) 2000

Procedure:

1. Control without sprinklers
2. Sprinklers at midday for 2 hours
3. Sprinklers at sunset for 2 hours

Output from sprinklers 3.6m/hr, applied 25-30 before harvest.

Results:

- Colour development was hastened and intensified with cooling at sunset
- Cooling at midday was intermediate between 1 and 3 treatments

### **Survey in Washington State of 21 apple growers with 10 varieties, covering 2200 hectares of orchard.**

Results:

- Colour – 70% reported colour enhancement in fruit, 27% no change
- General quality – 15-35% reported that fruit moved up a grade
- Maturity – 20% reported that harvest was advanced by up to a week, 11% reported delays up to a week and 27% no change.
- Negatives:
  - 65% say spray efficacy is reduced
  - 87% report increased disease pressure
  - 32% found fruit cracking
  - 37% used well water that may leave deposits
  - most growers are using 20-30% more water (some add fungicides to the water)
  - once you start canopy cooling you cannot stop mid season otherwise sun scald increases.

### **Local experience with apples – Tandou, Menindee NSW**

Tandou are producing varieties of apple such as Royal Gala and Pink Lady to capitalize on early domestic markets. Where they are producing the apples there are problems with winter chilling hours, sun scald and failure to colour.

Undertree sprinklers (Nelson R10's) were installed to lower the ambient temperature of the orchard at critical times of the season. The sprinklers are activated at 28°C and run 10 minutes on and 30 minutes off, for up to 12 hours. The interrow is planted to lucerne.

Sprinklers are also activated for night time cooling running 5 minutes on and 55 minutes off.

Tandou have received satisfactory reports from the market place on their fruit quality, however no objective data was found on fruit quality comparisons with non-sprinkled trees.

## **LITERATURE REVIEWS – Other crops**

### **Macadamias in Natal, SA – 1993**

Procedure: Field trials, 1-2mm/hr output sprays activated above 30°C, leaf temperatures measured using infra-red thermometers.

Results: Overhead irrigation usually reduced canopy temperatures below air temperature (as low as wet bulb). Large canopies required large volumes of water.

### **Stonefruit in Florida USA – 1981**

Applied to low chill varieties to improve uniformity of bud burst, flowering and fruiting.

### **Prunes in Washington State USA – 1971**

Used to reduce internal browning related to leaf curl, which was apparently related to high temperatures.

Fruit temperatures were maintained at 30°C when air temperatures were 32-38°C. Internal browning was not reduced but leaf curl was.

### **Strawberries in Georgia USA**

To reduce sun scald and heat stress. Temperatures exceeding 30°C, sprinklers were activated 15 minute on/off cycles at 2mm/hr. Temperatures around plants were reduced by 12-13°C.

### **Cherries in Oregon USA – 1991**

To reduce the incidence of abnormal fruit shapes. Fruit quality improved, however water used was significant and led to some leaf drop due to excessive levels of sodium, chloride and boron from well water.

### **Pears in Oregon USA – 1992**

Colour of Red Bartlett was increased and earlier maturity achieved.

### **Others – Ginger, Pawpaw, table grapes.**

## **SUMMARY OF LITERATURE – Cooling Vineyards**

Research into the cooling of vineyards using overhead sprinklers being activated intermittently during the hot part of the day, has demonstrated that significant reductions in fruit temperatures can occur and subsequent improvement of berry composition can result.

As ambient temperatures increase during the day, the resulting increase in fruit temperatures will depend on the exposure of the fruit to the radiation (sun) and the weather conditions, such as humidity and wind.

Intermittent sprinkling of vines reduced the temperature of the plant by 17-22°C, when the air temperatures were very hot (38°C), by 11-17°C when air temperatures were 32-38°C and by less than 11°C when air temperatures were 30-32°C.

Past research has demonstrated that high temperatures in vineyards reduce berry colour of red varieties. Specifically, the number of hours fruit temperatures were above 35°C were associated with a net loss of anthocyanin, whereas the number of hours above 30°C had positive effects on colour accumulation. Therefore optimum anthocyanin accumulation (for Merlot) may lie between 30-35°C (berry temperature).

Some research showed that overhead sprinklers reduced the plant temperature by 8.3-15°C, down from 40°C. This cooling process improved the colour of red varieties, maintained acid

levels and kept pH at lower, more desirable levels until harvest. Brix levels were apparently not affected by the cooling sprays, unless they were continually sprayed in which case sugar accumulation was delayed.

There were very few negative effects reported with overhead sprinkling of vineyards in the research reviewed by SRHS, however issues such as salt deposits, disease incidence and adherence of sprays were mentioned in the broader literature. These issues would need to be addressed in a commercial application of an overhead cooling system.

It is clear from the research that some benefits accrue from vineyard cooling in a trial situation with regards to berry composition, however there was little evidence of any trial work that carried the analysis into the wine making process.

## **SOME PRACTICAL IMPLICATIONS FOR THIS REGION**

If we accept that cooling using overhead sprinklers can generate benefits in some situations, we then need to consider the practical applications of such a management tool. In a time when growers of horticultural produce are being encouraged to move away from inefficient irrigation methods, many are converting from furrow and overhead irrigation to drip or undervine sprinklers in order to conserve water. This makes it more difficult to justify the installation of a new overhead system for vineyard cooling.

Growers who choose to keep their overhead system during conversion, to say drip, may have the opportunity to use the system for frost protection, cover crop management and some form of vineyard cooling.

Long term weather data tells us that during the period Dec-Feb there are 23 days with maximum temperatures 30-35°C, 23 days 35-40°C and 5 days over 40°C. If we roughly calculate the time the overhead sprinklers would be activated to reduce ambient temperatures, the total number of hours could be between 50 and 80. At an output of 2mm/hr this equates to 1-1.6ML of extra water to cool the vineyard. In times when water conservation is becoming more critical to the sustainability of horticultural regions in Australia, it will be difficult to encourage growers to adopt vineyard cooling practices that use more water.

This comment is also relevant to the permanent grassing down of vineyards as they too require more water to maintain a cool vineyard floor during summer months. The selection of a suitable grass mixture for the Sunraysia area that does not require vast amounts of water and will not die out over summer is not easy. Most grass swards being planted here at present require at least an extra 1-2ML of water to sustain it over the season.

Other messages pertaining to overhead application of water on vine canopies are salt damage (in some seasons), encouragement of disease particularly *Botrytis* and the washing off of sprays both fungicides on the canopy and herbicides on weed cover.

The kaolin product was mentioned earlier, where a physical barrier (clay-type substance) is sprayed onto the canopy including the fruit and that in turn reduces canopy temperatures, water stress and reduces disease pressure.

The product Surround® is used in apples, citrus and many other crops but has not yet been trialled in wine grapes. One area of concern with using this on wine grapes is whether the film can be left on the fruit at harvest. Most other fruits are washed in the packing shed to remove the kaolin, however acceptance by wineries of this product in the crush would be needed in the case of wine grapes. The product however is worth trialling and assessing for this purpose in this region.

Based on the existing body of research on this topic, we need to prove or disprove the following statements as they pertain to this region and the varieties we grow here.

1. Cooling the vineyard will make a positive difference to berry composition ie anthocyanins, flavour compounds, pH, acids and sugar accumulation.
2. These differences in berry composition translate to improved wine quality.
3. The investment in vineyard cooling technology and practices generates benefits over and above the costs of implementation, in terms of increased net return per hectare to the grower.
4. Vineyard cooling incorporates the responsible use of water resources in light of the increasing need to conserve water and its quality.



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