Leaf removal and flavonoids: a vigneron's compendium

A New Zealand researcher encounters difficulties in prescribing a best management practice for leaf removal, since there are many influencing factors such as trellis type, climate, variety and vine vigour. And it seems that Cabernet Sauvignon, Grenache, Merlot and Pinot Noir could be vulnerable to over exposure to sunlight.

Russell Moss

Introduction

Many vintners have successfully employed leaf plucking on an industrial scale to increase air movement and UV exposure within the canopy environment, which inhibits the proliferation of fungal pathogens. This technique also ensures better spray coverage, and hence increases the efficacy of the growers spray program. Some have also found that incidence of sunburn decreases in fruit where leaf removal occurs around fruit set as the fruit can become acclimated to sun exposure (Price *et al*. 1995).

Leaf removal also significantly effects mouthfeel and perceived colour. Flavonoids represent 80-90% of the total phenolic compounds of the grape. Flavonoids consist of anthocyanins, flavonols and flavan-3-ols (Lemut *et al*. 2011). These compounds are responsible for wine colour, astringency, bitterness, UV protection of the grape and grape pathogenic resistance.

Anthocyanins are the pigments directly responsible for wine and grape colour. They exist in many forms within a dynamic equilibrium. Other phenolic compounds, mostly catechins and procyanidins, form polymers with free anthocyanins in the must and within the berry itself, which can lead to greater stabilization and perception of wine colour.

Flavan-3-ols are a group of compounds which are particularly relevant to mouthfeel, since they result in the perception of astringency and bitterness. Flavan-3-ol polymers, like procyanidins (polymers of catechins) form structures that are perceived as astringent and less bitter than the flavan-3-ol monomers. Flavan-3-ols may also form associations with anthocyanins, which causes greater wine colour stability.

Flavonols are the least abundant of all the flavonoids. Their main sensory impact is their action as copigments with anthocyanins. Physiologically, flavonols act as a sunscreen for the berries (Diago 2012).

Copigmentation is the association of anthocyanins with noncoloured organic compounds, such as flavonols, which leads to the formation of chemical complexes. These complexes can enhance light absorbance (e.g. heightened colour density) and some associations can even shift the hue of the wine colour.

The significant flavonol increase among leaf removal treatments is of importance for the implications this has on wine colour.

The effects of warm versus cool climate leaf removal on anthocyanins

The research is seemingly at odds as to the effect of leaf removal upon anthocyanin accumulation. The picture becomes clearer upon separating the effects of opening the canopy. It has been found that only 10% of the total solar radiation is needed for the complete accumulation of anthocyanins (Bergqvist *et al*. 2001). Therefore, it stands to reason that total leaf removal around the fruiting zone will not increase anthocyanin concentrations in relation to a canopy that allows dappled sunlight through to the fruit. Another study found that fruit temperatures above 35°C can actually result in a net loss of monomeric skin anthocyanins. This effect occurs because anthocyanin synthesis is depressed by temperatures above 35°C (Spayd 2002). Further, Bergqvist *et al*. (2001) found in their warm climate study that the temperature of exposed fruit can be 10°C greater than that of shaded fruit. This effect is exacerbated after veraison, as the fruit becomes more efficient at absorbing solar radiation. This heightened temperature was provided as the reason as to why depressed anthocyanin concentrations were found in the leaf removal treatments of several warm climate studies. Higher temperatures that remain below the peak of 35°C may induce greater anthocyanin synthesis. In a cool climate study of leaf removal, it was found that leaf removal resulted in a 10-63% increase in total anthocyanins (Lemut *et al*. 2011). Leaf removal and anthocyanin accumulation may have differing effects upon which cultivar the practice is being employed.

The effect of leaf removal on flavonols

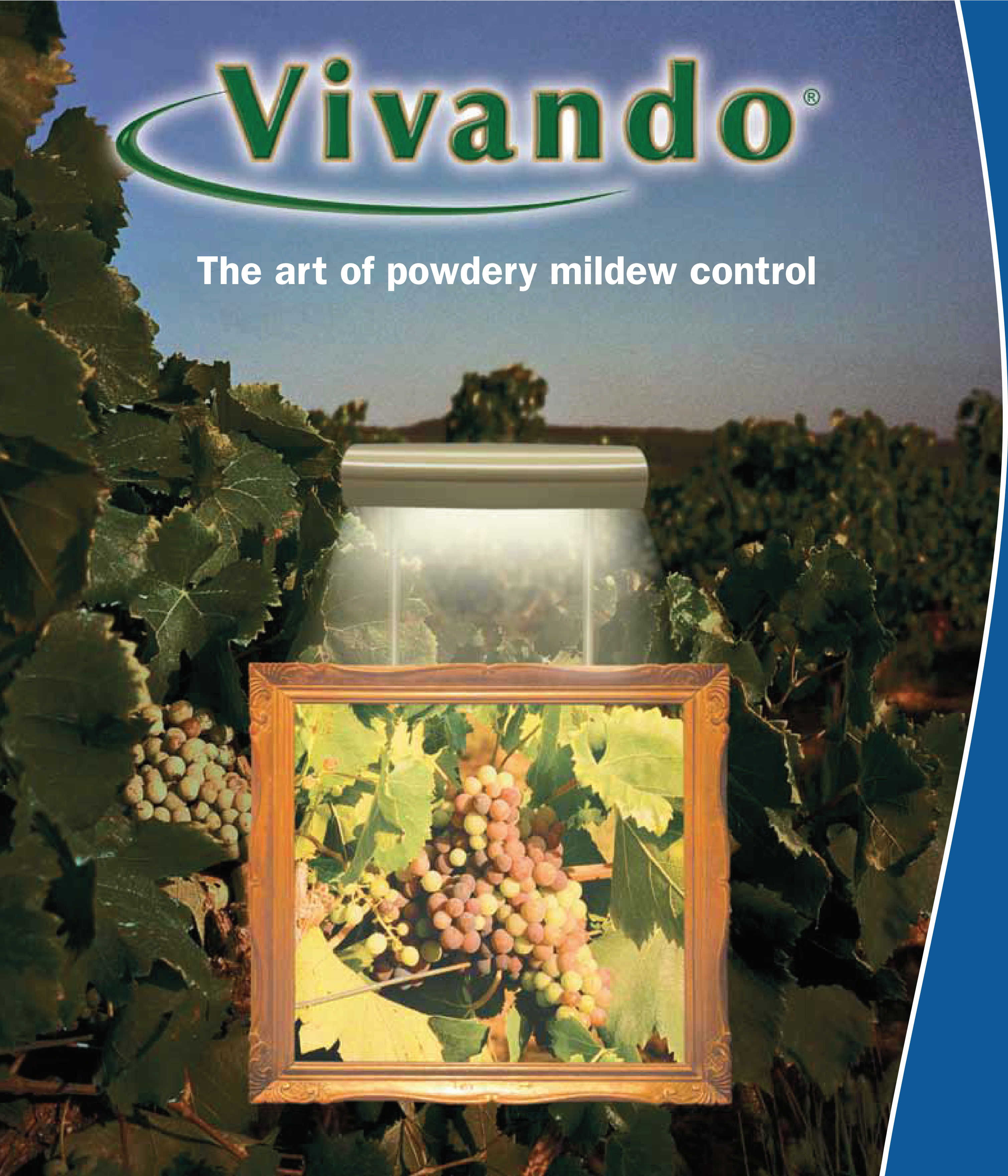
Although flavonol monomers may not contribute to wine colour directly, they can associate with anthocyanins to induce greater perceived colour.

Lemut *et al*. (2011) applied leaf removal treatments of 5-6 basal leaves at different times in the growing season and found a significant increase in the amount of flavonols within the leaf removed treatments in relation to the control ($P<0.05$).

The significant flavonol increase among leaf removed treatments is of importance for the implications this has on wine colour. Quercetin has been noted as having the ability to form anthocyanin co-pigments which will increase the colour density and hue of the resulting wine. Therefore, even though one may not affect anthocyanin accumulation through the use of leaf removal, the dramatic increase in flavonols may induce greater copigmentation and therefore perceived wine colour.

The effect of leaf removal on flavan-3-ols

A study of leaf removal treatments as applied to Pinot noir in New Zealand found that leaf removal had



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a positive correlation with flavan-3-ol concentrations (Kemp *et al*. 2011). This study evaluated the effect of different timings of fruiting zone leaf removal and the researchers analysed the effect of these treatments on the flavan-3-ols of the resulting wine from this fruit.

Kemp *et al*. (2011) found that early leaf removal (7 days and 30 days after flowering) induced the highest concentrations of flavan-3-ol monomers. The researchers found that leaf removal treatments significantly increased the concentration of catechin, epicatechin gallate and epigallocatechin in the resulting wine in relation to the control ($P \leq 0.01$). .

Tannins form covalent and non-covalent bonds with proteins and polysaccharides within the berry cells. This has important implications for tannin extractability during the winemaking process. Increased cluster exposure may lessen the impact of those bonds and thereby increase the amount of total extractable tannin in the must environment (Kemp *et al*. 2011).

The effect of leaf removal upon wine sensory impact

Joscelyne *et al*. (2007) performed a study which attempted to evaluate the sensory impact of leaf removal upon wine colour and mouthfeel upon Cabernet Sauvignon and Shiraz in a hot climate. This study found that the Cabernet Sauvignon wine that was made from shaded fruit resulted in a wine that was perceived as having less astringency, tannin and body ($p \geq 0.05$). The Shiraz wine made from shaded fruit was perceived as possessing a more ruby colour than the violet colour of the exposed fruit. The Shiraz wines made from shaded fruit were also perceived as being lighter and of lesser colour density than their expose fruit counterparts ($p \geq 0.05$).

The decrease in astringency and wine body found among the treatments of the Joscelyne *et al*. (2007) study indicates that perhaps the tasters perceived lesser flavan-3-ols among the shaded fruit when compared to the exposed fruit. Further the shift of wine colour from ruby to violet with increased exposure suggests a greater effect of copigmentation with flavonols such as quercetin which can affect this type of hue shift.

Price *et al*. (1995) conducted a similar trial upon cluster exposure and phenolic profiles. This study involved Pinot noir grown in a cool climate and an informal tasting of the resulting wines was undertaken. Tasters tended to prefer the wine from moderately exposed grapes rather than highly exposed fruit. Tasters described the wines from the highly exposed fruit as being "harsh." This may be due to the higher concentrations of phenolic monomers which can be perceived as bitter.

Application

Too little light inclusion in the canopy can lead to wines which are of a "green style" and too much light exposure can lead to increased risk of sunburn. The technique in which the grower removes leaves will have a major effect upon fruit quality. Many growers believe in using a "dappled sunlight" approach to leaf removal within the fruiting zone. This technique can prevent heat accumulation as the breeze can move freely through the canopy and sun flecks will appear on the clusters and move throughout the day as the sun's angle changes. If the grower allows too many leaves in the fruiting zone, shading may decrease air movement and increase air temperature and thereby increase berry temperature which can have a negative impact upon anthocyanin accumulation. The typical leaf removal regime tends to be basal leaves on the morning side of the vine at or after fruit set. The concept behind this strategy is to attain the most successful fruit set possible, while allowing the newly formed berries to acclimate to higher sun exposure early on. By removing leaves on the morning side, the grower is also shading the fruit from the hotter conditions of the afternoon sun, thereby reducing the chance of lower anthocyanin synthesis brought on by higher temperatures.

One can also use row orientation to aid in shielding the fruit from the hottest afternoon sun by positioning rows in relation to the angle of the sun at the hottest time of the day so that the sun is located directly over top of the row (i.e. the canopy shadow is directly under the vine). This may mean a row orientation that is slightly off North-South because the hottest time of the day is usually a couple hours after 12pm. This can help shade the fruit from absorbing solar energy as well as heat energy, thereby increasing cluster temperature and possibly leading to excessive heat and negatively impacting anthocyanin synthesis. Further, using a "dappled sunlight" approach may reduce the occurrence of sunburn, especially in warm and hot climates.

Leaf removal timing and position within the canopy is important. If leaves are removed pre-fruit set, one can significantly reduce yield, as decreased photosynthetic carbohydrate assimilation can induce flower and fruitlet abscission. This can lead to a more open cluster architecture and greater berry exposure which may benefit ones fungal fighting regime, but will reduce yield (Poni *et al*. 2005). Therefore, a post fruit set leaf removal of basal leaves is ideal for most situations.

A best management practice for leaf removal is impossible to provide because there are many factors which will influence this decision such as trellis type, climate, variety and vine vigour. In regards to variety, Cabernet Sauvignon, Grenache, Merlot and Pinot noir may be cultivars that are especially prone to issues resulting from over exposure. Due to the vast variability in grape farming systems, it would behove the savvy vigneron to employ a leaf removal trial using differing leaf removal severities and timings upon different varieties within their own systems. A trial of this sort should be in place for several years in order to evaluate weather variations from year to year and its effect on leaf removal. It would be advisable to perform this trial in fermentable lots in which the vintners can then undertake sensory and chemical analyses to decide upon the best practice for their particular system.

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