Smoke and Fire Retardant Effects on Foliage, Juice and Wine Quality

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DURING THE LATE SUMMER of 2010, a severe September heat spike, combined with stiff westerly winds, resulted in the breakout of a series of wildfires in several Northern California locations. Vine damage caused by a wildfire adjacent and upwind of a premium North Coast Pinot Noir vineyard was investigated. After the flames had subsided, it was found that vines had been directly affected by heat, smoke and fire retardant dropped in and around the vineyard to douse the fire.

Fire Retardant Damage

The westernmost edge of the vineyard was directly impacted by the adjacent scrub fire, resulting in a small number of vine fatalities and lost cordon and spur positions caused by the intense heat rather than flames—no vines were burned. In response to the fire, vineyard and adjacent scrub areas were doused with Phos-Chek® Fire Retardant Grade D-75F (ICL Performance Products LP, St. Louis, Missouri) by California Department of Forestry and Fire Protection aircraft.

The swift action of the authorities prevented fire from engulfing any vines but resulted in much of the vineyard being covered with fire retardant. After the fire was extinguished, the fire retardant-affected portion of the vineyard was hosed down with water to wash the material from the vines. It was soon evident, however, that foliage touched by the retardant was burned to varying degrees. Foliar burn symptoms included:

- Aerial shoots with burned and missing leaves.
- Burned leaves along the canopy wall with far more extensive symptoms evident on the west side of the rows than the east side. This is because the prevailing wind at the time of the fire was blowing from the west.
- It was estimated that approximately 50 percent of the leaves on the west side of the rows were damaged by fire retardant. At the time of examination, approximately half of these leaves had fallen from the vine while the remainder was still attached.

As the vine canopy sheltered fruit, retardant-damaged fruit was not observed.

At the time of the fire, the fruit was nearly ripe. We were concerned with the negative impact of both the fire retardant and smoke components on fruit quality and potential impacts on vegetative development in the present and new season.

Fire retardant damage to leaves and shoot tips is shown on the western side of the row. The western side was subject to direct impact of the fire retardant because the wind was from the west.

Phos-Chek Fire Retardant Grade D-75F is composed of the following materials:

Component	% by weight
Diammonium Sulfate	> 65
Monoammonium Phosphate	> 15
Diammonium Phosphate	> 5
Guar Gum, Hydroxypropyl	<10
Performance Additives	<5

The main components of the retardant are essentially fertilizer compounds. It was not clear whether these compounds would affect fruit or wine quality, but their chemical formulation indicated that monitoring ammonia levels (yeast-assimilable nitrogen) in harvested fruit would be prudent. The presence of higher than normal ammonia in the juice could promote overly vigorous fermentation which, in turn, might negatively impact yeast efficiency. It was considered, however, that the components' impact on 2011 season vine development would be minimal as it was expected that the retardant would be leached from the root zone by the typical North Coast winter rains.

Absorption of Smoke Components by Berries: Smoke Taint in Juice, Wine

Of greatest immediate concern was whether to proceed with harvest as much of the fruit had been enveloped in smoke for several hours. Had the fruit absorbed volatile components within the smoke and thus become unmarketable?

Smoke taint refers to the unpleasant organoleptic qualities of juice and wines derived from smoke-affected fruit. Until relatively recently, the biochemistry of smoke taint spoilage in wines was not understood. What is clear, however, is that minimal exposure to smoke can spoil wine, resulting in substantial financial losses.

A relationship between berry exposure to smoke and tainted juice and wine characteristics was first demonstrated experimentally in Australia. In their study, Kennison et al. exposed harvested Verdelho grapes to straw-derived smoke for one hour before fermentation. Sensory studies established a perceivable difference between smoked and unsmoked wines; smoked wines were described as exhibiting "smoky, earthy, burnt and ash" characters. Gas chromatography mass-spectrometry identified the volatile compounds guaiacol, 4-methylguaiacol, 4-ethylguaiacol, 4-ethylphenol, eugenol and furfural in the wines made from smoked grapes. These compounds were not detected in wines made from non-smoked control grapes (1).

Because many Australian viticultural regions are established adjacent to vast areas of brush, the majority of work on smoke taint has been undertaken on this continent. Australian research has proven critical in establishing practical levels of smoke-induced chemical components in juice and wine that permit numerical assessment of associated product spoilage. This work proved helpful in assessing smoke-damaged fruit harvested during a period of extensive wildfires in California in 2008.

Research has shown that the two volatile phenols—guaiacol and 4-methylguaiacol—are the most useful markers for assessing smoke taint. Levels of guaiacol in grapes not exposed to smoke seldom exceeded 0.3 micrograms per kilogram (µg/kg) ppb while samples from areas exposed to heavy smoke may be as high as 55 µg/kg. Higher concentrations of smoke compounds are found in fruit skins as compared with fruit flesh. Juice contact with skins, therefore, results in heightened levels of smoke markers. During fermentation, guaiacol concentrations increase and were found to be typically three times higher than in non-fermented grapes in white wines and up to five to 10 times higher in red wines (2).

The perception of smoke taint is strongly related to the structure or body of the smoke-affected juice or wine. In a white juice sparkling base, winemakers observed smoky characters with guaiacol concentrations as low as 6 to 10 picograms per liter (pg/L); in medium-bodied red wines thresholds were 15 to 25 pg/L while in fuller-bodied Shiraz wines the threshold ranged from 30 to 40 pg/L.

Guaiacol is stable, and its sensory impact on a wine becomes more prominent as the wine ages. This is a function of the loss of primary fruit characters, which tend to mask smoke characters. It is, therefore, not advisable to re-blend smoke-affected wines to a level just below sensory threshold before aging and bottling (3). Significant amounts of smoke taint compounds may be liberated from non-volatile precursors during the early stages of winemaking (2). Guaiacol and 4-methylguaiacol are found at extremely low concentrations in oak barrel-aged wines. Guaiacol is the principal component induced by oak barrel toasting where concentrations of 20 pg/L are considered a highly positive attribute. Guaiacol may also form naturally at levels of up to 20 pg/L through hydrolysis of fruit-derived precursors (4).

Numerical Guidelines for Assessing Smoke Taint in Fruit and Wine

ETS Laboratories (ETS) in St. Helena, California offers a range of juice and wine analytical services, including assessment of smoke taint components. Discussion with ETS' **Eric Hervé** and a review of the literature allowed compilation of numerical guidelines for the concentrations of smoke taint marker chemicals that are associated with smoke-damaged fruit, juice and wines (5). They include:

1. Australian fruit with more than 2 µg/kg (ppb) guaiacol is subject to quality down-grading (6).

2. ETS has found that grapes naturally contain native levels of guaiacol of around 0.1 to 0.3 ppb. Levels above 0.5 ppb suggest exposure to smoke but not necessarily a perceived smoke character in wine (5).

3. ETS clients experienced "smoky" 2008 wines from grapes containing guaiacol in the 2 to 3 ppb range (5).

4. A slight smoky character was found in 2008 white wines from grapes containing as little as 1 ppb (5).

5. No harvesting/winemaking options have seemed successful at minimizing smoke taint with red wines. Only fining (deodorizing carbon) or reverse osmosis, after completion of fermentations, has shown significant reductions in guaiacol numbers and smoke character (5).

6. Timing of exposure to smoke, relative to fruit ripeness, may play a role in the development of smoke taint (5).

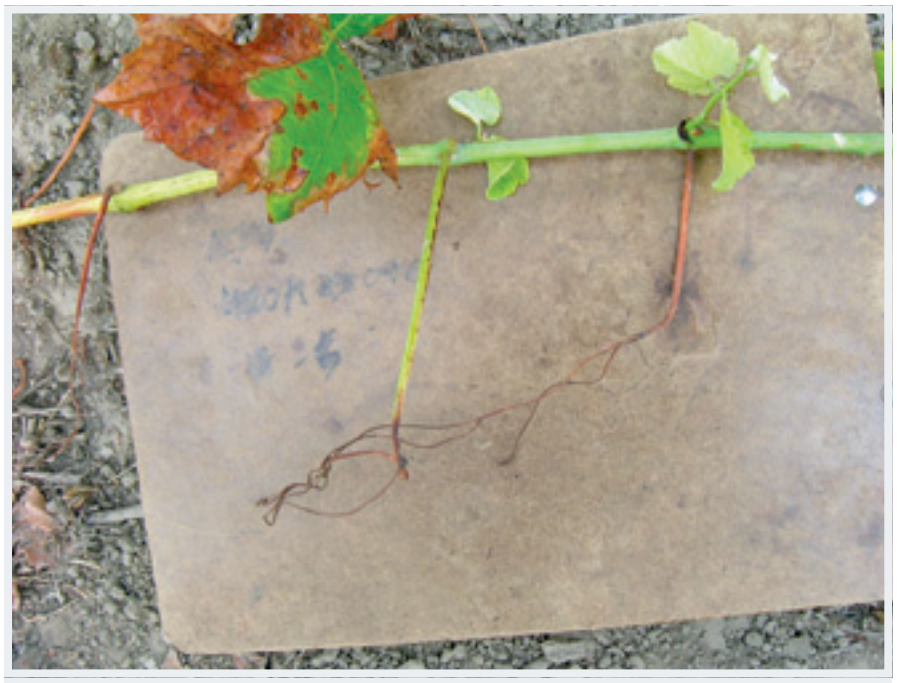
7. 4-methylguaiacol levels are usually three to four times lower than guaiacol (5).

8. Analysis of smoke-tainted fruit and corresponding wine has shown that guaiacol levels may increase ten-fold in red wines and three to five-fold in white wines (6).

Enartis Vinquiry offers smoke taint services as well.

Smoke Taint Components Found in North Coast Study Vineyard Blocks

As the fruit in a large part of the vineyard block was enveloped for some time in smoke from the adjacent fire, absorption by the berries of chemical components of the smoke was a serious concern. Client observations and CDF



Fire retardant-damaged leaves and tendrils

aerial photographs revealed that all blocks were enveloped to some degree in smoke from the fire. TABLE 1 indicates the concentrations of guaiacol and 4-methyl guaiacol detected in fruit samples collected from blocks directly and indirectly exposed to smoke from the fire. Samples were submitted to ETS Laboratories.

TABLE 1. Smoke taint chemicals in various blocks

Smoke and wind direction: West to East

Block	Exposure	Guaiacol*	4-m guaiacol*
West adjacent	direct	12.4	3.9
North east adjacent	semi-direct	2.4	0.6
North west adjacent	semi-direct	1.3	<0.5
South adjacent	indirect	0.8	<0.5
South distant	indirect	0.7	0.9

* µg/kg (ppb) *extracted by gas chromatography/mass spectrometry

DATA FROM ETS LABORATORIES, ST HELENA, CALIFORNIA

The data in TABLE 1 show that the vineyard blocks closest (and downwind) to the source of smoke (west adjacent) or most directly downwind of the fire (north east adjacent and north west adjacent blocks) possessed the highest levels of smoke markers.

Impact of Smoke and Fire Retardant on Vineyard Block and Harvest Value

In consideration of the level of smoke taint component compounds in the fruit (in comparison to known standards for smoke taint damage, see sidebar) the contracted buyer declined to purchase the fruit. In turning down the fruit, the winemaker noted that the smoke taint components were above those considered normal in non-damaged fruit and that the literature suggested that the levels of smoke markers were expected to increase up to tenfold in the finished red wine.

The value of the lost smoke-damaged 2010 season crop was put at $64,000 (16 tons at $4,000 per ton) based on historical average values and yields from the affected blocks. In addition to this loss, costs for replanting dead vines, future lost yields from dead and damaged vines, and costs for damaged hardware were calculated. These costs are currently in the hands of the insurance agency. **WBM**

References

1. Kennison K.R., Wilkinson K.L., Williams H.J., Smith J.H. and Gibberd M.R. (2007). Smoke-derived taint in wine: Effect of postharvest smoke exposure of grapes on the chemical composition and sensory characteristics of wine. J. Agric. Food Chem., 55, 10897-10901.
2. Eric Hervé, Steve Price and Gordon Burns, ETS Laboratories. (2009). ASEV Annual Meeting poster.
3. Simos, C. (2008). The implications of smoke taint and management practices, Australian Viticulture, 12 (1), 77-80.
4. Sefton, M.A. (1998) Hydrolytically-released volatile secondary metabolites from a juice sample of Vitis vinifera grape cvs Merlot and Cabernet Sauvignon. Australian Journal of Grape Wine Research, 4, 30-38.
5. Eric Hervé, Ph.D., ETS Laboratories. October 21, 2010. Personal communication.
6. Whiting, J. and Krstic, M. (2007). Impacts of bushfire smoke on grape and wine quality—Scoping study. Department of Primary Industries, Victoria, Australia.