Managing Sulphur Burn in Vineyards

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Murray Valley Winegrowers' Inc

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Wettable sulphur can be used safely at high temperatures in vineyards if it is applied in the right conditions. The damage to grapevine foliage by wettable sulphur is influenced by the interaction between temperature and the how long the leaves stay wet after spraying. Other factors may be involved too.

When the humidity is low, as is common in warm inland districts of Australia (that is, with less than 70% RH), it appears that sulphur may be used safely even at very high temperatures (that is, in the range 35°C - 45°C). At high temperatures and low humidity, the leaf drying time is short. However, the risk of damage to the vine foliage is higher when temperatures are in the low 30°C's if the relative humidity is above 70-75%. The foliage drying time then is longer.

Why use Sulphur?

For many years, sulphur has been widely used in Australian vineyards against powdery mildew and mites. It is an effective, low-cost fungicide accredited for use in regular and in 'organic' vineyards. Being a 'multi-site' fungicide (Group M2), it is active at various points in the metabolism of the powdery mildew fungus and in its growth cycle when the fungus develops from spore to hyphae (the fungal threads or 'filaments' that grow on the infected foliage) and from hyphae to new generation spores that soon develop.

The sulphur has 'multi-site activity', it is most unlikely to induce resistance in the population of powdery mildew spores in your vineyard. On the other hand, continued use of 'single site' fungicides (eg fungicides from Groups 2, 3, 5 or 11) is very likely to lead to the development of spores resistant to those fungicides. By appropriate use of sulphur in your spray program, you provide a buffer against this developing. If a population of resistant spores were to form against a single-site fungicide in your vineyard, applications of sulphur will 'kill off' those spores. In this 'integrated' way, the effective active life of the single-site fungicides can be extended.

Sulphur is a non-systemic fungicide that has both protectant and eradicant activity. This means that it both protects the vine against the mildew fungus and 'kills off' (but doesn't guarantee to eliminate) the powdery fungus.

How does sulphur Work?

Sulphur acts against powdery mildew in two ways. The first is by direct contact of the spray deposit with the fungus. In this way, sulphur prevents the mildew spores from germinating either by killing the spores or its germ tubes as they emerge. (The germ-tube on a spore is like a young root emerging from a grain of wheat). Direct contact of sulphur spray deposit also kills the fungal hyphae on the surface of the foliage.

The second action of sulphur is through its vapour (fumigant) activity. Provided that temperatures are moderate (more than 15°C), the sulphur in the spray deposit vaporises within an hour or two. This vaporisation releases sulphur gas which pervades the vine canopy. If spray dose and coverage of the vine foliage is adequate, the fumigating gas will directly contact the mildew fungus and the fumigated fungal hyphae will die.

Figure 1. Typical symptoms of powdery mildew on leaf and bunch. Sulphur is a very effective fungicide against this disease despite the (minor) risk of sulphur burn to the foliage in hot conditions with high humidity. Photos. PA Magarey.

With its many active roles and its availability for organic vineyards, sulphur is likely to remain an effective tool against powdery mildew for many years to come.

In earlier Years

Sulphur dust

From the 1940s to 1960s there were few spray machines in inland Australian viticulture. The main foliage disease was powdery mildew because until the mid-1950s, the 'wet weather' diseases black spot and downy mildew were generally only present in low numbers. Before then, water was rarely used as a medium to carry fungicide to the foliage of vines. To control powdery mildew, black spot and mites many growers used only dry sulphur powder – the applied this with a sulphur duster. But, if it rained, the dust washed off.

Sulphur is practically insoluble and won't mix in water. Because of these problems, to improve the 'stickability' of sulphur, wettable sulphur was commercially developed by formulating dusting sulphur with additional ingredients to make miscible – that is, more easily mixed in water.

Note:

Sulphur is an effective fungicide accredited for use against powdery mildew and mites both in regular and in organic vineyards. It has protectant and eradicant activity and, being a 'multi-site' fungicide, it is useful to reduce the risk of powdery mildew resistance in your vineyard.

Other formulations of sulphur

Later also, lime sulphur was manufactured by combining calcium hydroxide with elemental sulphur in water. Lime sulphur was, and is at times, still used as a fungicide and to control mites, but it is more expensive than wettable sulphur and has a very strong unsavoury smell! These 'manufactured' forms of sulphur persist on the vine for much longer than sulphur dust and consequently provide longer protection against powdery mildew.

Also in earlier days, sulphur was manufactured less precisely than it is currently. In more modern times, sulphur is sold either as: a wettable powder; a dry flowable wettable granule (micronised sulphur); or as a liquid flowable formulation each with greater uniformity of product quality than previously

produced. In the past, within the wettable sulphur formulations particle size varied considerably with some portions of the product at times being considerably larger or smaller. While the smaller particles (1-8µm) are more effective, they vaporise more quickly and are absorbed more readily into the breathing pores of the foliage (the stomates) where they may cause phytotoxicity (burning). On the other hand, the larger particles of 12µm or more have a reduced efficacy (capacity for active control) but they persist longer, they vaporise over a longer period and, under some circumstances, are also more at risk of causing burning to the foliage.

Note:

Sulphur has two modes of action – by direct contact and by its vapour activity. If it is applied with adequate spray coverage it is a low-cost and effective tool against powdery mildew ... but uncertainty exists as to the conditions under which sulphur may burn the foliage.

In more modern Times

In modern manufacture, sulphur particles in dusts average around 25µm. Wettable powders vary from 0.1-25µm (averaging 7.6µm) while improved dry flowable wettable granules average around 1-8µm and liquid flowables average approximately 3.5µm.

Rates of sulphur applied

Since the mid-1980's and the late 1990's in particular, bigger vine canopies on rootstocks generally replaced the small, free-standing (un-trellised) vineyard plantings. Subsequently, in the densely shaded and more humid canopies that became commonly grown, it has been more difficult to achieve effective control of powdery mildew. While low rates of sulphur product (200 – 300 gm/100L) had been effective 'for years' on the smaller and more open canopies, until that time, the low disease potential in the open canopies meant that lower doses of sulphur were effective. The lower canopy humidity, the increased exposure to the fungus-killing UV light, and the better spray coverage, fostered adequate control of powdery mildew at the lower rates of product.

These lower rates meant that the risk of sulphur burn in the foliage was less likely but the then more variable control of particle size increased that risk. As a result, when the array of single-site fungicides became available, many growers shifted from spraying sulphur in attempts to improve their control of powdery mildew and to reduce the risk of burning the foliage.

Around this time, a number of experiments with the use of sulphur were conducted in South Australian and Victorian vineyards. It was found that higher rates of sulphur (eg 600 gm/100L) were needed for effective control of powdery mildew in modern canopies. This higher rate of product (now the industry 'norm') was at times at risk of leading to burning the vine foliage and at times, the developing bunches too.

As said above, initially the variable quality of sulphur formulations and the exposure of the smaller canopies to UV light led to a higher risk of phytotoxicity of sulphur to the foliage and bunches, despite the lower rates of sulphur in use. In contrast, in more modern times, the better quality formulations of sulphur were counter-balanced by the higher rates of sulphur being applied in more humid canopies.

Burning by Sulphur

The world-around, recommendations are for sulphur to not be applied at 'high temperatures' because of the risk of phytotoxicity to the foliage and bunches – that is, the burning (or toxicity) of the foliage. Some countries declare vines are at risk with temperatures above 28°C (eg France) while others, have set a threshold temperature of 32°C or perhaps 34°C! It is likely that the rate of sulphur applied in these regions contributed to the amount of burning because the higher the rate of sulphur, the lower the temperature at which burning will occur.

When sulphur is applied to the foliage, a portion is converted to sulphur dioxide gas and when this mixes with water and sits in solution on the sprayed leaf or bunch, the spray forms a balance between sulphurous acid (H_2SO_3), sulphuric acid (H_2SO_4) and the bisulphite (HSO_3^-). It is thought that this weak mix of acid on the sprayed surface leads to the burning of the foliage or the berries.

Generally, it seems that if the temperature exceeds 28°C, the mixture will damage the vine tissue quickly – within two or so hours. For the most part, the recommendations relating to the use of sulphur in vineyards were concerned with temperature but this has proved to be only part of the story.

To retain or extend the use of sulphur in spray programs in Australia, a better understanding was required of the effects of high temperature on the phytotoxicity of wettable sulphur when applied to grapevine foliage. As a result, a series of vineyard studies applied sulphur on days when forecast maximum temperatures were above commonly accepted thresholds for its safe use on grapevines, that is, greater than 32°C.

Australian investigations in hot Weather

Between 1999 and 2001, eight field-experiments were conducted in three different climatic areas of South Australia including the warm inland region of Loxton. Wettable sulphur was applied to both sides of leaves on young shoots of cv. Sultana, Chardonnay, Shiraz, or Sauvignon Blanc. Each shoot carried at least three to five leaves less than six weeks old. The sprays were applied by hand when temperatures were between 33°C and 44°C and relative humidity (RH) was between 13 - 80%. In some experiments the temperatures exceeded 34°C for periods of 3-4 hours and exceeded 40°C for 1-2 hours at least.

Treatments were applied at rates of sulphur from 200g/100L (the then recommended rate of Thiovit), and at rates ranging up from the current recommended rate of 600g/100L to 1500g/100L. Most sprayed foliage dried within 3-5 minutes (minimum) and all foliage dried within 50 minutes. No phytotoxicity was observed in most experiments although in one, a slight burning was noticed. This was on <2% of the youngest leaves on Chardonnay vines sprayed at 40°C with either 200g/100L or 600g/100L Thiovit. The burning was seen only where young leaves were cupped and in which the spray mixtures sat for longer before drying.

In another experiment, similar slight burning was noted only on Chardonnay vines sprayed at 42°C with Thiovit 1500g/100L. In a further experiment, some minor burning of very young leaves at the tips of Shiraz shoots was observed after treatment with Thiovit® when temperatures exceeded 40°C.

These results were surprising given that reports elsewhere indicated that sulphur was phytotoxic at greater than 32°C. Of note however, phytotoxicity occurred with Thiovit at 200g and 600g/100L at temperatures of more than 40°C but only at humidity greater than 75%! Only with Thiovit at 800g or 1500g/100L was wettable sulphur slightly phytotoxic at lower humidity (viz RH 13% at 41°C).

These experiments had suggested that the phytotoxicity of wettable sulphur on grapevine foliage was influenced mostly by an interaction between temperature, the rate of sulphur applied, and the relative humidity just after spraying. It appeared that under conditions of lower humidity (RH <70%) as are common in inland Australian vineyards, the current 'standard' rate of wettable sulphur (Thiovit® at 600g/100L) can be used safely, even at very high temperatures.

However, further tests were needed to better determine threshold conditions for phytotoxicity with replication of other incidences of hot weather, especially in relation to vines under water stress.

Investigations in very hot weather in 2014/15

In 2014/15, a similar array of treatments was applied in very hot weather to Chardonnay and Gordo vines at Loxton as had been evaluated above.

The first trial.

The first trial was undertaken in January 2015 when hot weather was forecast. Wettable sulphur as Thiovit® was applied by hand sprayer to completely cover the upper five leaves of shoots of cv Chardonnay at rates of 600g/100L and 1200g/100L (twice recommended rate). In a trial with randomised design, the weather was monitored by a *Model T MetStation* located in the canopy of the sprayed vines (Figure 2).

To test for the role of exposure to sunlight (and UV light) and the length of high humidity on the level of phytotoxicity of sulphur, different combinations of the above two rates were made with each of the following: shoots exposed to the sun were sprayed then allowed to dry naturally; shaded shoots were sprayed then allowed to dry naturally; shaded shoots were sprayed then immediately sealed in a wetted plastic bag to retain high humidity for 1 hour; and similarly treated shoots were sealed in wetted plastic bags for 4 hours.

This trial was applied at two times - in mid-morning when the temperature increased from 39°C to 45°C and the relative humidity in the 'un-bagged treatments' ranged from 32% to 18%; and in the afternoon when the temperature ranged from 45°C down to 28°C and the ambient humidity rose from 19% to 68%.

Most leaves on the sprayed shoots dried (where relevant after the removal of the wet plastic bags) within 2-3 minutes and all leaves were dry in an average of less than 15-20 minutes.

Interestingly, there was no burning of the sprayed foliage in any treatment in these two trials when observed three days later and again five days after spraying ...not even in the shoots kept wet for 4 hours after spraying with twice the recommended rate of wettable sulphur!

The second trial.

The next trials were applied to Gordo vines in February 2015. In a similar replicated trial design, rates of wettable sulphur were applied at 600g/100L, 1200g/100L, 2400g/100L and 3600g/100L – that is from standard rates to six times that rate. As in the first trials on Chardonnay, sprayed shoots were either exposed or shaded and dried naturally or bagged but this time some shoots were bagged for 4 hours and others for 16 hours to retain leaf wetness for much longer periods of time.

Like the first trial, this experiment was applied at two times of the day (morning and afternoon) when the temperature ranged from 45°C to ~34°C and the relative humidity in 'un-bagged treatments ranged from 39% to 16%.

As in the first trials, there was effectively no burning evident in any treatment applied - that is, there was no burning when wettable sulphur was applied to young leaves on mature shoots of the variety Gordo which is known to be burnt by sprays of sulphur in some circumstances ...and this was when the rate of sulphur applied was up to six times the standard rate and when some of the shoots sprayed at that rate remained wet for 16 hours after spraying.

Despite the findings in these experiments, reports continue of the burning of the foliage following applications of wettable sulphur at high temperatures in some commercial vineyards. This means that we have more to learn yet! What actually triggers the burning of the foliage and in what conditions?

Figure 4. Automatic weather stations (AWS) like this Model T MetStation *monitor the vine canopy for leafwetness, rainfall, relative humidity (RH) and temperature. This provides a good guide to the weather conditions at the time of spraying sulphur. Such data will help you determine the risk from sulphur burning at moderate temperatures when the relative humidity is 70-75% or greater. Photo. PA Magarey.*

Further evaluation of the interaction between temperature and relative humidity on the burning of wettable sulphur is needed. In particular, a better understanding is needed of the threshold humidity conditions and of the interaction of high rates of sulphur products used in low spray volumes and/or on water stressed vines.

Note:

As a rule of thumb, the spraying of wettable sulphur is not likely to cause burning of the foliage when temperatures are very high as long as the relative humidity is less than 70% to 75% at the time of spraying.

Young bunches and vines suffering water stress are likely to be more at risk than young leaves.

Conclusion

The experiments described above in part support the idea that the burning of grapevine foliage by wettable sulphur is influenced by an interaction between temperature and how quickly the foliage dries after follows spraying. In conditions of low relative humidity (<70-75%) common in the warm inland districts of Australia, it appears that wettable sulphur may be safely used, even at very high temperatures. The risk of damage to vine foliage may be greater at temperatures above the low 30°C's when the humidity exceeds 75% and leaf-drying time is longer, than when temperatures are higher, relative humidity is lower and leaf-drying time is shorter.

These findings allow for potentially the best control of powdery mildew by vapour action of wettable sulphur applied during periods of very high temperature (more than 35°C) as long as the relative humidity is less than 70% - 75%.

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Further reading

- Emmett, R.W., Wicks, T.J. and Magarey. P.A. (2004). Sulphur formulations, particle size and activity - review. Ch 3. pp 52 -57 in Emmett, R.W. (Ed). Strategic Use of Sulphur in Integrated Pest and Disease Management (IPM) Programs for Grapevines. Dec 2003. DPI (Victoria). Final Report to GWRDC DAV98/1 220 pp.
- Magarey. P.A., Wicks, T.J., Hitch, C. and Emmett, R.W. (2004). Effects of temperature and application rates on the phytotoxicity of sulphur on grapevines. Ch 6.3. pp 110 - 116 (in the above publication).
- 'Magarey, P.A. *et al.* (1999). *The Australian and New Zealand Field Guide to Diseases, Pests and Disorders of Grapes.* - to view symptoms of sulphur burn on bunches and to help correctly diagnose other disease symptoms. This service is also available online at www.growcare.com.au.
- See also http://www.mvwi.com.au/weather_station_data/ for MVWI weather data to assess the risk of sulphur burning in your vineyard.