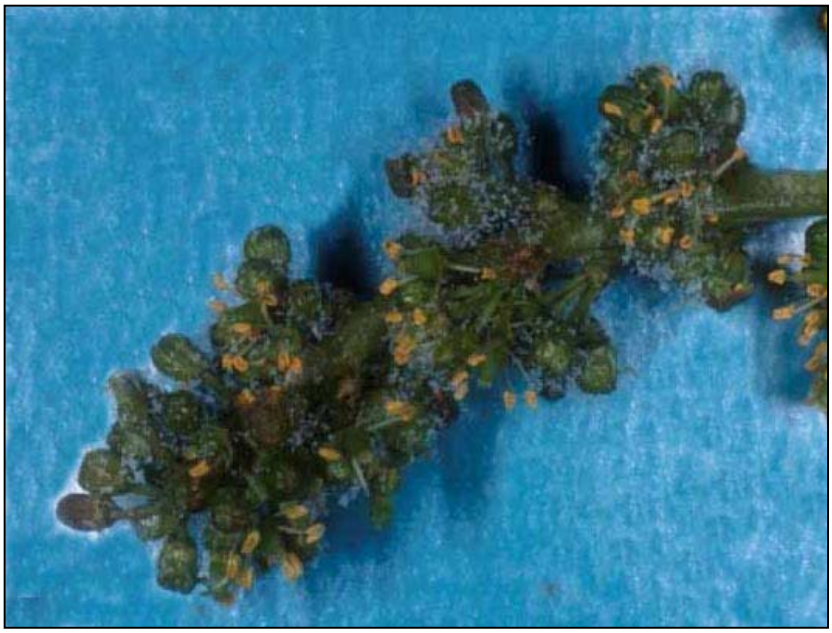
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SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

Australian Government

Grape and Wine Research and Development Corporation

Strategic Management of Flowering Sprays



FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT

Project Number: **SAR 03/03**

Principal Investigator: **Dr Trevor Wicks**

Research Organisation: **SA Research & Development Institute**

Date: **28 August 2007**

Strategic management of flowering sprays

GWRDC Final Report

Project no. SAR 03/03

Principal Investigators: Ms Lee Bartlett, Mrs Barbara Hall

Project Supervisor: Dr Trevor Wicks

South Australian Research & Development Institute

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1. Abstract

This project was undertaken to determine if fungicides applied during flowering are detrimental to fruit set. Laboratory and field experiments were carried out over 4 years to determine the effect of fungicides on fruit set, compare fungicide toxicity when applied during the flowering period, and whether there are differences between grape cultivars or climatic regions.

Saprophytic fungi and *Botrytis* were detected on anthers at flowering, with variations observed between the cultivars, area and season. Cabrio® and Filan® reduced the levels of fungi detected on anthers at flowering, and more fungi were detected on anthers from the cooler Lenswood region compared to Nuriootpa. When pollen viability was tested *in vitro* on agar amended with one of 9 fungicides, Rovral® and Filan® were the least inhibitory to pollen viability, and copper the most inhibitory, with no germination observed. However when fungicides were applied to inflorescences, the inhibitory effect on pollen viability was reduced compared to direct contact with amended agar.

The effect on fruit set of fungicides applied at flowering varied between treatments, grape cultivars and year of application, but there was no stand out treatment that consistently inhibited fruit set. There was no consistent correlation between high levels of stuck caps and inhibition of fruit set. Fungicides containing copper did not consistently increase the levels of stuck caps on flowers, however in some trials (but not all) there was a reduction in fruit set.

Overall these studies have shown that the application of commonly used fungicides during the flowering period is unlikely to significantly inhibit fruit set.

2. Executive Summary

Fungicides are often applied to grapes during full bloom. Although it is well known that some fungicides inhibit germination and growth of pollen in other crops, little research has been done on grapes. Poor fruit set has been reported from different grape growing areas over many seasons and has often been attributed to the application of fungicides at flowering. Laboratory and field studies were therefore undertaken to determine if fungicides applied to grapes during flowering were detrimental to fruit set.

Studies were first undertaken to determine the effect of fungicides on the fungal infection of flowers. Mainly saprophytic fungi were found on flower parts, including *Alternaria*, *Cladosporium, Ulocladium*, *Stemphylium* and *Penicillium*. The pathogen *Botrytis* was also detected in some bunches. Of the 16 fungicides evaluated, Cabrio® and Filan® were the most effective in reducing flower infection on five different cultivars.

In vitro studies were also carried out to determine the effect of fungicides on pollen vitality and viability. Despite problems that developed with the long-term storage of pollen, the results showed that of the 9 fungicides tested, Rovral® and Filan® were the least inhibitory to pollen viability when tested at 1 or 5ppm. On the other hand, no pollen germinated on agar amended with copper oxychloride at similar concentrations. Other fungicides only partially inhibited pollen germination and germ tube elongation. However fungicides applied to inflorescences were less inhibitory to pollen compared to their effect *in vitro*. For example copper fungicides that were lethal *in vitro* were only slightly inhibitory when applied to the flowers.

Field studies were undertaken over four seasons and on different cultivars to determine the effect on fruit set of fungicides applied during flowering. In these experiments the number of "stuck caps" was also measured as it was considered that this may affect the ability of the flower to be pollinated. Over 20 commonly used fungicides were evaluated at recommended rates. Both the percent stuck caps and fruit set varied between treatments, grape cultivars and year of application, but there was no stand out treatment that consistently inhibited fruit set. There was also little difference in fruit set or stuck caps where fungicides were applied either early (10 – 20%) or late (50 – 80%) flowering.

As fungicides containing copper were the most inhibitory to pollen growth and in some experiments reduced fruit set, two experiments were set up to compare copper fungicides. In one experiment Cuprofix® and Kocide® were more inhibitory to fruit set than copper oxychloride or Ridomil Gold Plus®. In the other experiment, copper oxychloride was the most inhibitory.

Fruit set was also measured in a number of experiments when fungicides were applied at flowering, but incorporated into multiple spray programs with other fungicides applied at 10-14 day intervals. In these trials none of the fungicides or fungicide combinations such as Kocide® plus Rubigan®, Scala® plus Flint®, Thiovit® plus Scala® or Thiovit® plus Kocide® were detrimental to fruit set.

Overall the main findings from these studies are that the application of fungicides during flowering is unlikely to significantly inhibit fruit set. The one exception is fungicides containing copper, as laboratory studies found that these materials inhibited pollen completely, and in some (but not all) field experiments, were slightly inhibitory to fruit set.

As flower clusters are highly susceptible to diseases such as downy mildew, powdery mildew and *Botrytis*, the potential complete loss of fruit from these diseases as a result of not applying fungicides during flowering far outweigh the minimal effect on fruit set and yield by applying fungicides.

3. Background

A number of different fungicides are regularly applied to grapes during the flowering period to control disease such as powdery mildew, downy mildew and Botrytis bunch rot. Although there are few scientific studies in this area, poor fruit set in many grape growing areas has been attributed to the application of fungicides during flowering.

On other crops, fungicides applied during flowering have inhibited pollen growth. For example, the strobilurin fungicide kresixom-methyl and surfactant Triton both inhibited pollen growth in apples, but the surfactant was applied at ten times the recommended rate (Kopcke *et al* 2002). In pecans, weekly applications of sulphur inhibited pollen germination in one season, but not in another, showing that the seasonal weather influenced the toxicity of the fungicides (He & Wetzstein, 1994).

Of the work reported on grapes, Dye & Hammett (1977) found that neither benomyl or thiram applied twice during flowering caused visible damage or reduced yields, whereas the bactericide streptomycin applied at this time reduced fruit set. Differences in fungicide toxicity to pollen of different grape cultivars were reported by Nikolov *et al* (1999). They found that cuprous fungicides inhibited pollen germination on Bolgar and Cabernet Sauvignon, whereas mancozeb and metalaxyl were inhibitory only to Cabernet Sauvignon pollen.

Poor fruit set was widespread in many grape-growing areas in the 2001/02 season. Whilst this has been attributed to a cool period during flowering, other factors such as the application of fungicides and rain over the flowering period may also be involved with poor set. Little Australian data is available on these factors, although as reported overseas some fungicides inhibit pollen germination and development.

4. Project Aims and Performance Targets

Aims:

1. To determine if fruit set is influenced by fungicides applied during flowering.
2. To identify the materials most detrimental when applied during flowering.
3. To determine if fungal infections at flowering influence fruit set.
4. To determine if varietal and/or climatic region influence the fungicidal effect at flowering.

Performance targets:

1. Isolation of fungi from flower parts from different cultivars in different geographic locations.
2. Fungicide effects on pollen viability and vitality measured after application to bunches at mid flowering.
3. Data collected on fruit set and yield after application of fungicides at flowering.
4. Data collected on fruit set in various different cultivars, regions and spray regimes.
5. Results presented at industry meetings and in industry journals.

5. Technical report

All trials were undertaken on grapevines either at the Lenswood Research Centre in the Adelaide Hills, a cool growing region approximately 30km East of Adelaide, or at the Nuriootpa Research Centre in the Barossa Valley, a warmer growing region approximately 80km North East of Adelaide.

1. Products and formulations

The following fungicides were used throughout the trials at their recommended rates unless otherwise specified.

Common Name	Active ingredient	Recommended rate/100L
Acrobat®	500g/kg dimethomorph	36g
Amistar®	500g/kg azoxystrobin	50g
Bavistin®	500g/L carbendazim	100ml
Bayfidan®	250g/L triamenol	10ml
BioCover®	98% petroleum oil	500ml
Bravo®	720g/L chlorothalonil	200ml
Cabrio®	250ml/L pyraclostrobin	40ml
Champ®	375g/kg cupric hydroxide	175g
Copper oxychloride	500g/kg copper oxychloride	250g
Cuprofix®	120g/kg tribasic copper sulphate	250ml
Dithane Rainshield®	750g/kg mancozeb	200g
Domark®	100g/L tetraconazole	30ml
Ecocarb®	940g/kg potassium bicarbonate	300g
Filan®	500g/kg boscalid	120g
Flint®	500g/kg trifloxystrobin	150g
Kocide Blue Xtra®	350g/kg copper hydroxide	190g
Legend®	250ml/L quinoxyfen	20ml
Liquicop®	93g/L copper ammonium acetate	500ml
Mycloss Xtra®	200g/L myclobutanil	16ml
Polyram®	700g/kg metiram	160g
Prosper®	500ml/L spiroxamine	60ml
Ridomil Gold MZ®	40g mefenoxam+ 640g/kg mancozeb	250g
Ridomil Gold Plus®	50g mefenoxam+ 600g/kg copper hydroxide	225g
Rovral®	250ml/L iprodione	200ml
Rubigan®	120g/L fenarimol	20ml
Teldor®	500g/L fenhexamid	100ml
Scala®	400g/L pyrimethanil	200ml
Serenade®	10% QST 713 strain dried *Bacillus subtilis*	400g
Switch®	250g fludioxonil + 375g/kg cyprodinil	80g
Systhane®	200g/L myclobutanil	25ml
Topas®	100ml/L penconazole	125ml
Thiovit Jet®	800g/kg sulphur	600g

2. Studies on fungal infections of flowers

2.1. Fungi present at flowering.

Inflorescences were collected at 50-80% flowering from different cultivars at Nuriootpa and Lenswood during the 2005/6 season to determine what fungi were present on the flowers.

Materials and Methods.

20 basal inflorescences at similar stages of anthesis on shoots with two inflorescences were collected from 6 different cultivars (Chardonnay, Sauvignon Blanc, Semillon, Cabernet Sauvignon, Merlot, Pinot). The inflorescences were placed into paper bags and stored for up to 2 weeks in a coolroom at 4^{o}C until processed.

Using sterile forceps, 20 flowers/inflorescence were removed at random from over the whole inflorescence and 5 individual anthers per plate were placed onto 2 plates of tap water agar (TWA) and 2 plates of ½ strength potato dextrose agar (PDA) agar. One plate of each agar was then incubated at 15^{o}C and 22^{o}C. After at least 2 weeks incubation, the anthers were assessed for the presence of fungi.

Results.

The main fungi detected in all cultivars were *Alternaria* and *Cladosporium* (Table 1a, Appendix 5). These are common saprophytic fungi that can be detected on a wide range of plant material and are unlikely to cause damage to the flowers. As there was no significant difference in levels of fungi detected between the two incubation temperatures or the different agar types, the data has been combined. Often more than one organism was detected on one anther.

Overall, fewer fungi were detected at the warmer region of Nuriootpa, most likely a result of the higher humidity and rainfall occurring at Lenswood during the flowering period.

Botrytis was detected in all cultivars in both regions, indicating the potential for latent infection in these bunches. The highest levels of *Botrytis* were detected in Merlot at Nuriootpa and Pinot at Lenswood. The levels in the Merlot were unexpected, as this area

does not have high levels of bunch rot. However high levels in the Pinot may be the result of high inoculum load in the vineyard where vines have been artificially inoculated for several seasons in trials on Botrytis bunch rot management.

There was significant variation in the anther infection between cultivars. For example 90% of anthers on Cabernet at Lenswood were infected, compared to 26% infection on Semillon at Nuriootpa.

Other organisms detected in low numbers were also common saprophytes, including bacteria, yeast and the fungi *Ulocladium, Penicillium, Stemphyllium* and *Fusarium* (Appendix 5).

Over the three seasons of testing, the level of fungi and other organisms detected on untreated anthers varied significantly (Table 1b). For example no infection was detected on over 34% of Chardonnay anthers in 2005/6, compared to 15% in 2003/4 and 0% in 2006/7.

Table 1a. Percent of anthers with fungi present in the cultivars tested in each region (Nuri = Nuriootpa, Lens = Lenswood).

Variety	***Cladosporium***		***Alternaria***		***Botrytis***		**No organisms**	
	Nuri	**Lens**	**Nuri**	**Lens**	**Nuri**	**Lens**	**Nuri**	**Lens**
Chardonnay	35.8 a	52.2 b	20.5 b	5.3 c	0.3 c	2.0 b	41.8 c	34.7 d
Sauvignon Blanc	15.2 c	38.8 c	6.0 c	5.5 c	1.0 bc	2.8 b	73.3 a	45.8 bc
Semillon	9.0 d	31.3 cd	4.6 c	3.2 c	2.6 b	2.1 b	74.4 a	53.9 a
Cabernet Sauvignon	23.0 b	65.6 a	14.2 b	16.7 a	0.2 c	2.8 b	58.5 b	10.4 e
Merlot	23.8 b	47.7 b	15.5 b	3.8 c	6.3 a	2.8 b	49.5 c	38.5 cb
Pinot	14.6 cd	26.8 d	32.6 a	9.5 b	1.0 bc	6.5 a	49.0 c	48.3 ab

Treatments with the same letter are not significantly different from one another (P=0.05).

Table 1b. Percent of anthers with no organisms detected at Lenswood, 2003/4, 2005/6 and 2006/7.

Season	**Chardonnay**	**Sauvignon Blanc**	**Semillon**	**Cabernet Sauvignon**	**Merlot**	**Pinot Noir**
2003/04	15	-	-	-	-	-
2005/06	34.7	45.8	53.9	10.4	38.5	48.3
2006/07	0.0	0.0	0.0	-	0.0	1.0

2.2. Effect of fungicides on fungi present at flowering.

Fungicides were applied to inflorescences at 50-80% from different cultivars and regions during the 2003/4 and 2006/7 seasons to determine if the treatments inhibited the development of fungi on the flowers.

Materials and Methods.

Experiment 1. In the 2004/5 season, fungicides (Table 2) were applied at the recommended rate using a hand held atomiser to 10 inflorescences at similar stages of anthesis on Chardonnay vines at Lenswood. Inflorescences either unsprayed or sprayed with water were used as controls.

Using sterile forceps, 10 flowers/inflorescence were removed at random from over the whole inflorescence and 5 individual anthers per plate were placed onto 1 plate of TWA and 1 plate of ½ PDA. After at least 2 weeks incubation at 22^{o}C, the anthers were assessed for the presence of fungi.

Experiment 2. In the 2006/7 season, fungicides (Table 3) were applied at the recommended rate using a hand held atomiser to 5 basal inflorescences at similar stages of anthesis on shoots with two inflorescences. Five cultivars were treated (Chardonnay, Sauvignon Blanc, Semillon, Merlot, Pinot) at Lenswood, with inflorescences either unsprayed or sprayed with water used as controls. The bunches were allowed to dry, then collected and placed into paper bags and stored for up to 2 weeks in a coolroom at 4^{o}C until processing.

Using sterile forceps, 20 flowers/inflorescence were removed at random from over the whole inflorescence and 5 individual anthers per plate were placed onto 2 plates of TWA and 2 plates of ½ PDA. One plate of each agar was then incubated at 15^{o}C and 22^{o}C. After at least 2 weeks incubation, the anthers were assessed for the presence of fungi.

Results.

The application of fungicides at flowering had variable effects on the development of fungi on anthers (Table 2, Appendix 5). The application of water alone reduced the number of anthers with fungi present, which was unexpected as it was assumed this treatment would increase the

humidity and provide an environment more conducive to the development of fungi. Copper was the most inhibitory as significantly fewer anthers were infected compared to the other treatments.

Table 2. Percent of anthers with fungi detected after application of various fungicides, 2004/5, Lenswood, cv. Chardonnay.

Treatment	***Cladosporium***	***Alternaria***	***Botrytis***	**Other**	**No fungi**
Untreated	70	3	0	12	15
Water	50	1	0	19	30
Kocide®	47	0	0	9	44
Thiovit®	48	1	0	38	22
Topas®	44	3	0	30	23

However in 2006/7, the application of water both increased and decreased the level of fungi detected on anthers, depending on the fungi and the cultivar tested (Table 3a, Appendix 5). Of the 16 fungicides evaluated, Flint® and Cabrio® were the most effective in reducing the levels of fungi detected on anthers in all cultivars (Table 3b).

Table 3a. Percent of anthers with fungi detected, collected from inflorescences of different cultivars either untreated or treated with water at flowering, Lenswood 2006/7.

Cultivar	***Cladosporium***		***Botrytis***		**No organisms detected**	
	Untreated	**Water**	**Untreated**	**Water**	**Untreated**	**Water**
Chardonnay	82.0	71.0	0.0	1.0	0.0	0.0
Merlot	78.8	81.0	2.5	0.0	0.0	0.0
Pinot	71.4	41.9	0.0	1.9	1.0	0.0
Sauvignon	82.0	57.0	0.0	2.0	0.0	3.0
Semillon	56.0	71.0	0.0	1.0	0.0	0.0

Table 3b. Percent of anthers where no fungi developed on inflorescences treated with fungicides at flowering, Lenswood 2006/7.

Treatment	Pinot	Merlot	Chardonnay	Sauvignon Blanc	Semillon
Untreated	1.0	0.0	0.0	0.0	0.0
Water	0.0	0.0	0.0	3.0	0.0
Bavistin®	3.0	8.0	0.0	3.0	1.0
Bravo®	4.0	17.0	-	0.0	4.0
Cabrio®	25.0	13.8	-	14.0	11.0
Dithane Rain Shield®	8.4	1.0	-	4.0	0.0
Filan®	2.1	2.0	0.0	7.0	2.0
Flint®	4.5	17.5	12.0	22.0	11.0
Kocide®	0.0	1.0	-	1.0	2.0
Mycloss Xtra®	2.7	0.0	-	2.0	2.0
Ridomil Gold Plus®	5.7	0.0	-	0.0	0.0
Ridomil Gold MZ®	0.0	0.0	1.0	2.0	2.0
Rubigan®	0.0	0.0	-	5.0	-
Scala®	0.0	1.0	-	0.0	0.0
Switch®	8.4	11.0	-	2.0	4.0
Teldor®	0.0	1.0	-	0.0	0.0
Thiovit Jet®	2.5	1.0	-	0.9	0.0
Topas®	7.0	12.0	0.0	3.0	4.0

3. Pollen studies

3.1. Effects of fungicides on pollen viability and vitality.

Experiments were undertaken to determine if commonly used fungicides were detrimental to pollen viability (the ability of the pollen to germinate) or vitality (whether the pollen is living). Initially pollen was germinated onto agar amended with various fungicides, however it was decided that a more realistic effect would be to spray flowering clusters in the field, then test the pollen to assess the effect.

Material and Methods.

Experiment 1. Flower clusters were removed from Chardonnay vines (Lenswood 2004) at the onset of flowering, with caps still in place. Whole clusters were carefully rubbed over a 1mm sieve to remove the caps and expose and remove anthers. The sieved material was placed into a petri dish with the lid slightly ajar, and dried either in an oven for approximately 24 hours at 25^{o}C, or in a desiccator containing silica gel for approximately 24 hours. The material was sieved again through a 0.7mm sieve and the sieved material vacuumed into either a test tube or an eppendorf tube. A fine paint brush was used to wipe the side of the test tube to collect the pollen grains, which were then carefully dabbed onto an agar plate containing sucrose germination media (Appendix 6), which was either unamended or amended with various concentrations of fungicides (Table 4). After 6 hours incubation at 25^{o}C, spore germination of at least 100 pollen and the length of the germ tube on at least 20 germinated pollen on each of 4 replicate plates was measured.

Experiment 2. Fungicides (Table 5) were applied at recommended rates with a hand atomiser to inflorescences at approximately 50% capfall, cv. Chardonnay at Lenswood in November 2004. After the clusters had dried, pollen was collected from the treated inflorescences as previously described and placed onto the sucrose media. The effect on the pollen was measured after 6 hours incubation at 25^{o}C by counting spore germination of at least 100 pollen and the length of the germ tube on at least 20 germinated pollen on each of 4 replicate plates.

This experiment was repeated with additional fungicides in Spring 2005 and 2006, however the germination of the pollen was erratic and too low to obtain reliable results.

Experiment 3. Fungicides were applied in 2005 (Table 6) with a hand atomiser at recommended rates to 5 Chardonnay inflorescences at approximately 50% capfall. Treatments were applied at random using shoots with two inflorescences. Inflorescences either untreated or sprayed with water were used as controls. Pollen was collected as previously described into eppendorf tubes and stored at $-80^{o}C$ for up to 2 months until required for testing (Heazlewood et al 2005).

Pollen was stained using the vital stain fluorescin diacetate (FDA) (Longbotton & Dry 2004) and fluorescing and non-fluorescing pollen grains were counted using fluorescence microscopy to determine the percentage of viable pollen grains for each treatment. At least 100 grains were counted for each replicate inflorescence.

Several tests for pollen viability were undertaken, including plating onto variations of the sucrose media as previously described (Appendix) and the hanging drop method (Heazlewood et al 2005). However while the frozen pollen was able to be stained and measured for vitality, it would not germinate sufficiently with any of the methods used to measure germ tube elongation.

This experiment was repeated in 2006 (Table 7), using 10 replicate inflorescences per treatment on 4 cultivars, Chardonnay, Merlot, Pinot and Sauvignon Blanc. Pollen from 5 of the inflorescences was collected into eppendorf tubes and stored at $-80^{0}C$ as previously described. The other inflorescences were stored in the coolroom at $4^{0}C$. Neither method provided pollen that would germinate sufficiently for viability assessments. The freeze-dried pollen was also not vital, however pollen collected from the coolroom stored inflorescences were stained and assessed for vitality.

Results.

Experiment 1. All fungicides inhibited germination and germ tube length when pollen was grown on agar amended with fungicide (Table 4). No pollen germinated on agar amended with copper whereas Rovral® and Filan® had the least detrimental effect to pollen viability. When repeated with 5 of the fungicides, the inhibition of the germ tube length was similar, however more pollen had germinated.

Table 4. Effect of fungicide amended agar on the germ tube length and percent germination of Chardonnay pollen grains, calculated as a percent of the values measured on the unamended agar.

Fungicide	**Rate of active ingredient (ppm)**	**Germ tube length as % of unamended**		**% Germination as % of unamended**	
		Expt 1a.	**Expt 1b.**	**Expt 1a.**	**Expt 1b.**
Bavistin®	1	60.5	57.4	32.7	121.8
Bavistin®	5	17.4	17.8	11.0	40.8
Cabrio®	1	19.2	-	-	-
Copper oxychloride	1	0	-	0	-
Copper oxychloride	5	0	-	0	-
Filan®	1	82.9	-	-	-
Filan®	5	83.8	-	-	-
Flint®	1	21.1	16.5	0.9	3.4
Flint®	5	7.9	6.4	1.0	3.8
Rovral®	1	88.5	-	81.0	-
Rovral®	5	63.7	-	78.5	-
Scala®	1	32.3	30.3	22.6	84.2
Scala®	5	37.6	23.2	17.5	65.3
Thiovit®	1	17.9	8.1	4.5	21.4
Thiovit®	5	17.4	13.1	5.7	16.8
Topas®	0.5	14.9	12.5	12.8	47.8
Topas®	1	17.9	15.2	4.5	16.8

Experiment 2. Fungicides applied to the inflorescences were less inhibitory to pollen compared to the inhibition *in vitro* (Table 5). For example copper was lethal to pollen germinated in direct contact with the fungicide in amended agar, but only reduced germination of pollen to 73% (calculated as a percentage of the untreated control). Topas® was the most inhibitory to pollen germination, but did not inhibit germ tube growth.

Table 5. Effect of fungicide applications at flowering on the germ tube length and percent germination of Chardonnay pollen grains, calculated as a percent of the values measured in the untreated control.

.**Treatment**	**Germ tube length as % of untreated**	**% Germination as % of untreated**
Copper oxychloride	72.9	73.1
Thiovit®	96.3	82.9
Topas®	108.2	43.7

Experiment 3. In the 2006 trial, all treatments except Amistar® reduced the vitality of the pollen when compared to the untreated control (Table 6). However the application of water alone with no fungicide also significantly reduced vitality. Kocide® was the most inhibitory to pollen vitality. Pollen germination results were extremely variable and ranged from only 0 to 20%. As a result the germination results are not reliable.

Table 6. Effect of fungicide applications at flowering on the vitality and viability of Chardonnay pollen grains, calculated as a percent of the values measured in the untreated control.

Treatment	Mean vitality as % of untreated	Mean vitality as % of water treatment	% Germination as % of untreated*
Water	71.2	-	44.7
Amistar®	103.4	145.2	59.4
Cabrio®	83.1	116.8	52.8
Filan®	79.5	111.7	33.4
Flint®	72.3	101.5	79.8
Kocide®	66.5	93.4	19.5
Ridomil Gold MZ®	83.6	117.4	10.9
Scala®	73.3	103.0	-
Thiovit®	76.5	107.5	134.4
Topas®	84.9	119.3	129.9

* Germination was variable and very low in all treatments, between 0 and 20%.

However in 2007, the water treatment was less inhibitory to pollen. Pollen tested was from the coolroom stored inflorescences, as the freeze-dried and frozen pollen was no longer vital. The effect of the fungicides on the pollen vitality was variable, particularly between the different cultivars (Table 7), with vitality of the Sauvignon Blanc pollen being the least affected by the fungicides. Copper products (Kocide® and Ridomil Gold Plus®) again reduced vitality of Chardonnay pollen, however vitality of the Sauvignon Blanc pollen was increased in the presence of copper.

Merlot pollen was the most affected by all fungicide treatments, however this is most likely as a result of the storage method, as some of the treatments with the lowest vitality had been stored in paper bags. The vitality of all other cultivars stored in plastic was much higher than those of Merlot.

Table 7. Effect of fungicide applications at flowering on the vitality of pollen grains from different cultivars, calculated as a percent of the values measured in the water treated control.

Treatment	Chardonnay	Sauvignon Blanc	Merlot	Pinot Noir
Bavistin®	102.9	93.6	-	118.6
Bravo®	125.0	98.5	35.6*	93.9
Cabrio®	102.1	92.2	80.3*	109.8
Dithane Rain Shield®	80.7	102.4	-	89.2
Filan®	89.6	99.8	-	-
Flint®	91.7	106.4	50.0*	84.9
Kocide®	82.2	104.1	41.2*	71.3
Mycloss®	108.2	91.0	77.5	107.7
Ridomil Gold MZ®	91.3	73.9	32.6*	104.5
Ridomil Gold Plus®	88.8	92.9	49.1	72.4
Rubigan®	94.5	84.4	72.9	99.1
Scala®	127.9	111.1	39.2*	110.1
Switch®	121.6	97.3	87.5	127.5
Teldor®	123.2	100.5	61.2*	107.1
Thiovit®	86.8	117.3	40.3	86.1
Topas®	89.8	96.1	39.6*	89.9

* Inflorescences were stored in paper bags instead of plastic, so vitality may have been reduced by the storage method.

4. Field Studies

The effect of fungicides applied during flowering on fruit set was assessed over several years on different cultivars. The effect of various spray programs on fruit set and components of yield was also assessed in several trials.

4.1. Effect of fungicides applied at flowering on fruit set.

Materials and Methods.

To determine fruit set, inflorescences were enclosed in mesh bags prior to anthesis. At either approximately 10-20% or 50 to 80% flowering (EL 23-25), the mesh bags were temporarily removed to allow the application of a commonly used fungicide at the recommended rate using a hand atomiser. Replicates of 5 inflorescences per treatment were used, with either water or no treatment as the control. At the completion of flowering, the caps collected in the bag were counted to determine the number of flowers per bunch. At approximately EL33 (berries pea size), the bunches were removed and the number of berries, live green ovaries (LGO's), and stuck flower caps were assessed. Percent fruit set was calculated as:

*No. berries per bunch not including LGO's /No. flowers per bunch)*100.*

Stuck caps were defined as any cap still attached to the flower and obscuring the anthers. If a cap was still attached, but was not affecting the ability of the flower to be pollinated, it was not classed as a stuck cap. Between 3 and 5 of the inflorescences were assessed for each treatment, as some had died or detached between treatment and assessment.

Experiment 1. Chardonnay vines at Lenswood 2005/6, fungicides applied at 50-80% flowering.
Experiment 2. Merlot and Sauvignon Blanc vines at Lenswood, 2006/7, fungicides applied at 50-80% flowering.
Experiment 3. Merlot and Sauvignon Blanc vines at Nuriootpa, 2006/7, fungicides applied at either 10-20% or 50-80% flowering.

Results.

Over the 3 experiments, the results were so variable that it was not possible to determine if any one fungicide consistently affected fruit set or caused stuck caps. In some experiments a relationship between high levels of stuck caps and low fruit set was obvious, however this was also not consistent and high levels of stuck caps did not consistently correspond to low fruit set.

Experiment 1. The level of stuck caps was not significantly different between the fungicide treatments, although both controls had no caps stuck and Kocide® had the highest level of 5.8% (Table 8). All fungicides reduced the level of fruit set, with Ridomil Gold Plus® having the lowest level of 30% fruit set compared to 52% in the water treated control.

Table 8. Effect of fungicides on fruit set and stuck caps when applied at 50-80% flowering cv. Chardonnay, Lenswood 2005/6.

Treatment	% Fruit set	% Stuck caps
Untreated	57.3 a	0.0 a
Water	52.0 ab	0.0 a
Acrobat®	38.9 cde	4.2 a
Amistar®	40.4 cde	4.0 a
Bavistin®	41.3 bcd	2.1 a
Bayfidan®	40.9 bcde	3.6 a
Bravo®	36.4 cde	1.1 a
Cabrio®	40.1 cde	4.5 a
Dithane Rain Shield®	37.3 cde	4.2 a
Domark®	42.0 bcd	3.3 a
Filan®	45.7 bc	5.1 a
Flint®	44.3 bc	2.7 a
Kocide®	38.7 cde	5.8 a
Legend®	44.3 bcd	0.0 a
Polyram®	42.3 bcd	0.6 a
Prosper®	47.0 abc	0.0 a
Ridomil Gold Plus®	30.0 e	2.1 a
Rubigan®	43.4 bcd	3.8 a
Scala®	32.5 de	1.0 a
Switch®	43.0 bcd	2.5 a
Systhane®	44.9 bc	3.5 a
Teldor®	47.2 abc	3.4 a
Thiovit®	42.0 bcd	1.1 a
Topas®	39.5 cde	2.9 a

Experiment 2. Due to the variation between the bunches, there was no statistically significant difference between any of the treatments in the % fruit set and % stuck caps of the Sauvignon Blanc vines (Table 9). However there were differences observed between the treatments on the Merlot assessment, which generally had higher levels of stuck caps. Teldor® and Thiovit® had high levels of stuck caps in both varieties, however only in the Merlot was there a corresponding significant decrease in fruit set. While Filan® also had high levels of stuck caps in both varieties, the decrease in fruit set in the Merlot was not significantly different from either the untreated or water sprayed controls. The Scala® treated Merlot had very high levels of stuck caps in three of the four inflorescences assessed, however this effect was not observed in any of the other experiments with this fungicide.

Table 9. Effect of fungicides on fruit set and stuck caps when applied at 50-80% flowering cvs. Sauvignon Blanc and Merlot, Lenswood 2006/7.

Treatment	% Fruit set		% Stuck caps	
	Sauvignon Blanc	**Merlot**	**Sauvignon Blanc**	**Merlot**
Untreated	41.4 a	33.7 ab	9.0 a	5.2 c
Water	48.3 a	31.8 abc	11.0 a	5.6 c
Bravo®	45.4 a	29.7 abc	2.6 a	4.8 c
Cabrio®	61.1 a	22.8 abcd	0.8 a	6.1 c
Filan®	46.8 a	21.5 abcd	15.5 a	31.2 b
Flint®	45.7 a	35.6 a	1.4 a	13.2 bc
Kocide®	33.9 a	35.2 ab	3.5 a	5.5 c
Mycloss Xtra®	41.4 a	26.1 abcd	6.6 a	5.2 c
Ridomil Gold MZ®	73.5 a	29.5 abc	2.4 a	4.7 c
Ridomil Gold Plus®	34.9 a	24.9 abcd	1.4 a	21.5 bc
Rubigan®	56.6 a	27.5 abc	4.2 a	5.7 c
Scala®	44.7 a	21.0 bcd	5.7 a	60.1 a
Switch®	47.7 a	28.9 abc	1.2 a	3.4 c
Teldor®	48.9 a	17.5 cd	13.4 a	15.4 bc
Thiovit Jet®	53.1 a	12.7 d	10.0 a	17.5 bc
Topas®	-	19.1 cd	-	14.6 bc

Treatments with the same letter are not significantly different from one another (P=0.05).

Experiment 3. Again the variation between bunches meant there was no statistically significant difference in the number of stuck caps between any of the treatments of either application time for either variety (Tables 10, 11). However there were some differences in the fruit set, and between the different application times. Both Filan® and Ridomil Gold Plus® had significantly higher levels of stuck caps when applied at early flowering on both the Merlot and Sauvignon Blanc. However a corresponding significant decrease in fruit set was only observed in the Sauvignon Blanc, in the Merlot the fruit set actually increased.

Overall there was no difference in either of the parameters between the different spraying times in the Sauvignon Blanc, however the Merlot had a slightly higher level of stuck caps when fungicides were applied at early flowering.

For both cultivars, fungicides applied at Lenswood in late flowering resulted in higher levels of stuck caps (Table 12), however this did not correspond to a decrease in fruit set. In addition, there was a greater variation in levels of stuck caps in the cooler region of Lenswood compared to Nuriootpa. Merlot had higher levels of stuck caps and lower fruit set than Sauvignon Blanc in both regions.

Table 10. Effect of fungicides on fruit set and stuck caps when applied at 2 stages of flowering cv. Sauvignon Blanc, Nuriootpa 2006/7.

Treatment	% Stuck caps		% Fruit set	
	10-20%	**50-80%**	**10-20%**	**50-80%**
Untreated	1.8 a	0.8 a	45.2 a	62.9 a
Water	1.0 a	2.3 a	34.2 a	34.5 ab
Bavistin®	1.0 a	4.3 a	51.4 a	56.9 ab
Bravo®	2.3 a	1.3 a	27.6 a	**59.9 ab
Cabrio®	0.9 a	0.3 a	41.1 a	44.2 ab
Dithane®	1.2 a	0.0 a	64.9 a	46.5 ab
Filan®	5.9 a	**2.4 a	31.7 a	**53.2 ab
Flint®	2.2 a	1.7 a	34.6 a	53.5 ab
Kocide®	0.3 a	0.8 a	60.3 a	54.3 ab
Mycloss Xtra®	3.0 a	0.5 a	56.6 a	60.9 a
Ridomil Gold MZ®	0.4 a	5.6 a	37.5 a	29.3 ab
Ridomil Gold Plus®	1.6 a	**1.4 a	36.8 a	38.7 ab
Rubigan®	0.8 a	1.2 a	33.3 a	34.8 ab
Scala®	3.3 a	6.1 a	31.8 a	24.9 b
Switch®	1.9 a	2.7 a	25.1 a	45.2 ab
Teldor®	4.3 a	1.2 a	42.5 a	52.5 ab
Thiovit Jet®	1.7 a	1.5 a	43.0 a	34.1 ab
Topas®	2.5 a	3.2 a	42.9 a	42.4 Ab
Mean of all treatments	2.0	2.1	41.1	46.0

Treatments with the same letter are not significantly different from one another (P=0.05).

** The 10-50% and 50-80% measurements are significantly different (P=0.05).

Table 11. Effect of fungicides on fruit set and stuck caps when applied at 2 stages of flowering cv. Merlot, Nuriootpa 2006/7.

Treatment	% stuck caps		% fruit set	
	10-20%	**50-80%**	**10-20%**	**50-80%**
Water	15.8 a	10.2 a	22.6 ef	26.7 cde
Bavistin®	12.5 A	10.2 a	32.9 bcde	29.4 cde
Bravo®	17.6 a	**13.5 a	22.0 ef	25.6 cde
Cabrio®	12.6 a	8.5 a	47.5 a	45.2 ab
Dithane®	23.2 a	11.3 a	46.6 ab	29.4 cde
Filan®	20.8 a	**11.1 a	28.4 def	19.7 ef
Flint®	8.5 a	8.9 a	26.8 def	24.5 de
Kocide®	22.3 a	**8.1 a	30.7 cde	25.3 cde
Mycloss Xtra®	14.6 a	10.9 a	29.7 cde	33.1 bcd
Ridomil Gold MZ®	10.1 a	9.5 a	15.9 f	**8.7 f
Ridomil Gold Plus®	18.6 a	**7.1 a	23.2 def	22.4 def
Rubigan®	13.9 a	13.6 a	48.8 a	50.5 a
Scala®	18.2 a	10.8 a	37.4 abcd	27.0 cde
Switch®	14.8 a	15.0 a	41.4 abc	39.0 abc
Teldor®	14.5 a	10.7 a	41.9 abc	30.1 cde
Thiovit Jet®	15.8 a	8.4 a	23.4 def	21.4 def
Topas®	12.8 a	13.0 a	27.7 def	25.1 De
Mean of all treatments	15.7	10.6	32.2	28.4

Treatments with the same letter are not significantly different from one another (P=0.05).

** The 10-50% and 50-80% measurements are significantly different (P=0.05).

Table 12. Effect of fungicides on fruit set and stuck caps when applied at 50-80% flowering cv. Merlot, Sauvignon Blanc at Nuriootpa and Lenswood, 2006/7.

Treatment	% Stuck caps				% Fruit set			
	Sauvignon blanc		Merlot		Sauvignon blanc		Merlot	
	Nuri	Lens	Nuri	Lens	Nuri	Lens	Nuri	Lens
Untreated	0.8	9.0		5.2	62.9	41.4	-	33.7
Water	2.3	11.0	10.2	5.6	34.5	48.3	26.7	31.8
Bavistin®	4.3	-	10.2	-	56.9	-	29.4	-
Bravo®	1.3	2.6	13.5	4.8	59.9	45.4	25.6	29.7
Cabrio®	0.3	0.8	8.5	6.1	44.2	61.1	45.2	22.8
Dithane®	0.0	-	11.3	-	46.5	-	29.4	-
Filan®	2.4	15.5	11.1	31.2	53.2	46.8	19.7	21.5
Flint®	1.7	1.4	8.9	13.2	53.5	45.7	24.5	35.6
Kocide®	0.8	3.5	8.1	5.5	54.3	33.9	25.3	35.2
Mycloss Xtra®	0.5	6.6	10.9	5.2	60.9	41.4	33.1	26.1
Ridomil Gold MZ®	5.6	2.4	9.5	4.7	29.3	73.5	8.7	29.5
Ridomil Gold Plus®	1.4	1.4	7.1	21.5	38.7	34.9	22.4	24.9
Rubigan®	1.2	4.2	13.6	5.7	34.8	56.6	50.5	27.5
Scala®	6.1	5.7	10.8	60.1	24.9	44.7	27.0	21.0
Switch®	2.7	1.2	15.0	3.4	45.2	47.7	39.0	28.9
Teldor®	1.2	13.4	10.7	15.4	52.5	48.9	30.1	17.5
Thiovit Jet®	1.5	10.0	8.4	17.5	34.1	53.1	21.4	12.7
Topas®	3.2	-	13.0	14.6	42.4	-	25.1	19.1
Mean of all treatments	2.1	5.9	10.6	13.7	46.0	48.2	28.4	26.1

Nuri = Nuriootpa, Lens = Lenswood.

4.2. Effect of copper fungicides on flower caps.

Materials and Methods.

At approximately 10% anthesis, on 5 inflorescences per treatment, all open flowers were removed and the remaining unopened flowers sprayed with a single application of a commonly used copper fungicide. Once dried, the inflorescences were enclosed in mesh bags until anthesis was finished. The number of caps still in place were counted and compared with the number of caps in the bags to determine the percentage of stuck caps.

Results.

The effects of copper were variable. Both Ridomil Gold Plus® and Kocide® increased the level of stuck caps on Chardonnay in 2005/6 (Table 13), however only with Kocide® was there a corresponding reduction in fruit set. Water alone increased the level of stuck caps to the same as all the copper products in the second trial on Merlot in 2006/7 (Table 14), and there was no significant difference in fruit set or bunch density between any of the treatments.

Table 13. The effect of copper fungicides applied at flowering to Chardonnay, Lenswood 2005/6.

Treatment	% Fruit set	% Stuck caps
Untreated	56.9bc	2.4b
Copper Oxychloride	85.7a	2.9b
Cuprofix®	43.7c	2.4b
Kocide®	43.0c	6.8ab
Ridomil Gold Plus®	73.2ab	9.1a

Treatments with the same letter are not significantly different from one another (P=0.05)

Table 14. The effect of copper fungicides applied at flowering to Merlot, Lenswood 2006/7

Treatment	Density	% Fruit set	% Stuck caps
Untreated	0.6	38.7	6.8 b
Water	0.5	32.8	13.6 a
Champ®	0.6	51.9	16.9 a
Copper Oxychloride	0.5	32.2	13.9 a
Kocide®	0.6	47.4	15.5 a
Liquicop®	0.6	51.6	17.1 a
Ridomil Gold MZ®	0.5	33.0	17.8 a
Ridomil Gold Plus®	0.5	50.8	18.7 a

Treatments with the same letter are not significantly different from one another (P=0.05)

4.3. Effect of spray programs on fruit set.

Materials and methods

Commonly used fungicides were applied to inflorescences in multiple spray programs, where fungicides were applied 10 to 14 days apart using hand held back pack sprayers to panels of 4 vines, 1 panel per rep, 4 panels per treatment. Various fungicides were applied during the flowering period within these programs.

At harvest, bunches were collected and assessed for components of fruit set and yield. These measurements included:

- Bunch density (No of berries >5mm/length of rachis in cm)
- Percent developed berries (No berries > 5mm/total number of berries*100)
- Percent fruit set (Number of berries >5mm/total number of berries including LGO's and florets*100)
- Mean berry weight
- Yield per vine (Mean bunch wt * No. bunches per vine)

Results.

Experiment 1. 2003/2004. Trials were undertaken on two cultivars at Lenswood and three at Nuriootpa (Table 15). To be able to compare different trials, measurements were calculated and expressed where possible as a percent of the untreated control. Although reductions in density were observed in the Crouchen and Chardonnay, none of the fungicides consistently reduced any of the components of fruit set or yield.

Table 15. Effect of fungicides applied at flowering on components of fruit set and yield at harvest, 2003/04.

Treatment	Density as % of untreated	Mean % of berries<5mm as % of untreated	Mean berry wt	Mean bunch wt
Lenswood Chardonnay				
Bayfidan®	91.5	94.7	0.9	106.8
Flint®	97.6	99.4	0.8	112.7
Lenswood Pinot Noir				
Switch®	110.0	100.1	0.8	106.0
Bavistan®	118.8	99.8	0.8	114.8
Nuriootpa Chardonnay				
Cabrio®	96.3	102.6	0.8	112.9
Flint®	94.6	100.5	0.7	97.4
Prosper®	92.2	103.3	0.8	146.3
Nuriootpa Crouchen				
Bayfidan®	88.4	94.8	0.8	194.1
Flint®	88.5	98.6	0.8	174.6
Nuriootpa Verdehlo				
Bayfidan®	114.5	90.8	0.6	100.7
Flint®	98.2	104.2	0.8	84.8

Experiment 2. 2004/5. Four trials were undertaken on Chardonnay at Lenswood and one on Chardonnay at Nuriootpa (Table 16). To be able to compare different trials, measurements were calculated and expressed where possible as a percent of the untreated control. As in the previous year, some reductions in density were observed, however most of the components of fruit set were increased with the application of fungicides.

Table 16. Effect of fungicides applied at flowering on components of fruit set and yield at harvest, 2004/05.

Treatment	Density as % of untreated	Berries >5mm as % of untreated	Fruit set as % of untreated	Mean berry wt	Mean bunch wt
Lenswood Chardonnay					
Prosper®	82.5	100.3	102.5	1.0	102.3
Rubigan®	111.8	98.8	97.0	1.0	109.3
Kocide® + Rubigan®*	86.9	100.7	108.9	1.1	104.7
Lenswood Chardonnay					
Thiovit®	69.8	103.5	103.8	1.2	83.5
Prosper®	65.5	102.3	100.0	1.2	87.3
Bayfidan®	75.8	100.8	99.5	1.2	93.0
Thiovit®	71.1	103.5	98.9	1.4	84.7
Serenade®	76.4	103.11	102.6	1.1	84.5
Liquicop®	90.4	102.4	97.3	1.1	94.8
Lenswood Chardonnay					
Cabrio®	108.8	100.2	97.8	1.2	103.2
Flint®	114.2	100.0	101.1	1.2	102.9
Scala®& Flint®*	91.8	100.0	94.2	1.2	79.9
Nuriootpa Chardonnay					
Flint®	124.5	100.5	95.1	0.9	158.3
Thiovit® + Scala®*	108.0	99.8	99.4	1.1	168.5
Kocide® + Thiovit®*	99.5	99.6	99.5	1.1	124.6
Filan	109.4	98.6	95.3	1.0	144.3

* Tank mixes

Experiment 3. 2005/6. This trial was undertaken on Chardonnay at Lenswood (Table 17). Kocide® again reduced the components of fruit set and yield. However when combined with either Systhane® or Topas®, the fruit set was not affected. The untreated control had low berry weight, as there was significant powdery mildew infection at harvest. Only Prosper®, Systhane ® and Kocide®, Systhane® and Topas® did not reduce fruit set compared to the untreated control.

Table 17. Effect of fungicides applied at 50-80% flowering on components of fruit set and yield at harvest, Chardonnay Lenswood, 2005/06.

Treatment	% Fruit set	Density	Berry weight	% Berries>5mm
Untreated	77.1 abcde	9.1 defg	0.5 d	75.4 abc
Acrobat®	70.9 fg	9.5 bcdefg	0.8 c	70.1 de
Biocover®	71.6 fg	9.4 bcdefg	0.8 bc	70.7 cde
Cabrio®	69.2 g	9.2 cdefg	1.0 abc	68.6 e
Cabrio® / Filan®*	74.9 def	8.8 efg	1.0 abc	74.0 bcd
Domark®	72.6 efg	9.3 bcdefg	0.9 bc	71.3 cde
Filan®	75.6 bcdef	9.4 bcdefg	0.9 abc	75.2 abc
Flint®	75.0 cdef	9.3 bcdefg	1.0 ab	74.5 bcd
Kocide®	63.3 h	8.5 g	0.8 bc	62.0 f
Prosper® / Filan® *	71.9 fg	10.1 abcde	0.9 bc	71.3 cde
Prosper®	79.7 abc	10.4 abc	0.8 bc	78.5 ab
Ridomil Gold Plus®	71.0 fg	10.0 abcde	0.8 bc	68.9 e
Scala®	74.4 def	8.8 fg	0.8 bc	72.5 cde
Sulphur®	74.7 def	11.0 a	0.9 bc	74.2 bcd
Systhane® + Kocide®#	77.8 abcd	10.1 abcd	1.2 a	74.5 bcd
Systhane®	80.0 ab	10.5 ab	0.8 bc	78.4 ab
Topas® + Kocide®#	74.8 def	10.8 a	0.9 bc	72.9 cde
Topas®	81.4 a	9.9 abcdef	0.9 bc	80.1 a

Treatments with the same number are not significantly different from one another (P=0.05)

* = Treatments applied at 10% and 80% flowering respectively.

= Treatments applied as a tank mix.

Experiment 4. 2006/7. Trials were undertaken on Chardonnay at Lenswood (Table 18). There was no significant differences in fruit set between any of the treatments, and the density of the untreated control was lower than any of the fungicide treated bunches. This was most likely due to the level of powdery mildew in the untreated bunches at harvest, with 97% of bunches being infected. There was also no observable reduction in components of fruit set where Kocide® was applied, however there was a reduction in yield.

Table 18. Effect of fungicides applied at flowering on components of fruit set and yield at harvest, Lenswood Chardonnay 2006/07.

Treatment	% Fruit set	Density	Mean berry wt	% berries>5 mm	Yield per vine (Kg)	Mean bunch wt (g)
Untreated	69.2 a	9.6 c	0.56 bcd	72.3 ab	2.5 cd	53.6 a
Cabrio®	64.9 a	12.3 ab	0.73 a	69.1 bc	3.1 abc	62.4 a
Filan®	62.9 a	12.7 ab	0.60 bcd	64.7 c	2.5 bcd	53.2 a
Flint®	68.5 a	13.8 a	0.63 abc	69.2 bc	3.5 ab	64.8 a
Kocide®	64.7 a	11.3 bc	0.53 cd	69.6 bc	1.9 d	47.4 a
Mycloss Xtra®	67.0 a	11.8 b	0.64 ab	69.6 bc	2.6 bcd	57.0 a
Ridomil Gold Plus®	72.2 a	11.1 bc	0.61 bcd	78.1 a	2.6 bcd	56.4 a
Scala®	69.4 a	11.9 b	0.51 d	72.5 ab	3.1 abc	62.4 a
Switch®	66.5 a	12.3 ab	0.65 ab	71.5 abc	2.8 abcd	62.8 a
Thiovit®	65.2 a	11.2 bc	0.64 abc	68.6 bc	2.7 abcd	55.4 a
Topas®	61.1 a	11.5 b	0.67 ab	67.4 bc	3.6 a	62.0 a

Treatments with the same number are not significantly different from one another (P=0.05)

7. Outcomes/Conclusion

Overall the main findings from these studies are that the application of fungicides during flowering is unlikely to have a significantly inhibitory effect on fruit set. The one exception is fungicides containing copper, as laboratory studies found that these materials inhibited pollen completely, and in some (but not all) field experiments, were slightly inhibitory to fruit set.

Studies undertaken by Heazlewood (2005) showed similar results, with no significant reduction in fruit set observed with botryticides that had inhibited pollen growth *in vitro*.

As flower clusters are highly susceptible to diseases such as downy mildew, powdery mildew and *Botrytis*, the potential complete loss of fruit from these diseases as a result of not applying fungicides during flowering far outweigh the unlikely and minimal effect on fruit set and yield by applying fungicides.

8. Recommendations

That fungicides be applied at flowering to prevent diseases such as downy mildew, powdery mildew and *Botrytis*, as losses due to disease are likely to be greater than losses due to reduction in fruit set. In years of potential poor fruit set from other causes, avoid the application during flowering of fungicides containing copper.

9. Appendices

9.1. Communication

Information contained in this report has been disseminated to growers in at least 5 grower meetings in the Barossa, McLaren Vale and South East regions.

The author presented preliminary findings at the ASVO seminar "Transforming flowers to Fruit", Mildura 29th July 2007, with an article included in the proceedings.

A workshop with researchers working in the area of fruit set was held in Adelaide July 5th 2005. Current research was presented and discussion held on future research.

9.2. Publications.

An article for the Australian and New Zealand Grapegrower and Winemaker is in preparation.

9.3. References

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9.4. Staff

SARDI Horticulture Pathology

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9.5. Field Trial Details and Results.

Table 1a. Percent of anthers with organisms detected in different cultivars, Lenswood, 2005/6.

Variety	CL	A	Y	B	UK	Clean	Pen	Fus	Ulo	Seim	Trich	Stem	Bact
Chardonnay	52.2 b	5.3 c	3.5 b	2.0 b	0.0 c	34.7 d	0.3 a	0.0 b	0.3 a	0.2 a	0.2 a	0.3 a	0.0
Sauvignon Blanc	38.8 c	5.5 c	7.0 a	2.8 b	0.3 abc	45.8 bc	0.5 a	0.0 b	0.3 a	0.5 a	0.0 a	0.0 a	0.0
Semillon	31.3 cd	3.2 c	6.3 ab	2.1 b	0.0 bc	53.9 a	0.5 a	0.0 b	0.3 a	0.0 a	0.3 a	0.0 a	0.0
Cabernet Sauvignon	65.6 a	16.7 a	6.6 ab	2.8 b	0.8 ab	10.4 e	0.5 a	1.5 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0
Merlot	47.7 b	3.8 c	7.0 a	2.8 b	0.0 c	38.5 cb	0.3 a	0.0 b	0.0 a	0.5 a	0.0 a	0.0 a	0.0
Pinot	26.8 d	9.5 b	8.8 a	6.5 a	1.0 a	48.3 ab	0.0 a	0.3 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0

Treatments with the same letter are not significantly different from one another (P=0.05)

Table 1a. Percent of anthers with organisms detected in different cultivars, Nuriootpa 2005/6.

Variety	CL	A	Y	B	UK	Clean	Pen	Fus	Ulo	Seim	Trich	Stem	Bact
Chardonnay	35.8 a	20.5 b	3.5 ab	0.3 c	0.0 b	41.8 c	1.5 ab	0.3 a	2.5 a	0.0 a	0.0 b	0.0 a	0.0 a
Sauvignon Blanc	15.2 c	6.0 c	1.5 b	1.0 bc	1.8 a	73.3 a	3.0 a	0.0 a	0.0 b	0.0 a	0.0 b	0.0 a	0.0 a
Semillon	9.0 d	4.6 c	3.3 ab	2.6 b	0.0 b	74.4 a	1.5 ab	0.0 a	0.0 b	0.0 a	2.1 a	0.0 a	0.3 a
Cabernet Sauvignon	23.0 b	14.2 b	1.5 b	0.2 c	0.3 b	58.5 b	1.0 ab	0.3 a	0.8 b	0.0 a	0.0 b	0.3 a	0.0 a
Merlot	23.8 b	15.5 b	4.5 a	6.3 a	0.5 b	49.5 c	1.5 ab	0.0 a	0.5 b	0.3 a	0.0 b	0.0 a	0.0 a
Pinot	14.6 cd	32.6 a	5.6 a	1.0 bc	0.3 b	49.0 c	0.3 b	0.0 a	0.5 b	0.0 a	0.0 b	0.0 a	0.0 a

Treatments with the same letter are not significantly different from one another (P=0.05)

CL = Cladosporium, A= Alternaria, Y=Yeast, B=*Botrytis,* UK = unknown fungus, Clean = no organisms detected on anthers, Pen = *Penicillium,* Fus = *Fusarium,* Ulo = *Ulocladium,* Seim = *Seimitectum,* Trch = *Trichoderma,* Stem = *Stemphylium,* Bact = bacteria

Table 2. Percent of anthesis with fungi detected after application of various fungicides, 2004/5, Lenswood.

Treatment	Cladosporium	Alternaria	Stemphylium	Other	Penicillium	No fungi
Control	70 a	3 a	0	12 b	0 c	15 b
Water	50 b	1 a	0	19 ab	0 c	30 ab
Kocide®	47 b	0 a	0	8 b	1 bc	44 ab
Thiovit®	48 b	1 a	0	29 a	9 a	22 b
Topas®	44 b	3 a	0	30 a	5 ab	23 b

Treatments with the same letter are not significantly different from one another (P=0.05)

Table 3. Percent of anthers with fungi detected, collected from inflorescences of different cultivars after application of various fungicides, 2006/7, Lenswood.

Treatments with the same letter are not significantly different from one another (P=0.05)

Clad = Cladosporium, Alt= Alternaria, Bot=*Botrytis,* UK = unknown fungus, Clean = no organisms detected on anthers, Pen = *Penicillium,* Fus = *Fusarium,* Ulo = *Ulocladium,* Trich = *Trichoderma,* Bact = bacteria, Asp= *Aspergillus*

Chardonnay.

Treatment	Clad	Alt	Yeast	Bot	UK	Clean	Pen	Fus	Ulo	Bact	Asp
Untreated	82.0 ab	22.0 b	0.0 a	0.0 a	2.0 a	0.0 b	0.0 a	4.0 b	0.0 a	0.0 a	0.0 a
Water	71.0 b	33.0 a	0.0 a	1.0 a	3.0 a	0.0 b	0.0 a	0.0 a	3.0 b	0.0 a	0.0 a
Bavistin®	93.0 a	8.0 c	0.0 a	0.0 a	2.0 a	0.0 b	1.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Filan®	87.5 ab	10.0 c	0.0 a	0.0 a	5.0 a	0.0 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Flint®	78.0 b	6.0 c	2.0 b	0.0 a	2.0 a	12.0 a	1.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Ridomil Gold MZ®	78.0 b	8.0 c	0.0 a	1.0 a	3.0 a	1.0 b	1.0 a	1.0 a	0.0 a	0.0 a	0.0 a
Topas EC®	74.0 b	22.0 b	0.0 a	2.0 a	2.0 a	0.0 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a

Merlot

Treatment	Clad	Alt	Yeast	Bot	UK	Clean	Pen	Fus	Ulo	Bact	Asp
Untreated	78.8 abcd	18.8 bcde	1.3 a	2.5 a	0.0 b	0.0 d	2.5	2.5 a	0.0 a	0.0 a	1.3 a
Water	81.0 abcd	23.0 abcd	5.0 a	0.0 a	1.0 b	0.0 d	0.0	5.0 a	0.0 a	0.0 a	0.0 a
Bavistin®	50.0 e	34.0 a	9.0 a	0.0 a	1.0 b	8.0 c	2.0	0.0 a	0.0 a	1.0 a	0.0 a
Bravo®	52.0 e	22.0 abcd	6.0 a	0.0 a	6.0 a	17.0 a	0.0	3.0 a	0.0 a	0.0 a	0.0 a
Cabrio®	68.8 cd	6.3 ef	10.0 a	1.3 a	0.0 b	13.8 ab	0.0	1.3 a	0.0 a	1.3 a	0.0 a
Dithane Rain Shield®	81.0 abcd	15.0 de	5.0 a	0.0 a	2.0 ab	1.0 d	0.0	0.0 a	0.0 a	0.0 a	1.0 a
Filan®	69.0 cd	32.0 ab	2.0 a	0.0 a	4.0 ab	2.0 d	3.0	0.0 a	0.0 a	1.0 a	0.0 a
Flint®	65.0 de	8.8 def	2.5 a	0.0 a	2.5 ab	17.5 a	5.0	0.0 a	0.0 a	0.0 a	0.0 a
Kocide®	84.0 abc	8.0 ef	7.0 a	2.0 a	1.0 b	1.0 d	2.0	3.0 a	1.0 a	0.0 a	0.0 a
Mycloss Xtra®	86.0 ab	17.0 de	5.0 a	0.0 a	0.0 b	0.0 d	3.0	3.0 a	0.0 a	0.0 a	1.0 a
Ridomil Gold MZ®	77.0 abcd	13.0 def	9.0 a	1.0 a	1.0 b	0.0 d	2.0	4.0 a	1.0 a	0.0 a	1.0 a
Ridomil Gold Plus®	73.3 bcd	20.0 bcde	4.4 a	0.0 a	3.3 ab	0.0 d	6.7	1.1 a	0.0 a	1.1 a	0.0 a
Rubigan®	81.0 abcd	11.0 def	6.0 a	0.0 a	1.0 b	0.0 d	1.0	3.0 a	0.0 a	0.0 a	0.0 a
Scala®	92.0 a	1.0 f	3.0 a	0.0 a	2.0 ab	1.0 d	3.0	2.0 a	0.0 a	0.0 a	0.0 a
Switch®	87.0 ab	0.0 f	1.0 a	0.0 a	0.0 b	11.0 b	0.0	1.0 a	0.0 a	0.0 a	0.0 a
Teldor®	83.0 abc	12.0 def	9.0 a	0.0 a	0.0 b	1.0 d	1.0	2.0 a	0.0 a	0.0 a	0.0 a
Thiovit®	74.0 bcd	18.0 cde	7.0 a	1.0 a	2.0 ab	1.0 d	2.0	2.0 a	0.0 a	0.0 a	0.0 a
Topas®	51.0 e	31.0 abc	6.0 a	2.0 a	1.0 b	12.0 b	0.0	1.0 a	0.0 a	0.0 a	0.0 a

Pinot Noir

Treatment	Clad	Alt	Yeast	Bot	UK	Clean	Pen	Fus	Ulo	Trich	Bact	Asp
Untreated	71.4 abc	15.2 b	18.1 a	0.0 a	2.9 bc	1.0 cd	1.9 a	0.0 a	1.0 a	0 a	0.0 c	0.0 a
Water	41.9 d	7.6 d	0.0 d	1.9 a	1.0 c	0.0 d	0.0 a	0.0 a	0.0 a	0 a	0.0 c	0.0 a
Bavistin®	49.0 cd	35.0 a	5.0 cd	0.0 a	3.0 bc	3.0 bcd	3.0 a	0.0 a	4.0 a	0 a	3.0 ab	0.0 a
Bravo®	66.0 abcd	27.0 ab	0.0 d	0.0 a	3.0 bc	4.0 bcd	3.0 a	0.0 a	0.0 a	0 a	0.0 c	0.0 a
Cabrio ®	50.0 bcd	7.5 d	5.0 cd	0.0 a	7.5 ab	25.0 a	8.8 a	0.0 a	1.3 a	0 a	0.0 c	0.0 a
Dithane Rain Shield®	75.8 ab	17.9 b	2.1 cd	0.0 a	2.1 bc	8.4 b	0.0 a	0.0 a	0.0 a	0 a	0.0 c	0.0 a
Filan®	86.3 a	6.3 d	4.2 cd	2.1 a	0.0 c	2.1 bcd	2.1 a	0.0 a	1.1 a	0 a	4.2 a	0.0 a
Flint®	75.5 ab	13.6 bc	4.5 cd	0.0 a	2.7 bc	4.5 bcd	4.5 a	0.0 a	0.0 a	0 a	0.0 c	0.0 a
Kocide®	88.0 a	5.0 d	6.0 cd	0.0 a	4.0 bc	0.0 d	7.0 a	1.0 a	0.0 a	0 a	0.0 c	0.0 a
Mycloss Xtra®	82.7 a	6.4 de	2.7 cd	0.0 a	4.5 bc	2.7 bcd	6.4 a	1.8 a	0.0 a	0 a	0.0 c	0.0 a
Ridomil Gold MZ®	77.0 a	17.0 b	3.0 cd	1.0 a	1.0 c	0.0 d	5.0 a	0.0 a	1.0 a	0 a	1.0 bc	0.0 a
Ridomil Gold Plus®	80.0 a	4.3 de	8.6 bc	0.0 a	0.0 c	5.7 bcd	2.9 a	0.0 a	0.0 a	0 a	1.4 abc	0.0 a
Rubigan®	83.5 a	23.5 ab	4.7 cd	0.0 a	0.0 c	0.0 d	0.0 a	0.0 a	0.0 a	0 a	0.0 c	0.0 a
Scala®	91.0 a	8.0 d	5.0 cd	1.0 a	2.0 bc	0.0 d	0.0 a	1.0 a	0.0 a	0 a	2.0 abc	0.0 a
Switch®	91.6 a	0.0 d	1.1 d	1.1 a	0.0 c	8.4 b	0.0 a	0.0 a	0.0 a	0 a	0.0 c	0.0 a
Teldor®	81.0 a	9.0 d	13.0 ab	0.0 a	2.0 bc	0.0 d	5.0 a	0.0 a	0.0 a	0 a	1.0 bc	0.0 a
Thiovit Jet®	71.3 abc	17.5 b	3.8 cd	0.0 a	3.8 bc	2.5 bcd	2.5 a	1.3 a	0.0 a	0 a	0.0 c	0.0 a
Topas®	68.0 abc	4.0 d	4.0 cd	3.0 a	10.0 a	7.0 bc	1.0 a	3.0 a	0.0 a	0 a	0.0 c	0.0 a

Sauvignon Blanc

Treatment	Clad	Alt	Yeast	Bot	UK	Clean	Pen	Fus	Ulo	Trich	Bact
Untreated	82.0 ab	12.0 fgh	0.0 a	0.0 a	4.0 bcd	0.0 d	2.0 d	4.0 a	0.0 a	0.0 b	1.0 a
Water	57.0 efg	25.0 cdef	3.0 a	2.0 a	3.0 cd	3.0 cd	11.0 a	3.0 a	1.0 a	0.0 b	0.0 a
Bavistin®	74.0 bcd	28.0 bcde	0.0 a	0.0 a	0.0 d	3.0 cd	0.0 d	0.0 a	1.0 a	0.0 b	0.0 a
Bravo®	42.0 h	57.0 a	3.0 a	0.0 a	2.0 cd	0.0 d	3.0 cd	1.0 a	1.0 a	0.0 b	0.0 a
Cabrio®	39.0 h	37.0 bc	3.0 a	0.0 a	5.0 bcd	14.0 b	2.0 d	1.0 a	0.0 a	0.0 b	0.0 a
Dithane Rain Shield®	41.0 h	33.0 bc	6.0 a	1.0 a	14.0 a	4.0 cd	3.0 cd	1.0 a	0.0 a	0.0 b	0.0 a
Filan®	49.0 fgh	29.0 bcd	3.0 a	0.0 a	6.0 bcd	7.0 c	9.0 ab	0.0 a	0.0 a	0.0 b	0.0 a
Flint®	48.0 fgh	18.0 defg	4.0 a	0.0 a	5.0 bcd	22.0 a	5.0 bcd	2.0 a	0.0 a	0.0 b	0.0 a
Kocide®	78.0 abc	18.0 defg	3.0 a	2.0 a	3.0 cd	1.0 d	2.0 d	3.0 a	0.0 a	0.0 b	0.0 a
Mycloss Xtra®	59.0 efg	28.0 bcde	1.0 a	0.0 a	7.0 bc	2.0 cd	4.0 bcd	1.0 a	0.0 a	0.0 b	0.0 a
Ridomil Gold MZ®	64.0 cde	28.0 bcde	0.0 a	1.0 a	5.0 bcd	2.0 cd	2.0 d	2.0 a	0.0 a	0.0 b	0.0 a
Ridomil Gold Plus®	78.2 ab	15.5 efg	2.7 a	0.0 a	1.8 cd	0.0 d	7.3 abc	1.8 a	0.0 a	0.0 b	0.0 a
Rubigan®	62.0 def	24.0 cdef	2.0 a	3.0 a	6.0 bcd	5.0 cd	5.0 bcd	1.0 a	0.0 a	0.0 b	0.0 a
Scala®	86.0 ab	0.0 h	3.0 a	1.0 a	10.0 ab	0.0 d	0.0 d	1.0 a	0.0 a	3.0 a	0.0 a
Switch®	91.0 a	1.0 h	7.0 a	0.0 a	1.0 cd	2.0 cd	1.0 d	0.0 a	0.0 a	0.0 b	0.0 a
Teldor®	88.0 ab	8.0 gh	4.0 a	0.0 a	3.0 cd	0.0 d	1.0 d	0.0 a	1.0 a	0.0 b	0.0 a
Thiovit®	60.0 ef	30.9 bc	1.8 a	0.9 a	3.6 bcd	0.9 d	2.7 cd	1.8 a	0.0 a	0.0 b	0.0 a
Topas®	46.0 gh	41.0 b	5.0 a	1.0 a	7.0 bc	3.0 cd	1.0 d	1.1 a	0.0 a	1.0 b	1.0 a

Semillon

Treatment	Clad	Alt	Yeast	Bot	UK	Clean	Pen	Fus	Ulo	Bact	Asp
Untreated	56.0	37.0 ab	1.0 a	0.0 a	7.0 a	0.0 b	1.0 a	2.0 a	2.0 a	0.0 a	1.0 b
Water	71.0	21.0 ab	2.0 a	1.0 a	4.0 a	0.0 b	7.0 a	2.0 a	0.0 a	0.0 a	0.0 b
Bavistin®	51.0	40.0 b	7.0 a	0.0 a	1.0 a	1.0 b	6.0 a	0.0 a	1.0 a	0.0 a	0.0 b
Bravo®	54.0	19.0 a	6.0 a	4.0 ab	11.0 a	4.0 b	3.0 a	3.0 a	0.0 a	0.0 a	0.0 b
Cabrio®	40.0	14.0 a	5.0 a	10.0 b	8.0 a	11.0 a	6.0 a	6.0 a	1.0 a	0.0 a	0.0 b
Dithane Rain Shield®	100.0	0.0 a	0.0 a	0.0 a	0.0 a	0.0 b	0.0 a	0.0 a	0.0 a	0.0 a	0.0 b
Filan®	61.0	23.0 ab	4.0 a	1.0 a	7.0 a	2.0 b	3.0 a	6.0 a	0.0 a	2.0 a	0.0 b
Flint®	44.0	19.0 a	11.0 b	1.0 a	8.0 a	11.0 a	7.0 a	1.0 a	0.0 a	0.0 a	0.0 b
Kocide®	50.0	30.0 ab	10.0 b	1.0 a	3.0 a	2.0 b	4.0 a	4.0 a	0.0 a	0.0 a	0.0 b
Mycloss Xtra®	36.0	38.0 b	6.0 ab	10.0 b	6.0 a	2.0 b	4.0 a	4.0 a	0.0 a	0.0 a	0.0 b
Ridomil Gold MZ®	52.0	42.0 b	1.0 a	0.0 a	7.0 a	2.0 b	3.0 a	0.0 a	0.0 a	0.0 a	0.0 b
Ridomil Gold Plus®	40.0	28.0 ab	4.0 a	0.0 a	6.0 a	0.0 b	4.0 a	0.0 a	0.0 a	0.0 a	0.0 b
Scala®	66.0	22.0 ab	5.0 ab	1.0 a	8.0 a	0.0 b	2.0 a	1.0 a	0.0 a	0.0 a	0.0 b
Switch®	82.0	2.0 a	16.0 b	0.0 a	0.0 a	4.0 b	0.0 a	0.0 a	0.0 a	2.0 a	0.0 b
Teldor®	59.0	27.0 ab	3.0 ab	1.0 a	11.0 a	0.0 b	3.0 a	2.0 a	0.0 a	0.0 a	0.0 b
Thiovit®	56.0	30.0 ab	7.0 ab	4.0 ab	3.0 a	0.0 b	8.0 a	1.0 a	2.0 a	0.0 a	3.0 a
Topas®	49.0	29.0 ab	4.0 ab	5.0 ab	7.0 a	4.0 b	2.0 a	3.0 a	1.0 a	0.0 a	0.0 b

9.6. Sucrose media for pollen germination

		g/l
Boric Acid (H3BO3)	l mM	0.62
Calcium Nitrate ($Ca(N0_3)2.4H2O$)	1 mM	0.236
Potassium Nitrate KNO3	1 mM	0.101
Sucrose	15%	150
Agar	1	10