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Better disease control using adjuvants







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BETTER DISEASE CONTROL USING ADJUVANTS

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ABSTRACT

Adjuvants can alter the surface tension of spray droplets and improve the spread of agrochemical mixtures on difficult targets like grape bunches. This offers the potential to customise pesticides application for maximum efficacy and minimum environmental risk. A series of laboratory trials in New Zealand and vineyard trials in Australia between 2002 and 2005 explored economic and efficacy gains when conventional, high-volume sprays were replaced with low-volume sprays that included organosilicone adjuvants.

None of the five classes of adjuvant tested altered the phytotoxicity of a range of fungicide tank mixes. Laboratory spread tests showed none of the fungicide formulations reduced the effectiveness of any of the adjuvants. A modified organosilicone blend adjuvant, at concentrations recommended for use in vineyards, provided droplet spread that was up to ten times that achieved using the industry standard adjuvant.

Effective control of the diseases *Botrytis*, downy mildew and powdery mildew was achieved with considerably lower spray volumes (applying only 25-50 % of the dilute volume) in most field trials but could not be clearly attributed to specific use patterns of the organosilicone type adjuvants. There were no adjuvant, or adjuvant/spray volume combinations that consistently outperformed the others. In some trials, low volume applications with the new classes of organosilicone adjuvants provided equivalent disease control and spray deposits to the high volume sprays with conventional adjuvants, offering potential to save on labour and machinery costs associated with spraying. However, in other trials spray deposits or disease control resulting from low volume sprays with no adjuvant were equivalent to or better than low volume sprays that included organosilicone adjuvants. In some canopies, spraying with organosilicone adjuvants in half the dilute spray volume lead to excess wetting of outer canopy and net reduction in deposits. Because of the risk of overwetting, organosilicone adjuvants are not recommended for high volume fungicide applications.

Spray deposition and disease severity in bunches was determined primarily by the efficiency of delivery of fungicide spray to the inner canopy, which is independent of adjuvant. The high degree of variability in spray deposition within grapevine canopies introduces a within-treatment variability that potentially masks any effect of adjuvants.

EXECUTIVE SUMMARY

Adjuvants can alter the surface tension of spray droplets and improve the spread of agrochemical mixtures on difficult targets like grape bunches. This offers the potential to customise pesticides application for maximum efficacy and minimum environmental risk. Based on previous NZ adjuvant research, there was an expectation that Australian trial data would allow generation of clear prescriptions for use of the new classes of organosilicone adjuvant in grapevines and allow spray volumes to be reduced 50 % or more while maintaining or improving disease and pest control. A series of laboratory trials in New Zealand and vineyard trials in Australia between 2002 and 2005 explored economic and efficacy gains when conventional, high-volume sprays were replaced with low-volume sprays that included organosilicone adjuvants.

Effective disease control was achieved with considerably reduced spray volumes (applying only 25-50 % of the dilute volume) in most field trials. However, this could not be clearly attributed to the use of particular adjuvants. In other words, there was no adjuvant, or adjuvant/spray volume combination that consistently outperformed the others. Low volume applications without adjuvants were generally as effective as the high volume applications and the low volume applications with adjuvants.

There was a high degree of variability in spray deposition and disease severity (*Botrytis*, downy mildew and powdery mildew) in all trials. Spray deposits on outer canopy bunches and leaves were typically 2-3 times higher than on inner canopy bunches and leaves. Even within a canopy position, there was a high degree of variability in spray deposition and disease control. Given the amount of variability in the experimental system, treatment differences had to be very large to be statistically significant.

In some trials, low volume fungicide applications with the new classes of organosilicone adjuvants improved disease control and spray deposition compared to the high volume sprays. In one trial, the use of organosilicone adjuvants in low spray volumes, resulted in the highest spray deposition in mature bunches. In two other trials, adjuvant treatments did not affect spray deposition on bunches at pre-bunch closure. In another pre-bunch closure trial, spray deposits on bunches were reduced by the use of an organosilicone adjuvant in a low volume spray. At flowering, the use of adjuvants did not improve spray deposition on bunches or disease control relative to the low volume treatments without adjuvants. Spray deposition on leaves was reduced by the use of organosilicone adjuvants in some trials with no loss in efficacy against foliar diseases, perhaps because of a more even distribution of fungicide deposit across the leaf surface as a result of the adjuvant.

Because of the risk of overwetting, organosilicone adjuvants are not recommended for high volume fungicide applications. In some canopies, spraying with organosilicone adjuvants in half the dilute spray volume lead to excess wetting of outer canopy and net reduction in spray retention on leaves.

Laboratory testing showed that none of the fungicide formulations reduced the effectiveness of any of the adjuvants. Similar amounts of droplet spread were obtained for the different fungicide tank mixes with a given adjuvant, except for mixes that contained spiroxamine. Tank mixes that containing spiroxamine had good spreading properties without the addition of extra adjuvant although spreading increased further in the presence of additional adjuvant. Spreading by conventional adjuvants was shown to increase very little as adjuvant concentration increased. The organosilicones behaved differently however, with spreading positively correlated with the adjuvant concentration. A modified organosilicone blend adjuvant, Du-Wett®, provided droplet spread that was up to ten times that achieved using the industry standard adjuvant at concentrations recommended for use in vineyards. The modified organosilicone adjuvants were considered to have the greatest potential to improve spray application in vineyards.

No phytotoxicity was observed for any of the five classes of adjuvants when tested in a range of fungicide tank mixes. Phytotoxicity was tested for both dilute (high volume) and concentrate (low volume) applications under field conditions.

The reasons why different conclusions on the performance of organosilicone adjuvants were drawn from the Australian work compared to the NZ research were not resolved. Some factors which may have contributed are differences in: canopy architecture, spray machinery, adjuvant rates and disease assessment protocols. Australian vine canopies (especially in warmer areas) often lack a discrete bunch zone while NZ canopies usually have a defined bunch zone. A broader range of spray equipment was used in the Australian trials. The NZ work generally used higher rates of organosilicone adjuvants than were tested in the Australian trials (Australian adjuvant rates were based on those that gave the best results in the initial trial). In addition, the Australian spray trials had multiple treatments and included low volume fungicide applications without added adjuvant to separate the effects of low volume application from adjuvant effects. Much of the NZ work involved season-long trials in commercial settings and compared low volume adjuvant treatments with conventional high volume spraying practices. In the Australian trials, grapevines were inoculated with pathogens after spraying to measure bioefficacy of each individual fungicide application. In the NZ work, disease control was measured at harvest and therefore was a measure of the efficiency of the season long spray program.

The Australian data clearly showed that overcoming deposition variability in the vine canopy is more critical than trying to improve coverage solely by adding adjuvants. No particular adjuvant treatment was clearly superior to all the others across all tissue types and canopy positions. Spray deposition and disease severity in bunches was determined primarily by the efficiency of delivery of fungicide spray to the inner canopy, which is independent of adjuvant. The high degree of variability in spray deposition within grapevine canopies introduces a within-treatment variability that potentially masks any effect of adjuvants. This project showed that fungicide spray volumes could be reduced without compromising disease control. While the use of adjuvants appeared beneficial in some experiments, the inclusion of adjuvants did not consistently demonstrate significant advantages over reduced volume fungicide applications without added adjuvants.

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1 INTRODUCTION

1.1 Background

Reduced chemical use, environmental sustainability and production efficiency continue to increase as priorities in Australian viticulture. Industry R&D investments in integrated pest management and spray application have assisted many growers to improve their control of bunch diseases and pests, going some way towards meeting these goals. However, despite this investment, traditional vineyard spray programs often still involve applying agrochemicals in high water volumes to wet canopies to the point of run-off, particularly if bunches are the main spray target. Such high volumes are inefficient in terms of spray losses through drift and run-off, use droplet sizes that limit canopy penetration and coverage, have low work rates and increase the use of water resources. Even using these high volume spray programs, many growers still report poor control of *Botrytis* bunch rot. The CRCV project, 'Spray application in vineyards: Getting the dose right', identified the lethal doses for fungicides on leaf, flower and berry tissue. That project found that fungicide residues on bunches resulting from typical spray applications are usually lower than the lethal dose for control of *Botrytis* bunch rot. For example, when a commercial sprayer was used to apply Rovral® at its recommended concentration to a VSP canopy, 67% of bunches received sub-lethal doses of chemical (Warren & Riches 2001).

Substituting old with new fungicide chemistry does not overcome spray coverage and retention limitations, so growers are looking to new formulations and new application systems to improve the efficacy of their spray programs.

Spray adjuvants hold great promise for the viticulture industry. They are at the forefront of a global trend to customise pesticides for specific applications and to reduce environmental contamination by maximising pesticide efficacy (Underwood *et al*. 2001).

The surface tension of spray droplets on the surface of grape berries is a major limitation to the movement of liquid film into a bunch during fungicide application (MISG 2001). Addition of spray adjuvants to agrochemical mixtures can alter the surface tension of spray droplets and improve spray deposits on difficult targets like grape bunches (Gaskin *et al*. 2002).

Solution surface tension is another physical property directly related to spray adhesion, retention and surface coverage. The hydrophobic part of a surfactant molecule is not soluble in water and as a result, is expelled out of the droplet. Hence, the surfactant concentrates at the water/air interface and this high concentration at the boundary of the liquid allows surfactants to decrease the surface tension of the solution. Water has a surface tension of around 73 mN m^{-1} which is decreased to around 30 mN m^{-1} in the presence of commonly-used non-ionic surfactants (Gauvrit 2002).

In New Zealand, recent studies with organosilicone adjuvants have demonstrated their ability, over and above conventional agricultural adjuvants, to improve the effectiveness of growers' spray programs in kiwifruit (Gaskin *et al*. 2001a), potato (Gaskin *et al*. 2000a), onion (Gaskin *et al.* 2001b) and winegrape (Gaskin *et al.* 2002) crops. The use of these adjuvants can reduce the water volumes required for spray applications while maintaining or even improving efficacy, which has practical and economic consequences. Lower spray volumes mean lower costs; more hectares sprayed per load, less travel to and from water supplies, lower fuel bills, reduced labour inputs and more flexibility in spraying operations. Additionally, reducing spray volumes provides environmental benefits through reduced spray drift, run-off and off-target contamination.

Grapegrower participants in the regular 3-day national workshops, Research to Practice™ - Spray Application have requested increasingly detailed information about using adjuvants to increase the effectiveness of pesticide applications. Meanwhile, a range of new adjuvants have recently been registered for a variety of horticultural crops in Australia, demonstrating an interest in horticulture among the companies supplying adjuvants. However, for registration of spray tank additives the companies are not required to provide data showing the effects of using adjuvants across the range of potential chemical + plant tissues + vine canopy combinations.

While the most recent class of adjuvant registered on grapes in Australia, organosilicone surfactants, can substantially reduce surface tension and increase the spread of spray deposits on a grape bunch (Murphy & Warren 2000), there is already evidence that they interact uniquely with different fungicide formulations. In a NZ study, spread factors varied by up to 8 and 25 times between adjuvants on fruit and leaves, respectively, and by up to 18 times when a single adjuvant was combined with different pesticide formulations (Gaskin and Manktelow, unpub). In addition, deposits on bunches and *Botrytis* control could be dramatically improved with the use of organosilicone adjuvants, particularly on heavy canopied vines (Gaskin and Manktelow unpub.). Plant Protection Chemistry, New Zealand (formerly Forest Research) holds significant Intellectual Property across the range of adjuvants now being used in horticulture (Gaskin, various publications) and that could potentially be used in grape production. The Forest Research/HortResearch project "*New Zealand Technology for Business Growth Project #5022 Develop new adjuvant and spray application technology to use on wine grapes*" was a valuable precursor to this Australian research. *Project #5022* provided information on the interactions between various adjuvants and the surface chemistry of grape berries, quantified the spread of different liquid films over the surfaces of berries and stems and into bunches, and looked at issues such as phytotoxicity. The NZ *Project #5022* demonstrated encouraging results for two organosilicone adjuvants. The difference between the two adjuvants is that one has spreading and rain fastening properties while the other offers greater spreading and penetration but with an increased risk of rainfall removal. The intellectual property related to measuring spread factors and moving liquids through grape bunches, generated in the New Zealand winegrape study, was valuable and available to this GWRDC project DNR 02/04.

Project DNR 02/04 proposed to repeat methods used in the NZ project, drawing on both the adjuvant chemistry expertise of Robyn Gaskin and the spray deposit work of David Manktelow. A key difference was that the Australian extension would explore a broader range of adjuvants than were included in the NZ trials, and in combination with Australian fungicide formulations, and using Australian canopies (narrow VSP and large, irrigated canopies), under Australian conditions.

Bioefficacy of adjuvant/agrochemical mixtures also needed to be confirmed, using methods developed in the recent CRCV project "Spray application in Vineyards: Getting the dose right".

Increases in the efficacy (retention and distribution) of spray applications to bunches could lead to significant reductions in the spray volumes required by grapevines. This in turn may lead to increases in production efficiency, reductions in the volumes of chemical used in Australian viticulture (thereby contributing to reducing residues), and increased agrochemical efficacy of pesticides and fungicides reducing crop damage. The annual benefit of reducing spray volumes from a dilute rate of 1000L/ha (or 30 L/100 m) to a concentrate rate of 300 L/ah (or 9 L/100 m), across an 8-spray annual program, is estimated as being nearly 20 hours of labour and $1946 (see Appendix 11). These outcomes are consistent with the industry aims to develop new technologies that enable environmentally sustainable, profitable and high quality grape and wine production.

1.2 Project objectives

1. Determine the physical and chemical interactions when conventional and organosilicone adjuvants are used with up to 20 combinations of active ingredient and formulations currently used in Australian viticulture.
2. Apply agrochemicals in combination with a range of adjuvants to vines and assess foliar deposits and penetration of liquid films into the grape bunches at flowering, pre-bunch closure and after bunch closure.
3. Conduct field and laboratory experiments to quantify changes in bioefficacy that result when adjuvants are used with viticultural fungicides and insecticides.
4. Conduct field trials with adjuvants to assess the potential to increase fungicide and insecticide efficacy and reduce spray volumes in commercial vineyards, aiming for reductions of up to 50% while maintaining or improving disease and pest control.
5. Provide recommendations for bunch spray applications that are suited to narrow, exposed bunch zones of Australian cool climate vineyards and to large, mechanically hedged, minimally pruned canopies of inland regions

1.3 Collaboration with Nufarm Australia Ltd and Bayer Crop Sciences

At the request of the Grape and Wine Research and Development Corporation, commercial partners were sought to provide supplementary financial support to the project, to the value of $20,000.

Nufarm Australia Limited and Bayer Crop Sciences were approached. Nufarm had an interest in expanding the portfolio of adjuvants they provide to Australian Horticulture. Bayer had a range of fungicides that complement the range marketed by Nufarm, providing a selection of tank mixes that represent the types that are being used in commercial vineyards.

Contracts were drawn with Nufarm Australia Limited and Bayer Crop Sciences in September 2002, representing a consultancy service period commencing on 1st September 2002 and ceasing by 31st December 2003.

Table 1-1: Outputs and performance targets contracted to DPI by Bayer Crop Sciences Pty Ltd and Nufarm Australia Ltd.

Outputs	Performance Targets
1. Information on the physical and chemical properties of adjuvant-agrochemical mixtures	Determine the compatibility of at least 10 tank mixtures with at least five candidate adjuvants, and report to Bayer Crop Science Pty Ltd and Nufarm Australia Ltd by June 2003. Detail on the tank mixes is provided in Table 2-3
2. Information on interactions of adjuvant-agrochemical mixtures with plant surfaces	Produce industry report by December 2003 describing surface chemistry studies: spray retention and distribution, droplet spread on leaves/berries/stems, potential phytotoxicity of formulations.
3. Information on the bio-efficacy of agrochemical-adjuvant mixtures	Conduct bio-efficacy studies for *Botrytis*, powdery mildew and downy mildew in the field and laboratory using 5 Australian agrochemical-adjuvant mixtures, completed by January 2005 and reported by September 2005. Preliminary reports to be provided to Bayer Crop Science Pty Ltd and Nufarm Australia Ltd by December 2003.

Table 1-2: Additional deliverables that, being public domain outputs comes of the of the larger GWRDC project, will be available to Nufarm Australia Ltd and Bayer Crop Science Pty Ltd.

Outputs	Performance Targets
4. Information on how adjuvants perform in field spray applications	Conduct field studies to assess disease control, work rates and chemical requirements with and without adjuvants conducted during 2003/4 and analysed and reported by June 2004. Field trials in 2004/05 seasons analysed and reported by June 2005. Report on the cost/benefits of using adjuvants within a commercial spray program published by June 2005.
5. Information on the effect of adjuvants on residue persistence	Residue degradation studies conducted in 2003/04 season using two fungicides and one insecticide. Residue analyses completed by April 2004 and reported to GWRDC and AWRI by June 2004.
6. Workshop on project results for wine industry	Workshop on adjuvant research held in Mildura in May (or August) 2005 (possibly as part of the ASVO seminar series).
	Field demonstration/training package on adjuvants developed by May 2005 for inclusion into Research to Practice workshops, or for use with grape cheque groups or by other training providers, to facilitate ongoing adoption.
7. Reports presented to NRE, GWRDC, Nufarm Aust Ltd and Bayer Crop Science Pty Ltd	Interim reports submitted to stakeholders on June 30th of 2003 and 2004. Final report submitted to stakeholders, including Bayer Crop Science Pty Ltd, by September 2005.

1.4 Laboratory trials to measure the spread provided by adjuvants

In a recent New Zealand study (Gaskin et al. 2002), several pesticide formulations were found to negatively affect the spreading properties of some adjuvants. The first phase of the current trials was therefore to confirm the stability and performance of several adjuvants when mixed in typical dilute and concentrate tank mixes of Australian formulations.

The laboratory trials were to:

1. Provide information on the physical and chemical properties of the ten agrochemical mixtures when combined at dilute and concentrate rates, together with five adjuvants at a range of rates.
2. Provide information on interactions of adjuvant-agrochemical mixtures with plant surfaces, in particular describe the surface tension, spray retention and spread capacity of droplets on leaves and berries.

Five adjuvant classes were selected as representative of the commercial candidates available to growers in Australia, and from each of these classes, a single adjuvant was chosen (Table 2-2).

Agral®, an ethoxylated alkylphenol, was included in the treatments because it is the most common horticultural adjuvant used in Australia. Ethoxylated alkylphenols are progressively disappearing because of concerns about their negative environmental impact. They are slow to degrade and are confirmed as endocrine disrupters (Isidori *et al*. in press). They are being

replaced with alcohol ethoxylates, such as Chemwet 1000, that lack the aromatic ring resistant to biodegradation.

Three classes of adjuvants containing organosilicone 'superspreader' surfactants were included, because of their increasing use in horticulture and successes in improving efficacy and reducing pesticide use. Designer® is a novel sticker-spreader adjuvant, Pulse® is a 'pure' organosilicone widely utilised as an adjuvant for herbicides, and Du-Wett® is a blend of organosilicone and conventional adjuvants developed specifically for horticultural use.

1.5 Selection of agrochemicals and adjuvants to include in laboratory and field trials

Spray diary information was sought to make sure that the tank mixtures selected for inclusion in trials represent those that are being commonly used by commercial growers. In August 2002, viticulturists at BRL Hardy (now Hardy Ltd), Cranswick Estate, Southcorp Wines (now Fosters Wine Group) and Simeon Wines were asked to list the most common combinations of fungicides and/or insecticides reported in their growers spray diaries, from a range of regions. Based primarily on responses from those companies' viticulturists, thirteen chemicals were combined into ten different tank mixtures (Table 2-3).

Consideration was also given to the need to include some of the newer chemistry in tank mixtures, plus limits on the timing of applications due to 'restrictions on use' recommended by the Australian Wine Research Institute (Bell, 2002).

When generic products (eg sulphur, mancozeb) were included, and a standard formulation of that product was available from Nufarm Australia Ltd or Bayer Crop Sciences, their products were included. Appropriate formulations, sourced from either Nufarm, Bayer or Syngenta, were sent to Plant Protection Chemistry, NZ to be included in laboratory trials.

1.6 Rationale and hypotheses for nine vineyard trials, March 2003 to January 2005

Vineyard trials were conducted in Mildura and the Yarra Valley between 2003 and 2005, in Chardonnay, Shiraz, Ruby Cabernet, Cabernet Sauvignon and Merlot grapes, at flowering, pre-bunch closure and pre-harvest, using four groups of adjuvant chemistry, a range of spray volumes and different spray machinery. The hypotheses of each trial and rationale behind the hypothesis are described below.

1.6.1 Trial 1 - March 2003:

Hypothesis: "*There is an inverse relationship between the concentration of organosilicone-based superspreader and water volume applied, to achieve the optimum retention of deposits on grape bunches and foliage*."

By January 2003, laboratory data had become available from Plant Protection Chemistry NZ, and the first field trial was planned for early March 2003 at a commercial vineyard in Dareton, NSW. Phytotoxicity was an important issue to explore as early in the project as possible, but foliage and bunches were too mature, post-veraison, to study phytotoxicity. The March 2003 trial therefore aimed to clarify the relationship between adjuvant concentration and spray volume when adjuvants are applied to a large canopy. This is a critical question to progress development of prescriptions for using the new classes of organosilicone adjuvants.

1.6.2 Trial 2 - October 2003:

Hypothesis: "*The new organosilicone adjuvants, applied at label rates and in low volume, concentrate sprays or high volume dilute sprays, will not cause more phytotoxicity than the non-ionic adjuvants that have been the industry standard*."

While adjuvants reduce the surface tension of a liquid film and allow spray deposits to spread better across the plant surfaces, surface tension can be reduced too far. If this occurs, the plant loses its ability to repel the film and pesticide mixtures can penetrate stomata or cracks in the cuticle. Pesticides entering plant tissues may result in phytotoxicity. While such phytotoxicity is desirable to enhance the effectiveness of some herbicides, it is not a desired outcome for crop protection chemicals such as fungicides and insecticides.

Designer, Pulse and Du-Wett are known to differ with respect to their ability to provide stomatal infiltration (Gaskin *et al*. 2000b), with Du-Wett and Designer considered less likely than the 'pure' organosilicone, Pulse, to cause crop damage if they are mixed with pesticides not intended to penetrate into plant foliage. The potential for crop damage with these adjuvants increases with increasing spray application volumes (Gaskin et al 2000b).

Vineyard trials were required to confirm whether organosilicone-based adjuvants could be safely used in high volume, dilute sprays on winegrapes. Also of particular interest was whether they would cause more phytotoxicity than the industry standard adjuvants when applied in combination with standard insecticide/fungicide treatments and applied as concentrate sprays.

A vineyard phytotoxicity trial was therefore conducted during flowering in the second season of the project. Treatments in the phytotoxicity trial provided a comparison between three organosilicone (Du-Wett®, Pulse® and Designer®), at various rates and volumes of tank mix, and the industry standards (Agral® and BS1000®) as controls, with respect to causing phytotoxicity that affected bunch numbers and weights. If there were any differences between the adjuvants, we aimed to determine if these were within the range acceptable to the industry.

1.6.3 Trial 3 - November 2003:

Hypothesis. "*The improved coverage achieved by applying organosilicone-based super spreaders in low volume sprays can also be achieved using different types of sprayers including those that are conventionally classed as 'high volume' sprayers*."

The pre-harvest trial in March 2003, which looked at the effect on deposits of altering adjuvant concentrations and application volume, indicated that Rovral plus Du-Wett gave equivalent *Botrytis* control at half or quarter of the spray volume needed with a conventional adjuvant. That comparison was made using an airshear sprayer that produces a fine droplet spectrum designed specifically for low volume application.

The effects of adding an organosilicone adjuvant to low volume (concentrate) sprays may be most pronounced when the comparison is made using a different sprayer that is primarily used for high volume application, for example an airblast sprayer delivering medium sized droplets. However, increased run-off and hence a reduction in efficacy may occur when organosilicone adjuvants are applied using a conventional airblast sprayer rather than the airshear sprayer used in the March 2003 pre-harvest trial (Trial 1).

Trial 3 was conducted in the first week of November 2003 to test whether the enhanced spread and efficacy of fungicide deposits that had been demonstrated when Du-Wett was added to a low volume (concentrate) application could be demonstrated consistently across a range of spray machinery.

The trial was designed to compare two classes of adjuvants, and no adjuvant, applied with fungicides at two different volumes (200 L/ha and 600 L/ha), and applied using three different spraying machines. The spray machines represented a conventional sprayer which is typically used to spray to the point of run-off, and two directed sprayers that deliver more uniform droplet sizes than the conventional airblast and are therefore more suited to low volume applications.

1.6.4 Trial 4 - October 2003 to January 2004:

Hypothesis "*Grapes treated throughout the season with fungicide plus Du-Wett in reduced water volumes have equivalent or less disease than grapes treated using conventional adjuvants and higher water volumes*."

Early in the project, Nufarm Ltd developed a commercial interest in registering Du-Wett with the APVMA for use in Australian viticulture. They were interested in seeing Du-Wett used as part of a full season program. Managers at Deakin Estate vineyards, near Mildura, agreed during the 2003-2004 growing season, to treat sections of Cabernet Sauvignon vines with either their standard vineyard spray program, or a program that was applied at lower volume but included an organosilicone-based adjuvant, Du-Wett. Prior to harvest, infection (powdery mildew, downy mildew and latent *Botrytis*) in blocks treated with low water volumes plus Du-Wett were compared with infection in blocks treated with the standard spray program.

1.6.5 Trial 5 - January 2004:

Hypothesis "*The type of adjuvant included in a low volume concentrate fungicide spray will affect the retention of spray deposits and efficacy against downy mildew and Botrytis*."

The focus in trials in March and October 2003 had been on comparing one organosilicone 'superspreader' (Du-Wett, a modified organosilicone blend) against the industry standard adjuvant (Agral).

The pre-harvest trial in March 2003 had indicated that the organosilicone improved deposits in bunch centres and generally on tight bunches, but the flowering trials in 2003 had not shown any improvements in deposition from using organosilicone adjuvants instead of Agral.

By January 2004, phytotoxicity trials had indicated that there was negligible risk of damage from the available adjuvants. Therefore four classes of adjuvant were applied to Shiraz grapevines at pre-bunch closure in January 2004: a nonyl phenol ethoxylate (Agral) as the industry standard, a modified organosilicone blend (Du-Wett), a pure organosilicone (Brushwet), and a vegetable oil (Synertrol). The vegetable oil was included in response to questions raised by growers in the wine industry about commercial adjuvants other than organosilicones.

1.6.6 Trial 6: April 2004

Hypothesis "*Adding a 'sticker' adjuvant to a fungicide mix will maintain deposits after a rainfall, whereas adding a pure organosilicone will decrease deposits, compared to the non-ionic, industry standard adjuvant*."

Achieving spread of fungicide across a target surface is a key limitation to disease control in grapes. The organosilicone adjuvants tested within this project aimed to enhance the spread of fungicides by reducing surface tension of the spray mixture. One property of the 'super adjuvants' added to reduce surface tension is that they are reactivated by subsequent moisture

on the leaf surface, for example due to a heavy dew or rain, and this may lead to run-off and hence loss of deposits from foliage or bunches. A trial was conducted to ascertain whether adjuvants containing 'sticker' compounds would improve the rainfastness of a fungicide applied to grapes, and, conversely, demonstrate that organosilicone adjuvant would reduce rainfastness. Three adjuvants, one containing both sticker and a spreader, one containing only an organosilicone spreader and the third a nonyl phenol ethoxylate, were applied with Rovral WG™ to Cabernet Sauvignon grapes at a vineyard in the Yarra Valley, prior to harvest in 2004. Fungicide residues were compared after a simulated 'rainfall'.

1.6.7 Trials 7, 8 and 9:

Hypothesis "*Addition of an organosilicone based adjuvant at flowering or at pre-bunch closure will lead to enhanced disease control when compared with the non-ionic industry standard*."

Trials at flowering in October 2004 and at pre-bunch closure in December 2004 and January 2005 were to confirm results obtained in October 2003 and January 2004 trials, and to repeat the same adjuvant treatments across two growth stages and two canopy types. The same treatments were used in each trial, simplified to one spray machine, four adjuvants, and both high and low volume applications of fungicide with and without adjuvant.

Of particular interest was the comparison between deposits achieved using the pure and the modified organosilicones. Although the January 2004 trial was hampered by missing data, the pure organosilicone had seemed superior to the modified organosilicone in one rep, and the comparison warranted repeating.

2 GENERAL MATERIALS AND METHODS

2.1 Four laboratory trials to assess the physical and chemical properties of adjuvants in spray mixtures

2.1.1 Influence of the surface tension of grape berries and leaves on droplet spread

To provide a measure of the 'surface roughness' or 'ease of wetting' of grape berries and leaves, the static contact angle of droplets of 20% acetone was measured on grape berries and grapevine foliage according to the method by Forster & Zabkiewicz (2001). A range of grape varieties were tested, using both leaves and bunches (Table 2-1).

Table 2-1 Tissue types used to measure static contact angle of droplets of 20% acetone in water.

Variety	Surface
Cabernet sauvignon	Upper leaf
Cabernet sauvignon	Lower leaf
Sauvignon blanc	Upper leaf
Italian Muscat	Immature berry
Red Globe	Mature berry

2.1.2 Influence of adjuvant type and concentration on the equilibrium surface tension of water and droplet spread

Equilibrium (static) surface tensions of surfactant solutions (Table 2-2) in water were measured using a Cahn balance with three replicates per treatment.

Each adjuvant was tested at the label rate, where a label rate existed. The spreading potential was also tested at a series of increasing concentrations, to find the concentration above which there was no additional spreading. The concentrations shown in Table 2-2 are those selected for testing in fungicide/insecticide tank mixes.

To assess the effect of adjuvant type and concentration on droplet spread, droplets (0.5 µl) of solutions containing each adjuvant (Table 2-2) at a range of concentrations were applied to berries. Droplet application was confined to berries with wax "bloom" visibly undisturbed. The berries were from immature grape bunches sampled in January (NZ Muscat Italia thinnings) and stored in a cool store (4°C). They were allowed to equilibrate to 20°C before use.

The adjuvant mixtures contained a fluorescent dye (0.5% Blankophore P; Bayer) as a tracer. When droplets were dried (and spreading complete), their images were captured by video camera and spread areas quantified by image analysis (V++ Software).

Table 2-2: Classes and trade names of adjuvants selected for inclusion in screening trials.

Adjuvant class/type	Adjuvant	Supplier	Rate/100L (bold = label recommended rate)	Range % v/v
Standard adjuvant (nonylphenol ethoxylate)	Agral®	Syngenta	10 mL and 30 mL in both dilute and concentrate tank mixes	0.01 – 0.03
Non-ionic adjuvant (linear alcohol ethoxylate)	Spraymate™ or Chemwet 1000	Nufarm	40 mL and 120 mL in both dilute and concentrate tank mixes	0.04 – 0.12
Sticker-spreader (latex + organosilicone blend)	Designer®	Nufarm	100 mL and 150 mL in dilute mix 300 mL and 450 mL in concentrate mix	0.1 – 0.15
Organosilicone super-spreader ('pure' organosilicone)	Pulse® Penetrant	Monsanto	25 mL and 50mL in dilute mix 50 mL and 100 mL in concentrate mix	0.025 – 0.1
	Brushwet®	SST products		
Modified organosilicone (blend, + organic fluid)	Du-Wett®	Elliott Chemicals	50 mL and 75 mL in dilute mix 150 mL and 225 mL in concentrate mix	0.05 – 0.225

2.1.3 Influence of adjuvant type and concentration on the droplet spread of fungicide tank-mixes

The spread of droplets of each of the pesticide tank mix/adjuvant combinations (Table 2-3, was measured by the method described in section 2.1.2.

Analysis of variance and least significant difference (LSD) tests at $P<0.05$ were used to compare treatment means.

Table 2-3: Tank mixes included in laboratory screening, representing common combinations used by vineyard managers.

Mix	Growth Stage	Tank Mix	Dilute rate per 100L	Concentrate rate per 100L
1	Bud burst to flowering	Microthiol Disperss WDG (sulphur) Penncozeb 750 DF (mancozeb)	400 g 200 g	1200 g 600 g
2		Microthiol Disperss WDG Captan WG (captan)	400 g 125 g	1200 g 375 g
3		Microthiol Disperss WDG Champ Dry Prill WG ($Cu(OH)_2$)	400 g 175 g	1200 g 525 g
4		Prosper 500 EC (spiroxamine)* Penncozeb 750 DF	60 mL 200 g	180 mL 600 g
5	Flowering to berry set	Bayfidan 250 EC (triadimenol)* Penncozeb 750 DF Dipel DF (BT)***	10 mL 200 g 100 g	30 mL 600 g 300 g
6		Scala 400 SC (pyrimethanil)* Champ Dry Prill WG Microthiol Disperss WDG Dipel DF	200 mL 175 g 400 g 100 g	600 mL 525 g 1200 g 300 g
7		Elect 720 (chlorothalonil) Microthiol Disperss WDG Dipel DF	160 mL 400 g 100 g	480 mL 1200 g 300 g
8		Dipel DF Scala 400 SC* Flint 500 WG (trifloxystrobin)*	100 g 200 mL 15 g	300 g 600 mL 45 g
9		Teldor 500 SC (fenhexamid)* Microthiol Disperss WDG Dipel DF	100 mL 400 g 100 g	300 mL 1200 g 300 g
10	Pre-bunch closure	Rovral 750 WG* (iprodione) Dipel DF Ridomil Gold Plus** (Cu/metalaxyl)	65 g 100 g 225 g	195 g 300 g 675 g

All products from Nufarm Ltd except: *Bayer CropScience, **Syngenta Crop Protection Pty Ltd, *** Valent Biosciences

2.1.4 Formulation-adjuvant compatibility/stability

Each tank mix plus adjuvant combination was screened at two different fungicide tank concentrations, equivalent to the label rate recommended for a dilute spray, and at 3 times the dilute rate concentration for a low volume application.

The conventional adjuvants, Agral and Chemwet 1000, were used at their recommended rates and at three-times recommended concentration in this study (Table 2-2). While this is below their threshold concentration for optimum spreading, pesticide formulations were considered unlikely to have any effects on Agral and Chemwet's physical properties in solution.

In contrast, certain surfactants and co-formulants in agrochemical formulations are well known to interfere with the physical properties of organosilicone surfactants and to affect their ability to superspread (Gaskin *et al.* 2000b; Policello & Murphy 1993). In addition, it has been established that organosilicone surfactant use rates on winegrapes are a complex function of agrochemical mixes and rates, spray application volumes, canopy type and target tissue (bunches or foliage) (Gaskin *et al*. 2002). Hence, the organosilicone adjuvants were used at different rates in Dilute and Concentrate sprays (Table 2-2), to maximise their benefits across the wide range of pesticide formulations and concentrations screened in the study (Table 2-3).

Tank mixes 1 to 10 (Table 2-3) were examined, at 0 and 6 hours after mixing at dilute and concentrate rates with each of the five adjuvants, for any sign of formulation instability (i.e. precipitation, flocculation, changes in settling time). All tests were carried out at 20°C.

2.2 Nine vineyard trials to compare bioefficacy and phytotoxicity of fungicides applied in combination with different adjuvants

Nine replicated field trials were conducted in vineyards, between March 2003 and March 2005.

One trial investigated the risk of phytotoxicity from using adjuvants.

Seven trials involved:

- Spraying grapevine canopies with fungicides, with or without adjuvant.
- Inoculating bunches and foliage with fungal spores
- Assessment of spray deposition.
- Assessment of disease.

One trial compared disease at harvest after a seasons spray program using either the grower's standard tank mixes or half volume, concentrated mixtures with added organosilicone adjuvant.

All the trial sites were at commercial vineyards (Table 2-4) and all were drip irrigated.

A general description of the methods for applying treatments, inoculating leaves and bunches, disease assessments, and assessing deposits, is provided in this chapter.

Specific details of material and methods used in each separate site and trial are provided in the specific appendix for that trial.

Table 2-4: Summary of site details for trials conducted between March 2003 and January 2005.

Order of trials	Year	Date	Variety	Growth stage	Location	Canopy type
1	2003	March 2003	Ruby Cabernet	Pre-harvest	Dareton	Box hedge
2	2003	October 2003	Chardonnay	Flowering	Irymple	Box hedge
3	2003	November 2003	Shiraz	Flowering	Irymple	Box hedge
4	2003-04	Full season	Cabernet Sauvignon	All	Iraak	Box hedge
5	2004	January 2004	Shiraz	Pre-bunch closure	Irymple	Box hedge
6	2004	April 2004	Cabernet Sauvignon	Pre-harvest	Coldstream	VSP*
7	2004	October 2004	Chardonnay	Flowering	Irymple	Box hedge
8	2004	December 2004	Chardonnay	Pre-bunch closure	Irymple	Box hedge
9	2005	January 2005	Merlot	Pre-bunch closure	Healesville	VSP

* VSP – vertical shoot positioned

2.2.1 Spray treatments

Details about the fungicides and adjuvants used in each trial, and the spray equipment used to apply treatments, are provided in the relevant trial appendix.

2.2.2 Fungicide bio-assays to assess efficacy

Botrytis inoculum preparation

Botrytis cinerea (isolate B33, obtained from Dr Tonya Weichel of Monash University, Frankston, Vic) was maintained on PDA (potato dextrose agar) at 20°C. To induce sporulation, 2 week old cultures were placed under a long wave UV light overnight. A spore suspension was prepared in distilled water containing 3 drops per mL of surfactant (Tween 20) to stop spores clumping together. The spore concentration was adjusted to the desired concentration using a haemocytometer.

Botrytis - inoculation

Bunches to be inoculated were tagged with flagging tape so they could be identified later for disease assessments. Spores were sprayed onto bunches using a hand held, trigger powered sprayer until wet (approximately 3 mL of spore suspension per bunch) (Figure 2-1). Inoculated bunches were bagged, using zip-lock plastic bags (15 cm × 23 cm), to maintain high humidity and allow the *Botrytis* spores to (Figure 2-1). Inoculations were performed in the early evening to prevent excessive heating of the tissue enclosed in the bag that would occur in direct sunlight. The plastic bags were all removed early the following morning.



Figure 2-1 Inoculating bunches with *Botrytis* spore suspension (left) and bunch then bagged to incubate overnight (right), before applying fungicide ± adjuvant treatments. Bags were removed before the treatments were applied.

Botrytis - disease assessments

Botrytis infection in the inoculated bunches was assessed at DPI Knoxfield. Bunches were collected from the field after a suitable incubation period (ranging from 1-2 weeks). Bunches were placed in zip-lock plastic bags with a piece of paper towelling moistened with distilled water to maintain a humid environment. Trial 7 was an exception - plastic take-away food containers (Genfac G750, Genfac Plastics Melbourne) were used instead of plastic bags. Bunches were placed in a domestic freezer (-18°C) overnight to break down the natural resistance of the host tissue to allow disease symptom expression to occur. The following morning, bunches were removed from the freezer and placed on a bench in the laboratory where they were exposed to ambient light to encourage sporulation. Bunches were incubated on the bench for seven days at room temperature, after which *Botrytis* had sporulated on infected berries. The number of *Botrytis* infected and non-infected berries in each bunch was scored using a dissector microscope. Berries were scored as infected if any characteristic conidiophores bearing bunch-like conidia were present.

Downy mildew - inoculum preparation

Downy mildew (*Plasmopara viticola*) inoculum was maintained on potted Chardonnay grapevine cuttings from a culture collected from a vineyard in Wantirna, Victoria in 1999. Sporangia were washed from infected leaves by shaking leaves in distilled water inside a glass bottle. The sporangia suspension was filtered through a fine nylon mesh to remove sporangiophores and other debris. Sporangia suspensions were adjusted to the desired concentration using a haemocytometer.

Downy mildew - inoculation

Shoots to be inoculated were tagged with a piece of flagging tape tied around the shoot so that 2 leaves of a least 3 cm length were between tag and the shoot tip. In this way leaf positions could be identified later during disease assessment. Sporangia suspension was sprayed onto the undersides of leaves between the tag and the shoot tip using a hand held, trigger powered sprayer until wet (approximately 5 mL of spore suspension per shoot tip). Inoculated shoots

were bagged, using zip-lock plastic bags (15 cm × 23 cm), to maintain leaf wetness to allow the zoospores to germinate. Inoculations were performed in the early evening to prevent excessive heating of the tissue enclosed in the bag that would occur in direct sunlight. The plastic bags were removed early the following morning.

Inflorescences were inoculated with downy mildew in the evening using the same protocol used for *Botrytis* inoculation of inflorescences.

Downy mildew - disease assessments

Downy mildew infection in the inoculated bunches and shoots was assessed at DPI Knoxfield. Bunches and shoot tips were collected from the field after a suitable incubation period (7-10 days).

After 12 hours incubation in darkness in sealed plastic bags, the underside of leaves were photographed with a digital camera (Olympus E-20P, Olympus, Japan). The area of the leaf covered with sporulation downy mildew and the total leaf area was measured using image analysis software (Sigmascan Pro, Jandel Scientific USA). A measure of the diseased area per shoot was calculated from the infected leaf area and total leaf area for the most susceptible leaves on the shoot.

Bunches were placed in zip-lock plastic bags with a moist piece of paper towelling to maintain a humid environment and were kept in darkness overnight at room temperature. The following morning, downy mildew had sporulated on infected berries. The number of downy mildew infected and non-infected berries in each bunch was scored using a dissector microscope. Berries were scored as infected if any characteristic white sporangiophores bearing downy mildew conidia were present.

When disease levels were very low, and not visible to the naked eye (as occurred in Trial 4), microscopic examination was used to confirm some pin-prick type lesions were downy mildew. Infected leaves were then washed to remove sporangia and concentrated by centrifugation. Six leaves were washed sequentially in 20 mL of distilled water containing the surfactant Tween 80. Fifteen mL of this solution was centrifuged at 3100 rpm (Centaur 2, MSE, UK). The pellet was resuspended in 1 mL dH_2O. Sporangia were then counted using a haemocytometer. Leaf area was measured using Sigma scan to determine sporangia production on a leaf area basis (sporangia/cm^2).

Powdery mildew inoculum preparation

Powdery mildew (*Uncinula necator*) spores were sourced from potted grapevines in the glasshouse at DPI Knoxfield.

Powdery mildew inoculation

A powdery mildew bioassay was conducted on leaves from the pre bunch closure vineyard trial in the Yarra Valley in January 2005 (Trial 9).

The tips of shoots were collected from the field into polyethylene bags the day after the spray was applied. The youngest leaf on each shoot of at least 3 cm length was detached from the shoot at the base of the petiole. The end of the stem was cut under water with a razor blade and placed into a 50 mL plastic cup (Solo brand) of water through a small hole punched in the lid so the upper leaf surface was facing upwards.

One leaf from both inner and outer canopy positions from each treatment were inoculated together per replicate. Leaves were inoculated in a 1.5 m high cardboard spore settling tower. Leaves were placed inside the settling tower and powdery mildew conidia from 14 heavily infected leaves were dislodged using an airstream from a pipette tip attached to the end of an

air compressor hose. Spores were allowed to fall onto leaves under gravity for approximately five minutes before inoculated leaves were transferred to constant temperature cabinets for incubation at 22 °C, 75 % RH, 12/12 hrs light/dark.

Powdery mildew Disease assessments

After 14 days incubation, leaves were examined under a dissector microscope and sporulating powdery mildew colonies were traced with a permanent marker. Leaves were then photographed with a digital camera and the percentage leaf area diseased was calculated using image analysis (Sigmascan Pro, Jandel Scientific USA).

2.2.3 Assessment of deposits on leaves and bunches collected from grapevine canopies.

The use of tracer dye to quantify spray deposits

Tartrazine[1] ($C_{16}H_9N_4Na_3O_9S_2$, Colour index No. 19140) was added to each spray mixture as a tracer dye. Tartrazine is highly soluble in water and provides good recovery when rinsed from treated bunches and foliage.

The concentration of tartrazine in each tank mix varied according to the water volume applied, with the aim being to maintain an equivalent amount of dye per 100 m of vine row (or per hectare) regardless of water volumes.

The amount of tartrazine recovered from treated berries or foliage, and in duplicate samples of each tank mix, was measured using a spectrophotometer at 700 and 430 nm.



Figure 2-2 Tartrazine dye in granular form (left), being pre-mixed (centre), and evident as a yellow plume leaving the sprayer (right).

Sample collection

The canopy was partitioned into ‘high-inner’, ‘high-outer’, ‘low-inner’ and ‘low-outer’. Bunches and leaves sampled from each partition were cut at the petiole or bunch stem, into plastic zip-lock bags and stored immediately in a cooler box until they could be transferred to a cool room.

Details on the number of leaves or bunches collected from each position, to make up each sample, are provided in the method details for each trial.

[1] Tartrazine synonyms: Acid Yellow, Artificial colouring 102 (Australia), Colouring #5 (USA)

Sample preparation for measuring dye recovery from bulk leaf or bunch samples

Tartrazine dye was rinsed from the bunch and leaf samples using the following method:

The weight of each bulk bunch or leaf sample was recorded. De-ionised water was dispensed into each plastic bag containing a bulk sample. The water was measured using a 50-mL volumetric dispenser - calibrated using a balance to deliver 50.0 ±0.1 g of water. Bulk leaf samples were rinsed in 100 mL of de-ionised water. Bulk bunches at pre-bunch closure or pre-harvest were rinsed in 200 mL (or 300 mL if they were very large bunches). Bulk bunches at flowering were rinsed in 50 mL.

Each bag was shaken for approximately 10 seconds – then left to stand - then re-shaken and filtered by taking 30 mL of rinsate from each bag with a 50 mL syringe and filtering through an 8-micron, 47-mm diameter nitrocellulose filter (Millepore catalogue number SCWP 04700) with an AP25 pre-filter (Millepore catalogue number AP2504700). The first 15 mL of filtered rinsate was ejected to waste. The second 20 mL was collected in a glass scintillation vial and stored at 4°C prior to analysis by spectrophotometry. Between samples, 20 mL of de-ionised water was passed to waste through the filter.

Sample preparation of sectioned bunches (March 2003 only)

Prior to sampling bunches in the vineyard, the 'front' (most exposed surface) of the bunch was recorded by marking a single 'front' berry with a dot of 'liquid paper' correcting fluid. Bunches were sampled into individual brown paper bags to prevent them sweating and so avoid redistribution of tartrazine dye.

In the laboratory at DPI Mildura, each bunch was sectioned to separate the berries that were at the front, the rear, the bottom and the centre of the bunch. The remaining berries in the bunch were also retained

The weights of each five-berry section were recorded. The berries were then rinsed in 10-mL de-ionised water, dispensed from a volumetric dispenser. The whole 10-mL of rinsate was drawn up from each bag, using syringe and filter as described above. The first 5-mL of filtered rinsate was ejected to waste. The second 5-mL was collected in a glass scintillation vial.

Between samples, the filter was rinsed by passing 20 mL of de-ionised through the filter.

Preparation of sectioned berry samples

The weights of five berries from each sectioned bunch (including bag weight) were recorded. The berries were then rinsed in 10-mL de-ionised water, dispensed from a volumetric dispenser. The whole 10-mL of rinsate was drawn up from each bag, using syringe and filter as described above. The first 5-mL of filtered rinsate was ejected to waste. The second 5 mL was collected in a glass scintillation vial.

Between samples, 20 mL of de-ionised water was passed to waste through the filter. When filters began to block they were back-flushed with 20-30 mL of water and re-used. When they began to block again they were discarded.

Measuring the area of the intercepting surfaces of leaves or bunches

Once rinsed, leaves were towel-dried. In 2003 they were passed through a Delta-T area meter to measure surface area. Leaf deposits were expressed in relation to leaf area. In 2004 and 2005 the leaves were photographed with a digital camera and image analysis software (Sigma scan Pro 3; Jandel Scientific) then used to measure their area.

In March 2003, whole bunches were also placed on the Delta-T Area Meter to provide an approximate measure of the intercepting surface of each sample. All whole-bunch deposits were expressed in relation to both bunch weight and the area of the intercepting surface. Sectioned bunch deposits were only expressed in relation to berry weight..



Figure 2-3: Examples of loose and tight Ruby Cabernet bunches (left) and the image of a tight bunches intercepting surface being recorded by the Delta-T area meter (right).

Measuring tartrazine recovered from treated leaves and bunches

Tartrazine concentration in sample rinsates was analysed using a GBC *Cintra 10e* UV-visible spectrophotometer, measuring absorbance at 430 nm and 700 nm, and zeroed against distilled and deionised water after every tenth sample.

Concentrated samples were diluted and injected into the spectrophotometer using an autosampler (GBC FS3000). Smaller volume and less concentrated samples were transferred into cells for manual processing in the spectrophotometer. Reported absorbances were adjusted for sample dilution and cell depth, and later for rinsate volume.

The concentrations of tartrazine in the solutions used to rinse leaves or bunches were expressed relative to the leaf area ($\mu g/cm^2$) or the bunch weight ($\mu g/g$). The concentrations were then adjusted according to the concentration of the original tank mix, to normalise the data. This enabled us to express deposits relative to a constant 'reference' application rate (1 kg tartrazine/hectare). Normalising the measured concentrations provided a point of comparison between treatments applied in different volumes or at different concentrations.

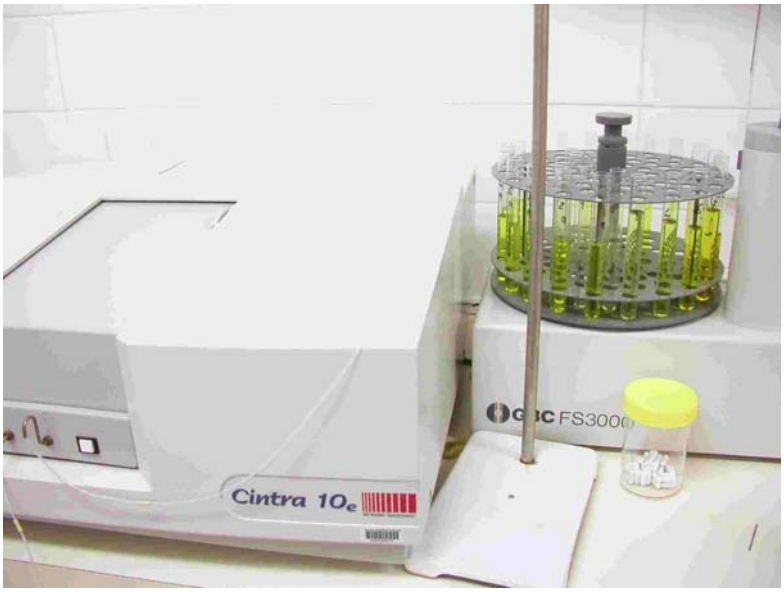


Figure 2-4: Tartrazine rinsate recovered from leaf or bunch sample being analysed by the GBC *Cintra 10e* UV-visible spectrophotometer.

Normalisation calculation to express deposits relative to a constant 'reference' application rate (1 kg tartrazine/hectare)

$$N_{(\mu g/g)} = D_{(\mu g/g)} \div R_{(kg/ha)}$$

where

$N_{(\mu g/g)}$ = Normalised deposit in $\mu g/cm^2$ or $\mu g/g$.

$D_{(\mu g/g)}$ = Deposit (in $\mu g/cm^2$ or $\mu g/g$) measured by spectroscopy and corrected for sample surface area or sample weight and also for rinse volume.

$R_{(kg/ha)}$ = Actual application rate applied in the trial = $T_{(\mu g/mL)} \times V_{(L/ha)} \div 1000$

$T_{(\mu g/mL)}$ = The concentration of tartrazine in the tank mix, in $\mu g/mL$, measured by spectroscopy

$V_{(L/ha)}$ = Application volume in litres per hectare measured by sprayer calibration

2.3 Statistical Analysis

Trials were designed according to randomised row\plot design with four to eight replicate plots per trial. Trial designs allowed for analysis for fixed effects and random effects.

Data was analysed using GenStat Release 6.2 (VSN International).

The effects of the canopy position samples were collected from, adjuvant treatment or water volume on spray deposits were analysed by Estimated Variance Components using the Wald tests for fixed effects.

Spray deposits on the separated bunch sections were compared by Analysis of Variance (ANOVA). Deposit data was transformed to the natural logarithmic scale to homogenise variance when necessary prior to analysis.

The effect of spray treatments on *Botrytis* infection (%) was analysed by ANOVA using logit transformed data.

Phytotoxicity (bunch damage) was analysed using REML with fixed effects = Adjuvant*Pesticide and Random effects = RepPair/(Row*Panel).

Effects in the data are reported as significant where $P<0.05$.

To increase the accuracy of comparison between treatments, recovered tartrazine dye was normalised to express the results relative to a constant application of 1 kg/ha, regardless of actual variations in the tank concentrations and application volumes (see page 28).

The normalised tartrazine measures were transformed to the natural logarithmic scale in order to satisfy modelling assumptions. Estimated means and least significant interval boundaries were back-transformed (standard errors and least significant differences cannot be back-transformed). The back-transformed least significant intervals were presented as graphs. The following description of Least Significant Intervals is by Murray Hannah, of DPI.

> "Least significant intervals (LSI's) are used to for comparing a set of means (or estimates) graphically, especially when their SEDs differ. LSIs are intervals (or error bars) that are designed to overlap where there is no significant difference between estimates, and to be disjoint where there are significant differences. LSIs address difficulties associated with unequal replication or unbalanced design (Snee, 1981) or graphically representing differences on back-transformed data (Hannah and Quigley, 1996)."

3 RESULTS AND DISCUSSION

The results presented in this section have been prepared with a non-scientist reader in mind, and to provide an overview of the research findings.

Where the word 'significant' is used to describe a treatment effect, this means that statistical analysis showed that there was at least a 95 in 100 chance that the observed difference between treatments was due to the treatment, and a less than 5 in 100 chance that the observed was due to coincidence. If differences are described in the text as being 'not significant', it means that researchers and statisticians would not say with confidence that the observed differences were due to the treatment.

No tables or figures are presented in this summary results section. The reader is encouraged, where there is a point of particular interest, to refer to the detailed data and statistics in the full trial reports, presented as Appendices (Sections 7-16).

3.1 Laboratory trials to assess the physical and chemical properties of adjuvants in spray mixtures

The contact angles of 1 µl droplets of 20% acetone in water, on a variety of grape surfaces, indicated that upper leaf surfaces are moderately difficult-to-wet, while lower leaf surfaces and berries are both classified as difficult-to-wet. Contact angles ranged from 93° on upper leaf surfaces to 132° on lower leaf or grape berry surfaces.

The equilibrium surface tension of water is approx. 73 nM m-1. Agral® and Chemwet® reduced the equilibrium surface tension of water to around 30 nM m-1 and increasing their concentration above 0.2% had no effect on lowering this. The adjuvants that contained organosilicone (Designer®, Pulse® and Du-Wett®) lowered solution surface tension to around 21 mN m-1 at concentrations as low as 0.02%. When droplet spread was measured on grape berry surfaces, the adjuvants were ranked (from most to least spread) Pulse > Du-Wett > Designer > Agral > Chemwet.

Droplet spread was also measured after combining each adjuvant, at different concentrations, with ten different fungicide tank-mixes, to explore the interaction between formulations of the different active ingredients and the adjuvants.

Agral: The nonyl-phenol ethoxylate class of adjuvants, including Agral, are widely used, and are the industry standard in viticulture. Increasing the concentration of Agral from 0.01 - 0.03% v/v did not result in a proportional increase in droplet coverage of either dilute or concentrate sprays. Nine of the ten fungicide tank mixes spread similarly, with 0.5 µL droplets covering only 1-2 mm^2 of berry surface. One tank mix, containing formulations of spiroxamine and mancozeb, spread well in its own right, and was not improved with Agral.

Chemwet 1000: Chemwet behaved similarly to Agral. Increasing the concentration of Chemwet from 0.04 to 0.12% v/v provided, at best, a 1.7x increase in droplet coverage. There was no effect when Chemwet was mixed to dilute or concentrate sprays. Nine of the ten fungicide tank mixes spread similarly, with 0.5 µL droplets covering only 1-2 mm^2 of berry surface. The tank mix containing formulations of spiroxamine and mancozeb again spread well in its own right. Chemwet provide some additional spread to this mix when a high concentration of Chemwet was added to a dilute fungicide mix, but Chemwet had no effect on spreading of droplets of a concentrate spray.

Designer: Increasing the concentration of Designer from 0.1 – 0.15% v/v increased droplet coverage. In dilute tank mixes, the increase was small and droplet coverage remained less than or similar to that provided by Agral or Chemwet. Spread was greater in concentrate fungicide mixes than in dilute mixes, and droplet coverage increased proportionately with the adjuvant concentration, usually to between 4 - 7 mm^2, and up to 13 mm^2. Spreading properties of Designer were slightly reduced by the tank mix containing iprodione (wettable granule), copper & metalaxyl (soluble powder) and *Bacillus thuringiensis* (dry flowable).

Pulse: The pure organosilicone adjuvants were developed as penetrants to improve herbicide uptake in a range of species (Monsanto 2002) and are now extensively used in horticultural sprays. Pulse is one example of the 'pure' organosilicone adjuvants. Pulse provided the greatest spread of all adjuvants tested. Droplets (0.5 µL) covered 25-30 mm^2 of berry surface. None of the ten fungicide mixes caused serious antagonism of the spreading properties of Pulse. With such extreme spreading, spray volumes and adjuvant concentrations must be optimised to prevent over-wetting and run-off, and to minimise the risk of sprays infiltrating stomata and causing phytotoxicity on foliage or fruit.

Du-Wett: Organosilicone blends, such as Du-Wett, have less spreading ability than the pure organosilicones. Droplet spreading increased proportionally to the Du-Wett concentration. At

low concentrations of Du-Wett (0.05% v/v), droplets (0.5 μL) covered approximately 5 mm^2 of berry surface, but at the highest concentration (0.225% v/v), droplet coverage increased to between 30-50 mm^2. There was no indication of any fungicide treatment antagonising the adjuvant's spreading properties, and pesticide concentration (dilute versus concentrate) had no effect on spreading. The interaction of spray volume with adjuvant concentration will require managing to avoid spray run-off and optimise retention on target tissues. Du-Wett has been formulated to reduce the risk of stomatal infiltration and the risk of crop phytotoxicity relative to the pure organosilicone superspreaders.

3.2 Vineyard trials to compare bio-efficacy and phytotoxicity of fungicides applied in combination with different adjuvants

3.2.1 Trial 1 Ruby Cabernet; Pre-harvest (March 2003)

Trial 1 explored the effect of adjuvant type on fungicide deposition and bioefficacy against *Botrytis* on Ruby Cabernet bunches treated post-veraison with iprodione (Rovral) fungicide. See Appendix 1 for detailed results.

NZ recommendations for the use of Du-Wett indicate that to achieve optimum retention of deposits on bunches and foliage there is an inverse relationship between the concentration of organosilicone adjuvant and the water volume applied.

The addition of adjuvant did not significantly alter the severity of *Botrytis* on bunches relative to the same water volume spray without adjuvant added. However, there was a trend (not statistically significant at P=0.05) towards improved disease control when reduced volume applications included adjuvants. The low volume sprays (250 L/ha) with Du-Wett at 0.1% and 0.2% v/v and medium volume sprays (500 L/Ha) with Agral at 0.02% v/v or Du-Wett at 0.05% v/v provided the greatest Botrytis control.

Significantly lower disease control was achieved when Du-Wett was mixed at a lower concentration (0.05% v/v) in the low volume spray (250 L/ha) relative to the two higher Du-Wett rates. By contrast 0.05% v/v Du-Wett in the high volume spray (1000 L/ha) performed well. While organosilicone adjuvants are expected to perform best in low volume sprays, and organosilicone concentrations are recommended to increase as volume decreases, that trend was not clear across the range of volumes and Du-Wett rates tested in this experiment.

The spray deposit and efficacy data supported the theory that lower rates of organosilicone are required when higher water volumes are applied. The greatest spray deposits were recovered from bunches (μg/g) and foliage (μg/cm^2) treated with Du-Wett at the middle concentration (0.1% v/v) in the medium water volume (500 L/ha). The lowest spray deposits were recovered from foliage and bunches treated with no adjuvant. The second highest spray deposits were on bunches treated using the highest Du-Wett rate (0.2 % v/v) applied in a low volume (250 L/ha). The third highest deposits were on bunches treated using the low Du-Wett rate (0.025 % v/v) applied in 1000 L/ha.

Assessment of spray deposits on tight bunches revealed that when fungicide were applied with no adjuvant or with Agral, they most effectively reached the centres of tight bunches when applied as high volume dilute sprays, but equivalent or improved penetration into bunch centres was achieved with a low volume spray that included Du-Wett.

Deposits on tight bunches, expressed relative to the intercepting surface area, were lower than deposits in loose bunches, but typically higher than deposits on inner bunches. This suggests that accessing bunches in the centre of a canopy is more of a limitation than penetrating to the centres of tight bunches. The greatest spray deposition in tight bunches was associated with use of Du-Wett at the medium to high concentrations (0.1 or 0.2% v/v) in the medium water volume (500 L/ha).

Fronts and bottoms of bunches intercepted and retained significantly more spray than the centres or backs of bunches. The highest deposits, on bunches treated with Du-Wett at 0.2% (v/v) in 500 L/ha were not due to that treatment carrying proportionally more of the liquid film into the bunch centres, but due to improved deposition equally across all zones.

Leaf deposits in the upper canopy were the lowest of all canopy positions and were not affected by type or rate of adjuvant. However there was a reduction in spray retained on lower leaves associated with using the Du-Wett at 0.1 % v/v in the high spray volume (dilute application). The high volume application with Du-Wett had probably caused excess wetting to the extent that spray was shed from foliage (low retention, across all treatment, of deposits on peripheral leaves also suggested excess wetting and run-off).

These results suggest that increased spray deposits on bunches and equivalent or increased control of *Botrytis* can be achieved at half or quarter of the spray volume used in a high volume fungicide application. There was a trend towards lower *Botrytis* severity on bunches when adjuvants were used but this was not statistically significant.

3.2.2 Trial 2 Chardonnay; Flowering (October 2003)

Phytotoxicity of adjuvant and fungicide tank mix combinations was assessed by comparing bunch weights and visual damage on bunches at harvest. See appendix 2 for detailed results. Of the 2400 Chardonnay bunches tagged at flowering, more than 98% were accounted for at harvest.

The very low occurrence of loss or damage to bunches and small differences between bunch weights and bunch condition were shown to be not due to the adjuvant or to the application rate. Nor were they due to any interactions between the adjuvants and the fungicide mixtures.

The results supported the hypothesis that the three new classes of organosilicone adjuvants, when applied at label rates, in low-volume concentrate sprays or in high-volume dilute sprays, will not cause more phytotoxicity than the non-ionic adjuvants that have been the industry standard.

3.2.3 Trial 3 Shiraz; Flowering (November 2003)

The aim of Trial 3 was to explore whether the spray deposits and bioefficacy seen in Trial 1 in low volume sprays using a sprayer classed as a 'low volume' sprayer could also be achieved by applying the same mixes with other sprayers including those that are classed as 'high volume' sprayers. The question arose because so many grapegrowers that use axial fan airblast sprayers are interested in using the adjuvant to improve disease control. See Appendix 3 for detailed results.

The type and/or set up of each sprayer affected how much spray was deposited in different sectors of the canopy (inner high, outer high, inner low, outer low). Overall, outer canopy bunches had three times higher spray deposits than inner canopy bunches.

All three sprayer types performed similarly for high-volume, dilute applications or for low-volume, concentrate applications. At high volume (600 L/Ha), sprayer type had no significantly influence on spray deposits retained on leaves. At low volume (200 L/Ha) the leaf spray deposits achieved with the axial-fan airblast were always equivalent to or significantly higher than the other two sprayers.

Leaf deposits were improved slightly (but not significantly) when Du-Wett rather than Agral was applied in low-volume by the Quantum Mist or Turbomiser sprayers. By contrast, leaf deposits were reduced slightly (but not significantly) when Du-Wett rather than Agral was applied using the axial fan airblast sprayer, regardless of water volume applied. A possible explanation for this trend is that the relatively coarser spray plume delivered by nozzles on the axial fan sprayer lead more rapidly to run-off, which was exacerbated at either volume by the increased droplet spreading using Du-Wett instead of Agral. As the differences were not significant they are not evidence to preclude use of the axial-fan to apply concentrate sprays but illustrate the importance of assessing deposition and run-off after any spray application.

Leaf deposits were generally not significantly altered by replacing Agral with Du-Wett in a high volume application, and neither adjuvant provided a benefit over using no adjuvant. There was some evidence that using an organosilicone wetter in a high water volume will cause excess run-off as there was a significant (40%) reduction in the retention of deposits on leaves for low canopy positions when Du-Wett was added to the high volume spray compared to using no adjuvant for one of the two sprayers tested.

Bunch spray deposits were also generally reduced by adding Du-Wett to a high volume spray, compared with using Agral or no adjuvant in the same volume. However, the difference was only significant on inner bunches treated with the airblast sprayer. The reduced deposition may have been due again to overwetting and demonstrates the likely disadvantage of using organosilicone adjuvants in high volume (dilute) sprays. The foliage and bunch deposit data supports recommendations from NZ trials regarding avoiding use of organosilicone adjuvants in high volume sprays.

In low volume sprays, there was no difference in deposition by the different adjuvants on inner canopy bunches. However, on outer canopy bunches, using the Turbomiser and replacing Agral with Du-Wett resulted again in a significant reduction in spray deposits. As this canopy position received the greatest amount of spray overall, the reduction in deposits is again attributed to over-wetting by Du-Wett, even at the low volume of 200 L/ha. This result highlights the importance but also difficulty of accurately estimating rates and volumes in grapevine canopies. Using Du-Wett with further reductions in spray volume would have reduced the time required to spray the vines while achieving adequate deposition on the outer canopy, but may have compromised deposits on the inner canopy. The difficulty in selecting an appropriate concentrate spray volume continues and increases through the season, particularly as a sprawling canopy matures.

All sprayed treatments had reduced *Botrytis* severity in bunches relative to the unsprayed control, but the reduction was only significant for five of the twelve treatments (axial fan at low volume with Agral or at high volume with Du-Wett; Quantum with Du-Wett in either volume; and Quantum with Agral at high volume). There was a significant increase in *Botrytis* severity in bunches when no adjuvant was used, compared to using Agral in high volume with the Quantum Mist sprayer. Replacing Agral with Du-Wett had no significant effect on *Botrytis* severity, and nor was there any apparent trend. *Botrytis* severity did not correlate well with estimated spray deposits using tracer dye recovery.

The Quantum Mist sprayer is designed for both low and high volume application. When the Quantum mist sprayer applied a tank mix containing Agral, changing from a high to a low volume application lead to a small (but not significant) reduction in deposits. When the same sprayer applied a mix containing Du-Wett, the reverse happened, ie a small (but not significant) increase in deposits when changing from a high to a low volume application. This result reflected the anticipated behaviour of the adjuvants in each volume.

If the high-volume airblast treatment with Agral is viewed as an industry standard treatment, against which to compare the new organosilicone 'super spreader' adjuvant, the data showed that the super spreader did not improve on the industry standard.

The results suggested that the axial-fan airblast sprayer, conventionally classed as a 'high volume' sprayer, performed better as a low-volume sprayer (with Agral) than as a high volume sprayer. This treatment also provided better deposition on foliage (inner and outer canopy) than was achieved by the other low volume sprayer/adjuvant combinations. On the inner canopy, higher spray deposits were delivered by the Airblast sprayer applying a low volume spray including Agral than by any of the high volume treatments, irrespective of sprayer or adjuvant, with the exception of the axial-fan airblast spray including Agral.

The benefit of using the airblast at low volume was diminished if Agral was replaced by Du-Wett. By contrast, replacing Agral with Du-Wett in low volume in the Quantum Mist or Turbomiser sprayers provided slight (although not significant) improvements in deposition. A clearer benefit from adding an organosilicone adjuvant in low volume applications was expected if the results were to be consistent with findings in similar trials conducted in New Zealand. A key difference between the NZ and Australian trials lay in the volumes and concentrations applied. The reasons for the difference are proposed: Spreading by Agral does not increase with concentrations above 0.02% v/v, but spreading by Du-Wett increases linearly with concentration (see section **Error! Reference source not found.**) and the rate of Du-Wett in the low volume applications was therefore low relative to the 3-times concentration factor used in the spray volumes and fungicide mixes in this trial. No data was available showing concentrations required for spraying inflorescences, and a concentration that reflected NZ recommendations for foliar spraying and was also the most cost effective rate from Trial 1 was assumed to be suitable at this stage in the season. In the light of more recent trials in NZ that are exploring rates of up to 0.4% v/v Du-Wett, the rate of 0.1% may have unfairly disadvantaging Du-Wett, and inflorescences may require concentrations similar to those now being trialed for wetting bunches.

3.2.4 Trial 4 Cabernet Sauvignon; Comparison between an organosilicone-based or an Agral-based spray program after spraying all season (October 03 to January 04)

Tartrazine was not included in the spray applications made in this trial. The trial relied on a comparison of disease severity in vines treated using Agral with the vineyard's standard fungicide concentrations and volumes, and using Du-Wett with double the fungicide concentration in half the volume. See Appendix 4 for trial details.

The spray program had targeted powdery and downy mildews, but not *Botrytis*. Bunches harvested from the trial showed no symptoms of powdery mildew or downy mildew infection. Nor did they, after incubation, show any *Botrytis* infection.

Lack of any disease in bunches may, in another season, have suggested that spray volumes could be reduced without compromising disease control, but the trial was conducted in a season with very low disease pressure. Therefore, in terms of providing evidence of equal or improved control using half spray volumes, the trial was unfortunately inconclusive.

The trial did highlight the importance of using inoculated tissue in vineyard trials, and not relying on field populations to provide disease pressure.

3.2.5 Trial 5 Shiraz; Pre-bunch closure (January 2004)

Trials 1 and 3 and 4 had focussed on spray retention and bioefficacy achieved using industry standard adjuvant Agral and one organosilicone 'superwetter'. A range of adjuvant chemistry is available to the grape industry. Trial 5 included a wider range of adjuvant chemistry, to test more broadly the hypothesis that the type of adjuvant included in a low volume concentrate fungicide spray will affect the retention of spray deposits and efficacy against downy mildew and Botrytis.

Concentrations of Du-Wett and Brushwet used in Trial 5 were maintained at the same rates as had been applied at flowering (Trial 3, Section 3.2.3). Concentrations of 0.1 and 0.2% v/v Du-Wett in 250 L/ha provided equal best control in the previous application to mature bunches (Trial 1), and greater cost effectiveness lead to selection of the 0.1% rate, in 300 L/ha, for Trial 5. Trial 3 results suggested that, at flowering, 0.1% v/v Du-Wett lead to excess leaf wetness with no increase in bunch deposits. Questions were raised after Trial 3 regarding the possibility that the organosilicone adjuvants were perhaps also causing over-wetting of bunches. Therefore, deposits retained on the upper and lower halves of bunches were measured separately in Trial 5. There was no significant difference between deposits recovered from the top halves compared to bottom halves of bunches, and it cannot be supposed that any of the adjuvant types caused coalescing of deposits at, or excessive run-off from, the bottoms of bunches.

Trial 3 had also lead to speculation that organosilicone concentrations may have been too low to wet flowering bunches. Comparing deposits from the five low volume adjuvant treatments in Trial 5 showed that deposits on individual bunches were significantly greater after treatment with Brushwet or with no adjuvant, than after treatment with Du-Wett. Deposits after treatment with Synertrol or Agral were ranked between no adjuvant or Brushwet and Du-Wett, and not significantly different from either. Evidence that there was no run-off but relatively poor deposition using Du-Wett in Trial 5 suggests that concentrations of Du-Wett were probably too low at this later growth stage, disadvantaging deposition by Du-Wett.

The trial was unable to confirm whether the type of adjuvant affected efficacy. Leaves from sprayed plots had 100% disease control (zero sporangia/cm^2) regardless of treatment. Similarly, disease in bunches was very low across all treatments and there were no differences between the treatments, including the unsprayed control, despite having inoculated bunches.

The trial inadvertently revealed the consequence of selecting a constant spray volume across a range of canopy sizes. The vineyard had been selected for the flowering trials in October and permission granted then to conduct the pre-bunch closure trial in January. Growth between November and January was greater at the western than eastern end of the site, due to western rows accessing water from a leaking irrigation channel. The gradient in canopy density was recognised when the pre-bunch closure trial was laid out, and trial replication was designed around the variation. But it was decided to maintain an average spray volume across all the replicates, underestimating the influence this would have on deposits. The differences in deposition due to canopy size were extreme and masked any adjuvant treatment effect. The approximately three-fold difference in the deposits on bunches from sparse compared to dense canopy demonstrates very clearly the importance of careful selection of water volumes for non-uniform canopies and also of adjusting water volumes to accommodate increasing canopy size through the season.

3.2.6 Trial 6 Cabernet Sauvignon; pre-harvest (April 2004)

Trial 6 aimed to test the hypothesis that adding an adjuvant that contains both a spreader and a 'sticker' to a fungicide mix will maintain fungicide deposits after a rainfall, whereas adding a pure organosilicone will decrease deposits and so reduce bio-efficacy when compared to the non-ionic, industry standard adjuvant. See Appendix 6 for detailed results.

The *Botrytis* inoculation was unfortunately unsuccessful, with very low disease severity on all treatments and no significant differences between treatments.

Residue analysis of the fungicide iprodione showed that, when averaged across all adjuvant and +/- rain treatments, iprodione decreased by only 8% during the seven days after spraying. Although statistically significant, this decrease was unexpectedly small, and atypical of degradation rates of many viticultural fungicides.

The type of adjuvant used with iprodione had no effect on the initial deposits or the persistence of iprodione on bunches sampled on the day of spraying or after 7 days.

When averaged across all adjuvant treatments, exposing bunches to rain after spraying did not reduce deposits compared to bunches that did not receive rain. When considering individual treatments, applying the sticker-spreader *Bond Xtra* (latex/organosilicone based) with iprodione late in the season did not significantly enhance the iprodione persistence after rain when compared against Agral or no adjuvant treatments.

Choice of fungicides for this trial was limited by the need to comply with winery restrictions on use close to harvest. The contracting winery agreed to the use of iprodione. The trial showed that the formulation is highly persistent, and that for this product there would be no advantage in using a sticker to make it more rainfast.

Consistent with the observations made in the Mildura trials, the bunch deposition was variable even in this small Yarra Valley canopy with its relatively exposed bunch zone. The variability was most extreme, with greatest mean iprodione deposits, in bunches treated with Du-Wett but no rain.

3.2.7 Trial 7 Chardonnay; Flowering (October 2004)

Trials 7, 8 and 9 in the 2004-05 season focussed specifically on testing whether adding an organosilicone-based adjuvant to sprays could provide equivalent or enhanced disease control when compared with an industry standard non-ionic adjuvant. A high volume, no adjuvant treatment was also included in this trial as a 'reference' treatment, representing common practice in commercial vineyards. See Appendix 7 for detailed results.

As in earlier trials, the position within the canopy that leaves were sampled from had a strong influence on deposits from each treatment. Outer leaves intercepted, on average, 2.5 times the deposits on inner leaves. The addition of adjuvants to spray mixes applied in high or low water volumes did not significantly change spray deposits on foliage (for any of the canopy positions) relative to the same water volume without adjuvant with the exception of Agral. The addition of Agral significantly reduced deposits on high outer position foliage for both low and high water volume applications.

Despite more spray being deposited on outer than inner leaves, there was significantly more downy mildew on outer than inner leaves when averaged across all treatments. This difference, most pronounced in the unsprayed control leaves, is most likely related to faster shoot growth and more young, highly susceptible leaves on shoots growing on the outside of the canopy. Leaves become more resistant to downy mildew as they age (Reuveni 1998) and the slower growing inner shoots have less young susceptible leaves. All sprayed treatments had significantly lower downy mildew severity on leaves than the unsprayed control. There were no significant differences in disease control due to including adjuvants in the spray mix relative to using no adjuvant. However, the low volume applications with Du-Wett and Brushwet resulted in downy mildew control equivalent to the high volume, no adjuvant treatment (conventional industry practice) while the low volume treatments with both no adjuvant and Agral did not. These low volume treatments with no adjuvant or Agral had poorer disease control than the high volume, no adjuvant treatment (conventional industry practice) in at least one of the canopy positions.

The greatest deposition on bunches (both inner and outer canopy) was achieved using a high volume application with no adjuvant, and on outer canopy bunches this treatment provided significantly more deposits than all other treatments. On the inner canopy, low volume applications with no adjuvant or with Du-Wett resulted in bunch deposits that were not significantly different to the high volume treatment without adjuvant, while those including Agral or Brushwet resulted in significantly worse deposition. All of the low volume treatments were not significantly different from each other regardless of adjuvant.

All sprayed treatments resulted in effective control of downy mildew in bunches, relative to the untreated control. Inner bunches had higher disease severity than outer bunches, which is in agreement with the spray deposit data. Disease control by all adjuvant treatments was not significantly different to the high volume treatment without adjuvant. However, disease control was significantly greater in outer canopy bunches treated with Du-Wett in a low volume than with Brushwet or Agral in low volume.

The *Botrytis* infection data was highly variable and could not be analysed statistically. It appeared that all treatments failed to reduce disease to any great extent although the high volume application with no adjuvant appeared to have the least disease which is in agreement with the deposit data.

The results highlight that organosilicone adjuvants generally reduced spray deposits relative to conventional high volume fungicide applications. Nevertheless, equivalent downy mildew control was achieved using a copper fungicide. However, low volume applications without adjuvant also usually (but not always) provided the same level of disease control.

3.2.8 Trial 8 Chardonnay; pre-bunch-closure (December 2004)

Detailed results for this trial are presented in Appendix 8. The severity of Downy mildew infection on leaves was overall very low. No infection was detectable on inner leaves and the outer leaves had a maximum disease severity of 2 % infection in the control treatment. All the sprayed treatments effectively controlled downy mildew (96-100% disease control) relative to the unsprayed treatment with no significant differences due to adjuvant or application volume. Low disease severity, especially on inner canopy leaves, was most likely due to lack of susceptible leaf tissue (young actively growing leaves) at this time of the year.

In keeping with the lack of differences in leaf infection between treatments, spray deposits on leaves in the outer canopy were similarly not significantly affected by adjuvant type or by spray volume. However, there were differences in deposition on the inner canopy with the greatest deposition achieved using the reference treatment (high volume with no adjuvant). All the other treatments lead to a significant reduction in spray deposition on leaves. Spray deposits on inner canopy leaves from the low volume applications ranked Pulse > Du-Wett > Agral, with deposits from the Pulse treatment being significantly greater than the Agral treatment.

The lack of treatment differences between spray deposits on outer canopy leaves suggest that all volumes and mixes were adequate to wet the outer canopy. Treatment differences on inner leaves suggest that high volumes were required to overcome poorer access to the inner canopy. When low volumes were used, the organosilicone treatments provided no advantage over no adjuvant although the Pulse treatment had higher deposits than the industry standard adjuvant, Agral.

Botrytis infection was low overall, and severity of infection unaffected by the adjuvant type or spray volume, with no significant differences between any of the sprayed treatments or the unsprayed control. There was however a significant effect of bunch position on infection, with more than 3 times as much disease on inner bunches than on outer bunches (8.7 and 2.2 % disease severity, respectively).

The pattern of *Botrytis* infection corresponded to the pattern of spray deposition, with significantly greater deposition on outer than on inner canopy bunches, but no significant effect due to adjuvant or volume.

3.2.9 Trial 9 Merlot; pre-bunch closure (January 2005)

Detailed results for this trial are presented in Appendix 9. Powdery mildew infection on outer leaves was reduced significantly by all the sprayed treatments compared to the unsprayed control treatment. Outer foliage on unsprayed vines had 3 to 9 times higher disease severity than treated vines. However, there was no statistically significant treatment effect on outer leaves that could be attributed to type of adjuvant. Possible adjuvant effects may have been masked by a high level of within-treatment variability. For example, the 50% reduction in disease severity that occurred on outer leaves treated with Du-Wett relative to the low volume treatments with no adjuvant or Agral was not statistically significant.

Powdery mildew infection on inner leaves was greater than on outer leaves across all treatments. On the inner canopy, there was no reduction in powdery mildew severity using high volume applications, with or without Agral. However, disease severity was significantly reduced by the low volume applications with Du-Wett, Brushwet and no adjuvant.

Spray deposits were also affected by adjuvant treatment, with the results raising concerns that the rates and water volumes were high for a foliage spray, leading to excessive losses from foliage treated with organosilicone. In the inner-low and outer canopy positions, the greatest deposits were on leaves sprayed at low volume with no adjuvant. Adding Du-Wett or Brushwet reduced deposition on inner leaves, usually significantly, suggesting that the chosen organosilicone rate caused the foliage to be over-wet at low volume.

There were no treatment differences between leaf deposits in the high-inner canopy, which had the lowest overall deposition and where over-wetting did not occur. Lack of treatment effect here was considered due to poor access to this position by the sprayer rather than being influenced by the adjuvant treatments.

Botrytis severity was significantly greater on bunches from the inner canopy relative to the outer canopy (50% increase). In the inner canopy, bunches treated at low volume with Du-Wett had least *Botrytis*, by a considerable margin and it was the only treatment to significantly reduce disease relative to the unsprayed control. In the outer canopy, bunches treated at high volume with Agral had the least *Botrytis*, while bunches treated at high volume with no adjuvant had the most, but the differences between these, or the treatments that ranked in between, were not significant.

Deposits on inner bunches were approximately half those on outer bunches, consistent with the higher level of disease observed on inner bunches. In the inner canopy, spraying high volume with or without Agral had no effect on bunch deposits. However, there was significantly more spray deposit on bunches sprayed at low volume with Brushwet than at high volume with Agral. In the outer canopy there were no significant differences in bunch deposits between any of the sprayed treatments.

4 DISCUSSION, CONCLUSIONS & RECOMMENDATIONS

Addition of spray adjuvants to agrochemical mixtures can alter the surface tension of spray droplets and improve spray deposits on difficult targets like grape bunches. Adjuvants are at the forefront of a global trend to customise pesticides for maximum pesticide efficacy and minimum environmental risk. This GWRDC project used methods from previous NZ research and new bioassay techniques developed during the project, to explore economic and efficacy gains when conventional, high-volume spray programs are replaced with low-volume sprays that included organosilicone adjuvants. The aim was to reduce spray volumes used in commercial vineyards by at least 50% while maintaining or improving disease and pest control.

Based on NZ experience, where organosilicone adjuvants have been used with greater success, there was an expectation that the current trials would lead to clear prescriptions for the use of organosilicone adjuvants in grapevines in Australia. Effective disease control, using 25-50 % of the water volume used in high volume dilute applications, was achieved in most of the nine field trials conducted between 2003 and 2005, but this could not be clearly attributed to specific use patterns of the organosilicone type adjuvants. Therefore it was not possible to make simple prescriptions for using organosilicone adjuvants across a range of growth stages and canopy types for the Australian viticulture industry.

The reasons why different conclusions about the performance of organosilicone adjuvants were drawn from the Australian and NZ research were not resolved. Factors which may have contributed are differences in: canopy architecture, spray machinery, adjuvant rates and disease assessment protocols. Australian vine canopies (especially in warmer areas) often lack a discrete bunch zone while NZ canopies usually have a defined bunch zone. A broader range of spray equipment was used in the Australian trials. The NZ work generally used higher rates of organosilicone adjuvants than were tested in the Australian trials (Australian adjuvant rates were based on those that gave the best results in the initial trial). In addition, the Australian spray trials had multiple treatments and included low volume fungicide applications without added adjuvant to separate the effects of low volume application from adjuvant effects. Much of the NZ work involved season-long trials in commercial settings and compared low volume adjuvant treatments with conventional high volume spraying practices. In the Australian trials, grapevines were inoculated with pathogens after spraying to measure bioefficacy of each individual fungicide application. In the NZ work, disease control was measured at harvest and therefore was a measure of the efficiency of the season long spray program.

The Australian data clearly showed that overcoming deposition variability in the vine canopy is more critical than trying to improve coverage solely by adding adjuvants.

This section discusses the outcomes and conclusions in the context of the project objectives.

Objective 1 "*Determine the physical and chemical interactions when conventional and organosilicone adjuvants are used with up to 20 combinations of active ingredient and formulations currently used in Australian viticulture*".

There was no evidence that fungicide formulations in the spray mixes were antagonistic to the spreading provided by the organosilicone adjuvants. This result was in contrast to results seen in a New Zealand wine grape study by Gaskin et al (2002) where some formulations reduced spread by the adjuvant.

The amount of spreading resulting from the addition of a given rate of adjuvant was relatively consistent for the different fungicide tank mixes, with the exception of tank mixes containing spiroxamine. This confirmed that prescriptions for use of the adjuvants in vineyard spray programs will require few exceptions for specific pesticides. Droplets of tank mixes that included spiroxamine spread much more than droplets from the other nine tank mixes,

whether mixed with Designer, Agral, Chemwet or Du-Wett. The spread was further increased as rate of adjuvant increased. When mixed with the pure organosilicone Pulse, spread by spiroxamine remained high but was comparable to the enhanced spread of the other tank mixes.

Spreading by conventional adjuvants was shown to increase very little as adjuvant concentration increased. The organosilicones behaved differently however, with spreading positively correlated with the adjuvant concentration. As spray volumes are reduced for concentrate spraying, due to the increased concentration of organosilicone required, the amount of adjuvant used on a hectare basis (and hence adjuvant cost) is not reduced in low volume sprays. Instead, economic gains are made through increased work rates and savings through labour and machinery efficiencies associated with using smaller spray volumes.

The increased spray coverage provided by the organosilicone adjuvants had the potential to also improve disease control. Recommendations were made for field trials to investigate such possible gains.

Objective 2: "*Apply agrochemicals in combination with a range of adjuvants to vines and assess foliar deposits and penetration of liquid films into the grape bunches at flowering, pre-bunch closure and after bunch closure"*.

4.1 Phytotoxicity

Some adjuvants are able to reduce surface tension of the spray to such an extent that some stomatal infiltration can occur which may lead to phytotoxicity. In addition, applying concentrate mixes has the potential to increase chemical concentrations of plant tissue and may cause phytotoxicity on foliage or inflorescences. Trial 2 was a phytotoxicity screen that included 30 treatments, and showed that:

- The new organosilicone adjuvants, when applied at label rates, in low-volume concentrate sprays or in high-volume dilute sprays, did not cause more phytotoxicity than the non-ionic adjuvants that have been the industry standard with the tank mixes tested. A very low occurrence of damage to bunches, and small differences between bunch weights and bunch condition, were not caused by the adjuvant or application rate, or due to any interactions between the adjuvants and the fungicide mixtures.
- Further work may be warranted to confirm whether a small (but not significant) reduction in bunch weights after applying the pure organosilicone adjuvant Pulse is a repeatable effect.

4.2 Bunch penetration

The penetration of spray liquid into bunches was assessed in field trials to confirm whether organosilicone adjuvants could assist fungicide and insecticide deposits to spread between berries, to protect the berry surfaces in the centres of bunches. Trial 1 showed that:

- *Botrytis* infection increased as deposition in bunch centres decreased, confirming that fungicide must penetrate into bunches to be effective for *Botrytis* control.
- When fungicides were applied with no adjuvant or with Agral, they most effectively reached the centres of tight bunches when applied as a high-volume dilute spray. Equivalent or improved penetration into bunch centres was achieved with a low volume spray that included the adjuvant Du-Wett.

- The highest deposits occurred on bunches treated with Du-Wett at 0.1 % and 0.2 % v/v in 500 L/ha and 0.1 % in 250 L/ha , but not because these treatments had proportionally more liquid film spreading into bunch centres. The increase reflected an increase in deposits, equally across all zones of the bunch.

Trial 5 showed that there was no differences between deposits at the tops and bottoms of bunches, indicating that organosilicone adjuvants did not over-wet or make deposits run and coalesce at the base of bunches, or cause uneven coverage on bunches.

Across all trials the data consistently showed that accessing bunches in the centre of the canopy was more of a limitation to good coverage than penetrating to the centres of tight bunches.

4.3 Persistence of residual fungicide deposits on bunches after rain

In Trial 6, the type of adjuvant (Agral, Du-Wett or Bond Xtra) added to a concentrate spray of iprodione had no effect on the initial deposits or on the persistence of iprodione on bunches during the 7 days after spraying.

When plots were exposed to a simulated rain, there were no significant differences in residual iprodione between any of the adjuvant treatments. There was no advantage associated with adding the sticker-spreader Bond Xtra to the spray mix. Iprodione was found to be naturally highly persistent, and there may still be a benefit in using a spreader-sticker with other fungicides.

4.4 Deposition

Spray deposits were measured in trials 1, 3, 5, 6, 7, 8 and 9. The effect of the organosilicone adjuvants varied across the range of canopy types and growth stages in the trials, for example over-wetting foliage on the outer canopy while under-wetting bunches on the inner canopy.

- Increased deposition associated with use of organosilicone adjuvants in low volumes was seen in Trial 8, where leaf spray deposits from low volume applications ranked Pulse > Du-Wett > Agral, with deposits from the Pulse treatment being significantly greater than the Agral treatment. Increased deposition in bunches associated with use of organosilicone (Brushwet) at low volume compared to Agral at high volume was also seen in Trial 9. Deposits measured in bunches in Trial 1 were greater after applying a concentrate (500L/ha) spray with Du-Wett than after applying a dilute (1000L/ha) spray with Agral.

- There was no effect due to type of adjuvant in leaf deposits in the upper canopy in Trial 1, which were low overall and did not change due to type or rate of adjuvant. On outer leaves in Trial 8, there was no change in deposits when no adjuvant or Agral were replaced with organosilicone. There was no effect of adjuvant on bunch deposits in Trial 8. In Trial 3, leaf deposits were reduced slightly but not significant when Du-Wett replaced Agral in high and low volume, applied with an axial fan airblast sprayer. This trend could be explained as due to the relatively coarser spray plume delivered by nozzles on the axial fan sprayer leading to more rapid run-off, exacerbated at either volume by using Du-Wett instead of Agral. In trial 7, the addition of organosilicone adjuvant did not significantly change deposits on bunches or leaves relative to no adjuvant in a low volume application.

- Reduced deposition associated with use of Du-Wett in high volumes was seen in Trials 1, 3 and 8. In Trial 1, across all treatments, deposits on peripheral leaves were low, suggestive of excess wetting and run-off. On lower leaves, a reduction in

deposits after using Du-Wett at 0.1% in high volume was also attributed to excess wetting to the extent that spray was shed from foliage. In Trial 3, using Du-Wett instead of no adjuvant reduced leaf deposits on the outer canopy by 40%. In Trial 8, using Pulse, Du-Wett or Agral reduced deposits on inner foliage relative to the high volume spray without adjuvant.

- Reduced deposition associated with use of organosilicone in low volumes was seen in Trail 5 and 9. In Trial 5, treatments were all applied at low volume (300 L/ha) and leaf deposits were significantly greater after treatment with no adjuvant or with Brushwet than after treatment with Du-Wett. Deposits after treatment with Synertrol or Agral were ranked between Du-Wett and Brushwet or no adjuvant, and were not significantly different from either. Leaves from Trial 9, from three out of four canopy sampling positions, had greatest deposits after spraying at low volume with no adjuvant. Adding Du-Wett or Brushwet reduced deposition suggesting that the chosen organosilicone rate caused the foliage to be over-wet even at low volume.

Possible reasons for the inconsistent spray deposit results are discussed under Objective 4.

Objective 3: *"Conduct field and laboratory experiments to quantify changes in bioefficacy that result when adjuvants are used with viticultural fungicides and insecticides."*

The efficacy of the treatments applied against grapevine pathogens was assessed in all trials except Trial 2. In nearly all trials, applying fungicides, with or without adjuvant, reduced disease severity, but the outcomes were inconsistent with respect to identifying an adjuvant or spray volume treatment that provided the best control. Trial 4 highlighted the importance of using inoculated tissue in vineyard efficacy trials, and not relying on field populations to generate disease pressure (bunches and shoots were inoculated in all trials except Trial 4).

Trials 1, 3, 5, 6, 7, 8, and 9 all included comparisons between a fungicide and either Agral, Du-Wett or no adjuvant, applied as high-volume dilute and low-volume concentrate sprays. Trial 5 additionally included an oil (Synertrol) and pure organosilicone (Pulse). Trial 6 compared *Botrytis* after applying either a latex-based adjuvant (Bond Xtra) or Du-Wett or Agral. Trials 7, 8 and 9 included pure organosilicones (Brushwet or Pulse).

Across this range of trials there was no consistent evidence that differences in disease severity were due to adjuvant choice. To a large extent the lack of significant effects of treatments was a consequence of good overall disease control by all treatments together with relatively high within-treatment variability, so that differences in infection within each treatment were large enough to obscure any differences between treatments.

- In Trial 1, an organosilicone blend adjuvant (Du-Wett) gave equivalent control of *Botrytis* at half or quarter of the spray volume than was required for a high volume application.

- In Trial 3, *Botrytis* severity in bunches was reduced significantly by high volume dilute applications (600 L/ha) when compared with unsprayed controls, ranking Agral[2] > Du-Wett[3] > Du-Wett[1]. *Botrytis* severity was also reduced significantly by low volume concentrate applications (200 L/ha) ranking Du-Wett[1] = Agral[4] = Agral[2]. A further five treatments of Agral, Du-Wett and no adjuvant did not significantly decrease *Botrytis* severity and no clear conclusion could be reached.

[2] Applied using a Quantum Mist sprayer
[3] Applied using a conventional airblast sprayer
[4] Applied using an airshear Turbomiser P55 sprayer

- In Trial 7, all sprayed treatments significantly reduced downy mildew on leaves when compared with the unsprayed control. Adding Du-Wett did not improve control compared to treatments sprayed at low volume with Agral or without adjuvant. On bunches, adding Du-Wett to a low volume application provided the best disease control but this was not a significant improvement over applying low volume without adjuvant.

- In Trial 8 there were no significant differences in downy mildew severity on leaves or in *Botrytis* severity on bunches that could be attributed to adjuvant or application volume.

- In Trial 9, all sprayed treatment reduced powdery mildew infection, with no significant differences between sprayed treatments. Treatments were applied in high (H) and low (L) volumes. On outer canopy leaves, treatments were ranked Du-Wett (L) > no adjuvant (H) > Agral (H) = Brushwet (L) > Agral (L) > no adjuvant (L). On inner canopy leaves Brushwet (L) or no adjuvant (L) ranked as better than Du-Wett.

Disease pressure occurring naturally in the vineyard in Trial 4 was insufficient to detect differences in control of *Botrytis*, powdery mildew or downy mildew between the treatments. Disease pressure from the *Botrytis* and downy mildew inoculations in Trials 5 and 6 were also low, with all sprayed treatments providing near to 100% disease control with no significant differences between treatments.

Results of these trials show that differences in disease severity were influenced by factors other than adjuvant choice. The primary factors were canopy position and the efficiency of delivery of fungicide spray to the inner canopy, which are independent of adjuvant choice.

Objective 4: *"Conduct field trials with adjuvants to assess the potential to increase fungicide and insecticide efficacy and reduce spray volumes in commercial vineyards, aiming for reductions of up to 50% while maintaining or improving disease and pest control."*

Trials to derive recommendations for use of adjuvants focused on comparing the effects of adjuvants, canopy positions, sprayer type, growth stages, and rates and application volumes on spray deposits and efficacy against disease.

4.5 Adjuvant type

All trials included treatments to compare the new modified organosilicone blend Du-Wett with the industry standard adjuvant Agral and no adjuvant.

In addition to Du-Wett and Agral, Trials 2 and 8 also included the pure organosilicone, Pulse. Trial 5 included Synertrol and Brushwet and Trial 6 included Bond Xtra.

The ranking of treatments in each trial are shown in Tables 4.1and 4.2. It is important to note that the differences between the means were in most cases not significant. Ranking of the treatments reveals at a glance that:

- Performance of any particular adjuvant was not consistent across all the trials. It also clearly shows that in some cases using no adjuvant did not compromise the application. Spray equipment and application volumes influenced the rankings.

- The rankings based on bioefficacy (Table 4.1) differ from the rankings based on deposits (Table 4.2) which may be a consequence of some treatments providing better distribution of spray deposits across the berry surfaces in a bunch, thus providing

better control with equivalent or less residual deposit, however this theory was not tested.

The trials showed that:

- Organosilicone adjuvants tended to perform better in low volume than in high volume applications.
- In general, the fungicide alone controlled disease and there were few significant differences in disease control due to adjuvant type.
- In general, there was a high degree of within-treatment variability in the deposition, obscuring any treatment differences due to adjuvant type.

Table 4.1: Treatments in each trial ranked best to worst based on control of disease on bunches

Trial 1 #		Trail 3 *		Trial 5		Trial 6	Trial 7		Trial 8		Trial 9	
Ruby Cabernet post veraison		**Shiraz flowering**		**Shiraz pre bunch closure**		**Cabernet pre harvest**	**Chardonnay flowering**		**Chardonnay pre bunch closure**		**Merlot pre bunch closure**	
Du-Wett 0.2%-250	a	Agral H QM	a	Du-Wett L	a		Agral H	a	Du-Wett L	a	Du-Wett L	a
Agral 0.02%-500	a	Du-Wett H airblast	ab	Agral L	a	no *Botrytis*	None H	a	None L	a	None H	ab
Du-Wett 0.1%-250	a	Du-Wett L QM	ab	Synertrol L	a	developed	None L	a	None H	a	Agral L	ab
Du-Wett 0.05%-500	ab	Agral L P55	ab	Brushwet L	a		Du-Wett L	a	Agral L	a	None L	b
Du-wett 0.05%-1000	ab	Agral L airblast	ab	None L	a		Agral L	a	Agral H	a	Agral H	b
Du-Wett 0.2%-500	ab	Du-Wett H QM	ab	Control	a		Brushwet L	a	Control	a	Control	b
No adjuvant 1000	ab	Agral L QM	abc						Pulse L	a	Brushwet L	b
Du-Wett 0.1%-1000	ab	Agral H airblast	bc									
No adjuvant 250	ab	None H QM	bc									
Agral 0.02%-1000	ab	Du-Wett L airblast	c									
Du-Wett 0.1%-500	ab	Du-Wett L P55	c									
No adjuvant 500	ab	control	c									
Agral 0.02%-250	ab											
Du-Wett 0.025%-1000	b											
Du-Wett 0.05%-250	b											
Control	c											

treatments are described as adjuvant, concentration (%v/v) and volume (L) applied per hectare.

* H refers to high volume. L refers to low volume. QM refers to application by Cropland Quantum Mist sprayer. P55 refers to application by Turbomiser airshear P55 sprayer.

Table 4-2: Treatments in each trial ranked best to worst based on mean spray deposits on bunches

Trial 1# Ruby Cabernet post veraison		Trail 3* Shiraz flowering		Trial 5 Shiraz pre bunch closure		Trial 6 Cabernet pre harvest		Trial 7 Chardonnay flowering		Trial 8 Chardonnay pre bunch closure		Trial 9 Merlot pre bunch closure	
Du-Wett 0.1%-500	c	Agral L airblast	a	Brushwet	a	Du-Wett L	a	None H	a	Du-Wett L	a	Brushwet L	a
Du-Wett 0.2%-500	bc	Agral L P55	a	No adjuvant	a	Bond Xtra L	a	Agral H	ab	Agral H	a	None L	ab
Du-Wett 0.1%-250	abc	Agral H airblast	b	Agral	ab	Agral L	a	None L	ab	Pulse L	a	Du-Wett L	ab
Du-Wett 0.025%-1000	ab	Du-Wett L P55	bc	Synertrol	ab	None L	a	Du-Wett L	ab	None L	a	Agral L	ab
Du-wett 0.05%-1000	ab	Du-Wett L airblast	bc	Du-Wett	b			Agral L	b	None H	a	None H	ab
Du-Wett 0.2%-250	ab	Du-Wett L QM	bcd					Brushwet L	b	Agral L	a	Agral H	b
Du-Wett 0.05%-500	a	Agral H QM	cd										
Du-Wett 0.1%-1000	a	None H QM	de										
Du-Wett 0.05%-250	a	Agral L QM	ef										
Agral 0.02%-1000	a	Du-Wett H QM	f										
Agral 0.02%-250	a	Du-Wett H airblast	f										
No adjuvant 500	a												
No adjuvant 250	a												
Agral 0.02%-500	a												
No adjuvant 1000	a												

treatments are described as adjuvant, concentration (%v/v) and volume (L) applied per hectare.

* H refers to high volume. L refers to low volume. QM refers to application by Cropland Quantum Mist sprayer. P55 refers to application by Turbomiser airshear P55 sprayer.

4.6 Canopy position as a cause of within-treatment variability

Deposits on the outer canopy leaves or bunches were typically 2 - 3 times greater than deposits on the inner canopy. Similar differences were obtained for the disease severity on bunches or leaves from the inner and outer canopy. These ratios in deposits are typical of applications to grapevines (Manktelow & Praat 2000, Furness & Pinczewski 1985; Furness 2004, MacGregor 2004, Murphy & Warren 2000).

The effect of canopy position on the data was reduced by analysing four canopy positions separately (high inner, high outer, low inner, low outer). However, even within each of the canopy positions, the variations in deposits or disease severity were high and may have obscured differences between adjuvant treatments. For example in Trial 9, a 50% reduction in disease on outer leaves treated with Du-Wett, compared to Agral or no adjuvant, was not statistically significant.

Variability in deposition through the canopy has many contributing factors.

- Choice of sprayer and volume had an effect on spray deposits recovered from different positions within the canopy in Trial 3.
- The effect of selecting a constant spray volume across a vineyard with variable canopy sizes was shown in Trial 5. The approximately three-fold difference in the deposits on bunches from dense compared to sparse canopy in Trial 5 demonstrates very clearly the importance of careful selection of water volumes for non-uniform canopies and also of adjusting water volumes to accommodate increasing canopy size through the season.

When treatments used in field trials were ranked on their ability to maximise spray deposition or disease control on tissues, treatments ranked differently for leaves in comparison to bunches. No one adjuvant treatment was clearly superior to all the others for all tissue types and canopy positions. Ranking the success of any particular treatment involves prioritising the canopy targets that are most important to protect (bunches or leaves, inner or outer canopy), taking into account growth stage and disease pressure. Recommendations could not be made for using adjuvants to optimise spray delivery to either bunches or leaves, or different zones within a canopy, as the adjuvants did not consistently demonstrate any advantages over current practices in the series of trials.

4.7 Sprayer type

A variety interactions between aspects of sprayer set up and the canopy impact on the evenness of deposition through the profile of a grapevine canopy, irrespective of the properties of the sprayed liquid. Such interactions include: Ground speed and nozzle selection (Manktelow 1998, Salyani 2000); Spray volume and travel speed (Salyani 2000); Air volume and air speed, and access to particular zones in the canopy (Murphy 1998, Cross et al 2003); Liquid flow rate from nozzles (Cross et al 2001a); Droplet size (Smith et al 2000, Cross et al 2001b); Air volume, air speed and direction (Furness & Pinczewski 1985; Furness 2004, MacGregor 2004).

Trial 3 included treatments to compare the performance of adjuvants when used in volumes typically applied by three different sprayer types. Sprayer type did affect the proportions of spray recovered from different canopy positions, but when the total canopy is considered, Trial 3 showed that the three sprayer types performed similarly when applying high-volume dilute sprays or low-volume concentrate sprays.

- When applying high volume, sprayer type had no significant effect on deposits retained on leaves.

- The Turbomiser P55 is considered a low volume sprayer. Replacing Agral with Du-Wett in a low volume application (200 L/ha) did not increase deposits.
- The Quantum Mist sprayer is considered both a low and high volume sprayer. When the spray volume was reduced from 600 to 200 L/ha, replacing Agral with Du-Wett did not significantly increase deposits.
- The axial-fan 'airblast' sprayer is considered a high volume sprayer. In Trial 3, it performed best when used as a low-volume sprayer, with Agral, but the benefit of low volume was diminished if Agral was replaced by Du-Wett.
- At low volume (200 L/Ha) the leaf deposits achieved with the axial-fan airblast were always equivalent to or significantly higher than the other two sprayers (Turbomiser and Quantum Mist).

The results shouldn't be considered as a recommendation for, or against, using axial-fan sprayers to apply concentrate sprays with organosilicone adjuvants, as differences between sprayers' overall deposition were not significant. The results do illustrate, however, that grape growers with axial fan airblast sprayers who want to use adjuvants to improve disease control should first ensure that the sprayer is set- up to provide even delivery, and should avoid volumes that 'over-wet' the canopy. Without these improvements, using organosilicone adjuvants may lead to losses in deposition.

4.8 Growth stage

As grape bunches progress through each development stage their properties as spray targets change. Access to bunches across a canopy is affected by canopy growth, and how readily the spray plume can reach bunches (Farooq & Landers 2005), and also by the interplay between airflow and the bunch structure (Murphy & Warren 2000). Adjuvants can potentially improve spray deposition on and in bunches, and trials were conducted at three key stages of bunch development: at flowering, pre bunch closure and after veraison.

Flowering trials conducted in Shiraz and Chardonnay suggest that if fungicides were applied with no adjuvant or Agral, they provided the best control when applied as a high volume dilute spray, but almost equivalent control was achieved using low volume applications, regardless of whether Agral, Du-Wett or no adjuvant was included. There was clearly potential to reduce spray volume by at least half at this growth stage, without adding an organosilicone adjuvant. Du-Wett was applied at 0.1% v/v in these trials, as this rate gave the most cost effective control in Trial 1. Higher rates of Du-Wett or Brushwet were not tested, but may have provided more benefits, although increasing the rates would probably also have reduced retention of leaf deposits. Further trials are required to confirm whether higher rates of organosilicone would provide an advantage when spraying inflorescences.

Applications at pre bunch closure in Shiraz, Chardonnay and Merlot suggested that Du-Wett applied in a low volume provided disease control that was equivalent to the control by other adjuvants in the comparisons. In the Merlot trial Du-Wett provided equivalent control to Agral in low volume and better control than no adjuvant in low volume or Agral in high volume.

In a pre-harvest trial in Ruby Cabernet, bunches treated with Du-Wett had superior *Botrytis* control and increased spray deposits compared to bunches treated with Agral or no adjuvant. However, Du-Wett did not outperform Agral at every rate and volume tested. In the Cabernet Sauvignon pre-harvest trial *Botrytis* failed to develop, and there were no significant differences between treatments based on bunch deposits.

4.9 Rates and volumes

Trials 1, 2, 3, 7, 8 and 9 included comparisons between high and low volume applications of the new modified organosilicone blend Du-Wett with the industry standard Agral and no adjuvant. The key effects of rate and volume in those trials have been described in Section 4.1.4. Some possible explanations for the observed effects are offered here.

Trial 1 results supported the theory that lower rates of organosilicone are required when higher rates of water are used, and that adjuvant rates should be increased when lower volumes are used. Ranking of treatments in Trial 1, based on deposition on bunches (μg/g) and foliage (μg/cm^2) was: 0.1% v/v in 500 L/ha > 0.2% v/v in 250 L/ha > 0.025% in 1000 L/ha > no adjuvant.

In Trial 3, reduced deposits on the outer canopy were attributed to over-wetting by Du-Wett, even when applied at low volume (200 L/ha). Trial 3 demonstrated the potential risk of excess run-off when using an organosilicone adjuvant in a high water volume. It also highlighted the importance and difficulty of accurately estimating rates and water volumes for grapevine canopies.

In Trial 3, wetting of inflorescences may have been improved by increasing the adjuvant concentration to match that recommended in NZ for wetting mature bunches. The adjuvant concentration used in this trial was based on deposit data from trial 1 and is similar to the rate recommended for foliar application in NZ. While increasing adjuvant concentration will increase run-off from foliage, it may improve spray retention in bunches. Increasing the application volume when using Du-Wett did not improve deposition into inflorescences. Deposits on inflorescences in the inner canopy were significantly reduced by adding Du-Wett to a high-volume dilute spray, compared with using Agral or no adjuvant in the same volume, suggesting that the dilute spray with Du-Wett at 0.1% v/v over-wet inflorescences.

In Trials 7, 8 and 9, maintaining rates of 0.1% Du-Wett and 0.02% Agral, regardless of application volume, may have unfairly disadvantaged Du-Wett, with the rate being too high for a high volume spray and too low for a low volume spray. A broader series of rates and volumes was required, as in Trial 1, to confirm the optimum rates and volumes for bunches at different growth stages. However, the total numbers of treatments that could be applied was limited by the logistics of spraying multiple treatments, inoculating plant tissues, collecting samples and analysing samples. The low volume concentrate rate of organosilicone used in Trials 7, 8, and 9 was therefore selected based on the results obtained with Du-Wett in Trial 1 and also on observed run-off, and a concern about over-wetting from Trial 3. But spreading by organosilicone adjuvants increases linearly with concentration and so the rate of Du-Wett used in the low volume applications was low relative to the NZ recommendation for the tank mix used in this trial.

The lack of treatment differences between spray deposits on outer canopy leaves in Trial 8 suggests that all volumes and mixes were adequate to wet the outer canopy. Treatment differences on inner leaves suggest that high volumes were required to overcome poorer access to the inner canopy, but when low volumes were used, the organosilicone treatments provide an advantage over Agral (the industry standard adjuvant).

Using Du-Wett with further reductions in spray volume would have reduced the time required to spray the vines while achieving adequate deposition on the outer canopy, but may have compromised deposits on the inner canopy.

Since completing the Australian trials in January 2005, new data from New Zealand has showing promising results in efficacy after applying 0.4% v/v Du-Wett in extremely low water volumes. There is potential that this may also work under Australian condition, in vineyards with a discrete exposed bunch zone, but the trials reported here show that reducing volumes and increasing concentrations does not automatically overcome variability in spray delivery, and is therefore unlikely to enhance deposition in many vineyards.

Minimum water volumes (for example 250 L/ha) are recommended for the application of some translaminar fungicides, to avoid too-rapid drying under arid Australian conditions. Paradoxically, discussion around the use of organosilicone adjuvants includes talk of setting maximum water volumes (also, for example, 250 L/ha). A question that must be resolved in Australia, before considering *even higher* rates in *even lower* volumes, is whether the resultant spray volumes would dry down too quickly to allow penetration of translaminar fungicides into vine tissue.

4.10 Potential to reduce application volumes by 50% or more while maintaining or improving disease and pest control

A clearer benefit from adding an organosilicone adjuvant in low volume applications in the trials was expected, if the results were to be consistent with findings in similar trials conducted in New Zealand.

The low levels of disease in sprayed treatments in most of the trials reported here indicate that disease was adequately controlled by low volume applications without adjuvant. Adding adjuvant provided no benefit in reducing disease severity in bunches or on leaves. The trials showed that there is potential to reduce spray volumes 50% or more while maintaining or improving disease and pest control There was no consistent evidence that any particular adjuvant provided an additional benefit over reduced application volumes alone.

4.11 Recommendations

Objective 5: *"Provide recommendations for bunch spray applications that are suited to narrow, exposed bunch zones of Australian cool climate vineyards and to large, mechanically hedged, minimally pruned canopies of inland regions".*

- The skins of grape berries are waxy and the undersides of grape leaves are covered in fine hairs, making these surfaces very difficult to wet without the addition of some surface tension reducing agent. Agrochemical products are generally formulated to contain an adjuvant that reduces the surface tension of the spray mix. Additional spread across grape berry surfaces can be achieved when organosilicone adjuvants are added to spray mixtures.

- Spreading by conventional adjuvants increases very little as adjuvant concentration increases (limited to a two-fold increase in spread).

- Spreading by organosilicones continues to increase as the adjuvant concentration increases, and at concentrations that are recommended for field use, Du-Wett achieved up to eight times the spread achieved by Agral.

- Formulations that can be used with organosilicone adjuvants without affecting their spreading properties include: Bayfidan 250 EC (triadimenol); Captan WG (captan); Champ Dry Prill WG ($Cu(OH)_2$); Dipel DF (Bacillus thuringienses); Elect 720 (chlorothalonil); Flint 500 WG (trifloxystrobin); Microthiol Disperss WDG (sulphur); Penncozeb 750 DF (mancozeb); Prosper 500 EC (spiroxamine); Ridomil Gold Plus (Cu/metalaxyl); Rovral 750 WG (iprodione); Scala 400 SC (pyrimethanil); Teldor 500 SC (fenhexamid)

- The new organosilicone adjuvants, when applied at label rates, in low-volume concentrate sprays or in high-volume dilute sprays, will not cause more phytotoxicity than the non-ionic adjuvants that have been the industry standard.

- In this project, the latex/organosilicone based Bond Xtra, did not enhance the persistence of iprodione Formulations of some contact fungicides already provide 'sticking' properties to deposits, protecting them from being removed by rain immediately after spraying. There may still be a benefit in using a spreader-sticker adjuvant to other less persistent formulations of fungicides, and further trials are required to quantify these effects.

- The optimum concentration of organosilicone is higher for a bunch application than a foliage application. At 0.2% v/v Du-Wett, bunch penetration may exceed that achieved at 0.1% Du-Wett, but at the cost of excess wetting of leaves. As applications tend to include treatments for both targets, growers using organosilicones will need to select the priority target (bunches or leaves) to select the best rate of adjuvant.

- Using a foliage rate of 0.1% v/v organosilicone at flowering was shown to provide no advantage over using no adjuvant. Further trials are required to confirm whether a higher concentration of organosilicone in a lower water volume is required to wet inflorescences.

- Organosilicone adjuvants should not be used in high volume dilute sprays. There was no evidence that such applications improve efficacy, and the increase in cost of the tank mix is not offset by savings in labour or machinery costs.

- Organosilicone adjuvants are recommended for use in low volume concentrate sprays, but trials conducted in this project showed that this does not provide benefits if reducing the application volume compromises deposits reaching the inner canopy.

- Organosilicone adjuvants used in low volume concentrate sprays may maintain or enhance deposits and efficacy, but won't compensate for poor targeting of sprays (sprayer set up) or poor matching of spray volumes to the canopy.

- Spray trials conducted in this project revealed that in some cases equivalent or better disease control was achieved by reducing spray volumes, without addition of adjuvant, highlighting the importance of the interaction between sprayer performance, canopy, spray volume and target.

- Grape growers should give priority to improving spray coverage into the canopy before relying on adjuvants to improve their spray efficacy. The benefit of adding particular adjuvants, for example the organosilicone adjuvants, depends heavily on whether the sprayer is able to deliver a relatively even coverage across the canopy.

- Replacing a conventional adjuvant with organosilicone in a spray that is applied with uneven coverage will exacerbate losses through excess wetting and run-off from areas of canopy that are well targeted, without overcoming the under-dosing of areas of canopy that are not well targeted, leading overall to a net reduction in deposition. In particular, accessing bunches in the centre of the canopy is more of a limitation to good coverage than getting penetration into tight bunches.

- Overcoming variability in deposition in the vine canopy is more critical than trying to improve coverage by adding adjuvants

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5 PROJECT OUTPUTS – COMMUNICATIONS

5.1 Reporting to GWRDC and DPI

Progress reports were provided GWRDC from 2002 to 2005, as per requirements.

DPI (2004). The wetter the better. *DPI Shorts*. July 2004.

Gaskin, RE, Hofstee ME and Steele KD (2003) Better disease control using adjuvants (Project DNR 02/04). Report to Agriculture Victoria on a laboratory evaluation to improve pesticide spray coverage on winegrapes. January - June 2003.

5.2 Industry publications

MacGregor A, Gaskin R, Riches D and Manktelow D (2003). Better disease control by using adjuvants. *Australian and New Zealand Grapegrower and Winemaker* **473**:47-50.

MacGregor A (2004). New Wetters. *in* Conference Abstracts - *Viticulture '04 – Growing Our Future* conference, Mildura, 26th to 28th October 2004.

Manktelow D, Gurnsey S and MacGregor A (2004). Deposit variability and prediction in fruit crops: What use are label rates anyway? *International advances in pesticide application*, held at Royal Holloway, University of London, UK, 5-7 January 2004. *Aspects of Applied Biology*, **71**

5.3 Industry presentations

Presentations at seminars, conferences and field days are summarised in Table 5-1.

Table 5-1: Summary of presentations at seminars, conferences, field days or to stakeholders.

Date	Location	Speaker	Event name	Event type	Presentation	Proceedings	Audience
29th July 2002	DPI Mildura	Bob Reeves, Loveland Industries Inc., Colorado, U.S.A	Using adjuvants to improve control of bunch diseases or pests	Two public seminars (Repeated morning and afternoon)	Half day seminar on application and performance of the range of available adjuvants.	no	Approx 70
12th June 2003	DPI Mildura	A MacGregor	Presentation to GWRDC	Presentation to GWRDC	"Better Disease Control By Using Adjuvants"	no	10
22nd Aug 2003	DPI Knoxfield	A MacGregor	Cool Climate Viticulture Forum	1-day conference	"Chemical Applications"		Approx 200
7th May 2004	La Trobe University Mildura Campus	A MacGregor	La Trobe / Riverlink PRN lecture series	Seminar	"Better Disease Control By Using Adjuvants"	no	4
28th July 2004	URS, Southbank, Melbourne.	D Riches and A MacGregor	Presentation to Bayer and Nufarm	Project review meeting	"Better Disease Control By Using Adjuvants"	no	4
July 2004	Robinvale	A MacGregor	Grapecheque meeting	Seminar	"Better Disease Control By Using Adjuvants"	no	10
July 2004	Euston	A MacGregor	Grapecheque meeting	Seminar	"Better Disease Control By Using Adjuvants"	no	15
11th Aug 2004	TAFE Mildura	A MacGregor	TAFE horticulture students	Seminar and class	"Better Disease Control By Using Adjuvants"	no	18
7th Oct 2004	DPI Mildura	A MacGregor	ADFA Training Workshop 3	Grower training workshops	"Effective use of chemicals for dried fruit production"	no	15
26th Oct 2004	Mildura Settlers Club	A MacGregor	Viticulture '04 – Growing Our Future	3-day conference	"New Wetters"	Abstracts only	Approx 100
11th Oct 2005	DPI Mildura	A MacGregor	ADFA Training Workshop 3	Grower training workshops	"Spray Technology"	no	12
10th Nov 2005	Coal River Valley Tasmania	A MacGregor	Vineyard Association of Tasmania spray application field day.	Seminar and field day	"Improve spray deposition to optimise efficacy and minimise environmental risk".	Handouts	Approx 150

6 REFERENCES

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Cross JV, Walklate PJ, Murray RA and Richardson GM (2001b). Spray deposits and losses in different sized apple trees from an axial fan orchard sprayer: 2. Effects of spray quality. *Crop Protection* **20**:333-343.

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Furness GO (2004). Quantum Mist™ grape sprayer: Optimising set up and operation. Effect of fan rotational speed, head placement and nozzle angling on spray distribution in large sprawl grapevine canopies. A report prepared for Croplands Equipment Pty Ltd, by the South Australian Research and Development Institute.

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Appendices

7 APPENDIX 1: TRIAL 1: MARCH 2003; RUBY CABERNET; PRE-HARVEST

7.1 Background

Data became available from the NZ laboratory studies in time to conduct one trial at the end of the first season of this project, a season earlier than anticipated. While the important spray applications are made early in the growing season, some questions were relevant to ask of a late season spray. One particular question related to the spray volumes that are appropriate to use if the OS adjuvants are included in a spray mixture because many growers increase spray volumes after bunch closure in order to penetrate bunches.

Increasing the concentrations of all adjuvants increases their wetting effect but also increases the risk that spray mixture will be shed from bunches and foliage and lost as run off. The concentration threshold, after which increasing concentrations provide little additional spreading, varies between adjuvants. To provide recipes for the use of adjuvants, it was important to explore the relationship between concentration of adjuvant and water volume, to optimise retention of deposits on grape bunches and foliage.

Trial 1 was designed to test the hypothesis that "*there is an inverse relationship between the concentration of organosilicone-based superspreader and water volume applied, to achieve the optimum retention of deposits on grape bunches and foliage*".

7.2 Materials and methods

Trial name	Trial 1: March 2003; Ruby Cabernet; Pre-harvest
Location	Vineyard of H & E Farnsworth, Dareton NSW
Grape variety	Ruby Cabernet
Growth stage	Pre-harvest
Number of treatments	15
Number of replicates	3
Area of trial	675 vines
Experimental design	Randomised block design across 9 vine rows. 15 vines per plot
Sprayer	Single row Silvan 'P55 Turbomiser' airshear sprayer fitted with a Kee MK5 spray computer®, travelling at 7.4 kph, volumes adjusted using the restrictor disc to deliver 16.7 L/min, 8.3 L/min and 4.2 L/min, adjusted from Kee controller.
Inoculation	6 bunches/plot inoculated with *Botrytis* (5×10^4 spores/mL)
Inoculation date	Friday 21st March 5 – 8 pm
Spray date	Saturday 22nd March
Sampling date	Saturday 22nd March (tartrazine samples from rep 1)
	Sunday 23rd March (tartrazine samples from reps 2 and 3)
	Monday 24th March (bunches for *Botrytis* bioassay)

Treatments

Number	Adjuvant	rate (mL/100L)	spray volume (L/ha)	Rovral (g/ha)[5]	Tartrazine (g/ha)
1	No adjuvant	none	1000	650	2400
2			500		
3			250		
4	Nonyl phenol ethoxylate Agral®	20 *	1000	650	2400
5			500		
6			250		
7	modified organosilicone blend Du-Wett®	25	1000	650	2400
8		50			
9		100			
10	modified organosilicone blend Du-Wett®	50	500	650	2400
11		100			
12		200			
13	modified organosilicone blend Du-Wett®	50	250	650	2400
14		100			
15		200			
16	Unsprayed controls sampled prior to spraying	-	-	-	-

* label rate

Disease assessments

Botrytis infection	48 hours after applying the treatments, the six inoculated bunches in each plot were collected, each picked into an individual plastic bag. The bagged bunches were sent by overnight courier to the DPI Knoxfield for assessment.

Deposit assessments

	zone	Bunches or leaves in each sample*
Leaves	High Inner canopy	6
	High outer canopy	6
	Low inner canopy	6
	Low outer canopy	6
	Peripheral leaves	6
Whole bunches	Inner (hidden) bunches	6
	Outer (exposed) bunches	6
	Tight bunches	6
	Loose bunches	6
Tight Bunches, to section into front, back, bottom, inner and rest #	Exposed No 1	1
	Exposed No 2	1
	Exposed No 3	1
	Exposed No 4	1
	Exposed No 5	1

[5] Rovral WG™ was selected for using in this trial because it has a short withholding period and so can be applied close to harvest.

* Three leaves or three bunches were collected from each side of the canopy to make each bulk sample

\# Before picking each bunch, one berry on the 'front' (most exposed surface) was marked with liquid paper.

500 bunches were inoculated with *Botrytis* prior to spraying according to the method described in Section 2.2.1.

Methods for recovery of tartrazine from leaves and bunches are described in Section 2.2.3

7.3 Results

7.3.1 Effect of adjuvant type on the incidence of *Botrytis* on berries from treated bunches

Fungicide treatment had a strong effect (F-prob<0.001) on Botrytis severity with all sprayed treatments having significantly lower Botrytis severity than the untreated control (Table 7.1). The addition of adjuvant did not significantly change Botrytis control relative to the same water volume without adjuvant added. However, there was a trend (not statistically significant at p=0.05) towards improved disease control when reduced volume applications included adjuvants with disease being reduced by up to 44% relative to the same spray volume without adjuvant. Applying Rovral as a low volume spray (250 L/ha) with Du-Wett at 0.1 % and 0.2 % v/v and as a medium volume spray (500 L/Ha) with Agral at 0.02 % v/v or Du-Wett at 0.05 % v/v provided the greatest Botrytis control.

Significantly lower disease control was achieved when Du-Wett was mixed at a lower concentration (0.05% v/v) in the low volume spray relative to the two higher Du-Wett rates. By contrast 0.05 % v/v Du-Wett in the high volume spray (1000 L/ha) performed well. While these three examples are consistent with general observations that organosilicone adjuvants perform best in low volume sprays, and that the OS concentration should increase as volume decreases, that trend was not clear across the range of volumes and Du-Wett rates.

These results suggest that equivalent control of Botrytis can be achieved at half or quarter of the spray volume used in a high volume fungicide application. There was a trend towards increased disease control for some adjuvant treatments: Agral in 500 L/Ha and Du-Wett at the two higher rates (0.1 and 0.2% v/v) in a spray volume of 250 L/Ha.

Table 7.1: Incidence of *Botrytis* infection in Ruby Cabernet bunches treated with varying spray volumes and varying types and concentrations of adjuvant.

	Treatment			*Botrytis* Infection %
	Adjuvant	rate (ml/100L)	volume (L/ha)	
1	No adjuvant	0	1000	17.8 ab
2	No adjuvant	0	500	20.3 ab
3	No adjuvant	0	250	18.9 ab
4	Agral®	20	1000	19.7 ab
5	Agral®	20	500	11.7 a
6	Agral®	20	250	20.5 ab
7	Du-Wett®	25	1000	21.6 b
8	Du-Wett®	50	1000	15.3 ab
9	Du-Wett®	100	1000	18.7 ab
10	Du-Wett®	50	500	12.8 ab
11	Du-Wett®	100	500	20.1 ab
12	Du-Wett®	200	500	16.8 ab
13	Du-Wett®	50	250	25.3 b
14	Du-Wett®	100	250	11.8 a
15	Du-Wett®	200	250	10.6 a
16	Unsprayed	0	0	38.2 c
LSD (p=0.05)				10.41

* Values followed by the same letter are not significantly different at P=0.05

7.3.2 Spray deposits on bunches and foliage

The highest deposits were recovered from bunches treated with Du-Wett at 0.1 % v/v and 0.2 % v/v in 500 L/ha (Table 7.2) and were significantly higher than the same spray volume without adjuvant. Du-Wett at 0.1 % v/v in 500 L/Ha also had higher spray deposits on leaves than the same water volume without adjuvant. The lowest spray deposits were recovered from foliage treated with 0.1 % v/v Du-Wett in 1000 L/Ha adjuvant which were significantly lower than the same water volume without adjuvant. All other adjuvant treatments resulted in leaf and bunch deposits that were not significantly different to the corresponding liquid volume spray without adjuvant.

When deposits on bunches are ranked, they were greatest when Du-Wett at 0.1 % v/v was applied in 500 L/ha, followed by treatments where the highest rate (0.2 % v/v) was applied in 500 L/ha, followed by the low rate (0.025 % v/v) applied in 1000 L/ha (Table 7.2). The data supports the concept of needing to consider lower rates of organosilicone when higher water volumes are used as recommended in New Zealand.

Table 7.2: Tartrazine deposits recovered from foliage (μg/cm^2) and from bunches (μg/g) treated with no adjuvant, Agral or Du-Wett.

	Treatment				Predicted mean deposit on foliage (μg/cm^2)	Predicted mean deposit on bunches (μg/g)
	Adjuvant	Rate (ml/100L)	Rate (mL/ha)	volume (L/ha)	LSD = 1.028	LSD = 2.3246
1	No adjuvant	0	0	1000	5.986 abc	4.996 a
2	No adjuvant	0	0	500	5.584 bcd	5.221 a
3	No adjuvant	0	0	250	5.642 bc	5.103 a
4	Agral®	20	200	1000	5.898 abc	5.61 a
5	Agral®	20	100	500	4.968 cd	5.002 a
6	Agral®	20	50	250	6.217 ab	5.292 a
7	Du-Wett®	25	250	1000	6.126 ab	7.157 ab
8	Du-Wett®	50	500	1000	5.547 bd	6.996 ab
9	Du-Wett®	100	1000	1000	3.858 e	6.499 a
10	Du-Wett®	50	250	500	5.701 ac	6.505 a
11	Du-Wett®	100	500	500	6.671 a	9.518 c
12	Du-Wett®	200	1000	500	5.262 bd	8.882 bc
13	Du-Wett®	50	125	250	5.343 bcd	5.871 a
14	Du-Wett®	100	250	250	5.651 ac	7.288 abc
15	Du-Wett ®	200	500	250	4.560 de	6.695 ab

Estimated Variance Components using the Wald tests for fixed effects

Fixed term	Wald statistic	d.f.	Wald/d.f.	Chi-sq prob
Trt (μg/cm^2)	41.90	14	2.99	<0.001
Trt (μg/g)	41.03	14	2.93	<0.001

Within each column the predicted means followed by the same letter are not significantly different

The greatest deposits overall were recovered from exposed bunches on the outer canopy. The addition of Agral did not significantly increase bunch deposits at any of the water volumes used.

The highest deposits were recovered from bunches treated with sprays containing Du-Wett at the two highest rates (0.1 % and 0.2 % v/v) in a 500 L/ha spray volume (Table 7.3). For these two treatments, spray deposits were significantly higher than the same spray volume without added adjuvant for 3 out of the 4 bunch types sampled. None of the reduced volume treatments, with or without adjuvants, resulted in significantly altered bunch deposits relative to the high volume treatment without adjuvant which can be considered to be industry standard practice. The addition of low rates of Du-Wett (0.025 % and 0.05 % v/v) to the high volume spray (1000 L/Ha) resulted in significantly higher deposits than the high volume treatment without adjuvant only on loose bunches.

Deposits on tight bunches or on difficult to access bunches are of greatest interest as these may become sources of infection in the vineyard. Deposits in tight bunches with Du-Wett at 0.1 % v/v in 500 L/ha were significantly greater than in bunches treated with no adjuvant or Agral. Deposits in tight bunches treated with the higher rate of Du-Wett were also

significantly greater than the medium and low volume treatments with no adjuvant or with Agral. Treatments were otherwise not significantly different.

The data shows a trend (non significant at p=0.05) towards increased fungicide deposition into tight bunches for high volume sprays applied with no adjuvant or with Agral. The inclusion of an organosilicone adjuvant such as Du-Wett in reduced volume sprays, always resulted in at least equivalent spray deposits on bunches, and in some cases, significantly improved deposition.

Table 7.3: Tartrazine deposits recovered from bunches (μg/g) treated with no adjuvant, Agral or Du-Wett.

					Predicted mean deposit (μg/g)			
trt	Adjuvant	Rate (ml per 100L)	Rate (mL/ha)	volume (L/ha)	Loose bunches	Tight bunches	Bunches from Inner canopy	Bunches from outer canopy
1	No adjuvant	0	0	1000	5.31 a	3.96 ab	3.93 abc	6.78 ab
2	No adjuvant	0	0	500	7.25 ab	2.90 a	4.4 abc	6.33 ab
3	No adjuvant	0	0	250	8.33 abc	3.15 a	3.04 a	5.89 a
4	Agral®	20	200	1000	7.90 ab	4.17 ab	4.38 abc	5.99 ab
5	Agral®	20	100	500	6.96 ab	2.68 a	3.00 a	7.36 ab
6	Agral®	20	50	250	9.13 bcd	2.64 a	3.97 abc	5.43 a
7	Du-Wett®	25	250	1000	10.51 bcd	5.08 abc	4.45 abc	8.59 abc
8	Du-Wett®	50	500	1000	10.59 bcd	5.61 abc	5.08 abc	6.71 ab
9	Du-Wett®	100	1000	1000	7.16 ab	4.02 ab	5.22 abc	9.6 abc
10	Du-Wett®	50	250	500	8.68 bcd	4.95 abc	5.2 abc	7.19 ab
11	Du-Wett®	100	500	500	12.02 d	7.97 c	5.81 abc	12.28 c
12	Du-Wett®	200	1000	500	8.61 bcd	6.98 bc	7.45 c	12.49 c
13	Du-Wett®	50	125	250	8.14 ab	3.78 ab	6.49 abc	5.08 a
14	Du-Wett®	100	250	250	9.19 bcd	5.62 abc	7.01 bc	7.33 ab
15	Du-Wett ®	200	500	250	11.89 cd	4.11 ab	3.57 ab	7.22 ab

*** Wald tests for fixed effects ***

Fixed term fixed model	Wald statistic	d.f.	Wald/d.f.	Chi-sq prob * Sequentially adding terms to
trt.zone	55.44	42	1.32	0.080

To compare deposition on bunches and leaves, bunch deposits in Table 7.3 were also expressed relative to the projected surface area of the bunch (Table 7.4 and Table 7.5). Across all treatments, the most deposits (based on μg/cm^2 projected surface area) were recovered from outer, exposed bunches and from loose bunches, with significantly less deposit on tight bunches and bunches from the inner canopy (Table 7.4). The lowest deposits were recovered from leaves high up in the inner canopy.

The relatively greater capture and/or retention of deposits on bunches than on leaves, relative to their two-dimensional projected surface areas shown in Table 7.5, suggests that spray was penetrating the bunches, and not entirely blocked by formation of menisci between berries.

The discrepancy would also be accentuated by the light meter underestimating the three-dimensional intercepting face of the bunch when the projected surfaces were measured.

Table 7.4: Deposits recovered from bunches and foliage expressed as μg/cm^2 projected surface area and as μg/g.

	Zone	Predicted mean deposit (μg/cm^2)*	Predicted mean deposit (μg/g)
		LSD = 0.9152	LSD = 0.8130
1	Low, inner-canopy leaves	5.952 c	
2	Low, outer-canopy leaves	7.618 d	
3	High, inner-canopy leaves	3.851 a	
4	High, outer-canopy leaves	5.284 bc	
5	Peripheral leaves	4.962 b	
6	Loose bunches	11.989 f	8.778 c
7	Tight bunches	8.814 e	4.508 a
8	Inner (hidden) bunches	7.213 d	4.865 a
9	Outer (exposed) bunches	12.247 f	7.618 b

Estimated Variance Components using the Wald tests for fixed effects

Fixed term	Wald statistic	d.f.	Wald/d.f.	Chi-sq prob
Zone (μg/cm^2)	67.39	8	83.42	<0.001
Zone (μg/g)	151.90	3	50.63	<0.001

* In this table the deposits expressed as μg/cm^2 are relative to the projected surface area of the leaves or bunches. In the case of bunches this does not reflect the total surface area of all berries within the bunch. Deposits expressed as μg/g are relative to the weight of the whole bunch.

Type and rate of adjuvant had no significant effect (data not shown) on the relatively poor capture and/or retention by leaves from the upper canopy. However there was a reduction in spray retained on lower leaves associated with using the Du-Wett at 0.1 % v/v in the dilute spray volume (1000 L/Ha). The dilute volume application with Du-Wett had probably caused excess wetting to the extent that spray was shed from foliage. The low retention, across all treatment, of deposits on peripheral leaves (Table 7.5) also suggests excess wetting and run-off.

The deposits in tight bunches, expressed relative to the intercepting surface area, were lower than deposits in loose bunches, but typically higher than deposits on inner bunches. This suggests that accessing bunches is more of a limitation than penetrating tight bunches. The greatest deposition in tight bunches was associated with use of Du-Wett at 0.1 % or 0.2 % v/v in the medium volume (500 L/ha) (Table 7.5).

Table 7.5: Predicted mean deposits of tartrazine (μg/cm^2) on leaves and bunches. Numbers within a column followed by the same letter are not significantly different (P>0.05).

Treatment		Predicted mean deposits (μg/cm^2 tartrazine) expressed relative to projected surface areas)								
		Rate (ml/100L)	Rate (mL/ha)	Volume (L/ha)	Leaves (mean of all positions)	Peripheral leaves	Loose bunches	Tight bunches	Bunches from inner canopy	Bunches from outer canopy
1	No adjuvant	0	0	1000	5.986 abc	6.17 a	6.53 a	7.23 ab	5.33 ab	10.28 ab
2	No adjuvant	0	0	500	5.584 bcd	3.65 a	9.6 ab	6.16 ab	6.85 abc	10.48 ab
3	No adjuvant	0	0	250	5.642 bc	5.86 a	10.79 b	5.94 ab	4.21 a	9.07 ab
4	Agral®	20	200	1000	5.898 abc	5.82 a	11.37 bc	8.69 ab	6.86 abc	9.91 ab
5	Agral®	20	100	500	4.968 cd	3.19 a	8.79 ab	5.55 ab	6.30 abc	13.17 b
6	Agral®	20	50	250	6.217 ab	6.98 a	12.43 bcd	5.03 a	5.94 abc	9.40 ab
7	Du-Wett®	25	250	1000	6.126 ab	4.71 a	15.06 cd	9.93 bc	6.75 abc	13.62 b
8	Du-Wett®	50	500	1000	5.547 bd	5.48 a	14.27 bcd	11.55 bc	8.16 abc	11.03 ab
9	Du-Wett®	100	1000	1000	3.858 e	3.56 a	10.62 ab	7.48 ab	8.52 bc	16.0 bc
10	Du-Wett®	50	250	500	5.701 ac	6.28 a	12.18 bcd	9.39 b	7.1 abc	10.79 ab
11	Du-Wett®	100	500	500	6.671 a	5.15 a	16.11 cd	15.95 d	9.01 bc	19.40 bc
12	Du-Wett®	200	1000	500	5.262 bd	4.48 a	13.75 bcd	13.74 cd	9.70 c	19.57 c
13	Du-Wett®	50	125	250	5.343 bcd	5.11 a	11.27 bc	7.08 ab	8.76 bc	8.54 a
14	Du-Wett®	100	250	250	5.651 ac	4.57 a	11.41 bc	10.25 bc	9.52 bc	10.26 ab
15	Du-Wett ®	200	500	250	4.560 de	3.42 a	15.65 cd	8.24 ab	5.19 ab	12.19 ab

7.3.3 Movement of spray deposits throughout the bunch

Fronts and bottoms of bunches intercepted and retained significantly more spray than the centres or backs of bunches (F-prob<0.001) (Table 7.6).

Table 7.6: Tartrazine deposits (μg/g) on each section of bunch, averaged across all adjuvant treatments (n=225).

	Tartrazine (μg/g) deposited on each section of bunch, averaged across all adjuvant treatments (n=225).				
	Front	Back	Bottom	Centre	Rest
Mean deposits (back transformed)	2.683	1.657	2.998	1.332	1.071
Log_e transformed	0.987 d	0.505 c	1.098 d	0.287 b	0.069 a

* Log transformed data followed by the same letter are not significantly different

Analysis of variance of total dye deposits (log transformed) per bunch indicated a significant treatment effect overall due to the adjuvant (F-prob 0.041) (Table 7.7). The highest deposits were achieved using Du-Wett at 0.2 % v/v in 500 L/ha, followed by Du-Wett at 0.1 % v/v in 500 L/ha, followed by Du-Wett at 0.1 % v/v in 250 L/ha. The lowest deposits were achieved by applying 250 mL/ha with no adjuvant. Bunches treated with Du-Wett at 0.2 % v/v in 500 L/ha retained more spray than bunches treated with Agral at any of the three volumes (P<0.05).

Table 7.7: Tartrazine deposits (μg/g) averaged across all sections of bunches (n=75).

	Treatment			**Log deposit** LSD = 0.206	**Mean deposit** (μg/g) (back transformed)
	Adjuvant	rate (ml/100L)	volume (L/ha)		
1	No adjuvant	0	1000	0.279 ab	1.32
2	No adjuvant	0	500	0.415 bc	1.51
3	No adjuvant	0	250	0.256 a	1.29
4	Agral®	20	1000	0.494 bc	1.64
5	Agral®	20	500	0.673 bc	1.96
6	Agral®	20	250	0.368 bc	1.44
7	Du-Wett®	25	1000	0.687 bc	1.99
8	Du-Wett®	50	1000	0.599 bc	1.82
9	Du-Wett®	100	1000	0.49 bc	1.63
10	Du-Wett®	50	500	0.661 bc	1.94
11	Du-Wett®	100	500	0.84 cd	2.32
12	Du-Wett®	200	500	1.239 d	3.45
13	Du-Wett®	50	250	0.571 bc	1.77
14	Du-Wett®	100	250	0.769 cd	2.16
15	Du-Wett ®	200	250	0.498 bc	1.65

Analysis of variance to explore the interaction between the adjuvant type/rate and deposition in each part of the bunch (and particularly bunch centres) showed that there was no interaction between treatment and bunch zone (F-prob = 0.992). This indicates that the significant increase in deposition achieved by Du-Wett applied at 0.2 % v/v in 500 L/ha (Table 7.7) was not due to that treatment having any greater ability than other treatments to carry the liquid film into the bunch centres. This treatment simply resulted in the greatest deposition across all zones (Table 7.8).

Table 7.8: Tartrazine deposits on different sections of bunches

				Deposits (μg/g) in each part of the bunch (log_e transformed, n=15, ,)				
	Treatment	**rate(mL/100L)**	**Vol (L/Ha)**	Front	Back	Bottom	Centre	Rest
1	No adjuvant	0	1000	0.2446	0.0796	0.3867	0.0221	-0.1261
2	No adjuvant	0	500	0.3599	0.1338	0.3224	0.0773	0.0088
3	No adjuvant	0	250	0.3008	0.0380	0.2300	0.0966	-0.1099
4	Agral®	20	1000	0.3945	0.1028	0.4292	0.1420	0.0044
5	Agral®	20	500	0.4270	0.2623	0.5207	0.1787	0.0719
6	Agral®	20	250	0.3095	0.0746	0.4450	0.0185	-0.0486
7	Du-Wett®	25	1000	0.4562	0.3108	0.4307	0.2067	0.0878
8	Du-Wett®	50	1000	0.4252	0.2378	0.4895	0.1257	0.0220
9	Du-Wett®	100	1000	0.3835	0.1788	0.4661	0.0691	-0.0345
10	Du-Wett®	50	500	0.3954	0.2823	0.6185	0.1550	-0.0156
11	Du-Wett®	100	500	0.5611	0.3653	0.4847	0.2039	0.2101
12	Du-Wett®	200	500	0.7625	0.5232	0.7629	0.3296	0.3128
13	Du-Wett®	50	250	0.4074	0.2756	0.5192	0.0893	-0.0523
14	Du-Wett®	100	250	0.5237	0.2666	0.5509	0.2281	0.1002
15	Du-Wett ®	200	250	0.4780	0.1604	0.4968	-0.0727	0.0186
	LSD = 0.6367							
	F-prob = 0.992							

7.4 Conclusion

The bioefficacy and deposit data both showed a trend, consistent with observations from NZ work, that organosilicone adjuvants perform best in low volume sprays, and that the organosilicone concentration should increase as volume decreases. However, the trend was not clear across the range of volumes and Du-Wett rates.

There was a trend (non-significant) towards increased deposits in tight bunches with increasing the water volume with no adjuvant or Agral. The highest spray deposits in tight bunches were achieved using the organosilicone blend at 0.1% and 0.2 % v/v in 500 L water per hectare. These adjuvant treatments also had the highest bunch deposits averaged across all canopy positions. There were no significant differences in spray deposits in the centres of bunches but the highest deposits were achieved using the organosilicone blend at 0.2 % v/v in 500 L water per hectare. Equivalent control of *Botrytis* was achieved at half or quarter of the spray volume used in a high volume fungicide application with or without added adjuvant. While not significantly different, there was a trend towards better *Botrytis* control when low volume applications included adjuvants.

8 APPENDIX 2: TRIAL 2 - CHARDONNAY; FLOWERING

8.1 Background

Trial 2 was conducted in October 2003 to confirm whether there was any risk of phytotoxicity associated with using adjuvants early in the season. The nonyl-phenol ethoxylate (industry standard) adjuvants to not enhance the phytotoxicity of fungicides used in Australian viticulture. Reducing the surface tension of fungicide mixes to the extents that were measured in laboratory trials suggested that the risk of phytotoxicity would be very low, but it was nonetheless an important consideration to test as part of the field trial program.

Trial 2 was designed to test that hypothesis that "*the new 'superspreader' adjuvants, used at recommended rates in dilute or concentrate fungicide mixes and applied at low or high volume, will not cause more phytotoxicity than the non-ionic adjuvants that have been the industry standard*".

8.2 Materials and methods

Trial Name	Trial 2 – Chardonnay - Flowering - October 2003
Location	DPI Mildura, Chardonnay block
Grape variety	Chardonnay
Growth stage	Flowering
Number of treatments	30
Number of replicates	8
Area of trial	0.3 hectares
Experimental design	Row-column design across 21 rows
Sprayer	Stihl SR400 motorised knapsack airshear sprayer.
Inoculation	No inoculations
Spray date	29-Oct-03 (50-80% capfall)
Sampling date	Late January 2004

Treatments

Treatment (Are these plots rather than treatments ?	Fungicide mix *	Adjuvant	Adjuvant application rate (mL/100L)	
			In 750 L/ha (dilute spray)	In 250 L/ha (concentrate spray)
1, 2, 3	A, B and C	Agral	20	
4, 5, 6	A, B and C	BS1000	100	
7, 8, 9	A, B and C	Designer		400
10, 11, 12	A, B and C	Designer		800
13, 14, 15	A, B and C	Pulse		200
16, 17, 18	A, B and C	Pulse		400
19, 20, 21	A, B and C	Pulse	400	
22, 23, 24	A, B and C	Du-Wett		200
25, 26, 27	A, B and C	Du-Wett		400
28, 29, 30	A, B and C	Du-Wett	400	

Details of fungicide mixes A, B and C

Fungicide mix		Treatments sprayed with the fungicide mix	Fungicide rate In 750 L/ha (dilute spray)	In 250 L/ha (concentrate spray)	
A	Prosper 500 EC (spiroxamine)	1, 4, 13, 22	60		mL/100L
	Penncozeb 750 DF (mancozeb)		200		g/100L
	Dipel DF (BT)		100		g/100L
A	Prosper 500 EC (spiroxamine)	7, 10, 16, 19, 25, 28		180	mL/100L
	Penncozeb 750 DF (mancozeb)			600	g/100L
	Dipel DF (BT)			300	g/100L
B	Elect 720 (chlorothalonil)	2, 5, 14, 23	160		mL/100L
	Microthiol Disperss WDG (sulphur)		400		g/100L
	Dipel DF		100		g/100L
B	Elect 720 (chlorothalonil)	8, 11, 17, 20, 26, 29		480	mL/100L
	Microthiol Disperss WDG (sulphur)			1200	g/100L
	Dipel DF			300	g/100L
C	Scala 400SC (pyrimethanil)	3, 6, 15, 24	200		mL/100L
	Flint 500 WG (trifloxystrobin)		15		g/100L
	Dipel DF		100		g/100L
C	Scala 400SC (pyrimethanil)	9, 12, 18, 21, 27, 30		600	mL/100L
	Flint 500 WG (trifloxystrobin)			45	g/100L
	Dipel DF			300	g/100L

Assessments

Sample	No per plot	Initial assessment	Final assessment
Whole bunches, tagged prior to spraying	10	Non destructive visual assessment of symptoms	Bunch weight, bunch damage

8.2.1 Fungicide mixtures

Two of the pesticide mixes were selected from Table 2-3 on the basis of having some risk of phytotoxicity. Prosper® already contains an adjuvant with high spreading potential, chlorothalonil causes berry marking on some varieties of berries, sulphur causes burn when applied at high temperatures with high humidity. The Flint® and Scala® mix was included as a low phytotoxicity risk mixture, to highlight whether different rates, volumes and fungicide mixtures have different risk of phytotoxicity.

8.2.2 Spray volumes

A series of pre-trial applications determined that run-off using the Stihl knapsack occurred at approximately 750 L/ha. 750 L/ha was therefore selected as the dilute volume. A 3× concentration factor was chosen as representing the higher end of likely concentration factors in commercial vineyards. The concentrate volume was therefore chosen to be 250 L/ha.

The knapsack sprayer was calibrated and found to delivered 750 and 250 L/ha at walking speeds of 15 and 5 seconds per panel, respectively, spraying both sides of each vine. Speed was timed with a stopwatch, and the volume remaining in the tank after each treatment was measured to confirm the applied volume.

8.2.3 Adjuvant types and rates

Non-ionic adjuvants (Agral and BS1000) were included to provide a reference or standard against which to compare any phytotoxicity caused by OS-based adjuvants. The non-ionic adjuvants were applied at label rates in high volumes, to reflect their highest potential to cause phytotoxicity.

Organosilicone-based 'superspreaders' (Du-Wett® and Pulse®) were included because at high rates, and applied to run-off, they were likely to cause stomatal infiltration and phytotoxicity. To reflect this 'worst case' risk, Du-Wett® and Pulse® were applied at 400 mL/100L (0.4% v/v), in a high volume (750 L/ha).

The organosilicone-based 'superspreaders' are generally recommended for use in low volume, concentrate sprays. To reflect a typical application, Du-Wett® and Pulse® were therefore applied in 250 L/ha, at the rate (0.2 % v/v) that had been shown to be appropriate in the laboratory retention study (section 3.1).

Adjuvants based on latex blended with an organosilicone adjuvants (Bond Xtra® or Designer®) do not have equivalent spread to the pure organosilicone adjuvants, and were therefore predicted to have a lower risk of phytotoxicity. The proposed label rate, based on laboratory spread tests and other data from New Zealand trials (Gaskin *et al* 2002) was 400 mL/100L (0.4 % v/v), twice the proposed rate for the organosilicone-based Du-Wett®. To explore potential phytotoxicity, Bond Xtra® was applied at 400 mL/100L (0.4 % v/v), and also at twice this concentration (800 mL/100L) in a low volume, concentrate spray.

8.2.4 Plot preparation

Prior to spraying, ten flowering bunches per plot were tagged using fluorescent pink plastic tape. The tape was attached around the bunch stem in such a way as to prevent shadowing of the bunch in case this reduced the access of spray deposits to the bunch. The tagged bunches were fairly exposed at the time of tagging and spraying, although they subsequently became hidden within the developing canopy.

8.2.5 Assessment of phytotoxicity

After spraying

A visual assessment of bunch and foliage damage was made in the vineyard a week after applying the treatments. As there was no damage apparent on either foliage or bunches, this assessment was discontinued.

At harvest

Surviving tagged bunches were retrieved for assessment at harvest. Bunches from each plot were collected into a single plastic ziplock bag, with care taken to maintain the integrity of each bunch and tag as they were placed into the bags.

The weights and condition of the surviving bunches were recorded at harvest. Bunches were classed into five categories: 1) healthy; 2) damaged at or soon after treatment at flowering; 3) dead on a broken cane; 4) missing; or 5) recently damaged.

8.2.6 Data analysis

Data were analysed using the Wald statistic to explore the effect of adjuvant, the effect of fungicide tank mix, and the interactions of these effects.

8.3 Results

8.3.1 Effects of treatments on bunch weight

There was no damage to bunches immediately after spraying.

At harvest, the highest mean bunch weight (136 g) was from plots sprayed with BS1000 at 100 mL/100 L in high volume, which we had included as representing a 'low risk' scenario. The lowest mean bunch weight (124 g) was from plots sprayed with Pulse at 400 mL/100L at low volume, which was included as a 'moderate to high risk' scenario. The small differences between bunch weight and bunch condition, associated with adjuvant types and fungicide types and rates, were not significant (Table 8.1).

Table 8.1: Mean weights (g) of Chardonnay bunches at harvest after applying adjuvants at flowering in several rate-volume combinations (n=240).

Treatment	Adjuvant	Rate (mL/100L)	Volume (L/ha)	Bunch weight (g)
1	Agral	20	750	130.9
2	BS1000	100	750	136.0
3	Designer	400	250	130.8
4	Designer	800	250	134.4
5	Pulse	200	250	127.2
6	Pulse	400	250	124.2
7	Pulse	400	750	132.9
8	Du-Wett	400	750	128.9
9	Du-Wett	200	250	128.9
10	Du-Wett	400	250	128.5
LSD				12.23

Table 8.2: Mean weight (g) of Chardonnay bunches at harvest after applying three tank mixtures, containing fungicide and adjuvant, at flowering (n=800).

Tank mix		Bunch weight (g)
A	spiroxamine, mancozeb, BT	129.3
B	chlorothalonil, sulphur, BT	128.6
C	pyrimethanil, trifloxystrobin, BT	132.8
LSD		23.26

Fungicide tank mix did not affect the bunch weight (Table 8.2).

When each tank mix and adjuvant combination was considered (Figure 8-1), the lowest mean bunch weights occurred after spraying with Tank mixes A and B containing Pulse at 400 mL/100 L in low volume. Despite the high number of bunches assessed, the analysis did not have adequate power to confirm whether the small reduction in average bunch weight after using Pulse in Tank mixes A or B would be a repeatable effect

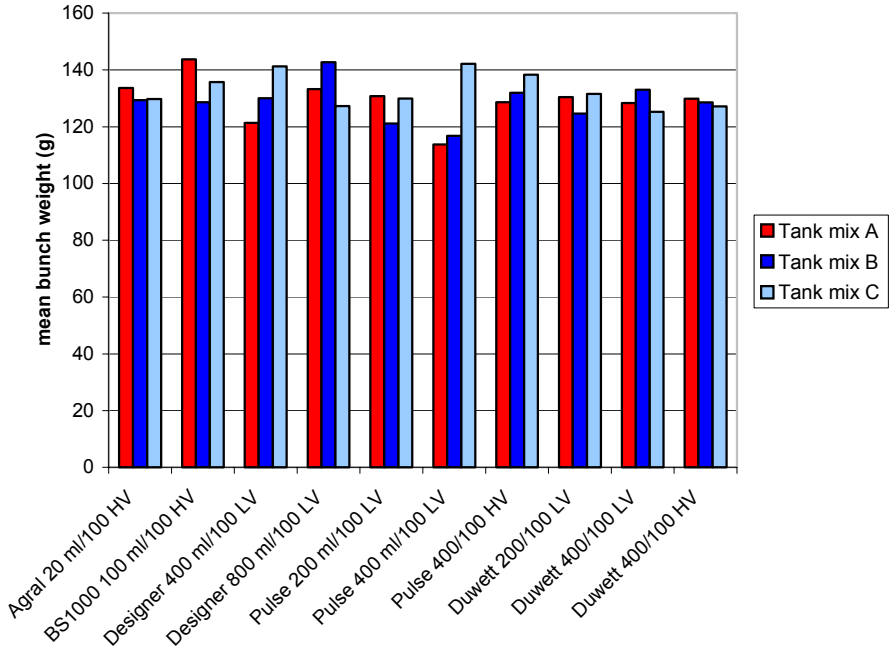


Figure 8-1: Mean bunch weights at harvest after treating vines at flowering with combinations of adjuvants and fungicide mixtures at varying rates and volumes (n=80).

8.3.2 Effects of treatments on bunch damage

Of the 2400 bunches tagged at flowering, only 41 (< 2%) were unaccounted for at harvest (Table 8.3). The low occurrence of loss or damage to bunches was not due to the adjuvant or rate (Table 8.3) nor to an interaction between the adjuvants and the fungicide mixtures (Table 8.4).

Table 8.3: Occurrence of each type of damage affecting bunches from plots treated with each adjuvant, ignoring fungicide mixture (n=240).

Type of damage	Adjuvant										Grand Total
	1	2	3	4	5	6	7	8	9	10	
dead on broken cane	0	0	2	3	0	1	3	1	1	1	12
missing bunch	5	4	5	3	3	3	3	5	5	5	41
shrivelled (since flowering)	4	2	0	1	2	2	1	3	1	1	17
shrivelled recently	0	1	3	0	3	1	1	2	3	0	14
Total (out of 240 bunches per adjuvant)	9	7	10	7	8	7	8	11	10	7	

Table 8.4 Occurrence of each type of damage to bunches from plots treated with each adjuvant and fungicide mixture (n=80).

Type of damage	Tank mix	Adjuvant										Grand Total
		1	2	3	4	5	6	7	8	9	10	
dead on broken cane	A	0	0	1	0	0	1	2	0	0	1	5
	B	0	0	1	0	0	0	1	1	0	0	3
	C	0	0	0	3	0	0	0	0	1	0	4
missing bunch	A	0	2	2	0	2	1	1	2	1	1	12
	B	4	0	2	2	0	0	0	2	1	3	14
	C	1	2	1	1	1	2	2	1	3	1	15
shrivelled (since flowering)	A	1	0	0	0	2	1	0	1	0	1	6
	B	3	2	0	1	0	1	1	0	1	0	9
	C	0	0	0	0	0	0	0	2	0	0	2
shrivelled recently	A	0	1	3	0	0	0	1	1	1	0	7
	B	0	0	0	0	3	0	0	0	1	0	4
	C	0	0	0	0	0	1	0	1	1	0	3

Tank mix A: spiroxamine, mancozeb, BT
Tank mix B: chlorothalonil, sulphur, BT
Tank mix C: pyrimethanil, trifloxystrobin, BT

8.4 Conclusion

The results of this trial showed that the new organosilicone 'superspreader' adjuvants, applied at label rates and in low volume, concentrate sprays or in high volume dilute sprays, did not cause more phytotoxicity than the non-ionic adjuvants that have been the industry standard.

Further work may be warranted to confirm whether the small (but not significant) reduction in bunch weights after applying the organosilicone adjuvant Pulse is a repeatable effect.

9 APPENDIX 3: TRIAL 3, NOVEMBER 2003; SHIRAZ; FLOWERING

9.1 Background

Trial 3 was conducted in the first week of November in Shiraz grapevines.

The trial compared the performance of OS-based adjuvants applied in low spray volumes, using three different sprayer types.

The trial was designed to test the hypothesis that "*while coverage is improved by applying organosilicone-based superspreaders in low volume sprays, the same improvement can also be achieved if organosilicone adjuvants are applied using sprayers that are conventionally classed as 'high volume' sprayers*".

9.2 Materials and methods

Trial name	Trial 3, November 2003; Shiraz; Flowering
Location	DPI Mildura
Grape variety	Shiraz
Growth stage	Flowering (50% capfall)
Number of treatments	12
Number of replicates	4
Area of trial	0.45 hectares
Experimental design	Resolvable row-column design Latinised along columns for the main factors (18-vine plots).
Three sprayers	▪ A conventional airblast sprayer - which produces a wide variety of droplet sizes and is typically used to spray to the point of run-off. ▪ A multi-fanhead sprayer (a Croplands 'Quantum Mist') which produces a more uniform droplet size than the conventional airblast sprayer and which is able to be directed more accurately at the canopy. ▪ An airshear sprayer (a Silvan 'Turbomiser') - which produces uniform small droplets and allows a smaller volume of spray to be used.
Inoculation	*Botrytis* at 5×10^4 spores/mL Downy mildew at 5×10^3 spores/mL
inoculation date	30th October 2003
spray date	1st November 2003
Sampling date	1st November bunches and leaves to recover tartrazine deposits 12th November 2003 – bunches and leaves for *Botrytis* and Downy mildew bioassay

Treatments

Treatment	Sprayer	adjuvant	Adjuvant rate (mL/100 L)	Spray volume (L/ha)
1	(unsprayed)	-	-	-
2	Quantum	No adjuvant	-	600
3	Quantum	Agral	20	200
4	Quantum	Agral	20	600
5	Quantum	Du-Wett	100	200
6	Quantum	Du-Wett	100	600
7	Airblast	Agral	20	200
8	Airblast	Agral	20	600
9	Airblast	Du-Wett	100	200
10	Airblast	Du-Wett	100	600
11	Turbomiser	Agral	20	200
12	Turbomiser	Du-Wett	100	200

Each tank mix included:

Sulphur (Microthiol®) at 400 g/100L in 600 L/ha, and 1200 g/100L in 200L/ha.

Chlorothalonil (Barrack 720®) at 160 g/100L in 600 L/ha and 480 g/100L in 200L/ha.

Water-soluble food dye (tartrazine) at maximum concentration 3.3 g/L in 600 L/ha and 10 g/L in 200 L/ha

Disease assessments

Botrytis	Inoculated bunches	6 bunches per plot
Downy mildew	Inoculated shoots	2 last expanded leaves per shoot on 6 shoots per plot

Deposit assessments

Leaves	high inner leaves high outer leaves low inner leaves low outer leaves	3 leaves per side of canopy were bulked to make a 6-leaf sample per zone per plot
Pooled bunches	Inner bunches Outer bunches	Five bunches per zone made up one bulked sample per zone per plot
Individual bunches	Individual bunch 1 Individual bunch 2 Individual bunch 3 Individual bunch 4 Individual bunch 5 Individual bunch 6	Six individual bunches (randomly sampled, ie not from any particular zone). These bunches were later cut for separate assessment of deposits on the top and bottom halves.

9.3 Results

9.3.1 Effect of adjuvants on deposits on leaves at flowering.

There were strong interactions between sampling position, sprayer type, volume and adjuvant.

Effect of canopy position on leaf deposits

The position within the canopy that leaves and bunches were sampled from had a strong influence on spray deposits from each treatment (chi-sq prob <0.001). The influence of sampling position on leaf deposits is shown in Figure 9-1, where tartrazine deposits on leaves were ranked in the order:

low-outer > high-outer > low-inner > high inner

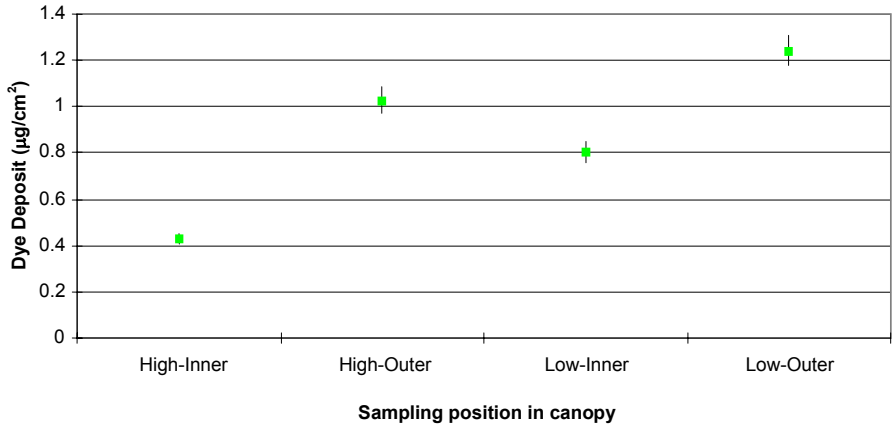


Figure 9-1: Estimated dye deposits (µg/cm^2) on leaves from different sampling positions within the canopy, averaged across all adjuvants, sprayers and volumes. Error bars indicate least significant intervals.

The following comparisons between adjuvants, volumes and sprayers therefore also consider the effect of sampling position. Bars on the left and right halves of Figure 9.2 show the mean deposits from each treatment recovered from the inner or outer canopy, respectively.

Bars on the left and right halves of Figure 9.3 show the mean deposits from each treatment recovered from the higher or lower canopy, respectively.

Each pair of bars in Figure 9.2 or Figure 9-3 represents one sprayer and volume but different adjuvants (Agral or Du-Wett). Note that the 600 L/ha Quantum Mist treatment also has a 'no adjuvant' third bar (treatment Q-N-600). Also note the control treatment N-N-0 (no sprayer, no adjuvant, zero volume).

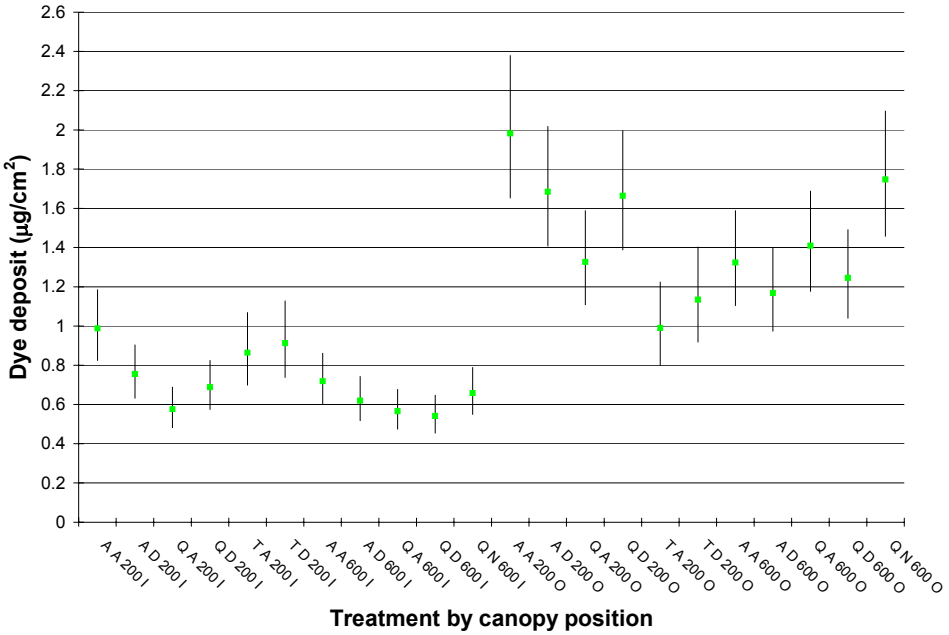


Figure 9-2: Dye deposits on leaves (estimated µg/cm^2 tartrazine recovered after applying 1 kg/ha) showing interaction between treatment (adjuvant type, sprayer and volume) and canopy position. 'I' denotes inner canopy. 'O' denotes outer canopy.

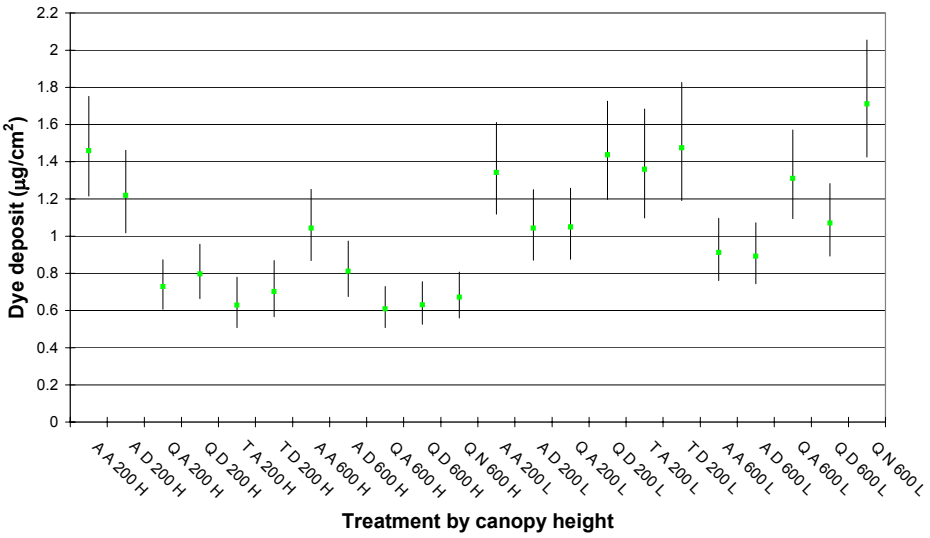


Figure 9-3: Dye deposits on leaves (estimated µg/cm^2 tartrazine recovered after applying 1 kg/ha) showing interaction between treatment (adjuvant type, sprayer and volume) and canopy position. 'H' denotes high canopy. 'L' denotes low canopy.

Effect of sprayer

The choice of sprayer and volume had an effect on spray deposits recovered from different positions within the canopy. It must be emphasised that this comparison is not to make judgement about any particular sprayer, but to explore whether changing sprayers would influence the apparent effects of adjuvant and reduced water volume treatments.

Comparing the eight Quantum Mist and Turbomiser treatments suggests that these sprayers always delivered more spray to the lower than the high canopy). By contrast, comparing the four airblast sprayer treatments showed no significant difference between deposits across the four canopy positions.

At 200 L/Ha, the spray deposits achieved with the axial-fan airblast were always equivalent to or significantly higher than the other two sprayers suggesting that the airblast sprayer can be successfully used for low volume, concentrate applications.

At a water volume of 600 L/Ha, sprayer type did not significantly influence spray deposits retained on leaves ($p>0.05$).

Effect of adjuvant and volume

Replacing Agral with Du-Wett appeared to provide no benefit, as there were no significant differences between deposits on each pair of samples from either inner or outer canopy). Removing the adjuvant from a high volume spray (treatment Q-N-600) did not reduce the deposits compared to using either Agral or Du-Wett with the same sprayer and water volume.

The only significant effect of adjuvant on deposits apparent in Figure 9-3 is also in the comparison between treatments Q-D-600 and Q-N-600, where using no adjuvant in a high volume spray resulted in approximately 60% higher deposits on low-canopy leaves than when Du-Wett was included ($P < 0.05$).

In the low volume sprays (200 L/ha) applied using the Quantum Mist or Turbomiser sprayers, deposits were improved slightly (but not significantly) by using Du-Wett rather than Agral).

By contrast, in the high volume sprays (600 L/ha), deposits were reduced slightly (but not significantly) by Du-Wett).

Regardless of volume, deposits from the airblast sprayer treatments were reduced slightly (but not significant) by using Du-Wett rather than Agral.

The axial fan airblast is conventionally classed as a high-volume machine. Despite this, the greatest deposits on foliage from the inner or outer canopy occurred in plots sprayed with the axial fan airblast, using Agral, at 200 L/ha (A-A-200). On the inner canopy, this treatment represented a significantly greater deposition than was achieved by any of the 600 L/ha treatments, irrespective of sprayer or adjuvant, with one exception; again the axial fan airblast and again using Agral). If the high-volume airblast treatment with Agral is viewed as an industry standard treatment, against which to compare the new organosilicone adjuvant, then this result shows that the organosilicone did not improve on the industry standard.

The results also suggests that the axial fan airblast sprayers, conventionally classed as a 'high volume' sprayer, performed better when it was used as a low-volume sprayer, with Agral, but the benefit of low volume was diminished if Agral was replaced by Du-Wett.

9.3.2 Effect of adjuvants on downy mildew infection on leaves

The downy mildew bioassay on leaves from this trial failed, and there is therefore no reportable data.

9.3.3 Effect of adjuvants on deposits on bunches at flowering.

Changing the type of adjuvant did not increase or reduce between-bunch variability, shown as the LSI bars in Figure 9-4.

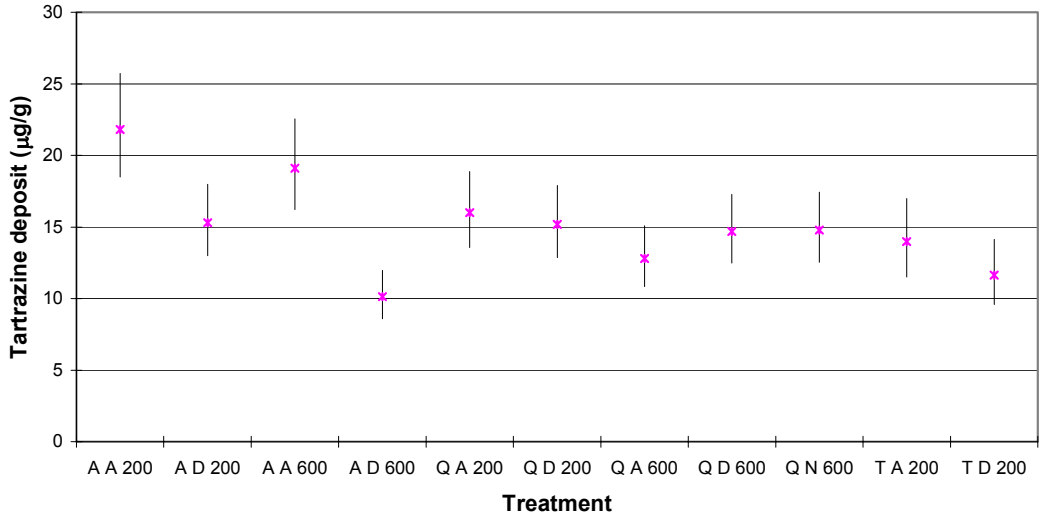


Figure 9-4: Estimated mean deposit on individual bunches, and least significant intervals, after normalising tartrazine deposits to an application of 1 kg/ha applied by three different sprayers, in two volumes and adding either Agral or Du-Wett adjuvant (n=274). Explanation of treatment: the first letter refers to the sprayer A=airblast, Q=Quantum mist, T=**T**urbomiser; the second letter refers to adjuvant, A=Agral, D=Du-Wett, N=none; the number refers to the water volume applied (L/Ha)

Effect of canopy position

Deposits on bunches were affected by canopy position in the same way that leaves were affected. Outer canopy bunches had three times more tartrazine dye than inner canopy bunches ($p<0.05$) (Figure 9-5).

Interaction between adjuvant and canopy position

Each pair of bars in Figure 9-5 represents one sprayer and volume but changing adjuvant (Agral or Du-Wett). Note that the 600 L/ha Quantum Mist treatment also has a 'no adjuvant' third bar, and note the unsprayed control (treatment N-N-0).

Comparing pairs of bars (adjuvants) treated at high volume shows that using Agral or adding no adjuvant resulted in more deposits than were achieved by adding Du-Wett, although the difference was only significant ($p<0.05$) on inner bunches treated with the airblast sprayer.

Comparing pairs of bars (adjuvants) at low water volume shows that there was no difference ($p>0.05$) in deposition by the different adjuvants on inner canopy bunches, However, on outer canopy bunches, replacing Agral with Du-Wett, using the Turbomiser, resulted in a significant reduction in deposits.

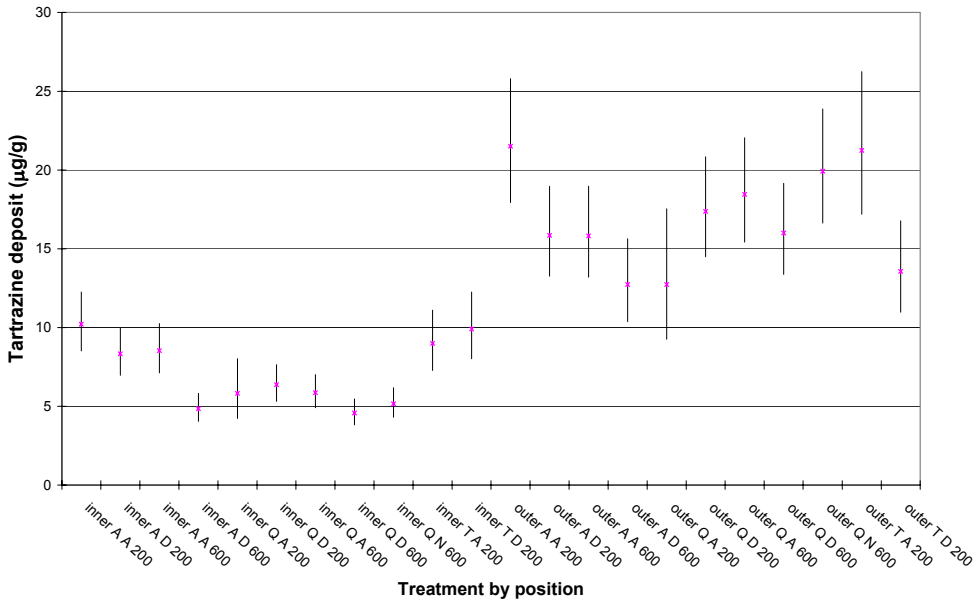


Figure 9-5: Estimated mean deposit on pooled bunch samples, and least significant intervals, after normalising tartrazine deposits to an application of 1 kg/ha applied by three different sprayers, in two volumes and adding either Agral or Du-Wett adjuvant (n=91). Explanation of treatment: the first letter refers to the sprayer A=airblast, Q=Quantum mist, T=turbomiser; the second letter refers to adjuvant, A=Agral, D=Du-Wett, N=none; the number refers to the water volume applied (L/Ha)

Effect of adjuvant and volume and sprayer

The effects of replacing Agral with Du-Wett in the tank mix in low and high volume sprays are shown in Figure 9-4 (individual bunch data) and Table 9.1 (bulked bunch data).

Data from both sets of samples concur in showing that replacing Agral with no adjuvant or with Du-Wett did not significantly affect deposits when either the Quantum Mist or Turbomiser sprayer applied the treatment. However when the airblast sprayer was used, at either low or high volume, replacing Agral with Du-Wett decreased deposits.

The implication in both Figure 9-4 and Table 9.1, like the leaf data in Figure 9-2, is that the airblast sprayer, conventionally classed as a 'high volume sprayer' performed better when it was used as a low volume sprayer, with Agral. The benefit of low volume application using the airblast sprayer was diminished if Agral was replaced by Du-Wett but this was not significant when inner and outer bunches were analysed separately but was significant when bunches from both positions were pooled for analysis. It is important to note the Du-Wett application at 200L/Ha is equivalent to (no significantly different at P=0.05) the Agral application at 600L/Ha (which could be considered conventional practice) with the airblast sprayer.

The Quantum Mist sprayer is considered a low and high volume sprayer. When the Quantum mist sprayer applied a mix containing Agral, changing from a high to a low volume application lead to a small (but not significant) reduction in deposits. When the same sprayer applied a mix containing Du-Wett, the reverse happened, ie a small (but not significant) increase in deposits when changing from a high to a low volume application. This result reflected the anticipated behaviour of the adjuvants in each volume.

Table 9.1: Deposits on bunches (log_e transformed data) after spraying Shiraz grapevines with either high or low volume, and varying adjuvants.

Sprayer	Adjuvant	Volume (L/ha)	Mean deposit ± s.e.	Back-transformed mean (μg/g)
Quantum Mist	Nil	600	2.316 (± 0.111)	10.14
	Agral	600	2.342 (± 0.109)	10.40
	Du-Wett	600	2.146 (± 0.109)	8.55
	Agral	200	2.153 (± 0.167)	8.61
	Du-Wett	200	2.353 (± 0.112)	10.52
Airblast	Agral	600	2.453 (± 0.112)	11.62
	Du-Wett	600	2.062 (± 0.117)	7.86
	Agral	200	2.696 (± 0.122)	14.82
	Du-Wett	200	2.442 (± 0.109)	11.50
Turbomiser airshear	Agral	200	2.626 (± 0.131)	13.82
	Du-Wett	200	2.451 (± 0.131)	11.60
Unsprayed	Nil	nil	0.171 (± 0.111)	1.19

9.3.4 Effect of adjuvants on *Botrytis* infection in flowering bunches

All sprayed treatments had less disease than the unsprayed control, but the reduction was only significant for treatments A-A-200, A-D-600, Q-D-200, Q-A-600 and Q-D-600.

Each pair of bars in Figure 9-6 represents one sprayer and volume but changing adjuvant (Agral or Du-Wett). The 600 L/ha Quantum Mist treatment also has a 'no adjuvant' third bar.

Replacing Agral (treatment Q-A-600) with no adjuvant (treatment Q-N-600) caused a significant increase in infection ($p<0.05$) (Figure 9-6). *Botrytis* infection did not correlate with

recovered deposits, ie similar tartrazine had been recovered from bunches from treatment Q-N-600 than treatment Q-A-600 (Figure 9-4, Figure 9-5 and Table 9.1).

Replacing Agral with Du-Wett had no significant effect on *Botrytis* infection, and nor was there any apparent trend. Du-Wett caused a (non-significant) increase in *Botrytis* infection by the low-volume airblast and Turbomiser applications, and high-volume Quantum Mist application. Conversely, Du-Wett caused a (non significant) decrease in infection in the high-volume airblast and low-volume Quantum mist treatments.

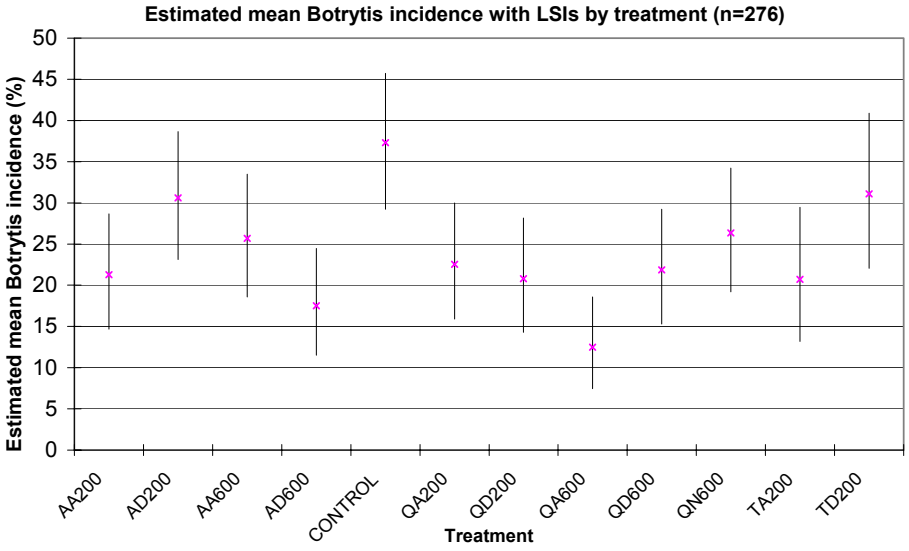


Figure 9-6: Estimated mean *Botrytis* incidence in bunches sampled from each treatment, with least Significant Intervals (LSIs) (n=276).

9.4 Conclusion

Trial 3 compared the performance of organosilicone-based adjuvants applied in low spray volumes, using three different sprayer types, to see whether claims of improved coverage when organosilicone adjuvants are used in low volume sprays are upheld when sprays are applied in low volume using sprayers that are conventionally classed as 'high volume' sprayers.

The assumption within this hypothesis, that organosilicone adjuvants enhance deposition when applied in low volume sprays, was not upheld in the data. There was no gain from adding organosilicone to low volume sprays using the 'low volume' Turbomiser sprayer. The Quantum Mist sprayer, considered both a high and low volume sprayer, performed better at low volume than high volume, when organosilicone was added. The 'high volume' airblast sprayer performed better when it was used to apply a low volume spray, but replacing Agral with Du-Wett, in either high or low water volumes reduced spray deposits.

Efficacy against *Botrytis* did not correlate with the recovered deposits and replacing Agral with Du-Wett had no significant effect on *Botrytis*. A shortcoming of the tartrazine recovery technique is that this method provides a comparison of total spray deposit, but does not reflect

spray coverage. Spray coverage has an important effect on efficacy, and this may explain why deposit data didn't correlate with *Botrytis* infections.

10 APPENDIX 4; OCTOBER 2003 TO MARCH 2004; CABERNET SAUVIGNON; COMPARISON BETWEEN AN OS-BASED OR AN AGRAL-BASED SPRAY PROGRAM AFTER SPRAYING ALL SEASON

10.1 Background

Deakin Estate vineyards at Iraak, Victoria, agreed to split their spray program in a 0.34 hectare patch of Cabernet Sauvignon grapevines into four plots, two to be sprayed using their standard vineyard spray program (including the adjuvant Agral®) and two to be sprayed using half the standard water volumes plus organosilicone adjuvant.

10.2 Methods

Treatments were applied to three-row plots. Each plot was replicated twice across 12 rows of Cabernet Sauvignon grapevines. The first two sprays for the season were applied according to the standard vineyard management. The 'low volume plus OS' treatment was applied to the five remaining applications for the season (from flowering to veraison).

Trial 5 was designed to test the hypothesis that grapes treated using fungicide with organosilicone in reduced water volumes throughout the season have equivalent or less disease than grapes treated using conventional adjuvants in higher water volumes.

10.3 Results

Bunches harvested from this trial showed no symptoms of powdery mildew or downy mildew infection. Nor did they, after incubation, show any *Botrytis* infection.

The spray program had targeted powdery and downy mildews, but not *Botrytis*. Lack of any disease in bunches may, in another season, have suggested that spray volumes could be reduced without compromising disease control, but the trial was conducted in a season with very low disease pressure. Therefore, in terms of providing evidence of equal or improved control using half spray volumes, the trial was unfortunately inconclusive. This trial highlighted the value of using artificially inoculated material rather than relying on field pressure for efficacy trials.

11 APPENDIX 5: TRIAL 5 - JANUARY 2004; SHIRAZ; PRE-BUNCH CLOSURE

11.1 Background

In trials conducted in March and November 2003 the emphasis had been on comparing deposition from applications made with the industry standard, nonyl phenol ethoxylate adjuvant (Agral®) or with a modified organosilicone blend adjuvant (Du-Wett®). Yet the flowering trials in Shiraz conducted in November 2003 failed to confirm a consistent benefit from substituting Agral with Du-Wett. A variety of adjuvant chemistry is available to growers, and were considered worth including in a comparison with Agral and the new organosilicones. Trial 5 was conducted pre-bunch closure and provided a comparison between five main adjuvant types.

Reducing the surface tension of a liquid film on a vertical (leaf or berry) surface reduces the spray volume at which run-off occurs. One of the questions raised in Trails 1 and 3 had been whether low recovery of deposits was perhaps (or in part) a consequence of low retention of deposits due to excessive wetting by an organosilicone. To identify whether this was occurring in the adjuvant trials, bunches were cut into bottom and top halves in Trial 4, and tartrazine deposits recovered separately from the two halves.

The trial was designed to test the hypothesis that "*the type of adjuvant included in a low volume concentrate fungicide spray will be reflected in the retention of spray deposits and in efficacy against downy mildew and Botrytis*".

11.2 Materials and methods

Trial name	Trial 4 – Shiraz - Pre-bunch closure - January 2004	
Location	DPI Mildura	
Grape variety	Shiraz	
Growth stage	Pre-bunch closure	
Number of replicates	4	
Number of treatments	6	
Area of trial	0.45 hectares	
Sprayer	Croplands *Quantum Mist* sprayer fitted with four SARDI fans, applying a concentrate spray of 300 L/ha # using Albuz hollow cone 'grey' nozzles.	
Inoculation	*Botrytis* at 1×10^4 spores/mL Downy mildew at 5×10^3 spores/mL	
Inoculation date	*Botrytis* Downy Mildew	14th January 2004 (6-8 pm) 15th January 2004 (6-8 pm)
Spray date	15th January 2004	
Sampling dates	15th January 2004 22nd or 29th Jan	Spray deposition *Botrytis* and Downy mildew bioassay

The Shiraz canopy showed a gradient in foliage density and dimensions from the rows in Replicate 1 to the rows in Replicate 4. In Replicate 1 the foliage was calculated, using Unit Canopy Row (Furness *et al.* 1998-have added to reference list), to require approximately 1200 L/ha to wet to run-off. In Replicate 4 it was calculated to require only 600 L/ha to wet to run-off. The average of these (900 L/ha) was selected as the dilute rate for the whole trial site. The sprayer was calibrated to deliver a 'concentrate' spray of 300 L/ha, requiring a 3× concentration factor in the tank mix.

Treatments

	Adjuvant		Adjuvant rate v/v	mL/ha
1	Unsprayed			
2	No adjuvant			
3	Vegetable oil	Synertrol®	0.40 %	1200
4	Non-ionic adjuvant	Agral®	0.02 %	60
5	Modified organosilicone blend	Du-Wett®	0.10 %	300
6	Polysiloxane	Brushwet®	0.06 %	180

* Each tank mix also included:

Rovral 750 WG® at 201 g/100L in 300 L/ha (equivalent to 67 g/100L dilute spray)

Ridomil® at 450 g/100L in 300 L/ha (equiv to 150 g/100L dilute spray)

Fluorescent Yellow Food Pigment at 300 g/100L

Water-soluble food dye (tartrazine) at maximum concentration of 1000 g/100L

Disease assessments

Botrytis	6 bunches per plot	Inoculated bunches
Downy mildew	6 shoots per plot	Inoculated shoots (2 last expanded leaves per shoot)

Deposit assessments

Leaves	high inner leaves high outer leaves	3 leaves per side of canopy were bulked to make a 6-leaf sample per zone per plot
Bunches	Top half of bunches Bottom half of bunches	

11.3 Results

11.3.1 Effect of adjuvants on downy mildew infection on leaves

Downy mildew infection on leaves was too low to be visible to the naked eye. Microscopic examination confirmed that some pin-prick type lesions were downy mildew, and leaves were therefore washed to remove sporangia for counting. The sporangia numbers were very low on leaves from control plots (29.7 sporangia/cm^2). Leaves from sprayed plots had 100% disease control (zero sporangia/cm^2) regardless of treatment.

11.3.2 Effect of adjuvants on deposits on bunches and leaves at flowering

A proportion of spectrophotometry results from the January 2004 trial were unfortunately lost.

In the case of leaf deposit results, the lost data represented too great a proportion to provide a clear result and so is not reported. In the case of bunch data, this represented replicate four from the Agral and Brushwet treatments and replicate three from the Du-Wett treatment. While the statistical power of the analysis in reduced, the data could be still be analysed and so is presented here.

Effect of canopy position

Contrary to the results from the flowering trial conducted in this same canopy, sampling position (high or low canopy) did not have a significant effect on deposits in the January (pre-bunch closure) trial. Nor was there any interaction between adjuvant and sampling position. Data from the different canopy positions was therefore combined for analysis.

Effect of adjuvant type

Adjuvant type had no effect on bunch deposits from the high or low inner canopy, according to a Wald test for fixed effects comparing deposits from pooled bunch samples (n=8).

However when deposits were compared on individual bunches (n=64) sampled from each plot, rather than pooled bunch samples, there was significantly more tartrazine on bunches treated with Brushwet, or with no adjuvant, than on bunches treated with Du-Wett (Table 11.1).

Effect of adjuvants on excessive wetting within the bunch

There was no significant difference between deposits recovered from the top halves compared to bottom halves of bunches (Table 11.1), and it cannot be supposed therefore that the organosilicone-based adjuvants caused excessive run-off from, or coalescing of deposits at, the bottoms of bunches.

Table 11.1: Estimated mean deposits of tartrazine (normalised to a constant application rate of 1 kg/ha) on bunches from plots treated with fungicide, with or without an adjuvant (n=64).

Treatment	Predicted means (log transformed)			Back-transformed (μg/g)
	Top half	Bottom half	Overall	
Agral	0.5682	0.6749	0.6234 ab	1.87
Brushwet	1.1378	1.0069	1.0712 a	2.92
Du-Wett	0.0767	0.1505	0.1120 b	1.12
No adjuvant	0.5560	0.7402	0.6553 a	1.93
Synertrol	0.4742	0.6214	0.5471 ab	1.73
LSD for comparing overall means			0.5375	

Variation in vigour across the vineyard site

There was a strong influence of plot position (replicate) across the trial site. This influence of replicate on deposits can be seen in Figure 11-1, with lowest deposits in replicate 1 plots and higher deposits in replicates 2, 3 and 4, presumed to be due to a gradient in the canopy density across the trial site. Although the gradient in canopy density was recognised when the trial was conducted, we had decided to maintain an average spray volume across all the replicates, underestimating the influence this would have on deposits.

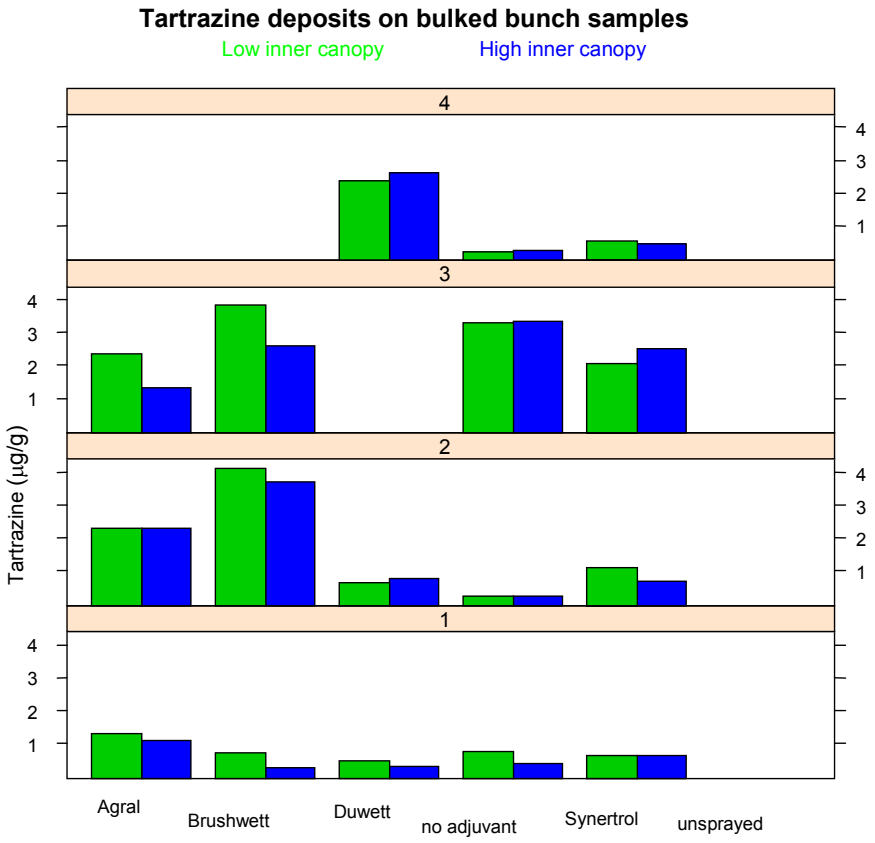


Figure 11-1: Deposits on bulk bunches from the high and low inner canopy, and the influence of replicate on the treatments (each panel in the Figure (1 to 4) represents a different set of vine rows (replicate)).

The 'box-and-whisker' plots in Figure 11-2, with each panel in the graph representing a different replicate, show the variation within the sample sets, and that tartrazine deposits in replicate 1 were lower than replicates 3 and 4.

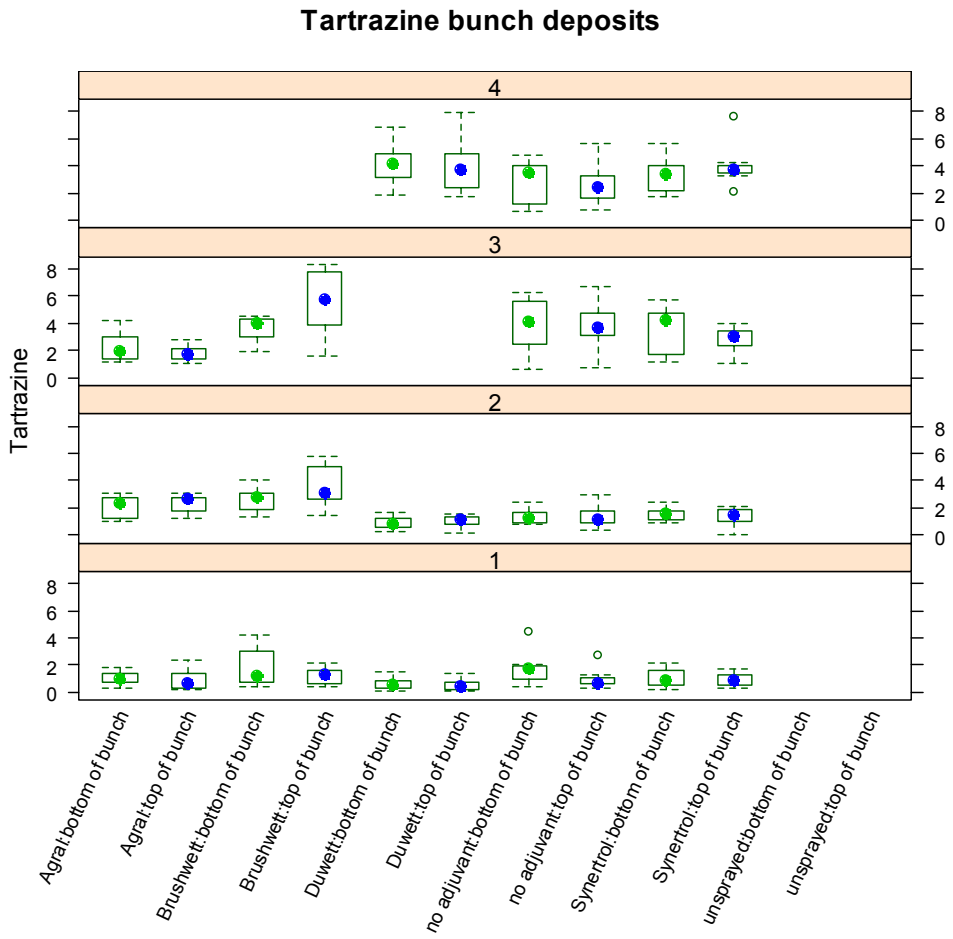


Figure 11-2: Deposits on individual bunches from the high and low inner canopy, and the influence of replicate on the treatments (each panel in the Figure (1 to 4) represents a different set of vine rows (replicate)).

11.3.3 Effect of adjuvants on *Botrytis* infection in bunches at flowering

Despite the bunches having been inoculated, disease in bunches was very low across all treatments and there were no differences between the treatments, including the unsprayed control ($p = 0.928$) (Table 11.2).

Table 11.2: Mean *Botrytis* incidence per bunch (back transformed)

Treatment	Du-Wett	Brushwet	Synertrol	Agral	No adjuvant	Control
% infected berries per bunch	1.95	3.36	3.14	2.54	3.44	3.47

11.4 Conclusion

This trial was inconclusive with respect to determining whether the type of adjuvant included in a low-volume, concentrate fungicide spray would have an effect on spray deposits or in efficacy against infection by downy mildew or *Botrytis*. The large variation in the canopy density across the trial site may have been responsible for this variation in spray deposits and obscured any treatment effects. This made it impossible to demonstrate any statistical differences between different adjuvant treatments. The results of trials 3 and 5 suggest that concentrations of Du-Wett may have been too low to maximise the wetting of bunches at pre-bunch closure, disadvantaging the deposits by Du-Wett and Brushwet.

The hypothesis of the trial was nonetheless an important one to resolve and the trial needed to be repeated, at a site where the canopy and other parameters would remain uniform across the trial for the duration of the growing season.

12 APPENDIX 6 TRIAL 6; APRIL 2004; CABERNET SAUVIGNON; PRE-HARVEST

12.1 Background

Adding a 'sticker' adjuvant to a fungicide mix will purportedly maintain deposits after a rainfall, whereas adding a pure organosilicone will decrease deposits, compared to the non-ionic, industry standard adjuvant. Trial 6 was designed to test the effect on the 'rain-fastness' of fungicides when a latex-based 'sticker', or organosilicone-based 'super-spreader' are added to the spray mixture.

This trial was planned late in the season, at the request of Nufarm. Choice of fungicides for this trial was limited by the need to comply with winery restrictions on use close to harvest. Iprodione was the only fungicide permitted for use by the vineyard owner and contracting winery. Earlier work by Murphy and Warren (2000) refers to the efficacy of iprodione being slightly hampered by organosilicone adjuvants, and the NZ laboratory trials (Appendix 10) revealed that a concentrate tank mix containing Rovral 750 WG, copper and Dipel reduced the performance of the organosilicone. Therefore neither active ingredient nor adjuvants were expected to perform optimally, but as the comparison was between the effects that adjuvant type has on persistence after rain, efficacy was not considered critical to achieving a result from the trial.

12.2 Materials and methods

Trial name	Trial 6; April 2004; Cabernet Sauvignon; pre-harvest	
Location	'Yeringberg', Coldstream, Vic 3770	
Grape variety	Cabernet Sauvignon, 2 years old, on a VSP canopy.	
Growth stage	14 days pre-harvest	
Number of treatments	12	
Number of replicates	3	
Experimental design	Randomised split-plot ? design with five adjuvant treatments allocated to 6-panel main plots, each treatment replicated across 3 rows and each row separated by a single buffer row. Each treatment plot was further divided into 2 sub-plots. Sub plots were randomly allocated an additional '*rain*' or '*no rain*' treatment.	
Sprayer	Hardi Force-10 sprayer, only spraying from one side and only 2 outlets operating, to target the bunch zone of this VSP canopy	
Inoculation	*Botrytis* (7×10^4 spores per mL) applied to 8 tagged bunches per sub-plot (80 per treatment)	
Inoculation date	14th April 2004	4-5 pm
spray date	15th April 2004	
sampling dates	For residue analysis	15th & 22nd April 2004
	For disease assessment	22nd April 2004

Treatments

Treatment	adjuvant	Adjuvant rate (mL/100 L)	Spray volume (L/ha)
1	Unsprayed control	-	Based on visual assessment of the canopy and its narrow bunch zone, we assumed that the bunch zone needed approximately 450 L/ha to wet to run-off. All treatments were applied
1 & rain	Unsprayed control	-	
2	No adjuvant	-	
2 & rain	No adjuvant	-	

3	Agral	20	using 150 L/ha at 3 × concentration to provide maximum separation between adjuvant and non-adjuvant treatments (applying the organosilicone-based adjuvants to run-off at 450 L/ha would have masked any benefit they provided).
3 & rain	Agral	20	
4	Du-Wett	200	
4 & rain	Du-Wett	200	
5	Bond Xtra	400	
5 & rain	Bond Xtra	400	
Tank mix for treatments 2 – 5 included Iprodione fungicide (Rovral WG®) at a concentrate rate of 201 g/100L (3 × label rate of 67 g/100L).			
A rain simulation equivalent to 5-mm rainfall was applied to the bunch zone in each 'rain' subplot, using a petrol-driven backpack sprayer ('Solo') with the single nozzle on the wand replaced by a 1 m boom with four off-set flat-fan nozzles.			

Assessments

Residue analysis	Ten bunches were collected from each sub-plot for residue analysis, on the day of spraying and seven days after spraying. The bunches were frozen and sent to AMDEL Laboratories, Clayton, Victoria, for analysis of iprodione residues by gas chromatography.
Botrytis infection	The eight inoculated bunches from each sub-plot were left in the vineyard for seven days before harvesting for *Botrytis* assessment at DPI Knoxfield.

12.3 Results

12.3.1 Degradation of iprodione deposits in the seven days after spraying

When averaged across all adjuvant and rain treatments, residues of iprodione decreased by 8% during the seven days after spraying (Table 12.1). Although statistically significant ($p = 0.03$), this decrease was unexpectedly small, and atypical of degradation rates of many viticultural fungicides (MacGregor 1998).

Table 12.1: Mean iprodione residues (mg/kg) on bunches on the day of spraying and seven days later

Days after spraying	Iprodione (mg/kg)
0	0.900 a
7	0.825 b
lsd = 0.0662	

12.3.2 Effect of adjuvant on initial deposits and persistence of iprodione

The type of adjuvant used with iprodione had no effect on the deposition or persistence of iprodione on bunches sampled on the day of spraying ($p = 0.581$) or after 7 days (Table 12.2).

Table 12.2: Mean iprodione residues (mg/kg) on the day of spraying on bunches treated with Rovral plus an adjuvant.

Adjuvant	Iprodione (mg/kg)	
	Day 0	Day 7
Agral	0.885 a	0.817 a
Bond X	0.932 a	0.880 a
Du-Wett	0.957 a	0.855 a
Nil	0.825 a	0.750 a

lsd = 0.2155 when comparing means with same level of day.
lsd = 0.1872 when comparing means with same level of adjuvant

12.3.3 Effect of adjuvant on deposits after rain

Comparing the mean deposits for each adjuvant treatment on each date showed that, when averaged across adjuvant treatments, exposing bunches to rain after spraying did not reduce deposits compared to bunches that did not receive rain (P = 0.163) (data not shown).

Considering the adjuvants separately (Table 12.3) shows a significant interaction of 'Adjuvant by Rain' (p = 0.035) at Day 7, due to the Du-Wett treatment. Adding the organosilicone Du-Wett and then exposing bunches to rain was the sole treatment that enhanced the degradation of iprodione during the 7 days after spraying.

Adding the latex 'sticker', Bond Xtra, provided no benefit in terms of iprodione persistence after rain or after 7 days when compared against the Agral or no adjuvant treatments. The iprodione deposits on bunches treated with Bond Xtra and then exposed to simulated rain appear higher than deposits without the "rain" but this is not a significant difference (P > 0.05).

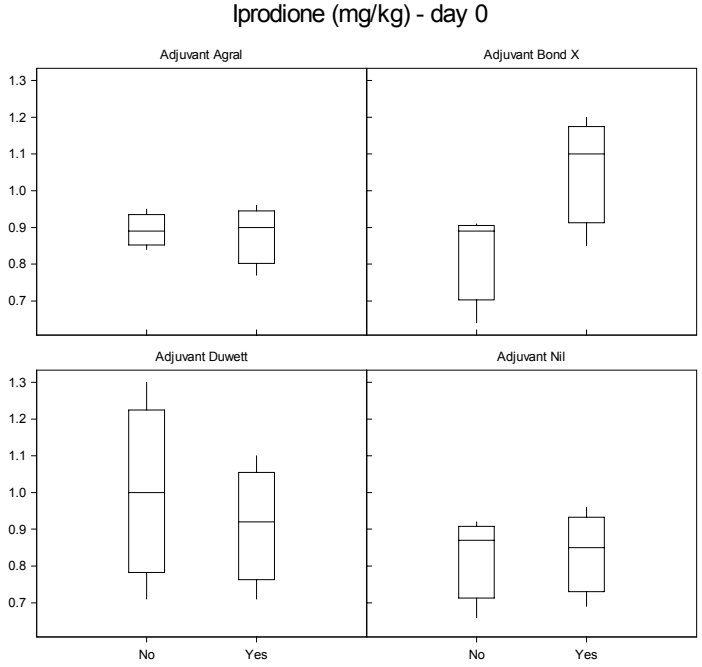
Table 12.3: Mean iprodione residues (mg/kg) on bunches treated with Rovral plus an adjuvant and then exposed to rain, and sampled on the day of spraying and again seven days later.

Days after treatment	Adjuvant	Rain	
		No rain after spraying	Simulated rain after spraying
0	Agral	0.893	0.877
	Bond X	0.813	1.050
	Du-Wett	1.003	0.910
	Nil	0.817	0.833
7	Agral	0.747	0.887
	Bond X	0.750	1.010
	Du-Wett	1.053	0.657
	Nil	0.783	0.717

lsd = 0.2611 - when comparing means with same level of day and adjuvant
lsd = 0.1872 - when comparing means with same level of adjuvant and rain

The variation in deposits of iprodione from bunches within each treatment is illustrated in the box and whisker plots (Figure 12-1). Consistent with the observations made in the Mildura

trials, the bunch deposition was very variable even in this small Yarra Valley canopy with a relatively exposed bunch zone and this variation hinders being able to find clear differences between the adjuvant treatments.



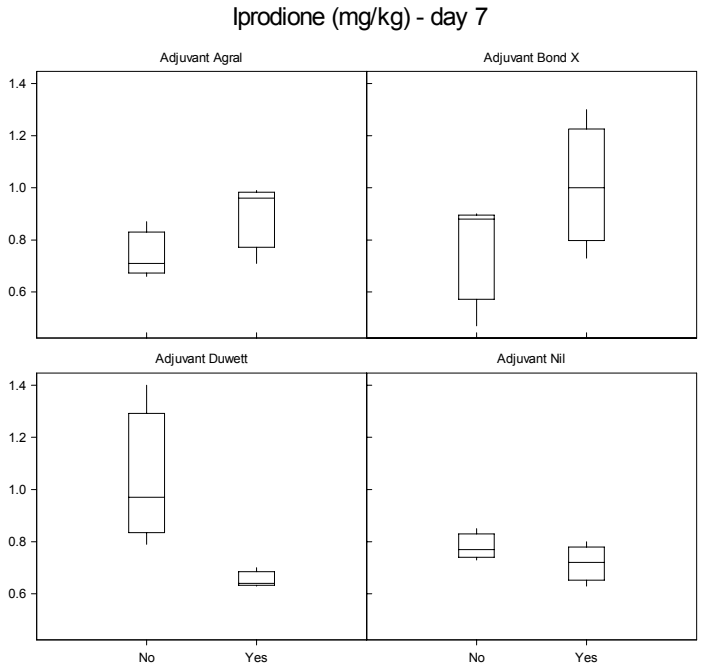


Figure 12-1: Iprodione residues (mg/kg) recovered on Day 0 or 7 after spraying, from bunches treated with Agral, Du-Wett or Bond Xtra. The data is presented as 'box and whisker' plots to highlight the within-treatment variability.

12.3.4 Effect of adjuvant type on *Botrytis* infection in bunches

The *Botrytis* inoculation was unsuccessful, with very low incidence on all treatments and no significant differences between treatments (Figure 12-2).

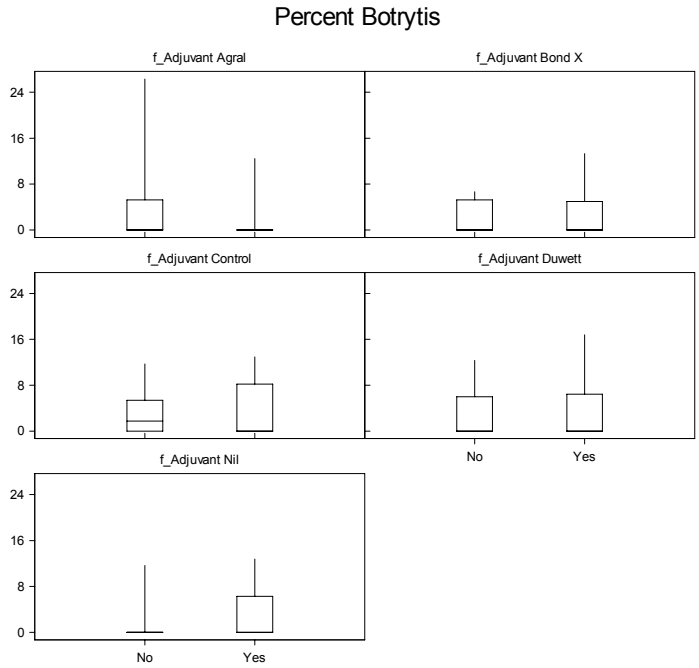


Figure 12-2: *Botrytis* incidence on bunches sprayed with iprodione fungicide and different adjuvant, and then exposed to a 'no-rain' or a 'yes-rain' treatment to compare rainfastness.

12.4 Conclusion

This trial tested the effects of adjuvants on rainfastness of spray deposits and included the sticker/spreader, Designer (a latex/organosilicone blend). The type of adjuvant used with iprodione had no effect on the persistence of fungicide deposits on bunches exposed to simulated rain after spraying. Fungicide deposits on all adjuvant treatments were not reduced significantly by the rainfall treatment. When considering individual treatments, applying Designer with iprodione late in the season did not significantly enhance the iprodione persistence after rain when compared against Agral or no adjuvant treatments. However, there was some indication that adding Du-Wett hastened the loss of iprodione after rain, based on the assessment 7 days after spraying although no significant reduction occurred immediately after the simulated rain. The trial showed that formulations for some products are highly persistent, in which cases there would be no advantage in using a sticker to make it more rainfast.

13 APPENDIX 7: TRIAL 7; OCTOBER 2004; CHARDONNAY; FLOWERING

13.1 Background

Trials at flowering in October 2004 and at pre-bunch closure in December 2004 and January 2005 were to confirm results obtained in October 2003 and January 2004 trials, and to repeat the same adjuvant treatments across two growth stages and two canopy types. The same treatments were used in each trial, simplified to one spray machine, four adjuvants, and both high and low volume applications of fungicide with and without adjuvant.

Of particular interest was the comparison between deposits achieved using the pure and the modified organosilicones. Although the January 2004 trial was hampered by missing data, the pure organosilicone had seemed superior to the modified OS in one rep, and the comparison warranted repeating.

Hypothesis "*Addition of an OS-based adjuvant at flowering or at pre-bunch closure will lead to enhanced disease control when compared with the non-ionic industry standard*."

Trial 7 was designed to test the hypothesis that adding an OS-based adjuvant at flowering will enhance disease control when compared with the non-ionic industry standard.

13.2 Materials and methods

Trial name	Trial 7; October 2004; Chardonnay; Flowering	
Location	DPI Mildura	
Grape varieties	Chardonnay	
Growth stage	Flowering (90% cap fall)	
number of treatments	7	
Number of replicates	6	
Experimental design	Randomised row-column design at each site	
sprayers	Non-directed axial fan sprayer applying 407 L/ha and 1079 L/ha - considered dilute for this growth stage)	
Inoculation	*Botrytis* at 1.6 x 10^5 spores/mL Downy at 1 x 10^5 spores/mL	4 outer bunches and 4 inner bunches 4 outer leaves and 4 inner leaves
Inoculation dates	27-Oct-04 (6:30 to 10:20 pm) 28-Oct-04 (6:30 to 10:30 pm)	*Botrytis* Downy mildew
Spray date	28-Oct-04	
Sampling dates	05-Nov-04 08-Nov-2004	Downy mildew shoots* *Botrytis*

Treatments

Adjuvant	Adjuvant rate	Application vol (L/ha)
No Adj	Nil	1079
Agral®	20	1079
No adj	nil	407
Agral®	20	407
Du-Wett®	100	407
Pulse®/Brushwet®	60	407
Control	nil	Nil

Each tank mix in the October 2004 flowering trial included:

Scala® at 200 mL/100 L in 1079 L/ha (or 2.65x in 407 L/ha).

Copper hydroxide at 150 g/100L in 1079 L/ha (or 2.65x in 407 L/ha).

Sulphur at 600 g/100 L in 1079 L/ha (or 2.65 x in 407 L/ha).

Water-soluble food dye (tartrazine) at 10 g/100L in concentrate mix at 200 L/ha (or 3.3 g/100 L in dilute mix of 600L/ha).

Disease assessments

Botrytis	8 bunches per plot	inoculated bunches
Downy mildew	8 shoot tips per plot	Inoculated shoot tips
Deposit assessments		
A1	high inner leaves	3 leaves per side of canopy were bulked to make a 6-leaf bulk sample
A2	high outer leaves	
A3	low inner leaves	
A4	low outer leaves	
B1	high inner bunches	Six bunches made up each bulked bunch sample
B2	high outer bunches	
B3	low inner bunches	
B4	low outer bunches	

A series of uninoculated, unsprayed shoots and bunches were sampled as untreated controls.

13.3 Results

13.3.1 Effect of adjuvants on deposits on leaves

Effect of canopy position

As in earlier trials, the position within the canopy that leaves were sampled from had a strong influence on deposits from each treatment. Outer leaves intercepted, on average, 2.5 times more tartrazine than inner leaves. To prevent the variation masking a treatment effect, deposits on leaves from the inner and outer canopy were analysed separately. Treatment means are shown in Table 13.1.

Low inner leaves had, overall, significantly more deposit than high inner leaves ($p<0.05$), but as the interaction between sampling height and treatment was not significant ($p>0.05$), the treatment means for the inner canopy shown in Table 13.1 are not split by sampling height.

On the outer canopy, there was a significant interaction between treatment effect and sampling height and the means are therefore presented separately in Table 13.1.

Table 13.1: Tartrazine deposit[6] on Chardonnay leaves ($\mu g/cm^2$) sprayed at flowering with dye, fungicide and various adjuvants.

Adjuvant	Spray volume (L/Ha)	Outer canopy deposits ($\mu g/cm^2$) high	Outer canopy deposits ($\mu g/cm^2$) low	Inner canopy deposits ($\mu g/cm^2$)*
None	1079	4.181 a	3.413 abc	1.425 a
Agral	1079	2.915 bcde	2.961 bcd	1.256 ab
None	407	3.033 bcd	2.246 de	1.116 abc
Agral	407	2.085 e	2.204 de	0.868 bc
Du-Wett	407	2.769 cde	2.661 cde	1.089 abc
Brushwet	407	3.663 ab	2.088 e	0.773 c
Control (unsprayed)	407	0.390 f	0.387 f	0.181 d

LSD for comparing outer canopy deposits = 0.840

LSD for comparing inner canopy deposits = 0.415

Values within the outer canopy (high and low) followed by the same letter are not significantly different.

Values within the inner canopy followed by the same letter are not significantly different.

The addition of adjuvants to the spray mix did not significantly change spray deposits on foliage relative to the same water volume without adjuvant with the exception of Agral. The addition of Agral significantly reduced leaf spray deposits in the upper, outer canopy position for both high and low water volume sprays. The low volume spray with Agral also resulted in significantly lower deposit than the high volume spray without adjuvant for all canopy positions

In the high outer canopy, the high volume spray without adjuvant deposited significantly more tartrazine ($p<0.05$) than all other treatments except Brushwet in the low water volume. The Brushwet low volume treatment resulted in significantly lower leaf spray deposits than both high volume treatments (None adjuvant and Agral) in both inner and low outer canopy positions.

In the low outer canopy position, the high volume treatment without adjuvant was again the best treatment, depositing significantly more spray ($p<0.05$) than the Agral Low Volume, None-Low Volume and Brushwet Low Volume treatments. The Du-Wett low volume treatment was not significantly different to the high volume treatment without adjuvant at this canopy position.

[6] Note that actual (rather than normalised) deposits are presented in Table 13.1. This does not favour the tartrazine deposits from high volume treatments, as the concentration of tartrazine in these treatments was decreased proportionally to their increased tank volume, ensuring that a similar rate (g/100 m or kg/ha) was delivered across all treatments.

A comparison between the low volume treatments suggests that adding adjuvant did not improve deposits compared to having no adjuvant.

13.3.2 Effect of adjuvants on downy mildew infection on leaves

Despite more spray being deposited on outer than inner leaves, there was downy mildew severity was significantly higher on outer leaves than on inner leaves when averaged across all treatments (Table 13.2). This difference was most pronounced in the unsprayed control leaves and is most likely related to faster shoot growth resulting in more young, highly susceptible leaves on shoots growing on the outside of the canopy. Leaves become more resistant to downy mildew as they age (Reuveni 1998) and the slower growing inner shoots have less young susceptible leaves. All sprayed treatments had significantly lower downy mildew severity on leaves than the unsprayed control. The highest levels of disease control (approximately 97% on both inner and outer canopy leaves) was achieved when the fungicide was applied in a high volume spray with no adjuvant added. This treatment had been included in the trial as a 'reference' treatment, representing common practice in commercial vineyards. There were no significant differences in disease control when adjuvants were included in the spray mix relative to the same water volume without adjuvant.

Table 13.2 Downy mildew severity on leaves

Adjuvant	Spray volume (L/Ha)	Outer canopy Disease severity (%)	Inner canopy Disease severity (%)
None	1079	0.97 a	0.49 a
Agral	1079	3.00 ab	1.59 ab
None	407	4.27 b	1.48 ab
Agral	407	5.26 b	4.09 b
Du-Wett	407	2.66 ab	2.65 ab
Brushwet	407	2.50 ab	2.34 ab
Control (unsprayed)	407	37.36 c	15.64 c

Adding Agral to a high volume spray resulted in a non-significant increase in disease compared to the reference treatment (no adjuvant, high water volume). Reducing the spray volume with no adjuvant, resulted in a non-significant increase in disease compared to the reference for the inner canopy but a significant increase in disease in the outer canopy.

The low volume treatments with Du-Wett and Brushwet resulted in disease control equivalent to the high volume, no adjuvant treatment (conventional industry practice) while the low volume treatments with both no adjuvant and Agral did not. These low volume treatments had less disease control than the high volume, no adjuvant treatment (conventional industry practice) in at least one of the canopy positions. These results suggest that it is preferable to use organosilicone wetters rather than no adjuvants when applying low volume sprays for downy mildew control on leaves.

13.3.3 Effect of adjuvants on deposits on bunches at flowering

Deposits on bunches reflected the pattern of deposition (already described) on leaves (see 13.3.1). Tartrazine deposits were significantly higher on outer canopy bunches (mean 20.7 μg/g) than on inner canopy bunches (mean 13.0 μg/g) and data from outer and inner positions were therefore analysed separately (Table 13.3). The highest spray deposits on bunches (both inner and outer canopy) were achieved using a high volume application with no adjuvant. For the outer canopy bunches, this treatment had significantly higher spray deposits than all other

treatments. For inner canopy, bunch spray deposits with no adjuvant and Du-Wett in low volume applications were not significantly different to the high volume treatment without adjuvant while low volume treatments with Agral and Brushwet were significantly lower. All of the low volume treatments were not significantly different from each other regardless of adjuvant.

Table 13.3: Tartrazine deposit[7] on Chardonnay bunches after spraying at flowering with dye, fungicide and various adjuvants.

Adjuvant	Spray volume (L/Ha)	Outer canopy deposits (μg/g)	Inner canopy deposits (μg/g)
None	1079	35.6 c	19.1 c
Agral	1079	26.2 b	14.2 bc
None	407	23.9 b	16.0 bc
Agral	407	20.6 b	11.9 b
Du-Wett	407	22.2 b	14.0 bc
Brushwet	407	20.6 b	12.2 b
Control (unsprayed)	407	7.74 a	7.3 a

Values within the same column followed by the same letter are not significantly different at P=0.05.

13.3.4 Effect of adjuvants on Downy Mildew infection in bunches at flowering

Downy mildew severity was significantly reduced on bunches treated with fungicides relative to the untreated control which had approximately 30% of berries infected in both canopy positions (Table 13.4). Inner bunches had higher disease severity than outer bunches which is in agreement with the spray deposit data. Disease control with all adjuvant treatments was not significantly different to the high volume treatment without adjuvant (conventional industry practice). However, disease control in outer canopy bunches treated with Du-Wett was significantly greater than when Brushwet and Agral were used in low water volume applications.

Table 13.4 Downy mildew severity on flowers (% flowers infected per inflorescence)

Adjuvant	Spray volume (L/Ha)	Outer canopy downy mildew severity (%)	Inner canopy downy mildew severity (%)
None	1079	1.5 ab	4.3 a
Agral	1079	1.7 ab	3.0 a
None	407	1.7 ab	6.9 a
Agral	407	3.5 b	7.4 a
Du-Wett	407	0.5 a	5.3 a
Brushwet	407	3.1 b	9.8 a
Control (unsprayed)	407	30.6 c	29.3 c

[7] Actual (rather than normalised) deposits are presented in Table 13.3. This does not favour the tartrazine deposits from high volume treatments, as the concentration of tartrazine in these treatments was decreased proportionally to their increased tank volume, ensuring that a similar rate (g/100 m or kg/ha) was delivered across all treatments.

13.3.5 Effect of adjuvants on *Botrytis* infection in bunches at flowering

The *Botrytis* infection data was highly variable and could not be analysed statistically. It appeared that all sprayed treatments failed to reduce disease to any great extent although the high volume application with no adjuvant appeared to have the least disease which is in agreement with the deposit data (table 13.5).

Table 13.5: *Botrytis* severity (percent berries infected/bunch) on bunches sprayed at flowering.

Treatment	Inner canopy					
	Minimum	Lower quartile	Median	Upper quartile	Maximum	Inter-quartile range
Agral High	0	0	0	0	37.5	0
Agral Low	0	0	0	11.7	62.5	11.7
Brush Low	0	0	0	49.2	100	49.2
Control	0	0	4.5	37.5	95.5	37.5
Du-Wett Low	0	0	0	23.5	99.3	23.5
None High	0	0	0	0	90.8	0
None Low	0	0	0	8.1	100	8.1
	Outer canopy					
	Minimum	Lower quartile	Median	Upper quartile	Maximum	Inter-quartile range
Agral High	0	0	81.3	86.1	97.8	86.1
Agral Low	0	18.8	37.5	95.5	100	76.7
Brush Low	0	0	14.1	62.5	97.8	62.5
Control	0	0	2.3	62.5	95.5	62.5
Du-Wett Low	0	0	18.8	62.5	95.5	62.5
None High	0	0	0	37.5	100	37.5
None Low	0	0	18.8	62.5	100	62.5

13.4 Conclusions

Overall, across the whole canopy, there was no evidence that adding adjuvant at either low or high volume improved retention of deposits on leaves or bunches, compared to applying a treatment containing no adjuvant.

The organosilicone adjuvants generally reduced spray deposits relative to conventional high volume fungicide applications on both foliage and flowers. Nevertheless, equivalent downy mildew control to the reference treatment (high volume spray without adjuvant) was achieved on both foliage and flowers when the organosilicone adjuvants were added to a tank mix containing a copper fungicide. However, low volume applications without adjuvant also usually (but not always) provided the same level of disease control. *Botrytis* infection levels on bunches were highly variable and it was not possible to statistically analyse the data

The lack of clear result was partly due to a high within-treatment variation, in deposits and disease levels, which caused the analyses to have low 'power' to detect anything other than very large differences between spray treatments.

There was little strong evidence to support the addition of adjuvants to improve spray application to bunches or leaves at flowering in either high water volumes (dilute applications) or low volume (concentrate applications). In this trial at flowering, the bunches were very open structures and the organosilicone rates chosen, matched the NZ recommendations for foliar application rather than bunch application. It is possible that applying the Du-Wett rate recommended for more mature bunches (approximately 50% higher than the rate used in this trial) may improve spray deposition of flowers.

14 APPENDIX 8; TRIAL 8 DECEMBER 2004; CHARDONNAY; PRE-BUNCH-CLOSURE

14.1 Background

Trials at flowering in October 2004 (see Section 13), together with this December 2004 trial at pre-bunch closure, and a final cool climate trial in Merlot in January 2005 (Section 15) were all to confirm results obtained in October 2003 and January 2004 trials by repeating the same adjuvant treatments across two growth stages and two canopy types. The same treatments were used in each trial, simplified to one spray machine, four adjuvants, and both high and low volume applications of fungicide with and without adjuvant.

Of particular interest was the comparison between deposits achieved using the pure and the modified organosilicones. Although the January 2004 trial was hampered by missing data, the pure organosilicone had seemed superior to the modified organosilicone in one rep, and the comparison warranted repeating.

Trial 8 was designed as a repeat of Trial 7, but at a later growth stage, testing the hypothesis that "*adding an OS-based adjuvant at pre-bunch-closure will enhancing disease control when compared with the non-ionic industry standard*".

14.2 Materials and methods

Trial name	Trial 8 – Chardonnay - pre-bunch closure - December 2004	
Location	DPI Mildura	
Grape varieties	Chardonnay	
Growth stage	Pre-bunch closure	
Number of treatments	7	
Number of replicates	6	
Experimental design	Randomised row-column design at each site	
Sprayers	Non-directed axial fan sprayer applying 7.27 l/min (404 l/ha) and 23.52 l/min (1079 l/ha) considered dilute for this growth stage	
Inoculation	*Botrytis* at 1.25×10^5 spores/ml downy at 5×10^4 spores/ml	4 outer bunches and 4 inner bunches 4 outer leaves and 4 inner leaves
Inoculation dates	21-dec-2004 (6 – 10:20 pm) 22-dec-2004 (9:00 – 10:30 pm)	*Botrytis* Downy mildew
Spray date	22-dec-2004	
Sampling dates	22-dec-2004 03-jan-2005 03-jan-2005	Leaf and bunches for tartrazine analysis Downy mildew shoots* *Botrytis*

Treatments

Adjuvant	Adjuvant rate	Application vol (L/ha)
		Pre-bunch closure December 2004
No adj	Nil	1307
Agral	20	1307
No adj	Nil	404
Agral	20	404
Du-Wett	100	404
Pulse	60	404
Control	Nil	nil
Each tank mix in the December 2004 pre-bunch closure trial included:		
Rovral WG® at 67 g/100 l in 1307 l/ha (or 3.24× in 404 l/ha).		
Copper hydroxide at 150 g/100l in 1307 l/ha (or 3.24× in 404 l/ha).		
Sulphur at 600 g/100 l in l/ha (or 3.24× in 404 l/ha).		
Water-soluble food dye (tartrazine) at 10 g/100l in concentrate mix at 200 l/ha (or 3.3 g/l in dilute mix of 600l/ha).		

Assessments

Botrytis	8 bunches per plot	inoculated bunches
Downy mildew	8 shoot tips per plot	Inoculated shoot tips
A1	High inner leaves	3 leaves per side of canopy were bulked to make a 6-leaf bulk sample
A2	High outer leaves	
A3	Low inner leaves	
A4	Low outer leaves	
B1	High inner bunches	Six bunches made up each bulked bunch sample
B2	High outer bunches	
B3	Low inner bunches	
B4	Low outer bunches	

14.3 Results

14.3.1 Leaf deposits

Deposits of tartrazine on outer leaves were, overall, approximately twice those on inner leaves (1.32 and 0.60 μg/cm^2, respectively), so leaf deposit data from the inner and outer canopy were analysed separately to remove the variation due to sampling position (Table 14.1).

Table 14.1: Mean deposits (ug/cm^2) of tartrazine dye recovered from Chardonnay leaves treated with adjuvants in high or low volume (n=12).

Treatment		Leaf deposits (ug/cm^2)	
Adjuvant	Volume (L/ha)	Inner canopy	Outer canopy
Control	Nil (unsprayed)	0.082 a	0.100 a
None	1307	0.810 d	1.386 b
Agral	1307	0.577 bc	1.293 b
None	404	0.543 bc	1.386 b
Agral	404	0.482 b	1.327 b
Pulse	404	0.658 c	1.340 b
Du-Wett	404	0.542 bc	1.246 b
LSD (P=0.05)		0.126	0.188

There was no interaction between canopy height and adjuvant treatment ($p<0.001$), so sampling height was not included in the analysis of the treatments. It is worth noting that despite the Chardonnay canopy used in this trial having different canopy architecture to the Shiraz canopy used in Trial 3 (see page 83), the ranking and mean values at each canopy position were comparable:

Low outer (1.194 µg/cm2)	>	High outer (1.095 µg/cm2)	>	Low inner (0.585 µg/cm2)	>	High inner (0.471 µg/cm2)

On the outer canopy, neither adjuvant type nor spray volume significantly affected deposits.

On the inner canopy, the greatest deposition was achieved by the high-volume treatment with no adjuvant (reference treatment). All other treatments had significantly lower spray deposits than the reference treatment. In the low volume sprays, adding Pulse achieved significantly greater deposits than adding Agral, but there were no significant differences between Pulse and Du-Wett or between Agral and Du-Wett.

The addition of adjuvant (Agral) to a high water volume spray resulted in significantly lower leaf spray deposits in the inner canopy but no significant difference in the outer position.

14.3.2 Effect of adjuvants on infection of leaves by downy mildew

There was no visible downy mildew development on inner canopy leaves. This is most likely due to the lack of actively growing tissue at this canopy position at this time of the year. Grapevine leaves naturally become more resistant to downy mildew with age (Reuveni 1998).

Disease development was also low on outer leaves with a maximum area infected of approximately 2 % in the unsprayed control treatment (Table 14.2). All the sprayed treatment effectively reduced downy mildew severity (96-100% disease control) relative to the unsprayed control treatment and there were no significant differences between sprayed treatments.

Table 14.2: Severity of downy mildew infection on outer canopy leaves (angular transformed, *n*=6)

Adjuvant	Spray volume (L/Ha)	Downy mildew severity (angular transformed)	Back transformed downy mildew severity
Control	NA	8.17 a	2.02
None	1307	1.56 b	0.07
Agral	1037	0.84 b	0.02
None	404	0.90 b	0.02
Agral	404	0.00 b	0.00
Pulse	404	0.00 b	0.00
Du-Wett	404	0.62 b	0.01
LSD (P=0.05)		2.48	

14.3.3 Effect of adjuvant on deposits on bunches pre bunch-closure

There was a significant effect on tartrazine deposits due to canopy position, but not due to adjuvant treatment in either the inner or outer canopy positions (Table 14.3, Figure 14.1).

Tartrazine deposits were significantly higher on outer canopy bunches (mean 1.74 µg/g) than on inner canopy bunches (1.15 µg/g). On the inner canopy bunches, there were no significant differences in spray deposits on bunches sampled from high or low canopy positions.

On the outer canopy, bunches from the high canopy position had 33% more spray deposited (mean 1.53 µg/g) than bunches from the low canopy (1.14 µg/g). While this difference was significant ($p<0.001$) the interaction between treatment and canopy position was not significant ($p=0.115$).

Table 14.3: Log_e transformed tartrazine deposits on bunches. Back transformed means (µg/g) are shown in parentheses (*n*=12).

Adjuvant	Spray volume (L/Ha)	Inner	Outer
Control	NA	-1.378 a (0.252)	-1.379 a (0.252)
None	1307	0.252 b (1.287)	0.653 b (1.921)
Agral	1307	0.095 b (1.100)	0.658 b (1.931)
None	404	0.143 b (1.154)	0.378 b (1.459)
Agral	404	-0.056 b (0.946)	0.495 b (1.640)
Pulse	404	0.229 b (1.257)	0.558 b (1.747)
Du-Wett	404	0.173 b (1.189)	0.597 b (1.817)
LSD (P=0.05) for comparing between bunch deposits from inner canopy = 0.308			
LSD (P=0.05) for comparing between bunch deposits from outer canopy = 0.307			

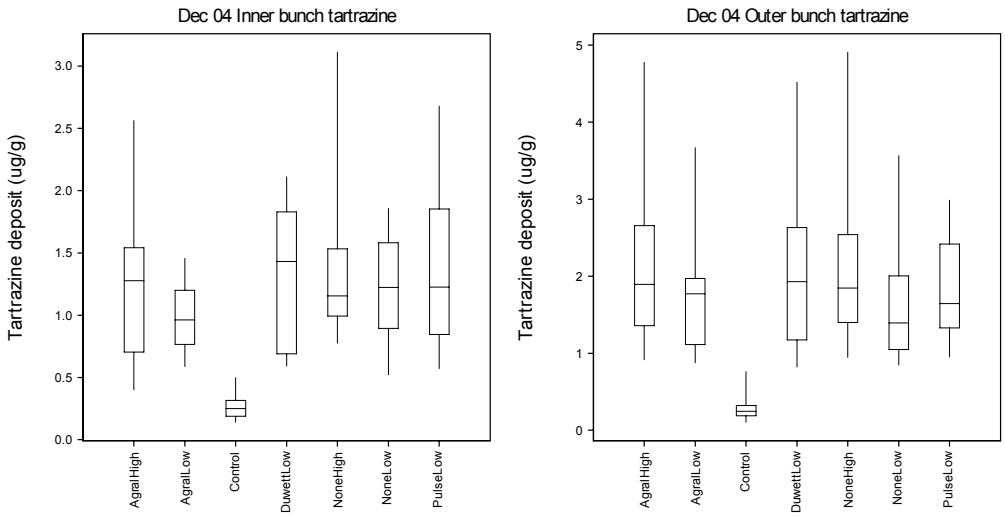


Figure 14-1: Boxplot of tartrazine (μg/g) deposits recovered from Chardonnay bunches (*n=12*).

14.3.4 Effect of adjuvants on *Botrytis* infection on bunches at bunch-closure

Neither adjuvant type nor spray volume had a significant effect on *Botrytis* severity (p=0.583). There were no significant differences between any of the sprayed treatment and the control (Table 14.4).

Sampling position within the canopy had significant effect on *Botrytis* severity (p<0.001) with more than 3 times as much disease on inner bunches than on outer bunches (8.7 and 2.2 % disease severity, respectively). However disease levels were low on all bunches regardless of position.

Table 14.4: Median *Botrytis* severity (angular transformed) on bunches. Back transformed medians (μg/g) are shown in parenthesis. *n*=12.

Treatment	Spray volume	Angular-transformed median	Back transformed medians
Control	NA	10.88 a	3.53
None HV	High	10.51 a	3.33
Agral HV	High	13.88 a	5.75
None LV	Low	13.25 a	5.25
Agral LV	Low	15.63 a	7.26
Pulse LV	Low	13.89 a	5.76
Du-Wett LV	Low	11.46 a	3.95
LSD (P = 0.05)		6.13	

14.4 Conclusions:

The tartrazine dye results show no benefit of adding adjuvant to a tank mix for leaf deposits. Generally there were no significant increases in spray deposits on leaves when adjuvant was added relative to the same tank mix without adjuvant. The downy mildew bioassay could not differentiate treatments on the basis of bioefficacy on leaves. At this stage of the season (pre-bunch closure), there was very little downy mildew development even on the unsprayed control treatment. This is probably due to a lack of sufficient young, highly susceptible leaf tissue at this time in the season. All spray treatments gave a very high level of disease control and were not significantly different from each other.

The low volume fungicide applications generally achieved spray deposits on bunches that were not significantly different to the reference treatment (No adjuvant, high water volume). There were no significant differences between any of the spray treatments for either inner or outer canopy bunches. The *Botrytis* bioassay was inconclusive. Disease levels were relatively low and none of the spray treatments resulted in a significant reduction in disease.

There was no demonstrated benefit in terms of increasing spray deposits when different adjuvants were added to a given tank mix in either a high or a low water volume. Bioassay results in this trial were inconclusive so an increase in efficacy by improved spray coverage cannot be discounted.

Du-Wett and Pulse may have performed better as bunch sprays if they had been applied at a higher concentration at pre-bunch closure. The Du-Wett rate chosen for this trial was based rates that gave the best spray deposition on bunches in previous trials. The rate used in this trial was equivalent to 400 mL/Ha while the NZ recommendation for this tank mix would be 600 mL/ha. Further work is required to determine if higher organosilicone rates in lower water volumes improve spray deposition and bioefficacy on bunches compared to conventional high volume spray applications.

15 APPENDIX 9: TRIAL 9 JANUARY 2005; MERLOT; PRE-BUNCH CLOSURE

15.1 Background

Trials at flowering in Chardonnay in October and December 2004, together with this trial in Merlot in January 2005, were to confirm results obtained in October 2003 and January 2004 trials, and to repeat the same adjuvant treatments across two growth stages and two canopy types. The same treatments were used in each trial, simplified to one spray machine, four adjuvants, and both high and low volume applications of fungicide with and without adjuvant.

Of particular interest was the comparison between deposits achieved using the pure and the modified organosilicones represented by Brushwet and Du-Wett respectively.

Trial 9 was designed to test the hypothesis that "*adding an OS-based adjuvant at pre-bunch closure will enhance disease control when compared with the non-ionic industry standard adjuvants*". This was a repeat of Trial 8 but in a cooler climate vineyard with a different canopy type.

A flowering application had also been planned for the same vineyard site, to confirm whether adding OS-based adjuvant at flowering would enhance disease control when compared with the non-ionic industry standard. The trial was designed and plots marked out at the vineyard ready to spray in mid November, but the treatments could not be applied because the site was flooded by the Yarra River and remained under water until mid December. Consequently, only the pre-bunch closure trial was completed at this cool climate vineyard.

15.2 Materials and method

Trial name	Trial 10 – Merlot - pre-bunch closure - January 2005	
Location	'Eyton on Yarra', Healesville	
Grape varieties	Merlot	
Growth stage	Pre-bunch closure	
Number of treatments	7	
Number of replicates	6	
Experimental design	Randomised row-column design	
Sprayers	Quantum Mist multiple fan sprayer provided by Croplands	
Inoculation	*Botrytis* at 3.5 x 10^5 spores/mL	4 outer bunches and 4 inner bunches
Inoculation dates	18-Jan-2005 20-Jan-2005	*Botrytis* Powdery mildew
Spray date	20-Jan-2005	
Sampling dates	20-Jan-2005 20-Jan-2005 1-Feb-2005	Deposit samples (leaves and bunches) Leaves for powdery mildew assay *Botrytis* infected bunches

Treatments

Adjuvant	Adjuvant rate (mL/100L)	Application vol (L/ha)
no Adj	Nil	852
Agral	20	852
no adj	nil	250
Agral	20	250
Du-Wett	100	250
Brushwet	60	250
Control	nil	nil
Each tank mix in the January 2005 pre-bunch closure trial included:		
Scala® at 200 mL/100 L in 852 L/ha (or 682 mL/100L in 250 L/ha).		
Copper hydroxide at 150 g/100L in 852 L/ha (or 511g/100L in 250 L/ha).		
Sulphur at 600 g/100 L in 852 L/ha (or 2.045 kg/100L in 250 L/ha).		
Water-soluble food dye (tartrazine)		

Assessments

Botrytis	8 bunches per plot	inoculated bunches
Downy mildew	8 shoot tips per plot	Inoculated shoot tips
A1	high inner leaves	3 leaves per side of canopy were bulked to make a 6-leaf bulk sample
A2	high outer leaves	
A3	low inner leaves	
A4	low outer leaves	
B1	high inner bunches	Six bunches made up each bulked bunch sample
B2	high outer bunches	
B3	low inner bunches	
B4	low outer bunches	

15.3 Results

15.3.1 Effect of adjuvants on leaf deposits

The adjuvant treatments, and also the interaction of treatment with position, significantly affected tartrazine deposits ($P<0.05$). Separating the deposits in each sampling position (Figure 15-1 to Figure 15-4) shows that the lowest deposition overall was on leaves sampled from the inner high position (Figure 15-2), with no significant differences between any of the spray treatments at this canopy position.

There was significantly more tartrazine deposited on inner low leaves (0.835 $\mu g/cm^2$) than on inner high leaves (0.312 $\mu g/cm^2$) ($P<0.05$). Despite a considerable time spent adjusting the sprayer to deliver an even deposit to the canopy, the deposit data shows that the set-up was deficient, reinforcing that sprayer set up is paramount to disease control, and that adjuvants cannot overcome poor targeting of sprayer heads.

In the inner-low (Fig 15.4), outer-low (Fig 15.3) and outer-high (Fig 15.1) canopy positions, the greatest deposits were on leaves sprayed at low volume with no adjuvant. Adding Du-Wett or Brushwet reduced deposition relative to the same spray volume without adjuvant, usually significantly (Du-Wett had significantly lower deposits than no adjuvant-LV for all three positions, Brushwet had significantly lower deposits at low inner and low outer positions).

Compared to the low volume, no-adjuvant treatment, adding Agral reduced deposits only in the high-outer sampling position. In the high volume application, adding Agral reduced deposits relative to the no adjuvant treatment only in the low-outer sampling position.

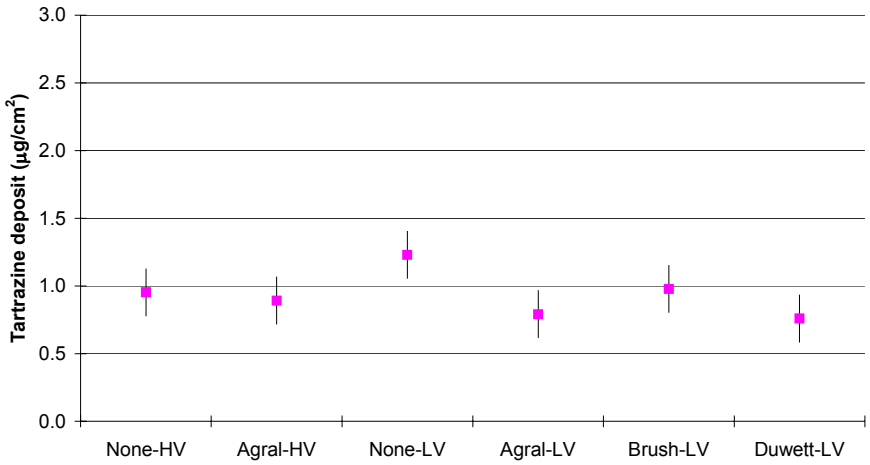


Figure 15-1: Mean leaf tartrazine deposit (µg/cm2) on Outer-high canopy leaves, showing least significant intervals. Deposits normalised to 1 kg/ha tartrazine application rate.

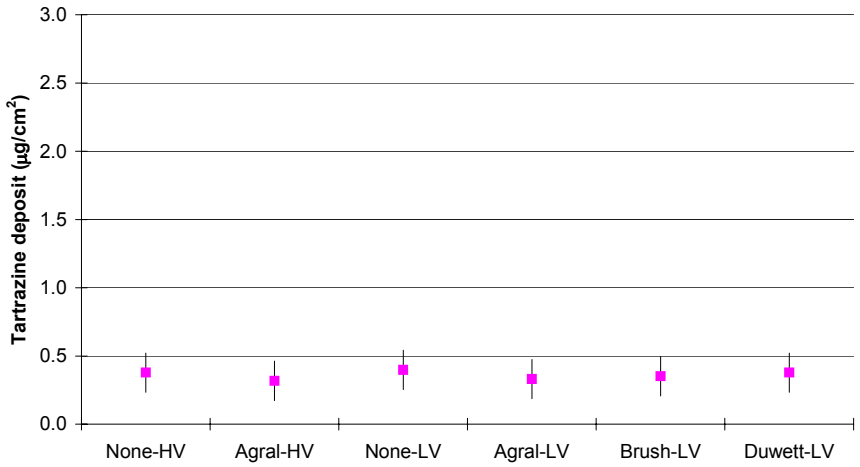


Figure 15-2: Mean leaf tartrazine deposit (µg/cm2) on Inner-high canopy leaves, showing least significant intervals. Deposits normalised to 1 kg/ha tartrazine application rate.

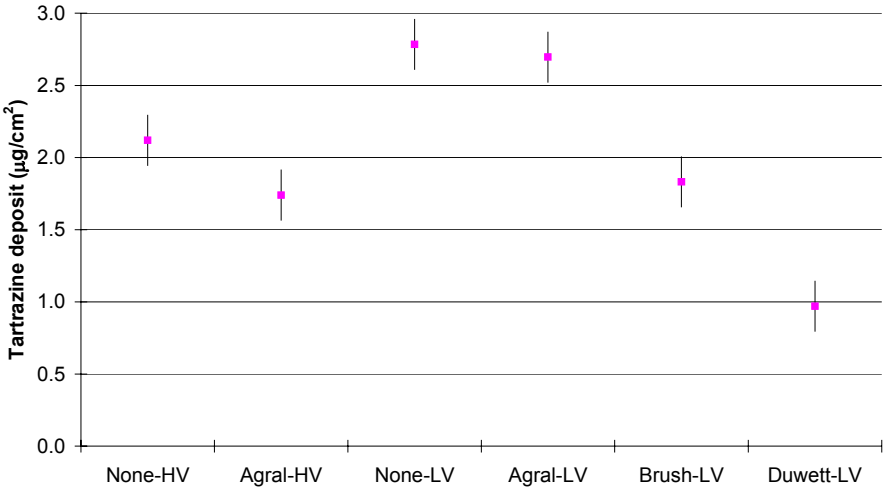


Figure 15-3: Mean leaf tartrazine deposit (µg/cm2) on Outer-low canopy leaves, showing least significant intervals. Deposits normalised to 1 kg/ha tartrazine application rate.

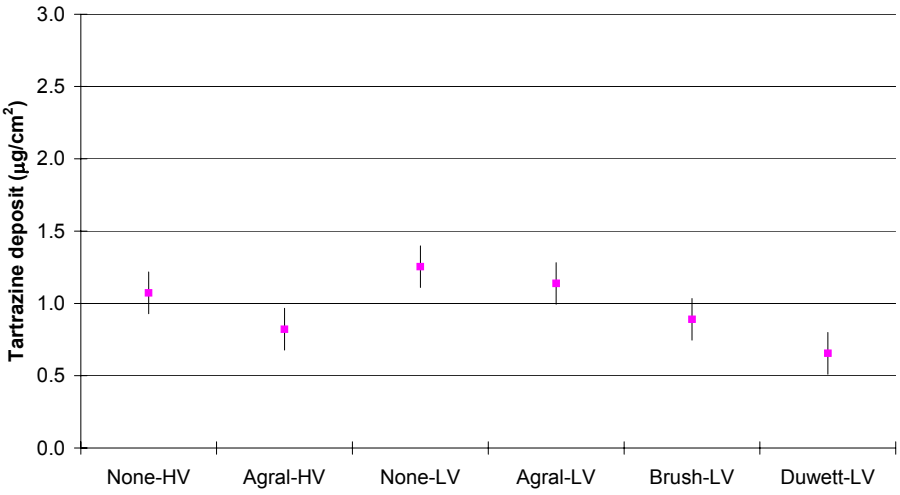


Figure 15-4: Mean leaf tartrazine deposit (µg/cm2) on Inner-low canopy leaves, showing least significant intervals. Deposits normalised to 1 kg/ha tartrazine application rate.

15.3.2 Effect of adjuvants on powdery mildew infection on leaves

The severity of powdery mildew infection on leaves varied with canopy position. For all treatments, outer canopy leaves had lower disease severity than inner leaves, with this difference being significant in the high volume treatments (None-HV, Agral-HV) and the Du-Wett low volume treatment (Figure 15-5, Figure 15-6).

All treatments significantly reduced disease on outer leaves relative to the unsprayed control. In the inner canopy, while all treatments had less disease than the control, the reduction was only significant for Du-Wett-LV, Brushwet-LV and None-LV treatments ($P<0.05$). The lower level of disease control on inner leaves would be expected from the lower spray deposits that occurred at this canopy position

The choice of adjuvant or liquid volume did not significantly influence powdery mildew severity at either canopy position. The addition of Du-Wett to the low volume spray resulted in a reduction in disease severity of approximately 50% on outer leaves relative to the no adjuvant treatment but this difference was not statistically significant. There were no significant differences between treatments on disease severity in the inner canopy.

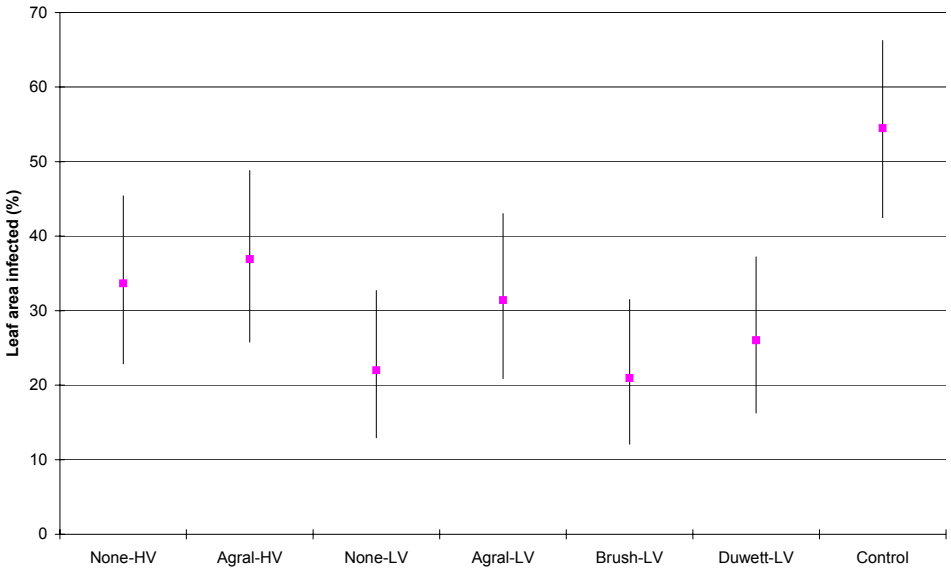


Figure 15-5: Powdery mildew infection (% leaf infected) on leaves from the inner canopy after treatment with fungicide and different adjuvants in high (HV) or low (LV) water volumes.

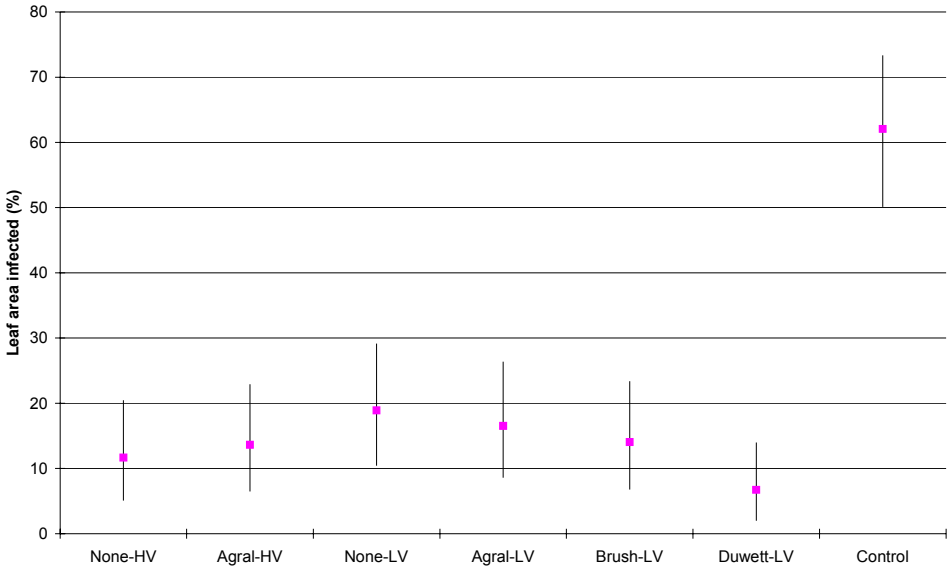


Figure 15-6 Powdery mildew infection (% leaf infected) on leaves from the outer canopy after treatment with fungicide and different adjuvants in high (HV) or low (LV) water volumes.

15.3.3 Effect of adjuvants on spray deposits on bunches at pre-bunch closure

Canopy position influenced spray deposits on bunches with approximately twice as much tartrazine deposited on outer bunches than on inner bunches (4.60 and 2.17 μg/g respectively). Adding adjuvant to the tank mix had no significant effect on spray deposition when compared to deposits from the same water volume without adjuvant (Figure 15-7, Figure 15-8). In the inner canopy position, there was significantly more spray deposited on bunches when Brushwet was applied in a low volume compared to the high volume application with. In the outer canopy, there were no significant differences in spray deposits on bunches between any of the sprayed treatments.

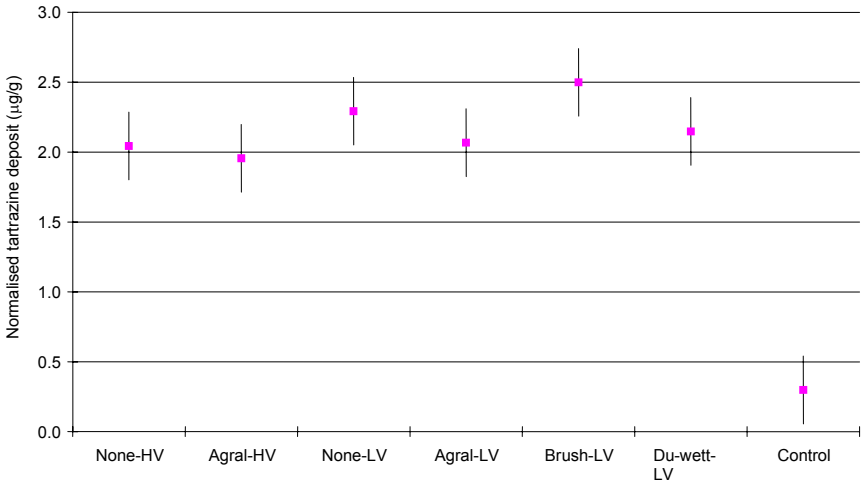


Figure 15-7: Mean tartrazine deposit (µg/g) on bunches from the inner canopy. Deposits normalised to 1 kg/ha tartrazine application rate. Bars represent the least significant interval at the 5% level.

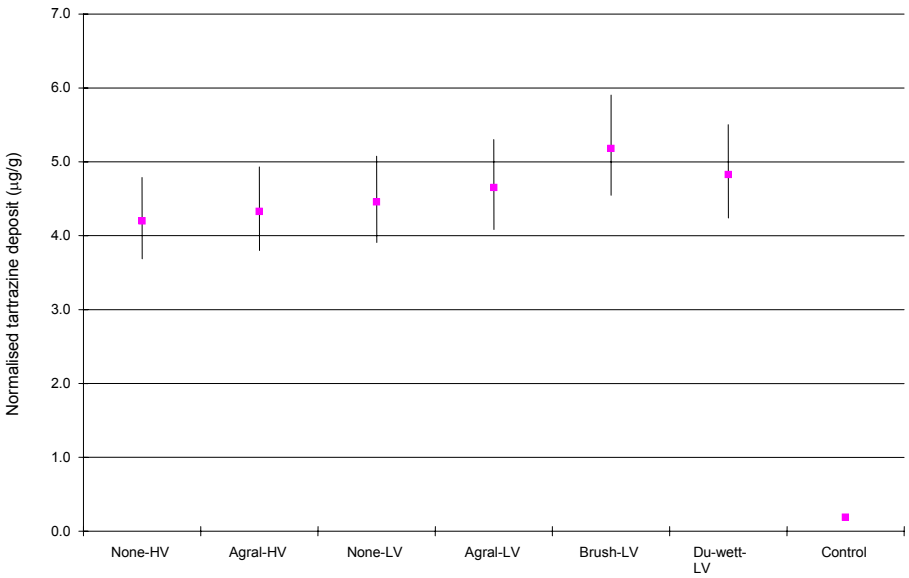


Figure 15-8: Mean tartrazine deposit (µg/g) on bunches from the outer canopy. Deposits normalised to 1 kg/ha tartrazine application rate. Bars represent the least significant interval at the 5% level.

15.3.4 Effect of adjuvants on *Botrytis* infection in bunches at pre-bunch closure.

Botrytis severity was significantly higher on bunches from the inner canopy position compared to outer canopy bunches ($P<0.05$) (44.4 %and 29.5% of berries infected respectively). Du-Wett had the lowest *Botrytis* severity at the inner position by a considerable margin (Figure 15-9) and was significantly different from the untreated control. All other sprayed treatments did not significantly reduce *Botrytis* severity relative to the untreated control and were not significantly different to each other at the inner canopy position.

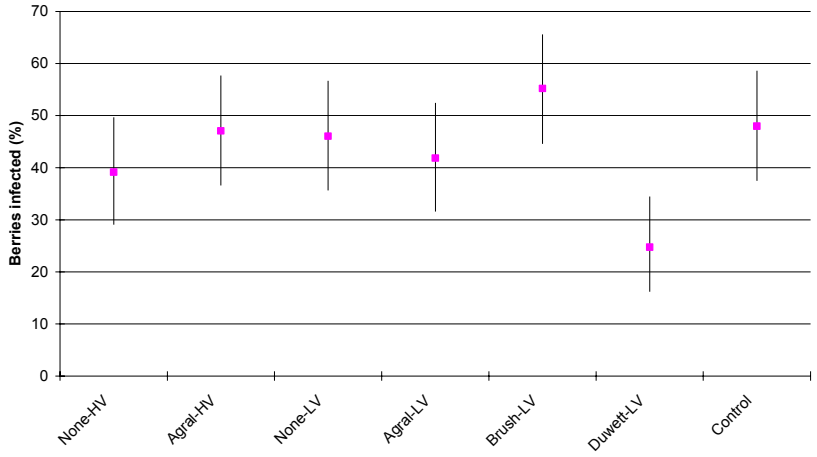


Figure 15-9: Mean *Botrytis* severity and least significant intervals (LSIs) on bunches from the inner canopy.

For the outer canopy positions, the high volume treatment with Agral had the highest *Botrytis* severity (Figure 15-10). However, *Botrytis* severity in the different treatments were not significantly different from each other ($P>0.05$) for outer canopy bunches. None of the sprayed treatments significantly reduced *Botrytis* severity relative to the untreated control.

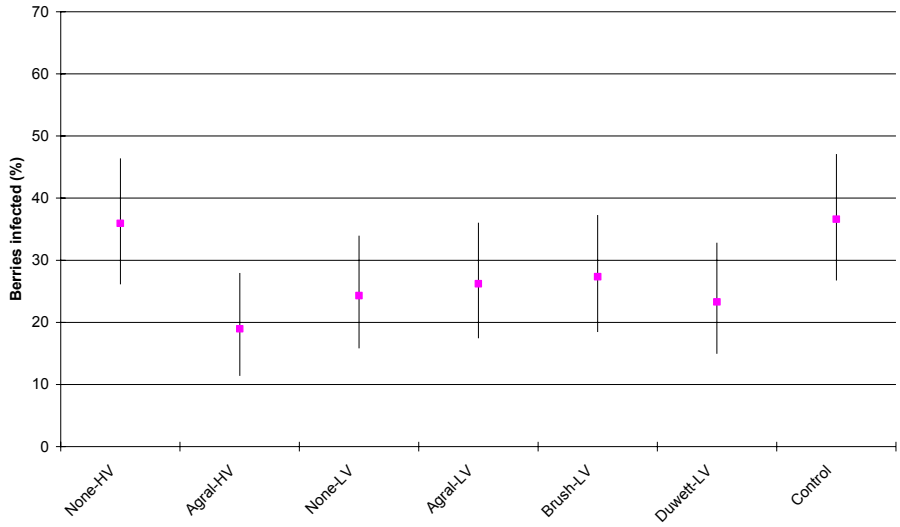


Figure 15-10: Mean *Botrytis* severity and least significant intervals (LSIs) on bunches from the outer canopy.

15.3.5 Conclusions

With respect to bioefficacy, control of neither powdery mildew nor *Botrytis* was significantly enhanced by any particular adjuvant, with the exception of Du-Wett improving *Botrytis* control in the inner canopy. All sprayed treatments reduced powdery mildew severity relative to the unsprayed controls, but no sprayed treatment was consistently significantly better than another. *Botrytis* severity was not significantly reduced by any of the spray treatments with the exception of Du-Wett in the inner canopy position.

An issue that emerged consistently in all the trials was that of variability in deposition due to either unevenness of the canopy or due to difficulties in delivering spray to the inner canopy. Deposits on the inner canopy were typically half to a third of the deposits on the outer canopy, and deposits were often highly variable within any sampling position. Trial 9 provided a clear example of this. All treatments had significantly lower powdery mildew severity than the untreated control. However, the within-treatment variability in powdery mildew severity exceeded the between-treatment variability, to the extent that even a 50% reduction in mean disease severity on leaves treated with Du-Wett in low volume, compared with leaves treated with no adjuvant or with Agral in low volume, was not statistically significant.

Powdery mildew severity on inner leaves was greater than on outer leaves across all treatments. On the inner canopy, there was no significant reduction in powdery severity using high volume applications, with or without Agral. Powdery mildew severity was significantly reduced by the low volume application with either Du-Wett or Brushwet. Unexpectedly, applying the fungicide as a low volume spray with no adjuvant was no less effective than the other treatment for controlling powdery on inner canopy leaves.

With respect to spray deposition, the Du-Wett organosilicone treatment resulted in significantly lower spray deposits on leaves than a low volume application with no adjuvant but the same difference was not reflected in efficacy against powdery mildew. The fact that bioefficacy was maintained despite a reduction in fungicide deposits (ie dose) suggests that better coverage was achieved by fewer droplets. However, the tartrazine tracer dye technique used in this experiment did not allow droplet coverage to be measured. Organosilicone

adjuvants may be of benefit for contact action chemicals by improving spray coverage but may reduce the retained dose of systemic chemicals by increasing run-off.

There was little compelling evidence to support the addition of adjuvants for improving spray deposition at pre-bunch closure on narrow, vertical canopies. Bioefficacy was maintained in reduced volume sprays with or without adjuvants. However, there were some indications (not statistically significant) that higher bioefficacy occurred in some canopy positions (but not all) with the organosilicone adjuvant, Du-Wett. The rate of Du-Wett used in this trial (250L/ha) is close to the NZ recommendation for foliar application which would be 300 mL/ha for the tank mix applied. While this Du-Wett rate was based on the rate that gave the best spray deposition on bunches in earlier trials, the NZ recommendation for this tank mix for bunch application would be 550 mL/ha Du-Wett. The higher rate of Du-Wett (NZ recommendation) may improve retention of spray on bunches but was not tested in this trial.

16 APPENDIX 10 FOUR LABORATORY TRIALS TO ASSESS THE PHYSICAL AND CHEMICAL PROPERTIES OF ADJUVANTS IN SPRAY MIXTURES

Report to Agriculture Victoria

Better disease control using adjuvants
(Project DNR 02/04)

Report on a Laboratory Evaluation to improve pesticide spray coverage on winegrapes

January - June 2003

RE Gaskin, ME Hofstee & KD Steele

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Better disease control using adjuvants:

A Laboratory Evaluation to improve pesticide spray coverage on winegrapes

16.1 Introduction

Winegrape growing is pesticide intensive and, like other horticultural operations, is coming under increasing pressure to reduce pesticide use, to avoid spray drift and to minimise soil and water contamination. Traditional vineyard spray programs involve high volume applications of agrochemicals to wet canopies to the point of run-off. Such high volumes are inefficient in terms of spray losses through drift and run-off, droplet sizes that limit canopy penetration and coverage, low work rates and high use of water resources. The products available to grape growers to control pests and diseases are limited and growers increasingly need to modify formulations and application systems to improve the efficacy of their spray programs. Industry R&D investments in integrated pest management and spray application have assisted winegrape growers to improve their control of bunch diseases and pests, but many growers still report poor control of *Botrytis* bunch rot. This is due primarily to poor canopy penetration and bunch coverage with pesticide sprays. When a commercial sprayer was used for example, to apply Rovral at its recommended concentration to a VSP canopy, 67% of bunches received sub-lethal doses of chemical (Warren & Riches 2001).

Spray adjuvants are at the forefront of a global trend to customise pesticides for specific applications and to reduce environmental contamination by maximising pesticide efficacy (Underwood et al. 2001). Adjuvants hold great promise for the viticulture industry. The surface tension of spray droplets on the surface of grape berries is a major limitation to the movement of liquid film into a bunch during fungicide application (MISG, 2001). Addition of spray adjuvants to pesticide sprays can alter the surface tension of spray droplets and improve spray deposits on difficult targets like grape bunches (Gaskin et al. 2002).

In New Zealand, recent studies with organosilicone adjuvants have demonstrated their ability, over and above conventional agrochemical adjuvants, to improve the effectiveness of growers' spray programs in kiwifruit (Gaskin et al. 2001a), potato (Gaskin et al. 2000a) onion (Gaskin et al. 2001b) and winegrape (Gaskin et al. 2002) crops. The use of these adjuvants can reduce the water volumes required for spray applications while maintaining or even improving efficacy, which has practical and economic consequences. Additionally, reducing spray volumes provides environmental benefits through reduced spray drift, run-off and off-target contamination.

The objective of this laboratory study was to determine how different adjuvant classes could affect the spray coverage of winegrape bunches by a range of Australian agrochemical mixes used in *Botrytis* bunch rot control. In the New Zealand study, several pesticide formulations were found to negatively affect the spreading properties of some adjuvants (Gaskin et al. 2002). The compatibility of, and physical interactions between, the adjuvants and pesticide mixes were quantified with respect to droplet coverage on berries. The aim in this laboratory study was to provide adjuvant prescriptions for field trials to quantify their effects on (i) phytotoxicity, (ii) spray retention on foliage and bunches, and (iii) bioefficacy of the spray formulations against *Botrytis* bunch rot.

16.2 Materials and Methods

16.2.1 Chemicals

Ten representative winegrape spray mixtures were identified for testing by A. MacGregor (Research Scientist, Agriculture Victoria). These included a total of 13 different pesticides, incorporating both fungicides and insecticides and up to four-way mixes of a.i.s (Table 16-1). Each tank mix was screened at two concentrations equivalent to the dilute label rate (D) (i.e. applied in 750 L/ha) and a 3× concentrate rate (C) (applied in 250 L/ha).

Table 16-1: Tank mixes screened for physical and chemical properties with adjuvant addition

Tmt	Tank Mix	Dilute (D) Rate/100L	CONC (C) Rate/100L	Mix instructions
1	Microthiol Disperss WDG (sulphur)	400 g	1200 g	Add to tank with mixing
	Penncozeb 750 DF (mancozeb)	200 g	600 g	Add to tank with mixing
2	Microthiol Disperss WDG	400 g	1200 g	Add to tank with mixing
	Captan WG (captan)	125 g	375 g	Add to tank with mixing
3	Microthiol Disperss WDG	400 g	1200 g	Add to tank with mixing Mix Champ first
	Champ Dry Prill WG (Cu(OH)2)	175 g	525 g	
4	Prosper 500 EC (spiroxamine)*	60 mL	180 mL	Add to tank with mixing
	Penncozeb 750 DF	200 g	600 g	Add to tank with mixing
5	Bayfidan 250 EC (triadimenol)*	10 mL	30 mL	Add to tank with mixing
	Penncozeb 750 DF	200 g	600 g	Add to tank with mixing
	Dipel DF (Btk)	100 g	300 g	Premix and add
6	Scala 400 SC (pyrimethanil)*	200 mL	600 mL	Add to tank with mixing
	Champ Dry Prill WG	175 g	525 g	Mix Champ first
	Microthiol Disperss WDG	400 g	1200 g	Add to tank with mixing
	Dipel DF	100 g	300 g	Premix and add
7	Elect 720 (chlorothalonil)	160 mL	480 mL	Add to tank with mixing
	Microthiol Disperss WDG	400 g	1200 g	Add to tank with mixing
	Dipel DF	100 g	300 g	Premix and add
8	Dipel DF	100 g	300 g	Premix and add
	Scala 400 SC*	200 mL	600 mL	Add to tank with mixing
	Flint 500 WG (trifloxystrobin)*	15 g	45 g	Add to tank with mixing
9	Teldor 500 SC (fenhexamid)*	100 mL	300 mL	Add to tank with mixing
	Microthiol Disperss WDG	400 g	1200 g	Add to tank with mixing
	Dipel DF	100 g	300 g	Premix and add
10	Rovral 750 WG* (iprodione)	65 g	195 g	Add to tank with mixing
	Dipel DF	100 g	300 g	Premix and add
	Ridomil Gold Plus** (Cu/metalaxyl)	225 g	675 g	Add to tank with mixing

All products from Nufarm Ltd except: *Bayer CropScience, **Syngenta Crop Protection Pty Ltd

Five adjuvant classes were selected as representative of the commercial candidates available to growers in Australia, and from these classes, a single adjuvant was chosen (Table 16-2). Agral is the most common horticultural wetter used in Australia but such ethoxylated alkylphenols are progressively disappearing because of concerns about their negative environmental impact, i.e. they are slow to degrade and are confirmed as endocrine disrupters. They are being replaced with alcohol ethoxylates, such as Chemwet 1000, that lack the aromatic ring resistant to biodegradation. Three classes containing organosilicone superspreader surfactants were included because of their increasing use in horticulture, and successes in improving efficacy and reducing pesticide use: Designer is a novel sticker-spreader adjuvant, Pulse is a 'pure' organosilicone widely utilised as an adjuvant for herbicides, and Du-Wett is a blend of organosilicone and conventional adjuvants developed specifically for horticultural use. Each adjuvant was screened with each pesticide treatment (1-10, at both D & C rates; Table 16-1) at two different adjuvant concentrations (Table 16-2). The latter were determined from recommended label rates, where these exist. A preliminary study was undertaken to determine the effect of increasing adjuvant concentration on solution spreading ability and on solution equilibrium surface tension, to justify the use rates.

Table 16-2: Adjuvants screened with each tank mix

Adjuvant class/type	**Adjuvant**	**Supplier**	**Rate/100L** **(bold = label recommended rate)**
Standard wetter (nonylphenol ethoxylate)	Agral®	Syngenta	10 mL and 30 mL (D&C)
Non-ionic wetter (linear alcohol ethoxylate)	Spraymate™ Chemwet 1000	Nufarm	40 mL and 120 mL (D&C)
Sticker-spreader (latex + organosilicone blend)	Designer®	Nufarm	100 mL and 150 mL for Dilute mix 300 mL and 450 mL for Conc. mix
Organosilicone super-spreader ('pure' organosilicone)	Pulse® Penetrant	Monsanto	25 mL and 50mL for Dilute mix 50 mL and 100 mL for Conc. mix
Modified organosilicone (blend, + organic fluid)	Du-Wett®	Elliott Chemicals	50 mL and 75 mL for Dilute mix 150 mL and 225 mL for Conc. mix

16.2.2 Formulation-adjuvant compatibility/stability

All treatments prepared for spreading measurements were visually examined at 0 and 6 h after mixing for any sign of formulation instability (i.e. precipitation, flocculation, changes in settling time). All tests were carried out at 20°C.

16.2.3 Droplet spread

Immature grape bunches were sampled in January (NZ Muscat Italia thinnings) and stored in a cool store (4°C). They were allowed to equilibrate to 20°C before use. Droplets (0.5 µl) of aqueous spray treatments were applied, at 15 mins after mixing, to 10 randomly-selected replicate berries per treatment. Droplet application was confined to berries with wax "bloom" visibly undisturbed. All treatments incorporated a water-soluble fluorescent dye (0.5% Blankophore P; Bayer), which was added immediately prior to sampling, to enable visualisation under UV light. When droplets were visibly dried (i.e. spreading complete), their images were captured by video camera and spread areas quantified by image analysis (V++

Software). Analysis of variance and least significant difference (LSD) tests at $P<0.05$ were used to compare treatment means.

16.2.4 Surface tension determinations

Equilibrium (static) surface tensions of surfactant solutions in water were measured using a Cahn balance, with three replicates per treatment.

16.3 Results and Discussion

16.3.1 Preliminary study: Effect of adjuvant and concentration on droplet spread and solution surface tension of water

Agral is a better spreader than Chemwet, reflected in their recommended use rates (Table 16-2). Increasing the concentration of such conventional adjuvants has little effect on spreading past a threshold value (Table 16-3). For Agral, this concentration is ca 0.1%, for Chemwet it is higher. In contrast, spreading continues to increase in a linear response to increasing concentration of organosilicone surfactant (Figure 16-1). The 'pure' organosilicone, Pulse, spreads more than the modified blend Du-Wett, which in turn spreads markedly more than the spreader-sticker, Designer, which only displays 'superspreading' behaviour at the highest concentration tested here (0.4%). All three exhibit superspreading activity roughly proportional to their organosilicone content. This preliminary study, undertaken in water alone (i.e. without pesticide formulations), indicated that recommended use rates (Table 16-2) would encompass a wide range of droplet spreading on grapes (Table 16-3).

Table 16-3: Effect of adjuvant concentration on droplet (0.24 μl) spread (mm^2 ±SE) on grapes.

Adjuvant	Concentration (% v/v)			
	0.02	0.10	0.20	0.40
Agral	1.06 ± 0.05	1.90 ± 0.15	1.83 ± 0.06	1.71 ± 0.09
Chemwet 1000	0.96 ± 0.06	1.22 ± 0.07	1.80 ± 0.10	1.56 ± 0.05
Designer	0.69 ± 0.03	1.20 ± 0.08	1.93 ± 0.06	4.35 ± 0.17
Pulse	2.49 ± 0.09	15.31 ± 0.78	28.53 ± 0.60	-
Du-Wett	1.73 ± 0.10	9.23 ± 0.35	19.49 ± 0.88	-

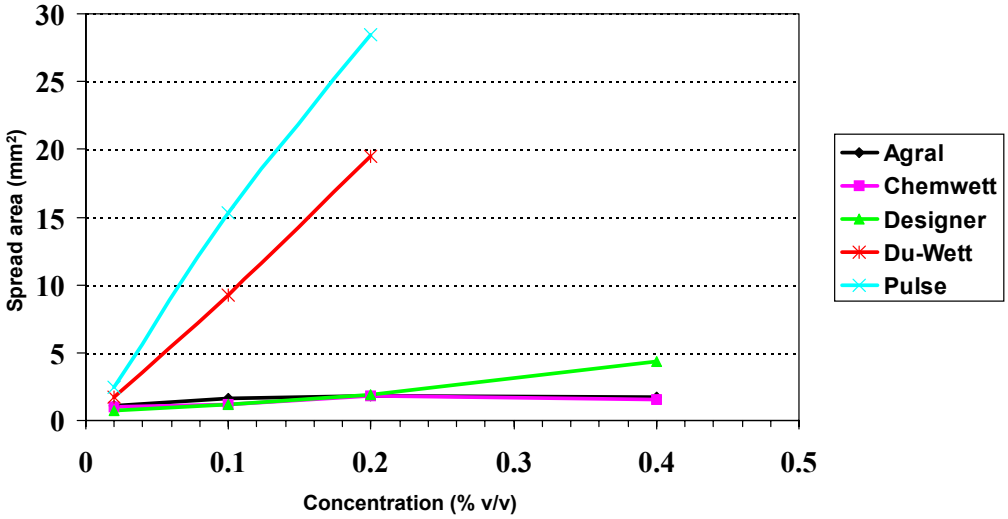


Figure 16-1: Effect of adjuvant concentration on droplet spread (mm^2) on grapes

Droplets (0.5 µl) were applied to individual grape berries as detailed in Materials and Methods and images were captured under UV light after droplet dry-down.

Agral 0.02% v/v	Agral 0.1%
Chemwet 1000 0.02%	Chemwet 1000 0.1%
Designer 0.1%	Designer 0.4%
Pulse 0.1% v/v	Pulse 0.2%
Du-Wett 0.1%	Du-Wett 0.2%

Solution surface tension is another physical property directly related to spray adhesion, retention and surface coverage. The hydrophobic part of a surfactant molecule is not soluble in water and as a result, is expelled out of the droplet. Hence, the surfactant concentrates at the water/air interface and this high concentration at the boundary of the liquid allows surfactants to decrease the surface tension of the solution. Water is around 73 mN m^{-1} and is decreased to around 30 mN m^{-1} in the presence of commonly-used nonionic surfactants (Gauvrit 2002). This is illustrated with Agral and Chemwet, where increasing surfactant concentration has no effect on reducing surface tension below 30 mN m^{-1} (Table 16-4). The organosilicones, however, can lower solution surface tension to around 21 mN m^{-1}, as seen with Designer, Pulse and Du-Wett (Table 16-4 & Figure 16-2). Lower surface tension favours droplet spreading and reduces bounce and reflection from the plant surface. The low surface tension of organosilicones contributes to their ability to superspread.

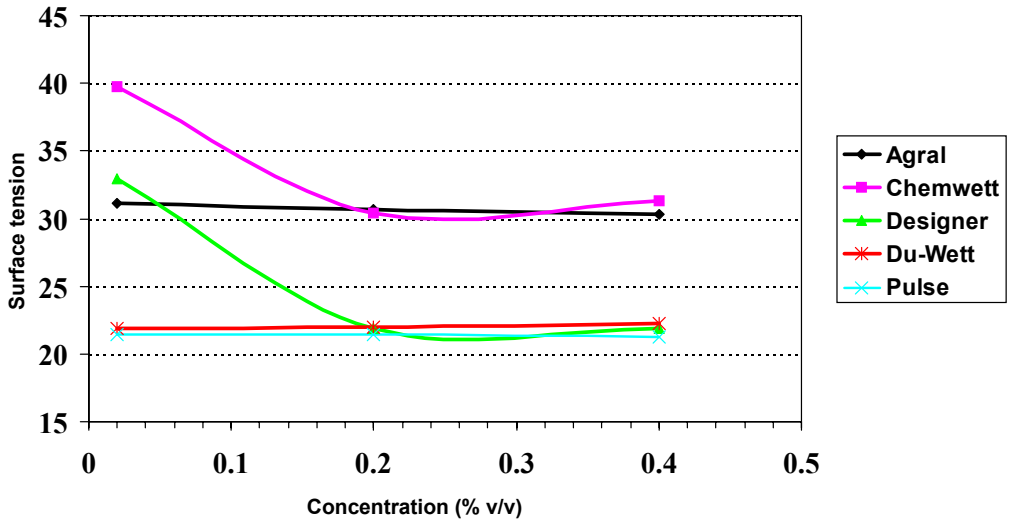


Figure 16-2: Effect of adjuvant and concentration on solution surface tension (mN m^{-1})

Table 16-4: Effect of adjuvant and concentration on equilibrium surface tension (mN m^{-1})

Adjuvant	Concentration (% v/v)		
	0.02	0.20	0.40
Agral	31.1	30.7	30.3
Chemwet 1000	39.7	30.4	31.3
Designer	33.0	21.9	21.9
Pulse	21.4	21.5	21.2
Du-Wett	21.9	22.0	22.3

Low surface tension, such as that exhibited by the organosilicones, also imparts another property; it allows solutions to enter plants through stomata. While this may be desirable for herbicide adjuvants, it can lead to unacceptable crop phytotoxicity when used with protectant or contact pesticides which are not intended to penetrate into foliage. Significant differences are known to exist between Designer, Pulse and Du-Wett with respect to their ability to provide stomatal infiltration (Gaskin et al. 2000b). Du-Wett and Designer are considered less likely than the 'pure' organosilicone, Pulse, to cause crop damage with pesticides not intended to penetrate into plant foliage, due to their lesser ability to infiltrate stomata (Figure 16-3). That study (Gaskin et al. 2000b) established that the potential for crop damage with these adjuvants is greater with higher spray application volumes. The use of organosilicone superspreaders in high volume, dilute sprays on winegrapes may not be advisable for this reason, but this should be determined through field trials.

The conventional adjuvants, Agral and Chemwet 1000, were used at their recommended rates and at three-times recommended concentration in this study (Table 16-2). While this is below their threshold concentration for optimum spreading (Table 16-3), pesticide formulations and

application rates (and their dilution in spray volume/ha) are unlikely to have any effects on Agral and Chemwet's physical properties in solution. In contrast, certain surfactants and co-formulants in agrochemical formulations are well known to interfere with the physical properties of organosilicone surfactants and to affect their ability to superspread (Gaskin et al. 2000b; Policello & Murphy 1993). In addition, it has been established that organosilicone surfactant use rates on winegrapes are a complex function of agrochemical mixes and rates, spray application volumes, canopy type and target tissue (bunches or foliage) (Gaskin et al. 2002). Hence, the organosilicone adjuvants were used at different rates in Dilute and Concentrate sprays (Table 16-2), to maximise their benefits across the wide range of pesticide formulations and concentrations screened in the study (Table 16-1).

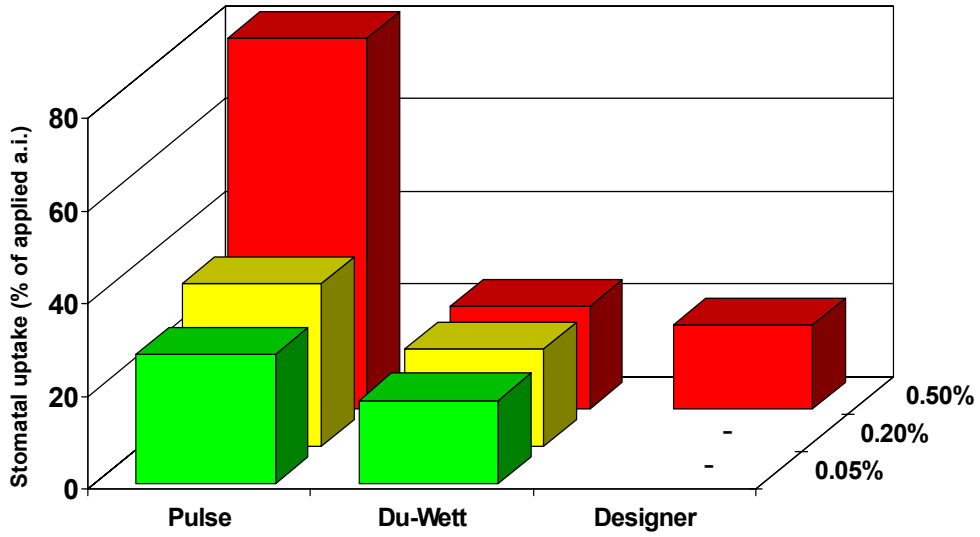


Figure 16-3: Stomatal uptake of adjuvant solutions into potato foliage at a spray volume of 200 litres/ha (adapted from Gaskin *et al*. 2000b)

16.3.2 Stability tests

No adjuvant had any visible effects on the solution stability, at 0 and 6 h after mixing, of any tank-mix screened in the study (Table 16-1).

16.3.3 Droplet spreading on berries

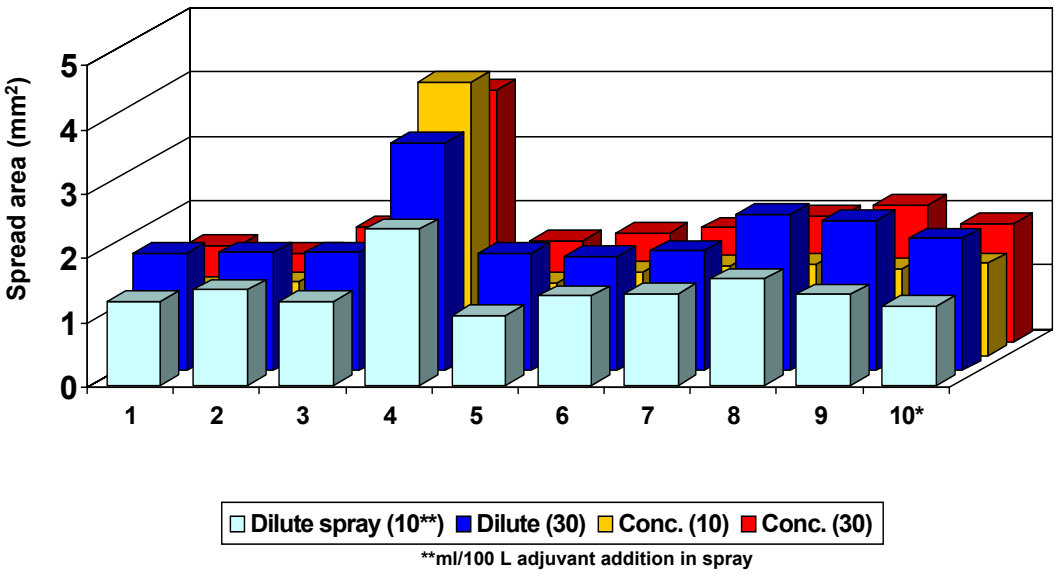
Waxy berries are generally accepted as being harder to wet than grapevine foliage. A simple technique for describing 'surface roughness' has been developed and is routinely used at Forest Research to characterise differences between plant surfaces (Forster & Zabkiewicz 2001). It is a measure of static contact angle using aqueous acetone (80+20) and the correlation between this and percentage adhesion of a wide range of different spray formulations on the plant surface is excellent (R^2=0.97; Forster & Zabkiewicz 2001). The contact angles on a variety of grape surfaces, including the Italian Muscat berries used in this study, indicated that while upper leaf surfaces are more readily wetted (i.e. a lower contact angle), lower leaf surfaces can be equally as difficult to wet as berries (Table 16-5).

Table 16-5: Contact angles (1 μl droplets of 20% acetone in water) on grape.

Variety	Surface	Contact angle (degrees)
Cabernet sauvignon	Upper leaf	93
Cabernet sauvignon	Lower leaf	132
Sauvignon blanc	Upper leaf	95
Italian Muscat	Immature berry	115
Red Globe	Mature berry	133

Agral

Agral is the most common horticultural adjuvant used in Australian vineyard sprays. Agral spread both dilute and concentrate sprays similarly; increasing the concentration of pesticide formulation (and associated co-formulants) in the spray had little effect on the physical properties of this adjuvant (Table 16-8, Appendix 10a & Figure 16-4). A threefold increase in Agral concentration (0.01 to 0.03% v/v) did not result in a proportional increase in droplet coverage of dilute and concentrate sprays. This result was not unexpected in light of that obtained in the preliminary study with water (Table 16-3). Most pesticide treatments spread similarly but not extensively, with droplets covering only 1-2 mm^2 of berry surface. Treatment 4 (Table 16-1) was the best spreading formulation in its own right (the inclusion of Prosper 500 EC is assumed responsible because Penncozeb 750 DF does not improve spread in other treatments) and Agral was unable to improve the coverage of the concentrate spray over and above that due to the emulsifiers and/or adjuvants contained in this commercial pesticide formulation.

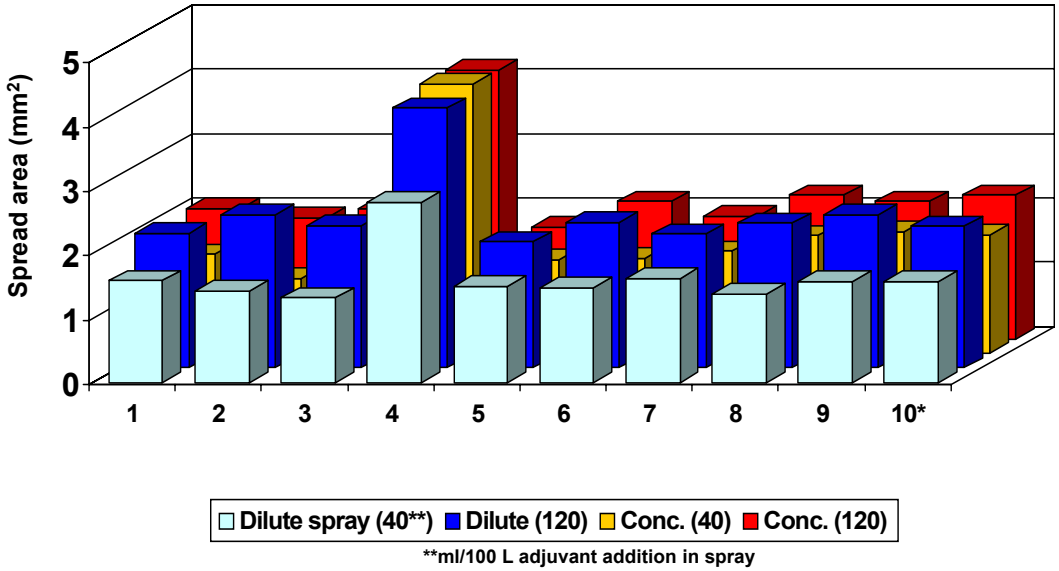


(*For description of Treatments 1-10, see Table 16-1; **for % v/v concentrations see Table 16.8)

Figure 16-4: Effect of Agral concentration on spreading of pesticide treatments on grapes

Chemwet 1000

Chemwet 1000 adjuvant spread treatments similarly to, or slightly less on a v/v basis than Agral (Appendix 1). Pesticide concentration (dilute vs concentrate) had little effect on Chemwet spread (Figure 16-), and while a threefold increase in Chemwet concentration (0.04 to 0.12 % v/v) generally improved spreading, the resultant increase in coverage was at best only 1.7 times. Treatment 4 was again highlighted as the best spreading formulation and Chemwet had no effect on its spreading as a concentrate spray. On the basis of these results, Chemwet 1000 can be considered to be a substitute for Agral as a horticultural adjuvant in a winegrape spray program, although slightly higher use rates (v/v) of Chemwet may be required to provide equivalent coverage of some spray formulations.



(*For description of Treatments 1-10, see Table 16-1; **for % v/v concentrations see Table 16.8)

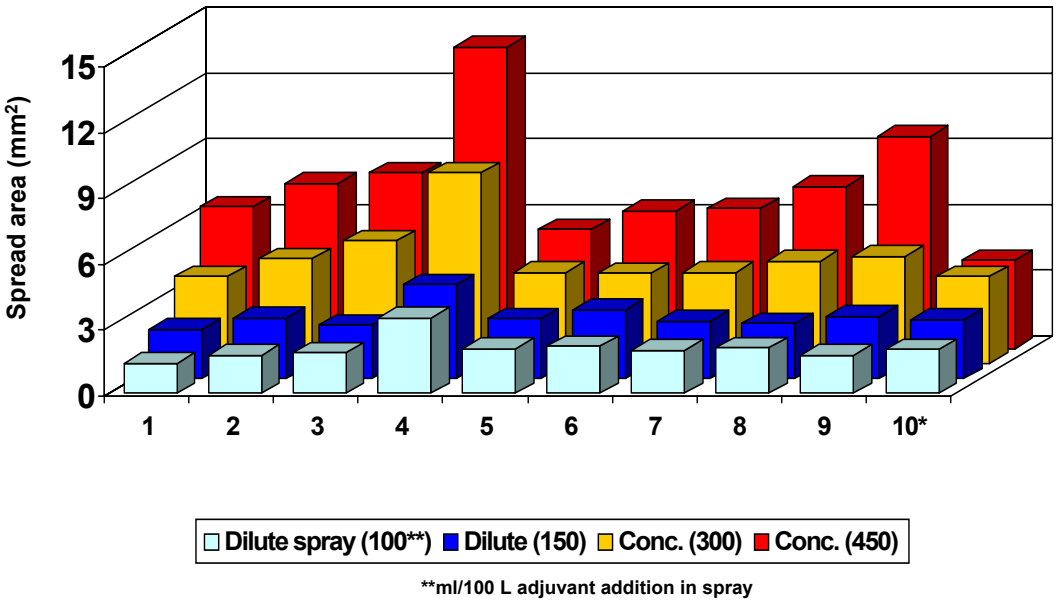
Figure 16-5: Effect of Chemwet concentration on spreading of pesticide treatments on grapes.

Designer

This adjuvant is designed to provide good spray coverage with low water volumes, improved deposition/retention (sticking) and resistance to rain wash-off. At the rates tested with Dilute sprays (0.1 and 0.15% v/v), droplet coverage increased with adjuvant concentration (Appendix 10a). This behaviour is expected of a superspreader, but the low organosilicone content in Designer (undisclosed proprietary information) means spreading increases are not very obvious at low concentrations of this adjuvant (Figure 16-6). However, spreading of dilute sprays by Designer was similar to or even slightly less than that provided by the conventional non-ionic adjuvants, Agral and Chemwet, which are cheaper and are recommended for use at much lower rates. Thus, use of Designer as a 'spreader' in dilute sprays is probably not justified unless rainfastness is an issue.

In concentrate sprays, Designer was used at the relatively high recommended rates of 0.3 and 0.45% (v/v). Generally, droplet coverage increased proportionately with the adjuvant concentration and its spreading properties were not negatively affected by any of the pesticide formulations, with the exception of Treatment 10 (Figure 16-6) This is believed to be due to the inclusion of Rovral and/or Ridomil in that spray mix (Table 16-1); such effects were seen

frequently in the New Zealand study (Gaskin et al 2002). Droplet spreading of all concentrate pesticide treatments was markedly increased by Designer (4-14 mm^2) and these treatments spread much more than the Agral standard (1-2 mm^2; Appendix 1). Of course Designer was used at 10-15 times higher concentration than Agral (which equates to a 3-5 times higher rate, per hectare, in concentrate spraying), but it should be kept in mind that Agral could never provide such coverage at any concentration (Table 16-3 & Figure 16-1). Therein lies the benefit of a superspreader; spreading is positively correlated with its concentration. Designer is expected to be useful in improving coverage of winegrape bunches with reduced-volume concentrate sprays.



(*For description of Treatments 1-10, see Table 16-1; **for % v/v concentrations see Table 16.8)

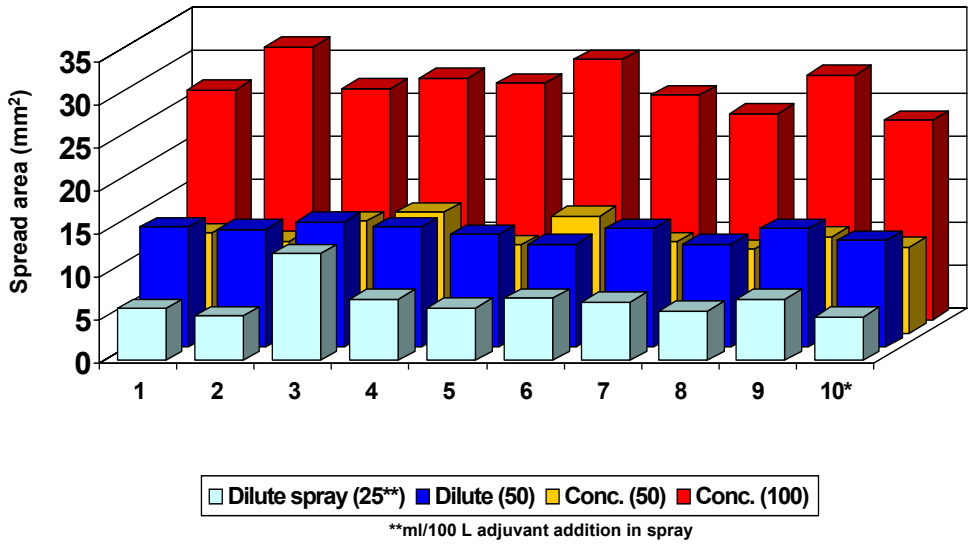
Figure 16-6: Effect of Designer concentration on spreading of pesticide treatments on grapes

Pulse

This adjuvant has no label recommendation for horticultural use and is described as a penetrant to improve herbicide uptake in a range of species (Monsanto 2002). However, it is a 'pure' representative of the class of organosilicone superspreaders which are now extensively utilised in horticultural sprays.

Pulse provided greatest spread (v/v) of all adjuvants tested and there was no indication of serious antagonism of its physical properties by any of the ten pesticide treatments, formulated as either dilute or concentrate sprays (Appendix 10a). Spreading was often reduced slightly in concentrate sprays relative to dilute (at 0.05% adjuvant addition), but the reduction was never more than approx. 20%. The proportional increase in spread was generally greater than expected with increased adjuvant concentration in concentrate sprays (Figure 16-7), indicating synergy rather than antagonism of Pulse's physical properties. Pulse has great potential to improve spray coverage on winegrape bunches. However it will be critical to minimise spray volumes and optimise adjuvant concentrations to prevent over-wetting and loss to run-off, and to eliminate any possibility of sprays infiltrating stomata and

causing phytotoxicity on foliage or fruit. For these reasons, the use of Pulse may be inappropriate in high-volume dilute sprays on grapes.



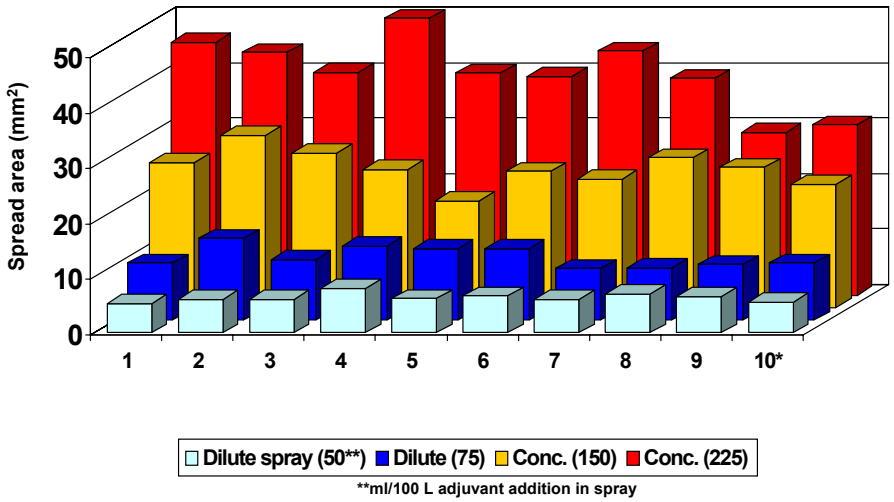
(*For description of Treatments 1-10, see Table 16-1; **for % v/v concentrations see Table 16.8)

Figure 16-7: Effect of Pulse concentration on spreading of pesticide treatments on grapes

Du-Wett

Du-Wett is a horticultural superspreader proven in New Zealand to provide improved control of *Botrytis*, powdery and downy mildew on winegrapes, in standard pesticide programs applied throughout a season in reduced-volume sprays of 200 litres/ha or less (Gaskin & Manktelow 2002). Use of Du-Wett reduced spray drift and off-target deposition, was not phytotoxic to fruit or foliage of Chardonnay, Merlot, Pinotage and Chenin Blanc varieties, and had no adverse effects on wine fermentation or taste, nor on pesticide residues in fruit or wine.

In this study, Du-Wett spread pesticide spray droplets on grapes much more than Agral, Chemwet and Designer, but not as well as Pulse on a v/v basis (Appendix 10a). This is an accepted differentiation between the 'pure' and blended superspreader adjuvants. Generally, there was a linear relationship between spreading and Du-Wett concentration; there was no indication of any pesticide treatment antagonising the adjuvant's spreading properties, and pesticide concentration (dilute versus concentrate) had no effect on spreading (Figure 16-8). As with Pulse, Du-Wett has the potential to markedly improve the spray coverage of bunches, particularly in low-volume concentrate sprays. The interaction of spray volume with adjuvant concentration will require managing to avoid spray run-off and optimise retention on target tissues.



(*For description of Treatments 1-10, see Table 16-1; **for % v/v concentrations see Table 16.8)

Figure 16-8: Effect of Du-wett concentration on spreading of pesticide treatments on grapes

16.4 Conclusions

In contrast to results seen in the New Zealand winegrape study (Gaskin et al 2002), there was no evidence of spray mixes antagonising (i.e. reducing) the spreading provided by the organosilicone superspreaders. This is a positive result, in that general prescriptions for each superspreader adjuvant can be made for most pesticide formulations encountered in an Australian vineyard spray program. In addition, there was not a huge variation in spreading between treatments with each adjuvant, with the exception of Treatment 4 with Agral, Chemwet and Designer. This further confirms that prescriptions for use of the adjuvants in vineyard spray programs will be able to be made with few exceptions for specific pesticides.

When adjuvants are used in concentrate sprays (applied at 250 litres/ha), their use rate per hectare is three times less than at the equivalent concentration in dilute sprays (applied at 750 litres/ha). For superspreader adjuvants, whose spreading ability is positively correlated with their concentration, this confers approximately three-times increased coverage in concentrate sprays for the same adjuvant cost, plus the associated cost benefits and work efficiencies gained in spraying reduced-volumes. In addition, the increased spray coverage provided by the organosilicone superspreaders has the potential to improve disease control. Recommendations are made for field trials to investigate any possible such gains.

16.5 Recommendations:

1. A preliminary field trial to determine if adjuvants cause phytotoxicity on winegrape fruit or foliage.

The suggested adjuvant treatments are detailed in Table 16-6. Each adjuvant treatment (ten total) would be combined with three selected spray treatments containing a good

representation of pesticide formulations, namely Treatments 4, 7 and 8 in Table 16-1. This will provide a phytotoxicity screen of 30 treatments.

Table 16-6: Recommended adjuvant rates for mixing with fungicide tank mixes to test phytotoxicity.

Adjuvant	Adjuvant rate (ml/100 litres)	
	Dilute spray[1] (750 litres/ha)	Concentrate spray[2] (250 litres/ha)
Agral	10	10
Chemwet 1000	100	100
Designer	-	400
Designer	-	800
Pulse	-	200
Pulse	-	400
Du-Wett	-	200
Du-Wett	-	400

[1]Superspreader use is not recommended in high volume sprays, so Dilute treatments need not be screened.
[2]Superspreaders are to be tested at a probable recommended rate and at twice that rate in low volume concentrate treatments only.

2. A preliminary field trial to determine how adjuvants affect spray retention and distribution, and pesticide bio-efficacy on a heavy Australian winegrape canopy:

- To provide quantitative information on how spray volume and adjuvant concentration interact to effect spray retention, distribution and spray efficacy on a heavy canopy.
- To determine how a conventional nonionic surfactant (Agral) performs, relative to a superspreader (Du-Wett), in dilute and concentrate sprays, and which type of adjuvant is preferable for these different spray volumes.
- To determine if superspreader adjuvant rate is best prescribed by concentration (% v/v) or rate/ha.

Use standard NZ TBG protocol with tartrazine dye incorporated in each spray for treatments 1-15 in the following table. Du-Wett prescriptions assume 650 g/ha Rovral 750 WG product in sprays (to be the same in all treatments).

Sample from six canopy zones (lower, mid, upper x inner, outer leaves) and two fruit locations (inner, outer bunches). Bunches further sectioned into outer, inner, lower (10 random berries each) + remainder.

Replication: each treatment applied to 3-4 bays of a row, on both sides; 6 leaves/rep; 4 reps/treatment, 2 from each side of the row; 3 bunches/rep; 4 reps/treatment, 2 from each side of the row.

Bunch samples only to be bio-assayed of *Botrytis* and downy mildew. Bunches and shoots would be inoculated prior to applying any spray treatments.

Table 16-7: Treatments for Retention study on leaves and bunches.

Tmt #	Spray volume (litres/ha)	adjuvant	*Adjuvant rate* (ml/100 L)	Adjuvant rate (ml/ha)
1	250	nil	-	-
2	500		-	-
3	1000		-	-
4	250	Agral	10	25
5	500		10	50
6	1000		10	100
7	250	Du-Wett	50	125
8	500		50	250
9	1000		50	500
10	250	Du-Wett	100	250
11	500		100	500
12	1000		100	1000
13	250	Du-Wett	200	500
14	500		200	1000
15	1000	Du-Wett	25	250

3 Based on the results from field trials (1) and (2) above, adjuvant prescriptions for full-season pesticide programs in commercial vineyards can be recommended.

Field studies should be undertaken using these prescriptions, to assess their effects on disease control and pesticide residues in the 2003/04 season.

16.6 Acknowledgments

Thanks are due to Alison MacGregor (Agriculture Victoria) for helpful advice, Elliott Chemicals Ltd (NZ) for supply of product and their permission to use the IP generated in their NZ Technology for Business Growth Project #5022 (on winegrapes), and to Nufarm Ltd and Bayer Cropscience for supply of products.

16.7 References

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Table 16-8 (Appendix 10a): Effect of adjuvant and concentration on spread of droplets (0.5 μl) of pesticide tank-mix treatments on grapes

Adjuvant	Rate (ml/100 L)	Concn (% v/v)	Treatments[1]									
			1D	1C	2D	2C	3D	3C	4D	4C	5D	5C
Agral	10	0.01	1.3 l	1.1 m	1.5 k	1.2 l	1.3 l	1.2 l	2.4 j	4.3 f	1.1 l	1.1 l
	30	0.03	1.8 i	1.5 jk	1.8 j	1.4 k	1.8 jk	1.8 jk	3.5 gh	3.9 fg	1.8 i	1.6 jk
Chemwet	40	0.04	1.6 j	1.5 jk	1.4 k	1.2 l	1.3 l	1.6 k	2.8 i	4.2 f	1.5 k	1.5 k
	120	0.12	2.1 h	2.0 hi	2.4 i	1.9 j	2.2 hi	2.0 ij	4.0 f	4.2 f	2.0 i	1.7 ij
Designer	100	0.10	1.4 kl	-	1.7 j	-	1.9 ijk	-	3.5 h	-	2.0 i	-
	150	0.15	2.2 h	-	2.8 h	-	2.4 h	-	4.3 f	-	2.7 h	-
	300	0.30	-	4.0 g	-	4.8 g	-	5.6 g	-	8.7 d	-	4.2 g
	450	0.40	-	6.5 e	-	7.6 e	-	8.0 f	-	13.8 c	-	5.4 f
Pulse	25	0.025	6.1 e	-	5.2 g	-	12.5 ef	-	7.2 e	-	6.1 f	-
	50	0.05	14.0 c	11.7 d	13.7 c	10.7 d	14.6 c	13.1 cd	14.0 c	14.1 c	13.1 d	10.3 e
	100	0.10	-	26.8 b	-	31.8 b	-	26.9 b	-	28.2 b	-	27.5 b
Du-Wett	50	0.05	5.3 f	-	6.1 f	-	6.0 g	-	8.1 de	-	6.2 f	-
	75	0.075	10.4 d	-	14.8 c	-	11.0 de	-	13.4 c	-	13.0 d	-
	150	0.15	-	26.2 b	-	31.1 b	-	28.0 b	-	24.9 b	-	19.3 c
	225	0.225	-	45.7 a	-	43.9 a	-	40.3 a	-	50.6 a	-	40.1 a

Means within treatments (includes D & C sprays) sharing common postscripts are not significantly different (LSD test, P<0.05)

[1]Treatments: (D in 750 litres/ha dilution, C in 250 litres/ha dilution; see Table 16-1 for pesticide rates)

1 Microthiol Disperss WDG + Penncozeb 750 DF
2 Microthiol Disperss WDG + Captan WG
3 Microthiol Disperss WDG + Champ Dry Prill WG
4 Prosper 500 EC + Penncozeb 750 DF
5 Bayfidan 250 Ec + Penncozeb 750 DF + Dipel DF

Table 16-8 (Appendix 10a continued): Effect of adjuvant and concentration on spread of droplets (0.5 μl) of pesticide tank-mix treatments on grapes

Adjuvant	Rate (ml/100 L)	Concn (% v/v)	Treatments[1]									
			6D	6C	7D	7C	8D	8C	9D	9C	10D	10C
Agral	10	0.01	1.4 l	1.3 l	1.4 lm	1.4 m	1.7 l	1.4 m	1.4 k	1.4 k	1.2 m	1.4 lm
	30	0.03	1.8 j	1.7 jk	1.9 ij	1.8 jk	2.4 h	2.0 jk	2.3 g	2.1 ghi	2.1 hij	1.8 jk
Chemwet	40	0.04	1.5 l	1.5 kl	.6 kl	1.6 klm	1.4 m	1.8 kl	1.6 jk	1.9 hij	1.6 kl	1.9 ijk
	120	0.12	2.3 i	2.1 i	2.1 i	1.9 ij	2.3 hi	2.2 hij	2.4 fg	2.1 gh	2.2 hi	2.2 h
Designer	100	0.10	2.2 i	-	2.0 ij	-	2.1 ijk	-	1.7 ij	-	2.0 hij	-
	150	0.15	3.1 h	-	2.6 h	-	2.5 h	-	2.9 f	-	2.7 g	-
	300	0.30	-	4.1g	-	4.2 g	-	4.7 g	-	4.9 e	-	4.0 f
	450	0.40	-	6.3 f	-	6.4 f	-	7.4 e	-	9.7 c	-	4.0 f
Pulse	25	0.025	7.2 e	-	6.9 f	-	5.8 f	-	7.2 d	-	5.1 e	-
	50	0.05	12.0 d	13.7 d	13.8 d	10.6 e	12.0 c	9.8 d	13.8 b	11.3 c	12.4 c	10.1 d
	100	0.10	-	30.4 b	-	26.2 b	-	24.0 b	-	28.5 a	-	23.3 b
Du-Wett	50	0.05	6.6 ef	-	6.1 f	-	7.1 e	-	6.6 d	-	5.5 e	-
	75	0.075	12.9 d	-	9.4 e	-	9.4 d	-	10.1 c	-	10.4 d	-
	150	0.15	-	24.7 c	-	23.3 c	-	27.0 b	-	25.4 a	-	22.3 b
	225	0.225	-	39.2 a	-	44.0 a	-	39.1 a	-	29.4 a	-	30.7 a

Means within treatments (includes D & C sprays) sharing common postscripts are not significantly different (LSD test, P<0.05)

[1]Treatments: (D in 750 litres/ha dilution, C in 250 litres/ha dilution; see Table 16-1 for pesticide rates)

6 Scala 400 SC + Champ Dry Prill WG + Microthiol Disperss WDG + Dipel DF
7 Elect 720 + Microthiol Disperss WDG + Dipel DF
8 Dipel DF + Scala 400 SC + Flint 500 WG
9 Teldor 500 SC + Microthiol Disperss WDG + Dipel DF
10 Rovral 750 WG + Dipel DF + Ridomil Gold Plus

17 APPENDIX 11 WORKRATE AND SPRAY APPLICATION COST COMPARISONS

Table 17-1: Costs comparisons for an 8-spray annual spray program, showing costs after making adjustments to travel speed (increase from 5 to 7 kph) and to the spray volume (reduction from 1000 to 300 L/ha). All other operations are maintained as constant.

Property	DPI Mildura				
Block	Chardonnay				
Sprayer/tractor	Airblast				
Date	04/01/05				
Comparison	**#1**	**#2**	**#3**	**#4**	
ASSUMPTIONS					
Travel speed	**5**	**7**	7	7	km/hr
Spray volume	**1000**	1000	**600**	**300**	l/ha
Tank size	2000	2000	2000	2000	l
Mix and fill time	15	15	15	15	minutes
Turning time per turn	5	5	5	5	seconds
Row spacing	3	3	3	3	m
Rows sprayed/pass	1	1	1	1	
Average row length	180	180	180	180	metres
Property area	10	10	10	10	ha
sprays per season	7	7	7	7	per season
Labour cost	40	40	40	40	$/hr
Tractor cost	35	35	35	35	$/hr
Sprayer cost	25	25	25	25	$/hr
WORK RATE *Includes fill, travel and turning times*	1.2	1.6	1.7	1.9	ha/hr
Cost per ha	$82	$63	$58	$54	per ha
Time to spray block	8.2	6.3	5.8	5.4	hours
Cost to spray block	$817	$627	$577	$539	per spray
Cost to spray block	$5,722	$4,388	$4,038	$3,776	per season
Annual benefit	$0	$1,333	$1,683	$1,946	per season

Developed by: David Manktelow: Note: This spreadsheet may be freely copied from www.hortplus.com/FreeStuf/SprayCal/SprayCalc/htm provided the acknowledgment to HortResearch is retained