Effects of chemical and natural product treatments on bunch openness and botrytis bunch rot in Sauvignon blanc grapes

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Abstract Products containing different gibberellic acids (GA) and GA inhibitors were applied to grapevines during the 2009/10 and 2010/11 growing seasons to evaluate possible effects on bunch architecture and subsequent botrytis bunch rot (BBR) severity. In the 2010/11 season, the timing, formulation and dose responses of the GA inhibitors in association with a biological control agent were also evaluated for their effects on BBR. In both seasons, the effects on yield and fruit quality and quantity were also measured to determine whether the treatments might affect commercial production. There were no significant differences in either BBR incidence or severity in either season between any treatments, including the standard fungicide programme. Bunch openness was significantly modified by treatments but with no consistent pattern.

Keywords gibberellic acid, bunch architecture, botrytis bunch rot.

INTRODUCTION

Botrytis bunch rot (BBR) is the main seasonal disease risk for grapes grown in Marlborough and many other wine production regions in New Zealand (Beresford et al. 2006). Wines often contain residues if fungicides are used late in the season for disease control, so there is a need for botrytis control products that are effective when applied early in the season. Pathways of infection of grape berries have been summarised (Elmer & Michailides 2007) allowing the potential risk factors that could be manipulated to be hypothesised. One of the factors influencing the potential for grape bunches to develop BBR is

bunch compactness. Investigations of BBR and bunch shape have suggested that a longer rachis and more open bunch result in a reduction in symptoms (Dry & Thomas 2003; Shavrukov et al. 2004).

Gibberellic acids are naturally occurring plant hormones that can also be commercially produced from selected fungi by fermentation. Gibberellic acid has been used in table grapes early in the season to open bunch architecture by elongating the rachis (Weaver & McCune 1962; Jawanda 1974; Weaver 1975). This lowers the risk of late season bunch rots, allowing fruit to meet

high consumer expectations and postharvest storage requirements. Wine grape producers in Germany have investigated using GA on wine grapes to regulate yield and quality (Weyand & Schultz 2006). However, the use of GA3 on wine grapes has been restricted because of concerns about reduced return bloom if used at concentrations above 10 ppm (T. Lupton, Lewis Wright Valuation and Consultancy, personal communication). Early studies in New Zealand had shown that on Seibel 5455 grapes, increased concentrations of GA3 from 5 to 40 ppm resulted in increasingly less compact bunches (Hopping 1976). As GA3 is unlikely to be used by the wine industry as a treatment because of the risk of reduced yield, it was included in the present experiment as a positive control that would change bunch openness and which could be compared with other treatment options. Hence to ensure that bunch openness was achieved, a high rate of application (40 ppm) was selected. This rate did result in reduced bloom the following season and is not intended as an industry treatment.

Acadian[®] seaweed extract is a certified organic product already in use in some organic programmes (Evans et al. 2013). The seaweed extract has been promoted as elongating the rachis (Holden et al. 2008), without stating the mechanism, so was included to determine if it produced more open bunches. Another product, prohexadione-Ca, has also been shown to inhibit the conversion of GA20, which is plant inactive, to GA1, which is plant active. Since deficiency of GA1 reduces grape vine growth, including berry development, it can increase bunch openness (Giudice et al. 2003; Giudice et al. 2004; Vaquero-Fernandez et al. 2009).

This project was initiated to investigate products that (1) could be applied to vines at flowering to reduce bunch compactness and BBR development and (2) were acceptable to conventional and/or organic wine grape growers. Five plant growth-regulating products were field-tested during the 2009/10 season to determine their impacts on fruit composition, yield and bunch architecture. LI-700[®] was added as an acidifying and penetrating surfactant to

the plant growth regulators, to allow consistent application between treatments. In the 2010/11 season, the investigation focused on whether a prohexadione-Ca formulation that did not require the addition of LI-700 (as Regalis[®] Xtra) applied early in the season, followed by *Bacillus subtilis* (as Serenade[®] MAX) applied late in the season, could provide BBR control equivalent to that of a standard industry fungicide programme. The discussion includes some possible reasons for within-vine differences in bunch shape observed during both seasons.

MATERIALS AND METHODS

Trial sites and treatments

Trials in both the 2009/10 and 2010/11 seasons were conducted on grapevines at the Marlborough Research Centre Trust premises (Rowley Crescent, Grovetown, Marlborough). *Vitis vinifera* Sauvignon blanc (mass selected) on 101–14 rootstock were planted in 2002 in 2.7 m rows with 1.8 m between vines (four vines per bay and 2057 vines/ha). Vines were cane-pruned to carry three canes or approximately 36 nodes per vine in winter. Canopy management consisted of vertical shoot positioning followed by standard summer trimming. The active ingredients of the products used are shown in Table 1. The treatments applied in the 2009/10 and the 2010/11 seasons are shown in Tables 2 and 3, respectively. The trials involved five and six replicates, respectively, in a randomised complete block design. Each replicate consisted of a separate vineyard row containing all treatments randomly allocated to plots within the row. Each treatment was applied to the four vines in a bay, except the first and last half of the end vines of every plot, which acted as buffer zones between the different treatments. In both seasons, treatments were applied as sprays directed to the bunch line using a 15-litre knapsack sprayer and a water rate of 800 litres/ha and 1000 litres/ha for the first and second seasons, respectively.

Crop management

In the 2009/10 season, vines were machine trimmed on 8 January 2010 and 19 February 2010 and machine leaf plucked on 20 January 2010.

Table 1 Product names, manufacturers and active ingredients used in botrytis bunch rot experiments on Sauvignon blanc grapes.

Product	Manufacturer	Active ingredient
Regalis®	BASF	100 g/kg prohexadione Ca
Serenade® MAX	BASF	<i>Bacillus subtilis</i>
Shirlan®	Syngenta	500 g/litre fluazinam
Switch®	Syngenta	375 g/kg cyprodinil and 250 g/kg fludioxonil
Pristine®	BASF	128 g/kg pyraclostrobin + 252 g/kg Boscalid
Regalis® Xtra	BASF	100 g/kg prohexadione Ca (new formulation)
Falgro®	Norac Concepts Inc.	1 g gibberellic acid per tablet
Novagib®	Fine Agrichemicals	0.95% gibberellic A ₄ A ₇
Acadian®	Acadian Agritech	Seaweed extract
LI-700®	Nufarm	350 g/litre soya phospholipids, 350 g/litre propionic acid

Table 2 Treatments, rates and date of applications in botrytis bunch rot experiments on Sauvignon blanc grapes for the 2009/10 season.

Treatment ¹	Growth stage	Date
1 Untreated control		
2 Novagib® GA4+GA7 40 ppm	50% cap-fall	19/12/2009
3 Falgro® GA3 40 ppm	50% cap-fall	19/12/2009
4 Acadian® Seaweed extract label rate	50% cap-fall	19/12/2009
5 Acadian® Seaweed extract 2 × label rate	50% cap-fall	19/12/2009
6 Prohexadione Ca 150 g/100 litres	50% cap-fall	19/12/2009
7 Prohexadione Ca 175 g/100 litres	50% cap-fall	19/12/2009
8 Prohexadione Ca 175 g/100 litres	2 weeks after 50% cap-fall	1/01/2010
9 Prohexadione Ca 175 g/100 litres	2 weeks before 50% cap-fall	5/12/2009

¹Treatments 2, 3 and 6-9 had LI-700® added to the tank at 0.1% volume.

Table 3 Treatments, rates and date of applications in botrytis bunch rot experiments on Sauvignon blanc grapes for the 2010/11 season. All treatments received *Bacillus subtilis* on 21 February (250 g/100 litres) and 30 March 2011 (300 g/100 litres).

Treatment ¹	Date
1 Untreated control (no flowering sprays)	
2 Prohexadione Ca 150 g/100 litres + LI-700 0.1%	12/12/2010
3 Prohexadione Ca new formulation 150 g/100 litres	6/12/2010
4 Prohexadione Ca new formulation 100 g/100 litres	12/12/2010
5 Prohexadione Ca new formulation 150 g/100 litres	12/12/2010
6 Prohexadione Ca new formulation 200 g/100 litres	12/12/2010
7 Prohexadione Ca new formulation 150 g/100 litres	17/12/2010
8 (Pyraclostrobin + Boscalid) 150 g/100 litres; (cyprodinil and fludioxonil) 80 g/100 litres	6/12/2010 & 17/12/2010; 12/01/2011

¹*Bacillus subtilis* (250 g/100 litres) was also applied to Treatments 1–7 on 12 January 2011.

No hand shoot thinning or hand leaf plucking was carried out, resulting in a dense canopy with 28% fruit exposure (visually estimated). In the 2010/11 season, vines were machine leaf plucked on 11 January 2011 and machine trimmed on 28 February 2011. No hand plucking or thinning was carried out, resulting in a canopy with 45% fruit exposure (visually estimated).

All plots, including the untreated control, received an overall maintenance fungicide programme of sulphur and demethylation inhibitor (DMI) fungicides in both seasons to control powdery mildew. In the 2009/10 season, all vines received a standard early and mid-season botrytis fungicide programme, consisting of 500 g/litre fluazanam (Shirlan®) on 16 December 2009 at approximately 30% capfall and 375 g/kg cyprodinil plus 250 g/kg fludioxonil (Switch®) on 25 January 2010 at pre-bunch closure (PBC). In the 2010/11 season, the untreated control received no application during flowering but was subject to the same late-season *Bacillus subtilis* (Serenade® MAX) programme as the other treatments (Table 3).

In 2009/10, fruit maturity was assessed on 15 April 2010, as this was the date of commercial harvest. However, as BBR severity was low, the vines were left unpicked in order to allow disease to develop further. Botrytis bunch rot and fruit yield were measured on 28 April 2010. In 2010/11, fruit maturity was assessed on 20 April 2011, as this was the date of commercial harvest. Botrytis bunch rot assessment took place on 19 April 2011.

Fruit yields, composition at harvest and volumes of bunches

At harvest in both seasons, total yields per plot and individual yield components were assessed after harvesting all bunches in each plot. The assessments included bunch number, average bunch weight calculated from total yield and number of bunches, berry number per bunch and average berry weight calculated from a 50-berry subsample. Berry composition was assessed with a 50-berry subsample.

In 2009/10, grape berry soluble solids content (°Brix) was analysed in triplicate using a digital

Atago Pocket PAL-1 refractometer (Atago Co., Ltd, Japan). Titratable acidity (TA) was analysed in triplicate by the titration of 5 ml of juice diluted with 30 ml of distilled water to pH 8.2 using a Mettler Toledo DL50 autotitrator and Mettler Toledo pH electrode (Mettler Toledo Gmbtt Analytical, Switzerland), with endpoint calculations performed by LabX Pro titration software (Mettler Toledo Gmbtt Analytical, Switzerland). Juice pH values were determined in triplicate using a Metrohm 744 pH meter and Metrohm Solitrode electrode (Metrohm AG, Switzerland). In the second season, grape berry soluble solids content, total acidity, ammonium and alpha amino acids were measured in duplicate, using a FOSS FT2 Winescan (Hillerød, Denmark) to obtain FTIR spectral data. Accurate concentrations were unable to be determined by this method, as the calibrations supplied were not validated at the time of analysis. However, relative concentration differences inferred by the analysis are considered valid.

In the 2009/10 season, measurements were made to compare the openness of bunches. The maximum width and length of each bunch was measured for five bunches from each plot. These values were then used to calculate a theoretical volume of the bunch based on a cone of these dimensions. Each bunch was also weighed before it was suspended in water, to determine the actual volume by displacement. The ratio of actual volume to calculated volume gave an estimation of bunch openness (Shavrukov et al. 2004). Values that approached 1.0 were tight bunches with less space between berries. Bunches with a ratio closer to zero were more open, with more space in them (Shavrukov et al. 2004). These measurements were not repeated in the 2010/2011 season, as only extreme differences in bunch shape could be detected by this method because of variability between bunches from a vine.

Meteorological data and disease risk

Environmental data (surface wetness, temperature and rainfall) were collected for both seasons from the nearby Marlborough Research Centre Blenheim weather station. The weather-related risk of BBR development in each season

was monitored using the early-season botrytis risk model within the Botrytis Decision Support website (www.botrytis.co.nz). The early-season model was run in each season and the prediction of either a minor (<3% severity at harvest) or a major ($\geq 3\%$ severity at harvest) botrytis epidemic was recorded, along with the number of days above the risk threshold.

The first season had a very low *B. cinerea* infection risk because of no wetness periods during the key growth stages (flowering, pre-bunch closure and from véraison to harvest). At the end of March 2010, there was almost no BBR in the trial area. To stimulate *B. cinerea* infection, the whole trial area was subject to 18, 20 and 48 h, respectively, of overhead misting on three occasions in early- to mid-April 2010.

The second season had moderate *B. cinerea* infection risk, with a number of wetness periods during the key growth stages. In anticipation of little BBR development because of dry weather before harvest, the trial area was subject to 40 h of overhead misting on one occasion in March 2011. Misting also occurred from 15 to 16 April 2011 before the harvest disease scoring on 19 April 2011.

Botrytis bunch rot

In 2009/10, assessments were carried out on 13, 16 and 26 April 2010 on 30 bunches per plot by visually assessing BBR incidence (% of bunches infected) and severity (mean of % infected areas of individual bunches). Mean percent severity is the variable used by wineries to determine whether a crop will be accepted, accepted with penalty, or rejected. In the 2010/11 season, BBR harvest assessments were carried out on 19 April 2011 using the same method.

Statistics

Data were analysed using one-way analysis of variance (ANOVA) for a randomised block design, followed by post hoc Dunnett's tests to compare treatments with a control. Before analysis, the disease data were averaged for each plot and then the plot means transformed to equalise variances using either angular (2009/2010) or logit transformations (2010/2011). The bunch

cone volumes and volume ratios were $\log_{10}$ -transformed before analysis. For the 2010/11 trial, the effect of dose of Regalis® Xtra (100, 150 and 200 g/100 litres) at the second application date (12/12/2010; Treatments 4, 5, 6), and the effect of timing of Regalis® Xtra (all three application dates) at a dose of 150 g/100 litres (Treatments 3, 5, 7), were analysed using two contrasts. Because these two contrasts were non-orthogonal, the ANOVA was performed once with each contrast. An additional contrast was used to compare Treatments 2 (old formulation) and 5 (new formulation). Following ANOVA, Dunnett's test at 5% significance was performed twice, firstly to compare all treatments with the no-flowering sprays control (Treatment 1), and secondly to compare all treatments with the standard chemical programme (Treatment 8).

RESULTS

Fruit composition and yield

In the 2009/10 season, significant treatment effects were observed ($P=0.003$, $P<0.001$ and $P=0.005$, respectively) in yield per plot, average bunch weight and soluble solids contents (Table 4). The untreated control (Treatment 1) had average yield of 25.4 kg/plot. Treatments 3, 7 and 9 (GA3, 175 g prohexadione-Ca applied at 50% cap fall and 175 g prohexadione-Ca applied 2 weeks before 50% cap fall) had significantly lower average yields ($P<0.05$) than the control (Table 4). Bunches on control vines (Treatment 1) had the highest average weight (124.4 g each). Average bunch weights that were significantly lighter than those in the control ($P<0.05$) were found only in Treatments 3 and 7 (GA3 and 175 g prohexadione-Ca applied 2 weeks before 50% cap fall; Table 4). Average berry weight for the 50-berry samples was not significantly different between treatments. Soluble solids contents (°Brix) for berries in the GA3 treatment were significantly higher than in the control ($P<0.05$). In the 2010/11 season, there were no significant differences in yield or fruit composition (Table 5). Titratable acidity and pH of the juice were not significantly affected by the treatments ($P>0.05$) in either season.

Table 4 Volume ratio (actual to calculated volume), plot weight (kg), mean bunch weight (g), mean berry weight (g), and juice parameters (soluble solids content (°Brix), pH and titratable acidity (TA)) for nine different botrytis bunch rot treatments applied to Sauvignon blanc grapevines in the 2009/10 season. *Means are significantly different ($P < 0.05$) from the untreated control (Treatment 1) using Dunnett's test following a two-way ANOVA.

Treatment ¹	Volume ratio	Plot weight	Bunch weight	Berry weight	°Brix	pH	TA
1 Untreated control	0.632	25.4	124.4	2.03	22.1	2.9	10.5
2 GA4+GA7 40 ppm	0.548	20.0	107.5	2.06	22.6	3.0	10.4
3 GA3 40 ppm	0.470*	14.8*	83.0*	1.90	23.6*	3.0	10.2
4 Seaweed extract label rate (750 g/ha)	0.612	20.4	111.9	2.08	22.4	3.0	10.6
5 Seaweed extract at 2 x label rate (1500 g/ha)	0.590	20.8	119.8	2.02	22.4	3.0	10.6
6 Prohexadione-Ca 150 g/100 litres	0.607	21.2	114.9	2.04	22.1	3.0	10.5
7 Prohexadione-Ca 175 g/100 litres	0.629	17.9*	106.5	2.08	22.3	3.0	10.5
8 Prohexadione-Ca 175 g/100 litres	0.518	23.2	117.7	2.05	22.1	3.0	10.3
9 Prohexadione-Ca 175 g/100 litres	0.580	18.3*	98.1*	1.98	22.6	3.0	10.3
P-value	0.007	0.003	< 0.001	0.48	0.005	0.49	0.92

¹Treatments 2-7 applied at 50% flowering (19/12/2009), Treatment 8 applied 2 weeks after (1/1/2010) and Treatment 9 two weeks before flowering (5/12/2009)

Table 5 Mean total yield per plot (kg), average bunch weight per plot (g) and average berry weight (g) in Sauvignon blanc grapevines for the 2010/11 season after different botrytis bunch rot treatments. Soluble solids content (°Brix), pH, titratable acidity (TA), Ammonium (ppm) and Alpha –Amino (ppm) determined using a Foss Winescan™. SED = standard error of the difference. No significant differences were detected between treatments.

Treatment ¹	Plot yield	Bunch weight	Berry weight	°Brix	pH	TA (g/litre)	Ammonium	Alpha Amino
1 No flowering sprays	24.0	114.9	2.02	21.8	3.07	10.1	94.8	199.0
2 Prohexadione-Ca+ LI-700®	23.2	111.4	1.86	21.6	3.07	10.1	93.2	185.0
3 Prohexadione Ca new formulation 150 g/100 litres early	21.5	112.2	1.89	21.8	3.08	9.9	95.2	195.0
4 Prohexadione Ca new formulation 100 g/100 litres	21.4	105.9	1.98	22.2	3.05	10.0	85.4	177.8
5 Prohexadione Ca new formulation 150 g/100 litres	25.1	106.2	1.91	21.8	3.04	10.2	90.8	184.6
6 Prohexadione Ca new formulation 200 g/100 litres	23.4	106.5	1.90	21.7	3.05	10.2	91.6	186.4
7 Prohexadione Ca new formulation 150 g/100 litres	21.8	96.7	1.86	22.1	3.06	9.9	82.8	171.0
8 Standard fungicide programme	23.9	114.0	1.90	21.6	3.07	9.8	87.4	177.0
SED	2.88	11.41	0.08	0.44	0.018	0.29	6.878	10.76

¹Treatments 2, 4, 5 & 6 had prohexadione-Ca applied at mid flowering (12/12/2010), Treatment 3 had prohexadione-Ca applied at early flowering (6/12/2010) and Treatment 7 had prohexadione-Ca applied at late flowering (17/12/2010).

Bunch openness

In the 2009/10 season, mean bunch weight was significantly lower for Treatment 3 (GA3) and Treatment 9 (early prohexadione Ca 175 g/100 litres) than Treatment 1 vines (control; Table 4). All other treatments had average bunch weight values that were between those of the control and GA3. The ratio of actual volume to calculated volume was significantly lower for GA3, showing that these bunches were significantly more open than those in the control. No significant differences were detected in the lengths or widths of bunches, or the calculated cone volumes.

Botrytis bunch rot incidence and severity

No significant treatment effects were observed on incidence of BBR in either season (Tables 6 & 7) although there was a trend for higher BBR incidences in 2010/11 than in 2009/10. In 2009/10, all mean percentage severities were lower than the 3% threshold used by many wine companies for imposing penalties. In 2010/11, BBR severity was only greater than 3% in control vines.

DISCUSSION

In the 2009/10 trial significant treatment effects were detected, with a reduction in bunch weight,

Table 6 Mean percentage incidence and severity of botrytis bunch rot at harvest in Sauvignon blanc grapes in the 2009/10 season. Treatment effects were not significant for incidence or severity ($P>0.05$).

Treatment ¹	Incidence (%)	Severity (%)
1 Untreated control	19.4	1.6
2 Novagib [®] GA4+GA7 40 ppm	10.0	0.6
3 Falgro [®] GA3 40 ppm	11.1	1.0
4 Acadian [®] Seaweed extract at label rate	16.7	1.4
5 Acadian [®] Seaweed extract at 2 × label rate	21.1	1.7
6 Prohexadione Ca 150 g/100 litres	16.1	1.3
7 Prohexadione Ca 175 g/100 litres	15.0	0.9
8 Prohexadione Ca 175 g/100 litres	18.3	2.1
9 Prohexadione Ca 175 g/100 litres	10.0	0.5

¹Treatments 2-7 applied 50% flowering (19/12/2009), Treatment 8 (1/1/2010) and Treatment 9 (5/12/2009).

Table 7 Mean percentage incidence and severity of botrytis bunch rot at harvest in Sauvignon blanc grapes in the 2010/11 season. Treatment effects were not significant for incidence or severity ($P>0.05$).

Treatment ¹	Incidence (%)	Severity (%)
1 Untreated control (no flowering sprays)	32.0	3.5
2 Prohexadione Ca 150 g/100 litres with LI-700 [®]	33.3	2.4
3 Prohexadione Ca new formulation 150 g/100 litres	22.0	1.9
4 Prohexadione Ca new formulation 100 g/100 litres	24.7	2.3
5 Prohexadione Ca new formulation 150 g/100 litres	26.7	2.0
6 Prohexadione Ca new formulation 200 g/100 litres	25.3	1.7
7 Prohexadione Ca new formulation 150 g/100 litres (late season)	31.3	2.6
8 Fungicide programme	19.3	1.8

¹Treatments 2, 4, 5 & 6 had prohexadione Ca applied at flowering (12/12/2010), Treatment 3 at early flowering (6/12/2010) and Treatment 7 at late flowering (17/12/2010).

plot yield and an increase in bunch openness as well as soluble solids content with the GA3 40 ppm with LI-700 (0.1%) treatment compared with the untreated control. The early and mid flowering applications of prohexadione-Ca 175 g/100 litres also reduced plot and bunch yield (Treatment 9) and bunch weight (Treatment 7), respectively, compared with the control. However, these changes in bunch openness, yield and composition were not associated with significantly less botrytis bunch rot. Nevertheless, some consistent treatment trends were observed. In the first season, Treatment 3 (GA3 40 ppm with 100 ml/100 litres LI-700) caused significant reduction in bunch weight and increase in openness compared with the untreated control. Similar experiments conducted in Gisborne in 2009 indicated that the label rate was too low to change bunch architecture under New Zealand conditions, but that rates higher than label rate (10 ppm) might result in decreased flowering in grapes in the following season (T. Lupton, Lewis Wright Valuation and Consultancy, personal communication). Thus, the high rates of GA3 used in this trial carried the risk of reduced return bloom in the following season, which was observed with a significant reduction of 40% in flower clusters in 2010 compared with the control (Mundy et al. 2011). The degree of yield reduction (equivalent to 5.1 tonnes/ha) resulting from that treatment within the season and the 40% reduction of flowering in the following season would not be acceptable to growers. GA3 produced a significant effect that could be measured regardless of the within-vine variability observed during the experiment. The GA3 treatment was an extreme treatment designed to open bunches. This treatment did produce bunches that were significantly more open even when large bunch-to-bunch variation was observed within the same vine. One possible reason for the variation observed in Sauvignon blanc bunch shape under Marlborough conditions is the variability of timing of flowering. Even within an individual vine, shoots at the ends of the cane will be more advanced in percentage cap fall than shoots near the crown at any stage of flowering (Trought et al. 2011). The

timing and concentration of GA3 application have been seen to affect BBR and cluster openness for Seibel 5455 under New Zealand conditions (Hopping 1976). Observed changes in the bunch for prohexadione-Ca have also been reported to depend on timing, with decreased fruit set pre bloom and decreased berry weight post bloom (Giudice et al. 2004). In the present experiments, individual bunches within the vine may have been at different relative stages of development as a result of node position and hence different responses within a single treated vine. To compare the detailed effects of a compound in field experiments, tagged shoots at the same node position may be needed.

The higher total soluble solids contents of fruit following GA3 treatment in 2009/2010 are likely to be the result of the lower total yield per vine. This treatment had the lowest volume ratio and lowest incidence and severity of BBR, consistent with the general view that more open bunches have less disease pressure. However, at the low disease incidence and severity observed during the experiment, no significant differences in BBR were found between treatments. This is consistent with reports of GA3 applied to Pinot gris, Pinot blanc and Pinot noir in Luxemburg having no significant control of BBR until combined with leaf removal or botryticides (Evers et al. 2010). While GA3 produced the most marked changes to bunch openness, many of the other treatments, produced results intermediate between those of the control and GA3. While the use of these other treatments may offer some possibility of altering bunch openness without the marked yield reduction associated with GA3, the effects of such bunch changes on botrytis incidence or severity can be expected to be small. Bunch shape was only significantly affected in one of the three years that prohexadione-Ca was applied to Riesling (Baus et al. 2011). Prohexadione-Ca applied to Pinot meunier, Pinot blanc and Pinot noir was effective, but results varied greatly for Rhine-Riesling (Bleyer & Kast 2011). Prohexadione-Ca applied at or around bloom reduced BBR when these treatments were used in combination with fungicides and leaf removal (Baus et al. 2011). When gibberellic acid

was applied with trash removal, a slight synergic effect was observed in Pinot gris (Bigot et al. 2008). Treatment 9 (prohexadione-Ca 2 weeks before 50% flowering) in 2009/10 and Treatment 7 (prohexadione-Ca applied at 50% flowering) used in the present experiments may also be effective for BBR control under conditions similar to those reported, as part of a combined management system. The prohexadione-Ca treatment results also suggest that there were fewer berries per plot at harvest, possibly because of a thinning effect of the product. Yield reduction has previously been reported with prohexadione-Ca at bloom (Bleyer & Kast 2011). For red varieties, a post-bloom application of prohexadione-Ca reduced berry size, with positive effects on fruit composition (Giudice et al. 2004). However, no positive or negative effects for the white variety used in the present study were observed. As growers currently pay to reduce yield by hand thinning, a means to reduce potential crop at flowering may be useful and more cost effective than hand thinning later in the season.

Bunch openness is only one factor to be considered when assessing the risk of a bunch becoming infected. Bunch trash and individual berry susceptibility due to skin thickness or chemical protection also need to be considered. Changes in bunch openness have been reported to decrease BBR when combined with manipulations of these other factors by removing trash (Bigot et al. 2008) or removal of leaves and/or applying botryticides (Evers et al. 2010; Baus et al. 2011). Therefore in the 2010/11 season the use of prohexadione-Ca was investigated as part of an integrated control programme with a biological control agent late in the season and compared with a standard fungicide programme.

In the 2010/11 season, BBR incidence was >20%, indicating that a substantial disease pressure was present in the experimental block. However, the untreated control (Treatment 1) did not have significantly more disease than any of the other treatments, including the standard chemical control programme. As all the treatments received two Serenade® MAX applications late in the season and most received

three, this may have reduced the expression of BBR late in the season, reducing the spread within the bunch that can lead to increasing severity once a bunch is infected.

Seaweed extract was used in the experiments because organic growers are not permitted to use GA or GA inhibitors. The product has been promoted as increasing rachis length and stimulating general growth and, although the product information does not directly describe a mode of action, some possibilities are suggested (Holden et al. 2008). In the experiment on Pinot noir vines in California, a whole-season application of the seaweed product reduced shatter of bunches as well as lengthening the rachis (Holden et al. 2008), which may have reduced bunch openness. The application at double the recommended rate (750 g/ha) was included in the present experiment because the label suggested more than one application might be needed. As neither of the rates of seaweed extract increased the bunch weights of the treated vines, and berry weights were not significantly different between these treatments, no reduction in shatter can be inferred in this experiment. Berry weights and bunch weights observed were similar to those recorded in other experiments conducted in Marlborough on Sauvignon blanc vines (Trought et al. 2011). Under the current experimental conditions the product was not effective, even at the high rate. However, the high vigour conventional vineyard selected might have influenced its efficacy, so further investigation at an organic site with lower vigour might be warranted.

The lack of significant differences in juice composition with the different timings and rates of Regalis® Xtra (equivalent to prohexadione-Ca but without an adjuvant/acidifier) can be seen as a positive outcome, as it indicates that the use of this product is not likely to result in changes in juice composition, which would be perceived negatively by winemakers.

When the early-season botrytis risk model from the Botrytis Decision Support website (www.botrytis.co.nz) was run for both seasons, it identified the likelihood of minor (<3% severity at harvest) botrytis epidemics. Therefore there was low risk of botrytis infection from flowering

to véraison in both seasons. The low BBR risk reported here is consistent with those from other trials in Marlborough with low harvest severity following one or more management applications preharvest (Beresford et al. 2006). The effectiveness of changing bunch openness on disease risk may have to be determined in another region with greater risk of BBR severity at harvest.

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