Research Note: Benefits and Drawbacks of Pre-bloom Applications of Gibberellic Acid (GA3) for Stem Elongation in Sauvignon blanc

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Dense grape clusters have a high predisposition to bunch rot. An elongation of cluster stems could result in a loosening of the cluster structure. To achieve such an elongation, gibberellic acid (GA3; 10 ppm) was applied to Sauvignon blanc either when three, five, seven, nine, 11 or 13 leaves were unfolded or at full bloom in the 2010 season. In the present season, all applications led to stem elongation, a reduction of cluster compactness as well as a reduction of bunch rot severity. The density index proved to be an efficient tool to describe the predisposition of grape clusters to bunch rot. Best success was achieved if the application took place when seven leaves were unfolded. In the subsequent season (2011; the year following the year of application), the number of inflorescences per shoot, the length of the clusters, as well as the yield were considerably reduced, especially in the treatments with promising positive effects on the cluster structure and disease severity. Hence, the present study shows the loosening potential as well as the risk of pre-bloom gibberellic acid applications. Due to the observed negative resultant effects, the pre-bloom application of GA3 at the present concentration (10 ppm) cannot yet be recommended for practical use in Sauvignon blanc.

INTRODUCTION

Grey mould or bunch rot caused by *Botrytis cinerea* is one of the most important diseases of grapevine (*Vitis* spp.) worldwide. Attacks can reduce grape yield, as well as wine quality, by causing off-flavours, unstable colour, oxidative damage, premature ageing and difficulties in clarification (Ribereau-Gayon, 1983; Smart & Robinson, 1991). Furthermore, berries infected by *B. cinerea* can readily be invaded by other fungi, such as *Penicillium expansum,* which further favours the risk of off-flavour development (Smart & Robinson, 1991; La Guerche *et al*., 2005).

The susceptibility of grapes to bunch rot is strongly influenced by the cluster structure (Vail & Marois, 1991; Hed *et al*., 2009). The reasons for the higher predisposition to fungal infections of dense clusters are the unfavourable microclimatic conditions in the interior parts (Vail & Marois, 1991) and the lower fungicide spray coverage of individual berries (Hed *et al*., 2011). Furthermore, berries in the interior parts of tight clusters often split (Smart & Robinson, 1991) under the increasing mechanical pressure caused by berries expanding after véraison, and these can easily be colonised by fungal pathogens. Consequently, practices that loosen the cluster structure could represent effective tools in integrated bunch rot protection programmes (Hed *et al*., 2009).

One approach to loosen cluster structure is to reduce the number and/or size of the berries. This can be induced by cultural practices such as leaf removal in the cluster zone in the period around bloom, leading to a deficit of assimilates for pollination and cell division processes (Ollat & Gaudillere, 1998; Intrieri *et al*., 2008; Tardaguila *et al*., 2008; Molitor *et al*., 2011a). Another possibility to induce loose clusters is the use of bioregulators, such as prohexadione-Ca (Molitor *et al*., 2011b; Lo Giudice *et al*., 2003) or gibberellic acid (Hed *et al*.. 2011; Evers *et al*., 2010). As early as 1962, Weaver *et al*. (1962) reported on studies using gibberellin on grapes to decrease bunch rot. Gibberellic acid is a plant hormone that occurs naturally in plants, where it regulates different metabolic processes. Meanwhile, many different gibberellins have been isolated and characterised (Tudzynski, 1999). In viticulture, mainly gibberellic acid GA3 is used as a plant growth regulator. GA3 is involved in cell division and enlargement during the development of grape berries (Ungsa *et al*., 2008). It has been used extensively for stem elongation in seedless table grape production and, more recently, its use in wine grape production has gained increased attention (Evers *et al*., 2010). Depending on the application time and dose, the developmental stage of the plant as well as the environmental conditions during application, the resulting effects of gibberellic acid applications can be very different (Weaver, 1975).

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In practical viticulture, the use of gibberellic acid is limited to a few varieties, in which it is aimed at a reduction in the number of berries per cluster; in this case, the recommended application date is at full bloom. However, Weaver (1975) found that pre-bloom applications of potassium gibberellate can lead to increased cluster lengths, inducing looser cluster structures and thus a lower predisposition to bunch rot. In the meantime, the potential of cluster stem elongation due to pre-bloom gibberellic acid applications has been confirmed in different countries (Cahoon & Scurlock, 1992; Nagao *et al*., 1997; Bugaret *et al*., 2006; Spies & Hill, 2008). However, the effects fluctuated, depending on the year, the variety and the application dose or time. To the best of our knowledge, examinations comparing the effects of different pre-bloom gibberellic acid application dates are lacking so far.

Even though Spies and Hill (2008) assume that pre-bloom gibberellic acid applications should be less hazardous than bloom applications (as described by Weyand and Schultz (2005)), precise examinations of the percentage of bud burst, the number of inflorescences per shoot and the yield in the subsequent season have not yet been published.

Thus, in the present study, the effects of pre-bloom applications of gibberellic acid (GA3) at different time points (between bud burst and full bloom) on (i) the cluster structure, (ii) the health status of the grape, (iii) the harvest parameters, and (iv) the consequences in the subsequent season were investigated.

MATERIALS AND METHODS

Studies were conducted in 2010 (season of application) and 2011 at the experimental vineyard of the Institut Viti-Vinicole in Remich/Luxembourg (49.54 N, 6.35 E) in the Moselle valley on the white *Vitis vinifera* L. variety Sauvignon blanc. The average annual temperatures in Remich reached 10.0°C in 2010 and 11.3°C in 2011, with total yearly precipitation of 695 mm (2010) and 533 mm (2011). The experimental vineyard, on a keuper soil, was planted in 2000, and the vines were grafted onto SO4 rootstock and trained to a vertical shoot positioning system with one cane per vine.

Experiments were realised using a randomised block design, consisting of four replicates and eight plants per plot. Applications of gibberellic acid GA3 (commercial product: Gibb3®; supplier: Globachem nv, Sint-Trudien, Belgium; application dose: 10 ppm active ingredient) took place when three, five, seven, nine, 11 or 13 leaves were unfolded or at full bloom (hereafter referred to as L3, L5, L7, L9, L11, L13, FB; phenological stages BBCH 13, BBCH 15, BBCH 17, BBCH 19, BBCH 55, BBCH 57, BBCH 65 (Lorenz *et al*., 1995); application dates: 2010-05-10, 2010-05-25, 2010-06-01, 2010-06-08, 2010-06-11, 2010-06-15, 2010-06-25) using a backpack sprayer until run-off (approximately 200 ml per plant). Control (C) plots remained untreated. Background coverage applications against *Plasmopara viticola* and *Erysiphe necator* were carried out throughout both seasons. No fungicides with activity against *B. cinerea* were applied. Cultural management was done in the same way in all treatments.

The length of the clusters was determined by ruler two times, at BBCH stages 71 and 79 (Lorenz *et al*., 1995) (a) in the season of the GA3 application (2010-06-29, 2010-08-10), as well as (b) in the subsequent season (2011-06-08, 2011-07-27), on 30 randomly chosen clusters per plot. Cluster structure was assessed using the density index according to the guideline of Ipach *et al*. (2005) prior to véraison in both years (BBCH 79; 2010-08-11, 2011-07-20), as previously described (Evers *et al*., 2010; Molitor *et al*., 2011b). Close to harvest (BBCH 89; 2010-09-28, 2011-09-13), the severity of bunch rot disease was assessed according to EPPO (European and Mediterranean Plant Protection Organization) guideline PP1/17 (Evers *et al*., 2010; Molitor *et al*., 2011b). The yield and sugar content of the clusters were determined at BBCH 89 (2010-09-29 and 2011-09-15), as previously reported (Molitor *et al*., 2011a). At BBCH 55 (2011-05-16), the percentage of bud burst as well as the number of inflorescences per shoot were determined on each shoot on five randomly chosen canes per plot.

Data were analysed by one-way ANOVA. For multiple comparison procedures between means, Tukey tests (α = 5%) were performed.

RESULTS AND DISCUSSION

Season of application

All GA3 treatments led to an elongation of the cluster stems directly after bloom (BBCH 71), as well as at the end of bunch closure (BBCH 79). At both assessment dates, the elongation was statistically significant compared to the control if the application took place in the period between L3 and L7. Indeed, clusters treated between L3 and L7 were around 28% (at BBCH 71) or 17 to 19% (at BBCH 79) longer than the control clusters, although without any significant differences between those three treatments (Table 1). Similar stem elongation rates were also observed for the same variety by Bugaret *et al*. (2006) and Spies and Hill (2008).

In the present study, all treatments led to a significant reduction of the cluster compactness (expressed as density index) compared to the untreated control (Table 1; Figure 1).

The loosest clusters were observed in the treatment L7. Two effects might have caused this loosening of the cluster structure: (a) an elongation of the stems and (b) a reduction of the number of berries. We suppose that, in case of the early applications, the elongation had the most important effect on the structure, whereas at the later applications dates, the reduction in the numbers of berries might have been of major importance. A looser structure generally leads to increased airflow and better sun exposure of the interior parts of the clusters and, consequently, to less favourable conditions for the establishment of fungal pathogens (Zoecklein *et al*., 1992). In this context, the disease severity of *B. cinerea* close to harvest was reduced in all treatments with an application of gibberellic acid. The reduction was statistically significant for the treatments L5, L7, L9 and FB. In the most efficient treatment, L7, the disease severity was reduced by 74% in comparison to the untreated control (Table 1). Spies and Hill (2008) reached a comparable efficiency level of around 62% in their trials with pre-bloom gibberellic acid applications in the variety Sauvignon blanc.

The strong and highly significant linear correlation (R^2 = 0.95, $p > 0.0001$) between the value of the density index and the disease severity shows that the density index developed by Ipach *et al*. (2005) represents an excellent tool to describe

TABLE 1
Cluster length at BBCH 71 and 79 (Lorenz *et al*., 1995), density index, disease severity of *Botrytis cinerea*, sugar content and yield observed in the year of GA3 application (2010). Treatments not marked with the same letter differ significantly according to the Tukey test (α = 5%).

Treatment	Cluster length (cm)		Density index	Disease severity (%)	Sugar content (°Brix)	Yield (kg * plant^{-1})
	BBCH 71	BBCH 79				
C	10.4 a	12.5 a	3.84 a	28.9 a	19.0 a	2.61 a
L3	13.4 c	14.6 bc	3.01 b	17.3 abc	19.1 a	3.34 a
L5	13.3 c	14.7 bc	2.58 bc	11.7 bc	19.3 a	3.39 a
L7	13.3 c	14.9 c	2.21 c	7.6 c	19.9 a	2.33 a
L9	11.6 ab	13.6 ab	2.94 b	15.6 bc	19.4 a	2.98 a
L11	11.8 b	13.1 a	2.78 bc	17.4 abc	19.4 a	2.81 a
L13	10.9 ab	12.9 a	3.07 b	20.8 ab	18.8 a	2.98 a
FB	10.9 ab	13.0 a	2.72 bc	15.0 bc	19.8 a	2.68 a

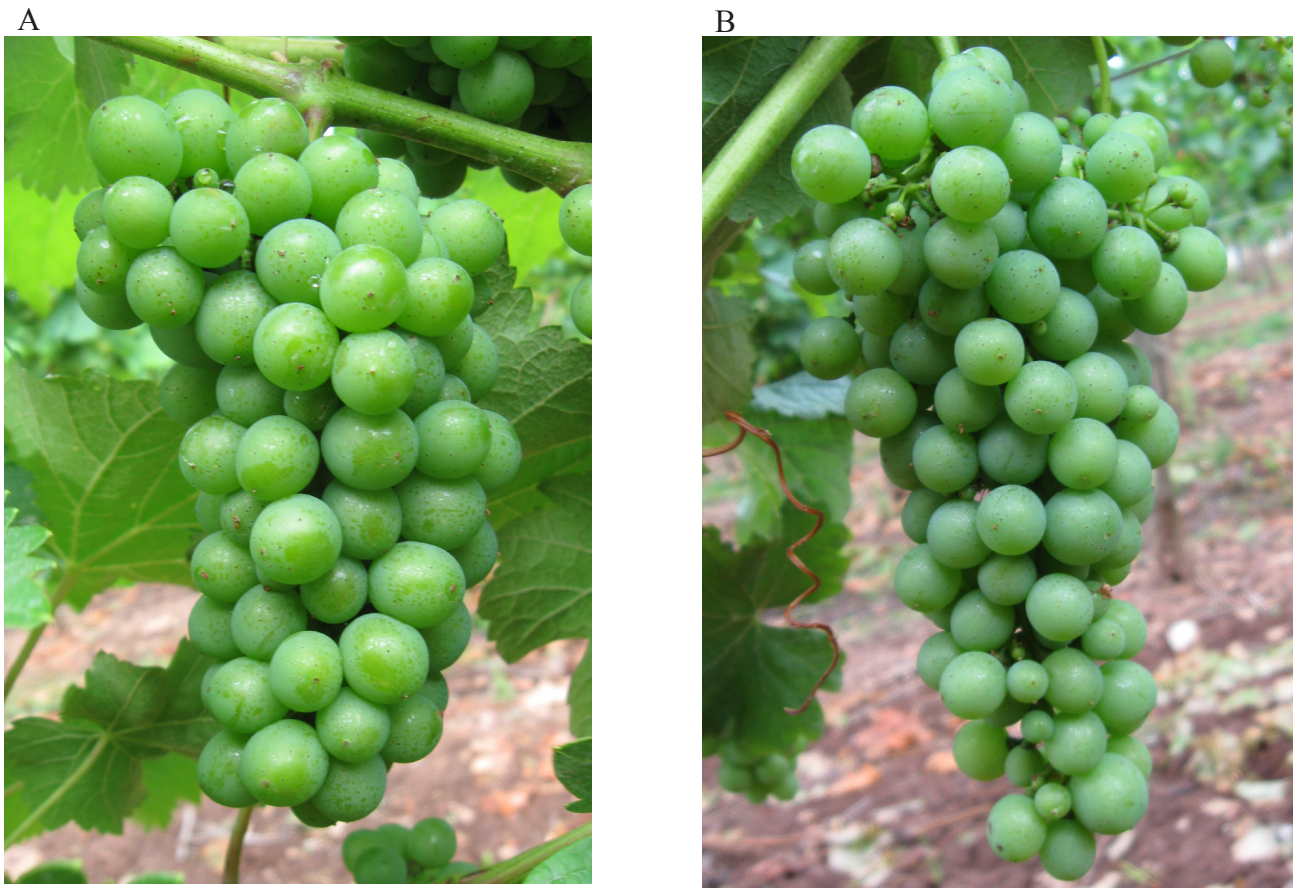

FIGURE 1
Cluster in the untreated control (A) and in the treatment L5 (application of GA3 when five leaves were unfolded) (B), in the year of application at BBCH 79.

the structure of the clusters and their predisposition to bunch rot (Figure 2).

No significant effects on the yield or the sugar content were observed in any treatment (Table 1). Obviously, the elongation of cluster stems did not have a significant impact on cluster weight.

Subsequent season

In the subsequent season (2011; the year following the year of application), no significant effects on bud burst were observed in any treatment. However, the treatment L7 significantly reduced the number of inflorescences per shoot, by 23% compared to the untreated control.

The number of inflorescences per shoot for the subsequent season is already defined in the previous season, when undifferentiated primordials differentiate either to inflorescences or tendrils (Currle *et al*., 1983). This process is supposed to start as early as five to seven weeks after bud burst, and the maximum number of inflorescences for the subsequent season is already determined between the

middle of July and August (northern hemisphere) (Currle *et al*., 1983). We assume that the application of gibberellic acid in this period had a direct or indirect influence on those differentiation processes favouring the development of a higher number of tendrils and a lower number of inflorescences.

Besides the reduction of the inflorescences, the cluster length in all the GA3 treatments was lower than in the untreated control. The reduction was statistically significant for the treatments L5, L7, L9 and L11, and reached up to 32% (assessment at BBCH 71) or 30% (assessment at BBCH 79) in treatment L7 (Table 2). Besides for the number of inflorescences, the size of the inflorescences is also determined in the previous season (Currle *et al*., 1983). Apparently, pre-bloom application of gibberellic acid also had an impact on the processes determining the inflorescence size.

The density index describing the cluster structure was not significantly influenced by any of the treatments compared to the untreated control (Table 2). This indicates that the number of berries relative to the cluster length was not influenced in those treatments in the year after the application. However, the reduced number of single flowers per inflorescence (due to shorter cluster lengths) in the treated variants further had a considerable effect on the yield. In all the GA3 treatments, the yield was reduced by at least one third compared to the control. The yield reductions compared to the control were statistically significant for the applications L7 and L11, and reached up to 73% (Table 2).

Negative effects on the yield in the subsequent season of GA3 applications at bloom have been described by Weyand and Schultz (2005). However, Spies and Hill (2008) assumed that an application of gibberellic acid in the pre-bloom period would exhibit a lower risk of negative effects in the subsequent season than bloom applications. The data presented here do not confirm this hypothesis – at least not for the variety Sauvignon blanc. However, Sauvignon blanc generally seems to be a variety with a pronounced susceptibility to gibberellic acid applications (Bugaret *et al*., 2006; Spies & Hill, 2008).

It is important to mention that the results presented here might have been impacted by specific weather conditions in the respective seasons. Furthermore, other varieties or grapes grown under different conditions may behave differently. Consequently, further research will be necessary regarding reproducibility, application dose, impact of weather conditions and variety effects. However, so far, pre-bloom applications of GA3 at the present concentration (10 ppm) cannot be recommended for practical use in the variety Sauvignon blanc.

CONCLUSIONS

Under the conditions in the 2010 season, pre-bloom applications of gibberellic acid GA3 (10 ppm) enabled the elongation of cluster stems, the loosening of the cluster structure and a reduction in predisposition to severe grey mould disease in the variety Sauvignon blanc. The greatest success was achieved if the application took place when seven leaves were unfolded. In general, a strong correlation was observed between the density index and disease severity, indicating that the density index is a good indicator of predisposition to bunch rot. However, especially in the treatments with promising positive effects on cluster structure and disease severity, the number of inflorescences, the length of the cluster stems and the yield were considerably reduced in the subsequent season. Consequently, pre-bloom application of GA3 at the present concentration (10 ppm) cannot yet be recommended for practical use in Sauvignon blanc.

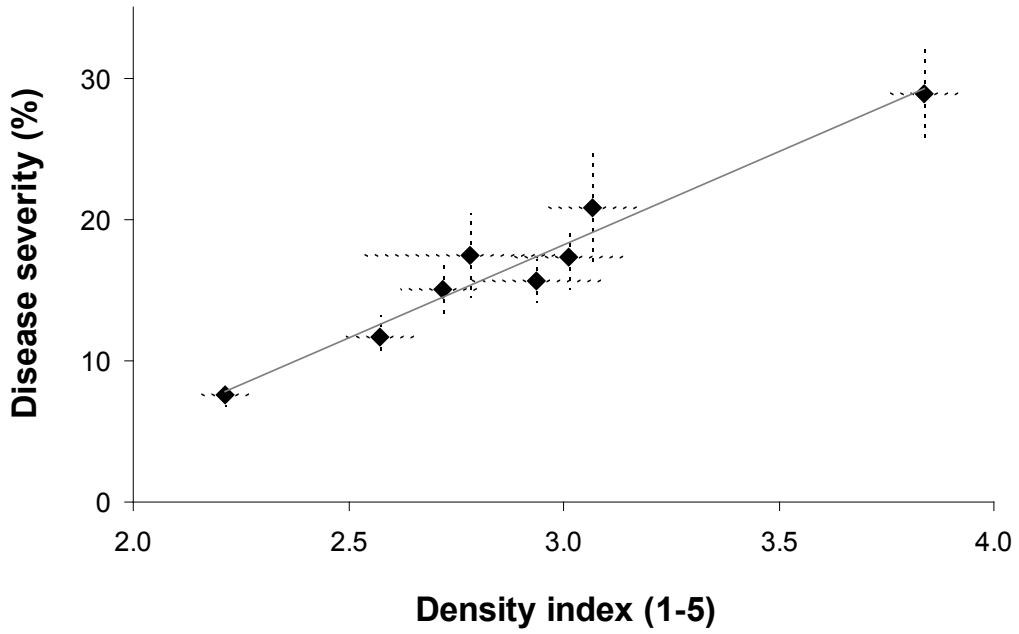

FIGURE 2
Disease severity of *Botrytis cinerea* plotted against the density index in the year of application (2010). Error bars = standard error. R2 = 0.95, $p < 0.0001$.

TABLE 2
Bud burst, number of inflorescences per shoot, cluster length at BBCH 71 and 79, density index, disease severity of *Botrytis cinerea*, sugar content and yield observed in the year after the application (2011). Treatments not marked with the same letter differ significantly according to the Tukey test (α = 5%).

Treatment	Bud burst (%)	Inflorescences per shoot	Cluster length (cm)		Density index	Disease severity (%)	Sugar content (°Brix)	Yield (kg * plant^{-1})
			BBCH 71	BBCH 79				
C	91.5 a	1.88 ab	12.1 a	13.8 a	2.77 a	14.8 a	19.4 a	3.7 a
L3	85.2 a	1.89 a	11.0 abc	12.6 abc	2.72 a	15.1 a	19.8 ab	2.5 ab
L5	91.0 a	1.94 a	9.8 cd	11.6 bc	2.49 a	7.7 a	20.3 b	2.1 ab
L7	89.3 a	1.45 c	8.2 d	9.7 d	2.45 a	5.3 a	20.2 b	1.0 b
L9	88.9 a	1.66 abc	10.3 bc	11.8 bc	2.67 a	12.5 a	19.3 a	2.1 ab
L11	89.5 a	1.45 bc	9.3 cd	11.0 cd	2.62 a	8.6 a	19.6 a	1.5 b
L13	88.5 a	1.61 abc	11.0 abc	12.9 ab	2.73 a	13.3 a	19.7 ab	2.5 ab
FB	86.7 a	1.69 abc	11.6 ab	13.1 ab	2.83 a	15.8 a	19.4 a	2.5 ab

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