EFFICIENCY OF DIFFERENT STRATEGIES FOR THE CONTROL OF GREY MOLD ON GRAPES INCLUDING GIBBERELLIC ACID (GIBB3), LEAF REMOVAL AND/OR BOTRYCIDE TREATMENTS

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Abstract

Aim : The present work evaluated different strategies for the control of grey mold, caused by *Botrytis cinerea*, on wine grapes, including the use of the plant growth regulator Gibb3, leaf removal and/or botryticide treatments. The efficiency of the different control strategies (disease incidence and severity, yield) as well as the effect on the cluster structure was investigated.

Methods and results : The trials were conducted in commercial vineyards in the Moselle Valley (Luxembourg) between the years 2007 and 2009, on the Pinot gris, Pinot blanc and Pinot noir grape varieties. The untreated control (T1) was compared to the following treatments : (T2) Gibb3, (T3) Gibb3 combined with leaf removal in the cluster zone after bloom, (T4) leaf removal after bloom combined with two times botryticides and (T5) Gibb3 combined with two times botryticides. The combination of Gibb3 with leaf removal or botryticide applications led to an efficiency level in grey mold reduction of around 60% and a decrease in cluster density when compared to the control. Moreover, we showed that the progression of grey mold disease was slowed down by the three treatments T3, T4 and T5.

Conclusions : Gibberellic acid applied at full bloom as stand-alone treatment did not reduce in a significant way the compactness of the grape clusters and the impact on grey mold development was low. For a significant decrease of disease severity, gibberellic acid had to be combined with an additional measure, such as leaf removal or the use of botryticides. Based on its positive effect on cluster structure and microclimate, leaf removal can be recommended as a basic measure that can be further combined with an application of botryticides or gibberellic acid.

Significance and impact of the study : All the tested strategies combining two measures have shown their potential to prolong the ripening period and therewith to improve wine quality. Moreover, the combined use of gibberellic acid and leaf removal represents a sustainable strategy for integrated viticulture due to its reduced input of organic-synthetic pesticides into the environment.

Key words : Bunch rot, botryticides, *Botrytis cinerea*, gibberellic acid, leaf removal, plant growth regulator, *Vitis vinifera*

Résumé

Objectif : Le présent travail a évalué au vignoble plusieurs stratégies de contrôle de la pourriture grise, causée par *Botrytis cinerea* : application du régulateur de croissance Gibb3, effeuillage et/ou application de traitements botryticides. L'efficacité de ces différentes stratégies (fréquence et intensité d'attaque, rendement) ainsi que leurs effets sur la structure de la grappe ont été étudiés.

Méthodes et résultats : Les essais ont été menés dans des vignobles commerciaux de la vallée de la Moselle au Luxembourg entre 2007 et 2009. Le témoin non traité (T1) a été comparé aux modalités suivantes : (T2) Gibb3, (T3) Gibb3 et effeuillage de la zone des grappes après floraison, (T4) effeuillage après floraison avec deux traitements botryticides et (T5) Gibb3 combiné avec deux traitements botryticides. Les combinaisons Gibb3 avec effeuillage ou deux traitements botryticides conduisent à une réduction de 60 % de l'attaque de *Botrytis cinerea* en moyenne et à des grappes plus lâches par rapport au témoin non traité. De plus, les modalités T3, T4 et T5 ralentissent la progression de la pourriture grise.

Conclusions : L'acide gibbérellique appliqué à la pleine floraison comme unique traitement ne change pas significativement la structure des grappes et son influence sur le développement de la pourriture grise est faible. Afin d'obtenir une baisse significative de la sévérité de la maladie, l'acide gibbérellique doit être combiné avec une autre mesure, comme un effeuillage ou l'application de botryticides. En raison de son effet positif sur la structure et le microclimat de la grappe, l'effeuillage peut être recommandé comme une mesure de base, mesure à laquelle on peut ajouter une application de botryticide ou d'acide gibbérellique.

Signification et impact de l'étude : Toutes les stratégies combinant deux mesures ont montré leurs potentiels de prolongation de la période de maturation et par conséquent l'augmentation de la qualité du vin. De plus, l'utilisation de l'acide gibbérellique combinée à un effeuillage représente une stratégie durable en viticulture intégrée, en raison d'une utilisation moindre de pesticides organiques de synthèse.

Mots-clés : Pourriture de la grappe, botryticides, *Botrytis cinerea*, acide gibbérellique, effeuillage, régulateur de croissance, *Vitis vinifera*

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INTRODUCTION

Botrytis cinerea, the causal agent of grey mold or bunch rot disease, causes important economic damages in vineyards worldwide (Elmer and Reglinski, 2006) by reducing the production yield. It can also affect grape quality as even slight contamination can result in wines with tainted flavors and higher sensitivity to oxidation (Jacometti *et al.*, 2007). Especially if the fungal pathogens *B. cinerea* and *Penicillium expansum* both occur at the same time, earthy-moldy off-flavors in the wine can be the result (La Guerche *et al.*, 2005).

As for its ecological requirements, *B. cinerea* favors temperate climate and moist environments for its development. Moreover, the severity of the disease increases in years with late-season rain events (Gubler, 1987). The infection is also influenced by the microclimatic conditions within the vine canopy and grape cluster (Savage and Sall, 1984), which is why bunch rot problems predominantly occur in varieties with dense canopies and tight berry clusters (Gubler, 1987). Moreover, in tight clusters, berries might burst and become more susceptible to fungal diseases.

B. cinerea is an important pre-harvest but also post-harvest disease, e.g. in table grape cultivation (Gabler *et al.*, 2003). The pre-harvest control of *B. cinerea* is essentially done by the use of organic-synthetic chemicals and cultural practices, such as rootstock selection, appropriate trellising system, vigor-adapted fertilization and canopy management (Jacometti *et al.*, 2007). In organic viticulture, there are few options for pathogen control, which is mainly dependent on cultivar resistance, canopy management and the application of natural products (Elmer and Reglinski, 2006). Investigations have shown that plant defense elicitors, which stimulate the natural plant response and induce protection, have the potential to be used as alternative control strategies. As an example, Aziz *et al.* (2003) have reported about the elicitation of defense responses and the induction of protection against *B. cinerea* and *Plasmopara viticola* on grapevine cell suspensions and detached leaves using laminarin. Most of the reported studies on plant defense elicitors still need to be validated in greenhouse and field conditions (Aziz *et al.*, 2004; Bru *et al.*, 2006; Iriti *et al.*, 2004). Nevertheless, they should be an interesting alternative to environmentally undesirable chemical control.

Already in 1962, Weaver *et al.* (1962) have reported about the use of gibberellin on wine grapes to decrease bunch rot. Many different gibberellins have been isolated and characterized (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 extensively used in seedless table grape production and more recently, its use in wine grape production has gained increased attention. However, depending on the application time and dose, the developmental stage of the plant, as well as on the environmental conditions during application, the results can be very different. For example, an application before bloom affects the extension of grape bunches, whereas an application during the flowering period leads to a dilution of the grape cluster structure (Korkutal *et al.*, 2008). Untimely use or over dosage might negatively affect the crop the year of treatment and decrease the bud burst and the number of grapes per shoot in the following season (Weyand and Schultz, 2005). These subsequent negative effects of gibberellic acid are dependent on the grape variety and this is the reason why the application of Gibb3 is only recommended for a defined group of varieties.

Because gibberellic acids are phytohormones naturally occurring in grapes, they are supposed to be less harmful to the environment than organic-synthetic fungicides. Thus, the use of gibberellic acid could probably lead to a reduced application of pesticides without negatively influencing the health state and the quality of the grapes. The reasons for reducing the use of fungicides are the global market demand for sustainable products (Spadaro and Gullino, 2005) and the avoidance of *B. cinerea* strains resistant to pesticides, as recently described for fenhexamid, one of the botryticides of the newest generation, in French and German vineyards (Fillinger *et al.*, 2008).

As previously mentioned, the canopy structure and microclimate is important for the development of bunch rot. In dense vine canopies, the environment is very favorable to the development of fungal pathogens due to reduced light quantity and quality, low wind speeds, high humidity and lower evaporation rates (Zoecklein *et al.*, 1992). Indeed, prolonged periods of cluster wetness favor successful conidia germination and infection through the cuticular membrane (Savage and Sall, 1984). Defoliation of the cluster-zone close to bloom has been shown to reduce bunch rot under different climatic conditions (Intrieri *et al.*, 2008; Ollat and Gaudillere, 1998) mainly due to better sun and wind exposure and looser cluster structure. Furthermore, the described strengthening of the berry cuticle due to leaf removal may induce a lower infection rate, and consequently a lower disease level (Percival *et al.*, 1993). Due to the combination of these positive effects, leaf removal has turned out to be an interesting option for bunch rot management.

The objective of this study was to compare the influence of different grey mold protection strategies including gibberellic acid, leaf removal and/or botryticides

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on the cluster structure, harvest-parameters like sugar content and yield, and finally on the grey mold infection level and the development of *B. cinerea* epidemics.

MATERIALS AND METHODS

1. Vineyard sites and experimental design

The study was conducted between the years 2007 and 2009 in private vineyards located between Remich and Machtum along the Moselle River in Luxembourg. The experiments were carried out on three *Vitis vinifera* L. varieties: Pinot noir (PN, planted in 2001, soil: keuper, rootstock: SO4, clone: 115/113), Pinot gris (PG planted in 1980, soil: loamy clay, rootstock: SO4, clone: Colmar 52) and Pinot blanc (PB planted in 2001, soil: keuper, rootstock: SO4, clone: Dreher 209). The vineyards were all trained to a vertical shoot positioning and southeast exposed with a slope of around 30%. The plantation density was between 1.8 (PG) and 2.2 (PN, PB) m^2 per plant. Pesticide applications against *Plasmopara viticola* and *Erysiphe necator* were carried out by helicopter and application gears driven by tractors as a background coverage and were identical in all treatments. Pruning as well as canopy and soil management work was done by the farmers.

Experiment-specific treatments were arranged in a randomized block design, consisting of 4 replicates of 10-12 vines (hereafter referred to as plot) per treatment (except for Pinot noir 2007: 6 replicates and Pinot blanc 2007: 2 replicates). The treatments (table 1) are defined as follows: T1 control (no treatment), T2 Gibb3 (Globachem, Belgium) (gibberellic acid Gibb3 at full bloom, BBCH 65 (Lorenz *et al.*, 1995)), T3 Gibb3 + leaf removal (gibberellic acid Gibb3 at full bloom, BBCH 65; leaf removal after bloom, BBCH 71), T4 leaf removal + botryticides (leaf removal after bloom, BBCH 71; 2*botryticides (teldor (Bayer Crop Science, Germany) at BBCH 77 and cantus (BASF, Germany) at BBCH 81), T5 Gibb3 + 2*botryticides (as previous). Gibb3 treatments were conducted in the early morning hours at high relative humidity. All experiment-specific applications (botryticides as well as Gibb3) were carried out manually with a backpack sprayer. The amounts of water used were 800 l/ha for Gibb3 and 400 l/ha for botryticides. The application dose of Gibb3 was 160 g/ha as recommended by the manufacturer. Leaf removal consisted in manually removing leaves in the cluster zone on the north or east exposed sides of each row after flowering at fruit set (BBCH 71).

2. Determination of *Botrytis cinerea* infection level

The disease incidence and severity were assessed at several time-points during the ripening period by examining 100 randomly selected clusters per plot (50 on each side of the row). The experiments were performed according to the EPPO guideline PP1/17(3).

3. Determination of the cluster structure

The impact of the different treatments on the cluster structure was evaluated in 2008 and 2009. The « density index » was determined according to the protocol of Ipach *et al.* (2005) which classifies the cluster structure from 1 (very loose) to 5 (very compact) (table 2). The density index was evaluated visually on the same day for all plots on 100 clusters (50 on each side of the row). This evaluation was performed in the time range BBCH 79 and BBCH 83. Values are the means of the observations on 100 clusters per plot, averaged from the four replicates.

4. Determination of maturity parameters and yield

Close to harvest, 25 berries were randomly collected on both sides of the row in each plot. Berries from each

Table 1 - Description of the treatments with indication on type of product used, date and dose of application.

Measures	Active ingredient(s)	Developmental stage (Lorenz *et al.*, 1995)	Application dose (g/ha or ml/ha)
untreated control			
Gibb3	GA3 (100 g/kg)	BBCH 65	160
Gibb3 + leaf removal	GA3 (100 g/kg)	BBCH 65 BBCH 71	160
leaf removal + botryticide (teldor) + botryticide (cantus)	fenhexamid (g/kg) boscalid (g/kg)	BBCH 71 BBCH 77 BBCH 81	1600 1200
Gibb 3 + botryticide (teldor) + botryticide (cantus)	GA3 (100 g/kg) fenhexamid (g/kg) boscalid (g/kg)	BBCH 65 BBCH 77 BBCH 81	160 1600 1200

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Table 2 - Description of the visual assessment of the density index according to the protocol of Ipach *et al.* (2005).

Index	Description
1	Very loose; no berry contact; bending of the stem to 90° possible
2	Loose; berry contact; bending of the stem up to 45°-90° possible
3	Dense; berries still flexible; bending of the stem up to 10-45° possible
4	Compact; berries not flexible; bending of the stem up to 10° possible
5	Very compact; berries not flexible; bending of the stem not possible

Table 3 - Average yield (kg/vine) (n = number of replicates) calculated by dividing the total yield recorded in the plot by the number of vines. There were no significant differences between the treatments according to a Tukey-test (P < 0.05).

	2007			2008	2009
	PN (n=6)	PG (n=4)	PB (n=2)	PN (n=4)	PN (n=4)
	Yield (kg/vine)				
T1	2.83	1.44	3.63	2.21	2.64
T2	2.80	1.70	2.51	2.52	2.52
T3	2.38	2.09	2.97	2.08	1.89
T4	2.68	1.43	4.45	2.73	2.05
T5	2.80	1.63	3.44	2.72	2.37

treatment were pooled to obtain a sufficient sampling volume for maturity analyses. After pressing, the juice was centrifuged. The sugar level was assessed with a digital refractometer, whereas pH and total acidity were measured by titration.

In each plot, selective harvesting of rotten and healthy grapes was done to determine the yield per plant (yield per plot divided by the number of vines).

5. Statistical Analysis

Data were analyzed by one-way ANOVA. Multiple comparison procedure between means was performed with a Tukey test with confidence limit of 95 % (SPSS18 for Windows). Data are shown as means ± SD in the figures. The fitting of the epidemic progress curves to the present data was conducted using SigmaPlot 2001 according to the best fitting equation (highest R^2).

RESULTS AND DISCUSSION

1. Pinot gris and Pinot blanc - experiments 2007

In PG, the disease severity in the control treatment T1 was moderate to high (28%) (figure 1). Even though the infection level in all treatments was lower than in the control, no significant differences in disease incidence and severity were observed between the control T1 and the treatments T2, T3 and T5. Only the treatment T4 resulted in a significant decrease of disease incidence and severity as compared to the control.

The total yield per PG plant recorded in the untreated control T1 was low (1.44 kg/vine) (table 3). No significant effect on yield was observed with any of the treatments as compared to the untreated control.

In PB, no significant differences in disease incidence and severity were observed between the treatments (figure 1), as only 2 replicates had been performed in this trial and as the disease pressure in this vineyard was low (the final disease severity was 8 % in the control and between 1 and 6 % in all the other treatments). Even though the PB results could not be validated statistically, it can be noted that the treatment T4 provided the most efficient protection.

The yield level in the PB experiment was high (3,63 kg/vine in the untreated control) and no significant effect on yield was observed with any of the treatments (table 3).

2. Pinot noir - experiment 2007-2009

a) Infection level and progress

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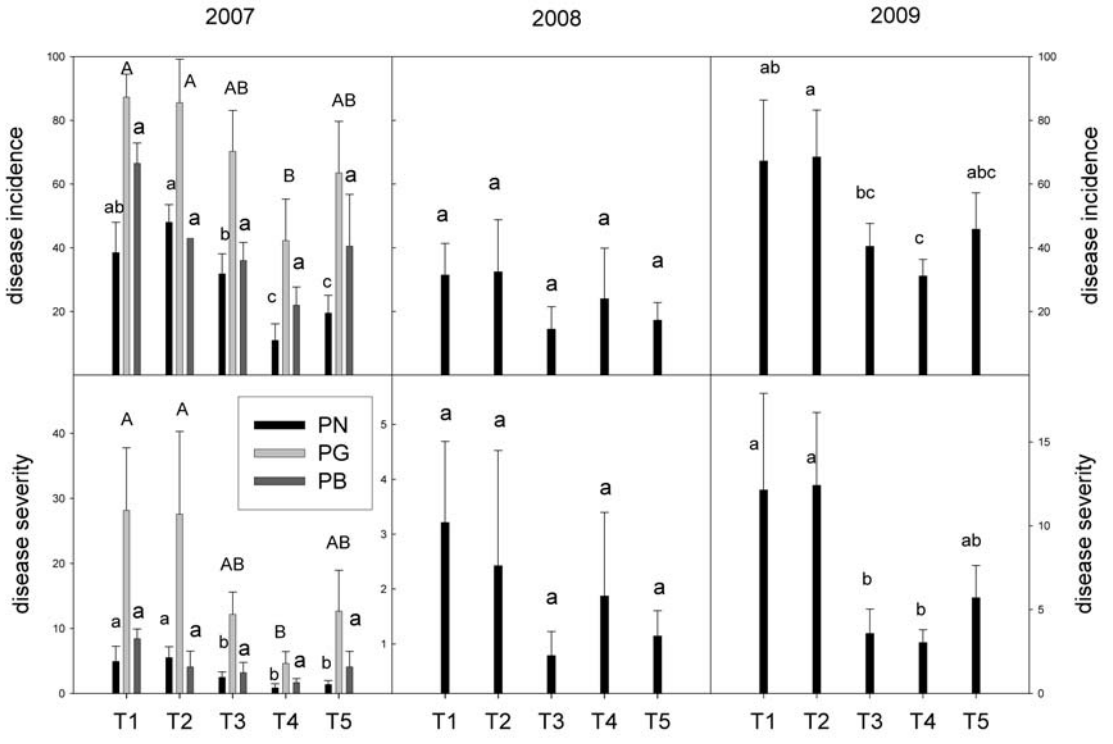


Figure 1 - Disease incidence (%) and disease severity (%) in the experimental vineyards Pinot noir (PN, 2007, 2008, 2009), Pinot gris (PG, 2007) and Pinot blanc (PB, 2007).
Different letters indicate significant differences between the treatments.

The disease severity in the control was 5 % in 2007, 3 % in 2008 and 12 % in 2009, indicating that the disease pressure was quite low (figure 1). In 2007, the disease incidence was significantly reduced in the treatments T4 and T5 whereas the disease severity was significantly reduced in the treatments T3, T4 and T5 as compared to the untreated control. In 2008, the variability between the replicates was high, with a very low disease pressure; there were no significant differences in disease incidence or severity, neither between any treatment and the control nor among each other. In 2009, the treatments T3 and T4 reduced the disease severity significantly when compared to the control. Overall, the most efficient treatments against *B. cinerea* were T3 and T4 or T4 and T5 depending on the year and the variety (figure 2). The efficiency was calculated using the equation:

efficiency (%) = ((disease severity treatment – disease severity control) / disease severity control) * 100 %

With the exception of the PN trial of 2008, T4 was the most efficient treatment with efficiencies of 75 % or more. The treatment T3 led to efficiencies around 60 % and could present an interesting strategy for sustainable viticulture due to the reduced pesticide input into the environment.

The disease progress curves in each year were compared for the different treatments in the variety PN.

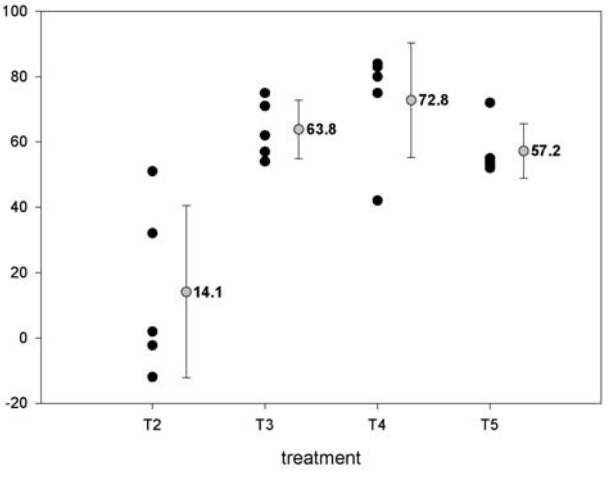


Figure 2 - Efficiencies of the treatments in the experimental vineyards Pinot noir (PN, 2007, 2008, 2009), Pinot gris (PG, 2007) and Pinot blanc (PB, 2007).
The mean value and standard deviations are indicated.

The number of days after flowering were counted starting on the day after BBCH 68. Curve fittings were performed for each treatment (on the mean values of the replicates) as well as for each consecutive year. The parameters used to evaluate each curve are indicated in table 4. The progress curves were best described with the formula :

J. Int. Sci. Vigne Vin, 2010, **44**, n° 3, 151-159
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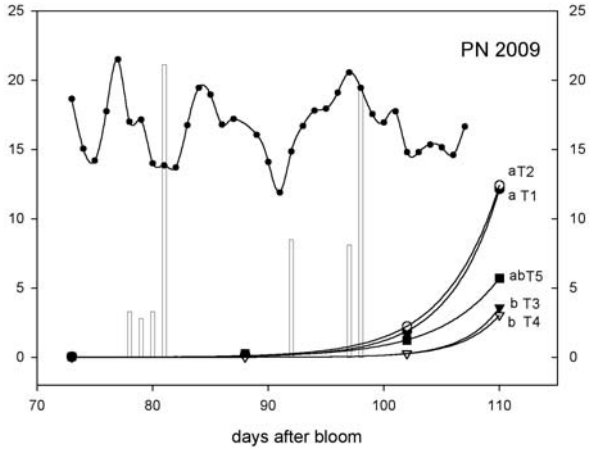


Figure 3 - Disease severity (%) during the ripening period in Pinot noir (PN, 2009).
Observed (dots) and calculated (line) data are shown. Curve fittings according to the equation $y = e^{a(x-x_o)}$ were performed on the mean values for each treatment. Statistically significant differences in the disease severity are indicated by different letters for the last observation date prior to harvest. Daily mean temperatures (°C) (dotted line) and precipitation (mm) (bars) are shown.

$$y = e^{a(x-x_o)}$$

Figure 3 shows the disease progress curves for the 2009 experiment. The results clearly show that the disease progress curves for the treatments T1 and T2 differ considerably from those of T3, T4 and T5. In 2009, relatively high temperatures and a rain event around 97-98 days after bloom probably favored the epidemiological development of *B. cinerea*. Similar observations (important precipitation and temperatures between 15-20 °C) just prior to the increase of *B. cinerea* severity were observed in 2007 and 2008 (data not shown). As previously mentioned, *B. cinerea* infection can occur under cool and humid conditions (Shtienberg and Elad, 1997), with optimum temperatures for spore germination and infection between 9 and 21 °C. The temperature conditions determine the speed of the epidemics. Indeed, under suboptimal conditions, *B. cinerea* infection progresses at a moderate rate, whereas under unfavorable conditions, the disease progress is slow (Shtienberg and Elad, 1997). According to Kassemeyer and Berkelmann-Löhnertz (2009), at 20-24 °C and humid conditions, a germ tube arises within hours and hyphae grow up to 4 mm per day, indicating that these conditions are very favorable for the disease progress.

Using the equation $y = e^{a(x-x_o)}$, it is possible to calculate the time required to reach an arbitrary threshold of disease severity. Assuming a 3 % disease severity threshold for the production of high quality red wines, in 2009 this threshold would have been reached 104 and 103 days after bloom in T1 and T2 and after 109, 110 and 107 days after bloom in T3, T4 and T5, respectively (table 4). When compared to an untreated control, these results suggest that the treatments T3, T4 and T5 would enable the winegrowers to delay harvest. Of course, the threshold for the acceptable percentage of grey mold could be discussed from an oenological point of view. Nevertheless, it gives an idea of the possibility to prolong the ripening period and thus to improve wine quality depending on the different control strategies.

Similar results were obtained in 2007 and 2008, where T3, T4 and T5 also reached the 3 % disease severity threshold at least 7 and 2 days, respectively, later than the control (table 4).

b) Cluster density

The epidemiology of *B. cinerea* is strongly influenced by the microclimatic conditions in the clusters (Piéri and Fermaud, 2005). Compact clusters lead to prolonged wetness durations and, in consequence, to a higher incidence of grey mold infection. Concerning the density of grape clusters, there were no significant changes in 2008, whereas in 2009, T3 and T5 (both using Gibb3) resulted in significantly lower density indexes, as compared to the control (table 5). This reduction of grape cluster density probably results from an increased abortion of inflorescences or young berries. The Gibb3 treatment alone did not induce any significant loosening of the cluster structure in 2009 whereas the combination of Gibb3 and leaf removal did. Thus, it is difficult to conclude on the effect of either Gibb3 or leaf removal or of both on the loosening of the cluster structure. Interestingly, Intrieri *et al.* (2008) observed a reduction of bunch compactness through leaf removal due to reduced berry number and size, indicating that leaf removal has an effect on grape bunch structure.

The reason for the more considerable impact of the treatments on the cluster structure in the year 2009 might be due to the less favorable temperature conditions during the flowering process. Cold temperatures during flowering are described to lead to higher abortion rates (Vasconcelos *et al.*, 2009) and we assume that a further interference in the flowering process due to Gibb3 and/or leaf removal might have had a more severe impact on the flowering process in the year 2009 with lower temperatures during flowering than in 2008.

According to Lo Giudice *et al.* (2004), a reduction of cluster compactness may lessen the incidence and severity of *B. cinerea*. It can be assumed that the treatments involving Gibb3 and/or leaf removal both resulted in an increased airflow and a reduced humidity at the cluster level, thus creating a less favorable environment for fungal development as described by English *et al.* (1989). Cluster density might influence parameters such as cuticle composition and number of pores (Gabler *et al.*, 2003).

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Table 4 - Parameters describing the disease progress curves in the variety Pinot noir for three consecutive years.

The calculated days reaching 3 % disease severity according to the equation $y = e^{a(x-x0)}$ are indicated. R2 is the coefficient of determination.

	PN 2007 (n=6)			
	a	x_o	R^2	days after which a disease severity of 3% would be expected
T1	0.1048	87.75	0.9977	98
T2	0.1029	86.38	0.9979	97
T3	0.1333	96.36	0.9787	105
T4	0.125	104.4	0.9932	113
T5	0.1049	100.2	0.9926	111
	PN 2008 (n=4)			
T1	0.1687	95.1	0.9989	102
T2	0.2478	98.43	0.9986	103
T3	0.227	103.1	0.9906	108
T4	0.2772	99.74	0.9956	104
T5	0.2495	101.5	0.9947	106
	PN 2009 (n=4)			
T1	0.2320	99.24	0.9998	104
T2	0.2137	98.21	0.9999	103
T3	0.3198	106.0	0.9999	109
T4	0.3059	106.4	0.9999	110
T5	0.1885	100.8	0.9982	107

In general, the cuticles of exposed berries are thicker and, in consequence, less susceptible to *B. cinerea* infections (Percival *et al.*, 1993). Furthermore, it was shown by Vail and Marois (1991) that in tight clusters, especially when the berries touch each other, the cuticles are thinner and the wax content is reduced. A further consequence of a looser cluster structure is the elimination of physical damage caused by berry contact pressure.

c) Harvest parameters

The total yield per vine in the untreated control ranged from 2,21 kg (2008) to 2,83 kg (2007) (table 3). There were no significant yield reductions in any treatment compared to the control. Moreover, following the experimental years 2007 and 2008, the percentage of bud burst was assessed in 2008 and 2009, respectively. Gibb3 applications did not have any negative effect on the fertility of the plants in the year after treatment (data not shown).

Maturity-related parameters of all trials (sugar level, pH, acidity) are indicated in table 6. The differences in these parameters between the treatments were marginal.

CONCLUSION

The present work evaluated the efficiency of several strategies including gibberellic acid, leaf removal and/or botryticides for the control of grey mold, caused by *B. cinerea*, on the grape varieties Pinot noir, Pinot gris and Pinot blanc.

Gibberellic acid applied at full bloom slightly reduced the compactness of the clusters, though not significantly, but its impact on grey mold infection was low. For a clear reduction of the disease severity, the use of gibberellic acid had to be combined with an additional measure, such as the use of botryticides or leaf removal. Leaf removal was especially efficient in combination with either botryticides or gibberellic acid.

It is noteworthy that the combined use of gibberellic acid and leaf removal emerged as a successful and sustainable strategy due to its excellent efficiency in grey mold control.

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Table 5 - Density index, rated on 100 randomly chosen clusters in each replicate (n = number of replicates).

Different letters indicate statistically significant results according to a Tukey-test (P < 0.05).

	2007			2008	2009
	PN (n=6)	PG (n=4)	PB (n=2)	PN (n=4)	PN (n=4)
	Density index				
T1	n.d	n.d	n.d	4.14 a	3.65 a
T2	n.d	n.d	n.d	3.59 a	3.44 ab
T3	n.d	n.d	n.d	3.36 a	2.88 c
T4	n.d	n.d	n.d	3.93 a	3.50 ab
T5	n.d	n.d	n.d	3.94 a	3.19 bc

Table 6 - Maturity parameters (sugar level, pH and total acidity) obtained at dates close to harvest in the different experimental vineyards PG 2007, PB 2007 and PN 2007, 2008 and 2009.

	2007									2008			2009		
	PN 20.09.2007			PG 22.09.2007			PB 18.09.2007			PN 01.10.2008			PN 29.09.2009		
	sugar level (°Oechsle) / pH / total acidity (g/l)														
T1	87	3.28	8.17	87	3.36	8.34	89	3.16	9.72	87	3.11	8.7	90	3.20	7.30
T2	88	3.16	9.62	100	3.34	8.47	86	3.1	9.70	86	3.11	8.5	92	3.23	6.70
T3	89	3.28	8.53	98	3.25	8.58	88	3.19	9.22	87	3.10	8.9	95	3.32	6.60
T4	90	3.23	8.51	96	3.27	8.84	84	3.13	9.28	87	3.13	8.4	93	3.33	6.60
T5	86	3.26	7.9	100	3.28	8.64	83	3.20	8.70	88	3.10	8.9	93	3.31	7.10

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