

Influence of curettage on Esca-diseased *Vitis vinifera* L. cv. Sauvignon blanc plants on the quality of musts and wines

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ABSTRACT

Aim: A study on Sauvignon blanc (SB) cultivar in France showed that curettage had an effect on the resilience of GTD grapevines. No experiments, however, have been conducted on its effects on wine quality, particularly on white Sauvignon blanc cultivar wines.

Methods and results: Grapevines from Sauvignon blanc cultivar that had expressed Esca-foliar symptoms were used for the study, with some of them having been curretted in 2014. Subsequently, bunches from Control (asymptomatic), Curretted and Esca-symptomatic vines were harvested in 2017 and 2018 in order to produce white wine. Technical and chemical results on both must and wine showed that wines from curretted plants were similar to those from asymptomatic vines. There were differences, however, for Esca-diseased vines, where the alcoholic fermentation of musts was faster than for the other modalities. Olfactometry results showed that, for the one-year-old 2017 vintage wines, no differences were detected, although they were for the 2018 vintage.

Conclusion: The results of the chemical analyses and wine tasting showed that the wines from curretted and asymptomatic grapevines were similar, and that their quality was the same.

Significance of the study: The quality of wines from curretted vines compared to asymptomatic ones was confirmed and validated through chemical and sensory analyses of the must and the one-year-old wines.

KEYWORDS

curettage, Esca, Sauvignon blanc, musts, chemical analyses, wine quality

INTRODUCTION

Esca of grapevine (*Vitis vinifera* L.) is one of the most harmful and difficult Grapevine Trunk Diseases (GTDs) to control in many vineyards worldwide, including in Europe (e.g., France, Italy, Portugal and Spain) (Scheck *et al.*, 1998; Mugnai *et al.*, 1999; Armengol *et al.*, 2001; Rumbos and Rumbou, 2001; Bruez *et al.*, 2013; Edwards and Pascoe, 2004; Gimenez-Jaime *et al.*, 2006). Worldwide increases in GTD incidence have been recorded ever since the banning in 2001 of sodium arsenite (the only chemical solution to control GTD diseases) (Carter, 1991; Graniti *et al.*, 2000; Surico *et al.*, 2000; Urbez-Torres *et al.*, 2006; Urbez-Torres *et al.*, 2008; Urbez-Torres *et al.*, 2009; Sosnowski *et al.*, 2007; Bertsch *et al.*, 2012). Increased GTD proliferation affects berry quality, leading to harvest loss (Calzarano *et al.*, 2004) and plant death (Larignon *et al.*, 2009).

Esca, known since Greek antiquity, comes in two forms: chronic and apoplectic. The chronic form corresponds to symptoms in the trunk, and to the presence of external secondary symptoms on leaves, shoots and sometimes berries (Mugnai *et al.*, 1999). Inside the trunk, the most common symptom is white-rot (Esca proper) that becomes spongy, with thick black or dark brown lines often separating the rot tissue from the necrotic wood. Esca-foliar symptoms can also appear, with interveinal islands of chlorotic and yellowish tissues that can become necrotic (leaf-tiger-stripe symptoms), but these do not systematically appear on the same plant every year (Larignon and Dubos, 1997). Berries can also present other symptoms, as observed in California and Southern Italy, especially in white grape cultivars (Mugnai *et al.*, 1999). The plants can suddenly die within a few days, which correspond to the apoplexy form (Mugnai *et al.*, 1999).

In an attempt to fight Esca, due to the ban on sodium arsenite in 2003, various international teams have been trying to (I) investigate the complex development of GTDs, in order to identify the factors responsible for decay, and (II) establish control methods compatible with sustainable vineyard management. Currently, no chemical or biocontrol products prove as effective as sodium arsenite. Consequently, various practices such as double pruning (Weber *et al.*, 2007) and curettage are now being revived. Curettage is an old viticultural technique, reintroduced into France by Ravaz in 1909. Removing the white-rot, currently done by means of a chain saw, prevents the development of fungi involved in the GTDs, particularly *F. mediterranea*, by

stopping the non-necrotic tissue from becoming necrotic. Necrotic tissue blocks normal sap flow and increases pathogenic fungi colonisation. Cholet *et al.* (2019) showed the impact of curettage on grapevine physiology and its ability to enhance plant resilience. The present study was designed to determine whether curettage also affects the quality of musts and one-year-old wines.

In a previous study, it was demonstrated that Esca had an impact on the aromatic composition of red wine (Lorrain *et al.*, 2012), indicating that this disease affected the phenolic composition of grapes and decreased the organoleptic quality of these red wines. Calzarano *et al.* (2001) observed that the rate of sugar and assimilable nitrogen differed between musts from diseased or healthy vines. Another study showed that the grapevines affected by Esca produced methyl salicylate (induced by a host defence mechanism against fungi attack) and modified bunch composition (Poitou *et al.*, 2018). Methyl salicylate is a good volatile indicator of a vineyard's infection state, being a volatile organic compound (VOC) synthesised from salicylic acid (SA), and a secondary plant metabolite associated with induced resistance plant defence (Tiedemann *et al.*, 1988; Tang *et al.*, 2015). Poitou (2016), also showed a strong correlation between the percentage of Esca-bunches used to make the wine and the quantity of methyl salicylate (MeSA) detected in it.

Dry, white Sauvignon blanc wines have characteristic aromas, usually described as green pepper, box tree, broom, grapefruit, passion fruit, and smoke. The major part of this broad range of nuances is released by yeast during the vinification stage from the non-volatile precursor aromas present in grape. Thus, grape maturation conditions and harvest date can impact wine quality. The main contributors to this grape variety's aromatic nuances are considered to be volatile thiols, such as 4-methyl-4-sulfanylpentan-2-one, 3-sulfanylhexyl acetate (4MSP, 3SHA, reminiscent of box tree and broom), or 3-sulfanylhexan-1-ol (3SH, with a grapefruit flavour) identified by Darriet *et al.* (1995) and Tominaga *et al.* (1998) respectively. 3SH and 4MSP are initially found as odourless precursors in grape and juice, subsequently becoming volatile thiols during the enzymatic reactions generated during alcoholic fermentation (Dixon *et al.*, 2010; Kobayashi *et al.*, 2011). In the case of Sauvignon blanc wines, the specific precursors are identified as *S*-conjugate forms (Tominaga *et al.*, 1998; Peyrot des Gachons *et al.*, 2002; Fedrizzi *et al.*, 2009; Murat *et al.*, 2001a).

White wines, especially Sauvignon blanc, can be affected by the oxidative evolution of their aromas and a loss of sensory quality. Generally, the floral and fruity aromas disappear in favour of new aromas reminiscent of cooked vegetables and honey. In the present study, we focused on methional, phenylacetaldehyde and o-aminoacetophenone components. These aldehyde components developed “honey-like” and “boiled-potato” off-flavours (Silva Ferreira *et al.*, 2002; Bueno *et al.*, 2010).

Grape maturity level can significantly affect the contents of specific varietal aromatic compounds. It has been shown, for example, that the alkyl-methoxypyrazine content of grapes, particularly 2-methoxy-3-isobutylpyrazine (MIBP), was directly linked to ripening conditions (Guillaumie and Ilg, 2013). The MIBP produces a vegetal, bell pepper flavour and aroma. It is a volatile component contributing to flavour at a very low concentration (1 to 30 ng/L) (Ebeler and Thorngate, 2009). The concentration of this wine component depends on its concentration in berries (Roujou de Boubée *et al.*, 2000; Ryona *et al.*, 2008). Other volatile components are impacted by the level of berry maturation. The family of lactones proves a good marker of maturity level (Allamy *et al.*, 2017). The lactone smell is described, for example, as “coconut-like” (gamma-octalactone) and “peach-like and milky” (gamma-decalactone) (Câmara *et al.*, 2006). Although it has little impact on white wines (Cooke and Capone, 2009; Pérez-Olivero and Pérez-Pont, 2014), the content of these compounds in Esca-diseased wines has never been studied.

As the aim of this work is to show the chemical quality of must and one-year-old-wine of curretted plants, it was important to determine whether the currettage had an impact on (I) the production of methyl salicylate as a host defence mechanism, and (II) the volatile components characterising Sauvignon blanc wine.

MATERIALS AND METHODS

1. Experimental vineyard

The sampling site was a commercial vineyard located at Beguey (near Bordeaux, in Gironde, France). To study the effects of currettage on Esca-diseased grapevines, a vine plot of Sauvignon blanc was selected in this vineyard, which was planted in 1994. This cultivar was selected for its high susceptibility to GTDS. Vines were omega-grafted onto the 101-14 rootstock (row distance x vine distances = 1.8 x 1 m). This conventional vineyard

was trained in simple ‘Espalier’ trellis and a double Guyot pruning regime, with two cordons per plant.

2. Design and Esca symptom assessment

Vine stocks expressing Esca-foliar symptoms were mapped from 2014 to June 2018. Leaf GTD symptoms were assessed according to a gradual scale previously used in a similar study (Lecomte *et al.*, 2018). Symptoms (chronic form) were categorised according to their severity into two groups: (I) E1/E2 corresponding to light leaf symptoms, mostly discolorations, on one or two cordons; and (II) E3/E4 corresponding to severe symptoms, with many drying zones and some wilts on one or both arms. Apoplectic vines were not used in this study.

The plot was divided into two equal parts. The first plot represented the asymptomatic vines that had not expressed Esca-foliar symptoms. The second plot represented the symptomatic plants that had expressed Esca-foliar symptoms, whether curretted or not in 2014. (Cholet *et al.*, 2019)

Thus, four experimental categories of vine were studied from 2014 to 2018:

- 1) Apparently healthy and asymptomatic vine stocks from 2014 to 2018 (hereafter referred to as “Control”)
- 2) Vines curretted in 2014 showing low foliar symptoms before currettage (hereafter referred to as “Curretted E1/E2”)
- 3) Vines curretted in 2014 showing strong Esca-foliar symptoms before currettage (hereafter referred to as “Curretted E3/E4”)
- 4) Esca-foliar symptomatic vines from 2014 to 2018 (hereafter referred to as “Esca”)

3. Small-scale winemaking

The day of harvest, bunches of grapes (*Vitis vinifera* L. cv. Sauvignon blanc) were collected from the vineyard in the morning. 8 kg of harvested grapes per vine category (asymptomatic vines, E1/E2 Curretted, E3/E4 Curretted and symptomatic vines) were rapidly returned to the laboratory and stocked overnight at 4° C. Each replicate was prepared in the same way. Before being pressurised, each category’s batch of bunches was separated into two replicates. Microvinifications were conducted in duplicate. 50 mg/L of sulphur dioxide (SO₂) was added, and the juice clarified overnight at 4 °C with

pectolytic enzymes (10 mg/L, LAFAZYM® CL Laffort oenologie). Must turbidity was adjusted to 180 - 200 NTU, and Yeast Available Nitrogen (YAN) was amended to 220 mg/L with Thiazote (0.1 mg/μL). The must was then inoculated with X5 yeast strain (ZYMAFLORE® X5–Laffort, final concentration of 20 mg/mL). Fermentation was carried out on 3.5 L glass fermenters at 20 °C, under nitrogen flux protection, with temperature and density being monitored daily in each tank. At the end of the fermentation, 50 mg/L of SO₂ was added and the wines stored at 4 °C before clarification.

Before addition of aqueous bisulphite solution, a 50 mL sample of must was frozen for the chemical must analyses.

4. Chemical analyses

For musts, classical oenological analyses were carried out: total acidity, assimilable nitrogen, acid malic concentration and reducing sugar indexes were determined following the OIV method. The pH was measured by infra-red, using Foss WineScan™ Foss, Nanterre, France).

For wine: reducing sugar indexes, total acidity, malic acid alcohol (% vol.) and pH were measured by infra-red, using Foss WineScan™ (Foss, Nanterre, France).

5. Volatile compounds analyses

5.1. Quantification in wines of volatile thiols, lactones and oxidative compounds

Volatile thiols (3SH, 3SHA, and 4MSP), lactones (massoia lactone, γ-octanolactone, γ-nonolactone, γ-decalactone, and δ-decalactone), and oxidative compounds (methional, phenylacetaldehyde, and o-aminoacetophenone) were quantified in wines by gas chromatography-tandem mass spectrometry (GC-MS/MS) adapted from (Thibon *et al.*, 2015). In brief, a 20 mL wine sample was spiked with an internal standard mix (50 μl) containing 6-sulfanyhexanol (6SH, 500 μg/L, EtOH), 4-methoxy-2-methyl-2-sulfanylbutan (MMSB, 500 μg/L), ethyl maltol (EM, 1 mg/L, EtOH), and 3-octanol (1 mg/L, EtOH). The sample was percolated through a conditioned SPE column (HR-X, 500 mg 6 mL, Macherey Nagel, France). After the adsorption step, the SPE columns were rinsed twice with 2 mL of hydro-alcoholic solution (10 %) and the aromas were eluted with 3 mL of pentane/dichloromethane (50/50; v/v), followed by 3 mL of dichloromethane/methanol (95/5; v/v).

The organic phases obtained were blended, dried over anhydrous sodium sulfate, and concentrated to 150 μL under a nitrogen stream.

5.2. Quantification of IBMP, IPMP, SBMP, 1,4-cineole, 1,8-cineol and methyl salicylate

The method for detecting pyrazine, 1,4-cineole and 1,8-cineole and methyl salicylate (MeSA) was detected according to Poitou (2016). Sample preparation involved 2.5 mL of grape juice or wine diluted in 7.5 mL of deionized water in a brown 20 mL SPME vial, along with 4 g of sodium chloride (NaCl) and internal standard mix (²H₃-IBMP and 3-octanol at 10 μg/L and 100 mg/L in ethanol respectively). The analyses were performed on a Carbowax 20 M capillary column (BP20, 50 m, 0.25 mm internal diameter, 0.2 μm film thickness, Scientific Glass Engineering). Helium 6.0 (Messer France) was used as a carrier gas at a flow rate of 0.9 mL/min. The temperature settings were as follows: 45 °C held for 5 min, then a 3 °C/min increase to 140 °C, followed by 30 °C min increase to 240 °C at which it was held for 10 min. The injector port was set at 240 °C. Data processing was carried out using MSD Chemstation software (5973n Data Analysis, Agilent Technologies®).

Selected ions for internal standards were *m/z* 83, 59 (3-octanol), quantitated ions were *m/z* 83. Methyl salicylate was detected using *m/z* 152, 120, 92, and quantitated using *m/z* 152. Ethyl salicylate was detected using *m/z* 166, 120, 92, and quantitated using *m/z* 120.

6. Sensory analyses

The sensory analyses of wines from the 2017 and 2018 vintages were carried out three months after the wines were bottled. The wines were evaluated by twenty judges, from the Oenology research unit, ISVV, Bordeaux University. They were all selected on the basis of their interest and availability, as well as their experience in white wine sensory analysis. Each of them came with a trainee. The candidates were screened for their sensitivity to descriptors conventionally used to describe Sauvignon blanc wines (good or bad example of Sauvignon wine, oxidation reminiscence or green aroma) in triangular tests in order to select those with good abilities to discriminate between samples. For this, we used spiked wines with increasing concentrations of a 3SH-4MSP mix, methional or IBMP. Next, two training sessions were set up, using linear-structured scales of 10 cm to indicate the

intensity of the descriptive terms, in which “0” meant “low intensity” and “10” meant “high intensity”.

All analyses were performed in a specific room at 20 °C with isolated booths. Six different triangle tests were first done using FIZZ software (Biosysteme®, France) in order to determine any significant overall difference between the control wine sample and wines from symptomatic and curretted plants. 20 mL samples were randomly presented in dark ISO-approved wine glasses labelled with three-digit random codes to panelists. Four different 20 mL-wine samples were presented per session, in the same conditions as for the triangular tests. Panellists were asked to describe the aromatic profile of each wine. After smelling and tasting, the panellists marked the intensity of each attribute on a scale of 0 to 5. The attributes were chosen from a list traditionally used for white wine sensory description. The panellists rinsed their mouths with water and paused for 30 s between samples. After checking that the factor *panellists* was not significant (homogeneity of the panel), one-way analysis of variance (ANOVA) was performed to test for the effects on each sensory attribute.

7. Statistical analyses

All measurements were performed in duplicate. Results are expressed as mean standard deviation. All the statistical analyses were carried out using the R statistical software, version 3.1.1. To compare different samples, an analysis of variance (Levene test) and a Kruskal-Wallis or ANOVA tests were performed using the Rcommander package.

RESULTS AND DISCUSSION

1. Must quality

The results of the must and wine analyses showed that there were no significant differences between the Curretted and Control experimental categories of vine (Table 1). In 2017 and 2018, the quantity of assimilable nitrogen was lower in musts from Control (47 g/L in 2017; 151 g/L in 2018) than in Curretted, with the highest quantity in the musts from Esca (89 g/L in 2017; 169 g/L in 2018). Titratable acidity in 2017 was very similar for all vine categories, except for Curretted E1/E2. In 2018, acidity was higher in wines from Esca wines, and lower in those from Curretted and Control. These results correlated with the malic acid analysis, with wines from Esca having the highest quantities. The quantity of sugar differed for the four types of wine for both years, and was highest for wines from Control (217.2 g/L in 2017; 211.5 g/L in 2018). All pH values ranged from 2.95 to 3.06.

No differences were observed between the musts from Curretted and Control vine categories for the 2017 and 2018 vintages. Even though Cholet *et al.* (2019) showed that the vigour and bunch quantity differed for the control and curretted vines, must quality remained the same. In our study, the resulting recovery in wine quality confirmed that currettage allowed Esca grapevine to re-establish wine quality.

The results of the 2018 vintage, in comparison to 2017 vintage, showed a lower quantity of sugars and the highest total acidity, particularly as regards acid rates, which indicated that Esca-grapevines bunches were harvested too early (before maturity).

TABLE 1. Values for assimilable nitrogen, sugars, total acidity, malic acid and pH of musts from 2017 and 2018 harvests.

	2017					2018				
	Assimilable nitrogen	Sugars	Total acidity	Malic Acid	pH	Assimilable nitrogen	Sugars	Total acidity	Malic Acid	pH
Control	47	217	5.4	5.1	3	151	212	5	4.8	3.1
Curretted E1/E2	72	215	4.6	4.5	3.1	176	199	5.7	5.5	2.96
Curretted E3/E4	87	209	5.4	5	2.96	173	201	6.1	5.4	3
Esca	89	208	5.4	5.1	2.95	169	187	6.6	6	2.98

Data are means to duplicate determination. In units of volume (mg/L) for assimilable nitrogen, (g/L) for sugars, (g/L) for total acidity equivalent sulfuric acid, (g/L) for malic acid and pH.

The results of Lorrain *et al.* (2012) for red musts, and of Calzarano *et al.* (2004) for white musts, showed differences between berry quality of symptomatic and asymptomatic vines.

The curretted grapes recuperated the same quality as the grapes from Control category.

2. Alcoholic fermentation kinetics

The alcoholic fermentation kinetics (Figure 1) showed that, whatever the year of study, values for the fermentation of Esca-grape wine were lower than for that of Control. In 2018, alcoholic fermentation time was the same, but in 2017 alcoholic fermentation was faster for the Esca-grape wines than for Control. The quantity of sugars in must was highest in wines from Control, which could explain why alcoholic fermentation was longer. In 2018, however, sugar levels were still high in the control wines, but the kinetics remained the same for all vine categories.

3. Plant resilience and defence

The results for the curretted and control grapevines showed that, four years after curettage, 58 % were asymptomatic, 33 % showed typical Esca-foliar symptoms, and 9 % were dead. For the uncurretted Esca-foliar vines, only 15 % were asymptomatic, 46 % expressed Esca-foliar symptoms, and 39 % were dead (Cholet *et al.*, 2019).

In addition, the quantification of methyl salicylate (MeSA) showed that the Esca-foliar symptomatic vines produced more methyl salicylate than the asymptomatic and curretted vines (Figure 2). The lowest quantity could not be identified in the wine tasting, even if the quantity for Esca wines was 4 times greater (2 µg/L) than for the other wines (less than 0.5 µg/L).

Poitou (2016) found that red wines from Esca-infected grapes had a concentration of 1.48 µg/L methyl salicylate, whereas the control only had 0.37 µg/L. Even though there were sufficient quantities of methyl salicylate for sensory detection, that could pose a problem in the future if berries from another cultivar or grapevines have a high quantity of it. The quantity of methyl salicylate in wines from curretted plants could prove a strong indicator of Esca-disease vine resilience, indicating that those grapevines can synthesise fewer plant defence components.

4. Chemical analyses of the wines

The results showed that the quantity of thiols varied depending on the vintage (Table 2). Due to the

low quantity of must per vine category (Control, Curretted E1/E2; or Curretted E3/E4, Esca), the volatile component analyses were performed once without replicates for the 2017 or 2018 vintages. 4MSP was more abundant in 2017 than 2018. For both vintages, 4MSP content was higher in wines produced from Curretted E1/E2 and lower in Esca (2017: 122.1 ng/L E1/E2, 57.8 ng/L Esca; 2018: 22.1 ng/L E1/E2, 4.8 ng/L Esca). Control and Curretted E3/E4 produced wines with intermediate level in 4MSP. Curettage (E1/E2) revealed similar values to those of Control.

3SH, with grapefruit reminiscence, was the most abundant volatile thiol in both vintages. In 2017, wines from Control and from Curretted E1/E2 plants had the highest 3SH content (204 and 209 ng/L), but differed for the 2018 vintage, in which the quantity was most abundant in wines from Esca (183 ng/L). The role of Esca on the 3SH contents released into wines is, highly dependent on the vintage in question (Wu *et al.*, 2019). This could be due to the impact of the climate on the synthesis of 3SH precursors in the berry. Indeed, 2018 had a drier and sunnier summer than 2017, when rainfall was approximately 130 mm in June. Grapes from the 2018 vintage were more acidic and had fewer sugars, meaning that phenological maturity was hard to obtain. It has been empirically observed that the aromatic potential of the berries is affected by a heat episode before harvest. In addition, the pathways of biogenesis of the precursors of 3SH are induced by biotic or abiotic stresses (oxylipin way) (Thibon *et al.*, 2011), which in our study increased in 2018 for Esca.

The results for the volatile thiols showed that wine from Esca was sometimes less typically “Sauvignon blanc” than wine from the other vine categories, whereas Curretted E1/E2 plants had similar results to Control. It should be remembered, however, that the thiol content of wines results from a balance between synthesis and degradation. Thiol release depends not only on precursor content, but also on must composition (including antioxidant compounds, amino acids, phenolic compounds, pH and Nitrogen), the yeast strains used, and the alcoholic fermentation parameters (Murat *et al.*, 2001a; Murat *et al.*, 2001b; Howell *et al.*, 2004; Masneuf-Pomarède *et al.*, 2006). Most of the thiols released were fairly quickly degraded; they were either trapped by phenolic compounds (Nikolantonaki and Waterhouse, 2012), or formed disulphide compounds (Bencomo-Rodriguez and Gambetta, 2011).

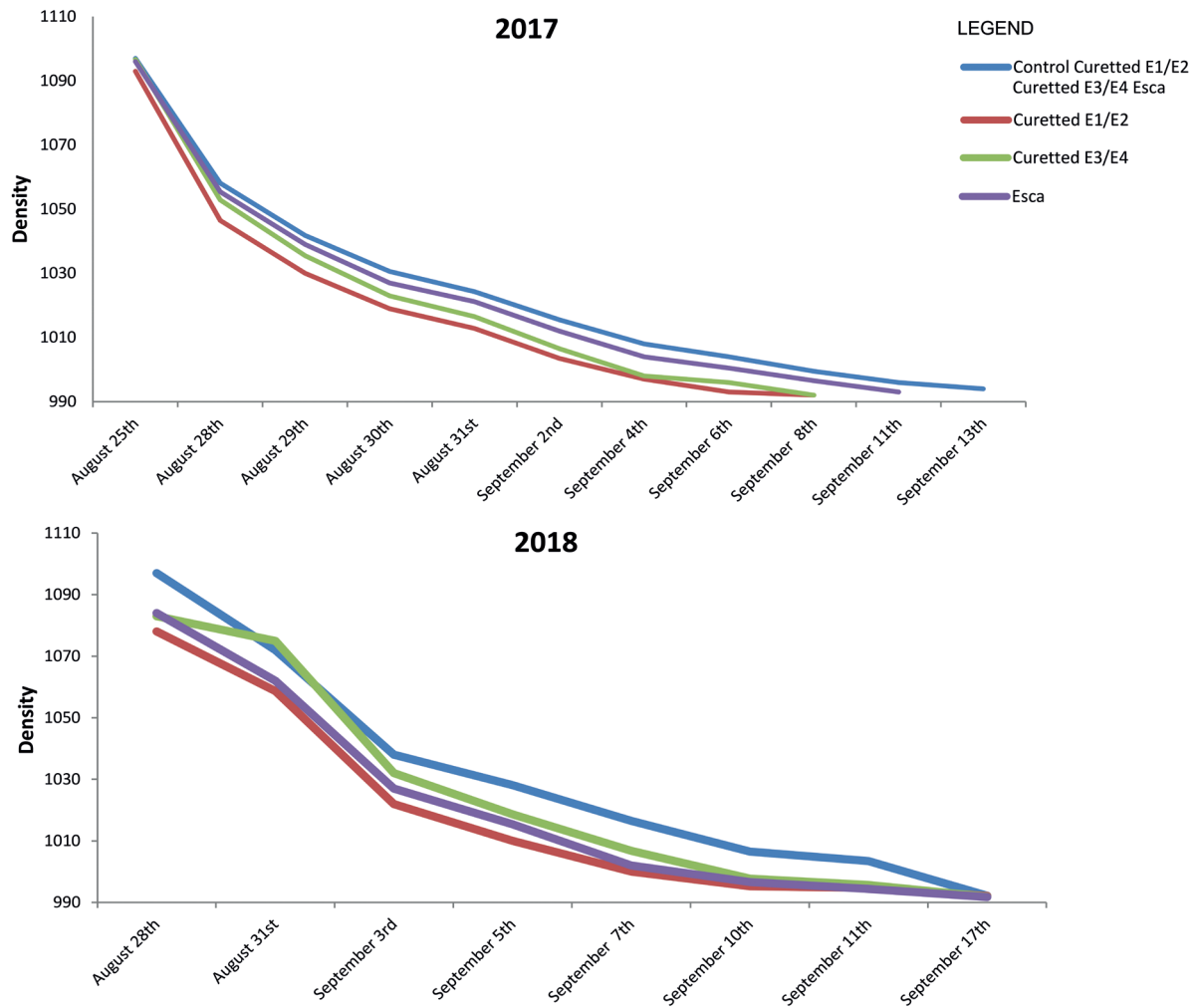


FIGURE 1. Alcoholic fermentation kinetic of Sauvignon blanc wines from Control (blue), Curretetted E1/E2 (green), Curretetted E3/E4 (purple) and Esca (red) vines from the 2017 and 2018 vintages.

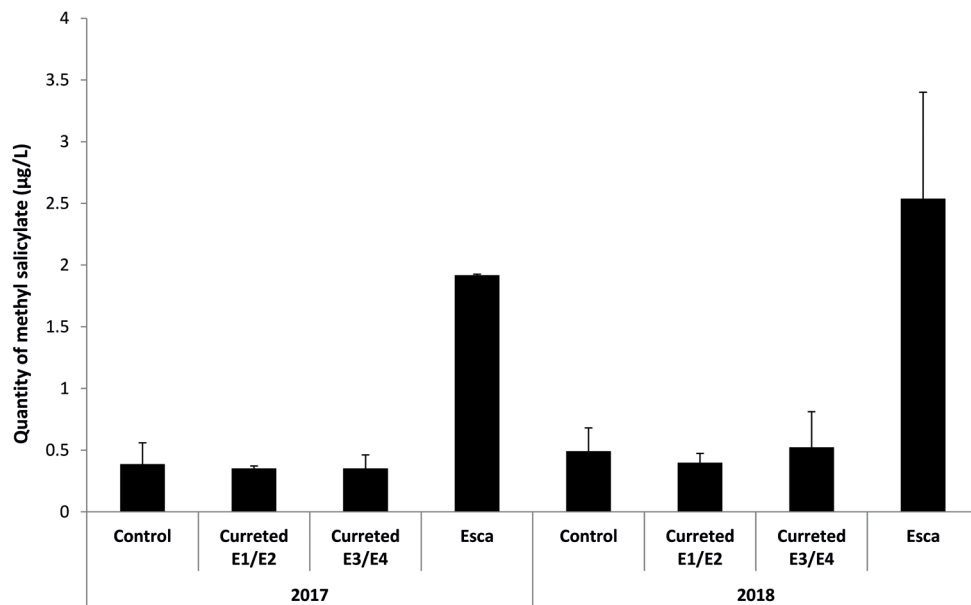


FIGURE 2. Methyl salicylate (MeSA) concentration ($\mu\text{g/L}$) in the vines opened 3 months after the end of alcoholic fermentation of Control, Curretetted E1/E2, Curretetted E3/E4 and Esca vines from the 2017 and 2018 vintages.

TABLE 2. Analyses of volatile components in the 2017 and 2018 vintages.

	2017				2018			
	Control	Curetted E1/E2	Curetted E3/E4	Esca	Control	Curetted E1/E2	Curetted E3/E4	Esca
Volatile thiols (ng/L)								
4MSP	90	122	56	58	9	22	17	5
3SH	204	209	61	124	41	47	94	183
Lactones ($\mu\text{g/L}$)								
γ -octalactone	0.6	0.4	0.4	0.6	0.3	0.2	0.4	0.5
γ -nonalactone	19.7	13.4	15.5	18.0	3.6	3.0	6.0	6.3
γ -decalactone	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
δ -decalactone	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
«Green» aroma ($\mu\text{g/L}$)								
MIBP	2.2	2.7	2.3	1.9	5.9	4.9	4.1	5.3
MIPP	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MPBs	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
1,4-cineole	0.2	0.2	0.2	0.2	0.04	0.05	0.09	0.06
1,8-cineole	0.3	0.5	0.3	0.3	0.09	0.07	0.09	0.08
Oxidation ($\mu\text{g/L}$)								
Methional	0.8	0.7	1.7	2.2	0.7	1.3	3.4	0.9
Phenylacetaldehyde	6.6	5.0	6.7	7.0	2.9	5.2	12.5	6.2
Ortho-amino-acetophenone	0.2	0.3	0.2	0.3	0.6	0.6	1.1	0.8

TABLE 3. Results of sensory analysis of 6-month-old wines from Control compared to the other experimental categories of vine (2017 and 2018 vintages).

	Wines from curetted E1/E2 vines	Wines from curetted E3/E4 vines	Wines from Esca vines
Control wines (2017 vintage)	No sensorial differences p value > 0.05	No sensorial differences p value > 0.05	No sensorial differences p value > 0.05
Control wines (2018 vintage)	<i>Sensorial differences</i> p value < 0.05	No sensorial differences p value > 0.05	<i>Sensorial differences</i> p value < 0.05

In terms of lactones, in our study, only γ -octa- and γ -nonalactone were detected. Quantities of γ -octalactone were less than 0.6 $\mu\text{g/L}$ for all vine groups in both 2017 and 2018, while γ -nonalactone levels were between 2 and 20 $\mu\text{g/L}$. As for lactones, no differences were found between Control, Curetted and Esca categories. Curettage, however, like Control, did not increase the lactone rate.

Regarding MIBP, the characteristic “green pepper” aroma was detected more in the wine from the 2018 vintage, but there were no differences between the four vine categories (wines from Control, Curetted E1/E2, Curetted E3/E4 and Esca-diseased bunches).

With respect to oxidation compounds, regardless of vintage, the levels detected of methional, phenylacetaldehyde and o-amino-acetophenone were low and below the olfactory detection threshold (8 $\mu\text{g/L}$), thus having little or no effect on the organoleptic component. These wines, however, should be considered as young wines, since they were analysed six months after vinification had ended. The wines from both vintages showed different rates for the three above-mentioned components. The 2018 vintage wines from Esca and Curetted E3/E4 showed the highest rates of phenylacetaldehyde; meanwhile, 2017 and 2018 vintage wines from Esca

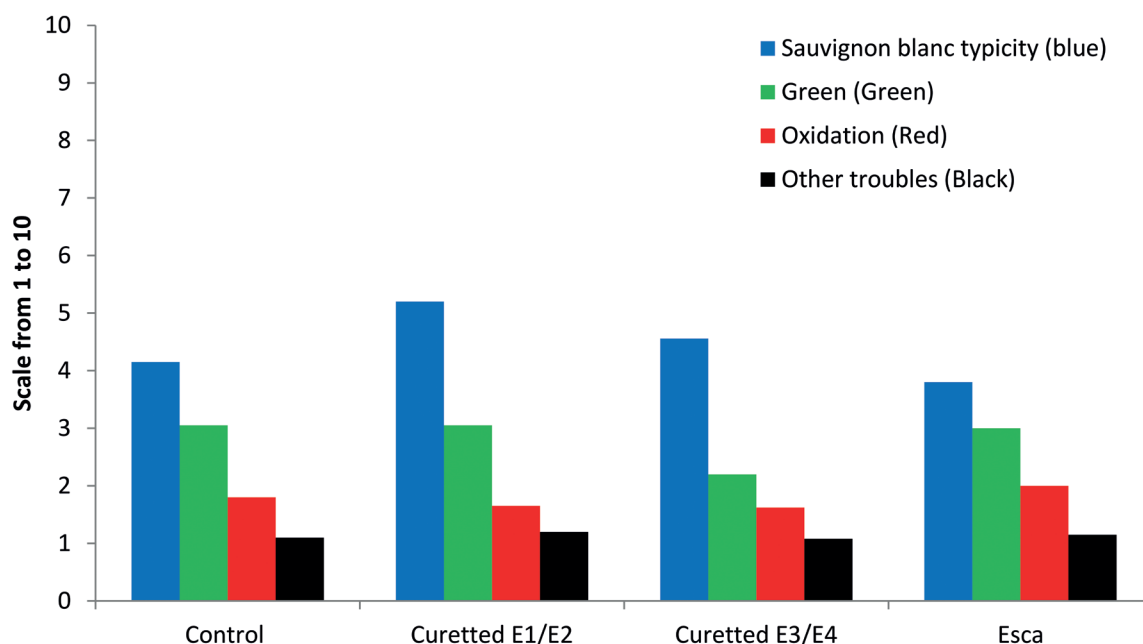


FIGURE 3. Using Fizz software, sensory profile of 2018 wines containing grapes from Control or Cured E1/E2 or Cured E3/E4 or Esca.

and Cured E3/E4 showed the highest rates of methional, a phenomenon which can only increase over time. We could, therefore, assume that wines produced from Esca-diseased vines, or cured ones with strong Esca-foliar symptoms (E3/E4), have a lower potential for being kept than for the control.

5. Sensory analyses

The triangular test (sensory analysis) showed no differences between the different experimental categories of vine for 2017 (Table 3).

The wine tasters could not differentiate the flavours of the wines from the Cured and Control vine categories. For the 2018 vintage, the tasters were also unable to differentiate between the wines from Cured and Control. While differences were observed between the wines from symptomatic and control vines (p value = 0.018), they were also observed (p value = 0.048) for wines from Cured E1/E2.

Descriptive wine analyses were possible for the 2018 vintage (Figure 3).

Our results showed that in one-year-old wines, tasters were unable to observe any differences between the wines from Cured and Control. For the wines from Esca-diseased vines, wine oxidation was observed. In the sensory analyses

wines from cured vines showed no differences from those of the control. The quality of Sauvignon blanc wine remained the same, indicating that curettage practices do not have negative impacts on the final product; *i.e.*, the wine.

CONCLUSIONS

Curettage is one of the methods currently being used to tackle Esca. Cholet *et al.* (2019) showed that vines are able to live for several years after curettage and to produce healthy bunches. The take-home message of our study is that musts and wines from cured plants share similar qualities with those from plant that do not expressed Esca-foliar symptoms. It was only in musts and wines from Esca-diseased vines that the high level of chemical methyl salicylate indicated that the plants were stressed. Lorrain *et al.* (2012) showed that the red wines produced from grapes from Esca vines differed in chemical composition and aroma flavours compared to wines from asymptomatic vines. The use of curettage to control Esca showed that plant recovered relatively fast because, just two years after curettage, our results showed that the quantity and quality of berries were similar to those of asymptomatic plants. Curettage could thus be a future solution to tackling Esca with the advantages of (I) avoiding having to replace Esca-diseased vines by young plants, and (II) maintaining the bunch quality of aged vines in order to preserve the typicity of Sauvignon blanc.

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