

Late defoliation of ‘Chardonnay’ grapevine in subtropical highland climate

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ABSTRACT: Chardonnay cultivar has shown great potential of planting and development in sites above 900 m of Brazilian southeast for sparkling wines production. The quality of this product is related to vineyard climate and management, since both affect the vine development and grape composition. In this study, three defoliation orientations (east, west and east/west face), at veraison, and a group without defoliation, were compared in order to observe the impacts of this management on the productivity, grape and base wine quality. Yield, grape components, must and base wine composition were analyzed for two years. East/west defoliation increased alcohol content and decreased acidity in base wines, while the group without defoliation increased acidity, according to the higher and lower sun exposure, respectively. Defoliation at veraison increased the incidence of bunch rots. Differences in the aromatic composition of the base wines between the harvests were identified. The east/west defoliation treatment presented more intense fruity, citrus and tropical aromas. For regions characterized by subtropical highland climate (Cwb) in the Brazilian Southeast, late defoliation is not recommended since defoliated plants were more susceptible to fungus infection at flowering and berry formation.

Key words: *Vitis vinifera*, aroma, bunch rot, sparkling wine, vitiviniculture.

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INTRODUCTION

Vines are very demanding in farming practices when compared to other fruit plants. Defoliation is a common management in the vegetative canopy of plants at any time, from the beginning of flowering until the fruit ripens (Leão et al. 2016; Würz et al. 2017), improving canopy microclimate by providing higher temperatures, solar radiation and aeration on fruits.

This management can improve grape quality, reducing problems caused by high precipitation and high air humidity during ripening (Hed et al. 2015). However, overexposure of bunches to light intensities and high temperatures, especially in hot climates, can reduce the berry color (Leão et al. 2016) and decrease excessively the acidity (Baiano et al. 2015). Leaf removal is also an effective technique for improving wine quality and providing positive effects on the sensory profile, favoring the concentration of aromatic compounds, increase of anthocyanins and phenolics (Baiano et al. 2015; Alessandrini et al. 2017). Defoliation provides wine with better sensory profile, less astringent and less alcoholic (Tessarini et al. 2014) and can modify the organoleptic properties of wines with citrus, floral and spicy notes (Alessandrini et al. 2017).



According to Manfroi et al. (1997) and Pötter et al. (2010), microclimate management of vegetative canopy in traditional wine-producing countries from Old and New World is an effective way to increase wine quality. It is also effective in controlling bunch rot, since defoliation can reduce the amount of fungicide applications (Hed et al. 2015).

There is a consensus among studies that climatic conditions, genotype and phenological stage will influence the effects of defoliation. Therefore, this work proposes to evaluate the impacts of defoliation applied in different orientations of vines in relation to sun exposure (east, west and east/west) performed at the phenological stage of veraison on the quality of the grapes and wine of Chardonnay cultivar.

MATERIAL AND METHODS

Plant material and experimental design

The experiment was conducted in a commercial vineyard located in the city of Caldas (21°55'S and 46°23'W, 1,300 m high), in the southern part of the state of Minas Gerais, Brazil. The region is characterized by subtropical highland climate (Cwb), with average annual rainfall of 1,600 mm, with highest volumes accumulated between October and March. The average temperature in this period is 20.4 °C with thermal amplitude of 10.7 °C. Figure 1 illustrates rainfall distribution during pre-flowering to harvest.

Vines were trained in a vertical shoot positioning trellis system, with bilateral cordon and double spur pruned at August 10, 2016 and August 5, 2017 in both seasons. The vine density had row spacing of 2.5 m and distance between plants of 1.0 m, resulting in 4,000 plants per hectare, and North-South planting direction.

The experiment started in 2016 with seven-years-old cultivar Chardonnay clone 76 -ENTAV-INRA grafted onto 1103 Paulsen, commonly used in subtropical climates. Defoliation treatments were applied at veraison (November 29, 2016 and November 27, 2017) at the east, west or east/west sites of the vines. The control consisted of plants without defoliation. All cultural practices were applied equally for all treatments, in accordance with standard commercial practices for Chardonnay cultivar. The experimental design was completely randomized with six replications for each treatment, represented by six plants per plot, totaling an experimental area of 144 plants.

Defoliation was intensively performed between the first and second wires at veraison, in order to expose the bunches.

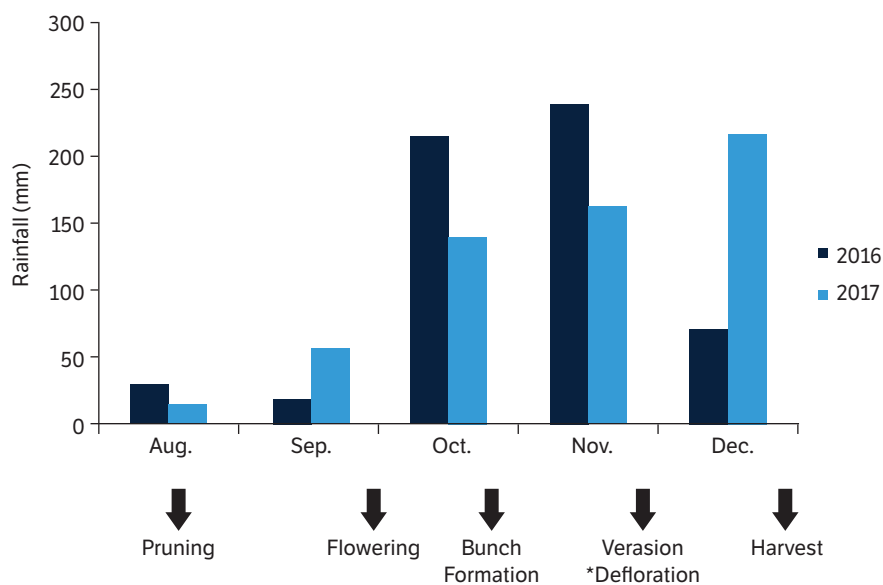


Figure 1. Rainfall distribution from pruning to harvest of 'Chardonnay' berries in 2016 and 2017 seasons.

Agronomical and physicochemical analyses

Berry temperatures were measured by piercing eight berries per plot (four berries facing east and four berries facing west) using a portable digital thermometer on sunny days on December 15, 2016 and December 13, 2017. Five measurements were taken throughout the day at three-hour intervals starting at 7 am.

Harvesting was performed at the four central plants per plot, on December 29, 2016 and December 28, 2017. Bunches average weight was estimated by the ratio between the average yield per plant and the number of bunches. Average weight of 100 berries per plot was determined. Yield per hectare was estimated by the average yield per plant and total plants per hectare (Mendonça et al. 2016).

In 2016, bunches rot was evaluated without differentiation by types. In 2017, due to the higher rot bunches incidence, *Botrytis cinerea* and *Glomerella cingulata* symptoms were quantified separately. One hundred bunches were evaluated by treatment, and they were rated from 1 to 9 according to infection severity (EMBRAPA/CNPUV s.d.).

Must samples were analyzed for pH, titratable acidity (TA) and soluble solids (°Brix), using a digital potentiometer (Micronal, B472), titration with 0.1 N NaOH with phenolphthalein as an indicator and a portable digital refractometer (ATAGO Pal 1) were respectively used.

Winemaking and physicochemical quality of wine

After harvest, the grapes were stored in a cool chamber for 24 h at 4 °C. For each treatment, 30 kg of grapes were destemmed by hand and thereafter crushed. Must was separated from the solid parts and placed in a 13.25 L Pirex glass carboy, then 2 g per hectoliter of pectolytic enzyme COAPECT VRC and 100 mg SO₂·kg⁻¹ were added for all must samples. Cold settled occurred at 10 °C for 48 h, following by the racking for a glass carboy with the same volume. Clear must was inoculated with *Saccharomyces cerevisiae bayanus* rehydrated wine yeast and added with 20 g·hL⁻¹ of fermentation activator. Density was measured daily during alcoholic fermentation at 17 °C. When density reached constantly 990 g·L⁻¹ and the residual sugars were below 3 g·L⁻¹, the wine was racked to remove lees and added with 50 mg·L⁻¹ potassium metabisulfite and 80 g·hL⁻¹ of bentonite. Wines stayed 12 days in cold stabilization at -2 °C and then racked to remove the clarification lees, still not limpid, more 30 g·hL⁻¹ of bentonite was added followed by 12 days of clarification.

Total acidity (g·L⁻¹ tartaric acid), pH, alcohol (%), crude extract (g·L⁻¹) and residual sugars (g·L⁻¹) analyses were performed after the final clarification in order to detect if the wine was within standards of the Brazilian law (Amerine and Ough 1980).

For the isolation and concentration of volatiles, the headspace solid-phase microextraction technique (HS-SPME) was used in accordance with Gürbüz et al. (2006), with some modifications. All extractions were carried out using a DVB/CAR/PDMS fiber of 50/30 µm film thickness (Supelco, Bellefonte, PA, USA). An aliquot of 10 g of wine was placed in 20 mL vials closed with Teflon cap. Vials were heated to 30 °C under agitation with a magnetic stir bar for 10 min for headspace equilibrium. Adsorption time was 45 min at the same temperature. The SPME fiber was then directly injected into a gas chromatograph mass spectrometer (Agilent Technologies Inc., Santa Clara, USA) operated with ChemStation software. The SPME fiber was held for 10 min at 250 °C for desorption of volatile compounds which were separated using a capillary column HP-5MS (30 m × 0.25 mm × 0.25 µm) with helium as carrier gas at constant flow of 1 mL·min⁻¹. Initial oven temperature was 40 °C held for 5 min, then increased to 160 °C at 3 °C·min⁻¹ and to 250 °C at 10 °C·min⁻¹ and hold for 10 min before return to 40 °C, in a total cycle of 64 min; transfer line temperature at 250 °C; MS detector in SCAN mode 30-500 m/z.

Volatile compounds were identified by comparison with the NIST library (NIST 11, version 2.0, Gaithersburg, USA) considering 70% similarity as the cut-off, further confirming the results with the retention indexes calculated according to Kovats index (Ettre 2003). Only aromatic compounds with difference in Kovats retention indices lower than 50 units up or down were accepted. Furthermore, only compounds described in the literature as aromatic were considered (Burdock 2010) and separated by classes according to Ilc et al. (2016). All analyses were carried out in triplicate.

With the exception of the volatile compound profile data of the base wines, all data were tested by analysis of variance (ANOVA), with one factor (defoliation orientations). The treatments mean values were compared by Scott-Knott test at 5% significance level. Profiles in volatile compounds of base wines were evaluated using the principal components analysis (PCA), by the program MetaboAnalyst 4.0 (Xia 2015), with the data normalized by median, treated in the logarithmic scale and scaled according to the range scale.

RESULTS AND DISCUSSION

Production

No significant differences in production parameters were observed between treatments and control group without defoliation in any of the evaluated harvests. Productivity declined in 2017, possibly due to crop biannuality (Table 1).

Higher quality fruits are expected with leaf removal, but lower plant yield. However, the present study showed that late defoliation does not affect grapevine yield rates. Alessandrini et al. (2017) observed that early defoliated vines, in flowering stage, produce fewer bunches and fewer berries per bunches, but this favors the beneficial compounds accumulation in the fruit, while late defoliated vines, at veraison or ripening stage, are not affected by this practice. However, defoliation, from flowering to veraison, can decrease vineyard yield and increase grape quality on Tempranillo and Graciano cultivars (Diago et al. 2010). Therefore, defoliation effects are more related to the phenological phase when it occurs, the vineyard environmental characteristics and the cultivars.

Bunch sanity

In this study, there was a significant increase of bunch rot from the first to the second year (Tables 2 and 3).

Table 1. Number of bunches per plant, bunch weight, 100 berry weight and yield of Chardonnay cultivar submitted to different late defoliation orientation.

Harvest Year	DEFOLIATION			
	Control	East	West	East/West
Yield/Plant (kg·plant⁻¹)				
2016	3.09 a	2.98 a	2.97 a	3.15 a
2017	2.54 a	2.36 a	2.43 a	2.08 a
Number of bunches				
2016	27 a	27 a	27 a	24 a
2017	27 a	27 a	26 a	24 a
Bunch weight (g)				
2016	114.37 b	110.19 b	109.85 b	131.38 a
2017	95.09 a	88.58 a	92.93 a	87.49 a
100 berry weight (g)				
2016	1.91 a	1.87 a	1.99 a	1.90 a
2017	1.85 a	1.83 a	1.82 a	1.85 a
Yield (t·ha⁻¹)				
2016	12.35 a	11.90 a	11.86 a	12.61 a
2017	10.17 a	9.44 a	9.73 a	8.33 a

Averages followed by same letter in same line were not significantly different at 5% of probability by Scott-Knott test.

Table 2. Bunch rot incidence on 'Chardonnay' submitted to different late defoliation orientation, 2016 season.

Defoliation	S1	S3	S5	S7	S9
Control	82 b	12 a	3 a	1 a	0 a
East	70 a	22 b	6 a	0 a	0 a
West	70 a	17 b	3 a	7 b	0 a
East/West	70 a	21 b	6 a	0 a	0 a

Legend: S1 = no infection, S3 = light infection, S5 = medium infection, S7 = strong infection and S9 = very strong infection. Averages followed by same letter in same column were not significantly different at 5% of probability by Scott-Knott test.

Table 3. Bunch rot incidence on 'Chardonnay' submitted to different late defoliation orientation, 2017 season.

Defoliation	S1	S3 G	S5 G	S7 G	S9 G	S3 B	S5 B	S7 B	S9 B
Control	40.5 c	24 a	7 a	4 a	3 a	4 a	1.5 a	1.5 a	5 b
East	33.5 b	25 a	11 b	5 a	4 a	3 a	2 a	2 a	1 a
West	33 b	25.5 a	12 b	4.5 a	6 a	2.5 a	1.5 a	1.5 a	1.5 a
East/West	25 a	21.5 a	15 b	10 b	11 b	1 a	1.5 a	3 a	2 a

Legend: S1= no infection, S3= light infection, S5= medium infection, S7= strong infection and S9= very strong infection – G= *Glomerella cingulata* and B= *Botrytis cinerea*. Averages followed by same letter in same column were not significantly different at 5% of probability by Scott-Knott test.

The control without defoliation showed lower incidence of bunch rot in both years, however, in 2017 it showed a tendency to severe *Botrytis cinerea* infection. In the same year, *Glomerella cingulata* infection was significantly higher than *Botrytis cinerea* infection for all groups evaluated, being more severe in the east/west treatment.

High temperatures and high humidity are favorable conditions for bunch rot occurrence (Thomas et al. 1988). In the region where this study occurred, during the flowering and harvest months, average temperatures and rainfall indices are high (Fig. 1). During December 2017, rainfall was higher than the same period in 2016, coinciding with the critical phase of fungal infection, which occurs during the ripening, when there are higher sugar concentrations in the berries (Jackson 2008), which may have contributed to higher bunch rot incidence in 2017.

With late defoliation, performed at veraison, the canopy microclimate at flowering and berry formation was favorable to fungal colonization. Little aeration, reduction of solar radiation on bunches zone and excess leaves that impair fungicides dispersal (Hed et al. 2015) are favorable for fungal colonization, even without visible symptoms (McClellan and Hewitt 1973), indicating that the fungus infected before veraison and the atmospheric conditions were favorable for fungus growth at grape ripening period.

Late defoliation also increased berry temperature (Figs. 2 and 3) and exposed the infected bunches to direct rainfall, which favored the development of the pathogen (Thomas et al. 1988), justifying the higher *Glomerella cingulata* incidence in 2017, in the east/west treatment, which had higher intensity of defoliation.

Data on berry temperature and bunch rot incidence in 2017 show that higher temperatures during the ripening of defoliated treatments favored the development of *Glomerella cingulata*, while milder temperatures of the control were favorable to *Botrytis cinerea* infection (Steel et al. 2011).

These results disagree with other studies that show defoliation as an efficient practice to control bunch rot (Hernandez-Orte et al. 2015; Alessandrini et al. 2017). However, they are explained by the late defoliation applied in this study, which has less impact on bunch rot control than early defoliation (performed on flowering) (Würz et al. 2017).

Must composition

In 2016 and 2017 seasons, the east/west treatment showed higher soluble solids content than the other treatments, while the control showed the lowest content in both years. A slight pH variation was observed among treatments, but not enough to change wine composition. The control showed higher total acidity in 2016 and maintained the trend in 2017, with higher

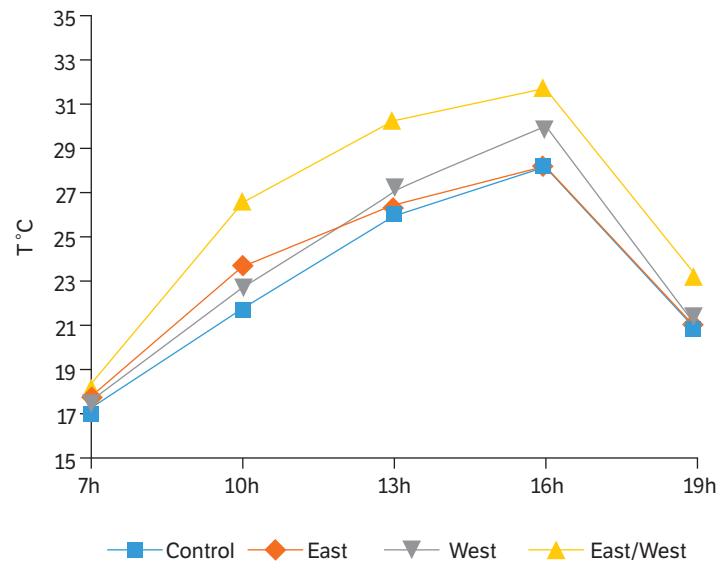


Figure 2. Evolution of daily berry temperatures of 'Chardonnay' vine submitted to different late defoliation orientation, 2016 season.

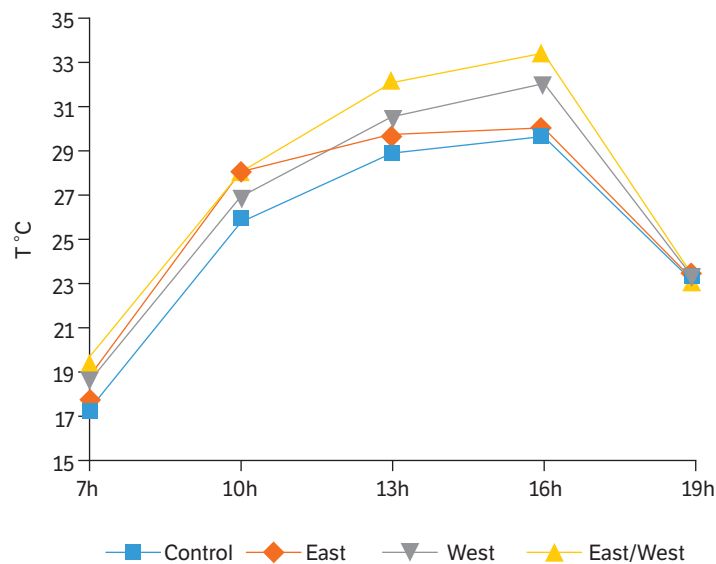


Figure 3. Evolution of daily berry temperatures of 'Chardonnay' vine submitted to different late defoliation orientation, 2017 season.

average than defoliation treatments. The largest reductions in total acidity were observed in the east/west treatment, but this did not affect sparkling wine quality, as acidity still remained high, similar to values observed in traditional producing regions (Rizzon et al. 2009) (Table 4). Higher acidity is beneficial to sparkling wines as it provides them more freshness (Mendonça et al. 2016).

Must composition reflects the influence of temperature on the acid and soluble solid concentration. In the control group, milder berry temperatures preserved acidity, while acid degradation was observed in defoliated treatments, which had higher berry temperatures. Regarding the soluble solids content, superior results were observed in the east/west treatment, with higher temperatures, opposing results of control group.

In studies with defoliation performed at different stages of bunch development, Baiano et al. (2015) noted that higher bunches exposure to solar radiation with consequent higher berry temperature increased the photoassimilate translocation

Table 4. Soluble solids (SS), pH and total acidity (TA) in 'Chardonnay' must of grapevines submitted to different late defoliation orientation, 2016 and 2017 seasons.

Harvest Year	DEFOLIATION			
	Control	East	West	East/West
SS (°Brix)				
2016	18.3 a	18.7 b	18.4 b	19.0 c
2017	17.8 a	18.2 c	18.0 b	18.3 d
pH				
2016	3.12 a	3.12 a	3.13 a	3.16 b
2017	3.22 a	3.22 b	3.18 b	3.24 c
TA (meq·L ⁻¹)				
2016	144.33 d	133.00 b	138.67 c	129.33 a
2017	158.67 c	150.67 b	156.67 c	141.33 a

Averages followed by same letter in same line were not significantly different at 5% of probability by Scott-Knott test.

rate and sugar concentration in the berry. On the other hand, Zoecklein et al. (1992) argue that defoliation causes a reduction in sugar content and attribute this fact to the removal of photosynthetically active leaves and the incomplete ripening of the bunches caused by the reduction of leaf area (Zoecklein et al. 1992). Different results are explained by the genotype, environmental conditions, soil type and management influence on the sugar concentration and other grapes substances (Van Leeuwen et al. 2004). In this study, late defoliation increased soluble solids content and decreased total acidity.

For the production of quality sparkling wine, the grapes must be yield with relatively low pH (3.20), high titratable acidity, up to 100 meq·L⁻¹ of tartaric acid, and soluble sugar content ranging from 16° to 19° Brix, in order to have a fresh beverage with final alcohol content between 9 and 10%. Therefore, grapes must be harvested before reaching full maturity, which will ensure the acidity and alcoholic content (Rizzon et al. 2009; Mendonça et al. 2016). Lower berry temperatures contribute to maintaining acidity levels (Morrison and Noble 1990).

Base wine composition

Base wine composition followed standards for sparkling wines production, and they are similar to those found in 'Chardonnay' base wines produced in the southern of Brazil, a traditional sparkling wine producer (Rizzon et al. 2009). In 2016 and 2017, base wine acidity was higher in the control group and lower in the east/west treatment, while alcohol content was higher in the east/west treatment in both seasons, and lower in the control treatment in 2016, following the same trend in 2017. Other parameters had fewer variations between groups (Table 5).

These results agree with Diago et al. (2010), who observed higher sugar and alcohol content in wines from defoliated 'Tempranillo', 'Graciano' and 'Mazuelo' vines. Baiano et al. (2015) also found that more intense leaf removal at ripening stage resulted in higher alcoholic wines for the Nero di Troia cultivar. However, Tessarin et al. (2014) suggest defoliation at veraison to reduce sugar concentration of berries and reduce alcohol content of red wines, as reducing leaf area it would affect carbohydrates reserve for fruit development during ripening, opposing the results of this study.

Volatile compounds

Thirty-four volatile compounds were identified in 'Chardonnay' base wine, including 2 aliphatic acids, 4 aliphatic alcohols, 1 aliphatic aldehyde, 15 aliphatic esters, 1 aliphatic ketone, 5 benzenoids, 4 branched esters, 1 cyclic ketone and 2 monoterpenoids (Table 6).

Base wines characterization was based on multivariate statistical analysis. Principal component analysis was applied to verify which trends or groups of wine samples occurred according to the aromatic composition by chemical classes.

Table 5. Total Acidity (TA), pH, dry extract (g·L⁻¹), residual sugars (g·L⁻¹), alcohol (%) in 'Chardonnay' base wine submitted to different late defoliation orientation, 2016 and 2017 seasons.

Harvest Year	DEFOLIATION			
	Control	East	West	East/West
	TA (meq·L ⁻¹)			
2016	148.33 d	135.33 b	140.33 c	132.67 a
2017	147.67 d	140.67 b	145.33 c	132.00 a
	pH			
2016	3.11 a	3.12 a	3.12 a	3.15 b
2017	3.20 c	3.17 b	3.15 a	3.20 c
	Dry Extract (g·L ⁻¹)			
2016	23.63 a	23.17 a	23.67 a	23.37 a
2017	25.07 b	25.10 a	25.17 a	24.43 b
	Residual Sugars (g·L ⁻¹)			
2016	0.86 a	0.93 a	1.06 a	0.93 a
2017	1.33 b	1.73 a	1.59 a	1.53 a
	Alcohol (%)			
2016	10.53 a	10.95 c	10.63 b	11.13 d
2017	9.47 a	9.81 b	9.44 a	10.29 c

Averages followed by same letter in same column were not significantly different at 5% of probability by Scott-Knott test.

Regarding the comparison between harvests, component 1 explained 45.4% and component 2, 24.6% variation between 2016 and 2017 seasons (Fig. 4).

The 2016 vintage was negatively carried to the left quadrant, with the exception of the east/west treatment, while the 2017 vintage was positively carried and grouped in the right quadrant with most aromatic classes. Both years remained close to the center indicating the presence of the same aromatic classes, but with higher concentration in the 2017 vintage, evidencing that the aromatic composition were influenced by the highest berry temperatures observed in this vintage. Studies show that climatic conditions influence aromas biosynthesis in the grapes, increasing or decreasing its concentration according to stresses suffered by the plants, and consequently this is reflected in wine (Hernandez-Orte et al. 2015; Alessandrini et al. 2017). High fruit temperatures also modify biosynthesis of aroma precursors (Šuklje et al. 2014).

Principal component analysis in 2016 explained 78.5% of variation between the different base wines, and the component 1 accounted for more than 60% (Fig. 5).

Aliphatic alcohol and aliphatic aldehyde were correlated and negatively carried with aliphatic acid, aliphatic ester, aliphatic ketone, benzenoids and branched ester, which were highly correlated with each other. The presence and absence of aromatic classes separated the treatments into four different groups in the graph: West treatment was highlighted by the presence of cyclic ketone and east treatment by the presence of monoterpenes, both characterized by floral notes. East/west treatment differed from the others by absence of aliphatic alcohol and aliphatic aldehyde, explained by the higher sun exposure and higher temperatures.

In the principal component analysis in 2017, the component 1 explained 43.2% and the component 2, 25.7% of variation between the different groups (Fig. 6).

The control group showed a tendency to higher concentrations of benzenoids and aliphatic aldehyde, characterized by floral notes. Defoliated treatments resulted in base wines with higher aliphatic ketone, aliphatic esters and monoterpenoids concentrations, giving fruity, tropical and floral notes.

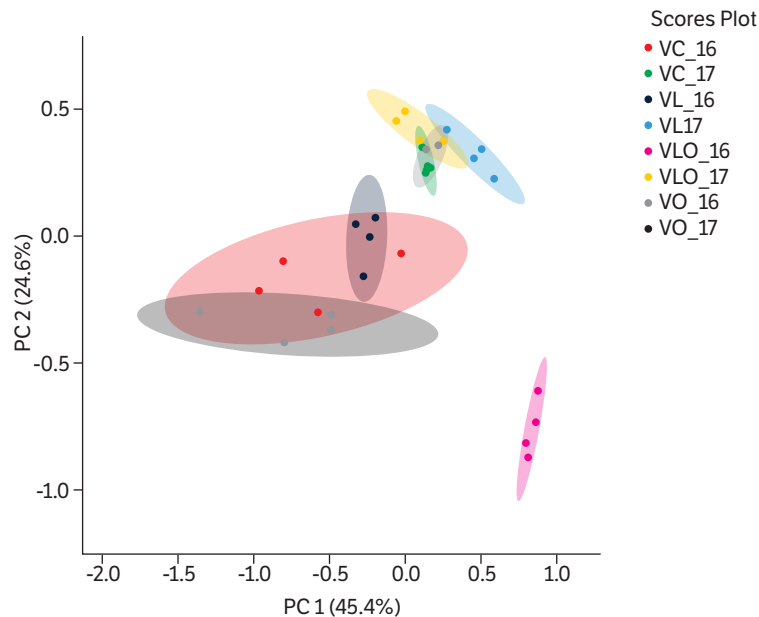
Leaf removal increases monoterpenes and other potentially volatile terpenes in 'Sauvignon Blanc', 'Gewürztraminer' and 'Chardonnay Musqué' grapes, resulting in wines with higher citrus, tropical and floral aromas and flavors than

Table 6. Volatile compounds identified in 'Chardonnay' base wine using GC-MS extracted by DVB/CAR/PDMS, 2016 and 2017 seasons.

Volatile compounds	CAS#	KI ^a	Aromatic notes
Aliphatic acids			
Hexanoic acid	000142-62-1	998	Rancid; Blue cheese
n-Decanoic acid	000334-48-5	1373	Rancid
Aliphatic alcohols			
1-Hexanol	000111-27-3	851	Herbaceous; Green fruit
1-Heptanol	000111-70-6	962	Herbaceous
1-Octanol	000111-87-5	1072	Citric; Green
1-Decanol	000112-30-1	1263	Orange flower
Aliphatic aldehyde			
Nonanal	000124-19-6	1104	Floral; Citric
Aliphatic esters			
Ethyl butyrate	000105-54-4	804	Fruity; Pineapple
Ethyl heptanoate	000106-30-9	1100	Fruity; Brandy
Ethyl laurate	000106-33-2	1596	Floral and Fruity
Ethyl decanoate	000110-38-3	1398	Grape; Brandy
Methyl octanoate	000111-11-5	1129	Orange
Methyl laurate	000111-82-0	1509	Floral
Diethyl succinate	000123-25-1	1167	Light fruity
Ethyl nonanoate	000123-29-5	1298	Fruity; Brandy
Ethyl hexanoate	000123-66-0	1002	Pineapple; Banana
Ethyl myristate	000124-06-1	1795	Orris root
Hexyl acetate	000142-92-7	1014	Pear; Floral
Propyl octanoate	000624-13-5	1294	Coconut; Yeast
n-Propyl hexanoate	000626-77-7	1097	Pineapple; Blackberry
Ethyl undecanoate	000627-90-7	1496	Coconut; Brandy
Ethyl palmitate	000628-97-7	1902	Wax; Sweety
Aliphatic ketone			
2-Nonanone	000821-55-6	1093	Rue
Benzenoids			
Phenylethyl alcohol	000060-12-8	1118	Rose
Styrene	000100-42-5	893	Balsamic; Floral
Benzaldehyde	000100-52-7	962	Toasted; Malt
Phenethyl acetate	000103-45-7	1260	Floral; Honey
Phenylacetaldehyde	000122-78-1	1049	Hyacinth; Honey
Branched esters			
Isoamyl acetate	000123-92-2	876	Banana
2-Methylbutyl acetate	000624-41-9	886	Banana; Apple
Isoamyl octanoate	002035-99-6	1450	Fruity
Isoamyl hexanoate	002198-61-0	1254	Fruity; Anise
Cyclic ketone			
(E)- β -damascenone	023696-85-7	1386	Floral
Nonoterpenoids			
Citronellol	000106-22-9	1232	Floral; Citric
6-Octen-1-ol, 3,7-dimethyl-, (R)-	001117-61-9	1232	Floral; Rose

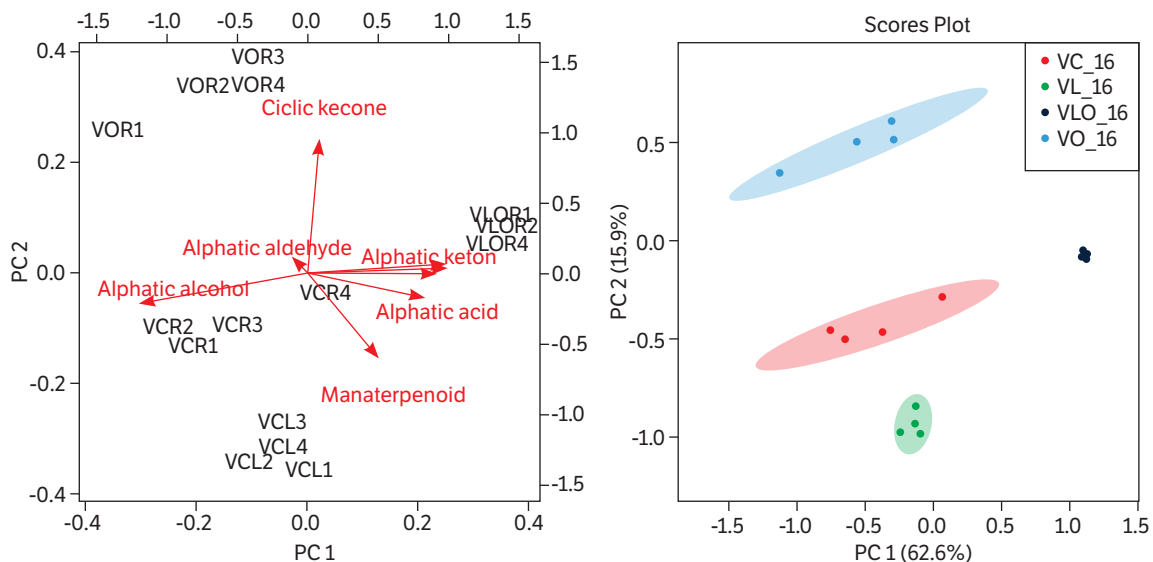
^a Confirmed by comparison with Kovats Index on DB5 Column (Adams et al. 2007).

wines from vines without leaf removal (Reynolds et al. 2007). Defoliation is also associated with fruitier/more tropical and floral drink perception. Most aroma precursors synthesis occur at higher temperatures and in sun-exposed grapes (Hernandez-Orte et al. 2015). On the other hand, wines from vines without leaf removal have a sensory profile with more intense herbaceous notes and higher acidity (Šuklje et al. 2014). Alessandrini et al. (2017) found a significant reduction in aliphatic alcohols in Semillon berries from defoliated plants, for example, when compared to berries from nondefoliated vines.



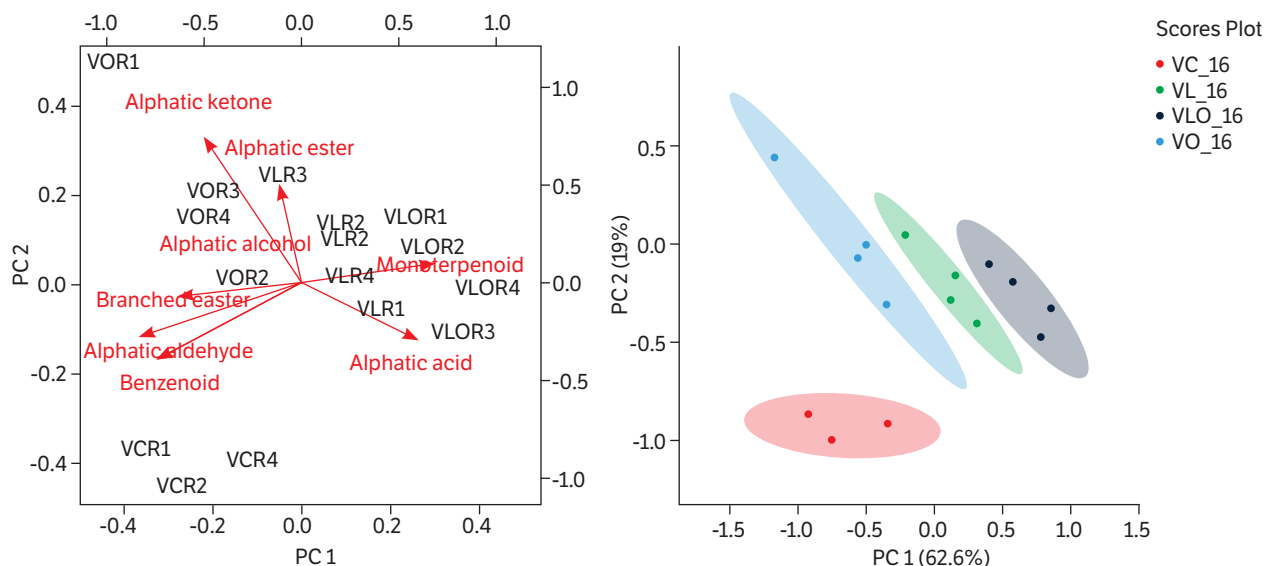
Each data represents the average of four replicates per treatment. (VC: control without defoliation; VL: east defoliation; VO: west defoliation; VLO: east/ west defoliation).

Figure 4. Principal component analysis of the aromatic composition of 'Chardonnay' base wines submitted to different late defoliation orientation in 2016 and 2017 seasons.



Legend: Each data represents the average of four replicates per treatment. VC: control without defoliation; VL: east defoliation; VO: west defoliation; VLO: east/ west defoliation.

Figure 5. Principal component analysis of the aromatic composition of 'Chardonnay' base wines submitted to different late defoliation orientation in 2016.



Each data represents the average of four replicates per treatment. VC: control without defoliation; VL: east defoliation; VO: west defoliation; VLO: east/west defoliation.

Figure 6. Principal component analysis of the aromatic composition of 'Chardonnay' base wines submitted to different late defoliation orientation in 2016.

CONCLUSION

The more intense defoliation (east/west) reduced the must and base wine total acidity, and increased the must and wine soluble solids and alcohol content, respectively. Late defoliation was also associated with a higher incidence of *Glomerella cingulata*. Defoliation did not affect vines yield, but modified the aromatic profile of base wines, favoring fruity, citrus and tropical notes.

Late defoliation is not indicated for regions characterized by subtropical highland climate (Cwb) of Southeastern Brazil.

AUTHORS' CONTRIBUTION

Conceptualization, Figueiredo G. M. and Mota R. V.; Methodology, Figueiredo G. M.; Souza C. R.; Mota R. V.; Peregrino I.; Investigation, Figueiredo G. M. and Fernandes F. P.; Writing – Original Draft, Figueiredo G. M. and Regina M. A.; Writing – Review and Editing, Figueiredo G. M.; Funding Acquisition, Souza C. R. and Mota R. V.; Resources, Peregrino I. and Regina M. A.; Supervision, Figueiredo G. M.

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