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Rootstock Effect on Volatile Composition of Albariño Wines

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Abstract: Background: Rootstock is a viticultural practice used to combat the devastating *Phylloxera vitifoliae* (Fitch). Additionally, it is well-known that wine aroma composition depends mainly on variety, viticulture management and winemaking; therefore, rootstocks can affect to berry quality. This study evaluated the influence of nine rootstocks (110R, SO4, 196-17C, Riparia G, 161-49C, 420A, Gravesac, 3309C and 41B) on volatile composition of Albariño wine in two consecutive vintages. Material and Methods: Volatile compounds belonging to eight groups (alcohols, C6-compounds, ethyl esters+acetates, terpenes + C_{13}-norisoprenoids, volatile phenols, volatile acids, lactones and carbonyl compounds) were determined in Albariño wines by GC–MS, during 2009 and 2010 vintages. Results: Rootstock 110R had a positive influence on Albariño wines, increasing total volatile concentration, due mainly to 2-phenylethanol, decanoic and hexanoic acids, ethyl esters and acetates, and C_{13}-norisoprenoids. However, the higher contribution of volatile fatty acids to Albariño wine was shown when grapevines were grafted onto SO4. Conclusions: This work provides new information about the impact of rootstocks on Albariño wine volatile composition, where 110R had a positive influence on Albariño wines under the edaphoclimatic conditions of Salnés Valley (Galicia, Spain).

Keywords: *Vitis vinifera*; viticultural practices; wine quality; aroma volatile compounds

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1. Introduction

In Europe, the use of rootstocks in viticulture started in the second half of the 19th century, as a consequence of phylloxera invasion. The choice of rootstock is also important for pest resistance and plays a central role in vine adaptation to environmental factors, as it is the link between the soil and the scion. According to Li et al. [1], there is no universal rootstock, i.e., none of the rootstocks is superior at all sites and in all seasons. Moreover, the selection of a suitable rootstock is becoming increasingly difficult due to the diverse regions and cultivars. It was already concluded that rootstocks must be tested for each cultivar and location, as the performance of rootstocks is not uniform [2]. Rootstock selection must be carefully matched with the scion variety, to optimize adaptation to the environment [3]. It is well-known that rootstocks can influence yield and fruit composition, as they affect the scion's vegetative growth, gas exchange, water status and nutrient uptake [3]. Ollat et al. [4] demonstrated that rootstocks can determine wine composition, by affecting berry size and specific fruit chemistry, such as sugar content, organic acids, anthocyanins, etc. Since rootstocks can affect the grapevine yield components and the grape composition, they can also influence the wine composition. Some authors suggested that the influence of the rootstock over the wine quality is a result from its vigor and consecutive influence on canopy expansion and subsequent fruit exposure [3,5–8].

However, information about rootstock-mediated effects on grape and wine secondary metabolites is very limited. In this sense, a few works have evaluated the influence of rootstock on wine volatile composition [9–14]. It was concluded that the rootstock choice is essential for the manipulation of wine chemistry and targeted style in the vineyard [3]. Albariño is a white cultivar grown in the NW of the Iberian Peninsula, Galicia and Northern Portugal, and currently it is produced in other countries throughout the world. However, no studies have been carried out on the rootstocks effect on volatile profile of Albariño wines, despite the importance of volatiles on white wine aroma. In this sense, the aim of the present work was to evaluate the volatile composition of wines from the *V. vinifera* cv Albariño grown grafted on nine different rootstocks (110R, SO4, 196-17C, Riparia G, 161-49C, 420A, Gravesac, 3309C and 41B) over two vintages and under edaphoclimatic conditions of Salnés Valley (NW Galicia, Spain). The importance of this work was to provide valuable information about rootstock adoption in *V. vinifera* cv Albariño under the Salnés Valley edaphoclimatic conditions in basis to wine volatile composition.

2. Materials and Methods

2.1. Vineyard Locations and Weather Conditions

Vitis vinifera L cv Albariño vines grafted on nine different rootstocks (110R, SO4, 196-17C, Riparia G, 161-49C, 420A, Gravesac, 3309C and 41B) were studied. The experimental plot consisted in 50 plant per rootstocks. All of them were sited in an experimental vineyard "Pe Redondo" of Martín Códax Winery located in Salnes Valley form Rías Baixas AOC sited in Galicia, NW Spain (42°30′21.11″ North, 8°43′32.55″ West, 150 m altitude). The area has a maritime Mediterranean climate, which is humid, with mild winters and warm summers. The average annual temperature is around 14.5 °C, and the average rainfall is from 1400 mm to 1500 mm. The most representative soils of the area are Haplumbrept, have an acidic pH, are rich in organic matter and have a loamy texture. Specific climatic conditions, by year, are shown in Table 1.

Table 1. Climatic conditions in "Pe Redondo" vineyard from Martín Códax Winery (NW Spain).

Climatic Conditions	Year (April–September)	
	2009	2010
Mean Temperature (°C)	16.38	16.80
Maximum Temperature (°C)	22.26	22.90
Minimum Temperature (°C)	11.59	11.83
Rain (L/m^2)	480.90	413.70

2.2. Musts Samples, Must Chemical Parameters and Yield Components

Grape samples from *V. vinifera* cv Albariño grafted on nine different rootstocks were collected during two consecutive harvests, 2009 and 2010, when the °*Brix* reached 22 to 24.

Grape chemical parameters, such as reducing sugars (as °*Brix*), pH, titratable acidity (as tartaric acid) and organic acids (tartaric and malic acids) were determined by using a Foss WineScan FT120, as described by the manufacturer (Foss, Hillerød, Denmark).

Clusters number per shoot and vine, cluster mass and yield were measured at harvest.

2.3. Vinifications and Wine Chemical Analysis

The Albariño white wines were made in the Martín Códax Winery (Vilariño, Cambados, Pontevedra, Spain). White musts were fermented in 100 L inox tanks, where sulfur dioxide (5 g/hL) was added to the musts. The wines were made, using standard white winemaking practices. The fermentation was conducted by yeast strain *Saccharomyces bayanus* CHP AZ 3 Oeno at 18 °C. After fermentation, sulfur dioxide (4 g/hL) was added, and the wines were filtered and transferred to 0.75 L bottles. The bottles were stopped with a cork and stored at 16 °C until analysis. Chemical parameters of Albariño wines, pH, titratable acidity (as tartaric acid), tartaric and malic acids and alcoholic strength by volume were determined. All analyses were performed in triplicate. The determinations were carried out by using a Foss WineScan FT120, as described by the manufacturer (Foss, Hillerød, Denmark). Foss WineScan FT120 was calibrated by WinISI calibration software (Foss, Warrington, UK) and by comparison with OIV official methods [15].

2.4. Wine Volatile Compounds Analysis

Volatile compounds were analyzed by gas chromatography–mass spectrometry in triplicate (GC–MS, Varian Inc., Walnut Creek, CA, USA) after extraction of 8 mL of wine with 400 µL of dichloromethane (Merck, 106054), spiked with 3.28 µg of 4-nonanol (Internal Standard; Merck, 818773), according to the methodology proposed by Coelho et al. [16]. A gas chromatograph Varian 3800 with a 1079 injector and an ion-trap mass spectrometer Varian Saturn 2000 was used. A 1 µL injection was made in splitless mode (30 s) in a Varian Factor Four VF-Wax ms column (30 m × 0.15 mm; 0.15 µm film thickness). The carrier gas was helium UltraPlus 5× (Praxair), at a constant flow rate of 1.3 mL/min. The detector was set to electronic impact mode, with an ionization energy of 70 eV, a mass acquisition range (m/z) from 35 to 260, and an acquisition interval of 610 ms. The oven temperature was initially set to 60 °C for 2 min and then raised from 60 °C to 234 °C, at a rate of 3 °C/min; raised from 234 °C to 250 °C, at 10 °C/min; and finally maintained at 250 °C for 10 min. The temperature of the injector was maintained at 250 °C during the analysis, and the split flow was maintained at 30 mL/min. The identification of compounds was performed, using the software MS Workstation version 6.9 (Varian Inc., Walnut Creek, CA, USA), by comparing their mass spectra and retention indices with those of pure standard compounds. The compounds were quantified in terms of 4-nonanol equivalents. Pure standard compounds were purchased from Sigma-Aldrich (Darmstadt, Germany) and had a purity higher than 98%.

2.5. Analysis of the Data

All data were analyzed, using the software XLStat-Pro (Addinsoft, Paris, France, 2011). Data were analyzed to test significant differences among different rootstocks and vintages by two-way analysis of variance (ANOVA). Fisher's Least Significant Difference (LSD) means comparison test ($p < 0.05$) was performed. Principal component analysis (PCA) was used on chemical groups of wine volatile composition, to discriminate among different rootstocks and vintages.

3. Results and Discussion

3.1. Chemical Composition of Musts

The yield components and chemical composition of *V. vinifera* cv Albariño grafted on nine different rootstocks (110R, SO4, 196-17C, Riparia G, 161-49C, 420A, Gravesac, 3309C and 41B) were evaluated during two consecutive vintages (Table 2).

It is known that rootstocks affect plant size and plant vigor and consequently the crop load [3]. In addition, the rootstock effects can be modified by vintage cultivar genotype and soil condition [17]. In this study, there were tendencies for rootstocks to confer increased vigor on the scion in 2010 vintages, where increases of clusters per vine, cluster mass and, therefore, yield were observed. From rootstocks, a trend to increase the yield for 161-49C and 41B was observed in the 2009 vintage; however, those were Gravesac, 41B, Riparia Gloria, 110R and SO4 in 2010. On the other hand, plant vigor influenced the leaf exposure to the sun and the proper fruit ripening, i.e., sugar accumulation. It can be seen that the °*Brix* at the harvest date of 2009 is slightly higher compared to the harvest date 2010. Moreover, the 2009 vintage had higher pH musts and higher contents of tartaric acid. However, the total acidities of the musts from vintage 2009 were lower compared to the musts from vintage 2010. Both vintages had similar content in malic acid. Tartaric acid and malic acid are the major grape acids; moreover, tartaric acid is characteristic of *Vitis vinifera*.

Table 2. Yield components and must composition attributes for Albariño wine grapes from different rootstocks, over two vintages.

Rootstock	Cluster/Shoot	Clusters/Vine	Cluster Mass (g)	Yield (kg/ha)	°*Brix*	pH	Titratable Acidity (g/L)	Tartaric Acid (g/L)	Malic Acid(g/L)
2009 vintage									
110R	2.07 ± 0.84	38.37 ± 12.48	80.11 ± 16.65	9700 ± 1290	24.2 ± 0.38	3.39 ± 0-07	8.14 ± 0.55	6.04 ± 0.31	4.32 ± 0.51
SO4	2.13 ± 1.14	36.93 ± 15.29	77.09 ± 29.15	8940 ± 3075	23.6 ± 0.35	3.35 ± 0.04	9.21 ± 1.23	6.10 ± 0.17	5.00 ± 0.93
196-17C	1.90 ± 0.27	34.80 ± 7.38	76.51 ± 28.81	8492 ± 2250	24.8 ± 0.21	3.39 ± 0.01	7.85 ± 0.61	5.91 ± 0.06	4.20 ± 0.74
Riparia Gloria	1.95 ± 0.54	34.73 ± 12.64	67.55 ± 22.47	7268 ± 2059	24.0 ± 0.42	3.40 ± 0.02	7.95 ± 0.61	5.84 ± 0.49	4.41 ± 0.49
161-49C	1.98 ± 0.34	39.12 ± 5.66	90.35 ± 23.07	11,768 ± 3397	23.7 ± 0.15	3.36 ± 0.04	8.00 ± 1,38	5.90 ± 0.59	4.10 ± 1.08
420A	2.03 ± 0.57	38.96 ± 10.88	74.34 ± 13.65	9844 ± 3579	22.7 ± 0.50	3.40 ± 0.04	7.52 ± 0.45	6.32 ± 0.06	3.73 ± 0.56
Gravesac	1.88 ± 0.32	39.52 ± 9.73	67.33 ± 22.93	9001 ± 4049	23.9 ± 0.55	3.47 ± 0.03	7.90 ± 1.00	6.21 ± 0.21	4.02 ± 0.97
3309C	1.83 ± 0.49	37.73 ± 11.80	61.52 ± 21.76	7700 ± 3196	23.4 ± 0.40	3.39 ± 0.11	7.67 ± 0.68	6.33 ± 0.64	4.10 ± 1.66
41B	1.93 ± 0.20	41.12 ± 7.11	79.53 ± 13.59	10,882 ± 2415	24.4 ± 0.35	3.47 ± 0.05	7.35 ± 1.00	6.10 ± 0.31	4.15 ± 0.69
2010 vintage									
110R	1.84 ± 0.22	38.27 ± 4.88	135.45 ± 28.63	17,161 ± 3594	21.8 ± 0.32	2.96 ± 0.03	10.48 ± 0.41	5.40 ± 0.26	4.20 ± 0.12
SO4	1.98 ± 0.19	40.96 ± 3.95	124.77 ± 12.46	17,077 ± 2677	21.5 ± 0.17	2.98 ± 0.03	11.44 ± 0.96	5.41 ± 0.12	5.02 ± 0.75
196-17C	1.93 ± 0.20	40.95 ± 5.68	106.18 ± 36.47	14,112 ± 4070	22.0 ± 0.55	2.91 ± 0.05	10.71 ± 0.31	4.70 ± 0.36	4.40 ± 0.31
Riparia Gloria	2.04 ± 0.05	44.90 ± 2.45	113.58 ± 28.74	17,128 ± 4951	21.9 ± 0.51	3.16 ± 0.03	9.19 ± 0.14	3.52 ± 0.38	4.81 ± 0.12
161-49C	1.84 ± 0.09	41.08 ± 3.91	115.85 ± 21.89	15,730 ± 2438	22.6 ± 0.47	3.01 ± 0.02	10.31 ± 0.38	5.51 ± 0.10	3.82 ± 0.55
420A	1.53 ± 0.29	32.43 ± 7.70	110.81 ± 34.33	11,852 ± 3735	22.0 ± 0.18	2.98 ± 0.05	10.78 ± 1.01	5.71 ± 0.32	4.42 ± 1.01
Gravesac	1.95 ± 0.09	41.90 ± 2.82	138.24 ± 35.12	19,137 ± 3820	22.0 ± 0.58	3.01 ± 0.02	10.60 ± 0.14	5.42 ± 0.17	4.30 ± 0.30
3309C	2.02 ± 0.16	39.92 ± 3.31	128.04 ± 27.37	16,887 ± 3299	22.3 ± 0.51	2.93 ± 0.01	10.24 ± 0.44	5.40 ± 0.46	3.52 ± 0.31
41B	1.91 ± 0.17	39.46 ± 4.88	133.72 ± 29.88	17,764 ± 5720	22.5 ± 0.21	2.95 ± 0.03	10.22 ± 0.68	4.70 ± 0.20	4.12 ± 0.78

In terms of sugar accumulation, as °*Brix* value, the range registered for 2009 vintage was higher than 2010. A trend to reaching higher °*Brix* was shown for 196-17C (24.8) and 161-49C (22.6) in 2009 and 2010, respectively. In contrast, a tendency to achieve lower values was observed for 420A (22.7) in the 2009 vintage and SO4 (21.5) in the 2010 vintage. Low values of °*Brix* were shown by SO4 in other studies performed in red cultivars, such as Cabernet Sauvignon [14] and Summer Black [18]. From our results, it can be observed a different tendency between vintages in terms of the rootstock influence on the sugar accumulation in the grapes.

It is known that the total acidity and pH in response to rootstock vary depending on the scion [3]. The highest total acidity, in both years, was registered for grapes grafted on SO4 with values of 9.21 g/L for the 2009 vintage and 11.44 g/L for the 2010 vintage. Selection Oppenheim 4 (SO4) is one of the most used rootstocks, together with 110R. It displays strong vigor and plants grafted with this rootstock produces high yields [19]. Rootstocks that induced higher vigor to the scion have higher total acidity, and the reduction in grapes from less vigorous rootstocks is possibly a consequence of increased fruit exposure [3]. It is reported that *V. berlandieri*–derived rootstocks have lower potassium uptake, which contributes to a reduction in juice pH [20]. However, in our study, this behavior was not observed with the *V. berlandieri*–derived rootstocks (41B, 161-49C, 110R, SO4 and 420A). The lowest pH value in the 2009 vintage was registered for SO4 (pH of 3.35) and for 196-17C in the 2010 vintage (pH of 2.91). However, the highest pH values for the 2009 and 2010 vintages were registered for 41B and Gravesac (pH of 3.47) and Riparia G (pH of 3.16), respectively. Juice titratable acidity and pH were not affected by either rootstock or season in Cabernet Sauvignon [14]; however, the influence of rootstocks on titratable acidity and pH was described by other authors [8,18,21–24].

With respect to tartaric (TA) and malic (MA) acids, the same trend was observed for both vintages, with highest values for 420A in TA and SO4 in MA (Table 2). The difference between samples in concentrations of tartaric acid for year 2009 was of 0.5 g/L, and for malic acid, it was of 1.27 g/L. Meanwhile, this range in concentrations for 2010 was of 2.19 g/L and 1.5 g/L for TA and MA, respectively.

In general, the chemical composition of Albariño musts showed a higher influence by the vintage than the rootstock. This was previously stated that environmental variables can strongly interact with the behavior of rootstocks [3]. Moreover, it is difficult to establish whether changes in grape composition are directly due to the accumulation of metabolites, or indirectly due to differences in vine vigor, yield or canopy architecture [3].

3.2. *Chemical Composition of Wines*

The chemical composition of the wines resulted from *V. vinifera* cv Albariño grafted on nine different rootstocks (110R, SO4, 196-17C, Riparia G, 161-49C, 420A, Gravesac, 3309C and 41B) was also evaluated, during two consecutive years (Table 3).

Table 3. Chemical composition of Albariño wines from different rootstock, over two vintages.

Rootstock	pH	Titratable Acidity (g/L)	Tartaric Acid (g/L)	Malic Acid (g/L)	Alcoholic Strength by Volume
2009 vintage					
110R	3.42 ± 0.02	8.63 ± 1.05	3.31 ± 0.33	4.01 ± 0.56	14.35 ± 0.20
SO4	3.39 ± 0.02	9.40 ± 0.55	3.50 ± 0.24	4.73 ± 0.98	13.88 ± 0.32
196-17C	3.45 ± 0.04	8.28 ± 0.71	2.91 ± 0.54	4.05 ± 0.65	14.16 ± 0.70
Riparia G	3.46 ± 0.01	8.79 ± 0.60	3.21 ± 0.43	4.04 ± 0.60	14.04 ± 0.45
161-49C	3.40 ± 0.02	8.56 ± 0.45	3.55 ± 0.33	3.89 ± 0.88	14.12 ± 0.67
420A	3.37 ± 0.01	8.65 ± 0.76	4.15 ± 0.23	3.49 ± 0.45	13.42 ± 0.40
Gravesac	3.46 ± 0.03	8.89 ± 1.03	3.60 ± 0.54	4.08 ± 0.30	14.06 ± 0.45
3309C	3.41 ± 0.04	8.38 ± 0.9	3.54 ± 0.56	3.64 ± 0.55	13.87 ± 0.34
41B	3.53 ± 0.10	7.78 ± 0.33	2.99 ± 0.35	3.92 ± 0.88	14.48 ± 0.67
2010 vintage					
110 R	2.96 ± 0.01	9.77 ± 0.35	5.17 ± 0.46	4.07 ± 0.55	13.15 ± 0.76
SO4	2.91 ± 0.01	10.33 ± 0.45	5.30 ± 0.34	4.56 ± 0.45	12.83 ± 0.43
196-17C	2.96 ± 0.01	10.06 ± 1.36	5.17 ± 0.45	4.24 ± 0.35	13.22 ± 0.30
Riparia Gloria	3.20 ± 0.02	8.37 ± 0.87	2.64 ± 0.65	4.68 ± 0.98	12.99 ± 0.42
161-49C	2.99 ± 0.01	9.22 ± 0.36	4.75 ± 0.22	3.60 ± 0.70	13.44 ± 0.33
420A	3.02 ± 0.03	9.62 ± 1.04	5.17 ± 0.76	4.04 ± 0.49	13.18 ± 0.46
Gravesac	2.97 ± 0.02	9.86 ± 0.87	5.31 ± 0.44	4.26 ± 0.57	13.21 ± 0.62
3309C	2.95 ± 0.01	9.13 ± 0.34	4.57 ± 0.45	3.59 ± 0.55	13.55 ± 0.27
41B	2.97 ± 0.02	9.58 ± 0.23	5.07 ± 0.66	3.97 ± 0.63	13.44 ± 0.30

In this study, chemical parameters were not affected by rootstock or season; however, some tendencies were observed. Malic acid was similar between years and rootstocks; however, a slight tendency to increase for SO4 in both vintages was observed. In general, after the fermentation process, the malic acid stayed almost the same, or increased slightly, with a maximum of 0.3 g/L. Tartaric acid diminished after the fermentation for the wines from vintage 2009. This may be due to a crystallization of the tartaric acid in the stored samples. However, the tartaric acid before and after the fermentation for grapes vintage 2010 was very similar for all samples. Malic and tartaric acids are normally found in large amounts in grapes and musts, and they do not undergo large changes during fermentation [25]. As expected from the initial concentration of sugars of the grapes, measured as °*Brix*, the alcoholic strength by volume of the wines from the 2009 vintage was higher compared to the wines from the 2010. A tendency to increase the alcohol values for 2009 wines from rootstocks 41B, 110R and 196-17C (14.48%, 14.35% and 14.16%, respectively) was observed. These results are in concordance with the results obtained for °*Brix* as the same rootstocks were the ones with the highest values. The same behavior was found for the wines from the 2010 vintage. The rootstocks that proportioned the highest °*Brix* were the ones with the highest alcohol values, i.e., 3309C, 41B and 161-49C, with values of 13.55%, 13.44% and 13.44%, respectively. Between the two vintages, rootstock 41B was the one that kept the tendency to proportion highest accumulation of sugars in the grafted vine and consequently higher alcohol values in the resulting wines. With respect to total acidity, wines from vine grafted on the rootstock SO4 proportioned the highest values (9.40 g/L and 10.33 g/L for the 2009 and 2010 vintages, respectively). The pH values of the resulting wines from grafted vines were similar to the pH values of the grapes for both vintages.

3.3. Wine Volatile Composition

Forty-one aroma compounds belonging to different chemical groups (alcohols, C6-compounds, ethyl esters+acetates, terpenes+C13-norisoprenoids, volatile phenols, fatty acids, lactones and carbonyl compounds) were analyzed in wines from *V. vinifera* cv Albariño grafted on nine different rootstocks (Figure 1 and Table 4).

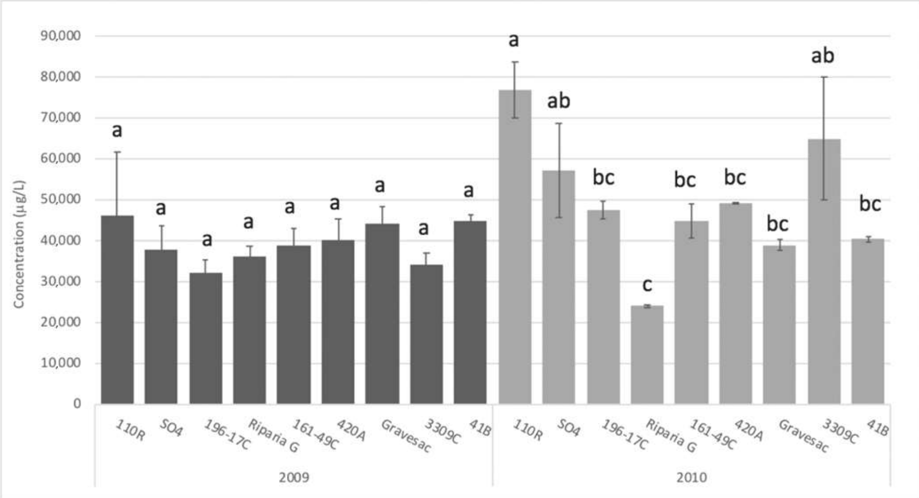

Figure 1. Total volatile concentration of Albariño wines from different rootstocks over two vintages (2009 and 2010). Error bars correspond to SDs. Different letters (a, b and c) indicate significant differences among rootstocks in each season according to Fisher's Least Significant Difference (LSD) test ($p < 0.05$).

The concentration of the total volatile composition of wines from the different rootstocks was compared (Figure 1). As it can be seen, in general, wines from the 2010 vintage accumulated a higher content of total volatiles. Significant differences among wines from different rootstocks were only shown in the 2010 vintage. Thus, wines from rootstock 110R had the highest total concentrations of volatiles (76.9 mg/L) in the 2010 vintage. The lowest value of volatiles was registered for Riparia G (2010), with a value of 24.0 mg/L. No significant differences were found for the concentrations of volatiles from the 2009 harvest; however, a tendency to show a higher total volatile concentration for wines from 110R was observed.

Table 4 shows the individual concentrations of the volatile compounds determined in Albariño wines, according to the rootstock and vintage. Table 4 also shows the results from the two-way ANOVA with interactions. A significant rootstock and vintage effects were observed, and the rootstock*vintage (R*V) interaction was also shown for the most volatile compounds. Thus, the rootstock affected twenty-seven aroma compounds (65.8%), and the vintage also showed influence on twenty-seven volatiles (65.8%). In addition, twenty-two compounds showed rootstock*vintage interaction (52.38%). Therefore, rootstock and vintage played a predominant role in determining the volatile modifications among Albariño wines from the grafted vines. In contrast, results obtained by Gutiérrez-Gamboa et al. [10] the dominant factor in Carignan noir wine volatile composition was the season, whereas rootstock did not have a significant effect in differentiating the wines. In this sense, in our study, more differences were found in the samples from the 2010 vintage (twenty-six volatiles) than in the samples from the 2009 vintage (fifteen volatiles).

Independently from the rootstocks and vintages, the group of alcohols showed the highest concentrations in the Albariño wines. A total of eleven alcohols were identified, representing between 35.3% and 71.1% of the total volatiles. This is in accordance with previous works of Albariño wine volatiles [26,27]. Three alcohols (2+3-methyl-1-butanol and 2-phenylethanol) exhibited the highest concentration, with significant differences among wines, where wines from rootstock 110R reached the highest levels of these compounds in both vintages. The lower values were exhibited by SO4, Riparia G, Gravesac and 41B wines. In agreement with this result, Merlot wines from SO4 also showed low levels alcohols, especially 2-phenylethanol, vs. other rootstocks [9]. Moreover, 2-phenylethanol has been reported to be a potential contributor to the floral character of wines, and this is attributed to its distinctive rose-like aroma [28,29]. Other alcohols (2-methyl-1-propanol, 3-methyl-1-pentanol, 2,3-butanediol and methionol) also reached the highest concentrations for 110R in the 2010 vintage. Higher alcohols contribute to the aromatic complexity of wines at concentration below 300 mg/L [30,31].

The groups of volatile acids and esters+acetates also show a high contribution to total volatile concentrations of wines (9.3% to 58.7% and 5.3% to 21.2%, respectively). With respect to volatile acids, five compounds were significantly affected by the rootstock (2+3 methylbutyric, hexanoic, decanoic and dodecanoic acids), with higher concentrations for wines from 110R in both vintages. The highest concentration of decanoic and hexanoic acids was also shown for 110R in the 2010 vintage. However, the higher contribution of ethyl esters to Albariño wine was shown when grapevines were grafted onto SO4 (58.7%). Carrasco-Quiroz et al. [9] found higher levels of total fatty acids in Merlot wines from grapevines grafted onto SO4 than those from grapevines grafted onto Gravesac and 110R. The rootstock also affected, to a greater extend, the esters and acetates in the 2010 vintage (nine compounds) than in the 2009 vintage (five compounds). Only ethyl decanoate was not influenced by the rootstock in any of the vintages. The highest values of these compounds were shown for 110R, with the exception of ethyl lactate and isoamyl acetate in 2009, where the highest concentration was found for 420A and 41B respectively. In the 2010 vintage, ethyl octanoate, hexyl acetate and isoamyl acetate exhibited the highest values for 420A. Gravesac and 110R showed lower values of ethyl octanoate in Merlot wines [9]. Moreover, Merlot wines from SO4 had lower diethyl succinate and higher ethyl lactate content than those from grapevines grafted onto other rootstocks included in the study [9]. In the same way to our work, Carrrasco-Quiroz et al. [9] showed that the total ethyl ester content was higher in wines obtained from grapevines grafted onto Gravesac when compared to those obtained from SO4 grafted vines. The vintage affected all ethyl esters and acetates. Ethyl esters are responsible for the fruity aromas, which improve the wine quality [32].

From terpenes and C_{13}-norisoprenoids, four compounds were identified in Albariño wines. The rootstocks significantly affected to linalool, α-terpineol and β-damacenone concentrations in 2009 and Ho-trienol in 2010. The highest values of C_{13}-norisoprenoids were reached for 110R (2009) and 3309C (2010). The 3309 Couderc (3309C) plant vigor is low to moderate, and the growth speed is a little slow. However, the obtained products of plants grafted with this rootstock have recognized quality [19]. Vintage effect and interaction R*V were only significant for β-damascenone. Studies reported the impacts of different rootstocks on quality of wine grape berries, where the highest wine quality was produced by Chardonnay and Pinot noir vines grafted on 110 R, as compared to the other rootstocks [8].

Esters and terpenes both contribute to the fruity and floral aromas. In addition, C_{13}-norisoprenoids, also characterized by floral aromas, are important volatile compounds due their contribution to wine aroma, because they showed low olfactory thresholds [33]. A recent study on rootstock effects on Cabernet Sauvignon showed that SO4 induced a reduction in concentration of total esters, whilst 110R increased the concentration of C_{13}-norisoprenoids at harvest [14]. In the same way, Jin et al. [18] also reported that Summer Black grafted on SO4 caused a reduction in ethyl ester content, compared to own-rooted. In agreement with those results, Albariño wine from vines grafted in SO4 showed lower ethyl esters and terpenes concentration, mainly in the 2010 vintage. In this sense, wines from vines grafted on SO4 may induce adverse effects, whereas 110R has a positive influence on Albariño wines. Olarte-Mantilla et al. [34] applied sensory analysis to determine the influence of rootstocks on Shiraz wine quality, showing that the highest quality scores were obtained by wines from vines grafted in110 Richter and the lowest by wines from own-roots.

Table 4. Volatile composition (µg/L) of Albariño wines from different rootstocks (R) over two vintages (V).

	2009									2010									Sig.		
Volatile Compounds	**110R**	**SO4**	**196-17C**	**RipariaG G**	**161-49C**	**420A**	**Gravesac**	**3309C**	**41B**	**110R**	**SO4**	**196-17C**	**RipariaG G**	**161-49C**	**420A**	**Gravesac**	**3309C**	**41B**	**R**	**V**	**R*V**
1-propanol	245 ± 86	218 ± 51	184 ± 36	215 ± 16	305 ± 45	220 ± 29	227 ± 20	149 ± 132	276 ± 17	159 ± 24	96 ± 38	109 ± 17	98 ± 0	100 ± 4	153 ± 3	71 ± 83	137 ± 64	126 ± 19	ns	***	ns
2-methyl-1-propanol	959 ± 386	721 ± 185	575 ± 154	794 ± 79	766 ± 182	1065 ± 178	1090 ± 97	437 ± 376	1021 ± 133	674 ± 123a	302 ± 189ab	367 ± 84ab	247 ± 1ab	355 ± 64ab	405 ± 8ab	317 ± 12ab	591 ± 283ab	167 ± 191b	ns	***	*
1-butanol	42 ± 16	38 ± 10	29 ± 6	37 ± 5	41 ± 8	37 ± 8	44 ± 3	28 ± 13	57 ± 7	*nd*	14 ± 11	50 ± 54	7 ± 1	13 ± 2	16 ± 2	13 ± 3	18 ± 3	15 ± 2	ns	***	*
2+3-methyl-1-butanol	25078 ± 10529	20290 ± 4902	15576 ± 2850	19468 ± 2059	19873 ± 4276	23288 ± 3400	25033 ± 2897	17184 ± 3050	25020 ± 1147	25031 ± 4073a	11503 ± 6789ab	14436 ± 2136ab	7572 ± 162b	14158 ± 2854ab	15787 ± 8ab	11903 ± 973ab	22583 ± 8943ab	12355 ± 669ab	*	***	ns
2-methyl-1-pentanol	36 ± 13a	29 ± 7ab	18 ± 3ab	26 ± 2ab	36 ± 4a	13 ± 5b	25 ± 5ab	33 ± 4a	11 ± 5b	17 ± 2ab	8 ± 6abc	11 ± 0abc	6 ± 1c	10 ± 1abc	13 ± 1abc	7 ± 2bc	19 ± 5a	9 ± 1abc	***	***	**
3-methyl-1-pentanol	17 ± 6	14 ± 3	11 ± 2	12 ± 1	16 ± 3	15 ± 2	16 ± 2	13 ± 1	18 ± 1	41 ± 6a	13 ± 6cd	27 ± 1abc	7 ± 3d	28 ± 1abc	24 ± 4bc	18 ± 2cd	36 ± 7ab	18 ± 3cd	***	***	***
2-phenylethanol	5415 ± 956a	4636 ± 320ab	4676 ± 442ab	4426 ± 179ab	4109 ± 783ab	3414 ± 1273b	5009 ± 1654ab	4578 ± 125ab	4876 ± 272ab	25112 ± 2722a	8145 ± 4395c	14352 ± 28bc	5500 ± 115c	14829 ± 1372bc	12262 ± 157bc	7547 ± 465c	20274 ± 5516ab	7999 ± 22c	***	***	***
2,3-butanediol	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	339 ± 43a	109 ± 40ab	245 ± 35ab	70 ± 74b	212 ± 51ab	199 ± 33ab	204 ± 25ab	311 ± 171ab	248 ± 5ab	*	ns	-
Methionol	5 ± 1	5 ± 2	5 ± 1	5 ± 1	3 ± 1	6 ± 1	6 ± 1	5 ± 0	6 ± 1	49 ± 3a	17 ± 8c	24 ± 3c	9 ± 2c	27 ± 3bc	19 ± 0c	14 ± 1c	44 ± 11ab	12 ± 0c	***	***	***
Benzyl alcohol	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	8 ± 0	*nd*	*nd*	9 ± 3	10 ± 5	*nd*	*nd*	11 ± 4	ns	-	-
Total Alcohols (%)	***68.8***	***68.4***	***65.7***	***69.1***	***64.6***	***69.6***	***71.1***	***65.6***	***70.0***	***66.9***	***35.3***	***62.5***	***56.2***	***66.3***	***59.0***	***51.6***	***67.8***	***51.9***			
1-hexanol	332 ± 121	287 ± 54	240 ± 39	339 ± 31	309 ± 30	285 ± 57	313 ± 42	258 ± 7	330 ± 39	227 ± 19	158 ± 86	209 ± 1	210 ± 5	140 ± 16	144 ± 168	129 ± 7	303 ± 76	163 ± 4	ns	***	ns
(*E*)-3-hexen-1-ol	22 ± 9	20 ± 5	11 ± 1	15 ± 2	16 ± 2	17 ± 1	21 ± 2	15 ± 1	12 ± 3	11 ± 1	10 ± 7	8 ± 1	7 ± 0	8 ± 0	13 ± 3	19 ± 4	15 ± 2	15 ± 2	*	***	ns
(*Z*)-3-hexen-1-ol	24 ± 9ab	37 ± 10ab	32 ± 7ab	18 ± 23ab	35 ± 8ab	11 ± 13b	46 ± 17ab	33 ± 1ab	50 ± 5a	13 ± 5ab	8 ± 4b	15 ± 0ab	15 ± 1ab	7 ± 3b	23 ± 4a	20 ± 1ab	19 ± 4ab	13 ± 4ab	ns	***	*
Total C6 compounds (%)	***0.8***	***0.9***	***0.9***	***1.0***	***0.9***	***0.8***	***0.9***	***0.9***	***0.9***	***0.3***	***0.3***	***0.5***	***1.0***	***0.3***	***0.4***	***0.4***	***0.5***	***0.5***			
Ethyl butytate	1199 ± 406	753 ± 320	447 ± 384	792 ± 261	994 ± 110	940 ± 399	52 ± 8	666 ± 509	1160 ± 182	175 ± 24a	67 ± 33cd	124 ± 19abc	83 ± 11bcd	57 ± 9d	161 ± 10a	134 ± 7abc	118 ± 17abcd	141 ± 2ab	ns	***	ns
Ethyl hexanoate	755 ± 240	680 ± 124	613 ± 60	647 ± 46	832 ± 127	689 ± 64	691 ± 87	552 ± 46	738 ± 19	680 ± 58a	297 ± 135bc	526 ± 133abc	297 ± 5bc	272 ± 31c	635 ± 1a	553 ± 32ab	453 ± 32abc	534 ± 10ab	**	***	**
Ethyl octanoate	868 ± 190	743 ± 15	763 ± 53	733 ± 39	776 ± 64	710 ± 7	729 ± 12	679 ± 37	734 ± 36	418 ± 41ab	101 ± 36f	290 ± 83cd	190 ± 8def	123 ± 4ef	513 ± 11a	348 ± 1bc	234 ± 6cdef	246 ± 3cde	***	***	***
Ethyl lactate	234 ± 86ab	182 ± 65ab	101 ± 15b	153 ± 15b	121 ± 26b	311 ± 52a	231 ± 26ab	146 ± 18b	146 ± 10b	575 ± 113a	347 ± 207ab	335 ± 41ab	163 ± 1b	331 ± 54ab	414 ± 1ab	375 ± 43ab	525 ± 232ab	408 ± 27ab	**	***	*
Ethyl decanoate	247 ± 21a	199 ± 6cd	254 ± 13a	236 ± 6ab	228 ± 23abc	190 ± 4cd	223 ± 8abcd	205 ± 3bcd	182 ± 11d	69 ± 8	44 ± 48	44 ± 14	31 ± 2	33 ± 15	70 ± 15	36 ± 40	51 ± 8	54 ± 6	*	***	**
Diethyl succinate	7 ± 1a	3 ± 1bc	3 ± 1abc	5 ± 1abc	4 ± 0abc	6 ± 1abc	6 ± 1ab	1 ± 0c	7 ± 0abc	256 ± 30a	107 ± 55cd	199 ± 34abc	83 ± 1d	206 ± 4ab	206 ± 11ab	156 ± 3bcd	252 ± 9ab	173 ± 3abcd	***	***	***
Diethyl malate	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	741 ± 74a	456 ± 239ab	499 ± 19ab	142 ± 5d	441 ± 11ab	436 ± 32ab	441 ± 50ab	670 ± 146a	480 ± 2ab	**	-	-
Hexyl acetate	158 ± 49	135 ± 24	130 ± 12	149 ± 10	180 ± 34	134 ± 10	163 ± 16	124 ± 11	185 ± 3	44 ± 9cd	38 ± 17cd	72 ± 17abc	81 ± 6ab	16 ± 0d	103 ± 7a	66 ± 4bc	64 ± 2bc	62 ± 4bc	ns	***	***
Isoamyl acetate	4372 ± 1554ab	3567 ± 783ab	2687 ± 467b	3041 ± 249b	4848 ± 785ab	3517 ± 409ab	4868 ± 542ab	3579 ± 458ab	5372 ± 229a	2348 ± 241bcd	1355 ± 675ef	1874 ± 330cdef	1990 ± 10cde	868 ± 108f	3329 ± 18a	3077 ± 86ab	1522 ± 105def	2854 ± 39abc	***	***	**
2-phenylethyl acetate	460 ± 71a	245 ± 160ab	258 ± 30ab	207 ± 18b	252 ± 13ab	183 ± 12b	260 ± 10ab	222 ± 24b	232 ± 16b	429 ± 73a	230 ± 97b	310 ± 38ab	277 ± 18ab	231 ± 0b	422 ± 22a	398 ± 13ab	348 ± 24ab	405 ± 30ab	***	***	*
Total esters+acetates (%)	***18.0***	***17.1***	***16.4***	***16.5***	***21.2***	***16.6***	***16.3***	***18.1***	***19.6***	***7.5***	***5.3***	***9.0***	***13.9***	***5.7***	***12.8***	***14.3***	***6.5***	***13.3***			
Linalool	59 ± 7a	37 ± 6ab	44 ± 11ab	49 ± 2ab	52 ± 10ab	42 ± 2ab	56 ± 7a	54 ± 1ab	32 ± 7b	*nd*	12 ± 0	33 ± 4	71 ± 82	31 ± 3	25 ± 3	24 ± 7	41 ± 18	28 ± 9	ns	ns	ns
α–terpineol	9 ± 1ab	8 ± 1abc	6 ± 1bc	9 ± 1a	11 ± 1a	9 ± 1a	9 ± 1ab	10 ± 0a	6 ± 1c	*nd*	*nd*	*nd*	*nd*	7 ± 1	*nd*	5 ± 0	13 ± 8	4 ± 0	*	ns	ns
HO-trienol	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	24 ± 1b	8 ± 6e	17 ± 3bcde	11 ± 0de	23 ± 2bc	18 ± 0bcd	15 ± 0cde	43 ± 2a	19 ± 2bcd	***	-	-
β-damascenone	14 ± 1a	11 ± 0ab	13 ± 1ab	11 ± 1ab	10 ± 1b	9 ± 1b	14 ± 2a	12 ± 2ab	6 ± 0c	*nd*	*nd*	*nd*	*nd*	12 ± 9	*nd*	*nd*	19 ± 5	14 ± 4	**	***	**
Total Terpenes+C13 (%)	***0.2***	***0.1***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.1***	***0.0***	***0.0***	***0.1***	***0.3***	***0.2***	***0.1***	***0.1***	***0.2***	***0.2***			
Butyric acid	35 ± 4	126 ± 180	93 ± 131	23 ± 2	23 ± 7	23 ± 4	8 ± 1	23 ± 2	92 ± 116	40 ± 15	15 ± 9	22 ± 4	14 ± 0	24 ± 3	31 ± 3	25 ± 1	46 ± 20	26 ± 2	ns	ns	ns
2+3-methylbutytic acids	263 ± 53a	215 ± 11ab	189 ± 17b	170 ± 6b	185 ± 9b	171 ± 4b	162 ± 6b	175 ± 5b	153 ± 10b	120 ± 19a	27 ± 26c	76 ± 7abc	31 ± 1c	66 ± 13abc	65 ± 2abc	51 ± 6bc	119 ± 44ab	53 ± 5abc	***	***	**
Hexanoic acid	814 ± 158	761 ± 47	700 ± 54	714 ± 39	664 ± 124	748 ± 22	729 ± 12	720 ± 12	737 ± 48	2746 ± 289a	1313 ± 727bc	1699 ± 25abc	897 ± 24c	1640 ± 165abc	2021 ± 50abc	1708 ± 150abc	2236 ± 658ab	1788 ± 112abc	***	***	***
Heptanic acid	20 ± 1	13 ± 3	17 ± 4	18 ± 1	13 ± 4	12 ± 2	12 ± 1	15 ± 5	18 ± 5	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	ns	-	ns
Octanoic acid	3172 ± 354	2828 ± 335	3057 ± 297	2647 ± 105	2965 ± 183	3068 ± 54	2890 ± 176	3039 ± 49	2223 ± 992	12478 ± 1321	29788 ± 27232	8400 ± 84	4499 ± 211	7654 ± 204	8861 ± 14	8244 ± 3	9679 ± 802	8707 ± 85	ns	***	ns
Decanoic acid	1248 ± 89a	1061 ± 90ab	1254 ± 96a	1132 ± 41ab	1165 ± 134ab	1111 ± 51ab	1204 ± 108a	1151 ± 9ab	919 ± 57b	3350 ± 438a	2245 ± 1064abc	2575 ± 462abc	1078 ± 95c	2380 ± 34abc	1833 ± 12bc	2449 ± 66abc	3216 ± 196ab	2775 ± 108ab	***	***	***
Dodecanoic acid	64 ± 4a	47 ± 4ab	42 ± 3bc	42 ± 8bc	27 ± 4cd	37 ± 9bc	40 ± 3bc	38 ± 2bc	12 ± 5d	*nd*	29 ± 19	29 ± 8	15 ± 2	23 ± 7	32 ± 13	56 ± 6	57 ± 35	32 ± 4	***	ns	***
Hexadecanoic acid	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	168 ± 99	*nd*	72 ± 36	78 ± 1	254 ± 131	174 ± 67	186 ± 113	83 ± 2	ns	-	-
Total acids (%)	***12.2***	***13.3***	***16.7***	***13.1***	***13.0***	***12.8***	***11.4***	***15.1***	***9.3***	***24.4***	***58.7***	***27.0***	***27.5***	***26.4***	***26.7***	***32.6***	***24.0***	***33.4***			
4-vinylguaiacol	36 ± 14	32 ± 3	33 ± 5	42 ± 1	42 ± 0	29 ± 2	42 ± 3	38 ± 1	43 ± 6	133 ± 18bc	47 ± 23e	84 ± 0de	123 ± 11bcd	116 ± 13cd	187 ± 14a	100 ± 13cd	170 ± 7ab	93 ± 0cde	***	-	***
4-vinylfenol	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	102 ± 31ab	23 ± 2c	27 ± 4bc	37 ± 4bc	48 ± 1abc	59 ± 1abc	46 ± 8abc	124 ± 51	45 ± 17abc	*	-	-
Total phenols (%)	***0.1***	***0.1***	***0.1***	***0.1***	***0.1***	***0.1***	***0.1***	***0.1***	***0.1***	***0.3***	***0.1***	***0.2***	***0.7***	***0.4***	***0.5***	***0.4***	***0.5***	***0.3***			
γ-butyrolactone	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	434 ± 83a	133 ± 77b	253 ± 31ab	81 ± 2b	255 ± 42ab	235 ± 2ab	183 ± 20b	308 ± 124ab	163 ± 8b	**	-	-
Total lactones (%)	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.6***	***0.2***	***0.5***	***0.3***	***0.6***	***0.5***	***0.4***	***0.5***	***0.4***			
Acetoin	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*	85 ± 106	12 ± 6	15 ± 1	8 ± 0	23 ± 6	26 ± 2	14 ± 5	29 ± 9	20 ± 2	ns	-	-
Total Carbonyl C (%)	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.1***	***0.0***	***0.0***	***0.0***	***0.1***	***0.1***	***0.0***	***0.0***	***0.1***			

Signification: *, **, *** and ns indicate a significant difference among rootstocks at $p < 0.05$, $p < 0.01$, $p < 0.001$ and not significant, respectively. The different letters indicate significant differences among rootstocks by season for Fisher's test LSD ($p < 0.05$).

Principal components analysis (PCA) was performed on the different groups of volatile compounds, to visualize the differentiation of the wines on the bases of the different rootstocks and vintages (Figure 2). The first two principal components (F1 and F2) accounted for 75.34% of the total variance (52.68% and 22.65%, respectively). PCA demonstrated good discrimination between samples in three main groups. The first principal component, F1, discriminated the samples on the bases of the vintage. The vintage of 2009 is sited on the negative load of F1, and the samples of 2010 are located on the positive load of the same axe. Two subgroups also were observed in the 2010 vintage. Thus, 3309C and 110R from 2010 are differentiated and sited on the positive loads of F1 and F2 and characterized by alcohols, carbonyl compounds, phenol volatiles and lactones. In general, esters, acetates, C6 compounds terpenes and C_{13}-norisoprenoids characterized the wines of the 2009 harvest, contributing fruity, floral and herbaceous nuances to these wines. However, volatile acids characterized most of the wines from the 2010 vintage.

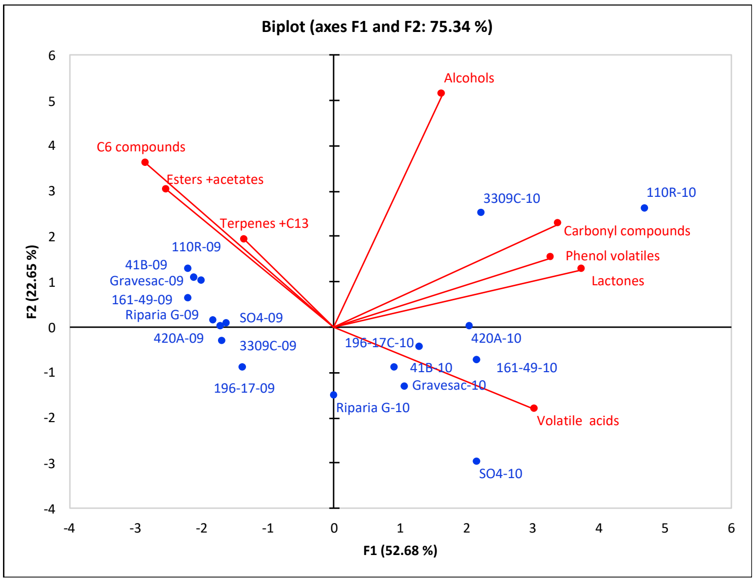

Figure 2. Principal component analysis (PCA) applied to chemical families of volatile compounds quantified in Albariño wine from different rootstocks over two vintages (2009 and 2010).

4. Conclusions

In the present study, rootstock and vintage showed an important effect on volatile composition of Albariño wines. Despite that, rootstocks had no significant effects on yield and basic chemical composition of musts and wines; wine volatiles were affected. Thus, 41B tends to accumulate sugars in grapes and, therefore, a higher ethanol amount in the resulting wines. Wines from vine grafted on the rootstock SO4 proportioned the highest values of organic acids in both vintages. With respect to wine volatiles, rootstock affected up to twenty-seven aroma compounds, mainly ethyl esters and alcohols, increasing the concentration of some of those when the grapevines were grafted in 110R. Lower concentrations of total esters were found in wines from vines grafted on SO4. Additionally, C_{13}-norisoprenoids increased in wines from 110R. Overall, according to these results, wines from vines grafted on SO4 may induce adverse effects, whereas 110R had a positive influence on Albariño wines under edaphoclimatic conditions of Salnés Valley (Galicia, Spain).

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References

1. Li, M.; Guo, Z.; Yuam, J.; Han, B.; Yin, Y.; Sun, Y.; Liu, C.; Zhao, S. Evalution of eight rootstocks on the growth and berry qualities of "Marcelan" grapevines. *Sci. Hortic* **2019**, *248*, 58–61. [CrossRef]
2. Rodrigues da Silva, M.J.; Paiva, A.P.M.; Junior, A.P.; Pereira, C.A.; Sánchez, C.; Callili, D.; Moura, M.F.; Leonel, S.; Tecchio, M.A. Yield performance of new juice grape varieties grafted onto different rootstocks under tropical conditions. *Sci. Hortic* **2018**, *241*, 94–200.
3. Sampaio, T.L.B. Using Rootstocks to Manipulate Vine Physiological Performance and Mediate Changes in Fruit and Wine Composition. Ph.D. Thesis, Oregon State University, Corvallis, OR, USA, 2007.
4. Ollat, N.; Tandonnet, J.P.; Lafontaine, M.; Schultz, R. Short- and long-term effects of three rootstocks on Cabernet Sauvignon vine behavior and wine quality. *Acta Hortic* **2003**, *617*, 95–99. [CrossRef]
5. Renouf, V.; Tregoat, O.; Roby, J.P.; van Leeuwen, C. Soils, rootstocks and grapevine varieties in prestigious Bordeaux vineyards and their impact on yield and quality. *J. Int. Sci. Vigne Vin.* **2010**, *44*, 127–134. [CrossRef]
6. Souza, C.R.; Mota, R.V.; Cardozo, D.V.; Pinentel, R.M.; Regina, M.A. Cabernet Sauvignon grapevine grafted onto rootstocks during the autumn-winter season in southeastern Brazilian. *Sci. Agricol.* **2015**, *72*, 138–146. [CrossRef]
7. Stevens, R.M.; Pech, J.M.; Taylor, J.; Clingeleffer, P.; Walker, R.R.; Nicholas, P.R. Effects of irrigation and rootstock on *Vitis vinifera* (L.) cv. Shiraz berry composition and shrivel, and wine composition and wine score. *Aust. J. Grape Wine Res.* **2016**, *22*, 124–136. [CrossRef]
8. Wooldridge, J.; Loow, P.J.E.; Conradie, W.J. Effects of rootstocks on grapevine performance, petiole and must composition, and overall wine score of *Vitis vinifera* cv Chardonnay and Pinot Noir. *S. Afr. J. Enol. Vitic.* **2010**, *31*, 45–48. [CrossRef]
9. Carrasco-Quiroz, M.; Martínez-Gil, A.M.; Gutiérrez-Gamboa, G.; Moreno-Simunovic, Y. Effect of rootstocks on volatile composition of Merlot wines. *J. Sci. Food Agric.* **2020**, *100*, 3517–3524. [CrossRef]
10. Gutiérrez-Gamboa, G.; Garde-Cerdán, T.; Marioli Carrasco-Quiroz, M.; Pérez-Álvarez, E.P.; Martínez-Gil, A.M.; Alamo-Sanzac, M.; Moreno-Simunovica, Y. Volatile composition of Carignan noir wines from ungrafted and grafted onto País (*Vitis vinifera* L.) grapevines from ten wine-growing sites in Maule Valley, Chile. *J. Sci. Food Agric.* **2018**, *98*, 4268–4278.
11. Koundouras, S.; Hatzidimitriou, E.; Karamolegkou, M.; Dimopoulou, E.; Kallithraka, S.; Tsialtas, J.T.; Zioziou, E.; Nikolau, N.; Kotseridis, Y. Irrigation and rootstock effects on the phenolic concentration and aroma potential of *Vitis vinifera* L. *cv. Cabernet Sauvignon grapes. J. Agric. Food Chem.* **2009**, *57*, 7805–7813. [CrossRef] [PubMed]
12. Miele, A.; Rizzon, L.A. Rootstock-scion interaction: 3. Effect on the composition of Cabernet Sauvignon wine. *Rev. Bras. Frutic.* **2019**, *41*, e642. [CrossRef]
13. Ough, C.S.; Cook, J.A.; Lider, L.A. Rootstock-scion interactions concerning wine making. II. Wine compositional and sensory changes attributed to rootstock and fertilizer level differences. *Am. J. Enol. Vitic.* **1968**, *19*, 254–265.
14. Wang, Y.; Chen, W.K.; Gao, X.T.; He, L.; Yang, X.H.; He, F.; Duan, C.Q.; Wang, J. Rootstock-mediated effects on Cabernet Sauvignon performance: Vine growth, berry ripening, flavonoids, and aromatic profiles. *Int. J. Mol. Sci.* **2019**, *20*, 401. [CrossRef]
15. International Organisation of Vine and Wine (OIV). *Compendium of International Methods of Wine and Must Analysis*; International Organisation of Vine and Wine (OIV): Paris, France, 2019.
16. Coelho, E.; Lemos, M.; Genisheva, Z.; Domingues, L.; Vilanova, M.; Oliveira, J.M. Simple and quick LLME/GC-MS methodology to quantify minor volatile compounds in alcoholic beverages. *Molecules* **2020**, *25*, 621. [CrossRef]
17. Keller, M.; Mills, L.J.; Harbertson, J.F. Rootstock effects on deficit-irrigated winegrapes in a dry climate: Vigor, yield formation, and fruit ripening. *Am. J. Enol. Vitic.* **2012**, *63*, 29–39. [CrossRef]
18. Jin, Z.X.; Sun, T.Y.; Sun, H.; Yue, Q.Y.; Yao, Y.X. Modifications of 'Summer Black' grape berry quality as affected by the different rootstocks. *Sci. Hortic* **2016**, *210*, 130–137. [CrossRef]
19. Catalogue of Vine Varieties and Clones Grown in France. Available online: https://plantgrape.plantnet-project.org/en/porte-greffes (accessed on 14 May 2020).

20. Wolpert, J.A.; Russell-Smart, D.; Anderson, M. Lower petiole potassium concentration at bloom in rootstocks with Vitis berlandieri genetic backgrounds. *Am. J. Enol. Vitic.* **2005**, *56*, 163–169.
21. Kodur, S.; Tisdall, J.M.; Clingeleffer, P.R.; Walker, R.R. Regulation of berry quality parameters in 'Shiraz' grapevines through rootstocks (*Vitis*). *Vitis* **2013**, *52*, 125–128.
22. Pulko, B.; Vršic, S.; Valdhuber, J. Influence of various rootstocks on the yield and grape composition of Sauvignon blanc. *Czech J. Food Sci.* **2012**, *30*, 467–473. [CrossRef]
23. Loureiro, M.D.; Moreno-Sanz, P.; García, A.; Fernández, O.; Fernández, N.; Suárez, B. Influence of rootstock on the performance of the Albarin Negro minority grapevine cultivar. *Sci. Hortic* **2016**, *201*, 145–152. [CrossRef]
24. Habran, A.; Commisso, M.; Helwi, P.; Hilbert, G.; Negri, S.; Ollat, N.; Gomès, E.; van Leeuwen, C.; Guzzo, F.; Delrot, S. Roostocks/scion/nitrogen interactions affect secondary metabolism in the grape berry. *Front. Plant Sci.* **2016**, *7*, 1134. [CrossRef]
25. Genisheva, Z.; Macedo, S.; Mussatto, S.I.; Teixeira, J.A.; Oliveira, J.M. Production of white wine by *Saccharomyces cerevisiae* immobilized on grape pomace. *J. Inst. Brew.* **2012**, *118*, 163–173. [CrossRef]
26. Vilanova, M.; Genisheva, Z.; Masa, A.; Oliveira, J.M. Correlation between volatile composition and sensory properties in Spanish Albariño wines. *Microchem. J.* **2010**, *95*, 240–246. [CrossRef]
27. Vilanova, M.; Genisheva, Z.; Tubio, M.; Álvarez, K.; Lissarrague, J.R.; Oliveira, J.M. Effect of vertical Shoot-Positioned, Scott-Henry, Geneva Double-Curtain, Arch-Cane, and Parral sraining Systems on the volatile composition of Albariño wines. *Molecules* **2017**, *22*, 1500. [CrossRef] [PubMed]
28. Clemente-Jimenez, J.M.; Mingorance-Cazorla, L.; Martínez-Rodríguez, S.; Las Heras-Vázquez, F.J.; Rodríguez-Vico, F. Molecular characterization and oenological properties of wine yeasts isolated during spontaneous fermentation of six varieties of grape must. *Food Microbiol.* **2004**, *21*, 149–155. [CrossRef]
29. Katarína, F.; Katarína, M.; Katarína, D.; Ivan, D.; Fedor, M. Influence of yeast strain on aromatic profile of Gewürztraminer wine. *LWT-Food Sci. Technol.* **2014**, *59*, 256–262.
30. Rapp, A.; Mandery, H. Wine aroma. *Experientia* **1986**, *42*, 873–884. [CrossRef]
31. Etievant, P. Wine. In *Volatile Compounds in Foods and Beverages*; Maarse, H., Ed.; Marcel Dekker: New York, NY, USA, 1991; pp. 483–546.
32. Ferreira, V.; Lopez, R.; Cacho, J. Quantitative determination of the odorants of young red wines from different grape varieties. *J. Sci. Food Agric.* **2000**, *80*, 1659–1667. [CrossRef]
33. Mateo, J.J.; Jiménez, J. Monoterpenes in grape juice and wines. *A Review. J. Chromatogr. A* **2000**, *881*, 557–567. [CrossRef]
34. Olarte-Mantilla, S.M.; Collins, C.; Iland, P.G.; Kidman, C.M.; Ristic, R.; Boss, P.K.; Jordans, C.; Bastian, S.E.P. Shiraz (*Vitis vinifera* L.) berry and wine sensory profiles and composition are modulated by rootstocks. *Am. J. Enol. Vitic.* **2018**, *69*, 32–44. [CrossRef]