MESOCLIMATE IMPACT ON ALBARIÑO cv. (*Vitis vinifera* L.) BERRY COMPOSITION IN THE EMERGING ATLANTIC WINEGROWING REGION OF URUGUAY IN THE CONTEXT OF CLIMATE CHANGE

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Abstract: Albariño is Uruguay's new encouraged white grapevine cultivar because of its final berry quality even under adverse climate conditions during the ripening period. This work aims to assess the effect of meso-climate on Albariño behavior. For this purpose, we installed a network of 10 temperature sensors in plots of a commercial vineyard in contrasting topographic situations. Bioindicators for grapevine were calculated, and relationships between site topography and plant response were analyzed using climatic and agronomic data for three growing seasons (2019, 2020, and 2021). Temporal climate variability between these three growing seasons was explained by rainfall, and spatial temperature variability was associated with plots topography. Plots in steeper slopes (8.8 to 11.6º) favored grapes with a higher acid content, while plots at lower elevations provided berries with higher amounts of secondary metabolites (phenols). This cultivar showed less difference in berry composition associated with climate than other cultivars such as Tannat (red cultivar).

Keywords: Climate variability, Oceanic wine region, Albariño, Topography, Uruguay.

Résumé : Impact du méso-climat sur la composition des baies d'Albariño cv. (Vitis vinifera L.) dans la région viticole atlantique émergente d'Uruguay dans un contexte du changement climatique. L'Albariño est le nouveau cépage blanc encouragé en Uruguay en vertu de la qualité finale de ses baies, même dans des conditions climatiques défavorables pendant la période de maturation. L'objectif de cette étude est d'évaluer l'effet du méso-climat sur le comportement de l'Albariño. À cette fin, un réseau de 10 capteurs de température a été installé dans des parcelles d'un vignoble commercial dans des situations topographiques contrastées. Des bioindicateurs pour la vigne ont été calculés et les relations entre la topographie du site et la réponse des plantes ont été analysées à l'aide de données climatiques et agronomiques pour trois saisons (2019, 2020 et 2021). La variabilité climatique temporelle entre ces trois cycles végétatifs a été expliquée par les précipitations et la variabilité spatiale des températures a été associée à la topographie des parcelles. Les parcelles situées dans des pentes plus fortes (8,8 à 11,6) ont favorisé une teneur plus élevée en acide dans les baies, tandis que les parcelles les plus basses ont fourni des baies avec des quantités plus élevées de métabolites secondaires (phénols). Ce cultivar a montré moins de différence dans la composition des baies associée au climat par rapport à d'autres cultivars comme le Tannat (cultivar rouge).

Mots clés : *Variabilité climatique, Région viticole océanique, Albariño, Topographie, Uruguay.*

Introduction

Albariño is Uruguay's new encouraged white grapevine cultivar because of its final berry good quality even under adverse climate conditions during the ripening period. This is important, considering that one of the impacts of climate change in the region is the increase in rainfall during the summer and autumn when the grapes ripen and are harvested. However, Albariño's adaptability to Uruguay climate conditions is unknown and needs investigation.

The objective of this work is to assess the effect of meso-climate (topography and distance to the Atlantic Ocean) on Albariño behavior in the emerging Atlantic wine region in Uruguay.

1. Study site, Data and Method

1.1 Study region and climate network in vineyards plots

The study was developed in a commercial vineyard in an emerging wine region on the Atlantic side of southeastern Uruguay (Garzón, located in the Maldonado Department) (Figure 1). The climate of the region was classified as temperate, with temperate nights and moderated drought, corresponding to the ISA$_1$IHA$_3$IFA$_2$, climatic group according to the "Multicriteria Climatic Classification" method for vineyards (Ferrer, 2007). The grape ripening period in southeastern Uruguay is characterized by temperate-high temperatures with an average temperature during the growing season of 18.9°C (Fourment *et al.*, 2020).

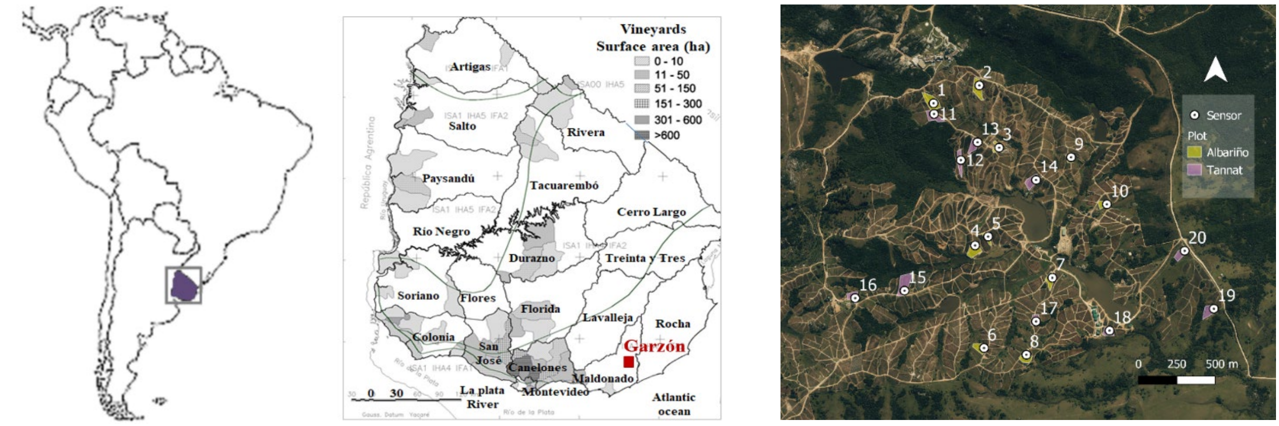

figure 1. Latin America (left) and Surface under vineyards in Uruguay with the location of the site in red (middle), the network of 10 Albariño plots in the commercial vineyard under different topography situations (described in Table 1) (right).

A network of 10 temperature sensors (Tinytag data loggers, Gemini, UK) were installed in plots of Albariño in contrasting topographic situations (Figure 1, right). For each geographical variable (altitude, slope, and aspect), a categorization was made based on the minimum and maximum reached by each parameter. The classes obtained for each plot according to these variables can be seen in table 1. We define aspect as the exposure of the plots.

Table 1. Geography features for the ten Albariño plots (Altitude, Slope and Aspect) and their categories.

Plot	Altitude (m)	Slope (º)	Aspect (º)	Altitude Category	Aspect Category	Slope Category
1	135	9,4	110	High	E	3
2	140	11,2	187	High	S	3
3	108	9,3	43	Medium	N	3
4	92	11	122	Low	E	3
5	92	11,6	160	Low	S	3
6	110	7,5	323	Medium	N	2
7	77	5,7	345	Low	N	1
8	106	5,5	135	Medium	S	1
9	96	7,9	128	Medium	E	2
10	88	4,4	172	Low	S	1

1.2 Climate analysis

Daily data were calculated from hourly data of temperature measured by temperature sensors (Tinytag data loggers, Gemini, UK) (Figure 1). Spatial and seasonal variability of temperatures were evaluated during the growing season (running from the 1st of September to the 15th of March) over 3 vintages (2018-2019, 2019-2020 and 2020-2021). The following bioclimatic indices for viticulture were calculated for each plot: Growing Degree Days (Winkler et al., 1974), Heliothermic Index (Huglin, 1978), Cool Night Index (Tonietto and Carbonneau, 2004), thermal amplitude during the ripening period (January and February) as well as the growing season average temperature.

The growing season climatic variables were used to study the grapevine response to seasonal climate variability. The climatic variables reached for each plot were used to evaluate spatial variability of temperature over the vintage.

1.3 Berry composition

Berry samples of Albariño grapes were collected at harvest following the recommendations of Carbonneau et al. (1991). For each plot, two double samples of 250 berries were collected. Grape berry composition was analyzed: sugar concentration (g/l) by refractometry, titratable acidity (g H_2SO_4/l) by tritation, pH by potentiometry, according to the O.I.V. protocol (1990). To analyze phenolic potential, such as phenolic richness of grapes, Glories and Agustin (1993) protocol was followed. All the measurements of phenolic potentials were carried out by duplication with a Shimadzu UV-1240 Mini (Shimadzu, Japan) spectrophotometer. Those variables are important to provide enology valorization of grape and improve vinification management (González-Néves et al., 2010).

1.4 Statistical analysis

A univariate procedure (ANOVA) was used to determine significant differences in climate and berry composition between plots (Tukey grouping; $\alpha = 5\%$), and a multivariate method (PCA) was performed to determine significant correlations between temperature and berry composition. The F value in the ANOVA procedure indicates the ratio between two means squares. The higher the F value, the more statistical significance or differences between samples are.

2. Results

2.1 Spatial variability of temperature

Within the analyzed temperature indices over the three growing seasons (2018-2019, 2019-2020 and 2020-2021) pooled together, the mean value of the CNI index was the only one to show significant statistical differences between plots (Table 2). However, correlations were founded when we analyzed differences in temperature grouping plots by altitude, slope, or aspect.

Table 2. Mean values of temperature of the growing season (T avg), Growing Degree Days (GDD), Thermal amplitude (TA), Cool Night Index (CNI) and Huglin Index (HI) from each plot, on average for the three studied growing seasons (2018-2019, 2019-2020 and 2020-2021).

Plot	Altitude Category	Aspect Category	Slope Category	T avg	GDD	TA*	CNI*	IH
1	High	E	3	19,17	1683,4	11,9	16,7	2176
2	High	S	3	19,26	1679,7	11,7	16,6	2173
3	Medium	N	3	19,33	1705,2	12,1	16,7	2203
4	Low	E	3	19,33	1700,8	12,8	16,3	2199
5	Low	S	3	19,32	1710,8	13,1	16,2	2213
6	Medium	N	2	19,44	1710,9	12,5	16,6	2220
7	Low	N	1	19,07	1632,8	13,7	15,4	2188
8	Medium	S	1	19,21	1679,4	12,0	16,5	2173
9	Medium	E	2	19,21	1689,5	12,2	16,4	2197
10	Low	S	1	19,02	1625,1	12,7	15,8	2159
			Average	***19,24***	***1681,8***	***12,5***	***16,3***	***2190***

* Statistical significance between plots (*p value <0.05*).

Altitude was the main feature that statistically differentiated the temperature of the different plots. The effect was observed on thermal amplitude (F value 3.92; p 0.03) and the Cool Night Index (F value 26.57; p <0.0001). Plots situated at the highest altitude (140 masl) reached 11.8 of TA, while plots situated mid-slope and at lower altitude (70 masl) reached the highest values (12.3 and 13.1, respectively). During summer, plots at lower positions showed the lowest CNI (15.94º minimal temperature in February) while the other plots (at medium and higher positions) showed CNI up to 16.57 ºC. The main factor conditioning this result was the slope exposure to sea breeze air circulation.

Aspect did not show statistical differences in temperature between plots, while slope showed significance only in minimal temperatures (CNI). Plots on slopes under 5.7º showed the minimum values of CNI compared with those at slopes up to 6º (15.91 and 16.51 ºC respectively).

2.2 Albariño berry composition at harvest and its relation to meso-climate

Albariño berry composition at harvest showed statistical differences in total acidity between plots, where plots 9 and 10 showed the lowest values (4.41 g/l) and plot 4 the highest (6.08 g/l) on average when the three 2019, 2020 and 2021 growing seasons are analyzed together. For the three studied seasons, the dates of harvest were 19th February in 2019, 14th February in 2020 and 16th February in 2021. Despite the difference in days due to climate variability between years, it was observed that the grapes ripen 5 to 8 days later than in the southern region of Uruguay (data not shown).

For the Uruguayan conditions, the final acidity of white cultivars such as Albariño is essential to obtain balanced wines. Compared to the origin region of this cultivar (Galicia, Spain), southeastern uruguayan Albariño is harvested with lower values of this content (5.2 on average compared with 6.2) (Cancela *et al.*, 2016).

Table 3. Mean values of Total Acidity (TA; g/l), Sugar content (SC; g/l), pH and Phenol Richness (PR) from each plot, on average for the three studied growing seasons (2018-2019, 2019-2020 and 2020-2021).

Plot	TA	SC	pH	PR
1	5.2	216	3.2	30.6
2	5.9	209	3.1	29.8
3	5.3	216	3.2	27.3
4	6.1	213	3.1	29.3
5	5.6	213	3.1	32.3
6	5.2	220	3.2	29.0
7	4.9	215	3.2	32.4
8	5.4	215	3.2	29.2
9	4.4	228	3.2	33.9
10	4.4	214	3.1	31.8
Average	***5.2***	***216***	***3.2***	***30.6***

Principal components analysis showed that elevation and slope were the variables that could influence final berry composition at harvest (Figure 2). Plots situated on greater slopes (8.8 to 11.6º) favored grapes with higher acid content (5.62 g/l), while those situated at lower elevations provided berries with higher amounts of secondary metabolites (phenols) (29.8 PR).

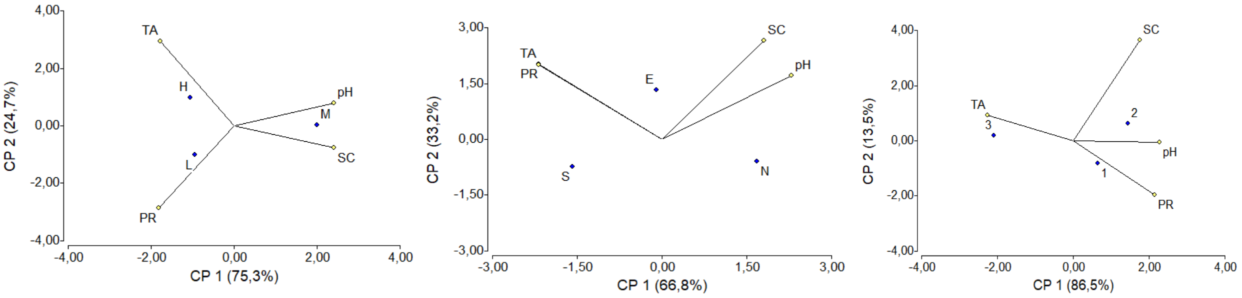

figure 2. Principal Components Analysis (PCA) of Albariño berry composition (Total acidity - TA, pH, Sugar content - SC and Phenol Richness - PR) and geographic features (altitude in the left, exposition at the middle and slope at the right).

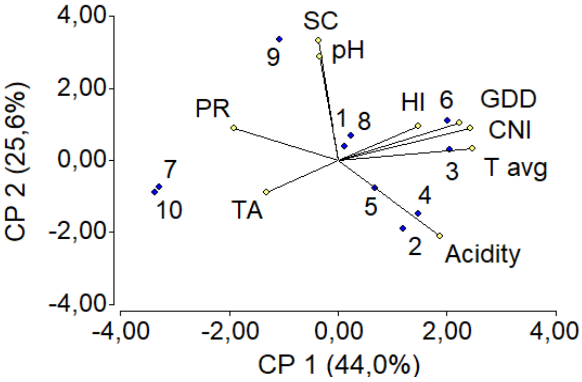

figure 3. Principal Components Analysis (PCA) of Albariño berry composition (Total acidity – Acidity, pH, Sugar content - SC and Phenol Richness - PR) and temperature indices (Huglin index – HI, Growing Degree Days – GDD, Cool Night Index – CNI, Temperature during the growing season – T avg and Thermal Amplitude – TA).

The correlations between climate and berry composition between plots represent 69.6% of the total variability. From Figure 3, it can be concluded that Plots 2 and 4 were associated with the acidity factor and plot 9 with pH and Sugar content, while other plots, especially 6 and 3, were strongly associated with temperature. This cultivar showed less difference in berry composition associated with climate than a red cultivar such as Tannat (Tachini et al., 2022).

Conclusion

Spatial climate variability experienced in this region is strongly influenced by altitude as well as the slope aspect of the plots. Berry composition of Albariño is affected by plots altitude and slope as seen for differences found in acidity and phenols at harvest.

These results quantify the cultivar sensitivity to climate and, therefore, its adaptability to local growing conditions. Albariño shows good agronomic performance and grape quality for making fine wines in the eastern region of Uruguay. However, further research is needed to provide sustainable Albariño management measures for Uruguay.

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