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PHENOLOGY RESPONSES OF GRAPEVINE CULTIVARS TO CLIMATE VARIABILITY IN A COASTAL REGION OF URUGUAY

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Summary: *Surface under vineyards are multiplying in the coastal region of eastern Uruguay and agroclimatic studies are being carried out in a commercial vineyard in the department of Maldonado. It aims at developing knowledge on climate of the new region compared to the traditional wine region of Uruguay and on the grapevine phenological responses to interannual climatic variability. Tannat and Albariño cultivars were monitored and climatic data were analysed during the 2012-2018 period. Results showed this coastal region is cooler than the traditional winegrowing region of the country. Rainfall over the growing season did not show significant differences, but the number of rainy days was statistically higher in Maldonado. Albariño and Tannat showed differences in its phenological cycle during the six years of study. Both cultivars showed sensitivity to climate conditions.*

Key words: *climate variability; viticulture; Tannat; Albariño; coastal region; Uruguay*

Résumé : *Réponses phénologiques de la vigne à la variabilité climatique dans une région côtière de l'Uruguay. Les surfaces en vigne se multiplient dans la région côtière de l'est de l'Uruguay et des études agroclimatiques sont menées dans un vignoble commercial du département de Maldonado. Elles visent à développer les connaissances sur le climat de la région par rapport à la région viticole traditionnelle de l'Uruguay et sur les réponses phénologiques de la vigne à la variabilité climatique interannuelle. Les données phénologiques des cépages Tannat et Albariño et les données climatiques ont été analysées au cours de la période 2012-2018. Les résultats ont montré que cette région côtière est plus fraîche que la région viticole traditionnelle du pays. Les précipitations pendant la période végétative n'ont pas montré de différences significatives, mais le nombre de jours de pluie est statistiquement plus élevé à Maldonado. Albariño et Tannat ont montré des différences phénologiques au cours des six années d'étude. Les deux cépages ont montré de sensibilité aux conditions climatiques.*

Mots clés : *variabilité climatique ; viticulture ; Tannat ; Albariño ; Région côtière ; Uruguay*

Introduction

The main winegrowing region of Uruguay is the Canelones department around Montevideo (INAVI, 2020), yet vineyards are increasingly planted nowadays to the East of the country such as in the coastal department of Maldonado and very little is known on climate for viticulture in this emerging winegrowing region of Uruguay. In parallel, the knowledge of the phenological behavior in different wine-growing regions is a tool that helps to adaptation of the viticultural practices to climate variability and climate change. Phenology concerns the timing of specific states of grapevine growth and development in the annual cycle. The timing and duration of these phases are influenced mainly by air temperature (Jones *et al.*, 2000; Keller, 2010), as well as by different cultivation practices (Jones *et al.*, 2000). The winegrowers, who are aware of local climate variability, take into account the phenological stages of the crop cycle to manage cultural practices such as the timing of pruning, thinning of bunches or applications of plant protection products. In addition to temperature, physiological relationships play a predominant role in the phenological behaviour of the vine. Barbeau (2008) reports a delay in phenology (veraison and ripening), when vine vigour is excessive, and conversely, a certain precocity when plant vigour is moderate to weak, due to greater photosynthetic efficiency and better source-sink ratio. In the same way, Sadras and Moran (2013) study the relationships between temperature and phenology when the vine is subjected to different temperature treatments (direct measures of effects), and establish an interaction between plant growth and development. The effect of a temperature increase on the ripening of the grape, for example, varies according to its source-sink relationship.

The aim of this work is then to assess the climate of the emerging winegrowing region of Maldonado compared to that of the traditional winegrowing region of Uruguay and to evaluate the phenology of Tannat and Albariño grapes, the two emblematic grape varieties of Uruguay, in relation to seasonal climate variability.

1. Study site, Data and Method

1.1. Study region

Two winegrowing regions of Uruguay were studied: the area of Juanicó situated in the Canelones Department within the traditional winegrowing region near the Rio de la Plata estuary south of Uruguay and the area of Garzón located in the Maldonado Department, an emerging wine region on the Atlantic side of southeastern Uruguay (Fig.1).

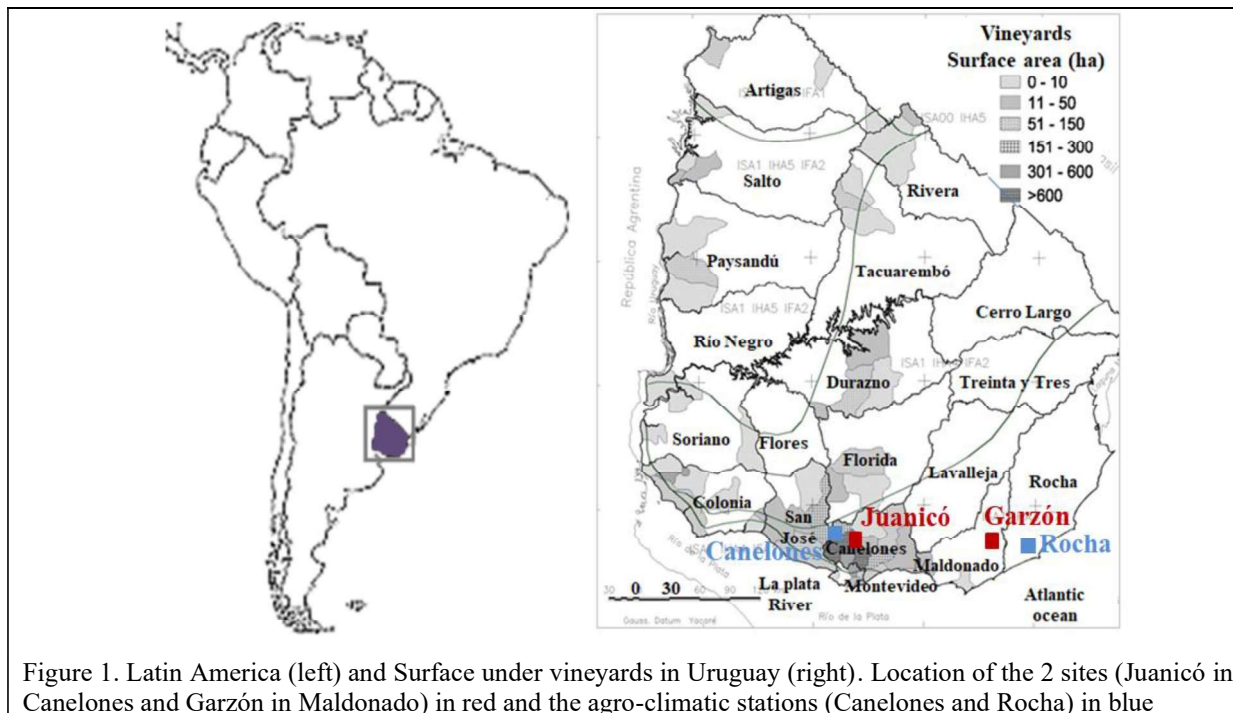


Figure 1. Latin America (left) and Surface under vineyards in Uruguay (right). Location of the 2 sites (Juanicó in Canelones and Garzón in Maldonado) in red and the agro-climatic stations (Canelones and Rocha) in blue

1.2. Climate analysis

Daily data of temperature and precipitation were obtained from the Canelones and Rocha agro-climatic stations (Fig.1). Canelones is the station of the National Research Institute (INIA) and the Rocha weather station belongs to the Meteorology National Institute (INUMET) network, both in accordance with the World Meteorological Organization (WMO) standards. Spatial and seasonal variability of temperatures and precipitations were evaluated during the growing seasons (from the 1st of September to the 15th March) over the 6 years starting from the 2012-2013 vintage to the 2017-2018 vintage. The following bioclimatic indices for viticulture were calculated: Growing Degree Days (Winkler *et al.*, 1974), Heliothermic Index (Huglin, 1978), Cool Night Index (Tonietto and Carbonnau, 2004) as well as the growing season (1st September to 15th March) average temperature, total rainfall and number of rainy days using different thresholds (between 0.1 and 5 mm ; between 5 and 15 mm and greater than 15 mm). The 6-year average was used to assess the climate of the emerging winegrowing region (Rocha) compared to that of the traditional winegrowing region (Canelones). The yearly climatic variables were used to study the grapevine response to seasonal climate variability.

ANOVA statistical test was performed to identify significant differences between the regions and the seasons (Tukey grouping; $\alpha = 0.05$).

1.3. Phenology data

Two commercial plots, one planted with Tannat and the other one with Albariño in Garzón (Maldonado Department) were selected for the monitoring of 4 key-phenological stages (Coombe, 1995). Dates of flowering, fruit set, bunch closure and veraison were notified after monitoring of 100 shoots per plot during six consecutive growing seasons (2012 to 2018). The growing degree-day - summation of mean temperature above 10°C (GDD) was calculated for each phenological stage in order to determine the sensitivity of the cultivars.

2. Results

2.1. Spatial climate variability between the emerging and the traditional wine regions

Significant climate differences between the emerging and the traditional wine regions of Uruguay were found. In terms of thermal conditions, the emerging winegrowing region (Rocha) is cooler than the traditional winegrowing region (Canelones). The bioclimatic Huglin index commonly used to assess the climatic potential of a region for viticulture reached the value of 2080 on average over the 6 years in Rocha. This corresponds to the “warm temperate climate” class and the average temperature during the growing season was 18.9°C. This is respectively 149 and 0.7°C lower than in Canelones (Tab.1). This is due to the proximity of the Atlantic Ocean and its moderating effect on temperature as well as the possible higher frequency of sea-breeze circulation during warm summer days preventing temperature to increase too much during the day (Tachini *et al.*, 2020).

Table 1. Climate variables for Rocha and Canelones averaged for the growing seasons of the 2012-2018 period. T= Average temperature during the growing season, GDD= Growing Degrees Day, HI= Heliothermal Index, CNI= Cool Night Index; PP = total rainfall (mm), DR = Number of days with rain >0,1mm, DR 5 = number of days with less than 5 mm of rain, DR 5-15 = Number of days with rain between 5 and 15 mm, DR 15+ = Number of days with rain greater than 15 mm. (*) represents statistical significance between regions ($\alpha=0.05$)

Climate variables	Rocha	Canelones	Difference
T *	18.9	19.6	-0.7
GDD *	1753	1860	-107
HI *	2080	2229	-149
CNI	16.8	17.4	-0.6
PP	760	744	+16
RD *	79.0	54.0	+25
RD 5 *	49.3	26.3	+23
RD 5-15	12.0	11.3	+0.7
RD 15+	17.7	16.3	+1.4

With respect to rainfall the amount for the growing season reached an average of 760 mm, which does not differ significantly from Canelones conditions (+16 mm only). However, a significant difference was found in the number of rainy days, higher in Rocha than in Canelones (79 and 54 days, respectively). This means the emerging wine region experienced 43% of its time over the growing season under rainy conditions against 29% in Canelones, especially low intensity rainfall (<5mm) associated with the impact of the Atlantic Ocean on the region's cloudiness. This may hinder the functioning of grapevine physiology and in turn impact on the berry typicity.

2.2. Seasonal climate variability and grapevine phenology responses in the emerging winegrowing region

With respect to climate, the Rocha station, close to the Garzón vineyards, showed a seasonal climate variability that could have conditioned the development and growth of the vine (Tab.2). With 1156 mm the 2013-2014 season was the most humid season. It received 396 mm more

than the 6-year average, while the 2015-2016 season was the coolest and least humid with -0.6°C and 318 mm less than the 6-year average, yet the number of rainy days was close to average.

Table 2. Climate variables for Maldonado (Rocha station) for the 2012-2018 growing seasons. T= Average temperature during the growing season, GDD= Growing Degrees Day base 10, HI= Heliothermal Index, CNI= Cool Night Index, PP = Precipitation during the cycle (mm), DR = Days with rain, DR 5 = Days with rain less than 5 mm, DR 5-15 = Days with rain between 5 and 15 mm, DR 15+ = Days with rain greater than 15 mm

<i>climate variables</i>	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	Average
T	19.0	19.1	19.4	18.3	18.9	18.8	18.9
GDD	1786	1805	1858	1603	1734	1733	1753
HI	2125	2115	2130	1954	2045	2110	2080
CNI	16.4	18.5	15.8	16.8	19.2	14.4	16.8
PP	857	1156	851	442	725	532	760
DR	83	91	66	78	81	75	79.0
DR 5	56	49	34	59	45	53	49.3
DR 5-15	8	14	13	9	18	10	12.0
DR 15+	19	28	19	10	18	12	17.7

In parallel, with respect to phenology phases, the Tannat and Albariño cultivars showed similar characteristics over the 6-year period. Early stages were recorded during the years 2014-2015 and 2017-2018 for both cultivars; while late stages were recorded during the 2015-2016 season (Fig.2).

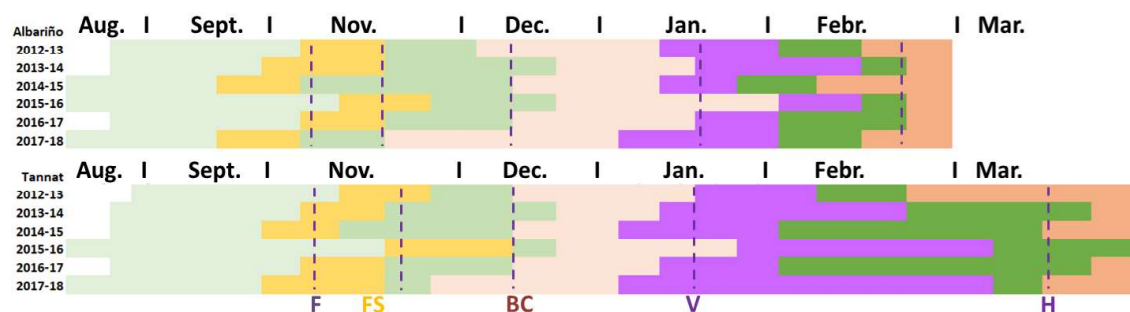


Figure 2. Phenological stages during 6 growing seasons for Albariño (top) and Tannat (bottom) cultivars at Maldonado. Where F = Flowering, FS = Fruit set, BC = Bunch closure, V = veraison and H = Harvest

The harvest of Albariño took place on average around February 25 in Garzón because it was decided on the basis of its primary components for quality wine independently whether technological maturity was reached. On the other hand, the harvest of Tannat in this region took place between March 20 and April 4 for years with suitable climate conditions (i.e. moderate temperatures and dry conditions) that allowed a late harvest enabling to reach technical maturity.

Temporal differences in two phenological stages, flowering and veraison from both Tannat and Albariño are shown in Figure 3. During the cool conditions of 2015-2016, both cultivars showed up to 11 days of delay in flowering and véraison compared to the warmer conditions (2012-2013 et 2014-2015).

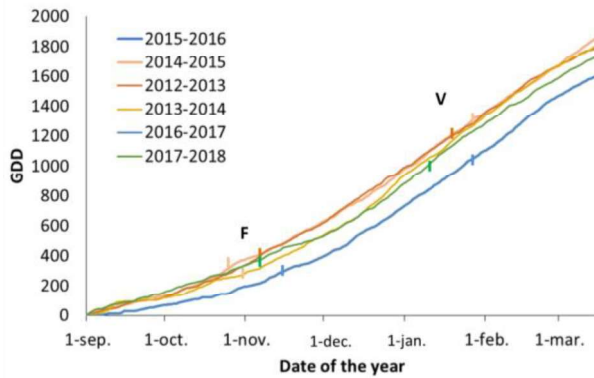


Figure 3. Growing Degree Days (GDD) evolution and temporal representation of Flowering (F) and Veraison (V) during the 6 studied seasons at Maldonado

The analyze of the differences in phenological responses of Albariño and Tannat during two contrasting seasonal climate conditions showed that the greatest differences were obtained between the 2014-2015 and 2015-2016 cycles for Albariño and between the 2012-2013 and 2017-2018 cycles for Tannat.

For Albariño an advance of 12.3 days on average for the flowering, bunch closure and veraison stages were recorded for the 2014-2015 season compared to that of 2015-2016. The greatest difference in the evolution of the stages was observed between flowering and bunch closure (Fig.4 left). Climate conditions during those phonological stages in 2014-2015 showed to be significantly different compared to 2015-2016 (difference of 2.2 ° in the average temperature and 161 mm more rain in the earliest season).

For Tannat, Figure 2 (right) shows the delay over the final phases of the most recent season, causing a delay in the harvest date (Fig.4 right). This is relevant, as for this red cultivar, a change in the speed of the phenological processes may cause an earlier or later harvest, an effect that is not affected in Albariño, a white cultivar that is harvested without the criteria of reaching technological maturity.

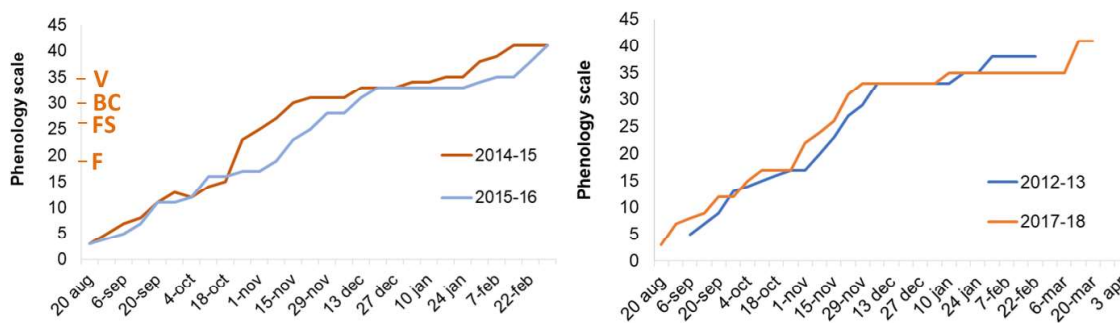


Figure 4. Phenology scale evolution of Albariño (left) and Tannat (right) during two years of contrasting thermal accumulation. Phenology scale is according to Coombe (1995)

For Albariño, the years that showed the greatest phenological mismatch are not associated with the years with greater or lesser final thermal accumulation. For example, the cycle 2014-2015 that presented precocity in the development of the states, was not the year that presented greater thermal accumulation during the states but temperatures and rainfall were higher than a contrasting season, as we showed before.

On the contrary, the precocity in Tannat phenology was associated with greater heat accumulation. This means that in this emerging winegrowing region of Uruguay, Tannat shows greater sensitivity to temperature, unlike what Fourment *et al.* (2020) found in the traditional wine region of southern Uruguay.

Conclusions and Discussion

The comparison between an emerging and the traditional wine region of Uruguay under different agro-climatic conditions contributes to the knowledge of the environmental conditions in which the cultivation of the grapevine takes place. The thermal and water conditions in the south and east of Uruguay showed differences. Within the emerging winegrowing region of Maldonado, the sensitivity of a white and a red cultivar to temperature was evaluated through phenology monitoring. Both studied cultivars, the white grape cultivar Albariño and red grape cultivar Tannat, showed sensitivity to climate, with greater or lesser precocity depending on heat accumulation and precipitations reached through the season.

These results may be of interest to provide sustainable management measures in a context of climate change. Grape typicity at harvest and the interannual behaviour of the crop as a function of the climate need to be further investigated.

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