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PROJECTIONS OF VINE PHENOLOGY AND GRAPE COMPOSITION OF TEMPRANILLO VARIETY IN RIOJA DOCA (SPAIN) UNDER CLIMATE CHANGE

María Concepción Ramos[1]*, Fernando Martínez de Toda[2]

[1]Department of Environment and Soil Sciences-Agrotecnio, University of Lleida, Spain
[2]ICVV- Institute of Grapevine and Wine Science (University of La Rioja, CSIC, Government of La Rioja), Logroño, Spain

*Corresponding author: cramos@macs.udl.es

Abstract

Aims: Some of the most direct effects of climate variability on grapevines are the changes in the onset and timing of phenological events and in the length of the growing season, which may affect grape quality. The aim of this research was to analyze the projected changes in vine phenology and on grape composition of the Tempranillo variety in Rioja DOCa under different climate change scenarios.

Methods and Results: Three zones of Rioja DOCa, located at different elevations and with different climatic conditions were compared. For the analysis, vine phenology referred to flowers separated and veraison (stage H and M, according to Baillod and Baggiolini) and maturity defined based on the date at which 13° were reached, were analysed in the three zones for the period between 2008 and 2018. Grape composition at maturity, including variables related to acidity and polyphenol content was also evaluated for the same period. The weather characteristics for the places where the plots were located were also analysed using data of different meteorological stations belonging to the Rioja government. The thermal requirements to reach each phenological stage were evaluated and expressed as the GDD accumulated from DOI=60, which were considered to predict the changes under future climatic conditions. The analysis was done for the future conditions predicted by 2050 and 2070 under two Representative Concentration Pathway (RCP) scenarios –RCP4.5 and RCP8.5-, which were simulated based on an ensemble of 10 models.
An advance of the phenological stages was predicted, higher for veraison and maturity than for floraison. The advance of the stage H, M and maturity for the three zones by 2050 could be up to 5, 8, and 12 days, respectively under the RCP4.5 emission trajectory, and up to 8, 12 and 15, respectively under the RCP8.5 emission trajectory. The predicted advances indicate that the differences in timing that already exists between zones will be maintained or even increase, which will imply reaching maturity in the second half of August in the warmer area and in earlier September in the coolest one. Grape acidity could suffer a decrease with increasing temperature, while anthocyanins could decrease by the increase of temperature but increase due to the higher expected water deficit, and these changes could differ among zones. In addition, due to the advance in the phenology a decoupling between anthocyanins and sugars could result, which suggest the need of applying new management techniques to maintain grape quality.

Conclusion: The Tempranillo variety cultivated in Rioja DO may suffer significant changes in phenology and in grape composition under climate change, affected both by increasing temperatures and higher water deficits. However, differences were found between zones within the Rioja DOCa.

Significance and Impact of the Study: The study allowed quantifying the differences in the impact that climate change may produce in phenology and in grape composition in zones with different climatic conditions, which may be taken under consideration to identify potential areas in which the Tempranillo variety may suffer lower impacts under climate change.

Keywords: Acidity, anthocyanins, berry weight, polyphenols, soil characteristics, available water content

Introduction

Among the different elements of terroir affecting vine development and berry composition, climate plays an important role (van Leeuwen *et al.,* 2004). Each cultivar is usually well adapted to a given range of temperature, which may be considered as one of the main drivers of the evolution of the growing cycle, of the final maturity and of the final grape quality (Sadras *et al.,* 2007). In different viticultural areas around the world, changes in phenology have been detected and associated to an increase in temperature (Petrie and Sadras, 2008; Webb *et al.,* 2011; Ruml *et al.,* 2015; Koufos *et al.,* 2014; Malheiro *et al.,* 2013), which could increase under climate change scenarios. The effect of increasing temperatures may vary between zones and cultivars, and may particularly affect the varieties with earlier phenological timing. Ripening will occur under warmer conditions with negative effects on the final quality of the grapes. This research focused on the Tempranillo variety, a variety with early maturity. The study was carried out in Rioja Designation of Origin (Rioja DOCa), comparing the vine response in three zones located at different elevations and with different climatic characteristics. The vine response (phenology and grape composition) in those zones at present were analysed in relation to the climatic conditions and the potential changes under climate changes were projected.

Material and Methods

Three zones were selected within the Rioja DOCa, which were located at about 350m (in Rioja Oriental, RO), 450 m and 650 m a.s.l (in Rioja Alta, RA) (Figure 1). Vines were bush trained and cultivated under rainfed conditions. Vine information, key phenological dates (flowers separated, veraison and maturity) and grape composition and maturity (titratable acidity, malic acid, total anthocyanins, total polyphenol index and color intensity) for the period 2008-2018, were analysed. This information was supplied by the Consejo Regulador of Rioja DOCa and included information on two vineyards in each zone. Soil surface characteristics (soil organic carbon, soil particle distribution and soil water retention capacity) of the selected plots were taken from the European Soil data base (ESDAC). The organic carbon contents were relative low (0.60 -1.53%); clay, silt and sand contents ranged between 21.1 and 29.7%; 38.4 and 49.6% and 27.9 and 39.4%, respectively. The maximum water holding capacity of the soils ranged between 145 and 176mm. The weather conditions (temperature, precipitation and potential evapotranspiration at daily scale) recorded during the study period (2008-2018) were obtained from weather stations located near the vineyards (in Alfaro, Aldeanueva de Ebro, Haro, Uruñuela and Villar de Torre), which belong to La Rioja Government. The data were averaged for the growing season and for periods between phenological events. Water deficits were quantified as accumulated precipitation minus crop evapotranspiration recorded in each period. All these variables were used to analyse the effect of climate on grape composition, using a multiple regression analysis. The climate conditions under two climate change scenarios RCP4.5 and RCP8.5 (by 2050 and 2070) were simulated with an ensemble of 10 models using the MarkSim weather file generator. Based on the thermal requirements observed at present to reach each phenological stage, and following the process described in Ramos and Martínez de Toda (2020), changes in phenology were projected for the three selected zones.

Results and Discussion

Weather Conditions: Present and Future

The average climatic conditions recorded during the growing season (April-October) in the period under study are shown in Table 1. Differences in temperature between zones within RA higher than 1°C were observed and also between the warmer area in RA and RO. In addition, high variability was recorded from year to year. Regarding precipitation, there were also differences in the total amount recorded among zones. However, the most remarkable result was the high variability from year to year and that the precipitation recorded during the growing season represented less than 50% of the annual rainfall. Under future climate scenarios, an increase in temperature and a decrease in precipitation are predicted, with differences between the analysed zones. Under the RCP4.5 emission scenario, the increase in maximum temperature in the summer months could be of up to 3.2°C and 2.4°C in the warmer and cooler zones, respectively. For Tmin, the increase could be up to 2.5 and 2.3°C in the summer month and up to 1.2 and 1.4°C in winter, respectively in RO and in the cooler area of RA (RA2). Under the RCP8.5 scenario, the increase in Tmax could be of up to 4°C while the Tmin could increase up to 3°C in the warmers months. In addition, a decrease in precipitation during the growing season is predicted, which may vary depending on the scenario between 10 % in RA2 and 30% in RO. Under the RCP8.5 scenario the decrease could be up to 40%.

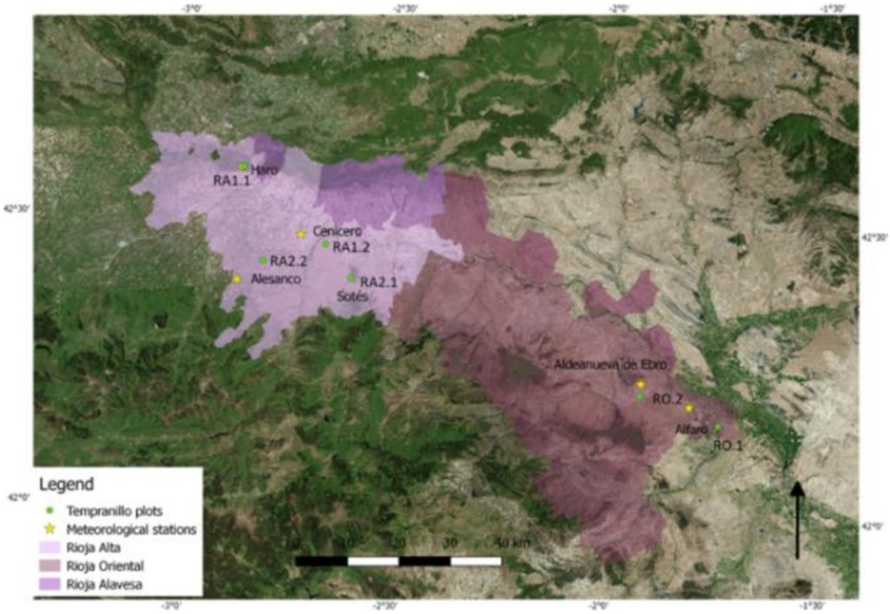

Figure 1: Location of the plots and meteorological stations used in this research.

Table 1: Average (±std) maximum, minimum and mean temperature and precipitation recorded in the growing season during the period 2008-2018 in the three selected zones (RO, RA1, and RA2) in Rioja DOCa.

zone	Elev a.s.l. (m)	TmaxGS (°C)	TminGS (°C)	TmGS (°C)	PGS (mm)
RA1	450-465	24.5±1.0	11.4±0.5	17.2±0.6	188±87
RA2	635-650	22.3±0.8	10.0±0.4	15.6±0.5	279±92
RO	325-296	25.9±0.9	12.2±0.6	18.7±0.7	217±70

Phenology

During the analysis period, differences in phenology were observed among years, in agreement with the variability of the climatic conditions recorded, and also among the three zones considered in this research (Table 2). The date at which the H stage was reached ranged between 12th May and 2nd June in RO, between 23rd May and 8th June in RA1, and between 26th May and 14th June in RA2. The differences between RA1 and RA2 in the average phenological date of the stage H were of 4 days while in RO that stage was reached, on average, 6 days before than in RA1. The later dates were recorded in the wettest and coolest years (e.g. 2008 and 2013), while the earliest dates were found under the direst conditions (2009 or 2015, with scarce precipitation during the growing season).

Table 2: Average phenological dates recorded in the three zones during the study period (2008-2018).

	Stage H	Stage M	Mat
RA1	27-May±4days	12-Aug±9 days	26-Sep±8 days
RA2	31-May±6days	17-Augo±6 days	4-Oct±8 days
RO	21-May±7days	3-Aug±8 days	13-Sep±7 days

Grape Composition

Table 3 shows the average values of the grape composition analysed during the period under study in the three zones. The highest acidity values were always found in the cooler zone, located at higher elevation (RA2). The regression analysis showed that acidity was mainly driven by maximum temperature and it was found a decrease of total acidity of 0.33, 0.42 and 0.73 g L^{-1}, respectively in RO, RA1 and RA2 per an increase of 1°C in the TmaxGS. Similarly, the malic acid concentration decreased 0.63, 0.75 and 0.4 g L^{-1}, respectively in RO, RA1 and RA2 per an increase of 1°C in TmaxGS. Total anthocyanins were also correlated to TmaxGS, being observed that they decreased 36 and 20 g L^{-1} for an increase of 1°C in TmaxGS, respectively in RA1 and RA2. It was also found that color was also affected by changes in temperature, as color intensity decreases with TmaxGS 0.6 and 0.75 units per 1°C increase of the TmaxGS, respectively in RA1 and in RA2. In RO, the change of anthocyanin with temperature was not calculated due to the fact that anthocyanins fitted with accumulated GDD. Maturity will be reached earlier, which may result in an imbalance with other grape parameters. In addition, total anthocyanin concentration increased with water deficits. The increase was of about 32.7, 18 y 13 g L^{-1} respectively in RA2, RO and RA1, per 100 mm water deficit.

Predicted Changes in Phenology and on Grape Composition

Under the projected changes in temperature, and based on the thermal requirements needed to reach the different phenological stages, evaluated at present, an advance of all stages is projected. The expected advance is higher for veraison and maturity than for the previous stage. Under the RCP4.5 scenario, the stage H (flowers separated) would occur in mid-May in RO and in the first third part of May in RA, while veraison would occur at the end of July in RO and at the beginning of August in RA, and maturity can take place, by 2070, up to 12 days before in RO under the emission scenario RCP4.5 and up to 22 days before under the emission scenario RCP8.5. The predicted advances are shown in Table 4. Regarding grape composition, based on the predicted changes in temperature and precipitation for future scenarios and the observed relationships between acidity and anthocyanins with climate, significant changes in grape composition could occur (Table 4). The results offer a first analysis of the possibilities that the areas located at higher elevation offer to maintain grape quality under changes in climatic conditions produced by climate change.

Table 3: Average values of the grape composition parameters (total acidity (AcT); malic acid (AcM), total anthocyanins (AntT); total polyphenol index (TPI), color index (CI) reached in the three selected zones (RA1 RA2 and RO) at ripening.

	AcT (gL^{-1})	Ac M (gL^{-1})	AntT (mgL^{-1})	TPI	CI
RA1	5.7±0.5	3.5±0.4	454±98	36.7±4.9	10.8±0.7
RA2	6.7±0.8	4.4±0.4	483±29	32.2±2.8	11.7±1.1
RO	5.2±0.3	3.2±0.5	473±48	40.0±1.2	11.1±1.0

Table 4.: Projected advances of the stage H, the stage M and maturity and changes in grape composition for the three zones (RA1, RA2: and RO) under the RCP4.5 and RCP8.5 emission scenarios by 2050 and 2070.

Emission scenario		time	Advance of phenology (days)			Changes in grape composition based on changes of					
						Tmax				Water deficit	
			stage H	stage M	Mat	AcT (gL^{-1})	AcM (gL^{-1})	AntT (mgL^{-1})	TPI (units)	AntT (mgL^{-1})	TPI (units)
RA1	RCP4.5	2050	3	5	9	-1.1	-2.0	-97	4.0	76	5.4
		2070	5	8	12	-1.3	-2.3	-108	4.4	93	6.5
	RCP8.5	2050	7	10	14	-1.4	-2.6	-122	5.0	97	6.8
		2070	10	16	20	-1.8	-3.3	-158	6.5	117	8.3
RA2	RCP4.5	2050	5	6	12	-1.2	-0.6	-32	4.5	66	3.1
		2070	7	8	14	-2.0	-1.1	-56	7.8	78	3.7
	RCP8.5	2050	8	11	15	-2.4	-1.3	-66	9.2	38	3.4
		2070	12	16	21	-2.6	-1.4	-70	9.8	44	4.3
RO	RCP4.5	2050	5	8	10	-0.9	-1.8	-	9.0	40	2,1
		2070	9	10	12	-1.1	-2.0	-	10.2	40	2.2
	RCP8.5	2050	8	12	15	-1.2	-2.2	-	11.2	72	2.9
		2070	12	17	22	-1.7	-3.2	-	16.0	92	2.8

References

Koufos, G., Mavromatis, T., Koundouras, S., Fyllas, NM., Jones, GV., 2014. Viticulture-climate relationships in Greece: the impacts of recent climate trends on harvest date variation. International Journal of Climatology, 34: 1445–1459.

Malheiro, AC., Campos, R., Fraga, H., Eiras-Dias, J., Silvestre, J., Santos, JA., 2013. Winegrape phenology and temperature relationships in the Lisbon wine region, Portugal. Journal International des Sciences de la Vigne et du Vin, 47: 287–299.

Petrie, PR., Sadras, VO., 2008. Advancement of grapevine maturity in Australia between 1993 and 2006: putative causes, magnitude of trends and viticultural consequences. Australian Journal of Grape and Wine Research, 14: 33–45.

Ramos, MC., Martínez de Toda, F., 2020. Variability in the potential effects of climate change on phenology and on grape composition of Tempranillo in the Rioja DOCa (Spain). European Journal of Agronomy,115.

van Leeuwen, C., Friant, P., Choné, X., Tregoat, O., Koundouras, S., Dubourdieu, D., 2004. Influence of climate, soil, and cultivar on terroir. American Journal of Enology and Viticulture, 55: 207-217.

Webb, LB., Whetton, PH., Barlow, EWR., 2011. Observed trends in winegrape maturity in Australia. Global Change Biology, 17: 2707-2719.