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SPATIAL VARIABILITY OF TEMPERATURE AND GRAPE BERRY COMPOSITION AT TERROIR SCALE IN URUGUAY

VARIABILITÉ SPATIALE DE LA TÉMPERATURE ET COMPOSITION DU RAISIN À L'ÉCHELLE DU TERROIR EN URUGUAY

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ABSTRACT

The knowledge of wine region diversity requires fine scale assessment of climate, soil and management conditions. Climate conditions of coastal wine regions vary according to the distance to the sea and topography. These different terroir conditions play an important role in the grapevine behaviour as well as in the composition of grape berry and wine. The aim of this work was to study spatial temperature variability in relation to the grape berry composition of Tannat at harvest, in southern Uruguay. Temperature sensors were installed in commercial vineyards of Tannat in the most important wine region of the country. Different distances to the La Plata River estuary, soils diversity and topography were taken into account. Temperature data obtained from ten plots in summer 2012 was analyzed and related to grape berry composition (sugar concentration, titratable acidity, pH, total and extractable anthocyanins potentials and phenolic richness). Results showed significant differences in spatial temperature highlighting the moderating effect of the estuary on temperature. Daily thermal amplitude increased with distance from the river. Plots situated in valleys had similar behavior than those situated away from the river, due to faster heat gain and loss. In the other hand, plots near the river showed lower differences in temperature, during the season and during the day. Grape berry composition showed a significant variablity that could be associated with the plot location. Adjacent plots situated in valleys showed significant differences in sugar concentration and titratable acidity, while their secondary metabolites were similar. It suggests for this year of study, that topography conditions could have had greater effects on sugar and acid than on polyphenol levels. The increasing knowledge of temperature spatial variability and its relation with grape berry composition contributes to improving canopy management during ripening period.

RÉSUMÉ

La connaisance de la diversité d'une région viticole nécessite l'évaluation du climat, du sol et des conditions de production du vignoble à une échelle fine. Les conditions climatiques dans une région viticole côtière varient en fonction de la distance de la mer et la topographie. Ces différents terroirs jouent un rôle très important sur le comportement de la vigne, la composition de la baie et du vin. L'objectif de ce travail a été d'étudier la variabilité spatiale de la température en relation à la composition finale de la baie du Tannat à récolte, dans la région sud de l'Uruguay. Des capteurs de température ont été installés dans dix vignobles commerciaux de la plus importante région viticole du pays. Des différentes distances à l'estuaire du Río de La Plata, la diversité des sols et la topographie ont été pris en compte. Les données de température obtenues par les dix capteurs pendant l'été 2012 ont été confrontées avec la composition finale de la baie à la récolte (sucre, acidité totale, pH, potentiels en anthocyanes totales et extractibles et richesse en polyphénols). Les résultats ont montré une forte variabilité spatiale de la température soulignant l'effet modérateur de l'estuaire sur les températures. L'amplitude therrmique journalière augmente sur les parcelles plus eloignées du Río de La Plata. Les parcelles installées en bas de coteaux ont eu un comportement similaire à celui des parcelles éloignées de l'estuaire, en raison de rapides perte/gain de chaleur. Les parcelles près de la mer ont montré de faibles différences en température, au cours de la saison et dans la journée. La composition de la baie indique une forte variabilité qui peut être associée à la localisation des parcelles. Les parcelles adjacentes installées dans differéntes situations topographiques ont montré des différences significatives en termes de sucre et acidité totale, mais pas de métabolites secondaires. Cela nous suggère pour cette année d'étude, que la topographie a eu un effet plus important sur la composition en métabolites primaires qu'en secondaires. La connaisance de la variabilité spatiale de la température et de sa relation avec la compositon de la baie contribue à améliorer la gestion de la canopée pendant la maturation de la baie.

Key Words: Temperature Variability, Berry Composition, Tannat, Meso-climate

Mots –Clés: Variabilité de la Température, Composition de la Baie, Tannat, Méso-climat

INTRODUCTION

The knowledge of a wine region diversity requires fine scale assessment of climate, soil and management conditions. Climate conditions of coastal wine regions vary according to the distance to the sea and topography. In order to bring some answers to the issues related to grapevine adaptability to climate change, we need to understand how local environmental factors impact grapevine behavior, and berry and wine composition. Results of many works have shown the impacts of temperature variation on grapevine functioning at meso-scale (Bonnardot *et al.*, 2012; Bonnefoy *et al.*, 2012; Hunter and Bonnardot, 2011; Neethling *et al.*, 2011; Quénol *et al.*, 2007). However, no study at this scale has been initiated under the conditions of Uruguay, as yet.

In Uruguay, Tannat is considered as the best suited cultivar variety to environmental conditions of the country. Tannat is characterized by a high oenological potential due to high level contents of anthocyanins, tannins and acidity (González-Neves *et al.*, 2006) producing wines with high originality and tipycity.

The aim of this work was to study temperature spatial variability in relation to the grape berry composition of Tannat at harvest, in southern Uruguay.

MATERIALS AND METHODS

1. Site selection and description

Canelones and Montevideo departments represent 76.4% of the total vineyard surface of the country (INAVI, 2013) (Figure 1b). The region experiences a warm temperate oceanic climate. Rainfall is relatively high with 1100 mm per year (INIA, 2013). The climate of the region was classified as warm temperate, with temperate nights and moderated drought, corresponding to the $IS_{A1}IH_{A4}IF_{A2,}$ climatic group according to the "Multicriteria Climatic Classification" method for vineyards (Tonietto, 1999; Tonietto and Carbonneau, 2004; Ferrer, 2007). The grape ripening period in southern Uruguay is characterized by high temperatures. January and February mean maximum temperatures are 28.9ºC and 27.8ºC respectively. January and February mean minimum temperature are 17ºC and 16.8ºC respectively (mean values for the 1971-2000 period. INIA, 2013). Rainfall close to harvest sometimes occur (Ferrer, 2007).

A network of ten experimental plots was installed in five commercial vineyards of Tannat in the most important wine region of the country, in southern Uruguay (Latitude 34º40'S; longitude 56º20'W). The study area covers an area of 16.8 km wide (Est-West) and 32km long (North-South) (Figure 1c). These vineyards were chosen in order to investigate the influence of the La Plata River on temperature, humidity and wind velocity. Soils diversity and topography were also taken into account. In three cases, two contiguous plots were selected, yet at different elevations and heterogeneous soil properties (depth, temperature, water reserve…) in order to evaluate how various environmental factors at plot scale may lead to differences in berry composition.

2. Temperature data and analysis

Temperature data was obtained from ten "TinyTag Talk 2" temperature sensors (Gemini Data Loggers Ltd., UK) installed in each plot during September 2009. In this article, the daily and monthly minimum and maximum temperature data of summer 2012 were analyzed to evaluate spatial variability. Temperature of the 15th of February 2013 was also used to show variability at fine scale under heat wave conditions as Bonnefoy *et al.* (2012) did in the Loire Valley, France.

3. Grape analytical determinations

Berry samples of Tannat grapes were collected at harvest following the recommendations of Carbonneau *et al.* (1991). For each vineyard, 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 titration, pH by potentiometry, according to the O.I.V. protocol (1990). To analyze phenolic potential, such as total potential in anthocyanins, the potential in extractable anthocyanins and 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. Total and extractable potential in anthocyanins and polyphenol richness are indices that provide enology valorisation of grape and improve vinification management (González-Néves *et al.*, 2010). An univariate procedure (ANOVA) was used to determine significant differences in berry composition between plots (Tukey grouping; $\alpha = 5\%$) and a multivariate method (PCA) was performed to determine significant correlations between temperature and berry composition.

RESULTS AND DISCUSSION

1. Spatial Variability of Temperature

Summer 2012 was characterized by high monthly temperatures in southern Uruguay, especially in February (between 1.1ºC and 2.2ºC above normal). Maximum temperature reached 30.9ºC (±0.9°C) in January and 30.0ºC (±0.5°C) in February, and minimum temperatures were 16.4ºC (±0.7°C) and 17.9ºC (±0.6°C) respectively.

Results showed a significant spatial variability of temperature over short distances in the region. Daily thermal amplitude within plots increased rapidly with distance from the river. The mean daily thermal amplitude during the ripening period of grapes (i.e. between the 1st of January and the 15th of March 2012) was about 4°C higher at the plot situated furthest from the river (Plot9 situated 32 km inland - Fig.1b) than at the plot closer to the La Plata River (Plot1) (14.28ºC ± 4.06 and 10.14ºC ± 3.28 respectively). On the other hand, plots near the river (Plot1, Plot2 and Plot3) showed smaller differences in temperature, during the season and during the day. These plots experienced cooler conditions during daytime and warmer conditions at night than those inland, due to the moderating effect of the La Plata River on temperature. These results corroborate those found in the Stellenbosch wine district in South Africa experiencing the sea breeze effect (Bonnardot et al., 2002; 2005). These effects on temperature may have caused differences in grape composition.

Despite the relative flat terrain of the study area (92 m is the highest elevation at Plot4), plots situated in the valleys had similar behavior than those situated away from the river, due to faster heat gain and loss. To illustrate this great temperature variability over short distances, results for the 15th of February, the hottest day of summer 2012 are presented. Maximum temperatures for this particular day reached between 31.9ºC at Plot1 and 38.9ºC at Plot7. Looking at hourly temperature data and assuming that grapevine experiences high temperature stress above 35°C (Coombe, 1987; Hunter and Bonnardot, 2011), it can be noted that no thermal stress was experienced at the plot near the river (no time with temperature over 35ºC at Plot1), while Plot6 and Plot7 inland experienced 2 and 6 hours with temperature above 35ºC respectively. In other words, beside the fact that thermal stress was experienced inland, the duration with stress was three times greater at Plot7 than at Plot6, although these two sites are 58 m apart only, due to a steeper slope (5.1%) at Plot7 than at Plot6 (flat). These significant differences could have hold implications on grapevine development. Sugar accumulation, malic acid content, skin colour and phenolic content on berries could be altered by these conditions during grape maturation (Coombe, 1987).

2. Grape Berry composition at harvest

For the 2011-2012 season, grapes were harvested between the 2nd and 7th of March. Grape berry composition showed a significant variablity that could be associated with plot location (Figure 2). This is underlined with results from the PCA with PC1 and PC2 representing 68.9% of the total variability (Figure 3). Acidity, pH, and total potential in anthocyanes showed significant correlation with Maximum temperature in January (r=0.65, p=0.12; r= 0.72, p=0.16; r=0.72, p=0.11 respectively) while phenolic richness showed significant correlation with maximum temperature in February (r=0.65; p=0.2). There was no significance correlation between minimum temperature and Tannat composition at harvest. Statistical results clearly displayed opposition between plots near the sea and inland.

The plots near the "sea" river had high levels in acidity, high pH, high sugar accumulation, lowest values in total potential in anthocyanin and intermediate polyphenols richness. Plot1, Plot2 and Plot3 had optimal temperatures for grapevine developement and no water stress during ripening that allowed continuous vegetative growth. These three plots were the most vigorous plots, and as a result balanced berry composition at harvest could have been affected.

Adjacent plots showed more significant variability in sugar concentration and titratable acidity, than in potential extractable anthocyanins and phenolic richness. In all cases, adjacent plots had the same vineyard management but there were different in their water retention properties, leading in differences in plant root growth and distribution. In one case in particular, at Plot4 and Plot5, there were always statistical significance in berry composition that could be explained by soil characteristics. Sodium soil content in B and C horizons (>2.63 meq 100g-1), may be the element that could slow down plant vigor at Plot4 (Sumner and Naidu, 1998). Consequently, Plot4 was the most advanced plots amongst the others, in terms of phenological stages and maturation. The low content in potential extractable anthocyanins at this plot may be explained by a decrease of this compound close to harvest by degradation (González-Néves *et al.*, 2010). It suggests for this year of study, that topography and soil conditions could have had greater effects on sugar and acidity than on polyphenol levels between adjacent plots with similar cultural practices.

CONCLUSIONS

Although results are based on a single season interesting preliminary conculsions can be drawn for Montevideo and Canelones wine region. The fine scale network of temperature loggers installed in the vineyards of Canelones and Montevideo departments contributed to increase knowledge of climate in coastal wine producing regions of Uruguay. Results showed significant spatial variability in temperature during summer 2012 in southern Uruguay. Sea and topography effects were identified at fine scale using differences in daily thermal amplitude and maximum temperatures during the ripening period. Analysis of extreme maximum temperatures helped in identifying how high temperatures could impact grapevine physiological functioning.

A clear sea and topography effects in grapevine were highlighted. It appeared that berry composition responded to maximum temperature during the ripening period, with acidity and total potential in anthocyanin related to

January conditions (beginning of the ripening period) while phenolic richness were correlated to February conditions (end of ripening period).

Plots near the La Plata River showed the most unbalanced berry composition at harvest. That may be explained by "*no thermal stress*" conditions during ripening period, leading to vegetative growth and therefore, high plant vigour. Adjacent plots with similar cultural practices showed more significant variability in sugar concentration and titratable acidity, than potential in extractable anthocyanins and phenolic richness. The increasing knowledge of spatial temperature variability and its relationships with grape berry composition contributes to improving vineyard management so as to modifying the canopy micro climate conditions during ripening period.

These preliminary results lead to further investigation on the "sea" river effect in the vineyards of southern Uruguay using humidity and wind data.

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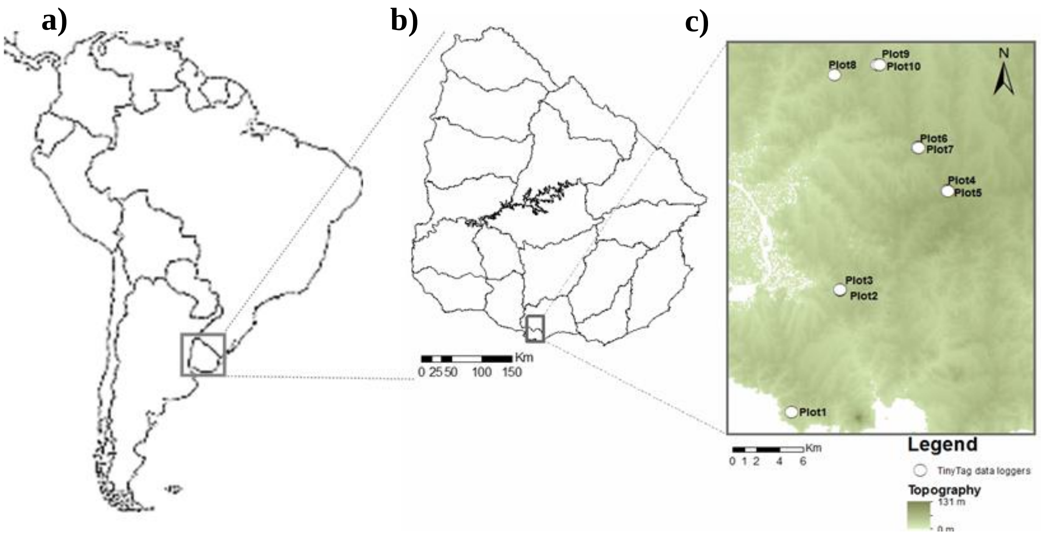

Figure 1. a) South-America. b) Location of the studied area in Southern Uruguay. c) Location of the network of TinyTag data loggers in Montevideo and Canelones wine regions (Map source: ArcGIS).

Figure 1. a) Amérique du Sud. b) Région étudiée dans le sud de l'Uruguay. c) Localisation du réseau de capteurs de température (TinyTag) dans les districts viticoles de Montevideo et Canelones (source du fond de carte : ArcGIS).

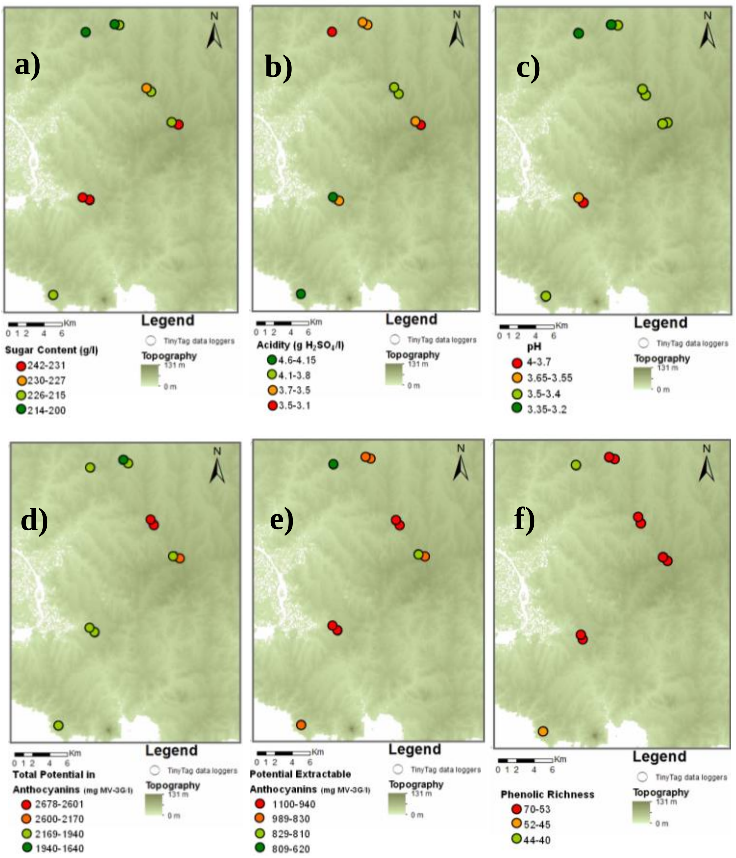

Figure 2. Grape Berry composition at harvest in 2012. a) Sugar content. b) Acidity. c) pH. d) Total Potential in Anthocyanins. e) Potential in Extractable Anthocyanins. f) Phenolic Richness. Colors display results from the Tukey grouping (α = 5%).

Figure 2. Composition du raisin à la récolte pour le millésime 2012. a) Sucres. b) Acidité totale. c) pH. d) Potentiel Total en Anthocyanes. e) Potentiel en Anthocyanes Extractibles. f) Richesse en Polyphénols. Les couleurs représentent les résultats du test de Tukey (α = 5%).

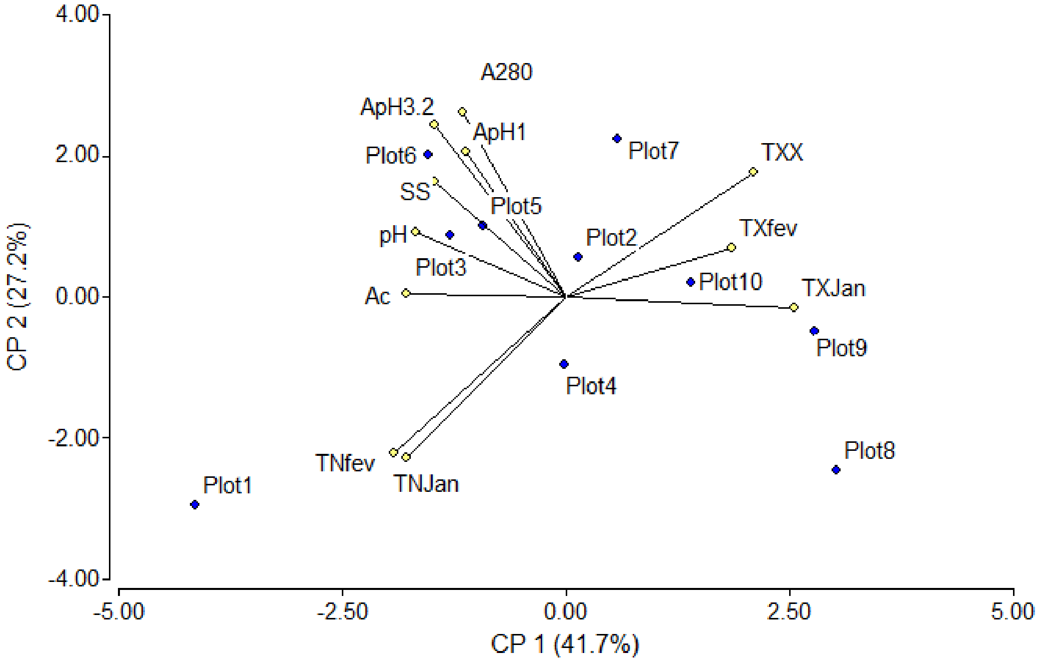

Figure 3. Principal Component Analysis. Eigenvectors of temperature and grape berry composition (yellow) and medium scores for each plot (blue). (Sc = Sugar content; Ac = Acidity; ApH1 = Total Potential in Anthocyanins; ApH3.2 = Potential in Extractable Anthocyanins; A280 = Phenolic Richness; TXX = Maximum Temperature of growing season; TXJan = January maximum temperature; Txfev = February maximum temperature; TNJan = January minimal temperature; TNfev = February minimal temperature).

Figure 3. Analyse de Composantes Principales. Vecteurs propres de température et de composition de la baie (jaune) et scores moyens des parcelles (bleu). (Sc = Sucres ; Ac = Acidité totale ; ApH1 = Potentiel Total en Anthocyanes ; ApH3.2 = Potentiel en Anthocyanes Extractibles ; A280 = Richesse en Polyphénols ; TXX = Température maximale du cycle ; TXJan = Température maximale de Janvier ; Txfev = Température maximale de Février ; TNJan = Température minimale de Janvier ; TNfev = Température minimale de Février).