THE DYNAMICS OF δ^{13}C AND δ^{18}O IN MUSTS DURING BERRY DEVELOPMENT

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Abstract

Aim: Many processes or reactions that occur in plants involved isotopic discrimination. Water availability, for example, affects the isotopic ratio of carbon (δ^{13}C) and oxygen (δ^{18}O). In viticulture, δ^{13}C is used in experiments related to water relations and irrigation in vineyards. δ^{18}O is used much less but it could be a good complement to δ^{13}C. The aim of this study was to generate knowledge on how these isotopic ratios, measured in musts, could help to better understand the water behavior of grape varieties.

Methods and Results: The present work was carried out in 2019 with a set of seven varieties selected to monitor the aforementioned ratios in musts obtained during berries development: three of them red (Bobal, Tinto Velasco and Syrah), managed with irrigation, and the other three white (Airén, Malvar and Albillo Real) kept without irrigation; the seventh, Tempranillo, was managed with or without irrigation.
Monitoring the dynamics of isotope ratios was undertaken through sampling of grapes carried out periodically, from shortly before closing cluster to maturity. In obtained musts, δ^{13}C and δ^{18}O were determined by mass spectrometry of isotope ratios.
The small changes observed between samples in δ^{13}C in a specific variety did not seem to follow any pattern. In most cases, the comparisons of means performed showed no significant differences between samples. However, differences were observed between the two management systems: irrigated and rainfed; in dry conditions, with the stomatal closure, ^{13}C isotopic discrimination declined during photosynthesis, and the ratio then increased.
This was not so with δ^{18}O, where the comparisons of means always showed significant differences between samples. Dynamics of δ^{18}O seemed to adapt, in this case, to a double curve pattern (cubic polynomial): the intense increase in the ratio of the first stages of fruit development was followed by a phase of slight decline, which lasted up to 15 or 20 days before harvest, at which point the ratio increased again. There were both inter-varietal and between management system differences: musts in early harvest varieties showed higher δ^{18}O values than late varieties, while the isotopic enrichment was lower for this isotopic ratio in irrigated vines.

Conclusions: Differences in the narrow margin in which δ^{13}C values of the grapes are maintained throughout their development seemed to respond more to the crop management practice than to the variety. However, the notable changes in δ^{18}O values seem to be due to a complex mechanism that involves the discharge of water in the grapes from the phloem at beginning of ripening and the loss of water due to transpiration through the skin.

Significance and Impact of the Study: In the search for the genotypes with the highest water efficiency that effectively respond to the proliferation and dilation of drought periods that are expected in many regions, it is urgent to explore the existing genetic variability. In this sense, δ^{13}C and δ^{18}O could be useful tools to take into account in any research related to water use by cultivars at physiological or agronomic levels.

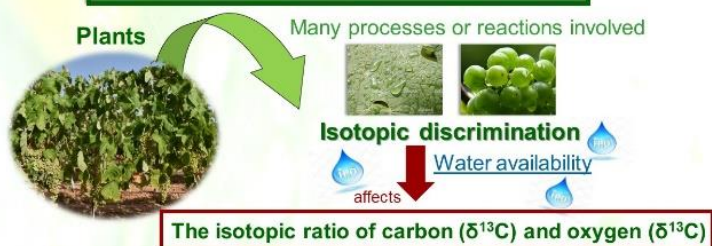**Keywords:** Grapevine, genotypes, musts, δ^{13}C dynamics, δ^{18}O dynamics, IRMS

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The dynamics of δ^{13}C and δ^{18}O in musts during berry development

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INTRODUCTION

Plants

Many processes or reactions involved

Isotopic discrimination

Water availability affects

The isotopic ratio of carbon (δ^{13}C) and oxygen (δ^{13}C)

In Viticulture

δ^{13}C → is used in experiments related to water relations and irrigation in vineyards

δ^{18}O → is used much less but it could be a good complement to δ^{13}C

The aim of this study was to generate knowledge on how these isotopic ratios, measured in musts, could help to better understand the water behavior of grape varieties.

MATERIAL AND METHODS

7 grapevine varieties

3 WHITE VARIETIES		3 BLACK VARIETIES
RAINFED	Tempranillo	IRRIGATED
✓Albillo Real ✓Airén ✓Malvar		✓Bobal ✓Syrah ✓Tinto Velasco

STUDY: In 2019 sampling of grapes carried out periodically from shortly before closing cluster to maturity

MUSTS

δ^{13}C   δ^{18}O from must water

CO_2 → complete combustion of the Must $C^{16}O_2 + H_2^{18}O \rightarrow C^{16}O^{18}O + H_2^{16}O$

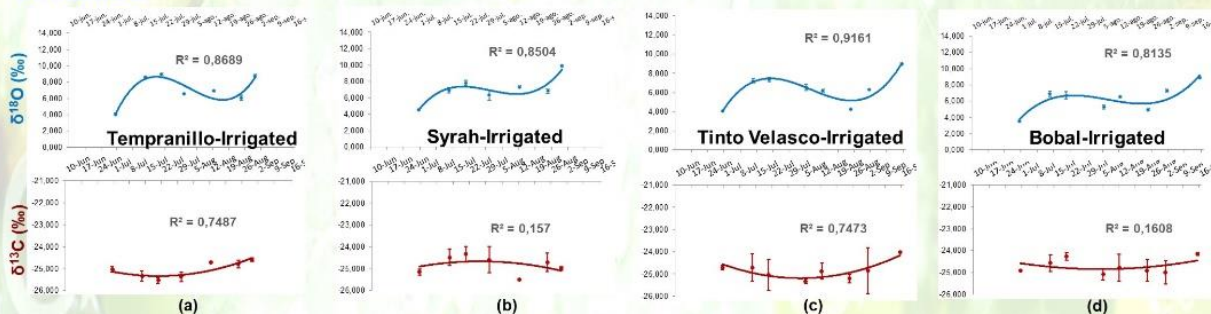**ANALYSIS OF ISOTOPIC CARBON (δ^{13}C) AND OXYGEN (δ^{18}O) RATIOS**

IRMS (Isotope Ratio Mass Spectrometry) (Gómez-Alonso and García-Romero, 2010)

$$R = \frac{\text{Amount of heavy isotope}}{\text{Amount of light isotope}}$$

$$\delta_{sample} = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000$$

RESULTS

IRRIGATED

RAINFED

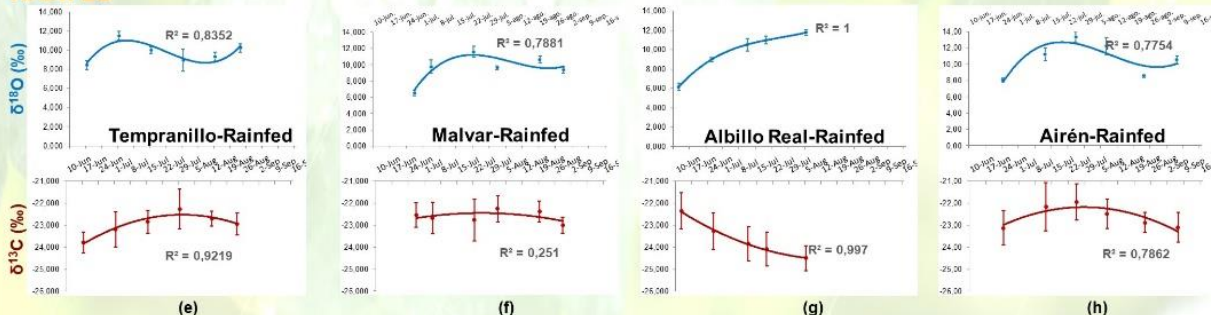**Figure 1:** *Dynamics of isotope ratios δ^{13}C (bottom of graph in red) and δ^{18}O (top of graph in blue) of 7 grapevine varieties: (a), (e) Tempranillo, managed with irrigation and without irrigation, respectively. Three black varieties managed with irrigation: (b) Syrah-Irrigated, (c) Tinto Velasco-Irrigated, (d) Bobal-Irrigated, and three white varieties kept without irrigation: (f) Malvar-Rainfed, (g) Albillo Real-Rainfed, (h) Airén-Rainfed.*

CONCLUSIONS

δ^{13}C measurements

The small changes observed between samples in δ^{13}C in a specific variety did not seem to follow any pattern. However, differences were observed between the two management systems: irrigated an rainfed.

In agreement with other studies, **differences** in values of the grapes are maintained throughout their development **seem to respond more to the crop management than to the variety** (Santesteban et al., 2015).

δ^{18}O measurements

The **notable changes** in δ^{18}O values **could be due to a complex mechanism that involves the discharge of water** in the grapes from the phloem at the beginning of ripening and the loss of water due to transpiration through the skin (Zhang and Keller, 2017).

Significance and impact of the study

δ^{13}C and δ^{18}O could be useful tools to taken into account in any research related to the water use by the cultivars at physiological or agronomic levels.

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Santesteban L.G., Miranda C., Barbarin I., Royo J.B., 2015. Application of the measurement of the natural abundance of stable isotopes in viticulture: a review. Australian Journal of Grape and Wine Research 21: 157-167

Zhang Y., Keller M., 2017. Discharge of surplus phloem water may be required for normal grape ripening.