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δ13C : A still underused indicator in precision viticulture

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Introduction : The first demonstration of the interest of carbon isotope ratio, as an integrated indicator of vineyard water status, dates back to 2000. (Gaudillère et al., 1999; Van Leeuwen et al., 2001). Thanks to the changes in isotopic discrimination under hydric stress, it is possible to accurately estimate the water deficit withstood by the vine during sugars accumulation. The higher the water deficit, the higher the assimilation of heavy isotopes of carbon C^{13}, fixed in the sugars. A value of δ13C near -22 ‰ stands for high water stress during ripening, whereas a value of -28 ‰ stands for no water stress.

Ever since, δ13C has been applied with success to zonation, terroir studies and vine physiology research, but is still not widely used by viticulturists. This is astonishing, considering the impact of global warming on viticulture and the need to improve water management, that would justify a widespread use of δ13C. The lack of private laboratories proposing the analysis, the cost of the technology, as well as the long analytical delays, have probably been detrimental to its development.

In this work, thanks to the recent acquisition of IRMS technology, three applications of δ13C for viticulture are proposed by EXCELL laboratories (Floirac, 33270, FR) . This includes the use of the analysis for terroir studies and parcel discrimination, vintage effect and authenticity.

Materials and method : The analysis of δ13C is performed on a UNICUBE elementar analyser coupled with an isotope ratio mass spectrometer (Elementar GmbH, Germany). For calibration, certified stable isotopes standard are supplied by IAEA. The CO2 used as reference gas is supplied by LINDE. Thanks to the abundance of sugars in grape berries at harvesting, the analysis of carbon is performed directly on juice after pressing. The juice must be rapidly analysed, to avoid the fermentation of sugars into ethanol. Freezing is recommended, but alternatively, the addition of 200 mg/L of sulphites works well to block any fermentation activity without adding any external source of carbon.

Approximately 5 mg of homogenised juice are pipetted in a small tin boat, and the weight is registered using an analytical balance (Mettler Toledo). Then oven dried at 60 °C overnight. The tin boat is tightly closed, and the sample is ready to be injected in the oven. The carbon contained in the sample is completely converted into CO2 and then transferred into the mass spectrometer.

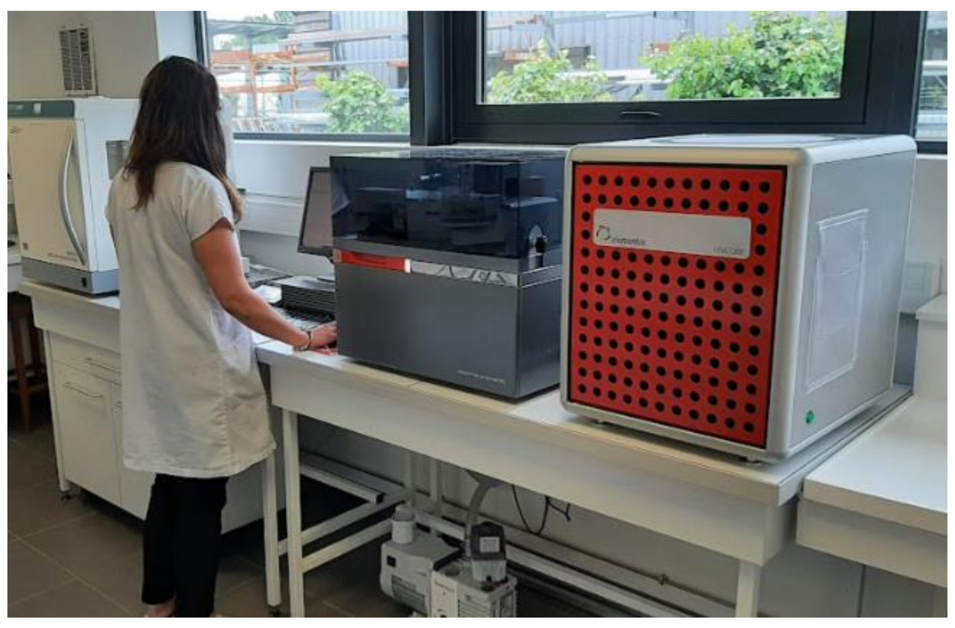

Fig. 1: EA-IRMS

Vintage effect

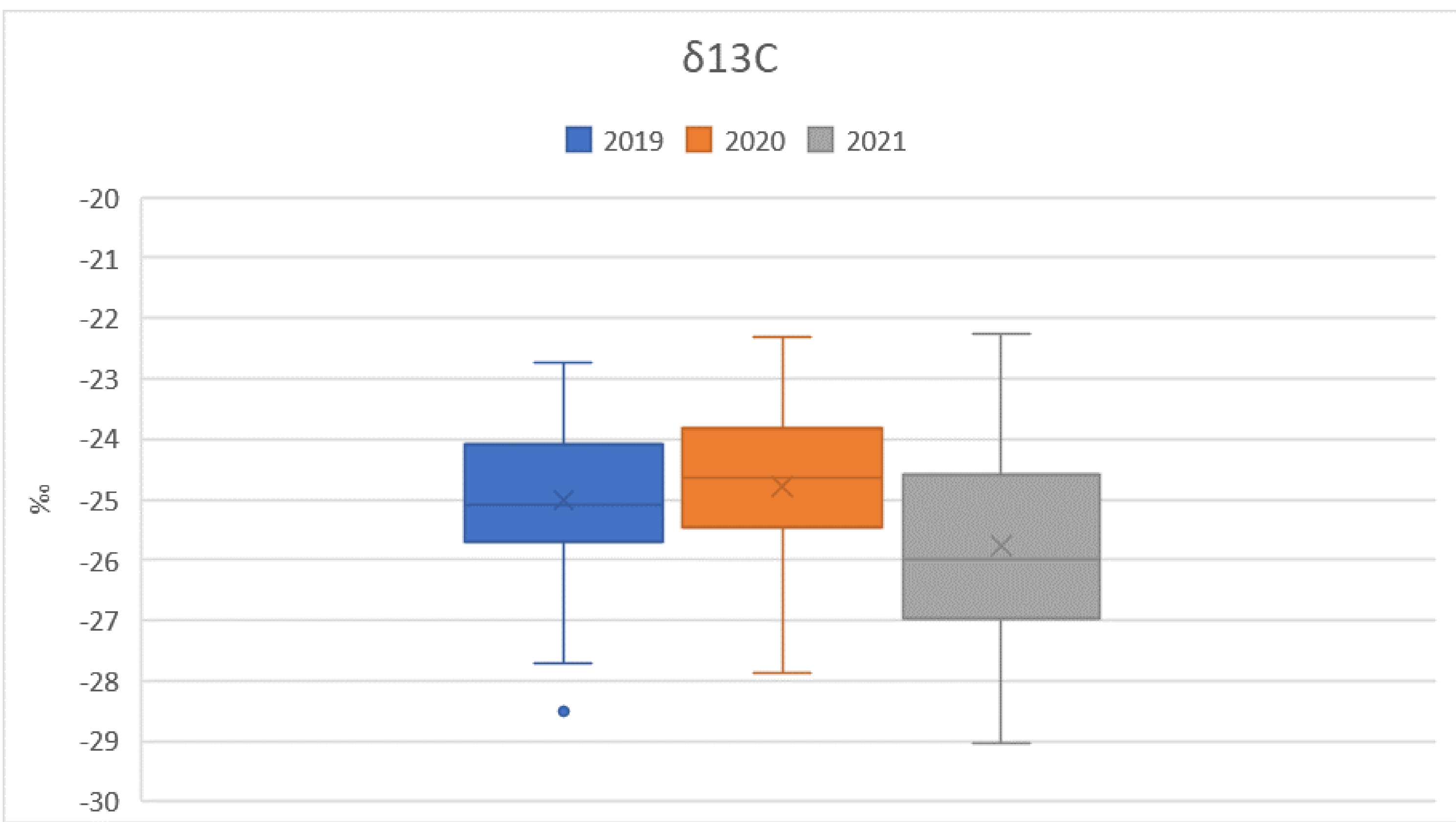

Fig. 2: Vintage comparison, average δ13C values of analysed samples.

The comparison between vintages based on δ13Csugars is an interesting tool to measure the effect of weather on vine physiology. In this work we present the data of the last three vintages collected by the laboratory.

2021 seems to be a more heterogenous vintage, with a lower ratio, compared to 2020. The values indicate that water stress was low to mild in 2021.

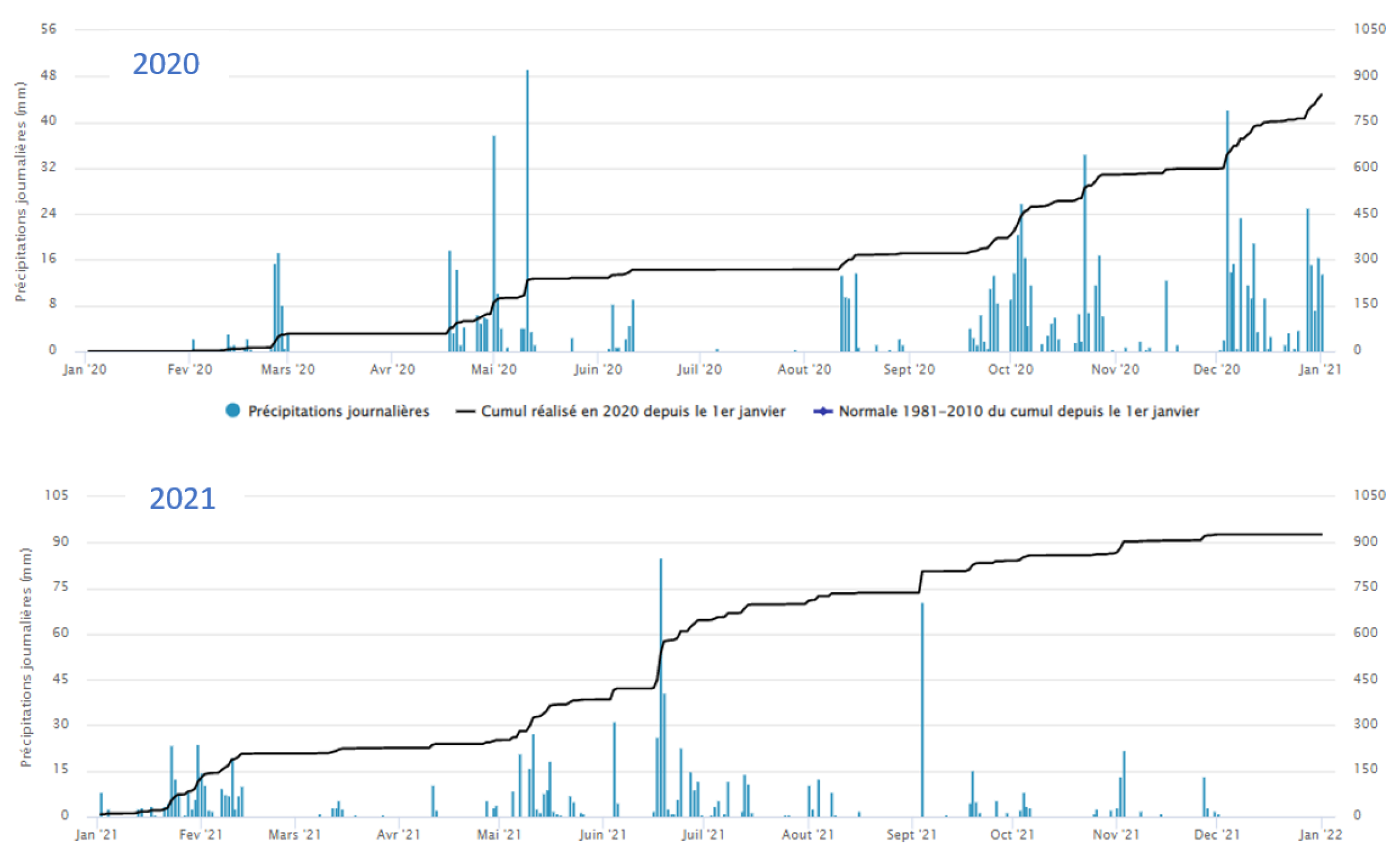

Fig. 3: Rainfall data (2020-2021), Bouliac Weather station (Infoclimat.fr)

The weather data confirm that 2020 was the dryer vintage between the two, with almost no increase in rainfall accumulation during summer months. In comparison 2021 had higher rainfall during summer, allowing the soil to recharge its water reserve.

Vineyard zoning

When the analysis is applied at vineyard scale, it is possible to observe the heterogeneity between parcels. The understanding of this variability allows more accurate vineyard management as well as parcel selection. δ13C mapping can be repeated every vintage, to get an insight of the capacity of the vineyard to react to different weather conditions.

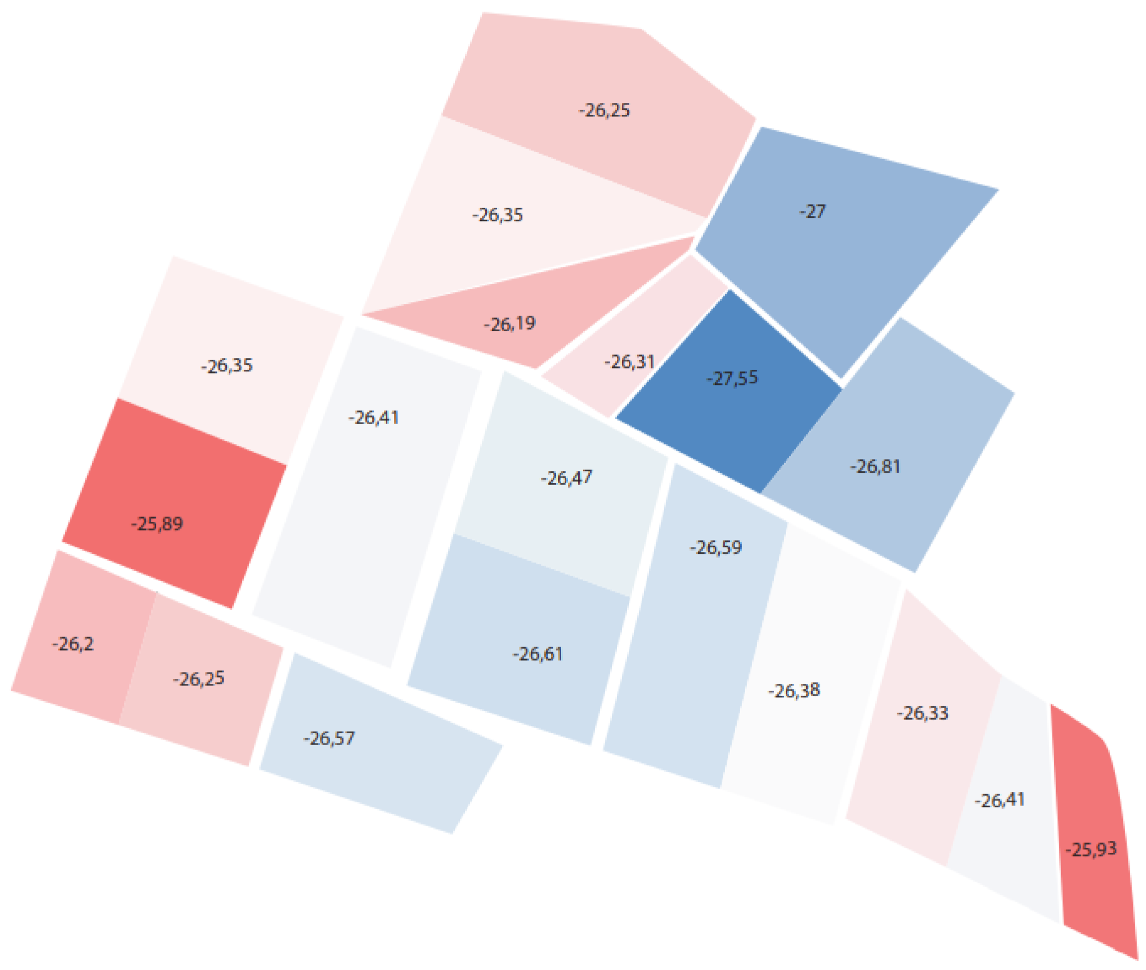

Fig. 4: δ13C data at vineyard scale, Vintage 2021

In the vineyard studied in this work, the vines located on the east and west borders were submitted to higher water deficit compared to the central area. This analytical approach can be complemented by pedological and soil analysis, as well as vigour and leaf nutrients data. Considering the impact on quality and wine style of water stress (Deloire et al., 2006), the information provided by δ13C can support selection and blending.

Authenticity

In plants, the isotopic signature of carbon, is strongly influenced by the metabolic pathway of photosynthesis. C3 plants (typical in temperature climates, approximately -25 ‰ δ13C) differs from C4 plants (tropical climate, approximately -12 ‰ δ13C) The identification of sugar cane addition prior to fermentation is based on this principle.

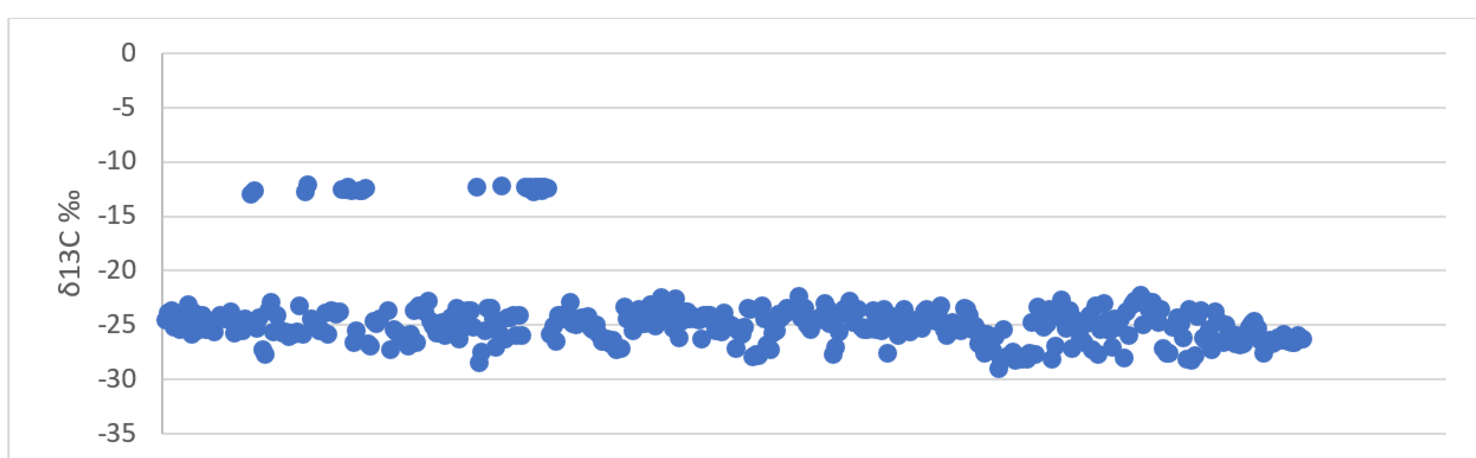

Fig. 4: δ13C of ethanol, in wine and spirits

Conclusion : Climate change is a reality that viticulture is facing in every producing country. The increase of average temperature can be favorable in some of them, but in most countries, it is generating new challenges. Among them, drought and water management are probably the hardest to solve.

δ13C seems to be a very relevant indicator to analyze water deficit and its availability will prove to be beneficial for viticulture.