MODELING SUGAR ACCUMULATION DYNAMICS OF A WIDE VARIETY OF GRAPE CULTIVARS (*Vitis Vinifera* L.)

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Abstract:

Context and purpose of the study - Climate change is a major challenge in wine production. The IPCC (2014) projected that by the end of the 21st century average temperatures will increase by 1-3.7°C. Consequently, harvest dates could advance by approximately 30 days. A general observed trend is the increase in berry sugar content and decrease in organic acids, posing challenges for winegrowers. Variability among cultivars is a precious resource to adapt viticulture to a changing environment.The aim of this study is to model and compare the sugar accumulation dynamics for a wide variety of *Vitis Vinifera* (L.) grape cultivars. Determining ripening dynamics with the help of a single mathematical function will allow for cultivar classification and provide a means of determining suitability of grape cultivars under conditions of climate change, or in potentially new wine producing regions.

Material and methods -Berry samples were collected from 50 different *Vitis Vinifera* (L.) cultivars at four replicate locations within a common-garden randomized complete block design at the ISVV from 2012-2018. Samples were collected weekly between mid-veraison and maturity, from which berry fresh weight, reducing sugar, and other parameters were measured. The integrative indicator of water status ($\partial^{13}C$) was measured at maturity for every cultivar. A 3-parameter logistic function was fitted for sugar accumulation expressed in both concentration (g/L) and content (mg/berry).

Results - A logistic model was parameterized to the sugar accumulation data from 50 grape cultivars and ripening traits were extracted. Analysis of variance revealed there was a strong cultivar effect on the rate of sugar accumulation, while there was a strong year effect on the total sugar concentration accumulated. The length of the ripening period showed to be dependent on both year and cultivar. This research aids in determining the suitability of grape cultivars under changing climate conditions or in newly projected viticultural areas. The coefficients extracted from the model allow for the testing of other hypotheses and research questions. One of the questions under investigation, is whether the rate of sugar accumulation is influenced by water deficit ($\partial^{13}C$) and climatic variables (temperature, PAR, etc.).

Keywords: Sugar accumulation dynamics, logistic function, ripening traits, water status, temperature, grapevine cultivars.

1. Introduction.

Modeling sugar accumulation dynamics of a wide variety of grape cultivars (*Vitis Vinifera* L.)

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01 INTRODUCTION

Variability among cultivars is a precious resource to adapt viticulture to a changing environment. The aim of this study is to model and compare the sugar accumulation dynamics for a wide variety of *Vitis Vinifera* (L.) grape cultivars. Determining ripening dynamics with the help of a single mathematical function will allow for cultivar classification and provide a means of determining suitability of grape cultivars under conditions of climate change, or in potentially new wine producing regions.

02 METHODS

Berry samples were collected weekly (mid-veraison until maturity) from 50 cultivars in the VitAdapt vineyard between 2012 and 2018. Among the data extracted were berry fresh weight and reducing sugar. The integrative indicator of water status ($\partial^{13}C$) was measured at maturity for every cultivar. A 3-parameter logistic function was fitted for sugar accumulation expressed in both concentration (g/L) and content (mg/berry).

$$S(t) = \frac{S_{max}}{1 + 0.05 * e^{\left(-4 * r_s * \left(\frac{t - t_{95}}{S_{max}}\right)\right)}}$$

Where:
S = sugar content (mg/berry) or concentration (g/L) at a given t
S_{max} = asymptote (estimated maximum sugar concentration or content)
r = rate of sugar accumulation (mg/berry/day or g/L/day)
t = day of year
t_{95} = estimated day of year when 95% of total sugar is accumulated

VitAdapt project

The VitAdapt project (Vitis adaptation) is a phenotyping study of 52 cultivars planted in 2009 in Bordeaux, France. It is set-up as a common-garden randomized complete block design with 5 replications. The aim of the VitAdapt project is to provide data from extensive phenotyping in order to optimize choice of the cultivar as a resource for adaptation to climate change.

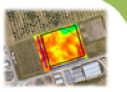
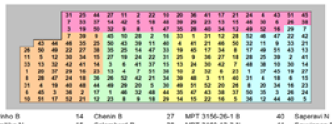


Figure 1. Top: Resistivity map of the VitAdapt parcel. Bottom: Experimental design of the VitAdapt parcel



1	Alvarinho B	14	Chenin B	27	MPT 3156-26-1 B
2	Agiorgitiko N	15	Colombard B	28	MPT 3160-12-3 N
3	Arinarnoa N	16	Cornalin N	29	Muscadelle B
4	Assyrtiko B	17	Cot N	30	Nero d'Avola (Calabrese) N
5	BX 648 N	18	Gamay N	31	Petit Manseng B
6	BX 9216 B	19	Grenache N	32	Petit Verdot N
7	Cabernet franc N	20	Hibernal blanc B	33	Petite Arvine B
8	Cabernet-Sauvignon N	21	Lilorita B	34	Pinot noir N
9	Carignan N	22	Marselan N	35	Prunelard N
10	Carnenère N	23	Mavrud N	36	Riesling B
11	Castets N	24	Merlot N	37	Rkatsiteli B
12	Chardonnay B	25	Mornastel N	38	Roussanne B
13	Chasselas B	26	Mourvèdre N	39	Sangiovese N
40	Saperavi N				
41	Sauvignon B				
42	Semillon B				
43	Syrah N				
44	Tannat N				
45	Tempranillo N				
46	Tinto Cao N				
47	Touriga Francesa N				
48	Touriga nacional N				
49	Ugni blanc B				
50	Vinhao (Souzao) N				
51	Viognier B				
52	Xinomavro N				

03 RESULTS

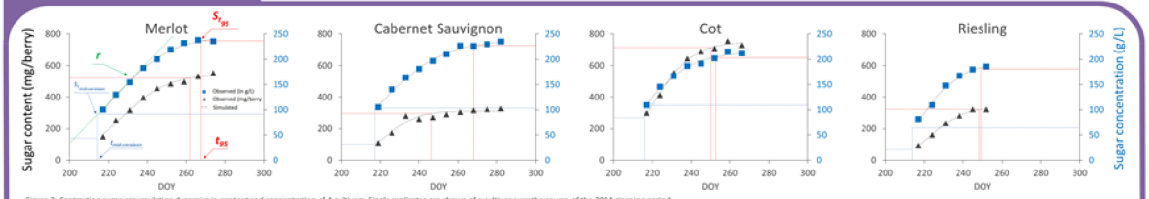


Figure 2. Contrasting sugar accumulation dynamics in content and concentration of 4 cultivars. Single replicates are shown of a cultivar over the course of the 2014 ripening period

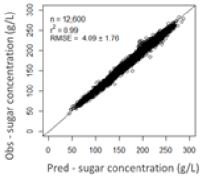
Key results:

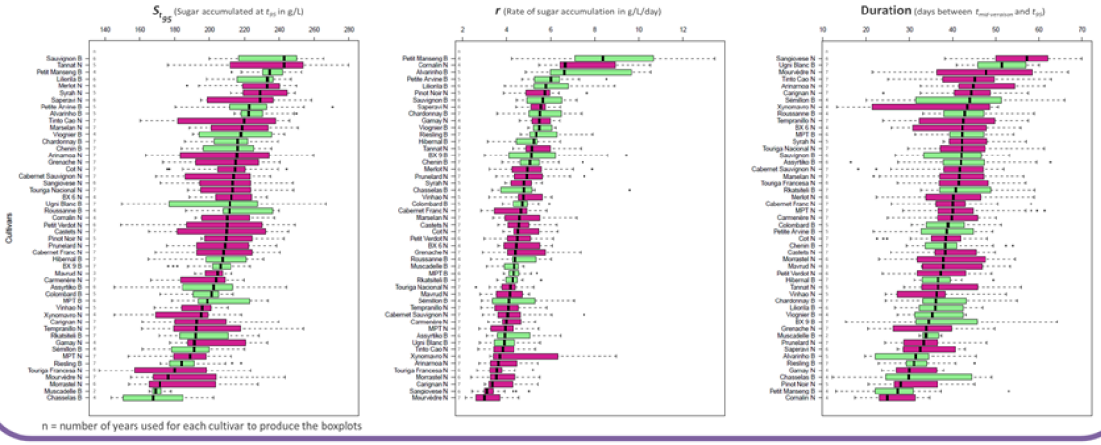
- Grape ripening dynamics were successfully modeled and ripening traits extracted
- Classifications were established for ripening traits of 50 cultivars
- Strong year effect on the total sugar accumulated
- Strong cultivar effect on the rate of sugar accumulation
- Length of the ripening period is both year and cultivar dependent

Table 1. Distribution of total variance (% sum of squares) among explanatory variables across ripening traits for sugar concentration data from 2012-2018 (n = 853)

Explanatory variable	$S_{t_{95}}$	r	Duration
Year	43.6%	11.9%	30.4%
Cultivar	28.4%	49.0%	32.2%
Year × Cultivar	19.1%	24.2%	20.9%
Residuals	8.9%	14.9%	16.5%

Predicted vs. Observed (50 cultivars)





n = number of years used for each cultivar to produce the boxplots

04 PERSPECTIVES

Conclusions and perspectives - This research aids in determining the suitability of grape cultivars under changing climate conditions or in newly projected viticultural areas. The coefficients extracted from the model allow for the testing of other hypotheses and research questions. One of the questions under investigation, is whether the rate of sugar accumulation is influenced by water deficit ($\partial^{13}C$) and climatic variables (temperature, PAR, etc.).