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The intravarietal diversity of sugar concentration in Merlot depends more on late evaporation than sugar loading

Victoria Lesbats-Sichel[1, 2], Patrice This[2,4], Thierry Lacombe[2,4], Loïc Le Cunff [3,4], Charles Romieu ✉[2,4]

[1] Petrus, Pomerol, France
[2] UMR AGAP Institut, Univ Montpellier, CIRAD, INRAE, Institut Agro, F-34398 Montpellier, France
[3] Institut Français de la Vigne et du Vin, F-34398 Montpellier, France
[4] UMT Geno-Vigne®, IFV-INRAE-Institut Agro, F-34398 Montpellier, France

The rise in temperature associated with climate change can lead to excessive sugar concentrations at harvest. To maintain varietal typicity in the future, more resilient genotypes need to be identified within clonal diversity. We studied a compendium of compositional and developmental traits in a private collection of 55 accessions and 3 ENTAV-INRA® clones of Merlot. Extensive single berry measurements revealed differences in post phloem arrest water losses at the origin of variations in sugar concentration among the most extreme genotypes.

Material and method

The private Merlot collection, located in the Pomerol appellation, contains 55 accessions and 3 ENTAV-INRA® clones (182, 343, 347) within a 0.25 hectares plot comprising four blocks of 6 plants per genotype. Vines were grafted on '3309 Couderc' rootstock and planted at a density of 5711 vines/ha (145 x 90 cm) in 2015. Traits analysed included vigour (pruning shoot number and total weight per plant) and measured mid-budbreak date. Cluster growth was estimated by periodically checking the volume of three clusters per genotype and per block[1]. All genotypes were harvested simultaneously. Yield was estimated by counting the number of bunch per vine and berries per bunches, and determining average berry weight on 3 destemmed bunches per genotype and per block. Berry juices were obtained by gently blending the same samples, without crushing the seeds. Sugar and organic acid concentrations were then determined by HPLC[2] and vine water status via carbon isotopic analysis (δ13C)[3].

Results and discussion

On average, cluster volume of the whole 2019 harvest increased approximately two-fold from the end of the herbaceous plateau (end of July) to mid-August, before progressively decreasing during the next 30 days until harvest. A similar trend was observed in 2020, but the initial growth rate was slower and the timing of the maximal volume more difficult to determine (Figure 1), which could indicate greater asynchrony in berry development than in 2019. These results indicate that the clusters concentrated sugars upon losing water and shrivelling prior to harvest, as expected after exceeding maximal volume, which

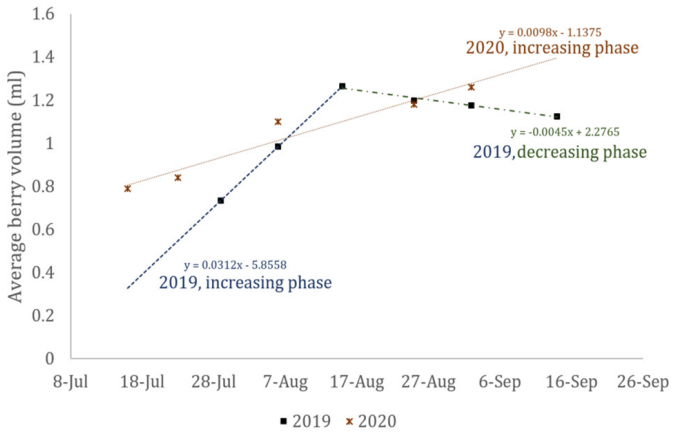


FIGURE 1. Average berry growth during the 2019 and 2020 vintages.

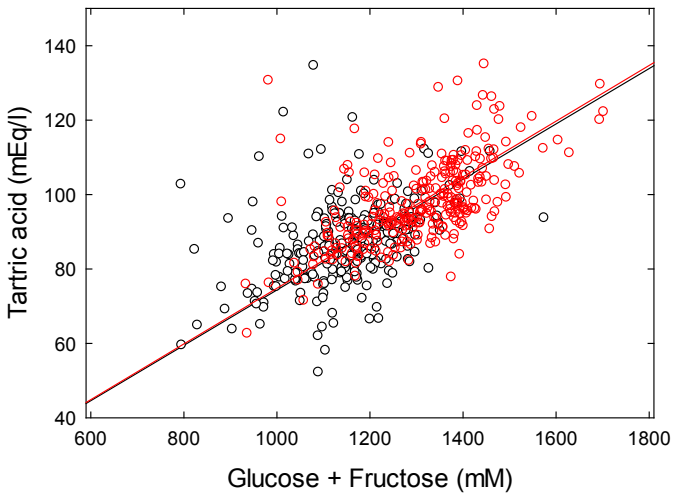


FIGURE 2. Sugar and tartaric acid concentrations at harvest in 5 individual Merlot clusters for each of the 58 genotypes.

corresponds to the cessation of phloem unloading and sugar import in berries[4]. Moreover, individual clusters mostly differed from each other by showing proportional changes in their sugar and tartaric acid concentrations (Figure 2), with the same slope in 2019 and 2020 as well, even if they were generally more concentrated in 2020. The simplest interpretation of these results is that bunches essentially differed in water content[2], while the amounts of tartaric acid and sugars, which had sequentially accumulated during the green stage and ripening, were more or less invariant. The respective effects of the genotype, plant position and environmental variables on canopy and berry related traits were then analysed (Table 1), using dedicated statistical models (Best Linear Unbiased Predictions or BLUPs[5, 6]). Genotypes were then compared, according to their genetic aptitude to concentrate sugars, undergo water deficit or develop voluminous clusters or vigorous canopies, among other traits (Figure 3). With a 1 % v/v probable ethanol variation between the top 4 genotypes and their most diluted counterparts, the genetic diversity of the collection outperformed variations among ENTAV-INRA registered clones. Such a strong clonal variability has already been documented for grape composition, wine quality, leaf stilbene content and downy mildew resistance in Cabernet franc[7]. Greater dilutions were associated with increased canopy vigour and resilience to water deficit, together with

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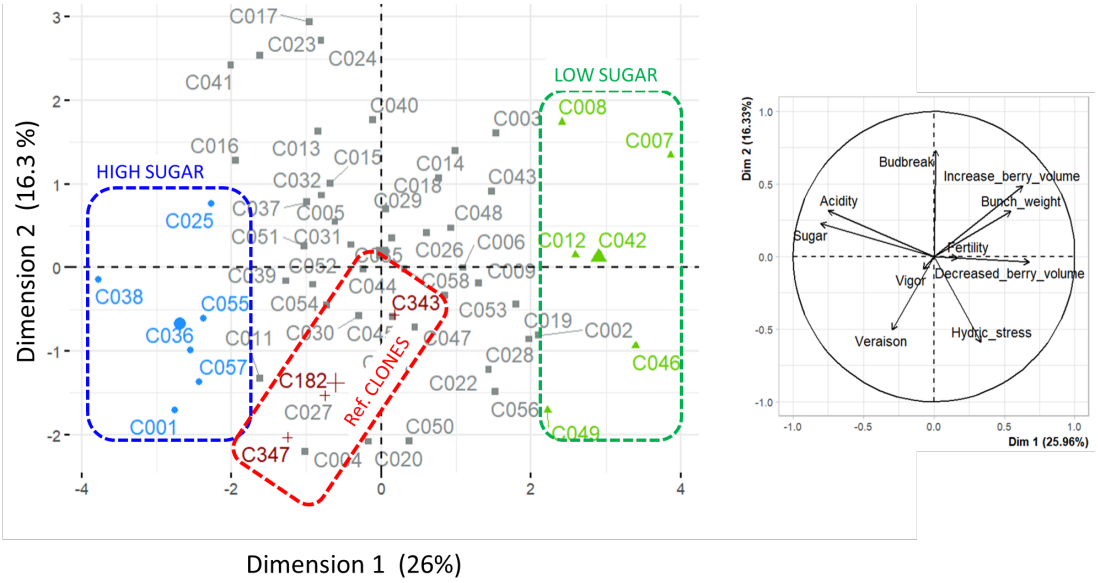


FIGURE 3. Principal Component Analysis of the genoBLUP values obtained from three years of phenotyping berry- and canopy-related traits.

TABLE 1. Phenotypic traits explicative variables. The P-value refers to the genotype effect.

Phenotypic Trait	Explicative variables*	P-value	Heritability
Pruning weight	Year, Resistivity, Genotype, X,Y	1.9e-06	0.61
Weight per shoot	Year, Resistivity, Genotype, X,Y	0.006	0.43
Bunches per shoot	Year, Genotype, X,Y, (Block:Year)	0.0064	0.41
Bunch weight	Year, Genotype, X,Y	0.0053	0.44
Sugar concentration	Year, Resistivity, Block, Genotype,X, (geno:year) , (Block:year)	0.021	0.40
Bunch contraction	Resistivity, Block, Genotype,Y	0.046	0.33
Bunch expansion	Genotype, X, Bunch_position	2.21e-5	0.55
Budbreak	Year, Genotype, X	0.0029	0.43
$\delta^{13}C$	Block, Genotype, X, Y	0.0013	0.50

* X : plant position in the row, Y : row number in the block, resistivity : soil resistivity.

the largest berry numbers and volume. In order to understand which genes contributed to these changes, screening was carried out to determine which mRNA transcripts were differentially expressed in berries from the two extreme genotypes. This confirmed that the berries were harvested after the arrest of phloem unloading, as illustrated by the sudden repression of aquaporins and sugar transport genes[4]. A very low number (37 out of 15000) of genes of unclear function displayed preferential expression in each genotype. Consequently, neither genotype statistically departed from the same developmental sequence between the end of the green stage and harvest. However, in the less concentrated genotype, this sequence noticeably slowed down during the final period of water loss associated with over-ripening.

Conclusion

Climate change is causing us to reconsider the objectives of clonal selection. Merlot's diversity becomes particularly apparent during the terminal phase of grape development, when the sugars concentrate due to evaporation. It does, however, seem to mobilise differences in the water use efficiency of the whole plant prior to this last phase. Merlot's diversity opens up possibilities for adaptation to moderate climate change.

Sourced from: Lesbats Sichel V. (2023) 'Identification et sélection intra-variétale de la vigne à l'aide des outils génomiques actuels'. PhD Thesis. Institut Agro Montpellier, Université Montpellier, 14 décembre 2023, 144 pages.

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