Varieties and rootstocks: an important mean for adaptation to terroir

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ABSTRACT
A large genetic diversity exists among *V. vinifera* varieties, but also among cultivated rootstocks. This diversity is important to adapt plant material to different environmental conditions and contributes to the expression of terroir. Plasticity, i.e. the level of modification of the expression of individual characteristics of a genotype in different environments, is also important for adaptation. The most important physiological parameters which contribute to this adaptation are briefly reviewed. For varieties, phenology, drought responses and ripening processes are crucial. For rootstocks, variability in nutrients and water uptake, as well as their effects on whole plant development is important. A better description and understanding of the genetic variability and plasticity for these traits is highly required in order to improve the adaptation of the plant material to the current growth conditions. It will also help to develop strategies in order to respond to the ongoing climate change.

Keywords: grapevine, genetic diversity, phenology, ripening, drought responses.

1 INTRODUCTION

Genotype is an important source of variability, taking into consideration the large diversity within the *Vitis* genus [1]. Within a given genotype (cultivar or clone), variability is the result of plasticity, which is "the amount by which the expression of individual characteristics of a genotype are changed by different environments" [2]. Genetic variability and plasticity offer the advantages to adapt existing cultivars to a specific location of production and terroir, to elaborate a large range of different wines from the same cultivar or to breed new cultivars well adapted to different specific g area [3]. Rootstocks which are used to cope with Phylloxera in most vineyards around the world represent an additional element to soil and environmental condition adaptation. They finally contribute to the enhancement of terroir expression. The needs to evaluate the genetic variability (both genetic diversity and phenotypic plasticity) are further increased by the ongoing climate change. Indeed climate change may alter the adaption of a cultivar to a specific growth season [4, 5, 6] However, existing varieties and rootstocks, but also new bred ones, can be a key element of adaptation to these new conditions [7, 8]. An overwiew of the different processes involved in plant material adaptation to terroirs will be presented.

2 VARIETIES

The adaptation of varieties to terroir is most probably linked to complex processes which are not only biological. Viticultural and oenological practices are also very important. However the understanding of the biological components of the adaptation is crucial if we want to use varieties as an adapting tool in a changing environment. Phenology, drought responses and ripening are among the biological processes which could participate to variety adaptation to terroirs.

2.1 Phenology

Phenology is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and interannual variations in climate. It has been principally concerned with the dates of first occurrence of biological events in their annual cycle. According to Chuine [9], phenology is a key adaptive trait. It is acknowledged that the production of high quality wines is associated to conditions where grapevine vegetative and reproductive development fits with local conditions, in order to reach optimum levels of sugar, acid, and flavour [5]. There is a large variability among grape varieties for the length of the growth period and the time to reach adequate berry composition [10]. Several studies provide information about the characterization of grape varieties for the temporal occurrence of the key phenological stages, based on bioclimatic indices [6, 11, 12]. Using the same indices to characterize various growing zones may provide information about the ability of a specific variety to ripen [13]. The genetic determinism of phenological stages is under analysis and several genomic regions involved in the control of these stages have been identified [14; Decroocq, personal communication; Duchêne, personal communication].

2.2 Drought responses

Water availability is an important parameter of terroir effect and wine quality [15]. Grapevines are well adapted to semi-arid climate due to the large and deep root system and physiological drought avoidance mechanisms [16]. There is a large genetic variability in the response to soil and atmospheric water deficits. However, most genotypes remain uncharacterized. Regulation of stomatal conductance and water use efficiency vary with grapevine variety [references cited in 16, 17]. Some genotypes which show a better control of stomata than others in response to water deficits are characterized as isohydric (or pessimistic or drought avoiders). On the opposite, anisohydric varieties maintain high transpiration under water deficit, which is supposed to be beneficial to ripening and sugar accumulation under limiting conditions [17, 18]. The ability to retain leaves under drought conditions which is most probably associated to the sensitivity to cavitation is also an important parameter to adapt varieties to various water conditions. Nevertheless the information is still very fragmentary and further work is needed.

2.3 Ripening processes

The physiological processes underlying ripening, i.e. mainly sugar accumulation, acid metabolism, polyphenol and aroma synthesis, are controlled by environmental parameters. In addition there is a large genetic variability among *V. vinifera* varieties for the potential accumulation of these compounds and for the plasticity of these traits [3]. At maturity, Kliewer [19] reported a range of total sugar concentration of 18.7 to 27°brix, of 4 to 9.4 g/L for tartrate, and 1.5 to 6.8 g/L for malate among 78 *V.vinifera* cultivars (grown at the same location). In the same study, tartrate to malate ratio, which is an important trait to evaluate acidity response to high temperature, varied from 0.64 to 3.4. Indeed elevated temperatures clearly decrease the malate concentration whereas tartrate does not appear sensitive [20, 21]. Sadras et al., [22] reported also variety-dependent dynamics of soluble solids and water in berries of *V. vinifera*. Each grape cultivar is also characterized by a distinct set of anthocyanins [23]. Additionally it was shown that the different forms of anthocyanins are not equally sensitive to environmental conditions, which results in more complex profiles [references cited in 3]. When quantifying the phenotypic plasticity of both anthocyanins and sugars in berries of Cabernet Sauvignon, sugar accumulation was shown to be more strictly associated to thermal time whereas anthocyanin accumulation was also affected by other sources of variations [24]. It may explain why the amount of anthocyanins display a much wider range of variation than sugar, and why the delay between maximal sugar and polyphenol accumulation increases under climatic change. These few examples show that for a better understanding of the adaptation of grape cultivars to terroir, and its further use in the frame of climate change, it is mandatory to characterize the genetic variability and the effects of environmental parameters not only on the potential accumulation of compounds, but also on the kinetic parameters of accumulation curves. Modelling will be the only way to take into account and extract useful information from this complexity [25].

3 ROOTSTOCKS

If the *sine qua non* reason to use rootstocks in viticulture is still to cope with phylloxera damages, rootstocks represent an important way to adapt a specific variety to different environmental conditions, especially edaphic ones. Moreover, the grafted grapevine is made from two genotypes which interact. Rootstock is known to affect varietal behaviour directly or indirectly via the development of the whole plant. The most important aspects of the rootstock contribution to adaptation to terroir are linked to mineral nutrition, water supply and effects on whole plant development.

3.1 Mineral nutrition

There is a large diversity between rootstocks for their ability to take up mineral nutrients, even if the underlying mechanisms are still unknown.

Depending on the situations, the effects can extend from mineral content of various organs and mild developmental effects to deficiencies or toxicities which prevent grapevines to grow properly.

For nitrogen, the absorption seems to be mostly related to the requirements of the aerial parts. There are many reports that rootstocks affect potassium, magnesium, and phosphorus nutrition [26]. The most documented effect on fruit quality is for potassium which plays a role in the acidic balance of the juice and consequently on wine quality. As a key factor of adaptation to some nutritional problems, as for example iron deficiency in calcareous soils, rootstocks are determinant for the development of grape growing on specific types of soils which are of particular interest for high quality [27].

3.2 Water supply

It is acknowledged that rootstocks contribute to the adaptation of drought of the grafted vine. Several classifications have been established for the cultivated rootstocks throughout the world [28, 29]. Rooting depth, root architecture and root water uptake capacities may explain the differences between rootstocks. Rootstocks may also differ in the hydraulic properties and their ability to draw water to the aerial parts [30-31]. It was also shown that rootstocks affect the regulation of water losses by the foliage. Root signals or indirect effects via leaf area could be involved [32].

3.3 Whole plant development

The complex relationships between the root and shoot systems of grafted grapevine have been widely studied particularly in relation to the effect of rootstock genotype on scion development, both in adult vines growing in a vineyard and in young potted vines. Rootstocks affect intensity and duration of individual shoot growth, leaf area and trunk size, pruning weight, bud fertility, yield, phenology [33,34, and references cited therein]. The combination of these effects could explain the rootstock effect on fruit composition and quality [35] and consequently the contribution of rootstock to the expression of the terroir.

4 CONCLUSIONS

This short report aimed at reviewing some physiological processes which are contributing to variety and rootstock adaptation to terroirs. In the context of climate change, it is highly necessary to improve our knowledge about the genetic diversity for the most important traits involved in quality and environmental effects. It will be the only way to adapt more efficiently viticulture to the new predicted conditions for the XXIst century.

REFERENCES

1. P. THIS, T. LACOMBE, M. THOMAS, 2006. Trends Genet. 22, 511-519.

2. A.D. BRADSHAW, 1965. Adv. Genet. 13, 115-155.
3. Z.W. DAI, N. OLLAT, E. GOMES, S. DECROOCQ, J.P. TANDONNET, L. BORDENAVE, P. PIERI, G. HILBERT, C. KAPPEL, C. VAN LEEUWEN, P. VIVIN, S. DELROT, 2011. Am. J. Enol. Vitic. 64, 413-425.
4. H.R. SCHULTZ, 2000. Aust. J. Grape Wine Res. 6, 2-12.
5. G.V. JONES , M.A. WHITE, O.R. COOPER, K. STORCHMANN, 2005. Clim. Change 73, 319-343.
6. E. DUCHENE, F. HAURD, V. DUMAS, C. SCHNEIDER, D. MERDINOGLU, 2010. Clim. Res. 41, 193-204.
7. C. VAN LEEUWEN, B. BOIS, N. CELLIE, O. TREGOAT, J.-P. ROBY, 2009. Rev. Française Oeno 235, 10-14.
8. N. OLLAT, L. FERNANDEZ, C. ROMIEU, E. DUCHENE, J.R. LISSARAGUE, D. LECOURIEUX, A. AGEORGES, M. KELLY, J. CACHO, J. RIVAS, R. LAMUELA, J.-P. GOUTOULY**,** C**.** VAN LEEUWEN**,** **E.** MARGUERIT, A. PECCOUX, F. BARRIEU, P. THIS, E. LEBON, A. PELLEGRINO, J.M. MARTINEZ ZAPATER, L. TOREGROSSA, 2011. XVIIth International GIESCO meeting.
9. I. CHUINE, 2010. Phil. Trans. R. Soc. B. 365, 3149-3160.
10. C. VAN LEEUWEN, V. RENOUF, O. TREGOAT, E. MARGUERIT, J.-P. ROBY, 2008. VIIth International Terroir Congress.
11. P. HUGLIN, 1978. C.R. Ac. Agric., 1117-1126.
12. A. PARKER, I.G. DE CORTAZAR ATAURI, C. VAN LEEUWEN, I. CHUINE, 2011. Aust. J. Grape Wine Res. 17, 206-216.
13. B. BOIS, 2007. Thesis, University of Bordeaux I, 210 p.
14. L. COSTANTINI, J. BATTILANA, F. LAMAJ, G. FANIZZA, M.S. GRANDO, 2008. BMC Plant Biol 8, 38.
15. G. SEGUIN, 1983. Bulletins de l'O.I.V. 623, 3-17.
16. M.M. CHAVES, O. ZARROUK, R. FRANCISCO, J.M. COSTA, T. SANTOS, A.P. REGALADO, M.L. RODRIGUES, C.M. LOPES, 2010. Ann. Bot. 105, 661-676.
17. J.A. PRIETO, E. LEBON, H. OJEDA, 2010. J. Int. Sci Vigne et Vin. 44, 9-20.
18. H.R. SCHULTZ, 2003. Plant, Cell & Env. 26, 1393-1405.
19. W.M. KLIEWER, 1967. Am. J. Enol. Vitic. 18, 87-96.
20. M. KELLER, L.J. MILLS, R.L. WAMPLE, S.E. SPAYD, 2005. Am. J. Enol. Vitic. 56, 91-103.
21. C.S. PARRA, J. AGUIRREOLEA, M. SÁNCHEZ-DIAZ, J.J. IRIGOYEN, F. MORALES, 2010. Plant Soil 337, 179-191.
22. V.O. SADRAS, M. COLLINS, C.J. SOAR, 2008. Aust. J. Grape Wine Res. 14, 250-259.
23. G. MAZZ, 1995. Crit. Rev. Food Sci. Nutr. 35, 341-371.
24. V.O SADRAS, M.G. MCCARTHY, 2007. Aust. J. Grape Wine Res. 13, 66-71.
25. Z.W DAI, P. VIVIN, F. BARRIEU, N. OLLAT, S. DELROT, 2010. Aust. J. Grape Wine Res. 16, 70-85.
26. J. DELAS, 1992. Am. Soc. Enol. Vitic., 1-14.
27. R. POUGET, J. DELAS, 1989. Conn. Sci. Vigne Vin, 27-31.
28. M. FREGONI, 1977. Bulletin de l'OIV 551, 1-17.
29. A. CARBONNEAU, 1985. Am. J. Enol. Vitic 36, 195-198.
30. E. PETERLUNGER, 1990. Vignevini 6, 43-46.
31. F. DE HERRALDE, M.M. ALSINA, X. ARANDA, R. SAVE, C. BIEL, 2006. J. Int.Vigne Vin 40, 133-139.
32. E. MARGUERIT, O. BRENDEL, E. LEBON, C. VAN LEEUWEN, N. OLLAT, 2012. New Phytol. 194, 416-429.
33. P. MAY, 1994. Winetitles, Adelaïde, Australia.
34. J-P. TANDONNET, S.J. COOKSON, P. VIVIN, N. OLLAT, 2010. Aust. J. Grape Wine Res. 16, 290-300.
35. N. OLLAT, J.P. TANDONNET, M. LAFONTAINE, H.R. SCHULTZ, 2003. Acta Hort. 617, 95-100.

Conservation de la diversité intravariétale de la vigne en France : inventaire exhaustif et perspectives
Conservation of intravarietal diversity in France: exhaustive overview and perspectives

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