A Combination of Phenotyping, Genetic and Physiological Approaches to Guide Breeding for Efficient Water Use in Grapevine

Aude Coupel-Ledru, Eric Lebon, Angélique Christophe, Agnes Doligez, Thierry T. Simonneau

A Combination of Phenotyping, Genetic and Physiological Approaches to Guide Breeding for Efficient Water Use in Grapevine

A. Coupel-Ledru[1,2], E. Lebon[1,2], A. Christophe[1,2], A. Doligez[2,3], T. Simonneau[1,2]
[1]*INRA, UMR 759 LEPSE, Montpellier, France*
[2]*Montpellier SupAgro, UMR 759 LEPSE, Montpellier, France*
[3]*INRA, UMR AGAP, Montpellier, France*

Water scarcity associated with climate change particularly threatens the sustainability of viticulture in most cultivated, drought prone areas. Breeding grapevine for reduced water use and maintained production (that is high water-use efficiency) is therefore of major interest. This requires a comprehensive knowledge of the physiological impacts of drought which are the most influential on yield and quality. Special attention should be paid to those mechanisms involved in the regulation of water status in plant tissues as the primary parameter affected by drought. Transpiration rate, which has major influence on plant water status, together with water-use efficiency, therefore require special attention in breeding programs.

To progress on the determinism of transpiration rate and water-use efficiency in grapevine, we used a F1 progeny made of 188 genotypes from a cross between two widespread cultivars, Syrah and Grenache, well-known for their contrasted water use. We showed the benefits of combining quantitative genetics (for QTL detection) and physiological experiments to study this population both in the vineyard and on potted plants. On the one hand, we developed an original experimental design in the field coupled to geostatistical modelling to take into account the spatial variability of soil water status inherent to vineyard conditions. This helped to identify significant genetic variability for the traits of interest. On the other hand, we combined powerful phenotyping tools on potted plants (high-throughput platform and controlled chambers) to control water deficit conditions and improve QTL detection.

First, we found evidence that a dual physiological mechanism controls the decline of leaf water status under drought with a key role for plant hydraulic conductance beside that of stomatal control of transpiration. Contrasted combination of these two controls may lead to more or less efficient maintenance of leaf water status in response to soil drying (i.e. iso- or anisohydric behaviour). An indirect role of abscisic acid on stomatal conductance was also identified, mediated by the downregulation of leaf hydraulic conductance, with a genetic variability which correlated with genetic variation in iso- or aniso-hydric behaviour. We then revealed wide genetic variations in nocturnal transpiration, which correlated with variations in whole plant water-use efficiency (WUE), and identified corresponding genetic and physiological determinants. Lastly, we showed some consistency between QTLs detected for daytime WUE in pots and in the vineyard.
Beyond the potential interest of the QTLs detected in this study for breeding prospects, this work demonstrated the interest of quantitative genetics to shed light on ecophysiological and physiological processes.

Key-words: Water deficit, QTL, high-throughput phenotyping, isohydric, transpiration, hydraulic conductance, abscisic acid, water-use efficiency, night time transpiration.

Acknowledgments: This work was supported by the French programs LACCAVE funded by the "Institut National de la Recherche Agronomique" and ANR-09-GENM-024-002. AC-L. received a PhD Grant from the French government.