The rootstock, the neglected player in the scion transpiration even during the night

Davide Bianchi[1,2], Bruno Baricelli[1], Gregory Gambetta[1], Nathalie Ollat[1], Elisa Marguerit[1]

[1] EGFV, Bordeaux Sciences Agro, INRAE, Univ. Bordeaux, ISVV, F-33882 Villenave d'Ornon, France
[2] Department of Agricultural and Environmental Sciences, University of Milan, via G. Celoria 2, 20133 Milano, Italy

***Corresponding author:** elisa.marguerit@agro-bordeaux.fr

Keywords: nocturnal transpiration, vapour pressure deficit, water deficit, plasticity, grapevine

Abstract

Improving drought adaptation in viticulture is an increasingly important issue under climate change. Genetic variability of water deficit responses in grapevine partly results from rootstocks, making them an attractive and relevant means to achieve adaptation without changing the scion genotype. The objective of this work was to characterize the rootstock effect on the diurnal regulation of scion transpiration.

A large panel of 55 commercial genotypes were grafted onto Cabernet Sauvignon. Potted plants were phenotyped on a greenhouse balance platform. Growth related traits and transpiration were recorded. $\delta^{13}C$ was measured in leaves for the baseline and stable water deficit periods. A large genetic variability was observed within the panel. The rootstock had a significant impact on nocturnal transpiration which was also strongly and positively correlated with maximum daytime transpiration. The correlations with growth and water use efficiency related traits will be discussed. Transpiration data were also related with VPD demonstrating the influence of environmental conditions on transpiration. These results highlighted the role of the rootstock in modulating water deficit responses and provide insights for rootstock breeding programs aimed at identifying drought tolerant rootstocks.

Introduction

Water is the main factor limiting yield in viticulture. Vine water status also strongly impacts grape quality (van Leeuwen et Seguin, 1994). In the context of climate change, cultural practices could be adapted, but in some regions this will not be sufficient (Garcia de Cortazar, 2006). Among the technical innovations to explore, the plant material is crucial. We consider the use of tolerant rootstocks as a relevant agronomical practice to cope with water deficit. Although drought tolerant and drought sensitive rootstocks are well identified in the vineyard, the mechanisms involved in drought tolerance are poorly understood and only one exhaustive classification built with quantitative criteria was published (Carbonneau, 1985). We are still looking for a trait, or a combination of traits, that can explain the drought tolerance induced by rootstocks observed in the field. Several authors analyzed the nocturnal transpiration between different scions to understand its impact in drought tolerance responses (Coupel-Ledru et al. 2016; Dayer et al. 2021). In this study, we have analyzed the scion transpiration induced by a large panel of rootstocks during the day and night. Our objective is to characterize the rootstock effect on scion transpiration regulation.

Materials and methods

The experiment was carried out in pots, in a greenhouse equipped with a 150 scale platform according to the protocol described by Marguerit et al. (2012). Three replicates per rootstock were grown in 7.5 L pots with a loamy clay soil characterized by a high water retention capacity (453g water retained per kg of soil). A progressive water deficit was applied after 10 days of well-watered conditions. It was followed by 7 days of stable water deficit characterized by a decreasing of 50% of water retention capacity. Irrigation was applied in the mid-morning in order to obtain the desired level of soil water content. This experiment was carried out during two independent years, 2015 and 2017, with a new set of plants.

Transpiration was evaluated daily by weighing each pot individually. Leaf area measurements were performed weekly in order to calculate the daily transpiration per unit of leaf area. Shoot length was measured every two days. $\delta^{13}C$ was measured in leaves for the baseline and stable water deficit periods.

Results and discussion

The transpiration followed the classical evolution during the day (Figure1). In control conditions, the nocturnal transpiration represented from 13% and 22% of daytime transpiration in 2015 and 2017 respectively. In water deficit conditions, it was difficult to get such an estimation because of stomatal closure and the very low values of transpiration during both day and night. The rootstock effect was highly significant for most of the time periods during the day and the night (Table 1). A large genetic variability was observed within the panel. The rootstock had a significant impact on nocturnal transpiration which was also strongly and positively correlated with maximum daytime transpiration.

The correlations between the shoot length grown during the control conditions and nocturnal transpiration or daytime transpiration were calculated (Figure 2). The correlation was only significant in 2017 between the shoot length and daytime transpiration (R^2=0,18). No significant correlations were observed between $\delta^{13}C$ and nocturnal or daytime transpiration in control conditions. These results highlighted the absence of negative effects of the nocturnal transpiration on water use efficiency. Transpiration data were also related with VPD demonstrating the influence of environmental conditions on transpiration.

The rootstock effect on scion transpiration plasticity was already demonstrated by the identification of QTLs (Marguerit et al. 2012). Here we demonstrated the significant effect of the rootstock on the scion nocturnal transpiration which could be a target in breeding programs for drought tolerance. However, because nocturnal transpiration was not related with the growth related traits and water use efficiency estimated by $\delta^{13}C$, the role of nocturnal transpiration diversity was not yet elucidated. Several theories explaining the purpose of nocturnal transpiration have been put forth (Wang et al 2021). The theory of the leaf cooling proposed by Coupel-Ledru et al. (2016) could be a relevant explanation in the context of the dialogue between the scion and the rootstock with the perception of the water deficit in the air and in the soil respectively.

Conclusion

The significant effect of the rootstock on nocturnal transpiration was demonstrated. The role of the rootstock in the scion transpiration regulation is here reinforced. This work allows a quantitative characterization for drought tolerance for a large range of rootstocks used all over the world. These results assessed in controlled conditions should be confirmed by a field experiment allowing the identification of candidates for registration of new rootstocks in France.

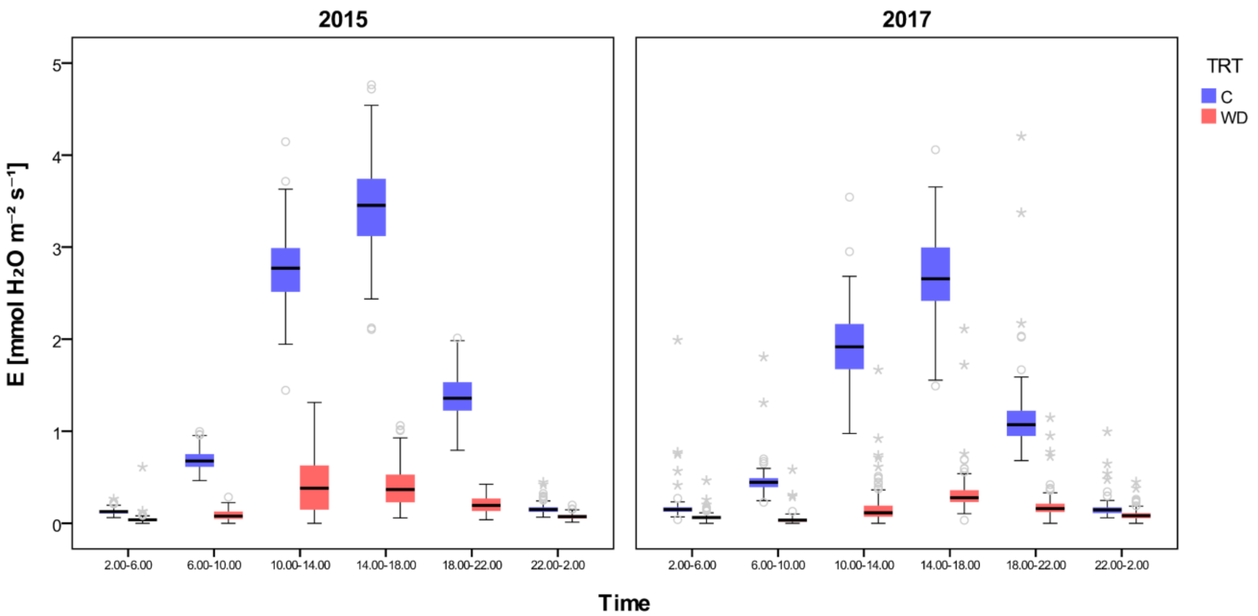

Figure 1. Transpiration (E in mmolH_2O m^{-2} s^{-1}) at the day scale for control (C) in blue and water deficit conditions (WD) in red.

Table 1. Significance of the rootstock effect on transpiration values with Kruskal Wallis test for 2015 and 2017 in control (C) and water deficit conditions (WD).

Condition	2:00-6:00	6:00-10:00	10:00-14:00	14:00-18:00	18:00-22:00	22:00-2:00	E_d	E_n	E_n/E_d
2015C	***	ns	***	***	***	***	***	***	***
2015WD	ns	***	***	***	***	***	***	***	***
2017C	***	ns	***	***	***	***	***	***	***
2017WD	***	***	***	***	***	***	***	***	***

*** is for a p-value <0.001 and ns is for non-significant p-value

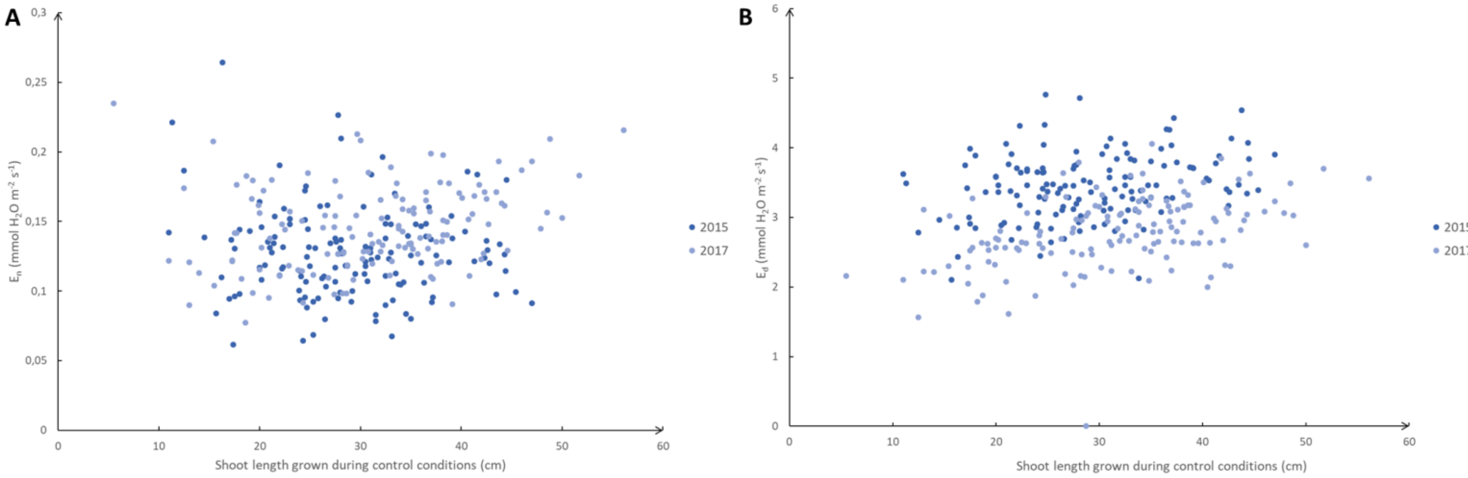

Figure 2. Relation between shoot length grown during control conditions and A) nocturnal transpiration (E_n in mmol H_2O m^{-2} s^{-1}) and B) daytime transpiration ((E_d in mmol H_2O m^{-2} s^{-1})

Acknowledgements

We would like to thank Maria Lafargue, Bernard Douens, Cyril Hévin, Jean Pierre Petit and Jean Paul Robert for the management of the plant material and the grafting of all the combinations. We also thank Guillaume Pacreau and Nabil Zirari for the management of the scales platform. Without the work of this team, it would not have been possible to collect such a large data set. We also thank CIVB (Conseil Interprofessionnel du Vin de Bordeaux) for financial support.

References

Carbonneau, A. (1985). The early selection of grapevine rootstocks for resistance to drought conditions. *American Journal of Enology and Viticulture, 36*(3), 195-198.

Coupel-Ledru, A., Lebon, E., Christophe, A., Gallo, A., Gago, P., Pantin, F., . . . Simonneau, T. (2016). Reduced nighttime transpiration is a relevant breeding target for high water-use efficiency in grapevine. *Proceedings of the National Academy of Sciences*. https://doi.org/10.1073/pnas.1600826113

Dayer, S., Herrera, J. C., Dai, Z., Burlett, R., Lamarque, L. J., Delzon, S., . . . Gambetta, G. A. (2021). Nighttime transpiration represents a negligible part of water loss and does not increase the risk of water stress in grapevine. *Plant, Cell & Environment, 44*(2), 387-398. https://doi.org/10.1111/pce.13923

Garcia de Cortazar, I. (2006). *Adaptation du modèle STICS à la vigne (Vitis vinifera L.). Utilisation dans le cadre d'une étude du changement climatique à l'échelle de la France.* Doctorat, Ecole Nationale Supérieure d'Agronomie de Montpellier, Avignon.

Marguerit, E., Brendel, O., Lebon, E., van Leeuwen, C., & Ollat, N. (2012). Rootstock control of scion transpiration and its acclimation to water deficit are controlled by different genes. *The New Phytologist, 194*(2), 416-429. https://doi.org/10.1111/j.1469-8137.2012.04059.x

Wang, Y., Anderegg, W. R. L., Venturas, M. D., Trugman, A. T., Yu, K., & Frankenberg, C. (2021). Optimization theory explains nighttime stomatal responses. *New Phytologist, 230*(4), 1550-1561. https://doi.org/10.1111/nph.17267