KEYNOTE LECTURE

Rootstocks: how the dark side of the vine can enlight the future?

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INTRODUCTION

Global challenges, including adaptation to climate change, decrease of the environmental impacts and maintenance of the economical sustainability shape the future of viticulture. These issues are highly complex and there is no chance that a simple and single solution can solve all of them. From the vineyard perspective, there is an urgent need to analyze cropping systems as a whole and to seek for combined levers which can result in more resilient growing conditions. Doing that, the belowground parts of the vines and the interactions between the soil compartment and the aerial parts require a special focus, as they can be central to develop more agroecological and climate smart practices.

Globally the soil functioning relies on its chemical composition, physical structure and conditions (temperature, water and oxygen content) in interactions with the organic matter content and biological activity. Climate change is not only affecting atmospheric conditions, but also the soil compartment with increases in temperature which could be much higher than for air temperature (Schultz, 2025). Whereas the increase in CO_2 concentration, temperature and the modifications of rainfall regimes have a direct impact on soil as a resource, their effects on the biological component are probably also huge. In addition, climate changer endangers the availability of arable land through enhanced erosion and salinization. The consequences on water supply, mineral nutrition and health of grapevines are an important matter of concern, as they are key factors of wine quality. Despite its importance the underground compartment of vineyards is most of the time neglected due to its complexity and to the difficulties to access (Follain et al., 2025; Schultz, 2025). According to the 4 for 1000 initiative, healthy soils, rich in carbon, are also considered as the basement to mitigate climate change and support agricultural production, which underlines the role of soil to a central component of our future (OIV, 2022).

In most vineyards worldwide, rootstocks represent the major biological link between the soil and the aerial parts of the vines, and their functioning results in transferring the soil properties into wines. Despite the fact they are a key factor of terroir, they have largely been neglected in terms of scientific studies and levers of the viticultural system. Difficulties to access to the hidden part of the plant may explain this lack of knowledge (Bernardo et al., 2025). Their potential contribution to tackle current and future challenges of viticulture and new technologies have changed the game. From genomics to modelling studies, through physiology, genetics and microbiology, interests in rootstocks have increased exponentially over the past 20 years. We consider that this new knowledge can be highly valuable to develop environment friendly and sustainable solutions for the future.

In this context, this communication will give an overview of the most recent findings regarding rootstocks properties. Data regarding the genetic determinism of biotic and abiotic stress resistance/tolerance, root system development characterization and modelling, physiological responses to abiotic stresses, interactions with soil microorganisms on one side and with scions on the other side will be presented.

GENETIC DETERMINISM OF BIOTIC AND ABIOTIC STRESS TOLERANCE

Over the past ten years, new insights have been brought regarding the genetic architecture of phylloxera and nematode resistances in wild Vitis, providing perspectives to the use of molecular markers to screen new rootstocks. Studies about the genetic determinism of abiotic stress tolerance at the root level remain scarce, all showing that it is highly complex and probably related to many traits and genes (Bernardo et al., 2025; Ollat et al., 2025). However, the recent development of genomic resources for a large set of Vitis and rootstocks provides new tools to analyze this complexity and identify the most relevant genes, as it was shown for resistance to salinity (Cochetel et al., 2023).

ROOT SYSTEM DEVELOPMENT CHARACTERIZATION AND MODELLING

The ability of the root system to explore the soil volume is central for its role in capturing the resources and adapting to the spatiotemporal variability of resource availability. While, for decades, the south African scientists were almost the only ones to explore the root system architecture of grapevine in response to soil type, planting density and rootstocks, a new generation of researchers is now tackling this challenge with modern approaches of phenotyping and the development of specific models (Fichtl et al., 2023, Bernardo et al., 2025). Data about the genetic architecture of rooting ability and early root system development have also been released for several genetic backgrounds, showing some complexity, but eventually shared controlling regions between species (Ollat et al., 2025).

PHYSIOLOGICAL RESPONSES TO ABIOTIC STRESSES

Drought and salinity are among the most deleterious abiotic stresses related to climate change and soils. The responses of various grapevine rootstocks have been studied widely trying to identify which traits would segregate sensitive to tolerant genotypes. Most reviews demonstrate that tolerance to such stresses is most probably associated to syndromes of characteristics including developmental and functioning responses such as anatomical and hydraulic properties, osmotic and anti-oxidant processes (Bernardo et al., 2025; Lai et al., 2024). Genes underlying these processes are probably numerous, although the genetic determinism may be simpler for salinity tolerance (Cochetel et al., 2023; Lai et al., 2025).

INTERACTIONS WITH SOIL MICROORGANISMS

The number of studies showing that grapevine rootstocks affect the communities of microorganisms in the soil and the rhizophere is increasing exponentially (Darriaut et al., 2022; Francioli et al., 2024). These interactions may modulate nutrient acquisition, water-use efficiency, and pathogen resistance and are highly promising to improve the resilience of grapevine in low fertility soils and harsh conditions. How it works from a functional perspective both at the microorganism and the plant sides remains largely unknown. Manipulating these communities or selecting rootstocks promoting interactions with beneficial microorganisms is promising, but will depend on many additional investigations.

INTERACTIONS WITH THE SCION

Rootstock means grafting, which also means interaction with the scion. Although most grapevines are grown grafted worldwide, investigations on the physiological and genetic mechanisms underlying grafting and which may explain rootstock-scion interactions are extremely rare. Using the most modern approaches to study one of the oldest horticultural practice showed that graft union formation involves complex interactions among signaling, carbon availability, dormancy release, wound responses and non-self-communication in grapevine (Loupit et al., 2025). Once both genotypes are developing as a single plant, most large-scale studies of rootstock-scion interactions demonstrate however a major scion effect which is often under-evaluated. This should be taken into account in all rootstock studies (Ollat et al., 2024).

CONCLUSION

Considering their role as interface between the physico-chemical and biological component of the soil on one side and the “noble” aerial part of the grapevine on the other side, rootstocks are fundamental to tackle the actual and future challenges of viticulture. Turning more interest to the dark side of the vine should for sure enlight the future. The effort is worth.

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