ROOTSTOCK DIFFERENCES IN SOIL-WATER UPTAKE DURING DRYING-WETTING CYCLES IMAGED WITH 3D ELECTRICAL RESISTIVITY TOMOGRAPHY

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Abstract:

Context and purpose of the study – Limited knowledge has been acquired on grapevine roots and rhizosphere processes because of harder access when compared to aerial parts. There is need for new methods to study root behavior in undisturbed field conditions, and relate these effects on canopy and yield. The aim of this multidisciplinary study was to image and quantify spatial-temporal differences in soil-water uptake by genetically different rootstocks and to assess the response of the canopy during drought and rewetting.

Material and methods – During two years, three replicates of 10 plants of Chardonnay, 5 plants grafted onto 110R and 5 on 101-14 Mgt, were monitored in a drip-irrigated experimental vineyard. Each experimental unit was equipped with time-domain reflecrometer sensors for continuous measurement of soil water and with stainless-steel rods and micro-borehole electrodes for time-lapse 2D and 3D electrical resistivity tomography (ERT). The soil profile was described with soil pits at both ends of the experimental units and sampled for physical-chemical analysis. Grapevine water status of each vine was monitored routinely with 3h-lag diurnal cycles of water potentials and leaf gas-exchanges (from predawn to following night) and $\delta^{13}C$ at harvest. Light and C_i photosynthesis response curves, predawn Fv/Fm were measured under dry and wet conditions. Grape composition, yield components and pruning-weights were also measured.

Results – Different models were tested to develop a pedotransfer function and transform electrical resistivity into soil volume wetness. Due to the sandy nature of the soil the Archie law performed well and was used to map water depletion in 3D with an error of 1.2 %vol., R^2 = 0.73 (measured on an independent test set). Before rewetting the grapevine experienced severe drought stress in both years of the study (< -10MPa in predawn), and amount of soil water per vine was significantly correlated to single plant water potentials and to canopy size. One fold differences in the amount of soil water absorbed by the two rootstocks were reached at the end of the drought period, with distinct spatial patterns. The 110R was more conservative, and soil depletion was localized in space around each vines, while the 101-14 was less conservative and more homogenously and deeply depleted the soil profile affecting whole plant water status and leaf physiology that was more depressed. Replenishment of the fraction of transpired soil water by drip irrigation was imaged by time-lapse ERT, and differences were observed in the reaction to rewetting by the two rootstocks.

Keywords: Grapevine, Rootstocks, Electrical Resistivity Tomography ERT, Water stress, Soil water, Drought, Drip irrigation

1. Introduction.

Rootstock Differences in Soil Water Uptake During Drying Wetting Cycles Imaged With 3D Electrical Resistivity Tomography

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Scope

BUILDING NEW, PERFORMANT TOOLS FOR FIELD MONITORING OF ROOT DEVELOPMENT & FUNCTIONING IN SPACE AND TIME TO DEVELOP MODERN, ROOT-ORIENTED CULTURAL PRACTICES.

Methods

VINEYARDS
- Chardonnay/different rootstocks, sprawling, 4m x 7.3m (vine x row), UC Davis

GRAPEVINE PHYSIOLOGY
- Pre-dawn water potential ($\Psi_{pre-dawn}$)
- Pruning weights

SOIL
- Texture and organic matter from soil pits, profile description

SENSING
- Time-domain reflectometry (TDRs, Acclima Inc.)
- Electrical resistivity tomography (ERT, Syscal Pro, Iris Instruments)

GEOPHYSICAL & STATISTICAL ANALYSIS
- Geophysical Inversion, PyGIMLI
- Statistical analysis and model fitting, R v.3.4.3

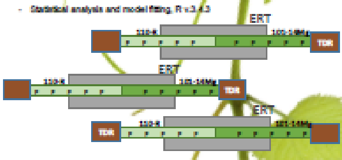
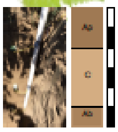


Figure 1. Scheme of the experimental site, with locations of plants and soil pits

Results

Figure 2. Soil of the experimental units and TDRs installed.
Table 1. Texture and organic matter at different depths.

Soil belongs to the Reiff series (coarse-loamy, mixed, superactive, nonacid, thermic Mollic Xerofluvents). A very deep well drained soil formed on an alluvium stream



Depth (cm)	OM (%)	Sand (%)	Silt (%)	Clay (%)	Texture class USDA	Horizon
0-20	2.20	58	26	16	Sandy Loam	Ap
20-40	2.03	58	26	16	Sandy Loam	Ap
40-60	2.33	40	32	20	Loam	C
60-80	2.32	40	35	18	Loam	C
80-100	2.42	40	38	18	Loam	C
100-120	2.81	41	37	22	Loam	Ab

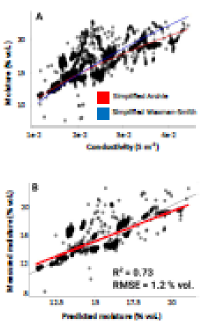


Figure 3. Relationship between soil conductivity, σ (S m⁻¹), and soil moisture, θ (% vol.) at the experimental site. A) train set; B) test set (black line is identity line).
Soil conductivity, σ, was brought to reference temperature (25 °C) before fitting a selection of petrophysical models to the data. Models were:
- simplified Archie, adapted to sandy conditions

$$\theta = \sqrt[n]{\frac{\sigma_{25}}{A}}$$

where A express influence of all soil properties except water on soil conductivity
- linearized version of the former: $\log(\sigma_{25C}) = n\log(\theta) + \log(A)$
- Simplified Waxman and Smith, to take into account for the electrolytic conductivity of clay

$$\theta = \sqrt[c]{\frac{\sigma_{25C} - b}{a}}$$

a is affected by pore water conductivity, b by the soil surface conductivity, c is a fitting parameter

Table 2. Results on the test set of the different models applied (see Figure 2 above). RMSE = Root Mean Square Error

Model	RMSE (% vol.)	R²
Linear Archie	1.23	0.73
Archie	1.23	0.73
Waxman-Smith	1.23	0.73

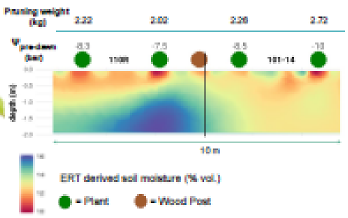


Figure 4. Comparison of soil moisture in 2D under 110R and 101-14 rootstocks. Figure acquired in post-harvest from a rainfed experiments that did not receive irrigation during the growing season. The variability in soil moisture reflect canopy size (expressed weight of pruning wood) and predawn water potential, with dryer soil regions under bigger and more stressed vines.

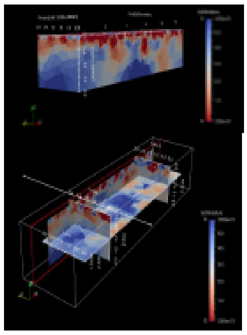


Figure 5. The first 3D images of water distribution under grapevines. Obtained in field conditions by electrical resistivity tomography. Figure shows the 3D cube and possibility of slicing across all directions.

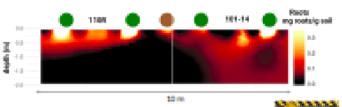


Figure 6. Assessing roots presence according to correlation with water depletion (r = 0.46, p < 0.05). PRELIMINARY RESULT, showing future directions of this study

Conclusions

This work shows some of the results obtained during the first of a multiyear project performed thanks to the funding from the American Vineyard Foundation. This project is devoted to the development of new, non invasive tools for the study of rootstock development and functions, especially in relationship to water uptake and irrigation.

In the first year of the study we successfully performed calibration of the ERT with soil volumetric water content, and compared different petro-physical models for this purpose. With this method we were able to estimate in 2D and, for the first time, in 3D soil water in a vineyard and compare it to canopy physiology.

Preliminary tests were performed to extend the methods to the mapping of root development, that will receive larger attention in year two, together with the spatial-temporal monitoring of water absorption under different rootstocks in field conditions.