

Root system monitoring using a mise-à-la-masse extension to time-domain IP

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Objectives

An advanced plant root phenotyping technology using geoelectrical methods:

- Using dispersive properties of biological tissue: conductivity to polarisation
- Reducing Time domain IP as a SP problem to invert and infer current density distribution

Introduction

The development, architecture, and activity of the plant root system has a key role in plant-soil-water interactions. The characterization of the flow of electric current in the root-soil system may provide non-invasive methodologies to observe the state and dynamics of this critical zone hidden in the shallow subsurface.

Hypothesis

- Accessible Low frequency polarisation (<64Hz)
- Polarisation mostly originates from root cell membranes

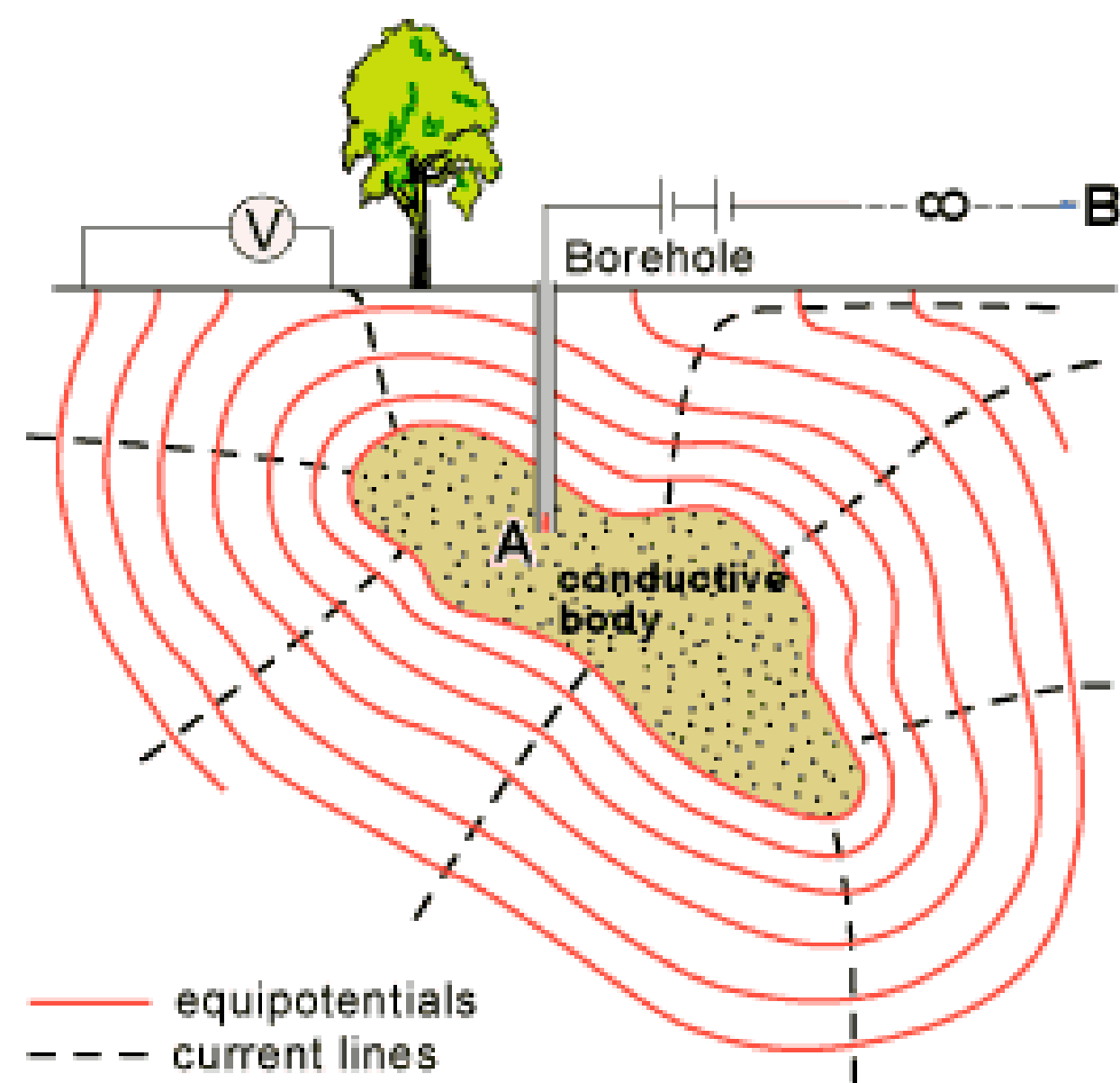


Figure: Body surface putting itself at the same potential V_p . In this study we aim at studying the time response of the conductive body by investigating the secondary voltages V_s . Source: <https://www-ig.unil.ch/>

Extending the CSD inversion to secondary voltages produced by secondary currents may provide insights into transient phenomena associated with the polarization of the roots.

Materials and methods

- *Vitis vinifera* were grown into hydroponic from cuttings
- A rhizotron composed of 72 stainless steel electrodes
- A syscal Pro, Iris instrument

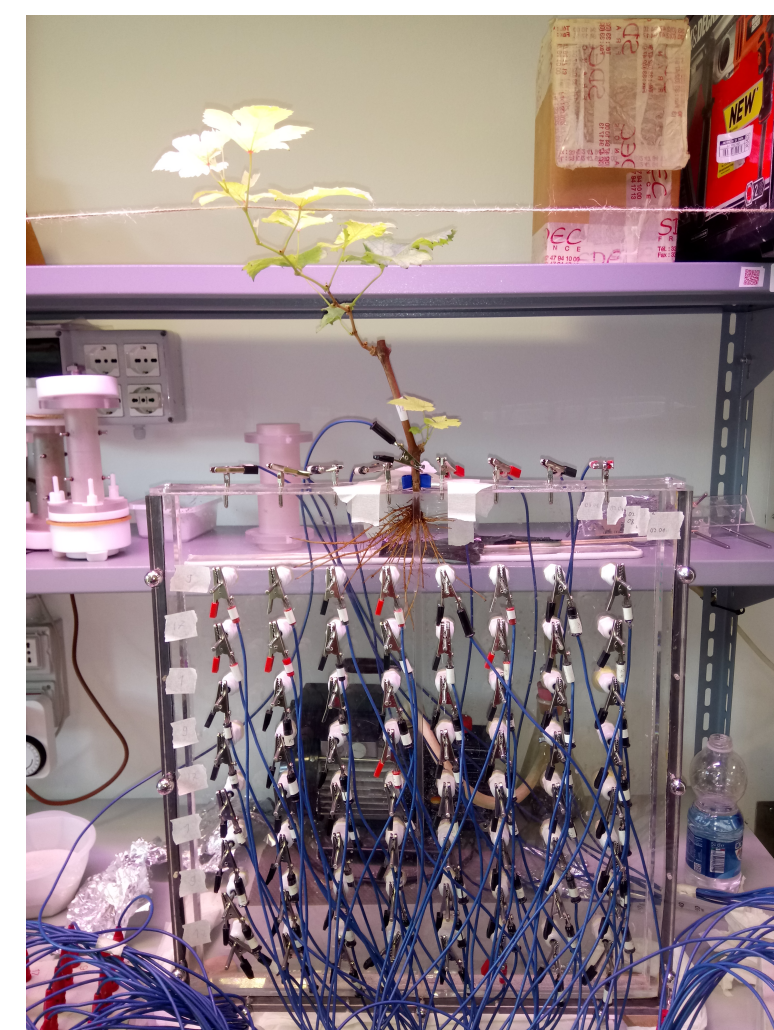
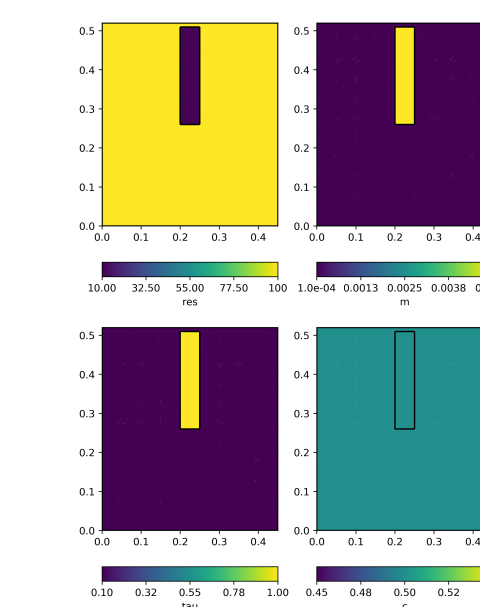


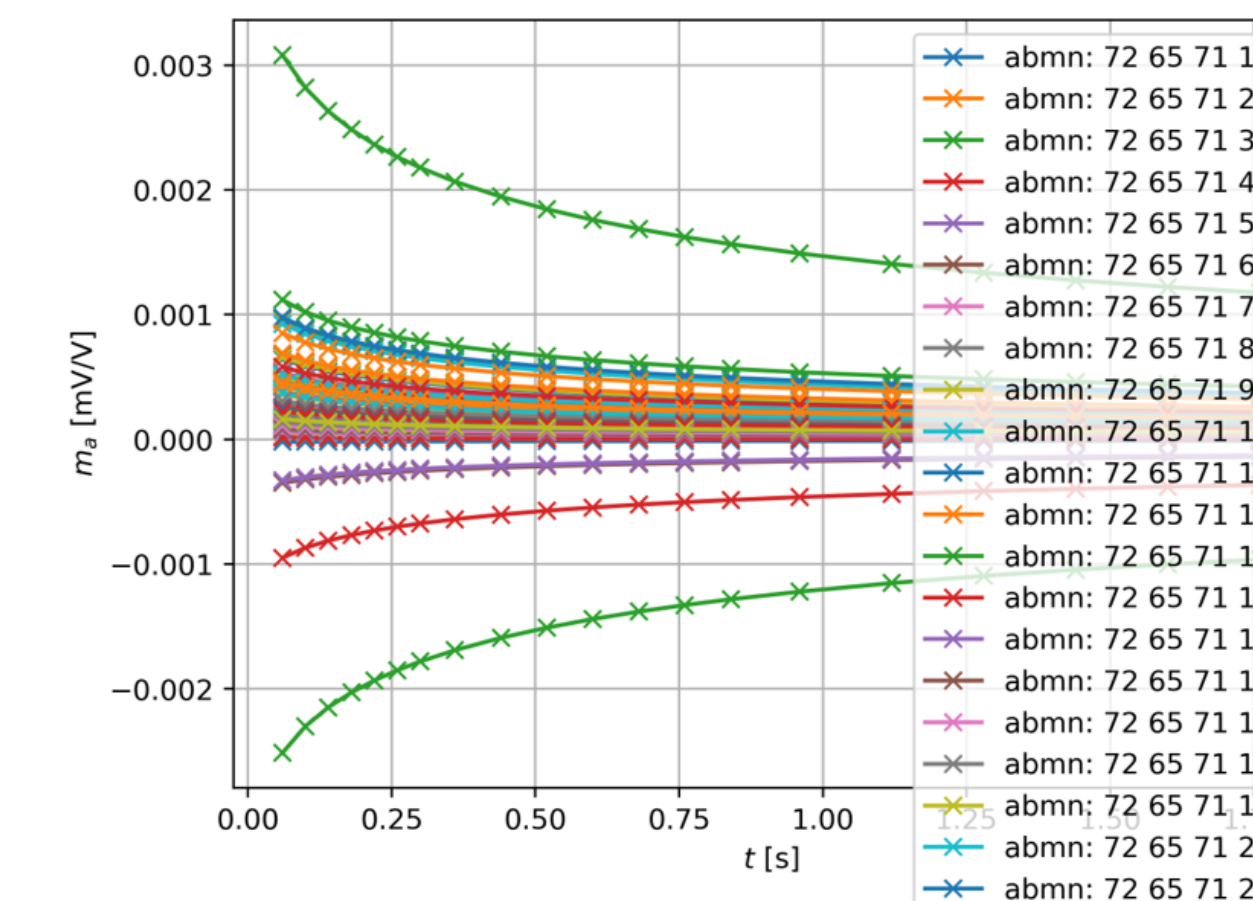
Figure: Vitis cutting growing in hydroponic

Synthetic study

- Forward modelling using eq.
- Stem current injection
- Specific protocol for Mise-à-la-masse measurements



(a) Initial CC model parameters



(b) Simulated decay curves

Conclusion

Time domain IP using a Mise-à-la-Masse acquisition protocol is challenging:

- Negative chargeabilities were both observed on synthetic and experimental data. This observation suggests an effect of the layout geometry and/or distribution of the chargeable body rather than bad data quality.
- Synthetic modelling shows evidence that: During the ON time, the charge build up; During the OFF time MALM IP manifests itself with a decaying voltage at the anomaly location.
- The current implementation of the inversion [1] extended to the inversion of the secondary potentials is not satisfactory and requires more attention.

Additional Information

Inversion code of current source density is made available on the github page [here](https://github.com/benjaminmary/malm-ip)

References

- Peruzzo, L. et al., (2020). Imaging of plant current pathways for non-invasive root Phenotyping using a newly developed electrical current source density approach. Plant and Soil, 450(1-2), 567-584. <https://doi.org/10.1007/s11104-020-04529-w>
- Mary, B. et al., (2019). Assessing the extent of citrus trees root apparatus under deficit irrigation via multi-method geo-electrical imaging. Scientific Reports, 9(1), 9913. <https://doi.org/10.1038/s41598-019-46107-w>

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Chargeability effect on MALM

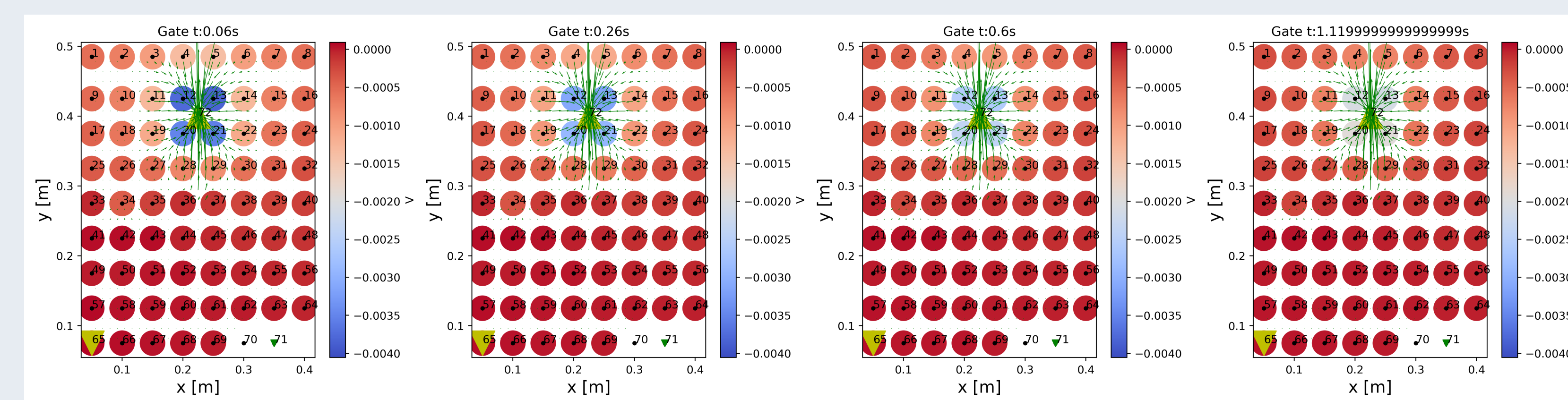


Figure: Time evolution (left to right, from early time to late decay times) of the voltage gradients into and outside the MALM chargeable anomaly

Processing steps

Green Kernel of secondary potential calculation using Seigel formulation:

$$g_f = \frac{V_p - V_\sigma}{V_p} = \frac{F_{DC}[\sigma(1 - m)] - F_{DC}[\sigma]}{F_{DC}[\sigma(1 - m)]} \quad (1)$$

Misfit formulation to retrieve secondary current source density by minimizing:

$$O(\alpha_i, V_m, G_{f,i}) = \left\| V_m - \sum_{i=1}^{N_s} \alpha_i g_f \right\|^2 \quad (2)$$

A CC model is fitted using Pelton's model:

$$m(t) = m_0 \sum_{n=0}^{\infty} \frac{(-1)^n (t/\tau)^{nc}}{\Gamma(1 + nc)} \quad (3)$$

Lab Data

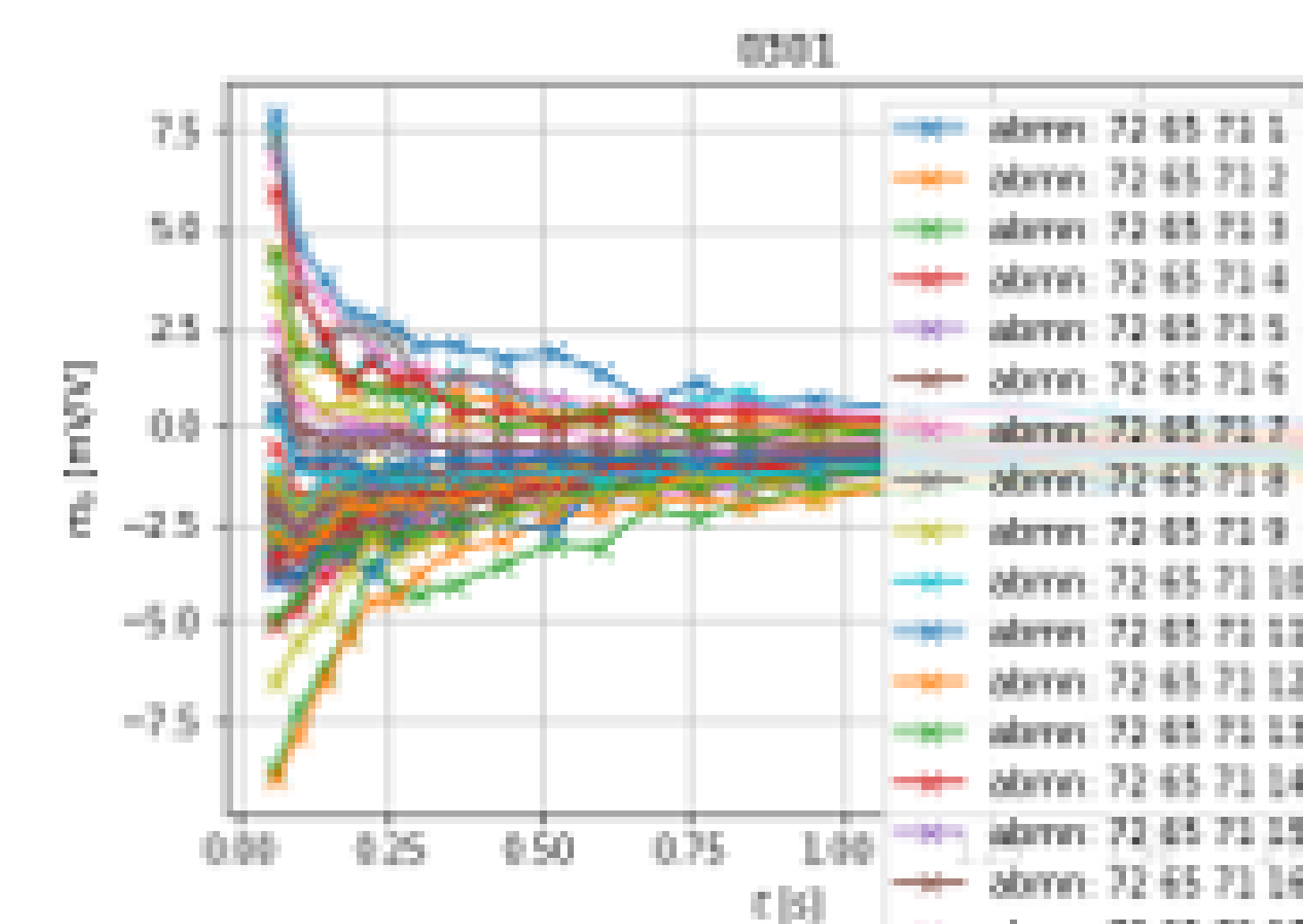


Figure: Raw Decay curves measured

At early stage growth of the plant, MALM TDIP appears noisy with very low IP effects. Sensitivity of the MALM to the roots system is assessed via a

