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A new method for characterizing the complex electrical properties of root segments

S. Ehosioke, S. Garre, T. Kremer, S. Rao, A. Kemna, J.A Huisman, E. Zimmermann, M. Javaux and F. Nguyen

ISRR-10
Exposing the Hidden Half
Root Research at the Forefront of Science
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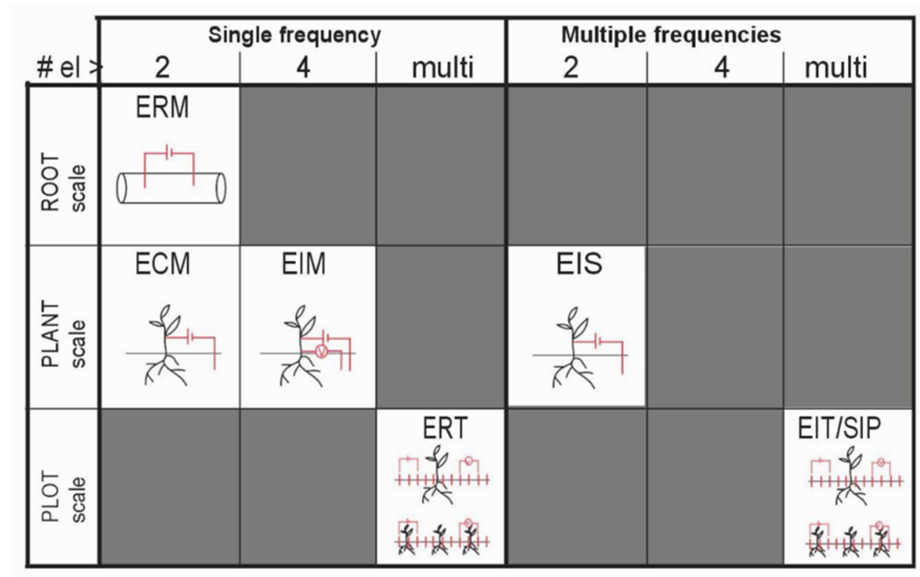
Introduction

- ❑ **Point sampling**
- ✓ Partially satisfactory
- ❑ **Geophysical methods**
- ✓ High resolution
- ✓ Non-invasive
- ✓ Applicable in lab and field
- ✓ EIT/SIP – more promising



Ehosioke et al. 2018

- ❑ **Our Contribution**
- ✓ High resolution characterization of Fine roots at segment scale (1-5 cm)
- ✓ Spectroscopic approach(1-45 KHz)

Objectives

❑ **High resolution characterization of root segments**

✓ Design a sample holder suitable for root segments

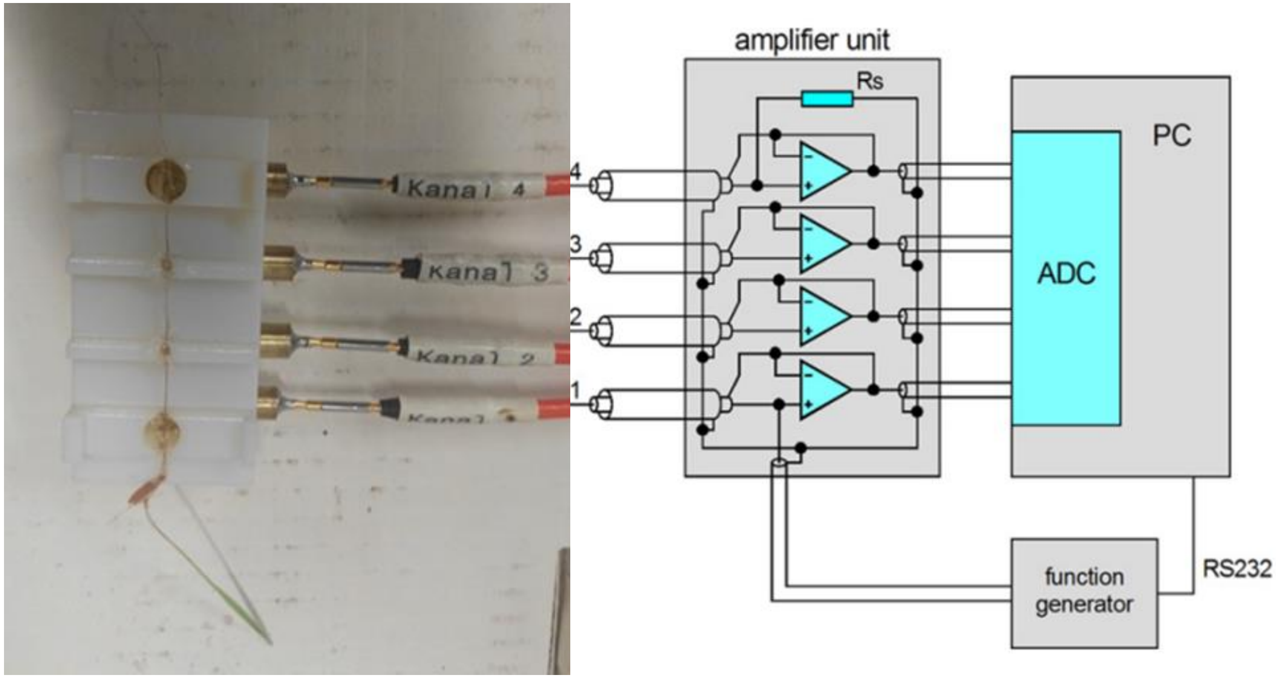
✓ Validation of the measurement set- up

✓ Use the set-up to study roots

❑ **Provide answers to these questions**

1. Does electrical response vary within and across species ?
2. What root properties influence their electrical response ?
3. Could fine roots be differentiated from soils ?

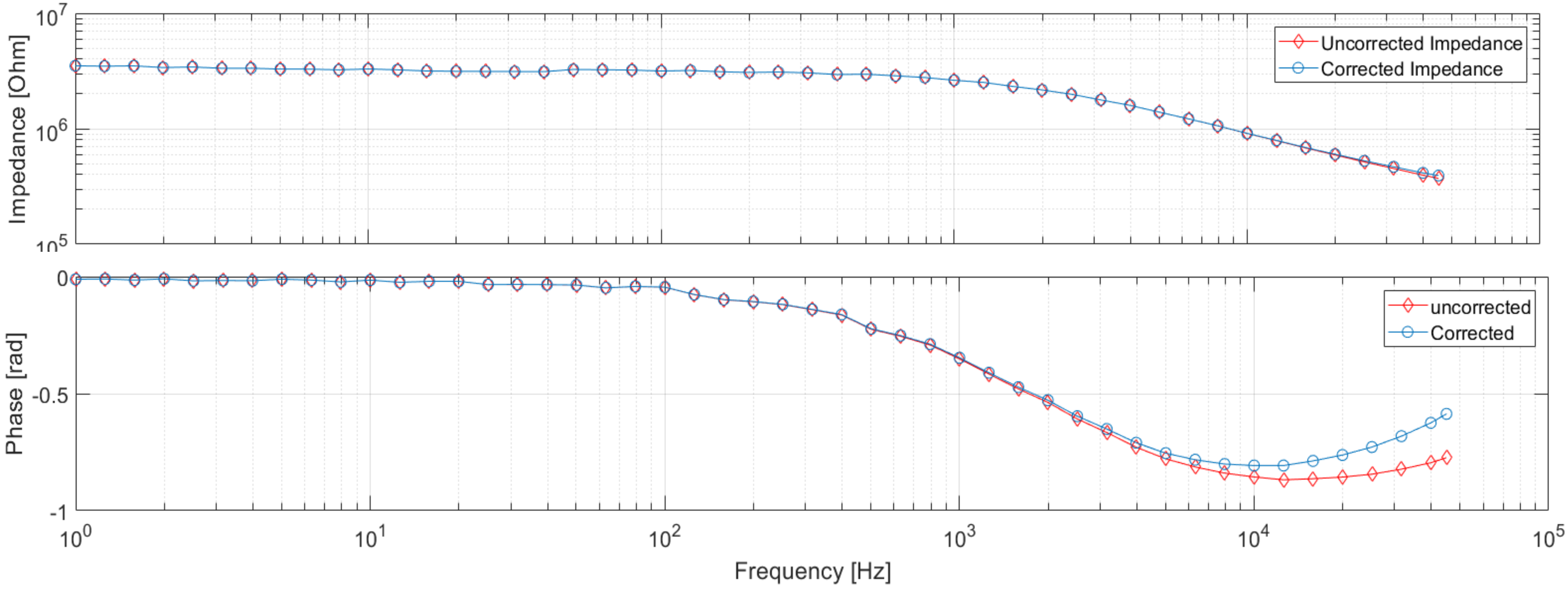
Measurement set-up



Zimmermann et al. (2008)

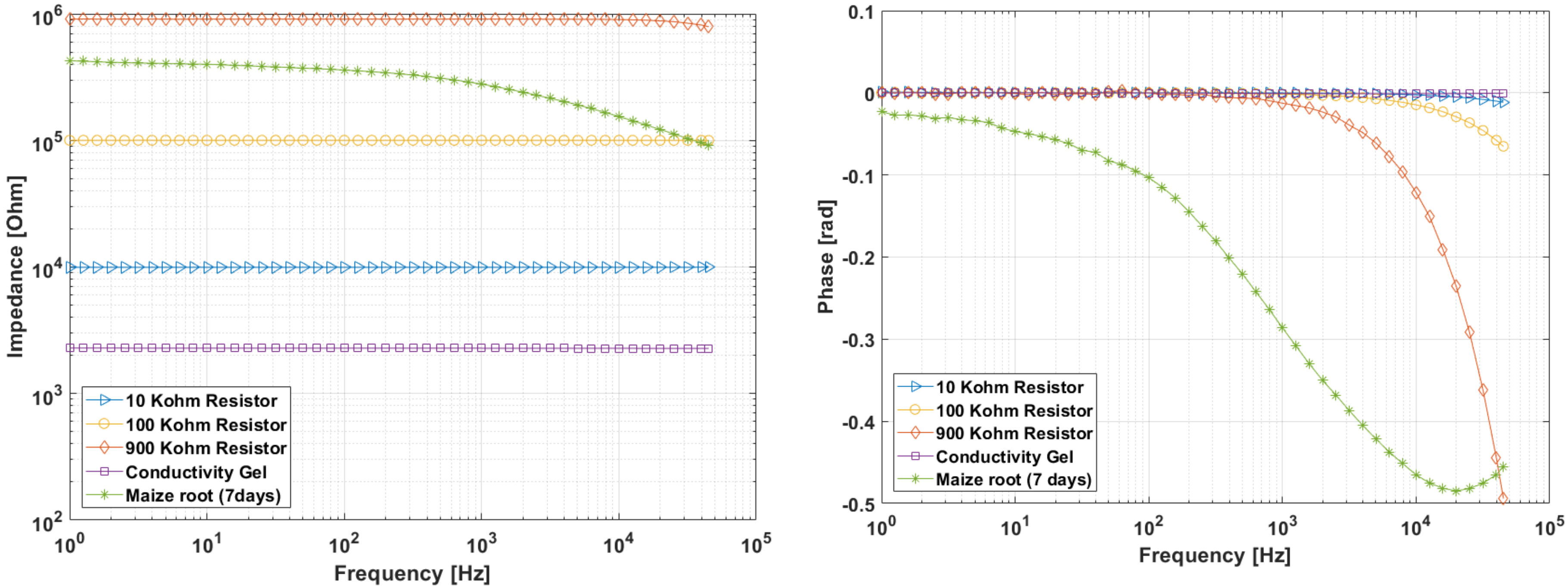
- Measurements were taken near the root collar
- Contacts between roots and electrodes were completely covered in gel
- Reciprocal measurements always taken before the normal to enable automatic correction
- Electrodes were kept out of the current path

Data Correction



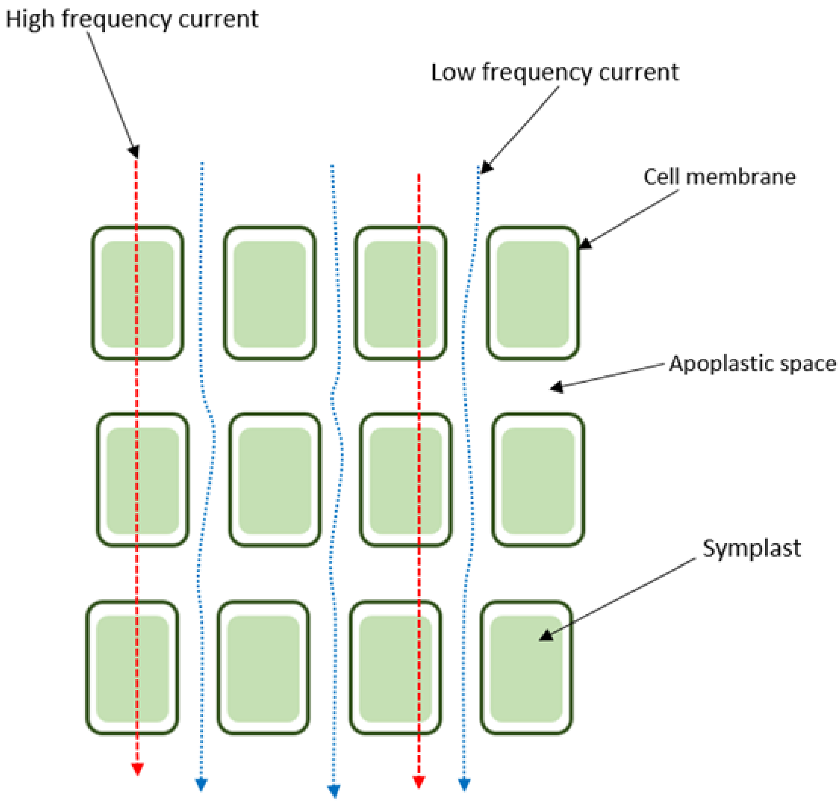
- Correction is used to minimize the error due to parasitic leakage currents
- By first taking reciprocal measurement before normal, the true excitation current is calculated using a matlab program
- With this, true sample impedance is determined
- This correction results in high phase accuracy of 0.1 mrad (Zimmermann et al. 2008b)

Calibration and Validation



- ✓ Calibration was performed using three ideal resistors
- ✓ Calculated impedances (using colour codes) matched the measured values
- ✓ Ideal resistors showed zero phase response as expected
- ✓ Polarization of maize root is clearly visible (480 mrad)
- ✓ The conductivity Gel showed negligible phase response compared to the root

Current passage in roots



Ehosioke et al. 2018

❑ Low frequency current

- Cell membrane inhibit current passage
- Current pass through apoplastic space
- Impedance depends on extracellular resistance

❑ High frequency current

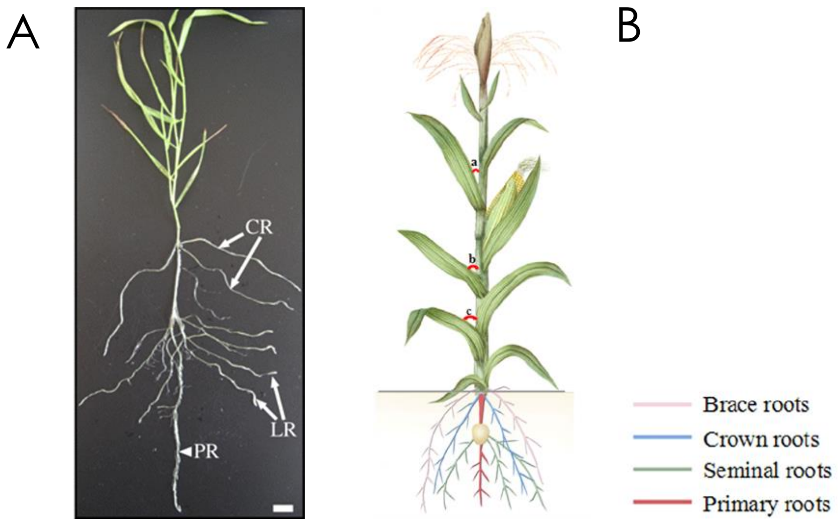
- Cell membrane becomes conductive
- Current pass through entire cells
- Impedance depends on both Extra- and Intracellular resistance

Polarization mechanisms in biomaterials

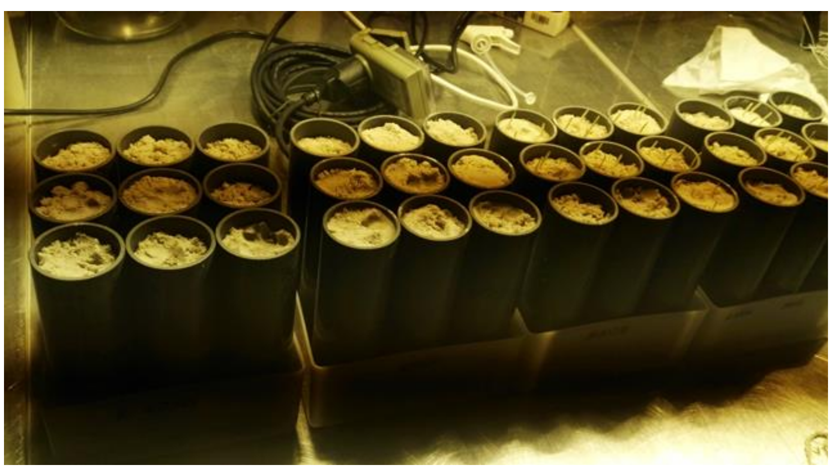
Mechanism	Frequency Range
Counter ion Polarization (α-dispersion)	< 20KHz
Interfacial Polarization (β-dispersion)	**KHz- MHz**
Dipole polarization (γ-dispersion)	MHz – GHz

- ✓ Exists in materials that have a heterogeneous microstructure
- ✓ Where high conductivity zone exists within the matrix of low conductivity material
- ✓ e.g. cell interiors surrounded by cell membranes).

Study Plants



(A) **Brachypodium** plant, composed of a primary root(PR), crown roots (CR) and lateral roots (LR) (Pacheco-Villalobos and Hardtke 2012) (B) **Maize** plant, showing the roots in colour (Gong et al. 2015)

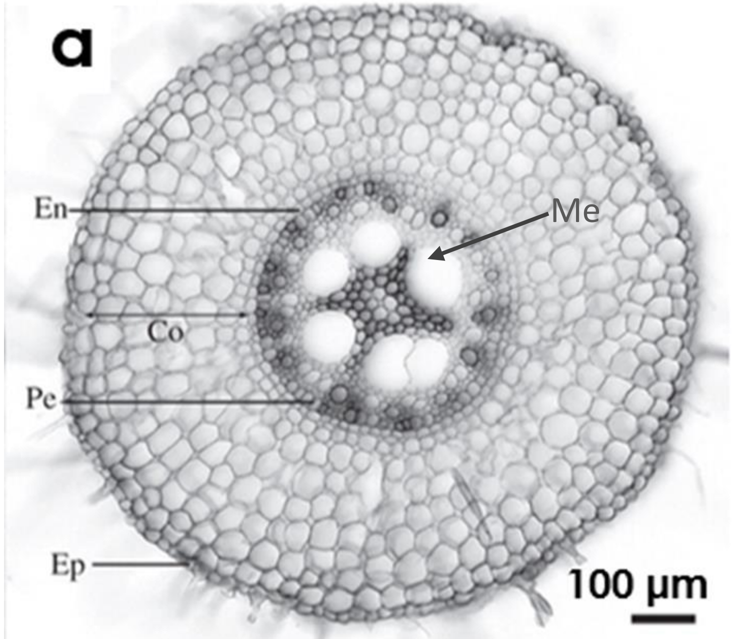


- **Plants grown in sand to enable easier cleaning without water**
- **Destructive sampling**
- **Measurement on primary roots close to root collar**
- **Total number of 32 plants were sampled (4*2*4)**
- **Root resistivity calculated using measured impedance and diameter**

$$\rho_r = Z_r \frac{\pi D_r^2}{4 L_r}$$

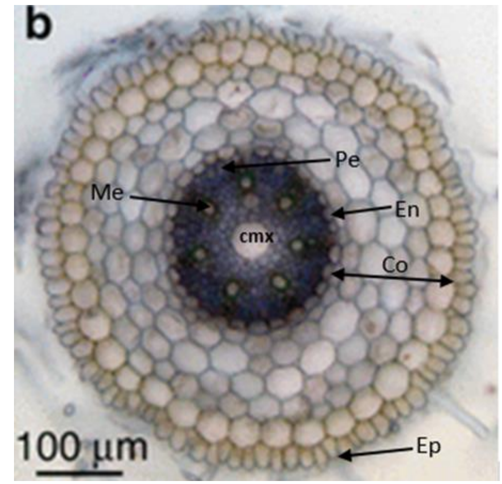
Microscopic sections

Maize



Smith and De Smeth 2012

Brachypodium

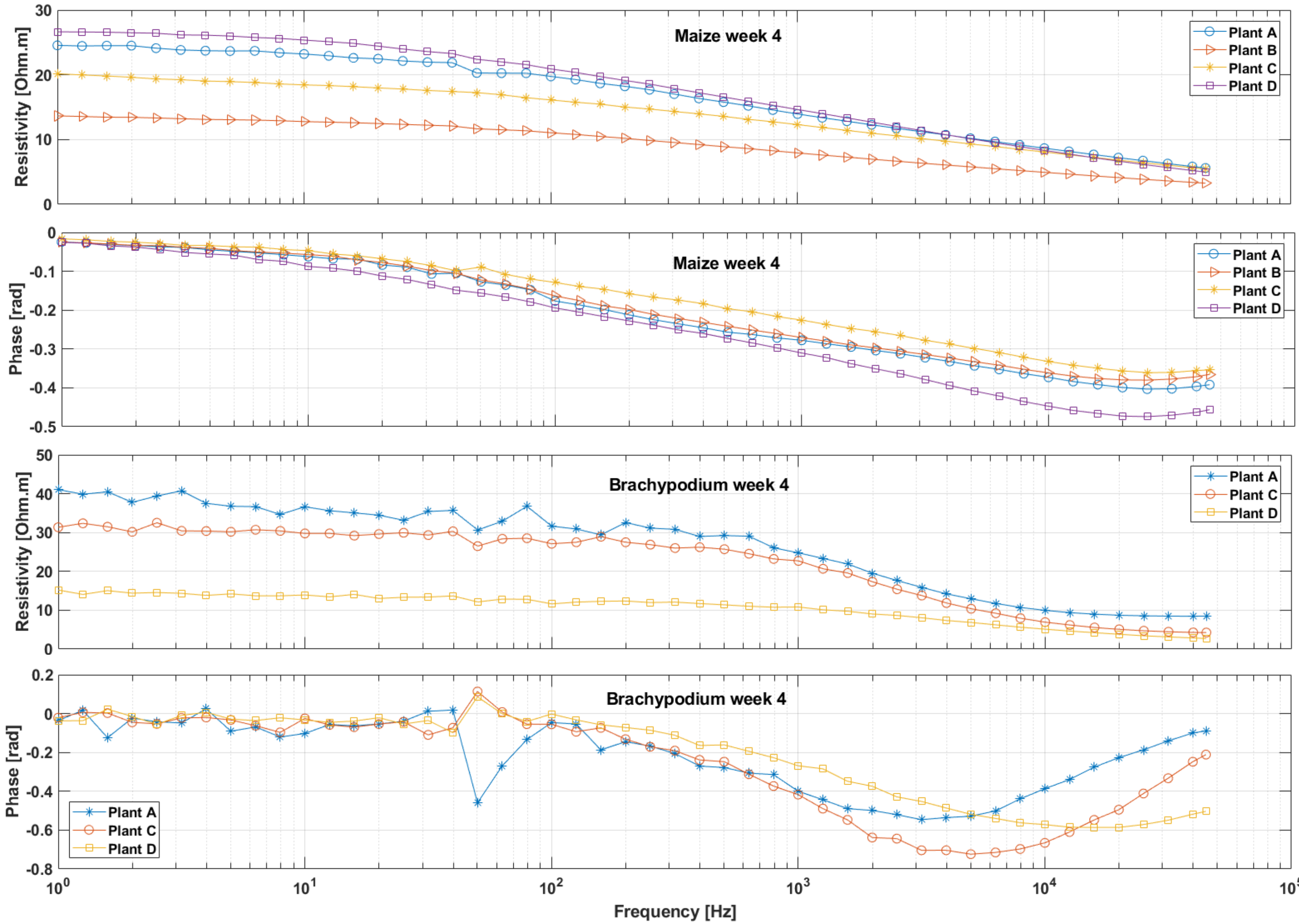


Pacheco-Villalobos and Hardtke 2016

- **T/S of Maize and Brachypodium primary roots .**

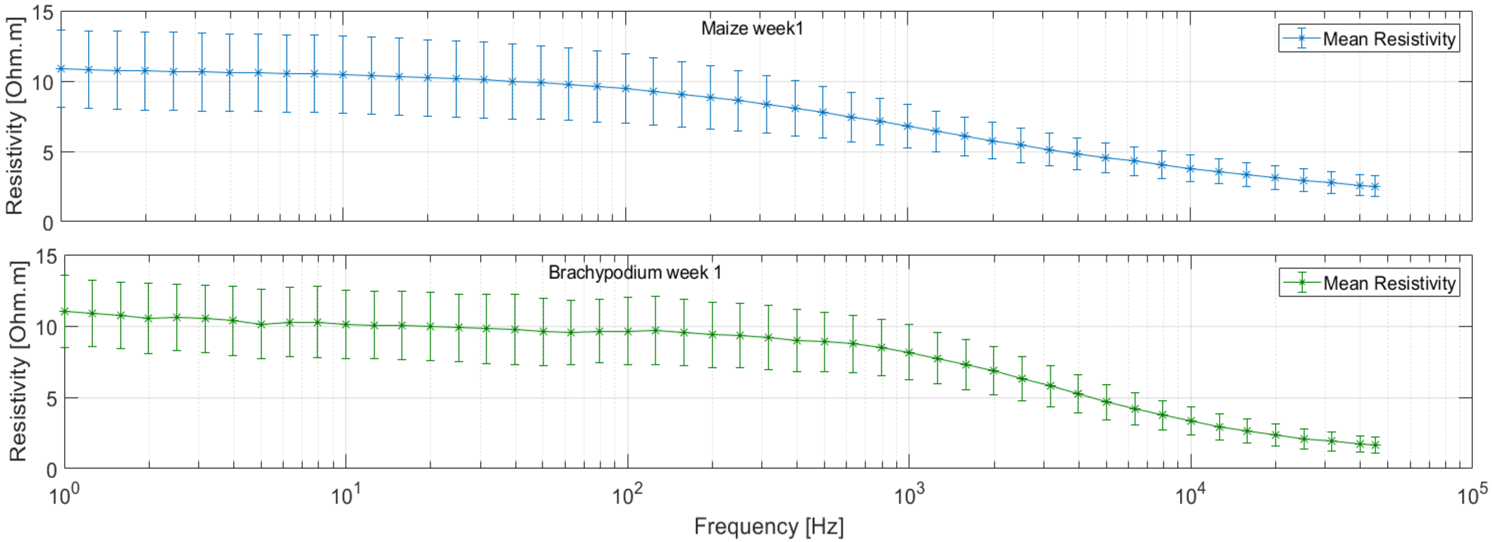
- ✓ Showing: Epidermis (Ep), Cortex (Co), Endodermis (En), Pericycle (Pe), Metaxylem (Me) and Central metaxylem (Cmx).
- ✓ Brachypodium root is smaller in size, with lesser cells in cortex than maize
- ✓ Maize is larger in size, with more cortex cells but no central metaxylem

Intra-species variability



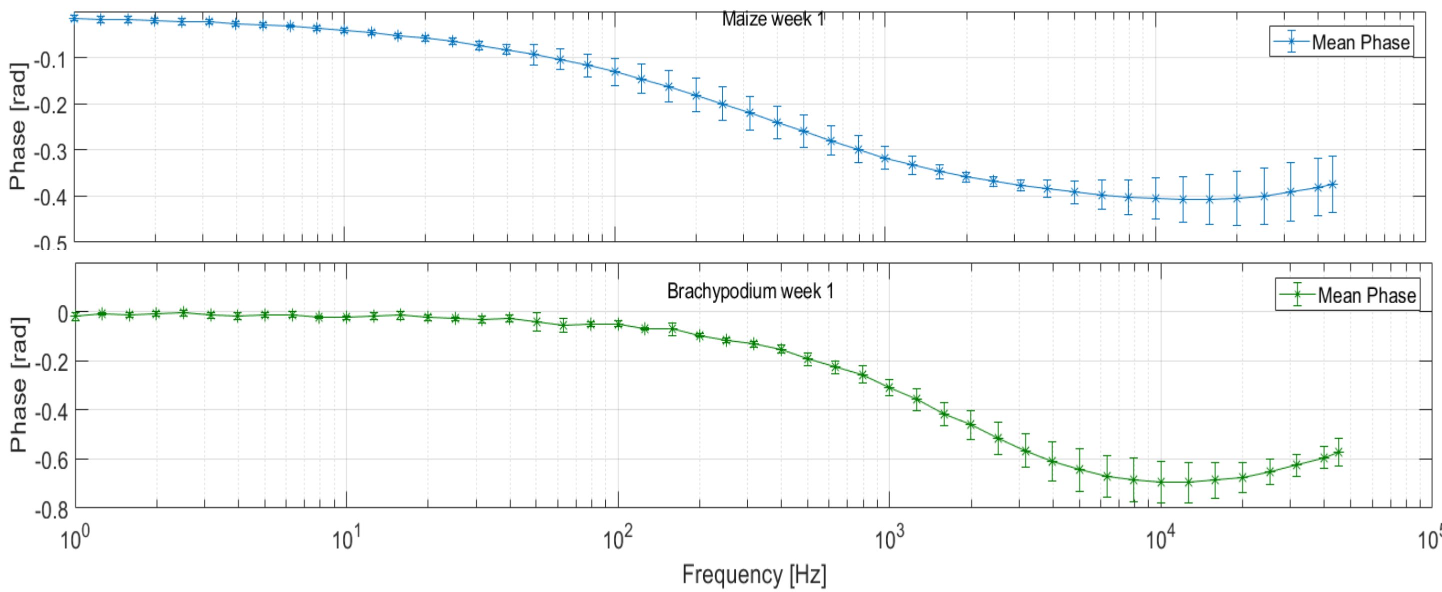
- Comparing plants A, B, C & D at week 4 (day 27) of maize (top) and brachipodium (bottom).

Inter-species variability [Maize vs Brachipodium]



Less variation in resistivity at day 8

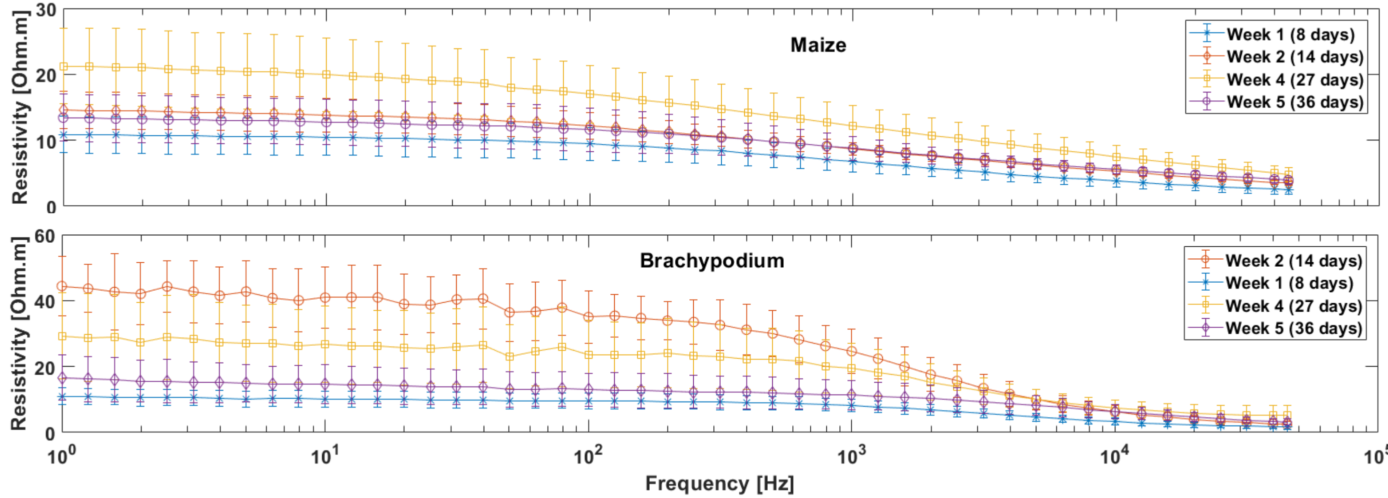
- Maize shows an average polarization of 430 mrad
- while that of Brachipodium is 700 mrad.

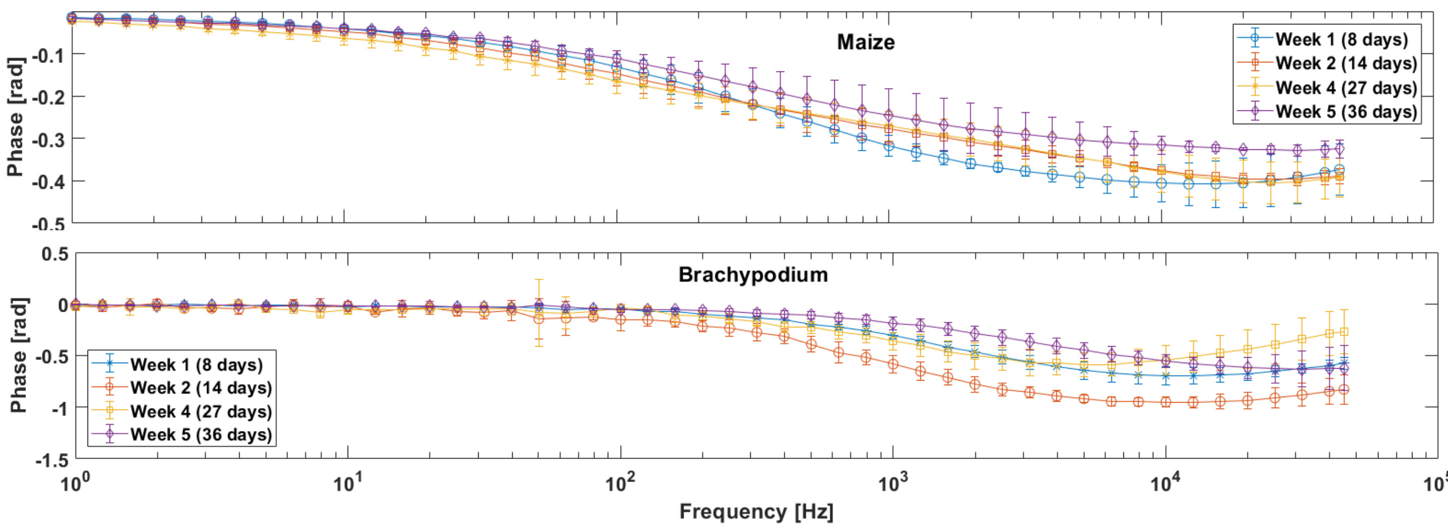


Age effect

Resistivity

- ✓ Maize: increased from Wk 1 to wk 4 and dropped
- ✓ Brach: increased from wk 1 to wk 2 and dropped





Phase

- ✓ Maize: decreased from Wk 1 to 5.
- ✓ Brach: increased from wk 1 to 2 and then decreased

Conclusions

- ❑ **Intra-species variability**

✓ Different plants of each species studied showed variation in their response

- ❑ **Inter-species variability**

✓ Maize and Brachypodium roots showed unique electrical signature which is largely dependent on their anatomy

- ❑ **Root differentiation from soils**

✓ The polarization range for various earth materials fall within 0.2-20 mrad

✓ The results suggest that root segments can be differentiated from soils based mainly on their stronger polarization response

Next Steps

❑ **Microscopic analysis of root sections**

✓ to explain the observed variability across species

✓ to identify root traits that control the observed response

✓ Proper understanding of the age effect (monitoring)

❑ **Hydraulic properties of roots**

✓ study hydraulic conductivity in roots using SIP

✓ effect of osmosis on the SIP signal

Thanks

... Funded by the F.R.S-FNRS

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