O3.3-672

Detectability of spectral changes in plants in response to ground motion

Szalay[1], Deakvari[1], Bercesi[1], Lehoczki, Olasz[1], Takacs[1], Jung[2], Kundathil[1], Rowlands[3]

[1] MATE Institute of Technology, Hungary
[2] Faculty of Informatics, Eötvös Loránd University, Hungary
[3] On-Site Inspection Division, CTBTO

CTBTO PREPARATORY COMMISSION | PUTTING AN END TO NUCLEAR EXPLOSIONS

Presentation Date: 11 September 2025

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Remote sensing

- Activity where the electromagnetic radiation is measured from a distance
- The measured signal is converted into valuable information
- An ability to read information based on different physical, chemical processes
- Acquired data can be processed to identify changes and describe relevant surface characteristics
- Potential to capture the actual state of large areas within a short period of time

Detectability of spectral changes in plants in response to ground motion

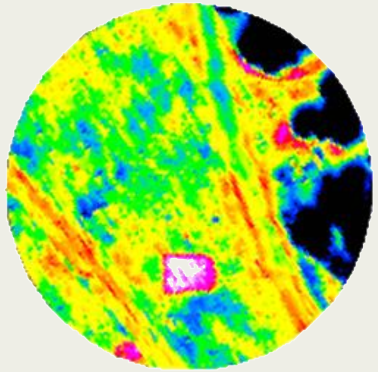
Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

O3.3-672

MSIR observables

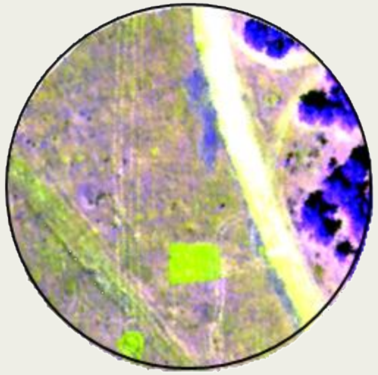
Thermal | Short-wave Infrared | Infrared | Visible and infrared | Visible

Thermal
14-7.5 µm



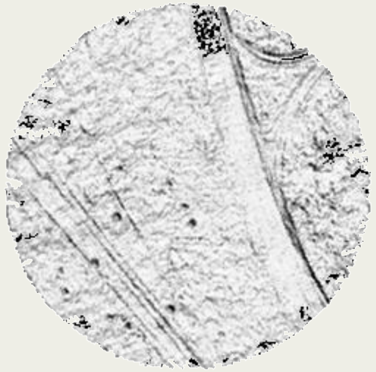
- Vehicle Movements
- Hydrological changes

SWIR
2.55 – 0.95 µm



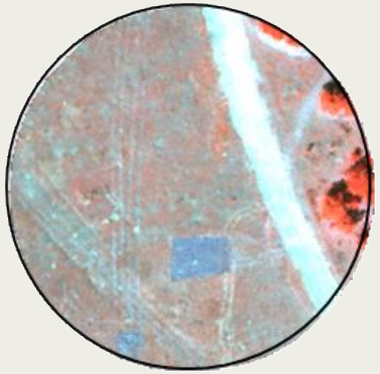
- Soil properties
- Water absorption features

LIDAR



- Fluffing
- Sub canopy features

VNIR
1 – 0.4 µm



- Vegetation stress
- Anthropogenic features

Visible
digital camera/video

- Context
- Anthropogenic features

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

MSIR observables

OSI-relevant observables that can potentially be detected by airborne multi-spectral remote sensing

Signature	Driver	Spectral Region	Spectral Resolution	Spatial Resolution	Temporal Behavior
Air and Satellite Accessible (> 10 m spatial resolution)					
Vegetative stress	Surface shock	VNIR (0.4-1.1 um) SWIR (1.3 & 1.45 um)	Low (≤100 nm)	10-30 m goal ≤ 1 km req'd	peak at 48-56 hours, low after 7 days, senescence - weeks
Surface disruption - spectral	Surface shock	VIS, NIR, SWIR req'd LWIR useful	Low to Med	10-30 m goal ≤ 1 km req'd	weeks if dry, hours to days if rain/wind likely
Surface "fluffing" - thermal mass	Surface shock and spall	Thermal IR (LWIR)	None	10-30 m goal ≤ 1 km req'd	Need to take data around maximum ΔT (e.g. local noon-2 pm)
Presence of geochemical gases	Surface fracture from shock	LWIR and ???	High	<=20 m goal 100 m req'd	Week to ~ 1year
Thermal hot spot	Heat convection through fractured material	Thermal IR (LWIR)	None	1 m goal < 10 m req'd	TBD to form Stable for years

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Explosion-related vegetation stress: previous work

Research conducted in the 1990s confirmed link between ground shaking and reflectance spectra

Observations of Temporary Plant Stress Induced by the Surface Shock of a 1-kt Underground Chemical Explosion

William L. Pickles

Detecting Plant Metabolic Responses Induced by Ground Shock Using Hyperspectral Remote Sensing and Physiological Contact Measurements

W.L. Pickles
G.A. Carter

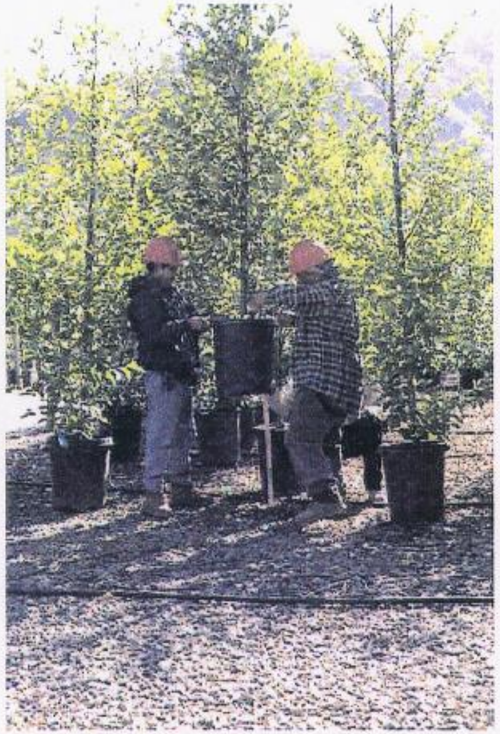
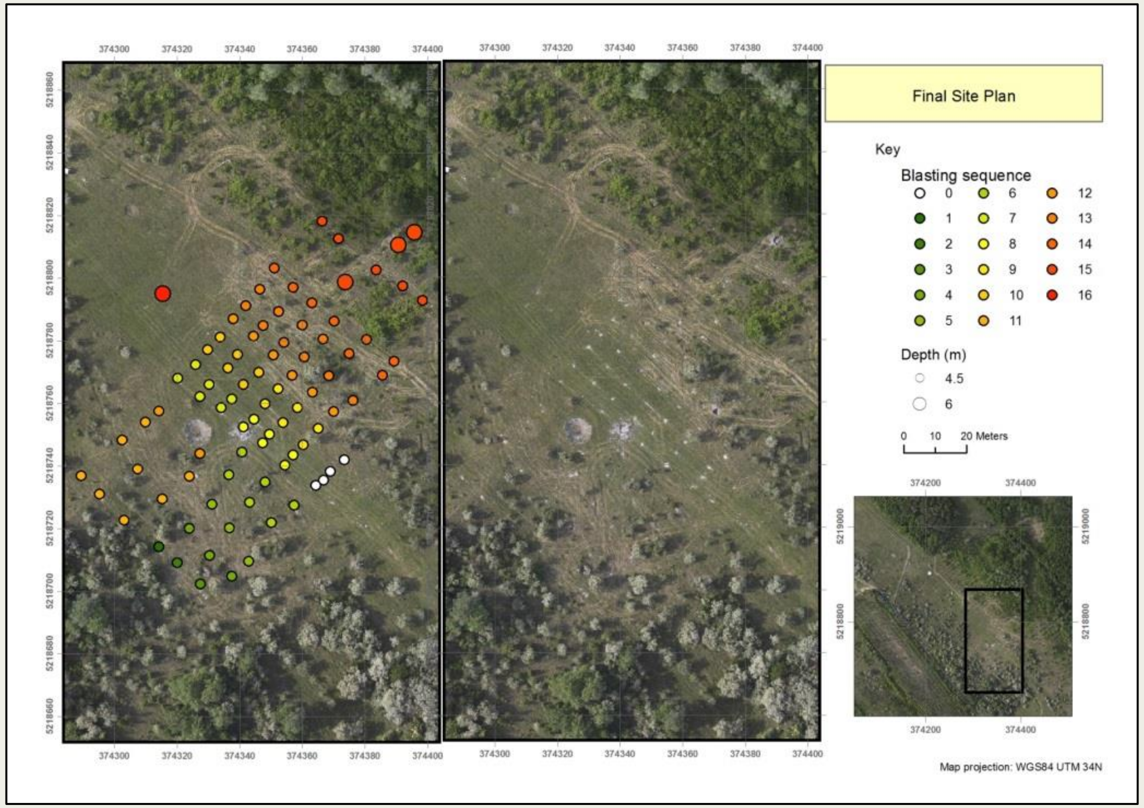


Figure 2. The pots were dropped from a measured height of one, two, or three feet.

Pickles & Carter (1996)
Lawrence Livermore National Laboratory UCRL-ID-127061

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

CTBTO vegetation stress tests in 2012



96 boreholes
500 kg of explosives
Ripple blasting not possible

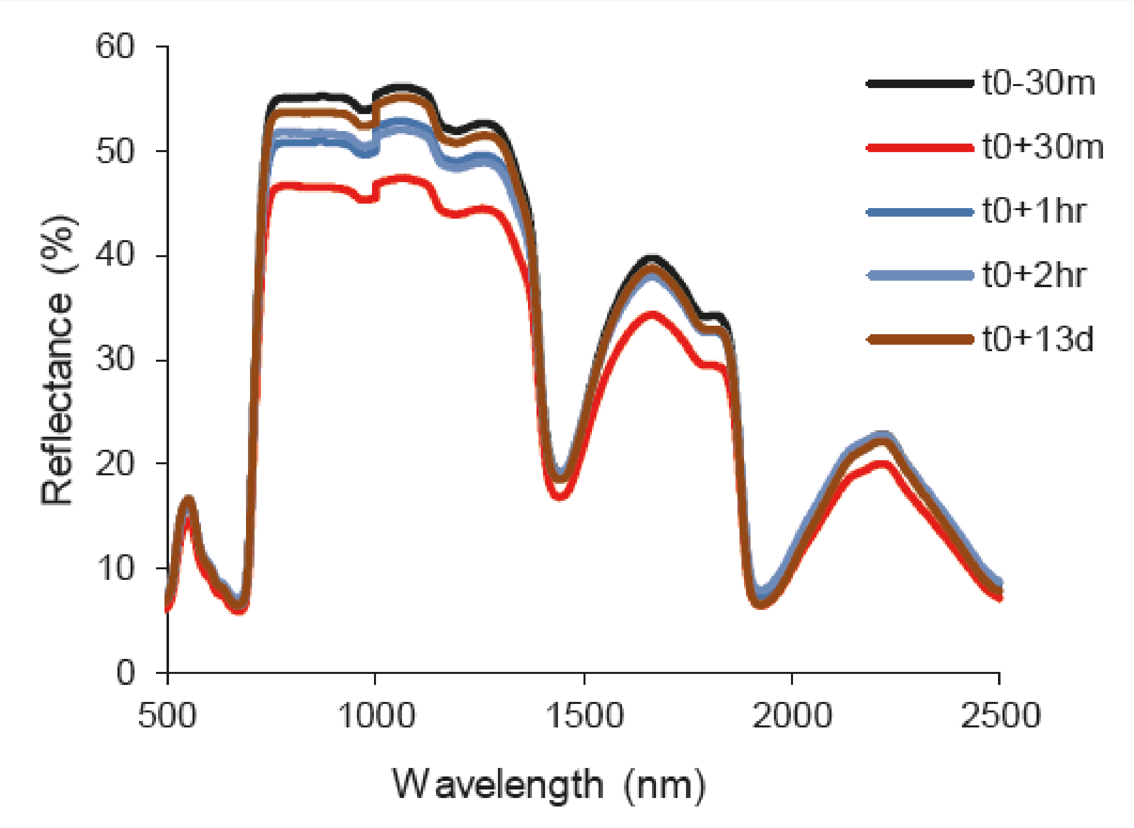
4.5 – 6 m depth
Charges 2-10kg
Surface acceleration started from 1 g

6 -8 m spacing
4 boreholes as control

The views expressed in this presentation are those of the author and do not necessarily reflect the view of the CTBTO.

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

CTBTO vegetation stress tests in 2012



Plant probe reflectance spectra for several trees in the vicinity of the detonations. Averaged spectra acquired for an *Elaeagnus* tree prior and post detonation

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Current investigations started in 2024

- Context - studies show stress-specific changes at different wavelengths in plants but identification of characteristic spectral response to ground motion remains an important step to detect related visual anomalies.
- Objective – to investigate the vibration related spectral changes of plants
- Stress - mechanical stress (vibration)
- Laboratory-based controlled (undisturbed) vegetation with an indoor growing system

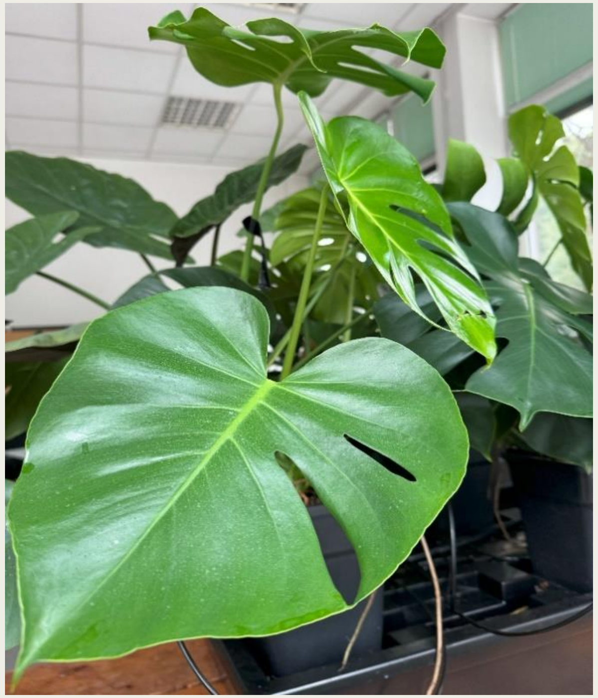
Detectability of spectral changes in plants in response to ground motion

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

O3.3-672

Plant selection

Ficus elastica



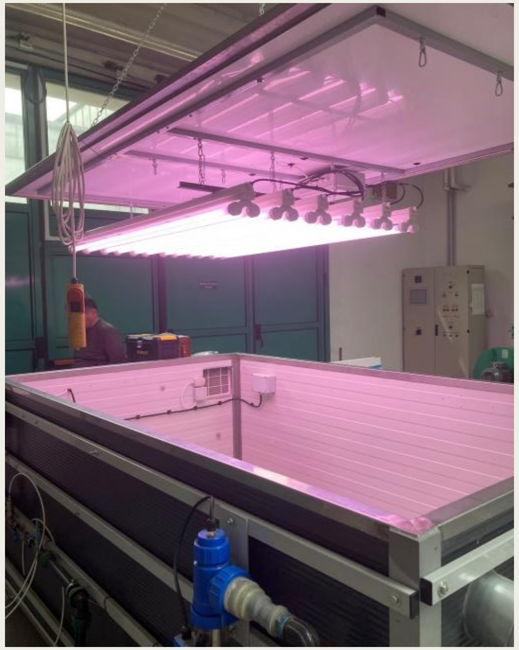
Monstera deliciosa

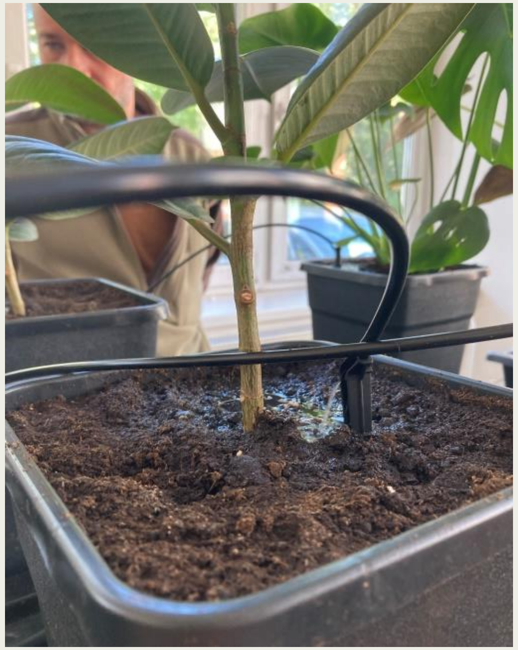
Alocasia sp.

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

O3.3-672

Growing conditions

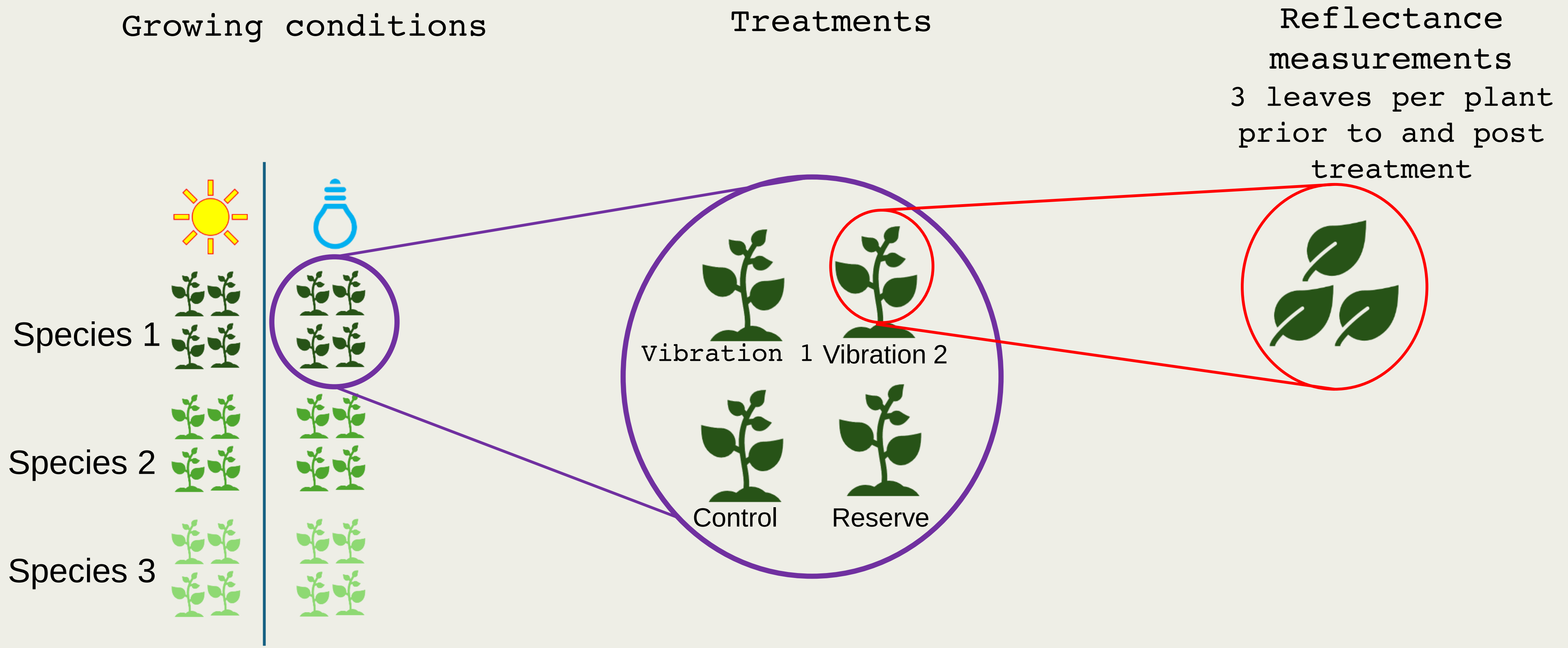


Automated irrigation and nutrition supply were set to be identical for the plants

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Experimental regime



Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Spectral measurements

ASD FieldSpec 3 Max portable spectroradiometer and a PlantProbe sensorhead were used to acquire spectral data.

The portable unit provides an opportunity to measure spectral reflectance in the plant growing laboratory by minimizing disturbance to plants other than the planned treatments

ASD FieldSpec 3 MAX spectroradiometer with PlantProbe sensorhead

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Where are we now?

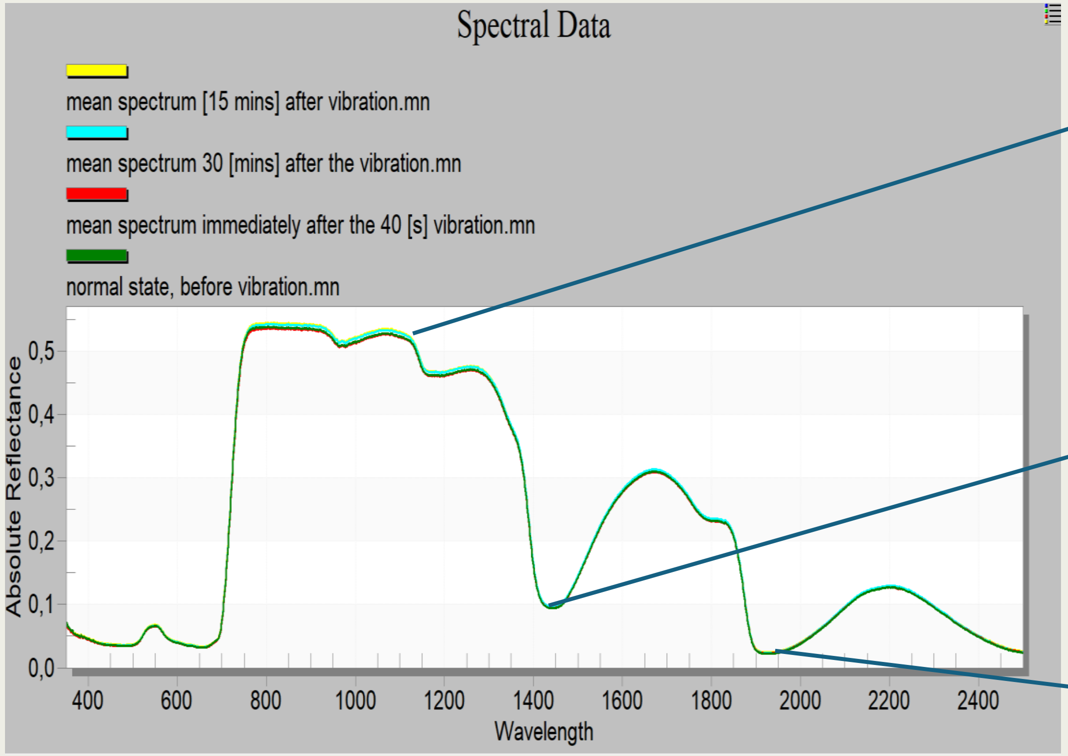
- Special experimental environment
- Homogenous, **undisturbed** set of evergreen plants (still active)
- Vast database of spectra (8,640 spectra), photos with visual rankings of each plants
- Repeatable and scaleable method to deliver mechanical stress
- First steps in data processing

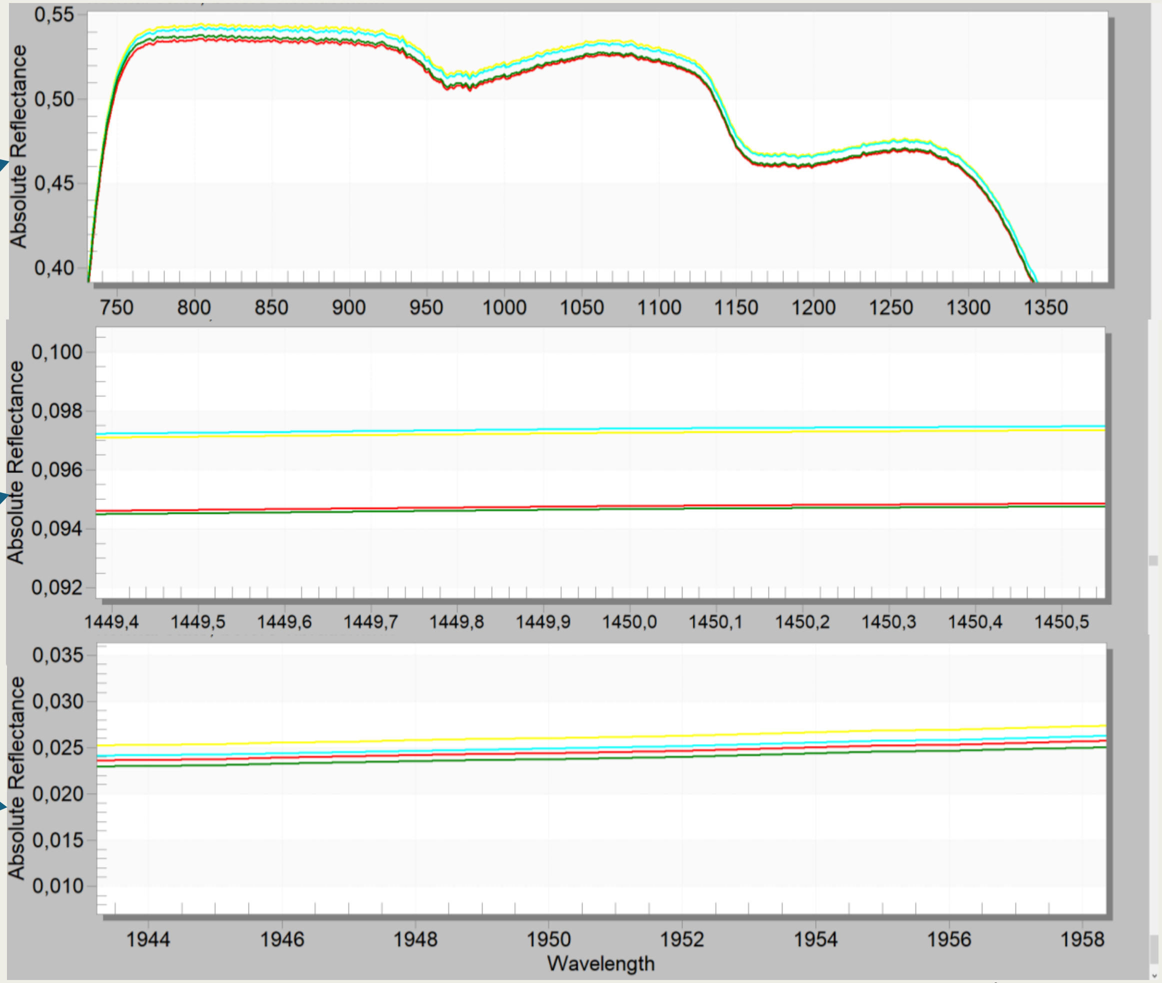
Detectability of spectral changes in plants in response to ground motion

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

O3.3-672

Results: Short term changes

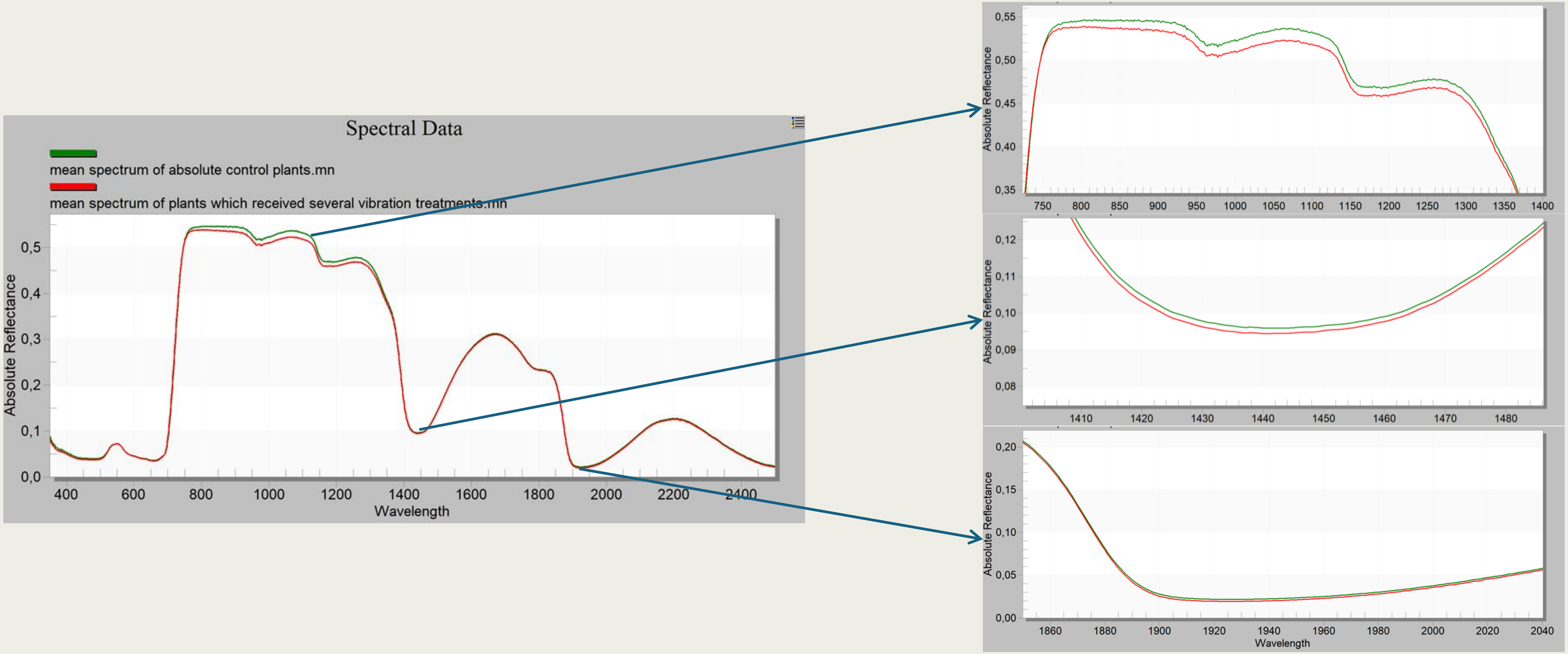




Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

O3.3-672

Results: Long term changes



Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Conclusions

Preliminary results of mean analysis show spectral changes over the short and long term, which means that the applied mechanical stress of 2g acceleration was sufficient to generate some reactions in plants.

In the short term – changes were observed in the wavelength range of 750 to 1350nm. Leaf reflectance is primarily affected by leaf structure in this region rather than pigments or water absorption.

Changes were also observed in typical water absorption bands, indicating a change in the water balance of the plants as a response to mechanical stress, 1350 and 1940nm.

In the long term – main differences between control plants and stressed plants were identified in the 750-1350nm region. There were some visible changes in typical water absorption bands but smaller than in case of short-term reactions.

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Caveats

- The use of an ’averaged approach’ may hide specific reactions of the studied species at different stages and the effects of lighting conditions.
- The mechanical stress (~2g) is a simplified model of a ground motion.
- Changes in spectra are within the range of measurement uncertainty.

Szalay, Deakvari, Bercesi, Lehoczki, Olasz, Takacs, Jung, Kundathil, Rowlands

Future plans

The experimental plants are still active, ready for further test cycles

The following analysis are being explored on the dataset:

- Vegetation indices (focusing on shifts in the red edge)
- Partial least squares discriminant analysis (PLS-DA)
- Spectral Angle Mapper (SAM) supervised classification
- Processing of visual ranking of each experimental plant

Expanding the measuring techniques:

- Thermal imaging
- Video spectroscopy to monitor spectral changes online