Towards a mechanistic understanding of the impact of volcanic ash on plants and soils

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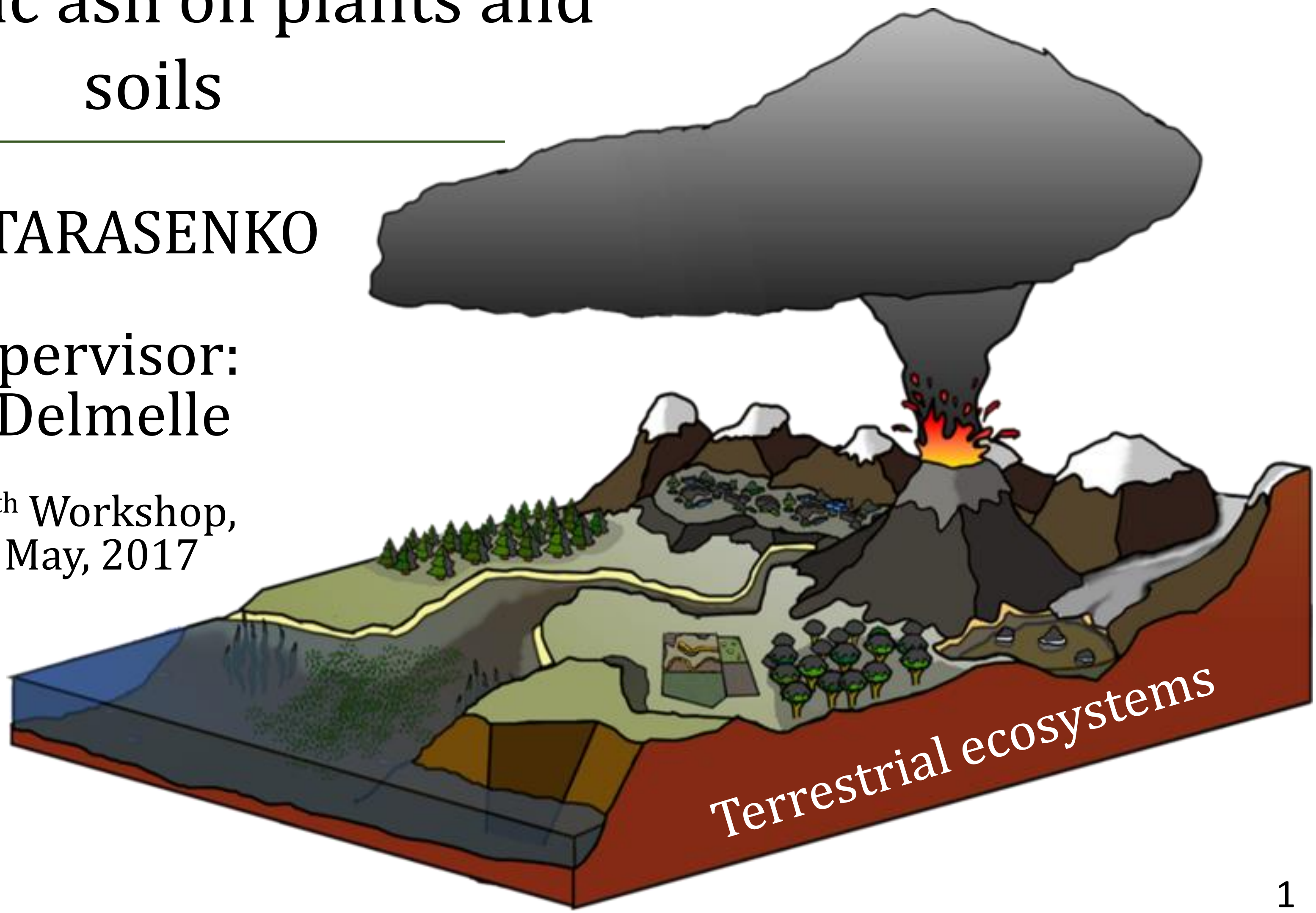


Tephra impact on vegetation

Tephra impact on vegetation

Objective:

to investigate experimentally the main factor dictating the impacts of tephra on plant leaf physiology

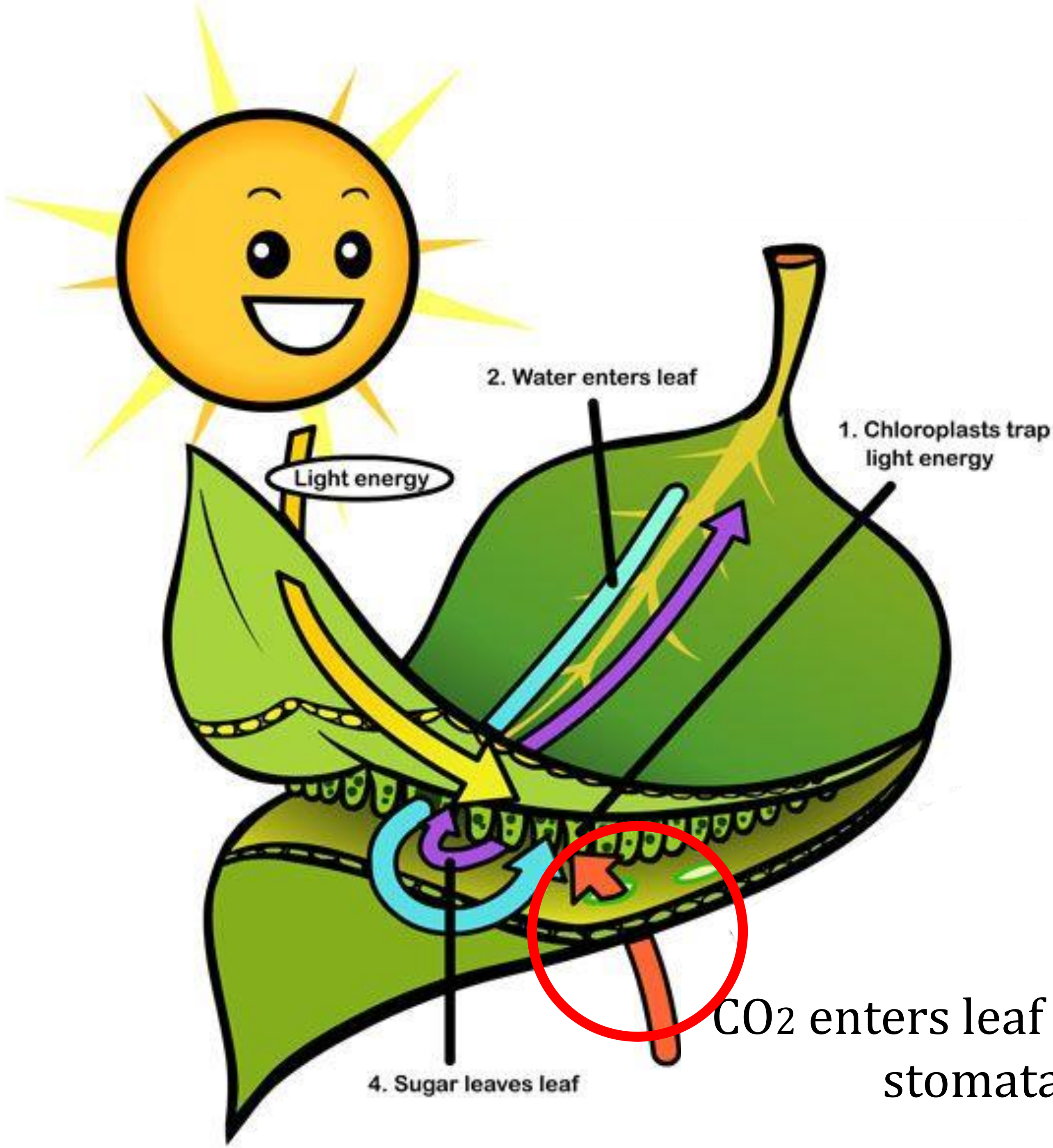
Plant species chosen for the experiment

Rice

- Hairless leaves
- Stomata on the upper and lower surfaces

Tomato

- Pubescent leaves
- Stomata on the lower surface



CO_2 enters leaf through stomata

Experimental procedure: growth conditions

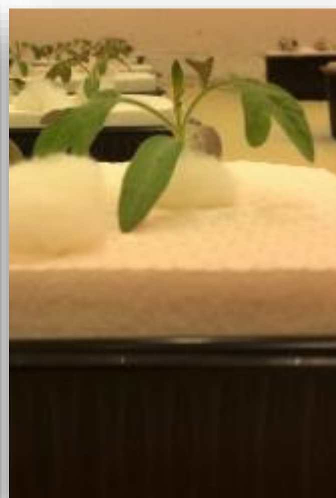
Seed germination

Transfer to hydroponic solution

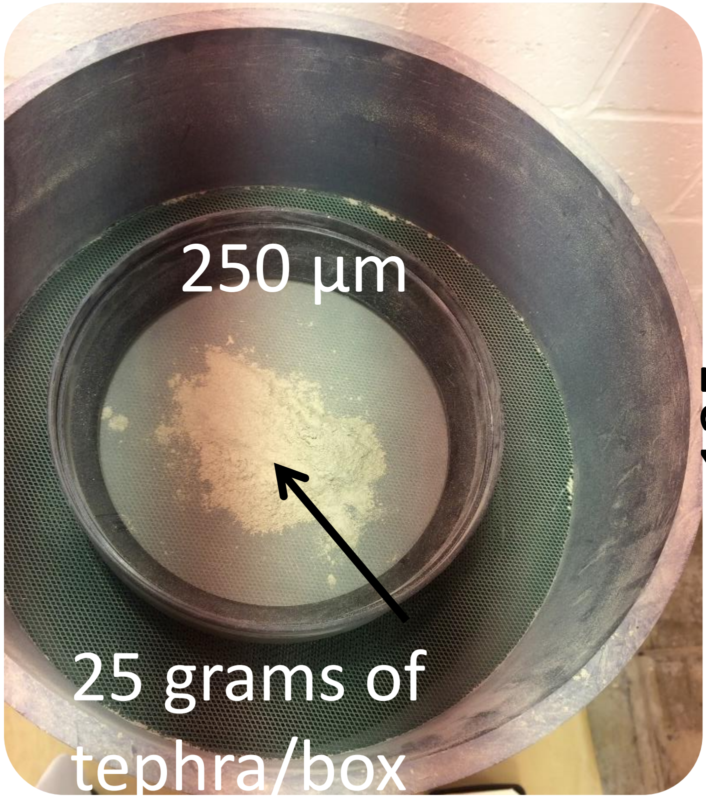
1st tephra application

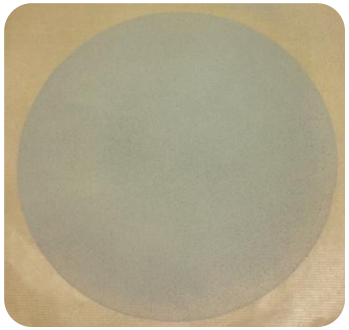
2d tephra application

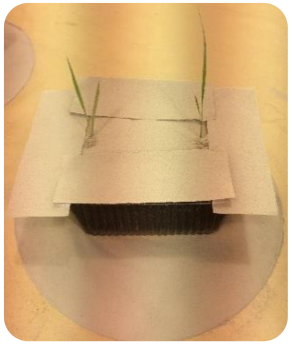
1st measurement



Experimental procedure: tephra application

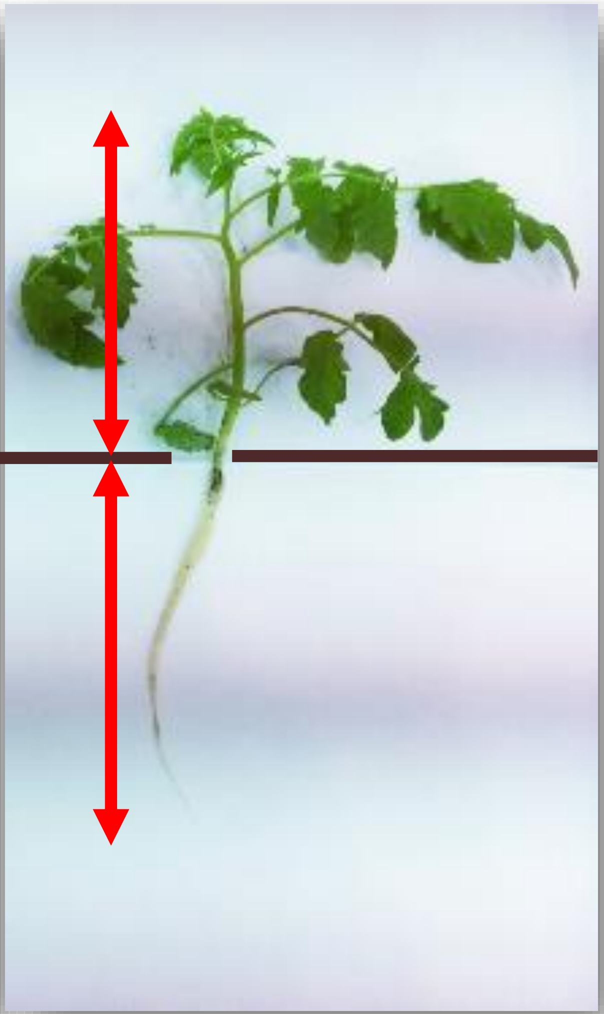






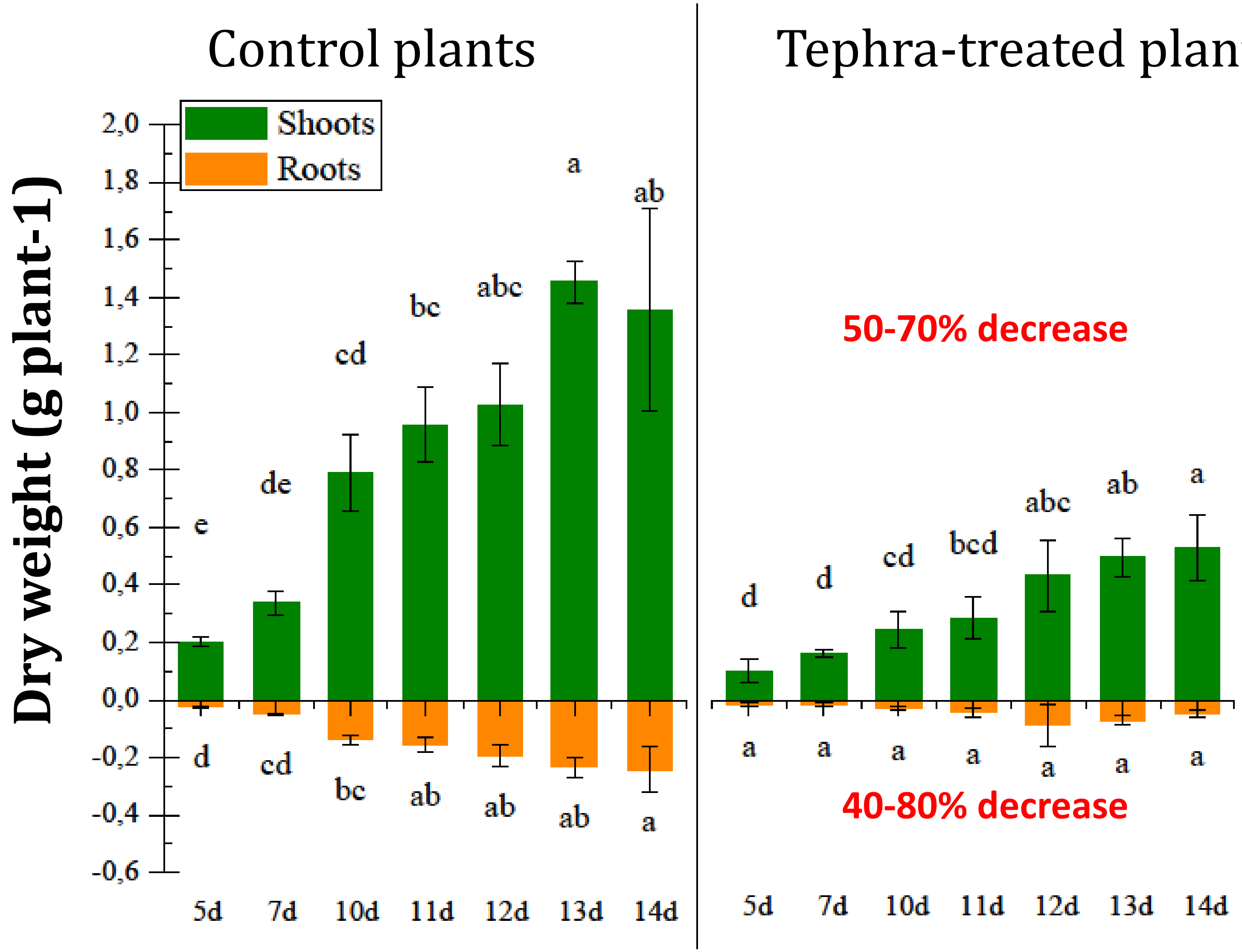
Physical damage of the plant: decreased growth

Control plant

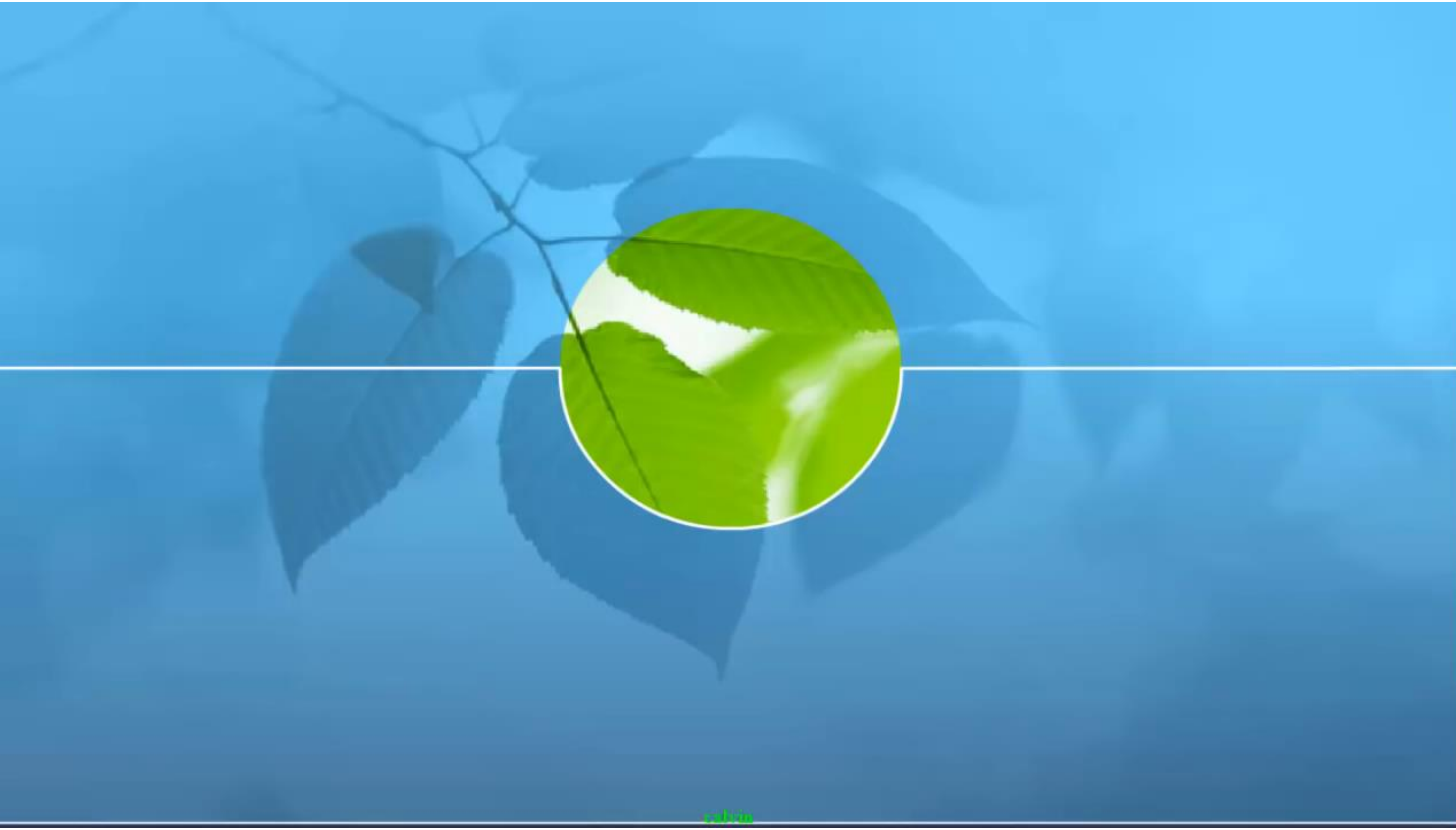


Tephra-treated plant

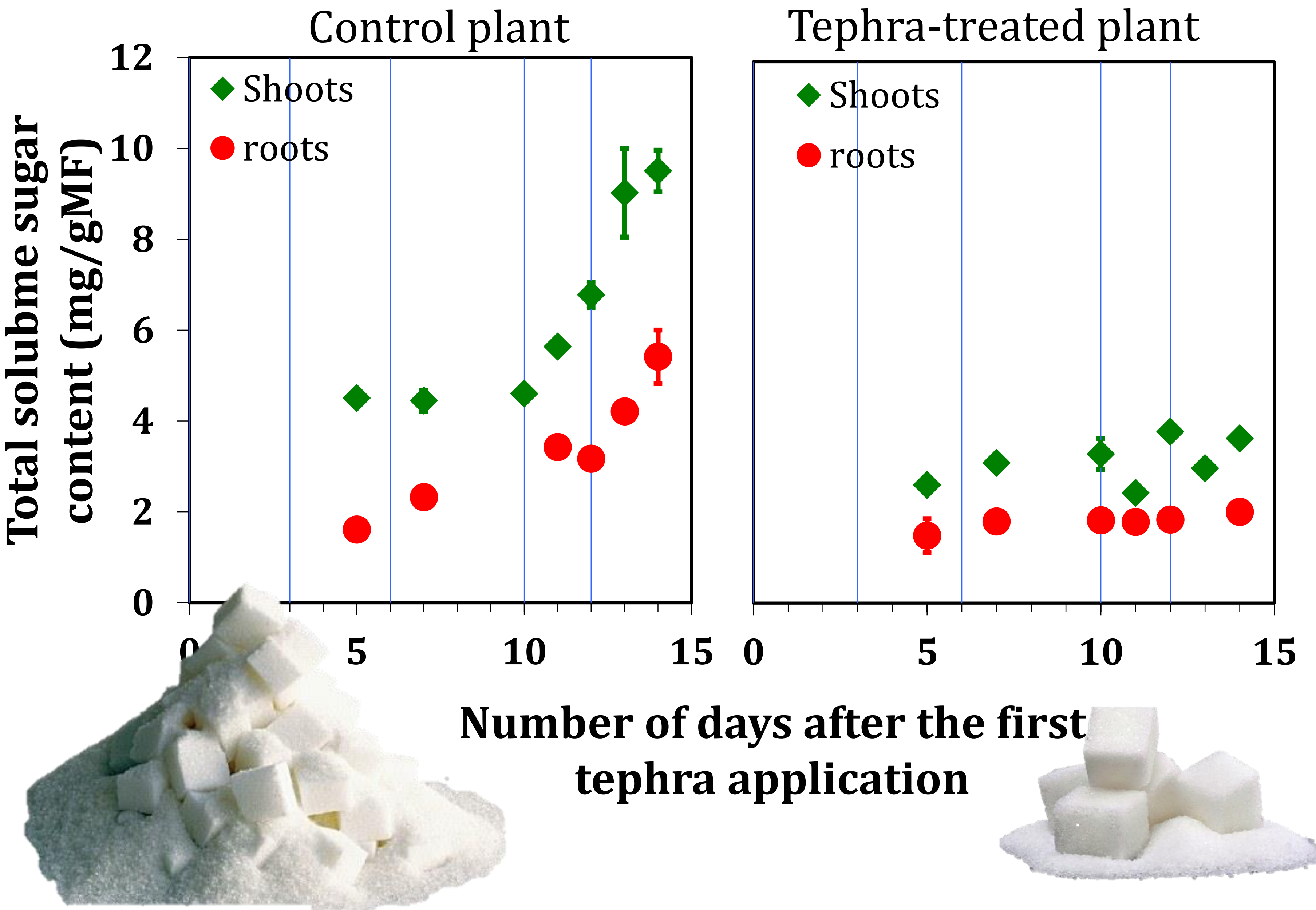
Lower biomass of tephra-treated plants

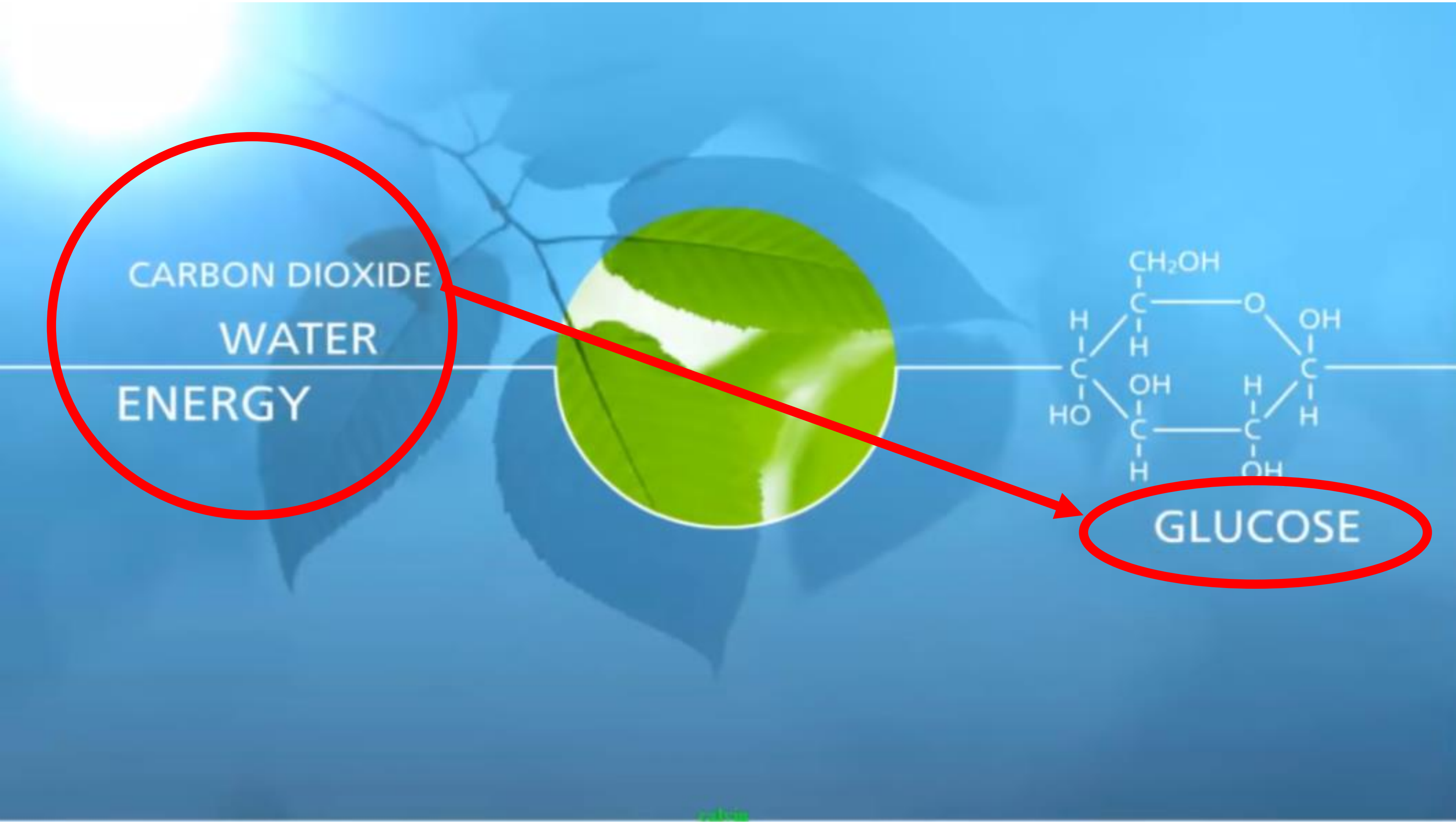


Number of days after the first tephra application



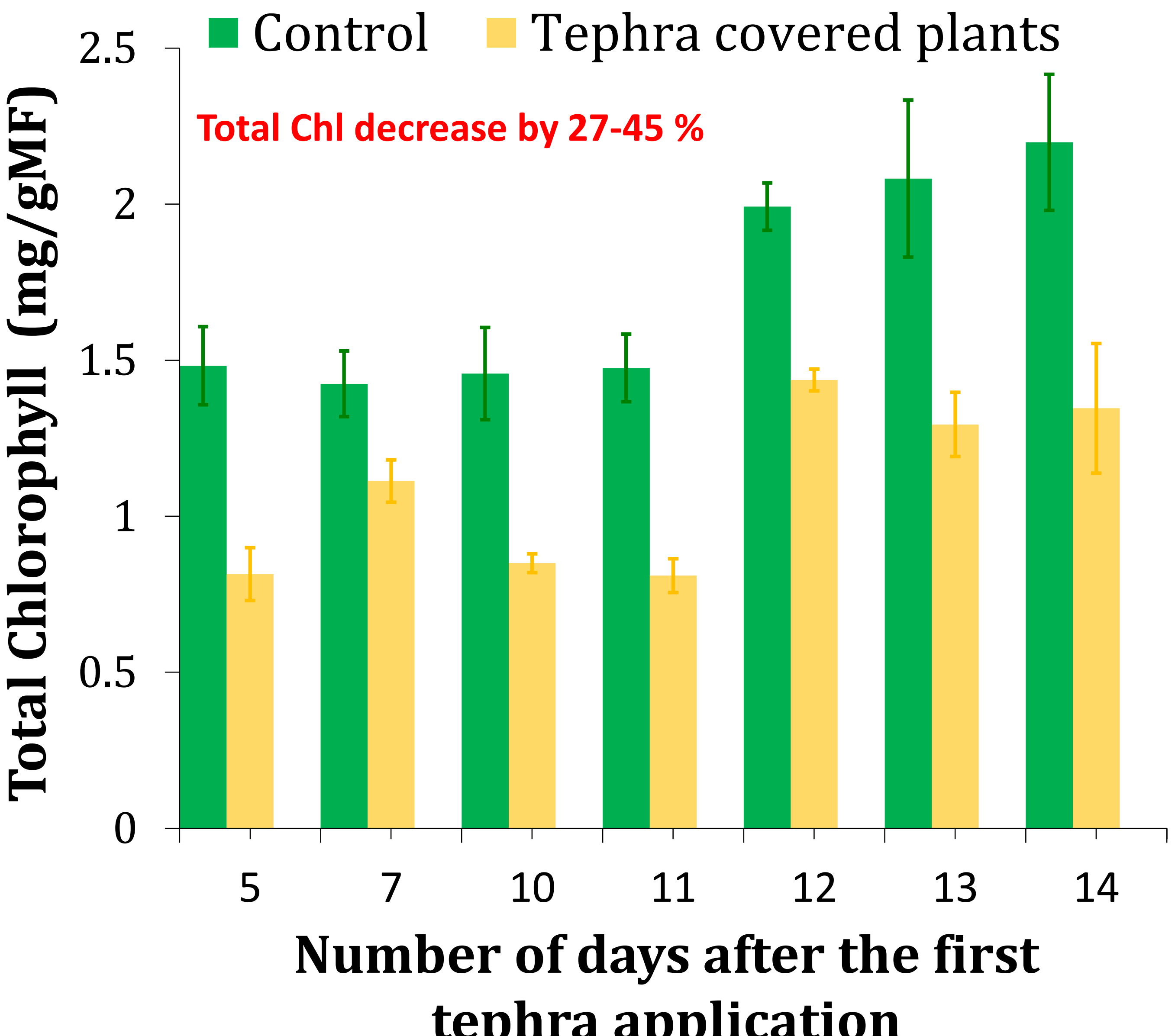
Lower sugar content in tephra-treated plants




CARBON DIOXIDE
WATER
ENERGY
CH₂OH
GLUCOSE

Energy source

Lower chlorophyll content in tephra-treated leaves

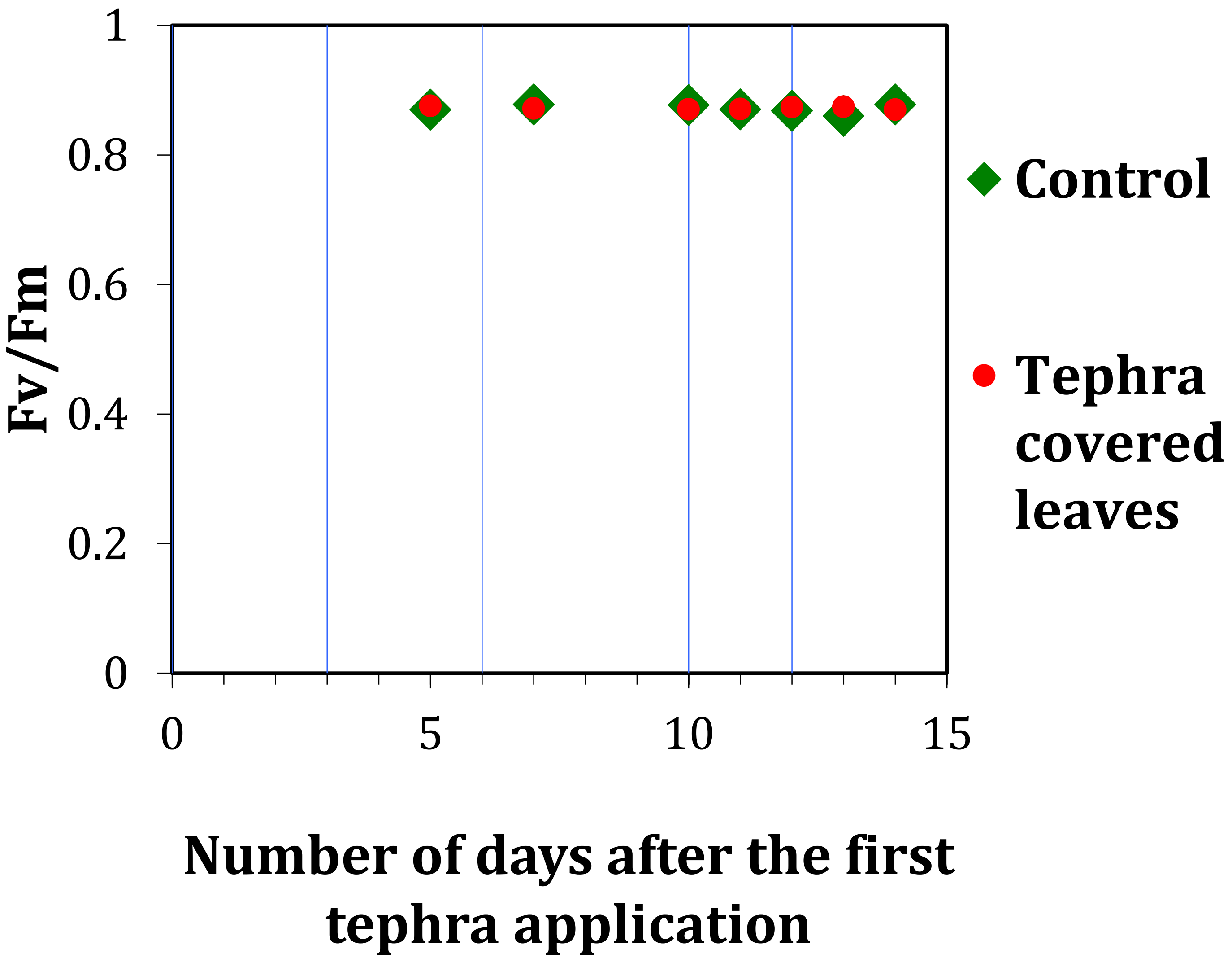


Light green color of tephra-treated leaves

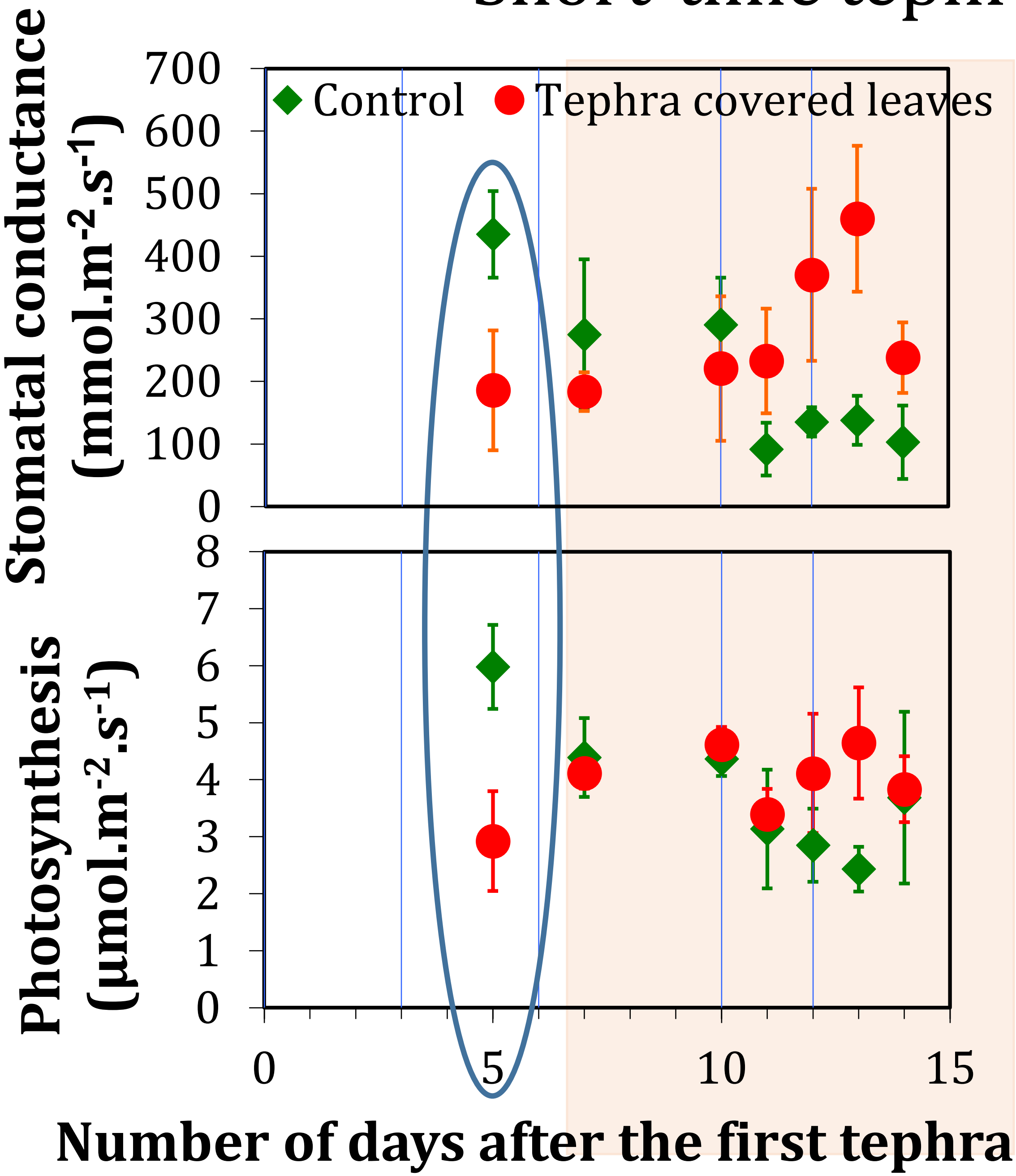
Control plant

Tephra-treated plant

Good photosynthetic efficiency



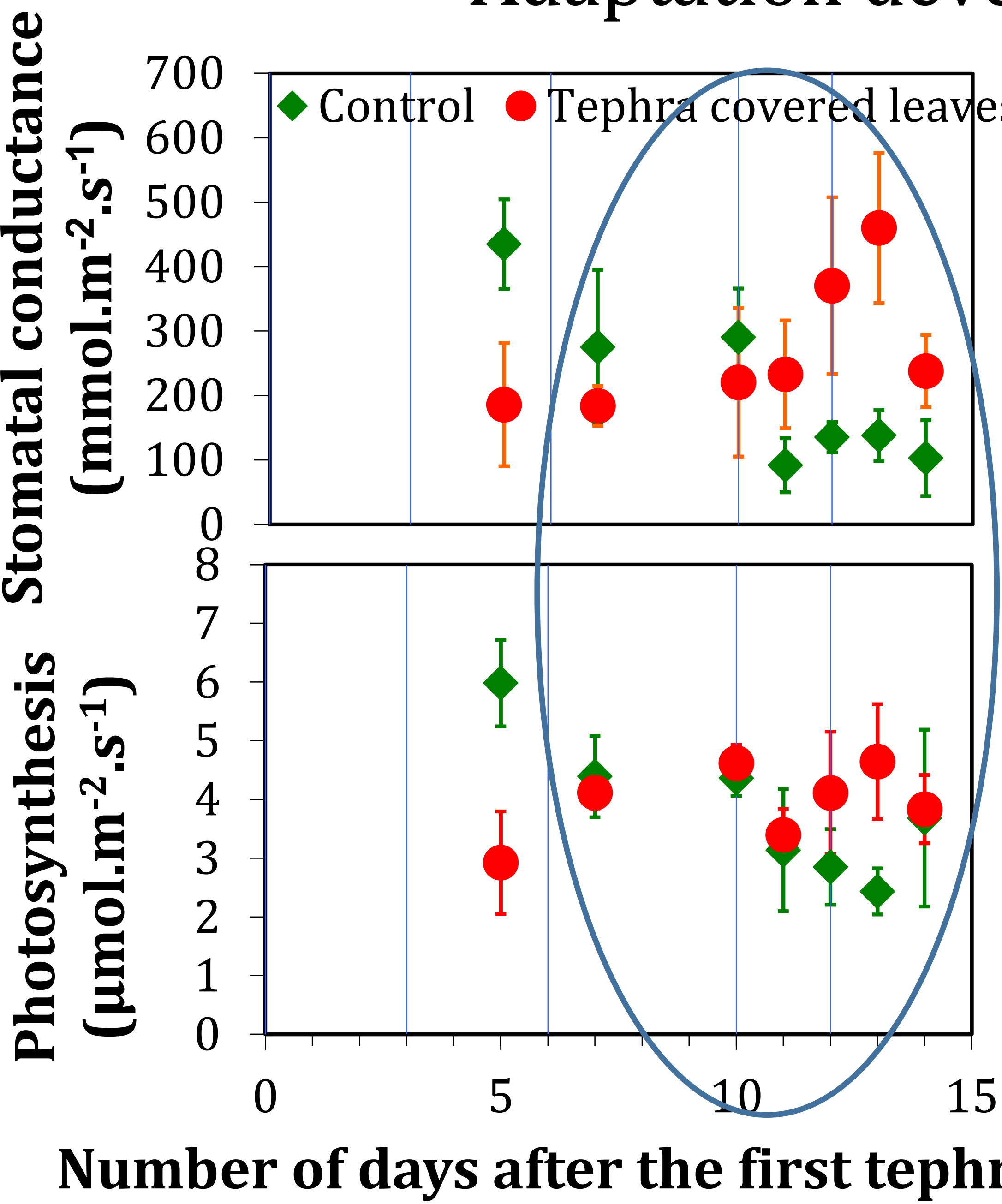
Short-time tephra effect



Gas exchange disfunction

Downregulation of photosynthetic activity

Adaptation development

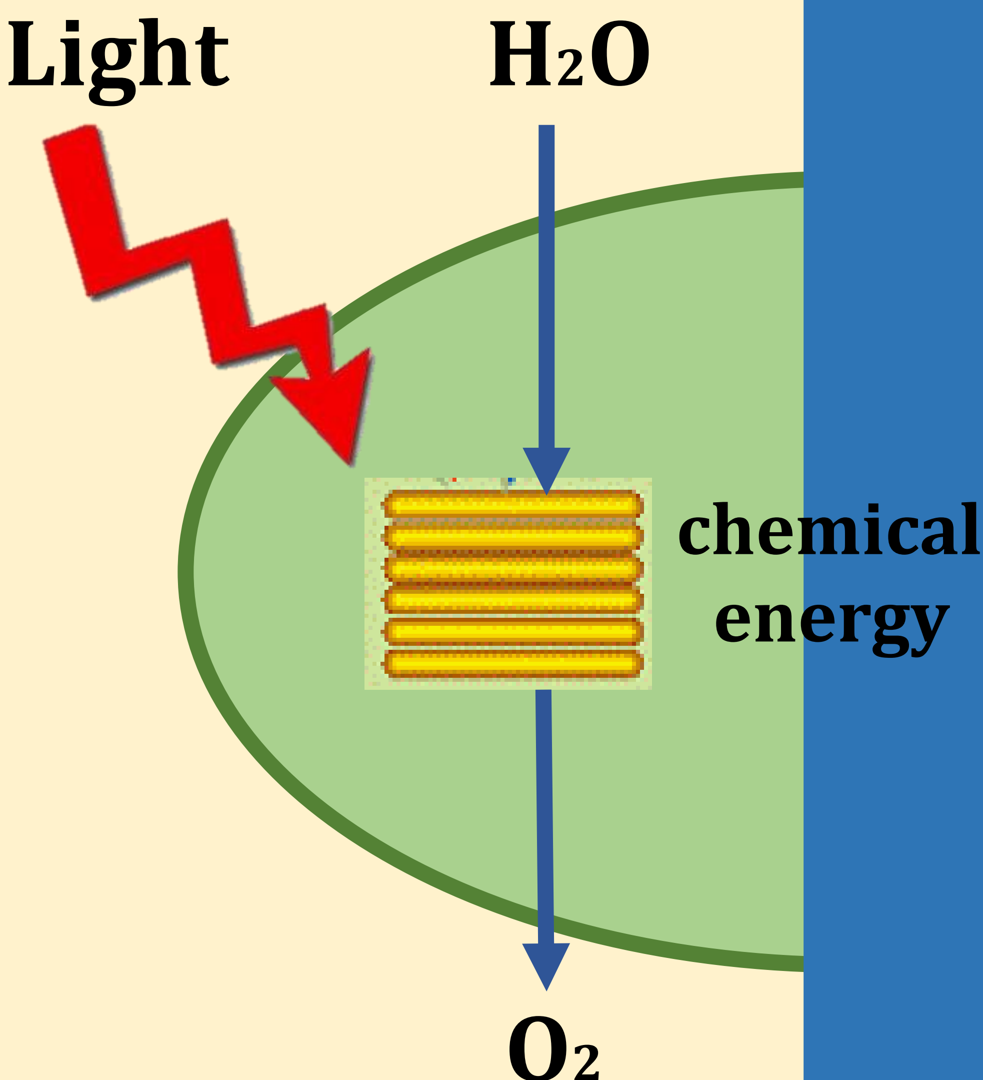


gas exchange regulation

Stabilization of photosynthetic activity

Light stage

Water + light = chemical energy

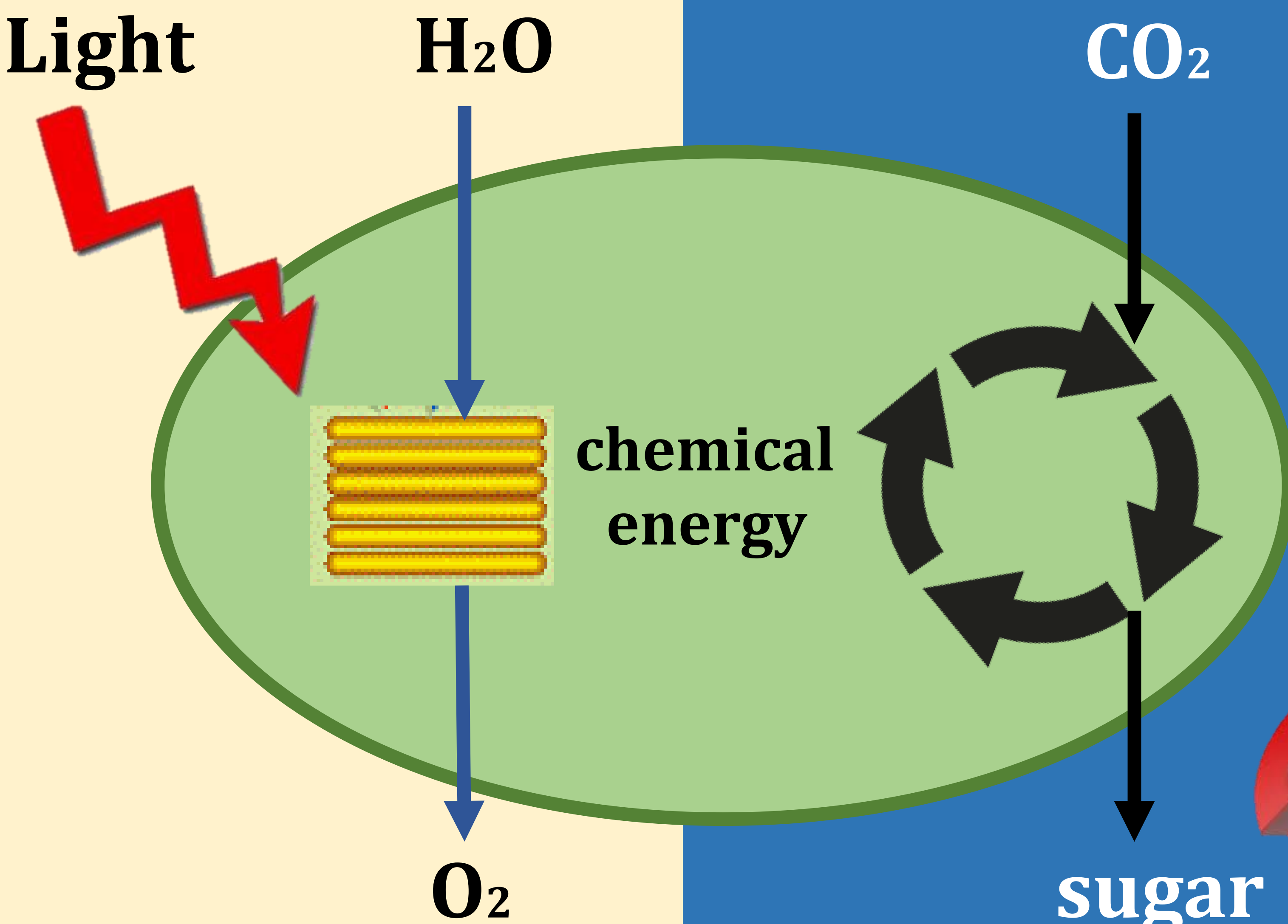


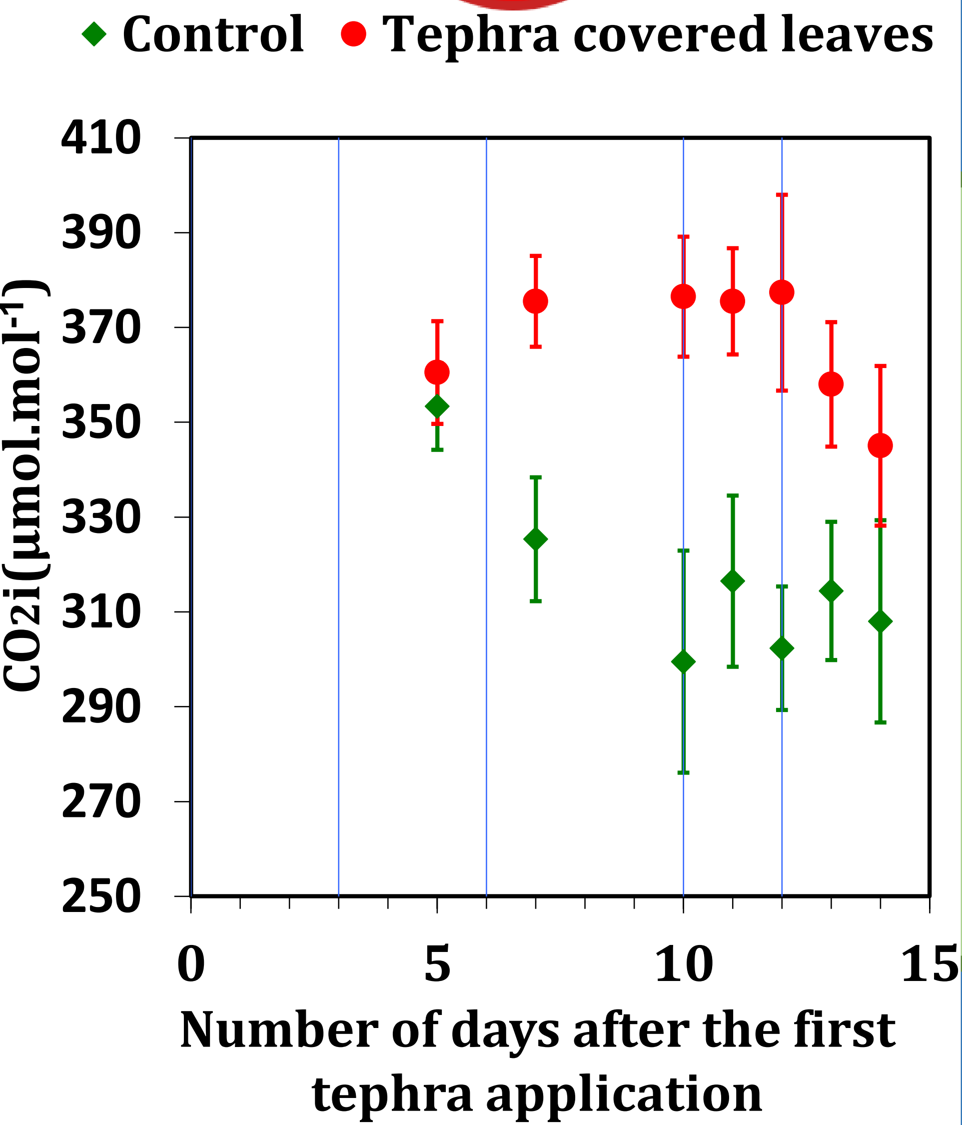
Light stage

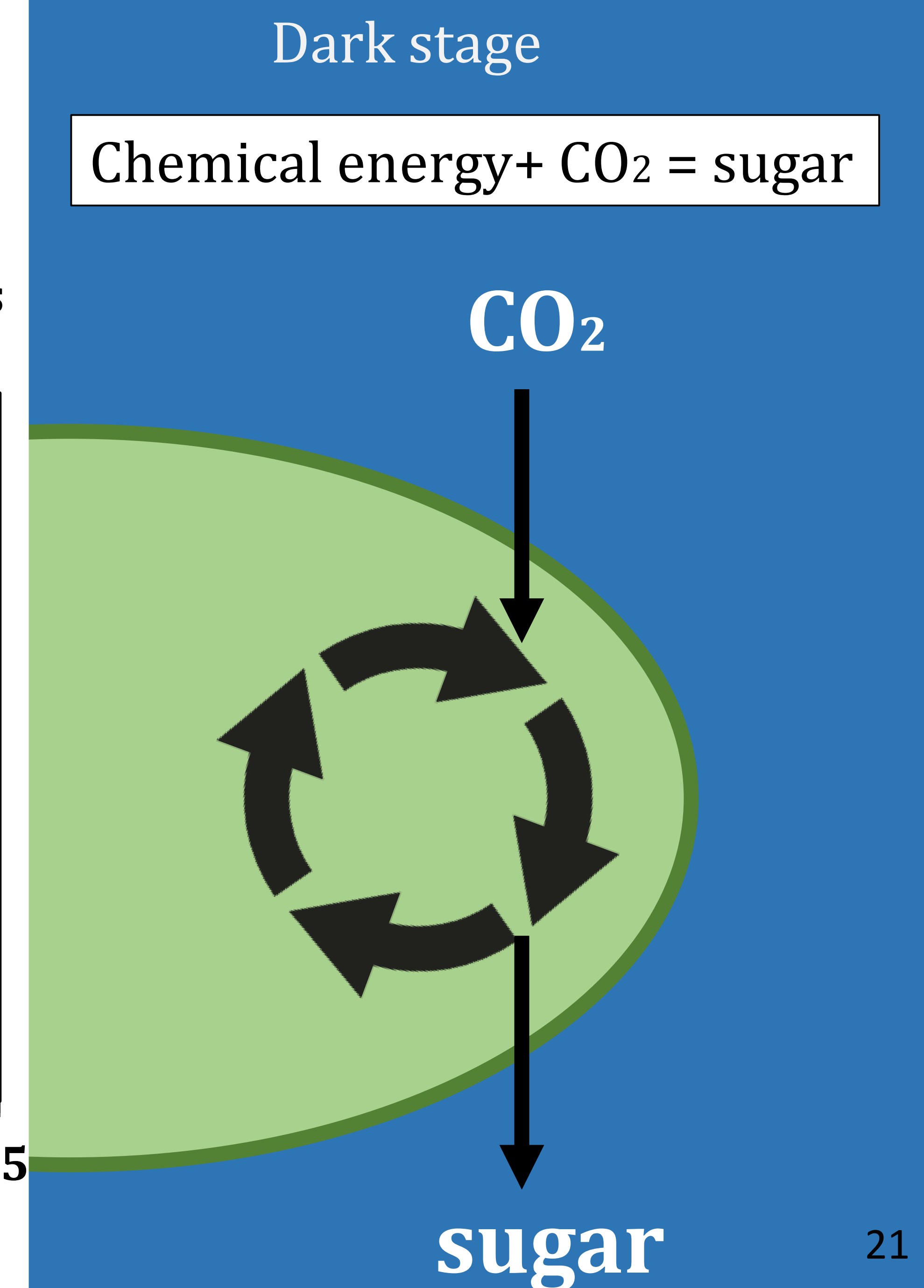
Water + light = chemical energy

Dark stage

Chemical energy+ CO_2 = sugar




Control
Tephra covered leaves
410
390
370
350
330
310
290
270
250
CO2i(µmol.mol-1)
0
5
10
15
Number of days after the first tephra application


Dark stage
Chemical energy+ CO2 = sugar
CO2
sugar

Conclusions: plant response to tephra stress

Direct effect
5- 7 days

Plant resistance: avoidance

- Stomatal closure

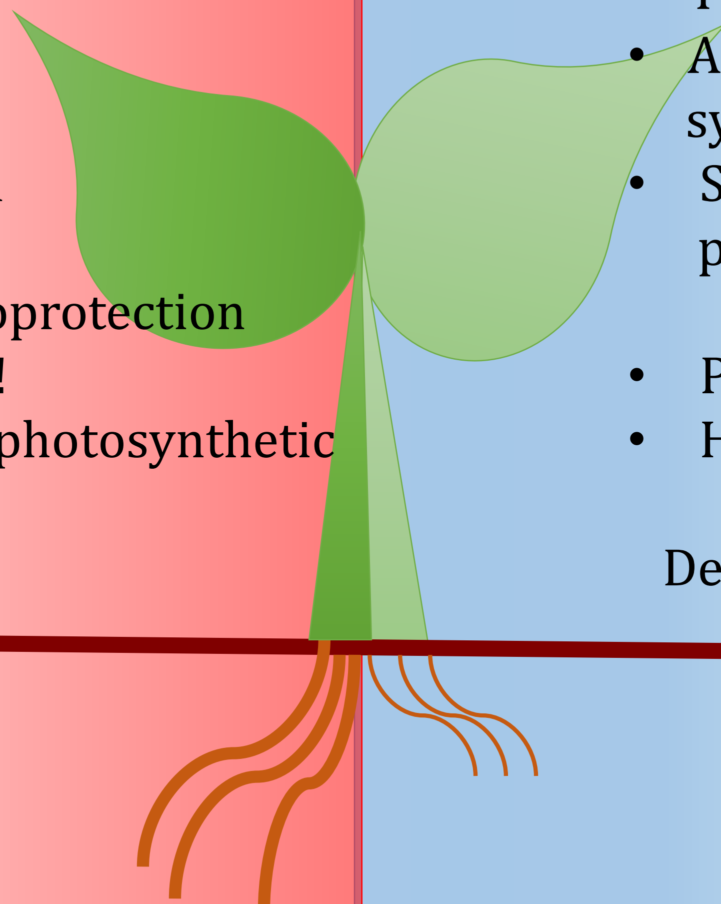
↓

- Heat shock
- Pigment degradation

↓

  - Decreased photoprotection function!

- Down-regulation of photosynthetic activity!



Acquired resistance
7-14 days

Plant resistance: tolerance

- Thermal regulation
- Activation of antioxidant system
- Stabilization of photosynthetic efficiency

- Pigment degradation
- Higher CO2 concentration

↓

Decreased sugar synthesis

Impact of tephra deposition on water infiltration in soil

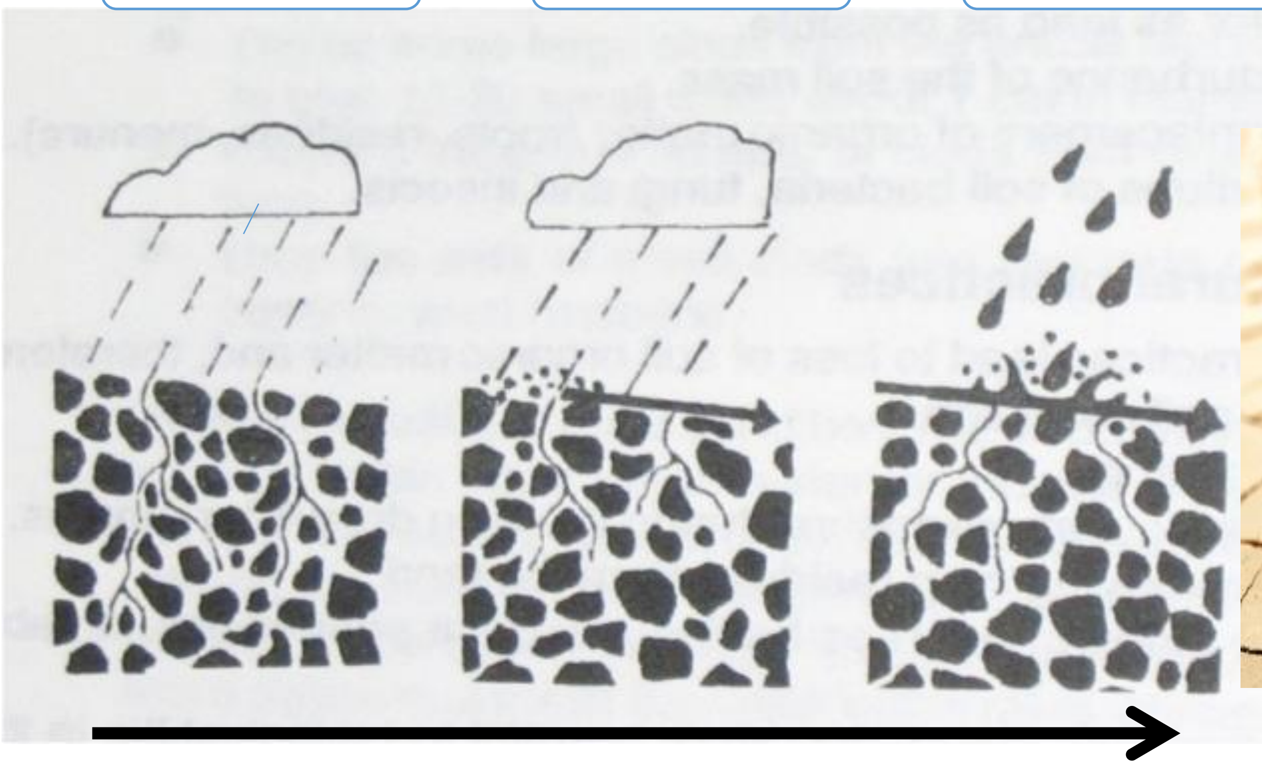
Rain-induced crusts effect on soils

Infiltration

Run-off

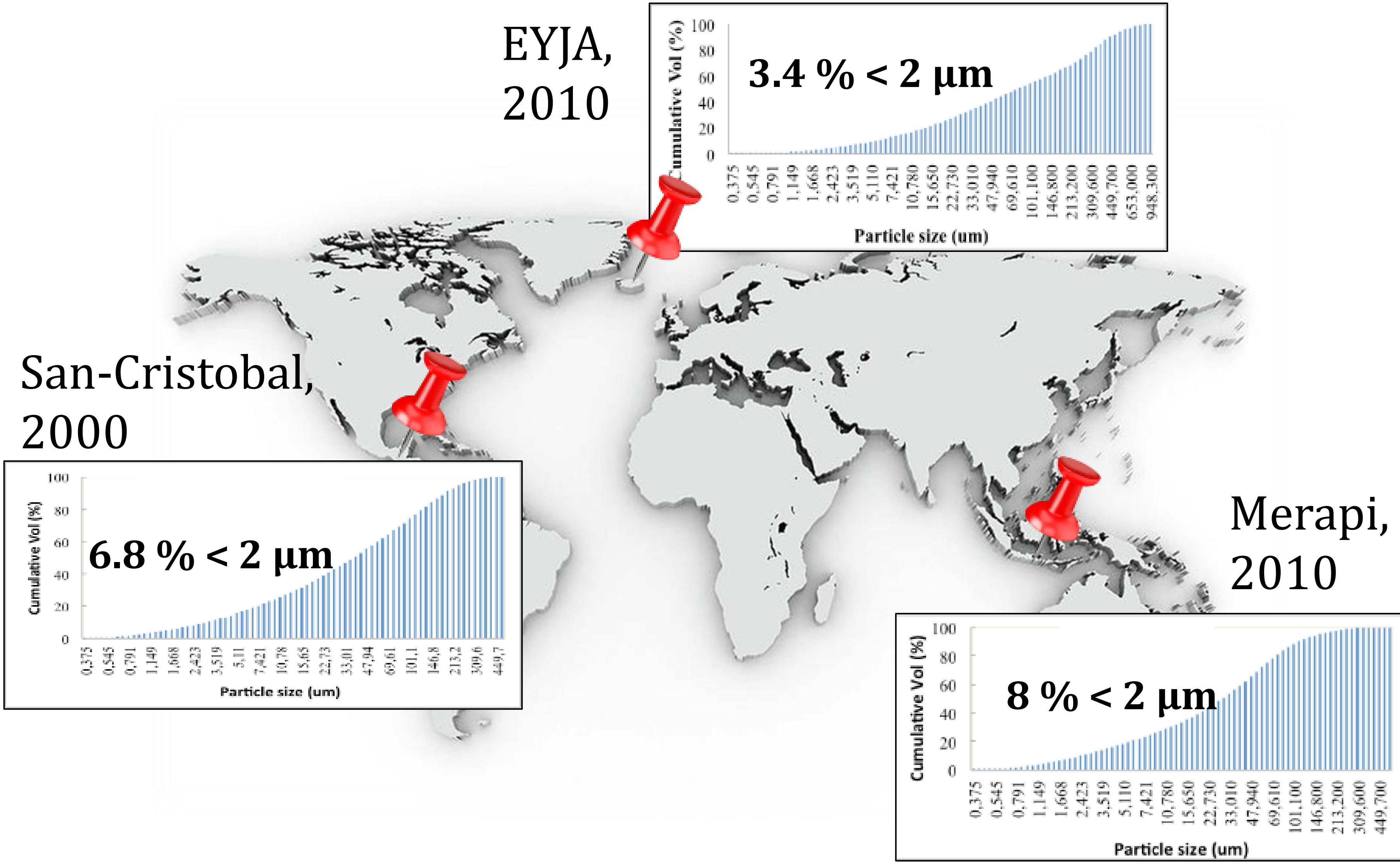
Water erosion

Gas exchange
Seed emergence

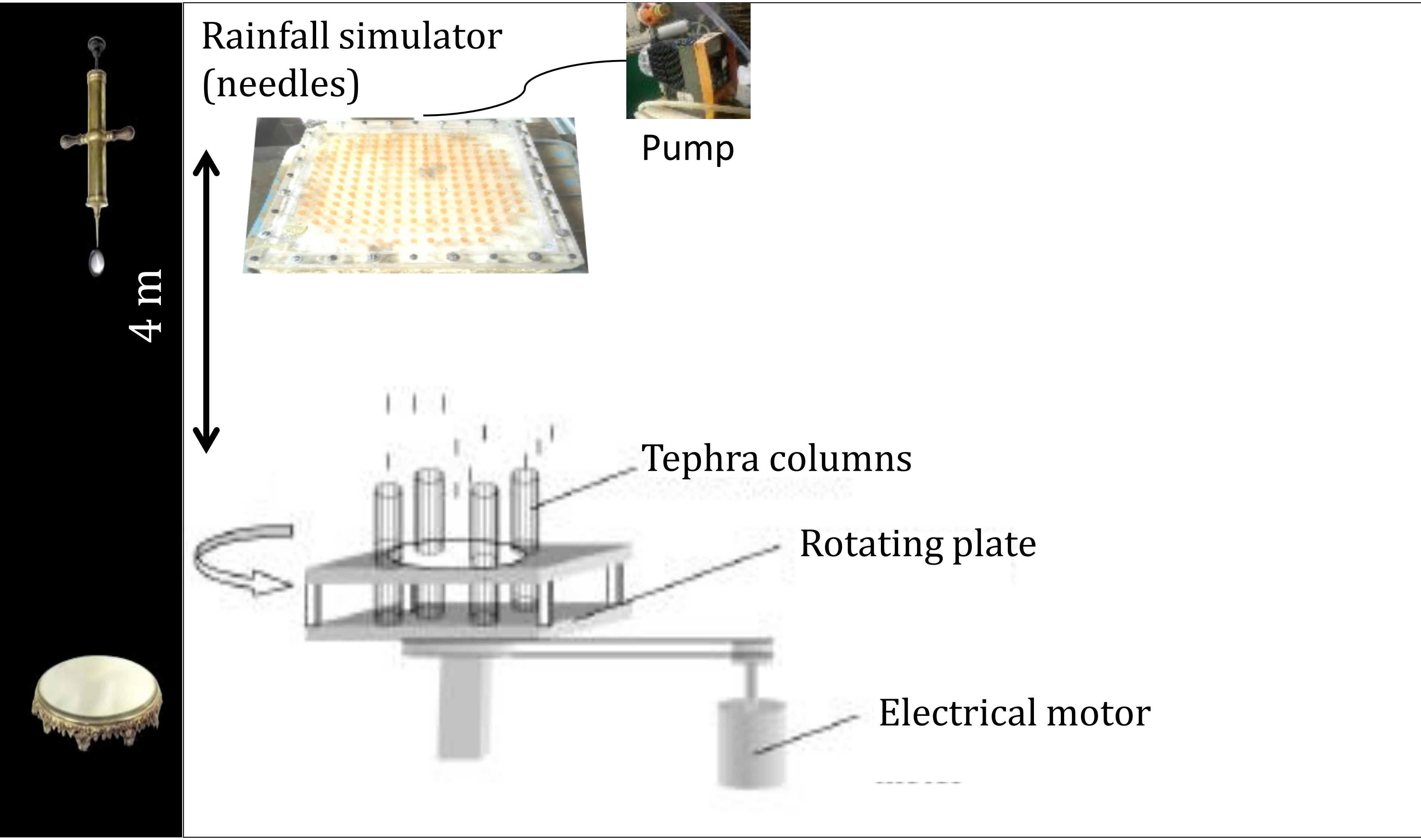


time

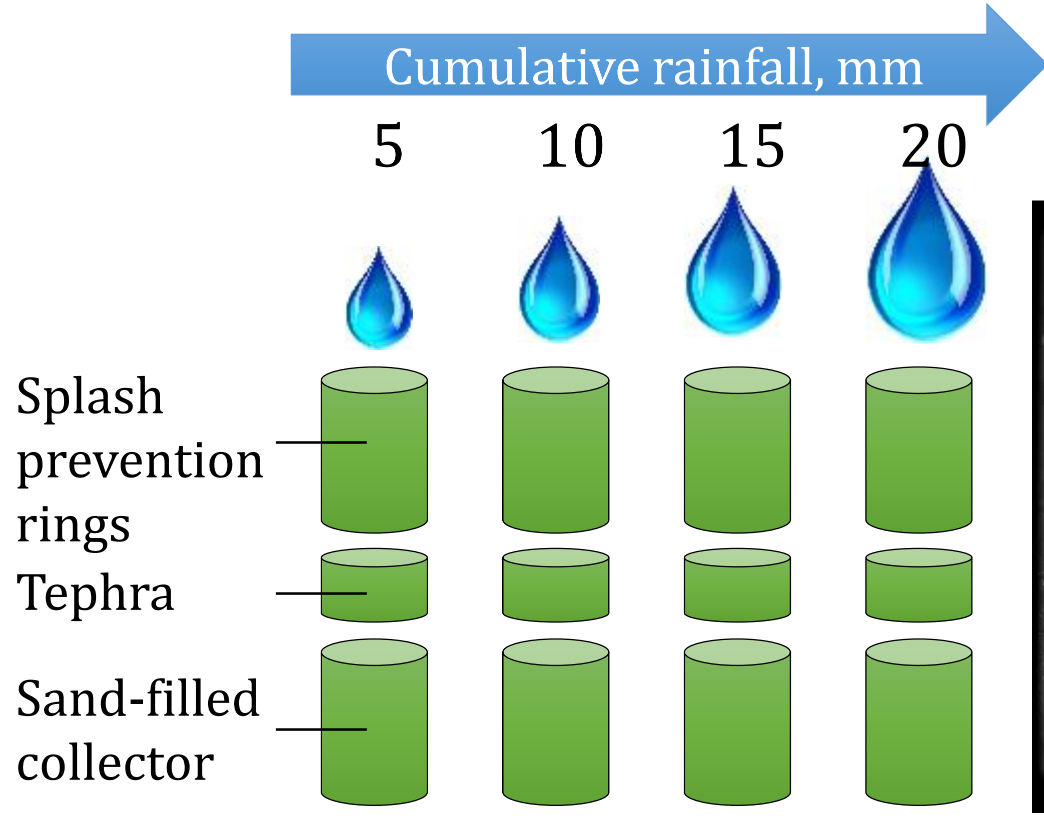
Tephra types for the experiment

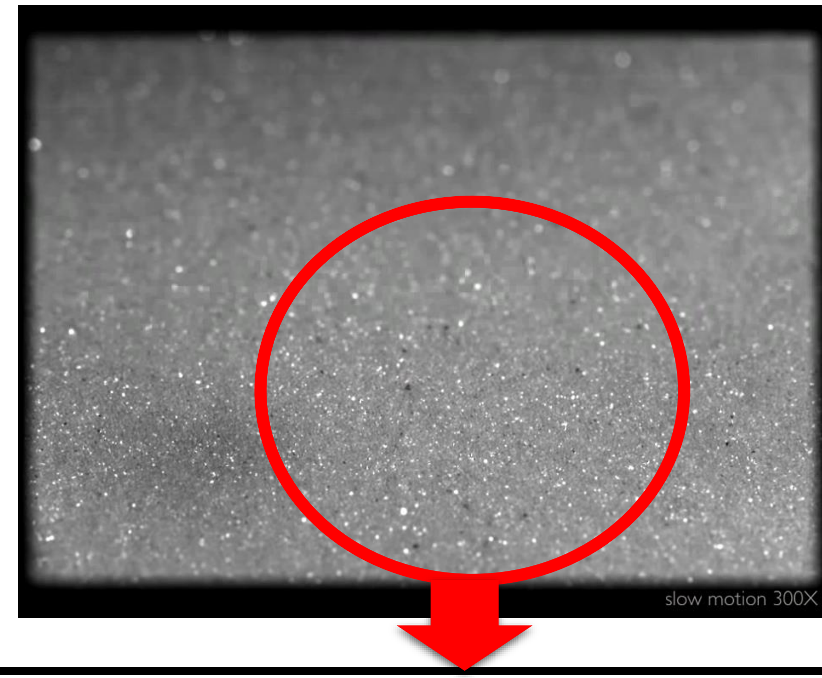


Experimental set-up



Experimental set-up





Objective:

to assess the mechanisms of formation of tephra crusts by looking at their morphological properties

MER SC EYJA

Rainfall initiation: distinct pellet formation (MER, SC)

Stage 1: 5 mm of rain

Stage 2: 10 mm of rain

Stage 3: 15 mm of rain

Stage 4: 20 mm of rain

Development of crater-like surface

Tephra surface characteristics

MER **SC** **EYJA**

Rainfall initiation

Stage 1: 5 mm of rain

Stage 2: 10 mm of rain

Stage 3: 15 mm of rain

Stage 4: 20 mm of rain

Tephra surface characteristics

MER **SC** **EYJA**

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Tephra surface characteristics

MER **SC** **EYJA**

Rainfall initiation

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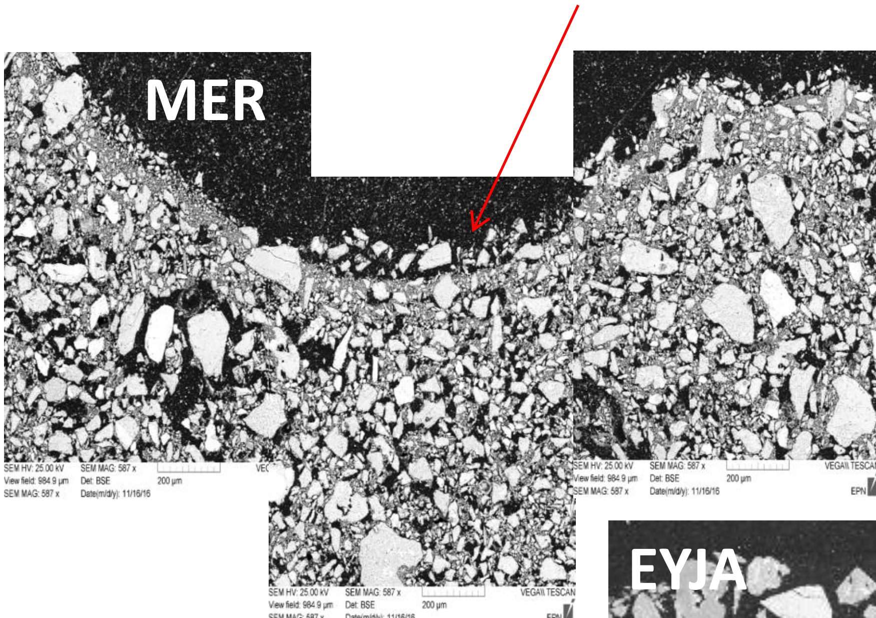
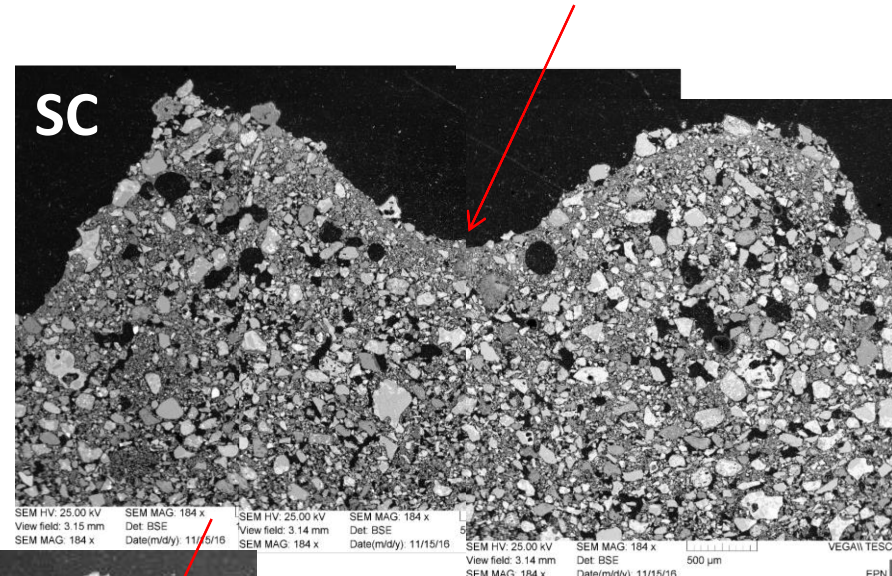
Stage 2: 10 mm of rain

Stage 3: 15 mm of rain

Stage 4: 20 mm of rain

Microscopic analysis: tephra crust continuity





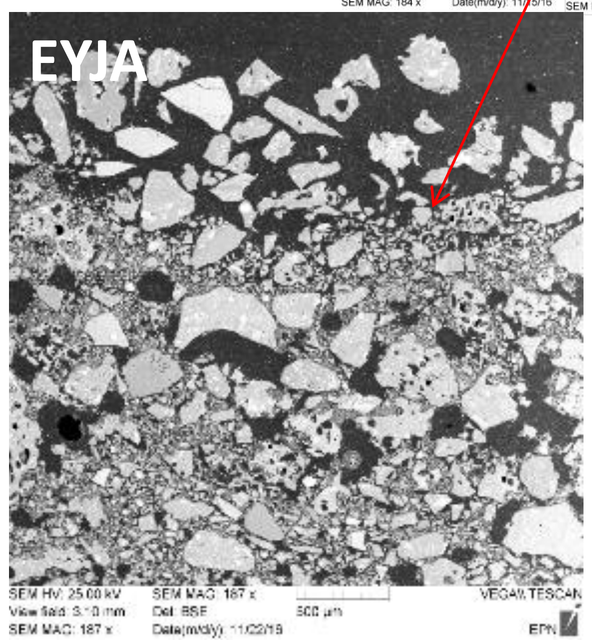


Image analysis: crust tephra porosity

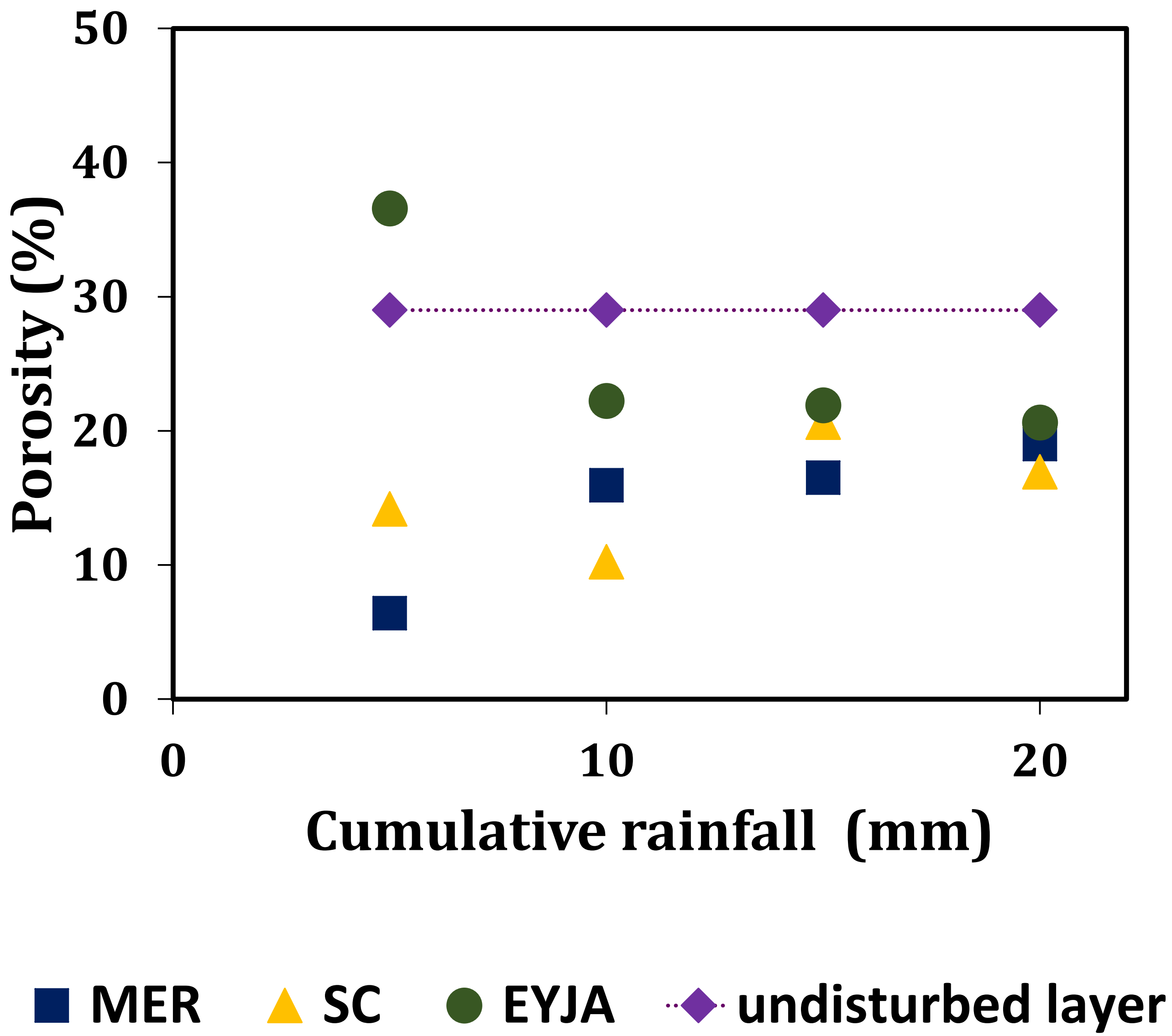
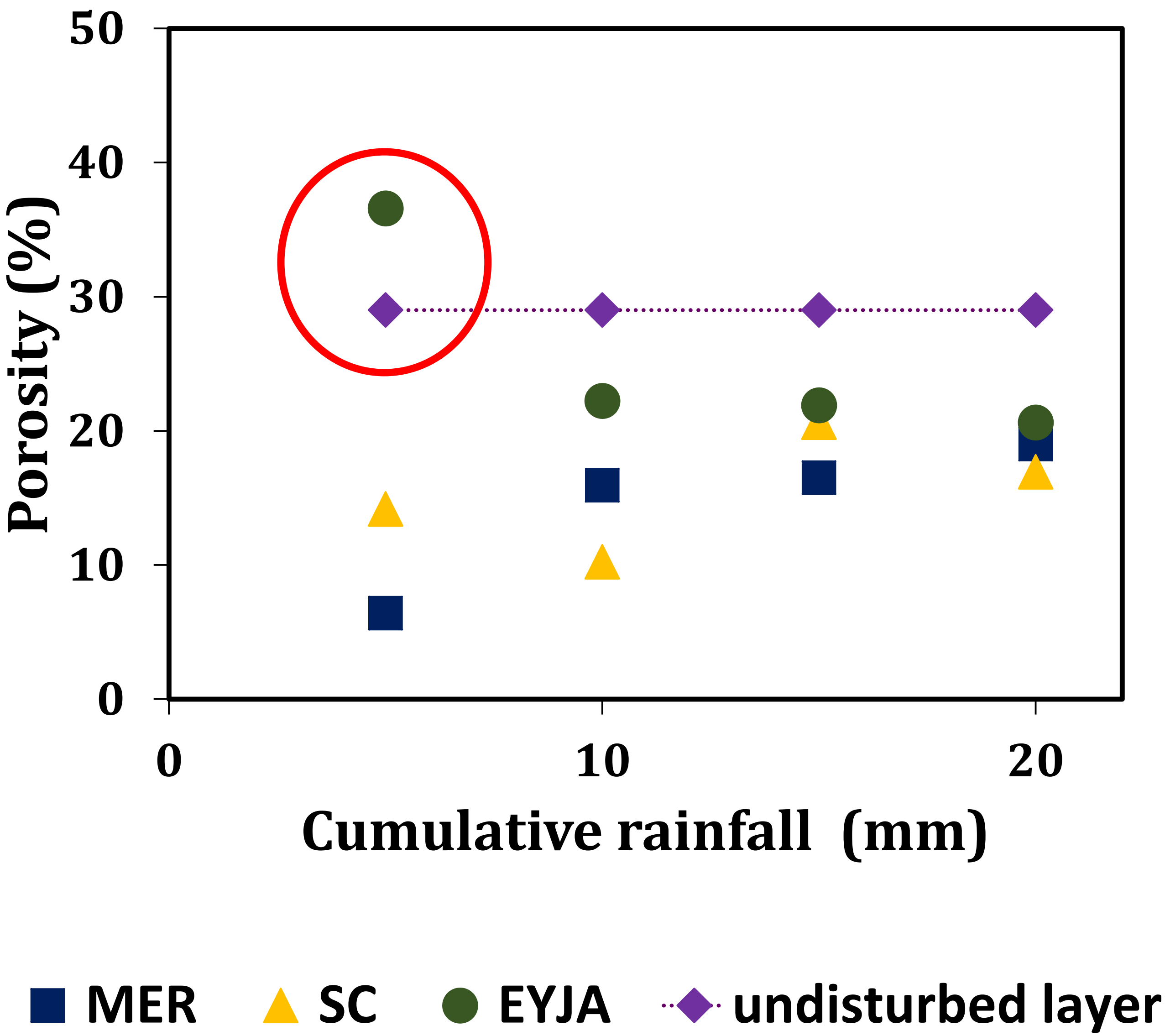
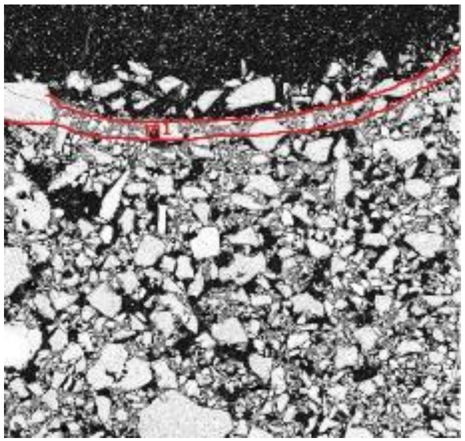


Image analysis: crust tephra porosity

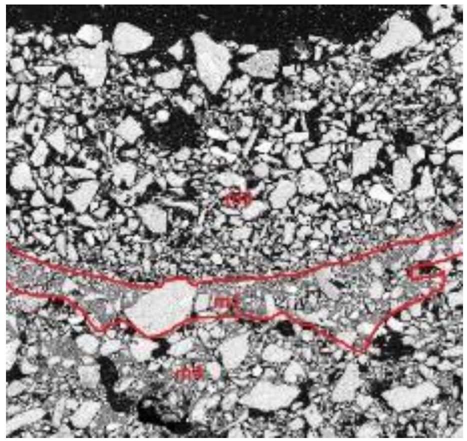


Main crust formation processes: MER

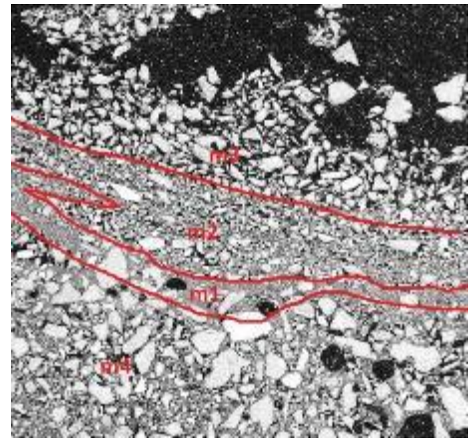
Stage 1:
5 mm of rain



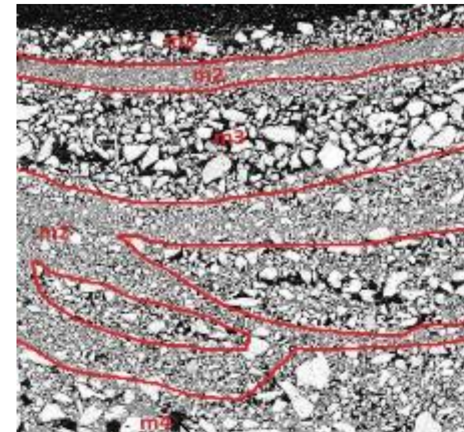
Stage 2:
10 mm of rain



Stage 3:
15 mm of rain



Stage 4:
20 mm of rain



Splash erosion

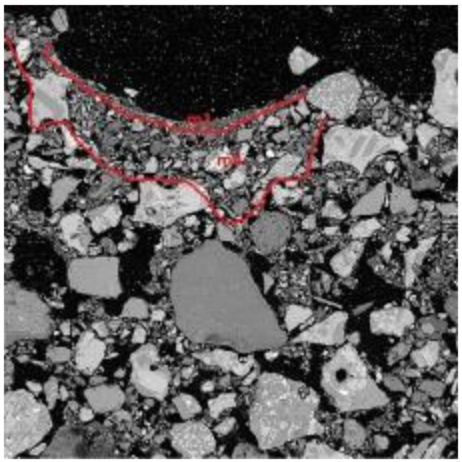
Vertical particle sorting

Vertical particle sorting

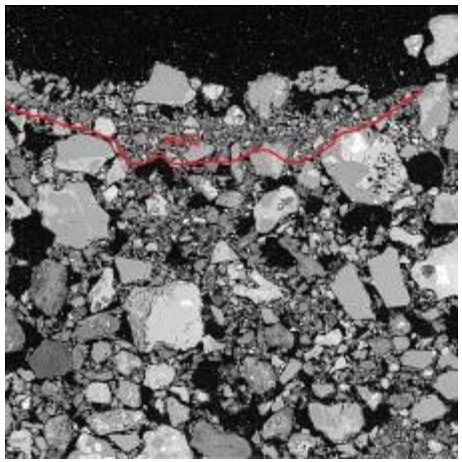
Particle sedimentation from suspension

Main crust formation processes: SC

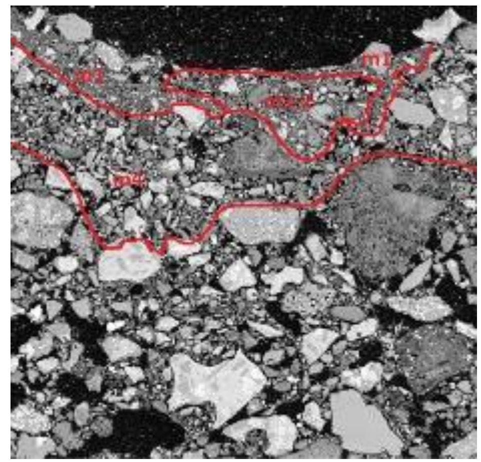
Stage 1:
5 mm of rain



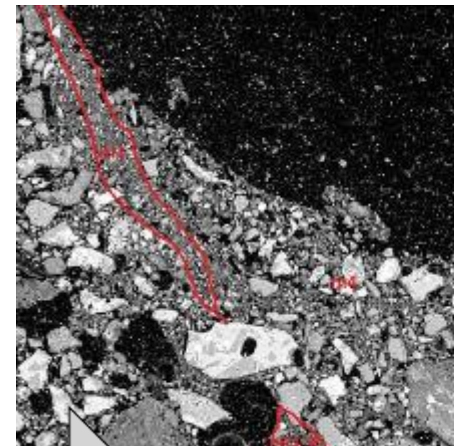
Stage 2:
10 mm of rain



Stage 3:
15 mm of rain



Stage 4:
20 mm of rain



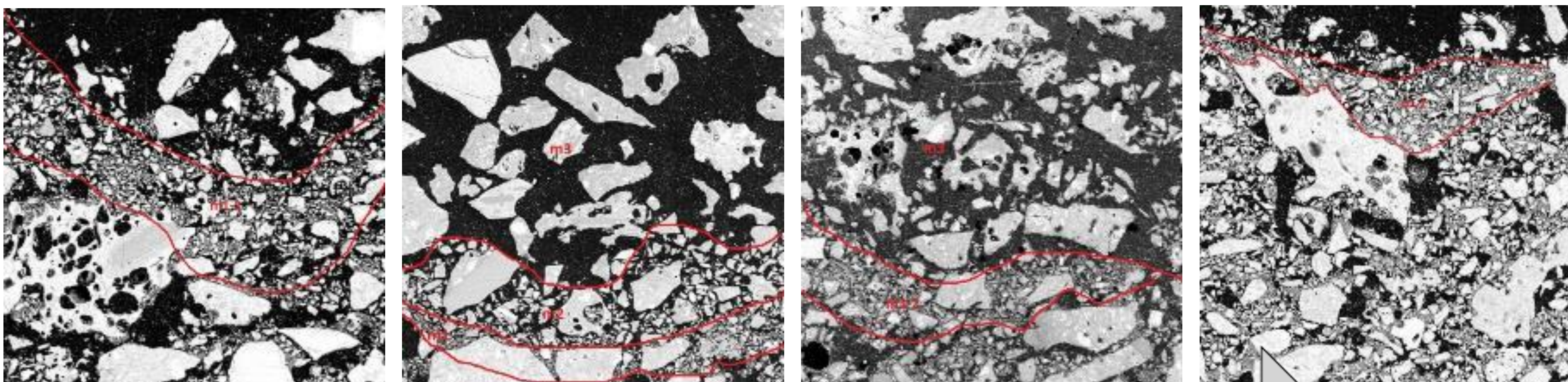
Splash erosion

Compaction

Minor vertical particle sorting

Main crust formation processes: EYJA

Stage 1: 5 mm of rain	Stage 2: 10 mm of rain	Stage 3: 15 mm of rain	Stage 4: 20 mm of rain



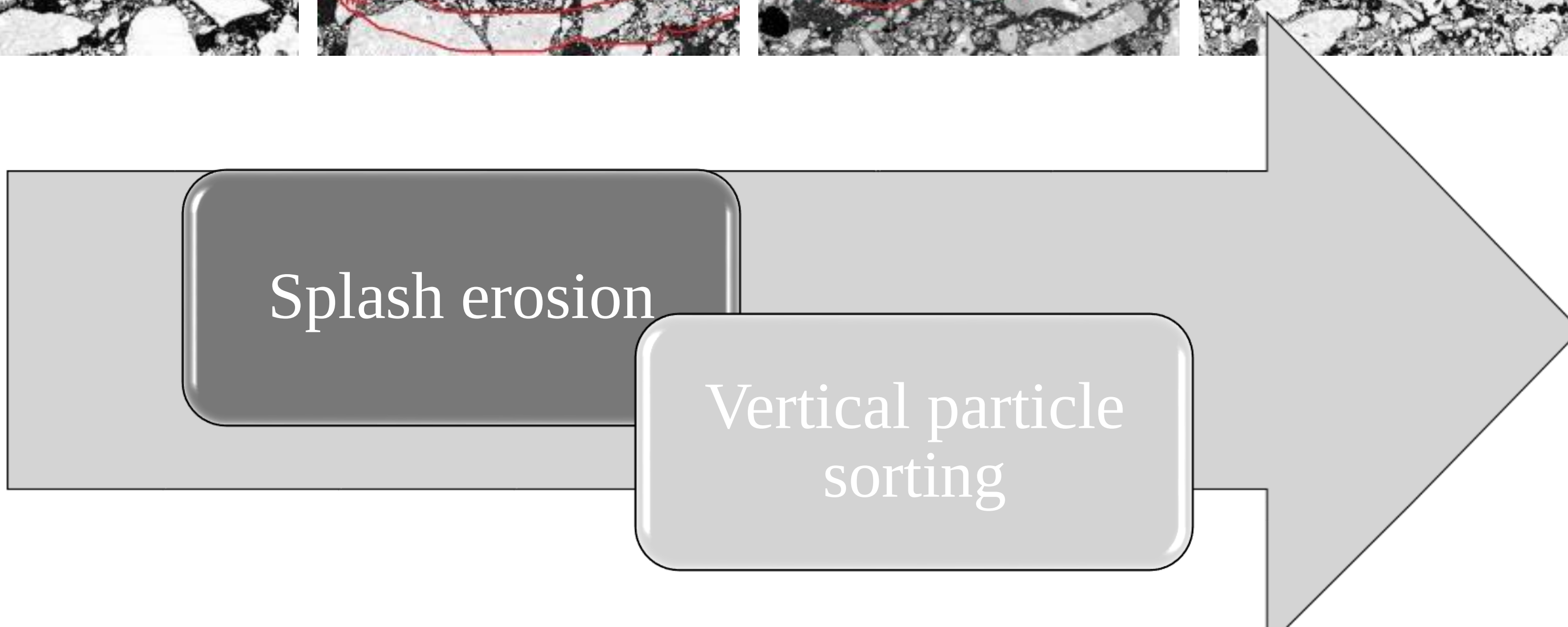
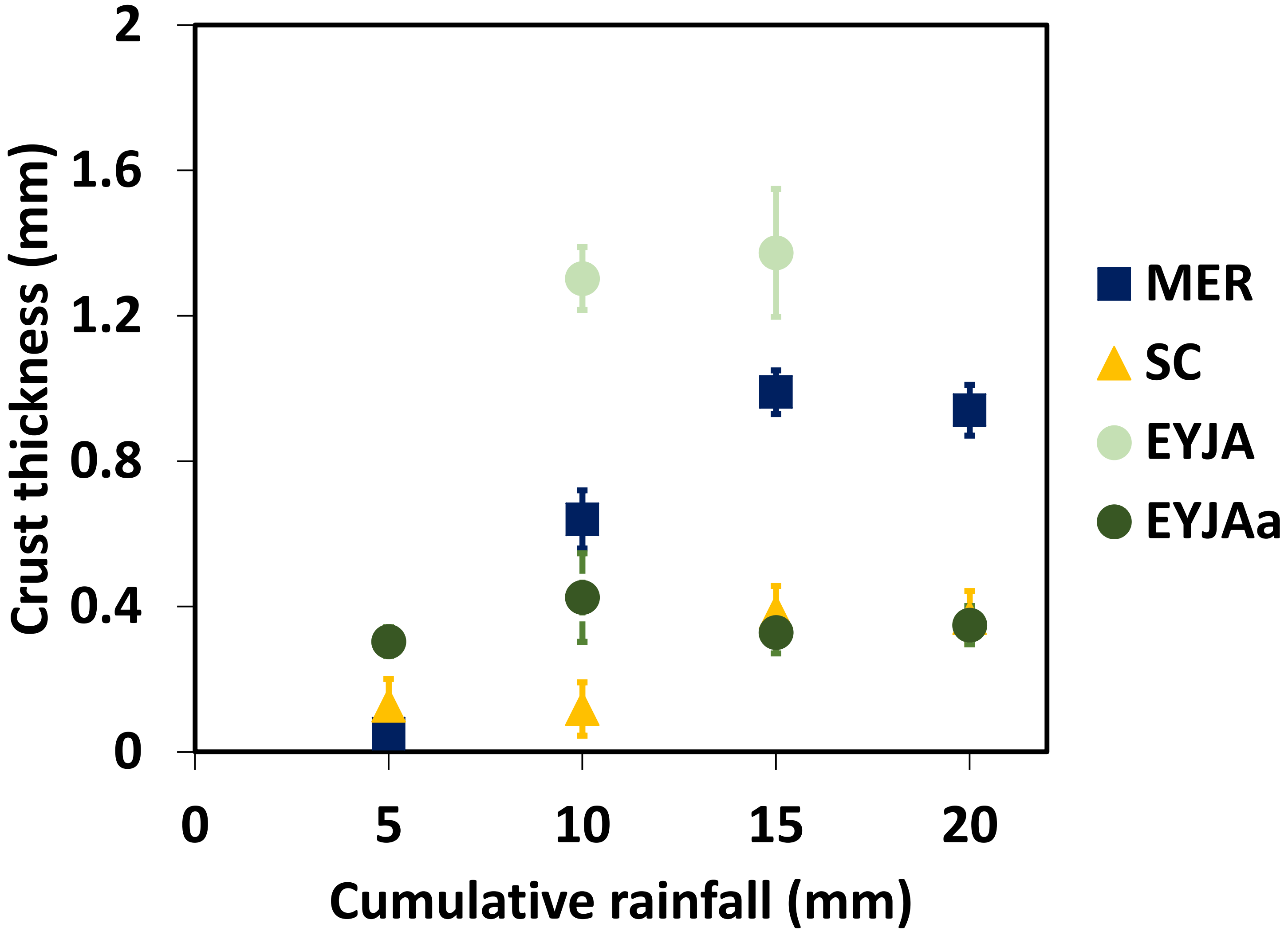


Image analysis: tephra crust thickness



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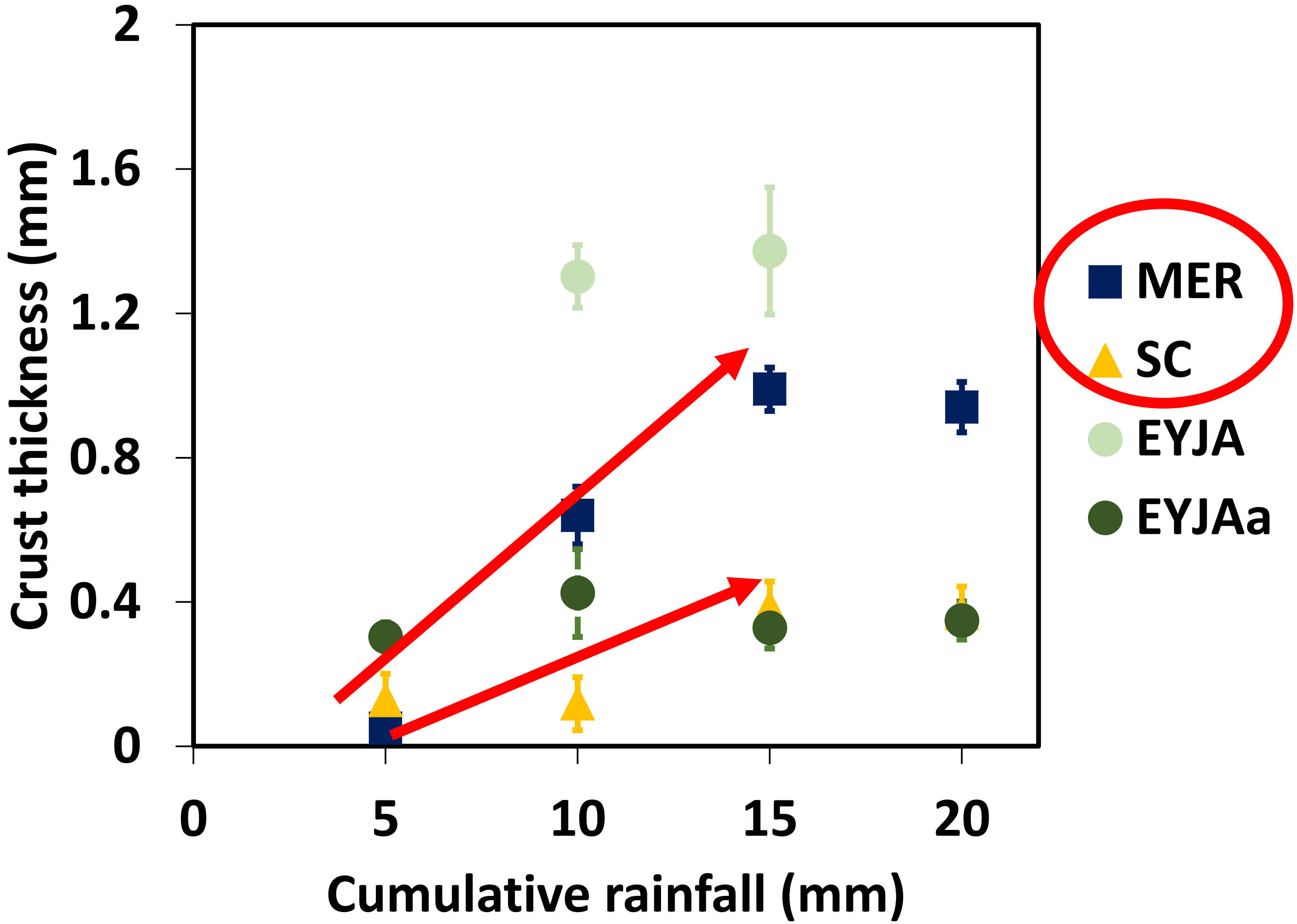
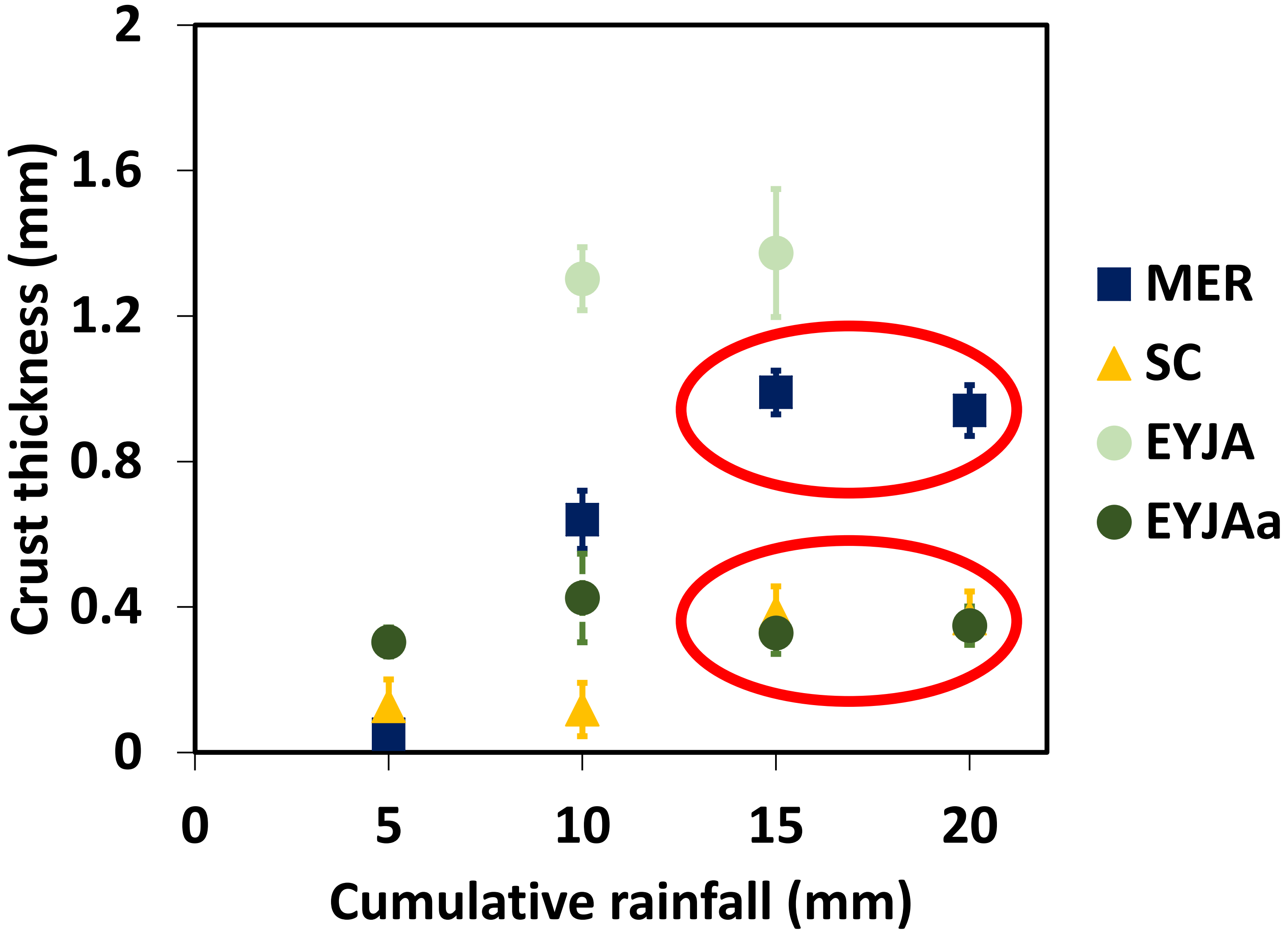
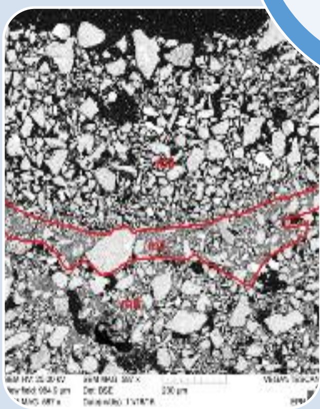


Image analysis: tephra crust thickness

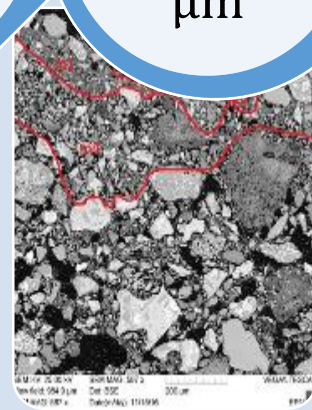


Conclusions

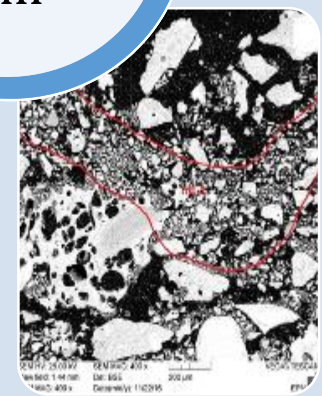
MER
D50=30 µm



SC
D50=38 µm



EYJA
D50=80 µm



MER

1) Main mechanisms:

Rainsplash erosion and vertical particle segregation

2) Formation of critical crust depth

SC

1) Main mechanisms:

Rainsplash erosion and compaction

2) Initiation of critical crust depth

EYJA

1) Main mechanism:

Rainsplash erosion

2) No evidence of critical crust depth development

Tephra impact on soil bioweathering

Study site

Sicily, Etna

Top

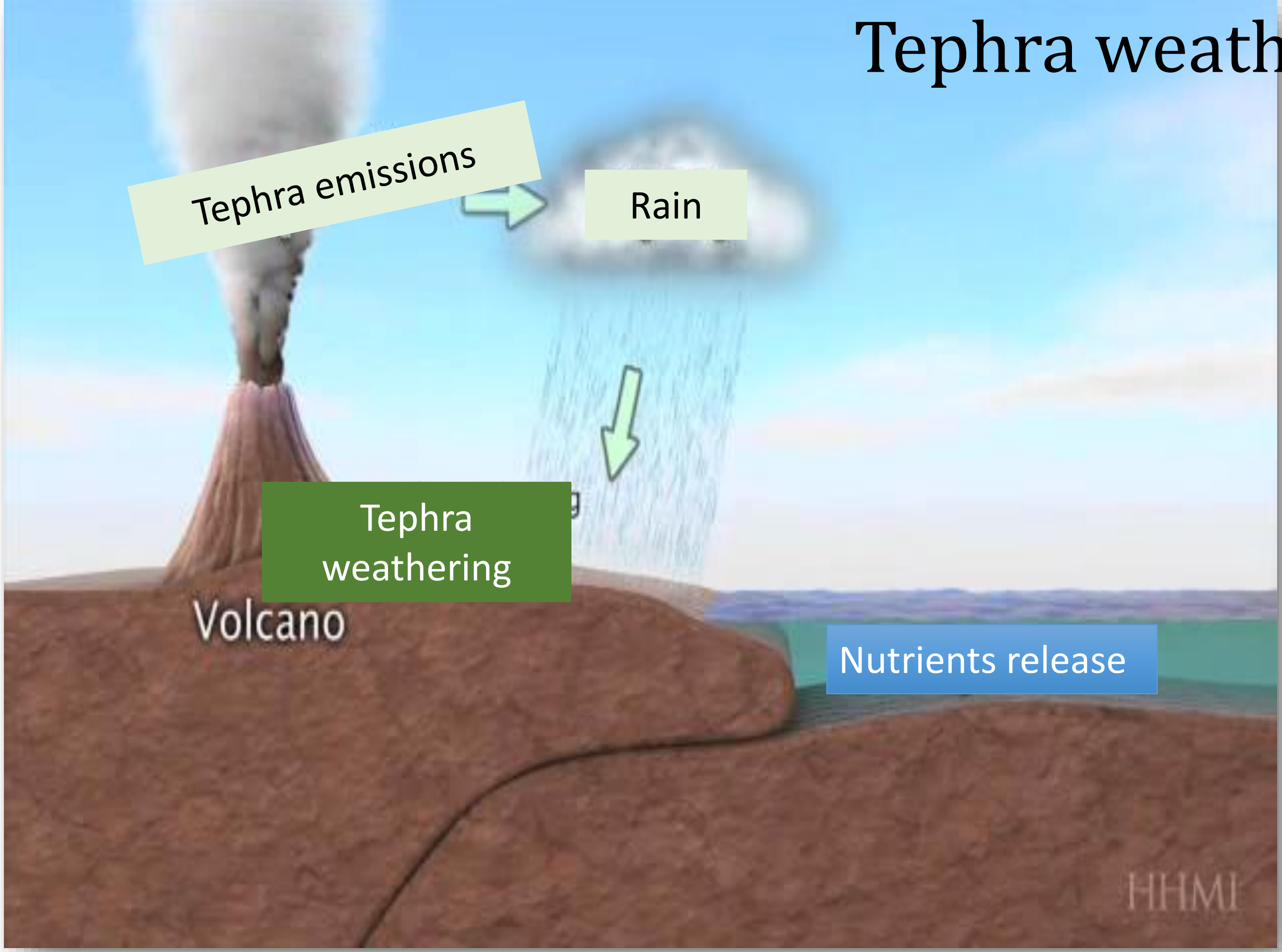
0-10 cm

Bottom

10-20 cm

Thank you for your attention!

Tephra weathering



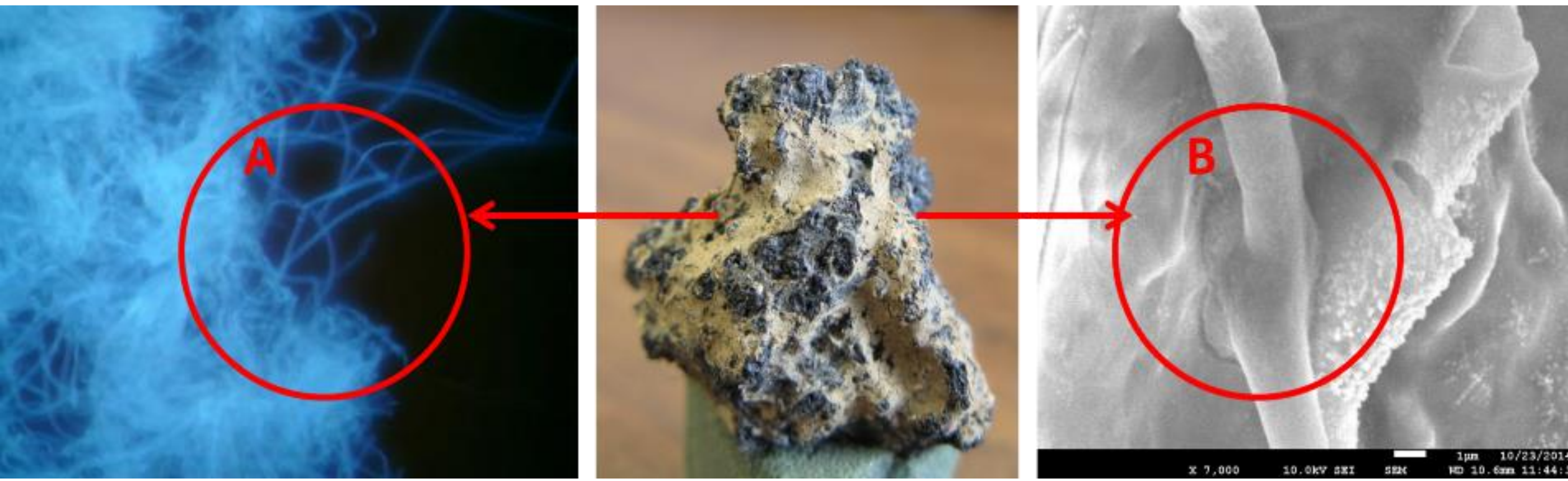
Objectives :

(1) to identify the ways of fungi-tephra interaction;
(2) to assess the effect of fungi on biochemical and biophysical weathering of tephra;
(3) to assess the response of organic matter and weathering to a tephra-mediated increase in soil fungal activity.

Fungal colonization

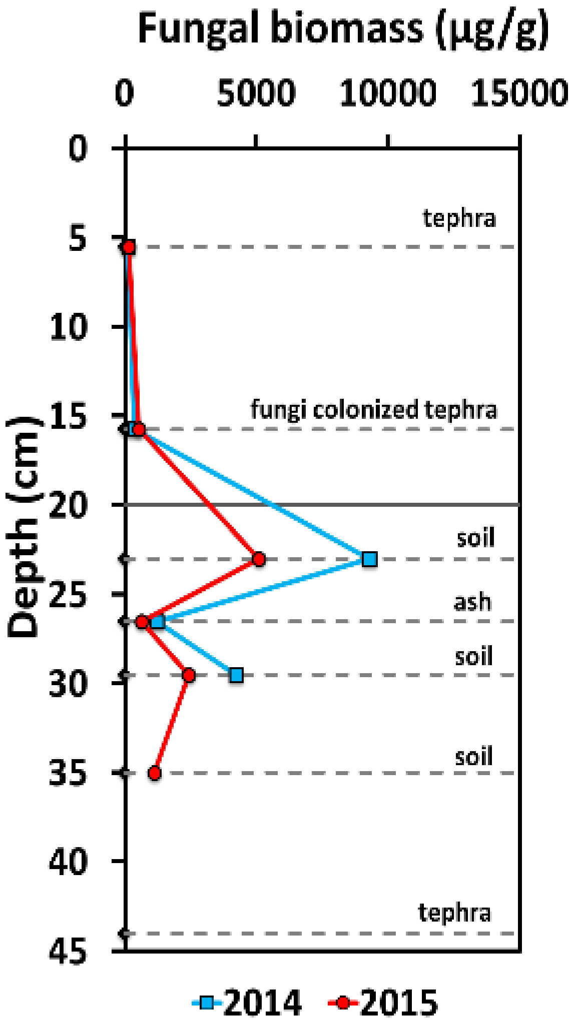
A.Fluorescence Microscopy

B. Scanning Electron Microscopy



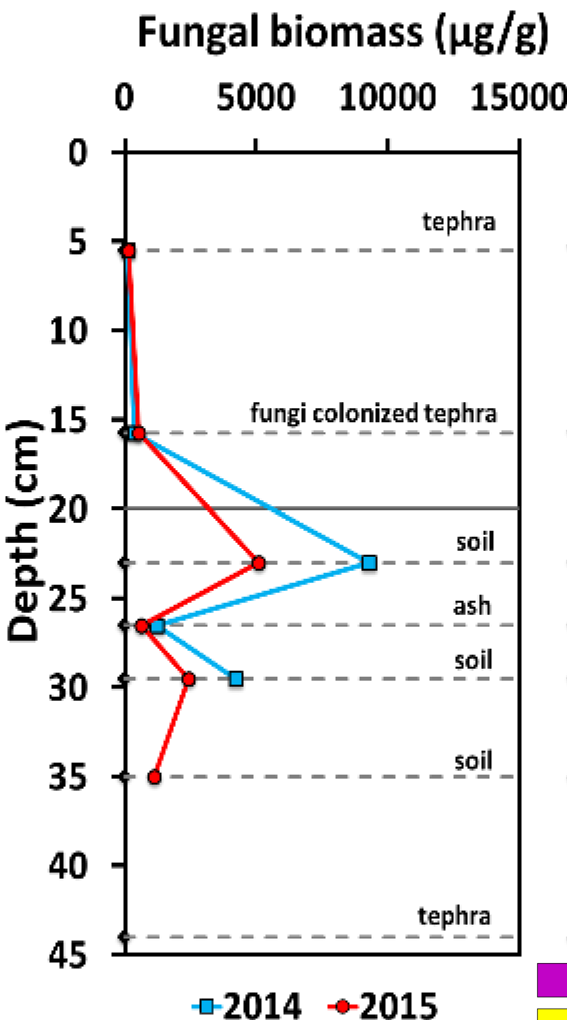
Volcanic soil profile

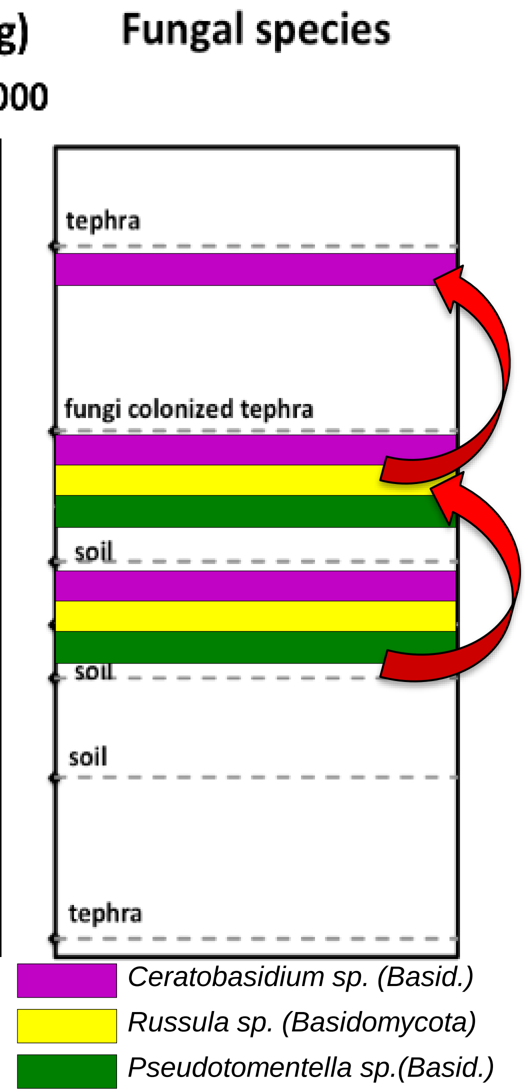
Fungal activity



Volcanic soil profile

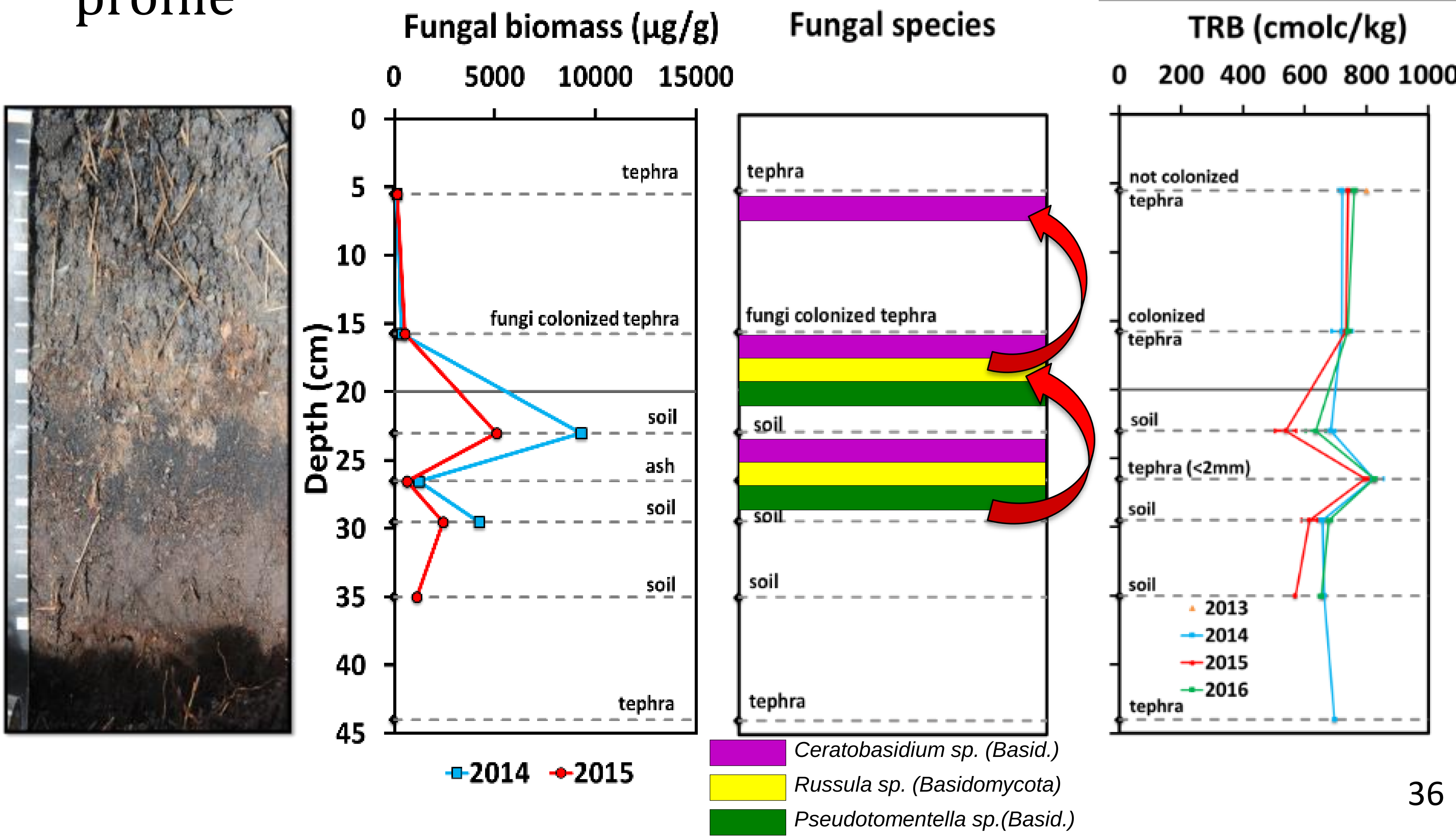
Fungal activity | Fungi origin





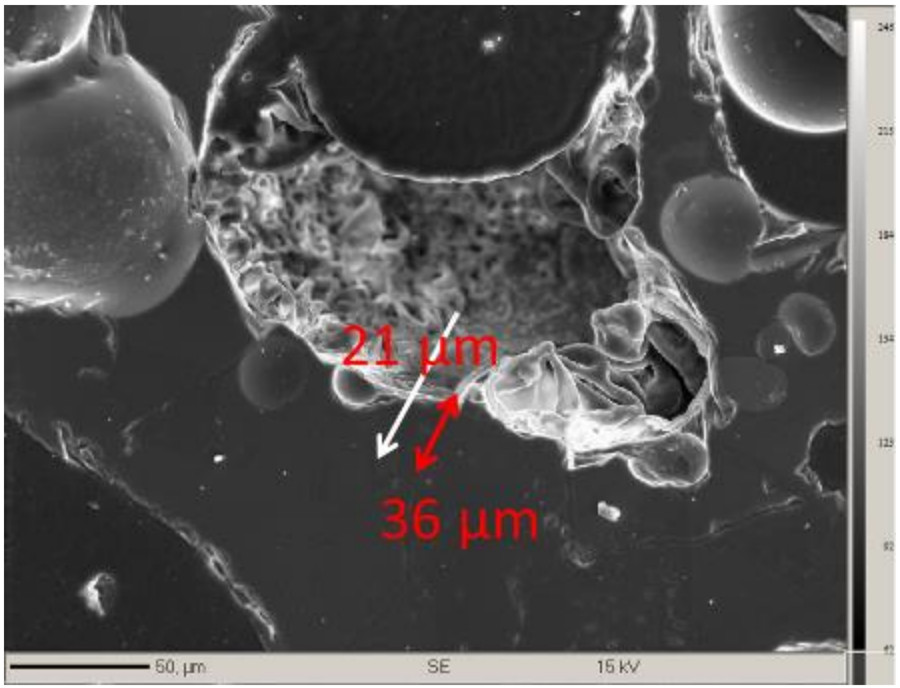
Volcanic soil profile

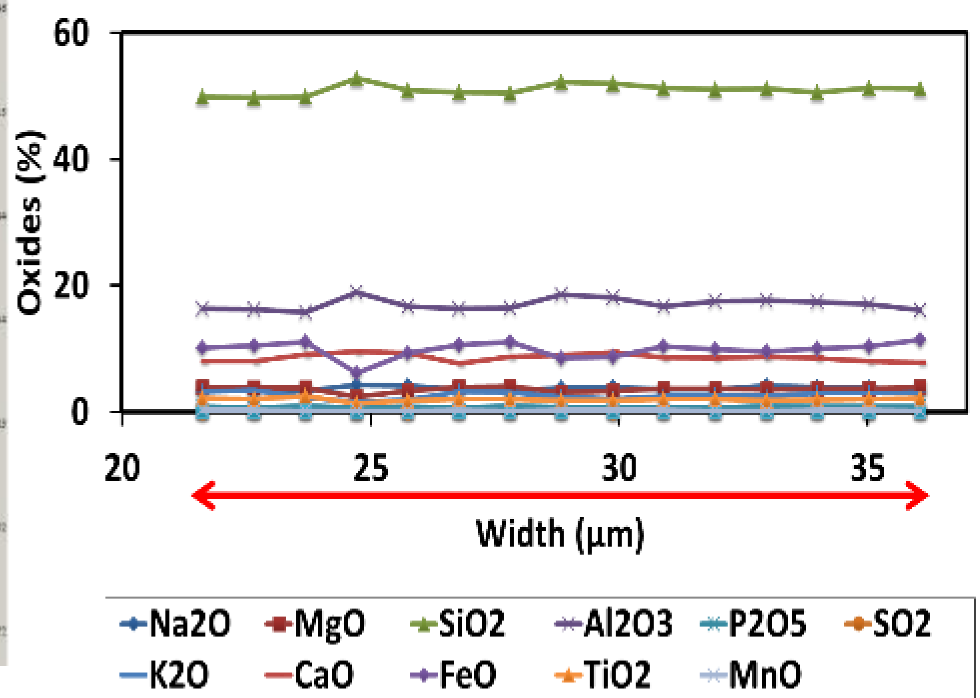
Fungal activity → Fungi origin → Tephra weathering



Fungi enhanced chemical weathering?

Electron microprobe analysis



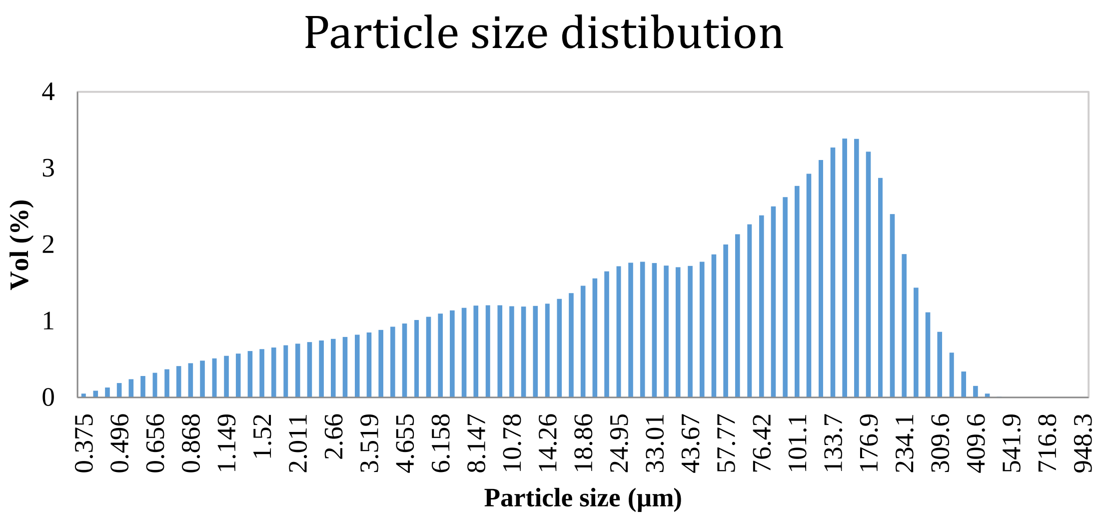


Conclusions

The results of microscopic and molecular analyses demonstrate that tephra colonization by fungi started less than 1 year after the eruption.

There is evidence of physical penetration of fungi into tephra. However, there is no indication of fungi-driven chemical weathering of tephra after two years following deposition

- Pinatubo ash → sieved with a 250 µm mesh



- Physiological measurements, extractions, …

→ What are the impacts of tephra deposits?