



UPDATES ON 2025 FIELD PHENOTYPING & OTHER ACTIVITIES TO REPORT

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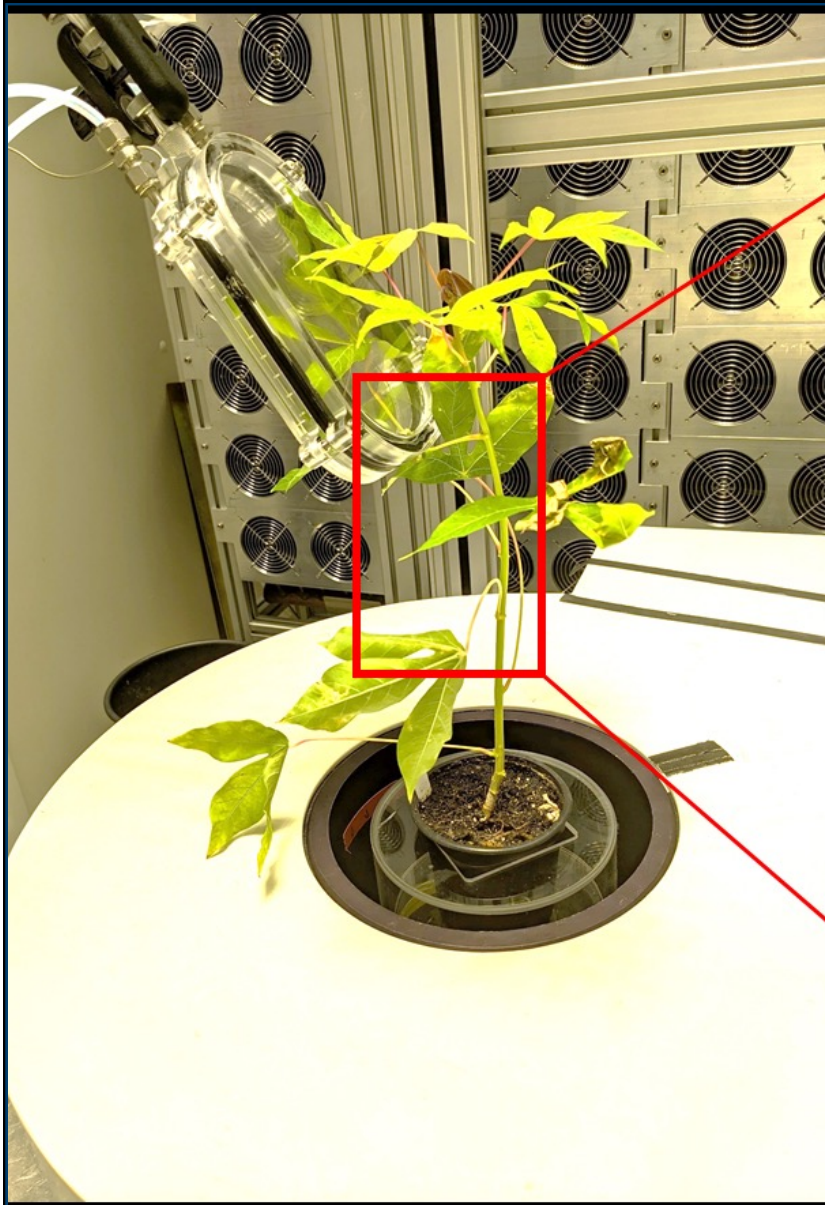
Special thanks to: Shu-Heng Chang, Tzu Jui Chiu, Silas Wungrampha, Grisse Wilhelm, Christina J. Muller, Simon Bull, Lukas Mueller, Mercedes Thieme and Wolfgang Zierer

**CASS – Cassava Source-Sink Project _ CASS3 meeting
Nigeria, September 2025**



CASSAVA SOURCE-SINK INNOVATION





Quantifying transport
and root growth
dynamics with MRI
and PET



Robert
Koller

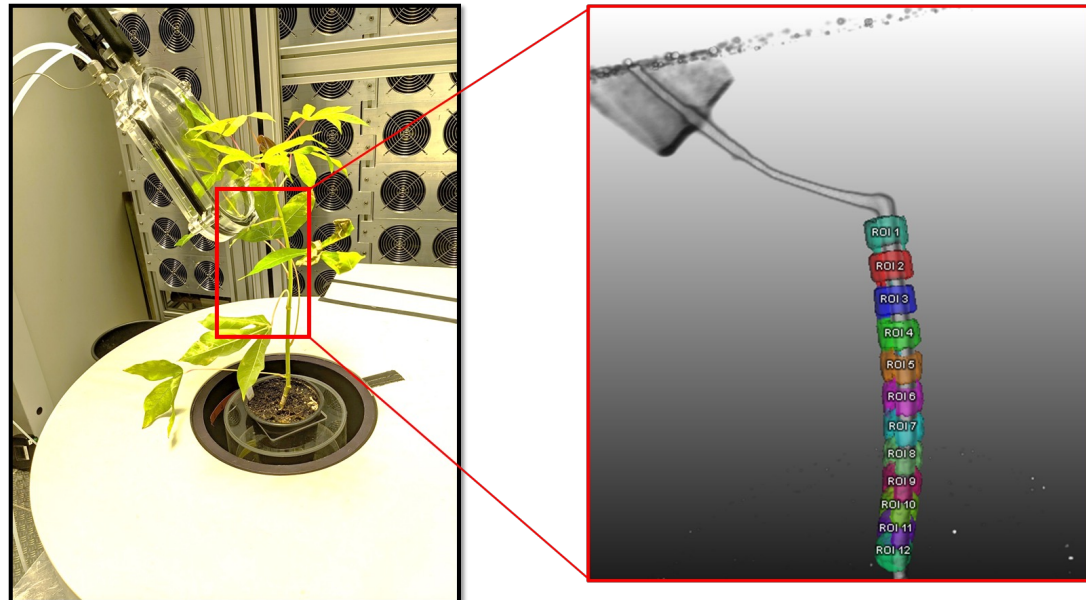
4. Highlights of work by R. Koller's Group: PET and MRI analysis of Cassava Storage Roots

- Positron Emission Tomography (PET) measurements of phloem flow velocities in 3 plants VC, C2-8_4261 and C2-8_4662:
 - Transport velocity and assimilation rate is higher in AKT2 constructs than in control



Ralf
Metzner

Julich Forschungszentrum
Institute of Bio- und
Geosciences:
Plant Sciences (IBG-2)



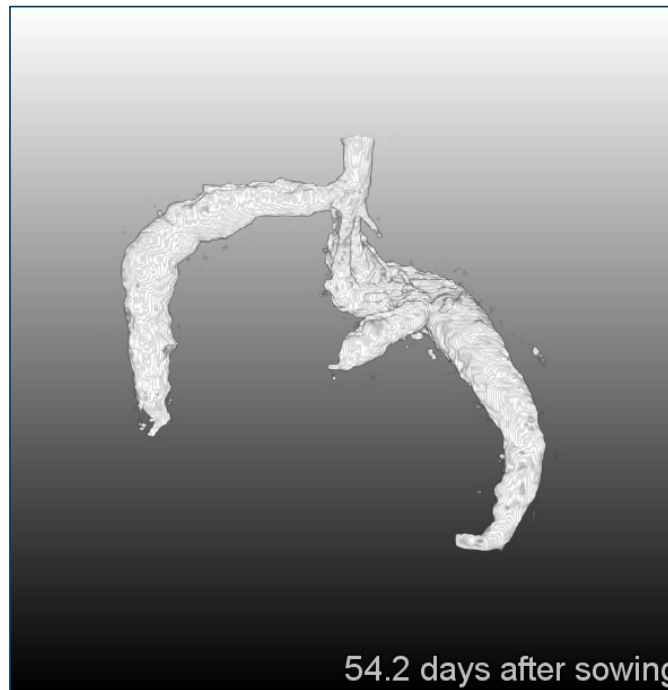
Zierer et al., 2025: <https://doi.org/10.1101/2025.05.26.655271>



Robert
Koller

4. Highlights of work by R. Koller's Group: PET and MRI analysis of Cassava Storage Roots

- Magnetic Resonance Imaging (MRI) for non-invasive 3D monitoring of storage root development over several weeks
 - Provided useful growth trajectories for modeling, even though variability was high



Development of wild type
storage roots from MRI
(soil segmented out)

Julich Forschungszentrum
Institute of Bio- und
Geosciences:
Plant Sciences (IBG-2)

Content

1. UAV Data Acquisition and Processing

- Fields and dates
- Improvements in data management for Cassbase

2. Seasonal Growth Dynamics

- Growth and speed
- Raceplot

3. PAM-Based Photosynthesis Data

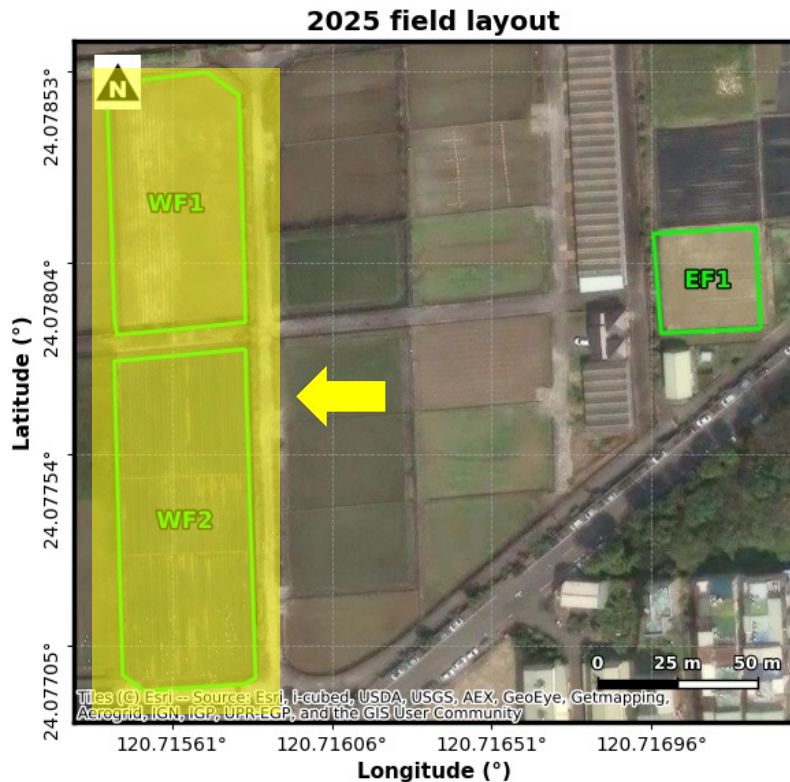
- Measurement
- Preliminary results (ETR, F_v/F_m , relationships)

4. Other Activities to Report



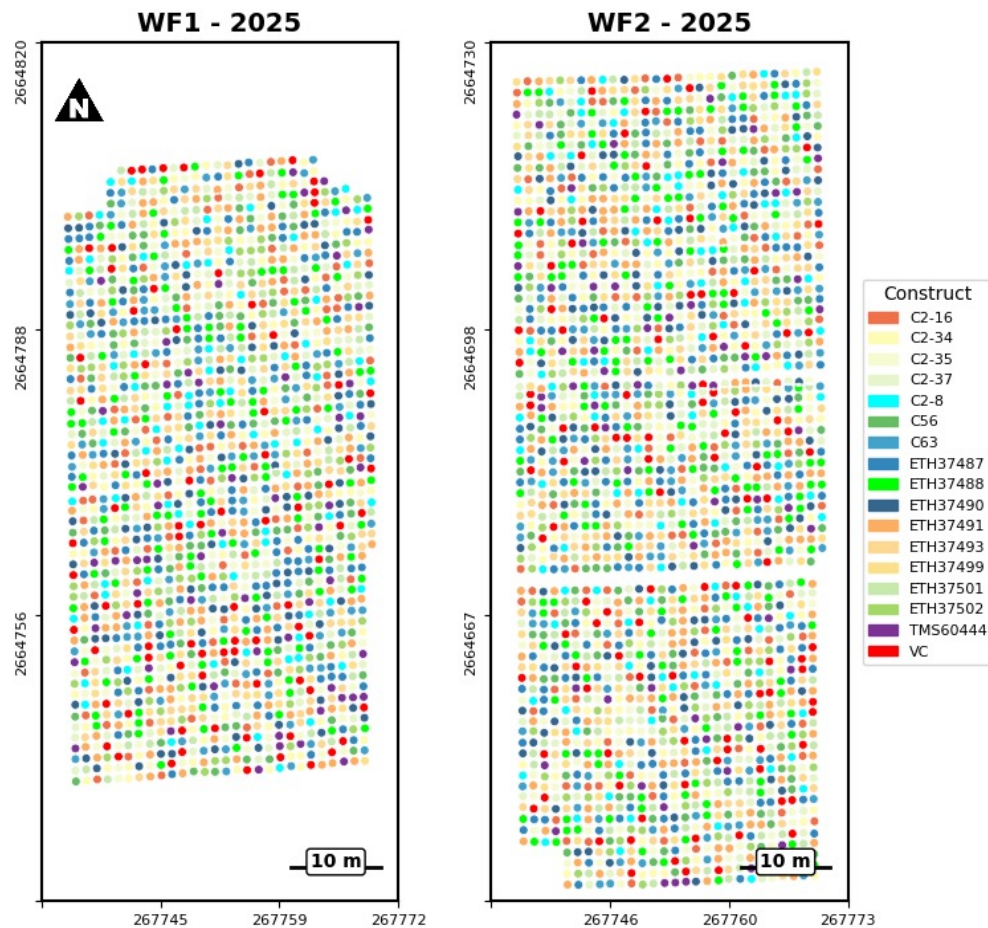
1. UAV data acquisition and processing

1. UAV data: fields used for analysis



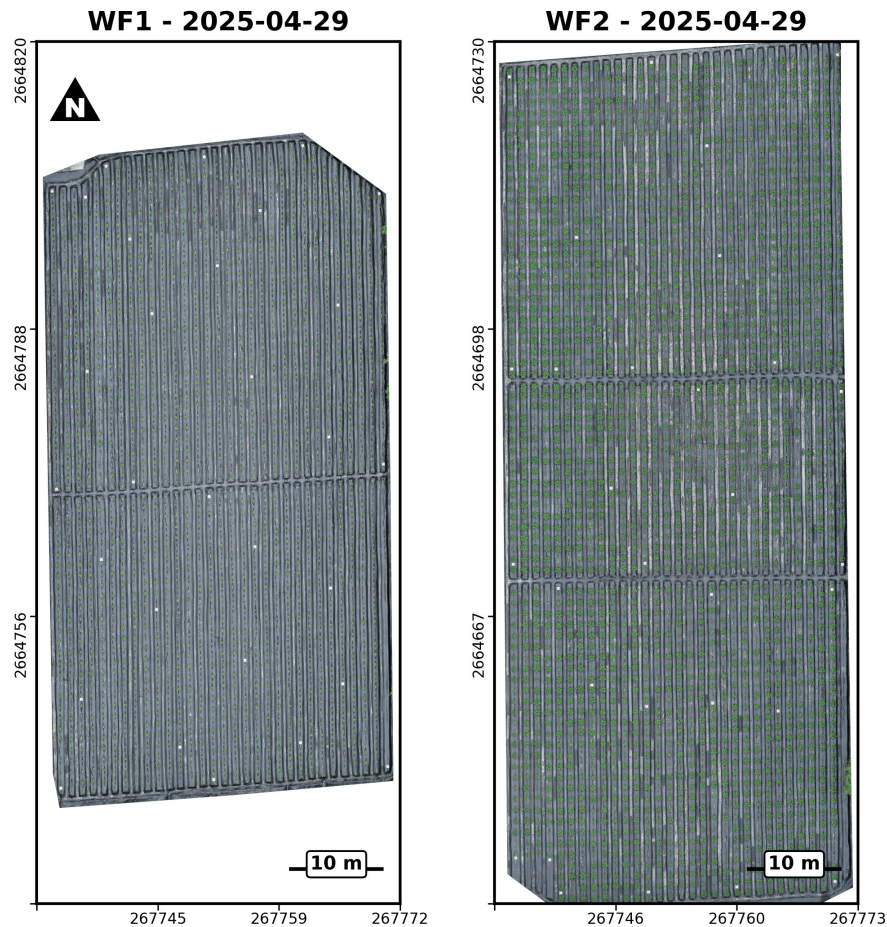
- All results going to be presented are focused on WF1 and WF2 fields
- Both with new transplants of 15+ constructs, 100 accessions
- WF1 with 16 replicates in most of the cases (1600 plants), while WF2 with 21 replicates in most of the cases (2100 plants)
- WF1 planted (24.03) about 3 weeks later than WF2 (03.03)

1. UAV data: fields used for analysis



→ Every single plant is geolocated and identified according to its genotype, event and replicate

1. UAV data: datasets collected

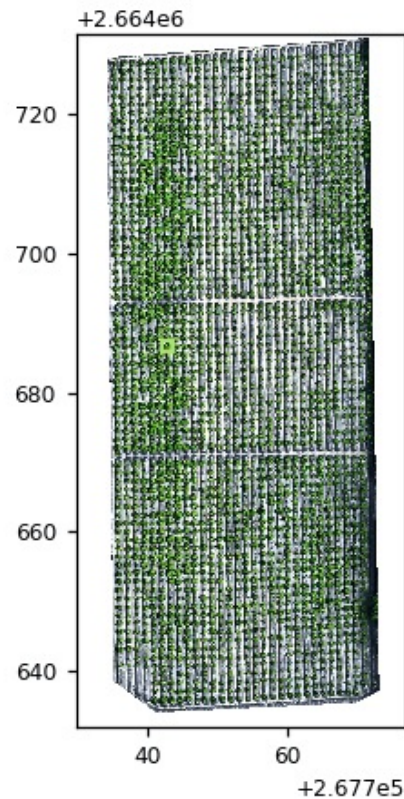


→ 8 UAV datasets collected on:

- April 29
- May 12
- May 23
- June 9
- June 28
- July 12
- July 21
- August 11

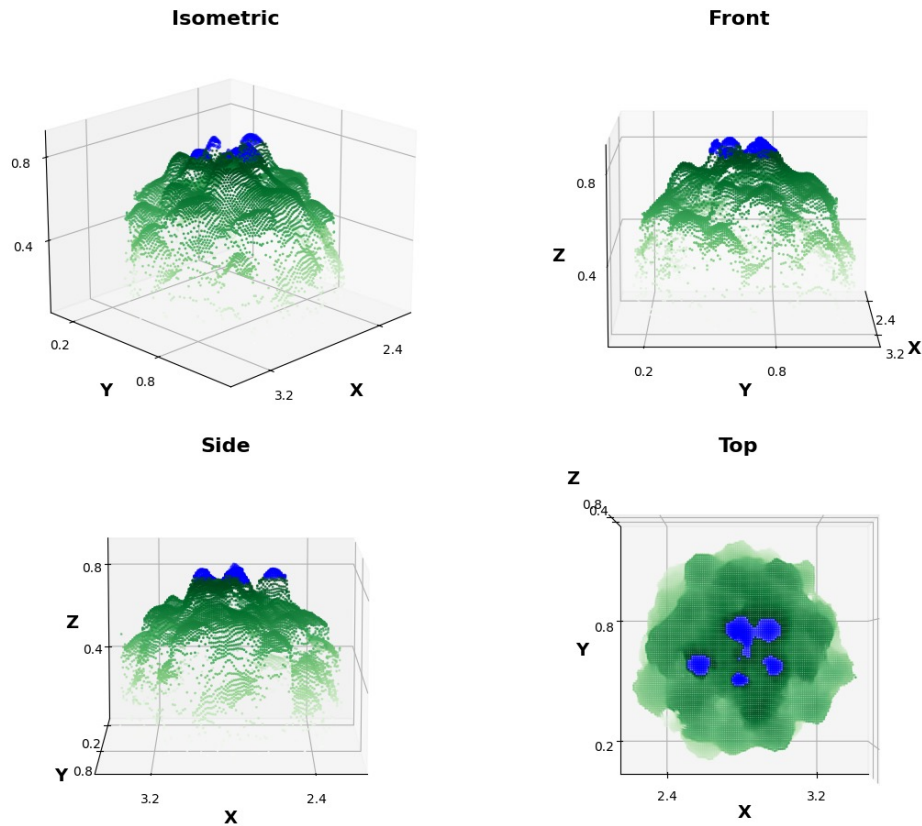
→ RGB is visible reflected light recorded in red, green, and blue

1. UAV data: RGB imagery to canopy structure



- From RGB imagery (visible light), elevation data are generated using 3D surface reconstruction
- Single plant level growth information

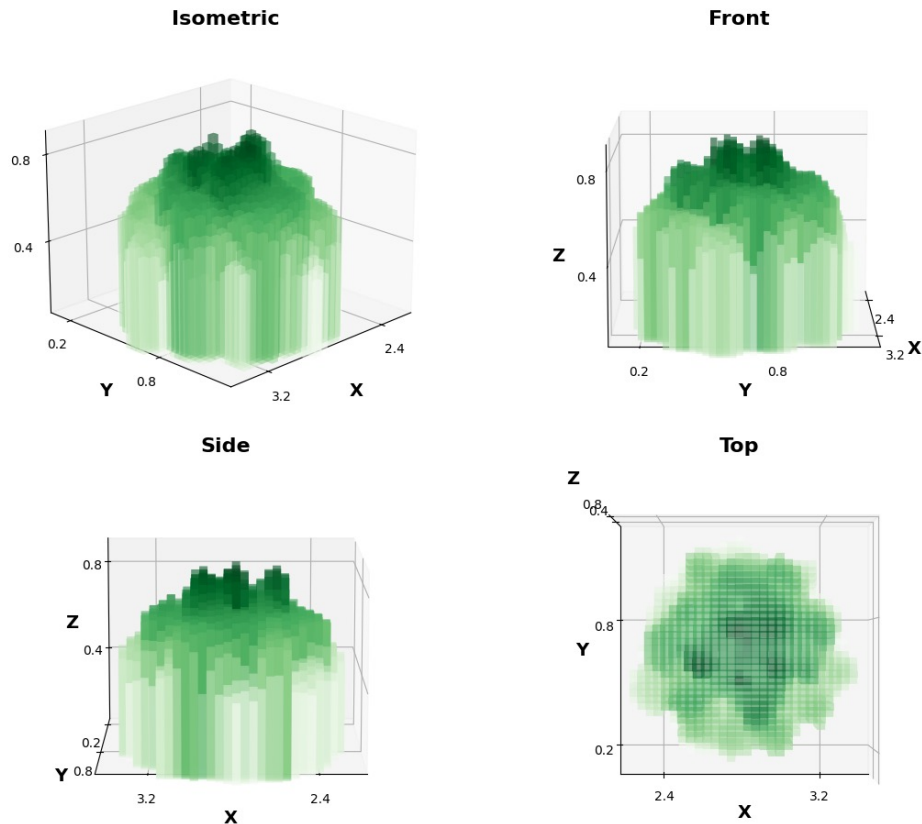
1. UAV data: RGB imagery to canopy structure



→ Plant height is represented as the 95th percentile (Q95), i.e., the value below which 95% of the data fall (**blue points**)

Note: Axis values are shown without scientific notation. Hidden offsets (e.g., +2.3e5) apply uniformly.

1. UAV data: RGB imagery to canopy structure

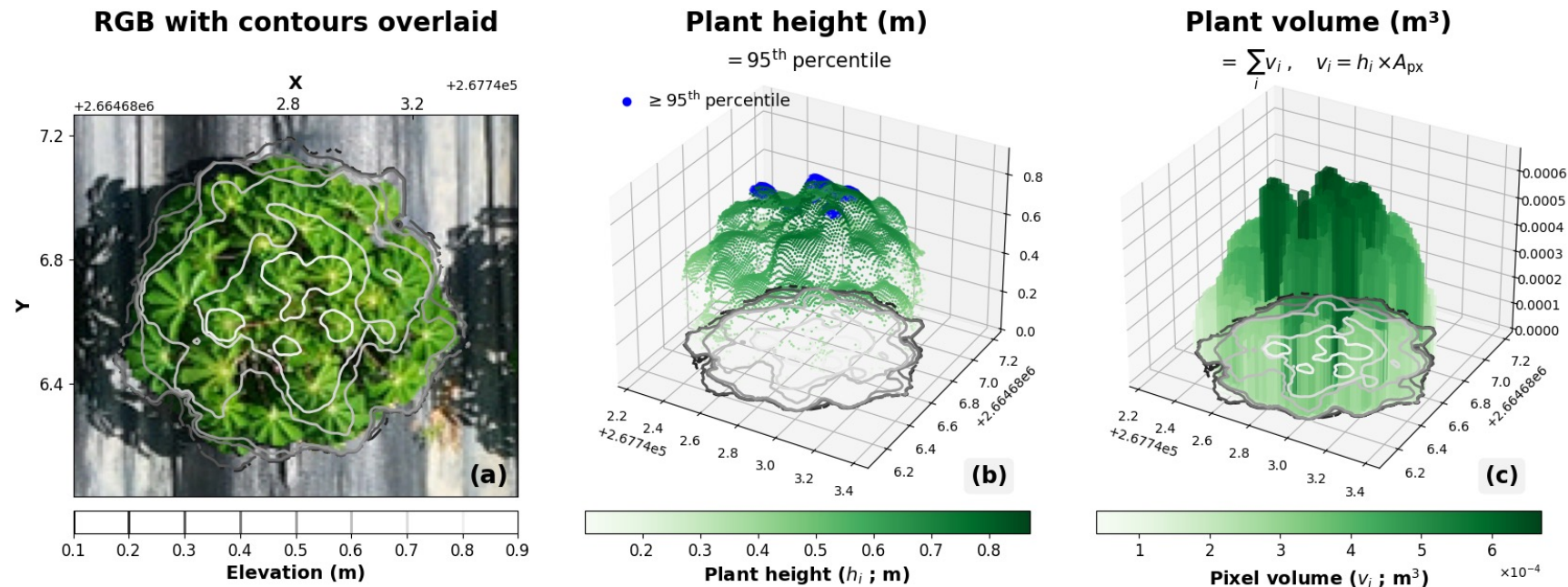


Note: Axis values are shown without scientific notation. Hidden offsets (e.g., +2.3e5) apply uniformly.

→ Plant height is represented as the 95th percentile (Q95), i.e., the value below which 95% of the data fall

→ Plant volume equals the sum of column volumes derived from each pixel

1. UAV data: Growth information at single plant level



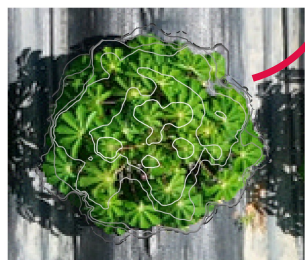
→ Since 2022, 9170 cassava plants have been measured

→ Data stored in CSV files by year (by trial) aligned with Cassbase standards

1. UAV data: improvements in data management for Cassbase

Plant-level unique ID	Trait name	Trait ID	DAP	cass day ID	Composite trait
observationunit_name	plant height per plot in m	CO_334:0002033	cass day 109	CASSTIME:0000182	COMP:0334464
2024_EF1-10_C2-8_ETH4261_S	1.3758698834313288,	2024-07-12 10:37			
...	...				

Repeated for all the traits and for all UAV datasets

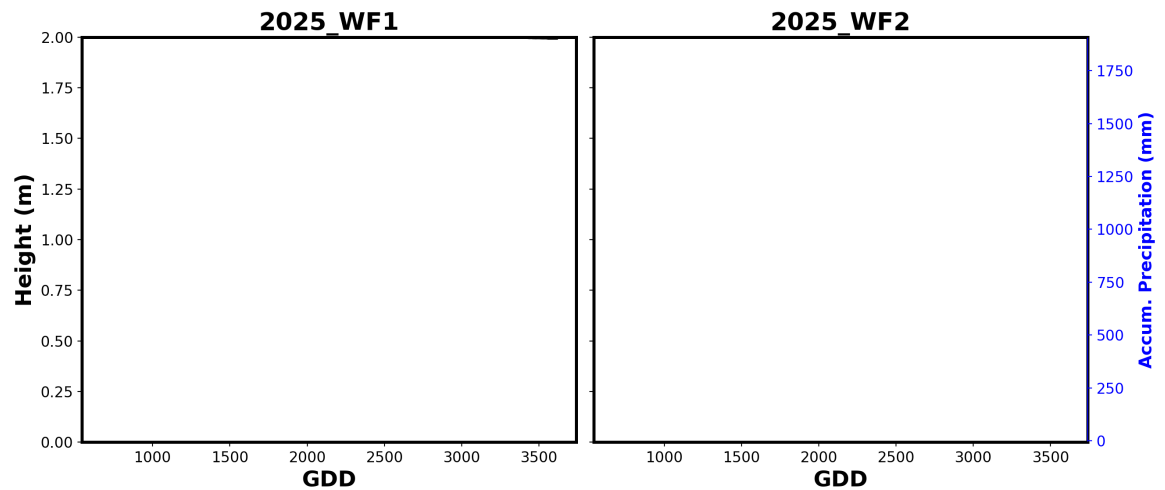
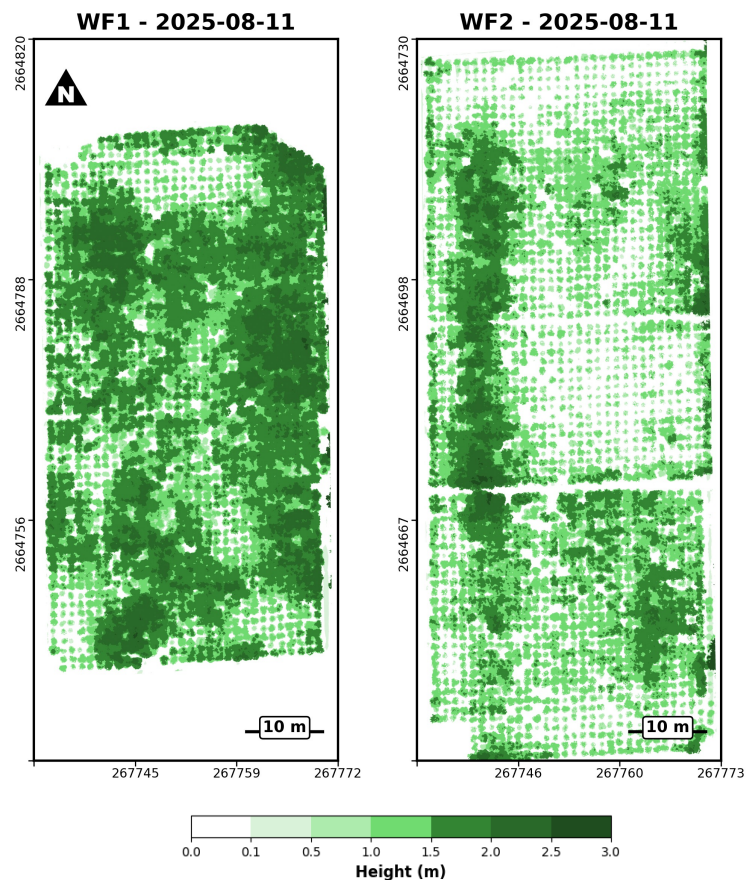




0429

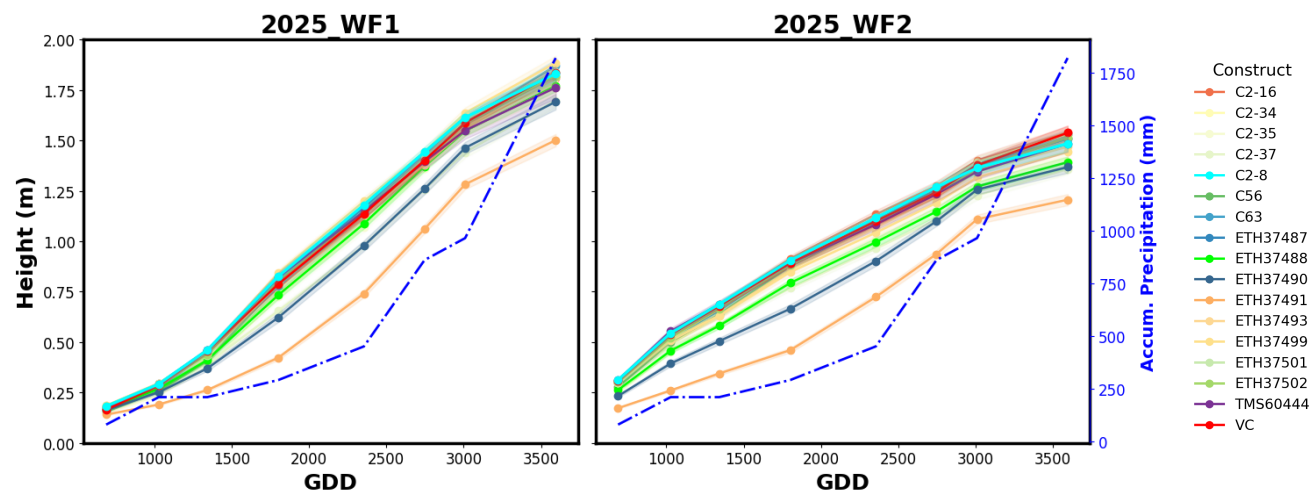
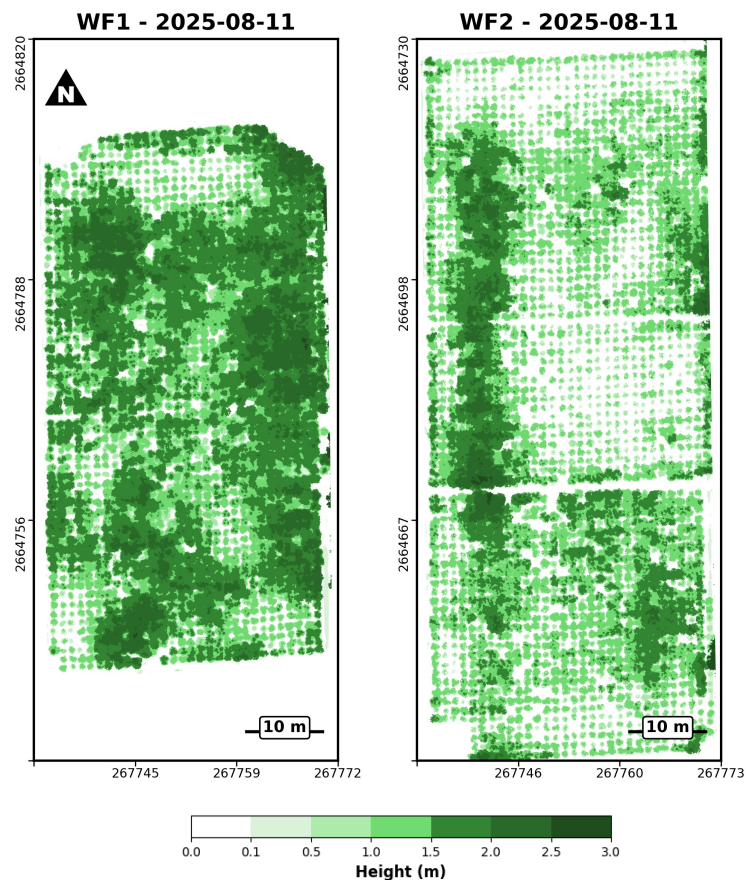
2. Seasonal growth dynamics

2. Seasonal growth dynamics: all events



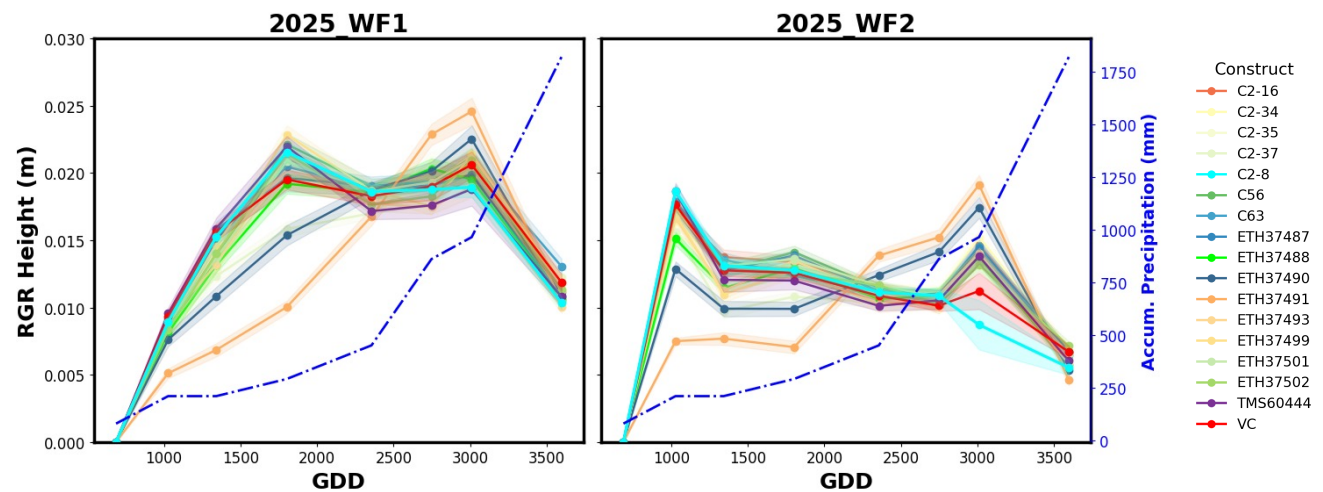
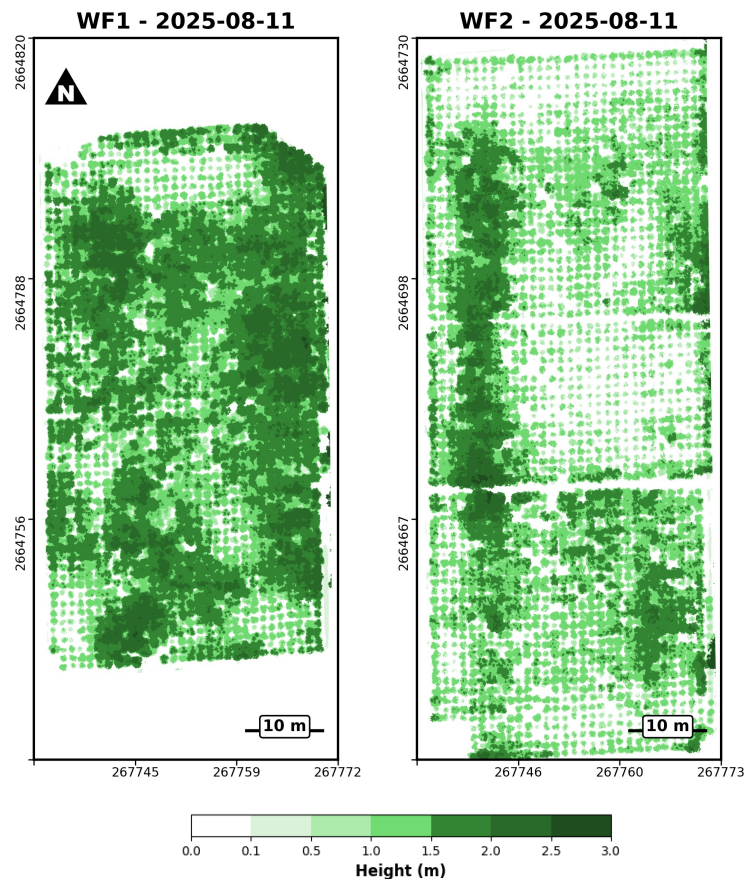
- Focus on plant height (for time reasons)
- Growing Degree Days (GDD) measure heat accumulation driving plant growth
- Shaded area = 95% conf. int. (uncert. around the mean)
- In blue: accumulated precipitation

2. Seasonal growth dynamics: all constructs



- Growth of most of the genotypes is similar to VC
- ETH37487 and ETH37490 show consistently smaller growth values

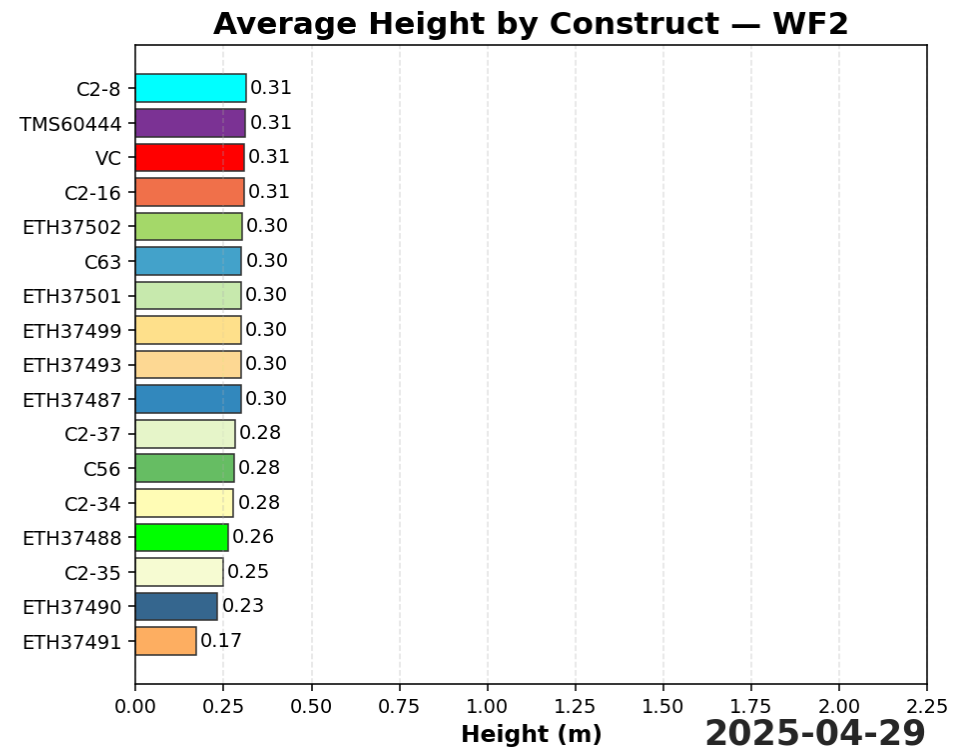
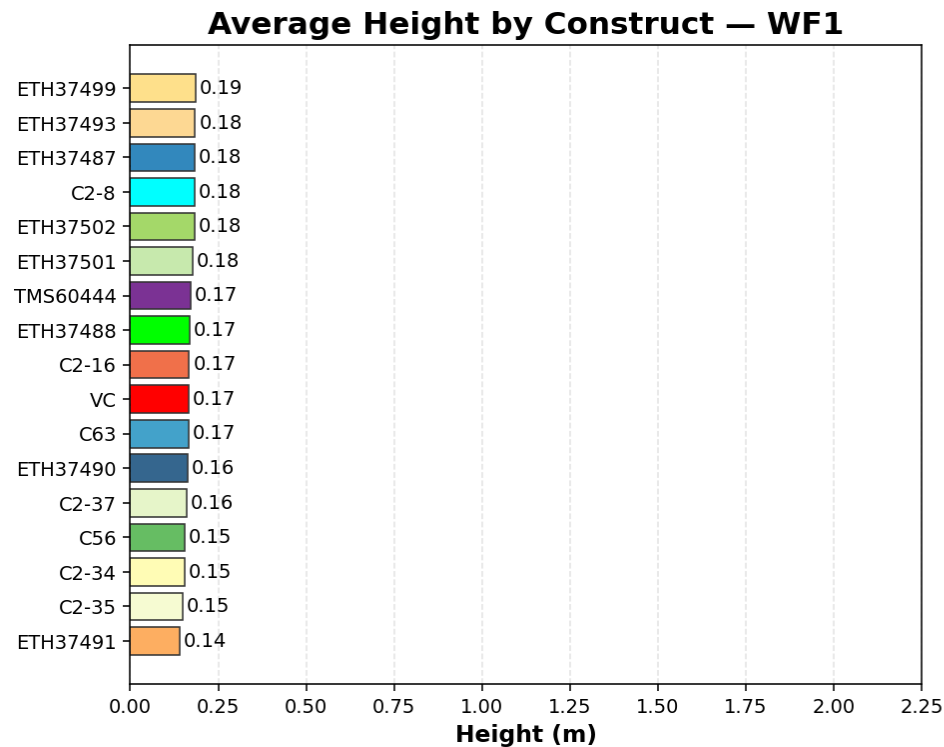
2. Seasonal growth dynamics (constr.): relative growth rate (RGR)



$$RGR = \frac{Growth_{t2} - Growth_{t1}}{\Delta_t}$$

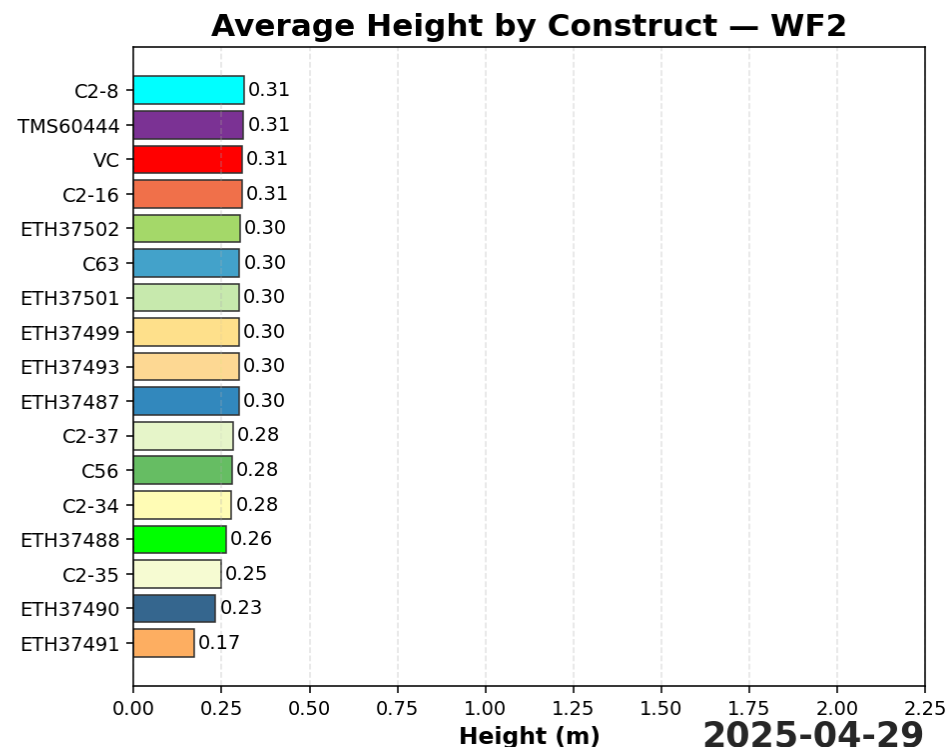
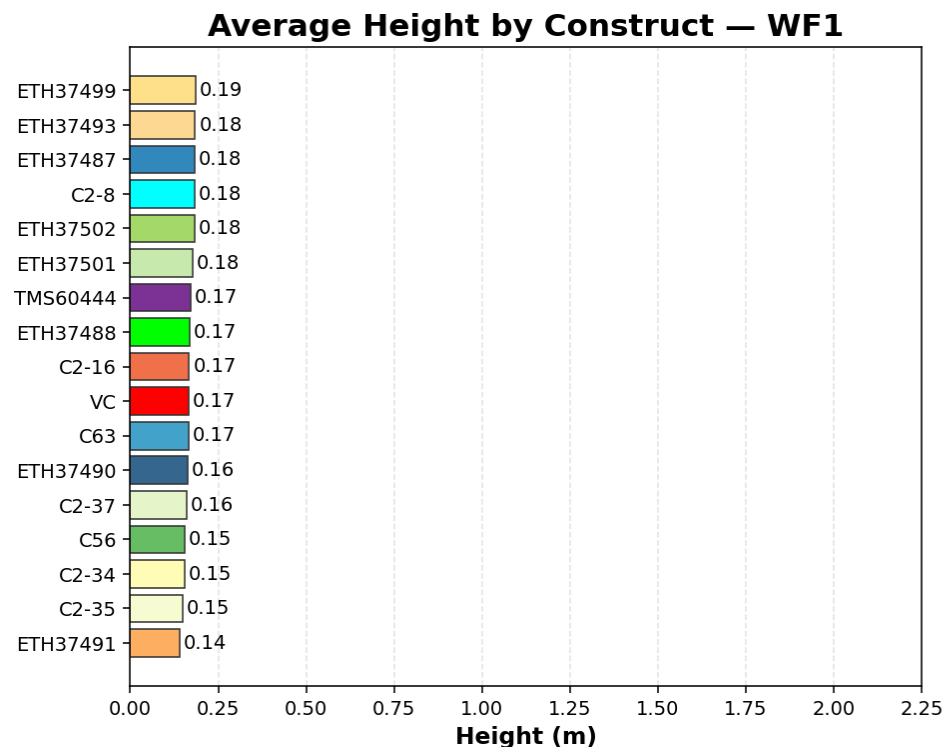
→ Despite their lower final canopy height, ETH37487 and ETH37490 exhibited greater shifts in growth rate, with noticeable accelerations and slowdowns across the season

1. Seasonal growth dynamics (constructs)



→ **VC** ... Shows a mid-season dip in canopy height, followed by renewed growth.

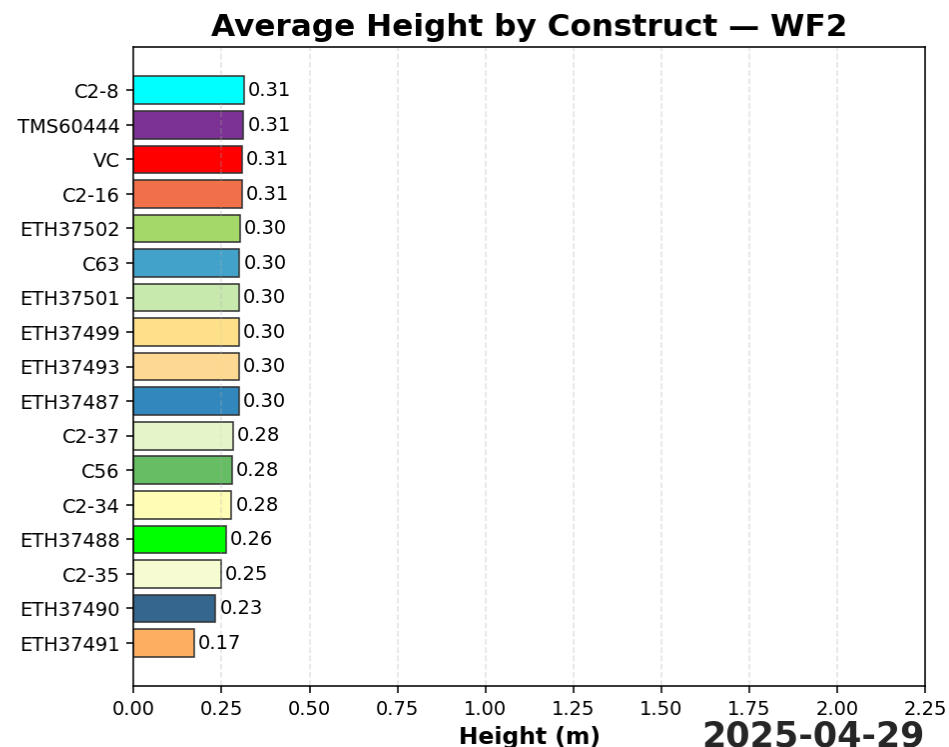
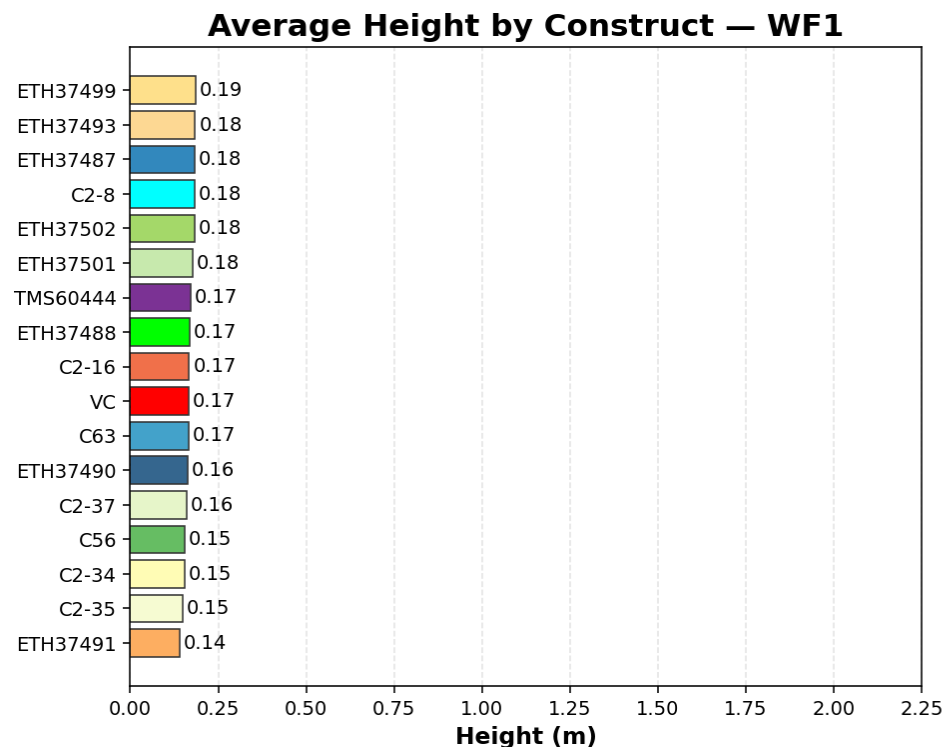
1. Seasonal growth dynamics (constructs)



2025-04-29

→ **C2-8 (AKT2)** ...Stays fairly stable through most of the season, then declines at the last measurement.

1. Seasonal growth dynamics (constructs)

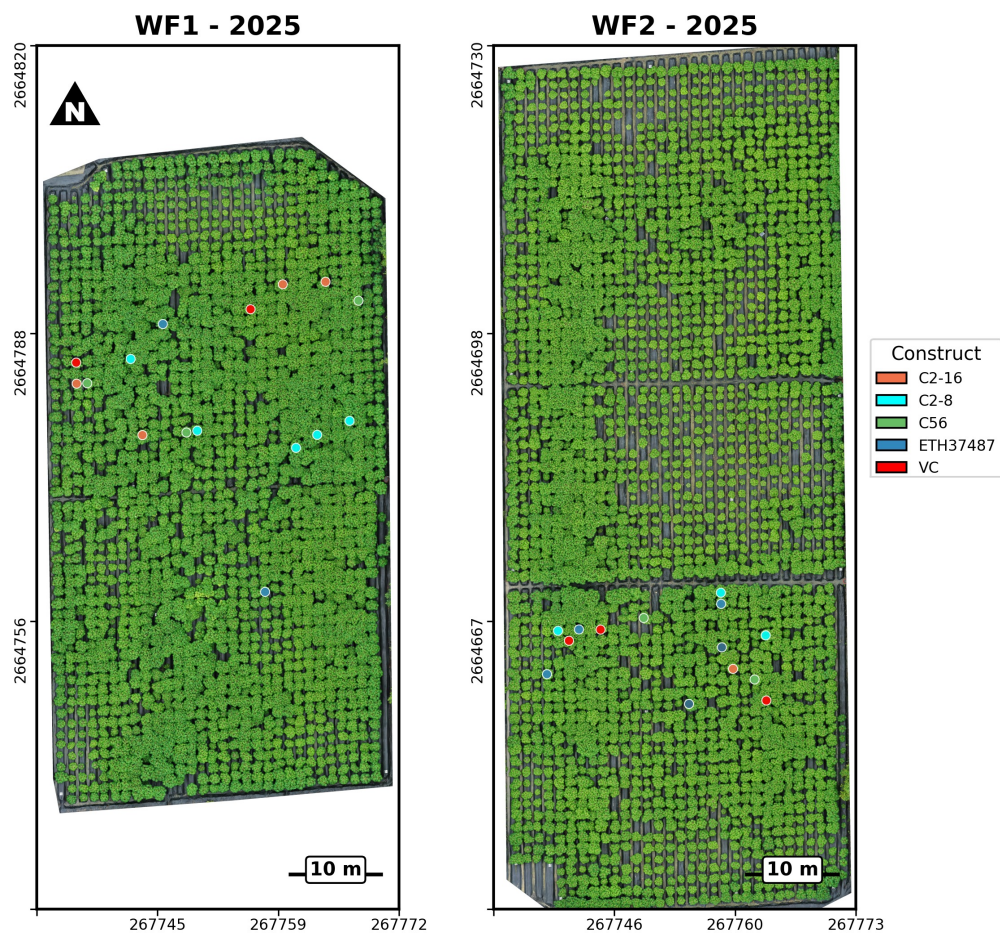


→ C56 (GPT/NTT) ... Starts shorter, grows strongly mid-season, and finishes in the upper-mid range.



3. Pulse amplitude modulation (PAM)-based photosynthesis data

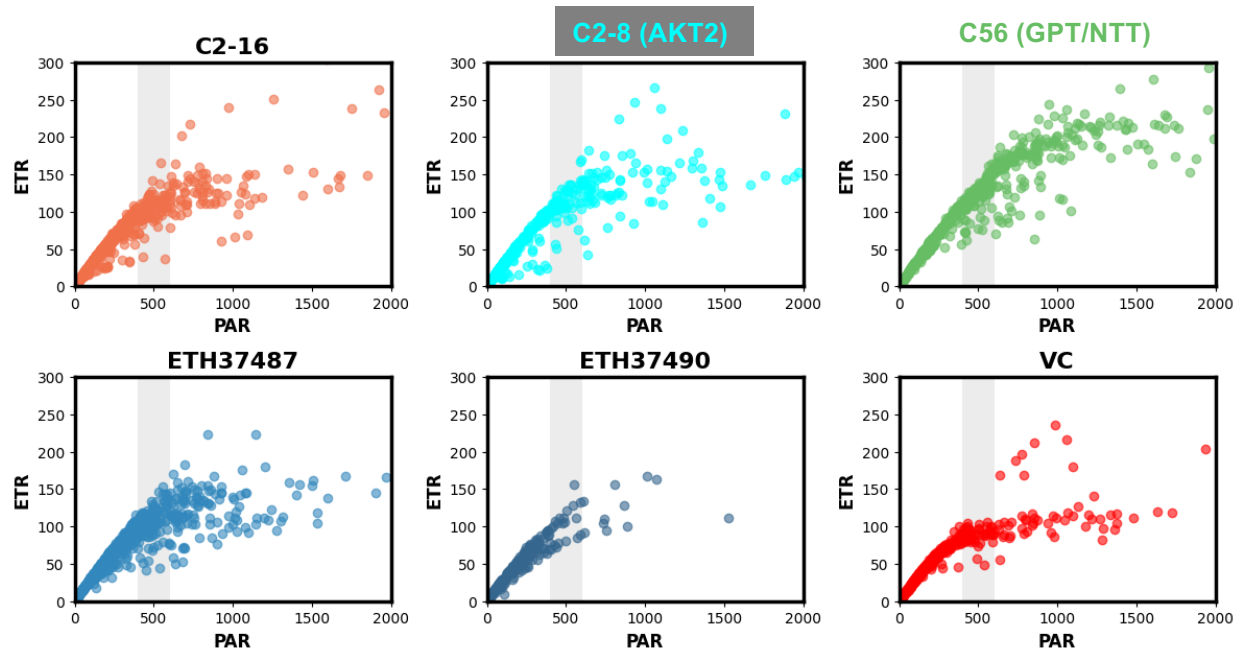
3. PAM-based photosynthesis: Measured plants



→ 36 plants of four constructs of interest and VC

Construct	Event	Event reps	Constr. reps
C2-16	C2-16_ETH4808	3	6
C2-16	C2-16_ETH4812	3	
C2-8	C2-8_ETH4261	2	9
C2-8	C2-8_ETH4262	3	
C2-8	C2-8_ETH4265	4	
C56	C56_ETH4838	3	7
C56	C56_ETH4847	4	
ETH37487	ETH37487-14	1	6
ETH37487	ETH37487-4	4	
ETH37487	ETH37487-55	1	
ETH37490	ETH37490-9	2	2
VC	VC_ETH4221	4	6
VC	VC_ETH4234	2	

3. PAM-based photosynthesis: ETR

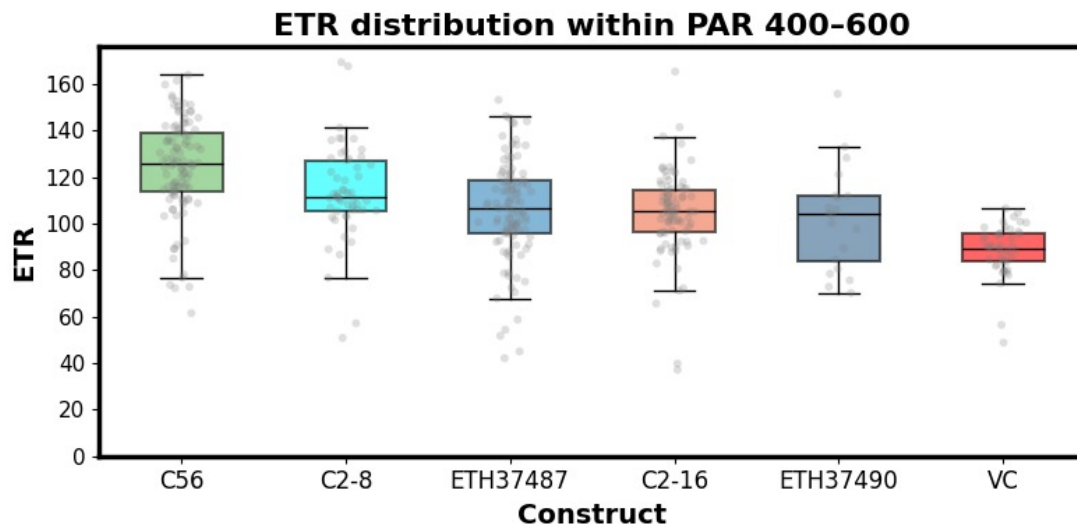


Light-response curves of six cassava constructs showing electron transport rate (ETR) versus photosynthetically active radiation (PAR). Curves are exponential rise-to-maximum fits. The reported values ($\text{ETR}_{\text{max}} \pm \text{SE}$) indicate the fitted maximum ETR with its standard error of the estimate, and n corresponds to the number of replicate plots per construct.



→ ETR (Electron Transport Rate): estimates the flow of electrons through PSII during photosynthesis and serves as a proxy for photosynthetic efficiency under varying daylight conditions

3. PAM-based photosynthesis: ETR

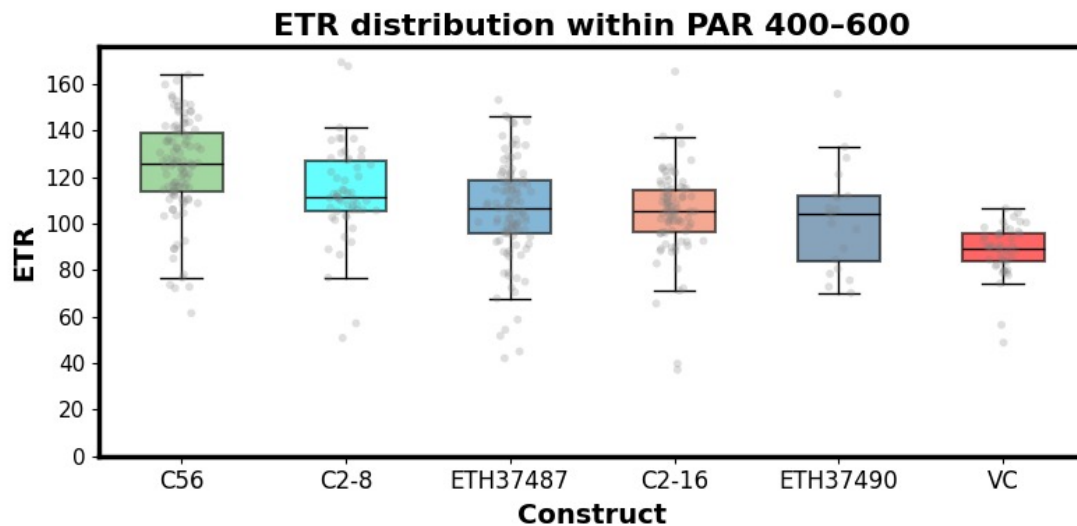


Distribution of electron transport rate (ETR, $\mu\text{mol m}^{-2} \text{s}^{-1}$) across constructs within a photosynthetically active radiation (PAR) window of 400–600 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Grey points show individual plot measurements.

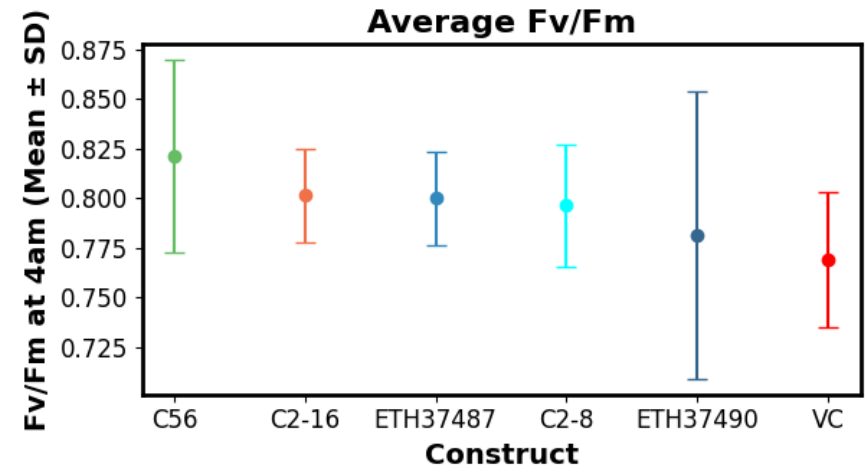


→ Fv/Fm (at 4 am): maximum efficiency of PSII in dark-adapted leaves, indicating overnight recovery after the demands of daylight exposure. Values near 0.83 reflect minimal stress, while reduced values signal photoinhibition

3. PAM-based photosynthesis: ETR + Fv/Fm

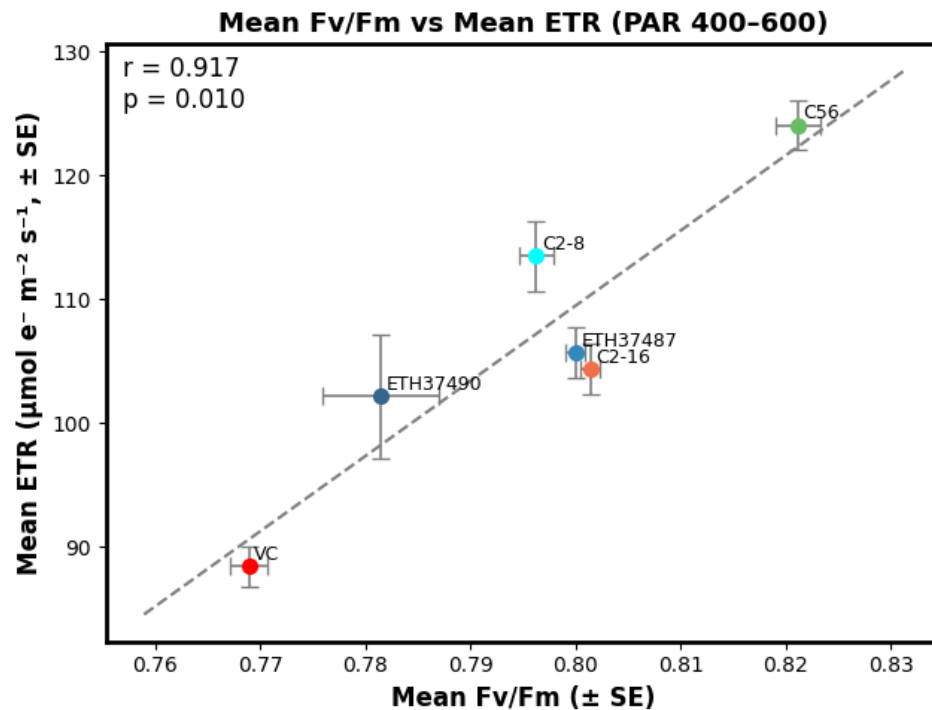


Distribution of electron transport rate (ETR, $\mu\text{mol m}^{-2} \text{s}^{-1}$) across constructs within a photosynthetically active radiation (PAR) window of 400–600 $\mu\text{mol m}^{-2} \text{s}^{-1}$. Grey points show individual plot measurements.



Average Fv/Fm values measured at 4 am across six constructs (C56, C2-16, ETH37487, C2-8, ETH37490, VC). Points represent mean values and error bars indicate standard deviation (SD).

3. PAM-based photosynthesis: ETR + Fv/Fm



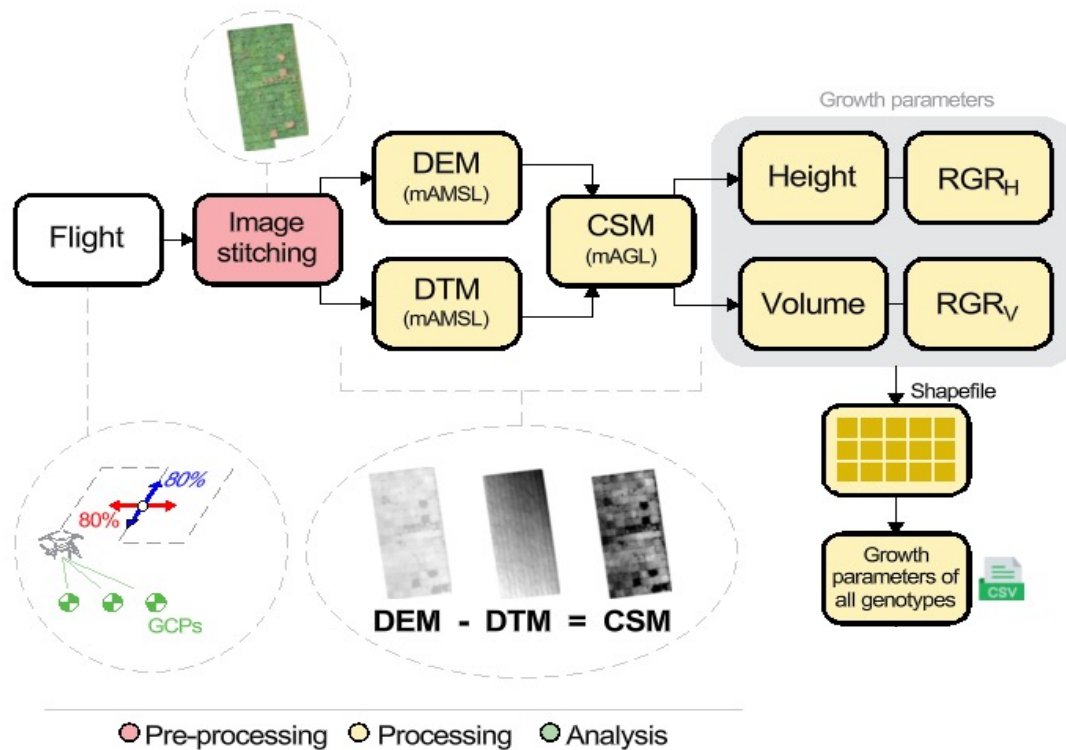
→ Constructs with higher early-morning Fv/Fm (better overnight recovery, less stress) show higher ETR, linking low stress status to improved daytime photosynthetic performance

Relationship between mean Fv/Fm (measured at 4 am, $\pm \text{SE}$) and mean electron transport rate (ETR, PAR 400–600 $\mu\text{mol m}^{-2} \text{s}^{-1}$, $\pm \text{SE}$) across six constructs

4. Other activities to report



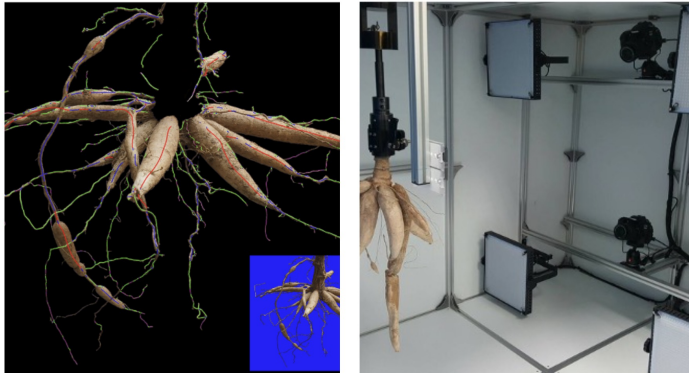
Other ongoing activities: Revisit of 'old' data from IITA field trail (2018-2020)



→ Reprocessing of the 2018-2020 field data using the now established workflow for UAV imagery

→ Advanced paper draft on heritability (H^2) and repeatability (R) of growth parameters of 52 genotypes

Other ongoing activities: Potential synergy with CASSAVASTORE project – database on root traits available



Wilhelm et al. 2022: Plant Phenomics,
article no 9767820

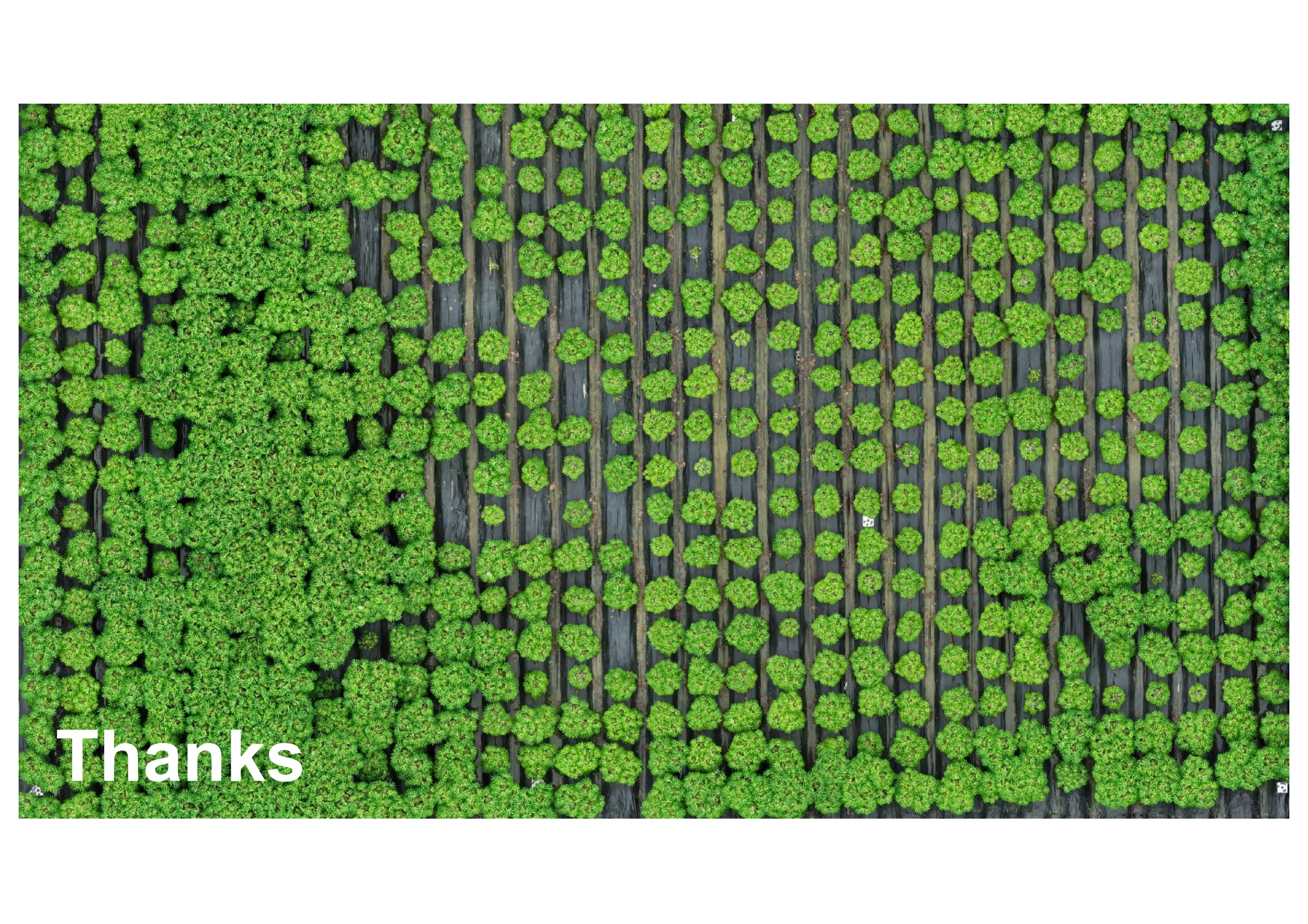
- High-throughput phenotyping of 54.000 cassava plants from 600 accessions screened; ~10 million root images analyzed with 2D and 3D imaging to extract key root traits
- Cassava growth model integrating physiology, environment, and phenotyping data
- Cassavastore database as a platform for data integration and breeding applications

www.cassavastoredb.nbt.or.th

www.international-bioeconomy.org/cassavastore_eng

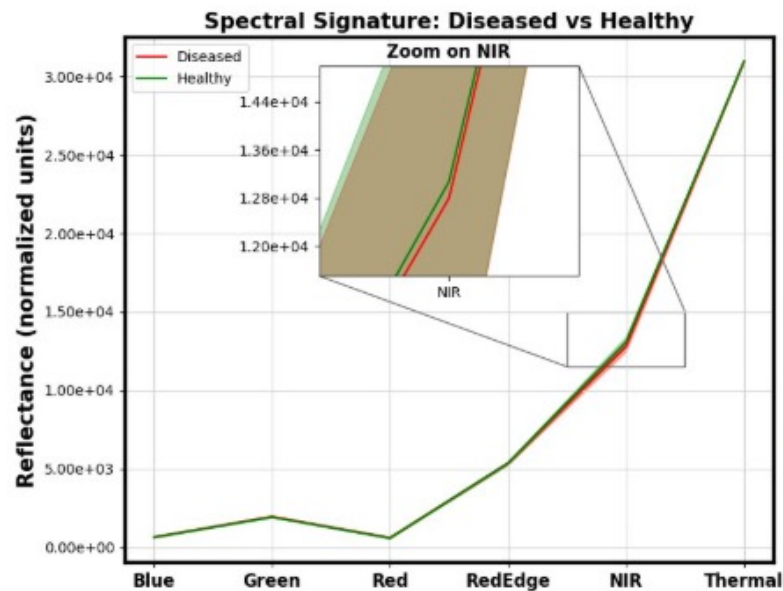
Take home messages

- UAV data (up to August 11) are stored in yearly, standardized CSV files aligned with Cassbase.
- Aerial information reveals diverse growth dynamics
 - ETH37487 and ETH37490 grew less overall but displayed greater shifts in growth rate, showing the value of UAV-derived dynamics beyond final canopy size.
 - UAV-based monitoring revealed varying growth patterns among constructs: VC dipped then recovered, C2-8 declined late, and C56 showed strong mid-season growth.
- PAM-based measurements show construct-level differences in photosynthesis. Constructs with higher early-morning F_v/F_m (lower stress, better overnight recovery) also exhibited higher ETR, particularly C56 (GPT/NTT).

An aerial photograph of a green roof. The roof is covered with a dense layer of green moss and small, rounded green plants arranged in a grid pattern. The plants are growing in a series of vertical rows, separated by dark, narrow channels. The overall appearance is a vibrant green, textured surface.

Thanks

Other ongoing activities: Brief disease analysis



→ Multispectral signals of disease are subtle and easily masked, limiting detection accuracy. Robust improvement requires combining RGB and spectral data with high temporal resolution and contextual information.

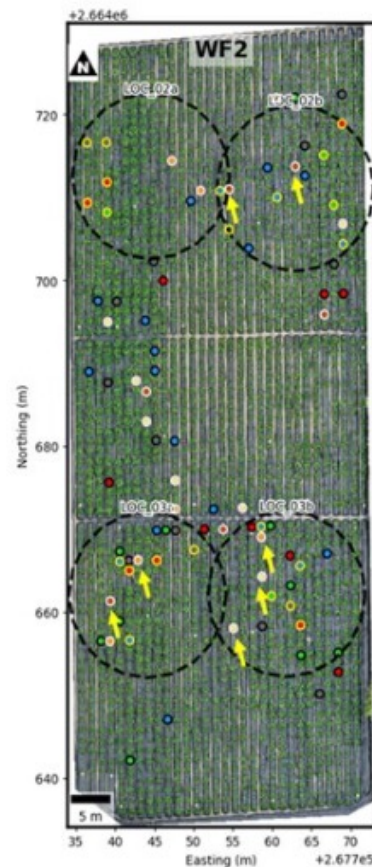
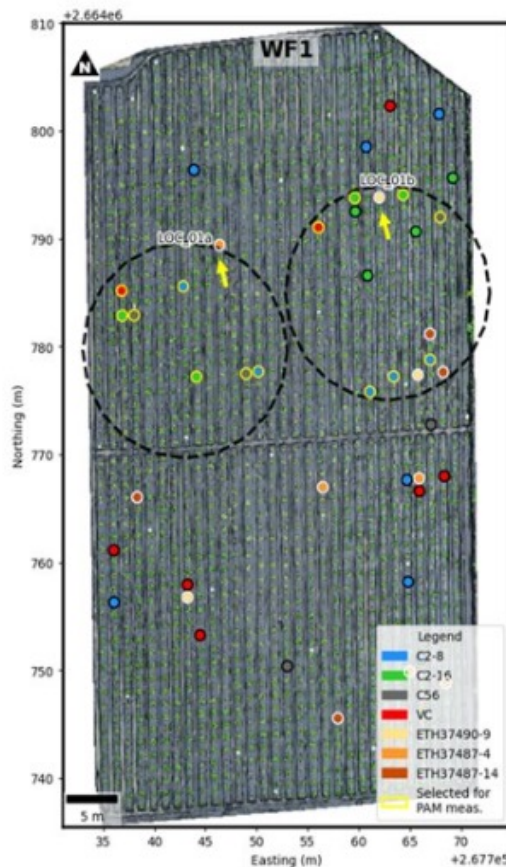
Spectral signatures of healthy and diseased cassava plants, with differences most pronounced in the NIR region (inset). Right: visual symptoms observed on diseased leaves

2. PAM-based photosynthesis data collected

→ The original plan to measure 48 plants monthly failed due to instrument issues in the first cycle

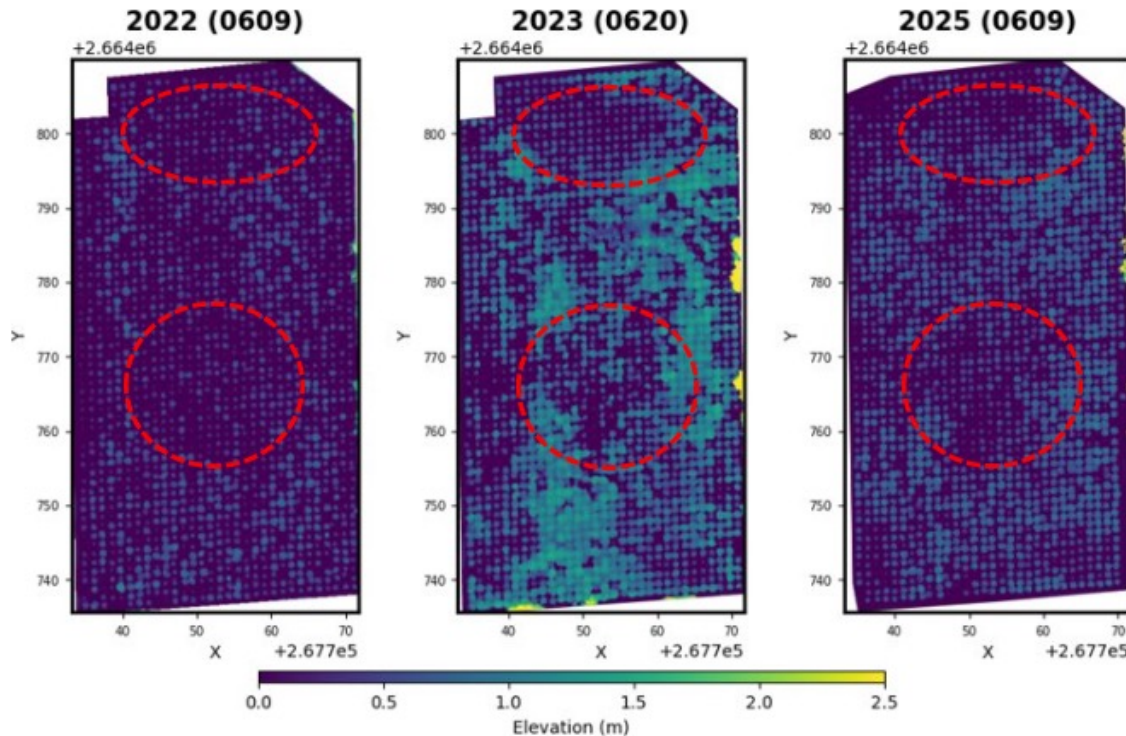
→ Designed to work with two working stations (MoniDAs) in tandem

→ But one stopped working about 3 weeks after being installed



→ Therefore only 36 plants could be measured in July

Multiyear spatial heterogeneity in WF1

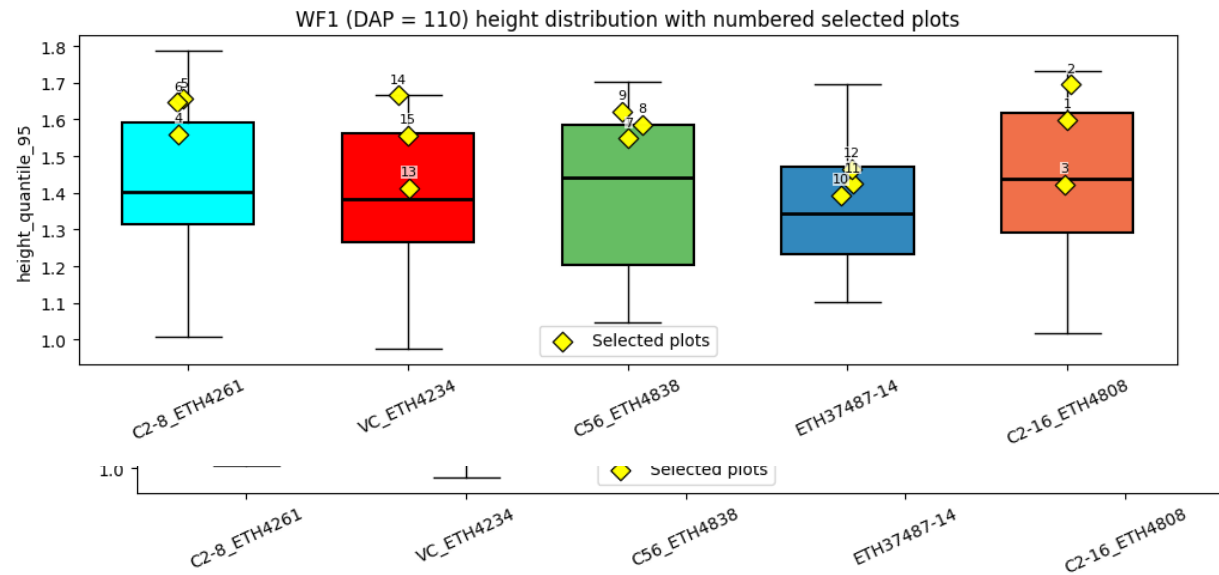
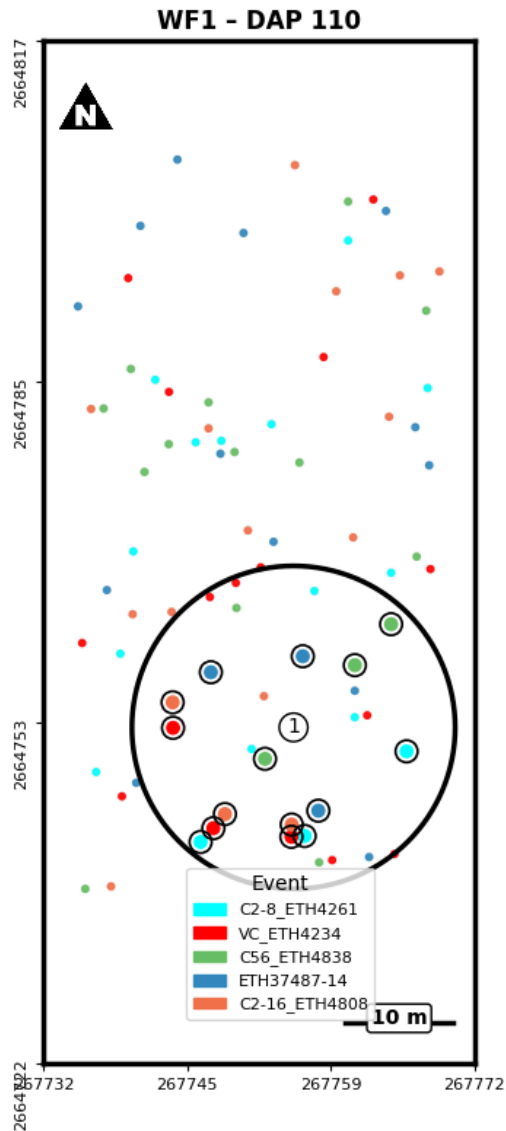


→ SSIM (Structural Similarity Index): Captures spatial pattern similarity by comparing two images in terms of properties like brightness, contrast, and spatial structure (0 = completely different; 1 = identical).

--- Smaller plants zones

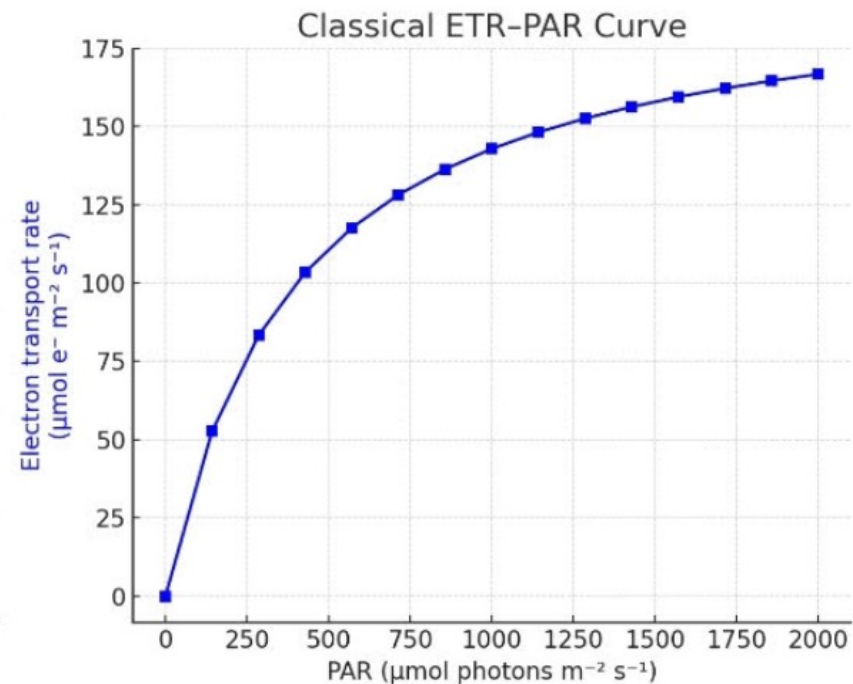
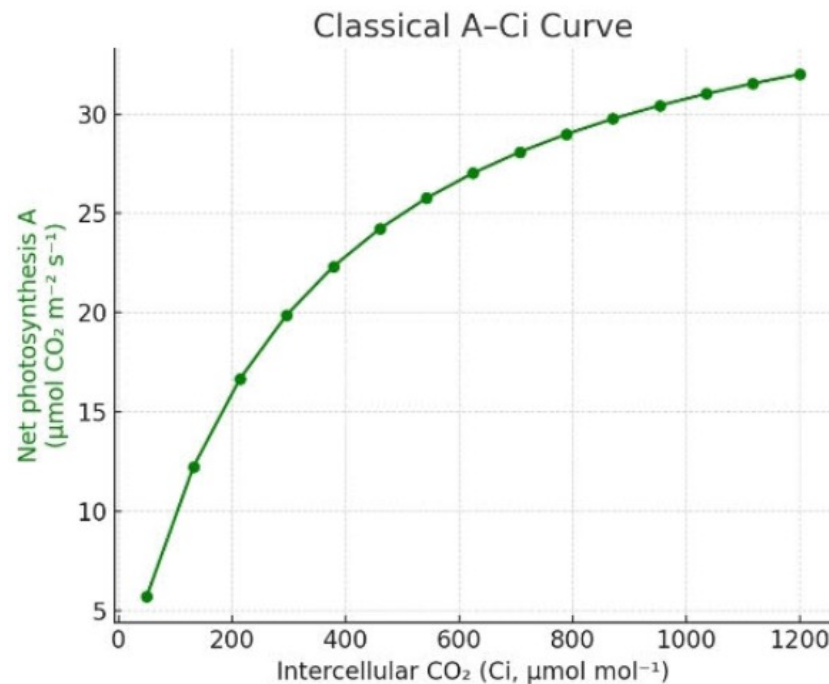
- 2023–2025: 0.705 and 2022–2025 $\approx$ 0.70 → similar spatial structure in those pairs.
- 2022–2023 = 0.201 → markedly different structure.

Selection of plants for PAM measurements



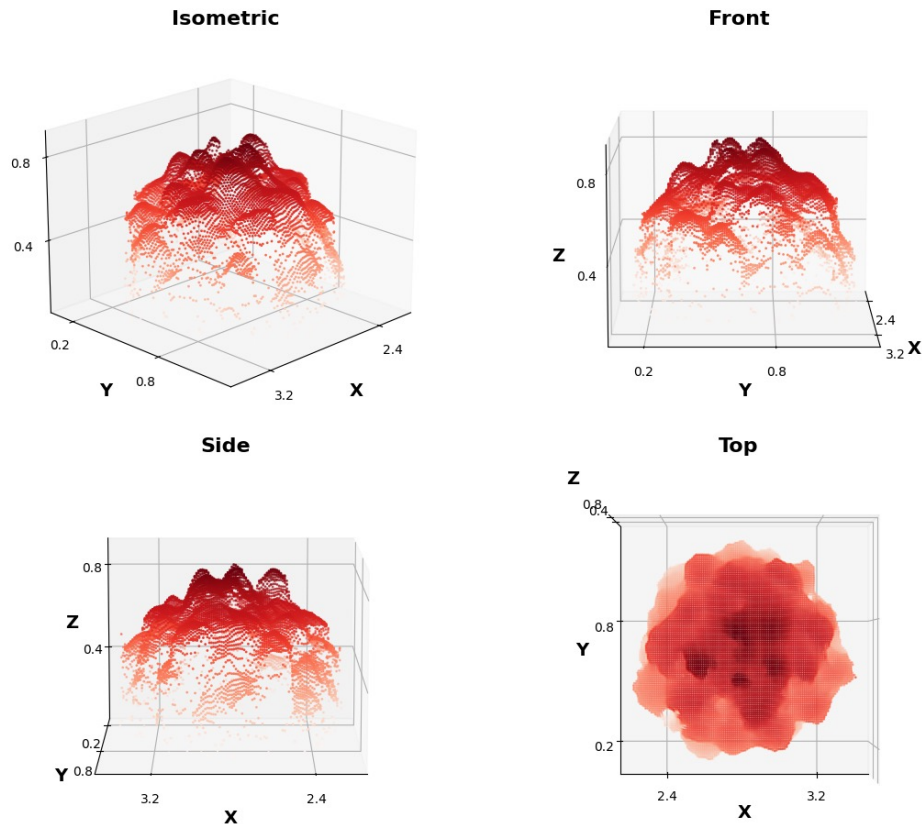
→ UAV-derived canopy height used to identify plants with non-extreme growth (avoiding outliers) to ensure representative PAM photosynthesis measurements.

Comparison between classical A-Ci and ETR information



→ Both the A-Ci curve and the ETR-PAR curve give information about photosynthetic performance, but from different angles. The A-Ci curve shows how photosynthesis changes with CO₂ availability, based on CO₂ gas exchange. The ETR-PAR curve shows how photosynthesis changes with light, based on chlorophyll fluorescence-derived electron transport rates.

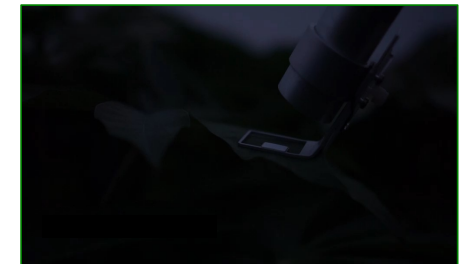
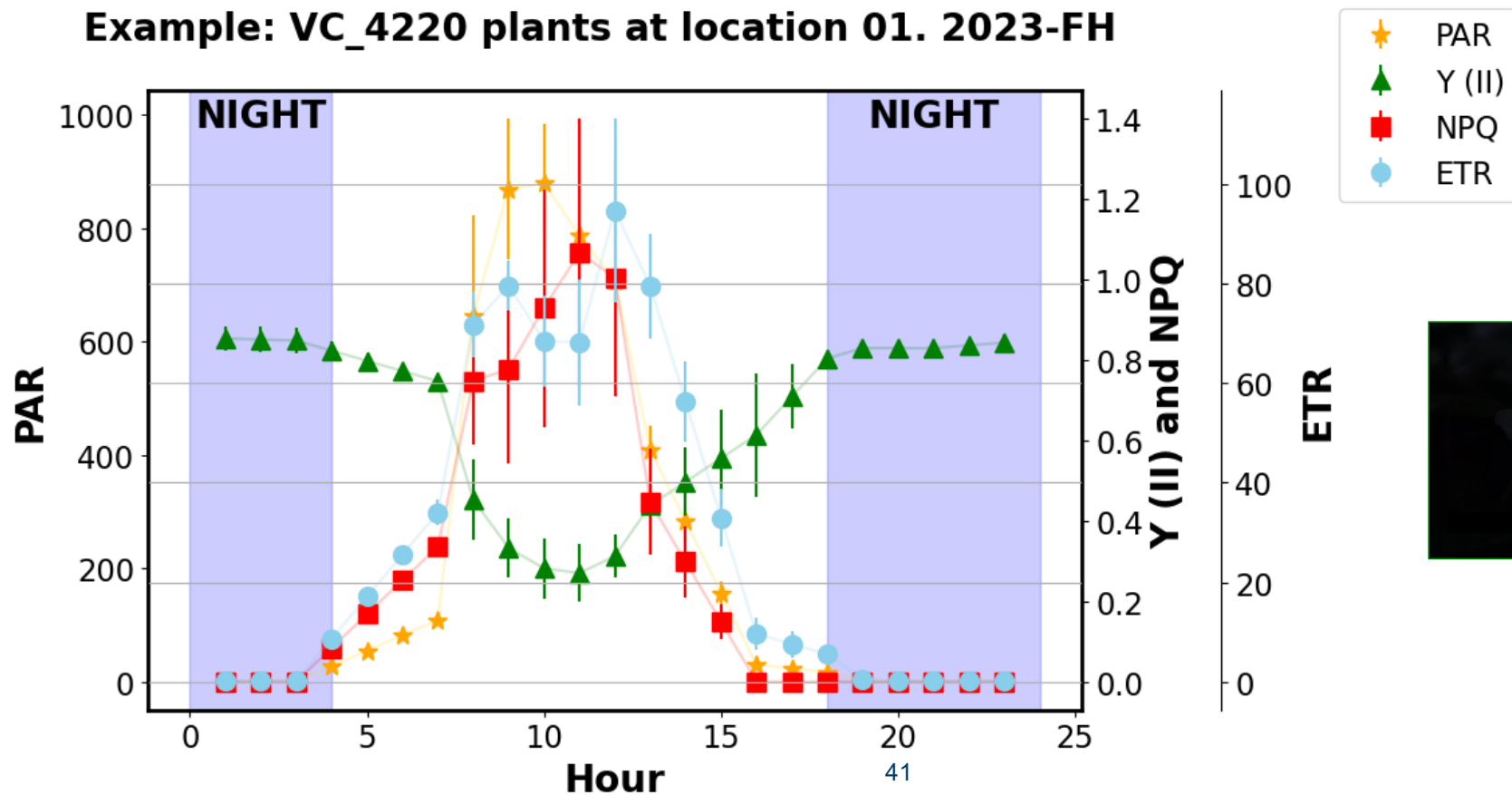
1. UAV data: multispectral imagery



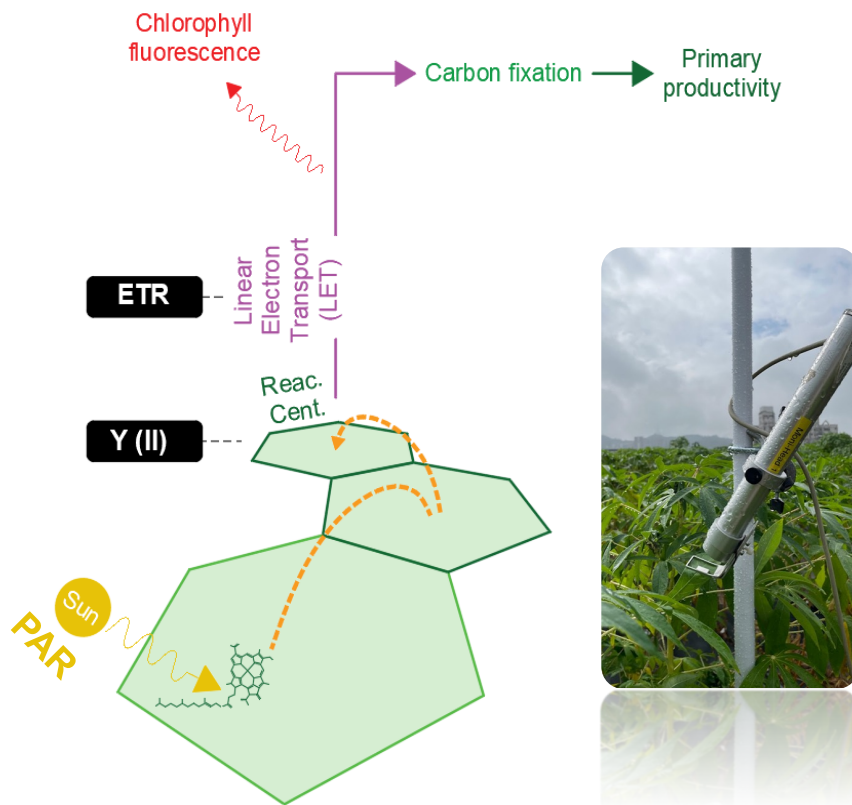
Note: Axis values are shown without scientific notation. Hidden offsets (e.g., +2.3e5) apply uniformly.

- From RGB imagery (visible light), elevation data are generated using 3D surface reconstruction
- Plant height is represented as the 95th percentile (Q95), i.e., the value below which 95% of the data fall
- Plant volume equals the sum of column volumes derived from each pixel
- From multispectral imagery (visible + non-visible light), we also obtain infrared information, where healthy plants reflect more and stressed plants reflect less

Pulse amplitude modulated (PAM)-based quantification of photosynthesis dynamics: example of diurnal dynamics



Pulse amplitude modulated (PAM)-based quantification of photosynthesis dynamics: Chlorophyll fluorescence (ChlF)



Key parameters:

- **Fv/Fm**: maximum photosynthetic quantum yield measured at night.
- **Y (II)**: effective quantum efficiency of photosystem II measured during the day.
- **ETR**: “electron transport rate”, electrons being transported between photosystems (II and I).
- **ETR_{max}**: maximum ETR at saturating light intensities.
- **NPQ**: “non-photochemical quenching”, heat dissipation as a mechanism of photoprotection.

