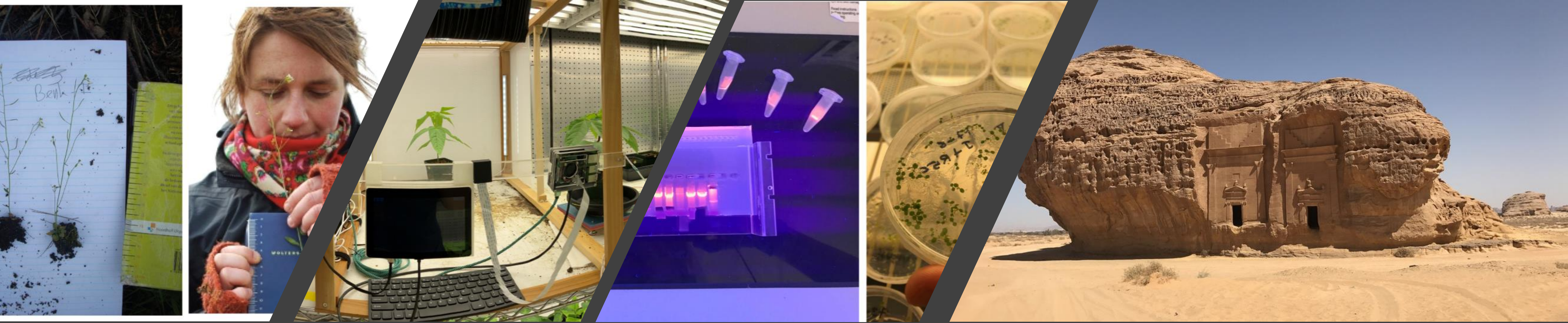
Phenotyping solutions for resilient legumes - case study of cowpea and tepary bean

Magda Julkowska

Assistant Prof. at BTI

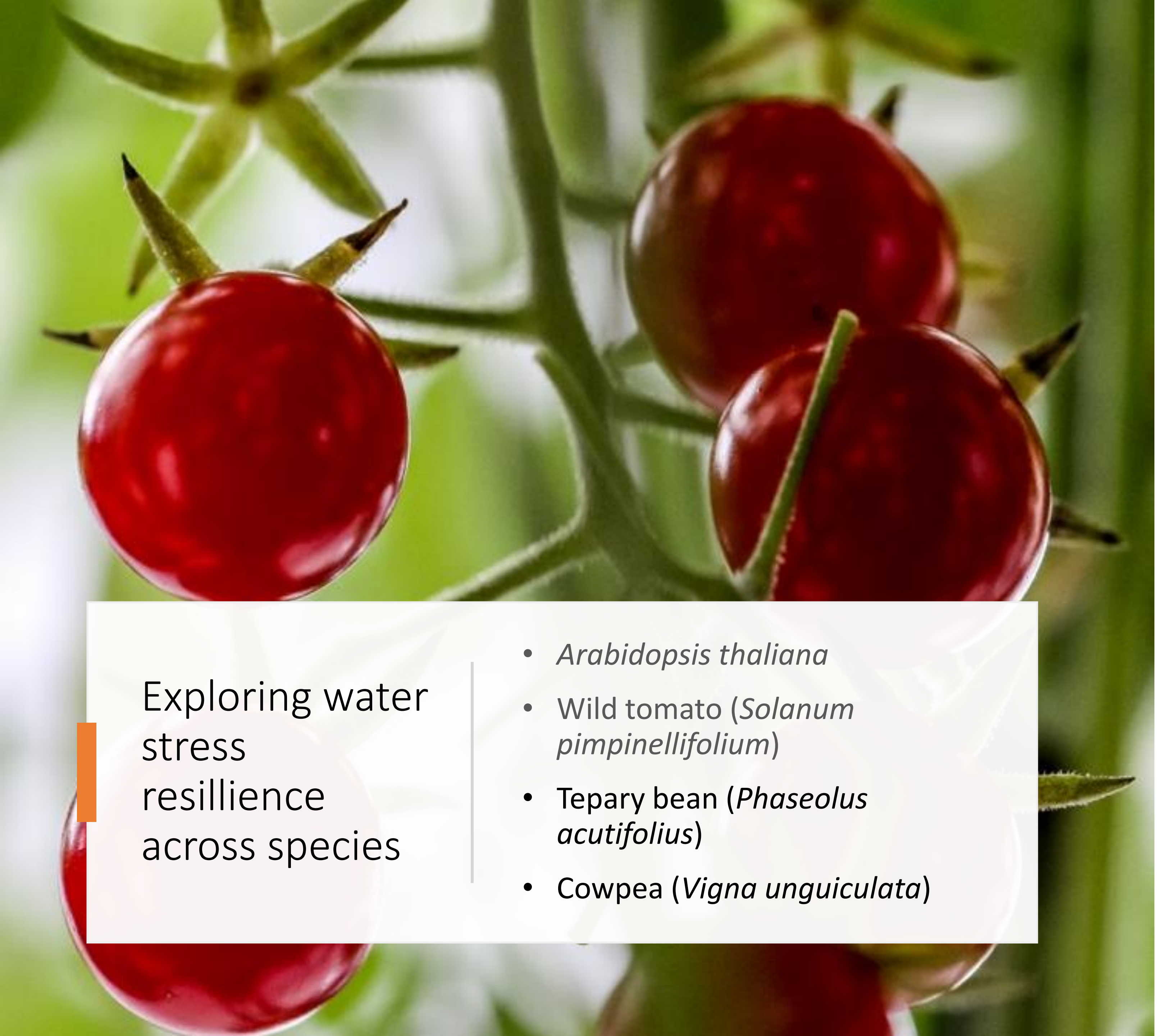
mmj55@cornell.edu

@mmjulkowska



Background

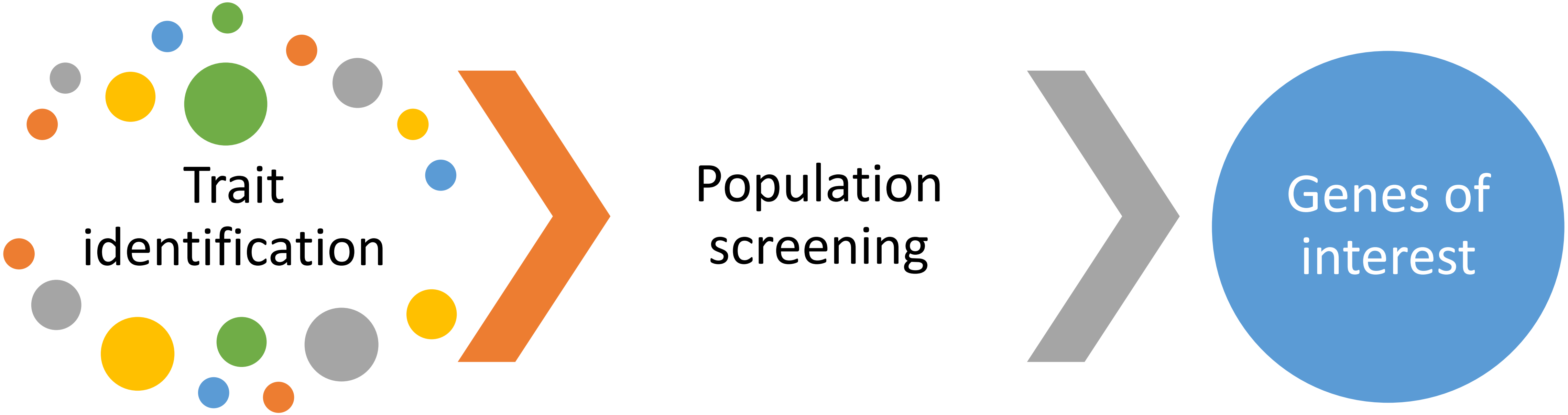
- Molecular plant stress physiologist
- Salt-induced changes in root architecture in Arabidopsis (PhD, Amsterdam, The Netherlands)
- Salt-induced changes in root-to-shoot ratio (Arabidopsis) and exploring salt tolerance in tomato (PostDoc, KAUST, Saudi Arabia)
- Current lab (started in 2020):
  - How environment changes plant architecture and which plant architecture traits contribute to improved resilience?
  - Learning from stress resilient plants
  - Looking for new ways to describe plant architecture
  - Developing affordable setups to democratize plant phenotyping



Exploring water stress resillience across species

- *Arabidopsis thaliana*
- Wild tomato (*Solanum pimpinellifolium*)
- Tepary bean (*Phaseolus acutifolius*)
- Cowpea (*Vigna unguiculata*)

Discovery pipeline in Plant Architecture Lab



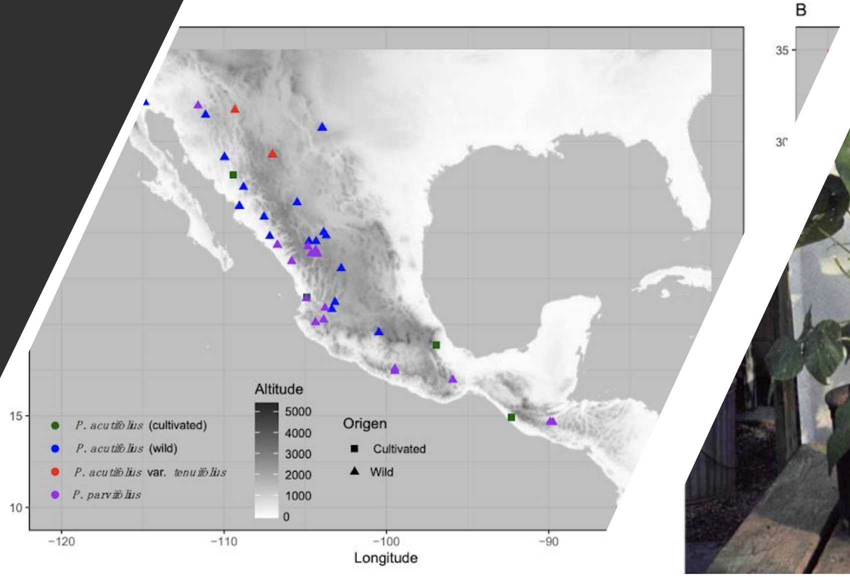
- Phene of interest
- Plasticity
- Heritability

- Phenotyping
- Forward Genetics

- Validation using reverse genetic tools
- Identification of molecular context
- Contribution to overall resilience in “real” conditions

Learning from tepary diversity

- Tepary bean is native to drought climates of South-Western US and Northern Mexico
- Tepary been previously used to improve stress resilience of common bean through crosses
- Reference genome of tepary bean published (Moghaddam et al., 2021)

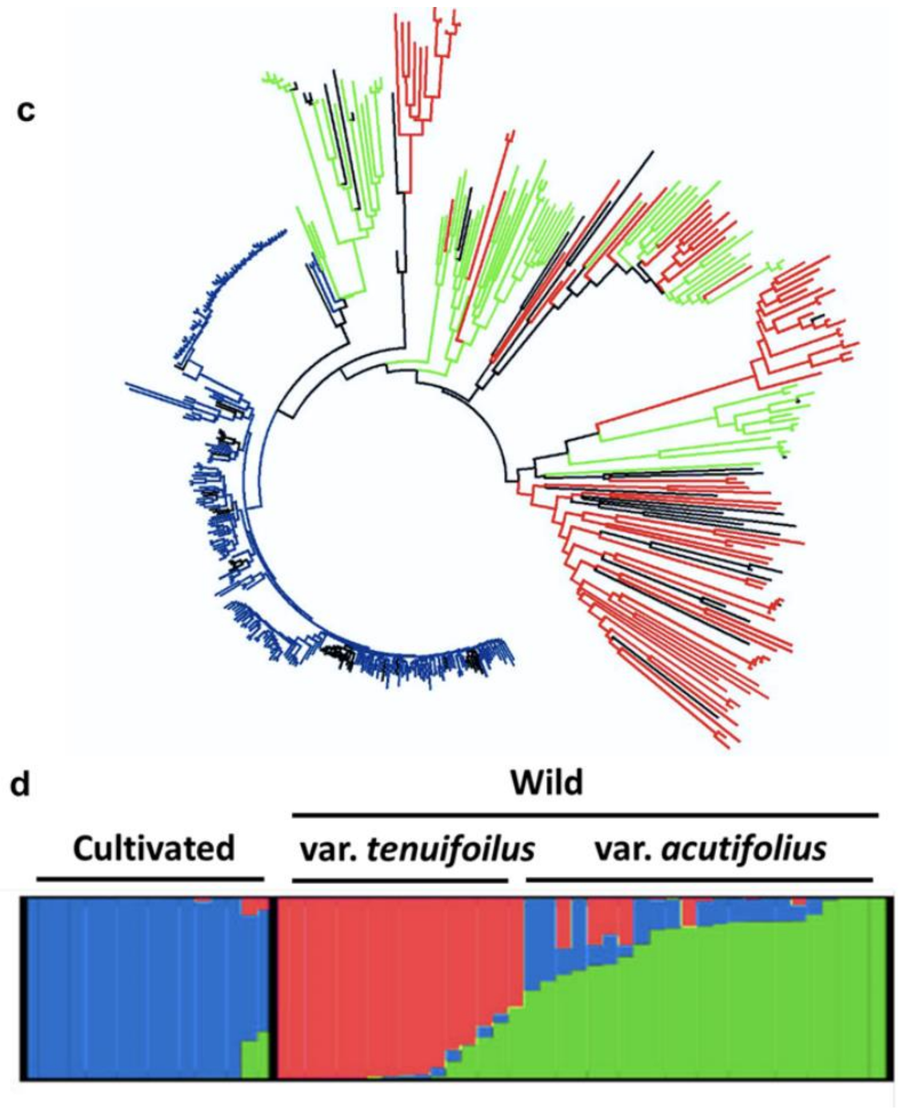


Buitrago-Bitar et al., 2021

Thomas et al., 1983

Learning from tepary diversity

- Current diversity panel overrepresenting cultivated accessions with little natural variation and 20,364 SNPs (GBS)
- Aim1: Develop natural diversity panel of 400 tepary accessions enriched in wild germplasm and free from mosaic-bean virus
- Aim 2: Evaluate panel under field conditions in tepary native environment (Arizona) for agronomic traits
- Aim 3: Evaluate panel under controlled conditions for seedling vigour and performance under control and drought stress conditions



Moghaddam et al., 2021

Timothy Porch, USDA

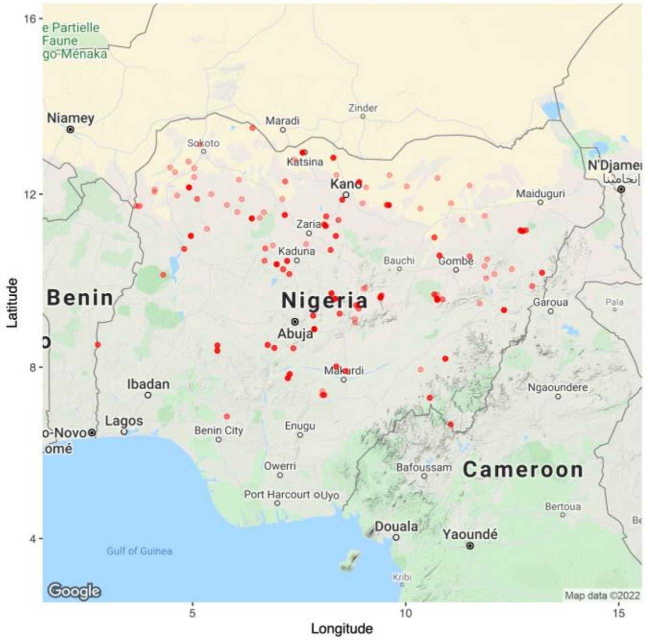
Duke Pauli, U of Arizona

Andrew Nelson, BTI

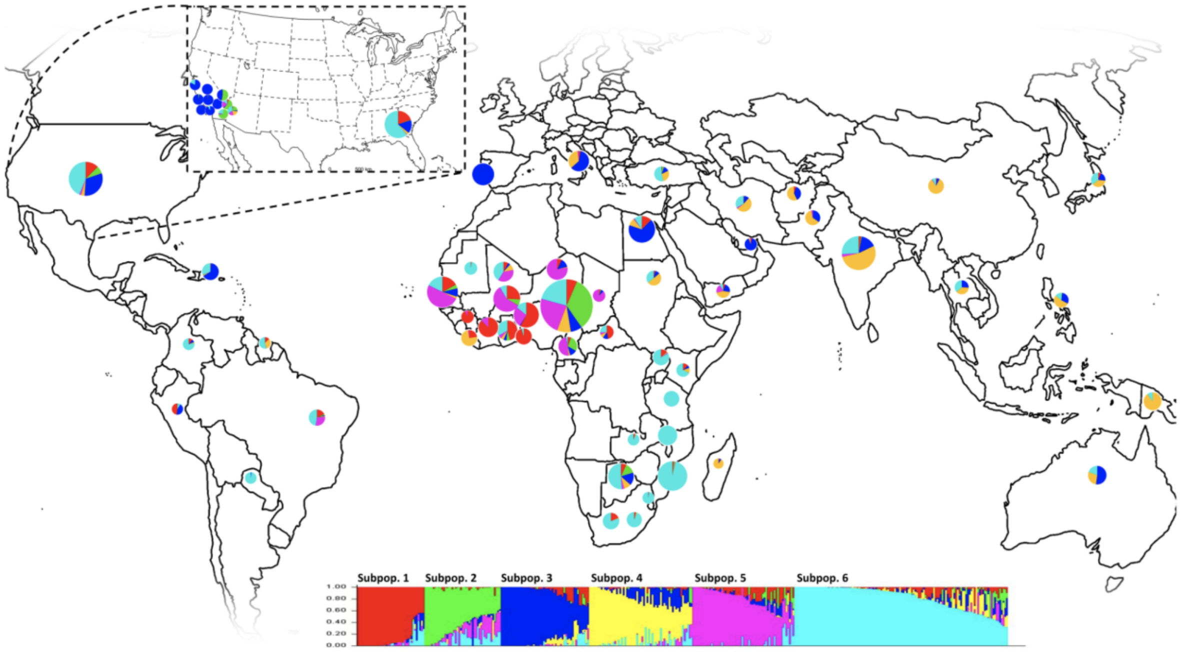
Learning from cowpea diversity

- Global natural diversity panel was developed in UC Riverside (Muñoz-Amatriaín et al., 2021) with 51,158 SNPs
- Genotyping the Nigerian cowpea collection in collaboration with Ahmadu-Bello University, Dr. Aliyu Ramatu Enehezeyi (Triad foundation)
- Evaluate the germplasm for drought induced changes in growth, architecture and photosynthetic efficiency

Maria Muñoz-Amatriaín



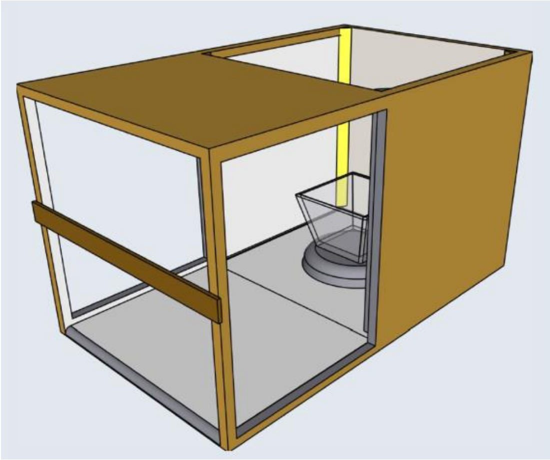
Nigerian germplasm from Ahmadu Bello University

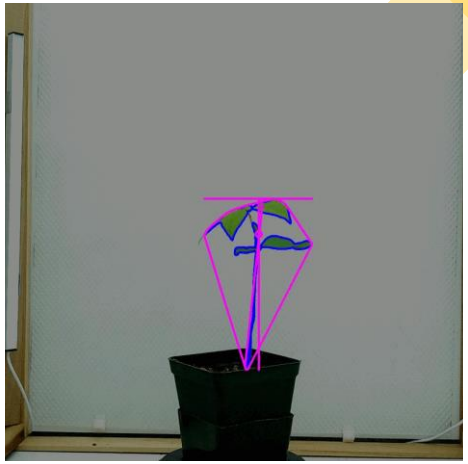


Muñoz-Amatriaín et al., 2021

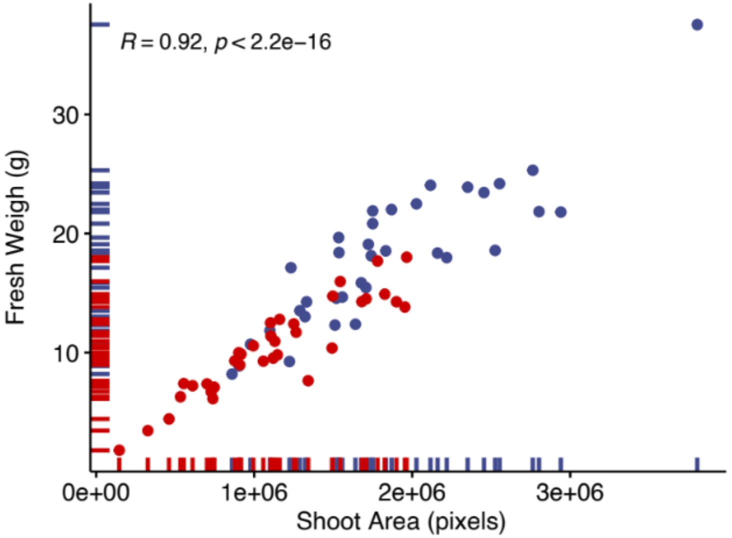
Developing phenotyping protocols for legumes

- Highly complex 3D architecture
    - Comprehensive side-view imaging to accurately capture the digital biomass

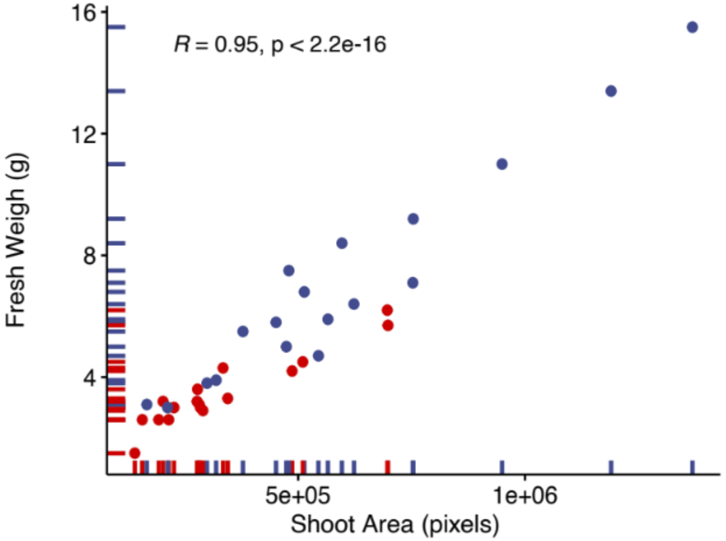




Cowpea



Tepary bean



Dr. Li'ang Yu

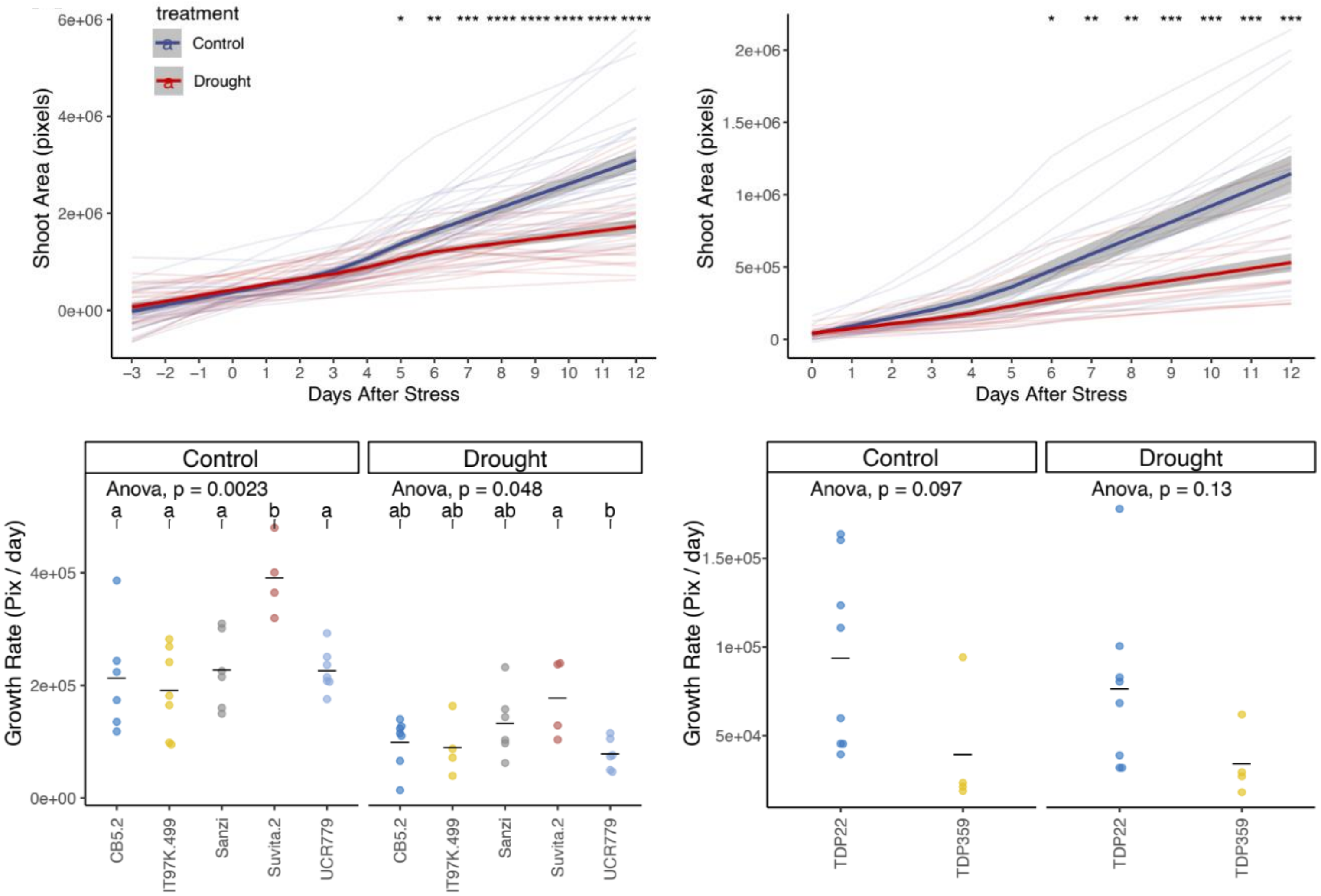
Yu, Sussman et al., in preparation

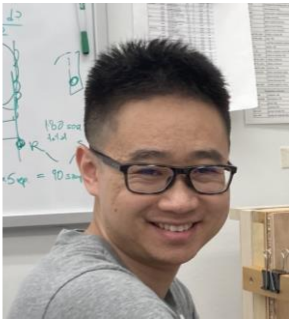
Developing phenotyping protocols for legumes

- Highly complex 3D architecture
  - Detection of drought induced changes in plant size and estimation of daily growth rate

Cowpea

Tepary bean



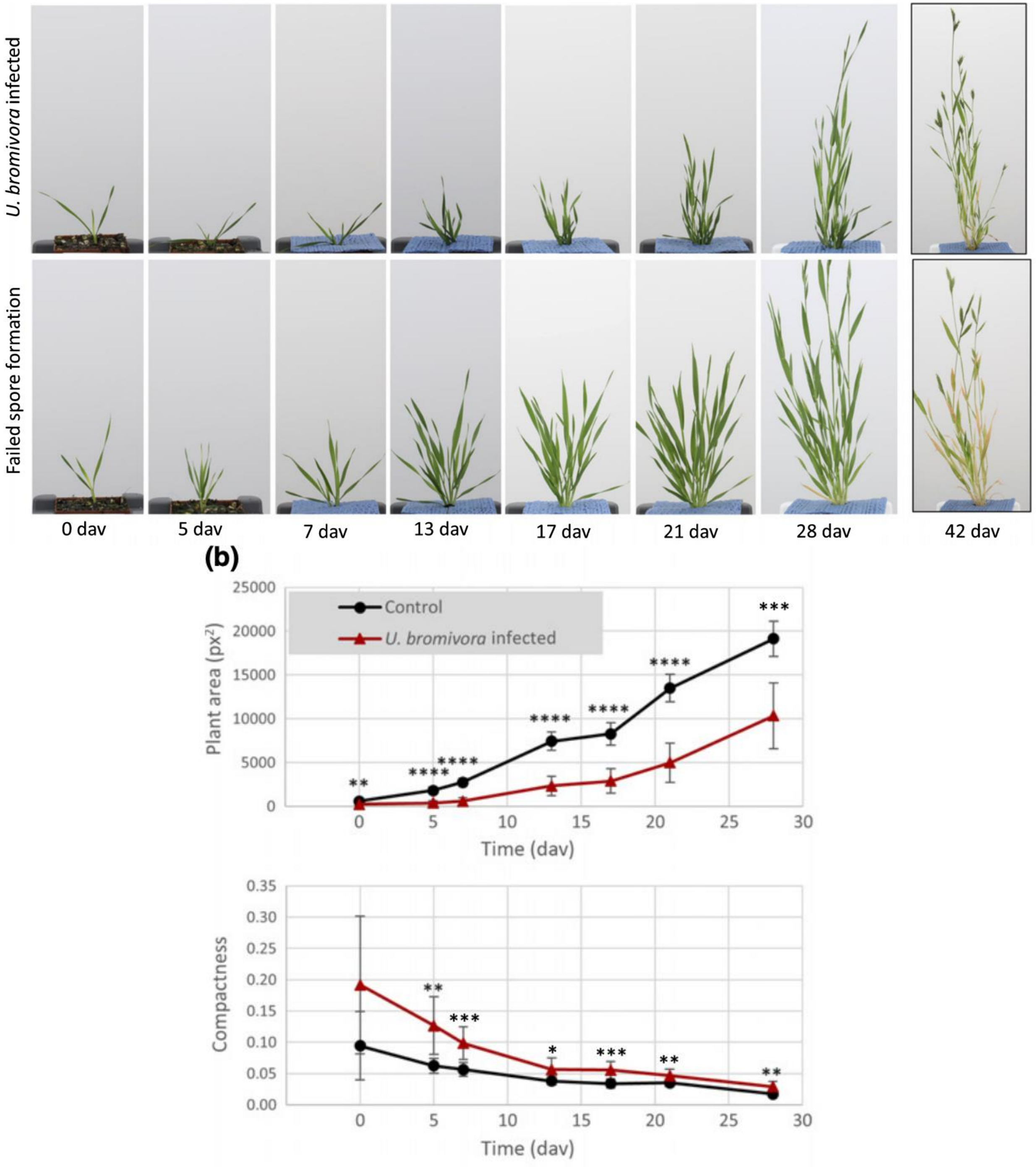


Dr. Li’ang Yu

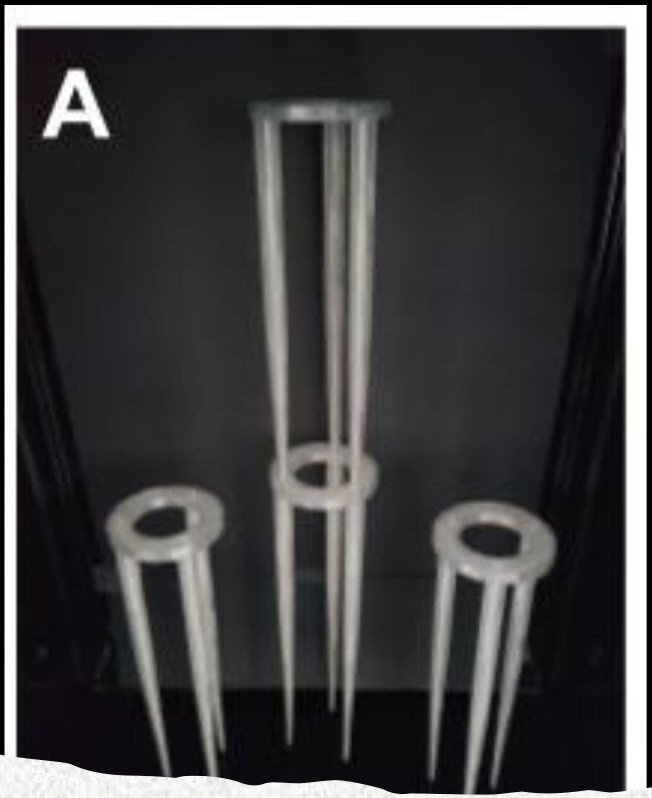
Yu & Sussman et al., in preparation

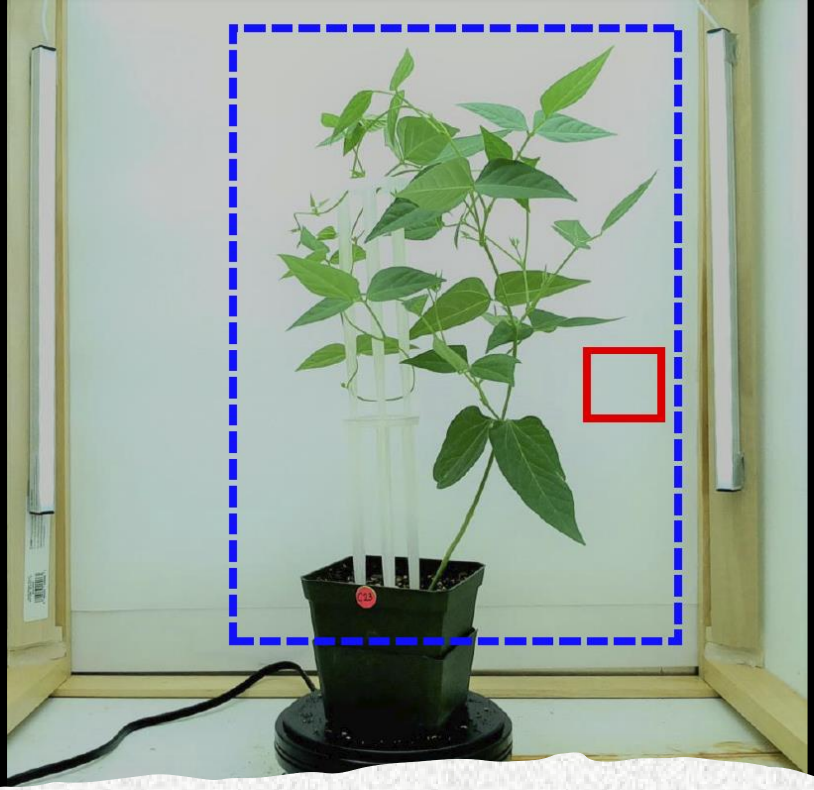
How can PhenoCage be usefull for you?

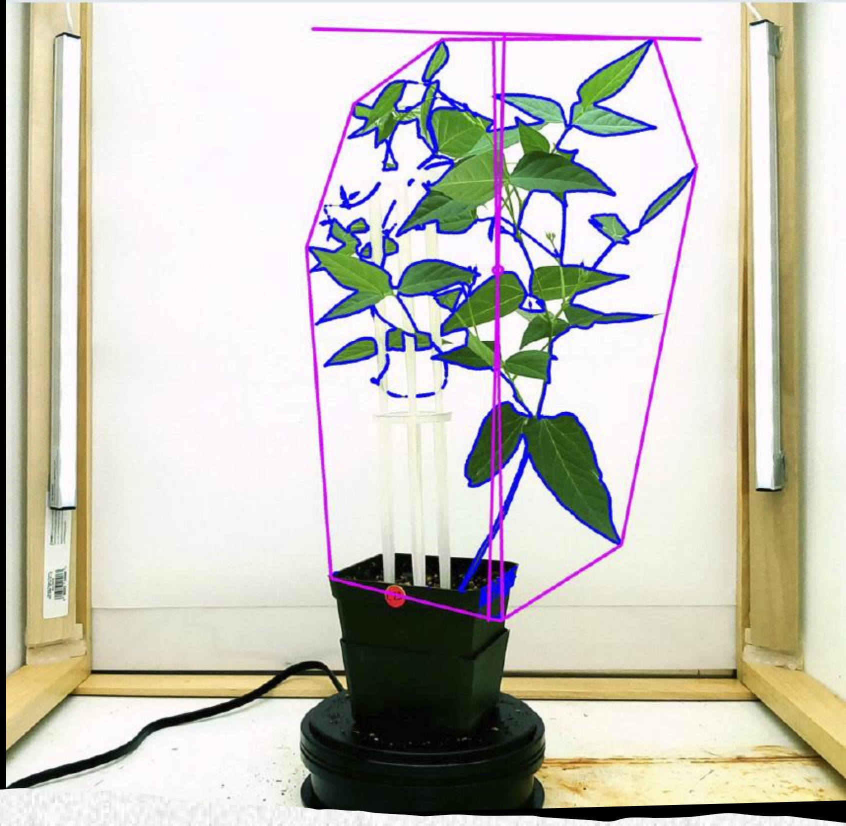
- Cheap setup for pot-grown plants (200 $ / setup)
- Based on afforable (10$) RaspberryPi RGB cameras
- Detailed evaluation of the disease / stress symptoms before spore formation
- Highly mobile
- Open-source code + instructions available https://github.com/Leon-Yu0320/BTI-Plant-phenotyping/



PhenoBox, Czedik-Eysenberg et al., 2018







Developing phenotyping protocols for legumes

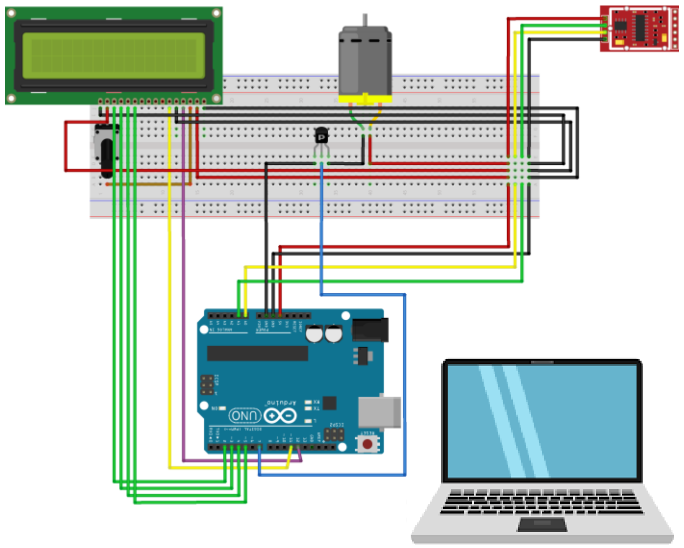
- Climbing / prostrate growth habit
  - Support structures that do not interfere with image-based extraction of traits
  - 3D printed transparent stackable trellis system

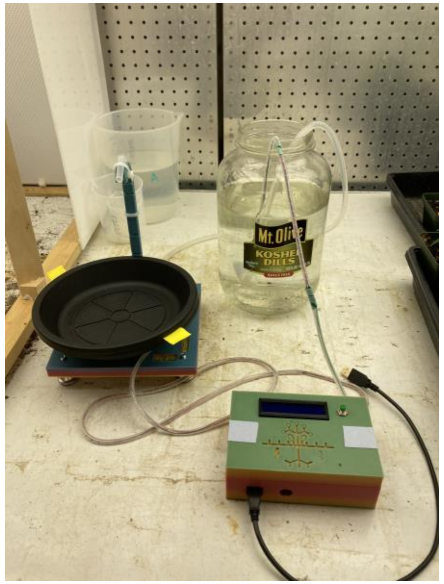
Dr. Aparna Srinivasan

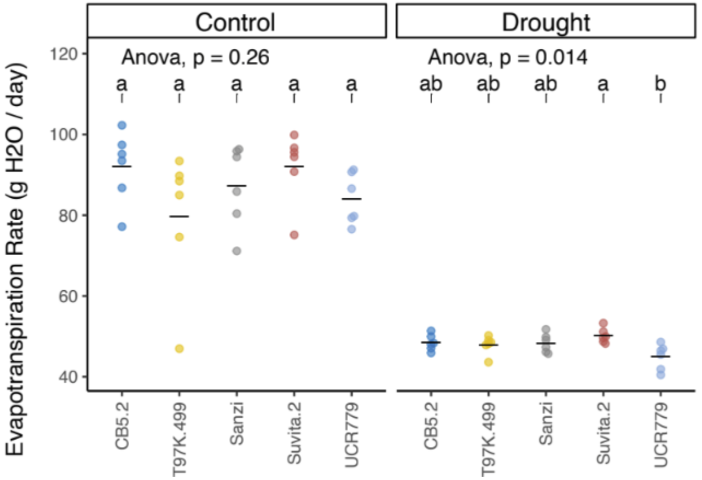
Yu & Sussman et al., in preparation

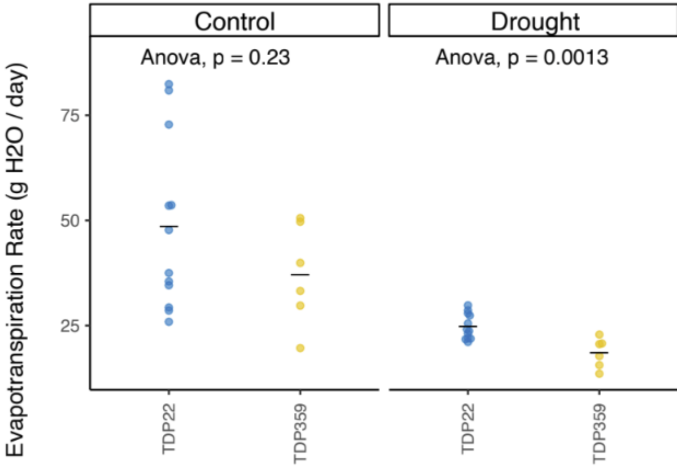
Developing phenotyping protocols for legumes

- AWWESMO – Arduino-based Weighing and Watering Unit for estimation of Evapotranspiration
  - Maintaining plants at specific soil-water holding capacity for drought experiments
  - Measuring daily evapotranspiration rate
  - Instructions on how to build and program AWWESMO at https://github.com/ok84-star/AAWSMO









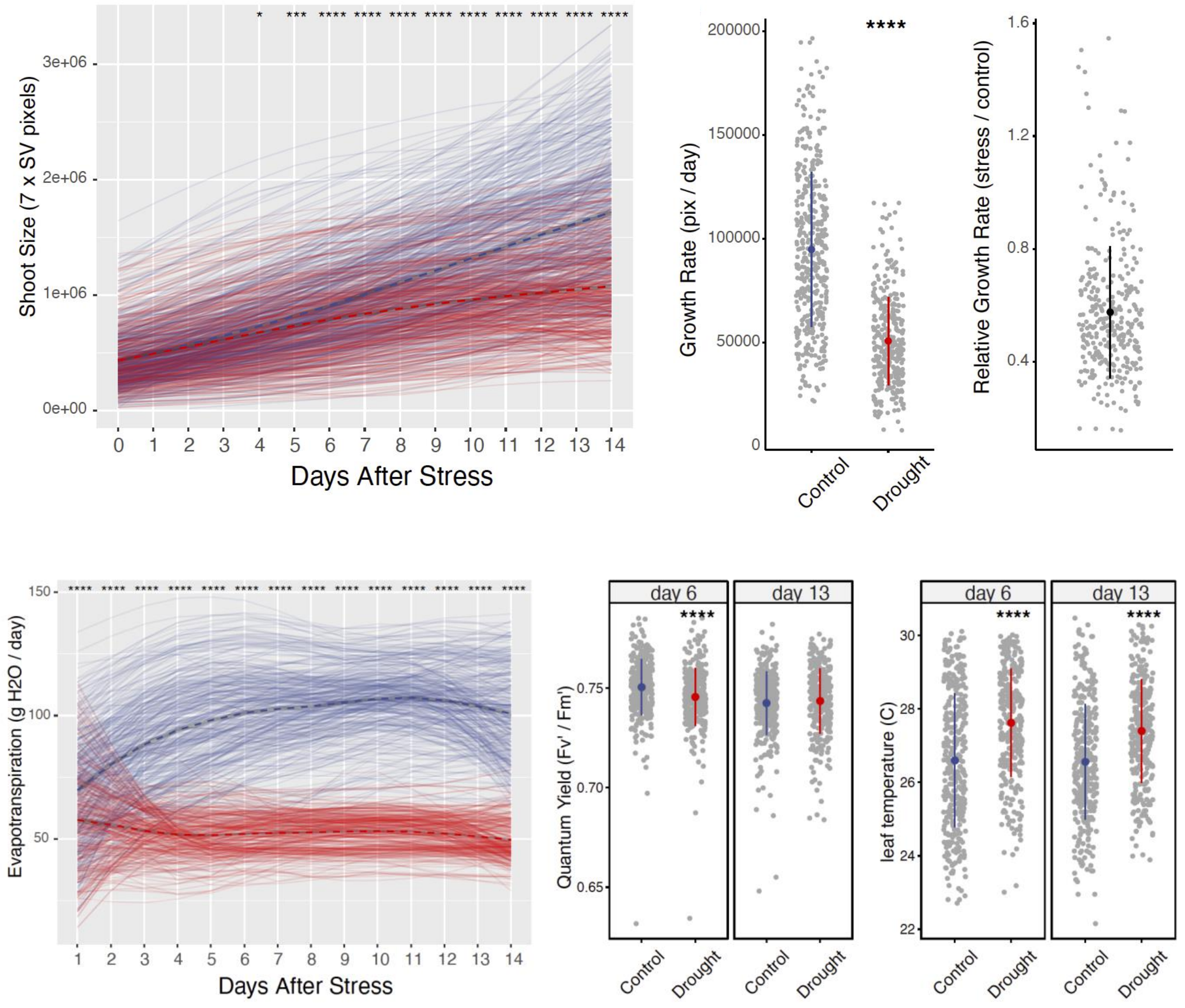
Olga Khmelnitsky

Yu & Sussman et al., in preparation

Developed phenotyping tools in action

- Screened UCR miniCORE diversity panel for drought-induced changes in growth, evapotranspiration and photosynthetic efficiency
- Most tolerant (TVu-12968, Tvu-14533, KVx 403-P-20-T) and most susceptible (Vazzano Brown, Cameroon 7-29, TVu-4557) lines are currently re-phenotyped for confirmation

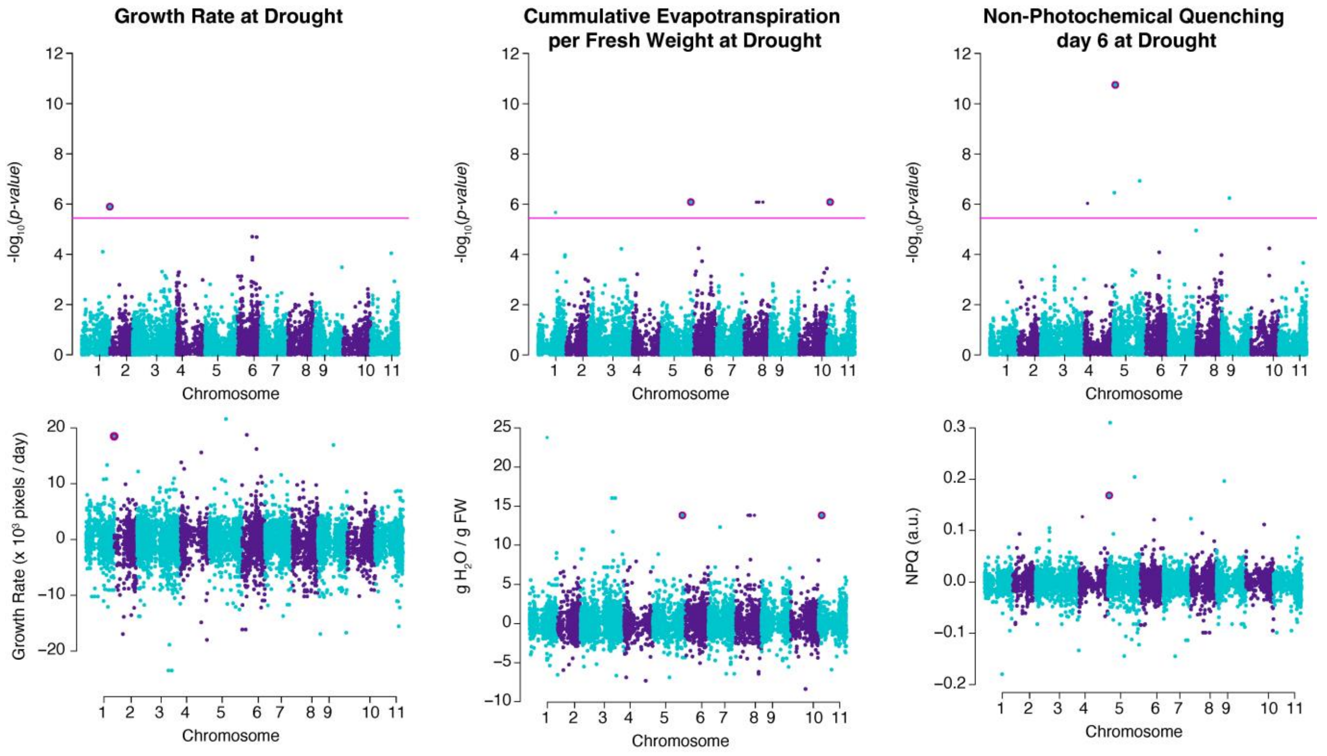
Hayley Sussman

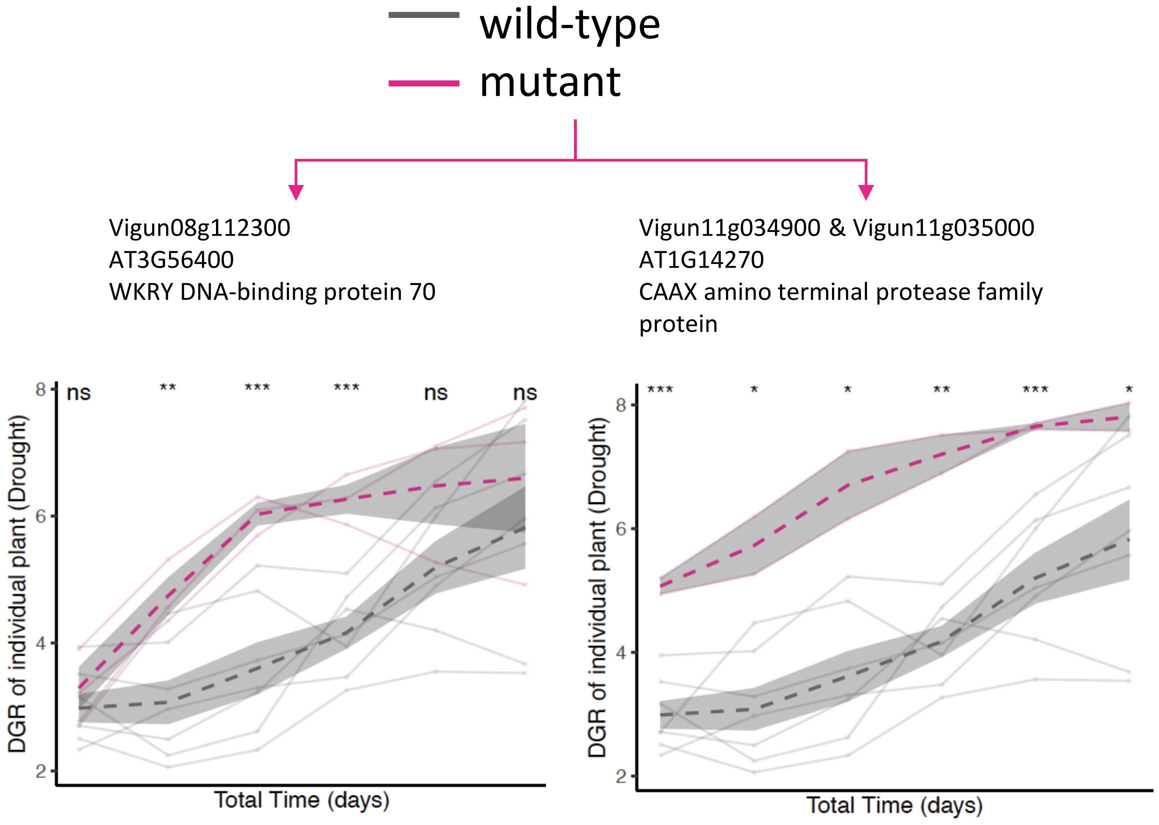


Yu & Sussman et al., in preparation

Developed phenotyping tools in action

- Identified 6 loci associated with natural variation in drought responses using ASReml based GWAS
- Validating the importance of identified genes for drought stress tolerance using Arabidopsis homologues

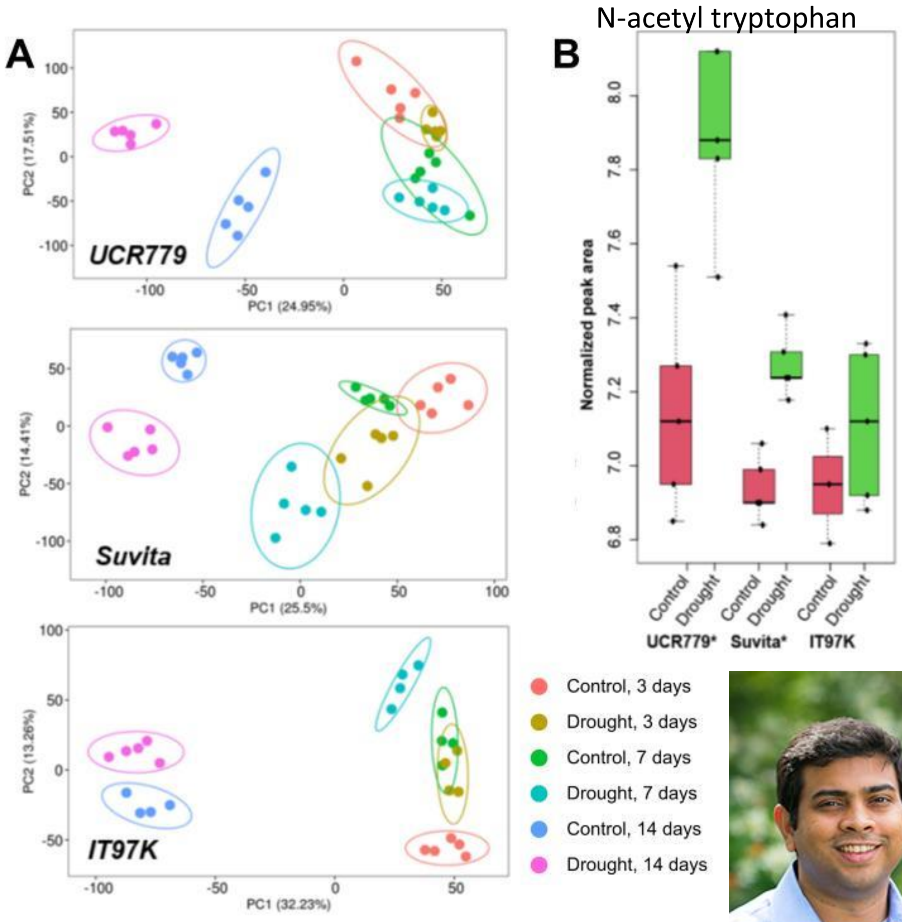




Yu & Sussman et al., in preparation

Further explorations of drought stress responses in cowpea

Metabolome changes in leaf tissue



Dr. Gaurav Moghe

Development of fogo-ponics for whole plant imaging & drought stress

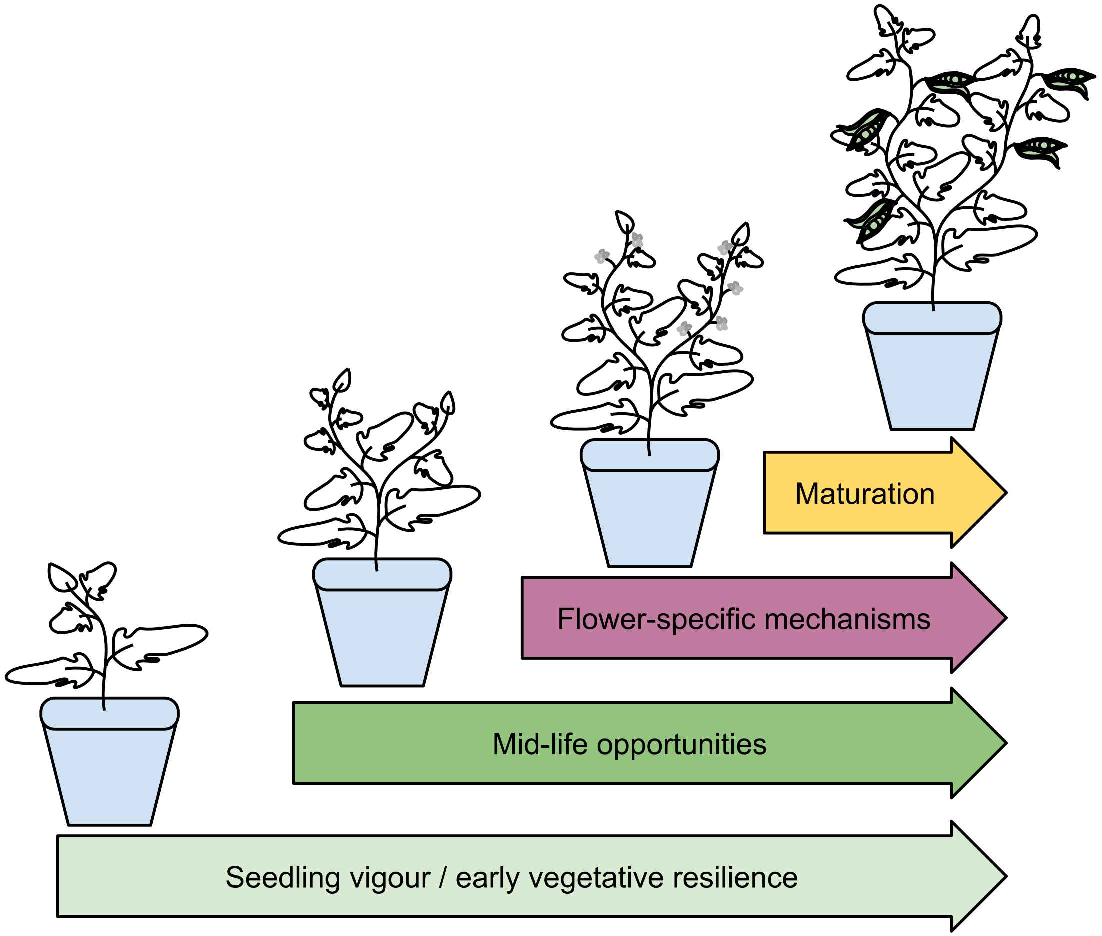
Dr. Perrine Pepiot

Dr. Miguel Pineros

Dr. Shannan Sweet

Future plans

- Generate transgenic lines for gain- and loss-of-function of identified candidate genes
- Evaluate the lines for drought stress resilience under controled conditions (BTI) at early vegetative stage
- Evaluate the lines for early, mid and terminal drought stress in field conditions (Ahmadu-Bello University)
- Look into plant architecture traits and their contribution to drought resilience
- Stack early drought stress resilience genes with other genes conferring drought resilience at other stages



Plant transformation / tissue culture network

- NSF funded network
- On-line webinars and workgroups on plant tissue culture / transformation
- Become a member, provide your interest in organism-of-transformation
- Get connected with people and form working groups on transformation / tissue culture methods in your crops of interest

https://plantgene.atlassian.net/

Plant GENE

Joyce van Eck

Thank you

Dr. Maria Muñoz-Amatriaín

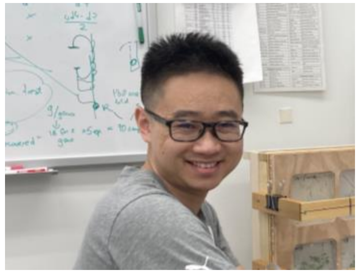
Dr. Miguel Pineros

Kirkhouse Trust

Dr. Shannan Sweet

Dr. Perrine Pepiot

Dr. Gaurav Moghe



Dr. Li’ang Yu

BTI BOYCE THOMPSON INSTITUTE

Hayley Sussman
Dr. Aparna Srinivasan
Olga Khmelnitsky
Dr. Maryam Rahmati-Ishka

Dr. Duke Pauli

Dr. Timothy Porch

Dr. Andrew Nelson

TRIAD FOUNDATION

Goelet foundation

USDA NIFA