Root structure and function traits: Overcoming the root phenotyping bottleneck in cereals (UOQ2312-009RTX)

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

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1. Round table introductions: what is your interest in this project? (All)
2. Initial ideas and results on new high throughput root phenotyping technologies, and project objectives (DR)
3. Traits of interest and potential industry applications (All)
4. Delivery mechanism of the proposed outputs (All)

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Dongxue Zhao (soil plant interactions)
Lee Hickey (wheat pre breeding)
David Jordan (sorghum pre breeding)
Karine Chenu and Vijaya Singh (crop physiology)
Emma Mace (genomics)
Peter de Voil (APSIM modelling)
Andries Potgieter (proximal sensing)

The University Of Queensland Australia
QAAFI Queensland Alliance for Agriculture and Food Innovation

Anton Wasson, CSIRO - crop physiology / roots
Hammad Khan, DPIRD - crop physiology
Bob French, DPIRD - agronomy
Hannah Schneider, IPK - root anatomy / plasticity

CSIRO
Government of Western Australia
80 Anniversary IPK Leibniz Institute

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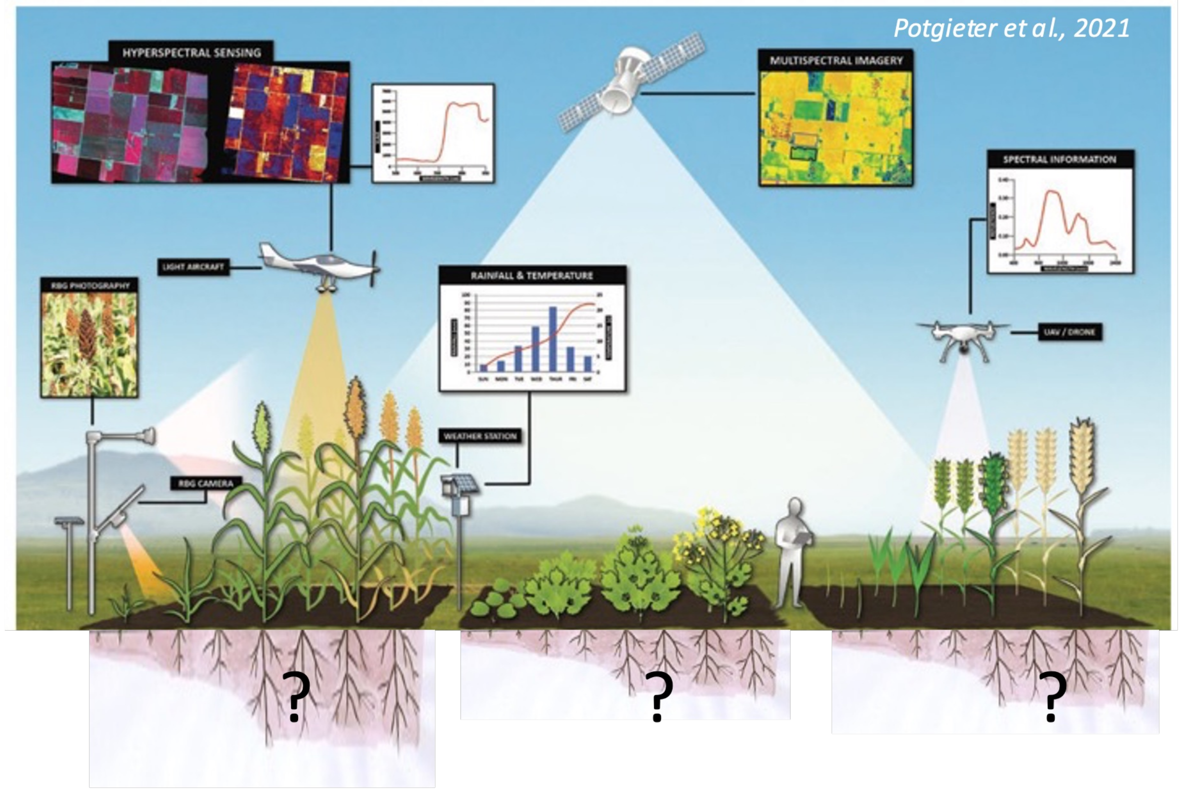
Phenotyping can help in crop climate adaptation

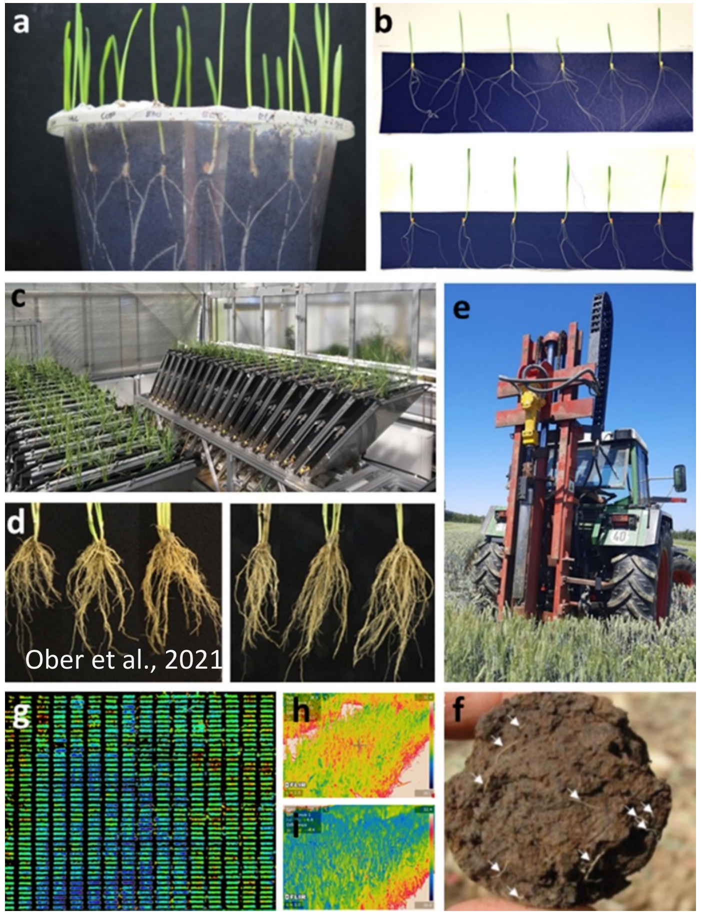


Most field phenotyping has been limited to half of the problem, the above-ground growth.

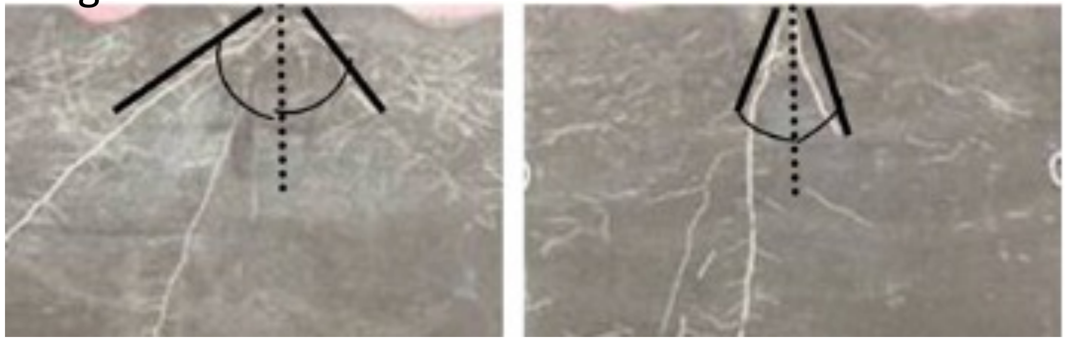
Approaches to root phenotyping

Structural phenotyping

"From form to function"



Sorghum

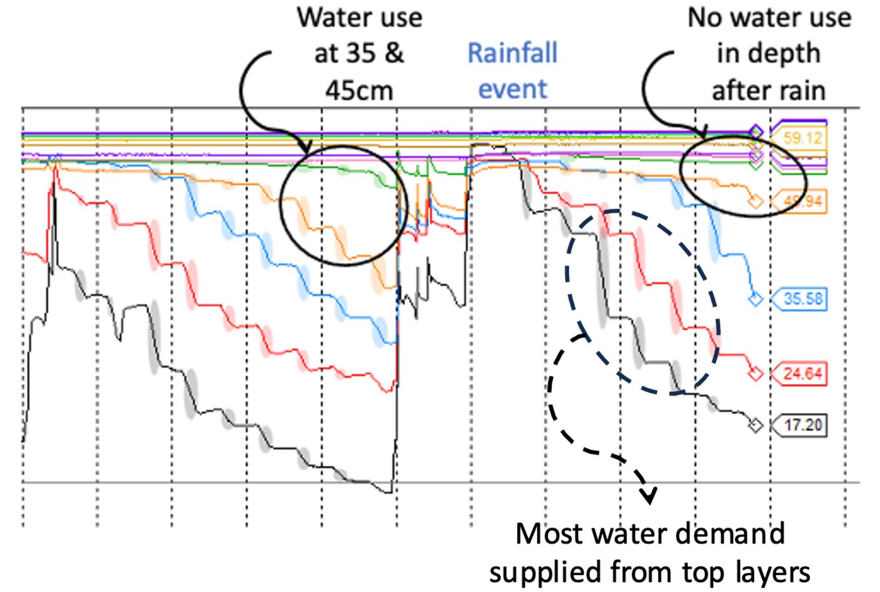


Putative associations between root angle and stay green and grain yield in sorghum are known (Mace et al., 2011; Menamo et al., 2023)

Approaches to root phenotyping

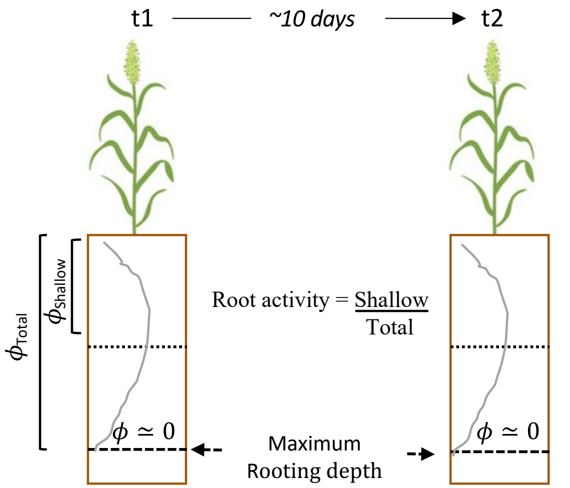
Structural phenotyping

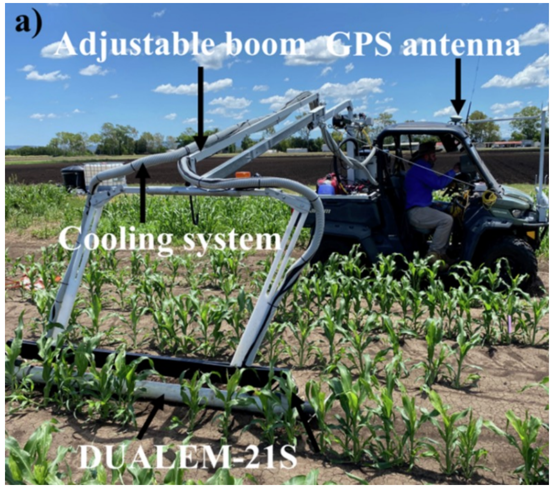
"From form to function"



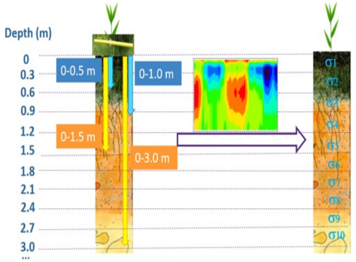
Functional phenotyping

"focus on function"



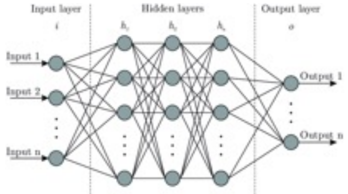


EC_a inversion

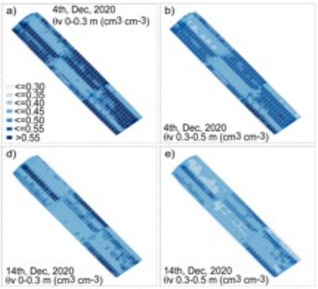


Data calibration

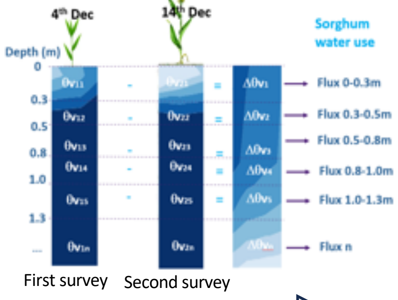
Artificial neural network



Moisture Prediction



Crop water use



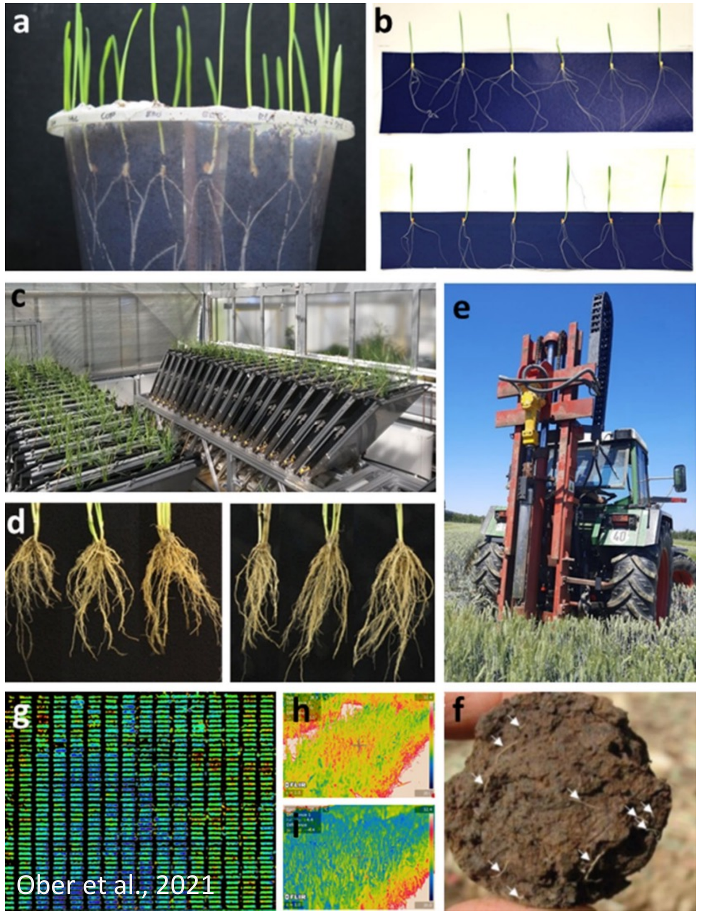
Pipeline

Zhao et al., 2022

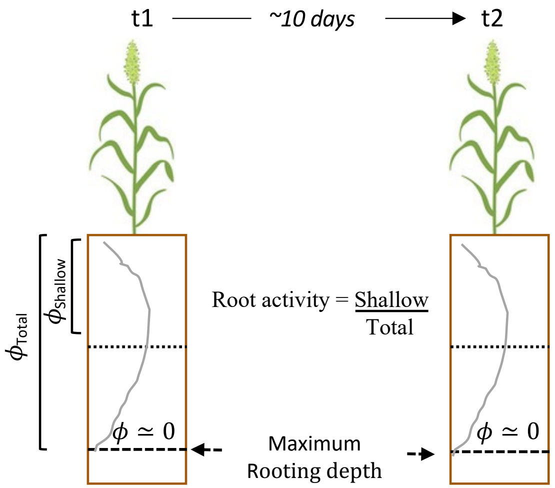
Approaches to root phenotyping

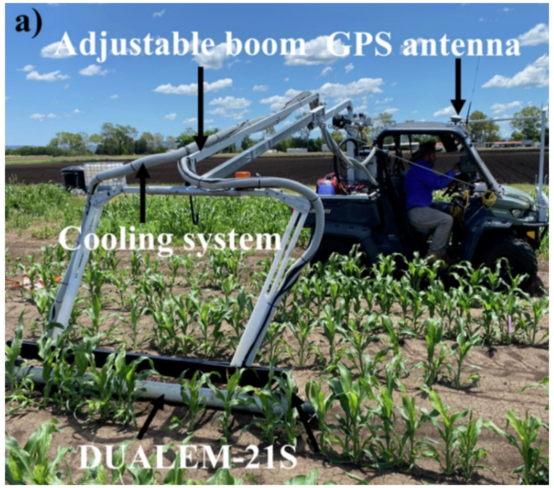
Structural phenotyping & Functional phenotyping

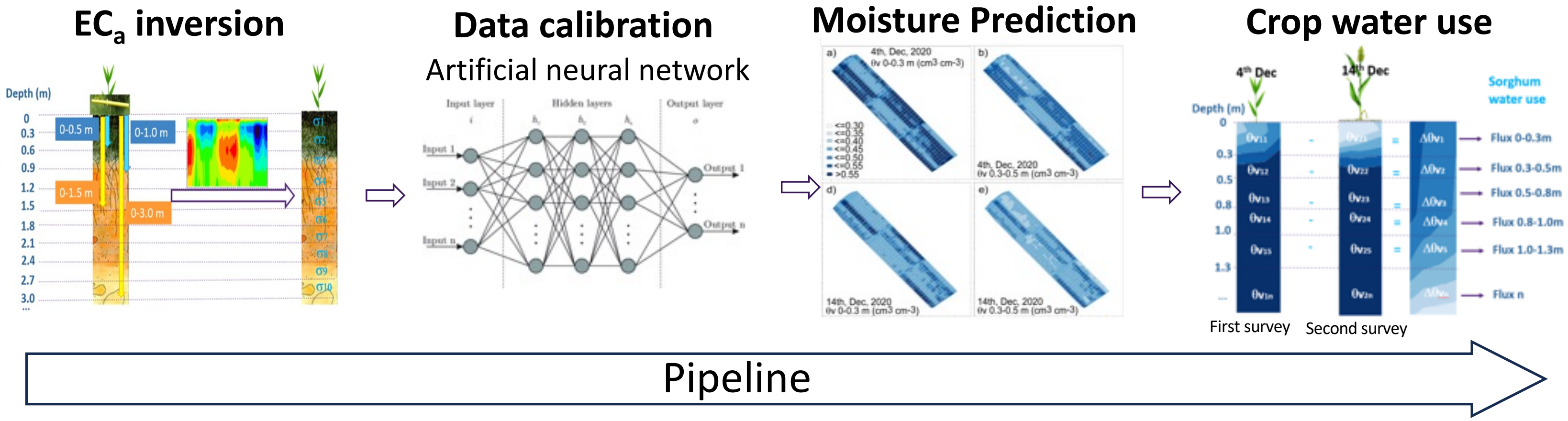
"From form to function"



"focus on function"





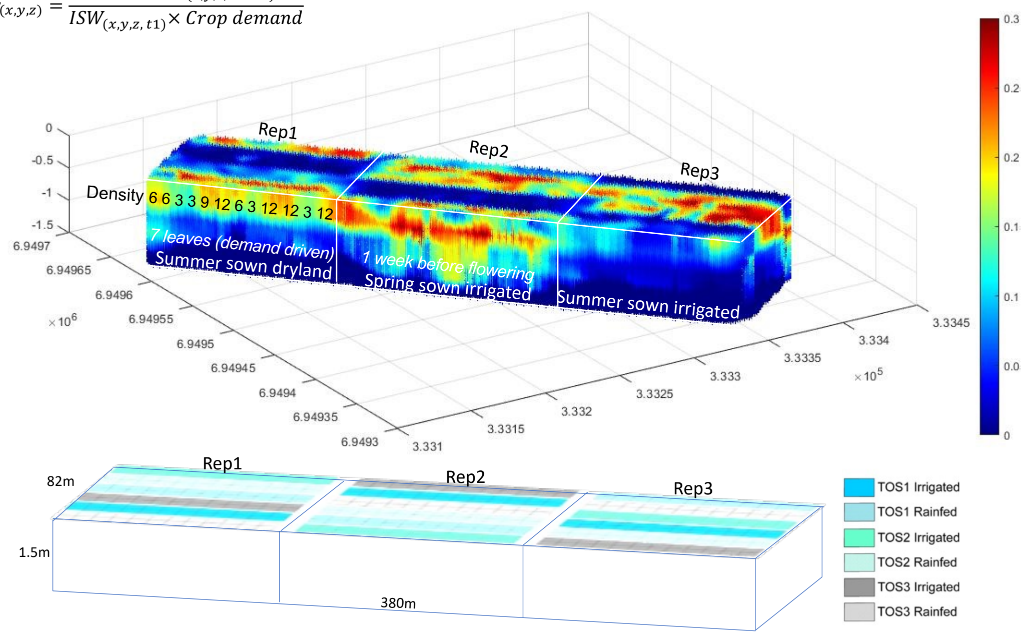


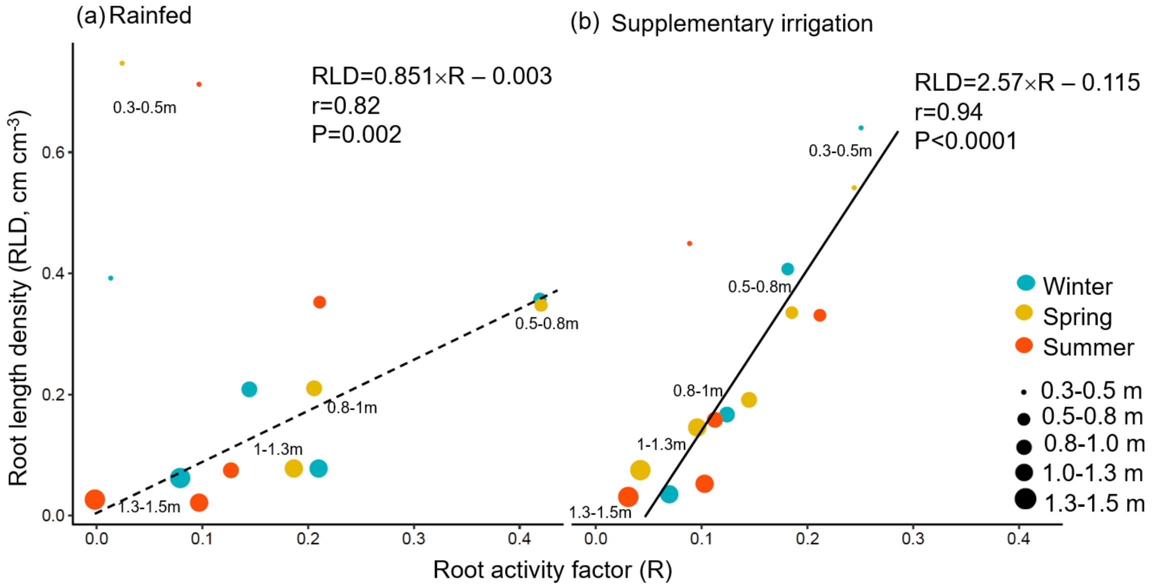
Zhao et al., 2022

Initial results: Root activity factor (R) and root length density (sorghum)

Naanwee Qld 2021, BLUPs from 6 Environments: 3 times of sowing x 2 levels of irrigation

$$Root\ activity\ factor_{(x,y,z)} = \frac{Water\ use_{(x,y,z,\,t1-t2)}}{ISW_{(x,y,z,\,t1)} \times Crop\ demand}$$

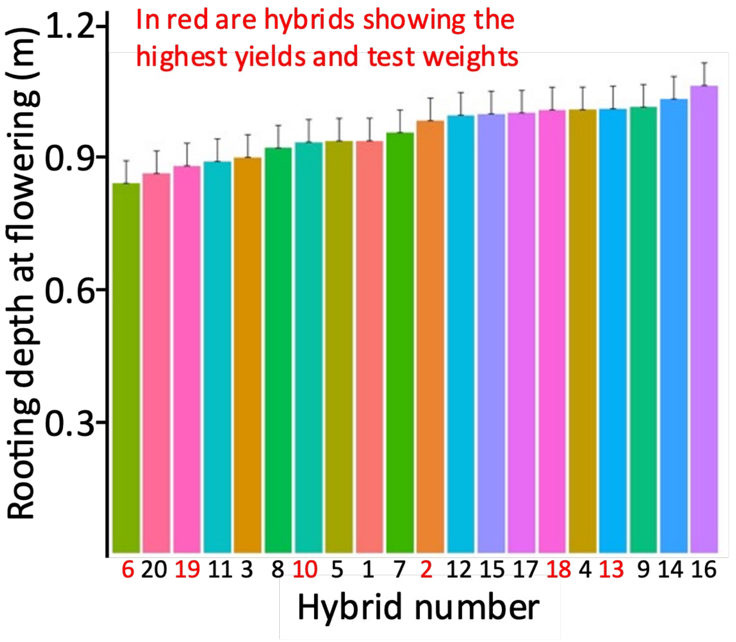


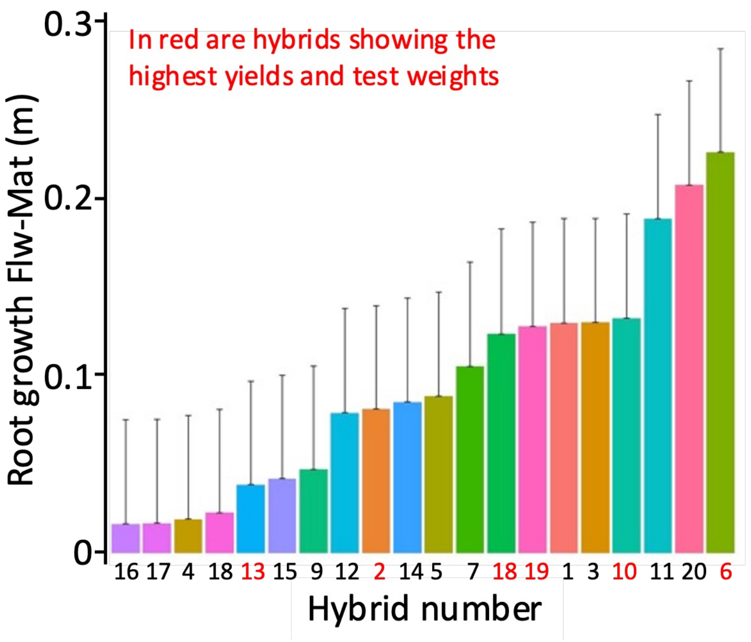


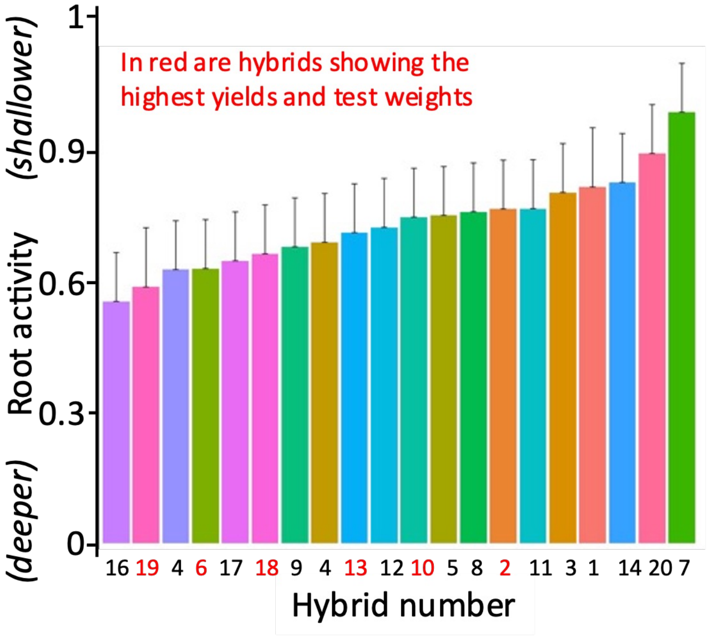
Zhao et al., 2024

Initial results: Variability in root traits (sorghum)

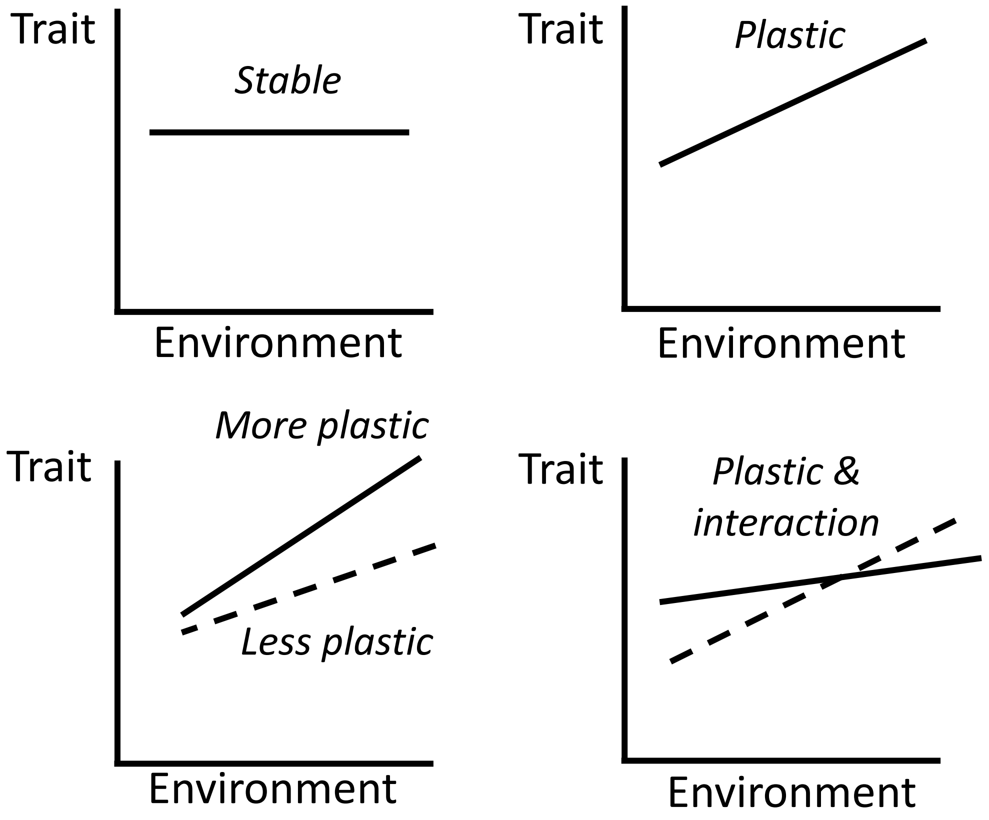
Brookstead Qld 2023, BLUPs from 20 sorghum hybrids 1 environment







Mean root trait value and its plasticity



Basic principles

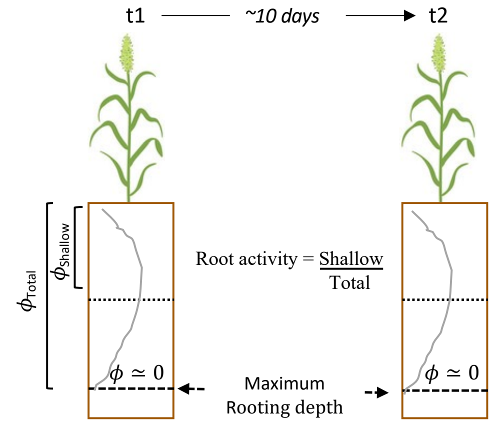
- *Being able to be altered to increase fitness??*

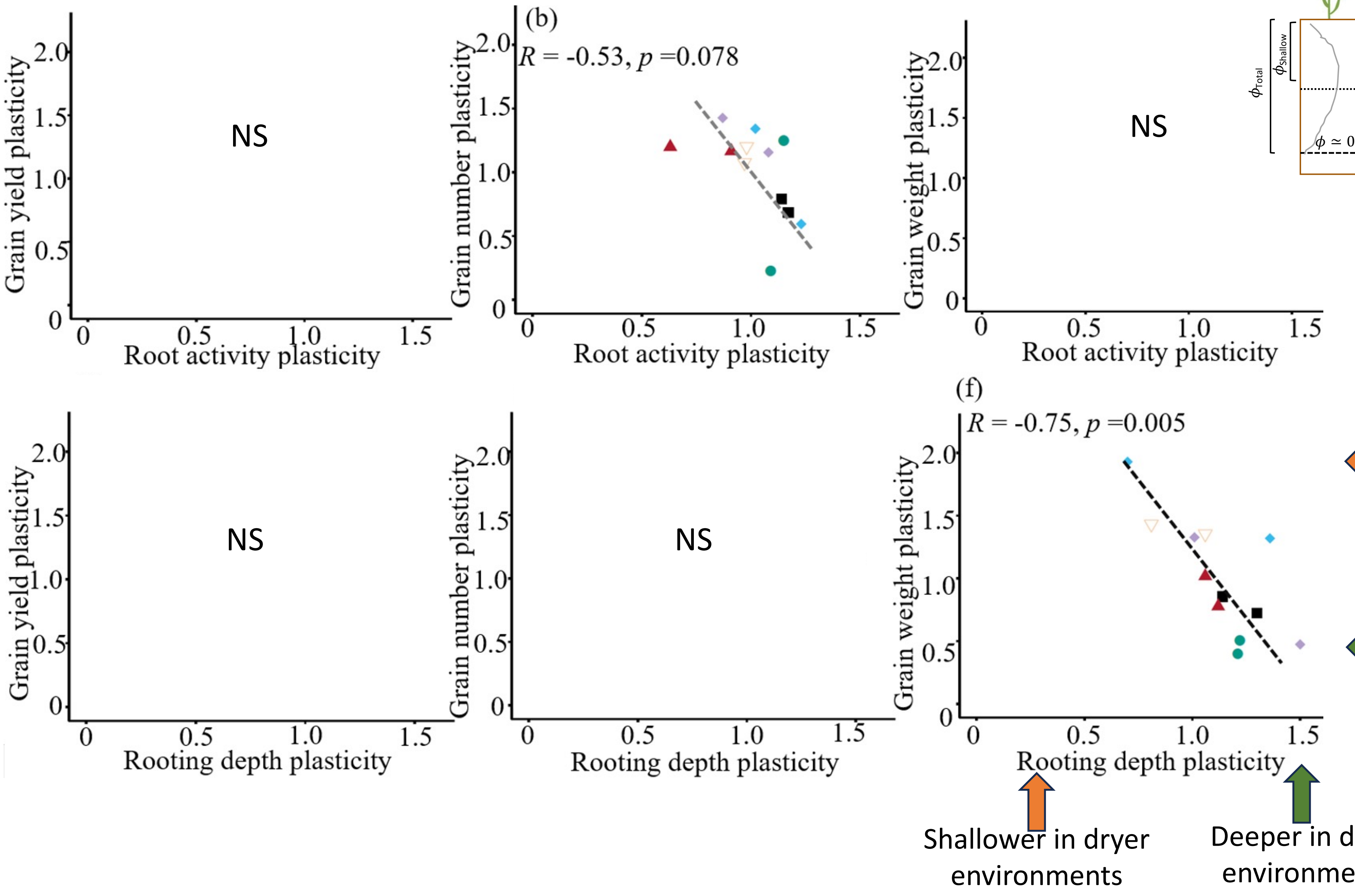
- *Can be quantified using the reaction norm*
- *Specific in patterns and directions*
- *Under specific influences (GxE; MxE)*
- *Plasticity is trait specific (plastic traits are associated to stable traits)*
- *There is a hierarchy of plasticity*
- *Specific fitness / cost / mal adaptation*

Phenotypic plasticity results from complex relationships between an individual's genotype (G) and the environment (E)

Phenotypic plasticity in root traits (sorghum)

Gatton Qld 2021, BLUPs from 6 commercial hybrids grown across 6 environments





Overcoming the root phenotyping bottleneck in cereals

Project deliverable: Phenomics methods and tools that enable root structure and function traits to be measured with at least 15% greater accuracy, cost-effectiveness, or throughput than current methods.

Research question: To what extent and for what target production environments, selecting for root traits is better than selecting for yield alone in wheat and sorghum?

Approach: *integrating new functional high throughput phenotyping tools with the trait pipeline approach applied in pre-breeding programs and commercial seed companies, where there is simultaneous development of screening methods and evaluation of valuable traits in relevant germplasm.*

Expected products:

- Accurate, fast and cost effective high-throughput phenotyping (HTP) tools for impactful root traits that increase yield, and yield stability.
- Genetic diversity of impactful root traits identified using the HTP methods on elite and non-elite panels in sorghum, and a nested-association mapping (NAM) populations in wheat.
- The value of selecting for root traits across TPEs in wheat and sorghum quantified.

Traits of interest:

Below grown

- Nodal root angles
- Rooting depth at flowering
- Rooting depth at maturity
- Root growth flowering-maturity
- Rate of root advancing front
- Relative deep/shallow water use
- Root hydraulic conductivity & root anatomy traits

Above ground

- Crop growth, grain yield and yield components
- Leaf area at flowering (proximal sensing & radiation interception)
- Stay green (proximal sensing)
- Crop water use

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