Proxy traits for drought avoidance and high yield under water-limited conditions in canola

Harsh Raman, Rosy Raman, Brett McVittie, Rameetha Pirathiban, Simon Diffey and Brian Cullis

Drought resistance is a multi-dimensional trait

Early flowering

Early maturity

Early vigour (shoot biomass, NDVI)

Transpiration efficiency

(A, gs)

Carbon isotope discrimination

Stem Carbohydrates

Cuticle wax

Root architecture

Accumulation of osmolytes

Osmoregulation

Escape — Avoidance — Tolerance

Multi-environment-trait phenotyping for drought avoidance

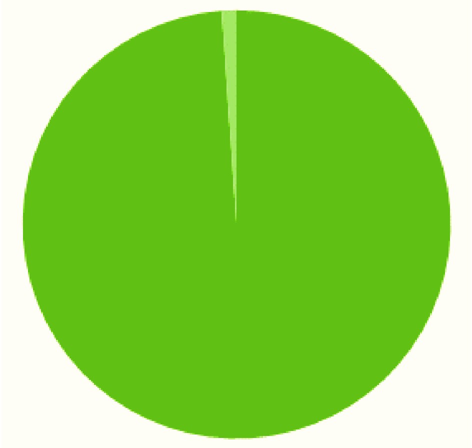
- Natural field conditions
- Rain-out shelters
  - Row plots (1000)
  - Pots
- Glasshouse
- Controlled environment chambers

NSW GOVERNMENT | Department of Primary Industries

Genetic variation in Water use efficiency (WUE)

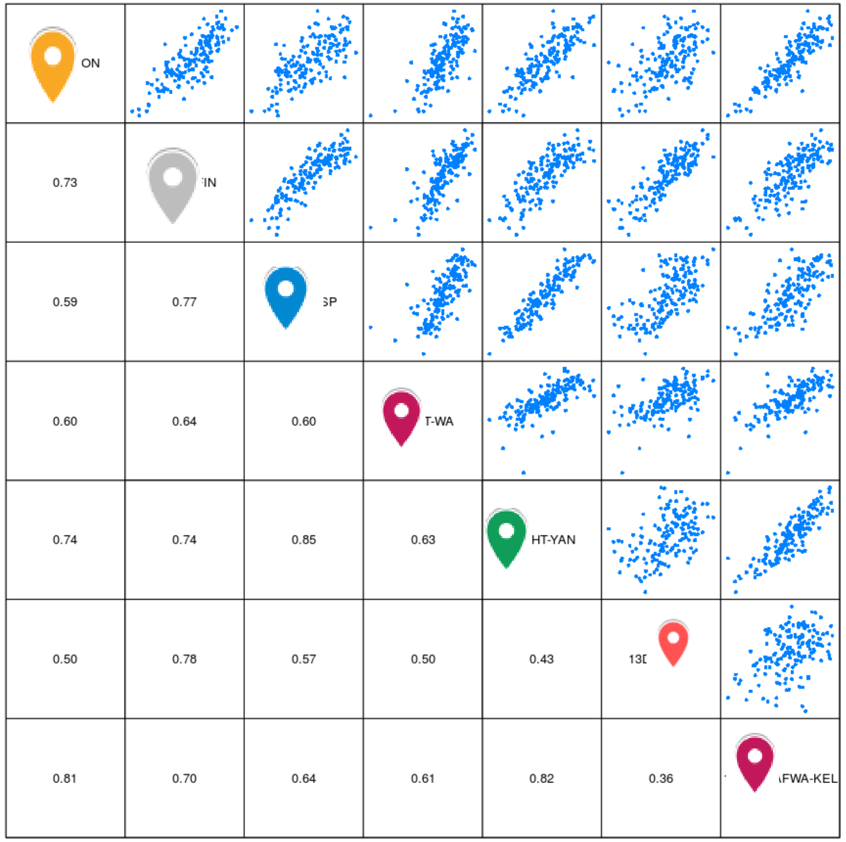
- **Plot level**, WUE
  - Grain yield/water received (irrigation or rain)
  - Total biomass/evapotranspiration
- **Plant level,** the transpiration efficiency (TE)
  - TE = biomass/water transpired.
- **Leaf level,** intrinsic WUE
  - Photosynthetic CO_2 assimilation/ Stomatal conductance
  - Carbon isotope discrimination (leaf Δ^{13}, $\delta^{13}C$) as proxy of TE

^{13}C (1.11%)



leaf $\delta^{13}C$ = the ratio of intercellular ^{13}C to atmospheric partial pressures of ^{12}C

Followed reductionist approach-MET analysis of seed yield (plot WUE, 144 lines)



Overall Performance

QTL mapping reveals genomic regions for yield based on an incremental tolerance index to drought stress and related agronomic traits in canola

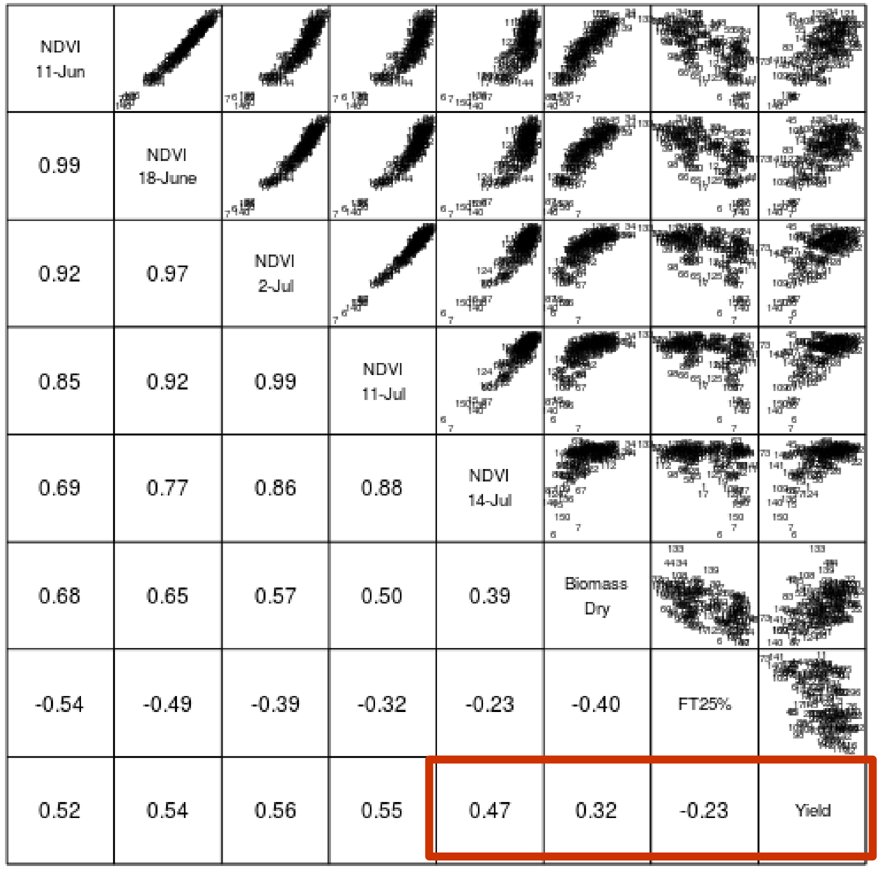
Harsh Raman [A F], Rosy Raman [A], Ky Mathews [B], Simon Diffey [C] and Phil Salisbury [D E]

+ Author Affiliations

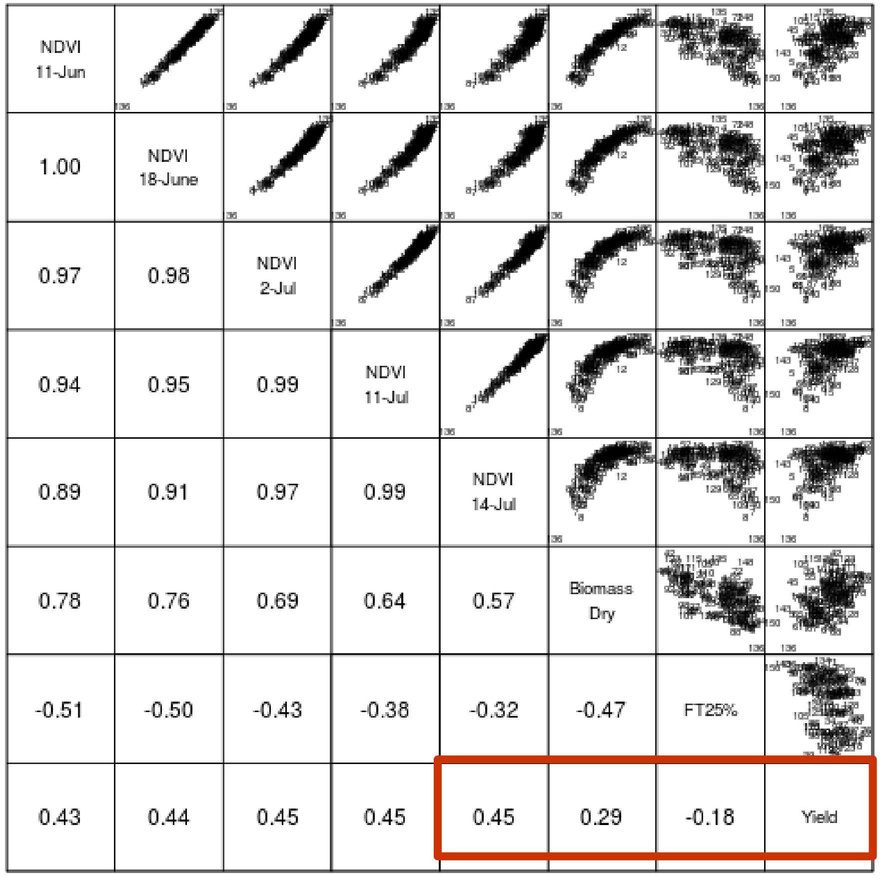
Crop and Pasture Science 71(6) 562-577 https://doi.org/10.1071/CP20046
Submitted: 14 February 2020 Accepted: 30 April 2020 Published: 16 May 2020

NSW GOVERNMENT Department of Primary Industries

Biomass and NDVI correlate with seed yield across environments



Finley (DRY)

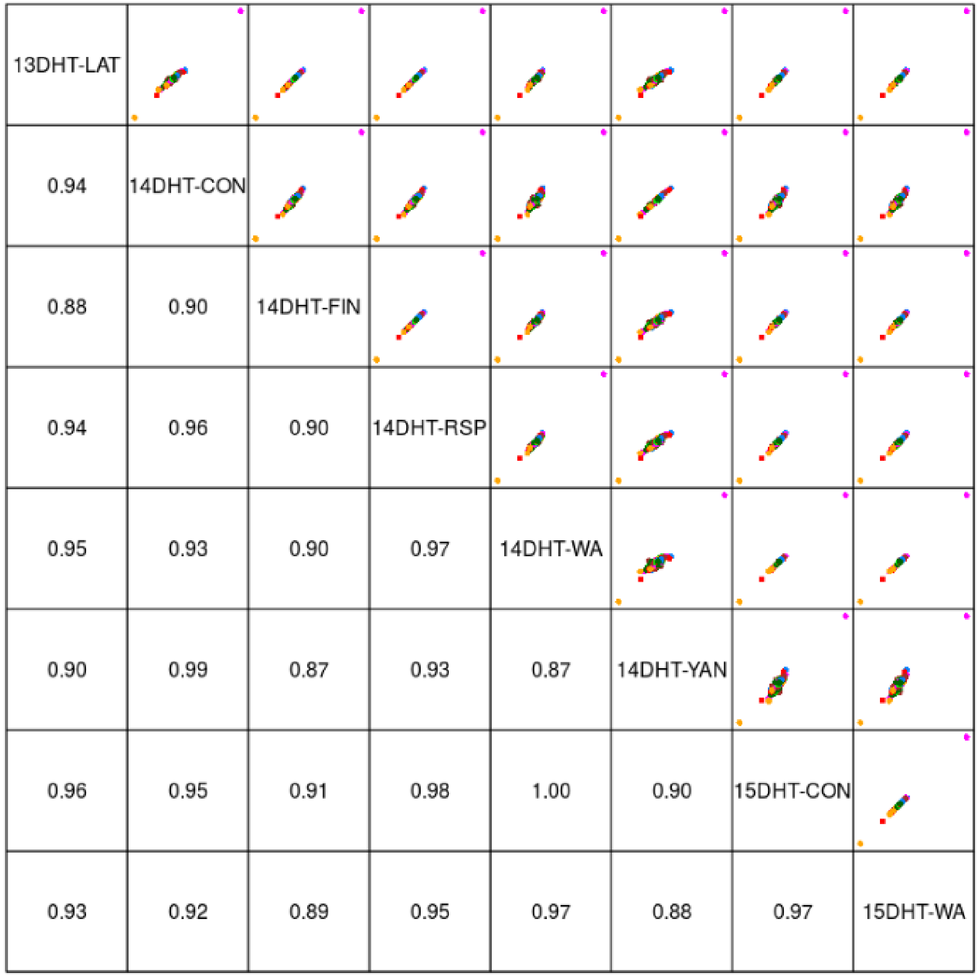


Finley (WET)

NSW GOVERNMENT Department of Primary Industries

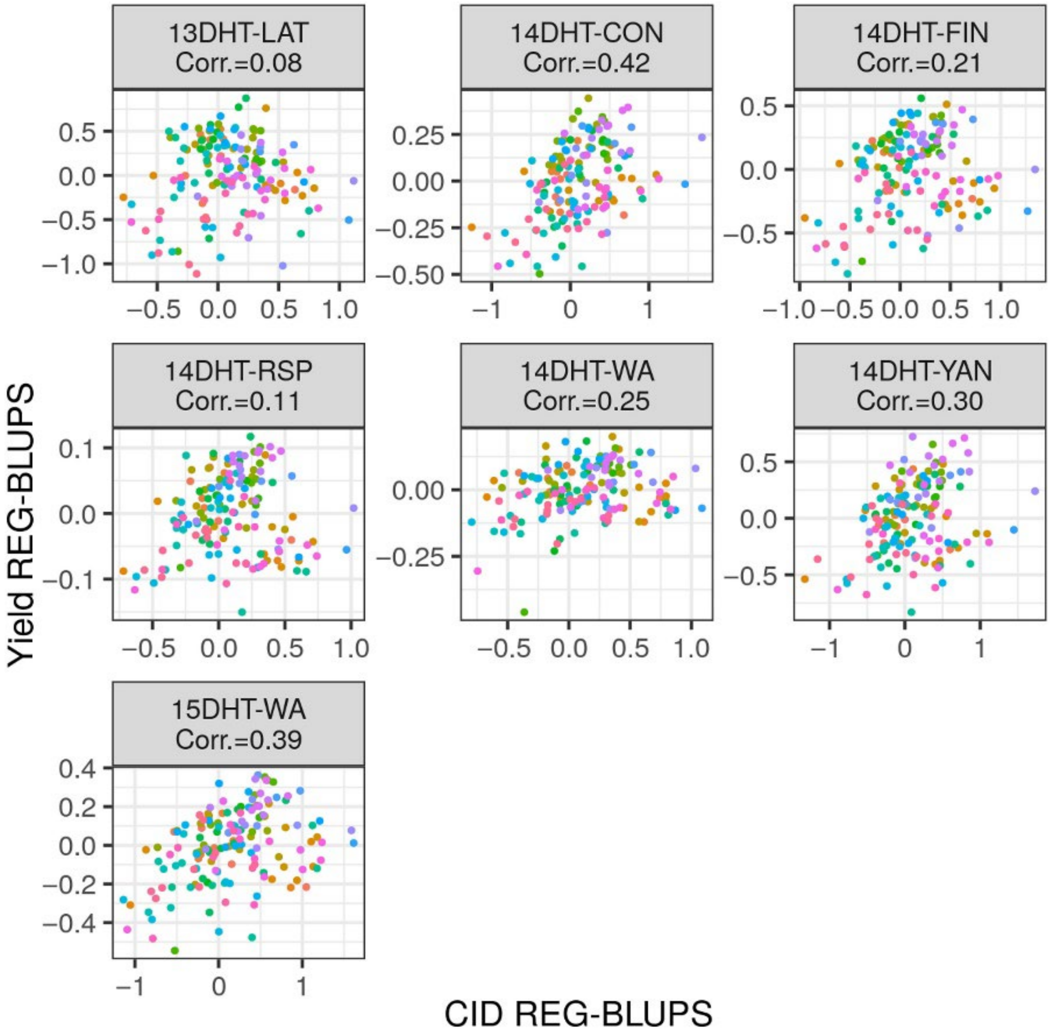
Genetic variation for leaf $\Delta^{13}C$ variation (8 Expts)

- **Field Phase**
  - Leaf sample from replicated field
- **Laboratory phase**
  - Internal replication
  - $\delta^{13}C$ analysis



NSW GOVERNMENT | Department of Primary Industries

Multi-environment analysis based Δ^{13} estimations showed a positive correlation with seed yield



Multi-trait QTL maps to Δ^{13}, most of R^2 is due to *FT* gene expression (A07)

Food and Energy Security
Open Access

ORIGINAL RESEARCH | Open Access

Genetic and physiological bases for variation in water use efficiency in canola

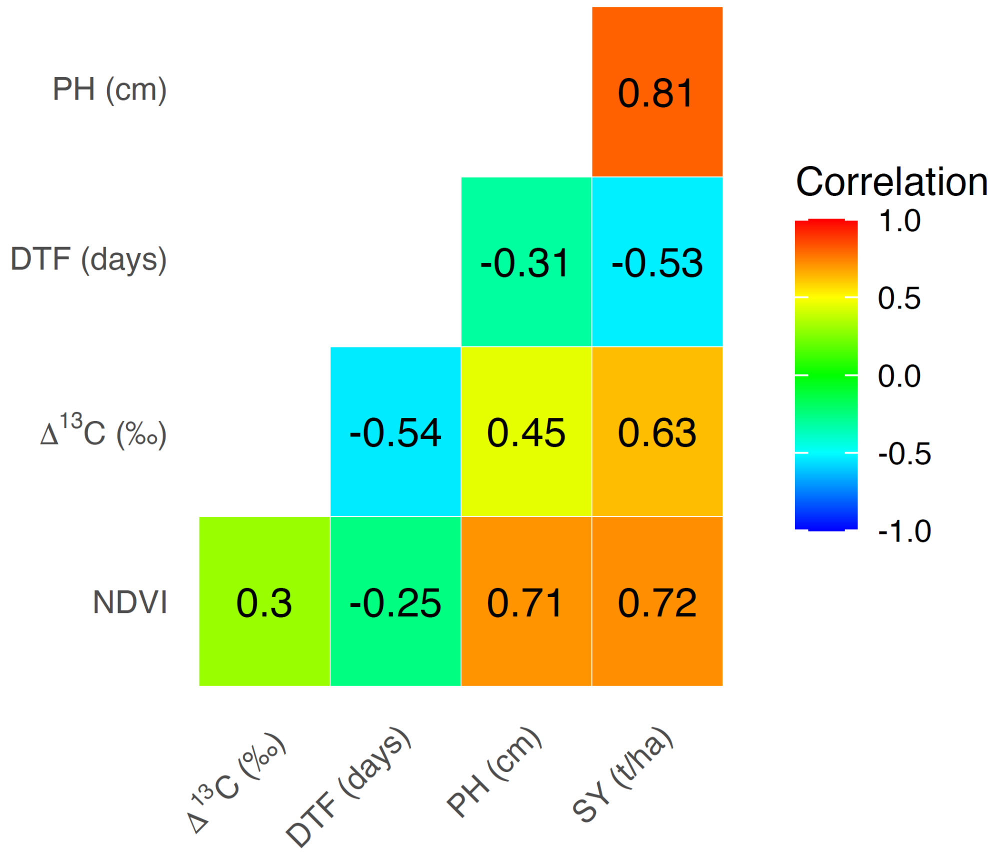
Harsh Raman, Rosy Raman, Brett McVittie, Lauren Borg, Simon Diffey, Avilash Singh Yadav, Sureshkumar Balasubramanian, Graham Farquhar

First published: 14 August 2020 | https://doi.org/10.1002/fes3.237

NSW GOVERNMENT | Department of Primary Industries

Δ^{13} as a proxy for high seed yield in three environments in a DH population (Raman et al. 2022)

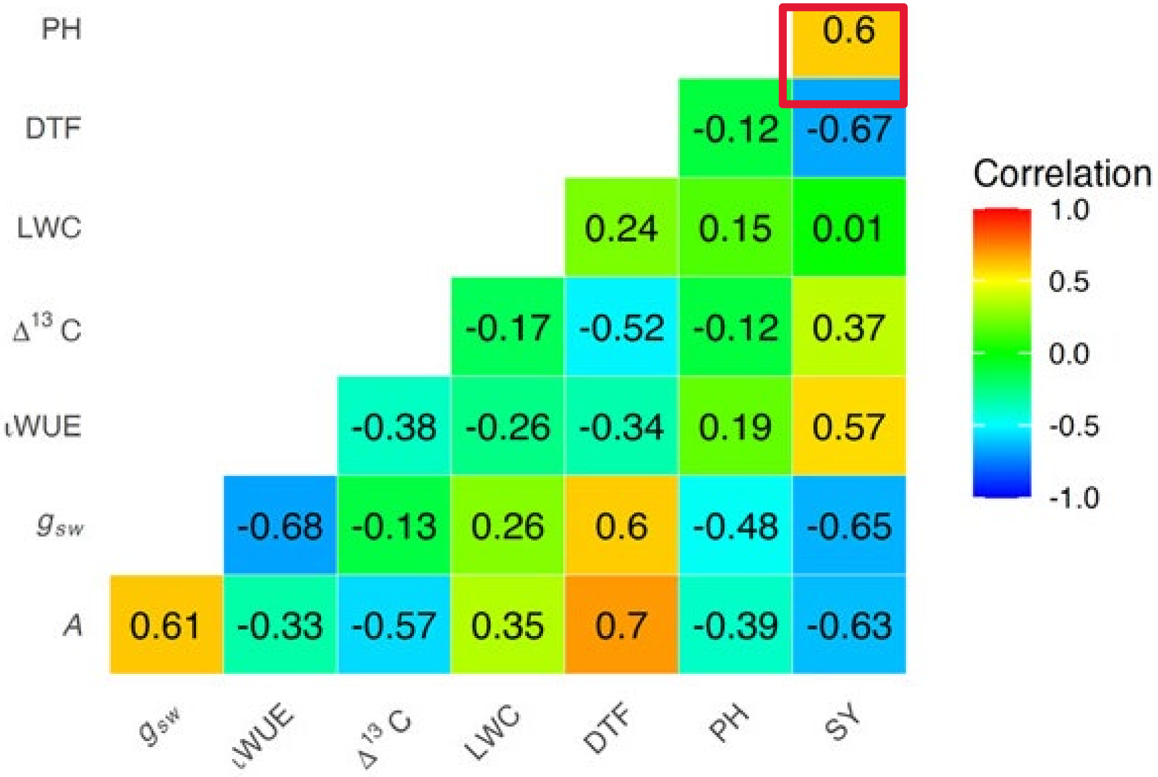
- BC1329/BC9102
  - 223 lines
- Phenotyping
  - Field (2017, 2018)
  - Rain-out shelter (WET/DRY)
- QTL for G and G x E interactions
- Candidate and gene expression analyses

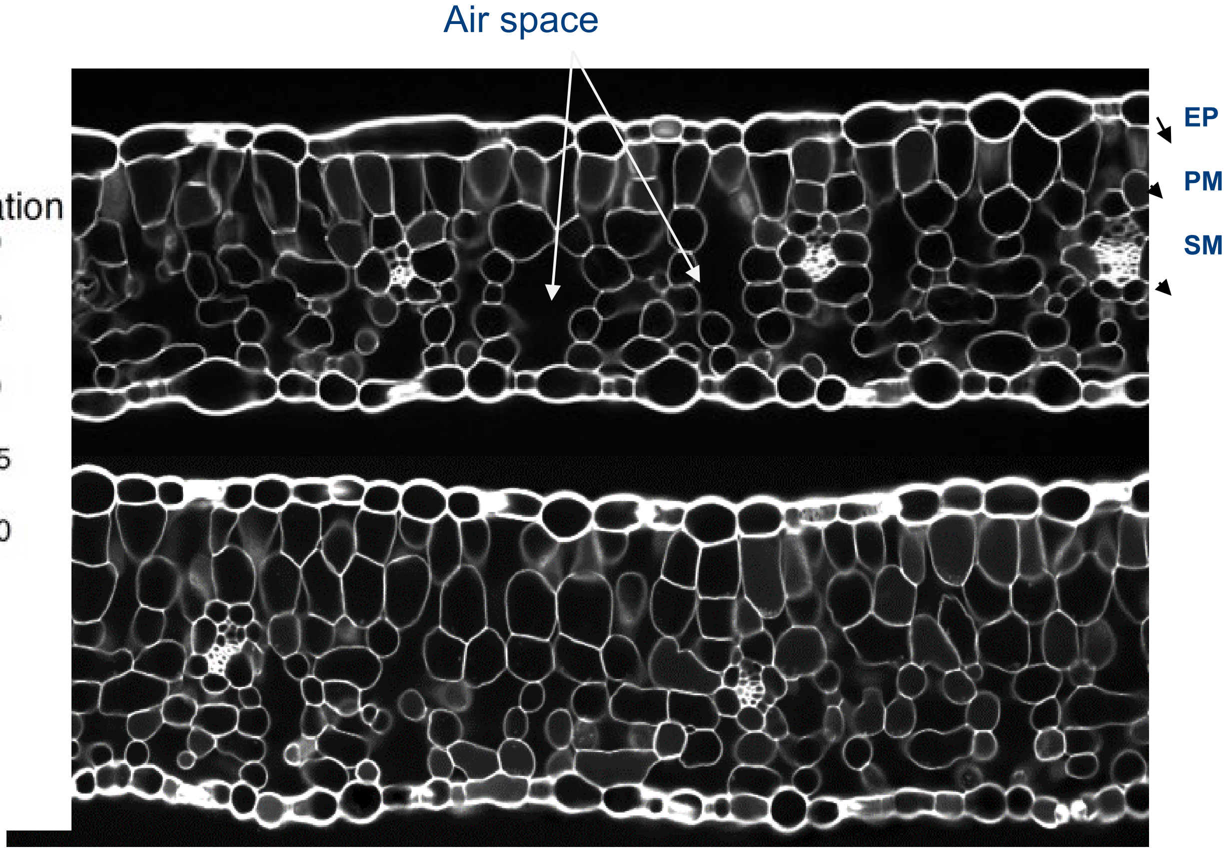


ADVANTA

NSW GOVERNMENT Department of Primary Industries

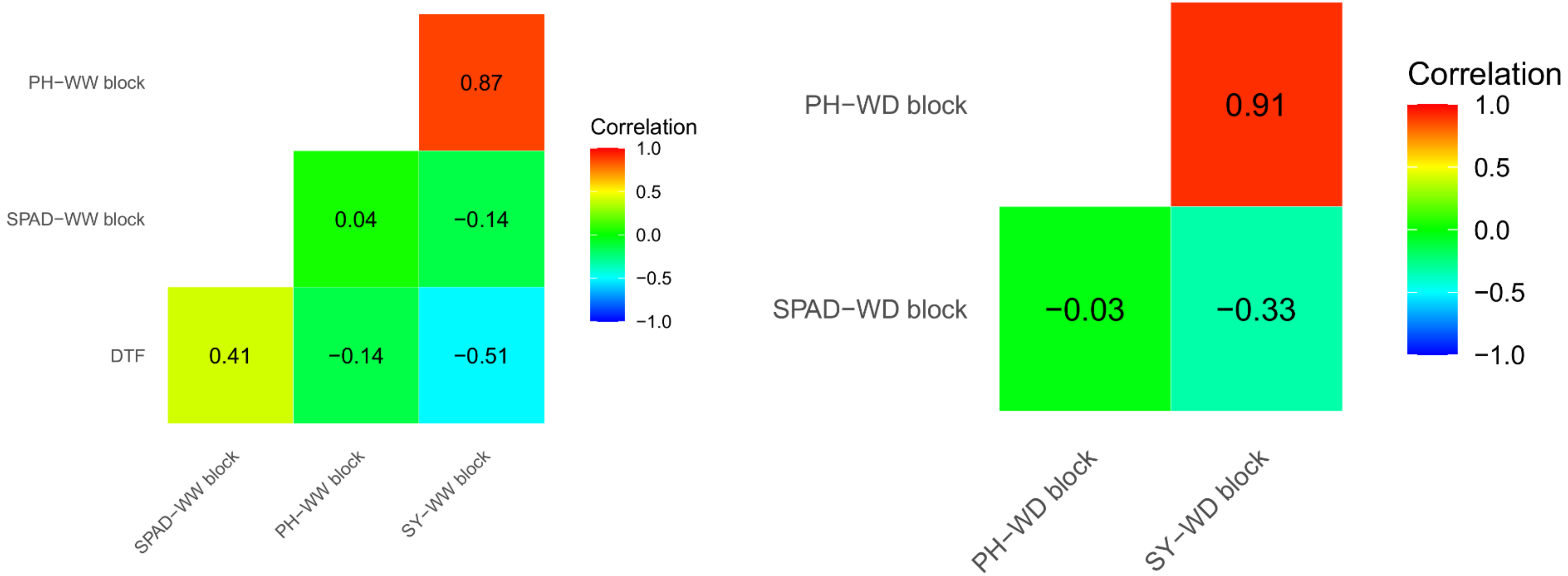
Positive genetic correlation between iWUE (TE) and seed yield (TE as a proxy)





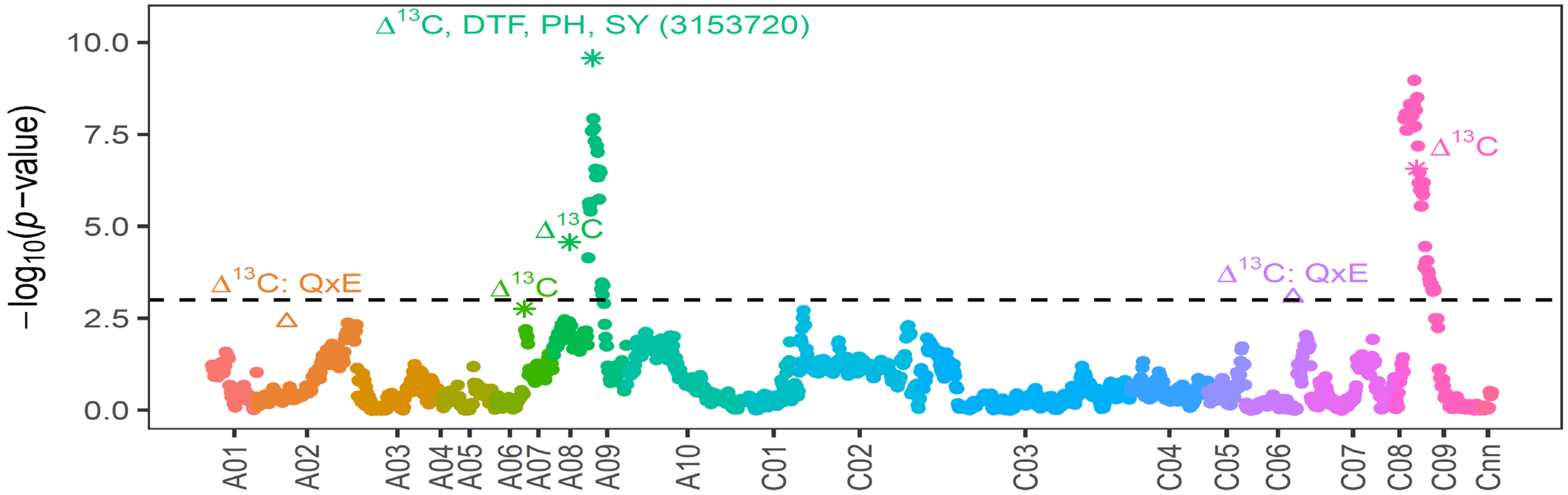
Rain-out shelter

SPAD can be used as proxy for seed yield (Raman et al 2023, *Plants*, *12*(4), 720



Department of Primary Industries

Multi-trait QTL collocates with seed yield (Raman et al 2022)



Role of pleiotropy can be dissected

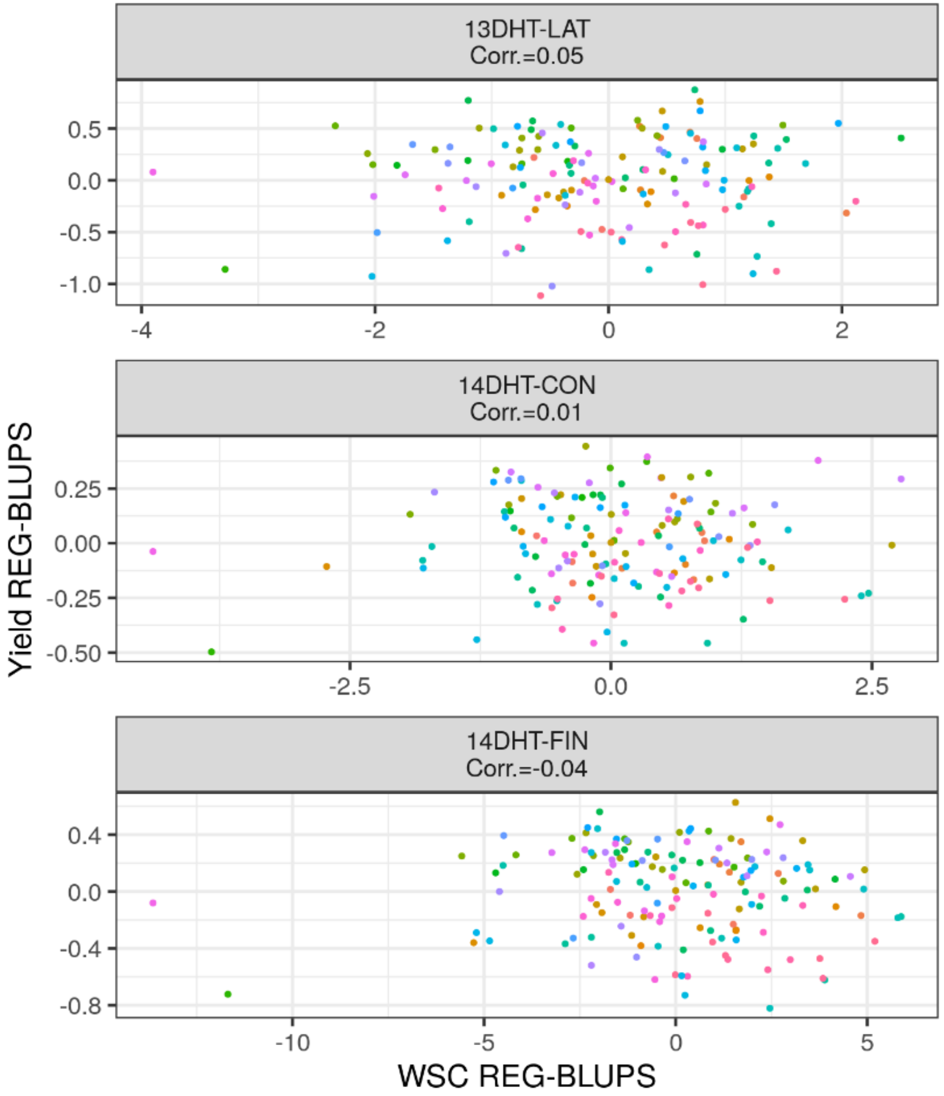
Plant, Cell & Environment

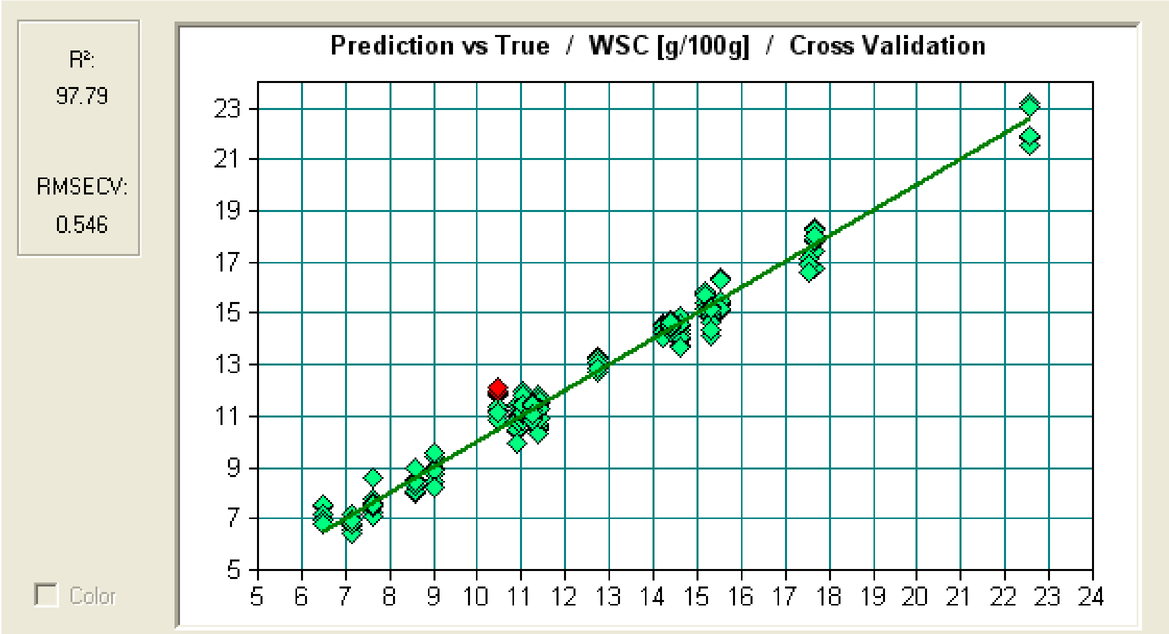
ORIGINAL ARTICLE | Open Access

Multienvironment QTL analysis delineates a major locus associated with homoeologous exchanges for water-use efficiency and seed yield in canola

Harsh Raman, Rosy Raman, Ramethaa Pirathiban, Brett McVittie, Niharika Sharma, Shengyi Liu, Yu Qiu, Anyu Zhu, Andrzej Kilian, Brian Cullis, Graham D. Farquhar, Hilary Stuart-Williams, Rosemary White, David Tabah, Andrew Easton, Yuanyuan Zhang

Water soluble carbohydrate content is **not correlated** with seed yield across environments





Richard Meyer, WWAI

NSW GOVERNMENT | Department of Primary Industries

Genetic variation for root pulling force in canola

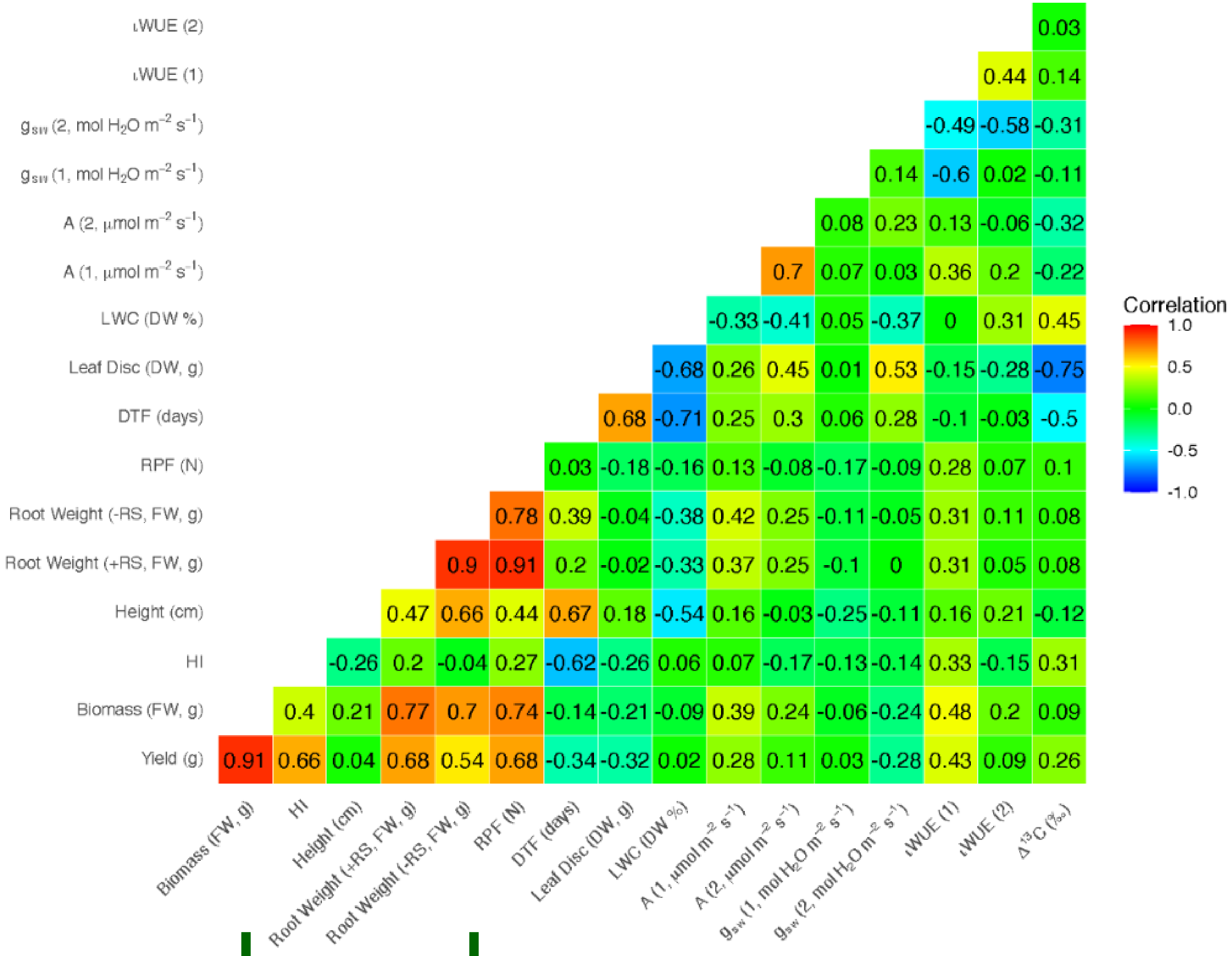
- GWAS panel
  - 320 lines
- DH panel
  - 223 lines
- *B. napus* (24 lines)
  - Field (WET and DRY)
  - Rain-out shelter (WET and DRY)

90 cm

ADVANTA

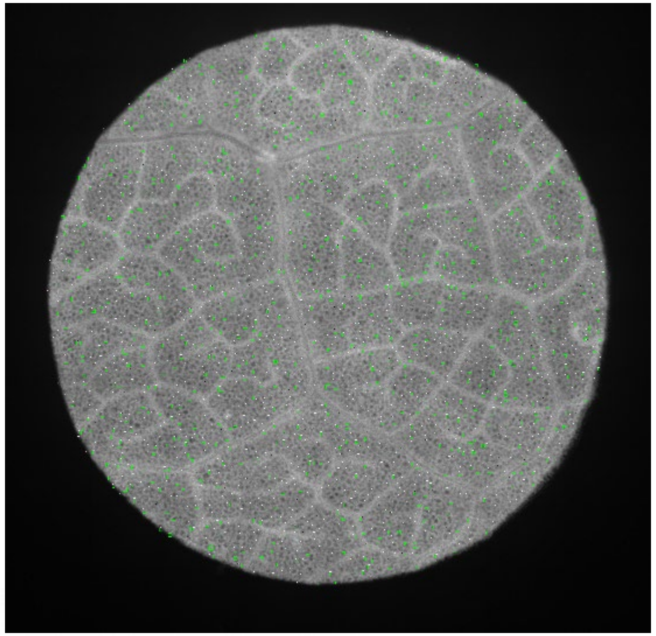
NSW GOVERNMENT Department of Primary Industries

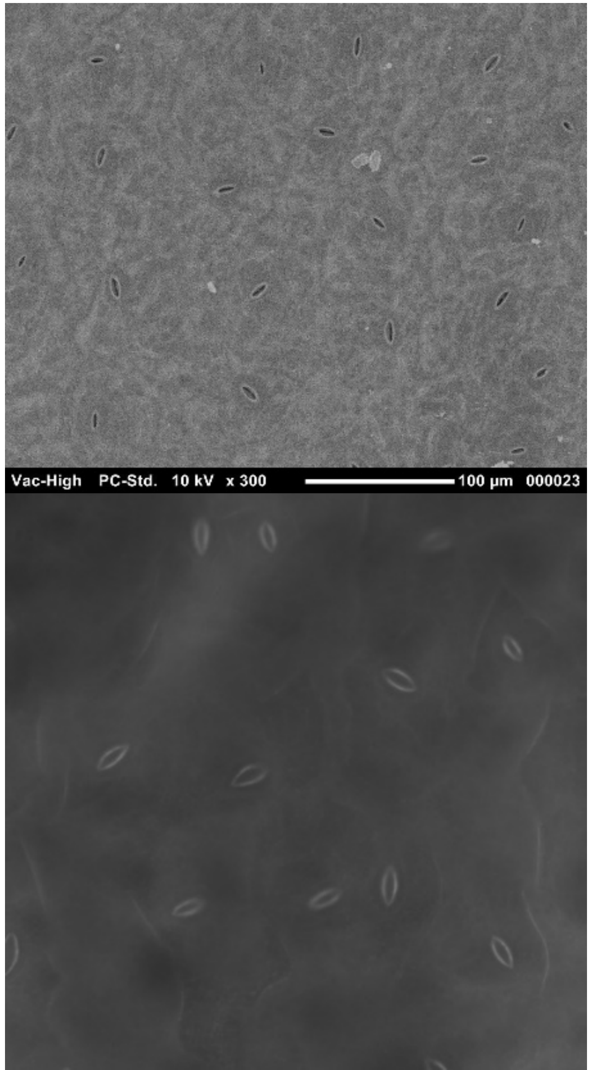
Positive relationship between seed yield and root pulling force (Raman et al, unpublished)

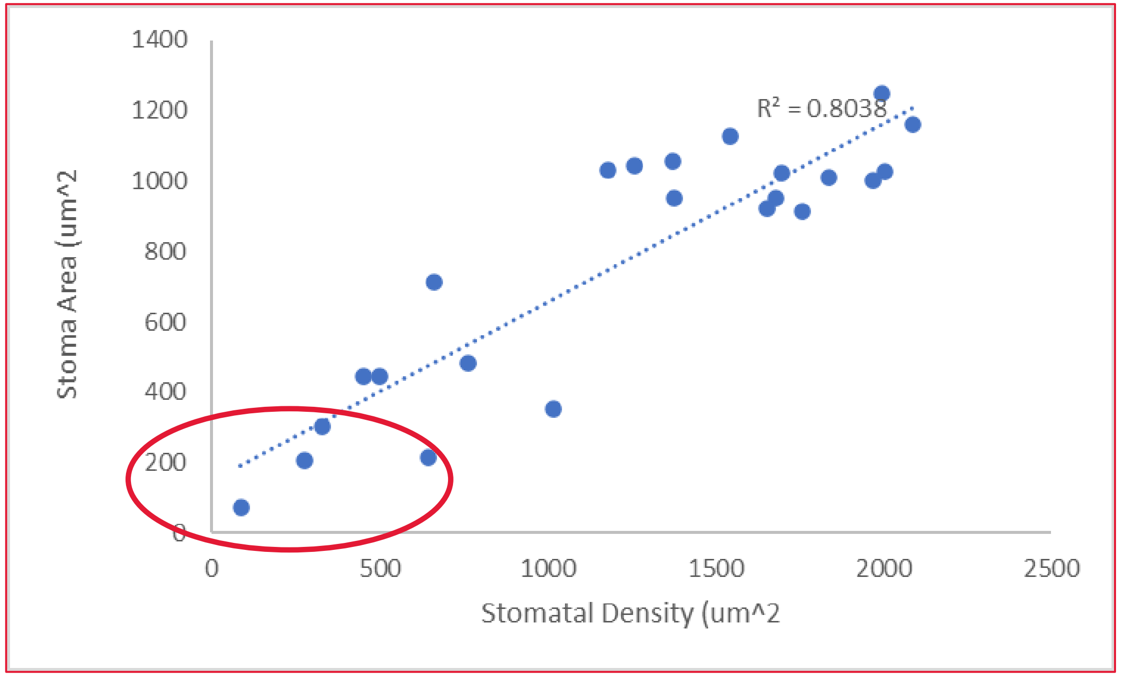


NSW GOVERNMENT | Department of Primary Industries

Machine learning based stomatal density & area relates to transpiration efficiency (unpubl.)





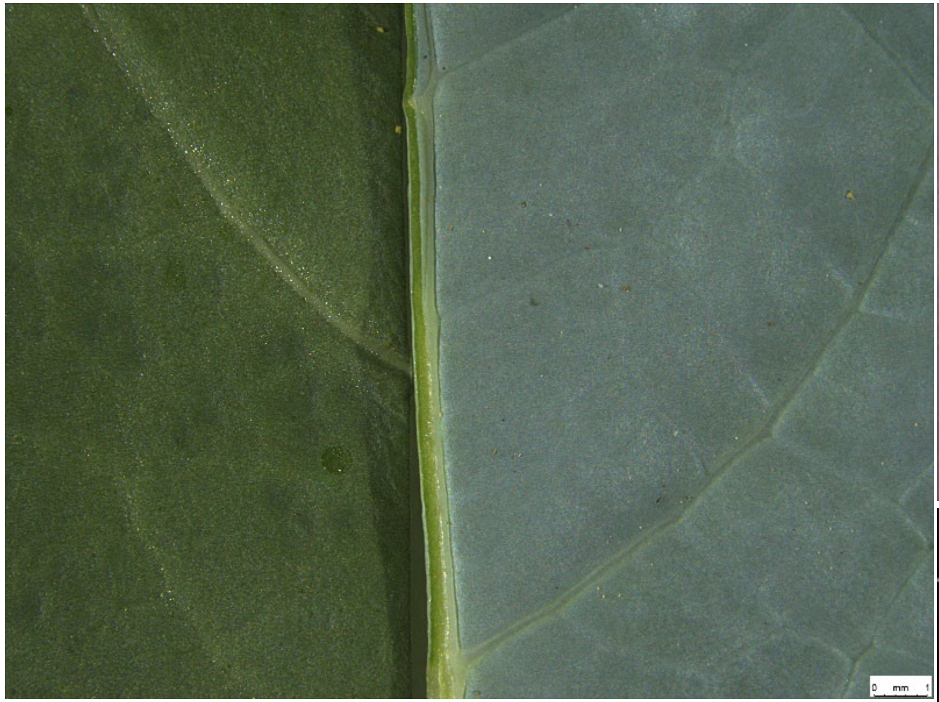


High TE lines

UNSW AUSTRALIA

NSW GOVERNMENT Department of Primary Industries

Potential proxy traits for drought avoidance



Summary

- Substantial variation in avoidance traits exists in canola
  - $\Delta^{13}C$ (>6.3‰)
  - Root pulling force
  - Specific leaf weight
  - SPAD
  - Transpiration efficiency (*iWUE*)
  - Waxiness
  - Stomatal and root hair density
- Markers + phenotypic tools can be used as proxies for drought avoidance traits
  - Some of the proxy traits need validation across environments

Multivariate analysis-based indexing

NSW GOVERNMENT Department of Primary Industries

Thank you!

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

中国农业科学院油料作物研究所
OCRI CAAS

ADVANTA

Apex Biometry
Your statistical partner in agricultural research

NSW GOVERNMENT
Department of Primary Industries