Drought adaptation in sorghum – associations with nodal root angle and root system architecture

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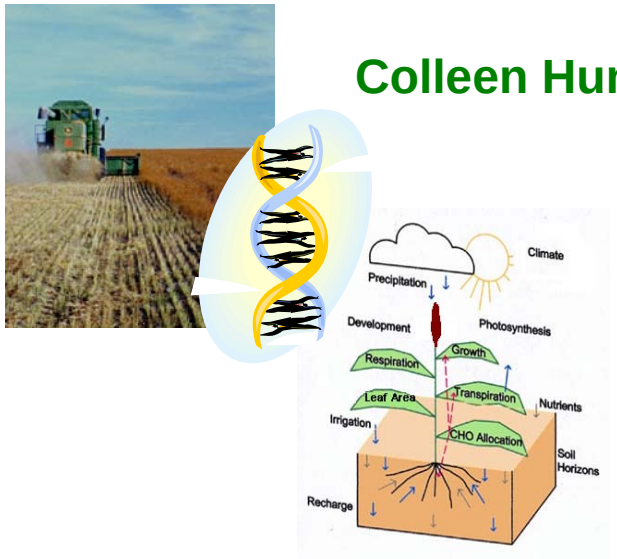

Working together with the Queensland Government

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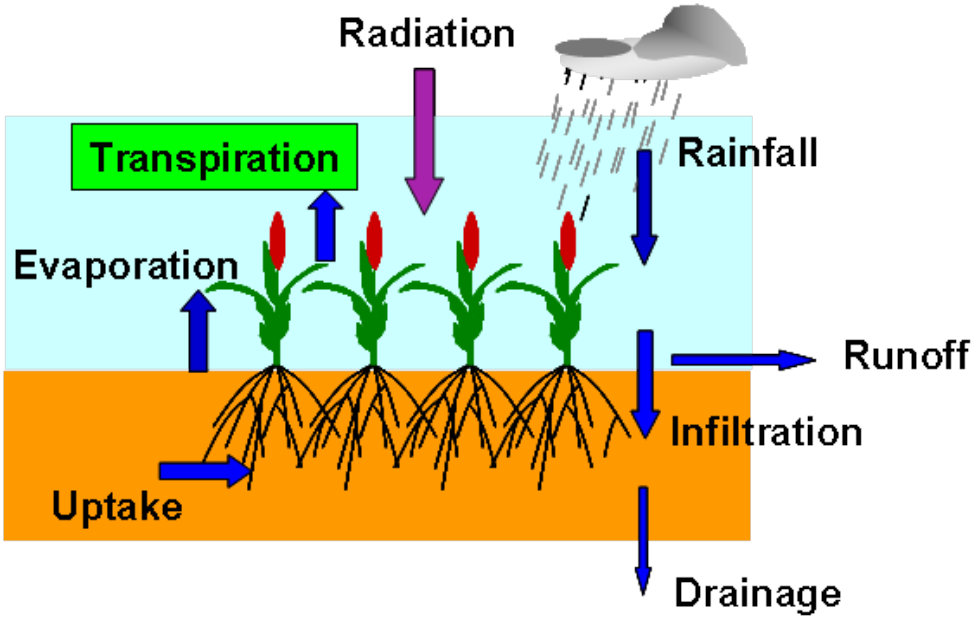
Outline

1. Dryland crop productivity and water capture - principles
2. What is the water foraging capacity of sorghum root systems?
3. How do sorghum root systems develop?
4. Is there genetic variation?
5. Does genetic variation in nodal root angle affect water capture of mature plants?
6. Does this genetic variation associate with dryland crop productivity?
7. So What?

1. Dryland Crop Productivity

- Dryland crop water balance components
- Grain mass (M) is given by T x TE x HI
- HI relates to distribution of T in the crop cycle



- Can aspects of root system architecture affect extent of water capture (T) and timing of access (HI)?

2. Water Foraging Capacity of Sorghum Roots?

Field assessment of potential uptake

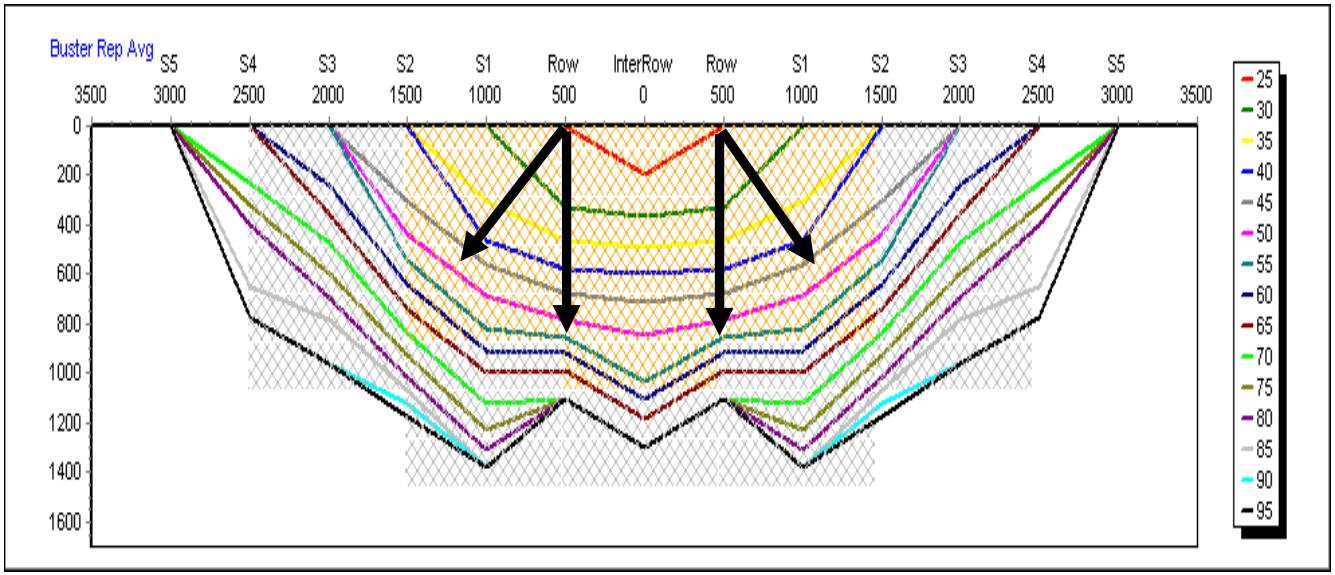
Broad and Hammer (2004) 4th ICSC, Brisbane

- RO shelter experiment
- Extent of root system growth and water capture
- Frequent sampling of soil water
- Less frequent sampling of roots!

2. Water Foraging Capacity of Sorghum Roots?

Field assessment of potential uptake

- Progression of water extraction front through soil profile



- Quantification of extraction front progression and extraction capacity
- Basis for modelling

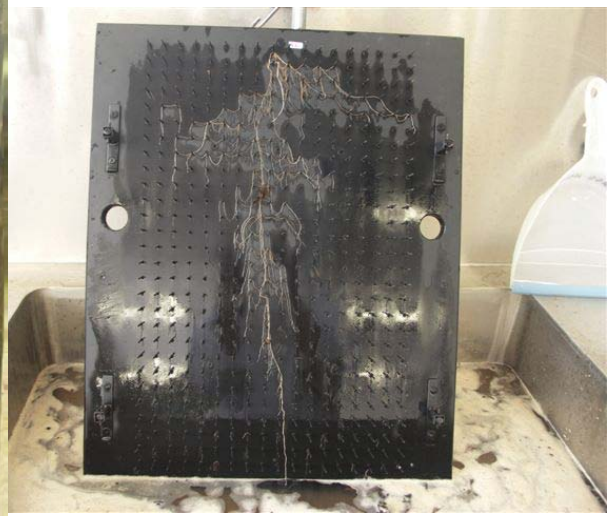
Broad and Hammer (2004) 4th ICSC, Brisbane

3. How do Sorghum Root Systems Develop?

Lab and glasshouse assessment of root development

Singh et al. 2010. Plant and Soil 333: 287-299

- Soil filled chambers
- 40 cm wide, 60 cm deep, 5 cm thick
- 4 hybrids; 3 reps
- 5 harvests (2-6 leaf stage)
- Wash out root systems on pinboard and image



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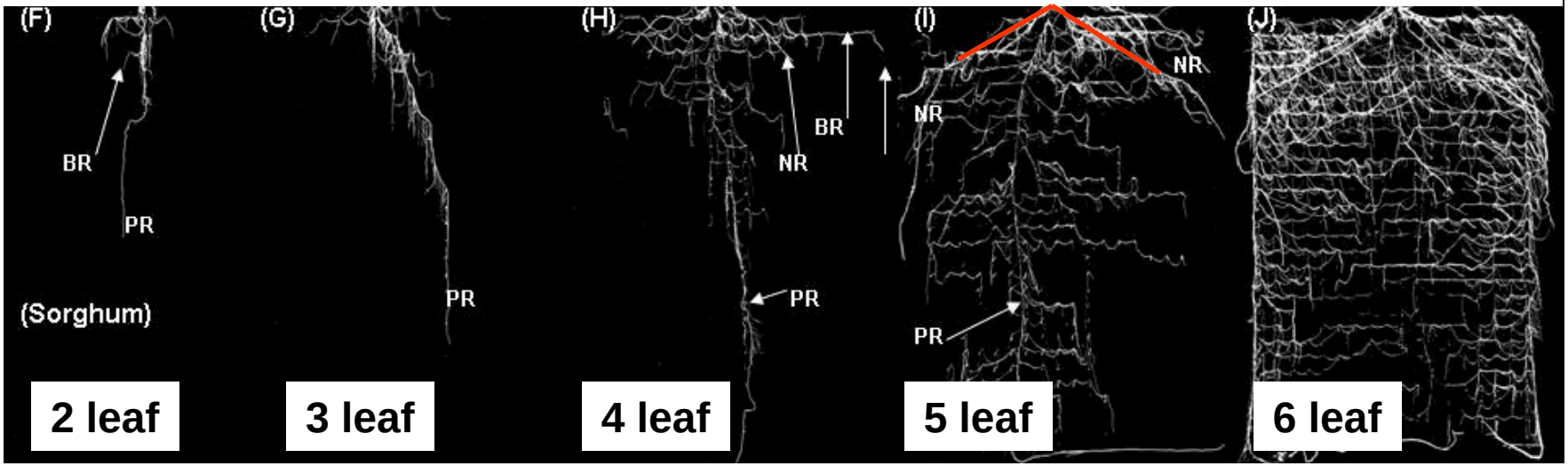


- Sorghum produced only 1 seminal root
- Nodal roots started to appear at 5-6 leaf stage
- Some suggestion of genotypic differences in nodal root angle
- Leaf 5-6 appears to be a critical stage for root screening (angle)
- Phenotyping requires chambers of at least 45 x 50 cm

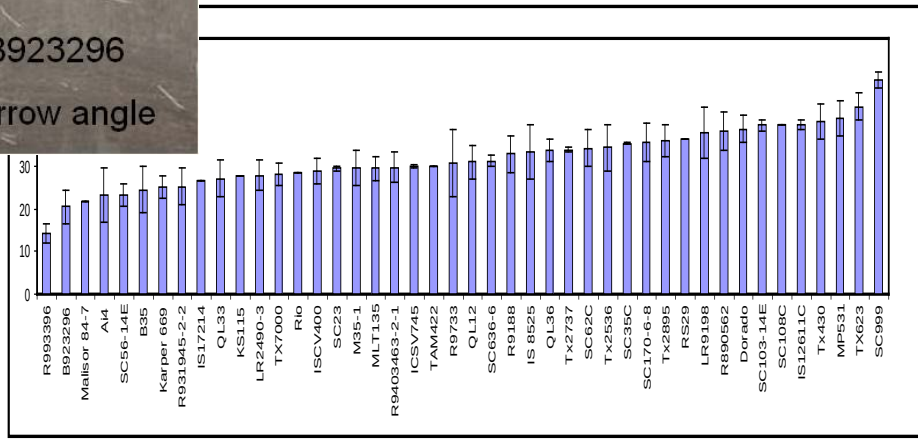
4. Is there Genetic Variation in Root System Architecture?

Glasshouse screen of nodal root angle

Singh et al. 2011. Crop Science, 51:2011–2020

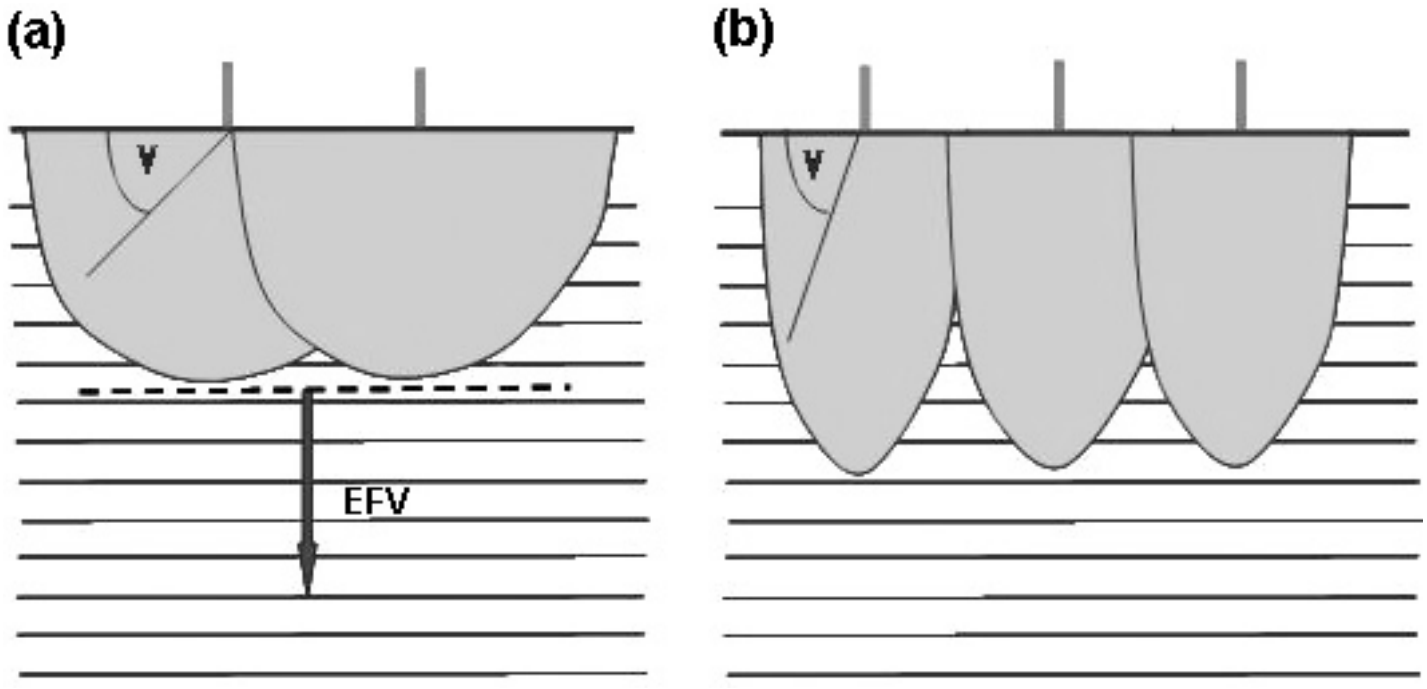
- 214 genotypes screened
- Inbred lines - variation
- Hybrids - inheritance

- Inbred range 15-50^{o}
- Heritability 70%
- Some SCA in hybrids
- Strong G effect



5. Does Genetic Variation in Seedling Nodal Root Angle Affect Water Capture of Mature Plants?

Hammer et al. 2009. Crop Sci. 49: 299-312.
Manschadi et al 2006 Funct Plant Biol. 33: 823-837.



5. Does Genetic Variation in Nodal Root Angle Affect Water Capture of Mature Plants?

Large rhizotron experiments

- Rhizotrons 120 x 240 x 10 cm
- 4 inbred lines grown on stored soil moisture and harvested at anthesis
- Plant positioned 60 cm from side
- GWC at anthesis on 20x20 cm grid

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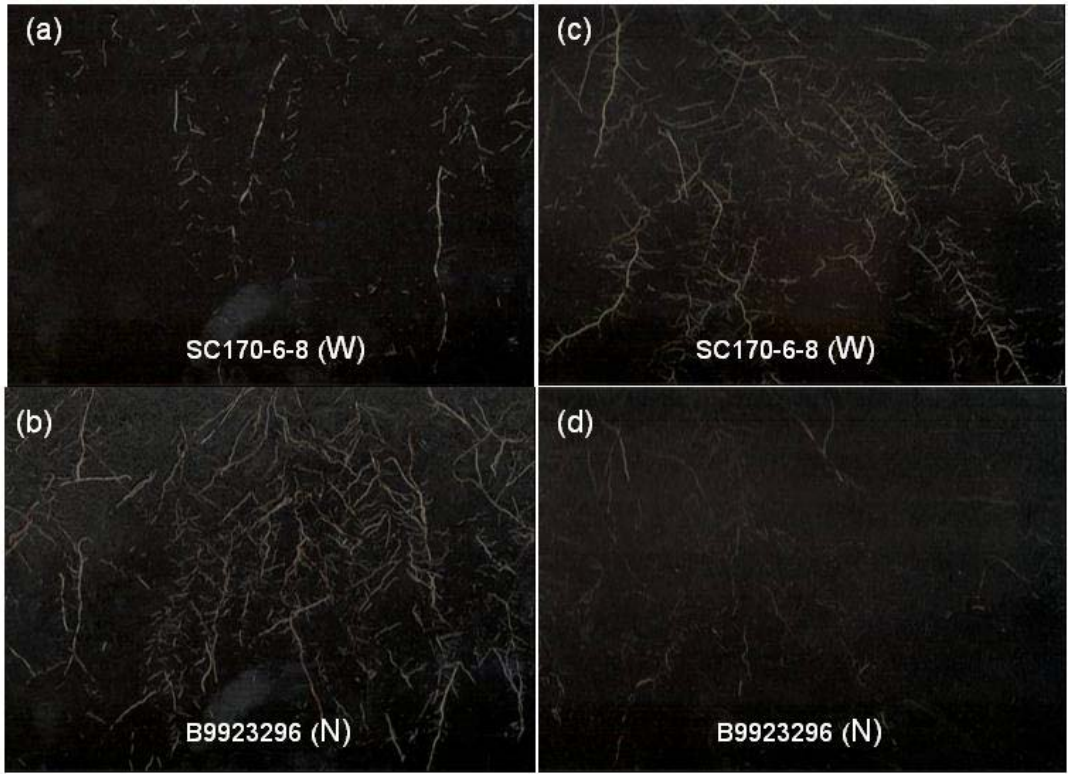
Large rhizotron experiments



Wide angle hybrid

Narrow angle hybrid

Below plant **Distant to plant**

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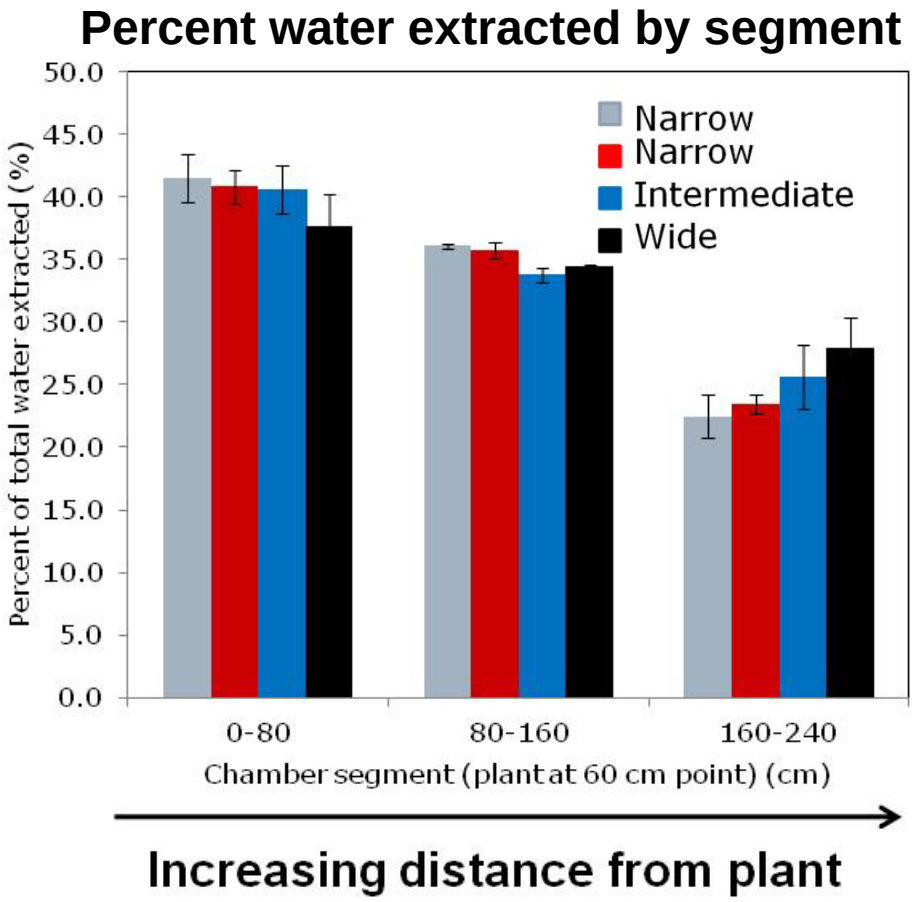
Large rhizotron experiments



- Used % to allow for differences in plant size.
- Wider root angle tended to have:
  - relatively less water extraction close to plant
  - and relatively more away from the plant

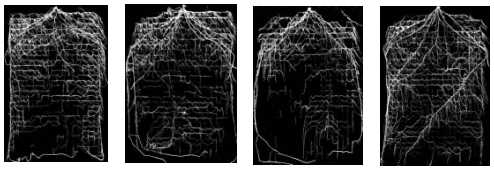
6. Does Genetic Variation Associate with Productivity?

QTL for nodal root angle and yield association

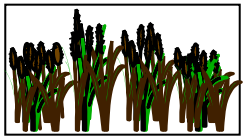
Mace et al. 2012. Theor Appl Gen, 124: 97-109

- QTLs from screening expt – parents & mapping population
- Check with yield performance in breeding trials :
  - Nested Association Mapping (NAM) populations
  - RILs in hybrid combinations

Mace et al. 2012. Theor Appl Gen, 124: 97-109

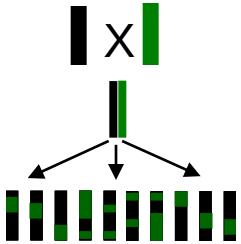


Root architecture variation: rapid screening methodology



Parental lines of mapping populations, NAM populations and breeding populations screened

Mapping population



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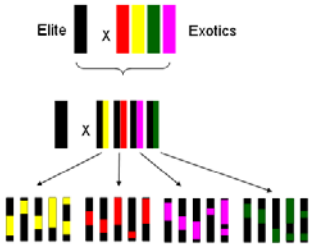
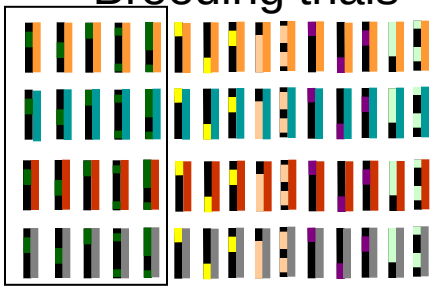
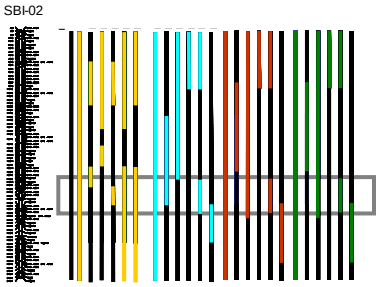


Breeding trials

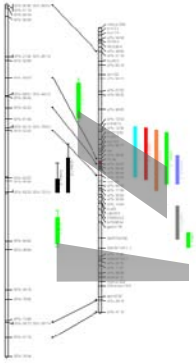




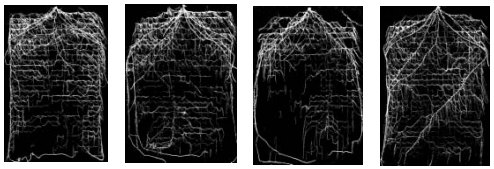
Identify genomic regions and multiple alleles

Project onto consensus map

and align to WGS



Mace et al. 2012. Theor Appl Gen, 124: 97-109



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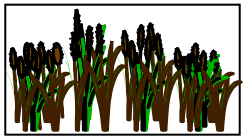

Parental lines of mapping populations, NAM populations and breeding populations screened

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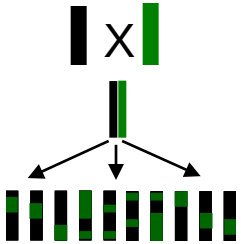
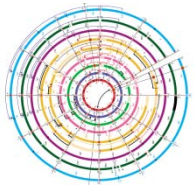


NAM populations

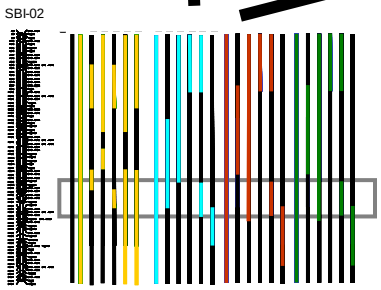
Breeding trials

Population screening and pre-existing performance data from NAM populations and breeding trials



List of candidate genes

Comparative genomics



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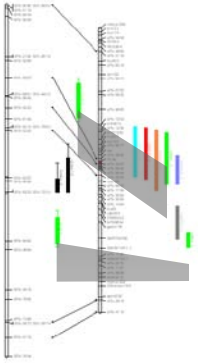
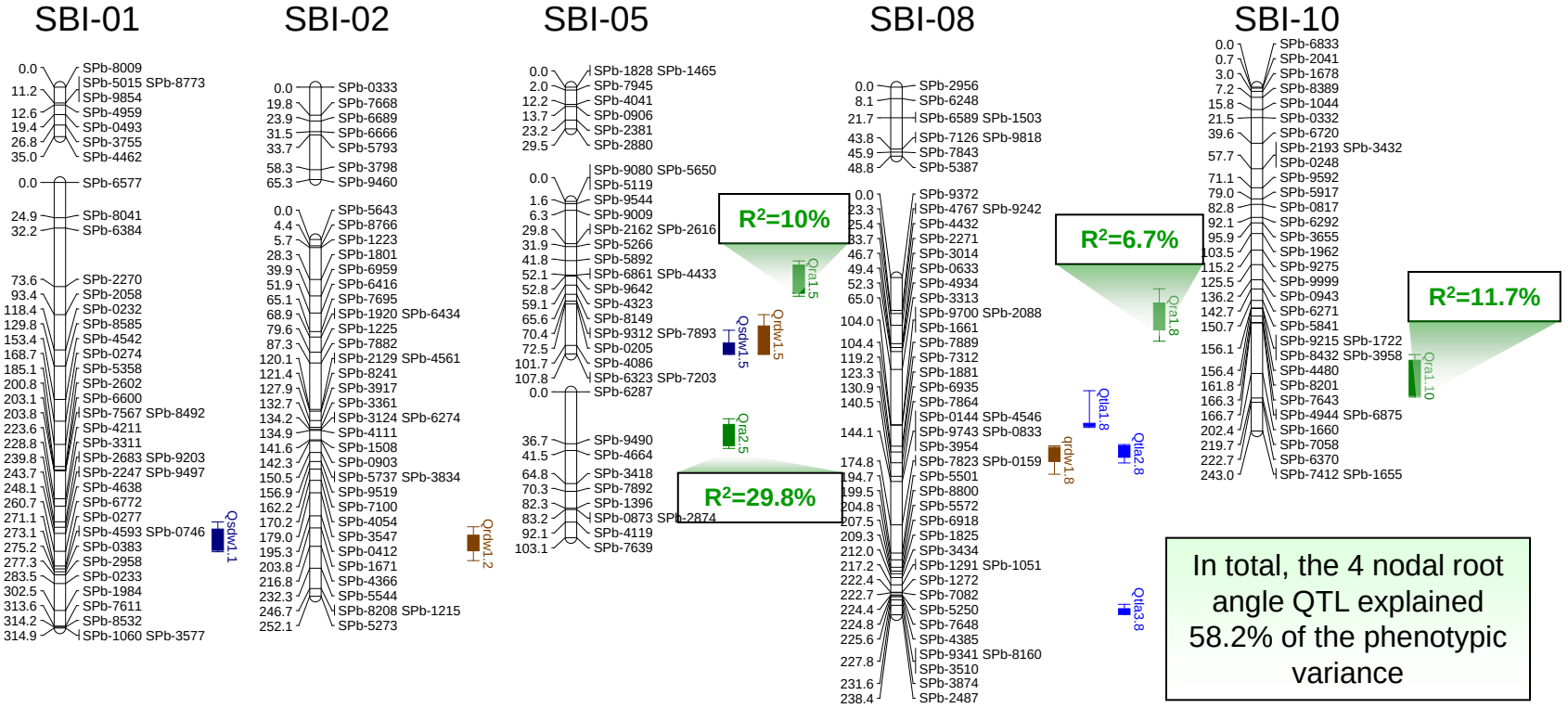


6. Does Genetic Variation Associate with Productivity?

QTL for nodal root angle and yield association



In total, the 4 nodal root angle QTL explained 58.2% of the phenotypic variance

Localisation of QTL for four traits measured in this study.

QTL are colour-coded according to trait;

nodal root angle - green; root dry weight - brown; shoot dry weight - dark blue; total leaf area - light blue.

Mace et al. 2012. Theor Appl Gen, 124: 97-109

6. Does Genetic Variation Associate with Productivity?

QTL for nodal root angle and yield association

Significance level of association between markers in the four nodal root angle QTL regions with grain yield in subsets of the RIL population in three different hybrid combinations (but small number of individuals - 53).

		Tester for RIL/hybrid combination		
QTL	**LG**	**R995248**	**R986087**	**R993396**
qRA1_5	SBI-05-II	0.0228 +	NS	0.0696 +
qRA2_5	SBI-05-III	NS	NS	NS
qRA1_8	SBI-08-II	0.0602 +	0.0780 +	NS
qRA1_10	SBI-10	0.0087 **	0.0415 +	NS

NS not significant P>0.1;
+ P<0.1;
** P<0.01;

The genetic regions controlling nodal root angle are also having an effect on yield

Yield was increased in the presence of the narrow root angle allele

Mace et al. 2012. Theor Appl Gen, 124: 97-109

7. So What?

- Good evidence for association of genetic variation in nodal root angle with drought adaptation via effects on RSA and water capture
- Targeted high(-ish) throughput phenotyping system derived from ecophysiological insight
- Strong genetic control, marker associations, species homology
- *Opportunity for phenotyping system and molecular breeding*
- *Opportunity for root system design simulation (G-to-P models & G(QTL)*M*E)*
- Needs confirmatory studies but the breeder is off and running!

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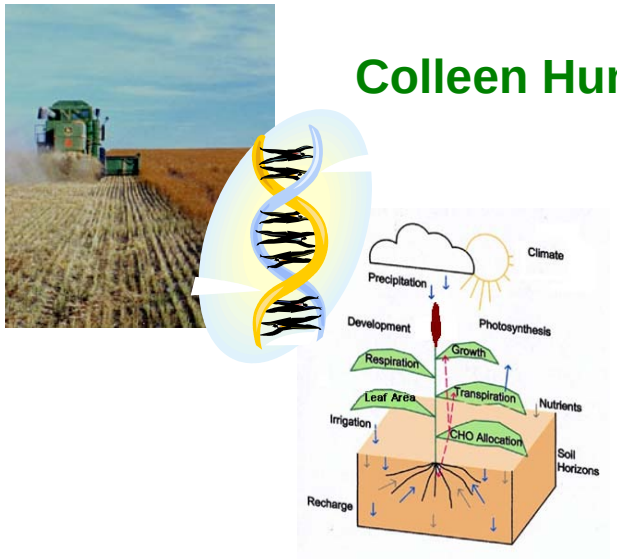

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