Modelling the ecophysiological and genetic control of the staygreen trait in sorghum

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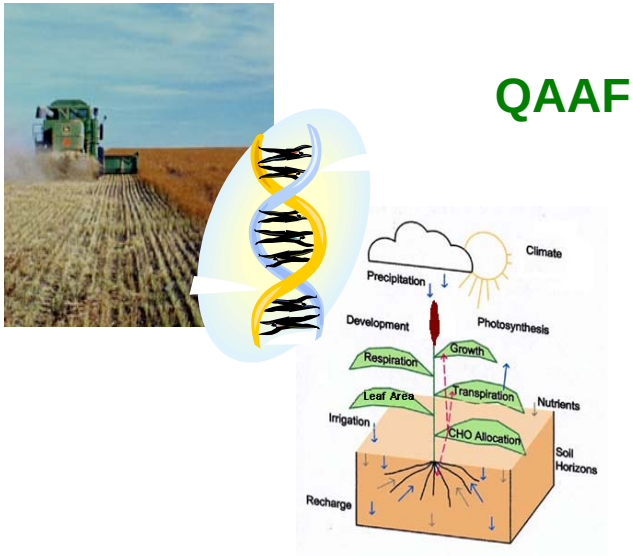

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Outline

1. Staygreen – What is it? Consequences on yield?
2. What is the genetic regulation?
3. What mechanisms might underpin the SG phenotype?
4. Can we model the mechanisms and simulate the phenotype as an emergent property?
5. What are the consequences on yield across sites and seasons?
6. So What?

1. Staygreen – What is it?

- Hybrids with the stay-green trait have the capacity to maintain more green functional leaves when subjected to drought during the grain filling period

Senescent

Impact

Reduced lodging

Increased grain yield

Increased grain size

Staygreen

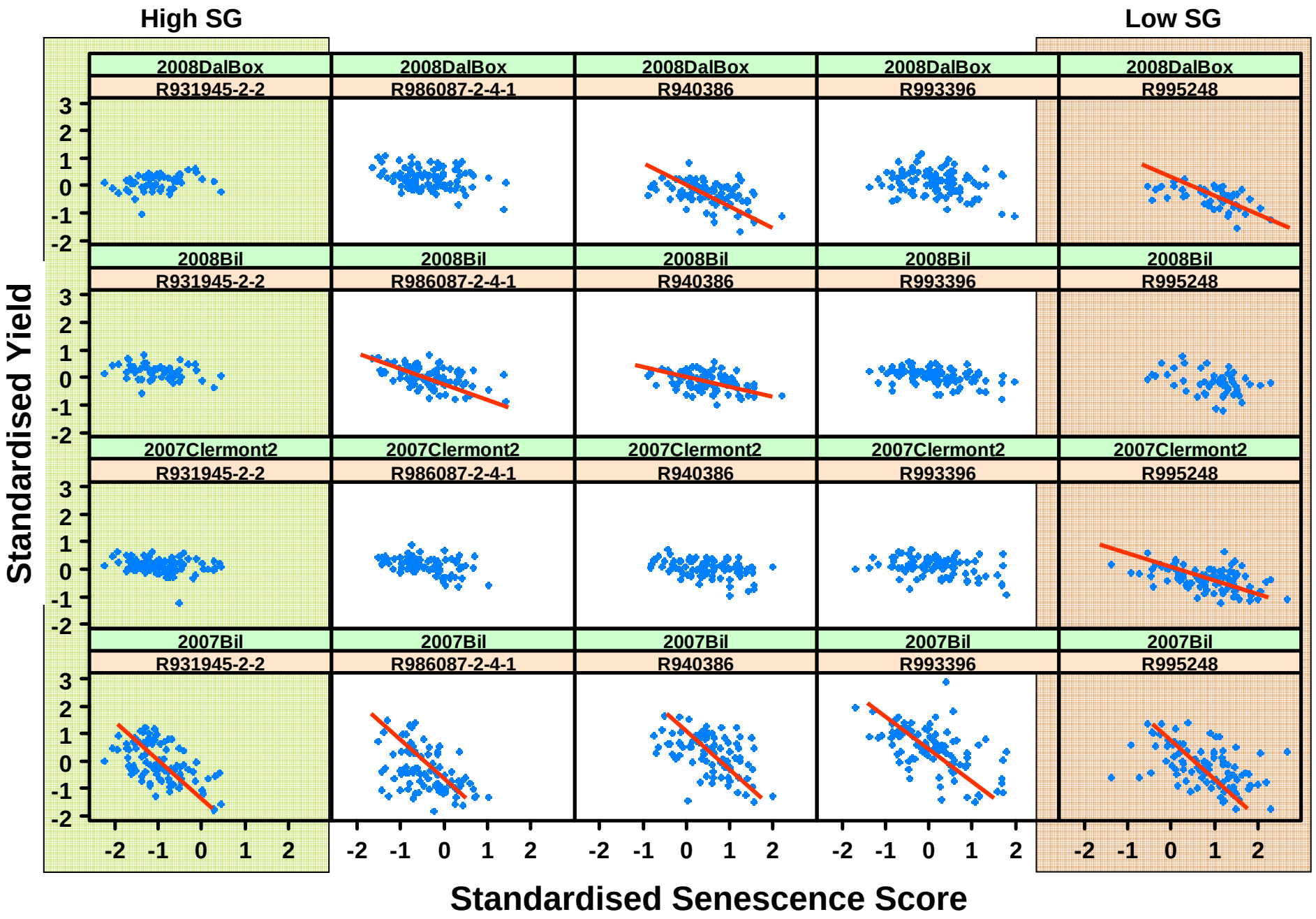
1. Staygreen – Effect on yield?

- Retrospective analysis of 4 years of breeding trials to quantify the relationship between stay-green and yield
- Small number of male parents contrasting in staygreen crossed with many females with varying levels of staygreen
- Examine yield-staygreen association for each site by male combination

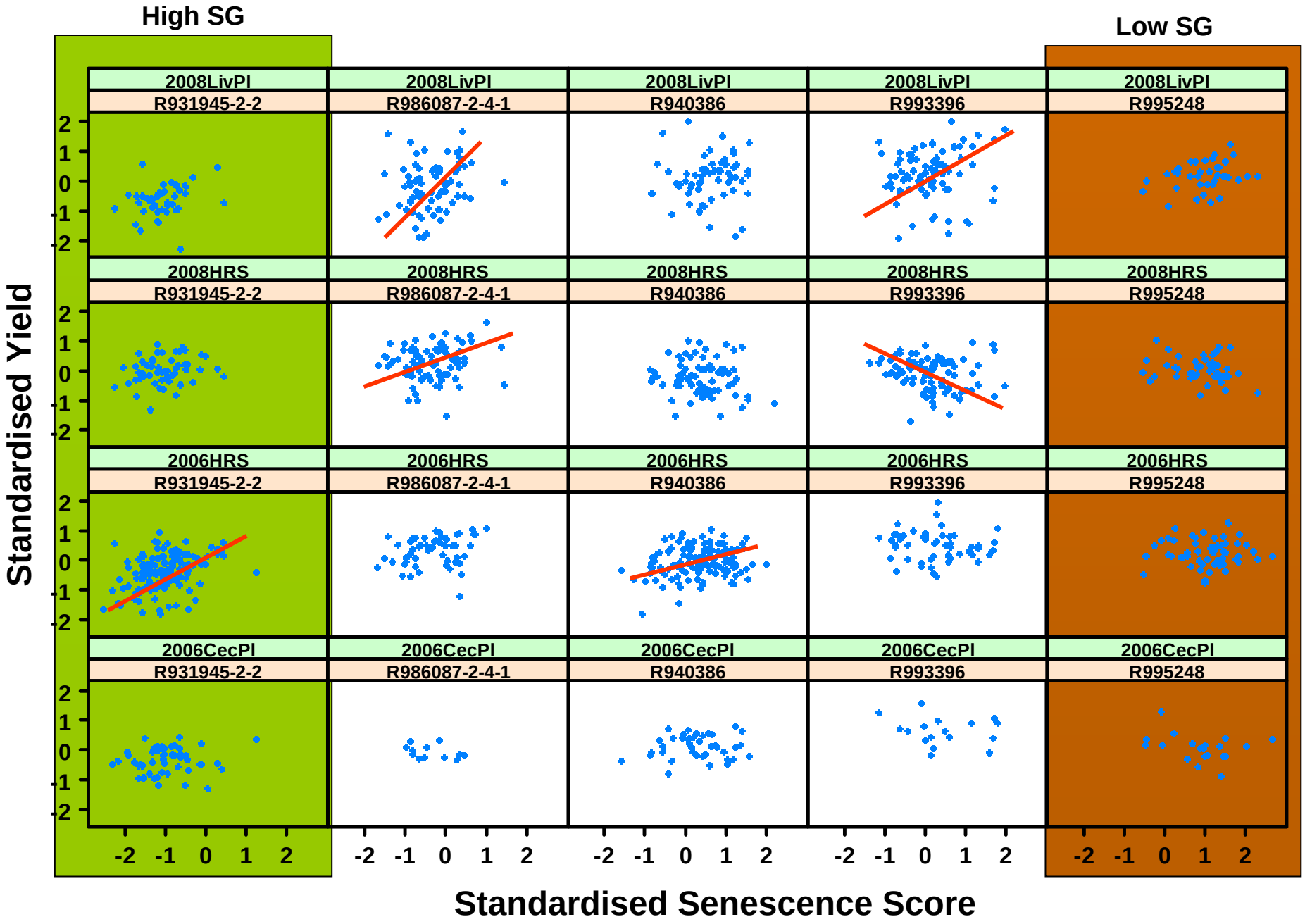
Male parent	Qualitative stay-green Rating	Qualitative ranking of yield potential in high yielding environments
R931945-2-2	High	Moderate
R986087-2-4-1	High	Moderately high
R933396	Moderately low	Moderately high
R940386	Moderately low	Moderately high
R995248	Low	Moderately high

Jordan et al. 2012. Crop Sci. 52:1153–1161

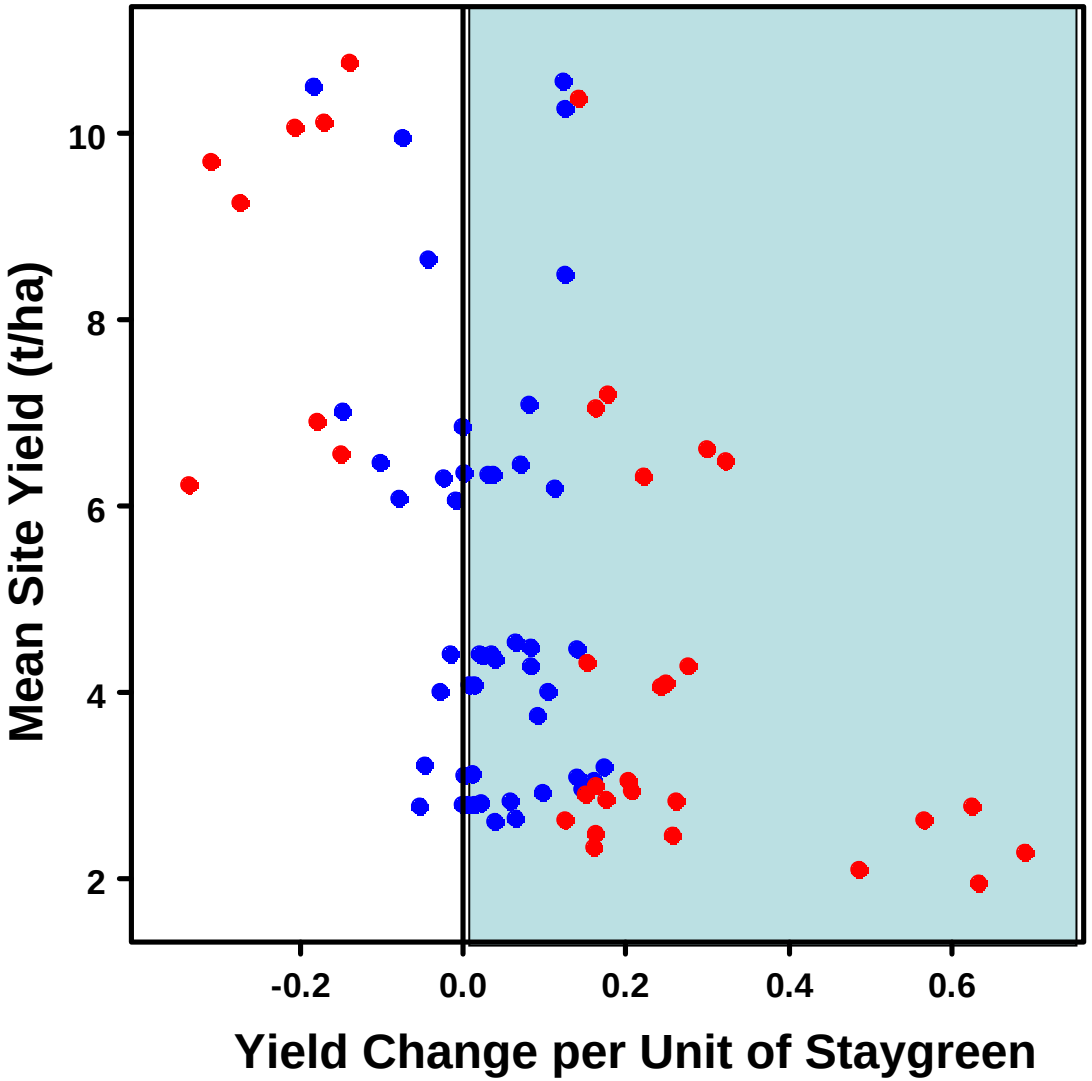
Low Yield environments



High Yield Environments



1. Staygreen – Effect on yield?



A generally positive effect on yield

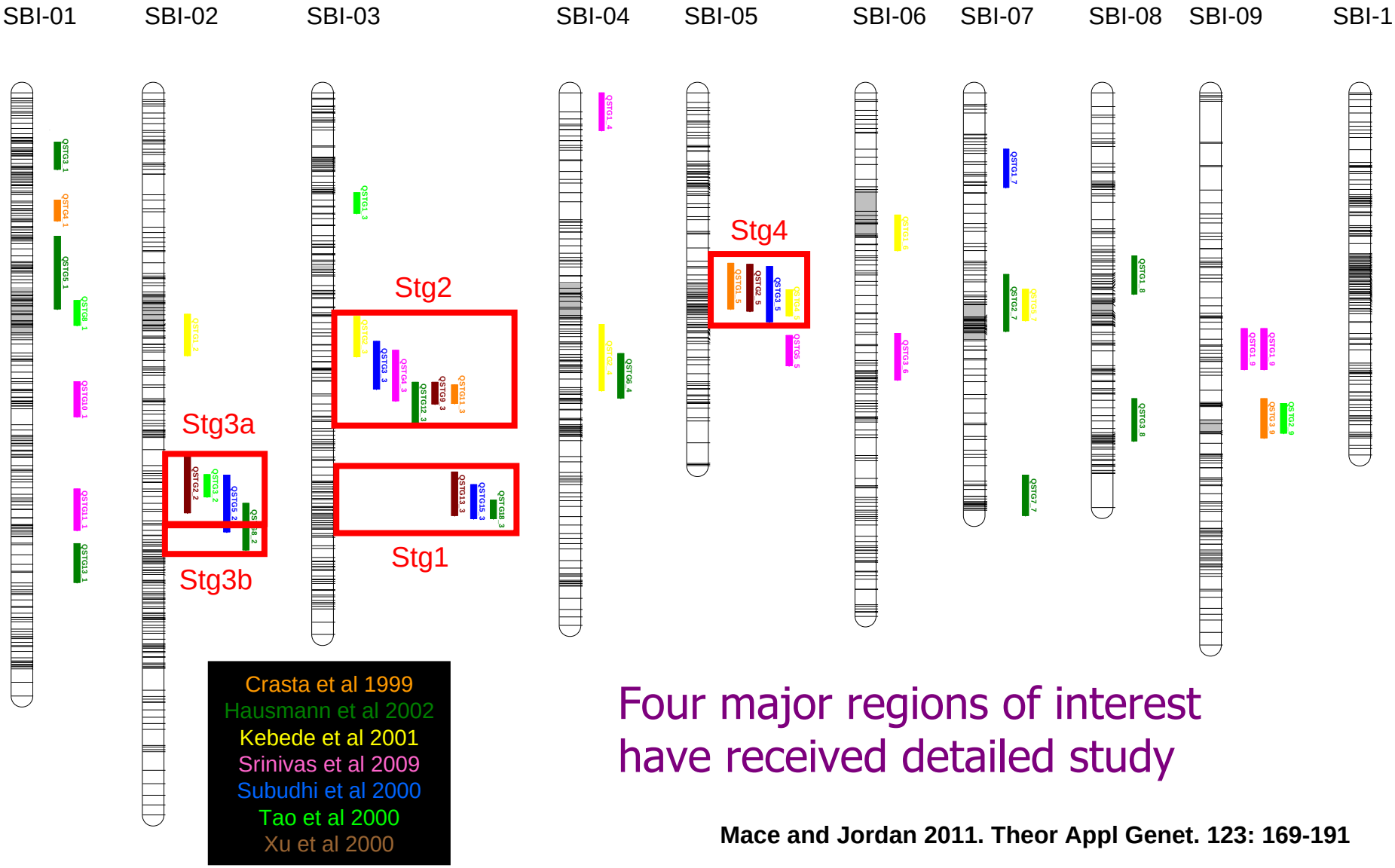
Especially at yield levels < 5t/ha

Aust average yield is about 2.5 t/ha

Jordan et al. 2012. Crop Sci. 52:1153–1161

2. What is the genetic regulation?

All Published stay-green QTL - 87 QTL; 27 unique regions

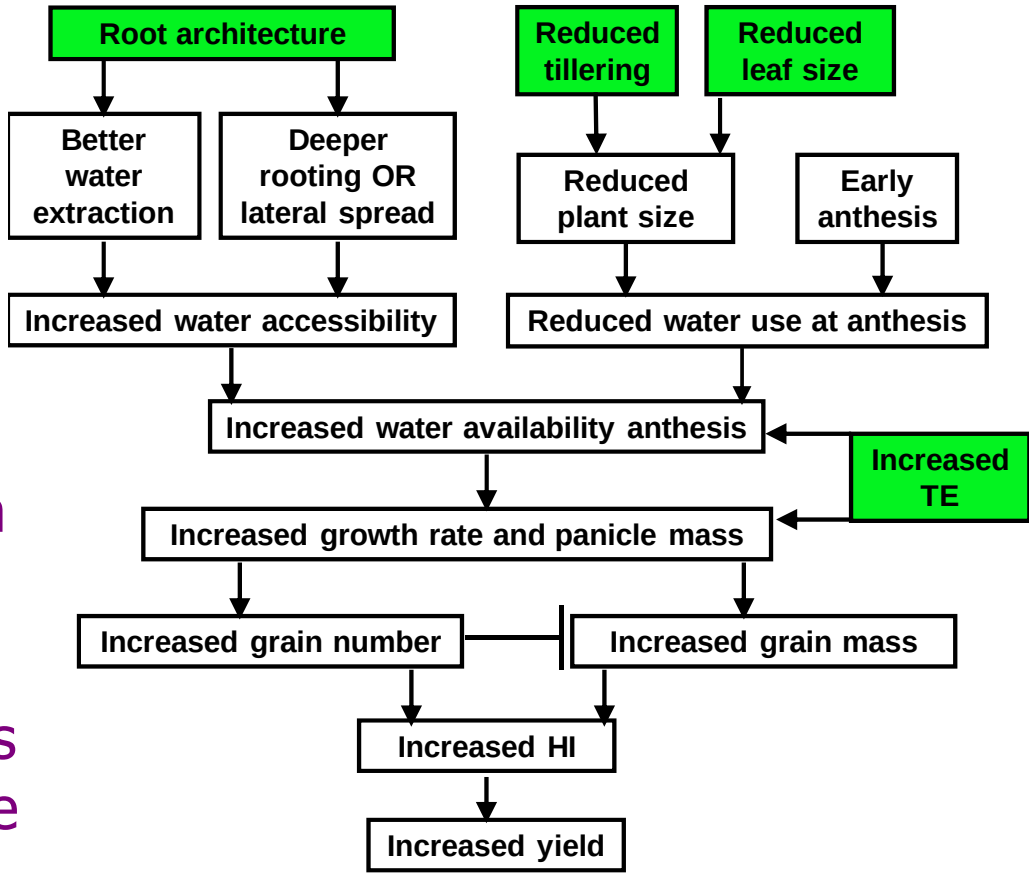


Four major regions of interest have received detailed study

Mace and Jordan 2011. Theor Appl Genet. 123: 169-191

3. What mechanisms underpin staygreen?

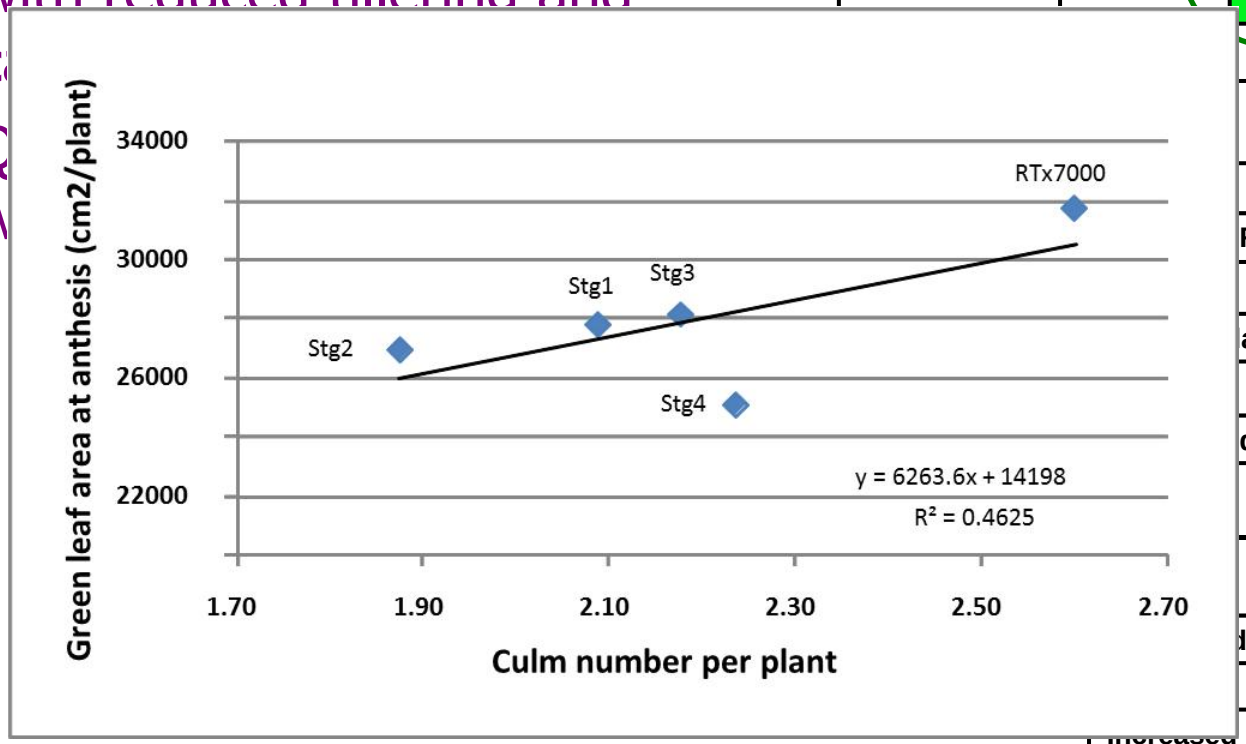
- Staygreen is a complex trait – not all mechanisms are desirable (eg reduced grain number)
- Studies with NILs and contrasting hybrids to seek mechanisms conferring yield advantage (Borrell, van Oosterom)
- Focus on canopy dynamics (water demand); root system architecture (water capture); transpiration efficiency
- Basis for modelling via effects on dynamics of water balance through the crop cycle
- Understanding supports gene discovery

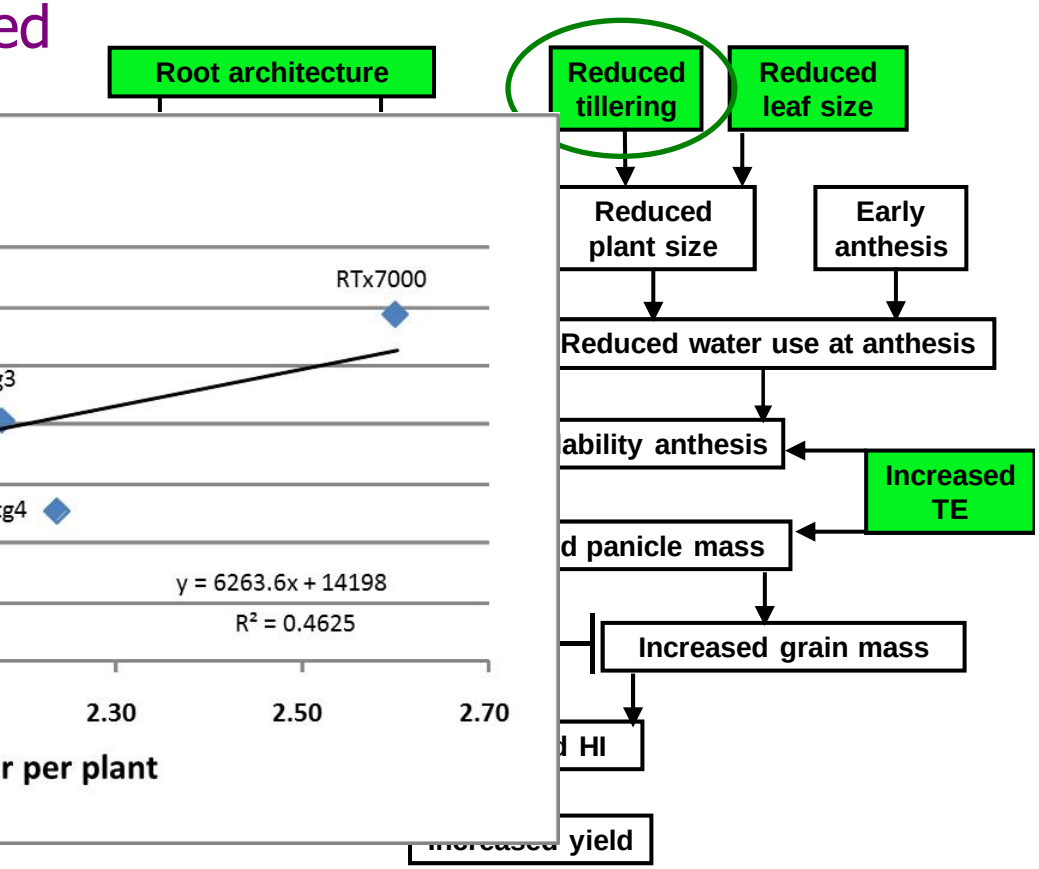


van Oosterom, Borrell et al 2011. Crop Sci. 51: 2728-2740

3. What mechanisms underpin staygreen?

- Reduced tillering is associated with staygreen
- Staygreen regions associated with reduced tillering and c
- Q w





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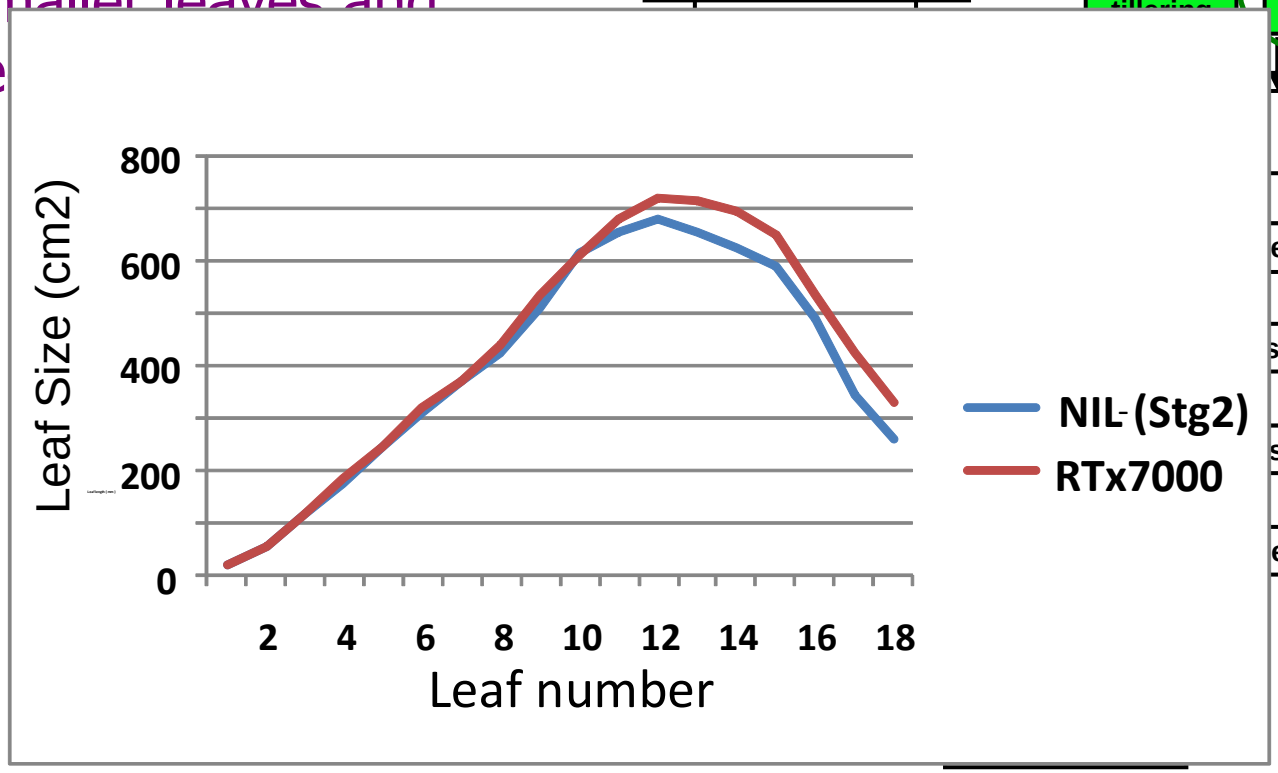
3. What mechanisms underpin staygreen?

- Reduced leaf size is associated with staygreen
- Staygreen regions associated with smaller leaves and reduce



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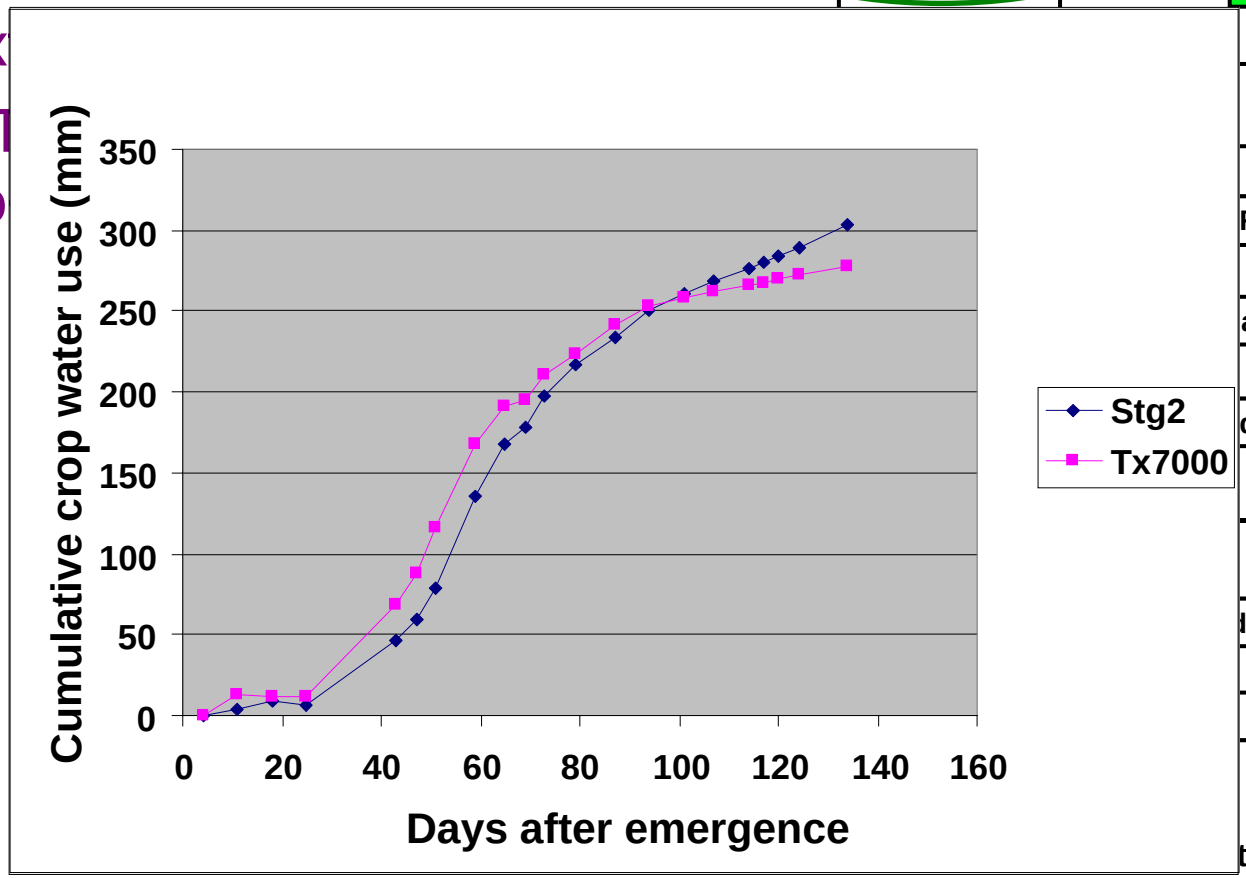
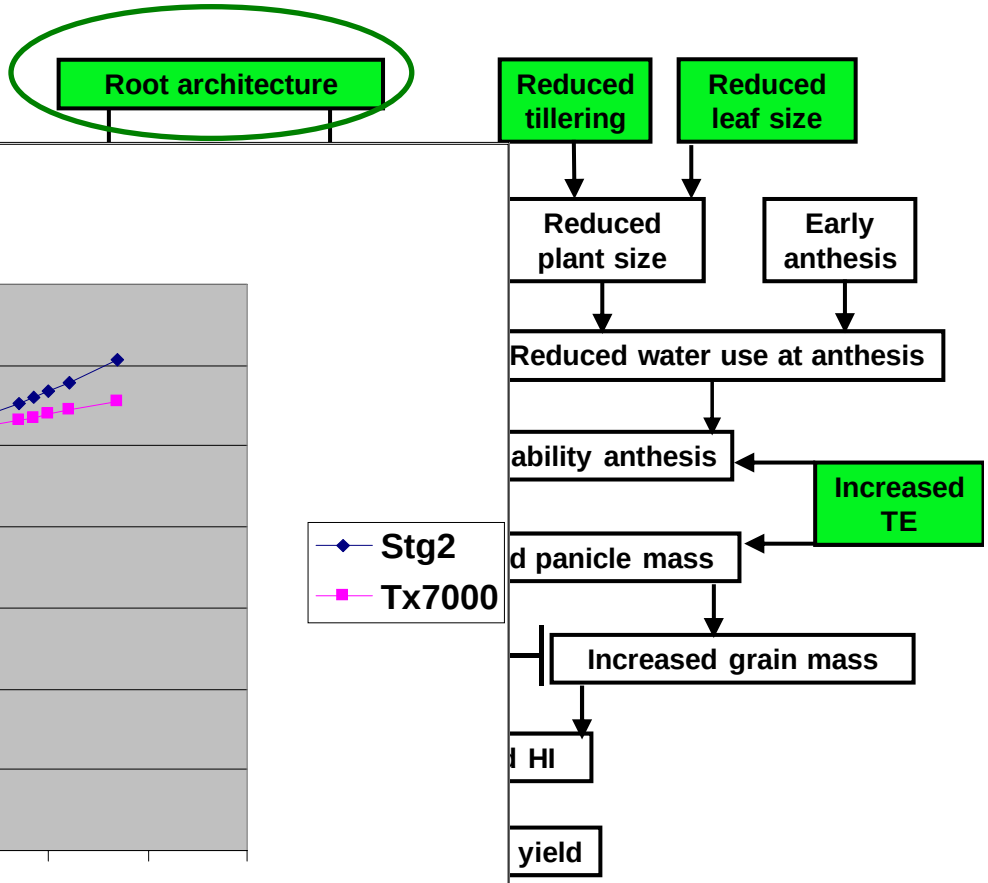
3. What mechanisms underpin staygreen?

- Additional water capture is associated with staygreen
- Staygreen regions associated with enhanced total water ex
- QT co





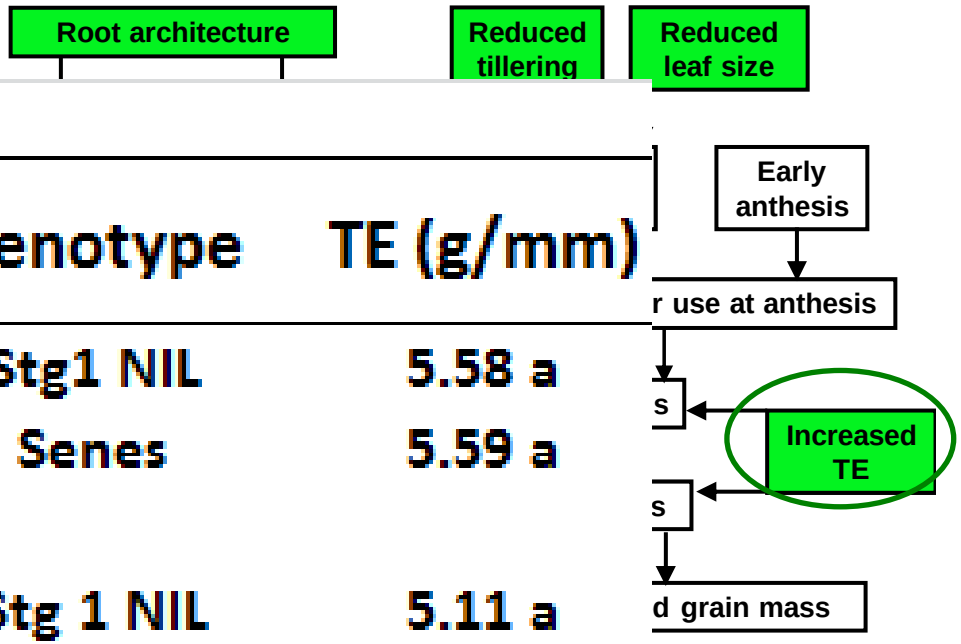
t al 2011. Crop Sci. 51: 2728-2740

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

3. What mechanisms underpin staygreen?

- Enhanced TE is associated with staygreen
- Staygreen regions associated with enhanced TE
- May be
  (SLA, S
  maxim
  mecha

Environment	Genotype	TE (g/mm)
Low vpd	Stg1 NIL	5.58 a
	Senes	5.59 a
High vpd	Stg 1 NIL	5.11 a
	Senes	4.65 b



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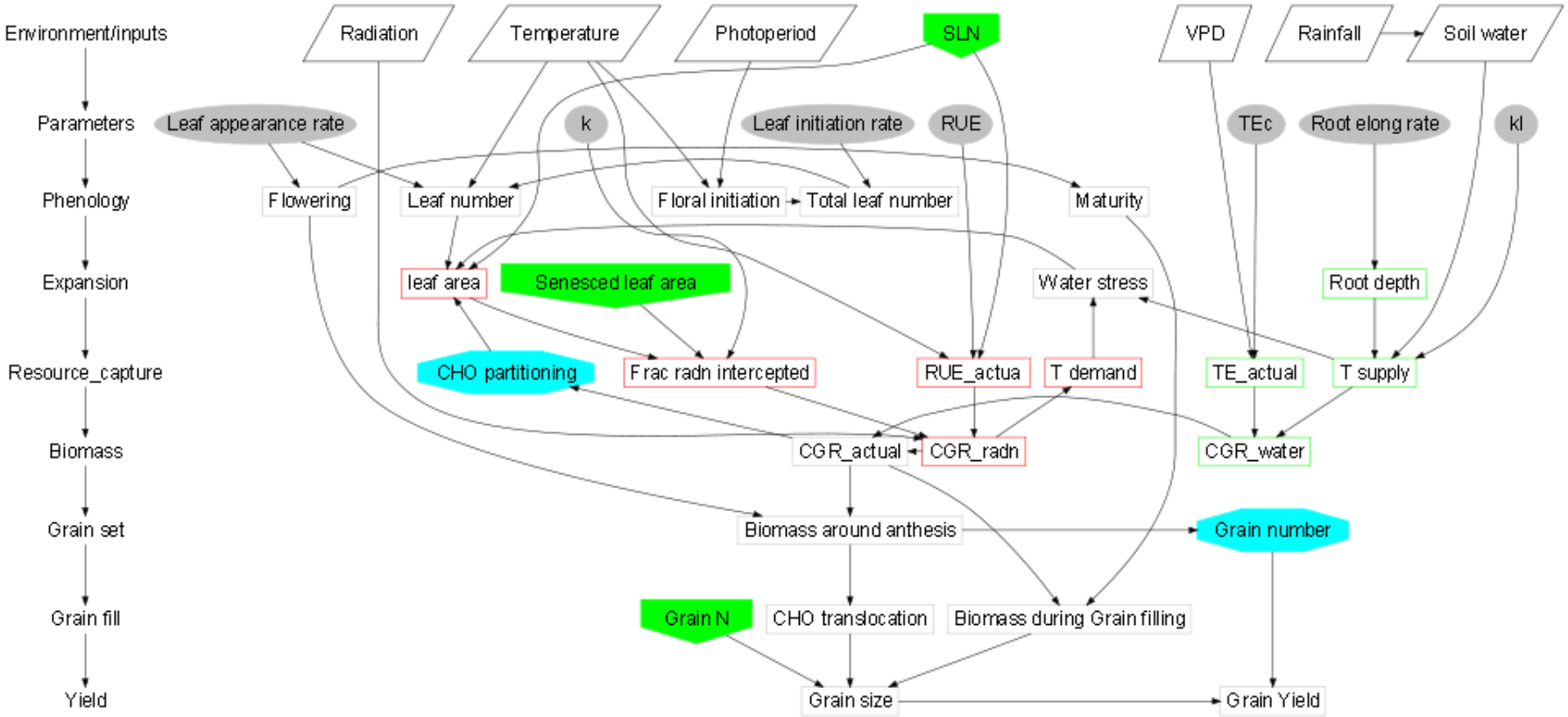
Sincalir et al 2005. Funct Plant Biol. , 32: 945-952.
Gholipoor et al 2010. Field Crops Res. . 119:85-90

4. Modelling staygreen - mechanisms

Incorporate effects in APSIM – sorghum model

- Modelling the tangled web of interactions and feedbacks



Hammer et al. 2010. J Exp Bot, 61:2185-2202

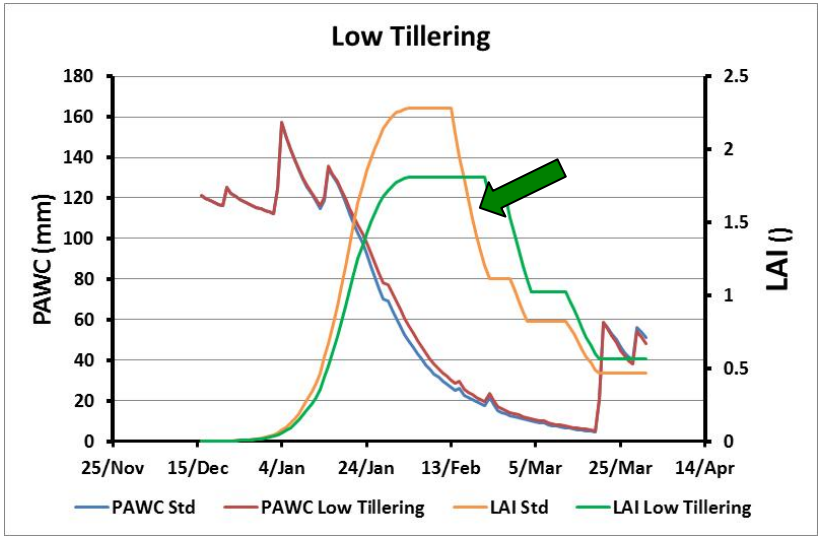
4. Modelling staygreen - mechanisms

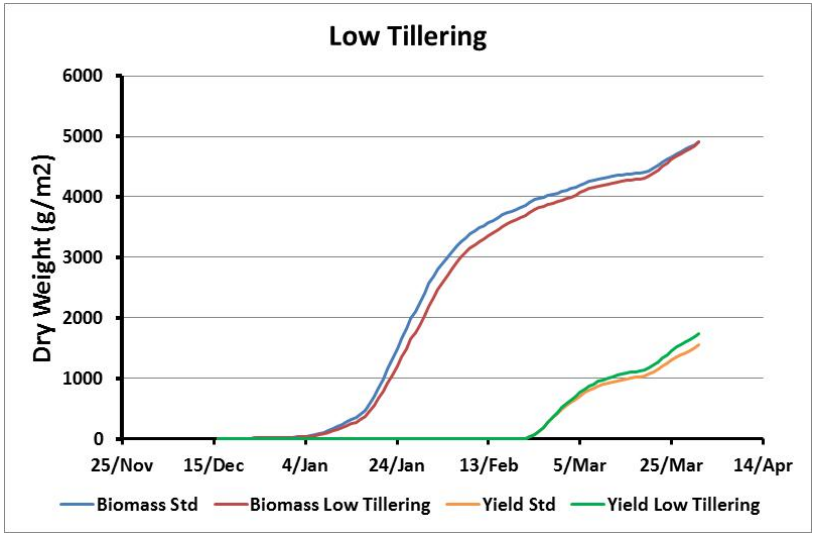
Incorporate estimates of known effects

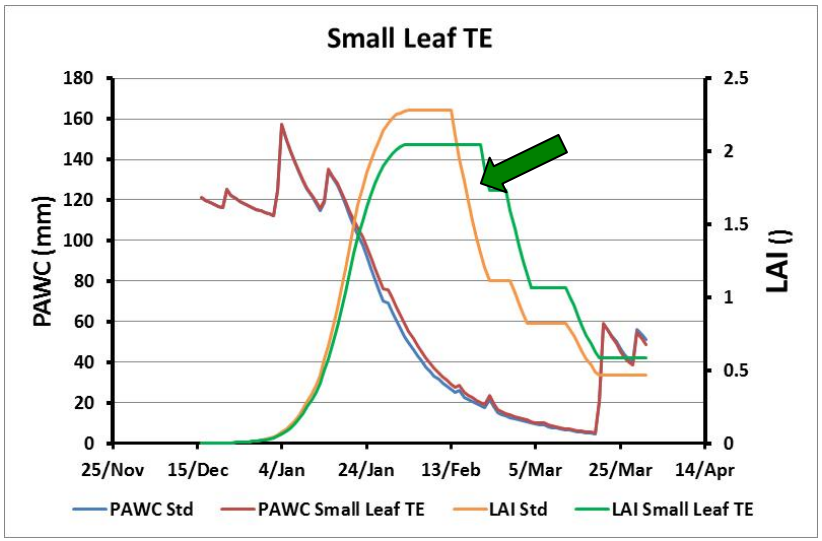
- Tillering – reduce propensity to tiller (0.5 tillers/plant)
- Leaf size – reduce potential leaf area per leaf by 10%
- Root architecture – increase potential extractable soil water by a maximum of 15mm over soil depth from 1-2m
- TE – increase intrinsic TE from 9 to 9.5Pa in combination with leaf size reduction
  - impose maximum transpiration rate of 1mm/hr
- Does this generate simulated staygreen phenotype under terminal stress?
- What are consequences on yield across environments?
- Simulation study for conventional agronomy and hybrid at key locations in NE Australia (with 100 years historical weather)

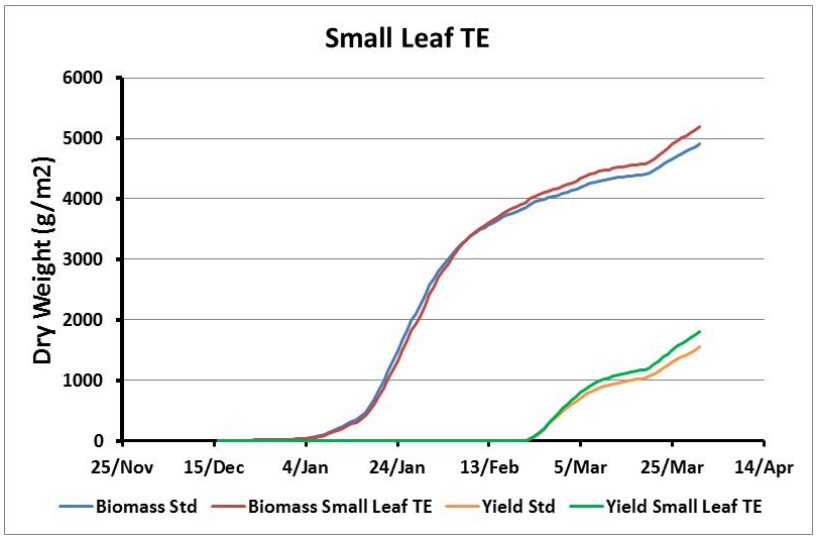
5. Modelling staygreen - phenotype

Staygreen phenotype emerges as consequence of dynamics









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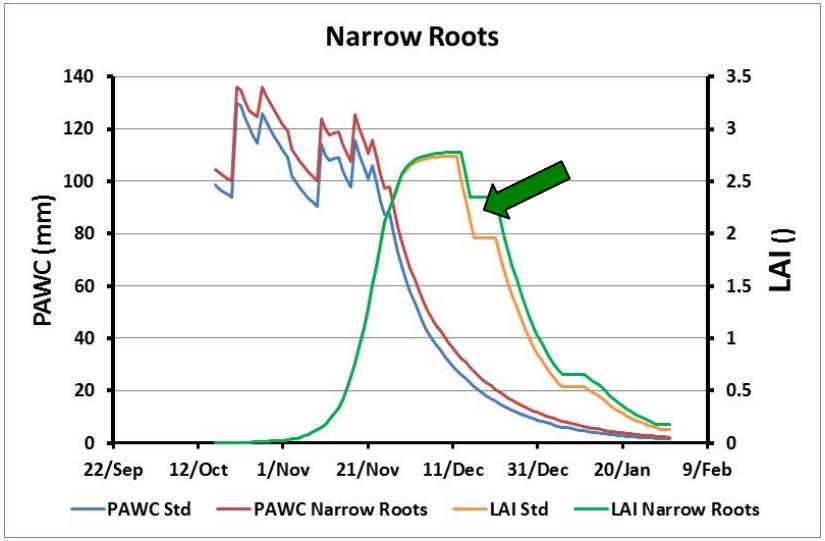
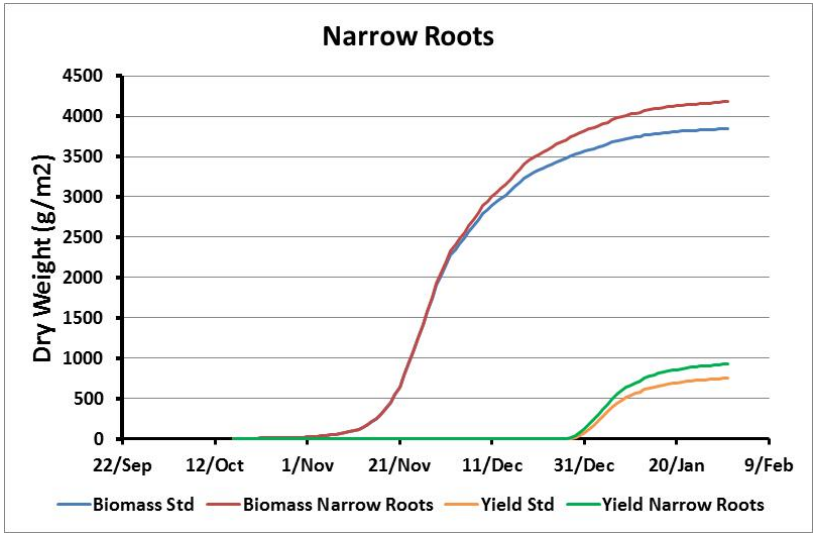
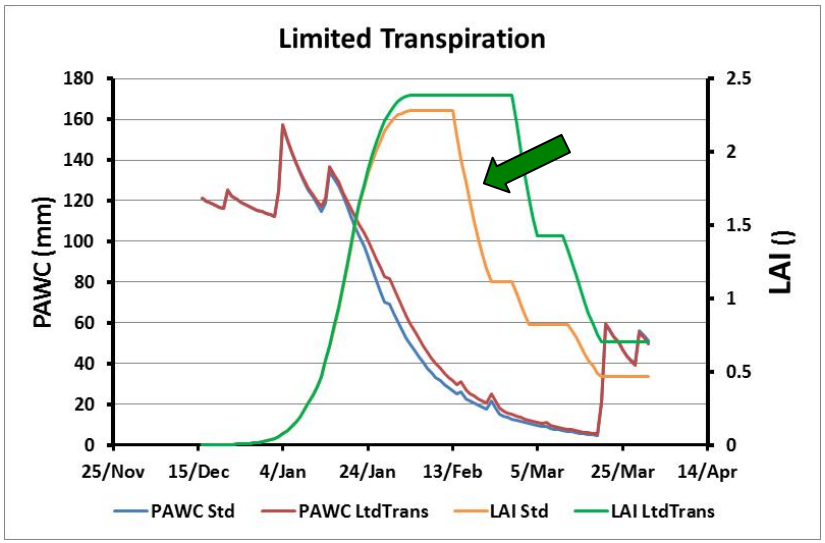
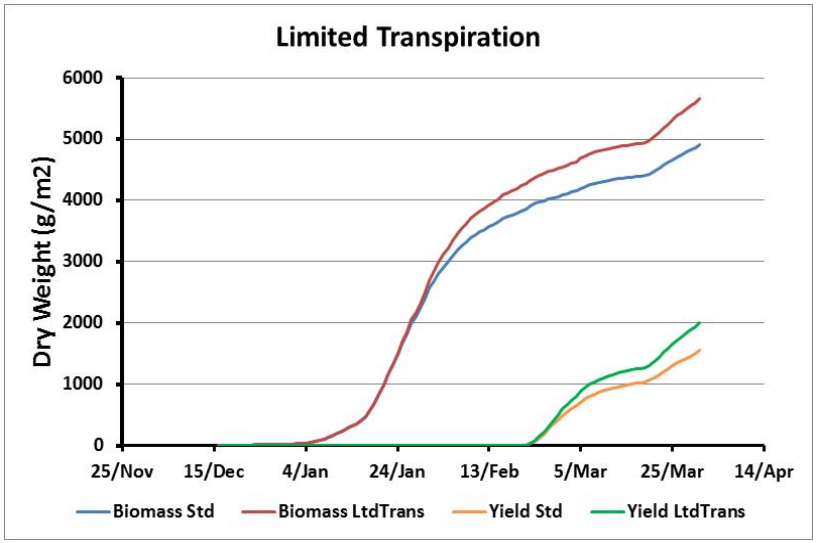


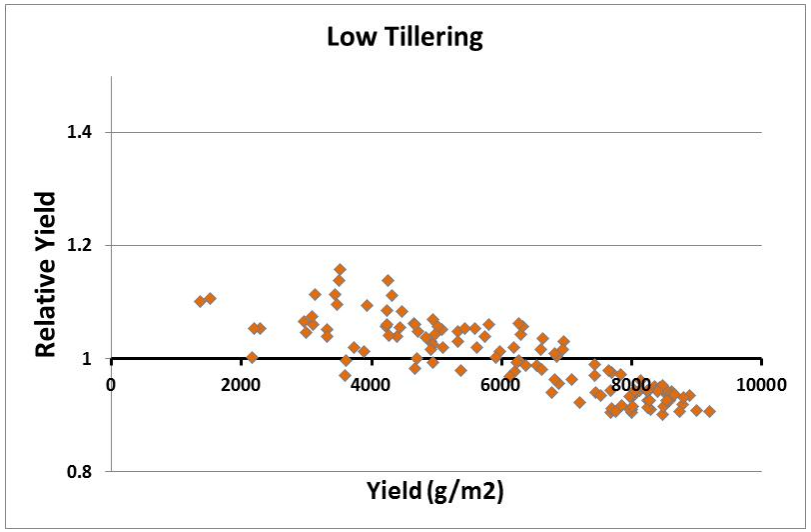


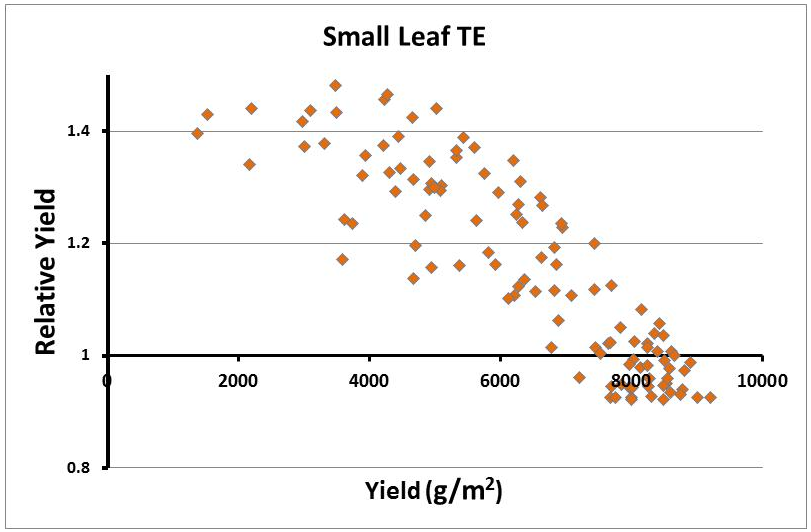


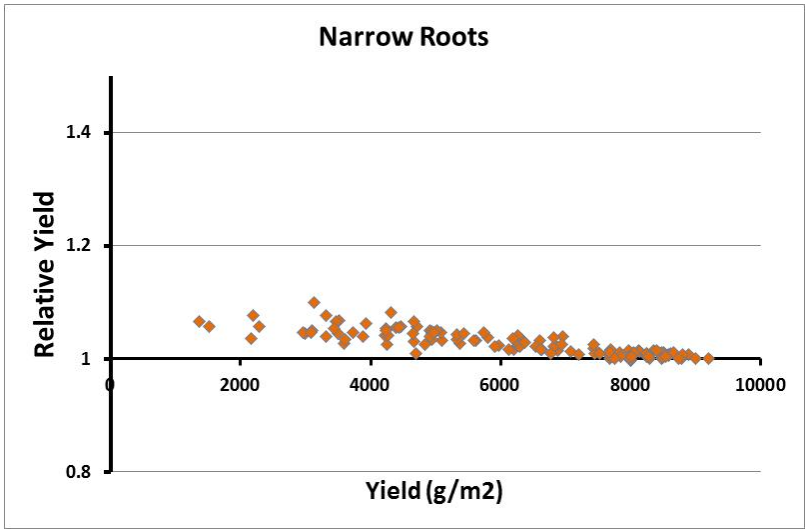


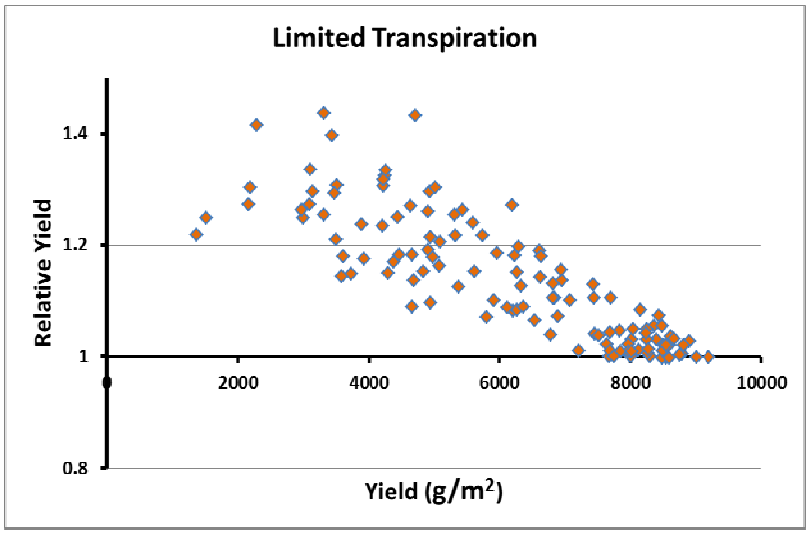
6. Simulating consequences on grain yield

Yield consequences reflect trends in field data (eg Dalby)



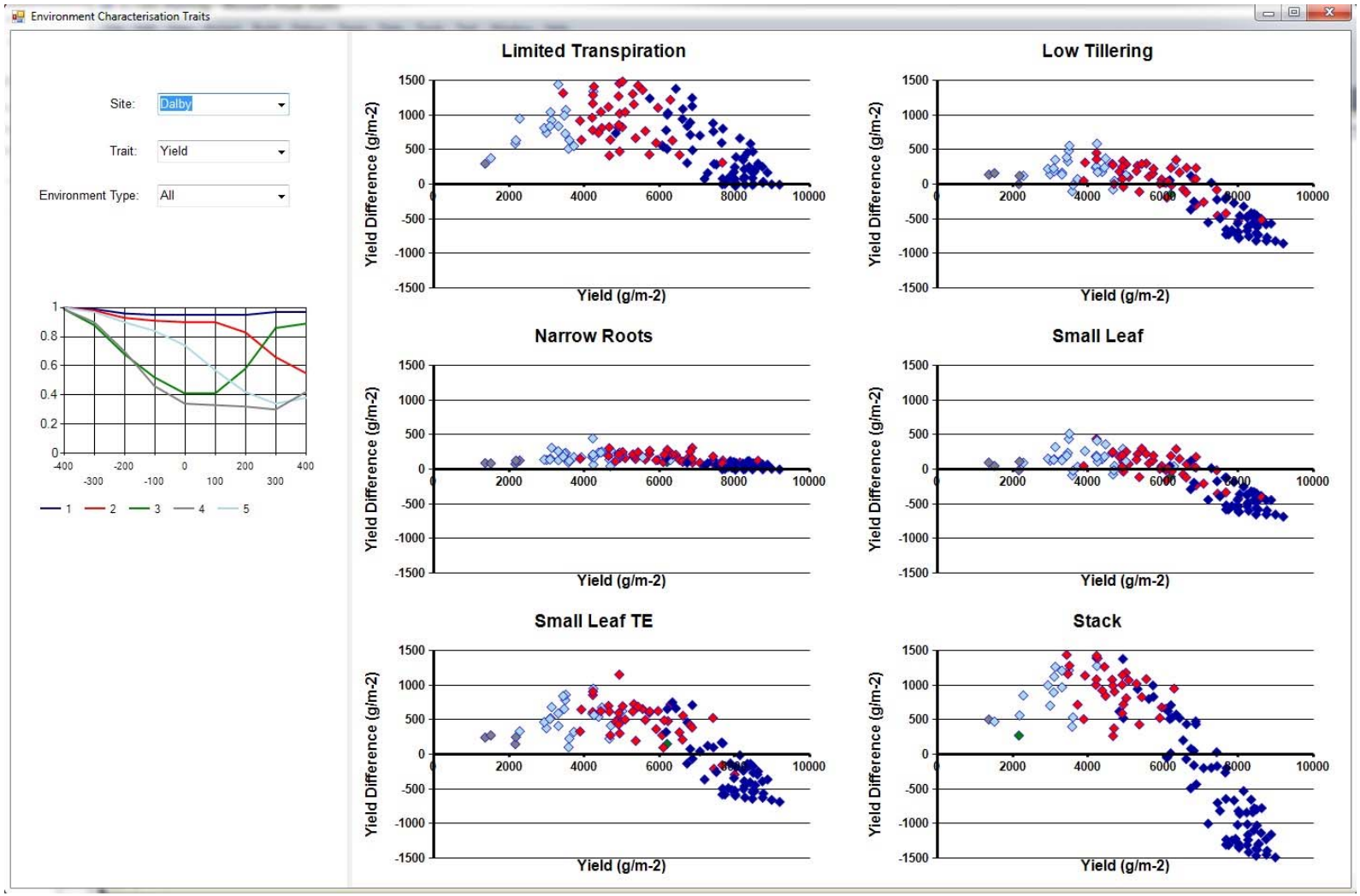






6. Simulating consequences on grain yield

Yield consequences relate to Environ Type (eg Dalby)



7. So What?

- Model captures dynamics and consequences of mechanisms
- Staygreen phenotype an emergent consequence
- Shifting a small amount of water from pre- to post-anthesis makes a big difference
- Different mechanisms generate different consequences and GxE
- *Opportunity for targeted phenotyping and molecular breeding*
- *Opportunity for plant design/improvement simulation (G-to-P models & G(QTL)*M*E)*
- Confidence to pursue use of model in molecular breeding
- Support for gene function targets in gene discovery

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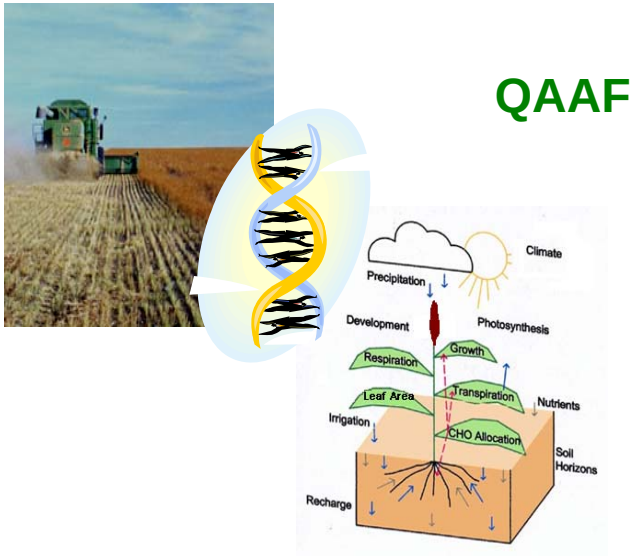

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