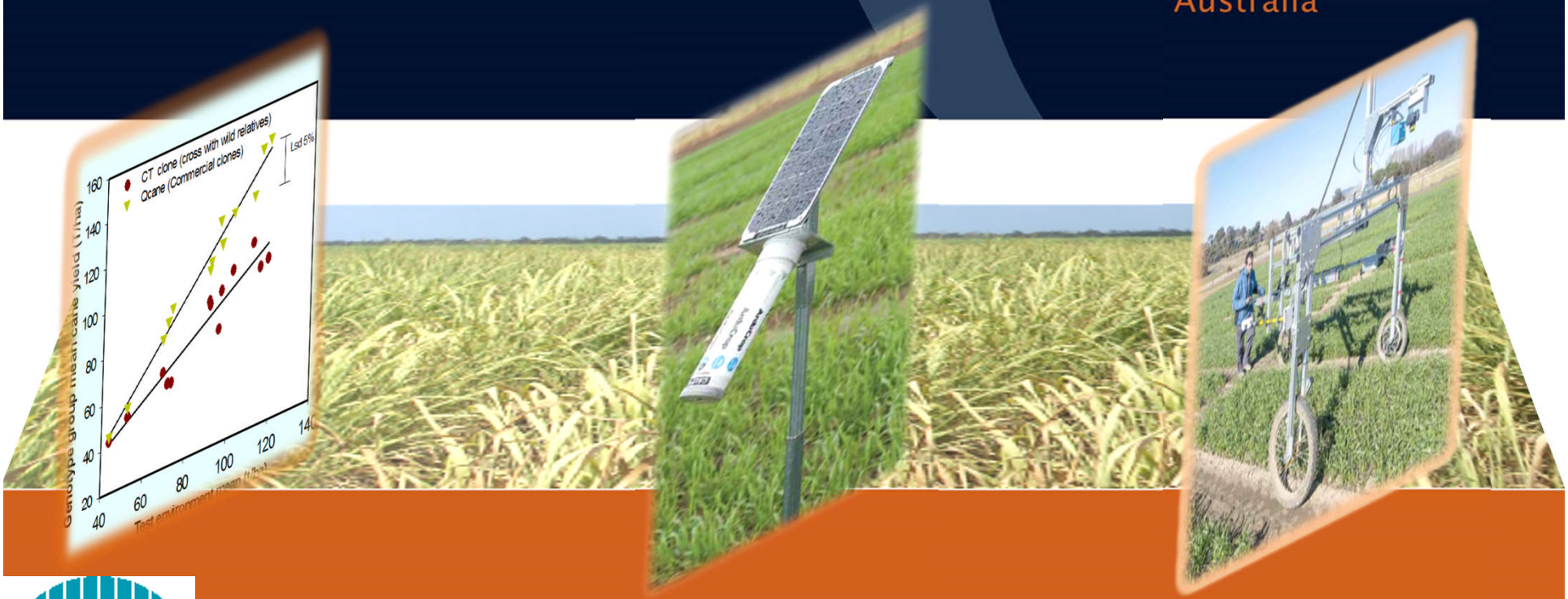
Sugarcane for water-limited Environments

Sugar Research Australia



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Drought tolerance breeding: current status in Australia

- Current breeding programs do not target specifically drought tolerance
- Any progress made (if) is indirect
- Faster and effective progress can expect if the trait was targeted





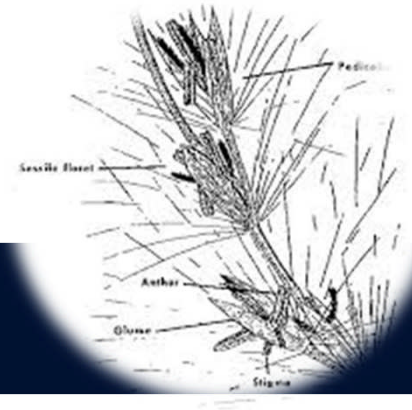


Severe water stress can be very deleterious even in fully developed crop.

Why less progress in breeding for water stress?

Breeding for water stress tolerance is difficult

- Complex physiological trait and little understanding of genetics
- Lack of elite breeding lines tolerant to water stress, and genetic variation for DT not known
- No clear selection criteria for selection



A physiological genetics approach

Hypothesis: Understanding physiological & genetic basis of water stress response may help in selection

Steps involved

- First – evaluate the genetic variation in response to water deficit (drought tolerance & efficient water use)
- Identify the major physiological mechanisms explaining the variation in genotypic responses to limited water
- Determine the key traits that can predict responses in target environments, and use them in selection indices

Genetic materials used - clone status and distribution across trials

Trial locations	Clones
Total clones	131
Crystal Creek trial	99
Home Hill trial	89
Dalbeg trial	40

F1 population	45
BC1 population	33
Foreign varieties	5
Parental lines	19
Q varieties (commercial)	29
Total genotypes	131

Crosses (F1 and BC1 populations wild relatives)
Type (CT04 (F1) and CT05 (BC1) crosses)
F1 (*E. arundinaceous)*
F1 (*E. rockii*)
F1 *S. spontaneunm*
BC1 (*S. spontaneum*)
BC1 (*E. arundinaceous*)
BC1 (*S. robustum*) x *E. arundinaceous*
F1 (*S. spontaneum*) x BC1 (*S. robust*)
F1 (*E. arundinaceous*) x BC1 (*S. robustum*)







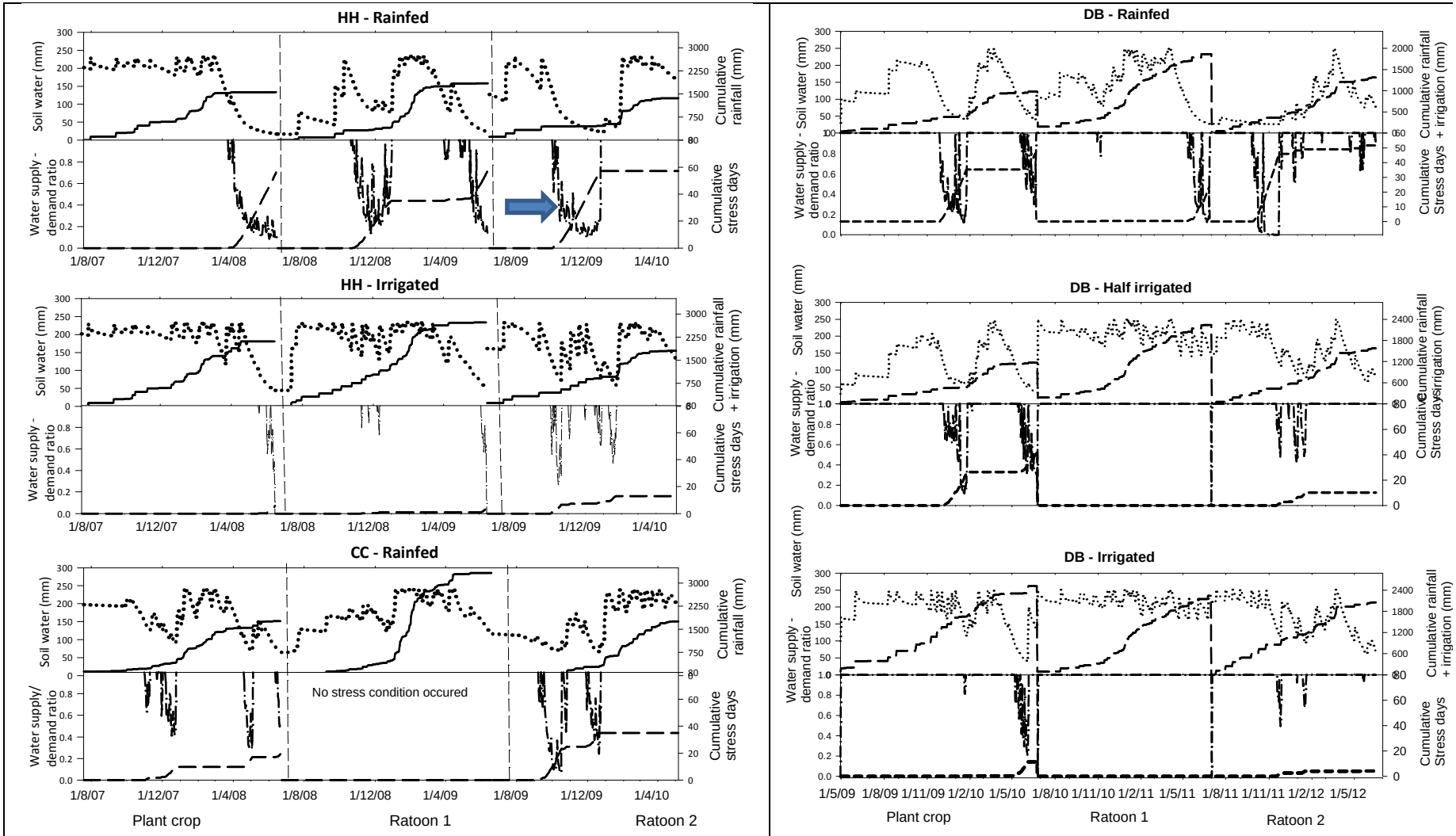
Developed drought environments by with-holding water in the summer season



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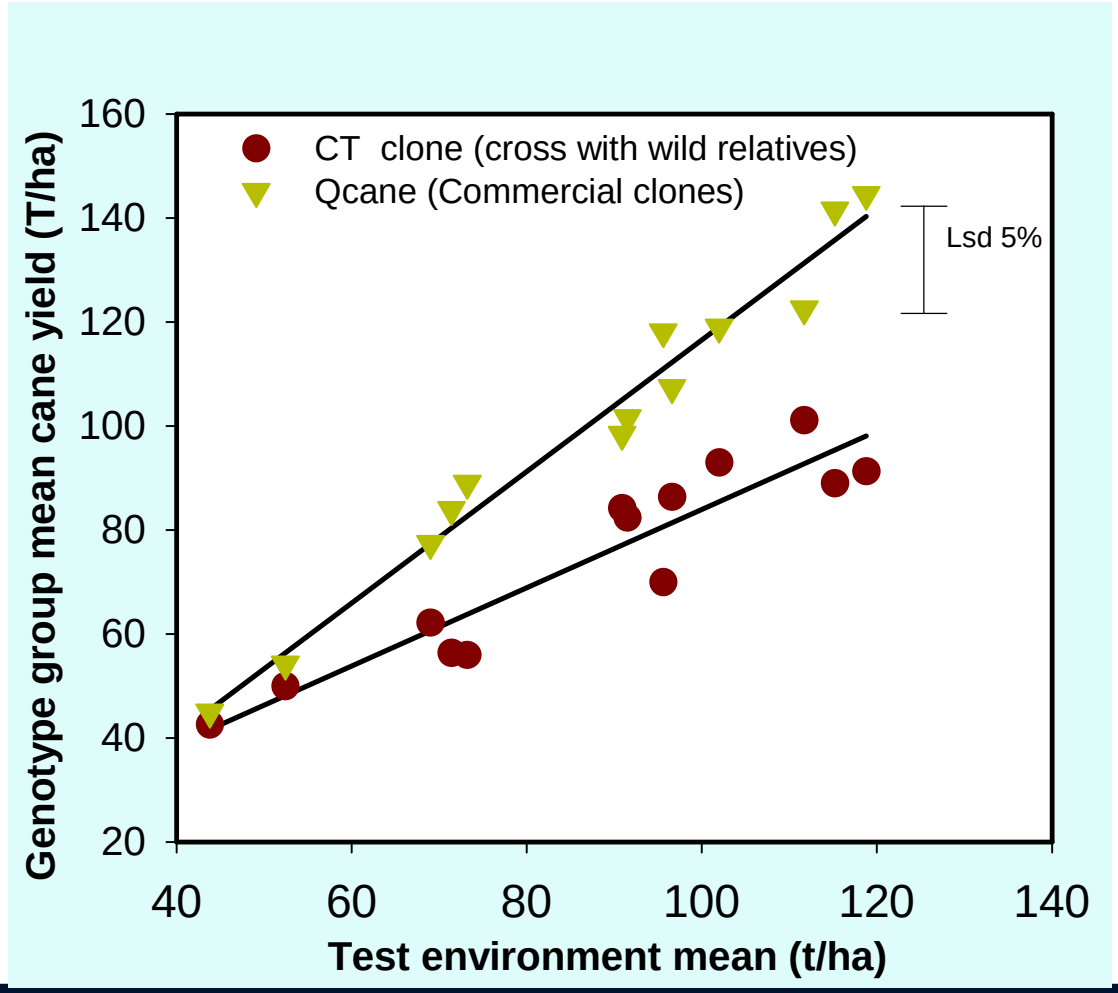
Test environments characterization



Genetic correlation between test environments

	Dalbeg (DB)		Home Hill (HH)					
	Half irrigated	Fully irrigated	Water stress			Fully irrigated		
	Plant (PC)		Plant (PC)	1 Ratoon (1R)	2 Ratoon (2R)	Plant (PC)	1 Ratoon (1R)	2 Ratoon (2R)
Total dry matter (TDM)								
DB-Water stress-PC	0.93	0.94	0.94	0.86	0.55	0.89	0.89	0.94
DB-Half irrigated-PC		0.99	0.99	0.90	0.58	0.93	0.94	0.99
DB-Fully irrigated-PC			0.99	0.91	0.58	0.94	0.95	0.98
HH-Water stress-PC				0.60	0.30	0.66	0.68	0.72
HH-Water stress- 1R					0.34	0.77	0.78	0.83
HH-Water stress-2R						0.38	0.39	0.41
HH-Fully irrigated-PC							0.87	0.92
HH-Fully irrigated- 1R								0.94

Mean TCH of commercial (▼) & unselected (●) clones vs mean TCH of all test clones in 15 test environments at Home Hill & Dalbeg



Mean yields of unselected & commercial clones are similar in severe water stress environments

Vertical error bar = Lsd 5% for pairwise comparison of group mean in each test environment

Stomatal conductance & productivity in sugarcane

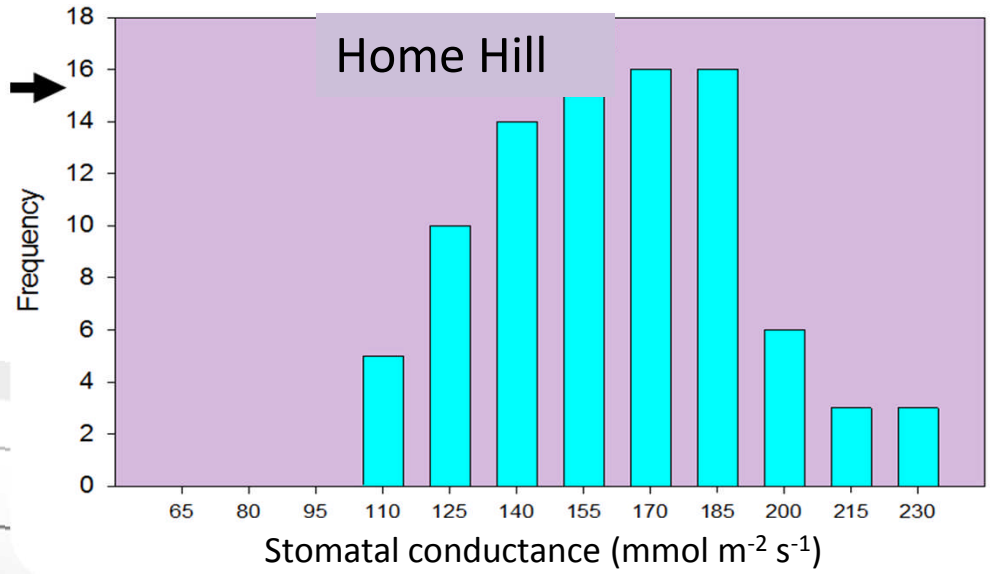


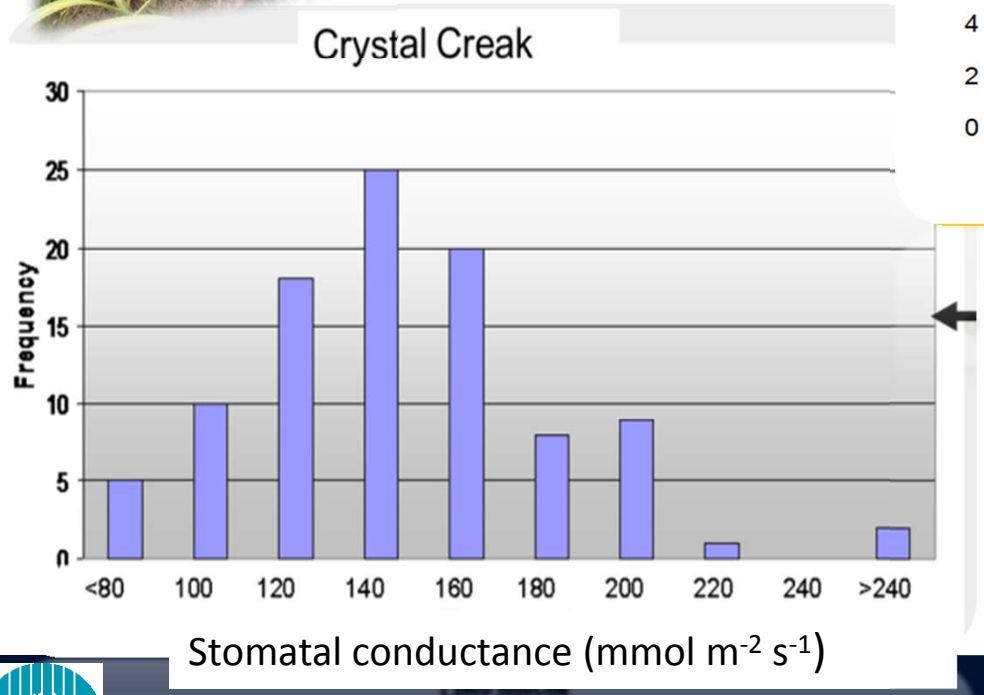
- Stomata play a central role in regulating plant growth & water loss through simultaneously affecting movement of CO_2 and water vapour into and out of leaves

- Studies have shown a generally positive correlation between stomatal conductance and yield in some crops (Blum, 1982, 1989; Fischer *et al*., 1998)

Significant genotypic variation was observed under drought & fully irrigated conditions







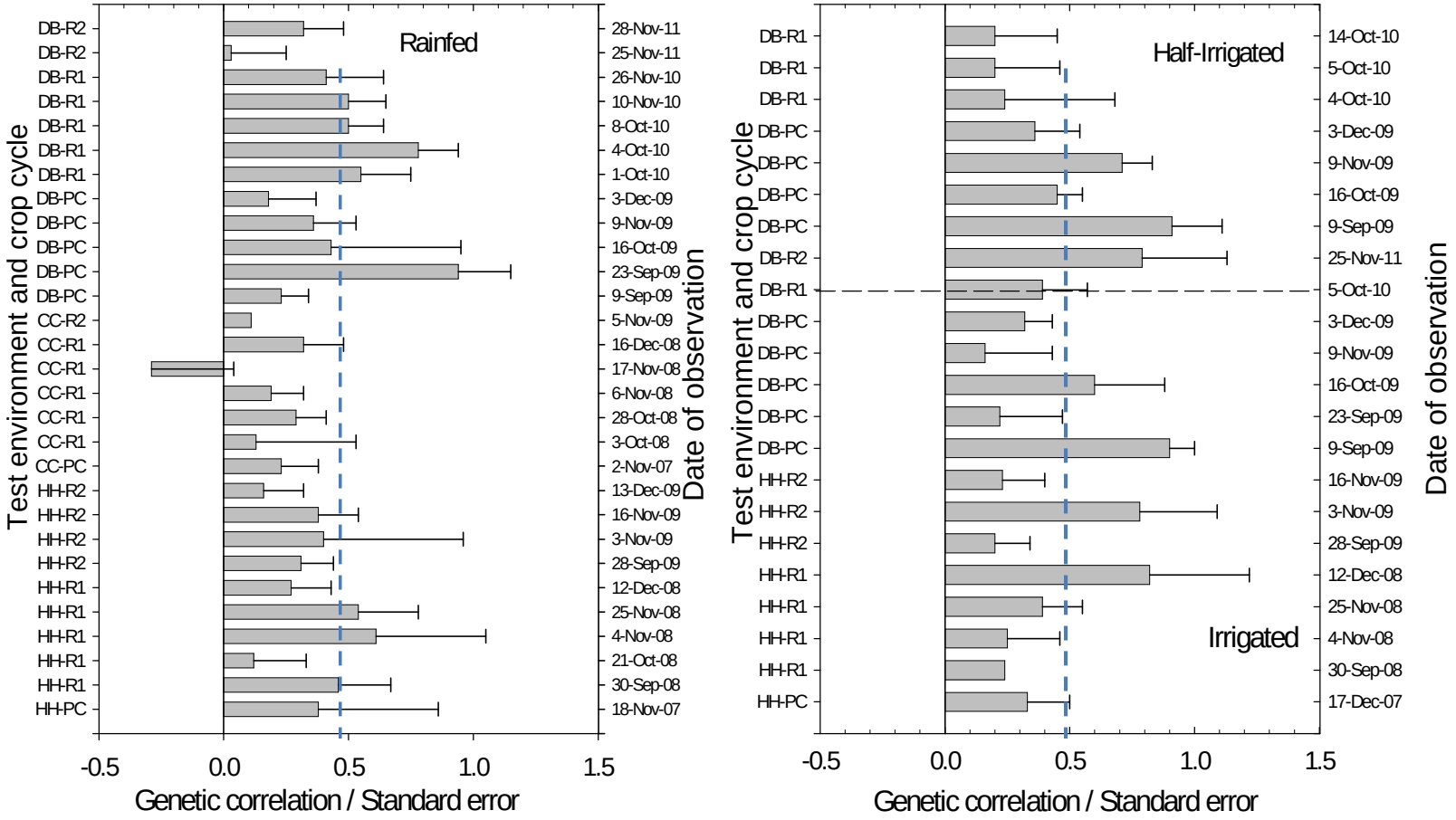
Relatively large genetic VC & small GE VC across number of measurements

Observations Combined [a]	Date	Crop class	Genetic variance	GxE variance	G:GE ratio	Error variance	Heritability broad sense
HH1-1 & HH4-1	18-Nov-07	PC[b]	699.6	52.3	13.4	102.4	0.93
HH2-1 & HH5-1	30-Sep-08	1R	479.2	218.0	2.2	630.9	0.64
HH2-3 & HH5-2	4-Nov-08	1R	244.0	207.0	1.2	677.2	0.47
HH2-4 & HH5-3	25-Nov-08	1R	363.0	473.0	0.8	339.1	0.53
HH2-5 & HH5-4	12-Dec-08	1R	594.0	103.0	5.8	293.2	0.83
HH3-1 & HH6-1	28-Sep-09	2R	719.0	147.7	4.9	251.4	0.84
HH3-2 & HH6-2	03-Nov-09	2R	271.0	187.0	1.4	281.8	0.62
HH3-3 & HH6-3	16-Nov-09	2R	753.0	144.3	5.2	275.8	0.84
DB1-1,DB4-1,DB6-1	9-Sep-09	PC	711.0	471.0	1.5	4788.0	0.51
DB1-2 & DB6-2	23-Sep-09	PC	831.0	1175.0	0.7	3887.0	0.50
DB1-3,DB4-2,DB6-3	16-Oct-09	PC	214.0	201.0	1.1	312.0	0.68
DB1-4,DB4-3,DB6-4	09-Nov-09	PC	210.0	276.2	0.8	90.7	0.67
DB1-5,DB4-4,DB6-5	03-Dec-09	PC	333.2	81.2	4.1	225.2	0.86
DB2-2,DB5-2,DB7-1	05-Oct-10	2R	1015.0	24.8	40.9	187.8	0.97
DB3-1 & DB8-1	25-Nov-11	2R	1125.3	1001.4	1.1	568.5	0.74

Relatively high genetic correlation (γ_g) among test environments for stomatal conductance

Genetic variance	Obser vation	CC1-1	CC2-2	CC3-1	HH1-1	HH2-5	HH3-1	HH4-1	HH5-3	HH6-1	DB1-4	DB2-3	DB3-2	DB4-1	DB5-3	DB6-1	DB7-1	DB8-1
579.2	CC1-1	1	0.46	0.27	0.70	0.69	0.76	0.65	0.54	0.75	0.69	0.7	0.46	0.75	0.74	0.72	0.71	0.79
847.2	CC2-2			0.18	0.47	0.46	0.51	0.43	0.36	0.50	0.46	0.47	0.31	0.50	0.52	0.48	0.47	0.53
443.9	CC3-1				0.28	0.27	0.30	0.25	0.21	0.30	0.27	0.28	0.18	0.30	0.29	0.28	0.28	0.31
336.5	HH1-1					0.71	0.78	0.66	0.55	0.77	0.71	0.72	0.47	0.77	0.76	0.74	0.72	0.81
516.8	HH2-5						0.76	0.65	0.54	0.75	0.69	0.70	0.46	0.76	0.75	0.72	0.71	0.79
890.2	HH3-1							0.72	0.61	0.83	0.76	0.77	0.51	0.83	0.82	0.80	0.78	0.87
732.5	HH4-1								0.51	0.71	0.65	0.66	0.43	0.71	0.71	0.68	0.66	0.74
1761.7	HH5-3									0.59	0.54	0.55	0.36	0.59	0.58	0.56	0.55	0.62
1099.1	HH6-1										0.75	0.76	0.51	0.82	0.81	0.79	0.77	0.86
727.1	DB1-4											0.70	0.46	0.76	0.75	0.72	0.71	0.79
1446.5	DB2-3												0.47	0.76	0.76	0.73	0.72	0.80
2137.2	DB3-2													0.50	0.50	0.48	0.47	0.53
839.9	DB4-1														0.82	0.79	0.77	0.86
1033.1	DB5-3															0.78	0.77	0.85
1159.5	DB6-1																0.74	0.83
2343.8	DB7-1																	0.81
1245.1	DB8-1																	

Genetic correlation between g_s & average TCH across 18 test environments

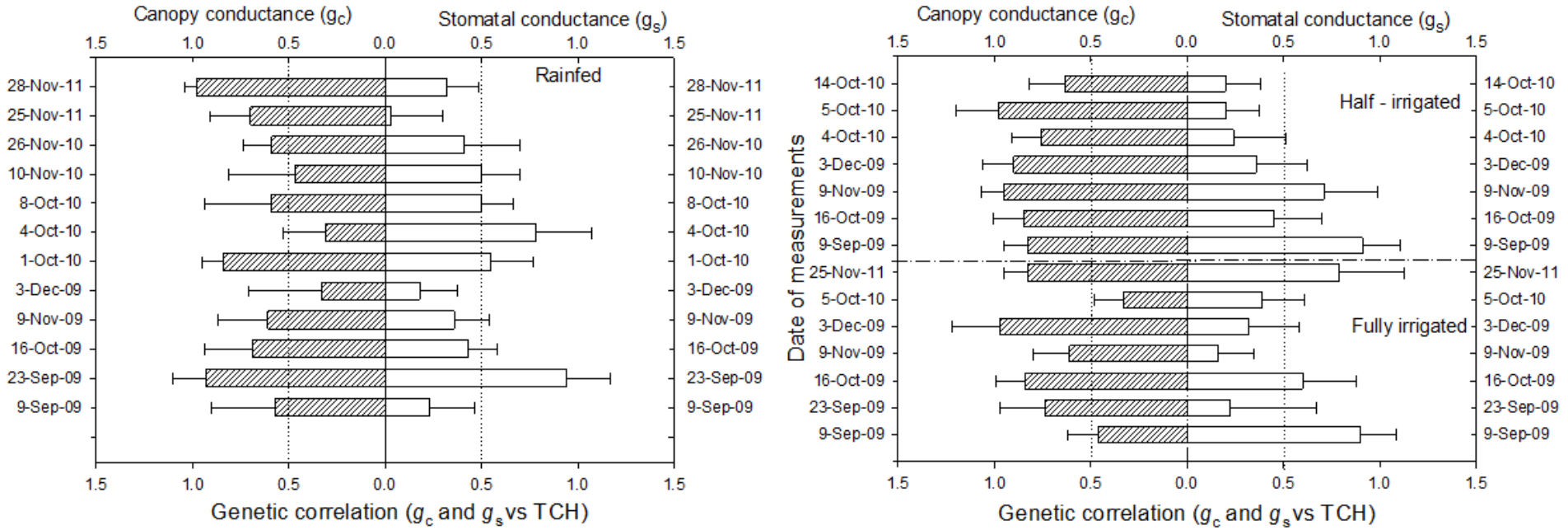


DB = Dalbeg, CC = Crystal Creek, HH = Home Hill
Genetic correlation = Bars, SE = Whiskers

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Canopy conductance is a good predictor than g_s of TCH irrespective of growing condition



- Genetic correlation between canopy conductance (g_c) & TCH (shaded Bars)
- Genetic correlation between stomatal conductance (g_s) & TCH (open Bars)
- Std errors (whiskers)
- 26 observations within 8 test environments at Dalbeg

Summary

- Large genetic variation for stomatal conductance was found under a range of water deficit conditions and it could be exploitable in a breeding program
- Canopy conductance (5-6 M) is a good predictor for TCH as it shows high genetic correlation with TCH in most well watered & moderate stress environments
- Canopy conductance as a selection trait in breeding programs will require rapid, high-throughput screening methods suitable for large selection trials
- Screening for canopy conductance will help combine increased WUE and productivity allowing to select high yielding clones suitable for different production environments

Thank you!

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Publications related to this work

J. Basnayake, PA. Jackson, NG. Inman_Bamber, P. Lakshmanan. 2015. Sugarcane for water- limited environments. Canopy conductance (g_c) is a major determinant of crop productivity. Journal of Experimental Botany, doi:10.1093/jxb/erv194

J. Basnayake, PA Jackson, NG. Inman-Bamber, P. Lashmanan. 2012. Sugarcane for water-limited environments. Genetic variation in cane yield and sugar content in response to water stress. Journal of Experimental Botany 63(16): 6023-6033. Impact Factor 5.79.