IWYP International Wheat Yield Partnership

Research to Deliver Wheat for the Future

Combining complex traits to improve heat and drought adaptation, without loss of yield potential in favorable seasons

IWYP, HeDWIC, CIMMYT

IWYP AGM, 10,12 September, 2025

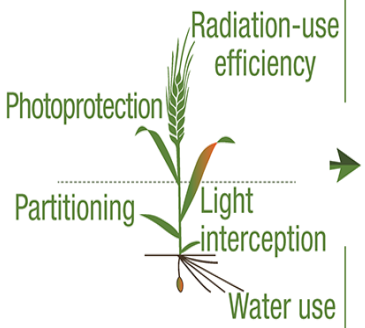
HeDWIC

CIMMYT | CGIAR

The IWYP & HeDWIC approach to "blend" complex traits capitalizes on models of yield, genetic resources, phenomics, genomics and validation via IWIN

PHYSIOLOGICAL PRE-BREEDING PIPELINE

CROP DESIGN



Determine traits/genes for adaptation

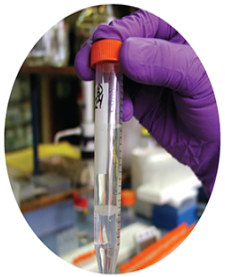
GENETIC RESOURCES

- Landraces
- Wild relatives
- Elite lines

PHENOTYPING

- High through-put remote sensing
- Precision phenotyping

GENETIC ANALYSIS



- Genetic complexity
- QTL identification
- MAS assay developed

CROSSING & SELECTION

- Strategic crosses
- Select best progeny (phenotyping/ molecular tools)

EVALUATION OF GENETIC GAINS

For example, through International Wheat Improvement Network

INFORMATICS

Database that integrates (phenomic and genomic) research, breeding and international trial data

Reynolds MP and Langridge P, (2016). Physiological Breeding. Current Opinions in Plant Biology 31: 162–171

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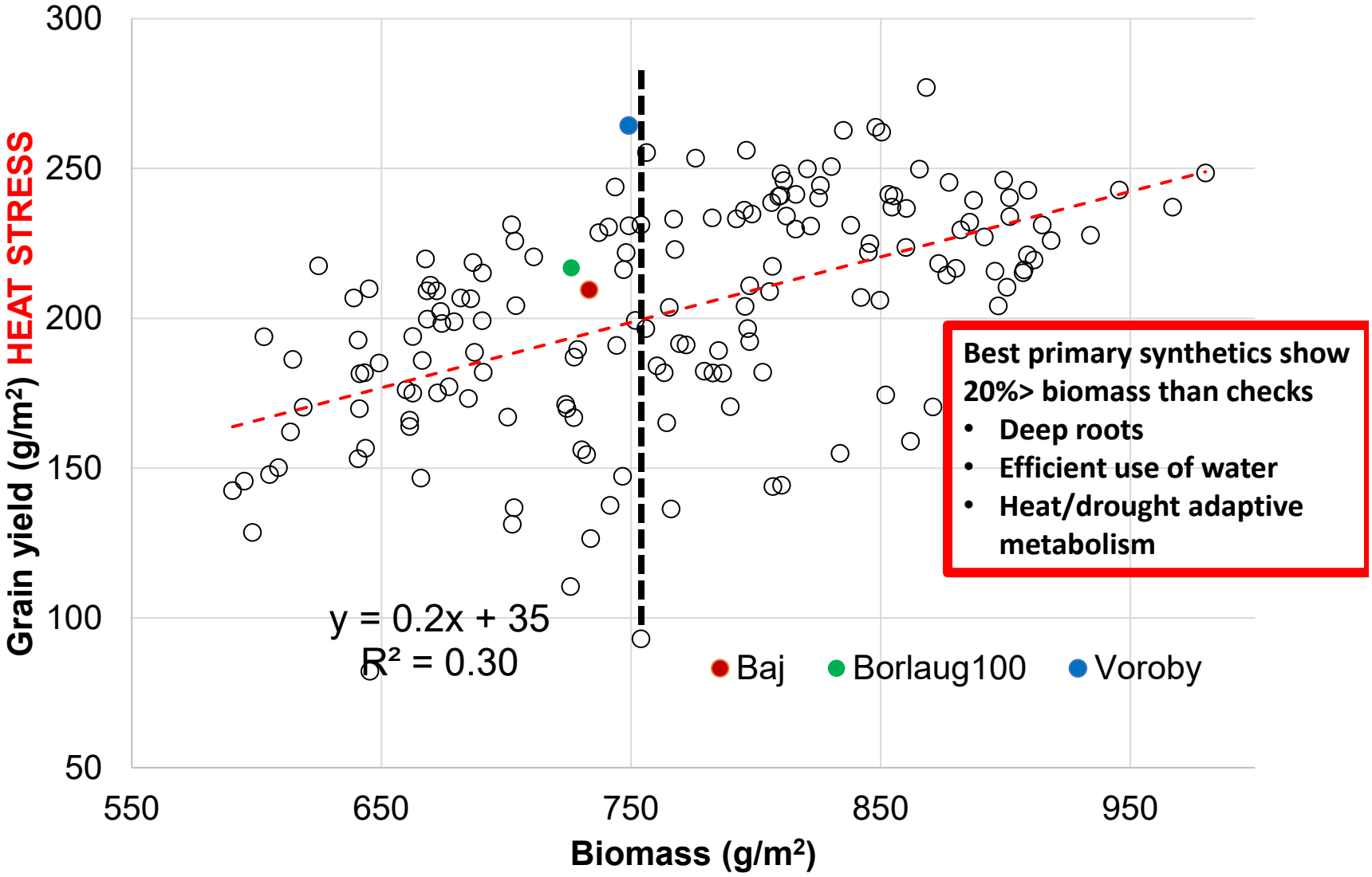
Novel alleles from wild-relatives are accessed via crossing with amphiploids like 'synthetic wheat'

NW Mexico, 2016 & 2017 (Late sown)



Gene-sequencing of progeny from crosses with amphiploids reveals heat tolerance haplotypes without yield penalty

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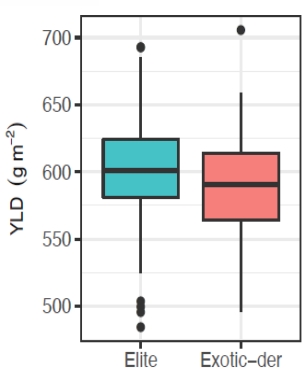
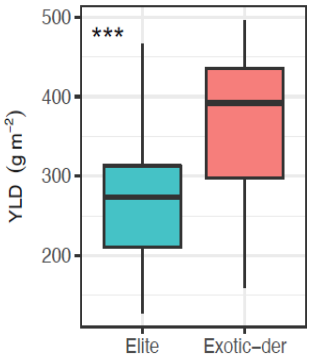
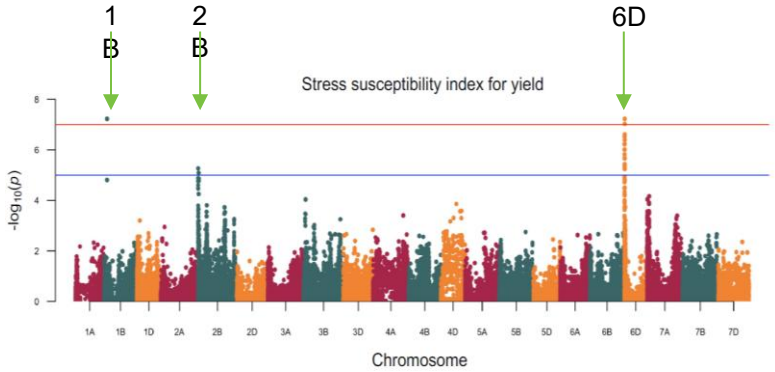
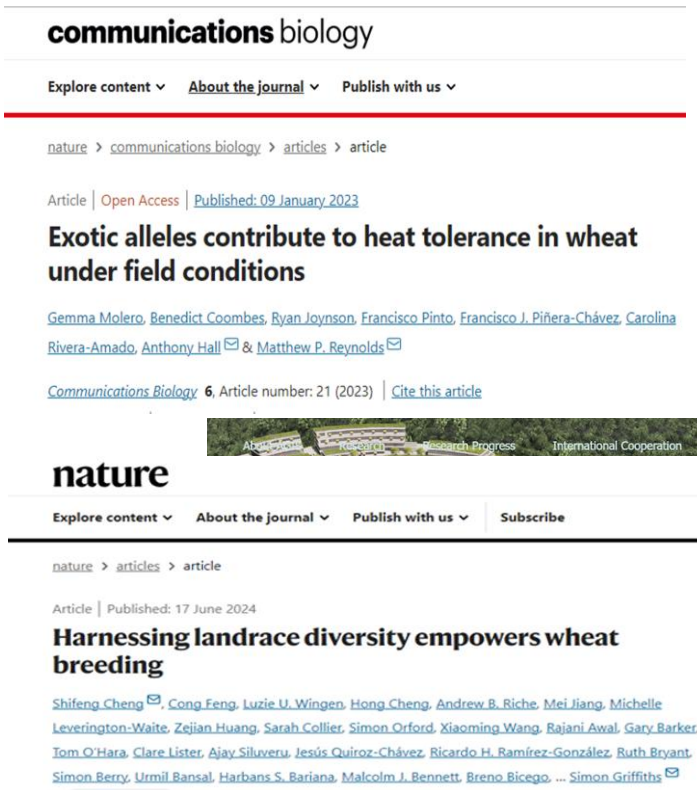
Sequenced IWYP & HeDWIC panels -by AGIS- leverages the vast phenotypic data sets for gene & haplotype discovery





Check yield **Heat stressed yield**

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Exotic alleles contribute to heat tolerance in wheat under field conditions

Gemma Molero, Benedict Coombes, Ryan Joynson, Francisco Pinto, Francisco J. Piñera-Chávez, Carolina Rivera-Amado, Anthony Hall & Matthew P. Reynolds

Communications Biology 6, Article number: 21 (2023) | Cite this article

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Article | Published: 17 June 2024

Harnessing landrace diversity empowers wheat breeding

Shifeng Cheng, Cong Feng, Luzie U. Wingen, Hong Cheng, Andrew B. Riche, Mei Jiang, Michelle Leverington-Waite, Zejian Huang, Sarah Collier, Simon Orford, Xiaoming Wang, Rajani Awal, Gary Barker, Tom O'Hara, Clare Lister, Ajay Siluveru, Jesús Quiroz-Chávez, Ricardo H. Ramírez-González, Ruth Bryant, Simon Berry, Urmil Bansal, Harbans S. Bariana, Malcolm J. Bennett, Breno Bicego, ... Simon Griffiths

HeDWIC
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Gene discovery in novel amphiploid genomes (Xu et al)

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	Environments CENEB, Mexico	Marr	Chromo-some	PVE all sig SNPs	Novel markers	PVE all novel SNPs
SYNPAN II	Irrigation	AX-94907052	1A	40%	Y	**23%**
		AX-158621657	5B		Y	
		AX-94951542	5B		Y	
	Heat	Excalibur_c32608_500	1B	47%	Y	**20%**
		Ex_c525_1401	2B		Y	
	Drought	AX-94537209	4D	15%	Y	**6%**
		AX-158587956	6B		Y	
	Combined	AX-158570322	1B	55%	Y	**24%**
		Tdurum_contig777_260	3A		Y	
		AX-158541430	3B		Y	
		D_contig59199_227	3D		Y	
		AX-158534283	5B		Y	
		Ex_c101666_634	7B		Y	
ISO-D RILs (Family 2)	Irrigation	5D@20.2	5D	21%	Y	**8%**
	Drought	1D@42.2	1D	24%	Y	**24%**
		5D@0.2	5D		Y	

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Gene discovery in diversity panels originating from the World Wheat Collection (large subset) at CIMMYT (Xu et al)

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MOLPAN (selected to maximize molecular diversity)	Environment	Chromo-some	P value adjusted	PVE per SNP	PVE all sig SNPs	Novel MTA	PVE all novel SNPs
					%		%
MOLPAN	Yield Potential	3A	0.0000181	8%	30.7	Y	20
	CENEB, Mexico	3B	0.0004115	10%		Y	
MOLPAN	Heat	3B	0.0000006	6%	21.5	Y	9
	CENEB, Mexico	4A	0.0064573	3%		Y	
MOLPAN	Drought	3B	0.0065973	7%	37	Y	17
	CENEB, Mexico	6A	0.0050185	7%		Y	
		7D	0.0020624	5%		Y	
MOLPAN	Combined	1A	0.0083901	NS	32	Y	9
	CENEB, Mexico	1A	0.0003131	7%		Y	
		3B	0.0000004	10%		Y	
EDPIE-MEX selected elite lines with highly diverse pedigrees	Heat	1A	0.0070	6%	43	Y	4
	Drought	5A	0.0004	13%	22	Y	22
	CENEB, Mexico	7A	0.0065	10%		Y	
EDPIE-International	Comb (22 sites)	4B	0.0039	8%	42	Y	18

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Physiological or Predictive Pre-Breeding (PPB)

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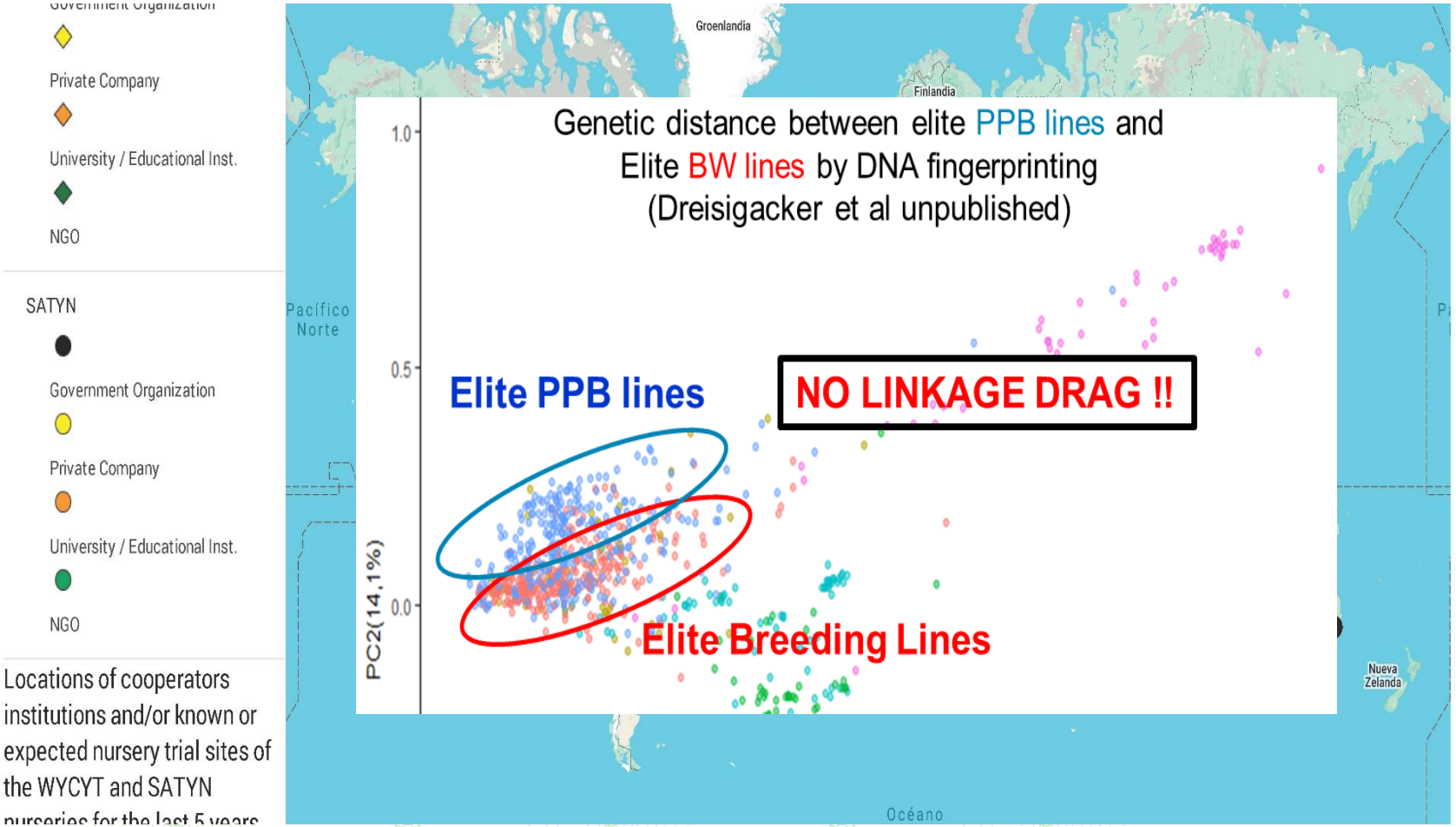
WYCYT & SATYN trial sites (>200 request p.a.)

Best lines locally/regionally used as parents



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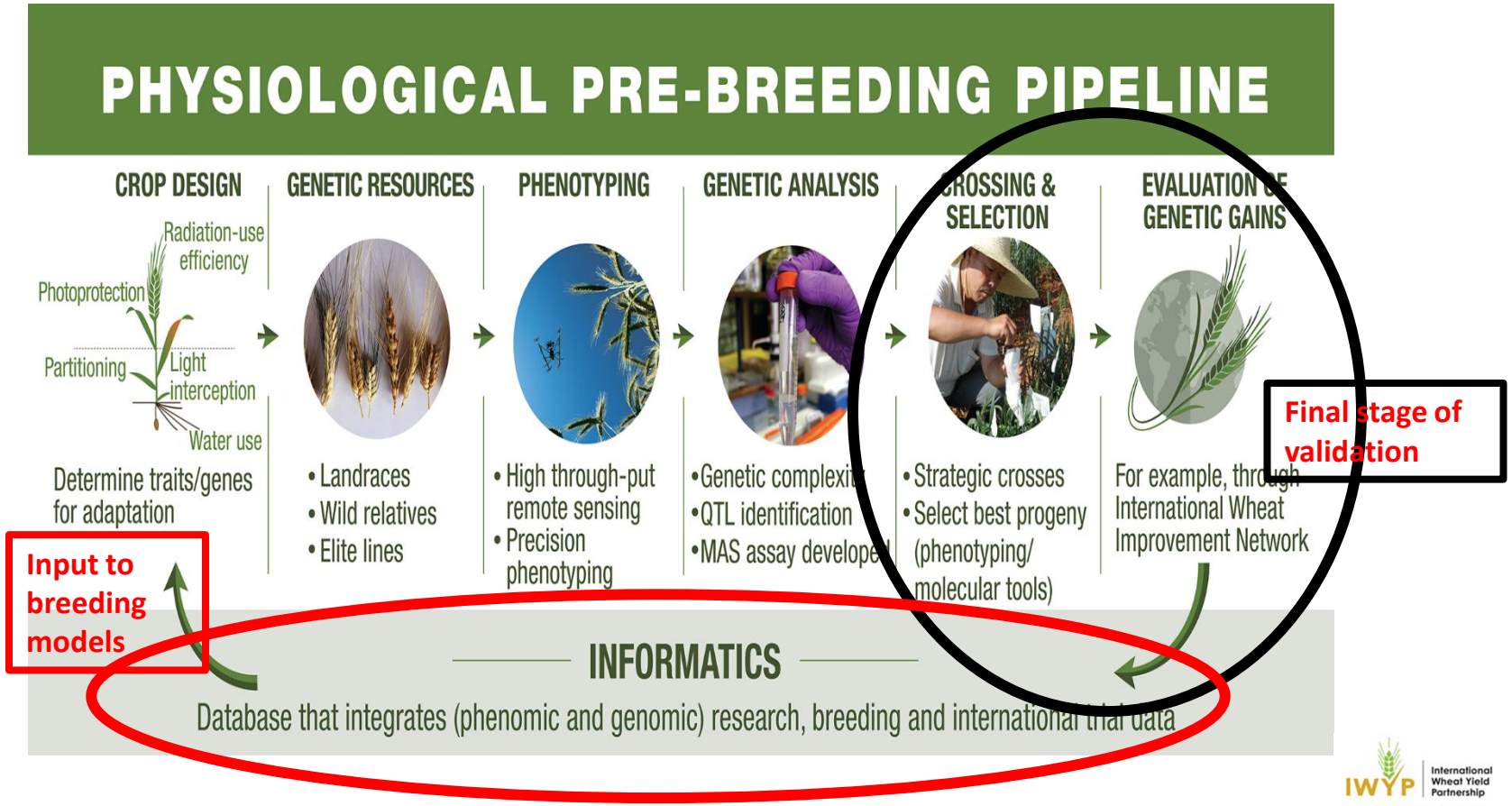
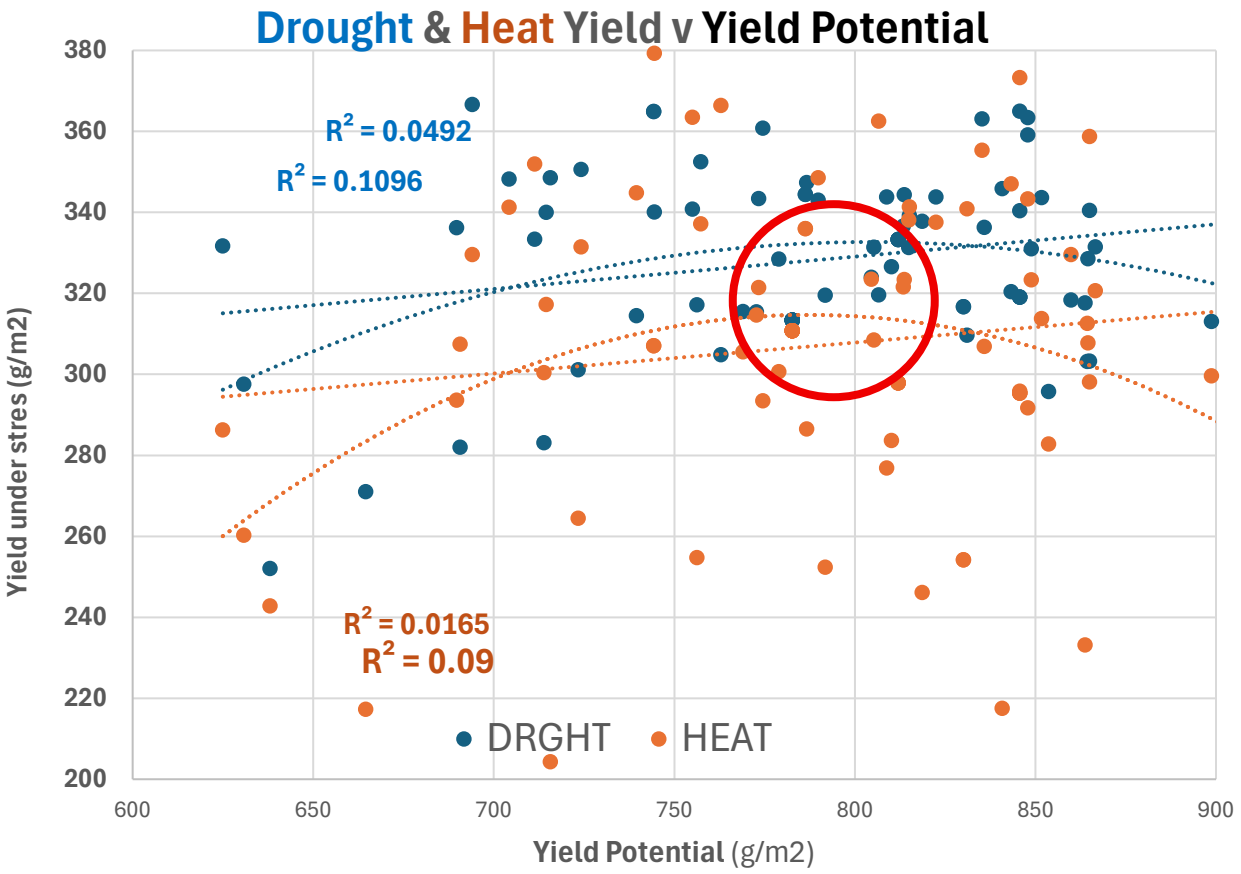
Dissecting traits conferring heat and drought adaptation



Reynolds MP and Langridge P, (2016). Physiological Breeding.
Current Opinions in Plant Biology 31: 162–171

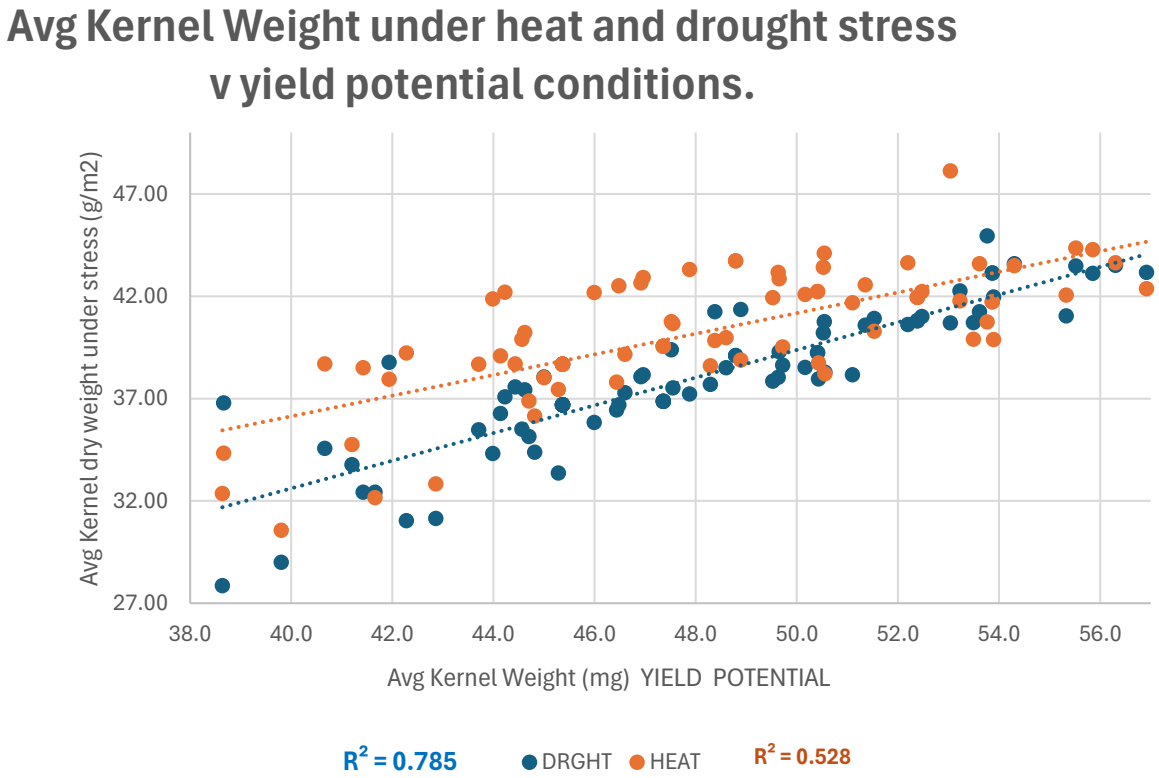
Yield potential: not a good predictor of stress adaptation



Yield potential -in the 30 selected PPB lines and their parents- is not a good predictor of heat or drought tolerance.

Polynomial analysis suggests yield potential above a threshold (8 t/ha in this scenario) may be detrimental to stress adaptation

The heritable trait Kernel Weight expressed under yield potential traits benefit stress adaptation



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Two crosses with drought adapted progeny and a degree of wide adaptation based on yield ranks, and the traits improved

PPB LINE				Potential	Drought	Source Trait	Sink Trait	Sink Trait	Sink Trait	Sink Trait	Source Trait	Source Trait
PPB Parent	RANK	RANK	RANK	YLD-YP	YLD-DRT	Final Biomass	Grains/m2	Grainfill Rate	Grains/	Peduncle	PhotoProtection Indices	
BW PARENT	Yield Pot	Drought	Heat	(g/m2)	gm^{-2}	gm^{-2}	#	$gm^{-2}\ day^{-1}$	Spikelet	length (cm)	PRI	PSRI
CROSS A							GN_Calc_G	m2			Idx	Idx
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/				757	353	841	9349	10.45	1.815	28.0	-0.030	0.052
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/	11	3	5	835	363	891	9986	12.10	1.826	29.7	-0.039	0.086
W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1				830	317	774	8128	10.23	1.622	27.0	-0.040	0.067
	Progeny v mid parent (%)			1.05	1.09	1.10	1.14	1.17	1.06	1.08	1.11	1.44
CROSS B												
RL6043/4*NAC//2*PASTOR/3/BCN/WBLL1				631	298	730	7667	8.84	1.814	27.4	-0.030	0.051
RL6043/4*NAC//2*PASTOR/3/BCN/WBLL1/4/KUTZ	6	2	8	848	363	794	9635	11.01	1.819	31.1	-0.029	0.065
KUTZ				814	344	780	8320	9.36	1.827	26.3	-0.025	0.064
	Progeny v mid parent (%)			1.17	1.13	1.05	1.21	1.21	1.00	1.16	1.08	1.12

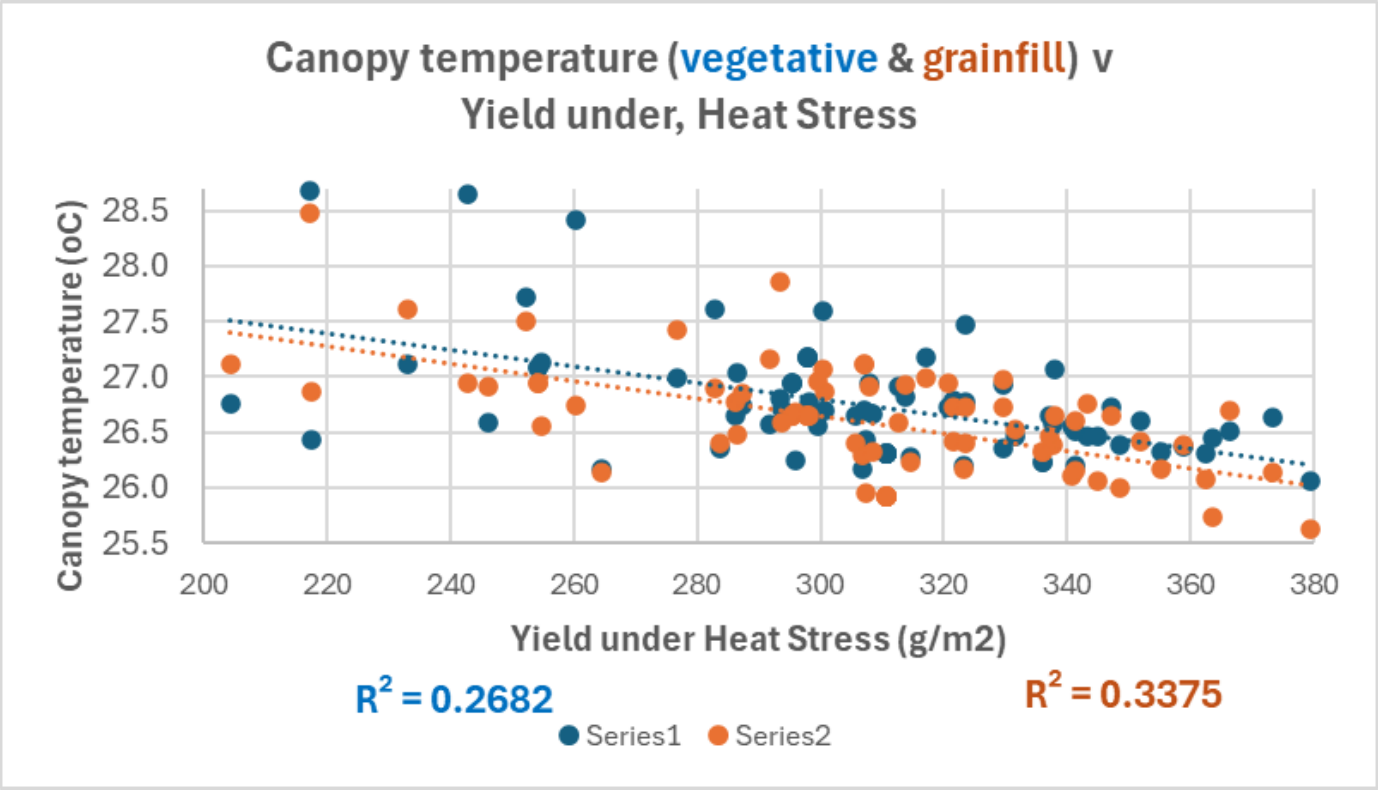
Two crosses with Heat and Drought adapted progeny and wide adaptation and the 'source' traits consistently improved

		Source traits						Photoprotection Spectral Indices			
	Heat Yield	Biomass	Biomas	RUE_preGF	RUE_GF	RUE_Total	Canopy Temp				
	gm^{-2}	at maturity (g/m2)	at 40 days	g/MJ	g/MJ	g/MJ	Avg AM	PSRI	Chl A:B	RARSc	NPQI
Cross Name											
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3	337	733	470.938	1.334	0.410	0.960	26.656	-0.003	1.342	15.502	-0.083
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3	355	804	524.392	1.752	0.420	1.043	26.330	-0.003	1.365	14.618	-0.100
W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	254	574	438.852	1.932	0.360	1.169	27.077	-0.003	1.262	13.269	-0.103
Progeny v mid parent (%)	1.20	1.23	1.15	1.07	1.09	0.98	0.98	1.10	1.05	1.02	1.07
Cross Name											
RL6043/4*NAC//2*PASTOR/3/BCN/WBLL1	260	615	342.561	1.534	0.410	0.935	28.410	0.001	1.223	12.276	-0.097
RL6043/4*NAC//2*PASTOR/3/BCN/WBLL1/4/KU	343	720	449.914	1.591	0.440	1.259	26.465	-0.002	1.239	13.376	-0.095
KUTZ	323	719	399.254	1.502	0.380	1.071	26.769	-0.003	1.116	13.798	-0.085
Progeny v mid parent (%)	1.18	1.08	1.21	1.05	1.11	1.26	0.96	1.16	1.06	1.03	1.04

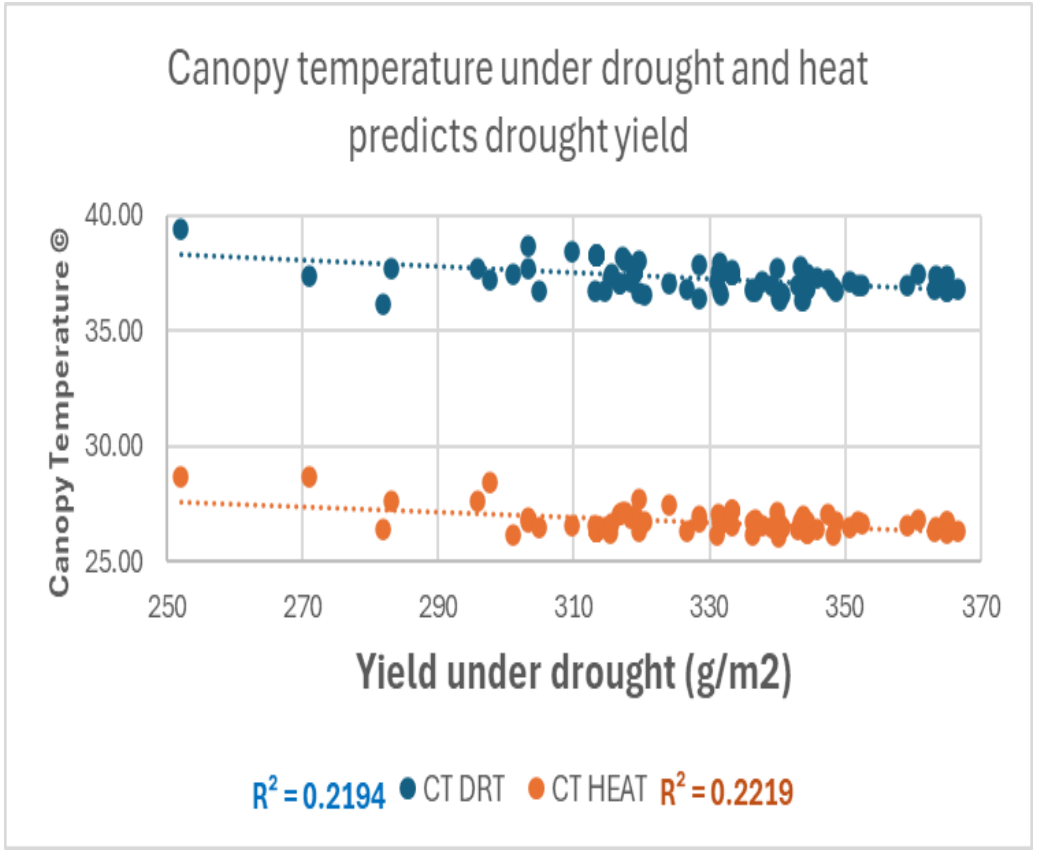
Same two crosses with Heat and Drought adapted progeny and wide adaptation and the 'Sink' traits consistently improved

		Sink Traits							
	Heat Yield	Grains/m2	Spikes/m2	Grainfill Rate	Tillers at Anth	Spikes at Ant	Spike Loss	Stored carboH	Ped length
	gm^{-2}			$gm^{-2}\ day^{-1}$	$\#m^{-2}$	$\#m^{-2}$	from anthesis	Anthesis (g/m2)	cm
Cross Name									
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92	337	8821	284	14.3	570	443	159	130	21.967
MTRWA92.161/PRINIA/5/SERI*3//RL6010/4*YR/3/PASTOR/4/BAV92/6/W15.92/	355	9422	330	15.4	587	443	113	208	25.238
W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	254	5787	206	10.9	468	393	187	235	22.613
Progeny v mid parent (%)	1.20	1.29	1.34	1.22	1.13	1.06	0.65	1.14	1.13
Cross Name									
RL6043/4*NAC//2*PASTOR/3/BCN/WBLL1	260	6900	210	11.0	438	401	191	125	22.970
RL6043/4*NAC//2*PASTOR/3/BCN/WBLL1/4/KUTZ	343	7971	253	14.0	451	394	140	211	28.202
KUTZ	323	8326	227	12.6	392	337	110	169	23.877
Progeny v mid parent (%)	1.18	1.05	1.16	1.18	1.09	1.07	0.93	1.43	1.20

Canopy temperature measured at different growth stages is a robust predictor of yield under heat stress

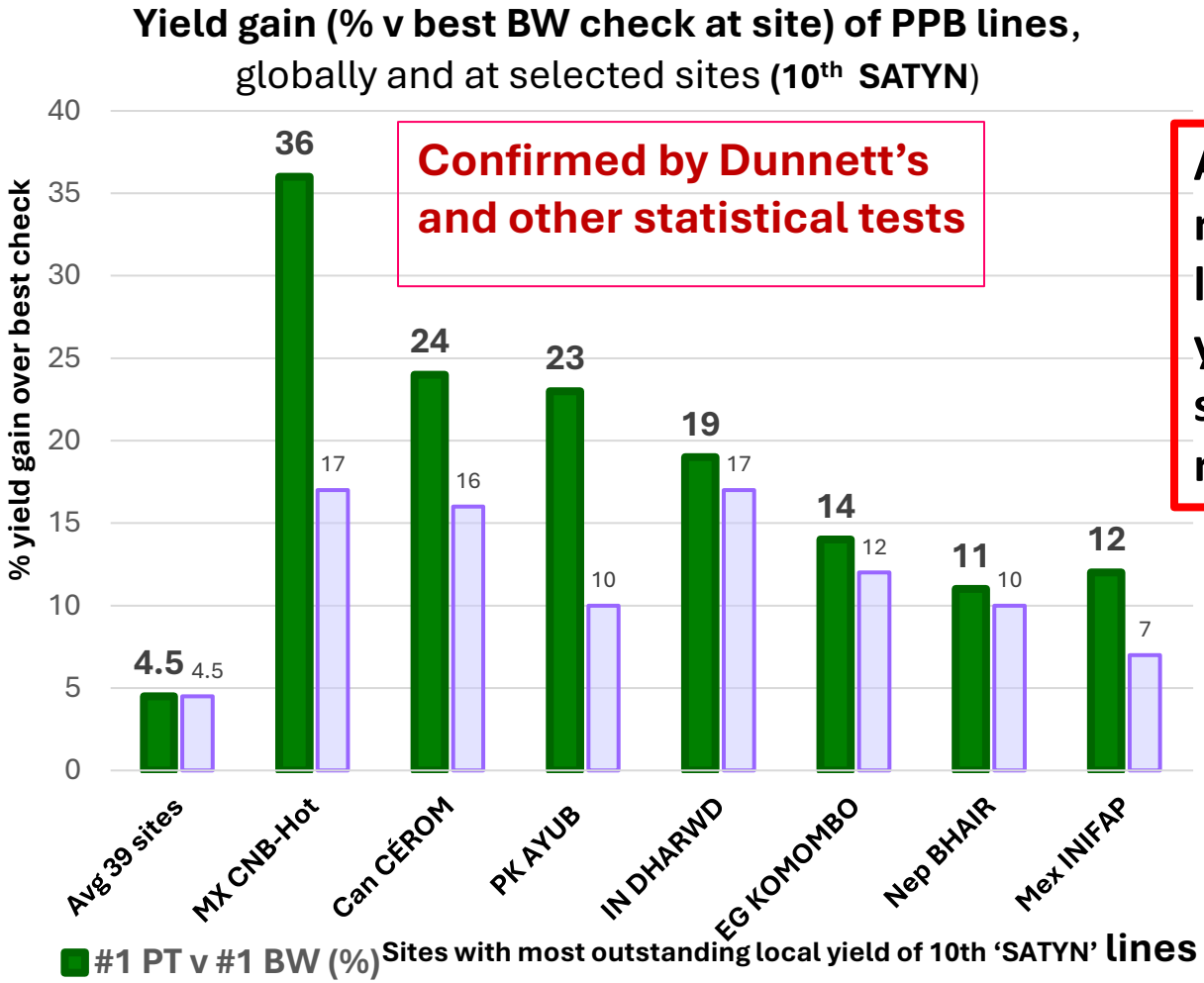


Canopy temperature measured at high VPD predicts yield under drought due to its coupling with root capacity



Outstanding Yields from Predictive Pre-Breeding lines

Mainly observed at local or regional level at ~40% of IWIN sites.



Confirmed by Dunnett's and other statistical tests

All WYCYT and SATYN nurseries have included lines with outstanding yields at between 3-7 sites, and typically mirrored in sister lines

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Reported released PT cultivars

Year	Name	Country	Cross / pedigree
2013	Pakistan-13	Pakistan	MEX94.27.1.20/3/SOKOLL//ATTILA/3*BCN
2016	Borlaug-16	Pakistan	SOKOLL/3/PASTOR//HXL7573/2*BAU
2017	Kohat 17	Pakistan	SOKOLL/WEEBIL
2018	CASCABEL (for SB)	S Asia (humid)	SOKOLL//W15.92/WBLL1 (SQWA or SUGA)
2020	Kunar 20	Afghanistan	MEX94.27.1.20/3/SOKOLL//ATTILA/3*BCN/4/PUB94.15.1.12/WBLL1
2022	Misr 7	Egypt	WBLL1//PUB94.15.1.12/WBLL1/3/MUCUY
2023	Misr 9	Egypt	BCN/WBLL1//PUB94.15.1.12/WBLL1/3/MUCUY
2024	WGE000006939945	Pakistan	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/SERI/BAV92//WBLL1
2025		Iran	MEX94.27.1.20/3/SOKOLL//ATTILA/3*BCN/4/PUB94.15.1.12/WBLL1

CIMMYT

Acknowledgements

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