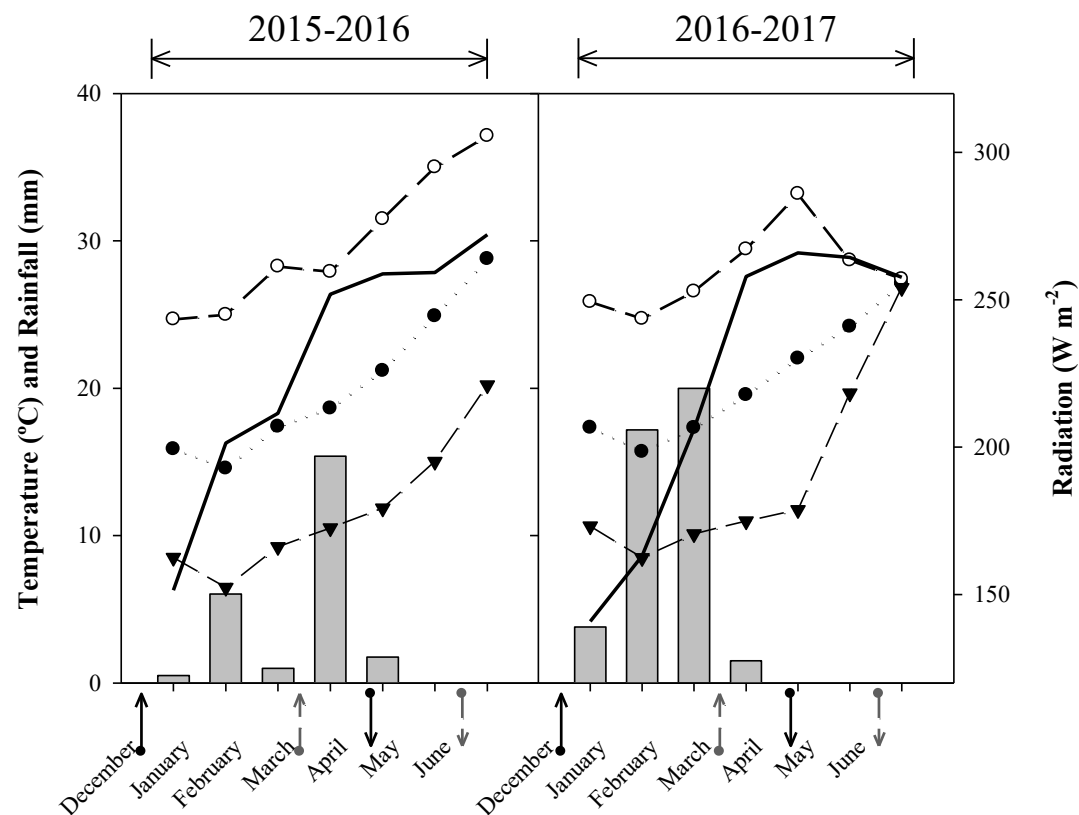
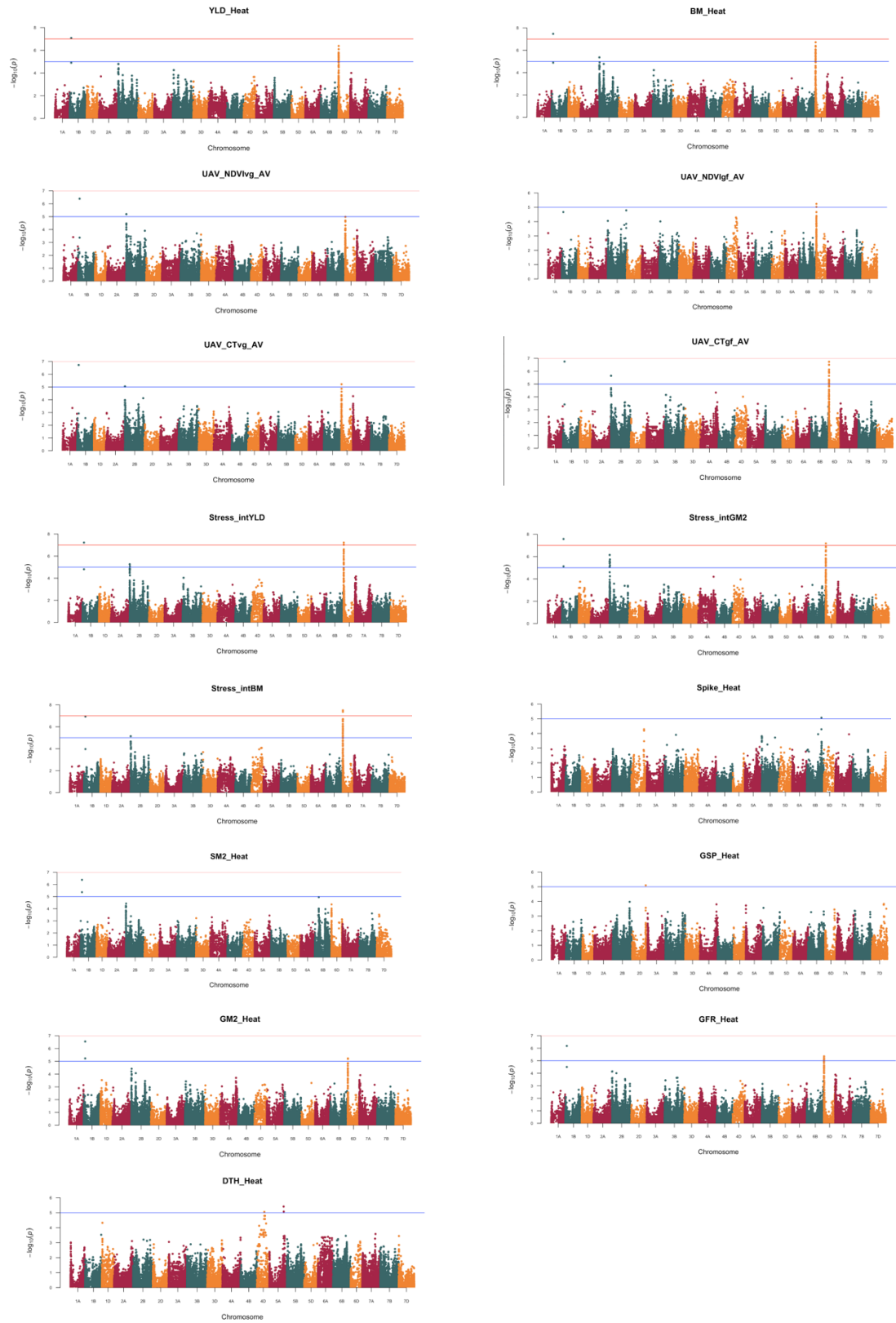


Supplementary Figure 1



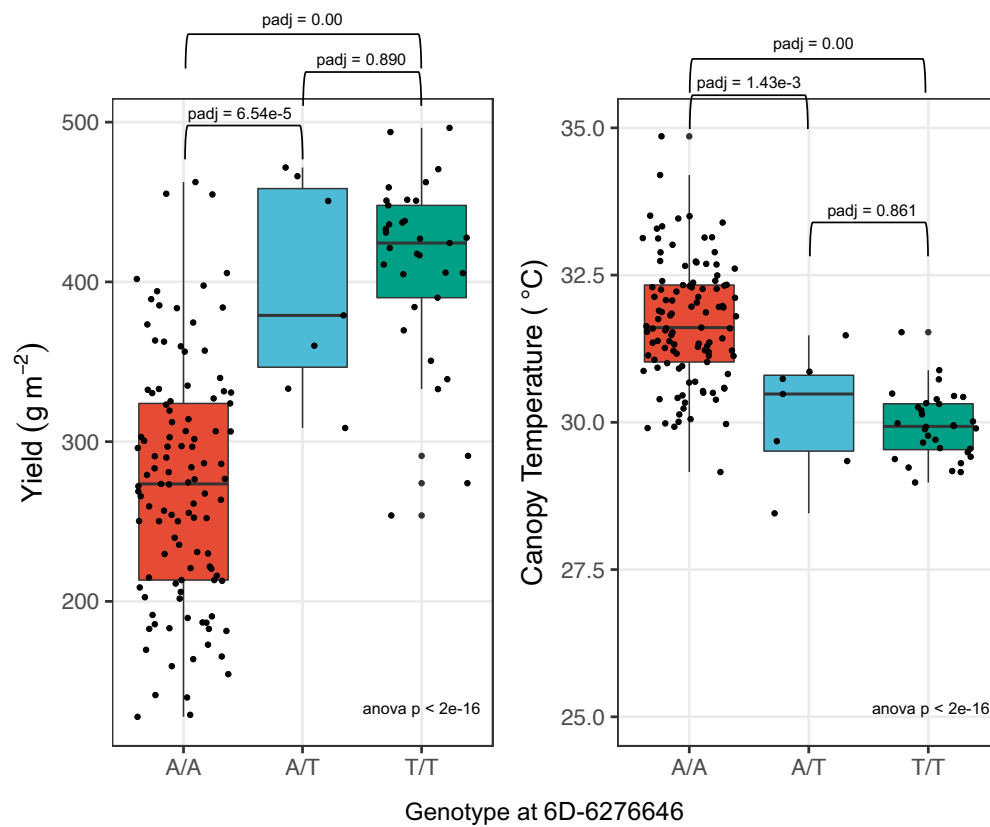
Supplementary Figure 1. Monthly accumulated rainfall (grey bars), average mean temperature (●), average maximum temperature (○), average minimum temperature (▼) and average monthly radiation (—) registered during the experiments in the IWYP-HUB situated at CENEB experimental station situated in Ciudad Obregon Sonora, NW-Mexico. (↑) Represents emergence date for yield potential trials, (↓) represents harvest date for yield potential trials, (↑, broken line) represents emergence date for heat stressed trials, (↓, broken line) represents harvest date for heat stressed trials.

Supplementary Figure 2



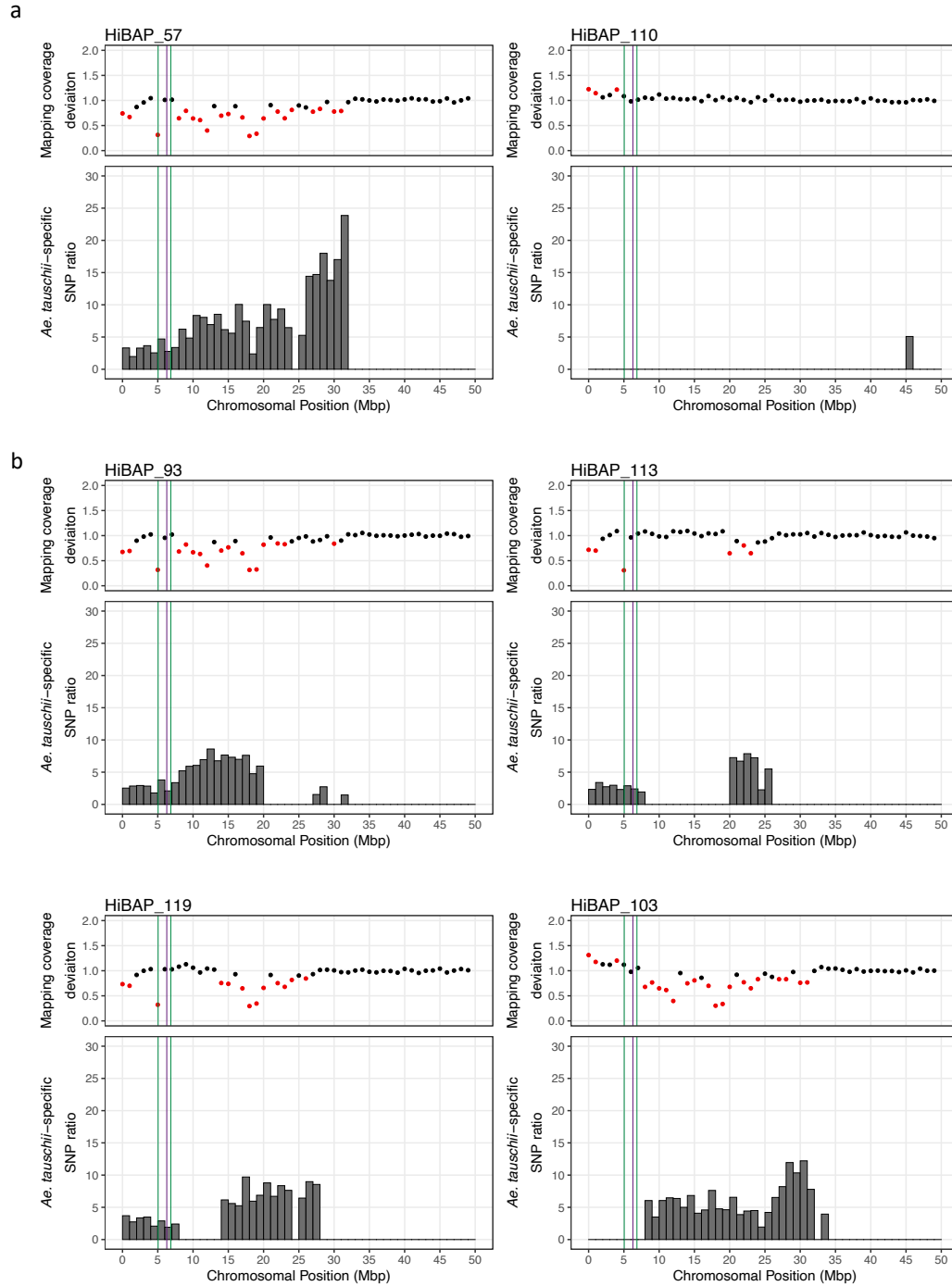
Supplementary Figure 2. GWAS results in HiBAP I based on BLUEs means obtained from the combined analysis from Ht16 and Ht17. The dotted horizontal line indicates threshold of significance.

Supplementary Figure 3



Supplementary Figure 3. Yield and vegetative canopy temperature under heat stressed conditions for lines with homozygous unfavourable allele (A/A), heterozygous for the favourable allele (A/T) and homozygous for the favourable allele (T/T). Black points indicate individual data points; this was done due to the small sample size of A/T. Significance was computed using a one-way ANOVA test (n=109, 7, and 32 biologically independently lines for A/A, A/T and T/T, respectively). Tukey's honest significance test was used to calculate adjusted p-values for each pairwise comparison.

Supplementary Figure 4



Supplementary Figure 4. *Ae. tauschii* introgressions within 6D:0-50Mbp in **a** Sokoll (HiBAP_57) and Weebil1 (HiBAP_110) and **b** four independent Sokoll/Weebil1 crosses. Mapping coverage deviation was computed between the HiBAP line and the median of the panel in 1Mbp windows. Red points are statistically significant outliers. *Ae. tauschii*-specific SNP ratio in each 1Mbp window was calculated by dividing the number of homozygous *Am. muticum*-specific SNPs in that window by mean number of homozygous SNPs in that window across the panel. Green lines mark the borders of the region common to all lines with the T haplotype, corresponding to a 1.80Mbp region in CS and a 1.49Mbp in *Ae. Tauschii*. The purple line indicates the 6D MTA position.

Supplementary Table 1: Experimental details for each panel evaluated in the present study among different years at the International Wheat Yield Partnership HuB (IWYP-HUB) situated at CENEB in the Yaqui Valley, near Ciudad Obregon, Sonora, Mexico.

	Env	Cycle	Plot size	#rows	Reps	Emergence date	Harvest date	Pre-sowing irrigation	Tmax >35°C†	Irrigations					
										1	2	3	4	5	6
HiBAP I	YP	2015 — 2016	6.4 m ²	4	4†	07-Dec-15	13-May-16	28-Nov-15	4	07-Jan-16	05-Feb-16	27-Feb-16	02-Mar-16		
(n =149 lines)		2016 — 2017	6.4 m ²	2	4†	30-Nov-16	26-Apr-17	07-Nov-16	9	27-Dec-16	27-Jan-17	03-Mar-17			
	Heat	2016	1.6 m ²	3	2	03-Mar-16	13-Jun-16	08-Feb-16	25	18-Mar-16	01-Apr-16	15-Apr-16	29-Apr-16	14-May-16	27-May-16
		2017	1.6 m ²	3	2	08-Mar-17	20-Jun-17	07-Feb-17	14	18-Mar-17	02-Apr-17	18-Apr-17	30-Apr-17	14-May-17	27-May-17

†Only 2 replicates were measured for most of the traits

‡From Emergence until Harvest

Supplementary Table 2: Summary statistics for physiological traits measured under heat stress or yield potential conditions over 2 years. Confidence intervals and p-values calculated using two-tailed t tests with no assumption of equal variance to compare Elite lines (N=83) with exotic-derived lines (N=66).

Trait	Condition	Elite mean $\pm$ S.D	Exotic mean $\pm$ S.D	95% confidence interval	p-value
YLD (g m⁻²)	Heat stress	265 $\pm$ 69.6	365 $\pm$ 88.1	[-126,-73.6]	9.61e-12
TGW(g)	Heat stress	32.3 $\pm$ 3.36	35.7 $\pm$ 3.27	[-4.43,-2.28]	7.66e-09
GM2(no. grains m⁻²)	Heat stress	8120 $\pm$ 1913	10246 $\pm$ 2054	[-2776,-1476]	1.685e-09
BM_PM (g m⁻²)	Heat stress	565 $\pm$ 138	786 $\pm$ 169	[-272,-170]	3.38e-14
HI	Heat stress	0.465 $\pm$ 0.0232	0.466 $\pm$ 0.0229	[-0.0009151, 0.000588]	0.668
Height (cm)	Heat stress	61.6 $\pm$ 4.55	67.2 $\pm$ 6.03	[-7.34,-3.80]	7.69e-09
YLD (g m⁻²)	Yield potential	560 $\pm$ 42.0	590 $\pm$ 35.6	[-2.51,22.6]	0.116
TGW(g)	Yield potential	42.4 $\pm$ 3.95	45.7 $\pm$ 4.06	[-4.69,-2.07]	1.03e-06
GM2(no. grains m⁻²)	Yield potential	14228 $\pm$ 1066	12986 $\pm$ 1374	[835,1649]	1.78e-08
BM_PM (g m⁻²)	Yield potential	1331 $\pm$ 84.4	1385 $\pm$ 97.2	[-83.6,-23.7]	5.54e-04
HI	Yield potential	0.478 $\pm$ 0.0242	0.456 $\pm$ 0.0225	[0.0140,0.0291]	9.21e-08
Height (cm)	Yield potential	97.9 $\pm$ 3.99	102 $\pm$ 4.98	[-5.22,-2.24]	2.41e-06

Supplementary Table 3. Average, minimum, maximum values, broad sense heritability (H²) and ANOVA for the main traits evaluated in the heat experiments and percentage of loss in comparison with experiments under favourable conditions.

Traits	HiBAP I (2015-2016 & 2016-2017)							%Loss vs. YP
	Heat stress							
	Mean	Max	Min	H ²	P(Gen)	P(Year)	P(GxY)	
YLD (gm ⁻²)	309	496	128	0.79	0.000	0.071	0.000	-48.1
TGW (g)	33.8	42.2	23.4	0.88	0.000	0.969	0.000	-22.9
GM2 (#m ⁻²)	9052	14370	4271	0.78	0.000	0.051	0.000	-33.8
BM_PM (gm ⁻²)	663	1052	279	0.8	0.000	0.076	0.000	-51.1
HI	0.47	0.51	0.35	0.45	0.000	0.074	0.001	-0.7
SM2 (#m ⁻²)	255	460	130	0.71	0.000	0.090	0.000	-15.9
GSP (#)	35.0 [†]	46.9	22.6	0.31	0.005	0.004	0.000	-27.7
GWSP (g)	1.2 [†]	1.7	0.6	0.62	0.000	0.013	0.000	-44.1
Plant Height (cm)	64	80.4	46.8	0.78	0.000	0.146	0.339	-35.7
SPKLSP ⁻¹ (#)	18.2	20.2	14.7	0.67	0.000	0.599	0.963	-8.2
Infertile SPKLSP ⁻¹ (#)	1.4	2.7	0.6	0.44	0.000	0.775	0.591	26.8
Spike Length (cm)	9.9	11.6	6.4	0.88	0.000	0.153	1	-17.8
Awns Length (cm)	5.3	7	4	0.76	0.000	0.054	1	-17.1
Peduncle Length (cm)	21.2	29.9	14.9	0.76	0.000	0.146	0.000	-43.5
DTA/DTH (days)	53	62	44	0.88	0.000	0.027	0.000	-31.2
DTM (days)	80	90	72	0.87	0.000	0.105	0.000	-30.6
Grain filling (%)	34	44.8	25.9	0.66	0.000	0.638	0.000	1.6

[†]COV DTH used to adjust the meas as its effect was significant

YLD: grain yield, TGW: thousand grain weight, GM2: grains per m², BM_PM: biomass at physiological maturity, HI: Harvest Index, SM2: spikes per m², GSP: grains per spike, GWSP: grain weight per spike, SPKLSP: spikelets per spike, DTA: days to anthesis, DTH: days to heading, DTM: days to maturity

Supplementary Table 4. Pearson's correlation tests between NDVI and Yield and between Canopy temperature and yield under either heat stressed or yield potential conditions and at either the vegetative or grain filling phenological stage.

Trait	Condition	Phenological stage	Line classification	Pearson's correlation coefficient (r)	95% confidence interval	p-value
NDVI	Heat stress	Vegetative	Elite	0.753	[0.641,0.833]	2.29e-16
NDVI	Heat stress	Vegetative	Exotic-derived	0.814	[0.712,0.882]	<2.2e-16
NDVI	Yield potential	Vegetative	Elite	-0.197	[-0.396,0.0197]	0.0745
NDVI	Yield potential	Vegetative	Exotic-derived	-0.187	[-0.410,0.0579]	0.133
NDVI	Heat stress	Grain Filling	Elite	0.444	[0.252,0.602]	2.64e-05
NDVI	Heat stress	Grain Filling	Exotic-derived	0.712	[0.568,0.814]	2.00e-11
NDVI	Yield potential	Grain Filling	Elite	-0.256	[-0.447,-0.0425]	0.0196
NDVI	Yield potential	Grain Filling	Exotic-derived	0.0943	[-0.151,0.329]	0.451
CT	Heat stress	Vegetative	Elite	-0.758	[-0.837,-0.648]	<2.2e-16
CT	Heat stress	Vegetative	Exotic-derived	-0.875	[-0.922,-0.804]	<2.2e-16
CT	Yield potential	Vegetative	Elite	-0.260	[-0.450,-0.0467]	0.0177
CT	Yield potential	Vegetative	Exotic-derived	0.00350	[-0.239,0.245]	0.978
CT	Heat stress	Grain Filling	Elite	-0.702	[-0.797,-0.573]	1.44e-13
CT	Heat stress	Grain Filling	Exotic-derived	-0.859	[-0.912,-0.779]	<2.2e-16
CT	Yield potential	Grain Filling	Elite	-0.206	[-0.403,0.0105]	0.0621
CT	Yield potential	Grain Filling	Exotic-derived	-0.265	[-0.476,-0.0243]	0.0317

Supplementary Table 5. Phenotypic correlations between NDVI and CT measured in the heat experiments at the vegetative stage (vg) or during grain filling (gf) and Stress Susceptibility Index calculated for yield (SSI_YLD) with main yield and yield components. Bold indicates significant at at least $P < 0.05$

Traits	NDVlvg_AV	NDVlgf_AV	CTvg_AV	CTgf_AV	SSI_YLD
YLD (gm^{-2})	0.849	0.700	-0.871	-0.851	-0.976
TGW (g)	0.591	0.472	-0.594	-0.574	-0.586
GM2 ($\text{\#m}^{-2}$)	0.795	0.659	-0.816	-0.801	-0.928
BM_PM (gm^{-2})	0.874	0.746	-0.895	-0.879	-0.962
HI	0.185	0.057	-0.195	-0.174	-0.369
SM2 ($\text{\#m}^{-2}$)	0.670	0.588	-0.680	-0.678	-0.829
GSP (#)	0.472	0.349	-0.500	-0.475	-0.455
GWSP (g)	0.665	0.518	-0.687	-0.658	-0.665
Plant Height (cm)	0.722	0.612	-0.727	-0.734	-0.680
SPKLSP ⁻¹ (#)	0.405	0.384	-0.392	-0.375	-0.219
Infertile SPKLSP ⁻¹ (#)	-0.010	0.063	-0.010	-0.015	0.046
Spike Length (cm)	0.407	0.311	-0.398	-0.371	-0.219
Awns Length (cm)	0.171	0.119	-0.153	-0.186	-0.093
Peduncle Length (cm)	0.536	0.438	-0.506	-0.522	-0.486
DTA/DTH (days)	0.270	0.504	-0.211	-0.268	0.009
DTM (days)	0.428	0.680	-0.353	-0.428	-0.181
Grain filling (%)	0.045	-0.055	-0.060	-0.053	-0.232
NDVlvg_AV	-	0.879	-0.954	-0.945	-0.850
NDVlgf_AV	0.879	-	-0.847	-0.905	-0.719
CTvg_AV	-0.954	-0.847	-	0.951	0.863
CTgf_AV	-0.945	-0.905	0.951	-	0.856

Supplementary Table 6. Summary of Marker-Trait Associations (MTAs) for different physiological traits and the chromosomes where they were identified, position, P-value and interval.

Trait	Chromosome	MTA ID	Position	P-value	Interval
Yield Traits					
YLD	chr1B	chr1B-63398861	63398861	8.32E-08	0.6-10Mbp
	chr6D	chr6D-6276646	6276646	4.16E-07	3-7.5Mbp
BM	chr1B	chr1B-63398861	63398861	3.4E-08	0.6-10Mbp
	chr2B	chr2B-820002	820002	0.00000434	1Mbp
	chr6D	chr6D-6276646	6276646	1.94E-07	3-7.5Mbp
GFR	chr1B	chr1B-63398861	63398861	6.55E-07	0.6-10Mbp
	chr6D	chr6D-6276646	6276646	0.00000439	3-7.5Mbp
GM2	chr1B	chr1B-63398861	63398861	6.4806E-06	0.6-10Mbp
	chr6D	chr6D-6276646	6276646	2.8069E-07	3-7.5Mbp
SM2	chr1B	chr1B-63398861	63398861	4.1647E-07	0.6-10Mbp
Stress Tolerance Index					
Stress_intYLD	chr1B	chr1B-63398861	63398861	5.9082E-08	0.6-10Mbp
	chr2B	chr2B-820002	820002	5.4266E-06	1Mbp
	chr6D	chr6D-6276646	6276646	5.9158E-08	3-7.5Mbp
Stress_intBM	chr1B	chr1B-63398861	63398861	3.1404E-08	0.6-10Mbp
	chr2B	chr2B-820002	820002	7.1692E-06	1Mbp
	chr6D	chr6D-6276646	6276646	3.1404E-08	3-7.5Mbp
Stress_intGM2	chr1B	chr1B-63398861	63398861	2.6569E-08	0.6-10Mbp
	chr2B	chr2B-820002	820002	7.1074E-07	1Mbp
	chr6D	chr6D-6276646	6276646	6.6123E-08	3-7.5Mbp
UAV measurements					
UAV_CTVg_AV	chr1B	chr1B-63398861	63398861	1.8924E-07	0.6-10Mbp
	chr2B	chr2B-820002	820002	9.0008E-06	1Mbp
	chr6D	chr6D-6276646	6276646	6.1095E-06	3-7.5Mbp
UAV_CTgf_AV	chr1B	chr1B-63398861	63398861	1.7673E-07	0.6-10Mbp
	chr2B	chr2B-820002	820002	2.2766E-06	1Mbp
	chr6D	chr6D-6276646	6276646	1.8452E-07	3-7.5Mbp
UAV_NDVlvg_AV	chr1B	chr1B-63398861	63398861	4.0814E-07	0.6-10Mbp
	chr2B	chr2B-820002	820002	6.4281E-06	1Mbp
UAV_NDVlfg_AV	chr6D	chr6D-6276646	6276646	5.7295E-06	3-7.5Mbp
Phenology					
DTH_Heat	chr4D	chr4D-299997620	299997620	0.00000875	1Mbp
	chr5A	chr5A-581257473	581257473	0.00000387	580-568Mbp

Supplementary Table 7. Yield and canopy temperature of the different allele combinations at the MTAs chr6D-6276646, 1B chr1B-63398861, and 2B chr2B-820002, where the combination of favourable alleles is T+C+C and the combination of unfavourable alleles is A+A+G. Significance of allele combinations was computed using a one-way ANOVA test and post-hoc test using Tukey's honest significance test

Trait	Condition	Anova p-value	Mean $\pm$ S.D			Tukey's HSD p-values		
			A+A+G	A+C+C	T+C+C	A+C+C-A+A+G	T+C+C-A+A+G	T+C+C-A+C+C
Yield	Heat stress	<2e-16	263 $\pm$ 67.3 g m ⁻²	327 $\pm$ 79.5 g m ⁻²	411 $\pm$ 59.8 g m ⁻²	2.58e-3	0	3.18e-4
Yield	Yield Potential	0.238	600 $\pm$ 44.8 g m ⁻²	591 $\pm$ 28.5 g m ⁻²	587 $\pm$ 27.7 g m ⁻²	0.681	0.242	0.937
CT	Heat stress	<2e-16	31.8 $\pm$ 0.987 °C	31.0 $\pm$ 0.963 °C	29.9 $\pm$ 0.556 °C	5.97e-3	0	2.21e-4
CT	Yield Potential	0.210	26.0 $\pm$ 0.255 °C	26.0 $\pm$ 0.318 °C	25.9 $\pm$ 0.243 °C	0.676	0.211	0.921

Supplementary Table 8: Summary of the UAV platforms, together with the cameras and the achieved used to evaluate HiBAP I under yield potential and Heat stress conditions.

<i>Multispectral (NDVI)</i>				
Cycle	Platform	Camera	Flight altitude	GSD (cm)
2015-2016	Falcon 8	ADC Lite (Tetracam, USA)	70 m	2.7
2016-2017	Matrice 100	RedEdge (MicaSense)	30 m	2
<i>Thermal (CT)</i>				
Cycle	Platform	Camera	Flight altitude	GSD (cm)
2015-2016	Falcon 8	TAU 640 (FLIR, USA)	80 m	5.4
2016-2017	Matrice 100	Zenmuse XT (DJI, China)	40 m	5.2

Supplementary Note 1. Evidence linking proposed candidate genes to heat tolerance

We found two type-B two-component response regulator genes, with members of this family acting as transcription factors in the cytokinin signalling pathway (1). They have been linked to photoperiod stress protection via root-derived cytokinins (2) and negative regulation of drought response (3) via root cytokinin pathways (4); the resulting elevated levels of cytokinin have been linked to heat stress tolerance (5). We also found a MIKC-type MADS-box transcription factor orthologous to the *Arabidopsis* gene *SOC1*, overexpression of which leads to chloroplast biogenesis, elevated photosynthesis, and tolerance to prolonged heat stress (6). Finally, we identified a novel MAPK gene. MAPKs play important roles in regulating responses to abiotic stress. They have been linked to oxidative stress tolerance under heat stress in wheat (7) and are involved in the heat stress response in *Arabidopsis*, maize and rice (8). The novelty of this gene and the presence-absence variation between *Ae. tauschii* accessions suggests this gene is recently evolved and possibly involved in environmental adaptation. The gene *DREB1A* was identified within the chr2B-820002 interval; this gene is part of a family of plant-specific transcription factors that bind DRE/CRT elements in the response to abiotic stresses. Overexpression of *DREB1* in wheat led to drought tolerance and increased photosynthetic efficiency (9) and *DREB2* overexpression lines displayed cold and heat tolerance (10). The 2B interval also contained *STEROL GLUCOSYLTRANSFERASE (SGT)* which has been identified to affect heat stability in both knockout and overexpression studies in *Arabidopsis* (11, 12).

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