Supplementary table 1. Panels of hybrids and corresponding experiments with analysed traits in this study.

Panel	Hybrid number	Composition	Indoor experiments number	Used traits in indoor experiments	Field experiments number	Used traits in field experiments	More info in
Diversity	246	246 dent lines x flint line UH007	4	LAR, LER, gs, rh_{PAD}, Leaf dimensions	25	Duration of vegetative phase, Leaf dimensions	https://doi.org/10.1038/s41588-019-0414-y
Genetic progress	56	Successful hybrids released from 1950 to 2015	4	LAR, LER, gs, rh_{PAD}, LER sensitivity to VPD, Final Leaf Number	26	Duration of vegetative phase, ALA, LAI	https://doi.org/10.15454/KLD0GH
Recent hybrids	86	Recent hybrids released from 2008 to 2020	1*	LAR, LER, rh_{PAD}	4	Duration of vegetative phase, LAR, ALA	Supplementary Tables 2 and 3

*One indoor platform experiment with a subset of 20 recent hybrids. LAR: Leaf Appearance Rate. LER: Leaf Expansion Rate. gs: Stomatal Conductance. rh_{PAD}: relative height at 50% of leaf area. Leaf dimensions: length and width. VPD: Vapour-pressure deficit. ALA: Average Leaf inclination Angle. LAI: Leaf Area Index. Detailed information for hybrids and experiments used for the diversity panel and the genetic progress panel are available at the URLs provided in this table.

Supplementary table 2. Hybrids of the 'recent hybrids' panel and experiments in which each of them was evaluated.

Hybrid	Year of release	Maturity group in France	FAO Index group	Breeder	Field 1	Field 2	Field 3	Field 4	PhenoArch
PR38V31	2008	G2 (mid-early)	(280 - 320)	PIONEER	X		X		
ADEVEY	2011	G2 (mid-early)	(280 - 320)	LIMAGRAIN	X		X		X
ESGALLERY	2012	G2 (mid-early)	(280 - 320)	EURALIS	X		X		
DKC3931	2013	G2 (mid-early)	(280 - 320)	BAYER	X		X		
P9234	2014	G2 (mid-early)	(280 - 320)	PIONEER	X		X		X
QUINCEY	2014	G2 (mid-early)	(280 - 320)	LIMAGRAIN	X		X		
RGTCONEXXION	2014	G2 (mid-early)	(280 - 320)	RAGT	X		X		
DKC3969	2015	G2 (mid-early)	(280 - 320)	BAYER	X		X		
VOLODIA	2015	G2 (mid-early)	(280 - 320)	BAYER	X		X		X
LBS3844	2016	G2 (mid-early)	(280 - 320)	PIONEER	X		X		
LBS3855	2016	G2 (mid-early)	(280 - 320)	PIONEER	X		X		X
DKC3978	2017	G2 (mid-early)	(280 - 320)	BAYER	X		X		
DKC4069	2017	G2 (mid-early)	(280 - 320)	BAYER	X		X		X
DKC4079	2017	G2 (mid-early)	(280 - 320)	BAYER	X		X		
DKC4178	2017	G2 (mid-early)	(280 - 320)	BAYER	X		X		
ESFARADAY	2017	G2 (mid-early)	(280 - 320)	EURALIS	X		X		
ESWADI	2017	G2 (mid-early)	(280 - 320)	EURALIS	X		X		X
KOLETIS	2017	G2 (mid-early)	(280 - 320)	KWS	X		X		
LISARO	2017	G2 (mid-early)	(280 - 320)	KWS	X		X		X
ESHOLMES	2018	G2 (mid-early)	(280 - 320)	EURALIS	X		X		
SYENERMAX	2018	G2 (mid-early)	(280 - 320)	SYNGENTA	X		X		
ESBROADWAY	2019	G2 (mid-early)	(280 - 320)	EURALIS	X		X		
EXENTRIK	2019	G2 (mid-early)	(280 - 320)	RAGT	X		X		
RGTINEDIXX	2019	G2 (mid-early)	(280 - 320)	RAGT	X		X		
DKC4302	2020	G2 (mid-early)	(280 - 320)	BAYER	X		X		
KWSANTONIO	2020	G2 (mid-early)	(280 - 320)	KWS	X		X		
RGTCOXXINELLE	2020	G2 (mid-early)	(280 - 320)	RAGT	X		X		
DKC4590	2009	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
DKC4795	2009	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
DKC4814	2011	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
ORGANDICS	2011	G3 (intermediate)	(320 - 400)	CAUSSADE	X	X	X	X	
FERARIXX	2012	G3 (intermediate)	(320 - 400)	RAGT	X	X	X	X	
DKC4444	2015	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
DKC4569	2015	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
KAMPONICS	2015	G3 (intermediate)	(320 - 400)	CAUSSADE	X	X	X	X	
LBS4414	2015	G3 (intermediate)	(320 - 400)	PIONEER	X	X	X	X	
RGTPREFIXX	2015	G3 (intermediate)	(320 - 400)	RAGT	X	X	X	X	X
SYIZOAR	2015	G3 (intermediate)	(320 - 400)	SYNGENTA	X	X	X	X	
DKC4652	2016	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	X
DKC4751	2016	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
EDONIA	2016	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	X
FURTI	2016	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
ITEA	2016	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
DKC4670	2017	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	

Field 1, Matzenheim. Field 2, St-Bonnet-de-Mure. Field 3, Binas. Field 4, Pusignan. See supplementary table 3 for more detail on experiments.

Supplementary table 2 (continued). Hybrids of the 'recent hybrids' panel and experiments in which each of them was evaluated.

Hybrid	Year of release	Maturity group in France	FAO Index group	Breeder	Field 1	Field 2	Field 3	Field 4	PhenoArch
BERGAMO	2018	G3 (intermediate)	(320 - 400)	KWS	X	X	X	X	X
KERALA	2018	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
KWSLYRUS	2018	G3 (intermediate)	(320 - 400)	KWS	X	X	X	X	X
SYORPHEUS	2018	G3 (intermediate)	(320 - 400)	SYNGENTA	X	X	X		X
TEXERO	2018	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
SYPREMEO	2019	G3 (intermediate)	(320 - 400)	SYNGENTA	X	X	X	X	
DKC4598	2020	G3 (intermediate)	(320 - 400)	BAYER	X	X	X	X	
GOBELIN	2020	G3 (intermediate)	(320 - 400)	KWS	X	X	X	X	
FUTURIXX	2010	G4 (mid-late)	(400 - 480)	RAGT		X	X	X	
BALASCO	2012	G4 (mid-late)	(400 - 480)	KWS		X	X	X	
LBS4148	2012	G4 (mid-late)	(400 - 480)	PIONEER		X	X	X	
MILANNO	2012	G4 (mid-late)	(400 - 480)	RAGT		X	X	X	
P0216	2012	G4 (mid-late)	(400 - 480)	PIONEER		X	X	X	
P9838	2012	G4 (mid-late)	(400 - 480)	PIONEER		X	X	X	
COURTNEY	2013	G4 (mid-late)	(400 - 480)	LIMAGRAIN		X	X	X	
DKC5031	2013	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	
MAS40F	2014	G4 (mid-late)	(400 - 480)	MAS_SEEDS		X	X	X	
P9903	2014	G4 (mid-late)	(400 - 480)	PIONEER		X	X	X	X
BORSALINO	2015	G4 (mid-late)	(400 - 480)	RAGT		X	X	X	
DKC5065	2015	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	X
HARMONIUM	2015	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	
LBS4293	2015	G4 (mid-late)	(400 - 480)	PIONEER		X	X	X	
LG30444	2015	G4 (mid-late)	(400 - 480)	LIMAGRAIN		X	X	X	
P0023	2015	G4 (mid-late)	(400 - 480)	PIONEER		X	X	X	
RGTEMERIXX	2015	G4 (mid-late)	(400 - 480)	RAGT		X	X	X	
RGTFUXXTER	2015	G4 (mid-late)	(400 - 480)	RAGT		X	X		
DEBUSSY	2016	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	
DKC5152	2016	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	X
ESLAGOON	2016	G4 (mid-late)	(400 - 480)	EURALIS			X		X
BOWEN	2017	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	X
LBS4378	2017	G4 (mid-late)	(400 - 480)	PIONEER		X	X	X	
PALIZICS	2017	G4 (mid-late)	(400 - 480)	CAUSSADE		X	X	X	X
QUERCI	2017	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	
RAFIKA	2017	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	
URBANIX	2017	G4 (mid-late)	(400 - 480)	RAGT		X	X	X	
KWSKASHMIR	2018	G4 (mid-late)	(400 - 480)	KWS		X	X	X	
RGTNOEMIXX	2018	G4 (mid-late)	(400 - 480)	RAGT		X	X	X	X
EPIKUR	2019	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	
ESRHODIUM	2019	G4 (mid-late)	(400 - 480)	EURALIS		X	X	X	
PESCALI	2019	G4 (mid-late)	(400 - 480)	BAYER		X	X	X	
DKC5001	2020	G4 (mid-late)	(400 - 480)	BAYER		X	X		
KWSINTELIGENS	2020	G4 (mid-late)	(400 - 480)	KWS		X	X		

Field 1, Matzenheim. Field 2, St-Bonnet-de-Mure. Field 3, Binas. Field 4, Pusignan. See supplementary table 3 for more detail on experiments.

Supplementary table 3. Experiments performed for the 'recent hybrids' panel and Experiment carried out at Field 5 for 'genetic progress' panel

Name exp.	Type exp.	Location	GPS Coord.	Year	Treatment	Hybrid number	Maturity groups	Measured traits
Field 1	Field	Matzenheim	48.401, 7.617	2022	WW	52	G2, G3	LAR, Emergence, Anthesis & Silking dates, Leaf 6 dimensions, Plant density
Field 2	Field	Saint Bonnet-de-Mure	45.714, 5.046	2022	WW, WD	58	G3, G4	ALA, LAI, fiPAR, Emergence, Anthesis & Silking dates, Plant density
Field 3	Field	Binas	47.919, 1.478	2022	WW	86	G2, G3, G4	LAR, Emergence, Anthesis & Silking dates, Leaf 6 dimensions, Plant density
Field 4	Field	Pusignan	45.741, 5.075	2021	WW	54	G3, G4	ALA, LAI, fiPAR, Emergence, Anthesis & Silking dates, Plant density
PhenoArch	Indoor Platform	Montpellier	43.618, 3.857	2021	WW, WD	20	G2, G3, G4	Leaf area, Biomass, LAR, LER, Plant architecture variables (rh_{PAD}), fiPAR
Field 5	Field	Mauguio	43.611, 3.971	2017	WW	56	G2, G3, G4	ALA, LAI, fiPAR, Emergence, Anthesis & Silking dates, Plant density

Name exp. : Experiment name used in the text; Year, year when the experiment was done. Treatment : WW, imposed well-watered (controlled by sensors). WD, imposed water deficit (controlled by sensors)

Supplementary table 4. Summary of correlation coefficients estimated between experiments genotypic values for four traits considered in this study.

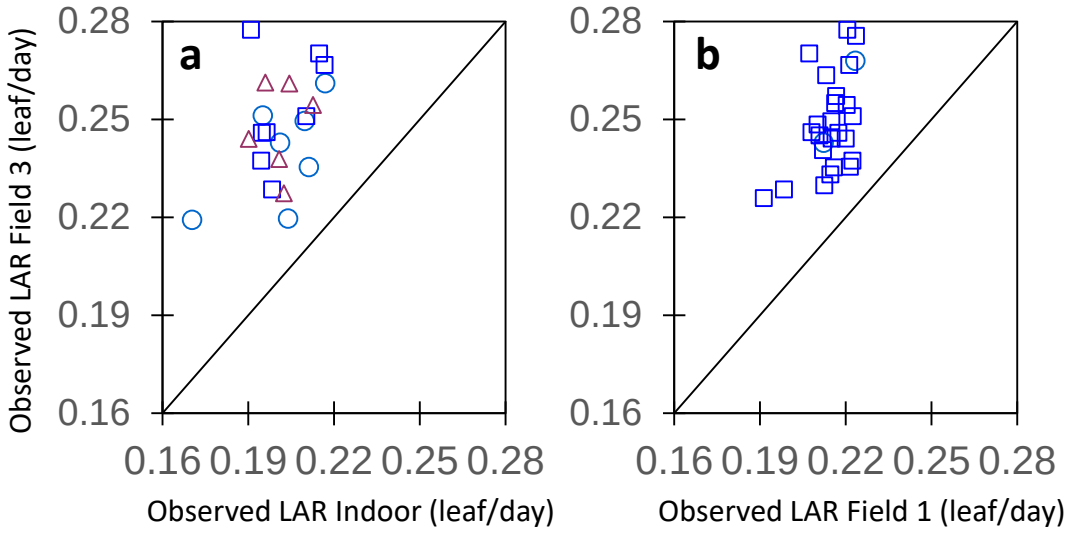
Traits	Unit	Experiments	Hybrid number	r	p_value r	rho	p_value rho	Mean value	RMSE	CV_{RMSE}	Bias	CV_{Bias}	FSA to the highest quartile	FSA to the lowest quartile
LAR (Leaf Appearance Rate)	leaf/ $day_{20°C}$	Indoor VS Field 3	21	0.57	0.0066	0.42	0.0587	0.259	0.020	7.7%	-0.012	-4.5%	0.60	0.40
		Field 1 VS Field 3	26	0.49	0.0114	0.35	0.0836	0.260	0.014	5.3%	-0.001	-0.3%	0.50	0.33
Duration of the vegetative phase	$days_{20°C}$	Field 1 VS Field 3	53	0.69	9.41E-09	0.66	2.24E-07	61.7	2.7	4.4%	-1.94	-3.2%	0.54	0.62
		Field 2 VS Field 3	55	0.47	0.0003	0.37	0.0059	64.1	4.5	7.0%	-4.05	-6.3%	0.60	0.37
rh_{PAD} (relative height at 50% of leaf area) VS ALA (Average Leaf inclination Angle)	rh_{PAD} (unitless), ALA (°)	rh_{PAD} Indoor VS ALA Field 5	56	0.78	2.39E-12	0.77	2.20E-16	0.28	Irrelevant (two different traits compared)				0.71	0.57
		rh_{PAD} Indoor VS ALA Field 4	18	0.58	0.0118	0.51	0.0321	0.34					0.60	0.60
		rh_{PAD} Indoor VS ALA Field 2	18	0.60	0.0085	0.60	0.0102	0.34					0.60	0.60
LAI (Leaf Area Index)	unitless	LAI Indoor (+Crop model) VS LAI Field 5 (UAV)	47	0.63	2.16E-06	0.66	4.63E-07	4.42	1.02	22.9%	-0.78	-17.6%	0.45	0.61

r, Pearson correlation coefficient. p_value r, r significance p-value. rho, Spearman correlation coefficient. p_value rho, rho significance p-value. RMSE, Root Mean Square Error. CV_{RMSE}, RMSE Coefficient of Variation. CV_{Bias}, Bias Coefficient of Variation. FSA to the highest quartile, Frequency of Similar Assignment to the highest quartile between experiments for each trait. FSA to the lowest quartile, Frequency of Similar Assignment to the lowest quartile between experiments for each trait.

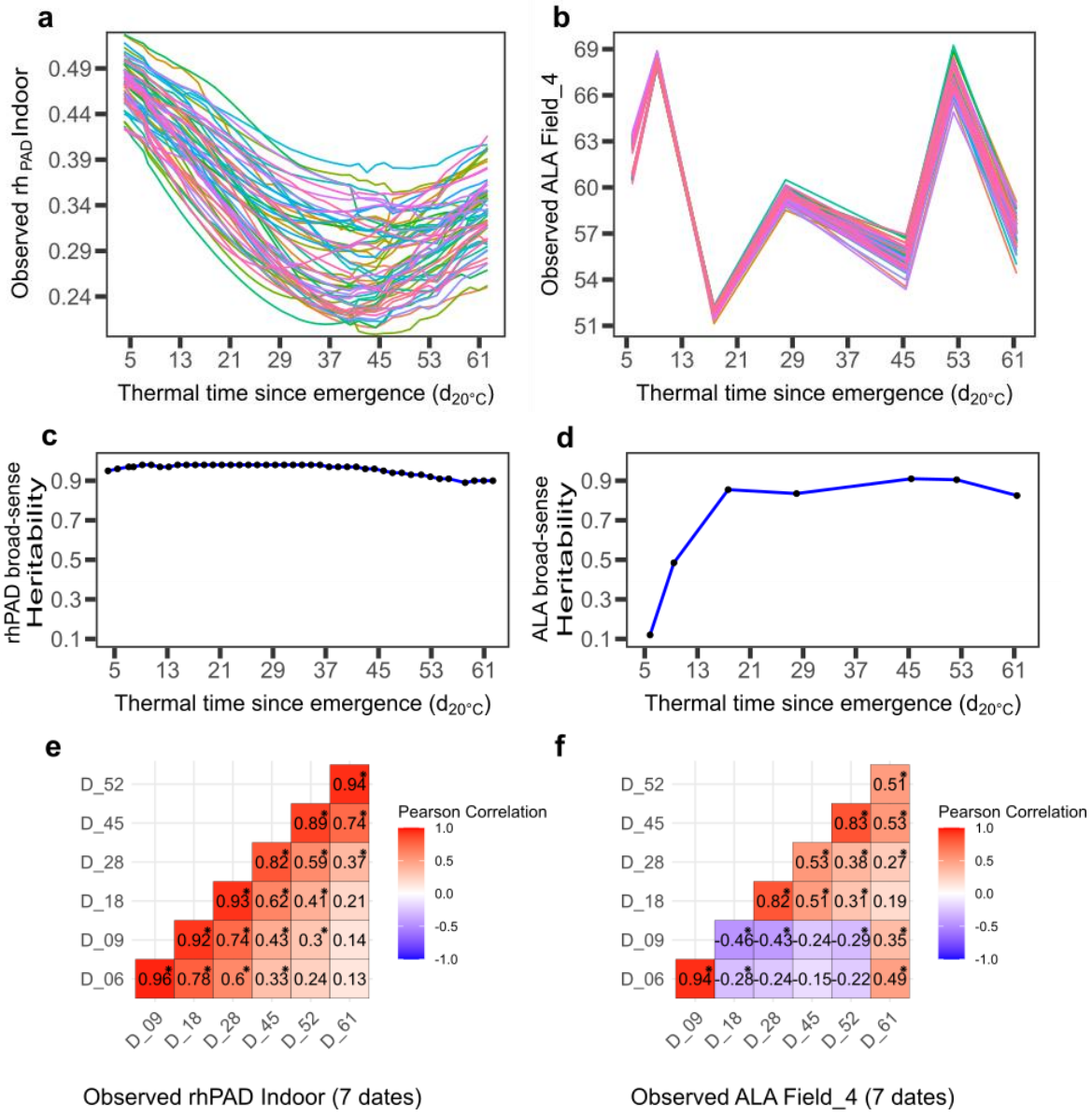
Supplementary table 5. Summary of genomic prediction results in cross-validation and external validation schemes

Trait	Unit	5-fold Cross-Validation (Diversity and Genetic Progress panels)						External Validation (Recent hybrids panel)					
		Hybrid number	Mean r	Mean rho	Mean RMSE	Observed mean value	Mean CV_{RMSE} (%)	Hybrid number	r	rho	RMSE	Observed mean value	CV_{RMSE} (%)
Duration of the vegetative phase	$days_{20°C}$	302	0.84	0.82	1.8	67.3	2.7	60	0.71	0.68	1.6	64.6	2.5
Leaf Appearance Rate	leaf/ $day_{20°C}$	302	0.57	0.54	0.013	0.254	5.2	50	0.53	0.48	0.007	0.262	2.8
rh_{PAD} (relative height at 50% of leaf area)	unitless	302	0.65	0.58	0.029	0.30	9.4	20	0.39	0.36	0.057	0.36	15.8
Leaf Expansion Rate (max LER)	cm^2/ $day_{20°C}$	302	0.77	0.76	12.17	140.12	8.7	20	0.33	0.30	19.99	146.91	13.6
Stomatal conductance (gs max)	$mmol/m^2/s$	302	0.55	0.53	9.30	110.40	8.4	Missing data					

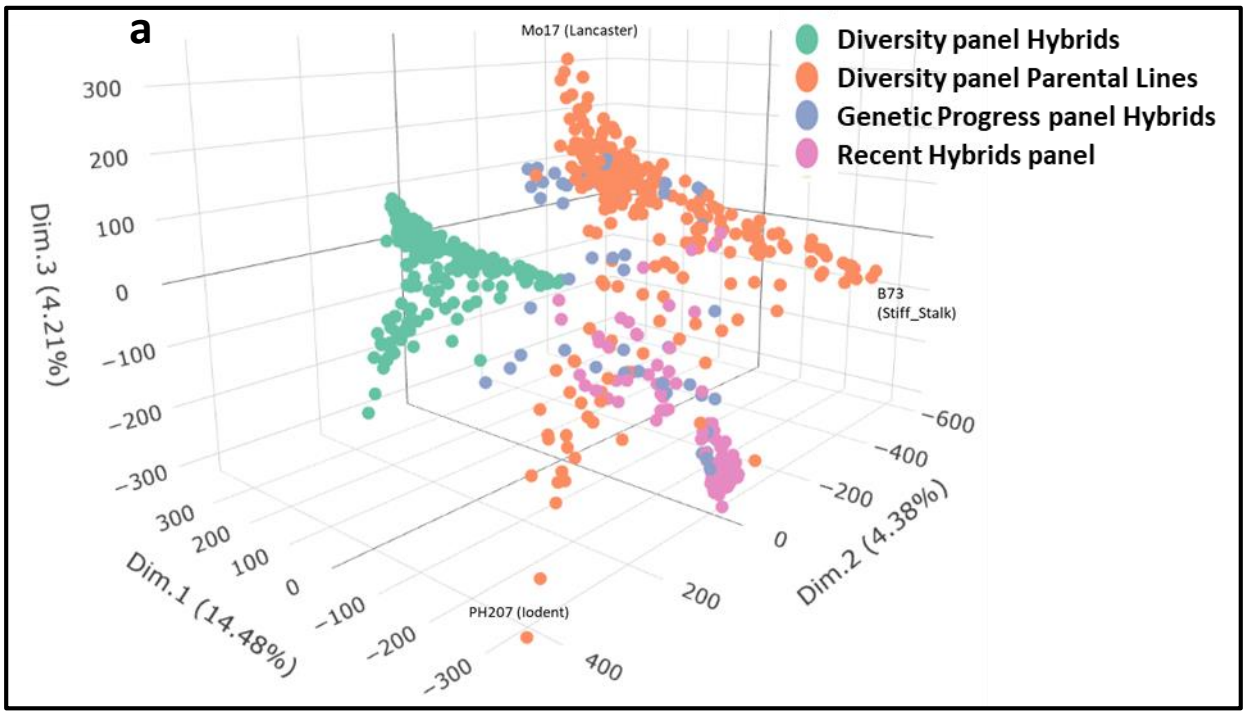
Mean r, Mean rho, Mean RMSE, Mean CV_{RMSE} : Pearson & Spearman correlation coefficients, Root Mean Square Error and RMSE Coefficient of Variation, respectively, estimated between G-BLUP predicted values and measured values, averaged across folds and 10 iterations in a cross-validation scheme including diversity and genetic progress panels. r, rho, RMSE, CV_{RMSE} : Pearson & Spearman correlation coefficients, Root Mean Square Error and RMSE Coefficient of Variation, respectively, estimated between G-BLUP predicted values (with training on diversity and genetic progress panels) and measured values in recent hybrids panel, used as external validation.



Supplementary Fig. 1. Leaf appearance rate (LAR) when calculated in calendar time had low correlations between genotypic values indoor and a field (a) or from one field to another field (b). Light blue circles, mid-early hybrids (G2), dark blue squares, intermediate hybrids (G3), red triangles, mid-late hybrids (G4). In a, r=0.40, p = 0.069, CV_{RMSE} = 23.8%. In b, r=0.49, p = 0.0117, CV_{RMSE} = 16.91%.



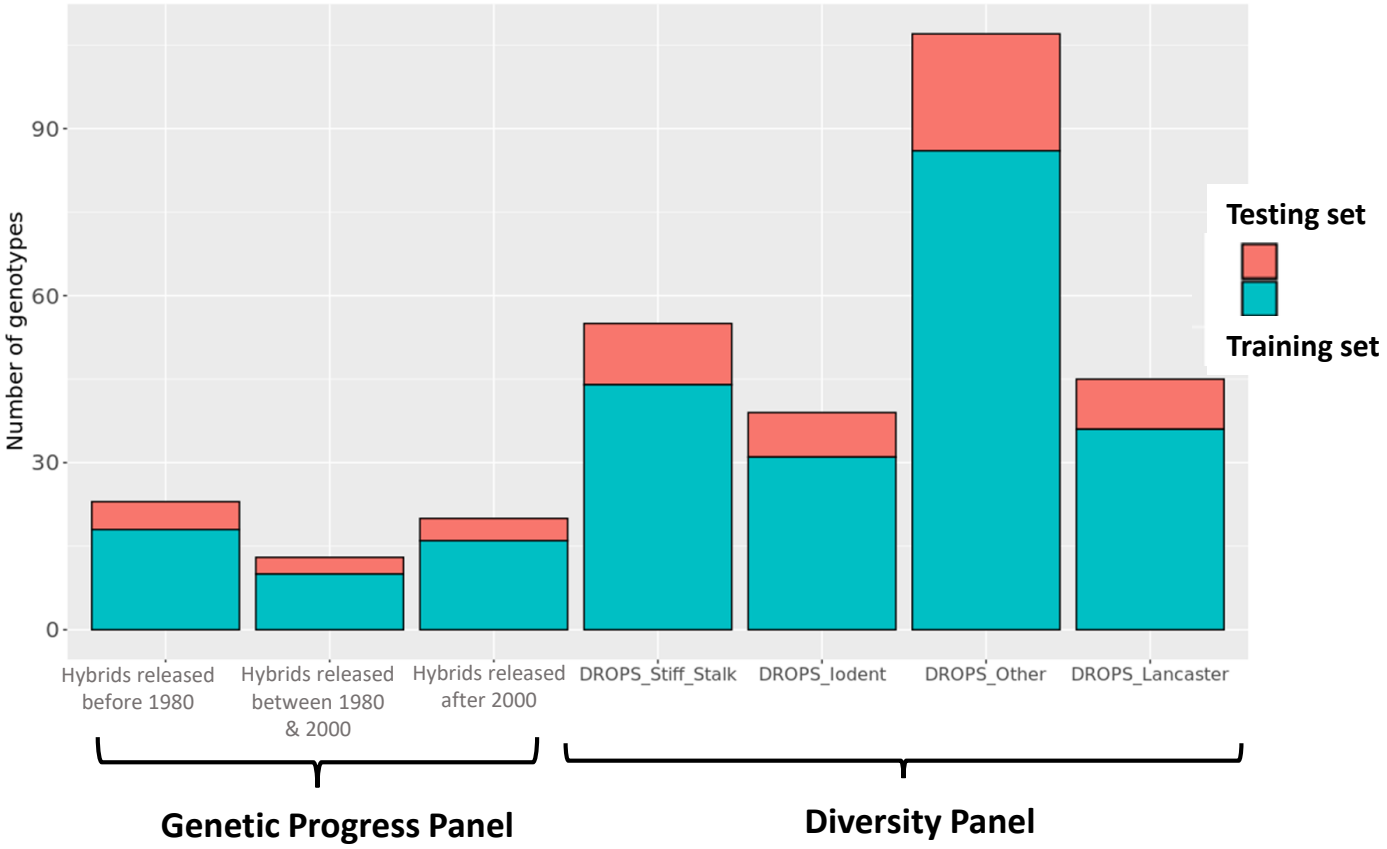
Supplementary Fig. 2. Time courses and broad-sense heritability over time of genotypic values of the architectural traits (rh_{PAD} and ALA) and their correlation heat maps for 7 dates. a & b, Time courses of rh_{PAD} observed in indoor plarform and ALA observed in the field from emergence to flowering. c & d, Broad-sense heritability over thermal time for rh_{PAD} and ALA. e & f, Heat map of Pearson correlations between 7 thermal time points for rh_{PAD} and ALA trait. rh_{PAD}, relative altitude, from the top of the plant, where 50% of leaf area is reached[15]. ALA: average leaf angle estimated from UAV images, via inversion of the model PROSAIL[39,71]. In a & b, lines represent 60 different hybrids. In e & f, statistically significant correlations are shown with an asterisk.



b

	Nei's Genetic Diversity Index	Observed Heterozygoty
Diversity Panel (246 Parental Dent Lines)	0.45	0.00
Diversity Panel (246 Hybrids : Dent Lines x UH007)	0.31	0.44
Genetic Progress Panel (56 Hybrids)	0.36	0.38
Recent Hybrids Panel (86 Hybrids)	0.31	0.35

Supplementary Fig. 3. Structure and diversity analysis of the panels used in this study. a, Principal Coordinate Analysis (PCoA) based on a set of 440 000 polymorphic SNP markers. b, Diversity indices (observed heterozygoty and Nei's index) based on 440 000 polymorphic SNP markers. The PCoA first shows the structuration of the diversity panel parental lines into 4 genetic groups (Iodent on the bottom left, Lancaster on the top, Stiff_Stalk on the bottom right and the other diverse admixed genotypes in the middle). The genetic progress and recent hybrids panels mainly overlap with the Iodent and admixed genotypes of diversity panel. The representation of the diversity panel hybrids corresponding to the lines crossed with UH007, highlights the effect of the common parent UH007, which induces a strong genomic relatedness between the diversity panel hybrids and separates them from the other panels following the first PCoA dimension.



Supplementary Fig. 4. Schematic representation of genomic prediction cross-validation strategy. Each training set was sampled randomly but proportionally to diversity panel genetic groups and across years of release of genetic progress hybrids.