

Article

Exploring the realm of possibilities: trying to predict promising crosses and successful offspring through genomic mating in barley

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Supplementary Material

Supplementary Data 1: Methodology of measurement regarding the five traits

Trait	Code	Methodology	Environment ^a	Environment ^b
Deoxynivalenol content in kernels	DON (ppm)	Evaluated three to four weeks before anthesis. Artificial inoculation was performed with maize (<i>Zea mays</i> L.) kernels infected with <i>Fusarium graminearum</i> (as per Prom et al. 1996). The inoculum consisted of a pool of four aggressive and virulent <i>F. graminearum</i> strains belonging to the same chemotype (specifier si possible) and representing the molecular diversity present in five agricultural locations in Quebec. The quantification of DON was performed using a commercial ELISA test (Veratox, Neogen Corporation, Saint Hyacinthe, QC, Canada) on 10- to 20-g samples of harvested kernels (Tangni et al. 2011).	20	2
Heading time	HTM (days)	Scored when 50% to 80% of ears in the plot had emerged from the sheath (Zadoks growth scale 55-59).	14	3
Days to maturity	MAT (Days)	Reached when 50% to 80% of ears had kernels (in the central part of the spike) at the soft dough to early ripening stages (Zadoks growth scale 86-90)	41	4
Thousand-kernel weight	TKW (g)	Measured on a sample of 1000 seeds obtained using a seed counter	19	2
Grain yield	GYD (kg/ha)	For each plot, grain yield was measured and converted to kg/ha	29	2

^a Number of environment (location × year) in which lines of the training population have been phenotyped.

^b Number of environment (location × year) in which the selection candidates have been phenotyped.

Supplementary Data 2: Descriptive statistics of phenotypic data in each environment for the five traits in training population

Trait^a	Environment^b	Minimum	Median	Maximum	Mean	S.d.^c
DON (ppm)	BE09	7.44	21.88	62.40	24.90	14.13
	LE06	5.30	12.40	24.30	13.17	5.66
	LE07	16.29	30.34	44.70	29.45	7.95
	LE08	14.93	46.47	141.50	50.52	18.23
	LE11	5.02	39.64	110.80	42.15	19.21
	NO04	6.75	13.18	31.86	15.73	7.28
	NO06	37.20	66.75	89.90	65.07	15.84
	NO08	27.95	64.89	146.44	69.11	20.93
	NO09	30.09	66.67	113.91	68.23	18.79
	SH04	6.80	16.55	29.40	16.93	5.69
	SH05	7.90	21.55	51.20	25.65	12.41
	SH15	37.05	67.23	163.86	72.58	25.79
	UL05	0.72	25.10	80.40	32.19	23.83
	UL07	2.40	35.70	133.58	37.92	24.14
	UL08	4.22	25.40	171.00	35.17	29.12
	UL09	9.60	48.30	112.20	47.66	20.68
	UL11	1.40	32.70	124.40	37.60	20.02
	UL12	1.30	16.50	46.30	17.68	8.79
	UL13	10.20	30.80	64.80	33.99	13.94
	UL15	13.50	44.35	158.50	47.00	23.65
HTM (days)	SA15	52.00	54.50	58.00	54.57	1.64
	SH15	48.00	54.00	56.00	53.29	2.13
	UL04	51.00	59.00	63.00	58.50	3.48
	UL05	53.00	55.00	61.00	56.00	1.83
	UL06	48.00	56.00	62.00	56.32	2.72
	UL07	48.00	55.00	63.00	55.16	2.92
	UL08	41.00	57.00	66.00	57.59	3.94
	UL09	51.00	60.00	73.00	60.82	3.97
	UL10	48.00	59.00	65.00	59.35	2.71
	UL11	52.00	60.00	66.00	60.29	2.26
	UL12	50.00	59.00	65.00	58.81	2.32
	UL13	60.00	68.00	74.00	67.68	2.91
	UL15	50.00	56.00	73.00	57.31	4.50
	UL16	51.00	54.00	59.00	54.06	1.43
MAT (days)	CA14	83.00	91.00	97.00	90.09	3.08
	CA15	85.00	88.00	98.00	88.77	3.53
	CA16	91.00	101.00	109.00	100.21	4.24
	HV14	87.00	92.00	97.00	92.02	2.14
	LP09	82.00	89.00	94.70	88.84	2.77
	LP10	73.00	88.00	106.00	88.59	6.69

	LP11	78.00	84.00	93.00	84.61	3.65
	LP12	76.00	79.00	88.00	79.98	3.01
	NO10	90.00	99.00	106.00	98.93	3.15
	NO14	93.00	95.00	97.00	95.08	1.11
	PO14	83.00	92.00	96.00	91.04	3.74
	PR07	75.00	89.00	95.00	87.67	4.37
	PR08	80.00	82.00	99.00	85.42	7.17
	PR09	88.00	92.00	94.00	91.31	1.82
	PV14	80.00	85.00	89.00	85.29	2.14
	SA09	86.00	92.00	98.00	91.53	3.10
	SA10	76.00	82.00	86.00	81.40	2.33
	SA11	65.00	75.00	83.00	74.70	3.23
	SA13	77.00	85.00	90.00	84.63	3.11
	SA15	85.00	88.00	91.00	87.73	1.39
	SA16	81.00	84.00	89.00	83.95	1.27
	SF11	77.00	86.50	93.00	86.11	3.80
	SF12	72.00	76.50	82.00	76.45	2.02
	SH07	83.00	88.00	93.00	87.89	2.55
	SH08	80.00	87.00	92.00	86.50	3.48
	SH10	91.00	92.00	95.00	92.21	1.19
	SH12	83.00	89.00	93.00	88.72	1.93
	SH13	82.00	90.00	96.00	88.28	3.80
	SH15	76.00	87.00	90.00	86.21	2.37
	SH16	82.00	84.00	87.00	84.41	1.27
	SH14	78.00	82.00	88.00	82.52	2.03
	SL10	83.00	86.00	93.00	86.55	2.94
	SR08	82.00	89.00	93.00	88.78	2.84
	SR10	78.00	87.00	90.30	86.00	2.74
	SR11	81.00	82.00	87.00	82.58	1.67
	UL08	53.00	86.00	91.00	85.29	6.42
	UL09	91.00	97.00	102.00	96.78	2.03
	UL10	79.00	87.00	91.00	86.48	2.86
	UL11	83.00	91.00	96.00	90.67	2.29
	UL12	80.00	88.00	95.00	87.66	3.05
	UL13	92.00	96.00	102.00	95.88	2.26
TKW (g)	LP07	32	39	45	39.15	4.28
	LP09	29	36	45	35.95	4.04
	LP10	30	41	45	39.83	3.83
	LP11	33	40	45	39.47	3.10
	LP12	28	34	40	33.78	3.23
	PR07	26	44	51	42.74	4.91
	PR08	29	37	44	36.51	4.09
	PR09	23	37	44	34.69	6.24
	SA11	32	44	50	43.55	3.42

	SA13	32	40	51	40.26	3.31
	SH06	30	40	56	39.75	5.47
	SH07	34	44	50	43.94	4.18
	SH10	30	38	44	37.47	4.26
	SH12	30	42	51	41.53	4.04
	SH13	32	37	52	37.36	3.69
	SR06	34	42	48	42.12	3.70
	SR07	34	45	54	44.90	4.13
	SR10	25	36	44	35.59	4.89
	SR11	38	45	50	44.84	2.78
GYD (kg/ha)	CA14	3709.00	5800.00	7785.00	5775.73	797.87
	CA15	1546.67	3897.78	5988.89	3922.63	1072.15
	CA16	2922.22	5313.33	7657.78	5265.69	917.25
	HV14	4044.00	6170.00	7812.00	6076.70	841.07
	LP07	4659.00	5759.00	7690.00	5786.00	842.96
	LP12	2051.00	3215.50	3992.00	3152.85	415.79
	NO11	4606.00	6064.00	7222.00	6046.72	564.19
	NO14	5622.00	7538.50	9777.00	7535.20	794.71
	PO14	5118.00	6546.00	8410.00	6542.22	548.41
	PR06	1623.00	4327.00	6487.00	4213.24	1288.73
	PR07	1327.00	4917.00	7586.00	4924.79	1577.08
	PR08	526.00	3450.00	6533.00	3250.75	1408.93
	PR09	1752.00	5993.00	7475.00	5397.62	1528.79
	PV14	4219.00	6039.00	7718.00	5956.64	787.64
	SA07	3833.00	5605.00	7525.00	5535.56	761.38
	SA11	2197.00	3906.00	5987.00	3926.79	799.03
	SA15	3675.00	6068.50	6983.00	5770.61	842.78
	SA16	1420.00	3877.98	5422.00	3867.86	896.00
	SH06	3012.00	3809.50	5542.00	4028.41	736.93
	SH07	3025.00	4609.00	5689.00	4519.94	723.47
	SH11	3856.00	4637.00	7781.00	4964.89	1117.19
	SH12	3308.00	5165.00	6572.00	5106.91	707.95
	SH13	1710.00	3198.00	7439.00	3448.23	1051.05
	SH15	5768.89	8628.94	10246.67	8342.10	1143.33
	SH16	5840.00	8924.44	10380.00	8707.22	1088.99
	SH14	2912.00	4232.00	5785.00	4202.26	489.30
	SR06	1721.00	3819.00	6610.00	3863.91	1297.69
	SR07	2142.00	4856.00	6483.00	4715.56	1184.99
	SR11	4229.00	6504.00	7979.00	6355.13	1062.29

^aFive traits were analyzed: DON: deoxynivalenol concentration, HTM: heading time, MAT: day to maturity, TKW: thousand kernel weight and GYD: grain yield

^bEach environment is a location-year combination. 14 different locations in Quebec and Ontario were selected: Beloeil (BE), Causapschal (CA), Hébertville (HV), Lapocatière (LP), Lévis (LE), Normandin (NO), Pintendre (PR), Princeville (PV), Quebec City (UL), St. Augustin (SA), St. Hyacinthe (SH), St. François (SF), St. Lambère (SL) and St. Rosalie (SR).

^c The standard deviation of the mean.

Supplementary Data 3: Broad-sense heritability and genotypic significance for each trait and each environment in training population

	Environment ^a	Heritability ^b	Genotypic Significance ^c
DON (ppm)	BE09	0.69	**
	LE06	0.70	**
	LE07	0.79	**
	LE08	0.70	**
	LE11	0.83	**
	NO04	0.49	*
	NO06	0.61	**
	NO08	0.79	**
	NO09	0.83	**
	SH04	0.55	**
	SH05	0.54	*
	SH15	0.97	**
	UL05	0.72	*
	UL07	0.97	**
	UL08	0.56	*
	UL09	0.67	**
	UL11	0.61	**
	UL12	0.55	**
	UL13	0.76	**
	UL15	0.80	**
HTM (days)	SA15	0.93	**
	SH15	0.71	**
	UL04	0.99	**
	UL05	0.82	**
	UL06	0.94	**
	UL07	0.88	**
	UL08	0.91	**
	UL09	0.88	**
	UL10	0.93	**
	UL11	0.91	**
	UL12	0.80	**
	UL13	0.76	**
	UL15	0.56	**
	UL16	0.60	**
MAT (days)	CA14	0.58	**
	CA15	0.82	**
	CA16	0.83	**
	HV14	0.84	**
	LP09	0.83	**
	LP10	0.90	**

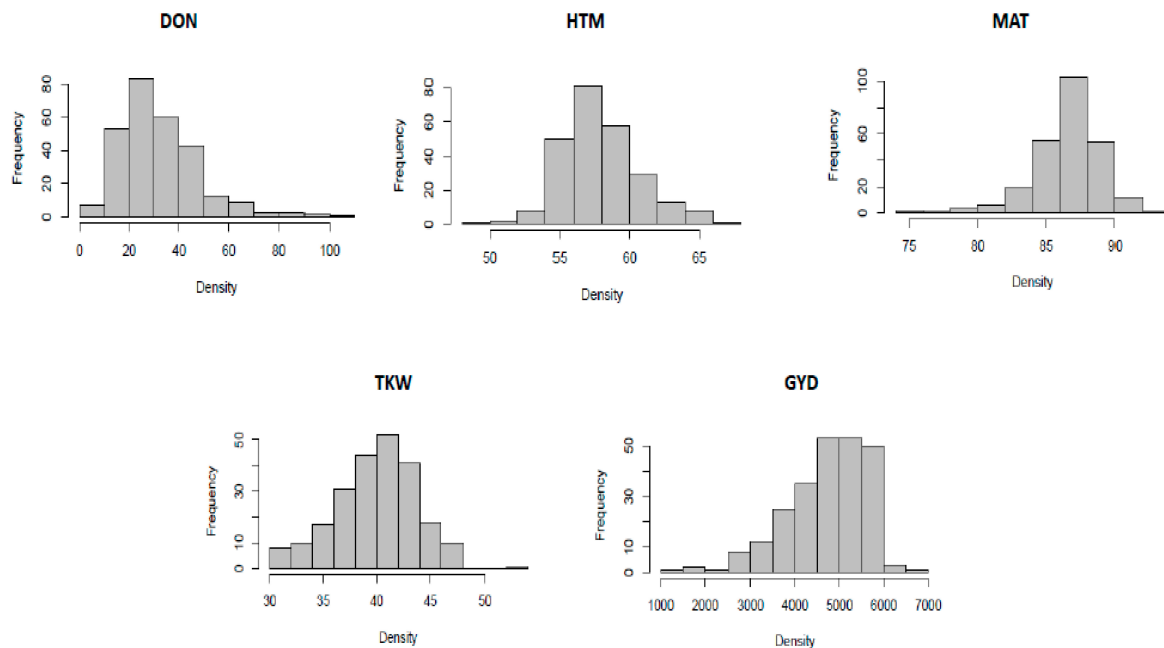
	LP11	0.97	**
	LP12	0.70	**
	NO10	0.72	**
	NO14	0.51	*
	PO14	0.87	**
	PR07	0.90	**
	PR08	0.94	**
	PR09	0.91	**
	PV14	0.73	**
	SA09	0.87	**
	SA10	0.75	**
	SA11	0.85	**
	SA13	0.83	**
	SA15	0.69	**
	SA16	0.41	*
	SF11	0.84	**
	SF12	0.77	**
	SH07	0.92	**
	SH08	0.95	**
	SH10	0.69	*
	SH12	0.87	**
	SH13	0.78	**
	SH15	0.89	**
	SH16	0.72	**
	SH214	0.86	**
	SL10	0.78	**
	SR08	0.95	**
	SR10	0.94	**
	SR11	0.70	*
	UL08	0.40	**
	UL09	0.54	**
	UL10	0.90	**
	UL11	0.89	**
	UL12	0.90	**
	UL13	0.81	**
TKW (g)	LP07	0.99	**
	LP09	0.95	**
	LP10	0.94	**
	LP11	0.91	**
	LP12	0.97	**
	PR07	0.97	**
	PR08	0.97	**
	PR09	0.87	**
	SA11	0.92	**
	SA13	0.91	**

	SH06	0.94	**
	SH07	0.95	**
	SH10	0.97	**
	SH12	0.96	**
	SH13	0.96	**
	SR06	0.89	**
	SR07	0.86	**
	SR10	0.91	**
	SR11	0.95	**
GYD (kg/ha)	CA14	0.64	**
	CA15	0.91	**
	CA16	0.74	**
	HV14	0.75	**
	LP07	0.93	**
	LP12	0.80	**
	NO11	0.91	*
	NO14	0.88	**
	PO14	0.84	**
	PR06	0.95	**
	PR07	0.91	**
	PR08	0.92	**
	PR09	0.85	**
	PV14	0.86	**
	SA07	0.86	**
	SA11	0.72	*
	SA15	0.94	**
	SA16	0.79	**
	SH06	0.86	**
	SH07	0.92	**
	SH11	0.97	**
	SH12	0.87	**
	SH13	0.91	**
	SH15	0.92	**
	SH16	0.76	**
	SH214	0.90	**
	SR06	0.92	**
	SR07	0.89	**
	SR11	0.92	*

^a Each environment is a location-year combination.

^b Broad sense heritability by environment

^c Differences are declared significant when P value ≤ 0.05 ($\alpha = 0.05$). The significance codes are: ‘**’ P value ≤ 0.01 , ‘*’ P value ≤ 0.05



Supplementary Data 4: Histograms of distribution of BLUE values combined across all environments for each trait.

Supplementary Data 5: Descriptive statistics of phenotypic data (BLUE) for each trait in the training population

Traits	Mean ^a	Units	Max.	Min.	S. d. ^b
DON	32.5	ppm	102.4	4.1	16
HTM	57.9	Days ^c	67.4	48.6	2.8
MAT	86.5	Days	92.3	74.6	2.5
TKW	40	g	54	30.4	3.8
GYD	4731	Kg/ha	6983.7	1049	907.6

^a Mean of phenotypic data (BLUE) across all the population

^b The standard deviation of the mean

^c Days after seedling

Supplementary Data 6: Pearson's correlation between BLUEs of the studied traits in the training population

	DON	HTM	MAT	TKW	GYD
DON					
HTM	-0.14				
MAT	-0.04	0.70			
TKW	0.21	-0.22	0.14		
GYD	0.38	-0.28	-0.0004	0.46	

Supplementary Data 7: Descriptive statistics of phenotypic data in each environment for the five traits among the selection candidates

Trait ^a	Environment ^b	Minimum	Median	Maximum	Mean	SD ^c
DON	UL2016	1.9	10.2	25.7	10.5	5.2
	UL2017	2.3	14.5	99.8	19.8	17.0
GYD	SA2016	1884.0	3368.0	5723.0	3429.6	721.7
	SA2017	2690.0	3928.5	5979.0	4065.8	662.2
HTM	SA2017	53.0	57.0	66.0	57.6	2.8
	UL2016	50.0	54.0	65.0	55.0	3.1
	UL2017	47.0	56.0	66.0	55.6	3.2
MAT	SA2016	78.0	84.0	97.0	84.8	4.8
	SA2017	83.0	87.5	96.0	88.3	3.4
	UL2016	82.0	84.0	91.0	84.9	2.1
	UL2017	85.0	88.0	96.0	88.4	2.3
TKW	SA2016	39.4	44.1	50.6	44.0	2.7
	SA2017	38.7	43.0	51.6	43.7	3.3

^aFive traits were analyzed: DON: deoxynivalenol concentration, HTM: heading time, MAT: day to maturity, TKW: thousand kernel weight and GYD: grain yield

^bEach environment is a location-year combination. two different locations in Quebec: Quebec City (UL) and St. Augustin (SA).

^c The standard deviation of the mean.

Supplementary Data 8: Broad-sense heritability and genotypic significance for each trait and each environment for selection candidates

Traits ^a	Environment ^b	Heritability ^c	Genotype significance ^d
DON	UL2016	0.44	*
	UL2017	0.70	***
HTM	SA2017	0.95	***
	UL2016	0.81	***
	UL2017	0.83	***
MAT	SA2016	0.63	**
	SA2017	0.90	***
	UL2016	0.56	**
	UL2017	0.80	***
TKW	ALL	0.72	***
GYD	SA2016	0.49	*
	SA2017	0.54	**

^a Only four traits had replicates; TKW was performed on composite of two replicates. Variance components for TKW were generated by considering environment as replicate.

^b Each environment is a location-year combination.

^b Broad sense heritability by environment

^c Differences are declared significant when P value ≤ 0.05 ($\alpha = 0.05$). The significance codes are: ‘***’ P value ≤ 0.001 , ‘**’ P value ≤ 0.01 , ‘*’ P value ≤ 0.05

Supplementary Data 9: Descriptive statistics of phenotypic data (BLUE) for each trait for selection candidates

Trait	Environment	Mean ^a	Units	Max.	Min.	S. d. ^b
DON	UL2016	10.5	ppm	25.7	1.9	5.2
	UL2017	19.8		99.8	2.3	17.0
HTM	SA2017	57.6	Days ^c	66.0	53.0	2.8
	UL2016	55.0		65.0	50.0	3.1
	UL2017	55.6		66.0	47.0	3.2
MAT	SA2016	84.8	Days	97.0	78.0	4.8
	SA2017	88.3		96.0	83.0	3.4
	UL2016	84.9		91.0	82.0	2.1
	UL2017	88.4		96.0	85.0	2.3
TKW	SA2016	44.0	g	50.6	39.4	2.7
	SA2017	43.7		51.6	38.7	3.3
GYP	SA2016	3429.6	Kg/ha	5723.0	1884.0	721.7
	SA2017	4065.8		5979.0	2690.0	662.2

^a Mean of phenotypic data (BLUE) across all the population

^b The standard deviation of the mean

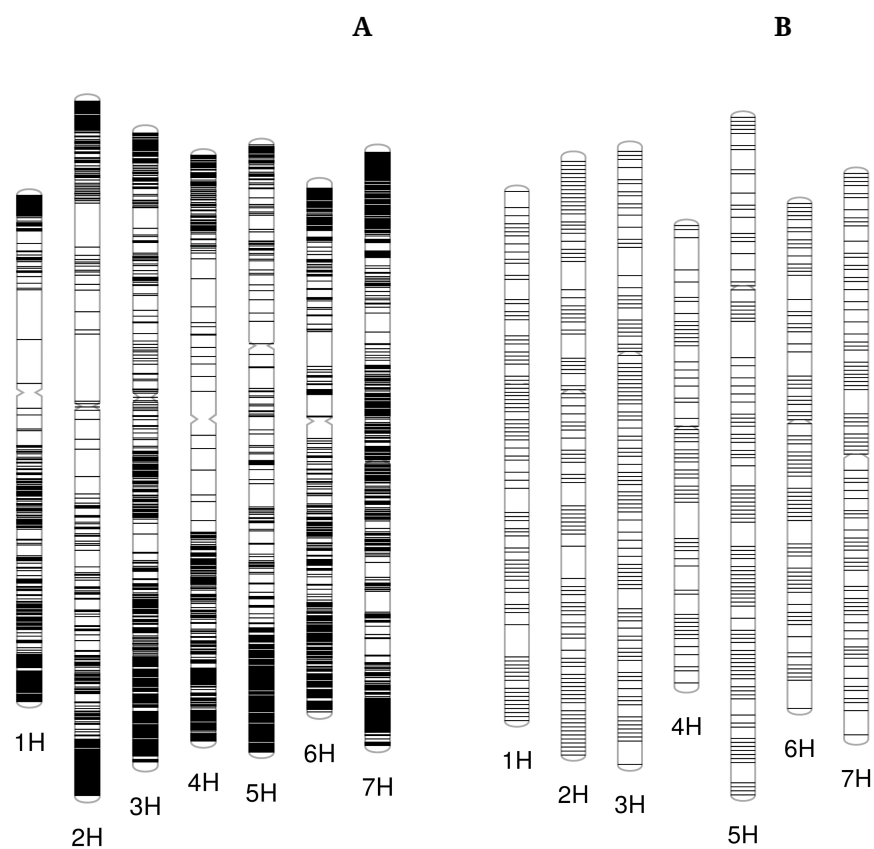
^c Days after seedling

Supplementary Data 10: Accuracy of genomic selection for five traits

		Environment				
		Traits	SA2016	SA2017	UL2016	UL2017
Pearson Correlation ^a	DON	-	-	0.47	0.33	
	GYD	-	-	0.20	0.51	
	HTM	-	-0.16	-0.04	0.11	
	MAT	0.19	0.05	0.09	-0.01	
	TKW	0.59	0.75	-	-	
Spearman Correlation ^b	DON	-	-	0.40	0.38	
	GYD	-	-	0.16	0.53	
	HTM	-	-0.19	-0.07	-0.05	
	MAT	0.11	-0.09	0.06	-0.03	
	TKW	0.62	0.74	-	-	

^a Pearson Correlation

^b Spearman Correlation



Supplementary Data 13: Distribution of SNP loci used in genomic mating based on their physical position (A) in the barley genome (IBSC_v.2) and their genetic position (B) on the POPSEQ map.