

Supplementary Figures

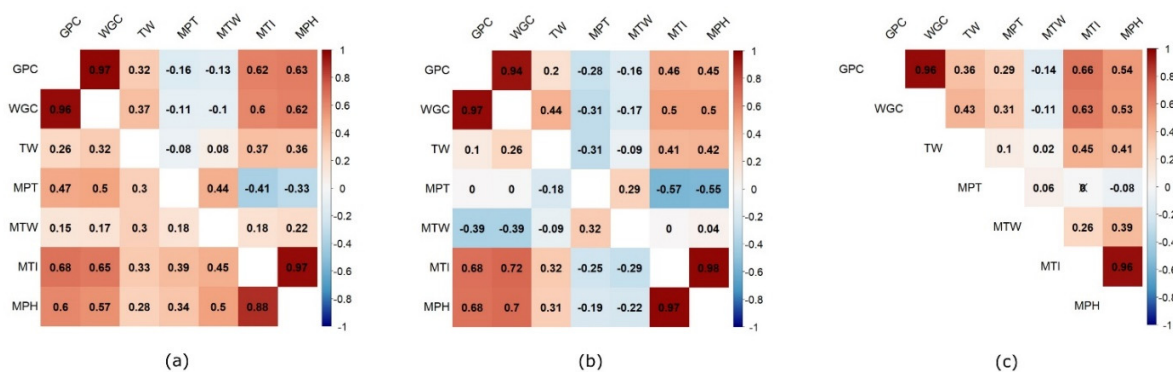


Figure S1: Pearson's correlation coefficients across environments for BK population. Years of experiment are marked as following: (a) 2009, (b) 2010, and (c) 2011. The data in the upper-right triangle represent the location Osijek, while those in the lower-left triangle represent location Slavonski Brod.

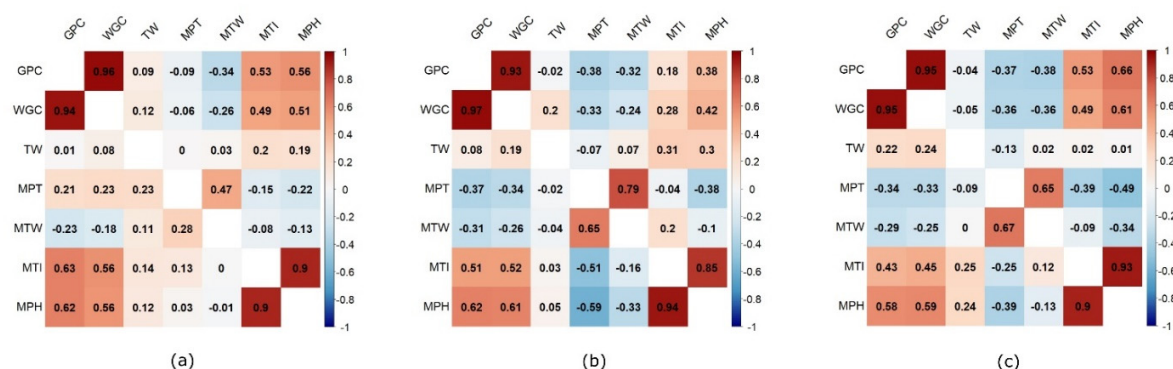


Figure S2: Pearson's correlation coefficients across environments for MG population. Years of experiment are marked as following: (a) 2009, (b) 2010, and (c) 2011. The data in the upper-right triangle represent the location Osijek, while those in the lower-left triangle represent location Slavonski Brod.

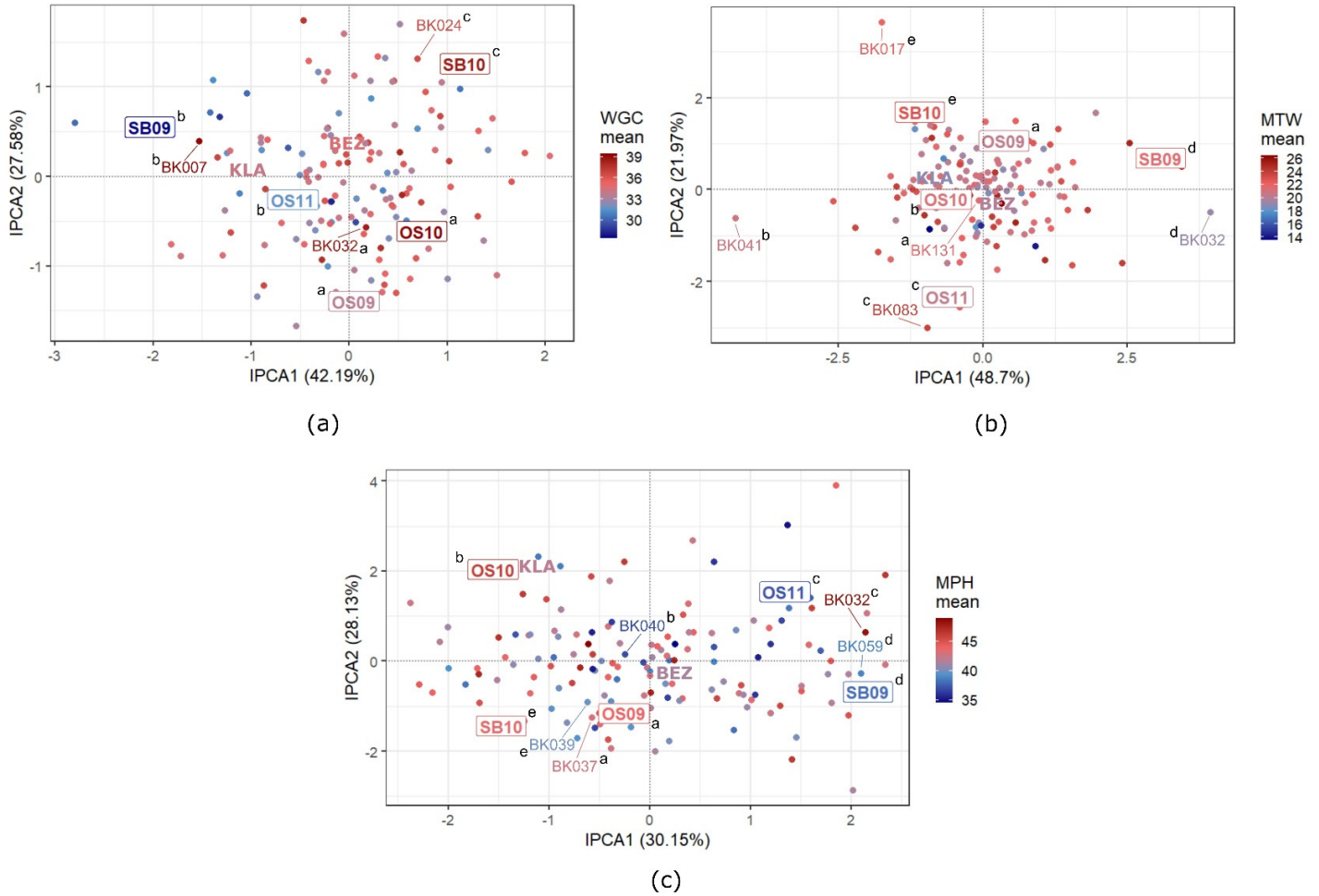
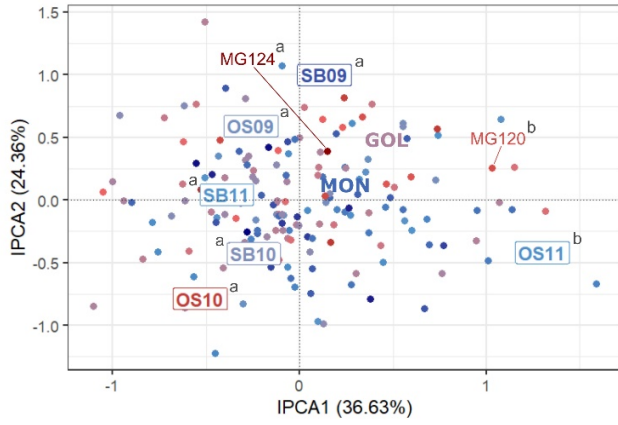
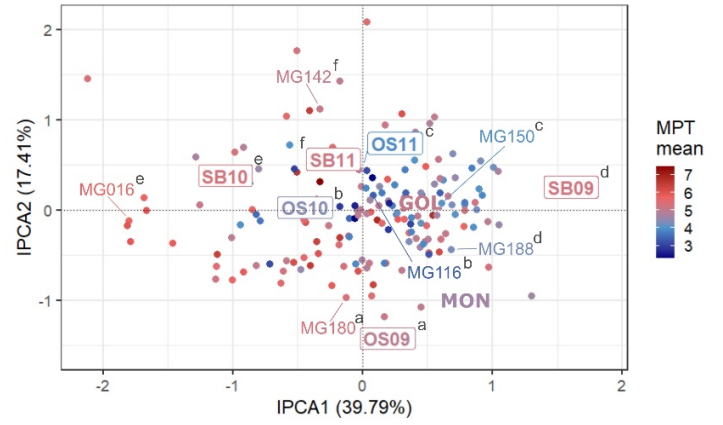


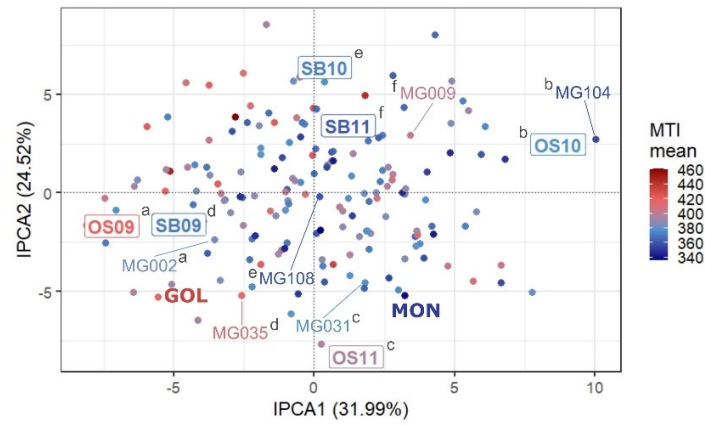
Figure S3: Modified AMMI2 biplots for (a) WGC, (b) MTW, and (c) MPH traits of BK RIL population. RILs are marked with dots, while environments and parental cultivars (Bezostaya-1 and Klara) are marked by abbreviated labels (with or without a frame, respectively). Within each environment one “winning” RIL is labeled and linked with its winning environment by a matching super/subscripted letter. The color indicates the mean value of the trait.



(a)



(b)



(c)

Figure S4: Modified AMMI2 biplots for (a) GPC, (b) MPT, and (c) MTI traits of MG RIL population. RILs are marked with dots, while environments and parental cultivars (Monika and Golubica) are marked by abbreviated labels (with or without a frame, respectively). Within each environment one “winning” RIL is labeled and linked with its winning environment by a matching super/subscripted letter. The color indicates the mean value of the trait.

Supplementary Tables

Table S1. Average daily temperatures (°C) per location during three growing seasons (from planting to harvesting).

Month	2008/09		2009/10		2010/11	
	Osijek	Slavonski Brod	Osijek	Slavonski Brod	Osijek	Slavonski Brod
X	13	12.2	11.5	11	9.1	8.9
XI	7.5	7.3	8.2	7.8	8.9	8.1
XII	3.8	3.8	3.1	3.4	0.2	0.3
I	-1.1	-1.6	-0.8	0	1.1	0.8
II	2.3	2.9	1.4	1.8	0.7	1
III	6.8	7.1	6.8	6.8	6.4	6.4
IV	14.6	14.2	12.4	12.3	13.2	13.1
V	18.3	18.1	16.5	16.2	16.7	16.3
VI	19.2	19.3	20.4	20.2	20.8	20.6
VII	23.2	22.6	23.2	22.7	22.2	22.6
Average	10.76	10.59	10.27	10.22	9.93	9.81

Table S2. Rainfalls (mm) per location during three growing seasons (from planting to harvesting).

Month	2008/09		2009/10		2010/11	
	Osijek	Slavonski Brod	Osijek	Slavonski Brod	Osijek	Slavonski Brod
X	34.4	44.2	55.3	45	67.1	58.2
XI	44.9	64.9	67.8	68.1	56.3	71.5
XII	40.5	46.8	100.8	106.1	73.5	68.5
I	60.3	62.9	83.9	79.5	23.6	27.2
II	28.6	26.2	58.6	81.8	18.4	16.6
III	26.5	41.4	22.2	49.5	37.1	35.9
IV	18.7	13	71.1	52.9	19.4	17.7
V	39.4	43.6	120.8	161.4	81.2	43.8
VI	62.8	103.8	234	176.9	49.9	47.4
VII	13.8	61.1	31.5	42.3	73.9	108.7
Total	369.9	507.9	846	863.5	500.4	495.5

Table S3. Soil temperatures (°C) at 5 cm soil depth per location during three growing seasons (from planting to harvesting).

Month	2008/09		2009/10		2010/11	
	Osijek	Slavonski Brod	Osijek	Slavonski Brod	Osijek	Slavonski Brod
X	13.9	13.9	13.4	13.3	10.6	11.5
XI	8.5	8.4	8.3	8.3	8.6	8.7
XII	4.5	4.2	4.8	4.8	2.3	2.2
I	0.4	0.8	1.6	1.7	1.6	1.5
II	2.8	3.2	1.9	2.0	1.5	2.0
III	6.9	7.3	6.7	7.2	6.2	6.9
IV	15.0	15.4	13.9	13.6	13.6	14.8
V	21.5	21.0	18.3	18.4	18.4	19.4
VI	22.8	21.7	22.8	21.9	23.8	24.1
VII	27.1	26.1	25.8	26.0	25.0	25.7
Average	12.3	12.2	11.8	11.7	11.2	11.7

Table S4. Structure of nested effects in optimal models for each trait in both RIL populations examined.

Trait	Population	Environments ¹		
		Rep	Row	Col
GPC	BK	3	All ²	2, 4, 5
	MG	1, 3	All	1, 3, 4, 5
WGC	BK	Single ³	All	4, 5
	MG	1, 3, 6	1, 3, 4, 5, 6	All
TW	BK	Single	1, 2, 4, 5	2, 4, 5
	MG	1, 2, 5, 6	2, 4, 5, 6	2, 4, 6
MPT	BK	2, 5	2, 3, 4, 5	4, 5
	MG	1, 3, 5	4, 5, 6	1, 3, 4, 6
MTW	BK	2	4	2, 4
	MG	Single	Single	None ⁴
MTI	BK	Single	2, 3, 4, 5	2, 4, 5
	MG	1, 2, 3, 6	1, 3, 4, 5, 6	3, 4
MPH	BK	3, 5	2, 3, 4, 5	4, 5
	MG	Single	All	All

¹ Numbers indicate environments for which this effect was included (1 – OS09, 2 – OS10, 3 – OS11, 4 – SB09, 5 – SB10, 6 – SB11).

² „All“ indicates different effect in all environments.

³ „Single“ indicates unique effects for all environments.

⁴ „None“ indicates that model did not include this effect.

Table S5. Summary of parental means, RIL means and ranges, and rates of transgressive segregants within environments for seven quality traits assessed in BK RIL wheat population.

Trait	Parental cultivars		RILs			Positive		Negative	
	Mean					transgressive	transgressive		
	Bezostaya-1	Klara	Min	Mean	Max	segregants ¹	%	segregants ²	%
OS09 environment									
GPC	14.1	13.9	11.9	14.1	15.9	74	51.8	57	39.9
WGC	33.4	33.7	25.6	33.6	39.5	73	51.1	63	44.1
TW	81.4	82.0	77.0	81.6	84.5	64	44.8	57	39.9
MPT	5.8	5.2	3.4	5.8	7.7	74	51.8	43	30.1
MTW	19.3	16.9	12.4	20.4	27.8	104	72.7	8	5.6
MTI	373.8	320.5	249.8	363.5	463.4	58	40.6	13	9.1
MPH	45.6	39.4	29.8	43.9	55.1	49	34.3	21	14.7
OS10 environment									
GPC	16.0	14.9	13.9	15.7	17.5	47	32.9	29	20.3
WGC	39.9	37.7	32.9	39.4	43.9	64	44.8	33	23.1
TW	73.9	76.8	64.8	75.3	79.8	53	37.1	38	26.6
MPT	6.9	4.6	2.5	5.8	9.2	27	18.9	21	14.7
MTW	20.8	20.8	13.9	21.2	29.6	71	49.7	71	49.7
MTI	378.0	456.1	311.3	409.5	504.9	14	9.8	27	18.9
MPH	43.0	52.5	36.7	46.2	58.9	11	7.7	37	25.9
OS11 environment									
GPC	12.7	12.7	11.0	12.5	14.6	54	37.8	88	61.5
WGC	32.5	32.5	26.4	31.6	37.3	48	33.6	94	65.7
TW	85.1	84.2	78.9	84.1	86.9	30	20.9	69	48.3
MPT	4.2	2.9	1.3	4.6	9.9	82	57.3	18	12.6
MTW	18.3	17.7	14.7	20.4	30.3	108	75.5	22	15.4
MTI	342.7	359.8	259.1	328.6	418.4	24	16.8	97	67.8
MPH	37.7	38.9	28.4	37.1	51.2	43	30.1	86	60.1
SB09 environment									
GPC	12.5	12.6	10.6	12.4	14.9	49	34.3	86	60.1
WGC	27.7	28.7	20.5	27.4	35.6	41	28.7	81	56.6
TW	79.6	79.3	73.7	79.3	82.5	66	46.2	67	46.9
MPT	5.0	4.9	1.3	5.1	8.2	79	55.2	60	41.9
MTW	21.1	16.3	10.8	21.7	35.1	67	46.9	3	2.1
MTI	304.1	290.9	237.3	323.5	411.3	96	67.1	26	18.2
MPH	36.7	34.9	25.5	38.0	49.8	88	61.5	39	27.3
SB10 environment									
GPC	16.0	15.1	12.6	15.3	17.2	38	26.6	58	40.6
WGC	40.1	37.6	30.7	38.6	43.9	44	30.8	47	32.9
TW	75.5	76.9	65.6	77.4	81.5	94	65.7	17	11.9
MPT	4.3	5.5	1.8	5.8	10.0	86	60.1	24	16.8
MTW	20.9	22.0	12.1	22.9	33.3	87	60.8	30	21.0
MTI	399.2	408.4	284.6	381.5	464.6	41	28.7	93	65.0
MPH	44.8	46.3	32.1	43.6	53.2	42	29.4	82	57.3

¹ RILs that exhibited values higher than the parental cultivar with higher trait value.

² RILs that exhibited values lower than the parental cultivar with lower trait value.

Table S6. Summary of parental means, RIL means and ranges, and rates of transgressive segregants within environments for seven quality traits assessed in MG RIL wheat population.

Trait	Parental cultivars		RILs			Positive		Negative	
	Mean					transgressive	transgressive		
	Monika	Golubica	Min	Mean	Max	segregants ¹	%	segregants ²	%
OS09 environment									
GPC	13.1	14.0	11.6	13.7	16.1	55	31.8	50	28.9
WGC	28.2	34.0	25.4	31.6	39.0	39	22.5	23	13.3
TW	81.5	84.3	77.9	82.1	84.3	0	0.00	44	25.4
MPT	6.4	5.1	2.0	4.9	7.6	31	17.9	92	53.2
MTW	10.0	22.2	6.5	19.6	35.4	53	30.6	19	11.0
MTI	359.4	510.4	329.9	420.8	527.8	4	2.3	10	5.8
MPH	42.1	60.8	36.9	49.3	73.2	8	4.6	20	11.6
OS10 environment									
GPC	14.8	15.1	13.5	15.3	17.3	106	61.3	51	29.5
WGC	32.3	39.5	32.0	38.4	43.9	59	34.1	1	0.6
TW	73.5	73.8	65.7	72.4	77.6	54	31.2	110	63.6
MPT	3.2	4.7	1.9	4.4	8.5	64	37.0	33	19.1
MTW	5.8	9.2	4.4	9.4	23.4	55	31.8	13	7.5
MTI	334.0	394.6	301.6	377.2	470.8	47	27.2	19	11.0
MPH	44.2	47.1	34.8	45.8	59.3	52	30.0	73	42.2
OS11 environment									
GPC	13.0	14.3	11.1	13.5	16.2	28	16.2	59	34.1
WGC	33.5	36.7	29.6	34.6	42.2	29	16.8	54	31.1
TW	84.6	84.5	81.9	84.4	86.2	74	42.8	89	51.5
MPT	2.9	3.4	1.8	3.9	7.4	126	72.8	22	12.7
MTW	11.6	13.3	6.9	15.2	23.7	127	73.4	23	13.3
MTI	442.8	485.4	327.1	394.0	489.3	1	0.6	162	93.6
MPH	53.8	58.0	36.1	46.8	62.9	2	1.2	157	90.8
SB09 environment									
GPC	12.6	14.0	10.9	12.9	15.6	16	9.3	61	35.3
WGC	26.1	32.7	21.8	28.0	36.4	8	4.6	40	23.1
TW	78.6	80.7	75.4	79.1	81.6	13	7.5	52	30.1
MPT	6.1	5.7	2.0	5.3	8.5	52	30.1	100	57.8
MTW	13.2	26.6	4.8	20.2	45.9	24	13.9	26	15.0
MTI	314.6	442.3	298.7	370.9	472.7	4	2.3	4	2.3
MPH	36.3	53.7	33.8	43.6	58.4	5	2.9	7	4.1
SB10 environment									
GPC	12.8	13.6	12.1	13.7	16.3	97	56.1	19	11.0
WGC	30.0	34.9	29.6	34.6	42.1	73	42.2	3	1.7
TW	78.4	79.1	75.3	79.0	82.4	85	49.1	51	29.5
MPT	2.8	4.3	1.6	5.3	9.1	122	70.5	7	4.1
MTW	8.1	21.2	5.1	14.3	30.1	14	8.1	30	17.3
MTI	347.5	436.9	285.5	372.4	502.9	9	5.2	44	25.4
MPH	39.2	50.5	30.8	43.1	60.8	16	9.3	47	27.2
SB11 environment									
GPC	12.0	13.3	11.7	13.5	16.4	103	59.5	5	2.9
WGC	29.4	33.8	28.0	33.7	41.4	84	48.6	9	5.2
TW	79.6	79.9	76.1	80.3	83.0	112	64.7	47	27.2
MPT	6.1	6.1	2.1	5.2	8.0	51	29.5	118	68.2
MTW	7.1	15.3	4.9	12.9	27.2	57	32.9	24	13.9
MTI	286.7	363.2	286.7	360.6	451.4	76	43.9	0	0.00
MPH	33.2	42.9	33.0	43.7	54.5	90	52.0	1	0.6

¹ RILs that exhibited values higher than the parental cultivar with higher trait value.

² RILs that exhibited values lower than the parental cultivar with lower trait value.

Table S7. Results of tests for IPCA terms for four mixograph traits containing missing values in the BK population. Tests were conducted on the imputed data sets based on different AMMI models.

	IPCA	MPT						MTW						MTI						MPH					
		Sum of Squares		Simple bootstrap		Fr-test		Sum of Squares		Simple bootstrap		Fr-test		Sum of Squares		Simple bootstrap		Fr-test		Sum of Squares		Simple bootstrap		Fr-test	
		IPCA SS	%	T	p value	F	p value	IPCA SS	%	T	p value	F	p value	IPCA SS	%	T	p value	F	p value	IPCA SS	%	T	p value	F	p value
AMMI0	1	400.2	45.5	0.41	0.000	2.04	0.000	1581.1	53.3	0.46	0.000	2.45	0.000	127383.3	38.2	0.32	0.269	1.36	0.009	1993.2	37.4	0.30	0.650	1.25	0.042
	2	268.8	30.6	0.47	0.001	1.74	0.000	797.4	26.9	0.42	0.084	1.44	0.005	111755.5	33.5	0.41	0.202	1.36	0.015	1869.9	35.1	0.40	0.281	1.32	0.024
	3	209.9	23.9	0.69	0.000	2.22	0.000	587.2	19.8	0.54	0.627	1.16	0.188	94516.5	28.3	0.59	0.120	1.40	0.024	1470.9	27.6	0.53	0.761	1.12	0.254
AMMI1	1	400.7	45.6	0.41	0.000	2.05	0.000	1712.4	55.5	0.48	0.000	2.68	0.000	127752.5	38.3	0.32	0.255	1.37	0.009	2008.5	37.7	0.30	0.606	1.27	0.036
	2	268.4	30.5	0.47	0.001	1.73	0.000	798.9	25.9	0.43	0.061	1.46	0.003	111537.2	33.4	0.41	0.210	1.35	0.016	1863.0	34.9	0.40	0.296	1.32	0.026
	3	210.2	23.9	0.69	0.000	2.23	0.000	573.7	18.6	0.54	0.684	1.14	0.215	94565.2	28.3	0.59	0.120	1.40	0.024	1463.8	27.4	0.53	0.792	1.11	0.275
AMMI2	1	400.2	45.5	0.41	0.000	2.04	0.000	1774.3	56.4	0.49	0.000	2.77	0.000	126404.6	37.5	0.31	0.370	1.33	0.015	1999.9	37.5	0.30	0.630	1.26	0.039
	2	268.8	30.6	0.47	0.001	1.74	0.000	800.3	25.4	0.43	0.059	1.47	0.003	116513.4	34.5	0.42	0.109	1.42	0.007	1866.4	35.0	0.40	0.286	1.32	0.025
	3	209.9	23.9	0.69	0.000	2.22	0.000	571.6	18.2	0.54	0.707	1.13	0.226	94460.8	28.0	0.59	0.120	1.40	0.024	1466.6	27.5	0.53	0.777	1.11	0.265
AMMI3	1	411.3	45.7	0.41	0.000	2.06	0.000	1654.6	54.6	0.47	0.000	2.58	0.000	183845.8	45.5	0.39	0.000	1.87	0.000	1970.9	36.6	0.30	0.772	1.22	0.063
	2	266.9	29.6	0.46	0.004	1.66	0.000	797.7	26.3	0.43	0.064	1.46	0.004	125226.6	31.0	0.44	0.030	1.52	0.001	1899.7	35.3	0.40	0.272	1.33	0.023
	3	222.8	24.7	0.71	0.000	2.37	0.000	576.7	19.0	0.54	0.662	1.15	0.204	94788.9	23.5	0.59	0.111	1.40	0.022	1514.9	28.1	0.54	0.639	1.16	0.193

Table S8. Results of tests for IPCA terms for four mixograph traits containing missing values in the MG population. Tests were conducted on the imputed data sets based on different AMMI models.

	IPCA	MPT						MTW						MTI						MPH					
		Sum of Squares		Simple bootstrap		Fr-test		Sum of Squares		Simple bootstrap		Fr-test		Sum of Squares		Simple bootstrap		Fr-test		Sum of Squares		Simple bootstrap		Fr-test	
		IPCA SS	%	T	p value	F	p value	IPCA SS	%	T	p value	F	p value	IPCA SS	%	T	p value	F	p value	IPCA SS	%	T	p value	F	p value
AMMI0	1	337.1	43.7	0.39	0.000	1.85	0.000	3879.2	48.5	0.43	0.000	2.23	0.000	254432.1	36.3	0.32	0.000	1.37	0.004	4704.7	34.3	0.30	0.001	1.26	0.025
	2	154.3	20.0	0.29	0.822	0.80	0.953	1560.6	19.5	0.31	0.390	0.87	0.855	195682.8	27.9	0.36	0.001	1.11	0.210	3670.4	26.8	0.34	0.028	1.00	0.508
	3	151.4	19.6	0.40	0.254	0.66	0.997	1392.2	17.4	0.39	0.330	0.64	0.998	137255.2	19.6	0.40	0.301	0.65	0.998	2770.1	20.2	0.38	0.561	0.61	0.999
	4	128.3	16.6	0.56	0.266	2.55	0.000	1160.2	14.5	0.54	0.556	2.35	0.000	113363.1	16.2	0.54	0.571	2.34	0.000	2567.0	18.7	0.57	0.156	2.67	0.000
AMMI1	1	349.8	44.7	0.40	0.000	1.93	0.000	3882.6	48.6	0.43	0.000	2.24	0.000	255288.9	36.4	0.32	0.000	1.38	0.003	4708.1	34.3	0.30	0.001	1.26	0.025
	2	154.0	19.7	0.29	0.817	0.80	0.953	1558.5	19.5	0.31	0.402	0.87	0.858	195528.2	27.9	0.36	0.001	1.11	0.211	3671.4	26.8	0.34	0.027	1.00	0.506
	3	149.7	19.2	0.40	0.302	0.65	0.998	1392.1	17.4	0.39	0.332	0.64	0.998	136972.1	19.5	0.40	0.311	0.65	0.998	2776.9	20.2	0.38	0.535	0.61	0.999
	4	128.3	16.4	0.56	0.283	2.54	0.000	1160.0	14.5	0.54	0.563	2.34	0.000	114204.8	16.3	0.54	0.509	2.38	0.000	2563.2	18.7	0.57	0.155	2.68	0.000
AMMI2	1	352.0	44.9	0.40	0.000	1.94	0.000	3996.4	48.3	0.43	0.000	2.23	0.000	255111.6	36.4	0.32	0.000	1.38	0.003	4709.2	34.3	0.30	0.001	1.27	0.024
	2	154.0	19.6	0.29	0.815	0.80	0.952	1726.7	20.9	0.31	0.397	0.96	0.612	195556.4	27.9	0.36	0.001	1.11	0.210	3671.7	26.8	0.34	0.027	1.00	0.505
	3	149.7	19.1	0.40	0.301	0.65	0.998	1391.3	16.8	0.39	0.333	0.64	0.998	137022.0	19.5	0.40	0.313	0.65	0.998	2779.2	20.3	0.38	0.538	0.62	0.999
	4	128.2	16.4	0.56	0.284	2.53	0.000	1165.1	14.1	0.54	0.561	2.38	0.000	114022.2	16.3	0.54	0.511	2.37	0.000	2562.1	18.7	0.57	0.155	2.68	0.000
AMMI3	1	538.3	54.5	0.49	0.000	2.87	0.000	3959.1	48.3	0.43	0.000	2.23	0.000	254779.7	36.3	0.32	0.000	1.38	0.004	4724.7	34.3	0.30	0.001	1.27	0.024
	2	171.1	17.3	0.31	0.291	0.89	0.816	1687.1	20.6	0.32	0.104	0.94	0.677	195614.1	27.9	0.36	0.001	1.11	0.210	3675.9	26.7	0.34	0.029	0.99	0.511
	3	152.9	15.5	0.40	0.196	0.67	0.996	1391.5	17.0	0.39	0.326	0.64	0.998	137126.5	19.6	0.40	0.305	0.65	0.998	2813.2	20.4	0.39	0.456	0.62	0.999
	4	126.2	12.8	0.56	0.327	2.50	0.000	1164.4	14.2	0.54	0.507	2.38	0.000	113691.5	16.2	0.54	0.544	2.36	0.000	2551.2	18.5	0.57	0.159	2.67	0.000
AMMI4	1	351.5	44.4	0.39	0.000	1.91	0.000	4205.2	48.6	0.44	0.000	2.27	0.000	256897.9	36.5	0.32	0.000	1.39	0.003	4718.0	34.3	0.30	0.001	1.27	0.024
	2	158.9	20.1	0.29	0.680	0.82	0.928	1897.0	21.9	0.35	0.005	1.06	0.333	195329.5	27.7	0.36	0.001	1.10	0.220	3674.1	26.7	0.34	0.028	1.00	0.507
	3	152.8	19.3	0.40	0.210	0.66	0.996	1390.8	16.1	0.39	0.330	0.64	0.998	136641.2	19.4	0.39	0.346	0.64	0.998	2798.2	20.4	0.39	0.483	0.62	0.999
	4	127.6	16.1	0.56	0.272	2.55	0.000	1167.3	13.5	0.55	0.494	2.39	0.000	116014.4	16.5	0.55	0.434	2.42	0.000	2555.0	18.6	0.57	0.154	2.68	0.000

Table S9. „Winner“ RILs within each environment for both populations examined.

Environment	Trait						
	GPC	WGC	TW	MPT	MTW	MTI	MPH
BK population							
OS09	BK032	BK032	BK012	BK042	BK131	BK059	BK037
OS10	BK032	BK032	BK037	BK042	BK041	BK040	BK040
OS11	BK007	BK007	BK012	BK131	BK083	BK057	BK032
SB09	BK007	BK007	BK012	BK124	BK032	BK059	BK059
SB10	BK034	BK024	BK048	BK042	BK017	BK039	BK039
MG population							
OS09	MG124	MG124	MG089	MG180	MG169	MG002	MG166
OS10	MG124	MG084	MG016	MG116	MG116	MG104	MG027
OS11	MG120	MG193	MG155	MG150	MG035	MG031	MG031
SB09	MG124	MG124	MG192	MG188	MG016	MG035	MG096
SB10	MG124	MG084	MG124	MG016	MG001	MG108	MG108
SB11	MG124	MG124	MG087	MG142	MG136	MG009	MG009