Supplement to:

Evidence for magnesium-phosphorus synergism and co-limitation of grain yield in wheat agriculture

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Supplement S1. Linear Mixed Model analysis results for fixed effects of year (2018, 2019, *df* = 1), treatment (compacted and non-compacted soil, *df* = 1), variety (*df* = 8), block (*df* = 3), and the interactions between year, treatment and variety; and random effect of mainplot (*df* = 7) on various traits assessed for nine wheat varieties field-grown in Sweden. ***F*** critical value for F-statistics, ***P*** significance (significant: *P* < .050 underlined), ***df*** degrees of freedom. Mainplot was included as a random effect to account for the varieties having been assigned to different plot positions in the two years

Trait	Year (Y)		Treatment (T)		Variety (V)		Block		Y x T		Y x V		T x V		Y x T x V	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
G_B	25.31	.000	13.90	.034	13.77	.000	.87	.543	5.35	.023	.63	.752	.98	.453	1.13	.353
G_Y	102.19	.000	3.81	.146	38.09	.000	11.04	.040	9.56	.003	4.68	.000	.96	.474	.76	.642
G_{no}	118.23	.000	11.05	.044	11.34	.000	.80	.571	6.90	.010	.91	.515	1.06	.396	1.21	.298
R_{no}	43.67	.000	3.60	.154	21.36	.000	.65	.636	.62	.434	.703	.689	.48	.867	1.12	.359
R_a	62.94	.000	6.23	.088	3.95	.000	.24	.865	.00	.991	1.00	.444	.74	.657	.58	.792
$E_{N,g}$	98.10	.000	1.76	.276	5.58	.000	1.83	.316	20.81	.000	1.36	.222	.41	.913	1.88	.072
$C_{N,g}$	873.8	.000	6.20	.089	75.31	.000	.69	.616	.73	.395	9.17	.000	.80	.604	.99	.448
NC_{till}	250.31	.000	27.90	.013	8.36	.000	5.27	.103	.26	.610	1.33	.237	.31	.963	.43	.900
CaC_{till}	19.13	.000	.80	.438	2.61	.012	3.02	.194	.15	.698	.64	.747	1.05	.408	.84	.567
KC_{till}	367.06	.000	26.27	.014	4.81	.000	.69	.617	.00	.962	2.27	.028	1.34	.232	1.13	.350
MgC_{till}	67.16	.000	.33	.605	2.74	.009	3.12	.187	.01	.908	.62	.756	.83	.579	.90	.521
PC_{till}	130.47	.000	5.12	.109	2.26	.029	5.82	.091	10.32	.002	.76	.639	.14	.997	.50	.854
SC_{till}	2.88	.093	3.17	.173	4.82	.000	1.85	.313	.75	.387	1.03	.417	.36	.937	.96	.469
NC_{flow}	11.59	.001	1.96	.256	4.25	.000	1.19	.444	5.83	.018	1.34	.231	.41	.914	.61	.769
CaC_{flow}	22.74	.000	6.50	.084	9.00	.000	16.00	.024	2.09	.151	1.21	.301	1.07	.390	1.00	.441
KC_{flow}	86.40	.000	1.16	.360	8.54	.000	2.84	.207	2.32	.131	1.56	.147	.50	.852	2.09	.043
MgC_{flow}	.01	.921	4.71	.118	15.94	.000	6.70	.076	6.16	.015	1.69	.110	.78	.621	1.90	.068
PC_{flow}	13.64	.000	16.01	.028	7.23	.000	1.65	.345	17.50	.000	1.13	.348	.258	.978	.849	.562
SC_{flow}	2.88	.093	3.17	.173	4.82	.000	1.85	.313	.75	.387	1.03	.417	.36	.937	.96	.469

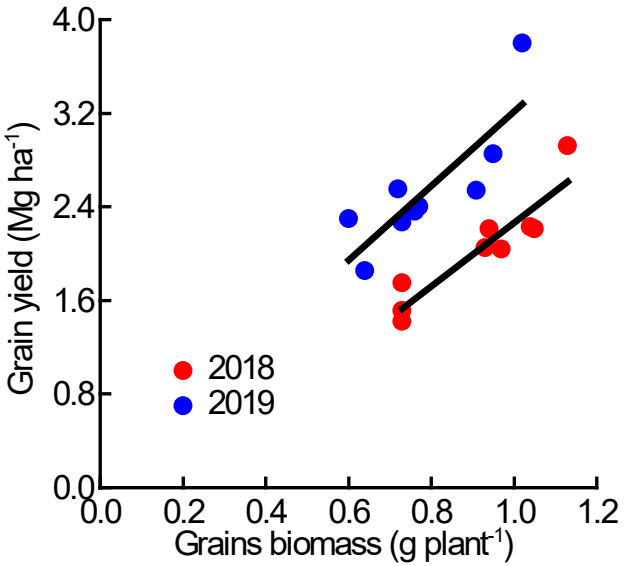
G_B Grains biomass (assessed on 5 indiv. plants), **G_Y** Agronomic grain yield (assessed on plot basis), **G_{no}** Number of grains per plant, **R_{no}** Seminal root number, **R_a** Seminal root angle, **$E_{N,g}$** Grain-specific N efficiency, **$C_{N,g}$** Grain N concentration, **NC** N concentration, **CaC** Calcium concentration, **KC** potassium (K) concentration, **MgC** Magnesium concentration, **PC** Phosphorus concentration, **SC** Sulfur concentration; subscripts ***till*** tillering (BBCH29) and ***flow*** flowering (BBCH65) stage

Supplement S2. Mean (± 1 SD, n = 8) agronomic grain yields (Mg ha^{-1}) (A) and relationships between the plot-based values of agronomic grain yield and individual-based values of grains biomass (g plant^{-1}) (B) for nine spring wheat varieties field-grown in Sweden during two years (2018, 2019). Linear regressions in B: y=2.738x-0.478, N = 9, R^2 = 0.85, P < 0.001 (2018); y=3.221x-0.005, N = 9, R^2 = 0.69, P = 0.006 (2019). The agronomic yields of the high-yielding varieties reported here (e.g., 'Alderon', 'Happy') were of a similar magnitude compared to the commercial grain yields for spring wheat achieved in Sweden (means 2.8 and 4.5 Mg ha^{-1} in 2018 and 2019, respectively; available at www.scb.se).

A

Variety	*2018*	*2019*
'Alderon'	2.92 ± 0.36	3.80 ± 0.40
'Bjarne'	1.75 ± 0.25	2.31 ± 0.36
'Boett'	2.05 ± 0.25	2.40 ± 0.50
'Dacke'	2.04 ± 0.23	2.36 ± 0.43
'Dala landrace'	1.51 ± 0.21	1.86 ± 0.18
'Diskett'	2.21 ± 0.21	2.27 ± 0.36
'Happy'	2.21 ± 0.21	2.85 ± 0.56
'Quarna'	1.42 ± 0.22	2.55 ± 0.44
'Rohan'	2.23 ± 0.22	2.54 ± 0.54

B



Supplement S3. Grouping of samples (A) and corresponding variable component loadings (B) according to Principal Components Analysis (PCA). Samples are attributes (mean trait values) measured on nine wheat varieties field-grown in Sweden during two years (2018 red colors, 2019 blue colors), i.e. the variables shown in (B). Eigenvalues 7.47 for dimension 1 (explanatory power 75 %), and 1.41 for dimension 2 (explanatory power 14 %). Varieties **Ald** 'Alderon', **Bja** 'Bjarne', **Boe** 'Boett', **Dac** 'Dacke', **Dal** 'Dala landrace', **Dis** 'Diskett', **Hap** 'Happy', **Qua** 'Quarna', **Roh** 'Rohan'. Variables: $\mathbf{B_T}$ Plant biomass plant^{-1} at tillering, $\mathbf{B_G}$ Grains biomass plant^{-1}, $\mathbf{R_{no}}$ Seminal root number plant^{-1}, $\mathbf{R_a}$ Seminal root angle, $\mathbf{E_{N,g}}$ Grain-specific nitrogen (N) efficiency, $\mathbf{C_{N,g}}$ Grain N concentration, $\mathbf{P{:}N_{till}}$ P:N ratio at tillering, $\mathbf{Mg{:}N_{till}}$ Mg:N ratio at tillering, ***Mg:P** Mean (tillering and flowering) Mg:P ratio, ***ScExp** scaling exponent (macroelements) based on data from tillering and flowering; **Year** (supplementary variable).