Supplementary material

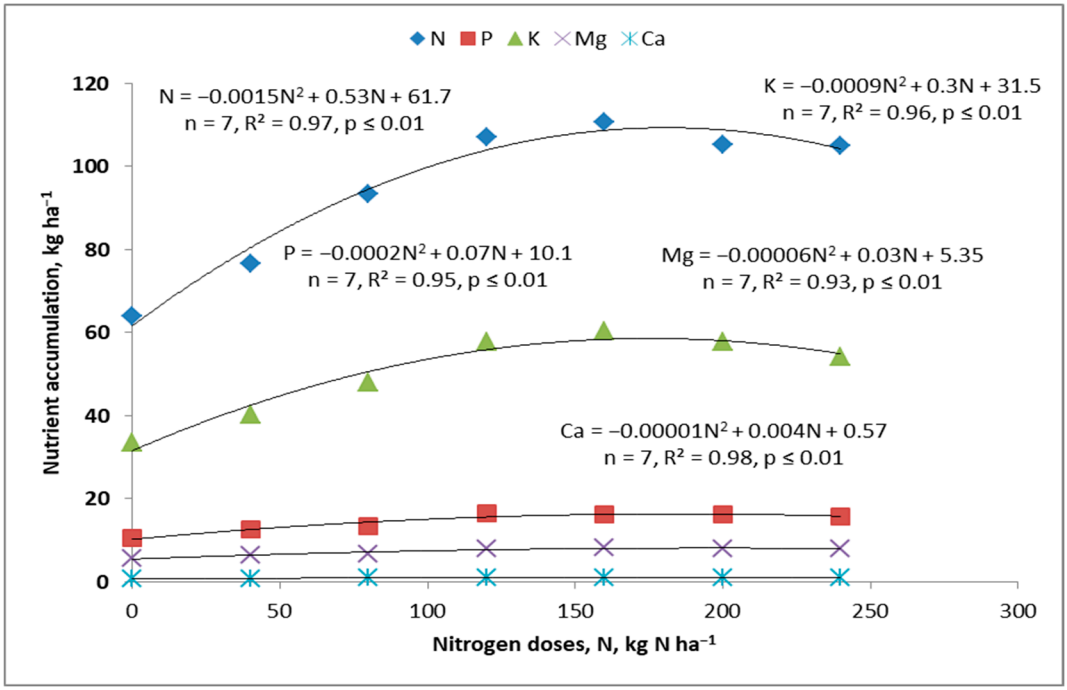

Figure S1. Trends in the mass of macro-nutrients in winter wheat ears in the full flowering phase in response to increasing N_f doses.

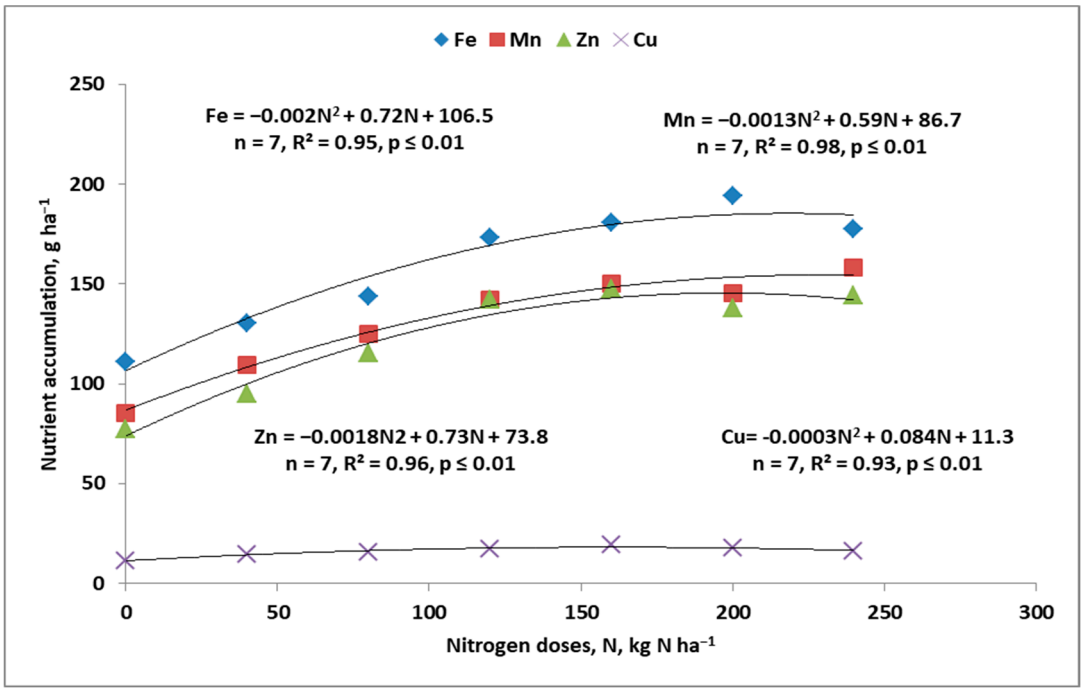

Figure S2. Trends in the mass of micronutrients in winter wheat ears in the full flowering phase in response to increasing N_f doses.

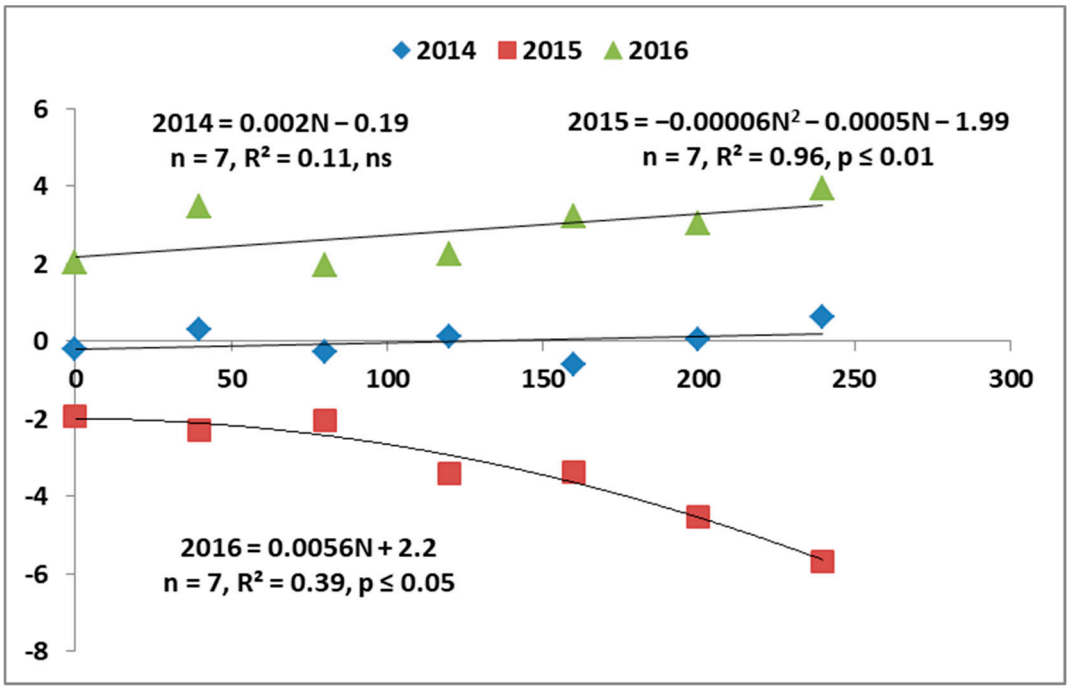

Figure S3. Trends in magnesium balance in leaves in subsequent growing season in response to an increase in N_f doses.

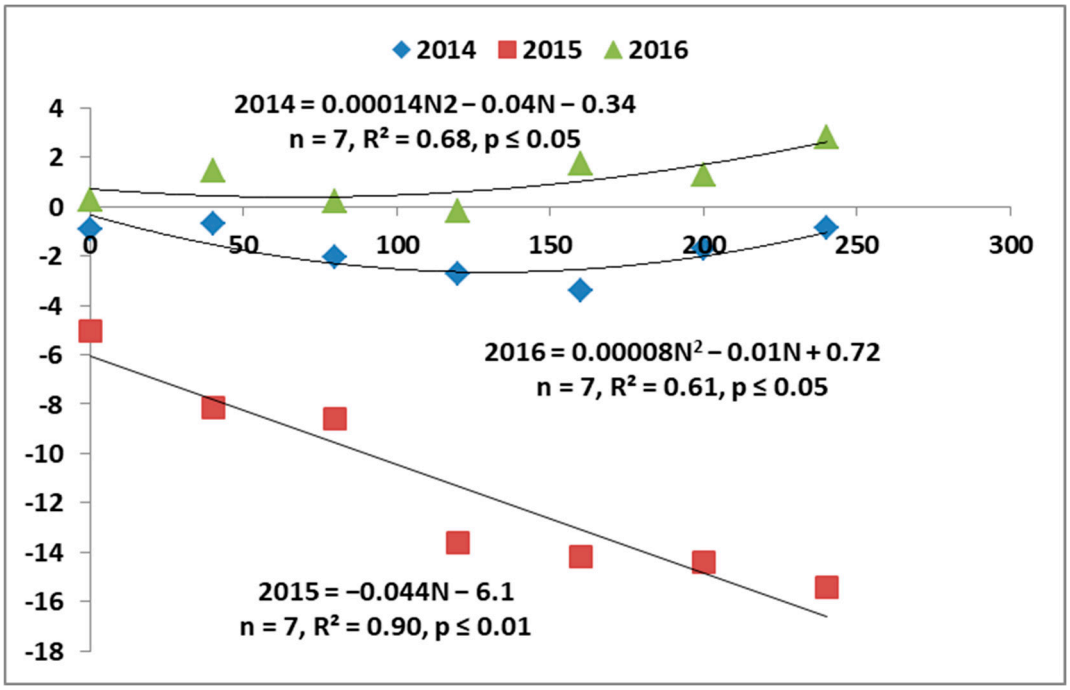

Figure S4. Trends in calcium balance in leaves in subsequent growing season in response to an increase in N_f doses.

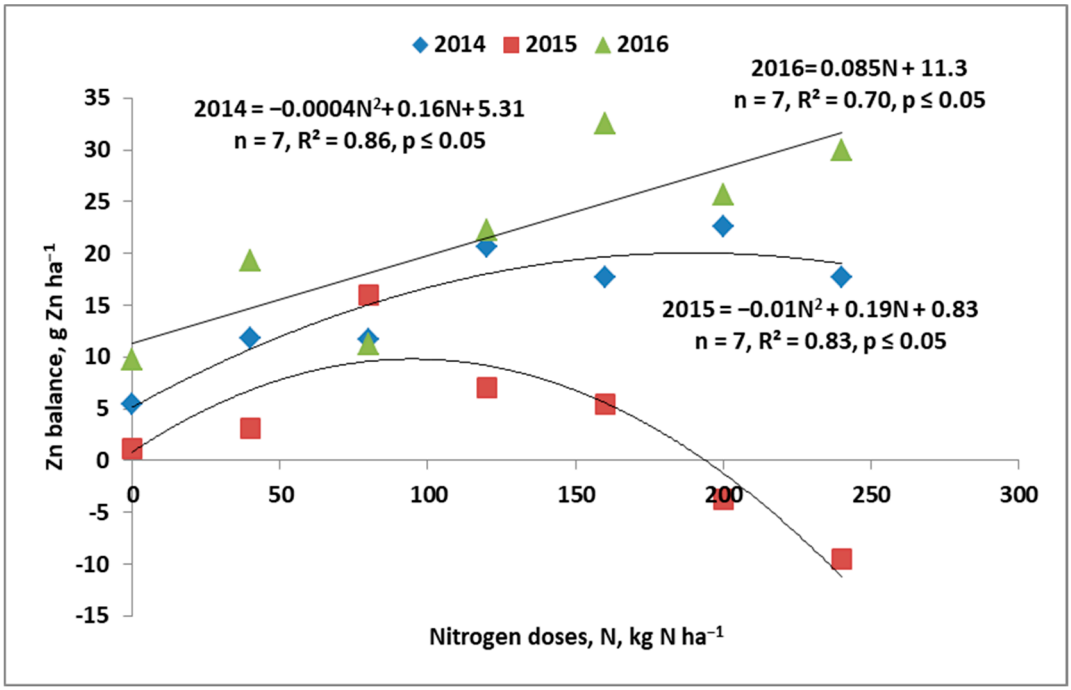

Figure S5. Trends in zinc balance in leaves in subsequent growing season in response to an increase in N_f doses.

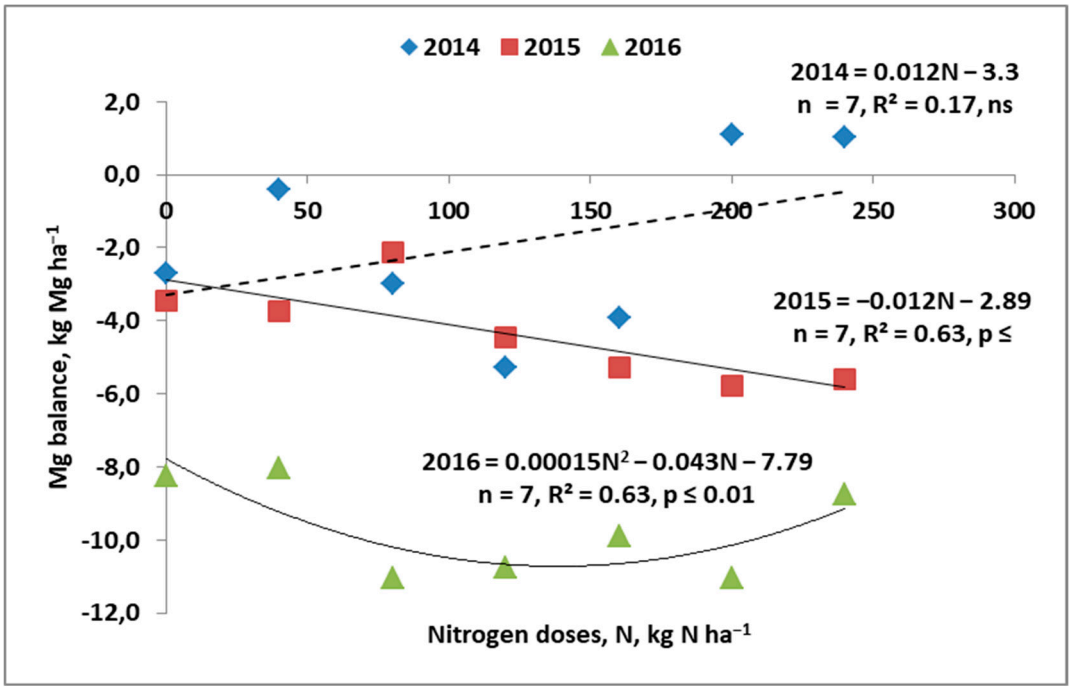

Figure S6. Trends in magnesium balance in stems in subsequent growing season in response to an increase in N_f doses.

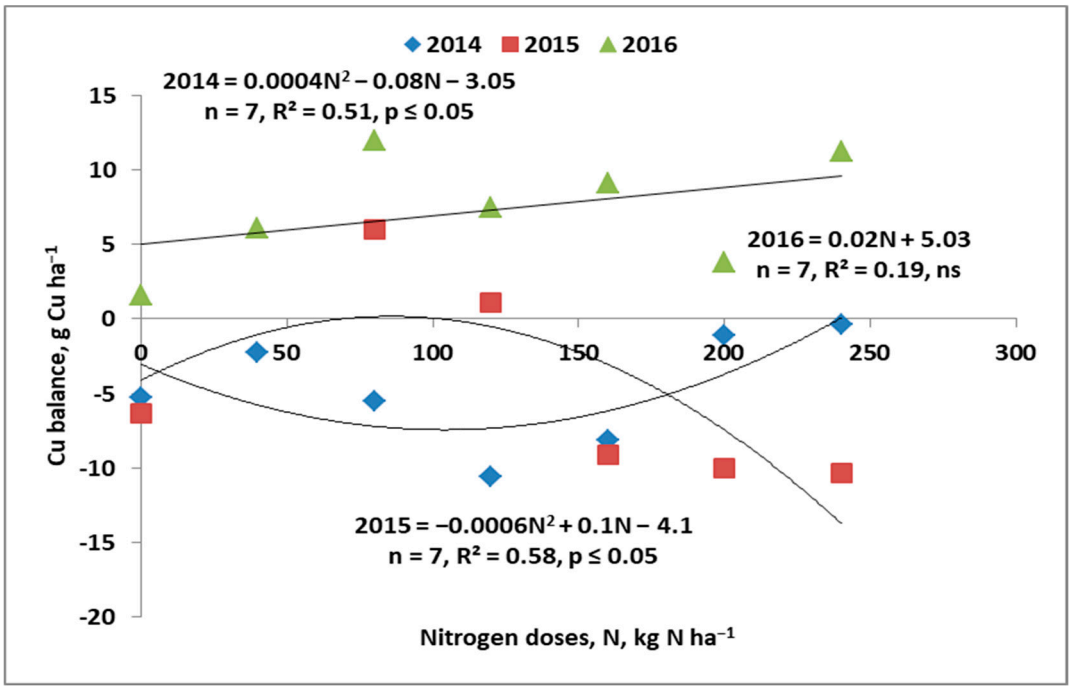

Figure S7. Trends in copper balance in stems in subsequent growing season in response to an increase in N_f doses.

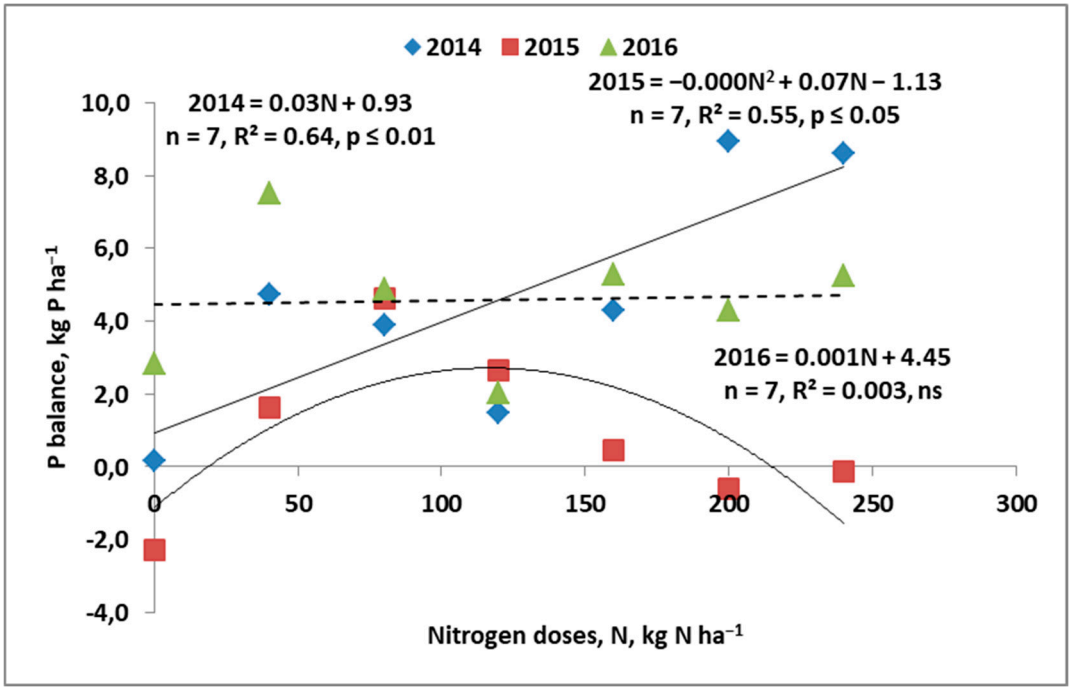

Figure S8. Trends in phosphorus balance in stems in subsequent growing season in response to an increase in N_f doses.

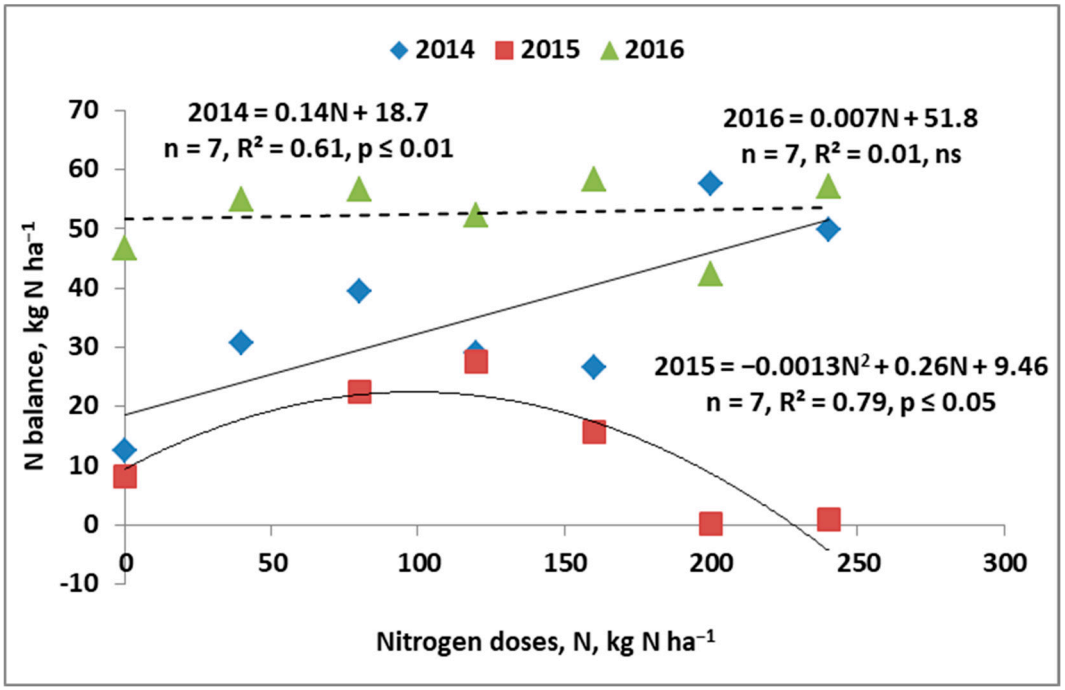

Figure S9. Trends in nitrogen balance in stems in subsequent growing season in response to an increase in N_f doses.

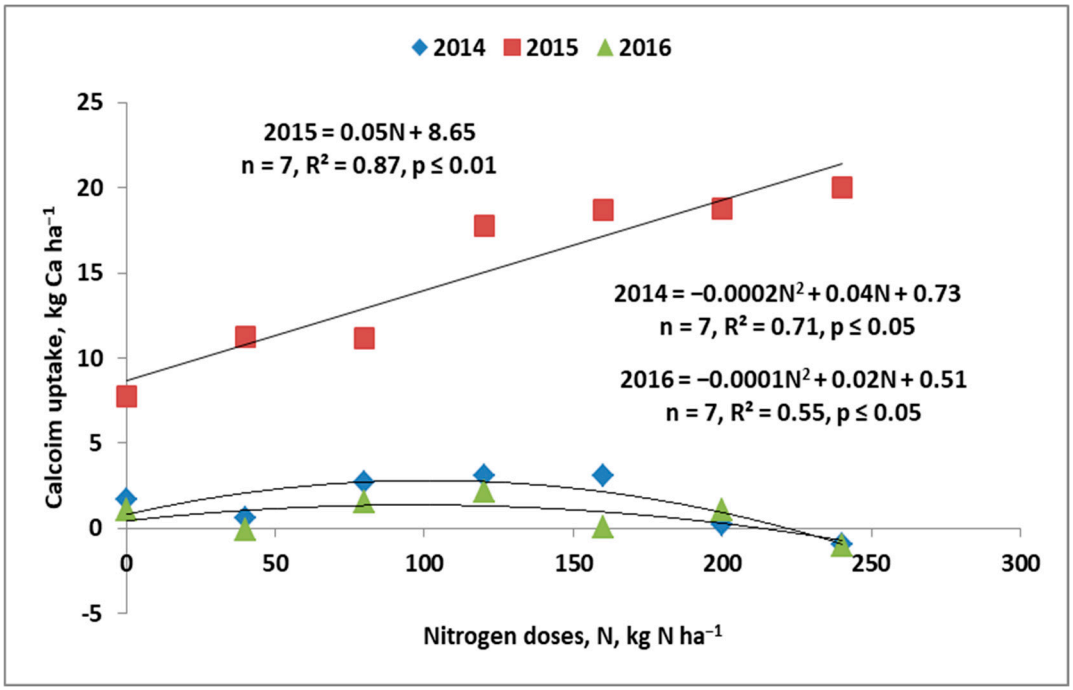

Figure S10. Trends in calcium soil uptake by winter wheat in CCW in subsequent growing season.

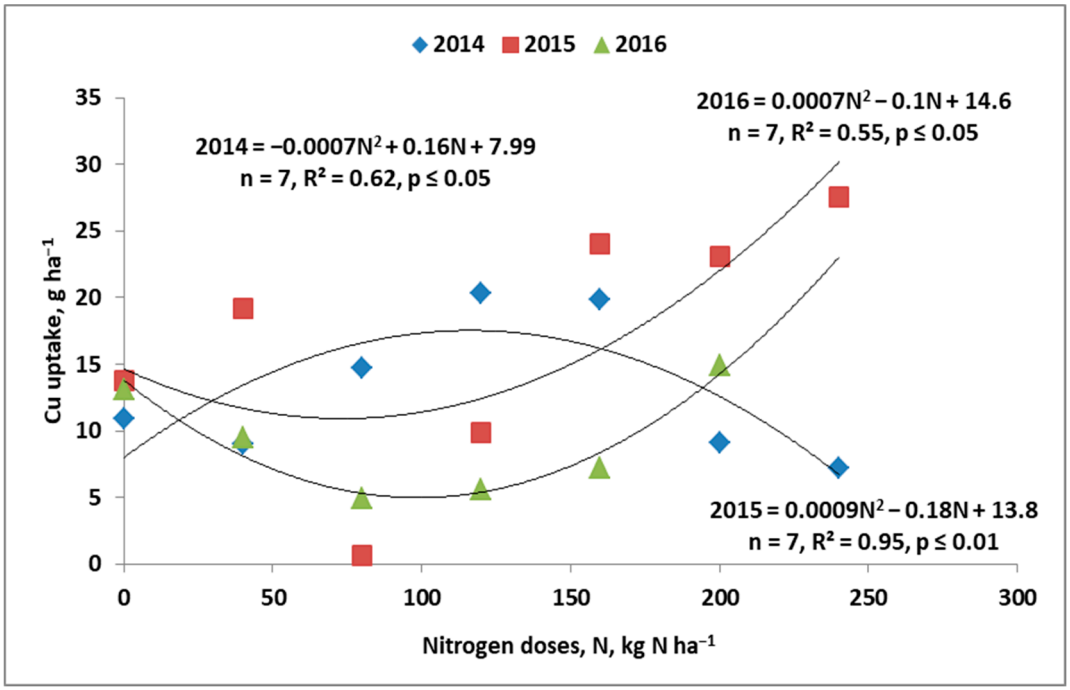

Figure S11. Trends in copper soil uptake by winter wheat in CCW in subsequent growing season.

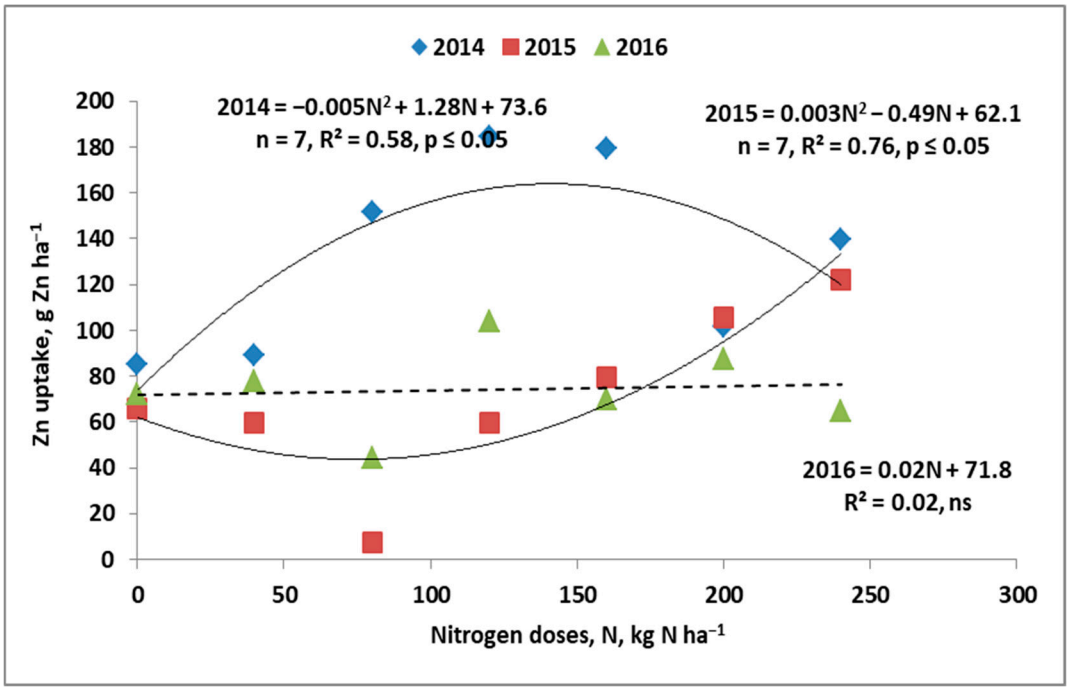

Figure S12. Trends in zinc soil uptake by winter wheat in CCW in subsequent growing season.

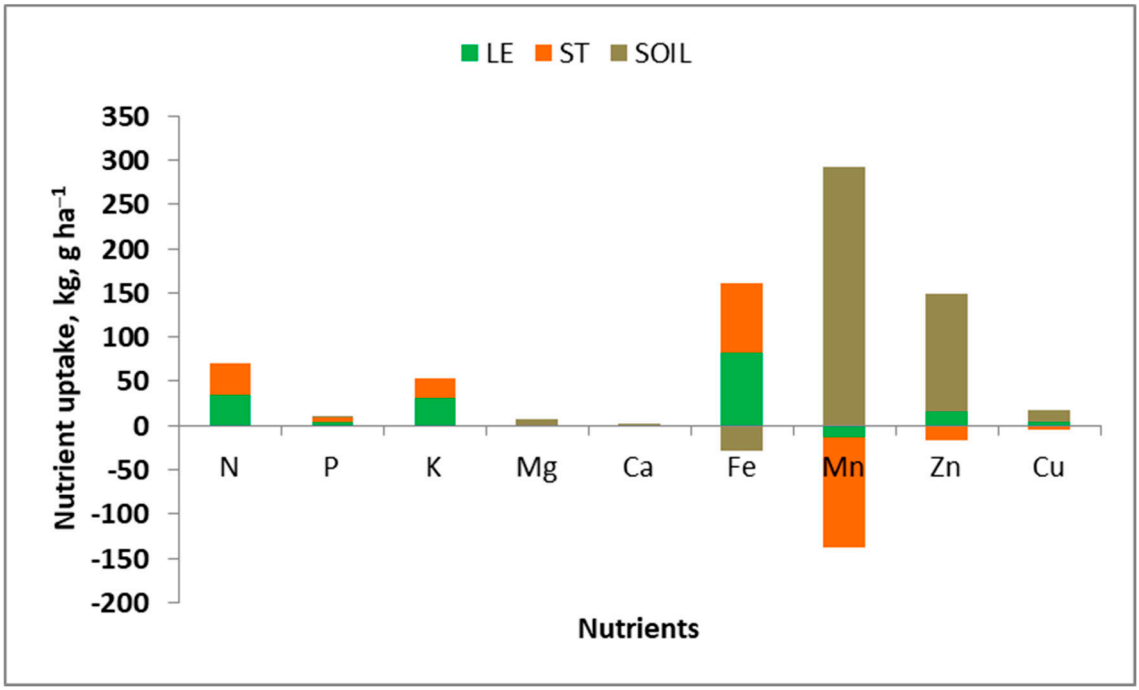

Figure S13a. Nutrient uptake by winter wheat in CCW and redistribution between plant organs. The 2014 growing season

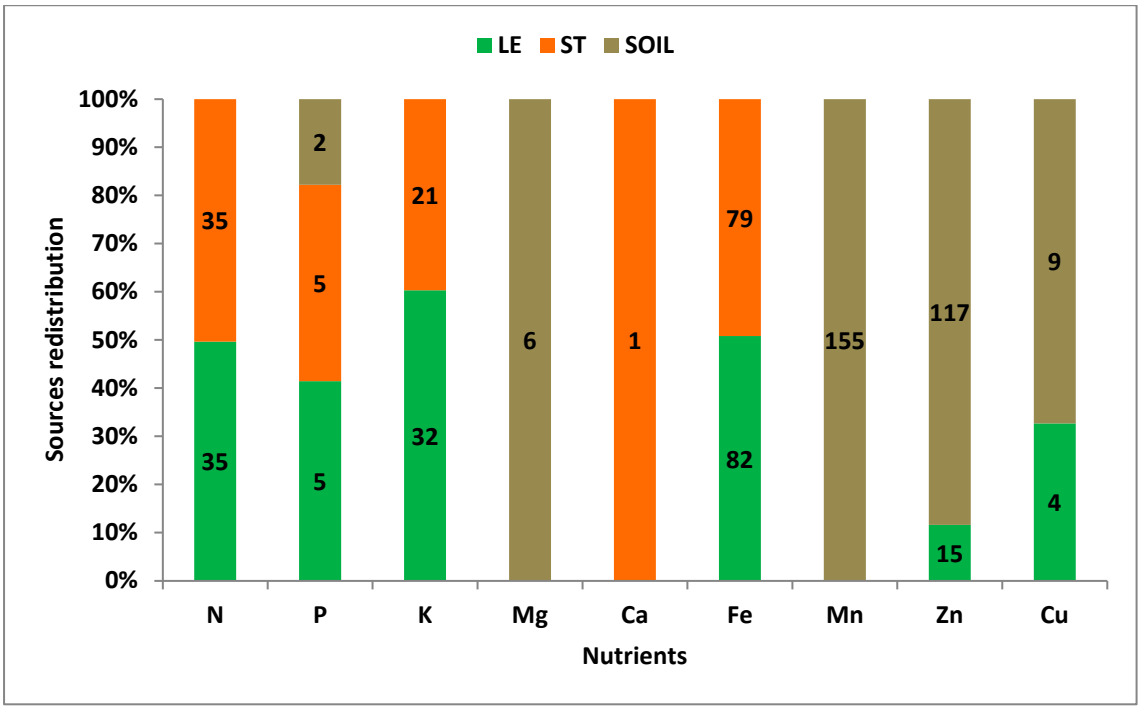

Figure 13b. Redistribution of nutrient sources for ear nutrients mass, 2014.

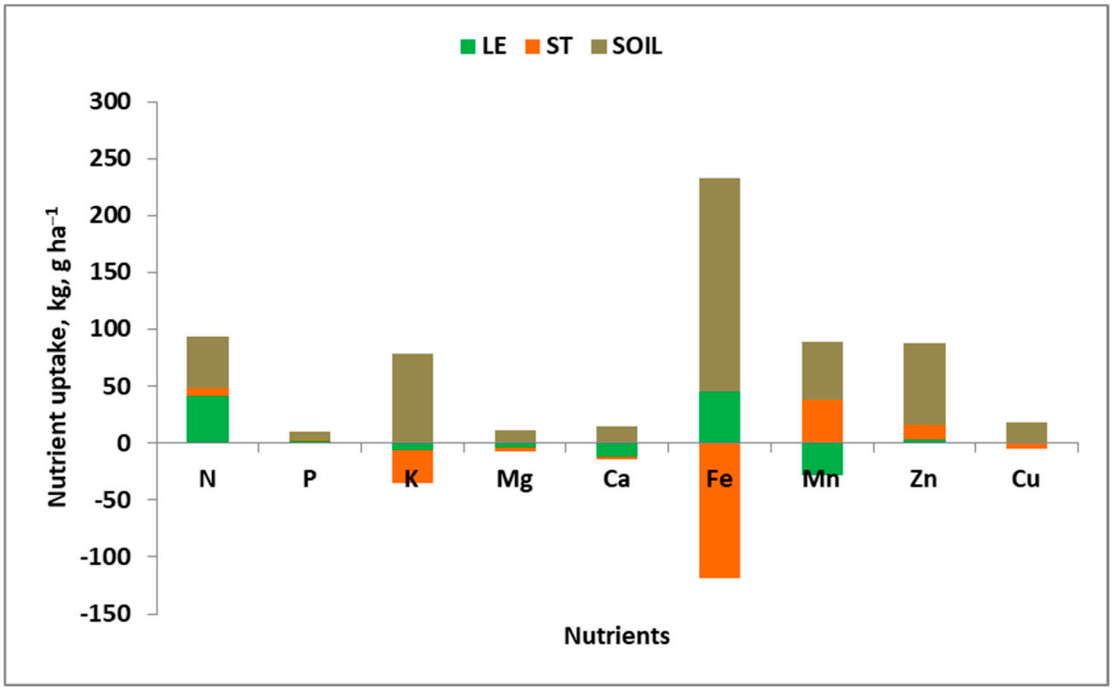

Figure S14a. Nutrient uptake by winter wheat in CCW and redistribution between plant organs, 2015.

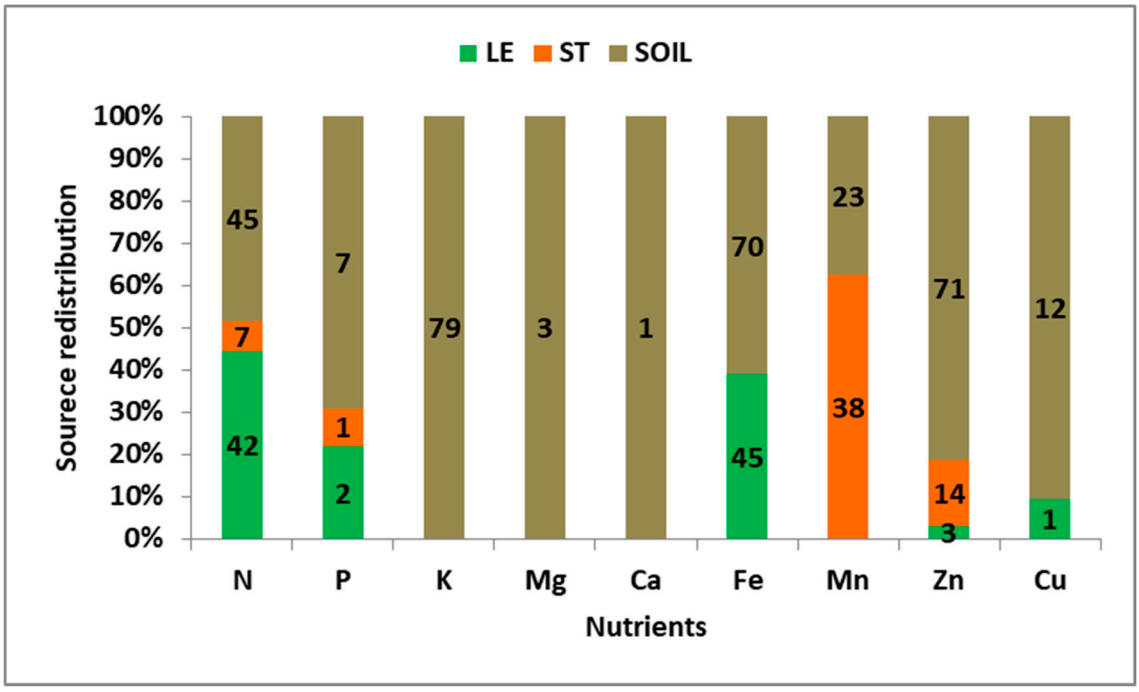

Figure S14b. Redistribution of nutrient sources for ear nutrients mass, 2015.

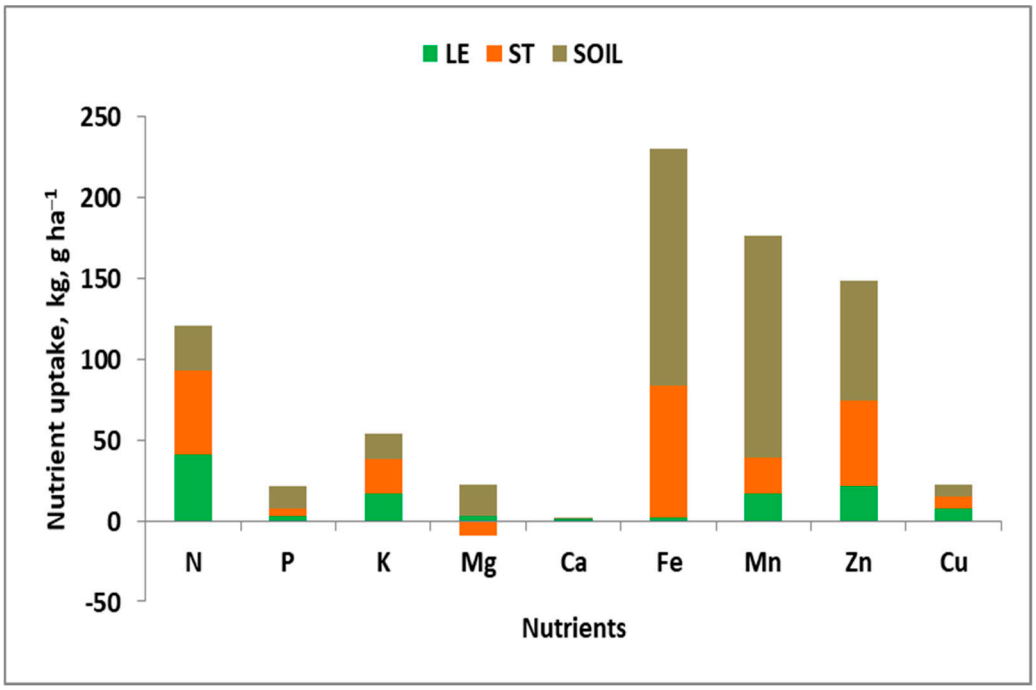

Figure S15a. Nutrient uptake by winter wheat in CCW and redistribution between plant organs. 2016.

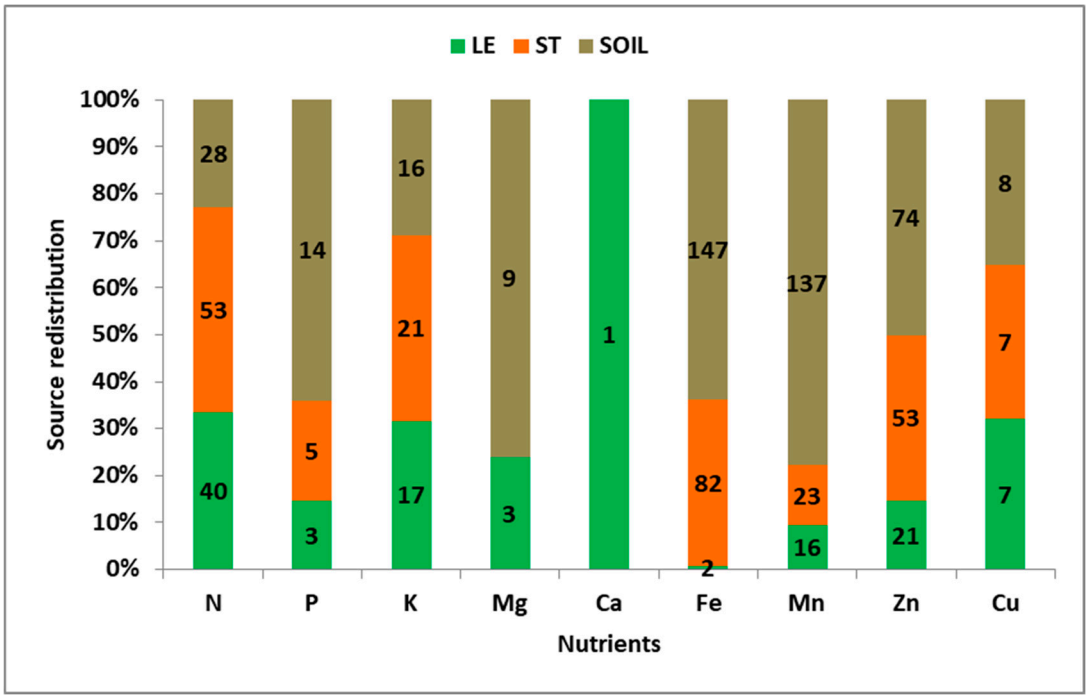

Figure S15b. Redistribution of nutrient sources for ear nutrients mass, 2016.

Table S1. Correlation matrix of nutrients accumulated in winter wheat ears with grain yield and grain protein content and yield components, n = 21.

Nutrients	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	GPC	GPY	CED	GE	CGD	TGW
N	0.83***	0.60**	0.70***	0.93***	0.83***	0.41	0.61*	0.85***	0.84***	0.01	0.86***	0.36	0.27	-0.35	-0.07	0.56***
P	1.00	0.62**	0.98***	0.68**	0.98***	0.77***	0.79***	0.94***	0.98***	-0.40	0.78***	-0.03	-0.10	-0.61**	-0.44*	0.32
K		1.00	0.53*	0.38	0.68**	0.74***	0.92***	0.60**	0.66**	0.26	0.59**	00.45*	0.49*	0.10	0.27	0.02
Mg			1.00	0.54*	0.95***	0.81***	0.75***	0.91***	0.96***	-0.54*	0.71**	-0.17	-0.25	-0.69**	-0.57**	0.26
Ca				1.00	0.69**	0.15	0.35	0.73***	0.66**	0.09	0.81***	0.42	0.26	-0.27	-0.01	0.72***
Fe					1.00	0.78***	0.81***	0.95***	0.96***	-0.31	0.83***	0.08	-0.01	-0.54*	-0.35	0.35
Mn						1.00	0.92***	0.66**	0.77***	-0.29	0.52*	-0.04	-0.06	-0.29	-0.26	-0.11
Zn							1.00	0.71***	0.80***	-0.03	0.65**	0.23	0.23	-0.15	-0.01	-0.01
Cu								1.00	0.95***	-0.33	0.78***	0.03	0.01	-0.59**	-0.37	0.37

***, **, * indicate significant differences between nutrient traits at $p < 0.001$, $p < 0.01$, and $p < 0.05$, respectively. Legend: N, P, K, Mg, Ca, Fe, Mn, Zn, Cu – nutrients; EAB – ear biomass; GY – grain yield; ; GPC – grain protein content; content; GPY – grain protein yield; CED – canopy ear drensity; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.

Table S2. Correlation matrix of nutrient balance in winter wheat leaves during the Critical Cereal Window and grain yield and crude protein content and yield components, n = 21

Nutrients	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	GPC	GPY	CED	GE	CGD	TGW
N	0.43	0.05	-0.01	-0.18	0.38	0.01	0.35	0.36	0.30	0.44*	0.58**	0.61**	0.53*	0.21	0.41	0.29
P	1.00	0.82***	0.36	0.39	0.70***	0.11	0.65**	0.57**	0.20	0.18	0.12	0.17	0.25	0.29	0.27	-0.47*
K		1.00	0.64**	0.76***	0.41	0.37	0.71***	0.62**	0.22	-0.28	-0.04	-0.29	-0.16	-0.08	-0.18	-0.60
Mg			1.00	0.95***	-0.27	0.79***	0.83***	0.81***	0.72***	-0.75***	0.34	-0.52*	-0.53*	-0.70***	-0.73***	-0.09
Ca				1.00	-0.18	0.74***	0.75***	0.71***	0.53*	-0.77***	0.14	-0.62**	-0.58**	-0.62**	-0.72***	-0.29
Fe					1.00	-0.27	0.17	0.14	-0.38	0.60**	-0.22	0.39	0.45*	0.77***	0.68**	-0.45*
Mn						1.00	0.66**	0.66**	0.46*	-0.67**	0.27	-0.47*	-0.58**	-0.61**	-0.69**	0.12
Zn							1.00	0.95***	0.68**	-0.35	0.40	-0.17	-0.13	-0.33	-0.31	-0.15
Cu								1.00	0.68**	-0.38	0.40	-0.20	-0.16	-0.37	-0.34	-0.15

***, **, * indicate significant differences between nutrient traits at $p < 0.001$, $p < 0.01$, and $p < 0.05$, respectively. Legend: N, P, K, Mg, Ca, Fe, Mn, Zn, Cu – nutrients; EAB – ear biomass; GY – grain yield; ; GPC – grain protein content; content; GPY – grain protein yield; CED – canopy ear drensity; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.

Table S3. Correlation matrix of nutrients remobilized from winter wheat stems during the Critical Cereal Window and grain yield and crude protein content and yield components, n = 21

Nutrients	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	GPC	GPY	CED	GE	CGD	TGW
N	0.72***	0.74***	-0.31	0.61**	0.75***	-0.05	0.49*	0.75***	0.71***	-0.43	0.47*	-0.188	-0.21	-0.44*	-0.40	-0.09
P	1.00	0.86***	0.13	0.74***	0.72***	-0.08	0.37	0.56**	0.40	-0.13	0.29	-0.03	0.05	-0.12	-0.06	-0.34
K		1.00	0.20	0.77***	0.75***	-0.07	0.31	0.60**	0.26	-0.37	0.04	-0.31	-0.25	-0.25	-0.29	-0.43
Mg			1.00	0.31	-0.07	-0.39	-0.60**	-0.51*	-0.81***	0.44*	-0.62**	0.11	0.20	0.70	0.53	-0.60**
Ca				1.00	0.84***	-0.60**	-0.13	0.23	0.19	-0.29	-0.07	-0.30	-0.18	-0.08	-0.12	-0.66**
Fe					1.00	-0.35	0.22	0.58**	0.49*	-0.49*	0.13	-0.39	-0.31	-0.35	-0.40	-0.47*
Mn						1.00	0.72***	0.41	0.18	-0.03	0.44	0.18	0.01	-0.31	-0.11	0.58**
Zn							1.00	0.88***	0.65**	-0.29	0.64**	0.01	-0.10	-0.52*	-0.35	0.45*
Cu								1.00	0.69**	-0.54*	0.48*	-0.28	-0.34	-0.63**	-0.56**	0.17

***, **, * indicate significant differences between nutrient traits at $p < 0.001$, $p < 0.01$, and $p < 0.05$, respectively. Legend: N, P, K, Mg, Ca, Fe, Mn, Zn, Cu – nutrients; EAB – ear biomass; GY – grain yield; ; GPC – grain protein content; content; GPY – grain protein yield; CED – canopy ear drensity; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.

Table S4. Correlation matrix of nutrients taken up by winter wheat from the soil during the Critical Cereal Window and grain yield, grain protein content and yield components, n = 21

Nutrients	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	GPC	GPY	CED	GE	CGD	TGW
N	0.60**	0.84***	0.55*	0.61**	0.79***	-0.40	-0.13	0.49*	0.26	0.13	0.24	0.29	0.25	-0.07	0.12	0.53*
P	1.00	0.40	0.94***	-0.03	0.67***	-0.21	-0.15	0.08	0.72***	-0.37	0.60**	-0.05	-0.05	-0.61**	-0.46*	0.61**
K		1.00	0.31	0.78***	0.73***	-0.27	0.07	0.71***	-0.11	0.43*	0.10	0.44*	0.36	-0.23	0.34	0.53*
Mg			1.00	-0.08	0.59**	-0.15	-0.13	-0.05	0.87***	-0.31	0.75***	0.07	-0.05	-0.61**	-0.40	0.62**
Ca				1.00	0.58**	-0.50*	-0.14	0.59**	-0.45*	0.69**	-0.05	0.59**	0.52*	0.51*	0.62**	0.42
Fe					1.00	-0.57**	-0.25	0.47*	0.17	0.06	0.39	0.25	0.12	-0.24	-0.06	0.78***
Mn						1.00	0.86***	0.09	0.15	0.04	-0.11	-0.04	0.10	0.21	0.12	-0.49*
Zn							1.00	0.50*	0.01	0.32	-0.05	0.24	0.33	0.38	0.36	-0.34
Cu								1.00	-0.32	0.49*	-0.10	0.40	0.43	0.38	0.46*	-0.33

***, **, * indicate significant differences between nutrient traits at $p < 0.001$, $p < 0.01$, and $p < 0.05$, respectively. Legend: N, P, K, Mg, Ca, Fe, Mn, Zn, Cu – nutrients; EAB – ear biomass; GY – grain yield; ; GPC – grain protein content; content; GPY – grain protein yield; CED – canopy ear drensity; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.