

Supplementary material

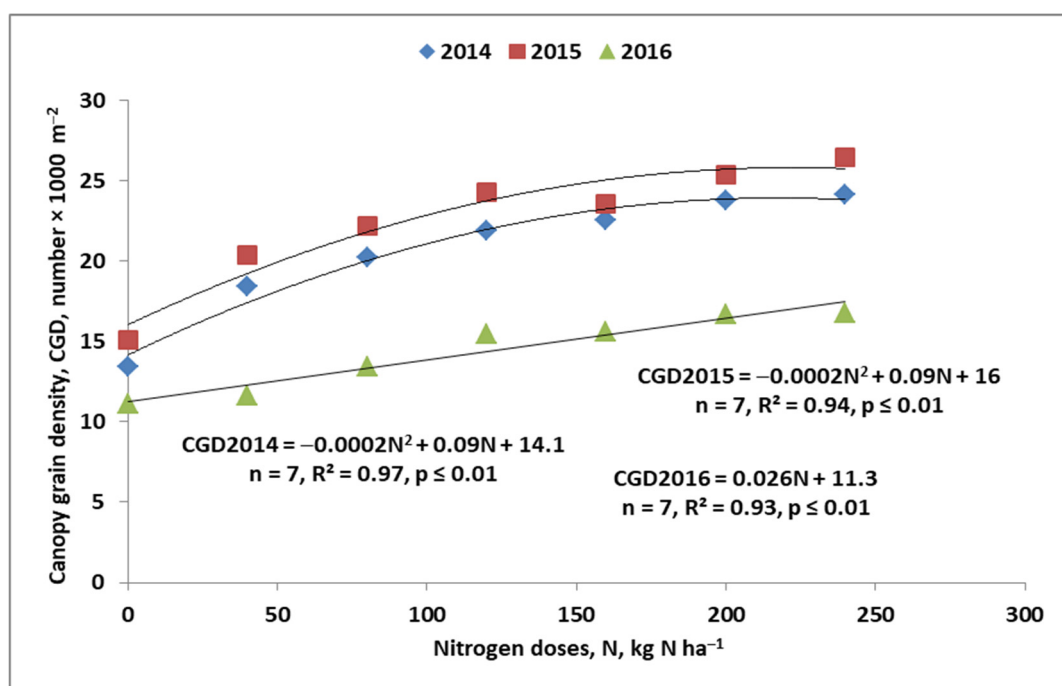


Figure S1. Trends of canopy grain density in response to increasing N_f doses in subsequent seasons.

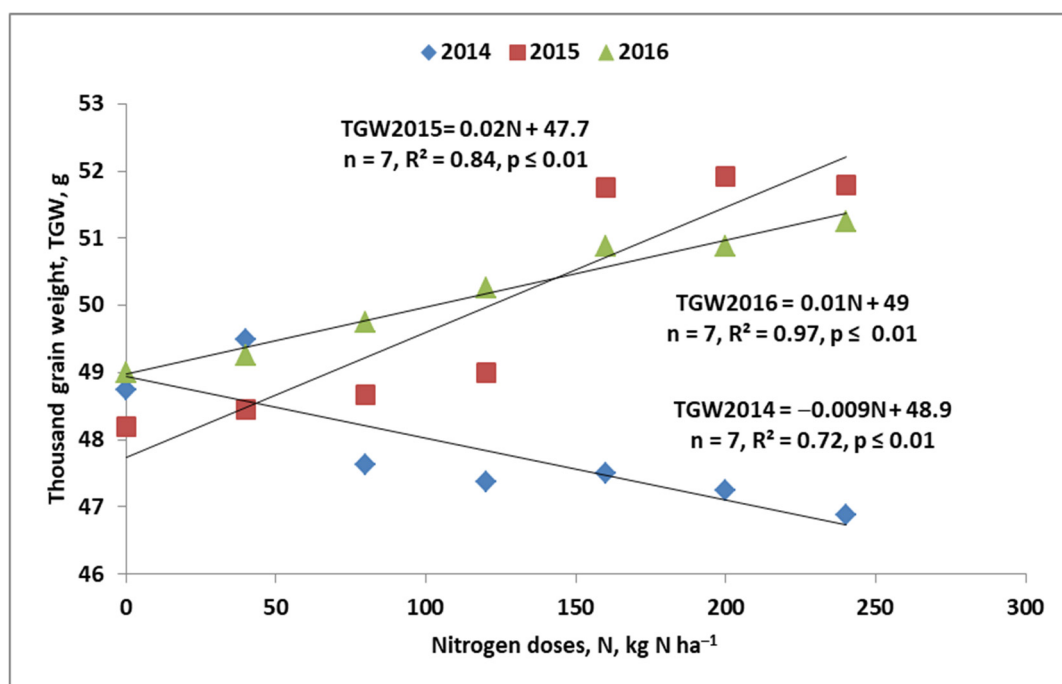


Figure S2. Trends of thousand grain weight in response to increasing N_f doses in subsequent seasons.

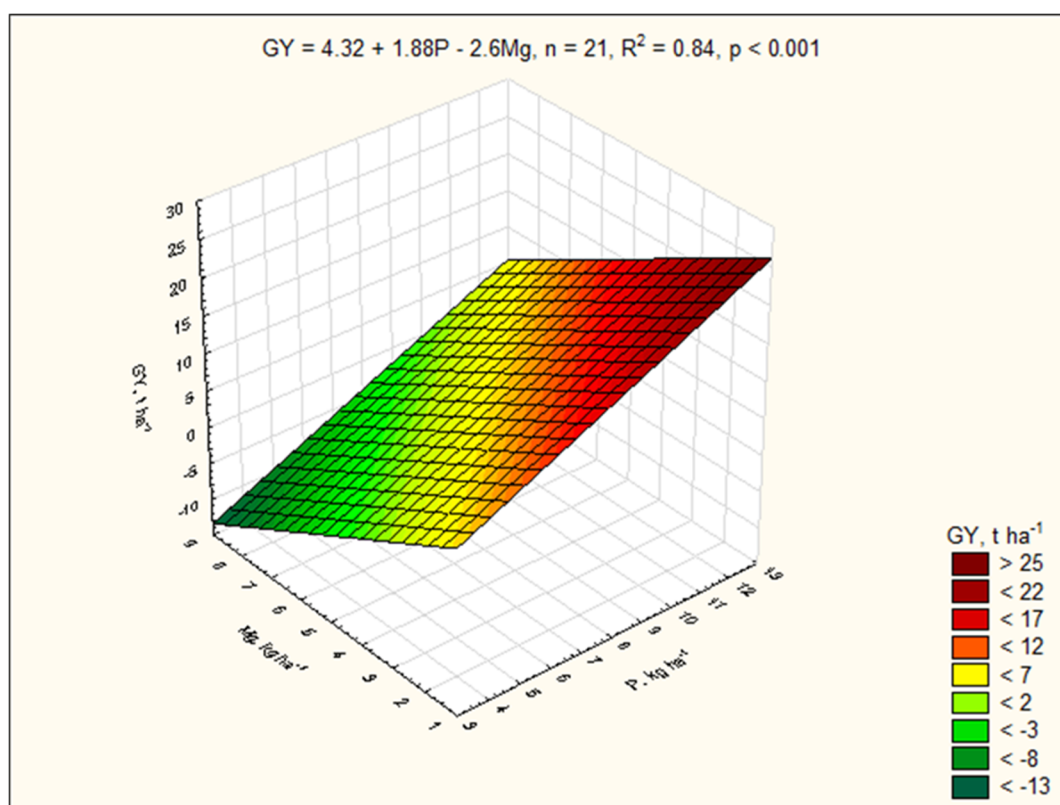


Figure S3. Grain yield as the function of Mg and P accumulation in leaves at the beginning of booting.

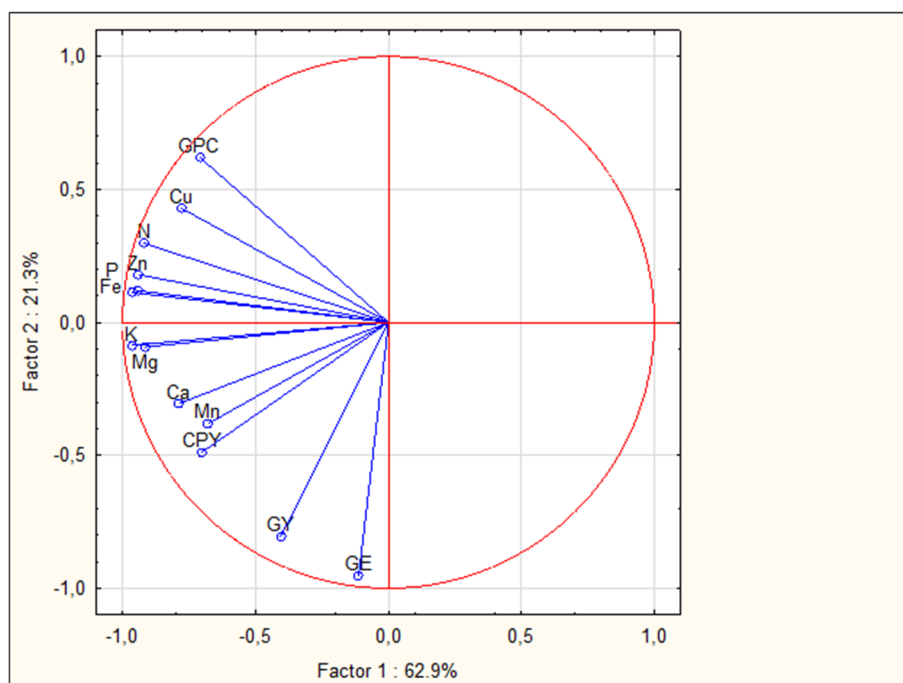


Figure S4. Score plot of winter wheat selected traits and nutrient accumulated in the stems at the beginning of booting in PC1 and PC2 axes. GY—grain yield, GE – number of grain per ear, GPC – grain protein yield, GPY – grain protein yield. N, P, K, Mg, Ca, Fe, Mn, Zn, Cu—nutrients.

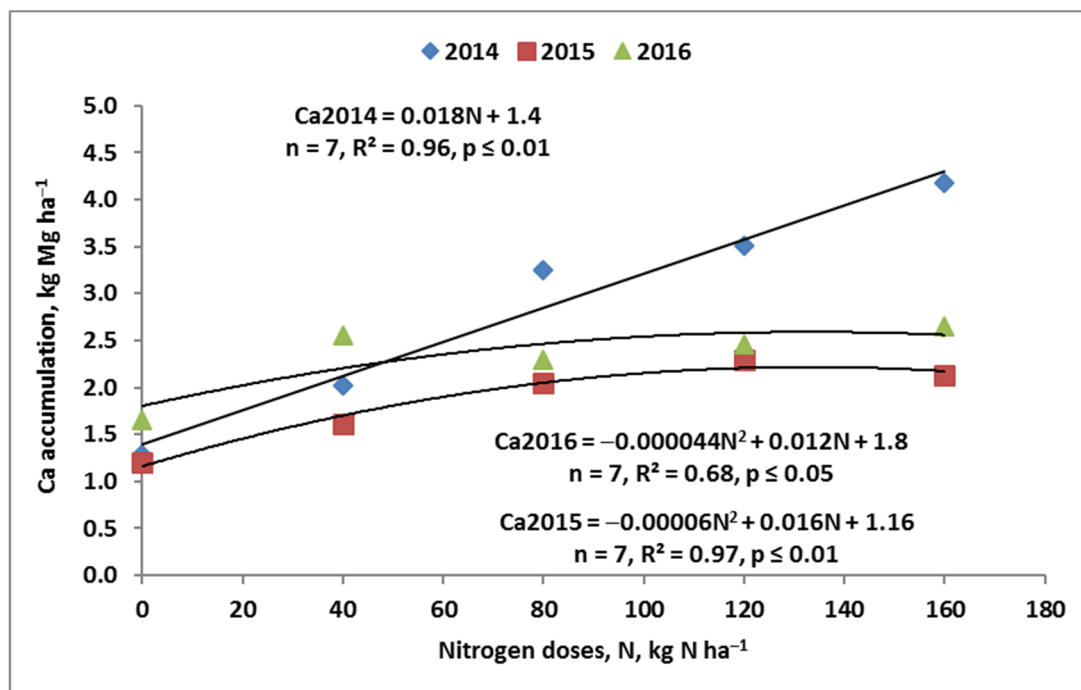


Figure S5. Trends in calcium accumulation in winter wheat stems in response to increasing N_f doses in subsequent seasons, BBCH 40.

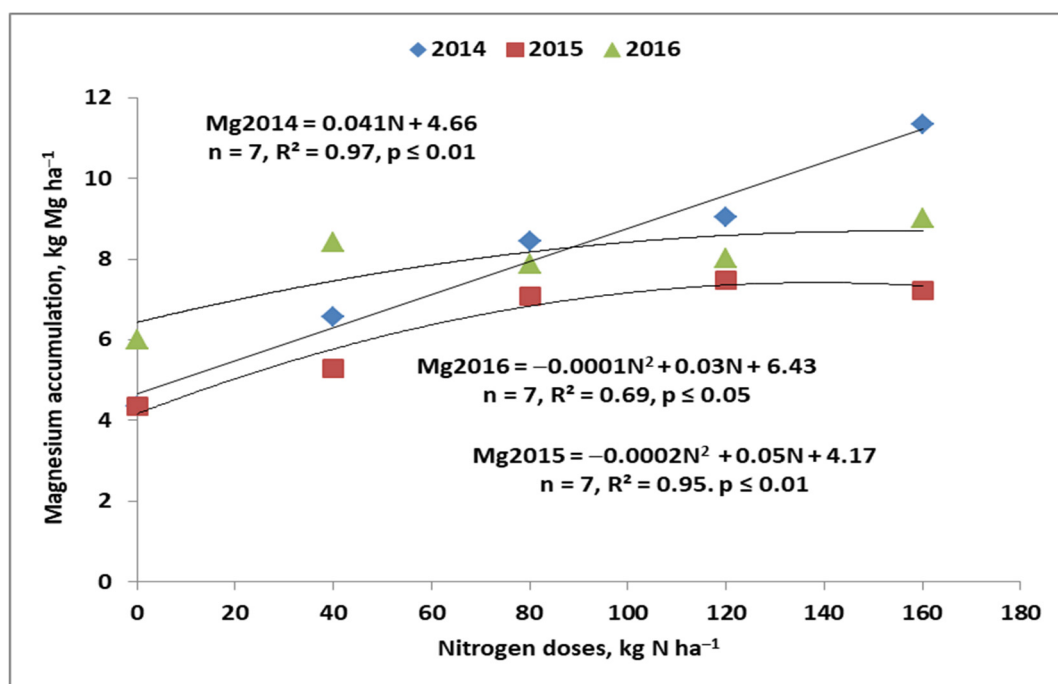


Figure S6. Trends in magnesium accumulation in winter wheat stems in response to increasing N_f doses in subsequent seasons, BBCH 40.

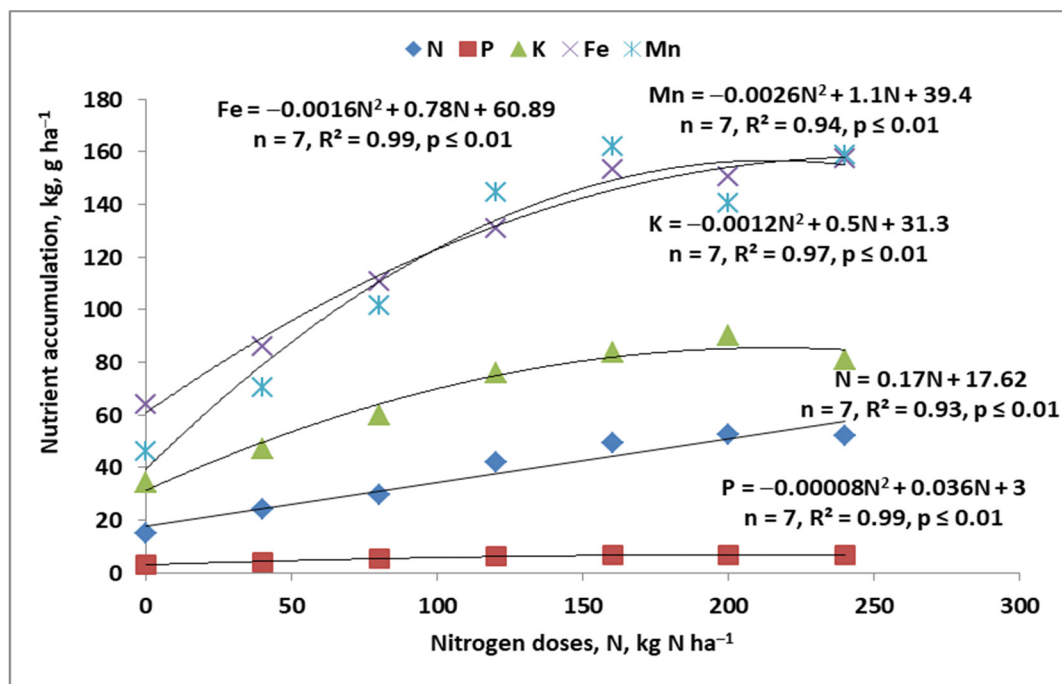


Figure S7. Trends in nutrients accumulation in winter wheat leaves in response to increasing N_i doses in subsequent seasons, BBCH 65.

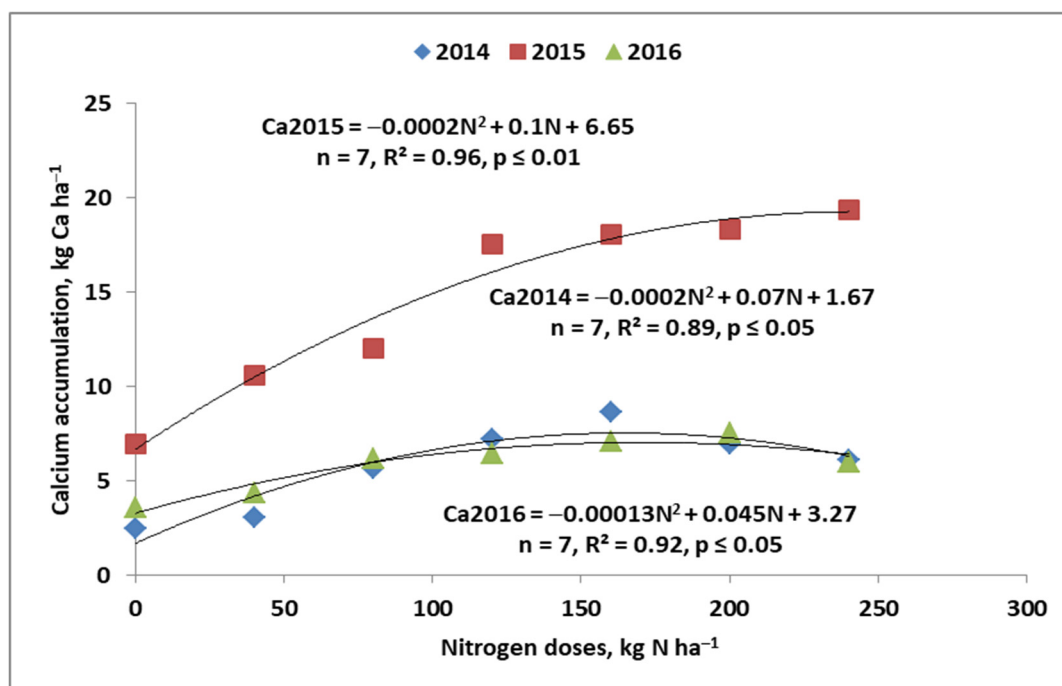


Figure S8. Trends in calcium accumulation in winter wheat leaves in response to increasing N_i doses in subsequent seasons, BBCH 65.

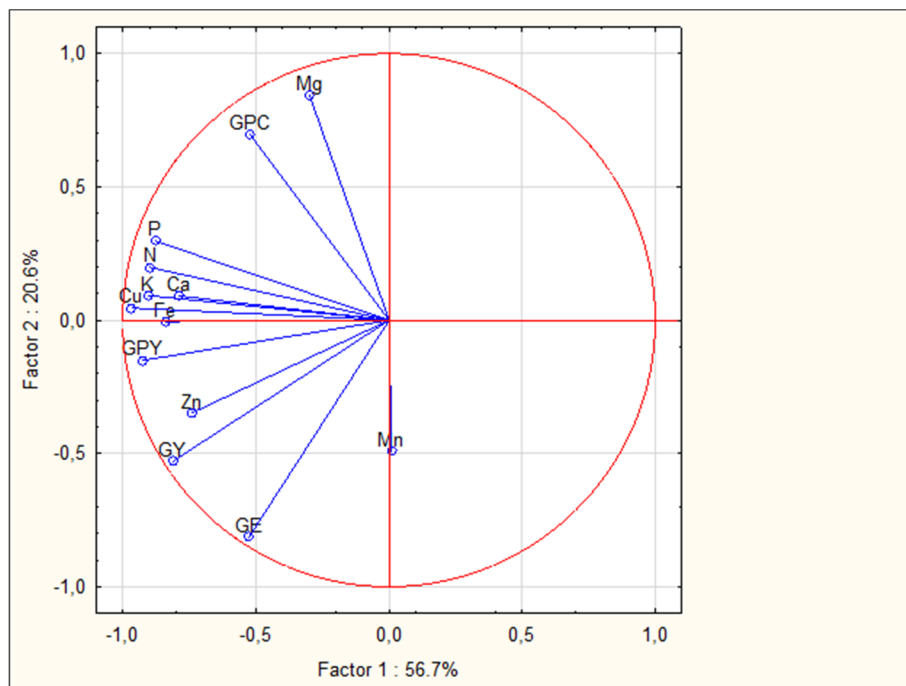


Figure S9. Score plot of winter wheat selected traits and nutrient accumulated in the stems at full flowering in PC1 and PC2 axes. GY—grain yield, GE – number of grain per ear, GPC – grain protein yield, GPY – grain protein yield. N, P, K, Mg, Ca, Fe, Mn, Zn, Cu—nutrients.

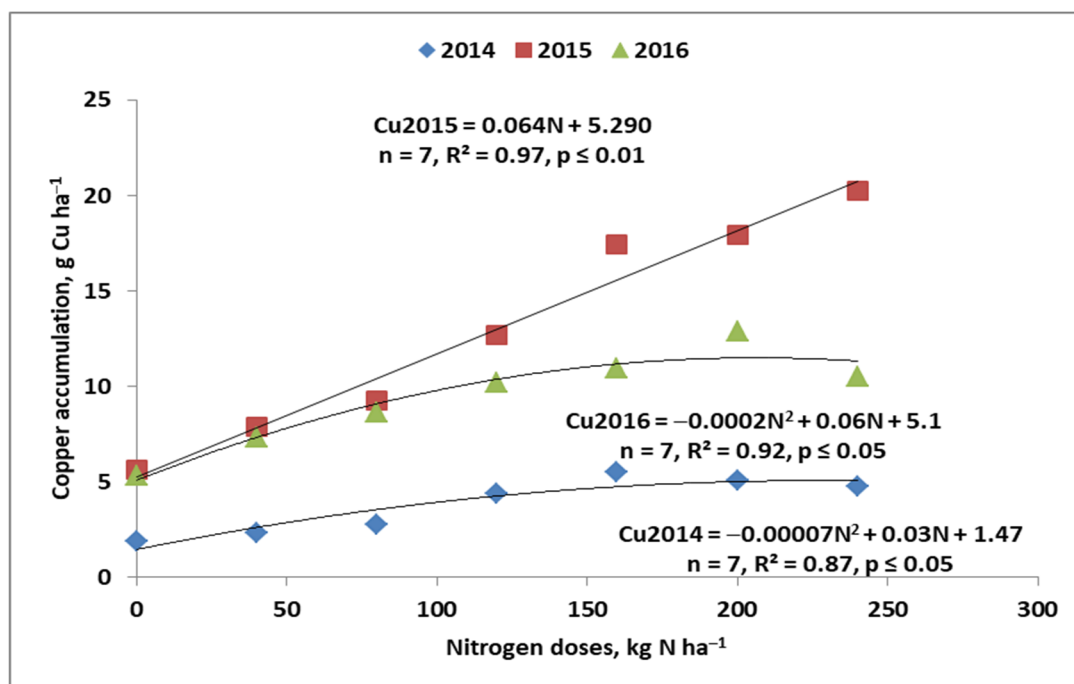


Figure S10. Trends in copper accumulation in winter wheat leaves in response to increasing N doses in subsequent seasons, BBCH 65.

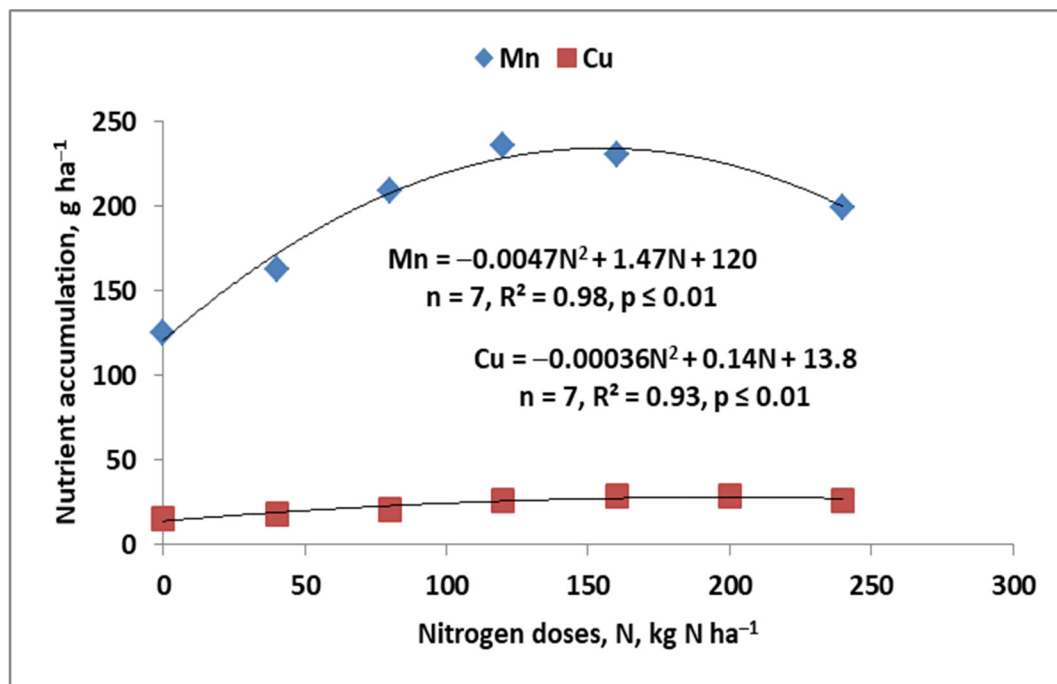


Figure S11. Trends in micronutrients accumulation in winter wheat stems in response to increasing N_t doses in subsequent seasons, BBCH 65.

Table S1. Correlation matrix of main characteristics of winter wheat, n = 21.

Traits	GY	GPC	CPY	CED	GE	GD	TGW
EAB	-0.38	0.76***	-0.02	-0.05	-0.60**	-0.41	0.30
GY	1.00	0.08	0.89***	0.85***	0.87***	0.99***	0.12
CP		1.00	0.52*	0.25	-0.24	0.02	0.63***
CPY			1.00	0.82***	0.64**	0.84***	0.41
ED				1.00	0.56**	0.86***	0.06
GE					1.00	0.90***	-0.14
GD						1.00	-0.03

***, **, * indicate significant differences between nutrient traits at $p < 0.001$, $p < 0.01$, and $p < 0.05$, respectively. Legend: EAB – ear biomass; GY – grain yield; GPC – grain protein content; content; CPY – crude protein yield ; CED – canopy ear density; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.

Table S2. Correlation matrix of nutrients mass in winter wheat leaves at the beginning of the booting phase with grain yield and crude protein content and yield, n = 15.

Traits	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	CP	CPY	ED	GE	GD	TGW
N	0.83***	0.90***	0.78**	0.88***	0.72**	0.61*	0.97***	0.95***	0.75**	0.18	0.91***	0.59*	0.43	-0.17	0.12	0.55*
P	1.00	0.98***	0.91***	0.89***	0.78**	0.89***	0.87***	0.69**	0.80***	0.19	0.75**	0.51	0.51	-0.07	0.18	0.17
K		1.00	0.92***	0.93***	0.77**	0.86***	0.93***	0.78**	0.82***	0.17	0.84***	0.54*	0.45	-0.11	0.14	0.34
Mg			1.00	0.97***	0.49	0.72**	0.81***	0.61*	0.93***	-0.21	0.86***	0.17	0.15	-0.43	-0.22	0.29
Ca				1.00	0.53*	0.67**	0.88***	0.74**	0.93***	-0.15	0.91***	0.27	0.19	-0.41	-0.18	0.41
Fe					1.00	0.80***	0.76**	0.70**	0.34	0.70**	0.46	0.87***	0.81***	0.46	0.68**	0.14
Mn						1.00	0.72**	0.48	0.56*	0.40	0.50	0.61*	0.54*	0.27	0.39	0.07
Zn							1.00	0.93***	0.74**	0.21	0.90***	0.62*	0.42	-0.08	0.16	0.54*
Cu								1.00	0.61*	0.27	0.83***	0.65**	0.44	-0.06	0.21	0.60

***, **, * 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 – ears biomass; GY – grain yield; ; GPC – grain protein content; content; CPY – crude protein yield ; CED – canopy ear density; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.

Table S3. Correlation matrix of nutrients mass in winter wheat stems at the beginning of the booting phase with grain yield and crude protein content and yield, n = 15.

Traits	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	CP	CPY	ED	GE	GD	TGW
N	0.88***	0.82***	0.74**	0.53*	0.91***	0.37	0.95***	0.94***	0.80***	0.23	0.87***	0.61*	0.53*	-0.13	0.19	0.40
P	1.00	0.94***	0.94***	0.81***	0.90***	0.67**	0.90***	0.74**	0.76**	0.25	0.71**	0.55*	0.60*	-0.04	0.25	0.14
K		1.00	0.97***	0.90***	0.86***	0.80***	0.84***	0.62*	0.69**	0.37	0.63*	0.63*	0.62*	0.15	0.36	0.11
Mg			1.00	0.95***	0.82***	0.83***	0.75**	0.51	0.66**	0.30	0.53*	0.51*	0.61*	0.09	0.31	-0.06
Ca				1.00	0.66**	0.89***	0.55*	0.26	0.48	0.36	0.28	0.45	0.62*	0.24	0.41	-0.30
Fe					1.00	0.57*	0.95***	0.84***	0.71**	0.31	0.69**	0.60*	0.58*	0.02	0.29	0.22
Mn						1.00	0.47	0.14	0.36	0.32	0.17	0.36	0.43	0.33	0.35	-0.19
Zn							1.00	0.91***	0.71**	0.31	0.80	0.67**	0.56*	-0.01	0.27	0.43
Cu								1.00	0.73**	0.14	0.85***	0.52*	0.40	-0.22	0.09	0.53*

***, **, * 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 – ears biomass; GY – grain yield; ; GPC – grain protein content; content; CPY – crude protein yield ; CED – canopy ear density; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.

Table S4. Correlation matrix of nutrients mass in winter wheat leaves at the full flowering phase with grain yield and crude protein content and yield, n = 21.

Traits	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	CP	CPY	ED	GE	GD	TGW
N	0.96***	0.88***	0.29	0.18	0.94***	0.36	0.65**	0.58**	0.83***	0.02	0.94***	0.42	0.23	-0.28	-0.05	0.58**
P	1.00	0.88***	0.35	0.20	0.97***	0.44*	0.64**	0.58**	0.85***	0.06	0.92***	0.44*	0.33	-0.28	-0.01	0.52*
K		1.00	0.64**	0.60**	0.94***	0.44*	0.89***	0.86***	0.60**	0.35	0.86***	0.67**	0.47*	-0.02	0.25	0.72***
Mg			1.00	0.90***	0.50*	0.68**	0.79***	0.76***	-0.10	0.89***	0.34	0.92***	0.87***	0.63**	0.85***	0.35
Ca				1.00	0.39	0.39	0.79***	0.84***	-0.23	0.80***	0.21	0.79***	0.70***	0.54*	0.73***	0.47*
Fe					1.00	0.47*	0.78***	0.73***	0.75***	0.19	0.92***	0.56**	0.44*	-0.20	0.11	0.62**
Mn						1.00	0.42	0.29	0.21	0.69**	0.38	0.74***	0.74***	0.57**	0.70***	-0.02
Zn							1.00	0.97***	0.25	0.55**	0.71***	0.81***	0.54*	0.20	0.44*	0.79***
Cu								1.00	0.18	0.52*	0.63**	0.7439	0.51*	0.16	0.40	0.82***

***, **, * 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 – ears biomass; GY – grain yield; ; GPC – grain protein content; content; CPY – crude protein yield ; CED – canopy ear density; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.

Table S5. Correlation matrix of nutrients mass in winter wheat stems at the full flowering phase with grain yield and crude protein content and yield, n = 21.

	P	K	Mg	Ca	Fe	Mn	Zn	Cu	EAB	GY	CP	CPY	ED	GE	GD	TGW
N	0.78***	0.76***	0.34	0.82***	0.81***	−0.31	0.44*	0.90***	0.18	0.66**	0.53*	0.79***	0.72***	0.32	0.60**	0.49*
P	1.00	0.94***	0.64**	0.59**	0.63**	0.10	0.71***	0.85***	0.50*	0.50*	0.67**	0.71***	0.65**	0.20	0.46*	0.36
K		1.000	0.50*	0.59**	0.60**	0.26	0.82***	0.85***	0.36	0.62**	0.56**	0.76***	0.71***	0.38	0.58**	0.32
Mg			1.00	0.16	0.08	−0.06	0.13	0.29	0.97***	−0.26	0.79***	0.11	0.06	−0.54*	−0.31	0.43
Ca				1.00	0.87***	−0.41	0.29	0.86***	−0.03	0.62**	0.27	0.65**	0.58**	0.34	0.53*	0.57**
Fe					1.00	−0.34	0.42	0.86***	−0.09	0.71***	0.32	0.76***	0.68**	0.43	0.63**	0.54*
Mn						1.00	0.62**	−0.12	−0.01	0.13	−0.22	−0.01	0.14	0.35	0.22	−0.54*
Zn							1.00	0.66**	0.03	0.71***	0.26	0.72***	0.70***	0.63**	0.72***	−0.02
Cu								1.00	0.09	0.75***	0.44*	0.84***	0.77***	0.44*	0.69**	0.46*

***, **, * 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 – ears biomass; GY – grain yield; ; GPC – grain protein content; content; CPY – crude protein yield ; CED – canopy ear density; GE – grains per ear; CGD – canopy grains density; TGW – thousand grain weight.