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Supplementary

Improvement of the Content and Uptake of Micronutrients in Spring Rye Grain DM Through Nitrogen and Sulfur Supplementation

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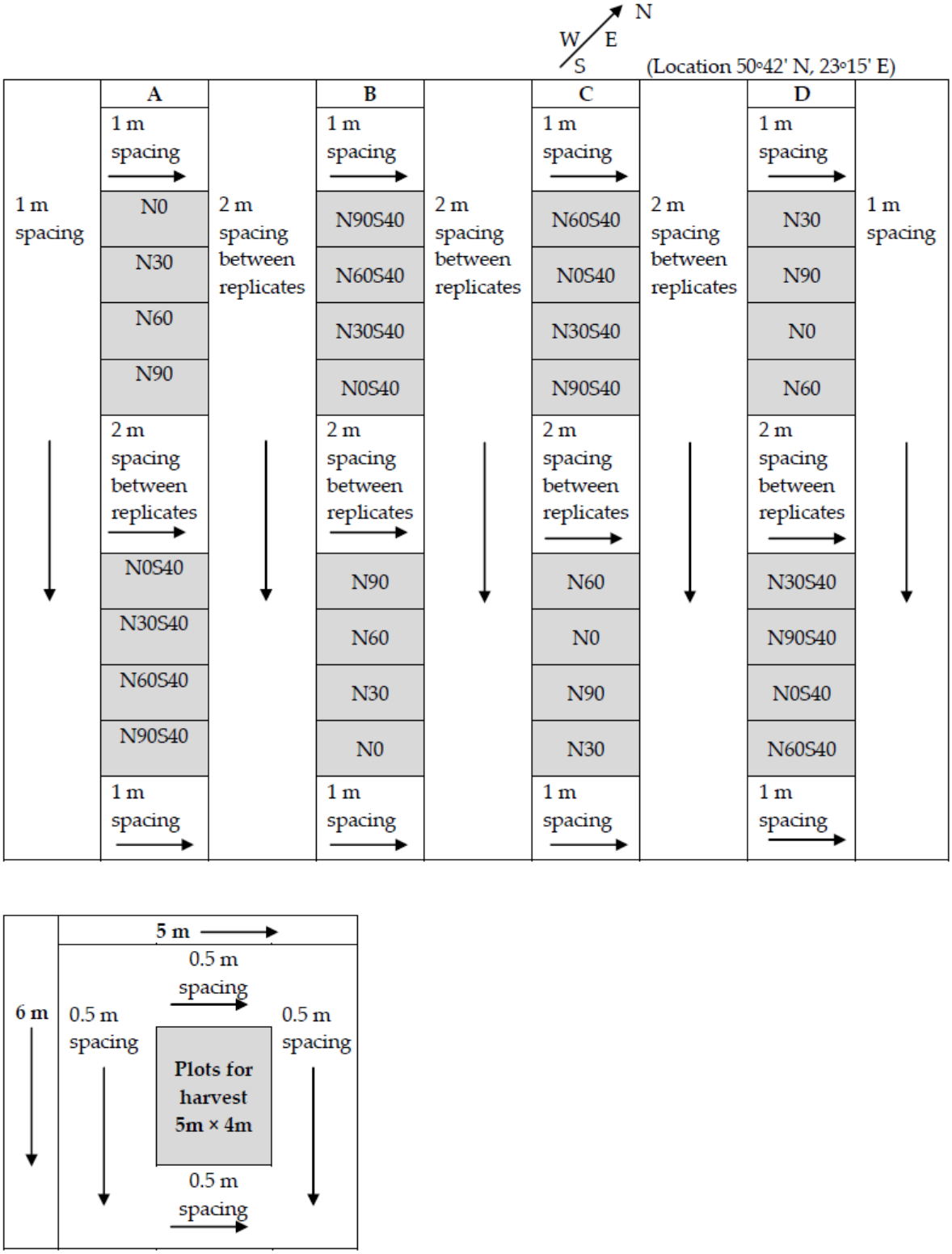

Figure S1. The scheme of the field experiment (52m × 28m) and plots. A, B, C and D – blocks (replicates). N – nitrogen fertilizer; NS – nitrogen fertilizer plus sulfur addition in dose of 40 kg S ha^{-1}. Plots for cultivation – 30 m^2 (5m × 6m), plots for harvest – 20 m^2 (4m × 5m).

Table S1. Basic data for the preparation of the Table 6

(yield DM – t ha^{-1}; content Fe, Mn, Zn and Cu – mg kg^{-1}; uptake Fe, Mn, Zn, Cu – g kg^{-1})

Combina-tions	Year	Yield DM	Fe content	Fe uptake	Mn content	Mn uptake	Zn content	Zn uptake	Cu content	Cu uptake
N0S0	2009	2.29	28.50	65.24	35.60	81.49	31.40	71.87	4.20	9.61
	2010	2.61	25.10	91.65	37.00	96.61	35.90	93.73	3.89	10.16
	2011	2.86	26.00	74.36	38.40	109.82	35.80	102.39	4.15	11.87
N0S50	2009	2.48	32.00	79.20	35.20	87.12	33.40	82.67	4.48	11.09
	2010	2.65	27.10	98.17	35.30	93.40	36.90	97.64	3.93	10.40
	2011	2.93	28.00	81.93	35.40	103.58	36.20	105.92	4.24	12.41
N40S0	2009	2.74	32.50	89.08	36.60	100.32	32.00	87.71	4.57	12.53
	2010	2.68	26.30	70.46	38.20	102.34	36.20	96.98	3.91	10.47
	2011	2.97	27.30	80.97	40.00	118.64	36.10	107.07	4.37	12.96
N40S50	2009	2.81	33.00	92.57	35.80	100.42	33.10	92.85	4.65	13.04
	2010	2.82	28.00	78.99	36.80	103.81	39.50	111.43	4.13	11.65
	2011	3.13	30.70	96.00	39.30	122.89	36.70	114.76	4.66	14.57
N80S0	2009	3.58	33.00	118.01	37.00	132.31	33.00	118.01	4.65	16.63
	2010	3.46	28.50	98.64	40.30	139.48	37.10	128.40	3.94	13.64
	2011	3.63	28.10	101.89	43.30	157.01	37.80	137.06	4.44	16.10
N80S50	2009	3.62	32.90	119.13	36.60	132.53	33.50	121.30	4.72	17.09
	2010	3.55	31.50	111.73	36.90	130.88	40.00	141.88	4.20	14.90
	2011	3.67	34.40	126.08	39.70	145.50	38.40	140.74	4.73	17.34
N120S0	2009	3.67	35.00	128.31	37.80	138.57	34.00	124.64	4.79	17.56
	2010	3.66	30.00	109.92	40.80	149.49	37.40	137.03	4.16	15.24
	2011	3.65	30.10	109.71	44.00	160.38	38.00	138.51	4.83	17.61
N120S50	2009	3.71	37.00	137.27	37.10	137.64	35.00	129.85	4.90	18.18
	2010	3.72	35.00	130.06	37.30	138.61	40.80	151.61	4.24	15.76
	2011	3.70	34.80	128.83	39.90	147.71	39.80	147.34	5.00	18.51

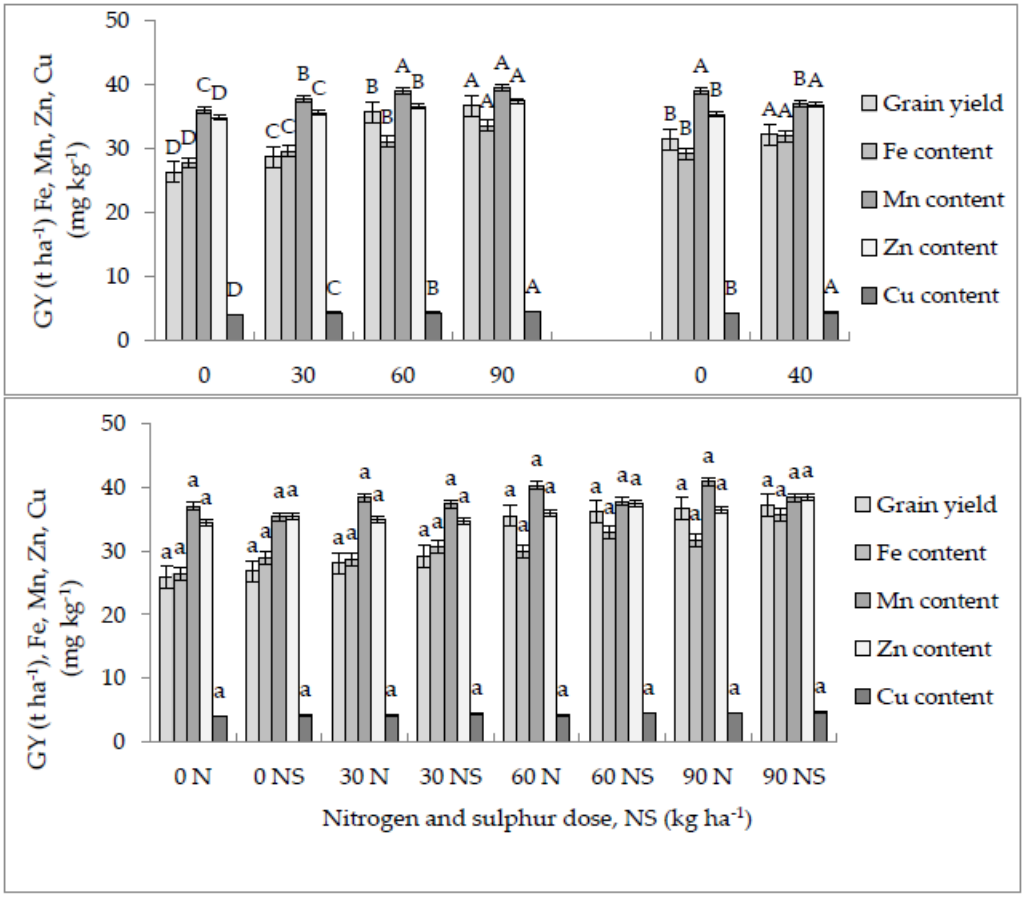

Figure S2. The influence of nitrogen (N) and sulfur (S) fertilization on the grain yield (t ha^{-1}) and content (mg kg^{-1}) of microelements in spring rye grain

Table S2a. Results of statistical calculations for the studied features of spring rye - for the preparation of the Table 6 and Table S1.

Variable		Yield DM	Fe content	Fe uptake	Mn content	Mn uptake
CV%	S	1.29	4.63	5.98	2.59	1.45
	N	14.17	7.08	20.86	3.36	17.19
	Y	2.81	5.63	4.86	3.82	6.68
	S × N	14.23	8.55	21.75	4.34	17.33
	S × Y	3.10	7.50	7.95	4.80	6.98
	N × Y	14.73	9.19	21.68	5.28	18.50
$LSD_{0.05}$	S	0.04	1.22	4.65	0.62	2.87
	N	0.06	1.72	6.57	0.88	4.06
	Y	0.05	1.49	5.69	0.76	3.52
	S × N	n.s.	n.s.	n.s.	n.s.	n.s.
	S × Y	n.s.	n.s.	n.s.	n.s.	n.s.
	N × Y	0.10	n.s.	n.s.	n.s.	n.s.
$LSD_{0.01}$	S	0.06	1.85	7.04	0.94	n.s.
	N	0.09	2.61	9.96	1.34	6.15
	Y	0.08	2.26	8.62	1.16	5.33
	S × N	n.s.	n.s.	n.s.	n.s.	n.s.
	S × Y	n.s.	n.s.	n.s.	n.s.	n.s.
	N × Y	0.15	n.s.	n.s.	n.s.	n.s.

Explanations: S – sulfur dose, N – nitrogen dose), Y – year, S × N – sulfur dose × nitrogen dose, S × Y – sulfur dose × year , N × Y – nitrogen dose × year; *CV%* - coefficient of variation. LSD – least significant difference, n.s.- not significant.

Table S2b. Results of statistical calculations for the studied features of spring rye - for the preparation of the Table 6 and Table S1.

Variable		Zn content	Zn uptake	Cu content	Cu uptake
CV%	S	2.14	3.40	1.86	3.11
	N	2.71	16.62	4.07	17.75
	Y	5.89	7.65	5.77	7.10
	S × N	3.49	16.97	4.50	18.03
	S × Y	6.36	8.45	6.08	7.77
	N × Y	6.53	18.37	7.21	19.36
$LSD_{0.05}$	S	0.62	3.00	0.08	0.38
	N	0.88	4.24	0.11	0.53
	Y	0.76	3.67	0.10	0.46
	S × N	n.s.	n.s.	n.s.	n.s.
	S × Y	n.s.	n.s.	n.s.	n.s.
	N × Y	n.s.	n.s.	n.s.	n.s.
$LSD_{0.01}$	S	0.94	4.54	0.12	0.57
	N	1.33	6.42	0.17	0.81
	Y	1.16	5.56	0.15	0.70
	S × N	n.s.	n.s.	n.s.	n.s.
	S × Y	n.s.	n.s.	n.s.	n.s.
	N × Y	n.s.	n.s.	n.s.	n.s.

Explanations: S – sulfur dose, N – nitrogen dose), Y – year, S × N – sulfur dose × nitrogen dose, S × Y – sulfur dose × year , N × Y – nitrogen dose × year; *CV%* - coefficient of variation. LSD – least significant difference, n.s.- not significant.

Table S3. Sielianinov's hydrothermal coefficient in the years 2009-2011 and for the long-term average. Basic data for the preparation of the Table 3. (Calculated on the basis of the data contained in tables S4 and S5)

Year	Decade	III	IV	V	VI	VII	IV-V	IV-VI	VI-VII	III-VII
2009	I	2.5	0.0	0.8	1.3	0.1				
	II	16.8	1.5	2.8	2.2	0.3				
	III	4.9	0.0	3.4	2.6	0.8				
	Mean	5.3	0.5	2.4	2.1	0.4	1.5	1.8	1.2	2.1
2010	I	21.3	2.0	1.9	2.2	1.4				
	II	0.2	0.3	2.6	1.1	2.2				
	III	1.5	1.4	1.6	0.0	2.5				
	Mean	1.8	1.1	2.0	1.1	2.1	1.7	1.5	1.7	1.6
2011	I	0.0	2.2	1.3	0.9	4.5				
	II	2.2	1.4	0.5	0.5	1.6				
	III	0.5	0.3	0.6	1.4	1.6				
	Mean	1.2	1.1	0.7	1.0	2.4	0.9	0.9	1.7	1.3
The long-term average 1971-2005)	I	25.0	2.2	1.4	1.3	1.8				
	II	9.7	2.0	1.2	1.8	1.4				
	III	2.3	1.5	1.8	1.6	1.9				
	Mean	5.1	1.8	1.5	1.6	1.7	1.6	1.6	1.6	2.3

Table S4. Total rainfall [mm] in 2009-2011 and long-term average. Research Station in Zamość. Basic data for the preparation of the Table 3.

Year	Decade	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	III-VIII	I-XII
2009	I			7.6	0	10.4	26.6	1.0	21.1	15.5					
	II			13.4	15.5	37.3	44.6	5.0	14.5	8.4					
	III			12.3	0	54.9	53.2	18.2	13.3	10.6					
	Sum	26.3	19.9	33.5	15.5	102.6	124.4	24.2	48.9	34.5	100.0	30.6	34.5	349.1	594.9
2010	I			8.5	15.1	28.0	41.7	27.5	21.6	36.7					
	II			0.6	2.5	40.1	20.9	53.4	5.1	4.9					
	III			10.5	17.6	30.1	0.3	62.6	24.9	23.6					
	Sum	17.6	25.0	19.6	33.1	98.2	62.9	143.5	86.1	65.2	12.7	39.4	23.8	443.4	627.1
2011	I			·	20.8	11.3	18.7	75.9	41.6	1.8					
	II			9.5	11.3	8.0	8.3	37.2	33.4	0.3					
	III			3.0	4.1	12.1	25.9	34.9	28.6	·					
	Sum	29.2	10.0	12.5	36.2	31.4	52.9	148.0	133.6	2.1	30.2	6.4	24.6	414.6	517.1
The long-term average 1971-2005)	I			5.0	14.8	18.0	21.2	31.5	24.1	13.2					
	II			12.6	14.5	17.6	31.3	26.7	18.6	20.1					
	III			8.5	14.9	30.0	26.4	40.3	11.6	18.9					
	Sum	23.4	20.0	26.1	44.1	65.5	78.9	98.4	54.3	52.2	40.3	25.6	24.6	367.4	553.3

Table S5. Air temperature [°C] in 2009-2011 and long-term average. Research Station in Zamość. Basic data for the preparation of the Table 3.

Year	Decade	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	III-VIII	I-XII
2009	I			3.0	10.2	13.3	19.9	19.6	20.9	18.4					
	II			0.8	10.3	13.5	20.1	19.8	20.5	16.8					
	III			2.3	13.4	14.6	20.5	20.5	19.0	15.5					
	Mean	-2.2	-0.6	1.2	11.3	13.8	20.2	20.0	20.1	16.9	6.4	4.2	-2.7	2652	3315
2010	I			0.4	7.5	14.7	19.1	19.7	21.8	12.0					
	II			3.5	9.3	15.3	18.7	23.9	21.7	12.5					
	III			6.5	12.5	17.0	17.3	23.0	19.0	12.0					
	Mean	-10.5	-3.5	3.5	9.8	15.1	18.4	21.5	20.2	12.0	4.6	7.3	6.5	2715	2815
2011	I			-1.8	9.4	8.7	19.9	16.7	17.5	18.0					
	II			4.3	8.3	14.6	17.4	23.1	18.1	14.5					
	III			5.9	14.1	17.0	18.1	20.1	21.2	10.5					
	Mean	-2.5	-6.5	2.8	10.6	13.4	18.5	20.0	18.9	14.3	6.4	3.4	0.7	2581	3073
The long-term average 1971-2005)	I			0.2	6.7	13.0	16.5	17.8	18.8	15.0					
	II			1.3	7.2	14.4	17.0	18.6	18.1	12.6					
	III			3.3	10.0	14.9	16.9	18.9	16.5	11.0					
	Mean	-3.5	-2.5	1.6	7.9	14.1	16.8	18.4	17.8	12.9	7.4	2.4	-1.7	2553	2811