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Supplementary Material

Improving micronutrient density in basmati rice and durum wheat through summer green manuring and elemental sulfur fertilisation

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Supplementary Table S1. The micronutrients added (mean \pm standard deviation) by green manuring crops

Summer green manuring crops	Zn (g ha ⁻¹)		Fe (kg ha ⁻¹)		Cu (g ha ⁻¹)		Mn (g ha ⁻¹)	
	2018	2019	2018	2019	2018	2019	2018	2019
Sesbania (<i>Sesbania aculeata</i>)	82.8 ± 2.35	85.4 ± 2.73	4.35 ± 0.06	4.49 ± 0.08	58.9 ± 2.10	60.7 ± 2.38	176.6 ± 2.71	182.2 ± 3.44
Sunhemp (<i>Crotalaria juncea</i>)	87.0 ± 3.27	94.7 ± 4.77	6.03 ± 0.21	6.56 ± 0.31	61.5 ± 2.72	66.9 ± 3.81	276.5 ± 4.93	300.7 ± 9.22

Supplementary Table S2. Effect of summer green manuring crops and sulfur fertilization on the total uptake of zinc, copper, manganese and iron by the *Basmati* rice

Treatment	Total uptake by the <i>Basmati</i> rice (g ha ⁻¹)							
	Zn		Cu		Mn		Fe	
	2018	2019	2018	2019	2018	2019	2018	2019
Green manuring crops (SGM)								
Fallow (no green manuring)	1031.9b ±136.19	1047.5b ±177.84	312.3b ±49.22	301.2b ±48.07	1734.8b ±296.22	1710.6b ±266.54	2400.0b ±483.34	2538.1b ±659.41
Sesbania (<i>Sesbania aculeata</i>)	1161.1a ±157.77	1234.2a ±222.15	354.6a ±42.17	369.4a ±50.83	2152.4a ±342.17	2209.6a ±177.04	3005.3a ±630.45	3251.6a ±847.30
(Sunhemp) (<i>Crotalaria juncea</i>)	1230.4a ±194.82	1317.1a ±213.83	369.9a ±41.87	395.1a ±46.27	2003.9a ±347.66	2104.0a ±246.38	3243.8a ±660.54	3577.7a ±833.08
Sulfur fertilization (SF)								
Without S fertilization	979.2d ±98.02	965.6e ±138.58	300.2c ±30.69	292.8f ±51.65	1809.6c ±331.29	1785.2e ±416.82	2205.7d ±387.77	2110.9d ±438.13
20 kg S ha ⁻¹ to rice	1102.7c ±76.36	1115.4c ±129.81	346.0b ±34.70	349.4d ±50.79	1844.2b ±324.79	1896.0e ±207.11	2972.7c ±392.34	3037.7bcd ±516.99
40 kg S ha ⁻¹ to rice	1298.0b ±89.75	1317.5b ±149.18	383.0a ±24.03	394.0b ±56.17	2213.8a ±115.79	2254.0b ±113.16	3410.7b ±446.31	3500.0b ±646.28
20 kg S ha ⁻¹ to wheat	1015.0d ±71.23	1041.7d ±98.65	303.6c ±34.18	313.3e ±44.74	1977.8c ±477.76	2032.8d ±494.29	2389.8d ±387.95	2536.2cd ±379.72
40 kg S ha ⁻¹ to wheat	1012.1d ±83.59	1116.9c ±142.14	306.9c ±30.70	335.1d ±44.67	1814.2c ±256.75	1984.2bcd ±231.43	2329.4d ±330.09	2852.9bcd ±538.58
20 kg S ha ⁻¹ to both rice and wheat	1174.9c ±112.09	1271.5b ±125.85	366.0b ±35.56	369.5c ±51.35	2191.5b ±423.39	2191.4bc ±304.57	3156.8c ±489.17	3275.5bc ±532.47
40 kg S ha ⁻¹ to both rice and wheat	1405.8a ±181.75	1568.5a ±190.77	413.5a ±19.90	432.6a ±43.22	1895.0a ±387.59	1912.8a ±321.64	3716.0a ±653.53	4544.2a ±688.10
ANOVA results (p-value)								
SGM	<0.0001	<0.0001	<0.0001	<0.0001	0.0479	0.0013	<0.0001	<0.0001
SF	<0.0001	<0.0001	0.02614	<0.0001	0.04004	0.01309	<0.0001	0.0006
SGM×SF	0.9971	0.9987	0.3678	0.9987	0.2581	0.2163	0.9998	0.4872

Supplementary Table S3. Effect of summer green manuring crops and sulfur fertilization on the total uptake of zinc, copper, manganese and iron by the durum wheat

Treatment	Total uptake by the durum wheat (g ha ⁻¹)							
	Zn		Cu		Mn		Fe	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
Green manuring crops (SGM)								
Fallow (no green manuring)	486.7b ±159.88	504.8b ±166.58	275.8b ±42.15	287.7b ±38.60	1839.5b ±281.49	1749.5b ±245.19	2283.1b ±339.88	2431.0b ±397.50
Sesbania (<i>Sesbania aculeata</i>)	631.9a ±144.40	657.9a ±103.05	345.5a ±50.11	363.1a ±52.93	2117.4a ±260.11	2028.4a ±312.36	2945.1a ±305.12	3089.0a ±355.11
(Sunhemp) (<i>Crotalaria juncea</i>)	719.8a ±134.78	749.3a ±142.64	375.1a ±49.30	392.0a ±61.29	2253.3a ±235.33	2090.0a ±270.50	3281.6a ±373.74	3458.9a ±356.12
Sulfur fertilization (SF)								
Without S fertilization	370.3f ±170.15	384.8f ±105.92	253.6e ±30.54	267.1d ±30.81	1506.5e ±210.10	1427.9e ±295.55	1406.1e ±353.93	1498.5e ±372.99
20 kg S ha ⁻¹ to rice	445.7e ±127.59	463.4e ±118.31	283.8d ±41.95	305.5c ±43.30	1659.2de ±244.82	1615.2e ±295.90	1932.5e ±325.09	1980.2e ±398.26
40 kg S ha ⁻¹ to rice	505.7e ±106.98	525.6e ±113.23	306.2cd ±48.30	323.1c ±54.49	1829.7cd ±257.62	1781.4d ±237.90	2663.6d ±35.14	2779.5d ±397.12
20 kg S ha ⁻¹ to wheat	579.3d ±120.85	603.2d ±125.82	326.9bc ±45.64	360.9b ±62.27	2013.5c ±205.17	1867.5c ±201.36	2883.8cd ±394.75	3069.6cd ±380.17
40 kg S ha ⁻¹ to wheat	798.0b ±143.33	829.8b ±148.04	388.2a ±67.22	389.9ab ±61.38	2508.2b ±261.67	2323.9b ±235.74	3661.8ab ±382.27	3850.9ab ±372.97
20 kg S ha ⁻¹ to both rice and wheat	672.0c ±130.41	700.1c ±137.71	351.2b ±54.95	385.9ab ±74.34	2102.1c ±248.44	1951.0c ±234.28	3249.5bc ±304.68	3470.0bc ±318.30
40 kg S ha ⁻¹ to both rice and wheat	918.7a ±178.35	954.5a ±146.14	414.3a ±69.73	400.8a ±53.01	2871.2a ±264.31	2724.7a ±234.13	4059.0a ±386.01	4302.1a ±336.61
ANOVA results (p-value)								
SGM	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001
SF	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SGM × SF	0.7436	0.6879	0.9871	0.8719	0.3614	0.9318	0.3687	0.5426

Supplementary Table S4. Effect of summer green manuring crops and sulfur fertilization on the final status of zinc, copper, manganese and iron contents in *Basmati* rice field soil after harvest of the crop

Treatment	Available Zn (mg kg ⁻¹)		Available Cu (mg kg ⁻¹)		Available Mn (mg kg ⁻¹)		Available Fe (mg kg ⁻¹)	
	2018	2019	2018	2019	2018	2019	2018	2019
Green manuring crops (SGM)								
Fallow (no green manuring)	0.64b ±0.06	0.60b ±0.10	1.66b ±0.15	1.52b ±0.15	3.00c ±0.36	2.7b5 ±0.35	3.39c ±0.45	3.11c ±0.42
Sesbania (<i>Sesbania aculeata</i>)	0.84a ±0.11	0.94a ±0.18	1.81a ±0.15	2.04a ±0.29	3.69b ±0.43	4.16a ±0.72	4.20b ±0.60	4.70ba ±0.89
(Sunhemp) (<i>Crotalaria juncea</i>)	0.90a ±0.12	1.01a ±0.18	1.86a ±0.17	2.10a ±0.31	4.16a ±0.79	4.70a ±1.10	4.73b ±0.90	5.31a ±1.28
Sulfur fertilization (SF)								
Without S fertilization	0.67c ±0.11	0.60e ±0.10	1.60c ±0.13	1.44e ±0.12	2.96c ±0.61	2.67d ±0.55	3.39c ±0.58	3.05d ±0.52
20 kg S ha ⁻¹ to rice	0.80b ±0.10	0.91bc ±0.16	1.74b ±0.06	1.92bcd ±0.42	3.66b ±0.23	4.03abc ±1.04	4.19b ±0.74	4.52bc ±0.97
40 kg S ha ⁻¹ to rice	0.87a ±0.12	0.99ab ±0.19	1.93a ±0.11	2.03abc ±0.42	4.16a ±0.97	4.27ab ±1.20	5.20a ±0.39	4.56bc ±1.22
20 kg S ha ⁻¹ to wheat	0.69c ±0.13	0.79d ±0.13	1.64c ±0.15	1.76d ±0.27	2.93c ±0.52	3.38cd ±0.65	3.45c ±0.68	3.74cd ±0.84
40 kg S ha ⁻¹ to wheat	0.70c ±0.15	0.83cd ±0.13	1.60c ±0.15	1.83cd ±0.36	3.10c ±0.61	3.57bc ±0.74	3.38c ±0.51	4.33bc ±1.25
20 kg S ha ⁻¹ to both rice and wheat	0.85b ±0.15	0.97ab ±0.16	1.74b ±0.06	2.08ab ±0.37	3.63b ±0.32	4.53a ±1.49	4.30b ±0.71	4.67b ±1.27
40 kg S ha ⁻¹ to both rice and wheat	0.89a ±0.19	1.06a ±0.19	2.00a ±0.14	2.15a ±0.31	4.28a ±0.90	4.65a ±1.44	5.25a ±1.26	5.74a ±1.94
ANOVA results (p-value)								
SGM	<0.0001	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SF	<0.0001	<0.0001	<0.0001	0.0002	0.0008	0.0007	0.0003	0.0006
SGM × SF	0.9984	0.9874	0.5871	0.6287	0.2697	0.5879	0.6841	0.7546

Supplementary Table S5. The residual effect of summer green manuring crops and sulfur fertilization on the final status of zinc, copper, manganese and iron contents in the durum wheat field after harvest of the crop

Treatment	Available Zn (mg kg ⁻¹)		Available Cu (mg kg ⁻¹)		Available Mn (mg kg ⁻¹)		Available Fe (mg kg ⁻¹)	
	2019	2020	2019	2020	2019	2020	2019	2020
Green manuring crops (SGM)								
Fallow (no green manuring)	0.62b ±0.17	0.66b ±0.10	1.59b ±0.17	1.45b ±0.14	2.88b ±0.38	2.61c ±0.33	3.25b ±0.74	2.95c ±0.40
Sesbania (<i>Sesbania aculeata</i>)	0.94a ±0.14	1.07a ±0.22	2.04a ±0.21	2.21a ±0.39	4.15a ±0.55	4.52b ±0.93	4.73a ±0.77	5.10b ±1.11
(Sunhemp) (<i>Crotalaria juncea</i>)	1.01a ±0.15	1.15a ±0.23	2.10a ±0.23	2.28a ±0.41	4.69a ±0.58	5.10c ±1.33	5.34a ±0.87	5.77a ±1.51
Sulfur fertilization (SF)								
Without S fertilization	0.71c ±0.17	0.57c ±0.09	1.68c ±0.2	1.37c ±0.11	3.14c ±0.88	2.53c ±0.52	3.58c ±0.89	2.89c ±0.49
20 kg S ha ⁻¹ to rice	0.73c ±0.20	0.95b ±0.24	1.72c ±0.2	1.87b ±0.57	3.30c ±0.97	3.59b ±1.39	3.65c ±0.98	3.98bc ±1.61
40 kg S ha ⁻¹ to rice	0.78bc ±0.23	1.00ab ±0.28	1.81b ±0.20	1.93b ±0.60	3.53c ±0.50	3.79b ±1.57	4.27b ±0.83	4.62b ±1.34
20 kg S ha ⁻¹ to wheat	0.86bc ±0.16	0.97ab ±0.30	1.86b ±0.21	2.04ab ±0.43	3.93b ±0.63	4.29ab ±0.94	4.50b ±0.69	4.79b ±1.17
40 kg S ha ⁻¹ to wheat	0.95ab ±0.19	1.05ab ±0.33	1.99ab ±0.30	2.15ab ±0.43	4.15ab ±0.83	4.55ab ±1.05	4.53b ±0.92	4.86b ±1.63
20 kg S ha ⁻¹ to both rice and wheat	0.93b ±0.23	1.03ab ±0.28	2.10a ±0.32	2.20ab ±0.54	4.56a ±0.63	4.84a ±1.88	4.70b ±0.94	4.98b ±1.67
40 kg S ha ⁻¹ to both rice and wheat	1.04a ±0.30	1.13a ±0.33	2.20a ±0.17	2.28a ±0.55	4.75a ±0.38	4.96a ±1.83	5.85a ±0.84	6.13a ±2.43
ANOVA results (p-value)								
SGM	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
SF	0.0024	<0.0001	0.00317	0.0008	0.00062	0.0014	0.00215	0.0013
SGM × SF	0.3684	0.9876	0.8934	0.3687	0.5879	0.1365	0.5842	0.4267