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CONTENT OF TOTAL CARBON AND AVAILABLE FORMS OF PHOSPHORUS, POTASSIUM AND MAGNESIUM IN SOIL DEPENDING ON THE SULPHUR RATE AND FORM

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Abstract

The reduction of sulphur emissions achieved over the last 20 years has led to sulphur deficit in soil, which decreases crop yields and deteriorated yield quality. Sulphur fertilisation affects both plants and physicochemical soil properties. The total carbon content in soil affects the capacity and quality of the sorption complex, which in turn determines the buffer capacity. The content of available forms of phosphorus, potassium and magnesium in soil has strong influence on the soil fertility. The uptake with yield and the acidification of soil, which intensifies the processes of retardation and nutrient leaching, result in depletion of those nutrients in soil.

In 2005-2007, an experiment was carried out at the Experiment Station of the Faculty of Agriculture and Biotechnology, the University of Technology and Life Sciences in Bydgoszcz, to assess the effect of sulphur fertilisation on the content of total carbon and available forms of phosphorus, potassium and magnesium in soil. Sulphur fertilisation was applied in the ionic form, i.e. sodium sulphate (VI), and in the elemental form. The rates were 0, 20, 40, 60 kg S ha^{-1}. The results demonstrated that increasing sulphur rates considerably decreased the content of available forms of phosphorus, potassium and magnesium in soil. A significant increase was also found in the total carbon content in soil after fertilisation with 20 and 40 S kg ha^{-1}. Interestingly, the organic carbon content in soil clearly depended on the form of applied sulphur: sulphate (VI) or elemental.

Key words: sulphur, fertilization, total carbon, phosphorus, potassium, magnesium.

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ZAWARTOŚĆ WĘGLA OGÓŁEM ORAZ PRZYSWAJALNYCH FORM FOSFORU, POTASU I MAGNEZU W GLEBIE W ZALEŻNOŚCI OD DAWKI I FORMY SIARKI

Abstrakt

Redukcja emisji siarki w ostatnim 20-leciu doprowadziła do deficytu tego pierwiastka w glebie, co spowodowało zmniejszenie plonów i pogorszenie ich jakości. Nawożenie siarką wpływa nie tylko na rośliny, ale również oddziałuje na właściwości fizykochemiczne gleb. Zawartość węgla ogółem w glebie decyduje o pojemności i jakości kompleksu sorpcyjnego, od którego zależą zdolności buforowe. Zawartość przyswajalnych form fosforu, potasu i magnezu w glebie w znacznym stopniu decyduje o jej żyzności. Wynoszenie z plonem oraz zakwaszenie gleb, które intensyfikuje procesy uwsteczniania i wymywania składników pokarmowych, powoduje zubożenie gleb w te składniki.

W latach 2005-2007 na terenie Stacji Badawczej Wydziału Rolnictwa i Biotechnologii UTP w Bydgoszczy realizowano badania, których celem była ocena wpływu nawożenia siarką na zawartość węgla ogółem i przyswajalnych form fosforu, potasu oraz magnezu w glebie. Nawożenie siarką stosowano w formie jonowej – siarczan (VI) sodu oraz w formie elementarnej: 0, 20, 40, 60 S kg ha^{-1}. Wykazano, iż wzrastające dawki siarki powodowały znaczące zmniejszenie zawartości przyswajalnych form fosforu, potasu i magnezu w glebie. Stwierdzono także istotny wzrost zawartości węgla ogółem w glebie po nawożeniu 20 i 40 kg S ha^{-1}. Warto zaznaczyć, że zawartość węgla organicznego w glebie była wyraźnie uzależniona od formy siarki stosowanej w badaniach – siarczanowej (VI) lub elementarnej.

Słowa kluczowe: siarka, nawożenie, węgiel organiczny, fosfor, potas, magnez.

INTRODUCTION

Sulphur is an essential nutrient in plants. Being incorporated into some organic compounds, it functions as a building block of matter (BEDNAREK et al. 2008). Until the early 1990s, it had been thought that the amount of sulphur introduced into soil with fertilisers and atmospheric pollution satisfied the requirements of crops for this nutrient (SZULC et al. 2004). Later, however, some economic changes and eco-friendly actions resulted in a very high reduction of sulphur emissions to the atmosphere, causing sulphur deficit in soil (MOTOWICKA-TERELAK, TERELAK 2000). Sulphur deficit or excess in soil can limit the yielding of crops (MCGRATH et al. 1996, KACZOR et al. 2004) and the soil capacity for meeting the sulphur requirements of plants. Soil is the key source of sulphur for plants, which absorb it from soil as sulphate (VI). At present, over half of the soils in Poland are poor in available sulphur forms (KOZŁOWSKA-STRAWSKA, KACZOR 2004). Sulphur fertilisation affects both the plant growth and development and the physicochemical properties of soil (KLIKOCKA 2004, KACZOR, ŁASZCZ-ZAKORCZMENNA 2009, SKWIERAWSKA, ZAWARTKA 2009). In view of the above, this research has been launched to evaluate the effect of two sulphur forms and their rates on the content of total carbon and available forms of phosphorus, potassium and magnesium in soil.

MATERIAL AND METHODS

The research was performed in 2005-2007, at the Experiment Station of the Faculty of Agriculture, located in Wierzchucinek near Bydgoszcz. The experiment was set up as a two-factor multiple experiment (3) in a split-plot design with 3 replications. It was run on Haplic Luvisol soil, assessed as good rye complex of agricultural usability in the Polish soil valuation system. The following crops were grown:

experiment 1: spring barley in 2005, narrow-leaf lupine in 2006 and mustard in 2007;
experiment 2: narrow-leaf lupine in 2005, mustard in 2006 and spring barley in 2007;
experiment 3: mustard in 2005, spring barley in 2006 and narrow-leaf lupine in 2007.

The experimental factors consisted of:

factor I – sulphur form: S elemental sulphur and sodium sulphate (VI);
factor II – sulphur rate: 0, 20, 40, 60 S kg ha^{-1}.

In 2007, after the harvest of crops, soil from the arable layer (0-20 cm) was sampled and the following were determined: the content of total carbon with Tiurin method, available phosphorus and potassium form with Egner--Riehm method (DL) and available forms of magnesium with Schachtschabel method.

The results were statistically verified with the analysis of variance at the significance of α=0.05 and the boundary differences were estimated with Tukey's test.

RESULTS AND DISCUSSION

Literature reports imply an invariably positive relationship between the content of sulphur and humus in soil, being the basic source of that element for plants (SPYCHAJ-FABISIAK et al. 2004, SZULC et al. 2004). The present results have demonstrated that sulphur fertilisation at the rates of 20 and 40 S kg ha^{-1} resulted in a significant increase in the content of total carbon in soil: by 6.2% and 1.7%, respectively, as compared to the control (Table 1). Interestingly, the lowest sulphur rate (20 S kg ha^{-1}) significantly increased (by 3.2% to 9.2%) the amount of total sulphur in soil of all the experiments. Significant increases in the content of that sulphur form in soil were noted following the application of 40 S kg ha^{-1} (experiment II) and 60 S kg ha^{-1} (experiment III), which suggests that low sulphur rates (20-40 kg ha^{-1}) are essential for humification processes in soil to run properly. The research demonstrated that the form of sulphur significantly modified the amount of

Table 1

Content of total carbon in soil (g kg^{-1})

Experiment	Form of sulphur	Doses of sulphur (kg S ha^{-1})				Mean
		0	20	40	60	
I	Na_2SO_4	5.82	6.00	5.76	5.46	5.76
	S elemental	5.46	5.64	5.40	5.34	5.46
	mean	5.64	5.82	5.58	5.40	
$LSD_{0.05}$	I – 0.073, II – 0.140, I in II – n. s., II in I – n. s.					
II	Na_2SO_4	5.64	6.18	6.06	5.78	5.92
	S elemental	5.88	6.00	5.94	5.74	5.89
	mean	5.76	6.09	6.00	5.76	
$LSD_{0.05}$	I – n. s., II – 0.167, I in II – n. s., II in I – n. s.					
III	Na_2SO_4	6.24	6.96	6.36	6.60	6.54
	S elemental	6.84	7.32	6.96	7.02	7.04
	mean	6.54	7.14	6.66	6.81	
$LSD_{0.05}$	I – 0.094, II – 0.181, I in II – n. s., II in I – n. s.					
Mean	Na_2SO_4	5.90	6.38	6.06	5.95	6.07
	S elemental	6.06	6.32	6.10	6.03	6.13
	mean	5.98	6.35	6.08	5.99	
$LSD_{0.05}$	I – 0.046, II – 0.089, I in II – n. s., II in I – n. s.					

total carbon in soil and the difference in the mean values was 0.06 units. KLIKOCKA (2004) showed that sulphur rates of 25 and 50 S kg ha^{-1} did not modify the amount of total carbon in soil.

According to KOZŁOWSKA-STRAWSKA (2007), excessive amounts of sulphur introduced into soil result in a decrease in the value of soil pH, which can stimulate changes in the content of available forms of nutrients. The effect of the content of available forms of phosphorus in soil on its reaction is common knowledge. In the present research, it was found that sulphur fertilisation, irrespective of the form, limited the availability of soil phosphorus to plants (Table 2). As for the control, there was a significant decrease in the content of P available in soil, ranging from 2.54 mg P kg^{-1} of soil at the rate of 20 kg S ha^{-1} to 4.18 mg P kg^{-1} of soil at the rate of 60 kg S ha^{-1}. The form of sulphur applied did not differentiate much the content of available phosphorus forms in soil.

The content of available forms of potassium in soil, depending on the sulphur fertilisation, ranged from 175.3 mg K kg^{-1} to 217.1 mg K kg^{-1} (Table 3). The form of sulphur, whether sulphate or elemental sulphur, did

Table 2

Content of available phosphorus in soil (g kg^{-1})

Experiment	Form of sulphur	Doses of sulphur (kg S ha^{-1})				Mean
		0	20	40	60	
I	Na_2SO_4	66.16	64.27	64.64	61.58	64.12
	S elemental	64.49	63.55	63.08	63.28	63.60
	mean	65.32	63.91	63.86	62.43	
$LSD_{0.05}$	I – n. s., II – 2.326, I in II – n. s., II in I – n. s.					
II	Na_2SO_4	62.79	59.29	56.68	58.28	29.26
	S elemental	63.80	59.22	57.55	58.55	59.58
	mean	63.30	59.26	56.72	58.42	
$LSD_{0.05}$	I – n. s., II – 2.935, I in II – n. s., II in I – n. s.					
III	Na_2SO_4	79.74	76.98	75.02	74.78	76.63
	S elemental	79.81	78.26	76.85	75.29	77.55
	mean	79.78	77.62	75.94	75.04	
$LSD_{0.05}$	I – n. s., II – 2.481, I in II – n. s., II in I – n. s.					
Mean	Na_2SO_4	69.56	66.85	65.45	64.88	66.68
	S elemental	69.37	67.01	65.57	65.71	66.91
	mean	69.47	66.93	65.51	65.29	
$LSD_{0.05}$	I – n. s., II – 1.301, I in II – n. s., II in I – n. s.					

not differentiate significantly the content of available potassium in soil. The rates of sulphur increasing from 20 through 40 to 60 kg ha^{-1} resulted in a significant decrease in the content of available potassium in soil, as compared with the control, by 7.5%, 3.6% and 3.7%, respectively. Identical relationships were observed in experiments II and III.

The relevant literature reports show that sulphur intensifies the processes of leaching of alkaline-forming nutrients deep down into the soil profile (Motowicka-Terelak, Terelak 1994, Spychaj-Fabisiak 2000, Skwierawska et al. 2006). These processes can lead to the depletion of soluble forms of potassium and magnesium in soil (Murawska et al. 1999, Spychaj-Fabisiak 1999). Kaczor and Łaszcz-Zakorczmenna (2009) claim that a decrease in the content of available forms of potassium and magnesium in soil induced by sulphur fertilisation was caused by a higher uptake of these elements by crops.

The present study has demonstrated that sulphur fertilisation, depending on the rate, decreased significantly the content of available forms of magnesium in soil from 1.1% to 3.6% (Table 4). According to the mean values, no significant effect of the sulphur fertiliser form on the content of

Table 3

Content of available potassium in soil (g kg^{-1})

Experiment	Form of sulphur	Doses of sulphur (kg S ha^{-1})				Mean
		0	20	40	60	
I	Na_2SO_4	177.8	180.2	182.7	175.3	179.0
	S elemental	175.3	175.3	177.6	177.9	176.5
	mean	176.5	177.8	180.2	176.6	
$LSD_{0.05}$	I – n. s., II – n. s., I in II – n. s., II in I – n. s.					
II	Na_2SO_4	195.1	182.8	180.4	182.7	185.2
	S elemental	197.5	180.4	182.8	180.2	185.2
	mean	196.3	181.6	181.6	181.58	
$LSD_{0.05}$	I – n. s., II – 6.29, I in II – n. s., II in I – n. s.					
III	Na_2SO_4	216.9	209.0	207.0	207.0	210.0
	S elemental	217.1	209.4	209.5	206.9	210.4
	mean	217.0	209.2	208.3	210.0	
$LSD_{0.05}$	I – n. s., II – 5.62, I in II – n. s., II in I – n. s.					
Mean	Na_2SO_4	196.6	190.7	190.0	188.3	191.4
	S elemental	196.6	188.3	190.0	188.3	190.8
	mean	196.6	189.5	190.0	188.3	
$LSD_{0.05}$	I – n. s., II – 4.81, I in II – n. s., II in I – n. s.					

available Mg in soil was determined, which was analogous to phosphorus and magnesium. However, a significant effect was attributed to the sulphur form on magnesium content in soil, and the values reported ranged from 0.73 Mg mg kg^{-1} of soil to 1.66 Mg mg kg^{-1} of soil.

CONCLUSIONS

1. The sulphur rates of 20 kg S ha^{-1} as well as 40 kg S ha^{-1} increased significantly the content of total carbon in soil.

2. Sulphur demonstrated an unfavourable effect on the content of available forms of phosphorus, potassium and magnesium in soil.

3. The sulphur form, sulphate or elemental, did not affect the content of organic carbon in soil or the availability of phosphorus, potassium and magnesium.

Table 4

Content of available magnesium in soil (g kg^{-1})

Experiment	Form of sulphur	Doses of sulphur (kg S ha^{-1})				Mean
		0	20	40	60	
I	Na_2SO_4	44.89	43.11	42.67	42.67	43.34
	S elemental	45.33	46.67	44.89	43.11	45.00
	mean	45.11	44.89	43.78	42.89	
$LSD_{0.05}$	I – 0.466, II – 0.894, I in II – n. s., II in I – n. s.					
II	Na_2SO_4	43.11	42.67	43.11	41.34	42.56
	S elemental	41.78	40.89	41.34	40.45	41.12
	mean	42.44	41.78	42.22	40.90	
$LSD_{0.05}$	I – 0.442, II – 0.849, I in II – n. s., II in I – n. s.					
III	Na_2SO_4	52.89	53.33	52.00	52.89	52.78
	S elemental	53.78	52.08	51.17	51.17	52.05
	mean	53.34	52.70	51.58	52.03	
$LSD_{0.05}$	I – 0.725, II – 1.391, I in II – n. s., II in I – n. s.					
Mean	Na_2SO_4	46.96	46.37	45.93	45.63	46.22
	S elemental	46.96	46.55	45.80	44.91	46.06
	mean	46.96	46.46	45.86	45.27	
$LSD_{0.05}$	I – n. s., II – 0.449, I in II – n. s., II in I – n. s.					

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