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CONTENT OF TOTAL NITROGEN AND ITS MINERAL FORMS IN SOIL AFTER THE APPLICATION OF A VARIED SULPHUR FERTILISATION

ZAWARTOŚCI AZOTU OGÓŁEM I JEGO FORM MINERALNYCH W GLEBIE PO ZASTOSOWANIU ZRÓŻNICOWANEGO NAWOŻENIA SIARKĄ

Abstract: Over years 2005–2007 research was carried out to determine the effect of sulphur fertilisation on the content of total nitrogen and its mineral forms in Luvisol. Sulphur was applied in an ionic form as sodium sulphate(VI) and in an elemental form as Siarkol Extra at the dose: 0, 20, 40, 60 kg per hectare. Following the application of sulphur at the dose of 60 S kg · ha^{-1}. A significant increase was recorded in the mean content of total nitrogen in soil, as compared with the control. There was shown no clear effect of neither the sulphur form applied nor its dose on the mean content of ammonium nitrogen in soil, while those factors significantly differentiated the content of nitrate nitrogen(V) in soil.

Keywords: sulphur, fertilisation, total nitrogen, mineral nitrogen forms

Over the recent years the transformation of economy and proecological actions have resulted in an about 40 % decrease in sulphur dioxide emissions in Poland. There has been a limited supply of sulphur from industrial emissions, which decreased the content of this macronutrient in soil considerably, thus decreasing the value of ratio N:S in plants, being an essential yield quality indicator [1, 2]. Today in Poland more than half of the soils used for agricultural purposes demonstrates natural or low sulphur content [3]. This element participates in plant metabolic processes, is a building component of proteins and an essential part of exogenous amino acids and thus constitutes an indispensable component of living organisms [4, 5].

With that in mind, research has been launched to determine the effect different forms of sulphur and the dose on the content of total nitrogen and its mineral forms in Luvisol.

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Material and methods

The research involved soil sampled from a two-factor static field experiment set up following the randomized complete block design, at the Experiment Station of the Faculty of Agriculture at Wierzchucinek in the vicinity of Bydgoszcz. The research was performed over years 2005–2007 based on three parallel field experiments carried out in three repetitions. The experiments involved the following crops:

Experiment I: 2005 – spring barley, 2006 – narrow leaf lupin, 2007 – mustard.

Experiment II: 2005 – narrow-leaf lupin, 2006 – mustard, 2007 – spring barley.

Experiment III: 2005 – mustard, 2006 – spring barley, 2007 – narrow-leaf lupin.

The experiment was carried out in Haplic Luvisol, of good rye complex. In the year in which the experiment was established the soil demonstrated the following properties: pH_{KCl} – 5.8; humus content 1.13 %; total nitrogen content – 0.72 g · kg^{-1}; ratio C:N – 8.9:1.

The factors investigated were the sulphur forms (n = 2, factor I) and doses (n = 4, factor II) of sulphur-containing compounds. They were used in an ionic form as sodium sulphate(VI) and as elemental sulphur in a form of Siarkol Extra, at the following doses in kilograms per hectare: 0, 20, 40, 60. Sulphur fertilisers were applied into soil, once prior to plant sowing. After three research years the soil was sampled from the arable layer (0–25 cm); the following were determined in the samples: total nitrogen with the Kjeldahl method, ammonium nitrogen with the distillation method and nitrate(V) nitrogen colorimetrically with phenoldisulphonic acid.

The results were statistically verified, applying the analysis of variance; the differences were verified with the Tukey test at the significance level of $\alpha = 0.05$.

Results and discussion

After the application of sulphur at the dose of 60 kg S · ha^{-1} there was noted a significant increase (by 1.4 %) in the mean content of total nitrogen in soil as compared with the control. The other sulphur doses investigated (20 kg · ha^{-1} and 40 kg · ha^{-1}) did not differentiate the mean content of total nitrogen in soil significantly (Table 1). Similarly Klikocka [6] did not observe significant changes in the content of total nitrogen in soil following the application of different sulphur doses (25 and 50 kg S · ha^{-1}) in a form of ammonium sulphate(VI) when growing triticale. One shall note that the highest dose (60 kg S · ha^{-1}) applied for lupin growing was the only one which resulted in a significant increase in the mean content of total nitrogen in soil as compared with the treatments with the fertilisation dose of 40 kg S · ha^{-1}. After three research years it was observed that the varied sulphur dose affected the nitrogen concentration in soil neither under spring barley nor under mustard. Interestingly, of all the sulphur doses applied, the dose of 20 kg S · ha^{-1} in a form of sodium sulphate(VI) was the only one which demonstrated a clearly more favourable effect on the content of total nitrogen than the same amount of sulphur contained in a form of Siarkol Extra.

Table 1

Content of total nitrogen in soil [N g · kg^{-1}]

Experiment	Form of sulphur	Sulphur dose [kg S · ha^{-1}]				**Mean**	$LSD_{0.05}$
		0	20	40	60		
I	Na_2SO_4	0.71	0.74	0.72	0.73	**0.72**	I – ns II – ns I in II – ns II in I – ns
	Siarkol*	0.73	0.71	0.73	0.74	**0.73**	
	Mean	**0.72**	**0.72**	**0.72**	**0.73**	**0.72**	
II	Na_2SO_4	0.62	0.67	0.67	0.63	**0.65**	I – ns II – ns I in II–0.049 II in I – 0.068
	Siarkol*	0.60	0.60	0.64	0.66	**0.62**	
	Mean	**0.61**	**0.63**	**0.65**	**0.64**	**0.63**	
III	Na_2SO_4	0.78	0.78	0.74	0.77	**0.76**	I – ns II – 0.030 I in II – 0.039 II in I – 0.042
	Siarkol*	0.75	0.73	0.73	0.77	**0.74**	
	Mean	**0.76**	**0.75**	**0.73**	**0.77**	**0.75**	
Mean	Na_2SO_4	0.70	0.73	0.71	0.71	**0.71**	I – ns II – 0.001 I in II – 0.026 II in I – 0.002
	Siarkol*	0.69	0.68	0.70	0.72	**0.70**	
	Mean	**0.70**	**0.70**	**0.70**	**0.71**	**0.70**	

* Siarkol – elemental sulphur.

As reported in literature [7], the excessive amount of sulphur introduced into soil both in a form of acid rain or dry deposition affects the soil processes thus decreasing eg the amount of cations Ca^{2+} and Mg^{2+}. As a result, the soil gets poorer in alkaline components. The soil researched showed a slightly acidic reaction, however, the application of sulphur at the doses and forms compliant with the assumptions of the experiment did not result in considerable changes in the content of total nitrogen.

Mineral nitrogen forms are most easily available for plants and their contents in soil are used to define nitrogen doses and they are an indicator of the soil environment status [8].

Mean contents of ammonium nitrogen, as affected by the experimental factors investigated, varied and reached in soil under mustard (experiment I), spring barley (experiment II), yellow lupin (experiment III), respectively: 13.8 mg · kg^{-1}, 13.4 mg · kg^{-1} and 16.2 mg · kg^{-1}.

Under the conditions of the present experiment, there was demonstrated no clear effect of neither the sulphur form applied nor its dose on the content of ammonium nitrogen in soil (Table 2). One shall, however, note that as a result of the sulphur doses applied, the contents of this nitrogen form slightly decreased, as compared with the control, reaching the lowest value equal to 16 mg · kg^{-1} after the use of 60 kg S · ha^{-1}. According to Kopec [4], a combined mineral fertilization (NPK) increases the nitrogen leaching considerably. Reports by Spychaj-Fabisiak and Murawska [10] confirm that ammonium nitrogen is especially heavily leached from acid soil, and one shall stress that the experiment was carried out on slightly acidic soil. The intensity of leaching also effected the mineral nitrogen dose, soil type and the amount and reaction of precipitation [11]. However, in the present research there was noted a more favourable

effect of Siarkol Extra thanks to which in each fertilisation treatment the mean content of ammonium nitrogen was significantly higher as compared with the treatments with sodium sulphate(VI) fertiliser. Siarkol Extra gets solved in water much harder, and so its acidifying effect is lower, which, in turn, could have led to lower ammonium nitrogen leaching. It was also demonstrated that the experimental factors did not differentiate the mean content of this nitrogen form determined in soil after harvest of mustard, spring barley and lupin.

Table 2

Content of ammonium nitrogen in soil [$N\text{-}NH_4^+$ mg · kg^{-1}]

Experiment	Form of sulphur	Dose of sulphur [kg S · ha^{-1}]				**Mean**	$LSD_{0.05}$
		0	20	40	60		
I	Na_2SO_4	14.4	13.5	12.6	12.2	**13.2**	I – ns II – ns I in II – ns II in I – ns
	Siarkol*	15.4	14.0	14.0	13.8	**14.3**	
	Mean	**14.9**	**13.8**	**13.3**	**13.0**	**13.7**	
II	Na_2SO_4	12.6	13.1	12.6	12.2	**12.6**	I – 1.398 II – ns I in II – 1.533 II in I – 0.739
	Siarkol*	14.0	13.6	14.6	14.4	**14.2**	
	Mean	**13.3**	**13.4**	**13.6**	**13.3**	**13.4**	
III	Na_2SO_4	20.6	21.4	21.0	21.3	**21.0**	I – ns II – 0.667 I in II – ns II in I – ns
	Siarkol*	21.8	22.4	22.4	22.0	**22.2**	
	Mean	**21.2**	**21.9**	**21.7**	**21.7**	**21.6**	
Mean	Na_2SO_4	15.5	16.0	15.4	15.2	**15.5**	I – 0.440 II – 0.278 I in II – 0.454 II in I – 0.393
	Siarkol*	17.4	16.7	17.0	16.7	**17.0**	
	Mean	**16.5**	**16.3**	**16.2**	**16.0**	**16.2**	

* Siarkol – elemental sulphur.

Nitrate(V) nitrogen is a form totally soluble in water. It shows a special mobility, does not undergo physicochemical sorption, which makes it easily leaching deep down the profile, thus contaminating ground and surface waters [12].

The content of nitrate(V) nitrogen in soil (Table 3) depended significantly on the experimental factors. The total mean content of this nitrogen form was 3.46 mg · kg^{-1}. On average the highest content of nitrate(V) nitrogen was recorded in the soil under mustard (5.98 mg · kg^{-1}), while the lowest – soil under narrow-leaf lupin – 1.82 mg · kg^{-1}. On average the highest content of nitrate(V) nitrogen was recorded for soil under mustard (5.98 mg · kg^{-1}), whereas the lowest – the soil under narrow-leaf lupin – 1.82 mg · kg^{-1}. However, due to Siarkol Extra fertilization, the content of nitrate(V) nitrogen in soil was on average 3.57 mg · kg^{-1} and it was 6.6 % significantly higher than the one recorded due to the application of sodium sulphate(VI). There was also observed a significant increase in the mean content of this nitrogen form due to different sulphur doses. This increase, as compared with the control, was highest after the application of 60 kg S · ha^{-1} and it accounted for 2.9 %.

Table 3

Content of nitrate nitrogen (V) in soil [N-NO_3^- mg · kg^{-1}]

Experiment	Form of sulphur	Dose of sulphur [kg S · ha^{-1}]				**Mean**	$LSD_{0.05}$
		0	20	40	60		
I	Na_2SO_4	5.21	5.39	5.21	6.53	**5.58**	I – 0.294 II – 0.249 I in II – 0.384 II in I – 0.352
	Siarkol*	5.52	5.85	6.33	7.86	**6.39**	
	Mean	**5.36**	**5.62**	**5.77**	**7.19**	**5.98**	
II	Na_2SO_4	3.12	3.27	2.58	2.36	**2.83**	I – 0.046 II – 0.315 I in II – ns II in I – ns
	Siarkol*	3.13	3.32	2.50	2.70	**2.91**	
	Mean	**3.13**	**3.29**	**2.54**	**2.53**	**2.87**	
III	Na_2SO_4	1.74	1.69	1.72	1.82	**1.74**	I – ns II – 0.103 I in II – 0.159 II in I – 0.146
	Siarkol*	2.05	1.65	1.85	2.07	**1.90**	
	Mean	**1.89**	**1.67**	**1.78**	**1.94**	**1.82**	
Mean	Na_2SO_4	3.35	3.30	3.17	3.57	**3.35**	I – 0.076 II – 0.034 I in II – 0.048 II in I – 0.070
	Siarkol*	3.57	3.61	3.56	3.54	**3.57**	
	Mean	**3.46**	**3.45**	**3.36**	**3.56**	**3.46**	

* Siarkol – elemental sulphur.

One shall note that the experimental factors studied clearly differentiated the content of nitrate(V) nitrogen in soil under spring barley. There was recorded a more favourable effect of Siarkol Extra after the application of which a 2.8 % increase in the content of nitrate(V) nitrogen in soil was identified as compared with the treatments with sodium sulphate(VI) fertiliser. Following the application of the highest sulphur doses investigated (40 kg S · ha^{-1} and 60 kg S · ha^{-1}), there was a clear decrease in the content of nitrate(V) nitrogen in soil which was, respectively: 18.8 % and 19.2 %, as compared with the control.

In the soil under narrow-leaf lupin, after the application of the dose of 20 kg S · ha^{-1} there was recorded a significant decrease, as compared with the control, in the content of nitrate(V) nitrogen (by 11.6 %). However, there was recorded no clear effect of the kind of the sulphur fertiliser on the content of this form of nitrogen.

Conclusions

1. After the application of sulphur at the dose of 60 kg S · ha^{-1} there was recorded a significant increase in the content of total nitrogen in soil, as compared with the control.

2. The content of nitrate(V) nitrogen in the soil researched depended significantly both on the sulphur form and its dose, however in the case of ammonia nitrogen no such relationship was recorded.

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ZAWARTOŚCI AZOTU OGÓŁEM I JEGO FORM MINERALNYCH W GLEBIE PO ZASTOSOWANIU ZRÓŻNICOWANEGO NAWOŻENIA SIARKĄ

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Abstrakt: W latach 2005–2007 przeprowadzono badania, których celem było określenie wpływu nawożenia siarką na zawartość azotu ogółem i jego form mineralnych w glebie płowej. Siarkę stosowano w postaci jonowej w formie siarczanu(VI) sodu oraz w postaci elementarnej jako Siarkol Extra w dawkach: 0, 20, 40, 60 kg na hektar. Po zastosowaniu siarki w dawce 60 S kg · ha^{-1} stwierdzono znaczny wzrost średniej zawartości azotu ogółem w glebie, w porównaniu do obiektu kontrolnego. Nie wykazano wyraźnego wpływu zastosowanej formy siarki, jak również jej dawki na średnią zawartość azotu amonowego w glebie, natomiast czynniki te w znaczny sposób różnicowały zawartości azotu azotanowego(V) w glebie.

Słowa kluczowe: siarka, nawożenie, azot ogółem, mineralne formy azotu