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EFFECT OF DIFFERENT DOSES OF NITROGEN ON SOIL QUALITY AND YIELD OF PLANTS GROWN IN THE LAND RECULTIVATED AFTER SULPHUR MINING

WPŁYW ZRÓŻNICOWANYCH DAWEK AZOTU NA GLEBĘ ORAZ JAKOŚĆ ROŚLIN UPRAWIANYCH NA REKULTYWOWANYCH TERENACH GÓRNICZYCH

Abstract: The aim of this work was to determine the effect of different doses of nitrogen fertilizers on soil properties and the yielding of plants and the usable value of the grass in the sulphur mining activity area where the recultivation efforts were carried out. It was found that sowing a mixture of grassland plants and the application of nitrogen fertilization in the recultivated area significantly improves the properties of the soil environment. The increasing doses of nitrogen contributed to the vigorous growth of plants, which resulted in a sulphur content reduction, changes of the reaction and a significant increase in the content of organic matter in the soil. The results showed that the mineral nitrogen fertilization favorably affects the yield of plants as well as the quality of the obtained grass.

Keywords: nitrogen fertilization, recultivated land, plant yield

Mine sulphur activity causes adverse changes in the natural environment. It results in the devastation of soils, the landscape components changes and hydrological and geomechanical transformations of the site, excluding the land from agricultural or forest production [1–3]. Rehabilitation of such sites should aim at restoration of the natural and the usable values of the environment. The last stage in the process of rehabilitation is the introduction of grasslands or forests [4, 5]. The mineral and organic fertilization is needed to provide the plants introduced to the recultivated areas with the adequate quantities of necessary nutrients for growth and development. [6]. One of the most important yield- generating elements is nitrogen. It substantially determines the fertility level of soils and obtained yields [7]. However, an excessive mineral fertilization can significantly deteriorate the quality of grasses [8].

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This paper presents the results of research aimed at identifying the impact of different doses of nitrogen fertilizers on the soil properties, yielding of plants and usable values of the grass in the area of sulphuric mining activities, where the recultivation efforts were carried out.

Material and methods

The research was conducted in the former sulphur mine 'Jeziórko' near Tarnobrzeg in Podkarpackie province, which was subjected to rehabilitation treatment. The recultivation included the neutralization, blockade and isolation of contamination, regulation of water conditions, cleaning of the terrain, mineral and organic fertilization and the introduction of vegetation. The last step in the biological rehabilitation was sowing of a grass and *Fabaceae* mixture and a supplementary fertilization.

The experiment was founded on a separate area, which had been prepared for the final phase of the recultivation. The experiment with 4 different doses of nitrogen fertilizers – 80 kg N · ha^{-1}, 160 kg N · ha^{-1}, 240 kg N · ha^{-1}, 320 kg N · ha^{-1}, each with 3 replications, was set up on the prepared fields covering a surface of 100 m^2. These fertilizers were sown in 3 doses: 50 % before sowing a mixture of grasses, 30 % after the first swath, 20 % after the second swath. The check plots were not fertilized.

In May of 2000 the fields were sown with a prepared grass mixture of 60 kg · ha^{-1}, which included: Meadow fescue *Festuca pratensis* 58 %, Red fescue *Festuca rubra* 15 %, Italian ryegrass *Lolium multiflorum* 14 %, Red clover *Trifolium pratense* 8 % and Cocksfoot *Dactylis glomerata* 5 %.

Before sowing the mixture of grass, the soil samples (0–20 cm level) for the laboratory analysis had been collected from each plot. These samples were dried, sifted through a sieve with a mesh with 1 mm openings. Then, the following indications were made: the granulometric composition due to Cassagrande method with the Proszynski modification, the soil reaction (potentiometrically in $H_2O_{dist.}$ and 1 M KCl), the organic matter quantity (Tiurin method) and the sulphur content (nefelometric method). The soil properties study was also carried out in autumn of 2000 and spring and autumn of 2001, while cropping of the plants (spring and autumn swath).

To determine the effect of nitrogen fertilization on the yielding of plants and the value of agricultural grass in the autumn of 2000 and in spring and autumn of 2001 the vegetation test samples were collected from the surface of 1 m^2. Based on the botanical-gravimetric analyses according to Filipek [9] the number of usable value of grass (LWU) was calculated. The obtained data was analyzed with a Tukey statistical test.

Results and discussion

The results of soil tests carried out before the foundation of the experience revealed considerable variation in the properties of the soil environment. The plots was established on soils granulometrically composed of loose sand. Soil reaction ranged

from very strongly acid to slightly acid (Table 1). The lowest reported reaction was in the plot number 3, where the highest sulphur content was found.

Table 1

The proprieties of soil environment before installed experience 1 – plot without fertilization, 2 – 80 kg N · ha^{-1}, 3 – 160 kg N · ha^{-1}, 4 – 240 kg N · ha^{-1}, 5 – 320 kg N · ha^{-1}

Plot	pH		Organic matter [%]	S-total [mg · kg^{-1}]	S-sulphate [mg · kg^{-1}]
	H_2O	KCl			
1	6.5	6.1	3.07	192	89
2	4.9	4.4	3.26	406	322
3	4.5	4.1	3.34	797	645
4	5.6	5.3	3.36	267	145
5	6.3	6.0	3.24	187	53

Very wide variations in the sulphur content (the total sulphur and sulphate) were found in the tested area. The studied soils contained from 187 mg · kg^{-1} (plot no. 5) to do 797 mg · kg^{-1} of total sulphur. The sulphur content found in the investigation area exceeds the average quantity of this element in Polish soils. Motowicka-Terelak and Terelak [10] report that the amount of total sulphur in Polish sandy soils ranges between 100 and 270 mg · kg^{-1}, and the amount of sulphate ranges between 16 and 169 mg · kg^{-1}. The test plots were also characterized by the slight diversity of organic matter – from 1.78 % to 1.95 %.

The differences in the properties of the soil environment were observed after sowing the mixture of grass and after the application of nitrogen fertilizers. The intensive development of plants in the first year of experience affected the soil reaction. A slight increase in the pH value was observed in almost all of the plots. The only one with reduced pH values was the plot number 3 – the one with the highest sulphur content. The growth of the mixture of grasses and papilionaceous plants contributed to the increase of organic matter content in soil. The largest increase in humus in relation to its quantity before the foundation of experience (about 20 %), was registered in the plots where the nitrogen was applied in a dose of 240 kg · ha^{-1}. In the plots with the highest dose of nitrogen fertilization the increase in the amount of organic matter was about 17 % smaller (Tables 1, 2).

Sulphur is one of the fundamental macroelements necessary for the proper development of plants. Plants absorb this element from the soil mainly in the form of SO_4^{2-} [10, 11]. Therefore, the development of plants in the first year of the experience contributed to the reduction of the amount of sulphur in the soil, both in the total form and as sulphate. The total sulphur content in the soil in the tested fields decreased proportionally with the increasing doses of nitrogen fertilizers (Fig. 1a). In the plot number 4, which got a nitric fertilizer in a dose of 240 kg · ha^{-1} the total amount of sulphur decreased by 17 %. In the plot number 5, where the quantity of sulphur was the lowest and the applied dose of nitrogen the highest, the total sulphur content decreased by 27 %. In the plot, that did not get any nitrogen fertilization the total sulphur content

Table 2

The proprieties of soil environment and crop of plants characteristic 1 – plot without fertilization, 2 – 80 kg N · ha^{-1}, 3 – 160 kg N · ha^{-1}, 4 – 240 kg N · ha^{-1}, 5 – 320 kg N · ha^{-1}

Plot	pH		Organic matter [%]	Crop of plants [Mg · ha^{-1}]	Number of usable value of plants LWU
	H_2O	KCl			
IX 2000					
1	6.6	6.3	3.64	3.24	9.77
2	5.2	4.4	3.78	3.26	8.98
3	4.8	3.8	3.91	3.42	9.63
4	5.9	5.5	4.05	3.35	9.87
5	6.1	6.0	3.81	2.79	9.83
Mean	5.7	5.2	3.84	3.21	9.62
$LSD_{0.05}$	0.30	0.22	0.20	—	1.02
V 2001					
1	6.6	6.4	3.91	3.89	9.61
2	5.3	4.6	3.86	6.22	9.55
3	4.6	3.9	3.95	5.18	9.42
4	5.7	5.3	4.21	4.14	9.69
5	5.9	5.7	4.05	4.92	9.56
Mean	5.6	5.2	4.00	4.87	9.57
$LSD_{0.05}$	0.37	0.47	0.15	1.55	0.25
IX 2001					
1	6.6	6.3	4.00	2.84	9.62
2	5.3	4.7	3.90	4.99	9.01
3	4.9	4.4	4.00	4.11	9.12
4	5.8	5.6	4.29	3.38	9.14
5	6.0	5.9	4.47	4.97	9.18
Mean	5.7	5.3	4.13	4.06	9.21
$LSD_{0.05}$	0.34	0.43	0.38	—	—

decreased only by 4 %. The amount of sulphur in the form of sulphate in the soil during the first year of experience altered more. The biggest changes in the content of sulphate was found in the plots with the lowest and the highest dose of nitrogen. The smallest change in the amount of sulphate in the soil was recorded in the plot number 3 and in the check plot (Fig. 1b).

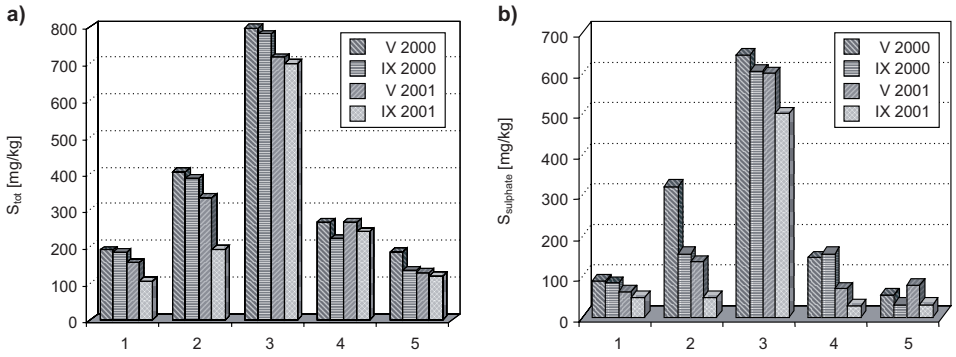

Fig. 1. Change of total sulphur and sulphate sulphur content in soil of plot with nitrogen fertilization (1 – 0 kg N · ha^{-1}, 2 – 80 kg N · ha^{-1}, 3 – 160 kg N · ha^{-1}, 4 – 240 kg N · ha^{-1}, 5 – 320 kg N · ha^{-1})

The highest yield of hay in the first year of experience was obtained by applying nitrogen fertilizer at a dose of N-160 kg · ha^{-1} (Table 2). The yield of plants obtained in this combination was 3.42 Mg · ha^{-1}. The smallest yield of the dry weight was found where the highest dose of nitrogen (320 kg · ha^{-1}) was applied. In terms of agricultural usefulness the meadow grass was valued as very good in the first year of vegetation. The highest number of utility value of the grass was found in the plot where the nitrogen was applied in a dose of 240 kg · ha^{-1}, where the LWU was 9.87.

The analysis of soil in the spring of the second year of experience showed a little change of the reaction. A considerably decrease in pH was found in the plots with the highest doses of nitrogen (Table 2). The studies of Wasilewski [12] confirm such a dependence. He found that higher nitrogen fertilization results in significantly lower pH values in the long- term pastures.

Further development of plants caused a reduction in the average sulphur content in the tested soils. There was more than a double increase in the sulphate content in the plot number 5 which is undoubtedly a result of the considerable variation in the soil environment in the rehabilitated sulphur mining areas.

In the soil of all of the plots, there was a increase in the amount of organic matter. As confirmed by a statistical analysis, higher doses of nitrogen fertilizers (240 kg · ha^{-1} and 320 kg · ha^{-1}) considerably influenced the content of organic matter in soil (appropriately by 4 % and 6 %).

The sulphur content in the soil in the spring of the second year of experience was significantly diversified. The average quantity of total sulphur and sulphur in the sulphate form in the soil decreased. The only plot with the same total sulphur content as it had been before the foundation of experience was the plot with the dose of nitrogen of 240 kg · ha$^{-1.}$ It is explained by a very strong transformation of the soil environment, the rehabilitation and the easy movement of sulphur in the studied area.

The yield of hay in the spring of 2001 increased twice in comparison with the previous autumn crop. The highest average yield, which was 6.22 Mg · ha^{-1} was obtained from the plots with the lowest (80 kg · ha^{-1}) dose of nitrogen. The combinations with the highest doses of nitrogen gave considerably lower crop of hay. In

the plot where nitrogen was applied 240 kg · ha^{-1} the yield of hay was lower by 34 % in comparison, in the plot with highest doses of nitrogen the yield decreased by 21 %. The smallest hay yield – 3.89 Mg · ha^{-1} was obtained from the plots without nitrogen fertilizer application. Obtained test results allow to value the grass as a very good. The highest number of utility value of the grass – 9.69 was obtained using nitrogen in a dose of 240 kg · ha^{-1}. These results confirm the results of several studies [8, 13, 14], which found that the mineral fertilizers, especially nitrogen, contributes positively to improvement of the quality of grass. The number of utility value of grass with the nitrogen in a dose of 80 kg · ha^{-1} and 160 kg · ha^{-1} showed significant statistical differences.

The study of soils in autumn in the second year of experience showed the increase of the reaction only in the plot with the nitrogen fertilizer in a dose of 240 kg · ha^{-1} (Table 2). The increase in organic matter content in soils of all examined fields in relation to the amount before the foundation of experience was found. In the plot number 5, where the nitrogen fertilizer was applied in a dose of 320 kg · ha^{-1} the organic matter content in soil increased by 14 % and in the plot number 4 it increased by 12 %.

The growth of plants contributed to a sulphur content reduction in the studied soils (Table 2). The average content of total sulphur in the soil decreased by 27 % and sulphate form of sulphur by 48 % compared with the quantity before the foundation of experience. The largest amount of sulphur (total and sulphate) was absorbed by the plants in the plot with the nitrogen fertilizer in a dose of 80 kg · ha^{-1}. The sulphate form of sulphur is the primary source of sulphuric acid in the soil, and at the same time it is a source of sulphur which is necessary for plants and microbes. It is important to note that even a small proportion of sulphates in the soil meets the needs of plant and animal organisms [10]. The lowest amount of sulphur was absorbed by the plants in the plot with higher dose of nitrogen (160 kg · ha^{-1} and 240 kg · ha^{-1}).

Dry matter yields from autumn 2001 swath were lower compared with yields from the spring one. At the same time, these yields were higher than the yields obtained in the first year of experience. The highest yield of 4.99 Mg · ha^{-1} was obtained with the application of the lowest dose of nitrogen. Higher doses of nitrogen reduced the yield from the autumn swath. Krzywy [1] showed similar results of nitrogen fertilization in the experience with Cocksfoot. He adopted the optimum nitrogen fertilization in the dose of 180 kg · ha^{-1}. In terms of agricultural usefulness the meadow grass was estimated, as in the other periods of research, as very good.

Conclusions

Areas anthropogenically transformed under the influence of sulphur mining activities have very variable characteristics of the soil environment, making it difficult to determine the doses of nitrogen fertilization in the final stage of plants rehabilitation.

The nitrogen fertilization positively influenced the properties of soil environment in the recultivated area. The increasing dose of nitrogen contributed to the vigorous growth of plants, which resulted in a reduction in the sulphur content in the soil, changes of the soil reaction and a significant increase in the content of organic matter in soil.

The mix of grasses introduced into the rehabilitated area positively responded to the nitrogen fertilization, which positively affected the yield of plants obtained. The highest yield of grass (6.22 Mg · ha^{-1}) was obtained in the second year after the introduction of plants, with the nitrogen application in a dose of 80 kg · ha^{-1}.

The nitrogen fertilization of the mix of grasses positively affected the quality of yield. The highest utility value was obtained in autumn swath in the first year of experience with the fertilization with nitrogen in a dose of 240 kg · ha^{-1}.

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WPŁYW ZRÓŻNICOWANYCH DAWEK AZOTU NA GLEBĘ ORAZ JAKOŚĆ ROŚLIN UPRAWIANYCH NA REKULTYWOWANYCH TERENACH GÓRNICZYCH

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Abstrakt: Celem pracy było określenie wpływu zróżnicowanych dawek nawozów azotowych na właściwości gleby oraz na plonowanie roślin i wartość użytkową runi na obszarze działalności górnictwa siarkowego, na którym przeprowadzono zabiegi rekultywacji. Stwierdzono, iż wysiew mieszanki roślin trawiastych oraz zastosowanie nawożenia azotowego na rekultywowanym obszarze znacznie poprawia właściwości środowiska glebowego. Wzrastające dawki azotu przyczyniły się do intensywnego rozwoju roślin, co spowodowało zmniejszenie zawartości siarki, zmiany odczynu oraz znaczny wzrost zawartości substancji organicznej w glebie. Uzyskane wyniki wykazały, że mineralne nawożenie azotowe wpływa dodatnio na ilość plonu roślin a także na jakość uzyskanej runi.

Słowa kluczowe: nawożenie azotem, tereny rekultywowane, plon roślin