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Monika SPOREK[1], Agata JURASZ[1] and Tomasz CIESIELCZUK[2]

EFFECT OF FERTILISATION ON THE CHANGES OF SOIL pH AND EXCHANGEABLE ALUMINIUM CONTENT IN SOIL

WPŁYW NAWOŻENIA NA ZMIANY ODCZYNU ORAZ ZAWARTOŚCI GLINU WYMIENNEGO W GLEBIE

Abstract: We assessed the level of acidification of the soil and the content of exchangeable aluminium in relation to the type and dose of mineral fertiliser. The study was based on a vase experiment with barley of the brewery variety Propino. The results showed that mineral fertilizing with NPK combined with ammonium nitrate gave the highest acidification and the highest contents of exchangeable aluminium. Calcium sulphate applied in different doses did not change soil reaction, and the content of exchangeable aluminium was lower than when combination of NKP fertilizing and ammonium nitrate was applied.

Keywords: acidification, exchangeable aluminium, mineral fertilization, *Hordeum vulgare*

One of the most important problems of agricultural production in the world is extensive and retaining acidification of soils [1]. In conditions of acidic soils typical for Poland the content of exchangeable aluminium in soil, which causes decrease in the quality of cultivated plants [2, 3], is one of the main factors that affect crops. Aluminium occurs in its insoluble forms in soils of the neutral and acidic reaction. With a decrease of pH aluminium changes into forms that dissolve in soil solution and are toxic for plants. The most toxic forms for plants are $AlO_4Al_{12}(OH)_{24}(H_2O)_{12}^{+7}$ (commonly denoted as Al_{13}) and $Al(H_2O)_6^{+3}$ (denoted as Al^{+3}) [4]. Unbalanced fertilizing without application of lime leads to strong acidification of soil, which causes considerable decrease in crops of cultivated plants, including barley.

This study was aimed to determine the effect of the fertilizer dose on the soil reaction and the content of exchangeable aluminium. In the experiment we used calcium sulphate ($CaSO_4 \cdot 2H_2O$) which is a waste during gas desulphurisation in heat and power stations.

Material and methods

We conducted the vase experiment with barley of the brewery variety Propino in 2014. The experiment was designed with the method of independent series in three repetitions and five variants. Dosing of fertiliser was conducted according to the methods of vase experiments:

- variant I: control cultivation without fertilizing;
- variant II: mineral fertilizing NPK at a dose of 20 g/12 dm^3;
- variant III: mineral fertilizing NPK at a dose of 20 g/12 dm^3, ammonium nitrate at two doses of 6 g/12 dm^3;

[1] Ecology and Nature Protection Unit, Chair of Biotechnology and Molecular Biology, Opole University, ul. kard. B. Kominka 6A, 45-035 Opole, Poland, phone +48 77 401 60 60, email: mebis@uni.opole.pl
[2] Faculty of Natural Sciences and Technology, Opole University, ul. Oleska 48, 45-052 Opole, Poland, email: tciesielczuk@uni.opole.pl
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- variant IV: mineral fertilizing NPK at a dose of 20 g/12 dm^3, ammonium nitrate at two doses of 6 g/12 dm^3 and calcium sulphate at a dose of 15 g/12 dm^3;
- variant V: mineral fertilizing NPK at a dose of 20 g/12 dm^3, ammonium nitrate at two doses of 6 g/12 dm^3 and calcium sulphate at a dose of 30 g/12 dm^3.

Soil used in the experiment was prepared earlier and fitted into 15 vases. The initial pH of the soil was measured. After four months of growth we again measured pH of soil and checked exchangeable aluminium by the method of Sokolow [5]. During growth period we determined the relative content of chlorophyll using chlorophyll meter CCM 200.

Results and discussion

In Poland at present 20% of arable soils have strongly acidic reaction (below 4.5 pH). Acidic and strongly acidic soils form 50% of arable land [6]. Optimum pH of soil enables proper growth and function of the root system that supplies plants with sufficient in water and nutrients, which provides high crop of good quality with efficient use of fertilizers [7]. Outwashing of calcium by rainwater, about 140 kg CaO/ha during a year, is the main cause for strong acidification of soils retained on a large area of Poland. Light and very light soils are particularly susceptible to washing out of calcium [8]. Retaining low pH (very acidic) in soils leads to their chemical degradation. This includes increase of concentrations of aluminium and manganese which are toxic for plants, and freeing heavy metals, mostly cadmium, zinc, lead and nickel, alongside with depletion of magnesium available for plants in soil. Highly acidic heavy soils deteriorate in structure which creates hydrological and aerial conditions unfavourable for plants.

Table 1

Reaction of soil used in the experiment

Repetitions	**pH [-]**	
	H_2O	**KCl**
1	4.98	4.50
2	4.99	4.59
3	5.04	4.82
Means (pH)	5.00	4.64

Table 2

Reaction of soil after the experiment in different variants

Repetitions	**pH [-]**									
	I		**II**		**III**		**IV**		**V**	
	H_2O	KCl	H_2O	KCl	H_2O	KCl	H_2O	KCl	H_2O	KCl
1	4.98	4.93	5.06	4.71	4.22	4.05	4.59	4.41	4.45	4.05
2	5.05	4.69	5.00	4.61	4.44	4.12	4.47	4.40	4.25	4.27
3	5.10	5.01	4.94	4.61	4.30	4.10	4.55	4.33	4.53	4.38
Means (pH)	5.04	4.88	5.00	4.64	4.32	4.09	4.54	4.38	4.41	4.23

Soil reaction measured before and after the experiment was acidic (Tables 1 and 2). Calcium sulphate did not change pH of soil despite it contains calcium. Thus it is unsuitable for improvement of reaction of acidic soils, but might be good fertilizer for soils of alkaline reaction with a deficiency of calcium. In such soils availability of calcium from chalk or

dolomite would be too low for plants. Thus application of calcium sulphate might give good results in soils where calcium occurs in soil in a form temporarily unavailable for plants.

In our study the control variant had low content of aluminium - 0.39 mg/100 g of soil, and variant I, where only NPK fertilizing was applied - 0.55 mg/100 g of soil (Table 3). Similarly low content of exchangeable aluminium at 0.4 mmol(+)·kg^{-1} (0.36 mg/100 g) was noted in studies of Rutkowska et al [3], also for the control sample with no mineral fertilization. In our study the highest content of aluminium occurred with the combination of NPK fertilizing and ammonium nitrate (1.9-2.2 mg/100 g of soil) (Table 3, Fig. 1). The mean content of exchangeable aluminium was in this variant more than five times higher than in the control sample. The literature shows that ammonium nitrate causes acidification [9], which favours increase of the content of exchangeable aluminium in soil [10].

Table 3

Effect of fertilizing on changes in the content of exchangeable aluminium in soil

	Content of exchangeable aluminium Al_w^{3+} [mg/100 g]				
	Variant				
	I	**II**	**III**	**IV**	**V**
	0.433	0.276	2.244	1.536	1.457
	0.354	1.062	2.087	0.827	1.575
	0.394	0.315	1.969	1.221	1.457
$\bar{x}$	0.394	0.551	2.100	1.194	1.496

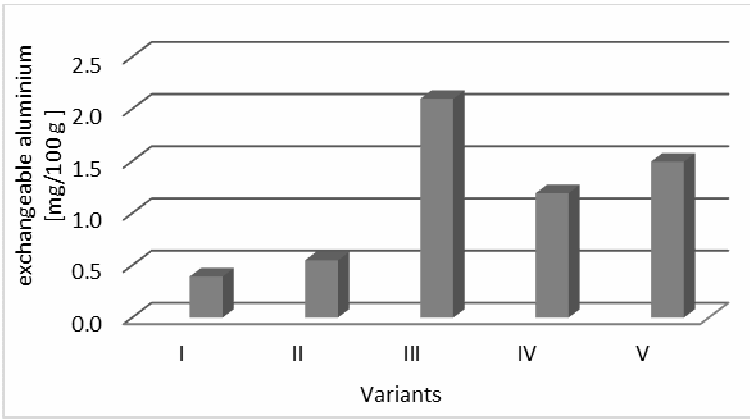

Fig. 1. Changes in exchangeable aluminium

Calcium sulphate used in different doses (variant IV and V) did not cause any change of the initial reaction of soil (Tables 1 and 2). We recorded three times higher content of exchangeable aluminium in the variant IV (1.2 mg/100 g of soil with the dose of calcium sulphate at 250 kg/ha) and more than three times higher in variant V (1.5 mg/100 g of soil with the dose of calcium sulphate 500 kg/ha). But in these variants also NPK with ammonium nitrate were applied, besides calcium sulphate. Ammonium nitrate causes decrease of soil pH and increase of the content of exchangeable aluminium, as shown in

variant III. Additional applying of calcium sulphate in the soil did not increase its reaction, but caused higher concentrations of exchangeable aluminium than in variant III.

The content of chlorophyll estimated in tissue of leaves using chlorophyll meter CCM 200 indicates varied in relation to applied fertilizing. This meter uses two wave length to determine absorbance. One wave length increases within the range of the absorbance by chlorophyll, while the other one is used to compensate for mechanical changes, such as thickness of the leaf. The meter measures transmittance of both wave lengths and calculates the CCI (Chlorophyll Content Index), which is proportional to the content of chlorophyll in a sample. Thus the value of the CCI is an index of a relative content of chlorophyll. The lowest CCI was recorded in the control variant. NPK fertilizing (variant II) or the combination of NPK with ammonium nitrate (variant III) cause small increase of the chlorophyll content in leaves of barley. Introducing calcium sulphate in the soil doubled the content of chlorophyll in relation to the control variant (Fig. 2).

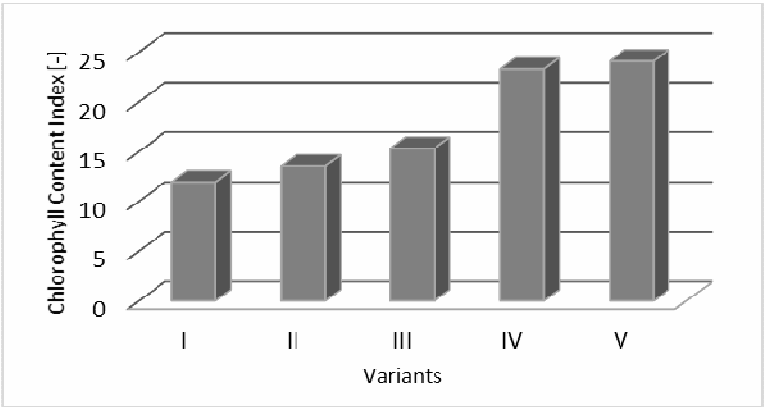

Fig. 2. Relative content of chlorophyll in leaves of barley

Mineral fertilizing in one of the most important factors that affect the amount of crop [11]. Application of calcium sulphate ($CaSO_4 \cdot 2H_2O$) in agriculture and gardening in Poland is not a common practice.

Studies in this direction should be continued with extended diagnostics including the value of crop, the content of protein in crop, and the control of the chemical content of barley. Preliminary results in this direction show that it is rather the chemical content of the waste from gas desulphurisation will be decisive for its commercial application in agriculture [12].

Conclusions

Based on the study the we drew the following conclusions:

1. NPK fertilising with ammonium nitrate increased acidic reaction and the content of exchangeable aluminium in soil.
2. Calcium sulphate did not cause change of soil pH, thus it can be used as fertilizers on soils of alkaline reaction with a deficit of calcium.

3. Application of calcium sulphate had a positive effect in on the content of chlorophyll in leaves of barley.

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[1] Samodzielna Katedra Biotechnologii i Biologii Molekularnej, Uniwersytet Opolski
[2] Samodzielna Katedra Ochrony Powierzchni Ziemi, Uniwersytet Opolski

Abstrakt: W pracy oceniono stopień zakwaszenia gleby oraz zawartość glinu wymiennego w zależności od rodzaju zastosowanego nawozu mineralnego oraz jego dawki. Badania prowadzono w oparciu o doświadczenie wazonowe z jęczmieniem jarym odmiany browarniczej Propino. Uzyskane wyniki wskazują, że największe zakwaszenie oraz największe zawartości glinu wymiennego stwierdza się w warunkach stosowania nawożenia w kombinacji NPK wraz z saletrą amonową. Zastosowany w różnych dawkach siarczan wapnia dwuwodny nie wpłynął na zmianę odczynu gleby, a odnotowana zawartość glinu wymiennego była niższa niż w kombinacji NPK wraz z saletrą amonową.

Słowa kluczowe: zakwaszenie, glin wymienny, nawożenie mineralne, jęczmień jary