

THE EFFECT OF VARIOUS SYSTEMS OF MINERAL FERTILIZATION ON THE CONTENT OF AVAILABLE FORMS OF PHOSPHORUS, POTASSIUM AND MAGNESIUM IN BROWN SOIL FORMED FROM LOESS

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A b s t r a c t. The paper presents the results of the study of 3 experiments carried out on brown soil derived from loess in the permanent fertilization field located in Rzeszów Submountaine Region, pertaining to the effect of mineral NPK fertilization applied against the background of the constant dose of farmyard manure, magnesium and magnesium combined with liming, on the content of available forms of phosphorus, potassium and magnesium. The experiments were carried out on acid soil with high phosphorus and magnesium and medium potassium availability as well as on a very acid soil with low phosphorus and potassium availability and medium magnesium availability. During the four-year long period of plant cultivation in crop rotation with differentiated mineral NPK fertilization against the background of the constant dose of farm manure, magnesium and magnesium combined with liming, the decrease in the available magnesium content in all the fertilization objects and the decrease in phosphorus and potassium contents in the objects without the NPK fertilization was found.

K e y w o r d s: NPK fertilization, available macronutrients, crop rotation, loessial soil

out the research pertaining to the interaction of the mineral fertilization and liming on the content of available phosphorus and potassium. The comparison of the effect of farmyard manure and mineral fertilizers on the content of available forms of potassium, phosphorus and magnesium [6] is also interesting. In spite of the often occurring magnesium deficiency, in the acidified soils not many authors carried out the research pertaining to the content of this component.

The aim of the present research was to determine the effect of the differentiated mineral fertilization: NPK+farmyard manure, NPK+Mg and NPK+Mg+Ca in the 4-year long crop rotation on the content of the available forms of potassium, phosphorus and magnesium in the acidified brown soil formed from loess.

INTRODUCTION

The long-term application of the mineral fertilization influences not only the quality and quantity of crop, but also soil environment [1-9]. The studies pertaining to the effect of mineral fertilization on the available phosphorus content were carried out by several authors [3-6,8], as well as the research on the available potassium content [1-9] and available magnesium content [1,5,7,9,]. Other authors [3,5] carried

MATERIALS

The research was carried out on the basis of 3 experiments located on a permanent fertilization field in the area of Rzeszów Submountaine Region. Various systems of plant fertilization were applied in these experiments. In the experiment I which was carried out in the years 1982-85, a differentiated mineral NPK fertilization was applied against the background of a constant dose of farmyard manure (FYM - 25 t/ha/ year). The plants

were cultivated in the following crop rotation: potatoes, spring barley, fodder sunflower, and winter wheat in this experiment. In the years 1986-89, two experiments were carried out, in which differentiated mineral NPK fertilization against the background of constant fertilizing with magnesium was applied (experiment II), as well as the differentiated mineral NPK fertilization against the background of constant fertilization with magnesium and liming- 4 t CaO/ha (experiment III).

The soil, on which the experiment II was carried out in the years 1982-85 was of acid reaction, high available phosphorus and magnesium contents and medium potassium content. The experiment in the years 1986-89 was carried out on a very acid soil with the low content of available phosphorus and magnesium and medium potassium content. The crop rotation in the experiments carried out in the years 1986-89 was similar with the exception of the fodder sunflower which was replaced by fodder cabbage. The remaining plants and mineral NPK fertilization was identical.

In these experiments 13 fertilizing objects were compared, where the basic level of $N_{1.5}P_1K_1$ fertilizations was the following:

- potatoes (AtoI): N - 120 kg, P_2O_5 - 100 kg, K_2O -160 kg/ha/year ;
- spring barley (Diva): N - 80 kg, P_2O_5 - 100 kg, K_2O - 120 kg/ha/year;
- fodder sunflower (Iregi): N - 100 kg, P_2O_5 - 90 kg, K_2O - 100 kg/ha/year;
- winter wheat (Emika): N - 100 kg, P_2O_5 - 90 kg, K_2O - 100 kg/ha/year;
- fodder cabbage (Puławska zielona): N -120 kg, P_2O_5 - 60 kg, K_2O -100 kg/ha/year.

In the experiments II and III, magnesium was applied in the dose of 40 kg MgO /ha under fodder cabbage in the form of magnesium sulphate. Nitrogen was applied in the form of ammonium nitrate, phosphorus in the form of triple superphosphate, potassium in the form of potassium salt (57 %) and lime was applied in the form of burnt lime (85 %) in the amount of 4 t CaO/ha.

Each year, after harvesting the crops, soil samples were taken from A_1 horizon of the sub-

sequent fertilization objects. Available phosphorus and potassium were determined with Egner-Riehm's method and available magnesium with Schachtschabel's method. The results of phosphorus, potassium and magnesium analyses were worked out statistically by calculating LSD according to Dunnet with the aim of comparing the average contents of available components from the subsequent fertilization objects after 4 years of crop rotation and fertilizing to the respective initial contents (before starting the experiment).

RESULTS

The contents of available phosphorus, potassium and magnesium depending on the mineral NPK fertilization against the background of the constant doses of farmyard manure, magnesium and magnesium combined with liming are given in Table 1.

The content of available phosphorus in the carried out experiments was the highest in the objects with the highest dose of mineral fertilizers: $N_{1.5}P_{1.5}K_{1.5}$ and the lowest in the objects without NPK fertilization. Low phosphorus content was also noted in the objects without phosphorus with the exception of the phosphorus objects from the NPK experiment against the background of the constant dose of magnesium combined with liming.

The increasing NPK fertilization at the constant ratio of N:P:K increased the content of available phosphorus in soil at all the systems of fertilizing such as: NPK+FYM and NPK+Mg and NPK+Mg+Ca.

After 4 years of the cultivation of plants in the plant cropping system and the differentiated mineral NPK fertilization against the background of the constant dose of FYM magnesium, and magnesium combined with liming, the average content of available phosphorus increased significantly only in the experiments with the highest dose of NPK ($N_{1.5}P_{1.5}K_{1.5}$). However, the content of phosphorus in the experiments I and II in the objects without NPK and without the fertilization with phosphorus decreased in a small degree.

The liming applied in the experiment III

Table 1. The effect of mineral fertilization on the content of available forms of phosphorus, potassium and magnesium (in mg P, K, Mg/kg soil) on the background of FYM, magnesium and magnesium+liming application in a 4-year crop rotation (mean values for 4 years)

Fertilization objects	Experiment I NPK+FYM			Experiment II NPK+Mg			Experiment III NPK+Mg+Ca		
	P	K	Mg	P	K	Mg	P	K	Mg
Nitrogen fertilization on the background of constant PK									
$N_0P_1K_1$	65.6	162.8	130	30.4	170.3	44.5	34.9	244.1	29.0
$N_{0.5}P_1K_1$	65.8	162.8	140	28.6	159.0	41.5	32.0	146.1	64.5
$N_1P_1K_1$	68.3	162.0	137	28.0	166.4	48.7	29.2	200.9	66.0
$N_{1.5}P_1K_1$	66.8	178.0	133	22.8	171.6	51.7	35.4	196.3	57.0
Phosphorus fertilization on the background of constant NK									
$P_0N_1K_1$	63.0	178.4	133	18.4	173.5	60.2	32.9	189.7	42.0
$P_{0.5}N_1K_1$	66.1	166.9	140	18.6	161.8	58.7	34.3	231.1	42.2
$P_1N_1K_1$	68.3	162.0	137	28.0	166.4	48.7	29.2	200.9	66.0
$P_{1.5}N_1K_1$	73.6	164.5	144	30.9	163.3	63.2	37.1	171.8	56.0
Potassium fertilization on the background of constant NP									
$K_0N_1P_1$	75.6	104.7	144	28.7	120.7	42.5	29.9	123.7	52.5
$K_{0.5}N_1P_1$	65.9	125.4	149	27.2	157.3	53.5	34.2	210.4	45.5
$K_1N_1P_1$	68.3	162.0	137	28.0	166.4	48.7	29.2	200.9	66.0
$K_{1.5}N_1P_1$	65.9	179.4	159	28.9	170.8	40.5	34.9	237.4	25.0
NPK fertilization at a constant N:P:K ratio									
$N_0P_0K_0$	60.5	103.7	140	18.3	84.3	28.7	28.0	118.7	32.7
$N_{0.5}P_{0.5}K_{0.5}$	67.1	121.3	149	27.7	158.9	60.7	28.9	232.8	56.7
$N_1P_1K_1$	68.3	162.0	137	28.0	166.4	48.7	29.2	200.9	66.0
$N_{1.5}P_{1.5}K_{1.5}$	91.5	208.4	156	36.9	156.6	45.2	40.8	254.7	41.0
Before setting-up the experiment	65.0	161.8	185	23.5	124.5	68.0	23.5	124.5	68.0
LSD at P=0.05	19.0	24.5	16.8	13.2	23.0	8.8	16.0	28.8	8.2

significantly mobilized the available phosphorus in soil, because the average content of the available phosphorus from the subsequent fertilization objects was always higher than the phosphorus content in soil before starting the experiment comparing to the respective objects in the experiment II, in which liming was not applied.

The content of available potassium was the highest in the objects with the highest potassium dose ($K_{1.5}P_1N_1$ and $N_{1.5}P_{1.5}K_{1.5}$) in the experiment I with the applied constant dose of farm manure, and the lowest in the objects without the NPK fertilization in all the experiments. In the experiments II and III, in which the NPK fertilization with magnesium and magnesium

combined with liming was applied this dependence did not always occurred. In all the experiments it is possible to note that the increasing potassium fertilization, both at the constant NP fertilization and the constant N:P:K ratios increased, in general, the content of available potassium in soil. The mineral NPK fertilization against the background of constant farm manure doses, magnesium and magnesium combined with liming in the 4-year long crop rotation, increased the content of available potassium in soil with the exception of the objects $N_0P_0K_0$ and $K_0N_1P_1$ and in the experiment with NPK+farm-yard manure with the exception of $K_{0.5}N_1P_1$ and $N_{0.5}P_{0.5}K_{0.5}$ in comparison to the

initial contents of available potassium.

The content of available magnesium in the brown soil formed from loess at the tested systems of fertilization after the 4-year long cultivation of plants in crop rotation was significantly lower in comparison to the initial content in spite of supplying soil with magnesium in farm manure and magnesium sulphate. No explicit effect of the increasing mineral fertilization with the subsequent elements and the proportional increase of NPK on the content of available magnesium in the A_1 horizon of brown soil formed from loess was noted.

DISCUSSION

The 4-year long cultivation of plants in the plant crop rotation system and differentiated mineral NPK fertilization against the background of constant fertilization with farmyard manure, magnesium and magnesium combined with liming modified the content of available forms of phosphorus, potassium and magnesium in the acidified brown soil formed from loess. Under the influence of the differentiated mineral NPK fertilization in the 4-year plant cropping system, the content of available phosphorus in soil fertilized with the highest dose of mineral NPK fertilizers increased significantly.

The increasing fertilization with phosphorus both at constant fertilization with the remaining components and proportional increase of all components increased in general the content of available phosphorus in the A_1 horizon of the acidified brown soil formed from loess.

The favourable influence of the fertilization with phosphorus on the content of this component in soil was noted by Wilk *et al.* [8]. Similar dependencies were obtained by Mercik *et al.* [4] in the long-term static experiments, achieving higher content of available phosphorus at phosphorus fertilization, and the lowest without fertilizing with phosphorus and lime against the background of constant NK.

The mineral NPK fertilization against the background of the constant dose of magnesium combined with liming increased available phosphorus content to a greater extent in comparison to NPK+Mg fertilization, which was con-

nected with the mobilization of phosphorus in soil under the influence of liming.

Moskal *et al.* [5] and Gajek *et al.* [3] obtained a significant increase of available phosphorus content at the application of mineral NPK fertilization and also after the liming of soil.

The content of available potassium was usually the highest after the application of the highest potassium dose, and especially after the application of the mineral fertilization with NPK+farmyard manure. The increasing fertilization with potassium against the background of constant NP fertilization at the constant N:P:K ratio increased, in general, the content of available potassium in A_1 horizon. Similar results were obtained by Demczuk *et al.* [2], who noted the lowest content of available potassium in the objects without potassium. Wilk *et al.* [8] obtained the increase in available potassium content in soil at complete NPK fertilization. Mercik *et al.* [4] noted the accumulation of available potassium as the result of long-term mineral fertilization in the objects with full mineral fertilization combined with liming. Moskal *et al.* [5] did not record the increase in available potassium content in the light textured soil as the result of liming and mineral fertilization. However, Gajek *et al.* [3] obtained the favourable effect of mineral NPK fertilization on the potassium content and not explicit effect of liming on the content of this component.

In my own research the liming of soil combined with mineral NPK+Mg fertilization increased the content of potassium in brown soil formed from loess comparing to the analogous fertilization objects NPK+Mg without liming. Dechnik *et al.* [1] noted the favourable effect of the fertilizing with potassium on the content of available potassium in brown soil formed from loess from the area surrounding Lublin. Wojnowska *et al.* [9] noted that the content of potassium was proportional to the fertilization with potassium in the 8-year long period of research.

Mineral NPK fertilization against the background of the constant dose of farmyard manure, magnesium and magnesium combined with liming in 4-year long crop rotation system decreased the content of available mag-

nesium in A₁ horizon of the acidified brown soil formed from loess. The application of 240 kg MgO/ha during the 4 years of cultivation did not increase the content of available magnesium in soil at such a high its acidification. No explicit effect of mineral NPK fertilization and the fertilization with the subsequent components against the background of the constant application of farm manure, magnesium and magnesium combined with liming on the content of available magnesium was noted. Ruszkowska *et al.* [7] noted especially high leaching of calcium and magnesium ions and not large elution of nitrogen and potassium ions, as well as the minimal elution of phosphorus ions in the strict lysimetric experiment with which would explain the lack of the enrichment magnesium of A₁ horizon of loess soils. Wojnowska *et al.* [9] recorded the increase in available magnesium content in the light acid soil formed from medium clay together with the increase of magnesium doses (up to 84 kg Mg/ha) in the 8-year long period of research. Dechnik *et al.* [1] on the basis of the research on brown soil formed from loess (the reaction - slightly acid to neutral) noted the very distinct decrease in available magnesium content under the influence of the fertilizing with high doses of nitrogen and potassium.

Nowosielski *et al.* [6] noted that the soil constantly fertilized with farmyard manure in comparison to the soil fertilized with mineral NPK fertilizers contains much more available phosphorus, potassium and magnesium.

CONCLUSIONS

1. The differentiated mineral NPK fertilization against the background the constant dose of farmyard manure, magnesium and magnesium combined with liming applied in the 4-year long crop rotation of plants modified the content of the available phosphorus forms, potassium and magnesium in the acidified brown soil formed from loess:

a) the increasing fertilization with phosphorus at the constant fertilizing with nitrogen and potassium and NPK fertilization at the constant N:P:K ratios increased the content of available

phosphorus in soil at all the systems of mineral fertilization;

b) the increasing fertilizing with potassium at the constant nitrogen-phosphorus fertilization and mineral NPK fertilization at the constant N:P:K ratios increased, in general, the content of available potassium in soil at the applied systems of mineral fertilization;

c) the increasing mineral fertilization with the subsequent components and the proportional increase of NPK did not have the explicit effect on the content of available magnesium in soil.

2. The mineral NPK fertilization decreased the average content of the available magnesium in soil during the 4-year long crop rotation as compared with the initial content in spite of supplying soil with magnesium in the farmyard manure and magnesium sulphate.

3. The highest content of available phosphorus and, in the majority of objects, of potassium was noted after the application of the highest doses of these components.

4. The lowest content of available phosphorus, potassium and magnesium in brown soil formed from loess was usually noted in the objects without NPK fertilization.

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**WPLYW RÓŻNYCH SYSTEMÓW NAWOŻENIA
MINERALNEGO NA ZAWARTOŚĆ
PRZYSWAJALNYCH FORM FOSFORU, POTASU
I MAGNEZU W GLEBIE BRUNATNOZIEMNEJ
WYTWORZONEJ Z LESSU**

W pracy przedstawiono wyniki badań 3 doświadczeń

prowadzonych na glebie brunatnoziemnej wytworzonej z lessu na stałym polu nawozowym położonym na Podgórzu Rzeszowskim, nad wpływem nawożenia mineralnego NPK zastosowanego na tle stałej dawki obornika, magnezu oraz magnezu wraz z wapnowaniem na zawartość przyswajalnych form fosforu, potasu i magnezu. Doświadczenia prowadzono na glebie kwaśnej o wysokiej zasobności w fosfor i magnez, a średniej w potas oraz bardzo kwaśnej glebie o niskiej zasobności w fosfor i potas, a średniej w magnez. W 4-letnim okresie uprawy roślin w zmianowaniu i zróżnicowanego nawożenia mineralnego NPK na tle stosowania stałej dawki obornika, magnezu oraz magnezu i wapnia stwierdzono obniżenie zawartości przyswajalnego magnezu na wszystkich obiektach nawozowych, oraz fosforu i potasu na obiektach bez nawożenia NPK.

Słowa kluczowe: nawożenie NPK, przyswajalne makroskładniki, zmianowanie roślin, gleba lessowa.