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EFFECT OF LONG-TERM DIFFERENTIATED FERTILIZATION WITH FARMYARD MANURE AND MINERAL FERTILIZERS ON THE CONTENT OF AVAILABLE FORMS OF P, K AND Mg IN SOIL

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Abstract

The investigations were carried out in 20022005, on proper grey-brown podsoilic soil originating from light loam (class IIIa in the soil valuation system, very good rye complex), on the basis of a two-factor experiment established in 1986 according to the random block design with four replications. The arable horizon of the soil, before the experiment, was characterized by slightly acidic reaction ($pH_{1 \text{ mol KCl dm}^{-3}}$ was 6.2) and the concentrations of available nutrients were as follows: 100.0 mg K, 53.2 mg Mg and 41.3 mg P kg^{-1} of soil. Soil samples for chemical tests were collected from the arable layer after harvesting crops grown in a rotation: sugar beet, spring barley, maize and spring wheat. The content of available forms of phosphorus and potassium were determined by Egner-Riehm method (DL), and that of manganese using Schachtschabel's method. The purpose of the study has been to determine the influence of mineral fertilization with or without FYM on the content of available macronutrients in soil. The statistical analysis of the results have shown a significant influence of manure on the level of available P, K and Mg in the tested soil. When both FYM and mineral fertilizers were introduced to soil, its abundance in available magnesium was 2.6-fold higher than after mineral fertilization alone had been applied. FYM raised nearly 3-fold the content of available forms of potassium in soil compared to the content found when only mineral fertilization was used.

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Key words: available nutrients (P, K, Mg), multi-year experiment, farmyard manure, mineral fertilization.

ODDZIAŁYWANIE WIELOLETNIEGO ZRÓŻNICOWANEGO NAWOŻENIA OBORNIKIEM I NAWOZAMI MINERALNYMI NA ZAWARTOŚĆ PRZYSWAJALNYCH FORM P, K I Mg W GLEBIE

Abstrakt

W latach 2002-2005 prowadzono badania na glebie płowej typowej wytworzonej z gliny lekkiej (klasa bonitacyjna IIIa, kompleks żytni bardzo dobry) oparte na dwuczynnikowym doświadczeniu, założonym w 1986 r. metodą losowanych bloków w czterech powtórzeniach. Warstwa orna gleby przed rozpoczęciem badań charakteryzowała się odczynem lekko kwaśnym ($pH_{1\ mol\ KCl \cdot dm^{-3}}$ wynosiło 6,2), a zawartość przyswajalnych składników pokarmowych kształtowała się na poziomie: 100,0 mg K; 53,2 mg Mg i 41,3 mg $P \cdot kg^{-1}$ gleby. Próbki gleby do analiz chemicznych pobierano z warstwy ornej po zbiorze roślin uprawianych w zmianowaniu: burak cukrowy, jęczmień jary, kukurydza, pszenica jara. Zawartość przyswajalnych form fosforu i potasu oznaczono metodą Egnera-Riehma (DL), a magnezu metodą Schachtschabela. Celem badań było określenie wpływu nawożenia mineralnego stosowanego z obornikiem lub bez obornika na zawartość przyswajalnych makroelementów w glebie. Analiza statystyczna wyników wykazała istotny wpływ obornika na zawartość przyswajanych form P, K i Mg w badanej glebie. Po zastosowaniu łącznie obornika i nawozów mineralnych stwierdzono średnio 2,4 razy więcej magnezu przyswajalnego oraz 2,6 razy więcej fosforu przyswajalnego w glebie w porównaniu z zawartością określoną po zastosowaniu nawożenia mineralnego. Nawożenie obornikiem spowodowało ponad 3-krotny wzrost zawartości przyswajalnych form potasu w glebie w porównaniu z zawartością określoną po nawożeniu mineralnym.

Słowa kluczowe: składniki przyswajalne (P, K, Mg), doświadczenie wieloletnie, obornik, nawożenie mineralne.

INTRODUCTION

The content of available nutrients (P, K and Mg) depends on the type of soil and its reaction, production intensity, rotation system, climatic conditions, organic and mineral fertilization, etc. Availability of nutrients increases under good mineral and natural fertilization (BARCZAK et al. 1999, MERCIK et al. 2000, SIENKIEWICZ et al. 2004). Frequent and intensive application of natural or mineral fertilizers alone may contribute to acidification of soil, causing, for example, retardation of phosphorus and reduced availability of calcium and magnesium to plants (ŁABĘTOWICZ et al. 1999, MERCIK et al. 2000, RICHTER et al. 2000). Another undesirable effect of unbalanced natural and mineral fertilization is the transfer of biogenic substances to waters (SPYCHAJ-FABISIAK et al. 1999, KOC et al. 2008, SKWIERAWSKI et al. 2008). Having applied full and balanced natural and mineral fertilization, one can notice an increase in the amounts of available nutrients, most probably caused by a higher capacity of the sorptive complex and improved buffer properties of soil (SIENKIEWICZ 2003).

The objective of this study has been to follow the effect of mineral fertilization applied with or without farmyard manure on the content of available forms of potassium, phosphorus and magnesium in soil.

MATERIAL AND METHODS

The study was conducted in 2002-2005, on proper grey-brown podsolic soil originating from light loam (class IIIa in the soil valuation system, very good rye complex), based on a two-factor experiment established in 1986 according to the random block method with four replications. The first-order factor consisted of natural fertilization (with or without FYM), while the second-order factor comprised differentiated mineral fertilization: treatments: $N_0P_0K_0$, $N_1P_1K_1$, $N_2P_1K_1$, $N_3P_1K_1$, $N_2P_1K_2$, $N_2P_1K_3$, $N_2P_1K_2Mg$, $N_2P_1K_2MgCa$. The design of the experiment as well as the rates of fertilizers can be found in Table 1. In each year, the same crop was tested on both fields (with or without FYM). Soil samples for chemical analyses were collected from the arable horizon after harvesting the crops grown in a rotation system: sugar beet, spring barley, maize and spring wheat. The content of available forms of phosphorus and potassium were determined by Egnar-Riehm method (DL), whereas that of magnesium according to Schachtschabel.

Table 1

Fertilization of crops ($kg \cdot ha^{-1}$)

Element	Sugar beet	Spring barley	Maize	Spring wheat
N_1 N_2 N_3 P_1 (P/P_2O_5) K_1 (K/K_2O) K_2 (K/K_2O) K_3 (K/K_2O) Mg (Mg/MgO) Ca (Ca/CaO)	60 120 180 34.9/80 66.4/80 132.8/160 199.3/240 48.2/80 1787/2500	30 60 90 34.9/80 33.2/40 66.4/80 99.7/120 18.1/30	60 120 180 26.2/60 49.8/60 99.7/120 149.5/180 24.1/40	40 80 120 34.9/80 24.9/30 49.8/60 74.7/90 18.1/30
FYM ($t \cdot ha^{-1}$)	40		40	

RESULTS AND DISCUSSION

Joint application of FYM and mineral fertilization or mineral fertilization alone over many years has largely modified the abundance of soil in the basic macronutrients (P, K and Mg). The content of available forms of phosphorus in soil fluctuated from 36.1 to 182.5 mg kg^{-1} (Table 2). FYM introduced to soil every two years improved the resources of available phospho-

Table 2

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

Factor I	Factor II								Mean
	$N_0P_0K_0$	$N_1P_1K_1$	$N_2P_1K_1$	$N_3P_1K_1$	$N_2P_1K_2$	$N_2P_1K_3$	$N_2P_1K_2Mg$	$N_2P_1K_2MgCa$	
FYM	124.7	150.0	149.8	142.1	142.0	149.9	145.5	182.5	148.3
Without FYM	36.1	57.4	51.7	47.3	51.3	53.5	61.8	87.2	55.8
Mean	80.4	103.7	100.8	94.7	96.7	101.7	103.6	134.9	

$LSD_{0.05}$ for the factor I – 6.79
$LSD_{0.05}$ for the factor II – 7.73
$LSD_{0.05}$ for interaction I×II – n.s.

rus in soil by an average of over 165%. Such beneficial influence of FYM was most evident in the soil which did not receive mineral fertilization, but was the weakest under balanced mineral fertilization including calcium and magnesium. The content of available P was less positively affected by mineral fertilization. A clear tendency appeared towards depressing the content of this nutrient in soil as the rates of nitrogen increased. This effect was most clearly seen in the soil amended only with mineral fertilizers, which was due to the action of nitrogen, whose acidifying influence was more profound in soil deprived of supply of organic substance since 1986. Liming produced a very beneficial effect on the amounts of phosphorus easily available to plants. Positive impact of FYM on abundance of soil in available P was also verified with the help of regression and correlation computation (Figure 1). Based on the analysis of the simple regression course, one can notice that regular fertilization with manure conducted for many years increased the content of available P by 90 mg kg^{-1} of soil. Should we assume that the abundance of soil in this nutrient declined to nearly zero as a result of mineral fertilization wasteful exploitation of farmland continued for then, under the very same conditions, the soil fertilized with manure should retain about 90 mg P kg^{-1} of soil.

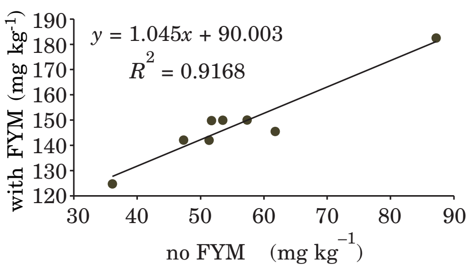

Fig. 1. Dependence between content of available P (mg kg^{-1}) in soil fertilized and not fertilized with FYM

The content of available forms of potassium in soil rose to even a higher degree than that of phosphorus owing to the long-term application of FYM (Table 3). Similarly to phosphorus, the concentration of K was most highly increased in soil fertilized with FYM alone. Increasing doses of nitrogen led to a steady decline in the abundance of soil in plant available forms of potassium. It can be assumed that the increasing acidification of soil caused by mineral nitrogen stimulated the leaching of potassium. In turn, increasing rates of potassium raised the amounts of available forms of K in soil, with the effect being evidently greater under exclusive mineral fertilization. Worth noticing is the fact that liming combined with moderate rates of N, P, K and Mg produced superior effects to the same rates of NPK.

Table 3

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

Factor I	Factor II								Mean
	$N_0P_0K_0$	$N_1P_1K_1$	$N_2P_1K_1$	$N_3P_1K_1$	$N_2P_1K_2$	$N_2P_1K_3$	$N_2P_1K_2Mg$	$N_2P_1K_2MgCa$	
FYM	265.8	311.5	299.2	267.4	315.8	371.3	334.3	337.6	312.9
Without FYM	64.1	86.5	77.6	66.3	107.3	161.2	109.7	129.4	100.2
Mean	165.0	199.0	188.4	166.8	211.5	266.2	222.0	233.5	

$LSD_{0.05}$ for the factor I – 14.45
$LSD_{0.05}$ for the factor II – 51.21
$LSD_{0.05}$ for interaction I×II – n.s.

Farmyard manure has been found to produce a beneficial effect on the content of available potassium (Figure 2). The availability of potassium rose on average by about 210 mg kg^{-1} following FYM fertilization. This effect is worth emphasizing because, even if the leaching of potassium was elevated or the soil was submitted to rabunkowa gospodarka, it would allow for maintaining resources of available K in soil for a longer period of time on a level that would guarantee proper functions of soil as the environment in which crops grow.

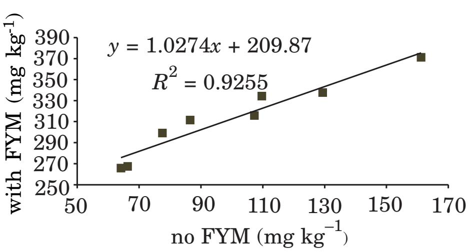

Fig. 2. Dependence between content of available K (mg kg^{-1}) in soil fertilized and not fertilized with FYM

In soil fertilized with FYM and mineral fertilizers, the content of available Mg fluctuated from 67.0 to 90.8 mg kg^{-1}, and in soil receiving only mineral fertilization it ranged from 23.3 to 45.3 mg kg^{-1} of soil (Table 4). Without any doubt, these results point to the beneficial effect produced by manure on the abundance of soil in plant available forms of magnesium. Based on the analysis of correlation and linear regression, it was determined that manure increased the content of available Mg by 46.198 mg kg^{-1}

Table 4

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

Factor I	Factor II								Mean
	$N_0P_0K_0$	$N_1P_1K_1$	$N_2P_1K_1$	$N_3P_1K_1$	$N_2P_1K_2$	$N_2P_1K_3$	$N_2P_1K_2$Mg	$N_2P_1K_2$MgCa	
FYM	78.3	71.3	75.5	67.0	67.8	71.0	90.8	83.3	75.6
Without FYM	33.0	27.3	27.3	23.3	26.8	24.3	45.3	42.0	31.1
Mean	55.6	49.3	51.4	45.1	47.3	47.6	68.0	62.6	

$LSD_{0.05}$ for the factor I – 3.09
$LSD_{0.05}$ for the factor II – 9.16
$LSD_{0.05}$ for interaction I×II – n.s.

(Figure 3). Manure not only contains magnesium but it also acts as a humus creating substance. It is a known fact that manure improves the soil complex sorptive capacity, which retains cations by physicochemical sorption, thus preventing the leaching of elements, for example magnesium. Therefore, soil regularly fertilized with manure will be able to sustain soil degrading processes for a longer time and will allow for a more efficient storage of elevated amounts of available nutrients.

Mineral fertilizers have also significantly affected the concentration of available magnesium in soil (Table 4). However, their effect, except compounds of magnesium or liming, was not as beneficial as that generated by manure. The highest rate of nitrogen depressed significantly the content of this element compared to its quantity observed in soil lacking mineral

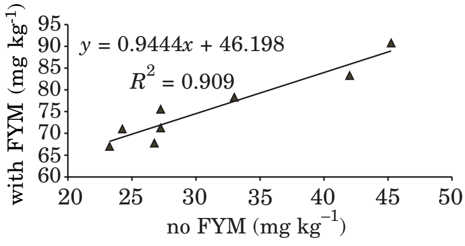

Fig. 3. Dependence between content of available Mg (mg kg^{-1}) in soil fertilized and not fertilized with FYM

fertilization. On the other hand, magnesium fertilization significantly increased the availability of Mg to plants. Liming led to a non-significant decline in the resources of Mg in soil. This could have been caused by the competition between Mg^{2+} and Ca^{2+} ions. Analogously, K^{+} ions, being antagonistic to Mg^{2+} ions, considerably depressed accumulation of available magnesium in soil. The competition between potassium and magnesium was the strongest in soil which received only mineral fertilizers. Analogously to available K, nitrogen probably accelerated the leaching of magnesium.

In the present study, the effect of FYM and mineral fertilizers on the content of basic nutrients in soil (P, K and Mg) has proven to be extremely favourable. Jaskulska and Jaskulski (2003), who discussed both Polish and foreign research in this field, have concluded that the most rational fertilization regime, considering the soil fertility and yielding, is a combined application of organic and mineral fertilizers. The authors also emphasize the role of mineral fertilizers in balancing nutrients. They empirically demonstrated that the content of available forms of P increased in soil following FYM fertilization. The relevant literature contains papers suggesting that soil can be depleted in phosphorus after a long period of being treated with FYM alone (Barczak et al. 1999). In turn, Zimny and Kuc (2005) found out that organic fertilization, and most profoundly FYM, increases the concentration of available forms of P and K in soil. There are also reports suggesting lack of response or sometimes even reduced availability of Mg in soil after it had been fertilized with magnesium (Kaniuczak 1999). In our experiment, both manure and magnesium in mineral fertilizers considerably increased resources of available magnesium in soil. This finding is supported by Piechota et al. (2000). Several researchers (Łabętowicz et al. 1999, Murawska et al. 2001, Jakulska and Jaskulski 2003, Sienkiewicz 2003) dealing with chemical properties of soil claim that liming can perfectly well regulate the availability of P, K and Mg in soil. Our own research demonstrated a similar tendency.

CONCLUSIONS

1. When applied regularly, FYM considerably increases the content of available forms of phosphorus, potassium and magnesium in soil.

2. Nitrogen introduced to soil together with mineral fertilizers reduces the availability of phosphorus, potassium and magnesium. Fertilization with calcium and potassium significantly depresses only the availability of magnesium.

3. Exclusive mineral fertilization results in a bigger increase in the availability of nutrients used in mineral fertilizers (P, K and Mg) than mineral fertilization in combination with manure.

4. With regular application of FYM, it is possible to reduce mineral fertilization and, at the same time, maintain higher abundance of soil in basic plant nutrients.

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