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EFFECT OF LAND USE OF FIELDS EXCLUDED FROM CULTIVATION ON SOIL CONTENT OF AVAILABLE NUTRIENTS

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Abstract

Fallowing farmland is one of the ways of keeping soil excluded from agricultural production. A fallow field is not cultivated or cropped for many years. Proper management of fallow land can bring meaurable profits for both the producer and the soil environment. The purpose of this study has been to evaluate the abundance of soil in avialable forms of phosphorus, potassium and magnesium on farmland excluded from production. In 1996, an experiment was run, comprising five treatments: a bare fallow field, a field turfed with fodder galega (*Galega orientalis* Lam.), a classical fallow field, a fallow field covered with fodder galega (*Galega orientalis* Lam.) with awnless bromegrass (*Bromus intermis*) and a fallow field sown with awnless bromegrass (*Bromus intermis*). The only agritechnical treatment performed periodically was mechanical weeding of the bare fallow. The plant biomass grown on plant-covered treatments remained on field every year. Plant material was sampled only for tests. Once the growing season finished, soil samples were taken from each treatment in four replicates from the 0-25 cm and 25-50 cm deep layers. The soil samples were assayed in order to determine concentrations of available forms of phsophorus, potassium and magnesium using generally applicable analytical methods. In both layers of soil (0-25 and 25-50 cm deep), significantly more P, K and Mg available to plants were found in soil turfed with fodder galega. It was also observed that the concentration of phosphorus in the subsoil from this treatment was significantly higher in 2007 than in 2000. Strong correlation was determined between the uptake of phosphorus by plants and the concentration of its bioavailable form in soil in the following year. Keeping soil as a bare field as well as leaving natural plants for several years resulted in the biggest depletion of bioavailable forms of macronutrients in soil.

Key words: soil, fallow land, bare field, available nutrients, P, K, Mg.

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WPŁYW ZAGOSPODAROWANIA GRUNTÓW WYŁĄCZONYCH Z UPRAWY NA ZAWARTOŚĆ SKŁADNIKÓW PRZYSWAJALNYCH W GLEBIE

Abstrakt

Odłogowanie gruntów jest jednym ze sposobów utrzymania gleb wyłączonych z produkcji. Pole odłogowane nie jest uprawiane i obsiewane przez wiele lat. Właściwe postępowanie z tego typu gruntami może przynieść wymierne korzyści zarówno dla producenta, jak i środowiska glebowego. Celem badań była próba oceny stanu zasobności gleb w przyswajalne formy fosforu, potasu oraz magnezu w gruntach wyłączonych z produkcji. W 1996 r. założono doświadczenie, które obejmowało 5 obiektów: ugór czarny, obiekt zadarniony rutwicą wschodnią (*Galega orientalis* Lam.), odłóg klasyczny, obiekt pokryty mieszanką rutwicy wschodniej (*Galega orientalis* Lam.) ze stokłosą bezostną (*Bromus intermis*) i obiekt obsiany stokłosą bezostną (*Bromus intermis*). Jedynym zabiegiem agrotechnicznym wykonywanym okresowo było mechaniczne odchwaszczanie czarnego ugoru. Biomasa roślinna wyrosła na obiektach zadarnionych pozostawała corocznie na polu. Materiał roślinny pobierano jedynie do badań. Po zakończeniu wegetacji pobierano próbki glebowe z każdego obiektu w 4 powtórzeniach z warstwy 0-25 cm i warstwy 25-50 cm, w których oznaczono zawartość przyswajalnych form fosforu, potasu i magnezu ogólnie dostępnymi metodami analitycznymi. W niniejszej pracy zaprezentowano wyniki badań przeprowadzonych w latach 2000-2007. W badaniach udowodniono, że sposób odłogowania i ugorowania gleby istotnie wpływał na zawartość przyswajalnych form fosforu, potasu i magnezu. W obydwu warstwach gleby (0-25 cm i 25-50 cm) istotnie najwięcej P, K i Mg przyswajalnego znajdowało się w glebie obsianej rutwicą wschodnią. W 2007 r. stwierdzono również istotny wzrost koncentracji fosforu na tym obiekcie w podglebiu, w porównaniu z 2000 rokiem. Określono silną zależność między pobraniem fosforu przez rośliny a zawartością przyswajalnej formy w glebie w roku następnym. Utrzymywanie gleby w czarnym ugorze, a także kilkuletnie pozostawienie roślinności naturalnej przyczyniło się w największym stopniu do zubożenia gleby w dostępne formy makroelementów.

Słowa kluczowe: gleba, odłóg, ugór, składniki przyswajalne P, K, Mg.

INTRODUCTION

Maintaining proper concentration of nutrients in bioavailable forms is one of the conditions shaping soil fertility (Kościk, Kalita 2000, Łętkowska, Strączyńska 2001). It can be assumed that while farmland is kept fallow or bare, the soil fertility is unimportant. This approach, however, is highly irresponsible. If agricultural production is to be restored on fallow land, proper abundance in nutrients is a necessary condition for obtaining high yields of demanded quality in the future. Should any of the nutrients required by crops be deficient, restoring the soil's necessary fertility would involve additional costs of fertilisation. The practice of fallowing land most often includes discontinuation of mineral fertilisation, which means that the input of nutrients to soil stops. Therefore, it is highly recommended to check the fertility of soil under fallow fields. According to Niedźwiecki et al. (1999), concentrations of bioavailable nutrients in soil under fallow fields is not variable. A study reported by Wójcikowska-Kapusta et al. (2003) demonstrated that fallow soil, similarly to cropped land, was very low and low in available phosphorus and potassium, and the way it was managed did not affect the concentration of total and available forms of these nutrients in deeper layers. These authors determined significantly higher concentrations of available forms of phosphorus in humus horizons of cropped or fallow soils than in the other soil genetic horizons. Other researchers observed considerably weaker leaching of phosphorus from fallow land turfed with grass (ULČN, MATTSSON 2003).

The purpose of the present study has been to evalutae the abundance of soils in available forms of phosphorus, potassium and magnesium under fields excluded from agricultural production.

MATERIAL AND METHODS

A large area experiment was established in 1996 on a field in Knopin (the commune of Dobre Miasto, the Province of Warmia and Mazury). The experiment was set up on a field which belonged to a private farmer. Prior to the experiment, all the land at that farm had been cultivated and in 1996 it was cropped with winter oat. The field set out for the experiment was turned into fallow land. The experimental field was divied into five treatments, each covering 1,600 m^2:

1) bare land,
2) fodder galega (*Galega orientalis* Lam.),
3) classical fallow,
4) fodder galega (*Galega orientalis* Lam.) with awnless bromegrass (*Bromus inermis*),
5) awnless bromegrass (*Bromus inermis*).

Prior to the establishment of the experiment, the soil was limed (3 t CaO ha^{-1}) and supplied with phsophorus and potassium fertilisers in the amounts corresponding to 26.1 kg P ha^{-1} and 74.7 kg K ha^{-1}. In late April of 1997, under the optimum temperature and humidity conditions, seeds of the test plants were sown on fields in treatments 2, 4 and 5. Seeds of fodder galega, scarified and inoculated with *Rihsobium galeage*, were sown. In the treatment with single-species seeding, 30 kg ha^{-1} were sown. When fodder galega was mixed with awnless bromegrass, 40 kg ha^{-1} (30 kg of fodder galega and 10 kg of awnless bromegrass of cv. 'Brudzyńska') were sown. The mixture of bromegrass and white clover of cv. Romena was composed of 10 kg of seeds of bromegrass and 5 kg of seeds of white clover (treatment 5). The first treatment was maintained as a bare field and, as a need arose, it was loosened and simultaneously weeded. In the following years of the trials, no fertilisation or any other chemical treatments were performed. Samples for analyses were taken from plant-covered treatments while the whole remaining biomass was left on fields. Before the trials began, 4 soil pits were made in order to obtain detailed characterictis of the soil. The humus horizon characterised by the particle size distribution of light loam reached down to 30 cm over the whole field. Soil under the whole experimental field was classified as good wheat complex, class II according to the Polish soil classification system. The abundance of the humus horizon in plant-available nutrients was within: 71.9-119.2 mg P kg^{-1}, 196.2-223.0 mg K kg^{-1} and 69.1-85.1 mg Mg kg^{-1} of soil. The content of organic carbon in this soil layer ranged from 9.50 to 12.03 g kg^{-1} and that of total nitrogen – from 1.08 to 1.24 g kg^{-1}.

The results of the study presented in this article come from 2000-2007. Every year after the growing season, soil samples were collected from each treatment in four replicates from the layers of 0-25 cm and 25-50 cm deep. The soil material was brought to the air-dry state, after which it was crushed and passed through a 1 mm mesh sieve. The ready samples underwent the following chemical analyses: available magnesium was determined with Schachtschabel's method and available phosphorus and potassium were assayed with Egner-Riehm's method. The results were subjected to analysis of variance for a two-factor experiment, using the software application Statistica v. 7.0.

RESULTS AND DISCUSSION

The authors' own study has demonstrated that the way farmland is kept fallow has strong influence on the concentration of avialable phosphorus in the 0-25 cm deep soil layer (Table 1), The highest abundance of soil in plant-available forms of this element, from the first to the last year of the experiment, was maintained in soil cropped with fodder galega. Significantly less available phsophorus was present in soil under the other treatments. It should be emphasised that soil cropped with the mixture of fodder galega and awnless bromegrass, although poorer in phosphorus than soil covered exclusively with the papilionaceous plant, mainatained a significantly higher concentration of this element compared to the classical or bare fallow field. Significant differences obtained for the interaction between the tested factors imply that the ways of keeping land idle have a varied influence on the amounts of available phosphorus in soil. Under the effect of fodder galega, a distinct tendency appeared for the soil concentration of available phosphorus to increase. When fallow land had been sown with awnless bromegrass for many years, soil became demonstrably poorer in available P. In soil under bare fallow, the quantity of available phosphorus also declined, but the decreasing tendency was weaker in later years. The references concerning this issue provide us with contradictory information. DZIENIA et al. (1997), for example, report that the concentration of this nutrient in fallow land

Table 1

Concentration of available P in soil in mg kg^{-1} (**0-25 cm** and 25-50 cm deep layer)

Treatment	Year								Average
	2000	2001	2002	2003	2004	2005	2006	2007	
Bare field	**79.95** 71.55	**75.60** 69.95	**73.90** 70.42	**74.50** 68.81	**75.15** 67.03	**76.23** 68.42	**74.51** 67.44	*73.81* 66.92	**75.45** 68.82
Fodder galega	**107.2** 72.51	**106.0** 66.46	**113.0** 73.23	**112.0** 78.85	**116.5** 78.03	**119.0** 68.89	**118.1** 69.04	**119.2** 75.20	113.9 72.78
Classical fallow	**73.05** 72.05	**72.25** 71.10	**75.63** 72.35	**76.45** 71.15	**78.80** 69.40	**76.36** 71.42	**61.48** 68.48	**74.32** 68.45	**73.54** 70.55
Fodder galega+brome grass	**89.00** 69.50	**87.50** 64.69	**81.45** 68.25	**79.01** 68.45	**78.83** 73.45	**81.45** 67.55	**82.25** 68.55	**81.92** 69.35	**82.68** 68.72
Bromegrass	**81.80** 62.51	**72.50** 61.24	**67.85** 60.41	**67.76** 62.45	**67.75** 63.60	**72.15** 65.24	**69.41** 64.99	**74.22** 62.81	**71.68** 62.91
Average	**86.20** 69.62	**82.77** 66.69	**82.37** 68.93	**81.94** 69.94	**83.41** 70.30	**85.04** 68.30	**81.15** 67.70	**84.69** 68.55	-

0-25 cm		25-50 cm	
$LSD_{0.05}$ for years	0.028	$LSD_{0.05}$ for years	0.011
$LSD_{0.05}$ for treatments	0.023	$LSD_{0.05}$ for treatments	0.008
$LSD_{0.05}$ for interaction	0.064	$LSD_{0.05}$ for interaction	0.025

increases. A completely different opinion is expressed by Wojnowska et al. (2003) or Phiri et al. (2001), who report that land fallowing leads to considerable depletion of available phosphorus from soil resources. In turn, the results of the experiments presented by Wojcikowska-Kapusta et al. (2003) indicate that the way farmland is kept idle has no influence on the soil concentration of plant-available forms of phosphorus.

The abundance of the subsoil (25-50 cm deep) in available phsophorus was also modified by the way the land was kept fallow (Table 1). Analogously to the surface layer, significantly more available phosphorus was determined in soil cropped with fodder galega. In addition, significantly more phosphorus available to plants in the subsoil under fodder galega was observed in 2004 than in 2007. Maintaining a bare or a classical fallow field resulted in a similar decline in the concentration of bioavailable phosphorus. These results correspond to the data reported by Ulčn and Mattisson (2003), who observed much smaller losses of this element from a similar soil horizon under grass. Noteworthy is the fact that plant cover, depending on its type, can maintain or even raise the resources of plant-available forms of phosphorus not only in the arable soil layer but also in the soil horizon directly underneath.

Our own tests did not confirm the results obtained by the above authors. On the contrary, it can be claimed that the way land is kept fallow has a dominant effect on modification of bioavailable forms of phorphorus. It should be added, however, that the concentration of this element was high or very high during the whole experiment. This, perhaps, was the reason why the results were different from the references. Another fact which seems to support this conclusion is a very strong dependence between the uptake of phosphorus by plants and the concentration of the bioavailable form of this element in the following year (Figure 1).

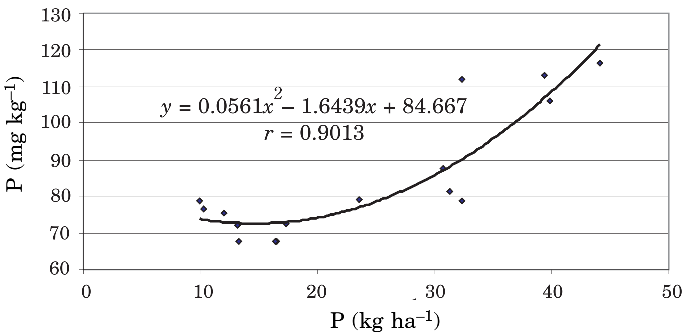

Fig. 1. Dependence of the concentration of available P in soil in mg kg^{-1} on the amount of the element accumulated in plant biomass in kg ha^{-1}

The abundance of soil (0-25 cm deep) in available potassium was also dependent on the type of fallowing (Table 2). Significantly more bioavailable potassium was maintained in soil under fodder galega, classical fallow and bare field than in soil under bromegrass and significantly less of this element was found in soil under the mixture of fodder galega and awnless bromegrass. The results suggest that the concentration of bioavialable potassium in the consecutive years was strongly depressed in soil from all the treatments. However, considering the fact that both species grown in the experiment demand much potassium and are highly productive plants, it can be claimed that much of the available potassium was temporarily acummulated in organic matter. After some time, it returns to the plant-available form, therefore the decrease in the concentration of potassium in plant-covered treatments need not be considered solely as a loss. An equally unfavourable effect of land fallowing on the concentration of available potassium in soil has been reported by Wojnowska et al. (2003), Łękowska and Strączyńska (2001), Niedźwiecki et al. (1998), Dzienia et al. (1997). Similarly to phosphorus, Wójcikowska-Kapusta et al. (20030) claim that land fallowing has no effect on the soil abundance in this nutrient. Amounts of substances leached from soil are directly dependent on water management and primarily on amounts of precipitation, which shape the extent of migration of ele-

Table 2

Concentration of available K in soil in mg kg^{-1} (**0-25 cm** and 25-50 cm deep layer

Treatment	Year								Average
	2000	2001	2002	2003	2004	2005	2006	2007	
Bare field	**206.6** 128.0	**209.3** 122.2	**209.7** 125.1	**207.7** 124.3	**191.5** 125.3	**199.2** 116.2	**190.5** 120.4	**194.9** 116.0	**201.2** 122.2
Fodder galega	**222.9** 125.3	**202.4** 123.3	**204.2** 122.5	**207.6** 115.5	**208.5** 122.2	**220.7** 98.30	**221.1** 99.60	**222.2** 121.5	**213.7** 116.0
Classical fallow	**211.3** 115.5	**201.5** 118.5	**209.2** 110.2	**204.9** 114.2	**207.5** 126.1	**210.5** 103.0	**195.1** 99.60	**207.3** 114.4	*205.9* 112.7
Fodder galega+brome grass	**195.9** 116.0	**186.8** 120.5	**189.6** 111.2	**184.6** 105.2	**183.5** 114.2	**195.8** 103.0	**182.6** 107.9	**198.8** 111.1	**189.7** 111.1
Bromegrass	**208.9** 119.0	**200.5** 115.2	**202.4** 108.2	**203.8** 112.3	**182.5** 104.3	**201.5** 103.9	**195.1** 99.60	**202.5** 103.8	**199.7** 108.3
Average	**209.1** 120.8	**200.1** 119.9	**203.0** 115.4	**201.7** 114.3	**194.7** 118.4	**205.5** 104.9	**196.9** 105.4	**205.1** 113.4	

0-25 cm		25-50 cm	
$LSD_{0.05}$ for years	0.207	$LSD_{0.05}$ for years	0.049
$LSD_{0.05}$ for treatments	0.164	$LSD_{0.05}$ for treatments	0.039
$LSD_{0.05}$ for interaction	0.463	$LSD_{0.05}$ for interaction	0.111

ments (Koc et al. 1999). Depressing the concentration of available potassium in soil under the bare fallow could have been due to its increased leaching. It should be remembered that this element accumulated in organic matter produced each year in all the treatments except the bare field remained on field. Potassium accumulated in biomass was therefore returned to soil and because it is not arrested in permanent organic bonds, it quickly becomes available to plants. Thus, it seems that even the losses in potassium demonstrated in our study in soil under plant cover could be smaller than the amounts determined by chemical analyses.

Similar relationships in terms of available potassium as in the surface layer of soil occurred in the 25-50 cm deep layer (Table 2). Statistical calculations proved that the way of keeping farmland fallow significantly modified the concentration of bioavailable K in the soil horizon under humus. Fluctuations recorded in our study were evidently smaller than in the surface soil layer. Differentiation in the abundance of the subsoil in this nutrient depending on years proved to be non-significant. However, it depended to a large extent on the way farmland was excluded from agricultural use. The best way of land fallowing, which prevented loss of ptassium, was by sowing a field with fodder galega. It is possible that the highest capacity of galega to take up potassium contributed to a more effective mobilisation of this nutrient. Other possible causes could be translocation of potassium from deeper horizons (the root system) and upper layers (leaching).

The most profound loss in soil abundance appeared in the treatment with awnless bromegrass. Good utilisation of nutrients from less dissolvable compounds and consequently their mobilisation by fodder galega may have resulted in larger accumulation of bioavailable magnesium in soil under this plant or under its mixture with awnless bromegrass (Table 3). In the soil from the other treatments, concentrations of available magnesium decreased in the following years of the trials. A similar opinion is expressed by BLECHARCZYK et al. (1985), DZIENIA et al. (1997), WOJNOWSKA et al. (2003). In contrast, MALICKI and PODSTAWKA-CHMIELEWSKA (1998) report that discontinuation of farming can contribute to an increase in the concentration of available magnesium in soil. Finally, BARAN et al. (2001) concluded that land fallowing did not change the soil abudance in this nutrient.

Based on the results of soil analyses, it can be assumed that there was some translocation of available magnesium from the 0-25 cm to the subsoil (Table 3). This effect was demonstrably more evident under the classical fallow field and the field overgrown with awnless bromegrass. In turn, the decreased abundance of the upper soil layer as well as the subsoil under the bare field may suggest that magnesium was translocated even deeper into

Table 3

Concentration of available Mg in soil in mg kg^{-1} (**0-25 cm** and 25-50 cm deep layer

Treatment	Year								Average
	2000	2001	2002	2003	2004	2005	2006	2007	
Bare field	**71.73** 78.75	**70.60** 74.25	**71.62** 72.12	**68.13** 73.51	**66.93** 69.00	**66.00** 72.00	**68.10** 68.50	**65.00** 71.00	**68.51** 72.39
Fodder galega	**80.00** 81.50	**78.00** 83.20	**79.25** 84.51	**81.98** 87.24	**85.50** 93.75	**81.00** 86.00	**84.00** 82.00	**86.00** 88.22	**81.97** 85.80
Classical fallow	**79.50** 86.50	**74.75** 95.51	**72.36** 94.25	**74.86** 98.51	**74.87** 104.0	**73.05** 96.00	**69.00** 95.00	**70.50** 100.0	**73.61** 96.22
Fodder galega+brome grass	**83.03** 85.50	**82.55** 84.25	**83.35** 89.42	**86.15** 94.52	**83.85** 97.75	**77.00** 94.00	**83.00** 96.00	**73.00** 95.50	**81.49** 92.12
Bromegrass	**68.75** 82.50	**66.63** 84.58	**63.50** 83.25	**63.50** 86.24	**64.25** 88.00	**51.00** 87.00	**68.00** 86.00	**50.00** 84.00	**61.95** 85.20
Average	**76.60** 82.95	**74.51** 84.36	**74.02** 84.71	**74.92** 88.00	**75.08** 90.50	**69.61** 87.00	**74.42** 85.50	**68.90** 87.74	

0-25 cm		25-50 cm	
$LSD_{0.05}$ for years	0.045	$LSD_{0.05}$ for years	0.113
$LSD_{0.05}$ for treatments	0.036	$LSD_{0.05}$ for treatments	0.089
$LSD_{0.05}$ for interaction	0.101	$LSD_{0.05}$ for interaction	0.253

the soil. The statistical calculations confirmed the significant effect of both the way land was kept fallow and the duration of land fallowing on the concentration of available magnesium. Decreased concentration of this nutrient was observed only under the bare field. Lack of plant cover resulted in a 19% decline in the concentration of plant-available forms of this element in the 25-50 cm deep soil layer compared to grass-covered fields. The presence of plant cover had positive influence on retaining available magnesium in the subsoil.

Time-related fluctuations in the soil abundance in available magnesium may be related to the amount of Mg accumulated in plants growing on fallow land (Figure 2). Strong correlation was found between soil abundance in available magnesium and the amount of the accumulated element in plants left on field in the previous year.

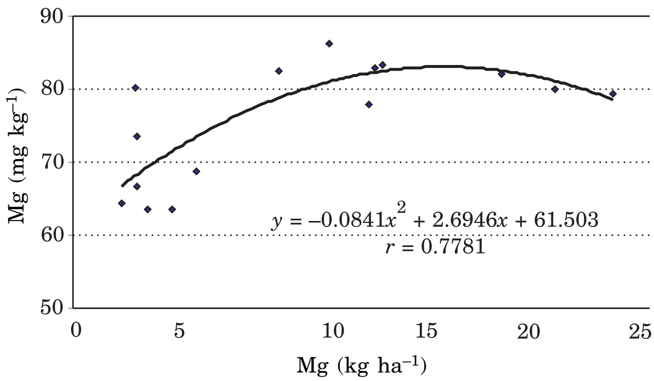

Fig. 2. Dependence of the concentration of available Mg in soil in mg kg^{-1} on the amount of the element accumulated in plant biomass in kg ha^{-1}

CONCLUSIONS

1. Keeping soil excluded from agricultural production for many years as a fallow field turfed with fodder galega may increase the availability of phosphorus, potassium and magnesium in the 0-25 and 25-50 cm deep soil horizons.

2. A mixture of fodder galega and awnless bromegrass shows a similar effect on available magnesium.

3. A bare fallow field and the classical fallow do not protect soil from losing plant-available forms of P, K and Mg.

4. Soil abundance in available phosphorus and magnesium when a field has been kept fallow for many years and plants have remained on field after harvest depends on the amount of these nutrients accumulated in biomass.

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