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ACCUMULATION OF MACROELEMENTS IN PLANTS ON NEWLY ESTABLISHED FALLOWS

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Abstract

In spring 1996, four types of fallows were established on good wheat complex soil (classified as IIIa in the Polish soil classification system): sown with oriental goat's rue (*Galega orientalis*, Lam.), traditional fallow, seeded with a mixture of oriental goat's rue (*Galega orientalis* Lam) and smooth brome (*Bromus inermis*) and under smooth brome (*Bromus inermis*). This paper documents the results obtained in 2000-2004. Plant samples (4 x 1 m^2) were taken from the fallows once every year at the same plant growth and development stage. The content of macroelements in the plant material was determined using conventional methods. The statistical elaboration of the results was based on the analysis of regression and correlation.

The results proved that fallow under perennial plants is superior in activating and cycling nutrients to traditional fallow, overgrown with wild plants. On the other hand, when fallow soil is covered exclusively with a papilonaceous plant (e.g. oriental goat's rue), it is more likely to experience transfer of nitrates (V) to ground waters. A good solution to this problem could be sowing fields which are set aside as fallows sown with a mixture of oriental goat's rue and smooth brome. Soil protected by these two plants remains fertile and does not create an ecological risk caused by migrating $N\text{-}NO_3$.

Key words: fallow, oriental goat's rue, smooth brome, N, P, K, Mg.

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AKUMULACJA MAKROELEMENTÓW W ROŚLINNOŚCI NA ZAINICJOWANYCH ODŁOGACH

Abstrakt

Wiosną 1996 r. na glebie kompleksu pszennego dobrego, klasy bonitacyjnej IIIa zainicjowano odłogi: obsiany rutwicą wschodnią (Galega orientalis Lam.), odłóg klasyczny, obsiany mieszanką rutwicy wschodniej (Galega orientalis Lam.) ze stokłosą bezostną (Bromus inermis), obsiany stokłosą bezostną (Bromus inermis). W niniejszej pracy przedstawiono wyniki uzyskane w latach 2000-2004. Z obiektów pokrytych roślinnością pobierano próbki (4 1 m2) raz w roku w jednakowej fazie wzrostu i rozwoju roślin. Zawartość makroskładników w materiale roślinnym oznaczono konwencjonalnymi metodami. Opracowanie statystyczne wyników wykonano w oparciu o analizę regresji i korelacji.

W badaniach wykazano, że odłóg obsiany roślinami wieloletnimi w większym stopniu uruchamia składniki pokarmowe i włącza je do obiegu niż roślinność naturalna odłogu klasycznego. Jednak roślina motylkowata (rutwica wschodnia) pokrywająca wyłącznie glebę może stwarzać ryzyko przemieszczania azotanów (V) do wód gruntowych. Dobrym rozwiązaniem może być utrzymywanie pól wyłączonych z produkcji w formie odłogu obsianego mieszanką rutwicy wschodniej i stokłosy bezostnej. Tak zabezpieczona gleba pozwala na utrzymanie żyzności i jednocześnie nie stwarza zagrożenia ekologicznego związanego z przemieszczaniem N-NO3.

Słowa kluczowe: odłóg, rutwica wschodnia, stokłosa bezostna, N, P, K, Mg.

INTRODUCTION

In order to adjust fertilization to soil conditions, it is necessary to determine the uptake of nutrients by plants. For agricultural reasons as well as ecological demands it is more common in Poland as well as in many other countries to prepare nitrogen, phosphorus and potassium balance calculations, which enable farmers to apply biogenic substances with maximum safety (Bach and Frede 1998, Fotyma 2000). Fallow land is not fertilized, which means that the nutrients accumulated by plants growing on fallow soil provide us with the information on the potential stocks of nutrients in the soil – plant – soil cycle. The fertilization value of the biomass produced on fallow depends on the type of plants, the amount of organic matter produced and its chemical composition (Wilczewski and Skinder 2005). Organic matter is an important link in the process of capturing elements via biological sorpotion (Żarczyński and Sienkiewicz 2007). According to Stupnicka-Rodzynkiewicz et al. (1996), weeds tend to accumulate more nutrients than crops. Thus, it seems reasonable to determine potential accumulation of nutrients by plants growing on fallow land. The objective of our study has been to trace the amounts of nitrogen, phosphorus, potassium and magnesium in plants growing on different types of fallows.

MATERIAL AND METHODS

In spring 1996 a field experiment was set up on good wheat complex soil, classified as IIIa in the Polish soil classification system. The fallows, covering 1600 m^2 each, were established on a field set apart for the experiment and were covered with the following plants:

1) oriental goat's rue (*Galega orientalis* Lam.);
2) traditional fallow;
3) oriental goat's rue (*Galega orientalis* Lam.) and smooth brome (*Bromus inermis*);
4) smooth brome (*Bromus inermis*).

No agronomic treatments were carried out while maintaining the fallows. This paper presents the results obtained in 2000-2004. Plant samples (4 x 1 m^2) were taken from the fallows in order to determine the biomass and chemical composition. Samples of the plants were collected once each year at the same growth and development stage, i.e. at the early inflorescence stage of goat's rue, when the plants had reached their maximum weight. The content of the macroelements in the plant material, following wet digestion, was determined using the following methods: Kjeldhal's method for nitrogen, vanadium-molybdenum method for phosphorus, ESA method for potassium and ASA method for magnesium. The results underwent statistical processing using analysis of regression and correlation.

RESULTS AND DISCUSSION

The highest nitrogen accumulation occurred in oriental goat's rue Table 1). Compared to the goat's rue monoculture, the uptake of nitrogen from the fallow sown with the mixture of goat's rue and smooth brome was 40% lower. The accumulation of nitrogen on the fallow covered with smooth brome alone – compared to the fallow sown with goat's rue – was nearly three-fold lower. The lowest potential accumulation of nitrogen was found for plants growing on the traditional fallow. This was due to a very small biomass produced on this fallow and the smallest concentration of nitrogen in the plant dry matter. Similar results on nitrogen uptake be weeds were reported by STINNER et al. (1997).

As large amounts of nitrogen collected in biomass which stays on a field can pose a risk of contaminating waters with nitrates, we compared the amounts of nitrogen accumulated in plants with the concentrations of mineral nitrogen in soil. It turned out that the nitrogen accumulated in the biomass was strongly correlated with the concentration of nitrates (V) in soil in the autumn: September and November (Figure 1). It is worth notic-

Table 1

Accumulation of macroelements in plants ($kg \cdot ha^{-1}$)

Object	Year				
	2000	2001	2002	2003	2004
N					
Goat's rue	345.9	343.6	259.1	360.6	311.6
Goat's rue + brome grass	222.4	238.9	196.7	267.8	223.1
Brome grass	128.3	133.1	93.4	141.0	117.3
Traditional fallow	74.1	61.7	54.0	66.6	61.2
P					
Goat's rue	39.9	39.4	32.3	44.2	36.6
Goat's rue + brome grass	30.7	31.3	23.5	32.3	28.8
Brome grass	17.3	16.5	13.3	16.4	14.1
Traditional fallow	13.2	12.0	10.3	9.9	10.8
K					
Goat's rue	299.6	348.8	250.9	328.6	317.0
Goat's rue + brome grass	277.3	322.3	233.0	337.0	274.0
Brome grass	149.5	169.7	122.1	168.8	144.5
Traditional fallow	148.8	122.9	106.6	125.9	111.9
Mg					
Goat's rue	21.2	21.8	13.8	23.9	19.1
Goat's rue + brome grass	11.4	13.1	8.9	13.4	11.1
Brome grass	5.8	5.3	2.8	4.3	3.3
Traditional fallow	3.6	3.4	2.7	2.8	2.1

ing here that the biomass left on the fields for the winter season, which never exceeded 250-270 kg $N \cdot ha^{-1}$, did not create a potential threat to the environment (Figure 1). Some higher nitrogen uptake occurred only in the case of oriental goat's rue. The organic matter left on the fields was a perfect substrate for microorganisms, which released the nitrogen it contained. Further transformation of nitrogen (nitrification) caused increased accumulation of $N\text{-}NO_3$ in soil. It is hardly possible for nitrate nitrogen (V) present in large amounts in soil during the autumn to remain there until spring (Koc et al. 2002).

In our experiment, the amount of P accumulated in goat's rue was slightly larger than reported by Ignaczak and Wojciechowska (1992), who assessed the phosphorus accumulation potential of goat's rue at 25-33 kg $P \cdot ha^{-1}$. We found out that goat's rue growing over nearly all the surface area of fallow

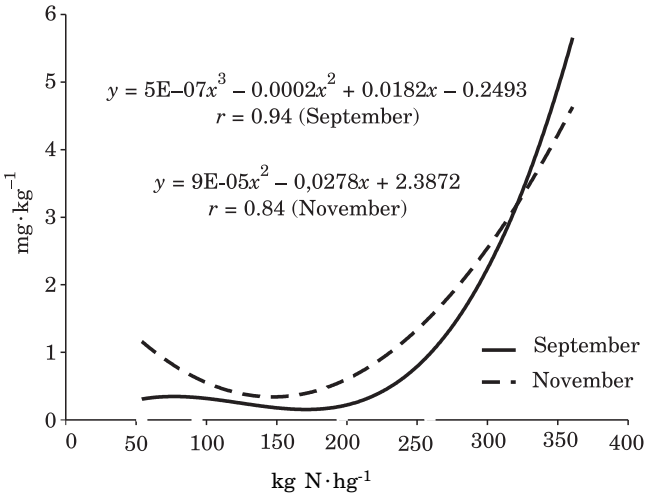

Fig. 1. Influence of the amount of N accumulated in plants (kg N·ha^{-1}) on the N-NO_3 content in soil during the autumn season

land accumulated from 32.2 to 44.2 kg P·ha^{-1} (Table 1), which is similar to the results obtained by CHYLIŃSKA (2003), who studied bird's foot which received mineral fertilization. In our own research, the mixture of goat's rue and smooth brome accumulated on average 30% more phosphorus than the monoculture of goat's rue. The traditional fallow as well as smooth brome growing alone accumulated much less phosphorus. The uptake of phosphorus by smooth brome was nearly two-fold lower than that by smooth brome and goat's rue growing together. The grass, however, collected over 38% more phosphorus than the plants growing on the traditional fallow.

The quantities of phosphorus stocked in plants were largely dependent on the amounts of available phosphorus in soil (Figure 2). However, it needs to be said here that this relationship could just as well have been reverse. Having been first mineralized, the phosphorus accumulated in biomass would most readily returned to soil as plant available forms.

The weather is one of the factors which significantly affected the accumulation of potassium. In the present study, the lowest K uptake occurred in the driest year, 2002 (Table 1). The shortage of rainfall limited the transfer of potassium to the plant roots, which made it more difficult for the plants to absorb this element; the effect was also related to a much lower amount of biomass produced in that year. Goat's rue as well as its mixture with smooth brome often collected over 300 kg K·ha^{-1}, whereas the amounts of potassium found in the plants sampled from the traditional and smooth brome fallows did not exceed 150 and 170 kg·ha^{-1}, respectively. Nonetheless, the above quantities were much higher than those reported by IGNACZAK and WOJCIECHOWSKA (1992), who concluded that goat's rue could potentially

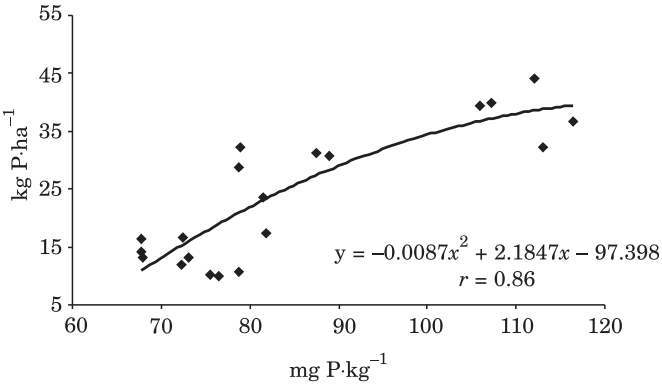

Fig. 2. Dependence of P uptake (kg·ha^{-1}) on the content of available phosphorus in soil (mg·ha^{-1})

accumulate about 130 kg K per ha^{-1}. SZYMANOWICZ and KALEMBASA (2005) determined even lower accumulation potential of this plant. They suggested that goat's rue was capable of accumulating just 65 kg·ha^{-1}. In contrast, SZOSZKIEWICZ et al. (1992) determined that the uptake of potassium by mixtures of meadow grasses was between 229 and 654 kg·ha^{-1}.

Among all the macroelements examined, magnesium proved to be most variable in the uptake by plants – the ratio between the highest uptake (by goat's rue in 2003) and the lowest one (traditional fallow in 2004) was over 11-fold (Table 1). The lowest magnesium accumulation occurred on the traditional fallow. The plants growing on this fallow accumulated on average just 2.9 kg·ha^{-1} magnesium. This was 6.5-fold less than the amount of Mg collected in goat's rue. On the other hand, the amount of magnesium accumulated by plants on the traditional fallow was comparable to that reported by CHYLIŃSKA (2003) for mineral fertilized bird's foot. Another interesting fact was that the quantities of Mg removed from soil to aerial parts of plants tended to decrease during the experiment.

Magnesium is more strongly bound in live organisms than potassium. It is also more slowly released from organic matter to soil solution than potassium. The results reported in this paper enabled us to conclude that the stock of available magnesium in soil was rather strongly correlated with the amount of this element accumulated in the plants which were left on the field (Figure 3). This is yet another piece of evidence suggesting that the availability of elements to plants is largely conditioned by their amounts which enter the matter cycling every year. This should also be taken into consideration when planning and managing fallows. Biological accumulation of elements can prevent their leaching inasmuch as improve stocks of their plant available forms in soil.

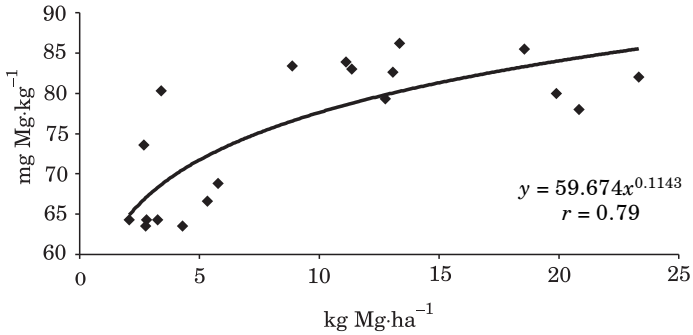

Fig. 3. Influence of Mg accumulated in plants (kg Mg·ha^{-1}) on the content of available Mg in soil (mg Mg·kg^{-1})

CONCLUSIONS

1. The plants sown on newly established fallows, particularly oriental goat's rue, are better at releasing and cycling nutrients than weeds growing on traditional fallow.

2. Goat's rue growing on land set aside from agricultural use can create a risk of excessive accumulation of nitrates (V) in soil and their transfer to ground waters.

3. Maintaining fields temporarily excluded from farming in the form of fallows sown with a mixture of goat's rue and smooth brome can be the best solution as this preserves soil fertility and protects the environment.

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