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EFFECT OF THE WAY SET-ASIDE LAND IS MAINTAINED ON THE CONTENT OF AVAILABLE FORMS OF SELECTED MICRONUTRIENTS IN SOIL

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Abstract

In 1996, a field experiment was set up on class IIIa soil, which consisted of 6 trials: 1 – bare fallow, 2 – fallow land seeded with annual plants, 3 – field swarded with goat's rue (*Galega orientalis* Lam.), 4 – traditional fallow, 5 – field swarded with a mix of goat's rue (*Galega orientalis* Lam.) and aweless brome (*Bromus inermis*), 6 – field swarded with aweless brome (*Bromus inermis*). During the tests, no agrotechnical measures were carried out apart from periodical mechanical weeding of the bare fallow and the sowing of annual plants. Plant samples for chemical analyses were taken from the swarded fields; the remaining biomass was left on the fields. After each growing season, soil samples were collected in four replicates from the 0-25 cm and 25-50 cm soil horizons, for determination of the content of Cu, Zn and Mn available forms. This paper discusses the results obtained in 2000-2007.

The experiment has demonstrated that the way farmland was laid fallow or set-aside had an effect on concentrations of the available forms of Cu, Zn and Mn in the 0-25 and 25-50 cm soil horizons. Particularly large changes occurred in the levels of Zn and Mn. The way set-aside arable land was kept had a weaker influence on the concentrations of easily soluble forms of copper. By seeding annual plants and leaving the grown biomass on a set-aside field, it was possible to maintain the soil abundance of available Zn on a high level and that of Cu and Mn – moderately high. Keeping soil as bare fallow favoured better accumulation of available forms of copper and manganese.

Key words: set-aside, fallow, available forms of Zn, Cu and Mn.

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WPŁYW SPOSOBU UTRZYMANIA GRUNTÓW WYŁĄCZONYCH Z UPRAWY NA ZAWARTOŚĆ PRZYSWAJALNYCH FORM WYBRANYCH MIKROELEMENTÓW W GLEBIE

Abstrakt

W 1996 r. na glebie klasy bonitacyjnej IIIa założono doświadczenie łanowe, które obejmowało 6 obiektów: 1 – ugór czarny, 2 – ugór obsiewany roślinami jednorocznymi, 3 – obiekt zadarniony rutwicą wschodnią (*Galega orientalis* Lam.), 4 – odłóg klasyczny, 5 – obiekt zadarniony mieszanką rutwicy wschodniej (*Galega orientalis* Lam.) ze stokłosą bezostną (*Bromus inermis*), 6 – obiekt zadarniony stokłosą bezostną *(Bromus inermis*). W czasie trwania badań, oprócz okresowego mechanicznego odchwaszczania czarnego ugoru i obsiewu obiektu jednorocznego, nie wykonywano żadnych zabiegów agrotechnicznych. Z obiektów zadarnionych pobierano tylko próbki materiału roślinnego do analiz chemicznych, a biomasę pozostawiano na polu. Po zakończeniu każdego okresu wegetacyjnego pobierano próbki gleby z każdego obiektu, w 4 powtórzeniach z warstw 0-25 cm i 25-50 cm, w których oznaczono zawartość przyswajalnych formy metali (Cu, Zn i Mn). W pracy zamieszczono wyniki badań z lat 2000-2007.

W badaniach wykazano, że sposób odłogowania i ugorowania gleby wpływał na zawartość przyswajalnych form Cu, Zn i Mn w warstwach 0-25 cm i 25-50 cm. Szczególnie duże zmiany wystąpiły w odniesieniu do Zn i Mn. W mniejszym zakresie sposób zabezpieczenia gleby wyłączonej z uprawy wpływał na koncentrację łatwo rozpuszczalnych form Cu. Coroczne obsiewanie pola wyłączonego z produkcji bez zbierania wyrosłej biomasy pozwoliło utrzymać zasobność gleby w Zn przyswajalny na poziomie wysokim, a Cu i Mn na poziomie średnim. Utrzymywanie gleby jako czarnego ugoru sprzyjało większemu nagromadzeniu przyswajalnych form miedzi i manganu.

Słowa kluczowe: odłóg, ugór, przyswajalne formy Zn, Cu i Mn.

INTRODUCTION

Being the most important component of agricultural production, soil should be ensured special protection (Firbank et al. 2003, Mertz et al. 2008). Having fulfilled certain prerequisites, periodical cessation of agricultural production may lead to some improvement in soil chemical properties. Modification of soil's fertility largely depends on plant cover (or its lack). Organic matter left on a field and undergoing mineralization is an important link in the cycling of elements, as it facilitates the return of the elements previously taken up by the plants (Żarczyński et al. 2008). On farmland set aside for some time it is one of the few ways of improving the soil's abundance in available nutrients (Sienkiewicz et al. 2011).

It is very important to know the levels of available forms of Cu, Zn and Mn in soil. These micronutrients are essential for the life of animal and plant organisms, which need their adequate supply (Spiak 2000). When trace elements are deficient, it is necessary to supplement the soil abundance. However, despite the application of balanced doses of nutrients and very precise fertilization techniques, fertilization is not indifferent to the natural environment (Anguelov, Anguelova 2009). Excessive concentrations of Cu, Zn and Mn in soil create a risk of plant contamination and poisoning of animals (McBride et al. 2004, Rattan et al. 2005, Diatta 2008).

The purpose of this study has been to evaluate how the way in which set-aside land is maintained affects concentrations of the available forms of copper, zinc and manganese in soil.

MATERIAL AND METHODS

A field experiment was set up in the spring of 1996, in Knopin, the community of Dobre Miasto, the Province of Warmia and Mazury. It was established on good wheat complex soil, class IIIa. This paper discusses the results obtained in 2000-2007. An area of 0.96 ha was divided into six equal parts:

1) bare fallow,
2) fallow seeded with annual plants,
3) plot swarded with goat's rue (*Galega orientalis* Lam.),
4) traditional fallow,
5) plot covered with a mixture of goat's rue (*Galega orientalis* Lam.) and aweless brome (*Bromus inermis*),
6) plot swarded with aweless brome (*Bromus ineris*).

The bare fallow was kept free from plant cover by mechanical weeding treatments carried out at regular intervals. On the seeded fallow, after the soil was mechanically tilled, cereals were sown. Since 2000, this plot was alternately cropped with oat and winter triticale. No agrotechnical treatments were carried out on the other plots. Samples of plants for chemical analyses were collected from the plant-covered plots, leaving all the remaining biomass on the field. Soil samples for analyses were taken once a year, i.e. in the autumn, when the growing season was over, from two soil horizons: 0-25 and 25-50 cm. The available forms of Cu, Zn and Mn were extracted in 1 mol HCl dm^{-3} solution and determined with the ASA method. The results were submitted to statistical analyses, including Duncan's test.

RESULTS AND DISCUSSION

The content of available forms of copper, zinc and manganese evidently depended on the way the set-aside fields were managed. Presence or absence of plant cover as well as the type of plants had a significant effect on the concentration of the analyzed metals in soil (Table 1). This dependence held true for both the topmost and deeper layer of soil (Tables 1-3).

Table 1

Content of available zinc in soil (mg Zn kg^{-1})

Layer	Treatment						Mean
	bare fallow	seeded fallow	goat's rue	traditional fallow	goat's rue + brome grass	brome grass	
0-25 cm	20.19	24.10	25.21	22.56	24.43	22.07	23.09
25-50 cm	19.43	20.23	20.51	19.47	18.69	18.65	19.50
Mean	19.81	22.16	22.86	21.01	21.56	20.36	
$LSD_{0.05}$ factor I 0.28 $LSD_{0.05}$ factor II 0.48 $LSD_{0.05}$ factor I×II 0.68							

Most of the available zinc (25.21 mg kg^{-1}) was determined in the soil from the plot swarded with goat's rue (Tabela 1). Slightly less zinc appeared in the soil under the mixture of goat's rue and aweless brome. Similar quantities of available Zn as in the soil covered with goat's rue mixed with aweless brome were detected in the soil seeded every year with cereals. According to CHUDECKA and TOMASZEWICZ (2001), absence of soil cultivation treatments leads to an increase in the content of available forms of heavy metals, the finding which these authors attribute to the fact that there is more organic matter, originating from the plants growing on set-aside and left there. This procedure reduces erosion and migration of micronutrients. Our own studies partly confirm the hypothesis formulated by the above authors. It can be claimed that discontinuation of soil cultivation, or rather the lack of plant cover, may result in a depressed content of available zinc in soil. Our results, however, suggest that the presence of plant cover has a particularly strong influence on the concentration of available zinc in the topmost layer of soil. Soil samples collected from the 0-25 cm horizon in the plant-covered plots contained significantly more of this micronutrient than the soil from a bare field. Thus, by keeping a set-aside field covered with plants it was possible to maintain its abundance in zinc on a high level, whereas when soil was left as bare fallow, the abundance of available zinc fell to a moderate level. Permanent sward as well as annual plant cover could have had some effect such as reduced zinc leaching from soil. The humus compounds which appear in such soil, as DZIADEK and WACŁAWEK (2005) suggest, may favour the formation of salts of simple chelates of complex compounds. This in turn might protect this element from excessive leaching from the top layer of soil. As STĘPIEŃ et al. (2004) claim, the solubility of zinc in soil solutions depends on the content of humus.

In the 25-50 cm layer, the impact of the tested ways of maintaining fallow land on the concentration of zinc in soil was much weaker than in the 0-25 cm horizon. In the subsoil, the content of available zinc was 15% lower than in the upper layer.

The way set-aside fields were managed had a significant effect on the concentration of available copper in the topmost soil layer (Table 2). The highest copper abundance was determined in the soil which was subjected to annual agrotechnical treatments (bare fallow and seeded fallow). Periodical weeding by ploughing or soil cultivating most probably stimulated the processes of mineralization and favoured the release of copper from more complex compounds. DZIADEK and WACŁAWEK (2005) state that organic substance plays the predominant role in binding copper compounds in soil. Soil sorptive capacity for Cu^{2+} is very high and in most soils it is a decisive factor affecting the mobility and plant availability of this metal. Thus, it is highly probable that once the mineralization conditions were improved owing to agrotechnical treatments, a significant increase in the concentration of available copper occurred in the topmost layer of the soil under bare fallow or seeded annually. Soil under permanent grass cover, compared to the former two variants, contained significantly less copper. This tendency appeared both in the upper soil horizon and in the subsoil. For comparison, it can be noticed that the arable layer of soil cropped with brome contained over 28% less available Cu^{2+} than that under bare fallow. According to SIENKIEWICZ-CHOLEWA and WRÓBEL (2004), copper is second to boron among all the micronutrients as the most heavily exhaustible and present in the smallest amounts in Polish soils. For this reason and in the light of the present results, it is recommendable to consider well how set-aside farmland should be managed. In our own studies, despite distinct differences caused by the different ways of maintaining fields temporarily excluded from agricultural production, the content of available Cu in the 0-25 cm layer of soil in all the treatments was on a moderate level. The content of available copper in the 25-50 cm horizon was on a slightly lower level and changed analogously to that in the 0-25 cm layer.

Table 2

Content of available copper (mg Cu kg^{-1})

Layer	Treatment						Mean
	bare fallow	seeded fallow	goat's rue	traditional fallow	goat's rue + brome grass	brome grass	
0-25 cm	3.81	3.73	3.30	3.62	2.68	2.49	3.27
25-50 cm	3.52	3.07	3.25	3.42	2.56	2.21	3.00
Mean	3.66	3.40	3.28	3.52	2.62	2.34	

$LSD_{0.05}$ factor I 0.08
$LSD_{0.05}$ factor II 0.14
$LSD_{0.05}$ factor I×II 0.19

Manganese is directly responsible for environmental contamination, but at the same time it is an essential microelement for plants (JAKUBUS 2004). Therefore, it is particularly important to monitor concentrations of this element in set-aside fields. In the soil maintained as bare fallow, the concentration of plant available manganese was the highest (Table 3). Higher accumulation of the available form of manganese in soil lacking any plant cover may have been an effect of the most strongly progressing soil acidification. These results correlate with the tests reported by CHUDECKA and TOMASZEWICZ (2001), who emphasized that fact that the soil's sorptive complex in a fallow

Table 3

Content of manganese (mg Mn kg^{-1})

Layer	Treatment						Mean
	bare fallow	seeded fallow	goat's rue	traditional fallow	goat's rue + brome grass	brome grass	
0-25 cm	127.64	121.03	116.27	98.39	124.01	113.22	116.76
25-50 cm	119.91	120.05	102.00	84.82	120.64	98.58	107.66
Mean	123.78	120.54	109.13	91.61	122.32	105.90	
$LSD_{0.05}$ factor I 1.27 $LSD_{0.05}$ factor II 2.20 $LSD_{0.05}$ factor I×II 3.11							

field undergoes negative changes, such as an increased share of H^+ cations and decreased share of alkaline cations, mainly Ca^{2+}. CHUDECKA and TOMASZEWICZ (2001) suggest that levels of available forms of heavy metals rise in set-aside soil once all or some of the agrotechnical treatments are discontinued. In our experiment, significantly more available manganese was determined in soil under a mix of goat's rue and aweless brome than in soil covered with monocultures of these two species or by natural plants. Irrespective of the way fallow land was maintained, the concentration of plant available manganese in soil, with respect to the threshold values, was on an average level.

The concentration of manganese in the subsoil (25-50 cm) was just as evidently affected by the way fallow land was managed as in the upper soil layer. The average concentration of Mn in the subsoil was nearly 8% lower than in the arable soil horizon. The highest supply of plant available manganese in the 25-50 cm layer was determined in the plots covered by annual plants and a mixture of goat's rue and aweless brome.

CONCLUSIONS

1. Long-term or annual sward of grass growing on fallow fields contributed to higher abundance of plant available copper in the upper soil layer.

2. When soil was kept as bare fallow, it tended to accumulate more of the available forms of copper and manganese.

3. Traditional fallow limited the availability of manganese in the two soil layers (0-25 and 25-50 cm) and fallow land swarded with aweless brome produced an analogous effect on copper.

4. Long-term fallowing or setting-aside may change concentrations of available forms of Cu, Zn and Mn in soil to the depth of 50 cm.

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