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THE EFFECT OF DIVERSE FERTILISATION OF A PEAT-MUCK PERMANENT MEADOW ON ZINC CONTENT IN SOIL AND IN MEADOW SWARD

Summary

Studies were carried out in plot experiment in the years 2006-2008 on permanent productive meadow on peat-much soil in the Biebrza Experimental Farm. Their aim was to demonstrate the effect of various types and intensity of fertilisation (including manure and liquid manure) on meadow yielding, soil pH and the content of zinc in soil and in meadow sward. The following levels of mineral fertilisation were applied:
PK - 30 kg of P and 60 kg of K·ha^{-1},
(I) NPK - 60 kg of N, 30 kg of P and 60 kg of K·ha^{-1},
(II) NPK - 90 kg of N, 45 kg of P and 90 kg of K·ha^{-1}.
Fertilisation with manure and liquid manure corresponded to the levels N-I and N-II after considering the equivalent of N, P and K utilization. Obtained results indicated substantial yield-forming potential of applied fertilisation – from 6 to 9 t of dry mass per ha. In the first study year the differentiated but acidic pH was found in the upper soil layers of all experimental plots. After three years of experiment, significant increase of soil pH and its further diversification was noted in some fertilisation variants. Soil richness in zinc was moderate. Zinc content was correlated with soil pH. Correlation coefficient was 0.5 in the years 2006 and 2008. Irrespective of the initial pH and zinc abundance, organic fertilisation markedly increased zinc content in soil. Mineral fertilisation caused the reverse effect. The highest mean concentrations of zinc in meadow sward were found in the first cut, slightly smaller in the second and third. Different ways of fertilisation and increasing content of zinc in organically fertilised soils did not result in marked increase of this element content in meadow sward.
Key words*: permanent meadow, fertilisation, soil richness, zinc content in sward*

WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA ŁĄKI TRWAŁEJ TORFOWO-MURSZOWEJ NA ZASOBNOŚĆ GLEBY W CYNK I JEGO ZAWARTOŚĆ W RUNI ŁĄKOWEJ

Streszczenie

Badania prowadzono na doświadczeniu łanowym w latach 2006–2008 w ZD Biebrza na wieloletniej łące produkcyjnej na glebie torfowo-murszowej. Celem badań było wykazanie wpływu różnych rodzajów i poziomów nawożenia (w tym obornika i gnojowicy bydlęcej) na plonowanie łąki, pH gleby, zasobność gleby w cynk i jego zawartość w runi łąkowej.
Stosowano następujące poziomy nawożenia mineralnego:
(bez azotu) PK - 30 kgP i 60 kgK·ha^{-1},
(I) NPK - 60 kgN, 30 kgP, 60 kgK·ha^{-1},
(II) NPK - 90 kgN, 45 kgP i 90 kgK·ha^{-1}.
Tak jak nawożenie mineralne, również stosowane nawożenie obornikiem i gnojowicą po uwzględnieniu równoważników wykorzystania N, P i K odpowiadały wskazanym ilościom nawożenia mineralnego na poziomie N-I i II. Uzyskane wyniki wskazywały na znaczny potencjał plonotwórczy stosowanego nawożenia – od ok. 6 do 9 t s.m.·ha^{-1}. W pierwszym roku badań, na wszystkich łanach doświadczenia, stwierdzono zróżnicowany ale kwaśny odczyn górnych warstw gleby. Po trzech latach badań na niektórych obiektach nawozowych stwierdzono istotny wzrost wartości pH gleby przy dalszym jej zróżnicowaniu. Zasobność badanej gleby w cynk kształtowała się na średnim poziomie. Na podstawie przeprowadzonych obliczeń współczynnika korelacji stwierdzono zależność między odczynem gleby a jej zasobnością w cynk. Współczynnik ten w 2006 i 2008 roku wynosił 0,5. Niezależnie od początkowego odczynu i poziomu zasobności gleby w analizowany składnik, stosowane nawożenie organiczne, powodowało wyraźne jego zwiększenie. Natomiast nawożenie mineralne powodowało efekt odwrotny. Największe średnie zawartości cynku z lat 2006-2008 w runi łąkowej stwierdzono w pierwszym pokosie, nieco niższe w drugim i trzecim. Wśród stosowanych sposobów nawożenia i przy zwiększającej się zasobności gleby w cynk na obiektach nawożonych organicznie, nie stwierdzono, wyraźnego wzrostu zawartości tego pierwiastka w runi łąkowej.
Słowa kluczowe*: łąka trwała, nawożenie, zasobność gleby, zawartość cynku w runi*

1. Introduction

Large animal stock in farms oriented to cattle (mainly dairy cattle) breeding increases a possibility of application of organic fertilisers even on grassland situated on peat-muck soils. Chief asset of using these fertilisers is their prolonged action in time and multiple effects on both plants and soil properties [9]. Many authors [3, 12, 13, 30] indicate the advantages of organic fertilisers like the improvement of species composition in the sward, increased yields and soil enrichment in organic matter.

Apart from proteins, carbohydrates and other organic components, mineral components i.e. macro- and microelements play a significant role in the assessment of biological value of meadow sward [8]. Zinc is an important microelement that stimulates proper functioning of plants, animals and humans. Its content is an indicator of the fodder value of grass vegetation [7]. Zinc is involved in the formation of growth hormones and many enzymes participating in carbohydrate, protein and phosphorus metabolism [1]. It also affects the permeability of cell membranes, controls the formation of ribosomes, participates in the synthesis of auxins and increases plant resistance to drought and diseases [2, 14, 21].

Zinc is an element of a high mobility in the soil habitat [6], its availability to plants is, however, determined by pH [22, 26] and by Ca/Zn ratio in soil solution [14]. Domańska and Filipek [7] showed that acidic pH favourably affects Zn uptake by plants only in mineral soils. Total Zn content in soils, moisture, the presence of carbonates, microbial activity of the rhizosphere, the content of other micro- and macroelements (mainly phosphorus, nitrogen and copper) and organic substances are all important for Zn uptake by plants [1, 17]. Tiller [28] is of the opinion that zinc uptake by plants is mainly determined by soil properties. According to some authors [14, 18] the properties of organic soils inhibit Zn availability for plants or do not affect it at all [15].

The aim of this study was to demonstrate the effect of various types and doses of fertilisers applied on permanent meadow situated on peat-muck soil on the content of zinc in soil and in meadow sward.

2. Material and methods

Studies were performed in a plot experiment in the years 2006-2008 in the Biebrza Experimental Farm on permanent meadow situated on peat-muck soil. In the years preceding the experiment, meadow was fertilised with liquid manure at a dose of 80 to 100 $m^3 \cdot ha^{-1}$, which, considering the equivalents of particular components, corresponded to ca. 200 kg of N, 100 kg of P and 200 kg of $Khan^{-1}$. So high rate of fertilisation could be the reason of decreased soil pH.

In presented study the effect of mineral fertilisation (PK and NPK) was compared with that obtained after application of cattle manure and liquid manure. The following variants of fertilisation were used: PK – 30 kg of P and 60 kg of $K \cdot ha^{-1}$, NPK/I – 60 kg of $N \cdot ha^{-1}$ and P and K in the same amounts as in PK, NPK/II – 90 kg of N, 45 kg of P and 90 kg of $K \cdot ha^{-1}$, O/I – manure 15–20 $t \cdot ha^{-1}$ depending on nitrogen content which was equivalent to NPK/I variant, O/II – manure 22.5–30.0 $t \cdot ha^{-1}$ with N, P and K content comparable with that in NPK/II, G/I – liquid manure 25–35 $m^3 \cdot ha^{-1}$, G/II – liquid manure 37.5–52.5 $m^3 \cdot ha^{-1}$ with N, P and K inputs comparable with NPK/I and NPK/II, respectively. Mineral fertilisation was applied in a form of ammonium saltpetre 1/3 of annual dose under each cut, phosphorite flour in spring and potassium sulphate in three equal doses in spring and after the first and second cut. Manure was applied once in autumn with manure spreader. Liquid manure was applied by splashing in equal doses in spring and after the first cut. The amounts of organic fertilisers were determined from their nitrogen content considering the equivalents of nutrient utilization Kutera [16]. The following equivalents were adopted for N, P and K:

	N	P	K
- manure	0.5	1.0	0.7
- liquid manure	0.7	1.0	0.8

Phosphorus deficits in liquid manure were supplemented with phosphorite flour. Six plots (objects) 0.3 ha each were marked off on the meadow for the needs of this study. To assess yielding and to take soil and sward samples for chemical analyses, 5 subplots (replicates) of an area of 25 m^2 were marked off on each plot. The yields were estimated from three cuts on particular objects. Obtained data on dry mass yields were statistically processed. Every year, zinc content was determined in the samples of meadow sward, after their drying, powdering and mineralization, with atomic absorption spectrophotometry Sapek [23].

Soil samples from study objects were collected with the Egner-Riehm cane from 0-10 and 10-20 cm soil layers in the first and after the third study year. The samples were dissolved in 0.5 N HCl. Zinc content in soil samples was determined with the same method as in plant material Sapek [1997]. Soil pH was determined in 1 M KCl soil extracts (pH_{KCl}). Obtained results were statistically processed using ANOVA procedures.

All analyses were carried out in the Laboratory of Environmental Chemistry, Institute of Technology and Life Sciences in Falenty.

3. Results and discussion

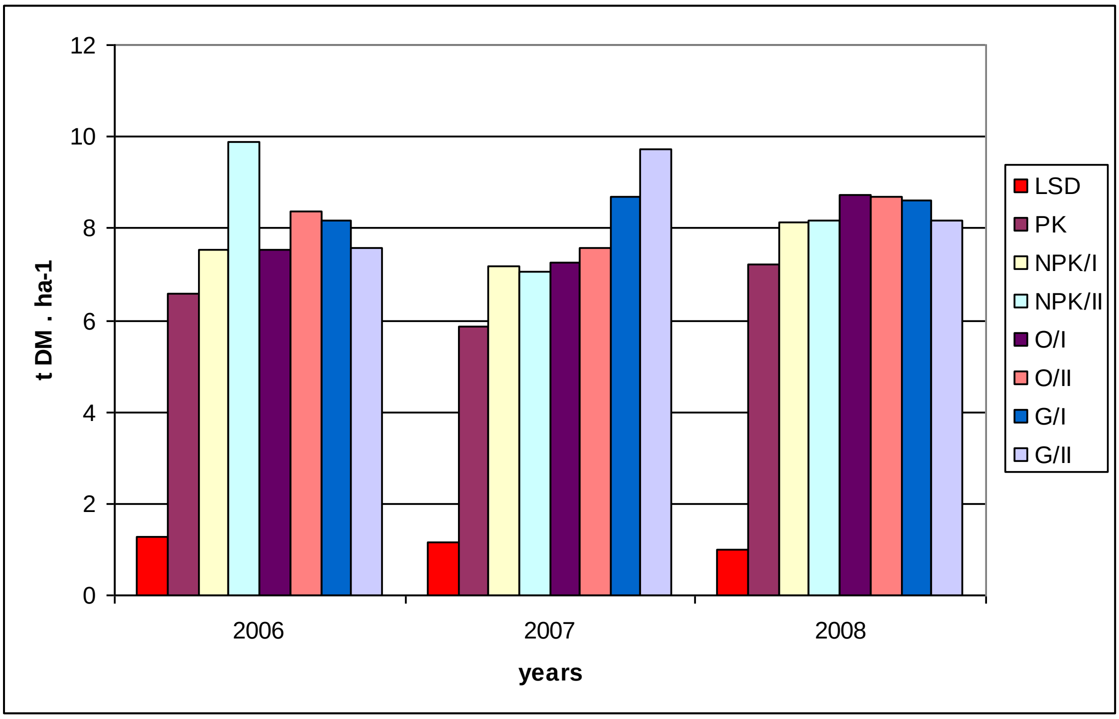
Annual dry mass yields differed markedly among study objects in 2006 (Fig. 1). Significantly higher than in other study objects was the yield from NPK/II treatment. Yields from G/I and O/II were significantly higher than that obtained from PK fertilisation. In the year 2007 the yields obtained from objects fertilised with mineral (NPK/I and NPK/II) and organic (O/I, O/II, G/I and G/II) fertilisers were significantly higher than that noted on PK object. Yields in the year 2008 were more uniform. Compared with the PK object, significantly higher yields were noted on plot fertilised with O/I, O/II and G/I.

Results of performed studies indicated substantial yield-forming potential of the soil since dry mass yields ranged from 6 to more than 9 $t \cdot ha^{-1}$. Fertilisation of peat-muck soil with only phosphorus and potassium increased the yield since such soils are usually poor in these elements, which was also reported by Okruszko et al. [20]. Complete NPK fertilisation, irrespective of fertiliser form, increased the yields as it did in studies by Niczyporuk [19], Grynia [11], Jankowska-Huflejt [12] and Wesołowski [30] but showed significant year-to-year variability.

In the beginning of the experiment, soil pH was acid to slightly acid in both layers in all study objects. Soil pH varied from 5.19 to 5.77 and from 5.29 to 6.00 in 0-10 cm and 10-20 cm layers, respectively (tab. 1). In most study objects soil pH increased after three years of experiment. Significantly higher pH was noted in objects fertilised with NPK/II, G/I and O/II in both soil layers in the year 2008.

Analysed soil had moderate but variable zinc content. In the beginning of experiment the highest Zn concentrations were found in soils of plots fertilised with mineral fertilisers (NPK/I and NPK/II). Application of mineral fertilisers in both doses resulted in a decrease of zinc content with the exception of 10-20 cm layer in NPK/II fertilised soil. During the three-year study period (2006-2008) in objects fertilised with both organic fertilisers a clear trend of increasing Zn content or its significant changes in soil were observed (fig. 2). The highest soil richness in zinc and significant increase of its content in the third study year was found in both soil layers of the object fertilised with manure at single dose (O/I).

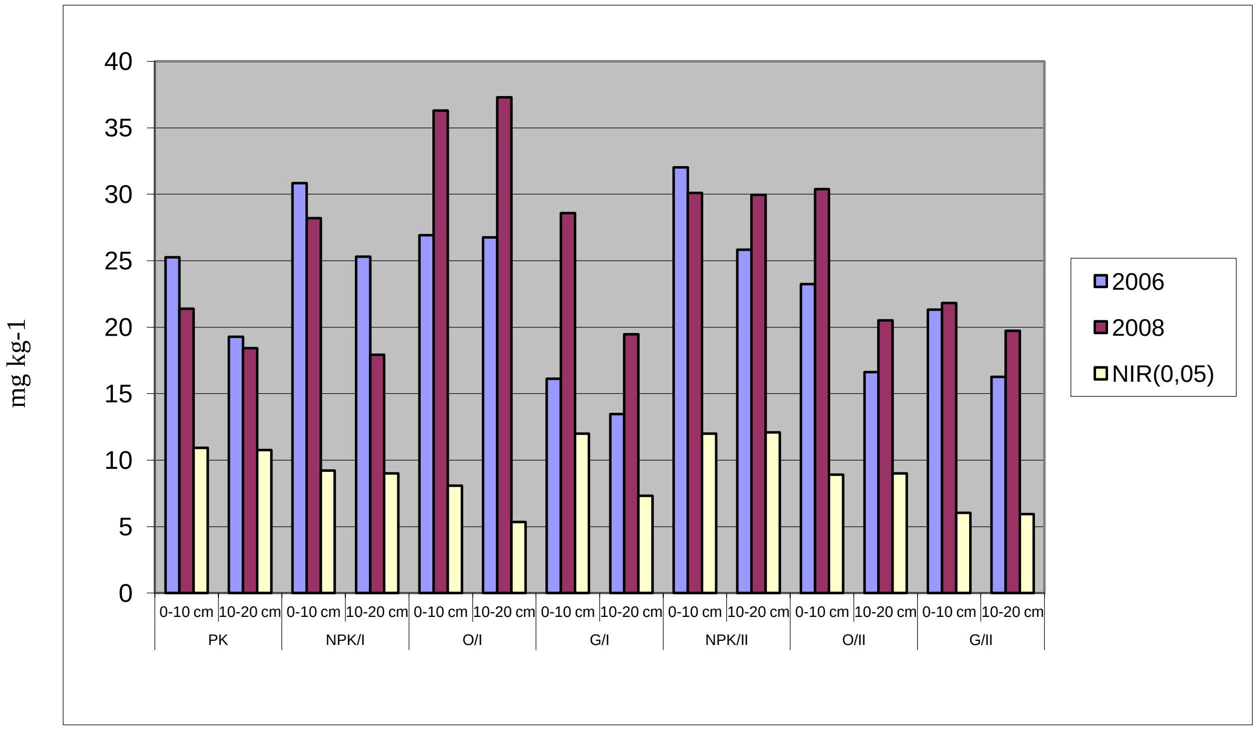
Unlike in studies by Barszczewski, Ducka [4] and Sapek [25], a weak positive relationship was found here between soil pH and Zn content. The coefficient for respective correlations in the years 2006 and 2008 was the same and equalled 0.5.



NIR – least significant difference at α = 0.05 / NIR – najmniejsza istotna różnica, gdy α = 0,05

Source: Own work / Źródło: opracowanie własne

Fig. 1. Annual dry mass yields (t·ha^{-1}) from particular objects
Rys. 1. Roczne plony suchej masy (t·ha^{-1}) z poszczególnych obiektów



NIR – least significant difference at α = 0.05 / NIR – najmniejsza istotna różnica, gdy α = 0,05

Source: Own work / Źródło: opracowanie własne

Fig. 2. Soil richness in zinc, mg Zn·kg^{-1}
Rys. 2. Zasobność gleby w cynk, mg Zn·kg^{-1}

Table 1. Soil pH in particular fertilisation objects
Tab. 1. Wartości pH gleby na poszczególnych obiektach nawozowych

Layer (cm)	Objects	Years		$LSD_{0,05}$
		2006	2008	
0-10	PK	5.31	5.59	0.17
	NPK/I	5.77	6.05	1.29
	O/I	5.19	5.78	0.94
	G/I	5.49	6.07	0.37* 0.25 *
	NPK/II	5.24	5.59	0.19 *
	O/II	5.31	5.95	0.32
	G/II	5.35	5.57	
10-20	PK	5.39	5.71	0.39
	NPK/I	6.00	6.33	1.38
	O/I	5.75	5.84	0.54
	G/I	5.79	6.24	0.20*
	NPK/II	5.29	5.64	0.24 *
	O/II	5.56	5.95	0.26 *
	G/II	5.59	5.77	0.25

NIR – least significant difference at α = 0.05 / NIR – najmniejsza istotna różnica, gdy α = 0,05

Source: Own work / Źródło: opracowanie własne

Zinc content in meadow sward in the years 2006-2008 (tab. 2) markedly differed among subsequent cuts being the highest in the first and gradually declining in the second and third cut. In the first study year, zinc content in meadow sward showed a great variability among replicates (shown by NIR values), which could have resulted from uneven distribution of previously applied liquid manure. Significantly higher Zn content in the first cut of 2006 was found on NPK/II fertilised plots compared with those fertilised with NPK/I and O/I. Zinc content in sward of the first cut in 2007 was similar among study object with a tendency of its increase in NPK/II fertilised object. The lowest concentration of zinc in sward from the first cut in 2008 was noted in O/I fertilised object and significant increase in the element content was found in PK, NPK/I, G/I and G/II fertilised objects. As in 2006, the NPK/II fertilised object showed significantly higher Zn content in sward of the first cut in 2008 compared with other study objects.

The first cut in NPK/I and O/I fertilised objects showed significant differences in Zn content among the years with its higher content in 2007. Three-year mean Zn content in sward from the first cut was significantly higher in NPK/II fertilised plot than that in NPK/I and O/I fertilised plots, which could have resulted from higher soil pH in the latter.

Significant differences among study objects were found in Zn content in the second cut. In 2006, significantly higher zinc contents were noted in O/I, O/II and G/II fertilised objects compared with the others. However, significantly higher Zn concentrations in sward were recorded in PK, NPK/I and G/II fertilised objects in the year 2007. In the next year, significantly higher Zn content in sward from second cut was only found in NPK/II fertilised object compared with O/I, G/I, O/II and G/II fertilised objects.

Significant differences among the years 2006, 2007 and 2008 resulted from high concentrations of Zn in the sward from G/I, O/II and G/II objects in the year 2006. No significant differences in the mean Zn content of the second cut were found among particular objects.

The sward of the third cut was not differentiated in Zn content among fertilisation objects and between the years 2006 and 2008. Significantly higher concentrations of Zn in sward were found in NPK/I, G/I and NPK/II than in O/II and G/II objects in the year 2007. In nearly all study objects, Zn content in sward was higher in 2008. No significant differences were found in mean concentrations of zinc in sward of the third cut from particular objects.

Correlation coefficients calculated for the year 2006 proved the relationship between soil richness in zinc and its content in sward. In the beginning of the experiment this coefficient was 0.55 but decreased to 0.08 in the year 2008. This effect confirms the results of Barszczewski and Ducka [4] but contradicts the data obtained by Borowiec and Urban [5] and by Trąba and Wolański [29] and is an evidence of a positive impact of soil Zn on the content of this element in meadow sward.

Table 2. Zinc content (mg $Zn \cdot kg^{-1}$) in the sward from particular cuts in the years 2006-2008
Tab. 2. Zawartość cynku w runi (mg $Zn \cdot kg^{-1}$) z poszczególnych pokosów w latach 2006-2008

Cut	Years	Content of Zn in sward on objects							
		PK	NPK/I	O/I	G/I	NPK/II	O/II	G/II	**$LSD_{0,05}$**
I	2006	25.91	18.54	20.20	25.80	35.78	29.71	29.20	**10.85***
	2007	31.64	30.61	26.98	31.88	34.58	31.52	31.17	**7.61**
	2008	32.30	27.75	22.99	27.47	36.97	23.43	27.67	**2.19 ***
	mean	**29.95**	**25.63**	**23.39**	**28.38**	**35.78**	**28.22**	**29.35**	**8.75 ***
	$LSD_{0,05}$	**7.64**	**4.94 ***	**5.49 ***	**7.96**	**3.94**	**9.14**	**8.63**	**-**
II	2006	28.47	26.89	28.14	32.34	26.20	40.78	40.20	**10.97***
	2007	27.08	27.66	24.18	19.79	21.85	18.89	25.07	**3.50 ***
	2008	24.58	25.20	23.96	23.63	26.96	18.20	22.01	**2.73 ***
	mean	**26.71**	**26.58**	**25.43**	**25.24**	**25.00**	**25.96**	**29.09**	**10.61**
	$LSD_{0,05}$	**7.10**	**3.56**	**6.65**	**6.01 ***	**5.78**	**4.65 ***	**12.15 ***	**-**
III	2006	18.54	21.35	15.47	22.27	20.87	19.78	25.14	**9.59**
	2007	25.55	27.47	24.84	27.74	28.81	22.13	23.62	**4.65 ***
	2008	31.04	27.36	29.19	31.39	30.40	28.33	27.11	**6.72**
	mean	**25.04**	**25.39**	**23.17**	**27.13**	**26.69**	**23.41**	**25.29**	**6.80**
	$LSD_{0,05}$	**5.63 ***	**6.35 ***	**2.05 ***	**7.97 ***	**9.71 ***	**5.68 ***	**7.10**	**-**

NIR – least significant difference at α = 0.05 / NIR – najmniejsza istotna różnica, gdy α = 0,05

Source: Own work / Źródło: opracowanie własne

As in the study by Spiak and Wall [27], our study did not show the relationship between soil pH and the content of Zn in meadow sward. As shown by Tiller [28] high solubility of zinc, and hence its uptake by plants, takes place when soil pH is below 4.5. At pH above 7, not observed in our experiment, zinc is strongly bound in soil. Acid or slightly acid soil pH in the beginning of the experiment did not increase Zn uptake by plants and thus did not confirm Gondek's [10] results indicating its bigger availability in such conditions.

4. Conclusions

1. Applied fertilisation with organic fertilisers markedly increased zinc content in soil, irrespective of pH and soil richness in Zn in particular objects,
2. Significant increase in zinc content in sward of the first cut was found in objects fertilised with higher doses of fertilisers.
3. Irrespective of the form and dose of applied fertilisers, the deficit of zinc in meadow sward from all cuts results from specific properties of peat-muck soil which limit zinc availability for plants.

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