Changes in the zinc content in the meadow sward under conditions of a long-term static fertilizer experiment (Czarny Potok)

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ABSTRACT

Changes in the zinc content in the meadow sward were studied in a long-term fertiliser experiment set up on a mountain meadow (20°54′E, 49°24′N) in 1968. The experiment is localized at 720 meters above sea level on the soil which belongs to Dystric Cambisols and comprises 8 fertiliser treatments in two series: 0Ca and + Ca (Table 1). In the course of the experiment the Zn content in the sward decreased and the time factor was of greater consequence than fertilization, P content in the sward or soil and acidification. In mountain meadow communities shaped by a long-term (over 30 years) NPK treatment and at yields between 6.7 and 7.1 t/ha the annual quantity of absorbed Zn ranged between 233 and 256 g Zn/ha dry weight. During the experimental period the biggest amount of Zn removed with the sward yield exceeded 500 g Zn/ha annually. In the limed series at slightly bigger yields the quantity of Zn removed with the yield was over 10% lower in objects receiving NPK fertilization than on the same treatments in the unlimed series. Liming is able to reduce soil Zn abundance.

Keywords: meadow sward; Cambisols; zinc; uptake by plants; long-term experiment

The proper utilisation of nutrients becomes particularly important in view of implementing a sustainable farming system in agriculture. Maintaining the soil in condition not worse than the one in which we found it becomes a vital issue when crop production is intensified. For high yields it is extremely important to supplement some elements to the soil as their lack may lead to disturbance of environmental balance due to their big amounts removed with yields (Southwood 1994, Anders 1996). It is difficult to decide whether microelements should or should not be applied in intervention or prophylactic treatment, particularly on grasslands. It results from many factors. One of them is uncertainty whether the chosen factor really constituted a minimum. Sustainable treatment is simpler but at low availability of a microelement in soil it may prove to be less effective, on the other hand at its high availability it may be unnecessary or even harmful. The meadow sward of permanent grasslands undergoes big changes (Mrkvička and Veselá 2002, Lemežienė et al. 2004). Besides fertilization, the botanical composition of the sward will modify its chemical composition to the greatest extent. Climatic conditions may cause a delay in appearance of some dicotyledonous practically obliterating representative character of a single sampling. Contents of the microelement in the meadow sward are to a considerable degree dependant on atmospheric conditions, the element content in soil and botanical composition of the sward, so an assessment of the effect of amount and quality of microelement fertilization is often subjective (Trąba and Wolański 2000).

The work presents changes in Zn contents and its amount taken up with biomass, which were observed during the 35-year research carried out as a static fertilizer experiment on a mountain meadow. Czuba and Murzyński (1993) demonstrated that copper and Zn deficiency occurred first as a result of long-term systematic fertilization of a cut meadow. Fertilization with 51 kg Cu and 13 kg Zn applied to the soil as regenerative treatment for 5 years restored the soil abundance by these components and improved their contents in the sward. However, the range of these changes was low from the practical point of view. The content of Zn increased from 23–25 mg/kg to 31–32 mg/kg dry matter of the sward on 120–600 kg N + PK treatments.

MATERIAL AND METHODS

The experiment was localised at Czarny Potok near Krynica (20°54′E, 49°29′N) at about 720 m above sea level, at the foot of Jaworzyna Krynicka within the south-eastern massif of the Beskid

Sądecki Mts. on a slope with 7° inclination and NNE exposition. The experiment was set up in 1968 on a natural mountain meadow of moor mat grass (*Nardus stricta* L.) and red fescue (*Festuca rubra* L.) type with a considerable share of the dicotyledonous. The soil belonged to Dystric Cambisols (FAO) soils developed from Magura sandstone with granulometric composition of light silty loam (40% of 1–0.1 mm, 37% of 0.1–0.02 mm and 23% of > 0.02 mm fractions) and three characteristic genetic horizons: turf – AhA (0–20 cm), browning – ABbr (21–46 cm) and matrix BbrC (47–75 cm). Detailed data of the experiment were given in an earlier paper (Kopeć 2000).

Since the autumn 1985 the experiment, at the same level of fertilization, was conducted in two series: unlimed and limed. In 1995 liming was repeated. First liming was carried out with the lime dose calculated on the basis of 0.5 hydrolytic acidity (Hh) value, the second considered total hydrolytic acidity.

In 1974–1975 and 1993–1994 intervals in mineral treatment were introduced and the experiment was limited to determining the sward yield and its chemical composition.

The experiment comprises 8 treatments (Table 1) where unilateral N or P fertilization (90 kg N/ha or 90 kg P_2O_5/ha) and against PK background (90 kg P_2O_5/ha and 150 kg K_2O/ha) of N was applied in two forms (ammonium nitrate and urea) in two doses (90 and 180 kg N/ha). In 1968–1980 P fertilizers (superphosphate in dose 90 kg P_2O_5/ha) and K fertilizers were applied in autumn. Since 1981 the fertilizers have been applied in spring and K (1/2 of a dose) was supplemented in summer after the first cut. During the whole period of the experiment N fertilizers were sown at two dates: 2/3 of the annual dose in spring when vegetation starts and 1/3 of a dose several days after the first cut harvesting. In 1994 10 kg Cu/ha and 8 kg Mg/ha was applied as intervention fertilization (in the form of sulphates). Since 2000 foliar treatment has been used (twice 2 dm^3/ha) with microelement Mikrovit-1 fertilizer (in the form of chelates), which in 1 dm^3 contains: 23.3 g Mg, 2.3 g Fe, 2.5 g Cu, 2.7 g Mn, 1.8 g Zn, 0.1 5 g B and 0.1 g Mo.

As a result of fertilization stabile meadow communities developed mainly with grasses predominant in their botanical composition (Kopeć 2000).

The yields of the first and second cut of the meadow sward were regularly assessed. Zn contents in the sward samples were determined always after their incineration and dilution in nitric and hydrochloric acids, in the soil samples after incineration and mineralization in the mixture of nitric and perchloric acids (2:1) using ASA technique or ICP technique (since 2000) (Ostrowska et al. 1991). Weighted means were calculated on the basis of the content and yield of two cuts.

Soil samples from each object were collected in autumn from soil layers: 0–100 mm. Available P content in soil was determined by colorimeter (according to the Egner-Riehma method) after extraction with calcium lactate and soil reaction (pH) was determined in 1 mol KCl/dm^3 (1:2.5) (Ostrowska et al. 1991).

RESULTS AND DISCUSSION

In the author's own studies (Figures 1–3) the Zn content of the sward decreased over the period of the experiment on all objects in both series to the level of 30–40 mg Zn/kg of the sward dry weight. Variability of the contents may be sought in a changeability of botanical composition and in climatic conditions, which were presented in the other publication (Kopeć 2000, Kopeć and Gondek

Table 1. Design of the static experiment at Czarny Potok

Fertilising objects	Annual nutrient rate in 0Ca and + Ca series (kg/ha)			N form
	P	K	N	
PK	39.24	124.5	–	
PK + N_{1an}	39.24	124.5	90	ammonium nitrate
PK + N_{2an}	39.24	124.5	180	ammonium nitrate
PK + N_{1u}	39.24	124.5	90	urea
PK + N_{2u}	39.24	124.5	180	urea
N_{1an}	–	–	90	ammonium nitrate
P	39.24	–	–	
0	–	–	–	

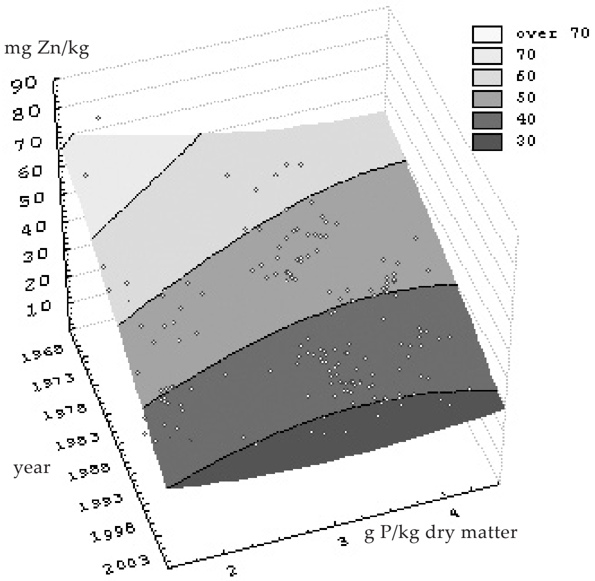

Figure 1. Dependency between weighted mean of Zn and P contents in sward of all objects over the 35 years of the experiment (n = 270)

2002). However, no significant dependencies were demonstrated between rainfall or temperature and Zn contents in the sward. A decrease in the Zn content in the sward depended on the amount of Zn removed with the yield and it was the most important factor responsible for changes in the Zn content in plants.

An increase in the Zn content in the sward occurs as a result of Zn application to the soil. In the nine-year meadow experiment Barszczewski et al. (2000) reported that Zn contents in the sward increased in the course of the experiment and the phenomenon was more pronounced when a bigger dose of N (240 kg N/kg) was used. However, the same authors demonstrated that in the ninth year after Zn fertilization its contents in the sward declined and a significant equalizing was observed among the treatments. Trąba and Wolański (2000) stated that low Zn content in the sward to a greater extent may result rather from various interrelations of site factors than from sward botanical composition, in which numerous dicotyledonous are present usually abundant in Zn.

Figure 2 presents a dependency of weighted mean Zn and available P content in soil of all treatments over the 35 years of the experiment (n = 268). The graphs primarily show the effect of time of the meadow utilisation on Zn content in the sward. P concentrations in plants (Figure 1), particularly within the range considered as permissible for sward (over 0.3% P) affects Zn content less than the time of the experiment. Bigger Zn concentrations may occur with low P contents in sward or low soil abundance in available P, which is strictly connected with it.

Soil acidification determined by the soil reaction and the Zn content are presented in Figure 3. A relationship between acidification, the zinc con-

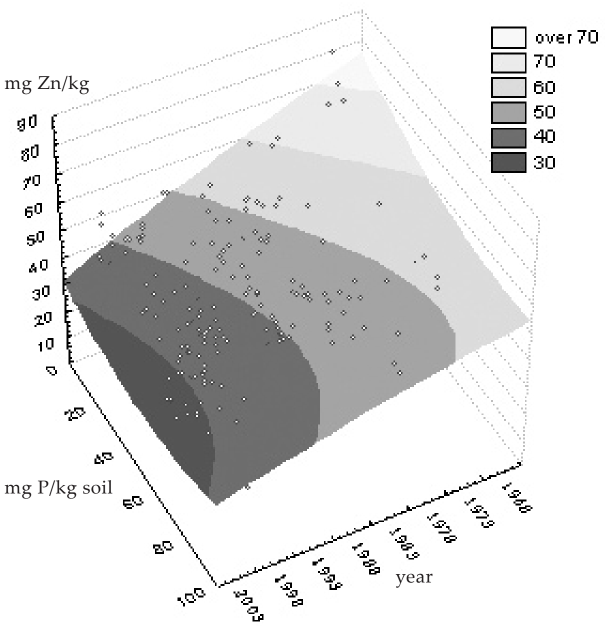

Figure 2. Dependency between weighted mean of Zn and available P content in soil of all objects over the 35 years of the experiment (n = 270)

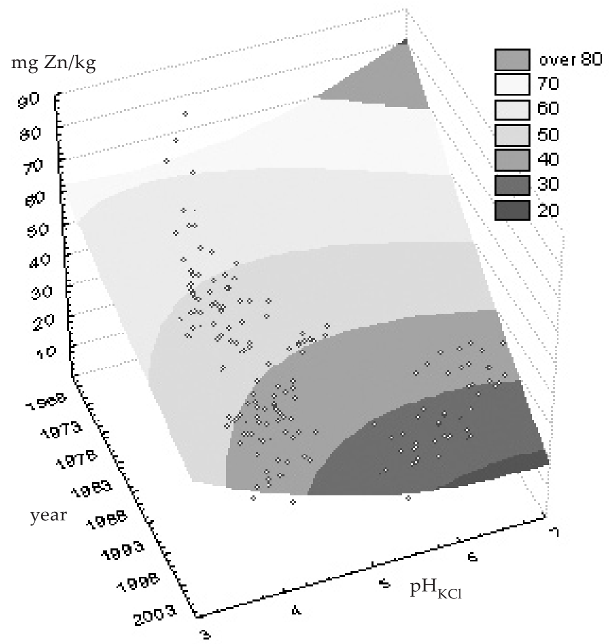

Figure 3. Dependency between weighted mean of Zn and soil reaction (pH_{KCl}) of all objects over the 35 years of the experiment (n = 270)

Table 2. Mean annual amounts of Zn taken up by plants and meadow sward yields dry matter (t/ha) in selected periods of the experiment

Fertilising objects	1971–1972		1979–1985		1986–1989				1996–2002			
	0Ca		0Ca		0Ca		+Ca		0Ca		+Ca	
	Zn (g/ha)	(t/ha)	Zn (g/ha)	(t/ha)	Zn (g/ha)	(t/ha)	Zn (g/ha)	(t/ha)	Zn (g/ha)	(t/ha)	Zn (g/ha)	(t/ha)
PK	207c*	4.3	179c	3.8	147d	3.5	160b	4.1	193b	5.4	123c	5.5
PK + N_{1an}	315b	6.6	332b	7.0	216b	5.3	187b	5.0	233a	7.0	177a	7.4
PK + N_{2an}	450a	8.4	495a	10.5	245a	6.4	223a	6.4	240a	6.7	184a	7.9
PK + N_{1u}	306b	6.6	309b	6.6	207b	5.2	186b	5.1	256a	7.1	156ab	7.2
PK + N_{2u}	379a	8.0	544a	10.4	252a	6.2	228a	6.4	247a	6.9	181a	7.8
N_{1an}	244c	3.9	279b	4.5	199c	4.3	185b	4.9	185b	4.5	145b	4.6
P	219c	4.1	210c	3.8	142d	3.0	155bc	3.8	158c	3.9	100c	3.7
0	134d	1.8	205c	4.0	135d	2.8	116c	3.0	111d	2.8	89d	2.9

*homogenous groups according to Tukey's test

tents in the sward and time shows that the time of the experiment most affected the Zn content. Higher soil reaction caused by liming reduced the Zn content in the sward (Figure 3) and prolonged the period of time in which the Zn content in soil remained on a higher level than in the case of soil without liming. Spiak and Wall (2000) found lack of dependence between the reaction and the Zn content in plants. The authors claim that the Zn content in plants under natural conditions (with reference to the soil unpolluted with this element) is connected with the amount of available forms of this element in the soil. Liming carried out in 1985 decreased sward Zn concentrations on all treatments, but in the subsequent years after treatment the contents grew. The next liming significantly lowered Zn content in the sward on all treatments and the effect of the treatment remained and intensified over the next few years. Gorlach and Curyło (1987) noted a similar result of liming in a 16-year experiment. Mikrovit-1 fertilization generated an increase in sward yield but the amount of the component introduced with fertilizer (6.4 g Zn/kg) was insufficient to increase Zn content in sward.

On the objects receiving full treatment (NPK – regardless of the nitrogen form) the amount of Zn taken up (Table 2) in the initial period of the experiment (until 1985) ranged between 306 and 544 g Zn/ha. The period was characterized by

Table 3. Total and available content of Zn (mg/kg) in soils in 2002

Fertilising objects	Total content				Available forms			
	0Ca		+Ca		0Ca		+Ca	
	0–10 cm	10–20 cm	0–10 cm	10–20 cm	0–10 cm	10–20 cm	0–10 cm	10–20 cm
PK	39.5	34.8	49.2	35.3	4.088	0.828	2.192	0.752
PK + N_{1an}	41.5	35.7	51.2	38.5	3.785	0.701	1.528	0.996
PK + N_{2an}	39.7	38.1	41.0	35.5	3.381	0.315	1.462	0.608
PK + N_{1u}	45.0	35.7	44.2	34.2	3.815	0.428	1.467	0.600
PK + N_{2u}	37.9	30.0	42.3	39.0	3.929	0.580	1.412	0.695
N_{1an}	36.2	34.7	47.7	38.7	3.372	1.088	1.220	0.664
P	46.2	38.9	52.0	42.7	4.417	0.513	1.183	0.636
0	47.5	40.5	53.5	38.7	4.508	0.880	1.009	0.824

a progressively increasing yields and reaching the highest productive potential (Kopeć 2000). A decline in yields observed in 1986–1989 was connected with smaller quantity of Zn absorbed by the sward. During this period of time, despite equalized yields on treatments differing with N dose, there was a difference in Zn concentrations in objects fertilized with 90 and 180 kg N + PK in both 0Ca and +Ca series. Over the last seven years the quantity of Zn taken up on the object receiving full treatment (NPK – regardless of the nitrogen form) in unlimed series has been highly approximate (233–256 g Zn/ha). After the first liming the amount of Zn taken up by plants was lower by 10–16% on the objects in limed series where full fertilization was applied. The decline occurred at similar yields in both limed and unlimed series. The second liming notably (by 30–64%) deepened a decline in the amount of Zn taken up by sward at considerably increased yields in the objects receiving 180 kg N + PK. During this period of time Zn quantity absorbed by sward of the limed series is the highest on the objects receiving double N dose where the average for this component forms is 182.5 g/ha.

The dynamics of microelements in the environment, including Zn, does not seem to be fully recognised. Strączyński and Wróbel (2000) demonstrated that utilisation of arable fields for many years may lead to depletion of soil microelement available forms, which results in insufficient supply of crop plants in these components. On the grounds of numerous agrochemical studies Strączyński and Wróbel (2000) revealed that during the period of several years the contents of Zn forms extracted with 1 mol HCl/dm^3 decreased in soils of all categories in Poland. The work confirms the results obtained at Czarny Potok. The lowest contents of total Zn forms in the 0–10 cm soil layer were found on unilateral N treatment and on objects receiving 180 kg N (Table 3). It should be supposed that applied liming protected soil resources of this element. In 2002 total Zn concentration in the 0–10 cm soil layer of the limed series was generally higher than in the analogous objects in the unlimed series. Significant differences among treatments concerning Zn blocking in soil occurred for the available forms assayed in ammonium nitrate but only in the 0–10 cm soil layer. As the total Zn content decreased the quantity of its available form decreased too (especially on ammonium nitrate treatments). On the other hand Mercik et al. (1992) reported that even long-term mineral or organic fertilization does not influence the contents of reserve forms of microelements in the soil. Their conclusion was based on results of soil analysis following the systematic 68-year fertilization in crop rotation and monoculture of rye and potatoes. The experiment has been carried out in Skierniewice on light soil with routine liming (pH$_{KCl}$ 6–6.5).

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ABSTRAKT

Změny obsahu zinku v lučním drnovém společenstvu v podmínkách dlouhodobého maloparcelkového výživářského pokusu (Czarny Potok)

Změny obsahu zinku v lučním drnovém společenstvu byly studovány v dlouhodobém výživářském pokusu založeném na horské louce (poloha 20°54’ východní délky, 49°24’ severní šířky) v roce 1968. Lokalita se nachází ve výšce 720 m n. m., půdní typ je dystrická kambisol a pokus byl založen v osmi variantách, každá jako vyvápněná a nevápněná. Během sledování byl zaznamenán pokles obsahu Zn v biomase rostlin. Časový faktor měl větší význam než hnojení, obsah P v drnovém společenstvu i v půdě a acidifikace půdy. V porostu horské louky hnojené dlouhodobě (více než 30 let) NPK s výnosy mezi 6,7 až 7,1 t/ha suché hmoty se každoroční množství absorbovaného Zn pohybovalo mezi 233 až 256 g/ha v suché hmotě. Během trvání pokusu bylo maximální množství Zn odebraného sklizní drnového společenstva vyšší než 500 g/ha ročně. Na vápněných plochách, kde byly mírně vyšší výnosy, množství Zn odebraného sklizní bylo o více než 10 % nižší než na nevápněných variantách. Vápnění je tedy schopné redukovat množství Zn v půdě.

Klíčová slova: louka; Kambizem; zinek; odběr rostlinami; dlouhodobý pokus

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