J. Elementol. 2009, 14(2): 265–270

THE EFFECT OF PROGRESSIVE ACIDIFICATION OF LESSIVE SOIL ON ZINC CONTENT AND ITS TRANSLOCATION IN SOIL PROFILE

Jacek Kiepul[1], Krzysztof Gediga[2]

[1]Institute of Soil Science and Plant Cultivation, State Research Institute in Puławy, Experimental Station, Jelcz-Laskowice
[2]Department of Plant Nutrition, Wrocław University of Environmental and Life Sciences

Abstract

In Poland 11% of soils feature elevated zinc content or slight zinc contamination. This investigation aimed at estimation of the effect of progressive acidification of slightly zinc-contaminated soils on zinc content in plants and translocation of this metal downwards the soil profile. The study involved a two-year lysimetric experiment on lessive soil. The amount of zinc indicating slight soil contamination was introduced into 0.2 m of topsoil, which was subjected to progressive acidification with sulfuric acid solution in the course of the experiment.

Zinc content proved to considerably increase in plants (barley straw and maize) only under strong acidification. Soil reaction did not significantly influence the zinc content in soil, both total and assayed in HCl zinc forms, while a considerable increase in easily soluble zinc forms (in $CaCl_2$ solution) occurred on strongly acidified soils.

Considering the whole research period, increasing soil acidification did not result in any alterations involving zinc content in Bbr and C horizons of soil profiles (below 30 cm).

Key words: Zn, soil reaction, plants, lysimeters.

dr Jacek Kiepul, Institute of Soil Science and Plant Cultivation, State Research Institute in Puławy. Experimental Station, ul. Łąkowa 1, 55-230 Jelcz-Laskowice, Poland, phone: (071) 318 36 44

WPŁYW SYSTEMATYCZNEGO ZAKWASZANIA GLEBY PŁOWEJ NA ZAWARTOŚĆ CYNKU W ROŚLINACH ORAZ JEGO PRZEMIESZCZANIE W PROFILU GLEBOWYM

Abstrakt

W Polsce 11% gleb charakteryzuje się podwyższoną zawartością lub słabym zanieczyszczeniem cynkiem. Celem pracy było określenie wpływu systematycznego zakwaszania gleby słabo zanieczyszczonej cynkiem na zawartość tego pierwiastka w roślinach i jego przemieszczanie w głąb profilu glebowego. Badania prowadzono w trakcie dwuletniego doświadczenia lizymetrycznego na glebie płowej. Do warstwy gleby 0-20 cm dodano cynk w ilości odpowiadającej słabemu zanieczyszczeniu tym pierwiastkiem. W czasie badań glebę systematycznie zakwaszano, stosując roztwór kwasu siarkowego.

Stwierdzono, że zawartość cynku w roślinach (jęczmień-słoma i kukurydza) istotnie wzrosła tylko na najbardziej zakwaszanych obiektach. Odczyn gleby nie wpływał istotnie na zawartość całkowitych i oznaczanych w HCl form cynku w glebie. Natomiast zawartość łatwo rozpuszczalnych form cynku (w roztworze $CaCl_2$) istotnie wzrosła w najbardziej zakwaszonych glebach. Rosnące zakwaszenie gleby nie wpłynęło w trakcie badań na zawartość cynku w poziomach Bbr i C profilu glebowego (poniżej 30 cm).

Słowa kluczowe: Zn, formy, pH gleby, rośliny, lizymetry.

INTRODUCTION

In Poland, soils characterized by elevated zinc content (I°) or slightly contaminated with zinc (II°) constitute 11 % of agricultural acreage (Mercik at al. 2003). Mobility of this metal is related to soil properties, especially its reaction (Gorlach, Gambuś 1991, Mercik et al. 2003). Therefore, prolonged acidification of soil potentially facilitates increased accumulation of zinc in plants and its translocation downwards the soil profile.

The aim of the work was to examine the effect of progressive soil acidification on zinc accumulation in plants, as well as on translocation of this metal from topsoil downwards the soil profile under slight soil contamination with zinc.

MATERIAL AND METHODS

In 2002-2003, a study was completed based on a lysimetric experiment. Lysimeters of 0.5 m^2 area and 1m depth were filled with lessive soil maintaining its natural genetic levels. Selected physicochemical soil properties are shown in Table 1. When filling lysimeters with soil, zinc in the form of $Zn(NO_3)_2$ was introduced to 0-20 cm topsoil in the amount indicating slight soil contamination (II°) with this metal. In this experiment it reached 350 mg $Zn \cdot kg^{-1}$. The experimental design involved 5 treatments (each with three

Table 1

Some properties of lessive soil used in experiment

Horizon, depth (cm)	Fraction (%)		C org. $(g \cdot kg^{-1})$	pHKCl	CEC* $(mmol(+) \cdot kg^{-1})$	Zn content $(mg \cdot kg^{-1})$		
	<0.02	<0.002				soil extract		
	mm	mm				$HClO_4$	HCl	$CaCl_2$
Ap (0-30)	17	9	9.0	5.8	106	36.4	16.5	2.72
Bbr (30-60)	15	6	4.2	5.5	68.3	19.9	6.07	0.85
C (60-90)	10	4	1.5	5.4	43.5	7.15	2.42	0.60

* CEC – cation exchangeable capacity

replications), representing various effects produced by factors regulating soil reaction. According to the experimental design, the soil in treatment 1 received two limings with a mixture of calcium carbonate and magnesium, following 0.5 Hh (spring and fall 2002) in order to prevent its acidification. The soil in objects 3-5 was systematically acidified using increasingly higher quantities of sulfuric acid solution which, expressed as (S), amounted yearly to 50, 150 and 300 $kg \cdot ha^{-1}$, respectively. Diluted sulfuric acid was spread on soil surface. Thus, the topsoil reaction (0-20 cm) was diversified during the investigation, with the pH values ranging from 4.7 to 6.1 (Table 2). Plants subjected to the test were spring barley (2002) and winter rape (2002/2003). The latter, because of its unsatisfactory winter survival, was removed and then maize was sown on that stand to be harvested in the early dough stage. In the years of the experiment, monthly precipitation generally did not exceed average multi-year values, while at the turn of 2002 and 2003 and in the subsequent months winter – spring drought occurred. The period between February and July received merely 47% of the average precipitation for many years. When the experiment was completed, soil samples were collected from the whole profile at every 10 cm to undergo the following analysis: pH was assayed with the potentiometric method in 1 mole $KCl \cdot dm^{-3}$, total Zn content was determined by sample etching in perchloric acid (Anonim 1987) and soluble forms of this metal were assayed in 1 mole $HCl \cdot dm^{-3}$ (Gembarzewski et al. 1987) and 0.01 mole $CaCl_2 \cdot dm^{-3}$ (Novozamsky et al. 1993). Plant samples were subjected to mineralization according to the microwave technique and zinc was assayed through the AAS method. Statistical analysis was applied using AWAR computer program.

Table 2

Zinc content in soil ($mg \cdot kg^{-1}$) after completion of the experiment as dependent on soil pH and soil extract solution

Soil layer (cm)	Treatment					$LSD_{0.05}$
	1	2	3	4	5	
pH value						
0-20	6.1	5.6	5.4	5.0	4.7	-
20-30	5.9	5.8	5.7	5.3	4.9	-
30-40	5.6	5.6	5.6	5.5	5.5	-
$HClO_4$ (ANONIM 1976)						
0-20	185.2	184.6	180.5	182.7	179.3	n.s.
20-30	114.7	117.3	119.1	117.6	119.8	n.s
30-40	19.6	21.0	20.5	20.0	21.0	n.s
1 mol HCl (GEMBARZEWSKI et al. 1987)						
0-20	153.6	154.2	156.8	155.3	158.4	n.s
20-30	73.1	74.4	74.2	74.4	77.8	n.s
30-40	6.40	6.83	6.45	6.68	6.97	n.s
0.01 mol $CaCl_2$ (NOVOZAMSKY et al. 1993)						
0-20	19.11	20.95	21.34	26.58	34.96	2.87
20-30	11.07	11.34	11.39	12.92	17.18	1.65
30-40	0.88	0.88	0.90	0.90	0.95	n.s.

RESULTS AND DISCUSSION

Gradual acidification of soil in the conditions of its slight contamination with zinc did not significantly affect yielding of cultivated plants (Table 3). However, on the most acidified treatments (4 and 5) zinc content in barley straw and maize did considerably increase as compared to non-acidified ones (1 and 2). In spite of this, the critical values taken for assessment of plant for consumption or fodder were not exceeded (KABATA-PENDIAS et al. 1993).

Total zinc content in soil and that assayed in HCl extract were not significantly dependent on soil reaction (Table 2). However, opinions regarding the influence of soil reaction on zinc solubility are contrary. MERCIK et al. (2003) demonstrated no effect on the total Zn form and the one extracted with HCl solution, while GORLACH and GAMBUŚ (1991) and KIEKENS (1995) reported that regardless the form of zinc, its solubility depended on soil reaction and decreased proportionally to the increase in pH value.

Table 3

Zinc content in dry matter yields of barley and maize ($mg \cdot kg^{-1}$ DM) and yield data (g per lysimeter)

Treatment	Yield			Zn content		
	barley		maize	barley		maize
	grain	straw		grain	straw	
1. Ca-2 x 0.5 Hh	174.2	280.9	870.6	29.14	32.61	37.25
2. Ca-0; S-0	162.1	274.3	867.4	31.05	34.02	39.93
3. S-50 kg*	171.6	279.1	873.5	31.43	34.14	40.78
4. S-150 kg*	184.8	287.4	892.1	32.09	36.07	44.92
5. S-300 kg*	180.3	281.2	914.7	33.68	39.12	54.16
LSD0.05	n.s.	n.s.	n.s.	n.s.	3.21	4.15

*Dose of sulfuric acid solution expressed as sulfur – S ($kg \cdot ha^{-1} \cdot year^{-1}$)

The smallest amount of zinc was assayed in $CaCl_2$ extract (Table 2). On the treatments characterized by slightly acid soil reaction (1 and 2), such zinc equalled 10.8% and when the soil reaction was 4.7 pH it reached 19.5% of the total zinc value. Therefore, our results are in agreement with the literature data, which implicate that on acid soils the quantity of soluble zinc forms increase, which favours availability of this element to plants (GORLACH, GAMBUŚ 1991, MERCIK et al. 2003).

Under progressive soil acidification, values of zinc forms assayed in soil profile below 30 cm did not increase. This can suggest that when soil contamination with zinc is slight, zinc accumulates in the arable layer but is not translocated downwards soil profile does. However, the present results could have been affected by the weather conditions. It is apparent that translocation of components in soil is strongly related to water content in soil as well as predominant direction of its movement (KOC et al. 2003). Taking into account the amount and distribution of precipitation in the course of this investigation, it is possible to hypothesize that rinsing was limited, which can be confirmed by the absence of soil leachate in the years when this experiment was conducted.

CONCLUSIONS

1. Gradual soil acidification under slight soil contamination with zinc did not significantly influence the yielding of cultivated plants.

2. Zinc content in plants, mainly in barley straw and in maize, considerably increased only on highly acidified treatments, but its amounts did not

exceed the critical values established for plants for consumption (barley grain) or fodder (barley straw and maize).

3. Total zinc content and zinc assayed in HCl extract in soil were not dependent on soil reaction, while on the most acidified treatments, the zinc content assayed in $CaCl_2$ extract did significantly increase in Ap (0-30 cm) horizon.

4. Under progressive soil acidification, no evidence emerged suggesting increase in zinc forms assayed in Bbr and C horizons of soil profiles (below 30 cm).

REFERENCES

ANONIM, 1976. *Praca zbiorowa. Oznaczanie makro- i mikroelementów w glebach i roślinach [Collective work. Determination of micro- and macronutrients in soil and plants].* Pr. Kom. Nauk. PTG. Warszawa, 36 ss.

GEMBARZEWSKI H., KAMIŃSKA W., KORZENIOWSKA J. 1987. *Zastosowanie 1 mol ·dm^{-3} roztworu HCl jako wspólnego ekstrahenta do oceny zasobności gleb w przyswajalne formy mikroelementów [Using 1 mol ·dm^{-3} HCl solution as a shared extractant for evaluation of soil abundance in available forms of micronutrients].* Pr. Kom. Nauk PTG, Warszawa, 1-9.

GORLACH E., GAMBUŚ F. 1991. *Desorpcja i fitoprzyswajalność metali ciężkich w zależności od właściwości gleby [Desorption and phytoavailability of heavy metals depending on soil properties].* Rocz. Glebozn., 42 (3-4): 207-215.

KABATA-PENDIAS A., MOTOWICKA-TERELAK T., PIOTROWSKA M., TERELAK H., WITEK T., 1993. *Ocena stopnia zanieczyszczenia gleb i roślin metalami ciężkimi i siarką [Evaluation of soil and plant contamination with heavy metals].* IUNG Puławy, 53: 20

KIEKENS L. 1995. *Zinc In: Heavy metals in soils.* ALLOWAY B.J. (Ed.). Blackie Academic & Professional Chapman & Hill, London. ss. 368.

KOC J., GLIŃSKA-LEWCZUK K., SOLARSKI K. 2003. *Opady atmosferyczne jako medium chemicznej degradacji gleb [Atmospheric precipitation as a medium causing chemical degradation of soils].* Zesz. Probl. Post. Nauk Rol., 493: 159-166.

MERCIK S., STĘPIEŃ W., GĘBSKI M. 2003. *Pobranie przez rośliny oraz rozpuszczalność Cu, Zn, Pb, i Cd w różnych roztworach ekstrakcyjnych w zależności od zakwaszenia gleby [Uptake by plants and solubility of Cu, Zn, Pb and Cd in different extracting solutions depending on soil acidification].* Zesz. Probl. Post. Nauk Rol., 493: 913-921.

NOVOZAMSKY J., LEXMOND T. M., HOUBA U. J. G. 1993. *A simple extraction procedure of soil for evaluation of uptake of some heavy metals by plants.* Int. J. Anal. Chem., 51: 47-58.