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Teresa Bowszys, Krzysztof Ruszkowski, Jadwiga Wierzbowska, Tomasz Wojciechowski

EFFECT OF LIMING ON MANGANESE CONTENT AND REMOVAL WITH WINTER RYE HARVEST

Chair of Agricultural Chemistry and Environmental Protection
University of Warmia and Mazury in Olsztyn

INTRODUCTION

One of the primary criteria for the assessment of plant supply with manganese is the content of this microelement in soil, which is shaped by liming and mineral fertilization among other factors. New hybrid varieties of winter rye cultivated on soils low in reaction may take up excessive amounts of manganese. As a result, the chemical composition of the crops undergoes modifications. Makarska et al. (2004) found significant differences in Mn content between kernels of some rye strains and parental forms. According to Schäfer and Anke (2005) as well as Schäfer and Seifert (2005) excess manganese in diet can have adverse effect on human and animal health. Manganese fertilization requirements of crops are assessed according to their nutritional demands and soil pH and Mn availability. Numerous studies suggest that soil supplies of microelements can vary under the effect of fertilization treatments applied (Czuba 2000, Łabętowicz and Rutkowska 2001, Obojski and Strączyński 1995). Heavy metals, including manganese, when present in excessive amounts in soil are transported to plants. Beckett and Davis (1997) claim that a thorough chemical analysis of aerial parts of plants is the best indicator of soil pollution.

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dr hab. Teresa Bowszys, prof. UWM, Uniwersytet Warmińsko-Mazurski, Katedra Chemii Rolnej i Ochrony Środowiska, 10-744 Olsztyn, ul. Oczapowskiego 8 tel (089) 523 32 39; e-mail bowter@uwm.edu.pl

The purpose of this study has been to determine the effect of liming and multi-component fertilizers on the content of manganese in soil and utilisation of this microelement by different varieties of winter rye.

MATERIAL AND METHODS

Field studies with two hybrid varieties of rye Nawid F_1 and Ursus F_1 as well as a population cultivar Dańkowskie Złote were carried out in 2001–2003. The trials were established on typical brown soil, classified as class IVa in the soil bonitation system, good rye complex, which contained moderate amounts of manganese (Table 1). A two-factor experiment was established in a random sub-blocks design.

Table 1
Tabela 1

Some physical and chemical properties of the soils used in the experiment
Niektóre właściwości fizyczne i chemiczne gleb użytych w doświadczeniu

Year Rok	Soil Gleba	Organic matter Materia organiczna $g \cdot kg^{-1}$	pH 1 mol $KCl \cdot dm^{-3}$	Content Zawartość Mn $mg \cdot kg^{-1}$
2001	psg	12.1	4.8	120.92
2002	psg	12.9	5.8	139.70
2003	psg	12.6	5.3	110.78

psg – silghtly loam sand – piasek słabo gliniasty

Fertilization with 100 kg N, 30 kg P and 72 kg $K \cdot ha^{-1}$ was applied in the form of multi-component and single fertilizers (ammonium nitrate 34%, urea 46%, triple superphosphate 46%, potassium salt 56%). Nitrogen fertilization was balanced for all the objects of the experiment. The experiment design involved 12 fertilization objects (6 in a series with lime added at 1.76 t $CaO \cdot ha^{-1}$ and 6 without liming): 1) without fertilization, 2) NPK (single fertilizers), 3) Polifoska 8, 4) Polimag 305, 5) Luboplon 4, 6) Lubofoska.

The concentration of manganese in soil (extraction with 1 mol $HCl \cdot dm^{-3}$) and in the crops (mineralization in a mixture of the acids H_2SO_4, $HClO_4$ and HNO_3) was determined by ASA method using a Schimadzu AA apparatus (a lamp with a hollow cathode and SR correction). The results of the chemical analyses were processed statistically using analysis of variance and regression.

Results of the analysis of reference materials
Wyniki oznaczeń materiału certyfikowanego

Value – Wartość $mg \cdot kg^{-1}$ s.m.	Virginia Tobacco Leaves CTA-VTL-2
	Mn
Certified – Certyfikowana	79.7 ± 2.6
Determined – Oznaczona	77.6 ± 1.4

RESULTS AND DISCUSSION

The liming treatments applied in the experiment raised the soil reaction measured in 1 mol $KCl \cdot dm^{-3}$ (Table 2). The most beneficial effect on the soil reaction was demonstrated for the following multi-component fertilizers: Luboplon 4 and Lubofoska, which are additionally enriched with CaO and MgO, and for Polimag 305 (MgO).

Table 2
Tabela 2

Soil pH after winter rye harvest
Odczyn gleby po zbiorze żyta ozimego

Year Rok	Treatment Obiekt	Fertilizers – Nawozy					
		0	NPK	Polifoska 8	Polimag 305	Luboplon 4	Lubofoska
1 mol $KCl \cdot dm^{-3}$							
2001	+ Ca	5.90	5.93	5.73	5.63	6.23	6.00
	– Ca	5.73	5.53	5.40	5.40	5.87	5.11
2002	+ Ca	6.09	6.45	6.30	6.30	6.16	6.17
	– Ca	5.41	5.69	5.38	5.40	5.42	5.33
2003	+ Ca	7.19	6.95	6.37	6.65	7.01	6.90
	– Ca	6.17	6.07	6.23	6.09	6.26	6.16

After the harvest of winter rye soil was characterized by a moderate content of available manganese, ranging on average from 121 to 151 mg $Mn \cdot kg^{-1}$ depending on the cultivar. Although liming limited the amount of this form of manganese in soil, it did not change the class of soil fertility in this microelement (Figure 1). Also MERCIK and STĘPIEŃ (2000) proved that soils did not alter their manganese fertility class under the effect of varied mineral fertilization which had been carried out for more than twenty years. On the other hand, CHOROMAŃSKA (1992) claimed that liming, and the subsequent change in soil reaction, always limited the content of manganese in soil. The analysis of regression completed in

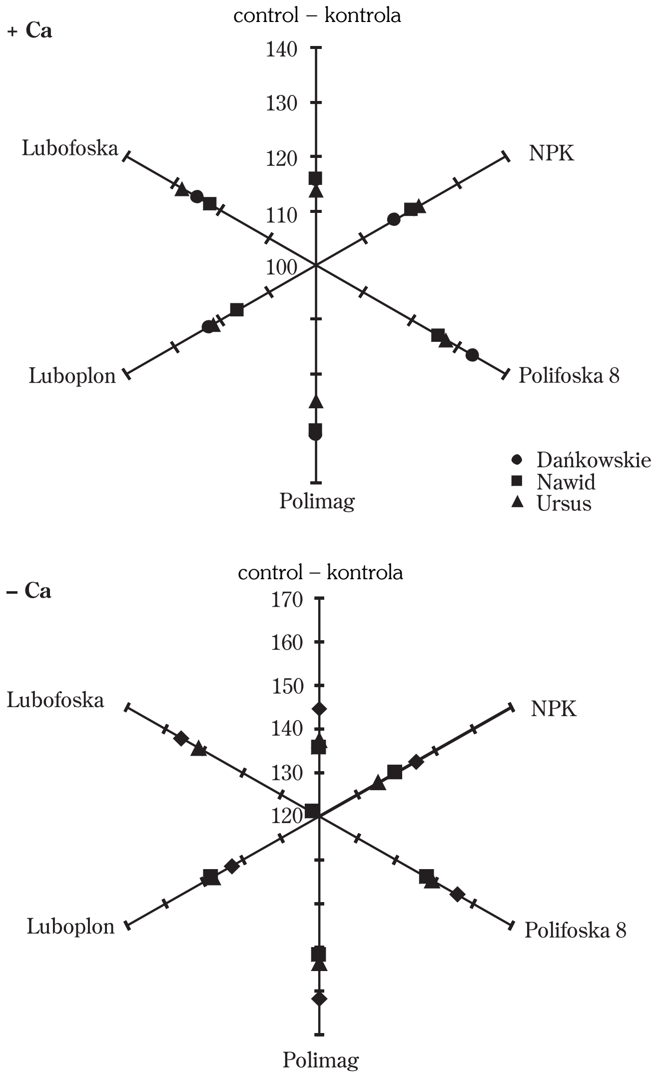

Fig. 1. The influence of applied fertilizationon on manganese content in soil after hervest of rye
Rys.1. Wpływ nawożenia na zawartość maganu w glebie po zbiorze żyta

our study demonstrated a significant positive correlation between hydrolytic acidity and the content of available manganese in soil. This correlation was stronger in the objects which had not been limed (R^2=0.75; $b_{y/x}$=5.811) – Figure 2.

The concentration of manganese in rye grain and straw was cultivar-dependent (Table 3). The smallest Mn content was determined in the hybrid cultivar Ursus (22 mg $Mn \cdot kg^{-1}$ d.m.), while the highest Mn concentration occurred in cv. Nawid and the population cultivar Dańkowskie Złote (ca 25 mg $Mn \cdot kg^{-1}$ d.m.).

Table 3
Tabela 3

Manganese content in winter rye in relation to cultivar and fertilization (mg·kg^{-1} d.m.)
Zawartość manganu w życie ozimym w zależności od odmiany i nawożenia (mg·kg^{-1} s.m.)

Part of plant Część rośliny	Treatment Obiekt	Fertilizer – Nawóz						
		0	NPK	Polifoska 8	Polimag 305	Luboplon 4	Lubofoska	mean średnia
Dańkowskie Złote								
Grain Ziarno	+ CaO – CaO	25.28 28.43	22.57 23.86	23.92 25.61	24.08 24.76	22.98 23.97	23.98 26.15	23.80 25.46
Mean – Średnia		26.86	23.22	24.77	24.42	23.48	25.07	24.63
Straw Słoma	+ CaO – CaO	10.53 11.19	11.15 12.49	10.26 13.91	11.08 13.44	10.28 13.55	12.57 14.74	10.98 13.22
Mean – Średnia		10.86	11.82	12.09	12.26	11.92	13.66	12.10
Nawid								
Grain Ziarno	+ CaO – CaO	25.57 28.85	24.24 25.19	19.55 24.55	21.49 25.59	24.94 28.75	24.53 26.48	23.39 26.57
Mean – Średnia		27.21	24.72	22.05	23.54	26.85	25.51	24.98
Straw Słoma	+ CaO – CaO	12.36 14.13	11.25 15.53	12.17 12.20	11.90 13.41	13.15 14.45	12.39 13.74	12.20 13.91
Mean – Średnia		13.25	13.39	12.19	12.66	13.80	13.07	13.06
Ursus								
Grain Ziarno	+ CaO – CaO	22.98 25.38	20.31 24.42	21.24 21.93	20.75 21.83	20.23 21.58	21.03 23.08	21.09 23.04
Mean – Średnia		24.18	22.37	21.59	21.29	20.91	22.06	22.07
Straw Słoma	+ CaO – CaO	10.57 11.37	10.75 12.12	11.93 11.99	10.11 11.36	9.83 12.70	11.61 18.36	10.80 12.98
Mean – Średnia		10.97	11.44	11.96	10.74	11.27	14.99	11.89

$NIR_{0.05}$ $LSD_{0.05}$	part of plant część rośliny	Dańkowskie Złote	Nawid	Ursus
a- liming wapnowanie	grain – ziarno	n.i	2.70	1.73
	straw – słoma	1.96	1.70	2.11
b-fertilizers nawozy	grain – ziarno	3.53	3.65	2.58
	straw – słoma	2.79	n.i	3.65
a x b	grain – ziarno	n.i	n.i	n.i
	straw – słoma	n.i	4.29	5.16

Similar tendencies appeared for the Mn content in straw. Liming significantly reduced the content of manganese in grain yielded by cv. Nawid (ca 14% decline) and cv. Ursus (9%). Significant depression, compared to the control, in the manganese content in grain of the hybrid cultivars obtained after fertilization treatments with Luboplon 4 and Lubofoska could have been caused by the effect

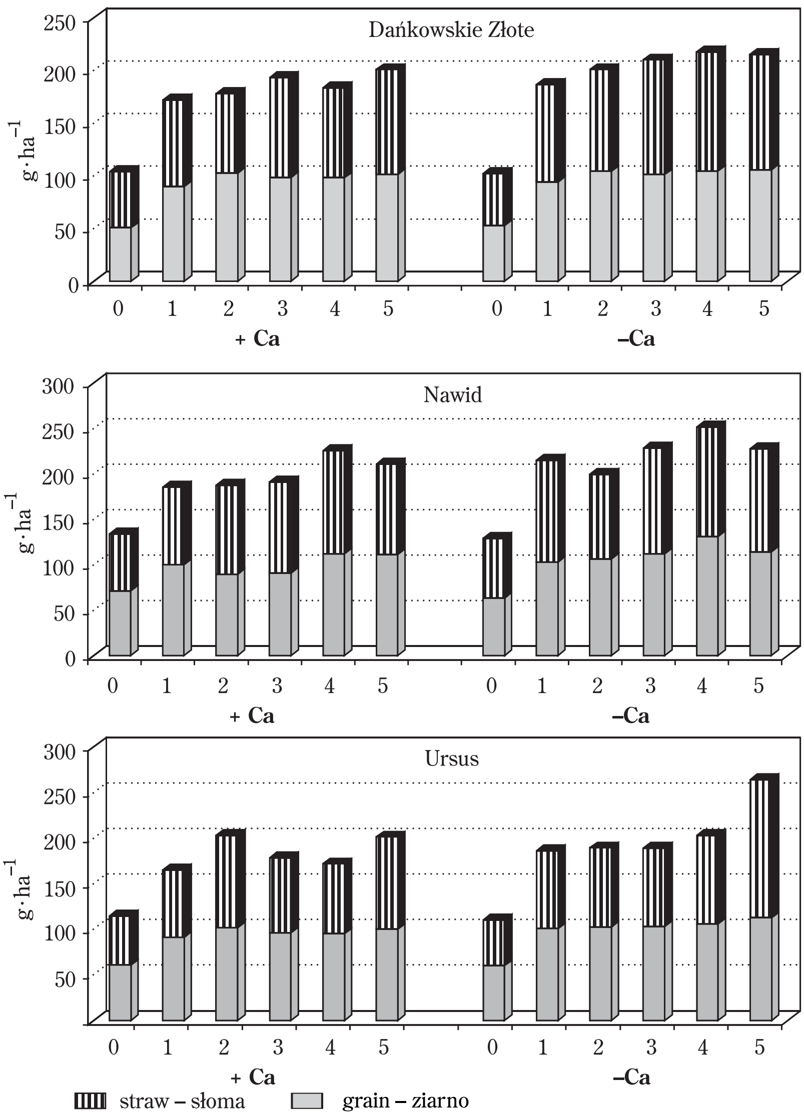

Fig. 2. Removal of manganese with yield of grain and straw of rye: 0 – control, 1 – NPK, 2 – Polifoska 8, 3 – Polimag 305, 4 – Luboplon 4, 5 – Lubofoska

Rys. 2. Wynos manganu z plonem żyta: 0 – kontrola, 1 – NPK, 2 – Polifoska 8, 3 – Polimag 305, 4 – Luboplon 4, 5 – Lubofoska

of 'dissolution' of the microelement in greater yield volumes. The effect of liming on the lowering of manganese content in straw was significantly stronger in the case of cv. Ursus and Dańskowskie Złote (20%) and slightly weaker for cv. Nawid (14%). In general, all the fertilizers resulted in some increase in the Mn content in straw, but it was only after the application of Lubofoska that the increase was

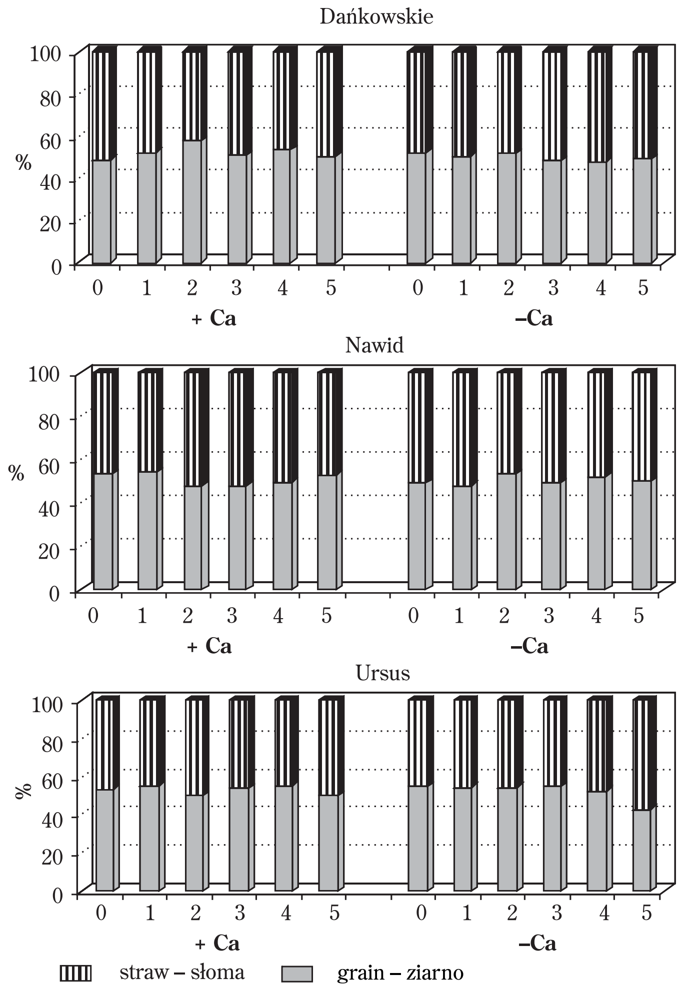

Fig. 3. The influence of applied fertilization on manganese distribution in grain and straw of rye (legends as Fig. 2)

Rys. 3. Wpływ nawożenia na dystrybucję manganu w ziarnie i słomie żyta (objaśnienia p. rys. 2)

significant versus the control. The removal of manganese with crop harvest depended on both the type of fertilization and the crop cultivar. Among the cultivars tested, the lowest amounts of manganese were taken up by cv. Dańkowskie Złote (175 g), followed by Ursus (181 g) and Nawid (197 g $Mn \cdot ha^{-1}$) – Figure 3. The results of our experiments enabled us to conclude that the percentage of manganese accumulated in winter rye grain and straw depended on the cultivar. Cultivar Ursus is capable of accumulating higher quantities of Mn in grain than cv. Nawid (Figure 4). The research completed by SPIAK (1996) also confirmed that

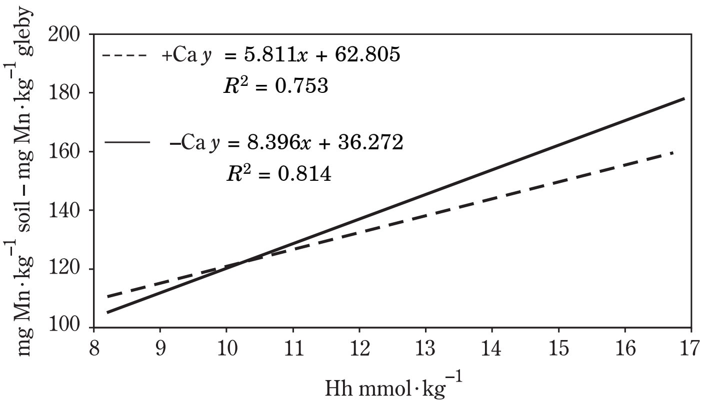

Fig. 4. Relationschip between hydrolytic acidity and the concentration Mn in the soil

Rys. 4. Zależność między kwasowością hydrolityczną a zawartością Mn w glebie

under identical conditions of growth and development plants were capable to accumulate various amounts of microelements in their tissues, which was related to a plant species and variety.

CONCLUSIONS

1. Liming in the dose of 1.76 t CaO·ha^{-1} evidently depressed the amount of available manganese in soil.

2. The content of manganese in rye grain, depending on the cultivar, varies from 22 to 25 mg Mn·kg^{-1} d.m. Higher concentration of this element was determined in the limed objects and the type of a fertilizer applied had a much weaker influence.

3. The removal of manganese with rye yield from non-limed objects was ca 10% smaller and depending on the cultivar varied from 175 to 197 g Mn per hectare.

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Teresa Bowszys, Krzysztof Ruszkowski, Jadwiga Wierzbowska, Tomasz Wojciechowski

EFFECT OF LIMING ON MANGANESE CONTENT AND REMOVAL WITH WINTER RYE HARVEST

Key words: winter rye, cultivars, manganese, liming, mixed fertilizer.

Abstract

A two-factorial fild experiment in a randomized subblock desing was performed in the years 2001–2003 on light soil. The aim of reasearches was qualification of fertilization of winter rye and of liming intervention's influence on formation of mobility manganese content (1 mol $HCl \cdot dm^{-3}$) in the soil and on the concentration and removal of this element from tested cultivars' yield. Balanced NPK fertilization (N – 90, P – 30, K – 72 $kg \cdot ha^{-1}$) was applied with and without liming (CaO 1.76 $t \cdot ha^{-1}$). The following fertilizers were applied: single-component fertilizers – ammonium nitrate (pre-sowing fertilization), urea (top-dressing), triple superphosphate, 56% potassium salt; multi-component fertilizers – Polifoska 8, Polimag 305, Luboplon and Lubofoska. The soil after harvest of rye characterised with middle abudance in available manganese and according to cultivar fluctuated aproximatety from 121 to 151 mg $Mn \cdot kg^{-1}$. Although limmng interventions reduced the amount of this form of manganese it hasn't changed its class of resources. The last contents of manganese was stated in grain of hybrid cultivar Ursus F_1, more in grain Dankowskie Złote and Nawid F_1. Similar tendency showed concentration of manganese in rye straw. On removed manganese from plants' crop had influence both liming and cultivar. From testd cultivars the least of component was drawn by rye Dańkowskie Złote – 175 g, more Ursus – 181 g and Nawid – 197 g Mn per ha.

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WPŁYW WAPNOWANIA NA ZAWARTOŚĆ I WYNOS MANGANU Z PLONEM ŻYTA OZIMEGO

Słowa kluczowe: żyto ozime, odmiany, mangan, wapnowanie, nawozy wieloskładnikowe.

Abstrakt

W latach 2001–2003 na glebie lekkiej przeprowadzono dwuczynnikowe doświadczenie metodą losowanych podbloków. Badano wpływ nawożenia żyta ozimego oraz zabiegu wapnowania na kształtowanie się zawartości manganu ruchomego (1 mol $HCl \cdot dm^{-3}$) w glebie, a także koncentrację i wynos tego pierwiastka z plonem testowanych odmian. Zbilansowane nawożenie NPK (N – 90, P – 30, K – 72 $kg \cdot ha^{-1}$) stosowano w serii wapnowanej (CaO 1,76 $t \cdot ha^{-1}$) i bez wapnowania. Z nawozów pojedynczych stosowano saletrę amonową (przedsiewnie), mocznik (pogłównie), superfosfat potrójny, sól potasową 56%, a z nawozów wieloskładnikowych: Polifoskę 8, Polimag 305, Luboplon 4 i Lubofoskę. Gleba po zbiorze żyta ozimego była średnio zasobna w mangan przyswajalny i – w zależności od odmiany – wartość ta wahała się średnio od 121 do 151 mg $Mn \cdot kg^{-1}$. Mimo że zabieg wapnowania ograniczał ilość tej formy manganu, to nie zmieniał jej klasy zasobności. Najmniejszą zawartość manganu stwierdzono w ziarnie odmiany mieszańcowej Ursus F_1 (22 mg $Mn \cdot kg^{-1}$), więcej w ziarnie odmian Dańkowskie Złote i Nawid F_1 (25-30 mg $Mn \cdot kg^{-1}$). Podobną tendencję wykazywała koncentracja manganu w słomie żyta. Na wynos manganu z plonem roślin miały wpływ zarówno wapnowanie, jak i odmiana. Z testowanych odmian najmniej tego składnika pobierało żyto odmiany Dańkowskie Złote – 175 g, więcej Ursus – 181 g i Nawid – 197 g Mn z 1 ha.