Polish Journal of Agronomy
2011, 4, 7–11

The content of some micronutrients in rendzina soil cultivated using different tillage systems and catch crops

Piotr Kraska

Department of the Agricultural Ecology, University of Life Sciences in Lublin
ul. Akademicka 13, 20-950 Lublin, Poland

Abstract. The research was carried out in 2006/2007–2008/2009, using the experiment started in 2005 on Bezek experimental farm, the property of University of Life Sciences in Lublin. The experimental field was set on a medium-heavy mixed rendzina. The aim of the research was to estimate the impact of different tillage systems and different catch crops in spring wheat monoculture on the levels of Zn, Cu, Mn, Fe on topsoil.

Two-factor field experiment was established with split-plot method in four replitcations. The first factor included plough tillage (A) and two variants of conservation tillage with autumn (B) and spring disking (C) of catch crops. The second factor covered four methods of field reclamation in spring wheat monoculture in the form of undersown crops (red clover, westerwold ryegrass) and stubble catch crops (lacy phacelia, white mustard). Fields without catch crops were the control treatments.

Plough soil tillage system increased the level of Cu, Mn, and Fe in arable soil in comparison with both methods of conservation tillage. The content of zinc was significantly lower on conservation tillage treatments with autumn catch crop incorporation than on the treatments with plough soil tillage, and with conservation tillage involving spring catch crops disking. The highest level of zinc was found on the treatments with red clover seeding, a copper and iron – on the treatments with red clover and lacy phacelia, and manganese – in the control plots.

In spring, the levels of copper, manganese and iron in the soil were significantly higher than in autumn. As for zinc, its level in spring was significantly lower than in autumn. The levels of copper and iron in soil were significantly increasing, and the content of zinc – decreasing with every consecutive year. The content of micronutrients in the soils of 0–20 cm deep did not exceed their natural level, characteristic of this type of soils.

key words: tillage systems, catch crops, micronutrients

Corresponding author:
Piotr Kraska
e-mail: piotr.kraska@up.lublin.pl
tel. +48 81 4456778

Received 20 October 2010

INTRODUCTION

The level of elements in the soil is highly shaped by the richness of mother rock, soil-forming processes, eolian processes, granulometric composition, and the method of soil utilization (Dudka, 1992; Kabata-Pendias, 1993, 2004). Yields of cultivated crops are determined by nutrient richness of soil (Gembarzewski, 2000). Another important feature of crops for feed and consumption use is the content of microelements (Czuba, 2000).

Conservation methods of soil tillage increase the content of soil organic matter, which positively influences physical, chemical and biological properties of the soil (Håkansson, 1994; Rasmussen, 1999; Zimny, 1999; Holland, 2004; Wróbel and Nowak-Winiarska, 2007; Weber 2010). Catch crops can have a conditioning effect in specialized cereal rotations. They can also improve the soil balance of organic matter and nutrients, including microelements (Łoginow, 1985; Parylak, 1998; Parylak at al., 2002; Pałys at al., 2009).

Czekała and Jakubus (2000), as well as Strączyńska and Strączyński (2000) stated that the level of copper, zinc and manganese were higher in the soils with the highest level of organic carbon. The research by Strączyński and Wróbel (2000) showed that the content of soluble forms of Cu, Mn, Mo, Zn increased with the increase of soil silt and clay fraction. Kucharzewski and Dębowski (2000) stated that soils in Poland contain a medium content of copper, zinc, manganese and iron. They also attribute negative microelements balance in soils to the decrease in organic fertilization.

The aim of the research was an evaluation of the impact of plough tillage and two conservation tillage methods and different catch crops in spring wheat monoculture on the content of selected microelements in the topsoil.

MATERIALS AND METHODS

The research was carried out in 2006/2007–2008/2009, using the experiment started in 2005 on Bezek experimental farm (N: 51°19', E: 23°25'), the property of the University of Life Sciences in Lublin. The experimental field was set on medium-heavy mixed rendzina, developed from chalk bedrock that had granulometric composition of a medium silty loam. That soil had an alkaline reaction (pH 7.35), high content of P (117.8 mg kg^{-1}) and K (242.4 mg kg^{-1}) and very low of magnesium (19 mg kg^{-1}), the content of organic carbon was 24.7 g kg^{-1}. The soil belonged to IIIb valuation class and to defective wheat complex.

The layout of a static, two-factor field experiment, established with split-plot method in four replications. The first factor included plough tillage (A) and two variants of conservation tillage with autumn (B) and spring disking (C) of catch crops. The second factor covered four methods of field reclamation in spring wheat monoculture in the form of catch crops: undersown crops (red clover, westerwold ryegrass) and stubble catch crops (lacy phacelia, white mustard). Fields without catch crops were the control treatments. Harvested field area was 30 m^2 . Winter wheat, produced on this field for three years, was a preceding crop for the spring wheat. In 2005, treating as a pre-initial year, all crops were sown, and tillage systems were used in accordance with the methodology.

Plough tillage, as a part of seedbed preparation for spring wheat, was started with skimming and harrowing after preceding crop harvest. Medium-deep ploughing was performed before winter. Harrowing was done in spring, cultivating with harrowing – before sowing. At that time phosphorus and potassium fertilizers were delivered, as well as the first dosage of nitrogen fertilizers 60 kg N ha^{-1} in ammonium nitrate form. Phosphorus fertilizers at a rate of 30.5 kg ha^{-1} P in triple superphosphate form, and potassium at a rate of 74.7 kg ha^{-1} K in the 60% potash salt form, were applied in spring. Second nitrogen dose, at a rate of 40 kg ha^{-1} was applied at shooting (30-33 development phases BBCH). Spring wheat cv. 'Zebra' was sown at the number of 5 millions of seeds per ha in rows 10 cm apart. The seed was treated with Panoctine 350 SL (350 g l^{-1} of guazatine in an acetate form) seed dressing. The red clover of 'Dajana' variety – 20 kg ha^{-1} and westerwold lolium multiflorum of 'Mowester' variety – 20 kg ha^{-1} were sown on the same date as spring wheat. Lacy phacelia of 'Stala' variety – 20 kg ha^{-1} and white mustard of 'Borowska' variety 20 kg ha^{-1} were sown after spring wheat harvest and post-harvest tillage.

On the treatments with conservation tillage (B and C) after preceding crop harvest on the plots without red clover and westerwold ryegrass grubbing and harrowing were performed (18–20 cm deep). Next, lacy phacelia and white mustard were sown, analogous with plough tillage variants. Catch crops were disked before winter (B) or they were left as mulch for winter, and disk harrowed in spring (C). On the treatments with autumn catch crops disked (B), spring soil tillage was the same as in ploughed ones. On the plots with another variants of conservation tillage (C), the field was harrowed after being disked, and then harrowed again before spring wheat sowing.

The programme for spring wheat field protection included: Chwastox Extra 300 SL 3.5 l ha^{-1} (300 g l^{-1} MCPA) – 23-29 BBCH, Alert 375 SC 1 l ha^{-1} (125 g l^{-1} of flusilazole and 250 g l^{-1} of carbendazim) – 26-29 BBCH.

The soil samples for analysis were first taken in the autumn of 2006 and the spring of 2007 (the subsequent dates of taking samples are autumn 2007 and spring 2008 as well as autumn 2008 and spring 2009). Samples were taken in spring from a depth of 0–20 cm, before field works, and in late autumn before ploughing on plough tillage plots, and disking in conservation tillage variant with autumn catch crop incorporation. At the same time were soil samples taken on treatment where catch crops spring disking.

From each plot, soil samples were taken with the use of Egner's sampling stick in five randomly chosen places. Next, the samples collected in that way from four plots, constituting replications in the experimental model, were combined into one collective sample. In a cumulative samples from combinations of three repetitions Cu (PN-92R-04017), Zn (PN-92/R-04016), Mn (PN-93/R-04019), Fe (PN-R-04021:1994) were determined with ASA method. The results were statistically processed using the analysis of variance. Mean values were tested for the least significant differences based on Tukey's test (P = 0.05).

RESULTS

In the soil with conservation tillage with autumn catch crop disking, the level of zinc and manganese was significantly lower than in the soils with plough tillage and the soil with conservation method combined with spring catch crop disking (Tables 1 and 2). The level of manganese in an arable layer of plough tillage treatments was significantly higher than on conservation tillage treatments with catch crops preserved for winter (Table 2). The level of copper and iron were the highest in the soil taken from plough tillage treatments, significantly lower on mulch-free conservation tillage treatments, and the lowest on the conservation tillage variant with spring catch crop incorporation (Tables 2 and 4).

The level of Zn in soil was the highest on the treatments with red clover seeding, significantly lower on the plots with catch crop of lacy phacelia and white mustard, and the lowest – on the treatments with westerwold ryegrass and on the control treatment (Table 1). The level of copper was the highest in the soil under lacy phacelia, significantly lower on red clover, control, and undersown with westerwold ryegrass treatments, and the lowest on white mustard treatments (Table 3). The level of manganese was the highest in the soil taken from the control plots, significantly lower on the plots with stubble catch crops of white mustard and lacy phacelia, lower from the westerwold ryegrass treatments, and the lowest on red clover treatments (Fig.

Table 1. Content of Zn [mg·kg-1] in topsoil (mean in the years of study).

Experimental factors	Tillage systems# A	B	C	Mean
Catch crops				
Control	20.09	20.53	22.92	21.18
Red clover	28.51	20.90	22.32	23.91
Westerwold ryegrass	20.24	20.24	23.27	21.25
Lacy phacelia	22.80	21.16	24.68	22.88
White mustard	23.83	21.15	22.42	22.46
Sampling date				
Autumn 2006–2008	26.30	22.29	23.58	24.06
Spring 2007–2009	19.89	19.30	22.66	20.61
Years				
2006/2007	23.44	25.67	28.02	25.71
2007/2008	26.74	20.09	22.15	22.99
2008/2009	19.11	16.62	19.20	18.31
Mean	23.09	20.79	23.12	–
LSD(0.05)	tillage systems 0.041 catch crops 0.061 sampling date 0.028 years 0.041 tillage systems x catch crops 0.132 tillage systems x sampling date 0.070 tillage systems x years 0.093			

A – Plough tillage
B – Conservation tillage with autumn catch crops disking
C – Conservation tillage with spring catch crops disking

3). The level of Fe was the highest on the treatments with lacy phacelia, significantly lower on plots undersown with red clover, on control treatments, on stubble catch crop treatments with white mustard, and the lowest in variant with westerwold ryegrass (Table 4).

In spring, the levels of copper, manganese and iron were significantly higher than in autumn. But the level of zinc was significantly lower than in autumn (Tables 1, 2, 3, 4).

In plough tillage system on red clover treatments the levels of Zn, Cu and Fe in the soil were significantly higher than on other catch crop treatments and the control treatment (Tables 1, 3, 4). At the same time, the level of copper and iron on plough tillage fields on all catch crop treatments were higher than on all variants of conservation tillage (Tables 3, 4). Similar dependence for zinc and manganese was recorded on the red clover and white mustard treatments, and for manganese – additionally on lacy phacelia plots (Tables 1, 2).

In the soil of conservation tillage treatments with autumn disk harrowing of catch crops, the highest level of zinc was recorded on the lacy phacelia and white mustard plots. On conservation tillage treatments with spring catch crop incorporation, the highest level of zinc was recorded on lacy phacelia plots (Table 1). On catch crop treatments, the highest levels of copper and iron in a conservation variant with autumn disking were found in the soil under red clover, whereas in another conservation variant, in the treatments with lacy phacelia (Tables 3, 4). In both conser-

Table 2. Content of Mn [mg kg-1] in topsoil (mean in the years of study).

Experimental factors	Tillage systems# A	B	C	Mean
Catch crops				
Control	197.15	202.66	200.33	200.05
Red clover	200.62	187.41	192.24	193.42
Westerwold ryegrass	197.51	188.34	196.75	194.20
Lacy phacelia	199.54	190.82	196.62	195.66
White mustard	200.58	189.51	197.33	195.81
Sampling date				
Autumn 2006–2008	194.31	186.45	188.05	189.61
Spring 2007–2009	203.85	197.04	205.26	202.05
Years				
2006/2007	203.70	194.35	197.49	198.51
2007/2008	195.16	192.66	193.88	193.90
2008/2009	198.38	188.23	198.60	195.07
Mean	199.08	191.75	196.66	–
LSD(0.05)	tillage systems 0.265 catch crops 0.399 sampling date 0.181 years 0.265 tillage systems x catch crops 0.859 tillage systems x sampling date 0.456 tillage systems x years 0.609			

for explanations see Table 1

Table 3. Content of Cu [mg kg-1] in topsoil (mean in the years of study).

Experimental factors	Tillage systems# A	B	C	Mean
Catch crops				
Control	3.49	2.80	1.43	2.57
Red clover	4.11	2.46	1.45	2.67
Westerwold ryegrass	3.64	2.12	1.55	2.44
Lacy phacelia	3.58	2.41	2.07	2.68
White mustard	3.58	1.91	1.68	2.39
Sampling date				
Autumn 2006–2008	3.54	2.22	1.51	2.43
Spring 2007–2009	3.82	2.46	1.76	2.68
Years				
2006/2007	3.51	2.05	1.29	2.28
2007/2008	3.61	2.28	1.61	2.50
2008/2009	3.93	2.69	2.01	2.88
Mean	3.68	2.34	1.64	–
LSD(0.05)	tillage systems 0.007 catch crops 0.010 sampling date 0.005 years 0.007 tillage systems x catch crops 0.022 tillage systems x sampling date 0.012 tillage systems x years 0.015			

for explanations see Table 1

Table 4. Content of Fe [mg·kg^{-1}] in topsoil (mean in the years of study).

Experimental factors	Tillage systems# A	B	C	Średnio Mean
Catch crops				
Control	218.00	210.06	86.72	171.59
Red clover	271.56	208.72	96.22	192.17
Westerwold ryegrass	235.28	153.72	85.67	158.22
Lacy phacelia	241.28	204.56	137.06	194.30
White mustard	229.50	155.78	117.28	167.52
Sampling date				
Autumn 2006–2008	244.37	179.67	89.53	171.19
Spring 2007–2009	233.89	193.47	119.64	182.33
Years				
2006/2007	227.60	162.83	73.03	154.49
2007/2008	237.77	184.10	105.97	175.94
2008/2009	252.00	212.77	134.77	199.84
Mean	239.12	186.57	104.59	–
LSD(0.05)	tillage systems 0.422 catch crops 0.635 sampling date of study 0.288 years 0.422 tillage systems x catch crops 1.367 tillage systems x sampling date 0.726 tillage systems x years 0.968			

for explanations see Table 1

vation variants, the highest level of manganese was found in the control treatments (Table 2).

The levels of Cu and Mn in the soils with all tillage systems in autumn season were lower than in spring. Similar dependence for Fe was found in both conservation tillage variants (Tables 2, 3, 4). The level of Zn in the soil of all estimated tillage systems was higher in autumn than in spring season (Table 1).

The levels of copper and iron were significantly increasing with every consecutive year (Tables 3, 4), while for Zn – decreasing (Table 1). The highest level of manganese was recorded in the first period of evaluation, significantly lower in the last, and the lowest in the second season of analysis (Table 2). In all evaluated tillage variants, the level of Zn in soils in the last period of research was lower than in the first two periods (Table 1). In all tillage systems, the levels of Cu and Fe were subsequently increasing in consecutive seasons of observation (Tables 3, 4). The level of Mn on plough and conservation tillage treatments with autumn catch crop disking was significantly higher in the first season of research than in the consecutive ones. Its highest level on conservation tillage treatments with spring disking was recorded in the last season of research (Table 2).

DISCUSSION

In conservation tillage variant with spring disking of catch crops, the level of zinc in the soil 0–20 cm deep was slightly higher than on plough tillage treatments, and by 11.2% higher than on conservation tillage treatments with autumn catch crop incorporation. Blecharczyk at al. (2007) observed the increase in Zn level in the soil 0–5 cm deep on ploughless cultivation treatments and direct sowing in comparison with plough tillage. In the layer 10–20 cm deep, this dependency was reversed. The introduction of red clover undersowing into the monoculture of spring wheat resulted in the increase of zinc by 4.5% in comparison with lacy phacelia treatments, by 6.5% with white mustard, by 12.5% with westerwold ryegrass, and by 12.9% with the control plots without catch crop but with voluntary spring wheat seedling.

In plough tillage treatments, the level of manganese in the soil was by 1.2% to 3.8% higher than in conservation tillage treatments. Similarly, Blecharczyk at al. (2007) recorded the decrease in Mn level in the soil layer of 10–20 cm deep of ploughless tillage treatments with direct sowing in comparison with plough tillage treatments, whilst in the layer of 0–5 cm, only in direct sowing treatments. In non-catch crop control treatment, the level of Mn in the soil was higher by 2.2% to 3.4% than in spring wheat monocultures with undersown catch crops or stubble catch crops.

On plough tillage treatments, the level of copper was by 57.3% to 124%, and iron – by 28.2% to 128% as high as in non-plough tillage soil. Also Blecharczyk at al. (2007) observed that the level of copper in upper layer of soil was by 19.4% higher in plough tillage in comparison with a ploughless one, whilst the level of iron did not change significantly in different tillage systems. Wróbel and Nowak-Winiarska (2007) recorded a higher level of copper, manganese, iron and zinc in 0–10 cm layer of non-plough cultivated soil in comparison with plough cultivation, whilst in the layer of 10–20 cm deep, the level of these elements was lower in reduced tillage and no-tillage in comparison to conventional one. In other studies, Wróbel at al. (2007) confirmed this dependency for 0–5 cm soil layer in comparison to 20–25 cm layer.

In plough tillage treatments, the levels of copper and iron in all plots with catch crop, of zinc in red clover and white mustard plots, and of manganese additionally in lacy phacelia, were higher than in both conservation tillage variants. It can indicate a faster organic matter mineralization in plough tillage system and elements release into the soil. Kuś and Jończyk (1999) point to the slowed organic matter mineralization in the mulch conditions and lack of pre-winter soil cultivation.

In spring, the levels of Cu, Mn, and Fe were higher by respectively 10.3%, 6.6%, 6.5% than the concentration of these elements in autumn. It can be a result of the incorporation of these elements into the biomass of catch crops, and their slow release due to mineralization in the early spring season. Such a dependency was not recorded for zinc.

The levels of copper and iron in the topsoil were increasing in consecutive years of studies. It could be a result of positive influence of catch crop biomass – the source of micronutrients. Andrzejewska (1999), as well as Kuś and Jończyk (2000) emphasize the special role of catch crops due to their multilateral impact on biological and physico-chemical soil properties.

CONCLUSIONS

1. In the cultivation of spring wheat grown in monoculture, plough tillage system fostered the occurrence of higher level of copper, manganese and iron in surface layer of soil (0–20 cm) in comparison with conservation tillage.
2. The levels of iron and copper in soil surface layer were higher when catch crops were disk harrowed in autumn, whereas zinc and manganese – when this procedure was done in spring.
3. All the catch crops decreased the level of manganese in the soil, but increased the level of zinc. The level of copper in the soil decreased in the treatments where white mustard was grown as a catch crop, and the level of iron – on the treatments with westerwold ryegrass.
4. The highest level of zinc was recorded in the soils where red clover was grown, and copper and iron – where lacy phacelia and red clover were used as catch crops. The highest level of manganese was observed in non catch crop treatments.
5. The level of copper, manganese and iron in the soil was higher in spring, and zinc – in autumn.

LITERATURE

Andrzejewska J., 1999. Intercrops in cereal crop rotations. Post. Nauk Rol., 1: 19-31. (in Polish)

Blecharczyk A., Małecka I., Sierpowski J., 2007. Long-term effects of tillage systems on physico-chemical soil properties. Fragm. Agron., 1: 7-13. (in Polish)

Czekała J., Jakubus M., 2000. Occurrence of copper, zinc and manganese in arable soils. Zesz. Probl. Post. Nauk Rol., 471: 219-228. (in Polish)

Czuba R., 2000. The micronutrients in recent fertilization systems. Zesz. Probl. Post. Nauk Rol., 471: 161-169. (in Polish)

Dudka S., 1992. Ocena całkowitych zawartości pierwiastków głównych i śladowych w powierzchniowej warstwie gleb Polski. IUNG, Puławy, R(293): 5-48.

Gembarzewski H., 2000. Microelement contents and tendencies of their changes in soils and plants from arable fields in Poland. Zesz. Probl. Post. Nauk Rol., 471: 171-179. (in Polish)

Håkansson I., 1994. Soil tillage for crop production and for protection of soil and environmental quality: a Scandinavian viewpoint. Soil Till. Res., 53: 109-124.

Holland J.M., 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agric. Ecosys. Environ., 103: 1-25.

Kabata-Pendias A., 1993. Behavioural properties of trace metals in soils. Appl. Geochem., vol. 8, Suppl. Issue 2: 3-9.

Kabata-Pendias A., 2004. Soil-plant transfer of trace elements – an environmental issue. Geoderma, 122: 143-149.

Kucharzewski A., Dębowski M., 2000. Reaction and content of microelements in soils of Poland. Zesz. Probl. Post. Nauk Rol., 471: 627-635. (in Polish)

Kuś J., Jończyk K., 1999. The effect of intercrops and the method of its cultivation on crop yielding and content of mineral nitrogen in soil. Rocz. Nauk Rol., ser. A, 114(3-4): 83-95. (in Polish)

Kuś J., Jończyk K., 2000. Regenerating role of intercrops in cereal crop rotation links. Zesz. Probl. Post. Nauk Rol., 470: 59-65. (in Polish)

Łoginow W., 1985. Nowoczesne podstawy nawożenia organicznego. Post. Nauk Rol., 6: 25-37.

Pałys E., Kuraszkiewicz R., Kraska P., 2009. The residual effect of undersown crops and nurse crops on chemical properties of light soil. Ann. UMCS, Sec. E, 4: 81-92. (in Polish)

Parylak D., 1998. Stubble catch crops as regenerative factor in winter triticale monoculture grown on light soil. Zesz. Probl. Post. Nauk Rol., 460: 709-718. (in Polish)

Parylak D., Wojciechowski W., Tendziagolska E., 2002. Changes in physical and chemical properties of soil in winter triticale monoculture as a result of varying pre-sowing tillage. Pam. Puł., 130: 541-548. (in Polish)

Rasmussen K. J., 1999. Impact of ploughless soil tillage on yield and soil quality: A Scandinavian reviev. Soil Till. Res., 53: 3-14.

Strączyńska S., Strączyński S., 2000. Some chemical properties of fallowed and cultivated soils. Zesz. Probl. Post. Nauk Rol., 471: 543-547. (in Polish)

Strączyński S., Wróbel S., 2000. Micronutrient concentration in soils of diverse agronomic categories. Zesz. Probl. Post. Nauk Rol., 471: 549-554. (in Polish)

Weber R., 2010. Soil properties as affected by duration of using no-tillage systems. Post. Nauk Rol., 1: 63-75. (in Polish)

Wróbel S., Nowak-Winiarska K., 2007. Dostępność składników pokarmowych dla roślin w warunkach uproszczeń w uprawie roli. Stud. Rap. IUNG-PIB, 8: 177-192.

Wróbel S., Pabin J., Mickiewicz A., 2007. The effect of reduced soil tillage on nutrient availability in the maize monoculture. Zesz. Probl. Post. Nauk Rol., 520: 791-797. (in Polish)

Zimny L., 1999. Conservation tillage. Post. Nauk Rol., 5: 41-52. (in Polish)