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CONCENTRATION OF SELECTED MICRONUTRIENTS IN SANDY SOIL IN RELATION TO LONG-TERM DIRECT DRILLING METHOD

Ewa Stanisławska-Glubiak, Jolanta Korzeniowska, Urszula Sienkiewicz-Cholewa

Institute of Soil Science and Plant Cultivation
National Research Institute in Pulawy
Department of Weed Science and Tillage Systems in Wroclaw

Abstract

Compared to conventional tillage method, physical and chemical properties of soil treated with long-term zero-tillage method (direct drilling without ploughing) are different, especially soil porosity, moisture conditions, concentration of organic carbon and macronutrients. The aim of a three-year field study was to compare the content of micronutrients in soil under traditional and zero-tillage. The difference in micronutrient concentration in soil treated with different soil tillage method can affect quantity and quality of yields. The study was conducted using seven fields with 4-5 or 11 years period under diverse tillage method. Soil samples were colleted from three random points in every field on the beginning of June. Samples were obtained from two layers: 0-10 and 10-20 cm in depth using an Eijkelkamp soil sampler (diameter 2.5 cm). Micronutrients (Cu, Mn, Zn) in soil samples were determined by the AAS method after extraction with HCl at 1 mol dm^{-3}. The results were compared using t-Student test. The tillage methods were found to have produced differences only in Cu concentrations in soil. However, it was impossible to point clearly which method resulted in a higher Cu concentration as the actual differences depended also on the year of study and the soil layer. The zero-tillage method compared to the conventional method did not produce differences in Mn and Zn concentrations. The general level of the three microelements and the differences in their levels in relation to a tillage method were similar in both soil layers.

Keywords: soil tillage methods, zero-tillage, micronutrients, Cu, Zn, Mn.

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dr hab. Ewa Stanisławska-Glubiak, Institute of Soil Science and Plant Cultivation - National Research Institute in Pulawy, Department of Weed Science and Tillage Systems in Wroclaw, Orzechowa 61, 50-540 Wrocław, Poland, e-mail: e.glubiak @iung.wroclaw.pl

ZAWARTOŚĆ WYBRANYCH MIKROELEMENTÓW W GLEBIE LEKKIEJ W WARUNKACH WIELOLETNIEGO STOSOWANIA SIEWU BEZPOŚREDNIEGO

Abstrakt

Gleba pozostająca przez wiele lat w systemie uprawy zerowej (siew bezpośredni w niezaoraną glebę) charakteryzuje się, w stosunku do uprawianej tradycyjnie, zmienionymi właściwościami fizycznymi i chemicznymi, zwłaszcza warunkami powietrzno-wodnymi oraz zawartością węgla organicznego i makroelementów. Celem trzyletnich badań polowych było porównanie zawartości niektórych mikroelementów w glebie lekkiej uprawianej metodą tradycyjną oraz utrzymywanej w systemie siewu bezpośredniego. Różnice w zawartości mikroelementów w glebie w różnych systemach uprawy mogą wpływać na kształtowanie wielkości i jakości plonów. Wykorzystano ogółem 7 pól o 4-5-letnim lub 11-letnim okresie zróżnicowanej uprawy roli. Na początku czerwca pobierano próbki z trzech losowo wybranych punktów na każdym polu. Pobierano je z dwóch warstw, 0-10 i 10-20 cm, próbnikiem glebowym (firmy Eijkelkamp) o średnicy 2,5 cm. Oznaczano w nich zawartość Cu, Mn i Zn (ekstrakcja 1 mol $HCl \cdot dcm^{-3}$) metodą ASA. Wyniki opracowano statystycznie. Stwierdzono istotne różnice wyłącznie w zawartości Cu. Nie można jednak wskazać jednoznacznie, która z metod uprawowych determinowała większą jej zawartość w glebie. Różnice te były uzależnione od roku uprawy oraz głębokości warstwy gleby. Nie wykazano również wpływu uprawy zerowej na zmiany w zawartości Mn i Zn w porównaniu z uprawą tradycyjną. Ogólny poziom zawartości wszystkich badanych mikroelementów, a także różnice wynikające z metody uprawy roli były podobne w obu warstwach glebowych.

Słowa kluczowe: metody uprawy roli, metoda zerowa, mikroelementy, Cu, Zn, Mn.

INTRODUCTION

Soil maintained under a no-till farming system (direct sowing to unploughed soil) for many years is different from conventionally tilled soil in physical parameters, including density as well as water and air conditions (ARSHAD et al. 1999, PABIN et al. 2002, MCGARRY et al. 2000) Reduced or zero soil tillage continued for several years also impacts chemical properties of soil (TARKALSON et al. 2006). Changes in the chemism of soil concern mainly organic carbon accumulation (SIX ET AL. 1999) and content of micronutrients as well as their distribution in the soil horizon. No-till farming means that fertilizers cannot be mixed with soil down to a proper depth, which may result in higher concentration of nutrients in the top soil horizon (MATOWO et al. 1999). Differences in the distribution of macronutrients in soil, depending on the type of tillage, can result in a different nutritional status of crops during their vegetative growth and different yield volumes (YIN, VYN 2002, KORZENIOWSKA, STANISŁAWSKA-GLUBIAK 2006).

The purpose of this study has been to compare the abundance of soil in some micronutrients in the top horizon of sandy soil under long-term no-till farming versus conventionally ploughed soil. Different concentrations of micronutrients in soil caused by different tillage techniques, likewise those of macronutrients, may affect the volume and quality of yields.

MATERIALS AND METODS

The study, completed in 2005-2007, was carried out on fields maintained under different tillage systems at the IUNG-PIB Experimental Station in Jelcz-Laskowice near Wrocław. In 2005 and 2006 the fields selected for the tests were the ones on which different tillage methods had been applied for 4-5 years. In 2007, fields cultivated for 11 years were examined. No-till and conventional, ploughing farming were compared. In general, the soils from the experimental fields belonged to heavy loamy sand, acidic or very acidic in reaction and low in organic carbon. The soils differed in their content of phosphorus, potassium, magnesium and micronutrients (Table 1).

Table 1

Characteristics of soil from tested fields (0-20 cm)

Year	Field	Type of soil	pH (1 mol $KCl \cdot dcm^{-3}$)	C org. ($g \cdot kg^{-1}$)	P	K	Mg	Cu	Mn	Zn
					($mg \cdot kg^{-1}$)					
2005	1	pgm	4.3	7.0	34.7	138	29.0	2.8	163	6.0
	2	pgm	4.5	6.4	43.6	121	38.3	3.5	158	7.5
2006	1	pgmp	5.1	7,6	71.9	168	28.5	3.0	200	10.5
	2	pgmp	5.2	6.6	58.0	168	46.7	3.0	187	8.7
	3	pgm	5.2	7.3	66.2	152	29.0	2.9	175	8.5
2007	1	pgm	5.3	7.4	91.8	158	62.0	5.0	203	7.5
	2	pgm	5.3	7.6	67.9	143	62.0	6.7	120	7.3

In order to determine the concentration of selected micronutrients in soil in correlation with the type of soil tillage, soil samples were taken in early June at three random locations on each field. The soil samples were collected from two soil horizons, 0-10 and 10-20 cm, using an Eijkelkamp soil sampler of the diameter size equal 2.5 cm. Two drillings made up a single soil sample. Having been first extracted in 1 mol $HCl \cdot dm^{-3}$, the soil samples were then analysed with the AAS method to determine the content of Cu, Mn and Zn. having The results of the tests from each field were used to calculate an arithmetic mean for a given year. The statistical calculations carried out to compare means between the tillage methods relied on t-Student test and accounted for variance uniformity (Statgraphics software package).

The weather conditions from March to May, i.e. from the onset of the growth season to the soil sampling, were quite similar in each year (Table 2). Although the rainfall distribution was highly varied, the total rain-

Table 2

Temperature and precipitation for the 3-month period before sample collecting

Year	Average temperature (°C)				Sum of precipitation (mm)			
	III	IV	V	III-V	III	IV	V	III-V
2005	1.3	9.3	14.2	8.2	12.3	20.3	86.2	118.8
2006	0.0	9.4	14.1	7.8	28.9	50.2	29.9	109.0
2007	5.7	10.2	15.7	10.5	52.4	4.2	54.4	111.0

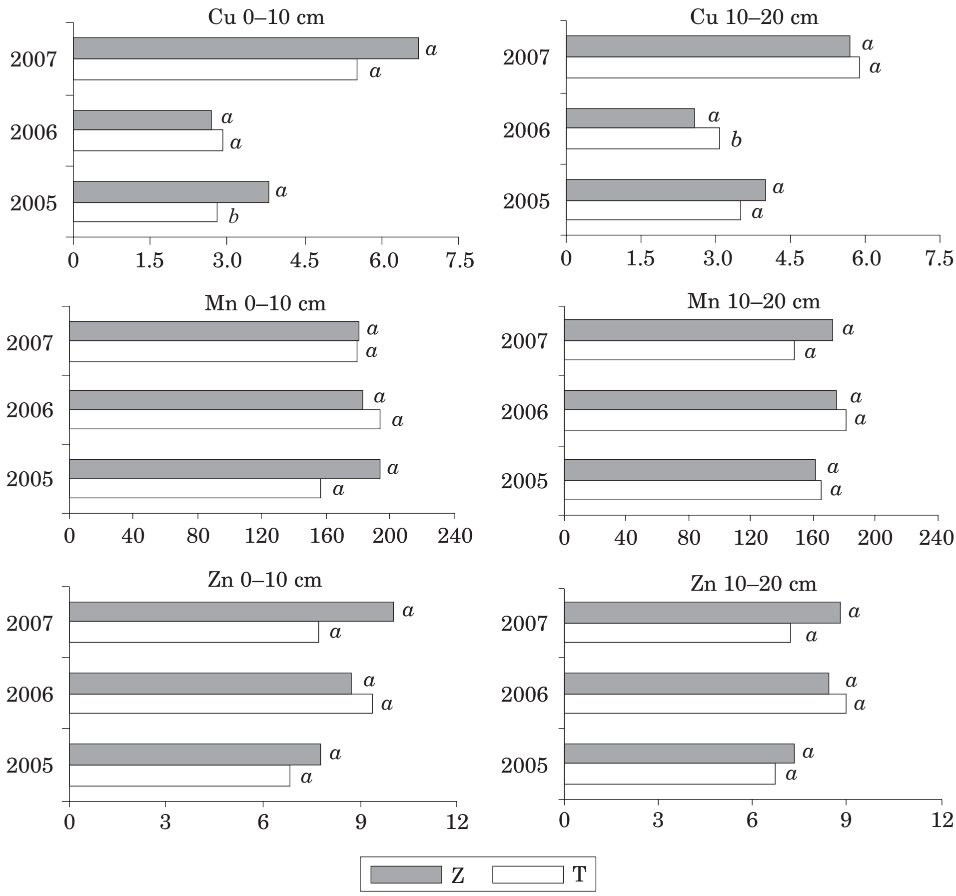

Fig. 1 Concentration of micronutrients in soil (mg·kg^{-1}) under traditional (T) and no-tillage method (Z). Different letters for the same year indicate significant differences at $p < 0.05$ acc. to Student's test

fall for the three-month period analysed was no more than 8% different. The three-month average air temperatures in 2005 and 2006 were similar, reaching about 8°C. The last year, 2007, was slightly warmer.

RESULTS AND DISCUSSION

Our comparison of the content of micronutrients depending on the method of tillage showed significant differences only in the concentration of copper (Figure 1). However, it is impossible to state without any doubt which tillage method resulted in a higher level of copper as the differences depended on the year and depth of the soil horizon. In 2005 the no-till soil was more abundant in copper, but only in the 0-10 cm layer. In 2006, more copper was found at the depth of 10-20 cm of the conventionally tilled soil. Finally, in 2007, concentrations of copper were not significantly different relative to the tillage method.

The levels of zinc and manganese were not significantly diverse relative to the tillage method in either of the years. Analogously to the copper levels discussed above, we could only observe a tendency towards higher concentrations of these elements in the no-till soil in the year 2005 and a reverse trend in the following year. It needs to be added that such a tendency for zinc was observable in both soil horizons, whereas for manganese – only in the 0-10 cm layer.

There is a scarcity of studies on the effect of tillage on micronutrients in soil, and the few reports that are available contain contradictory results. It is so because changes in the chemical properties of soil which occur when ploughing is completely discontinued depend also on how long a given soil has been ploughed before, on the type of soil as well as on the climatic conditions. It can be expected that in our study the duration of no-till farming (4 to 5 years and 11 years at the most) was too short to attain stable differences in the concentration of the analysed micronutrients compared to conventional tillage. Tarkalson et al. (2006) did not discover any differences in the chemical properties of soil after 14 years of no-till faming versus conventionally tilled fields, but found out that such changes occurred after 27 years of continuous zero-tillage. In another experiment, which involved fields after 21 years of different tillage farming, it was revealed that more Cu, Mn and Zn appeared in a 0-5 cm horizon of soil under no-till faming (De Santiago et al. 2008). Lavado et al. (1999) reported that after 18 years of zero-tillage, the topmost layer of soil (0-5 cm) contained more $Zn_{(DPTA)}$ than an analogous soil layer under traditional tillage. However, in the deeper soil horizon, conventionally tilled soil was more abundant in this macronutrient. Differences in the content of $Cu_{(DPTA)}$ and $Mn_{(DPTA)}$ appeared only in the 0-5 cm soil profile, with the conventionally tilled soil being more abundant.

Carter (2005) found out that after 18 years of no-till farming the surface layer of soil (0-10 cm) contained more Mn than conventionally ploughed soil. Franzluebbers, Hons (1996), who carried out an 8-year study on loamy soil, demonstrated that the most extensive changes caused by no-till occurred in the 0-5 cm soil layer, where Zn and Mn were more abundant, whereas the content of Cu was depressed (DTPA+EDTA extraction) compared to conventionally tilled soil. At the same time, they found that the 0-30 cm soil horizon was richer in all the three elements. According to Wright et al. (2007), after just 5 years of zero-tillage on loamy soil, the content of Zn in the topmost layer of 0-15 cm was elevated in comparison to conventional tillage. Moreover, independently from the tillage method, the content of Zn tended to decline at deeper soil layers more profoundly than that of Mn or Cu. Another report (Martin-Rueda et al. 2007) concludes that a four-year zero-tillage farming has led to elevated concentrations of Mn, Zn and Cu in soil (0-15 cm) versus ploughed soil. However, it is impossible to draw any reliable conclusions on the effect of soil tillage on the content of micronutrients in soil as the few available reports dealing with this issue are based on experiments which are frequently incomparable. It seems, nevertheless, that changes in the concentration of micronutrients caused by extensive simplification of tillage appear more promptly in heavier soils and are observable not only in the topmost soil horizons but also in deeper layers, down to 30 cm depth.

CONCLUSIONS

1. No-till faming of sandy soil carried out for no more than 11 years, under the conditions encountered in our tests, did not change in any significant manner the concentration of zinc and manganese down to 20 cm depth of a soil profile as compared to conventionally ploughed soil.

2. The general abundance of the analysed micronutrients, as well as some small differences resulting from the two different tillage methods, were similar in both soil layers: 0-10 and 10-20 cm.

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