Effect of Soil Tillage and N- Fertilization in a Spring Triticale Field Experiment on Soil Physical Properties and the Content of Plant Available Microelements in the Soil

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Summary

A two-factorial field experiment was started in autumn 1996 on a leached brown soil formed from coarse sand (clay 15% and 1.65 % of humus). The soil was light acid (pH=6.3). The experiment had two factors: different soil cultivation and different nitrogen fertilization. A - conventional soil tillage; B -simplified soil tillage, with double cultivation; C -simplified soil tillage, with simple cultivation and 3 doses of nitrogen fertilization (1- 60, 2 - 90, 3 - 120kg N/ha^{-1}).
On the basis of investigations it was found that: systems of soil tillage and nitrogen fertilization level didn't affect soil density and pH. With the extension of simplifications, soil volume density increased and organic carbon content decreased. Extension of nitrogen fertilization doses had an influence on the growth of soil volume density and the amount of organic carbon in the soil. Modifications in the soil tillage didn't influence the quantity of soluble forms of iron and copper in the soil. However, they decreased manganese content and increased the level of zinc. After extension of nitrogen fertilization, an increase of soluble iron and manganese and reduction of zinc and copper were observed. The content of all elements was concentrated in arable layer of the soil (0-25 cm). One didn't state any relationship between physical properties and content of microelements in the soil. On the other hand, numerous positive correlations between particular microelements accumulated in the soil, and organic carbon and manganese were observed.

Key Words: conventional and simplified soil tillage methods, nitrogen fertilization, spring triticale, soil physical properties, microelements

Zusammenfassung

Auswirkung von Bodenbearbeitung und Stickstoffdüngung auf bodenphysikalische Parameter und den Gehalt an pflanzenverfügbaren Mikroelementen in einem Feldexperiment mit Sommertriticale

Im Herbst 1996 wurde ein zweifaktorieller Feldversuch auf einer grobkörnigen sandigen Braunerde nahe Zamosc in Südostpolen angelegt (15% Ton, 1.65 Humus). Der pH-Wert des Bodens lag mit pH 6.3 im leicht sauren Bereich. Das Experiment enthielt mit unterschiedlichen Bodenbearbeitungsvarianten und unterschiedlicher Stickstoffdüngung zwei Faktoren: A-konventionelle Bodenbearbeitung, B-vereinfachte Bodenbearbeitung mit zweifacher flacher Bearbeitung, C- vereinfachte Bodenbearbeitung mit einmaliger flacher Bearbeitung. Die Stickstoffgaben betrugen 1- 60, 2- 90, 3-120 kg ha^{-1}.

Als Ergebnisse des Experimentes können herausgestellt werden: Die Intensität der Bodenbearbeitung und die Höhe der Stickstoffdüngung beeinflussten die Bodendichte und den pH-Wert nicht. Mit zunehmender Vereinfachung der Bodenbearbeitung verringerte sich der org. C-Gehalt. Die Bodenbearbeitungsvariationen hatten keinen Einfluß auf die Menge an pflanzenverfügbarem Eisen und Kupfer im Boden, jedoch wurden mit abnehmender Bearbeitungsintensität geringere Mangangehalte und höhere Zinkgehalte ermittelt. Mit Zunahme der Stickstoffdüngung wurden höhere pflanzenverfügbare Eisen- und Mangangehalte sowie geringere Zink- und Kupfergehalte festgestellt.Ein Zusammenhang zwischen den physikalischen Bodeneigenschaften und den Gehalten an Mikroelementen wurde nicht festgestellt.Andererseits wurden einige positive Korrelationen zwischen einigen Mikroelementen im Boden und der org. Substanz ermittelt.

Schlüsselworte: Konventionelle und vereinfachte Bodenbearbeitunsmethoden, Stickstoffdüngung, Sommertriticale, bodenphysikalische Eigenschaften, Mikroelemente

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Introduction

Contents of elements in soils-according to Dudka (1992) - mainly depend on mineral composition of mother rock, climatic and biological factors and human influence on soil environment, containing the level of mineral and organic fertilization. Kukurenda (1986) claims, that in acid solutions of sandy soils there are bigger total amounts of microelements than in solutions of loamy soils. According to investigations carried out by Obojski and Straczynski (1995), the soils from the Zamosc region have a mean-high level of available forms of zinc and small content of copper.

Investigations on spring triticale in Poland have been carried out since the second half of the eighties. They concern mainly growing functions and agricultural technology under different habitat conditions.

There aren't any investigations with spring triticale on the influence of soil tillage methods (including its relinquishment) and nitrogen fertilization on physical properties and content of microelements in soil.

Material and methods

In spring 1997, in Malice - a village near Zamosc (Poland), a two-factorial field experiment by split-plot method was started in four replications. The experiment was carried out on leached brown soil, formed from light loamy silty soil (texture: sand -57 %, silt -28 %, clay -15 %), poor soil with 1.65 % of humus. pH in the topsoil was 6.3 and 5.9 in the subsoil. Total nitrogen content was on average 0.085 %. Content of plant-available P in the topsoil (vanadium-molybdene method according to Egner-Riehm; phosphorus with colorometric method and potassium with photometric method) was 22.1mg P_2O_5 100g^{-1} and for K 17.1g^{-1} K_2O 100g^{-1} .Content of magnesium was in average 3.7 mg 100 g^{-1} soil. Accumulation of manganese, copper and iron was the average content for mineral soils, and zinc content was rather high (Mn – 91, Cu - 3.62, Fe – 294 and Zn – 5,25 mg kg^{-1} soil) .

On such characterised objects there were marked 36 plots with an area of 30 m^2 each. The area of plots put into harvest was 19.5 m^2 (3m. * 6.5m.). The crop preceding triticale was potatoes, cattle-manure in a dose of 30 t ha^{-1}. After harvesting potatoes, 3 different methods of soil tillage and 3 doses of nitrogen fertilization (60, 90, 120 kg N ha^{-1}) were applicated. Phosphorus-potassium fertilization depended on abundance of plant available forms and has been 90 kg P_2O_5 and 100 kg K_2O ha^{-1} Methods of soil tillage have been as follows:

A. Conventional soil tillage: medium ploughing in autumn,. harrowing, cultivation, PK fertilization, harrowing, sowing, harrowing in spring.
B. The simplified soil tillage, with double cultivation: cultivation in autumn, cultivation, PK fertilization, harrowing, sowing, harrowing in spring.
C. The simplified soil tillage, with simple cultivation: without tillage in autumn, cultivation, PK fertilization, harrowing, sowing, harrowing in spring.

Nitrogen fertilization was used in doses of 1 - 60, 2 - 90, 3 - 120 kg N ha^{-1}. Fertilization was used three times: 1st dose - 1/3 before sowing; 2nd dose - 1/3 when vegetation started; 3rd dose - 1/3 in phase of stalk shooting up.

In the end of the spreading phase, the herbicide Granstar was used in a dose of 20 g ha^{-1}.

Total rainfall in the seasons 1997-1999 have been higher by 161, 102, and 74 mm than the long-term sum of 358 mm. Only June 1997, and May and July 1999, were dry, but other months of three years had higher rainfalls. In 1998 no heavy droughts or rains were observed. Generally rainfall in particular months of shown vegetation seasons was regular and didn't affect growth phases of triti-

Table 1: Sums of rainfalls [mm] and temperature [^{0}C] in the growing seasons 1997-1999 and in long-term period at Zamosc

Tab.1: Niederschlagssummen (mm) und Temperatur (^{0}C) in den Wachstumsperioden 1997-1999 im langjährigem Mittel in Zamosc

	Month						Sum
Years	April	May	June	July	Aug.	Sept.	
			Rainfall				
1997	57	69	28	198	93	74	519
1998	58	53	124	115	67	43	460
1999	114	32	108	69	58	51	432
1981-94	37	53	73	76	57	62	358
			Mean Temperature				
1997	7,8	12,8	16,0	19,0	18,1	13,4	2669
1998	10,1	13,7	17,9	18,2	16,5	12,8	2724
1999	9,6	12,0	18,8	20,0	16,9	14,9	2815
1981-94	7,0	12,9	14,8	17,5	16,6	12,1	2481

Table 2: Effect of soil tillage and nitrogen fertilizers on soil physical properties (∅ 1997-1999)

Tab. 2: Einfluss von Bodenbearbeitung und Stickstoffdüngung auf bodenphysikalische Parameter, (∅ 1997-1999)

Nitrogen Fertiliser		Soil Tillage A	Soil Tillage B	Soil Tillage C	Mean	LSD (α=0.05)
			Soil Density (g m.$^{-3}$)			
1		1,47	1,48	1,48		
2		1,48	1,49	1,48	1,48	-
3		1,48	1,48	1,48	1,48	
	0-25	1,46	1,46	1,46	1,46	
Soil	25-35	1,50	1,51	1,50	1,50	0,01
MEAN		1,48	1,49	1,48	1,48	
LSD (α=0.05)			-			
			Soil Volume Density (g m.$^{-3}$)			
1		2,34	2,37	2,36	2,35	
2		2,40	2,38	2,41	2,40	0,01
3		2,37	2,37	2,39	2,37	
	0-25	2,30	2,30	2,31	2,31	
Soil	25-35	2,45	2,45	2,45	2,45	0,01
MEAN		2,38	2,38	2,39	2,38	
LSD (α=0.05)			0,01			
			pH KCl			
1		5,8	5,7	5,6	5,7	
2		5,8	5,6	5,7	5,7	
3		5,3	5,7	5,6	5,6	-
	0-25	5,7	5,7	5,7	5,7	
Soil	25-35	5,6	5,6	5,5	5,6	-
MEAN		5,6	5,7	5,6	5,6	
LSD (a=0.05)			-			
			C-org. (%)			
1		0,85	0,89	0,94	0,90	
2		0,87	0,89	0,87	0,88	
3		0,86	0,87	0,90	0,87	0,01
	0-25	0,90	0,93	0,90	0,92	
Soil	25-35	0,82	0,83	0,82	0,84	0,01
MEAN		0,86	0,88	0,90	0,88	
LSD (α=0.05)			0,01			

cale. The monthly averages of the air temperatures in the vegetation season in 1997-1999 were much higher than over a long term. June, July and August were particularly hot months.

Generally, we can say that the vegetation seasons 1997-1999 were very warm and wet (table 1).

Every year, the soil samples from the 0-25 and 25-35 cm layers were taken before NPK fertilization. From the soil samples, according to obligatory methods, were determined: soil density (in Kopecky's cylinders), volume density (pycnometrically), pH in 1M KCl (electrometrically), the amount of organic carbon with a method by I. W. Tiurin (oxidisation with $K_2Cr_2O_7$). Content of solid forms of iron, manganese, zinc and copper were determined with atomic absorption spectrometry after extraction in 1 M KCl extract according to Rinks, solution 1:10.

Obtained findings were fixed with a statistical method calculating lowest significant differences (α=0.05) with the Tukey-test.

Results and discussion

The soil density didn't depend significantly on experiment factors. It was on average 1.48 g m.$^{-3}$. Significant differences were shown between the depths of soil samples. In the subsoil, the soil density was significantly higher than in the arable layer (by 3 %) (table 2). According to Baranowski (1980) the soil density influences significantly the air-water and thermal conditions and the mechanical resistance. According to Swiecicki (1969), when the density is higher, the uptake of nutrients is more difficult. Swiecicki (1969) also claims that if this characteristic lies between 1.5 - 1.7 g m.$^{-3}$, it means, that the soil is compact and can be the cause of plant yield decrease. In this experiment one didn't observe such phenomenon, because the soil density balanced from 1.47 to 1.49 gm^{-3}.

Table 3: Effect of soil tillage and nitrogen fertilization on the content of soil microelements (plant available forms) (∅ 1997-99)

Tab. 3: Auswirkung von Bodenbearbeitung und Stickstoffdüngung auf den Gehalt an pflanzenverfügbaren Mikroelementen im Boden, (∅ 1977-99)

Nitrogen Fertiliser		Soil Tillage A	 B	 C	 Mean	LSD $_{(a=0.05)}$
			Iron (mg kg^{-1})			
1		336	340	338	338	
2		291	294	304	297	-
3		327	333	354	377	
	0-25	331	336	345	377	
Soil	25-35	305	308	319	311	8
MEAN		318	443	332	324	
LSD $_{(\alpha=0.05)}$			9			
			Manganese (mg kg^{-1})			
1		83,5	87,3	2,36	2,35	
2		74,3	2,38	2,41	2,40	3,9
3		74,2	2,37	2,39	2,37	
	0-25	84,0	90,6	93,3	89,3	
Soil	25-35	70,7	78,6	79,8	76,3	3,2
MEAN		77,3	84,6	86,9	82,8	
LSD $_{(\alpha=0.05)}$			0,01			
			Zinc (mg kg^{-1})			
1		3,3	4,3	4,4	4,2	
2		4,8	4,8	3,7	4,8	0,4
3		5,4	5,8	4,9	5,9	
	0-25	4,8	5,2	4,5	5,3	
Soil	25-35	4,3	4,8	3,8	4,7	-
MEAN		4,5	5,0	4,1	5,0	
LSD $_{(a=0.05)}$			0,4			
			Copper (mg kg^{-1})			
1		1,8	2,1	2,0	1,9	
2		2,2	2,1	2,0	2,0	
3		2,3	2,3	2,4	2,3	0,01
	0-25	2,1	2,2	2,1	2,1	
Soil	25-35	2,0	2,1	2,0	2,0	0,01
MEAN		2,1	2,1	2,0	2,1	
LSD $_{(\alpha=0.05)}$			0,1			

The method of soil tillage didn't have important influence on change of soil density. Mackiewicz (1998) and Dzienia (1990) had similar remarks. They demonstrated, that differentiated systems of plough tillage and their simplified forms did not influence specific gravity and soil porosity. In their opinion only no-tillage causes an increase of specific gravity and a decrease of porosity. Radecki (1986) proved that the soil density formed in result of the tillage isn't permanent and changes during vegetation under the influence of natural factors (gravitation, weather conditions, plant, etc.) or mechanical factors (tools, machines, tractors).

The volume density of soil was affected by the methods of soil tillage and nitrogen fertilization doses. The use of simplified tillage with single cultivation caused the increase of the volume density of soil by 4 % in relation to other methods of soil tillage. The increase of nitrogen fertilization level to 90 and 120 kg ha^{-1} increased this characteristic by 0.05 and 0.03 g $m.^{-3}$ (table 2).

The soil pH didn't significantly depend on experimental factors. Also, it wasn't affected by the depth of soil samples. It was mean 5.6 (pH in 1 M. KCl) (table 3). According to Grzebisz and Potarzycki (1996), the system of soil usage plays a secondary part in trace elements adsorption. In this investigations one observed, that when simplifications in the soil tillage were introduced, there was a negative correlation between the soil pH and content of soluble forms of zinc ($r = -0.4878$) and copper ($r = -0.4575$).

Organic carbon content in the soil significantly depended on the soil tillage and nitrogen fertilization. After using simplifications in soil tillage, the quantity of organic carbon increased, by 2 and 5 % respectively, with higher amount of N the amount of C decreases (by 2 and 3 %). In subsoil there was also less organic carbon, by 9 %, than in arable horizon (table 2). In the opinion of Hardgrowe based on Pudelko (1994) multi-year use of simplified tillage is profitable and contributes to maintenance of organic matter in the soil, better moistening and improvement of its structure. The organic carbon content in the soil was positively correlated with content of soluble manganese in the soil ($r = 0.5683$).

Content of soluble iron significantly increased in the case of using simplifications in the soil tillage. Nitrogen fertilization didn't affect iron content in the soil. However the depth of taken samples had significant influence. In the arable layer there was more plant available iron in subsoil (25-35 cm) by 8 % (table 3). The iron content in examined soil is conformable to investigations of Kabata-Pendias and Pendias (1999). In their opinion, solubility of iron compounds proportionally increased with the level of soil acidification, though this phenomenon wasn't confirmed. The iron solubility significantly depended on the content of soluble manganese in the soil ($r = 0.6734$).

Manganese in the soil doesn't depend on the method of soil tillage. Though, according to Motowicka-Terlak (1989) active manganese is neutralised by organic manure. Where there is a high content of organic manure (objects with simplified soil tillage) - manganese is there in smaller amounts. According to Kabata-Pendias and Pendias (1999), content of soluble manganese in the light soil in conditions of Poland is 15-1500 mg kg^{-1} soil. In their opinion this element is also in negative correlation with organic matter. In the experiment presented, an inverse tendency was observed, because soluble manganese was positively correlated with content of organic matter ($r = 0.5683$). The manganese content was modified by the level of nitrogen fertilization. The increase of nitrogen fertilization dose to 90 and 120 kg ha^{-1} decreased the content of soluble form of manganese in the soil, respectively by 7.5 and 4.1 mg kg^{-1} of soil. Significant differences were also in depths of taking samples. In the layer of 0-25 cm this element was found to be 15% higher than in the 25-35 cm layer (table 3).

The level of soluble zinc content was modified by soil tillage. The highest amount was stated in the soil taken from plots with the soil tillage double cultivation (6.5 mg kg^{-1}). It was in significantly smaller amounts in two other tillages and so, in conventional tillage respectively - in comparison with the tillage with double cultivation. The doses of nitrogen fertilisation also influenced the content of this element in the soil. After increasing its doses, solubility of this element increased too, respectively by 0.6 and 1.7 mg kg^{-1}. In the subsoil there was less zinc, by 0.6 mg kg^{-1}, than in the arable layer (table 2,3). It is in conformance with investigations of Kabata-Pendias and Pendias (1999) who claim that zinc accumulation is in surface horizons of the soil, because organic matter makes quite permanent bonds with zinc. In their opinion, zinc in heavy connection with iron and manganese oxides significantly limit taking up of zinc by plants. This phenomenon wasn't confirmed.

The content of soluble copper in the soil was modified by the soil tillage. The greatest amounts of copper were in the soil with conventional tillage and tillage with single cultivation. The use of other simplifications in spring decreased copper solubility, average by 0.1 mg kg^{-1}. No significant differences in copper content in dependence on depth of taking soil samples (table 3) were recorded. According to Kabata-Pendias and Pendias (1999) copper in soils is heavy combined by organic matter and clay minerals. Larger amounts of soluble forms of copper is also in surface soil layers, but it isn't intensively moved deep in the soil profile. It is consistent with this investigations. Mucha and all (1983) show, that deep ploughing causes a decrease of copper in the soil. Besides these authors record negative correlation between copper and pH. This phenomenon was confirmed in this work, because soluble copper correlated negatively with pH ($r = -0.4575$). One also observed very heavy connection between copper and zinc ($r = 0.8643$).

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