Effect of Different Soil Tillage and Weed-Control Methods in a Potato Field Experiment on Soil Physical Properties and the Content of Plant Available Micro-Elements in the Soil

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Introduction

The tasks of soil tillage for potatoes issue from potatoes' growth and development requirements in relation to the habitat. Cultivation treatments should create quite deep, mellow soil layer with proper water and air relations which are profitable for the development of tubers and root systems. It is obtained by careful soil tillage (particularly using pre-winter ploughing), repeated weeding and earthing up.

In local and foreign literature you can find research about the simplification of potatocultivation (Dzienia 1990, Marks 1996, Neubauer 1995, Spiess 1991, Scholz 1990). This also lies in forming ridges in autumn with the help of furrow plough and in maintaing them over the winter, and then planting potatoes into formed ridges with the help of a planting machine in spring. Marks (1996) and Scholz (1990) recommend such method of simplification (without earlier cultivation treatments) particularly in soils which tend to agglutinate and which are located in areas with definite climatic conditions in winter (mountainous and piedmont areas). Such a tillage method has an effect on the improvement of physical relations in the soil. Initial research on new tillage techniques of potatoes on light soil (autumn intensive tillage) proved that extension of the yield was present but elimination of autumn treatments under potatoes provokes a drop in tuber-yield.

Such elements of tillage and weed cultivation are also used in the experiment.

Summary

The work refers to the influence of different methods of soil tillage and weed-control on soil and subsoil physical properties and on the content of plant-available forms of microelements in the soil. Results were gathered in a field experiment, carried out from 1997-1999.

The experiment had two aspects: three methods of soil tillage (conventional, autumn intensive and simplified soil tillage) and three methods of weed control in potatoes (mechanical-chemical, mechanical and chemical) were studied. According to the investigations, it can be stated that: modifications in soil tillage methods and type of applied cultivation did not change soil density. Soil tillage methods and weed control differentiated soil volume density, pH and organic carbon. They also influenced significantly the content of iron, zinc and copper in the soil. Zinc and copper were independent of the weed control method used.

Key Words: potato, soil tillage, cultivation, soil physical properties, microelements

Zusammenfassung

Auswirkung unterschiedlicher Bodenbearbeitung und Beikrautkontrolle auf bodenphysikalische Parameter und den Gehalt an pflanzenverfügbaren Mikroelementen in einem Feldexperiment mit Kartoffeln

Mit dem Feldexperiment sollten die Wirkungen unterschiedlicher Bodenbearbeitungssysteme und Beikrautbekämpfungsmaßnahmen auf bodenphysikalische Parameter und auf die Gehalte an pflanzenverfügbaren Mikroelementen im Boden untersucht werden. Der Feldversuch wurde von 1997 bis 1999 durchgeführt. Das Experiment beinhaltete zwei Faktoren: Drei Bodenbearbeitungsvarianten (konventionell, herbstintensive und vereinfachte Bodenbearbeitung) und drei Methoden der Beikrautkontrolle in Kartoffeln (mechanisch-chemisch, mechanisch und chemisch).Aufgrund der Untersuchungsergebnisse ist festzuhalten: Auf das Volumengewicht des Bodens hatten weder die unterschiedlichen Bodenbearbeitungsverfahren noch die Art der Beikrautbekämpfung einen Einfluß.Beide Faktoren beeinflußten dagegen die Bodendichte, den pH-Wert und den Gehalt an org. Kohlenstoff. Ebenfalls beeinflußten sie die Eisen- Zink- und Kupfergehalte im Boden signifikant. Zink- und Kupfergehalte wurden durch die Art der Unkrautregulierung nicht beeinflußt.

Schlüsselworte: Kartoffeln, Bodenbearbeitung, physikalische Bodenparameter, Mikroelemente

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Material and methods

In autumn 1996, 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-molybdenum 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 characterized objects there were marked 36 plots with an area of 30 m^2 each designated for potato cultivation, variety Mila. The crop preceding potatoes was spring triticale, variety Migo.

The experiment has had two factors: 3 methods of soil tillage and 3 methods of weed control in potatoes.

Factor I - soil tillage:

A- Traditional soil tillage - after gathering of spring triticale - plough skimming, harrowing, 30 t cattle-manure per hectare, reversible ploughing, pre-winter ploughing (25 cm). In spring: harrowing, ducfoot cultivation, harrowing, mineral fertilizers (N,P,K), potato planting with the help of a planting machine. Harvesting with a digger elevator.

B - Autumn ridge tillage - after gathering of spring triticale - plough skimming, harrowing, 30 t cattle-manure per hectare, reversible ploughing. In autumn - forming 20-25 cm ridges with a furrow plough ridger. In spring - mineral fertilizers (N,P,K), potato planting into ridges with a planting machine. Harvesting with a digger elevator.

C- Spring simplified soil tillage - after gathering of spring triticale - plough skimming, harrowing, 30 t cattle-manure per hectare, reversible ploughing. In spring: cultivation, mineral fertilizers (N,P,K), potato planting with the help of a planting machine. Harvesting with a digger elevator.

Factor-methods of weed control

1 - Mechanical-chemical - mechanical treatments from potato planting until germination, harrowing with a spring - light weeder, weeding and earthing up. A short time after germination - herbicides (Sencor 70 WP- metribuzin in the dose of 0.75 l ha $^{-1}$), without other treatments.

2 - Mechanical - mechanical treatments with generally available cultivation implements from potato planting until germination. Harrowing with a spring - light harrow until first plants appear. After germination weeding and earthing up - until furrows are dense.

3 - Chemical - after planting - herbicide (Afalon 50 WP- linuron, 2 l ha $^{-1}$), after germination - herbicide (Sencor 70 WP- metribuzin, 0.75 l ha^{-1}).

The area of plots put into harvest was 19.5 $m.^2$ (3m. * 6.5m.). Mineral fertilization in kg ha^{-1} was: N -100, P_2O_5 - 100, K_2O -180. 44000 tubers ha^{-1} with a row- space of 67.5 cm have been planted. Potato planters are equipped with fertilizer applicators and in some cases with attachments to apply materials to control *Rhizoctonia* (Dithane M.-45). Preventive application of fungicides for the control of *Phytopthora* and other foliage diseases will also be made (Sandofan Manco). The control of potato-beetle is using safe, economical insecticides (Nomolt 150 S.C., Bancol 50 WP, Fastac 10 EC, Karate 025 EC).

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- im langjährigem Mittel in Zamosc

Years	Month						
	April	May	June	July	Aug.	Sept.	Sum
	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	2662
1998	10,1	13,7	17,9	18,2	16,5	12,8	2724
1998	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	2474

Table 2: Effect of soil tillage and weed control on soil parameters (∅ 1997-99)
Tab.1: Einfluß von Bodenbearbeitung und Beikrautkontrolle auf Bodenparameter, (∅ 1997-1999)

Weed-Control	Soil Tillage A	B	C	Mean	LSD $_{(\alpha=0.05)}$
		Soil Density (g m.$^{-3}$)			
1	1,48	1,47	1,47	1,47	
2	1,48	1,48	1,48	1,48	
3	1,49	1,48	1,48	1,48	-
Soil 0-25	1,46	1,44	1,45	1,45	
Soil 25-35	1,50	1,50	1,50	1,50	0,01
MEAN	1,48	1,47	1,48	1,48	
LSD $_{(\alpha=0.05)}$	-				
		Soil Volume Density (g m.$^{-3}$)			
1	2,34	2,41	2,39	2,38	
2	2,37	2,38	2,37	2,37	
3	2,37	2,40	2,39	2,38	-
Soil 0-25	2,30	2,30	2,30	2,30	
Soil 25-35	2,42	2,45	2,45	2,44	0,01
MEAN	2,36	2,38	2,38	2,38	
LSD $_{(\alpha=0.05)}$		0,01			
		pH KCl			
1	6,1	6,0	5,6	5,7	
2	6,0	5,9	5,9	5,5	
3	5,7	5,7	5,9	5,4	0,2
Soil 0-25	6,2	6,0	6,0	6,1	
Soil 25-35	5,6	5,7	5,5	5,6	0,1
MEAN	5,9	5,9	5,7	5,8	
LSD $_{(\alpha=0.05)}$	0,2				
		C-org. (%)			
1	0,78	0,68	0,63	0,69	
2	0,89	0,91	0,76	0,85	
3	0,85	0,74	0,81	0,80	0,03
Soil 0-25	0,86	0,85	0,78	0,83	
Soil 25-35	0,82	0,70	0,68	0,73	0,02
MEAN	0,84	0,78	0,73	0,78	
LSD $_{(\alpha=0.05)}$		0,02			

Autumn field works (ploughing, skimming, harrowing – Variants A, B, C) were made in the first decade of September, manure and reversible ploughing (in Variants A, B,C) in the third decade of September. Pre-winter ploughing and autumn forming ridges were realised in the third decade of October. Spring field works were carried out for second decade of March, NPK fertilization was used before potato planting in second decade of April. Tuber harvesting happens in second decade of September. Mechanical weed-control was realised after showing weed seedlings.

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; particularly July 1997, June and July 1998, April, and June 1999. Generally rainfalls in particular months of shown vegetation seasons were regular and didn't affect growth phases of potatoes. The month averages of the air temperatures in the vegetation season in 1997-1999 were much higher than in 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, 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.

Table 3: Effect of soil tillage and weed control on the soil and layer of soil microelements (plant available forms) (Ø 1997-99)
Tab. 3: Wirkung von Bodenbearbeitung und Unkrautkontrolle auf die Gehalte an pflanzenverfügbaren Mikroelementen (Ø 1997- 99)

		Soil Tillage				
	Weed-Control	A	B	C	Mean	LSD $_{(\alpha=0.05)}$
			Iron (mg kg^{-1} soil)			
	1	384	298	358	335	
	2	369	314	321	335	-
	3	333	325	335	331	
	0-25	361	330	353	348	
Soil	25-35	340	295	323	319	10
MEAN		351	312	338	334	
LSD $_{(\alpha=0.05)}$			12			
			Manganese (mg kg^{-1} soil)			
	1	76,7	75,2	73,4	75,7	
	2	90,3	76,8	74,4	80,5	-
	3	84,8	79,3	72,5	78,9	
	0-25	86,9	83,6	79,7	83,3	
Soil	25-35	81,0	70,7	68,4	73,3	3,6
MEAN		83,9	77,2	74,1	78,3	
LSD $_{(\alpha=0.05)}$			4,4			
			Zinc (mg kg^{-1} soil)			
	1	3,1	4,6	6,7	4,8	
	2	4,6	4,8	6,8	5,4	-
	3	4,6	4,7	5,8	5,0	
	0-25	4,4	5,0	6,2	5,2	
Soil	25-35	3,7	5,7	5,5	5,6	-
MEAN		4,1	4,7	6,5	5,1	
LSD $_{(\alpha=0.05)}$			0,6			
			Copper (mg kg^{-1} soil)			
	1	1,6	2,1	2,3	2,0	
	2	1,5	1,6	1,7	1,6	-
	3	1,9	1,4	2,5	1,9	
	0-25	1,8	1,9	2,5	2,1	
Soil	25-35	1,8	1,8	2,2	2,0	-
MEAN		1,8	1,9	2,3	2,1	
LSD $_{(\alpha=0.05)}$			0,2			

Tiurin (oxidization with $K_2Cr_2O_7$). Content of solid forms of iron, manganese, zinc and copper have been determined with atomic absorption spectrometry after extraction in 1 M KCl extract according to Rinks, solution 1:10.
Obtained findings were fixed with statistic 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 depth of taking soil samples. In subsoil, the soil density was significantly higher than in arable layer (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 up-take of nutrients is difficult. Swiecicki (1969) also claims, that if this characteristic is between 1.5 and 1.7 g m.$^{-3}$, it means that the soil is compact and can be the cause of potato yield decrease. In this experiment one didn't observe such a phenomenon, because the soil density balanced from 1.47 to 1.49g m.$^{-3}$. Soil tillage method for potatoes and methods of cultivation didn't have an important influence on soil density changes.

Mackiewicz (1998) and Dzienia (1990) had similar remarks. They proved that differentiated systems of plough tillage and their simplified forms didn't influence differences in soil density and soil porosity. In their opinion only causes increase specific gravity and decrease of porosity. Radecki (1986) demonstrates that the soil density formed as a result of the tillage isn't permanent and changes during vegetation under the influence of natural factors (gravitation, weather conditions, plants, etc.) or mechanical factors (tools, machines, tractors).

The soil volume density was affected by soil tillage methods. The use of the tillage with autumn forming ridges and simplified tillage caused the increase of the soil volume density by 8% in relation to conventional tillage. It can evidence faster mineralization of organic matter in case of alternative tillage (Table 2).The soil pH significantly decreased by increasing simplifications in tillage. The use of chemicals (Afalon and Sencor) also caused significant pH of arable layer. (table 2)

Organic carbon content in the soil significantly depended on soil tillage and weed-control. After using simplifications in soil tillage methods, the quantity of organic carbon decreased. In the case of using mechanical cultivation, carbon content was highest. Carbon content decreased after chemical and mechanical-chemical weed control. The smallest content of organic carbon was noted in the case of using conventional tillage spread with Afalon and Sencor (Table 2).

Content of soluble iron was affected by the method of soil tillage. Significantly most amounts of iron were in the soil after the use of conventional tillage 351 mg kg^{-1} soil (100 %), less by 4 % in simplified tillage, and by 8 % in autumn intensive tillage. Much more iron, by 8 %, was in arable layer than in subsoil. Modifications of soil tillage methods and weed control differentiated content of this element. Iron in soil was positively correlated only with copper content (Table 3, 4).

Manganese in soil significantly depended on tillage method. The highest amounts of manganese were recorded in soil samples taken from plots with conventional tillage (83.9 mg kg^{-1} soil), a bit less in soil with autumn intensive tillage and much less in soil with simplified soil tillage (12% less in comparison with conventional tillage). It is conformable to investigations of Motowicka-Terlak (1989) who claims that active Mn is neutralized by organic manure. Where there is high content of it (simplified soil tillage) - there manganese is in smaller amounts. The differences were also in depths of taking soil samples. In the layer of 0-25 cm there were higher amounts of this element by 12 % than in the layer of 25-35 cm. Manganese in the soil positively correlated with zinc and copper content and the soil pH (Table 3, 4). The quantity of manganese was highest in objects with conventional tillage.

Table 4: Correlation coefficients between soil-properties
Tab. 4: Korrelationskoeffizienten zwischen Bodenmerkmalen

Elements	Zn	Mn	Cu	Fe
pH	-	0,4769	0,5380	-
Zn		0,4040	0,6645	-
Mn			0,4917	-
Cu				0,4597

Coefficients significant at < 5%.

Level of soluble zinc content was modified with soil tillage. The highest amounts were recorded in soil taken from plots with simplified tillage (6.5 mg kg^{-1} soil). Significantly less zinc was in both other forms of tillage; and so in the autumn intensive tillage there was less zinc with 28 % and in conventional tillage with 37 % - in comparison with spring simplified tillage. Methods of weed-control and depth of taking soil samples didn't modify content of soluble zinc. Zinc in soil is positively correlated with content of manganese and copper (Table 3, 4).

Content of soluble copper in the soil was modified by tillage methods. The highest amounts of copper were in soil with spring simplified tillage - 2.7 mg kg^{-1} soil. Significantly less copper were in both other forms of tillage, mean by 20 %. This is not in conformance with investigations of Mucha and all (1983) who demonstrate that deep ploughing causes negative correlation between copper and pH. This phenomenon wasn't confirmed in this work, and even there was invert tendency - copper positively correlated with soil pH. Weed-control didn't have an influence on copper content in the soil. Copper in the soil positively correlated with zinc and manganese content (Table 3, 4).

According to research conducted by Obojski and Straczynski (1995) the soils of Zamosc region have high content of plant available forms of zinc and small content of copper. These investigations confirm these results.

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