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IMPACT OF SOIL CULTIVATION SYSTEMS ON CHEMICAL SOIL PROPERTIES

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ABSTRACT

The research included a static crop-rotation field experiment set up in 1993: sugar beet – winter wheat – faba bean – winter barley + stubble intercrop and covered the effect of three soil cultivation systems: A – ploughing cultivation, B – ploughless cultivation, C – direct sowing on selected chemical properties of soil sampled from three soil profile layers: 0 – 10 cm, 10 – 20 cm and 20 – 30 cm. The ploughless soil cultivation and direct sowing increased the contents of organic C, total N and available K and decreased the content of exchangeable Mg in the upper soil layers. The content of available P and exchangeable Ca did not depend on the factors studied significantly. Giving up ploughing cultivation and taking up direct sowing increased the sum of exchangeable bases and the tendency to decrease soil pH_{KCl}.

Key words: chemical soil properties, soil cultivation systems, plant nutrients

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INTRODUCTION

A need to maintain the soil production potential, to protect the environment and a necessity to take cost-cutting measures encourages abandoning the traditional soil cultivation and going for ploughless cultivation or direct sowing [3,7,22]. Long-lasting simplified soil cultivation can bring about changes in chemical properties of soil and can intensify soil deterioration [9,10,12,16,17,19,23].

The monitoring of chemical changes and their dynamics in soil due to a long-lasting simplified soil cultivation is of both theoretical and practical value and can help changing from one soil cultivation system to another as soon as soil deterioration symptoms appear [13].

The aim of the present research was to define a long-lasting effect of the three respective soil cultivation systems on chemical changes in light soil in crop rotation, including sugar beet – winter wheat – faba bean – winter barley + white mustard as stubble intercrop.

MATERIAL AND METHODS

The study was carried out over 1998-2000 as a static crop-rotation field experiment: sugar beet – winter wheat – faba bean – winter barley + white mustard (stubble intercrop) set up in 1993 on IVb quality class (brown) soil of good rye soil suitability complex at the Lipnik Agricultural Experiment Station of the Szczecin Agricultural University. The contents of clay-and-silt particles amounted to 11-13%, of humus – 1.3-1.5% and of macronutrients – close to optimal content in that agronomic soil category.

The experiment included the following factors:

I – soil cultivation systems for respective crops

A – ploughing cultivation
B – ploughless cultivation
C – direct sowing

II - soil profile layers:

0 – 10 cm
10 – 20 cm
20 – 30 cm

The details of soil cultivation systems are presented in Table 1. The soil was sampled following the harvest of winter barley which ended the 4-crop rotation: sugar beet – winter wheat – faba bean – winter barley + white mustard (stubble intercrop).

There were defined the following soil parameters:

- organic C content with the Westerhoff colorimetric method,
- total N with the Kjeldahl method,
- available P content with the Egner and Riehm colorimetric method,
- available K content with the Egner and Riehm flame photometry method,
- exchangeable Mg content with the atomic spectrophotometry absorption method,
- exchangeable Ca content with the flame photometry method,
- pH_{KCl} with the potentiometer method,
- sum of exchangeable bases with the Kappen method.

The results obtained were statistically verified with the variance analysis for two-factor experiment and the Tukey test at p=95%.

Table 1. Agronomic practices in soil cultivation systems applied

Crop	Soil cultivation	Agronomic practices
Sugar beet	Traditional ploughing	In autumn - deep ploughing (30 cm) + skimplough, light harrow. In spring - cultivation unit: cultivator + cage roller, precision drilling
	Ploughless	In autumn - Roundup 360 SL (3 $dm^3 \cdot ha^{-1}$) In spring - cultivation unit: cultivator + cage roller, precision drilling
	Direct sowing	In autumn - Roundup 360 SL (3 $dm^3 \cdot ha^{-1}$) In spring - direct sowing
Winter wheat	Traditional ploughing	In autumn - ploughing (25 cm), light harrow, row drilling, light harrow
	Ploughless	In autumn - Roundup 360 SL (3 $dm^3 \cdot ha^{-1}$), cultivation unit: cultivator + cage roller, row drilling, light harrow
	Direct sowing	In autumn - direct sowing
Faba bean	Traditional ploughing	In autumn - deep ploughing (30 cm). In spring - light harrow, cultivation unit: cultivator + cage roller, row drilling, light harrow
	Ploughless	In autumn - Roundup 360 SL (3 $dm^3 \cdot ha^{-1}$) In spring - cultivation unit: cultivator + cage roller, row drilling, light harrow
	Direct sowing	In autumn - Roundup 360 SL (3 $dm^3 \cdot ha^{-1}$) In spring - direct sowing
Winter barley	Traditional ploughing	In autumn - ploughing (25 cm), light harrow, row drilling, light harrow
	Ploughless	In autumn - cultivation unit: cultivator + cage roller, row drilling, light harrow
	Direct sowing	In autumn - direct sowing
White mustard	Traditional ploughing	In autumn – shallow ploughing (12 cm), light harrow, row drilling, light harrow
	Ploughless	In autumn – shallow ploughing (12 cm), light harrow, row drilling, light harrow
	Direct sowing	In autumn – shallow ploughing (12 cm), light harrow, row drilling, light harrow

RESULTS AND DISCUSSION

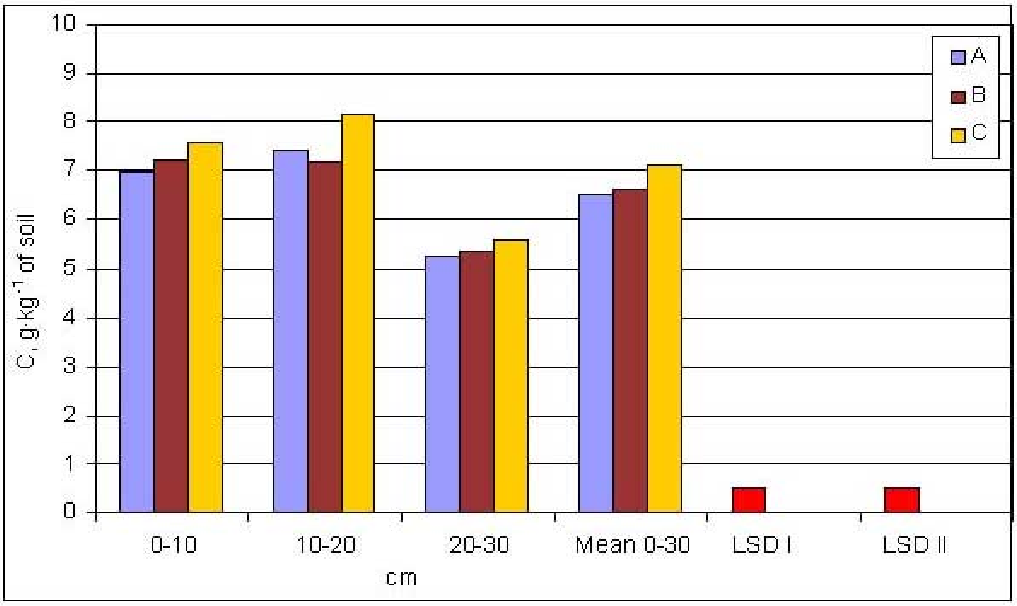
The weather conditions namely rainfall and mean air temperature, over research years were analysed (Table 2). The 1998-2000 period recorded increased rainfall in winter, while mean rainfall over vegetation period was lower than over 1960-1990. The mean air temperature over research years was higher than the multi-year mean, in 1998 by 1 °C, in 1999 by 1.8 °C and in 2000 by 2.2 °C. The highest temperature differences were recorded in spring, which accelerated the vegetation period. A higher rainfall and increased temperature could have intensified the changes and the mobility of soil macronutrients due to the soil cultivation practices applied across cultivation systems.

Table 2. Rainfall and air temperature over 1998-2000 recorded by the Lipnik Meteorological Station against the multi-year means

Month	Temperature, °C					
	Monthly mean for			Mean for 1998 - 2000	Multi-year mean for 1960 -1990	Difference, °C
	1998	1999	2000			
January	2.5	1.9	1.5	2.0	-1.6	+0.4
February	5.3	0.5	3.6	3.1	-0.8	+2.3
March	3.4	4.5	4.4	4.1	2.5	+1.6
April	10.0	9.0	11.4	10.1	7.0	+3.1
May	14.6	14.0	16.5	15.0	12.6	+2.4
June	16.9	17.1	17.8	17.3	16.1	+1.2
July	16.4	20.1	16.6	17.7	17.4	+0.3
August	16.0	18.8	18.1	17.6	16.9	+0.7
September	13.5	17.0	13.2	14.6	13.1	+1.5
October	8.5	8.9	11.8	9.7	8.7	+1.0
November	0.7	3.7	6.2	3.5	4.0	- 0.5
December	0.2	2.6	1.4	1.4	0.4	+1
Mean	**9.0**	**9.8**	**10.2**	**9.7**	**8.0**	**+1.7**
Month	Rainfall, mm					
	Monthly rainfall			Mean for 1998 - 2000	Multi-year mean rainfall for 1960 -1990	Difference, mm
	1998	1999	2000			
January	46.4	32.7	32.1	37.1	32.0	+5.1
February	29.0	43.1	39.1	37.1	26.0	+11.1
March	62.9	56.6	57.2	58.9	26.0	+32.9
April	56.2	80.0	17.2	27.1	40.0	-12.9
May	38.6	97.8	22.5	53.0	53.0	0.0
June	30.0	69.2	71.6	56.9	57.0	-0.1
July	55.8	48.1	105.1	69.7	69.0	0.7
August	62.9	44.3	33.1	46.8	62.0	-15.2
September	73.3	27.1	57.1	52.5	48.0	+4.5
October	57.2	28.4	18.0	34.5	48.0	-13.5
November	53.8	26.2	32.6	39.2	46.0	-6.8
December	53.6	58.9	56.2	56.2	42.0	+14.2
Total	**619.7**	**612.4**	**839.7**	**569.0**	**549.0**	**+20**

There was recorded a significant effect of soil cultivation systems and sampling depth on the content of soil organic C (Fig. 1). Ploughless soil cultivation (B) and, especially, direct sowing (C) coincided with a higher content of organic C in all the layers studied by an average of 9% in 0 – 30 cm, as compared with the ploughing soil cultivation (A).

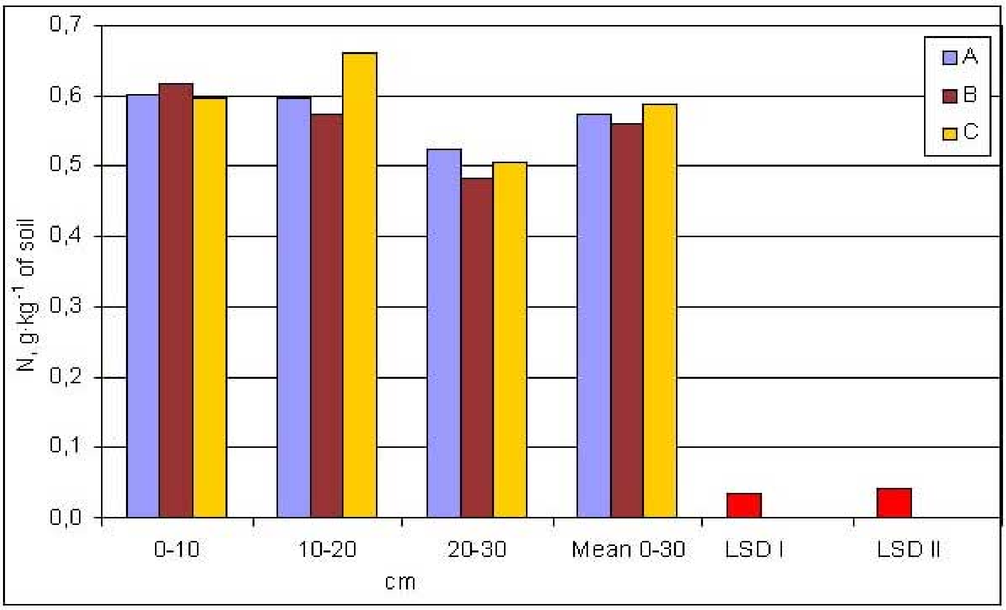
Fig. 1. Impact of soil cultivation system on the content of organic C in soil



Soil cultivation system (I) Soil profile layer (II) in cm
A – ploughing B – ploughless C - direct sowing

Similar results were observed for total N content (Fig. 2), especially in the 0 – 10 cm soil layer. The results obtained confirmed earlier reports both at home and abroad [1,2,8,9,10,11, 18,19,21,22,24] which show that simplified soil cultivation including soil ploughing increases the contents of organic C and total N in the upper soil layer due to decreased mineralization of plant residue organic matter when exposed to an increased compaction of soil which has not been loosened.

Fig. 2. Impact of soil cultivation system on the content of total N in soil



Soil cultivation system (I) Soil profile layer (II) in cm
A – ploughing B – ploughless C - direct sowing

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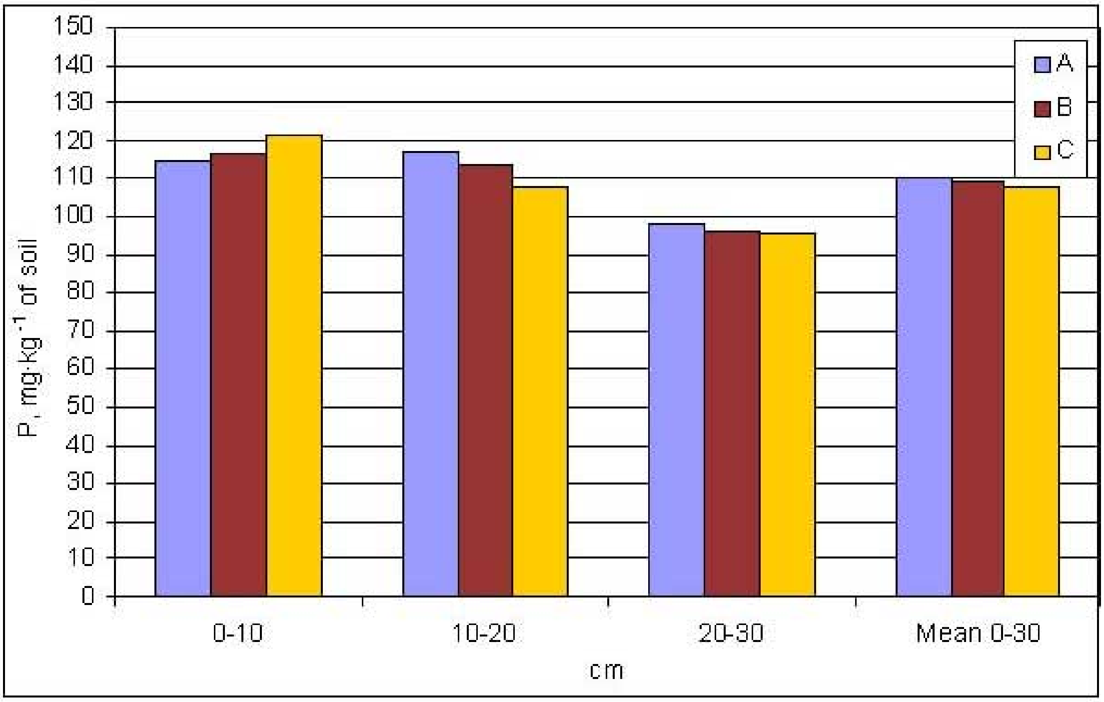
The content of available P in soil was comparable in the systems studied and differed slightly only in the soil layers (Fig. 3). There was observed, however, a tendency to a greater accumulation of available P in the 0 –10 cm layer following direct sowing.

Fig. 3. Impact of soil cultivation system on the content of available P in soil



Soil cultivation system (I) **Soil profile layer (II) in cm**
A – ploughing **B – ploughless** **C - direct sowing**

The ploughless soil cultivation (B) and direct sowing (C) increased considerably the content of K in the 0 – 10 cm layer and significantly decreased it in deeper layers (Fig. 4), which must have been due to an accumulation of plant residue and residua of mineral fertilisers. The content of exchangeable Mg was observed to be considerably higher in 10 – 20 cm soil layer and significantly lower in the other layers due to ploughless cultivation (B) and direct sowing (C) (Fig. 5). The changes in the content of Mg in the profile of simplified-cultivation soil can be the result of increased soil bulk density which inhibits Mg cation leaching deep into the soil profile. The results obtained confirm the reports of numerous authors including De Maria et at. [9], Dowdell and Cannell [10], Dzienia and Sosnowski [11], Hussain et al. [12], Terbrugge et al. [22], White [23], yet they do not coincide with those of Smettern and Rovira [19] and Sołtysova [20].

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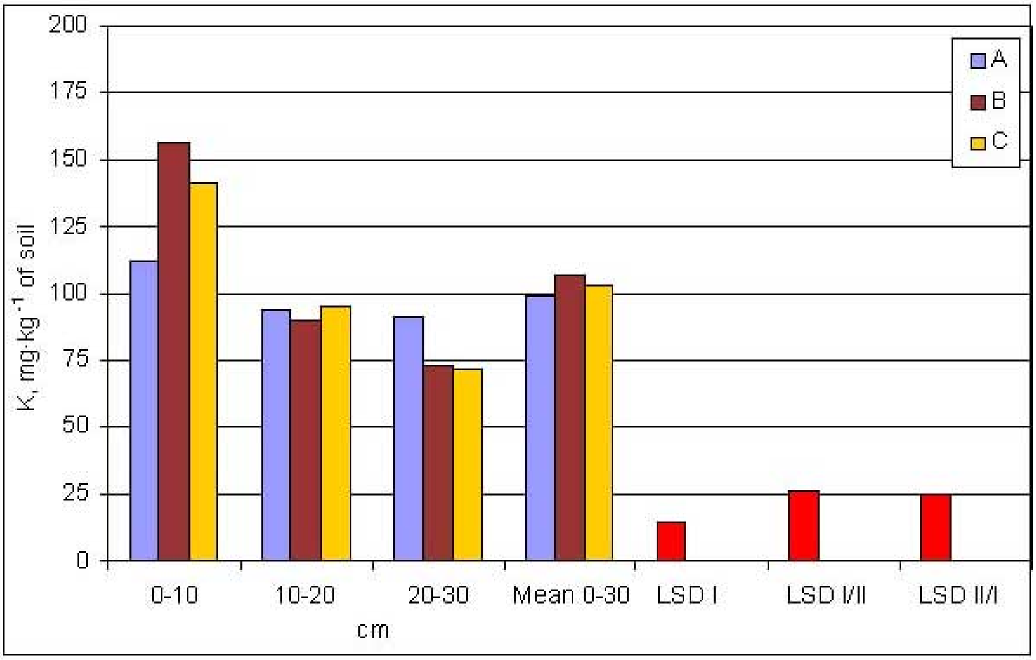
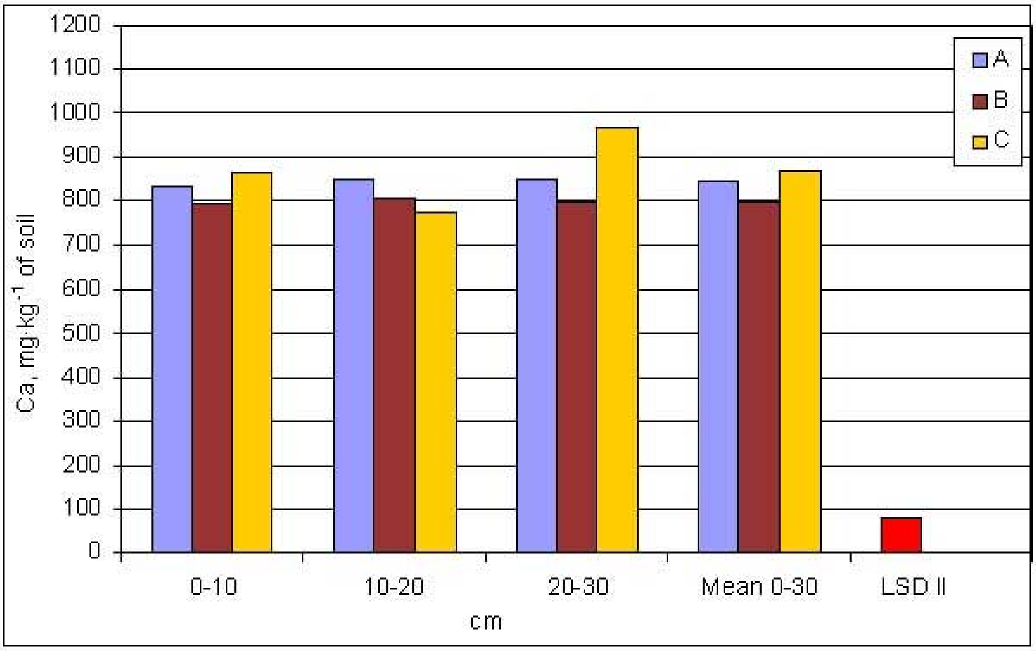
Fig. 4. Impact of soil cultivation system on the content of available K in soil



Soil cultivation system (I)   Soil profile layer (II) in cm
A – ploughing   B – ploughless   C - direct sowing

Fig. 5. Impact of soil cultivation system on the content of exchangeable Ca in soil



Soil cultivation system (I)   Soil profile layer (II) in cm
A – ploughing   B – ploughless   C - direct sowing

There were observed no significant differences in the content of Ca in soil across the soil cultivation systems; it was only the sampling depth which differentiated the Ca content significantly (Fig. 6). The highest content of exchangeable Ca content was noted in the deepest layer of ploughed soil (A) and in direct sowing (C), which could have resulted from leaching and mobility of Ca exchangeable forms.

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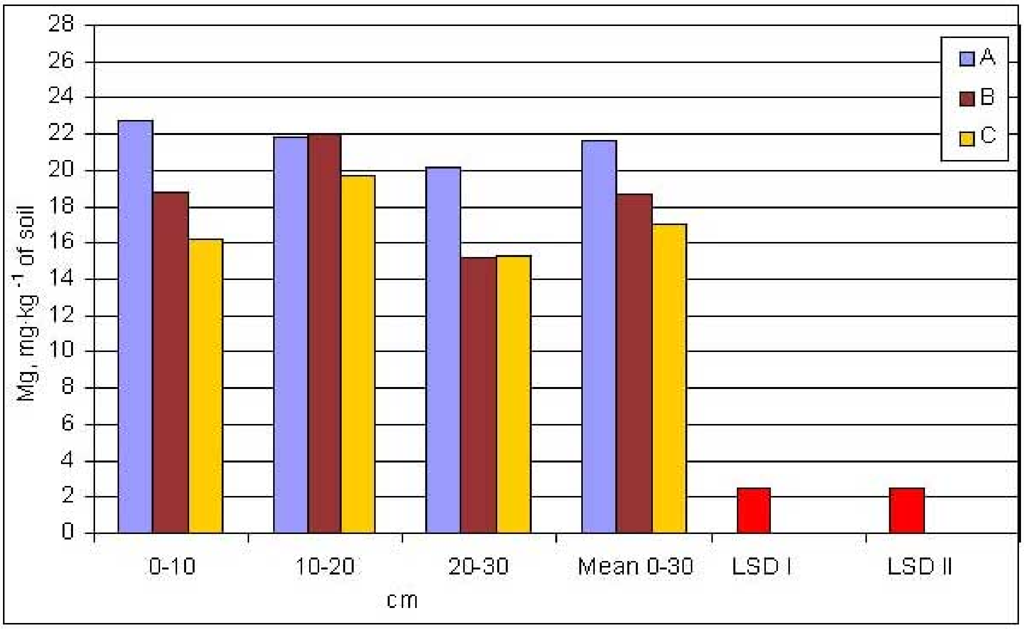
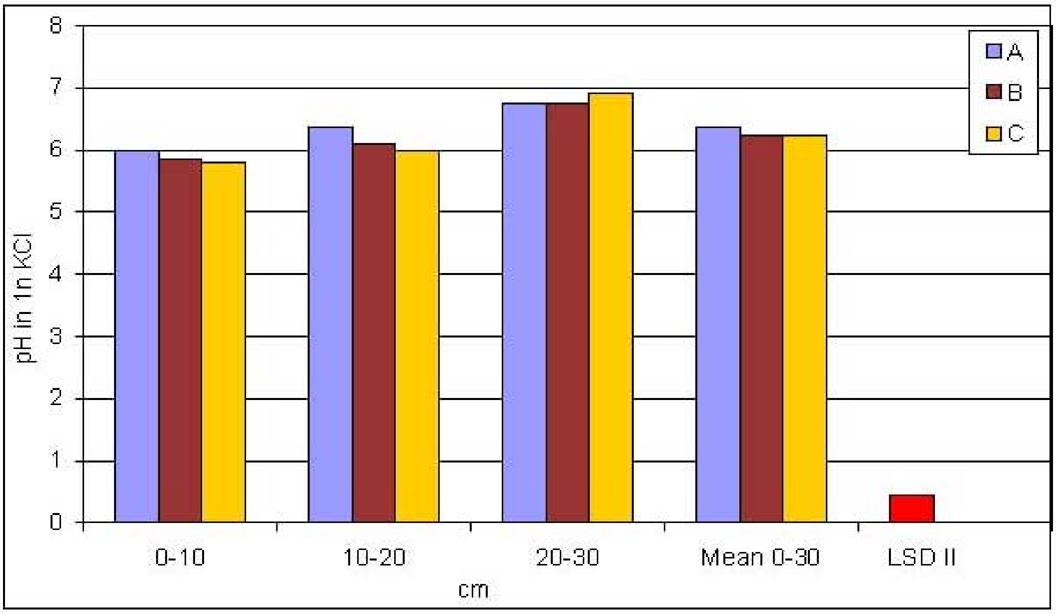
Fig. 6. Impact of soil cultivation system on the content of exchangeable Mg in soil



Soil cultivation system (I) Soil profile layer (II) in cm
A – ploughing B – ploughless C - direct sowing

However, the tendency was noted to decrease the pH_{KCl} in 0 – 10 cm and 10 – 20 cm ploughless (B) soil layers (Fig. 7). The change in soil pH seems to come from an increased organic matter mineralization and $N\text{-}NH_4$ nitrification leading to increased concentration of H^+ in soil solution. A similar tendency in soil pH due to soil cultivation simplification was recorded by many other authors, including Blecharczyk et al. [4], Blevins et al. [5], Carter [8], Dowdell and Cannell [10], Dzienia and Sosnowski [11], Hussain et al. [12], Kuś [14], Paul et al. [15], Quiroga et al. [16] and Rasmussen [17].

Fig. 7. Impact of soil cultivation system on soil pH_{KCl}



Soil cultivation system (I) Soil profile layer (II) in cm
A – ploughing B – ploughless C - direct sowing

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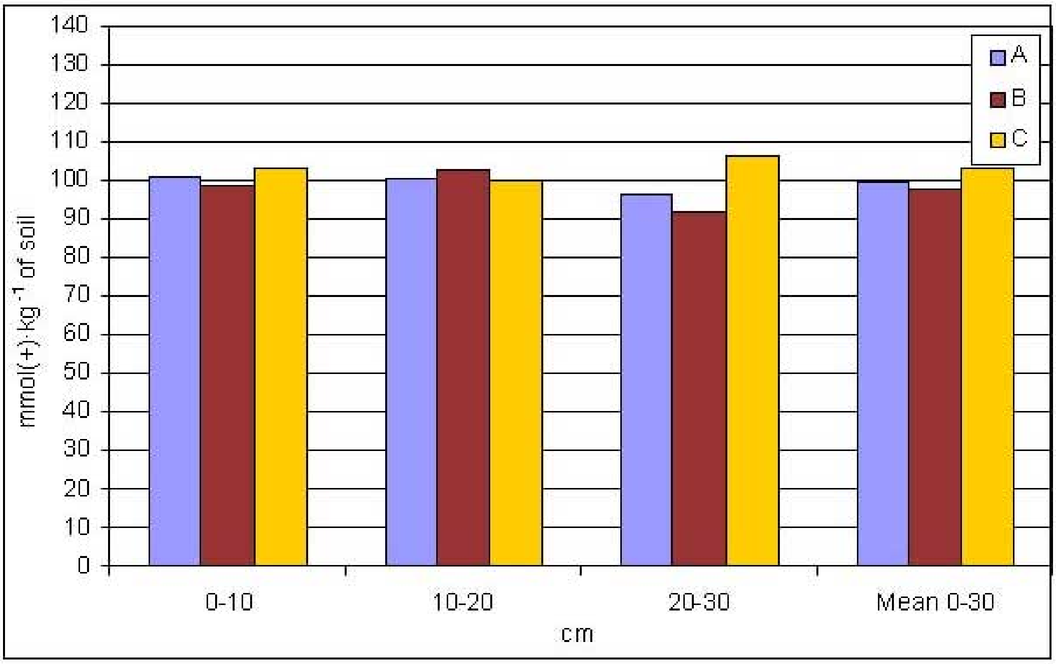
There was recorded an increase in the sum of exchangeable bases in soil exposed to direct sowing (Fig. 8), which could have been due to an increased content of organic matter in soil. Similar changes in the content of alkaline cations in simplified and ploughless cultivation soil were noted by De Maria et al. [9].

Fig. 8. Impact of soil cultivation system on sum of exchangeable bases in soil



Soil cultivation system (I) Soil profile layer (II) in cm
A – ploughing B – ploughless C - direct sowing

CONCLUSIONS

1. The ploughless soil cultivation and direct sowing were observed to enhance the accumulation of organic C, total N and available K in the upper soil profile layers.
2. Abandoning ploughing cultivation and the application of direct sowing resulted in a decreased content of exchangeable Mg in all soil profile layers.
3. The soil cultivation systems studied showed no difference in the contents of available P and exchangeable Ca in the soil layers.
4. Direct sowing over the seven years increased the sum of exchangeable bases in soil and decreased pH_{KCl}.

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