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INFLUENCE OF DIRECT SOWING IN CROP ROTATION ON SOME SOIL STRUCTURE INDICES

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A b s t r a c t. The paper presents results on the influence of four-year simplified tillage and direct sowing in the 4-year long crop rotation on some soil structure and water stability indices. The results obtained indicate a significant influence of tillage and direct sowing on the soil structure. The experiment showed that compared with traditional tillage and direct sowing, overall soil clodiness was improved and soil pulverisation was lowered. A significant increase of the mean weight diameter of aggregates was found with a simultaneous increase of water stability properties.
K e y w o r d s: soil cultivation, direct sowing, crop rotation, soil structure index.

INTRODUCTION

A great significance of aggregate soil structure for its physical, chemical and biological properties has been emphasised by many authors [2,3,6]. Proper air-water soil conditions have a great influence on the biological and chemical soil properties and in consequence, on the plant growth and yield conditions [3,6]. Maintaining optimal air-water soil conditions depends, to a great extent, on the resistance of soil aggregates to erosion processes as well as to an excessive breakdown and build-up of the soil. Water stability and aggregate size depend not only on the natural factors but also on a variety of agricultural factors, such as application of organic fertilisers [6], and tillage system [3]. They are also indicators of the quality of the soil environment [1,6]. One of the ways to improve these indices is the limitation of tillage and application of direct sowing [3,8]. The aim of the research was to estimate the influence of different plant cultivation systems on some of the soil structure indices and the water stability properties of soil aggregates by a long-term application of direct sowing in crop rotation.

MATERIALS

The field experiment run by a split-plot method in four replications was carried out in 1993-1997 in the Experimental Station of the Agricultural University of Wrocław in Swojec on a very good rye soil complex. After pre-crop harvest (winter wheat), 4 t/ha of lime and NPK-30/60/100 kg/ha was applied. Then, as scheduled (Table 1), tillage and catch crop sowing (20 kg/ha white mustard) were carried out. The catch crop was left till the following spring (treatments 1, 2, 3, 4), and sugar beets were then sown in the mulch. In the following years, a traditional cultivation method was applied in the treatment No. 1. However, in the remaining treatments, no tillage was applied and the plants were sown by direct sowing. The soil samples for establishing soil structure indices, were collected at the harvesting time from every field. After drying, the soil samples were sieved through the following mesh sizes: 0.25, 0.5, 1.0, 3.5, 7.0, 10.0 mm. On the basis of the obtained results the following indices of soil structure were calculated: B - solid figure index, and S - soil break down index (index of soil solidity) and MWD water stability index.

$$B = \frac{\text{aggregates with the diameter} > 10.0 \text{ mm (in \%)}}{\text{aggregates with the diameter} < 10.0 \text{ mm (in \%)}}$$

$$S = \frac{\text{aggregates with the diameter} < 0.25 \text{ mm (in \%)}}{\text{aggregates with the diameter} > 0.25 \text{ mm (in \%)}}$$

MWD = MWDa - MWDg; MWDa - mean weight diameter of aggregate (dry), MWDg - mean weight diameter of aggregate (wet).

The water stability index was measured in 3 replications by the Bakszejev's method (wet sieving). The percentage of each soil aggregate fraction obtained by dry sieving was taken into account. Soil compaction was established with a dynamic penetrometer at harvest in five replications in the 0-30 cm layer, every 5 cm on each plot.

RESULTS

Data concerning indices of the solid figure indicate that an application of the direct sowing system instead of conventional cultivation had a direct influence on the index of the solid figure B (Fig. 1). An exceptionally high value of this index characterised the soil after winter triticale (treatment 3) and was on average higher by 142% than the results obtained from the soil cultivated in the traditional way (treatment 1). In such a situation, also the remaining variants of the experiment indicated

Table 1. Scheme of field experiment

Stubble tillage and stubble crop	Pre-winter soil tillage	Pre-sowing tillage		Tillage		Stubble crop	Tillage		Stubble crop	
Skimming	Convent.-	Convent.-		Convent.-		White mustard	Convent.-		Convent.-	
	dung	sow.	conven.	sow.	conven.		sow.	conven.	sow.	conven.
Ripper - swirl harrow - s.c.	-	-	direct sowing	-	direct sowing	White mustard	-	direct sowing	-	direct sowing
Ripper - medium ploughing - s.c.	-	-	direct sowing	-	direct sowing	-	-	direct sowing	-	direct sowing
Swirl harrow - s.c.	-	-	direct sowing	-	direct sowing	-	-	direct sowing	-	direct sowing
Crop succession		Sugar beet		Winter wheat			Field pea		Winter triticale	
Years of crop rotation		1994		1995			1996		1997	

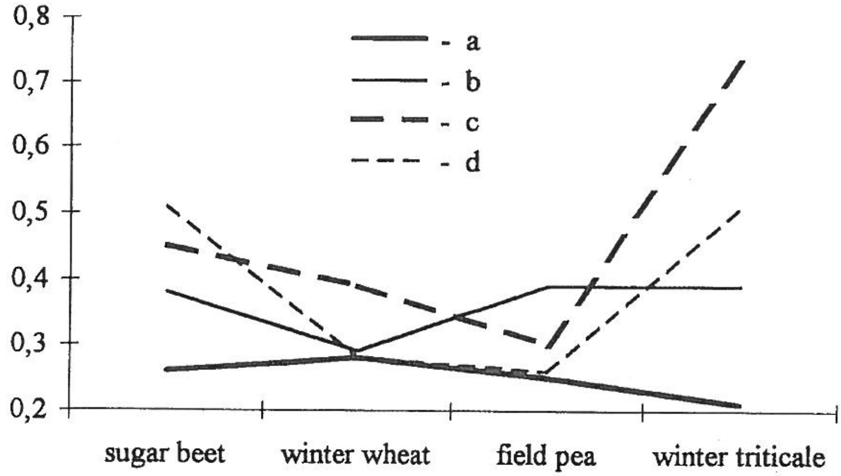

Fig. 1. The effect of cultivation system (a - conventional, b - ripper, plough 15 cm, stubble crop, c - ripper, swirl harrow, stubble crop, d - swirl harrow, stubble crop) on index of solid figure (mean 1994-1996).

significant differentiation of that index. In the remaining cases the index of the solid figure was on a similar level and oscillated between 0.3-0.5. Using a swirl harrow in stubble tillage for sugar beets (treatments 3 and 4) clearly influenced the increase of index of the solid figure in the sugar beet cultivation. However, the use of direct sowing in the field pea cultivation caused a clear decrease of the index in comparison with the remaining plants.

Another factor describing changes in the soil under the influence of direct sowing, is the index of soil pulverisation S (Fig. 2). This index clearly depended on soil cultivation. Ploughing and other agricultural practices in traditional cultivation (treatment 1) applied in subsequent years caused a constant increase of the soil pulverisation index from 0.14 to 0.26, regardless of the plant species. In the case of direct sowing, the influence of plant was more noticeable, especially in the case of cereals, particularly winter triticale, which had the highest index of soil pulverisation of up to 0.25, while field pea, wheat and sugar beet reached 0.15, 0.16, and 0.19, respectively. An important index describing soil structure is MWDa - mean weight diameter of an aggregate (Fig. 3). The analyses carried out indicated the influence of the soil structure differentiation and plant cultivation. This fact was clearly noticeable in the case of sugar beet, where mean weight diameter of an aggregate in traditional cultivation amounted to 4.46 mm and in direct sowing 2.28 mm. In the case of the remaining plants, in the subsequent years

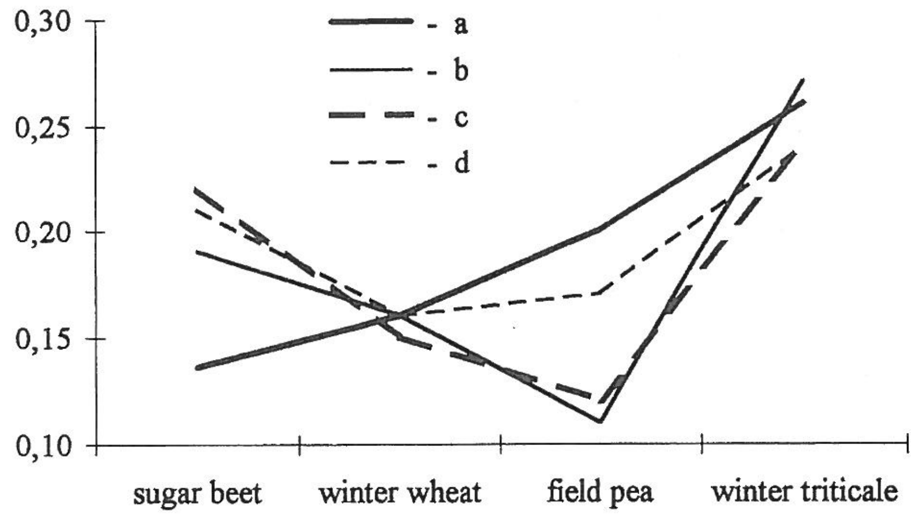

Fig. 2. The effect of cultivation system (a - conventional, b - ripper, plough 15 cm, stubble crop, c - ripper, swirl harrow, stubble crop, d - swirl harrow, stubble crop) on index of soil pulverization (mean 1994-1996).

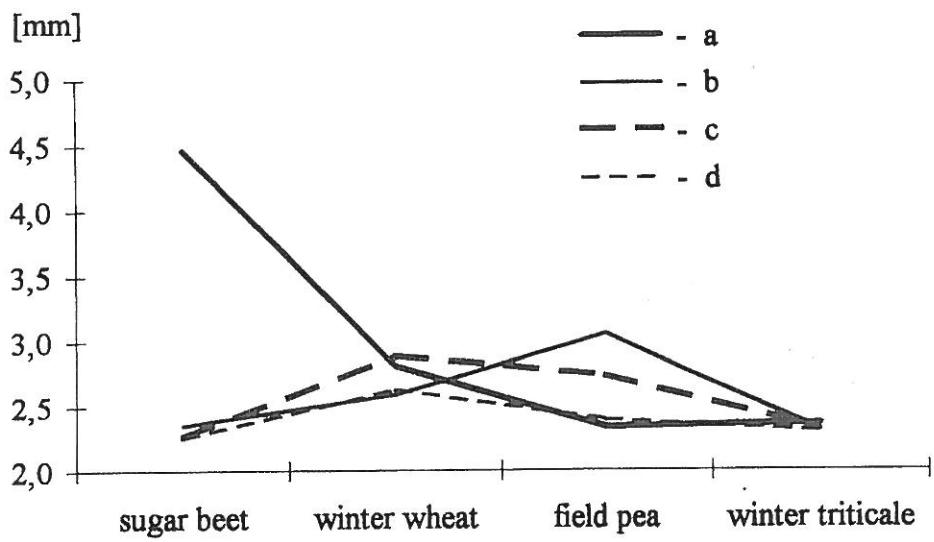

Fig. 3. The effect of cultivation system (a - conventional, b - ripper, plough 15 cm, stubble crop, c - ripper, swirl harrow, stubble crop, d - swirl harrow, stubble crop) on mean weight diameter of aggregate (mean 1994-1996).

of crop rotation, differences were decidedly smaller. Application of direct sowing in crop rotation resulted in a small increase of the mean weight diameter of aggregate from 2.28 up to 2.63 mm. One of the best indices describing soil resistance is MWD - the water stability index. The presented data (Fig. 3) indicate that both the method of soil cultivation and plant cultivation had a great influence on it. The lowest water stability index was characteristic for traditional cultivation. On the other hand, a limitation of number of ploughing treatments (treatment 2) or its complete exclusion (treatments 3 and 4) resulted in an increase of the water stability index by 12.3 and 15.1%, respectively (Fig. 4). The above means that also the cultivated plant exerted some influence. Sugar beet and field pea caused an increase of this index by 5 and 7%, respectively. On the other hand, cultivation of wheat and winter triticale retarded growth and even lowered water resistance of aggregates when compared to other crops. Results of soil compaction measurements (Fig. 5) indicate that when ploughing is excluded, the above value increases by an average of 27.7% in majority of the tested plots and plants. In the case of field pea and winter triticale these differences were significant. The plots with sugar beets were an exception as the soil texture after direct sowing was lowered there by an average of 13%, but the differences obtained were not significant. The soil from the plots with winter wheat had an exceptionally high values of texture indices in both direct sowing (on the average higher by 18.0 MPa) and traditional cultivation (on the average higher by 13.9 MPa). No traditional cultivation during stubble tillage of sugar beets (treatment 1) and application of a ripper and ploughing (treatment 2) or a ripper and a swirl harrow (treatment 3) caused an increase of the soil texture index in the subsequent years. A similar relation, was observed in the plots where no ripper was applied and only swirl harrow was used (treatment 4), except for the plots with winter wheat.

DISCUSSION

Kordas [4] and Radecki [7] emphasised the significant influence of tillage on the physical soil properties and on yield. Soil compaction mirrors the conditions of plant growth in the best way. Hence, numerous papers on direct sowing give results of soil compaction measurements. Majority of studies showed higher soil compaction with direct sowing than in traditional cultivation [4,5,7]. Also our own studies on soil compaction confirm that a simplification of soil cultivation by omitting ploughing in the whole crop rotation process as well as

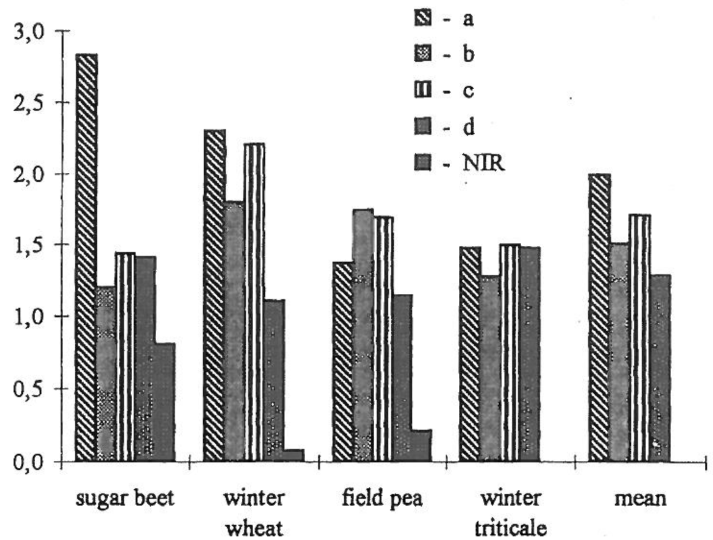

Fig. 4. The effect of cultivation system (a - conventional, b - ripper, plough 15 cm, stubble crop, c - ripper, swirl harrow, stubble crop, d - swirl harrow, stubble crop) on waterproof index (mean 1994-1996).

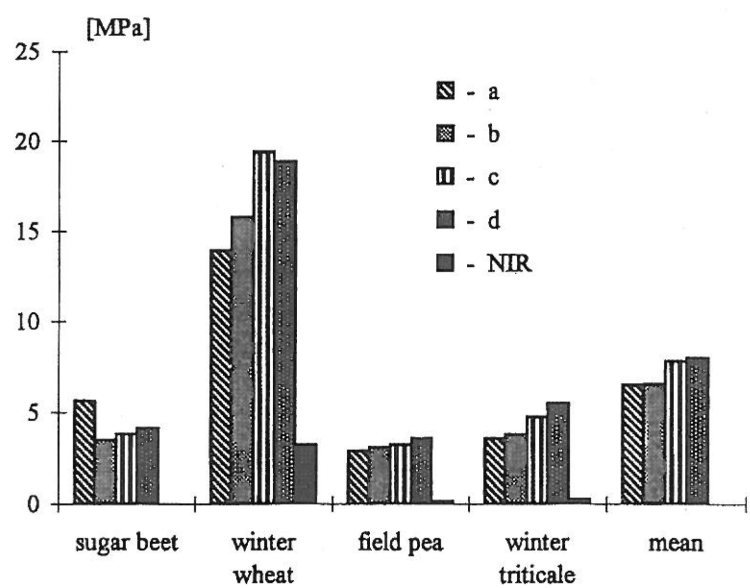

Fig. 5. The effect of cultivation system (a - conventional, b - ripper, plough 15 cm, stubble crop, c - ripper, swirl harrow, stubble crop, d - swirl harrow, stubble crop) on soil compaction (mean 1994-1996).

application of direct sowing increased soil compaction by 12.6% on the average during a four-year study period. According to many authors [2,3,6], the proper soil structure and its stability exert a positive influence on the physical soil properties. Kordas and Zimny [3] and Radecki [7] thought no tillage and formation of mulch from the stubble crop caused a general increase of aggregate diameter and stabi-lity. The data obtained confirm the above finding. A clear increase of soil solidity was observed. The influence of soil cultivation is clearly modified by the cultivated plants species. The mean weight diameter of aggregate (MWDa) and water resistance is often quoted [3,6,7] as an important indicator of soil structure quality from the agricultural point of view. An increase in the aggregate diameter and specially of its water resistance is seen as positive feature. In some studies [1,3,7], a great influence of the above properties was stressed. The above data indicate a greater importance of plants than tillage, specially in the case of mean weight diameter of aggregates. When direct sowing is applied in a 4-year period, there was an increase of this property from 2.28 to 2.63 mm. Similar relations were found in the case of the index of water tability properties. The influence of plants and soil cultivation on water resistance of aggregates was more balanced. A long-term omitting of conventional cultivation and application of direct sowing resulted in the growing increase of water resistance in the subsequent years of crop rotation. The above trends depended not only on the soil cultivation system but also on the cultivated plant. The greater importance of the root system type and leguminous plants was observed than in the case of cereals [7].

CONCLUSIONS

1. A long-term application of direct sowing causes a significant increase of soil compaction which varies according to the cultivated species.

2. Elimination of all the forms of soil loosening and application of direct sowing leads to an increase of soil solidity and decrease of soil pulverisation.

3. Aggregate mean weight diameter, as well as water resistance increase when the number of tillage practices is limited and direct sowing is applied.

4. The cultivated plant species has a significant influence on the examined soil properties.

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