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THE EFFECT OF CROP ROTATION ON THE STABILITY OF SOIL AGGREGATE

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A b s t r a c t. Aggregation of soil lessivé developed from loess and water resistance of soil aggregates were determined in the fields of grain crops rotation (without farmyard manure), vegetable rotation (manure applied every other year) and also in herbicide and grass strips in apple orchard. Different land utilization system were maintained for more than 20 years.

The most advantageous effect on soil structure expressed as the greatest contribution of water resistant aggregates and of aggregates of agricultural value was under grass strips. Different agrotechnics used in the fields of grain crop or vegetable rotations did not affect significantly the water resistance of soil aggregates.

K e y w o r d s: crop rotation, soil aggregate stability, loess soil

INTRODUCTION

Cultural practices used in agricultural production have various effect on soil structure. Well-arranged crop rotation with perennial plants, which leave abundant mass of plant residues, organic fertilization, liming and also mechanical soil cultivation practised with optimal soil moisture have beneficial influence on formation of crumby soil structure. However, we often observe considerable deviations from laboured and consolidated rules of correct agrotechnics, for example narrow specialization in farm management and soil utilization, one-crop system, simplifications in soil cultivation, high doses of mineral fertilizers and pesticides. Moreover, big power tractors and heavy harvesters used in modern agriculture compact the soil and destroy its structure [3,6].

In orchards and small fruit plantations the heavy machinery equipment pass many times the same traces during vegetation period causing soil compaction which inhibit penetration of roots to interrows [9]. Many years' maintenance of herbicide strips in the rows of trees caused significant pH diminution of arable layer and also of soil beneath arable layer in comparison with the soil in interrows [4]. It should be noted that in herbicide strips the soil is more humid and leaching of calcium and magnesium is more intensive what is causing an increase in soil acidification. This process is favoured by the high doses of nitrogen fertilization, especially when they are applied in the rows only. Therefore it can be expected that the long-term using of different agrotechnical treatments exerts an influence on soil properties.

The aim of this study was to compare the soil aggregation state and water resistance of selected aggregate fractions in different soil cultivation systems: grain crops rotation, vegetable crops rotation and in apple orchard.

MATERIAL AND METHODS

The studies on aggregation and water resistance of crumbs were conducted on soil lessivé developed from medium silty loam on marl subsoil. The soils from three following objects were analysed:

- field of grain crops rotation,
- field of vegetable crops rotation,
- apple orchard with regard to herbicide and grass strips and to ruts on passages of tractor and other machinery equipment.

The different ground utilization systems were maintained for more than 20 years.

Each year the plants grown in grain crops rotation (spring wheat, leguminous and grain plant mixture for green fodder, winter wheat, spring crops mixture, rye) were cultivated and fertilized (without farmyard manure) according to agrotechnical recommendations.

Tomatoes, root vegetables and several species of brassicas and onions were grown in the vegetable crops rotation using 30 T FYM/ha every other year and mineral nutrition suitable for each species.

The trees in apple orchard were planted in 1970 in a spacing 4 m x 3 m, using herbicide strips in rows and grass strips in interrows from the beginning of orchard cultivation. The grass strips were cut down several times during the vegetation period.

In the autumn after harvest 2 kg soil samples were collected and than dryed up to air-dry state in laboratory. The dry samples were screened through screen set with 10, 7, 5, 3, 1, 0.5 and 0.25 mm mesh diameter to obtain quantitative fraction of different size aggregats in soil. Definition of soil aggregate composition made possible classification of aggregates of agricultural value and determination of soil structure indexes: index of soil structure, index of soil silty, index of soil cloddiness [7].

The water resistance was evaluated on the aggregates with the diameter of 5-3 and 3-1 mm. Samples as 25 g of these aggregate fractions were screened wet in the Baksheev's apparatus for 12 min [8]. The aggregates which have remained on screen were flushed on filters, dryed 6 h in 105 °C and than kept in room conditions several hours to obtain air-dry state. Finally the weight of aggregates was measured. As the results of this analysis the water resistance of aggregates, which were formed as a result of decomposition of tested fraction under destructive water activity, were determined.

RESULTS

The granulated part of soil with the particles of 0.25 to 10 mm diameter was differentiated depending on tested soil layer and also on soil cultivation system (Table 1). Less content was constated in the superficial 0-0.1 m soil layer in grain and vegetable crops rotations and also in herbicide strips of apple orchard than under grass strips and in tracks of wheels on the passages of tractors. Percentage of aggregates of these fractions in the superficial soil layer was from 49.1 % in grain crops rotation to 58.9 % in vegetable crops rotation and to 58.4 % in herbicide strip. The lower horizons of these objects (0.2-0.3 m) contained more aggregates - from 70.2 % in soil of grain crops rotation to 67.9 % in soil under herbicide strip. Other distribution of aggregates was in grass strips and in tracks of wheels. In grass strips contribution of granulated fraction (0.25-10 mm) was clearly high - 78.3 % in superficial layer (0-0.1 m) and 76 % in lower layer (0.1-0.2 m).

Silt of <0.25 mm diameter contributed in superficial soil layer from 10.6 % in grain crops to 14.4 % in grass strips. Considerably less was the contribution of silt in 0.2-0.3 m layer, which contained from 9.1 % in grain crops rotation to 5.0 % in tracks of wheels.

The cloddy forms of >10 mm diameter were the most numerous in the superficial soil layer of grain crops rotation (40.3 %) and of herbicide strips (29.0 %). The smallest contribution of cloddy fraction aggregates (7.3 %) was in all tested soil layers of grass strips and especially in the superficial 0-0.1 m layer.

Table 1. Soil aggregate fractions of agricultural value

Object	Depth (m)	Silty forms <0.25 mm	Soil aggregates 0.25-10 mm	Cloddy forms > 10 mm
Grain crops	0 - 0.1	10.6	49.1	40.3
rotation	0.1 - 0.2	14.6	65.2	20.2
	0.2 - 0.3	9.1	70.2	20.7
Vegetable	0 - 0.1	14.9	58.9	26.2
rotation	0.1 - 0.2	9.8	65.8	24.4
	0.2 - 0.3	7.4	63.1	29.5
Orchard	0 - 0.1	12.6	58.4	29.0
herbicide	0.1 - 0.2	12.3	75.4	12.3
strips	0.2 - 0.3	8.9	67.9	23.2
Orchard grass	0 - 0.1	14.4	78.3	7.3
strips	0.1 - 0.2	5.6	76.0	18.4
	0.2 - 0.3	14.5	67.4	18.1
Orchard ruts	0 - 0.1	9.6	64.0	26.4
on passages	0.1 - 0.2	8.6	66.4	25.0
of tractor	0.2 - 0.3	5.0	56.4	28.6

The aggregates of 0.25-0.5 and 0.5-1 mm liameter had the smallest contribution, less han 10 % in 0.25-10 mm aggregate compoition in all tested objects (Table 2). The nost valuable in agricultural meaning ag;regates of 1-3 and 3-5 mm diameter ocurred in quantities from 14.7 % to 26.8 %. ;maller quantities were found in superficial oil layers of grain crops rotation (15.3 % nd 14.7 %) and of vegetable crops rotation oth in 0-0.1 m layer (16.3 % and 15.1 %) nd in 0.1-0.2 m layer (17.9 % and 14.9 %). 'he aggregates of discussed fraction >(1-3 nd 3-5 mm) occurred in greater quantities in ıe soil of herbicide and grass strips.

The smallest index of soil cloddiness equal to 0.96 was determined in the superficial soil layer of grain crops rotation and the biggest index was determined in the soil under grass strips - 3.60 for 0-0.1 m layer and 3.16 for 0.1-0.2 m layer. Index of soil clodiness was equal to 0.67 for superficial soil layer of grain crops rotation and diminished to 0.35 under vegetable crops and to 0.40 under herbicide strips and it achieved the smallest value - 0.08 under grass strips (Table 3).

The results illustrating water resistance of soil aggregates of 1-3 mm fraction are shown in Table 4. The most resistant to the

able 2. Frequency factor of soil aggregate fractions 0.25 - 10 mm

)bject	Depth (m)	Frequency factor (%) 0.25 - 0.5 (mm)	0.5 - 1	1 - 3	3 - 5	5 - 7	7 - 10
;rain crops	0 - 0.1	6.1	5.7	15.3	14.7	13.0	45.2
rotation	0.1 - 0.2	7.5	6.4	24.2	21.0	14.5	26.4
	0.2 - 0.3	4.6	3.7	20.2	15.0	14.2	42.3
'egetable	0 - 0.1	6.3	5.4	16.3	15.1	12.6	44.3
rotation	0.1 - 0.2	5.0	4.3	17.9	14.9	12.5	45.4
	0.2 - 0.3	5.2	4.5	15.2	16.0	12.2	46.9
ırchard	0 - 0.1	8.6	7.4	20.5	17.3	14.7	31.5
herbicide	0.1 - 0.2	8.4	8.5	26.8	18.0	12.9	25.4
;trips	0.2 - 0.3	5.2	5.2	18.4	16.3	16.0	38.9
'rchard	0 - 0.1	6.3	6.3	21.6	19.5	12.8	33.5
;rass	0.1 - 0.2	2.9	3.0	18.3	14.9	11.6	49.3
;trips	0.2 - 0.3	6.8	6.5	20.6	19.5	16.5	30.1
rchard ruts	0 - 0.1	5.0	4.5	19.7	19.5	14.1	37.2
)n passages	0.1 - 0.2	5.3	5.3	18.2	19.1	14.3	37.8
)f tractor	0.2 - 0.3	4.6	5.0	17.0	15.4	14.7	43.3

Table 3. Indexes of soil structure evaluation

Object	Depth (m)	Index of soil		
		structure	silty	cloddiness
Grain crops rotation	0 - 0.1	0.96	8.43	0.67
	0.1 - 0.2	1.87	5.84	0.25
	0.2 - 0.3	2.35	9.98	0.26
Vegetable rotation	0 - 0.1	1.43	5.71	0.35
	0.1 - 0.2	1.92	9.20	0.32
	0.2 - 0.3	1.71	12.51	0.41
Orchard herbicide strips	0 - 0.1	1.40	6.94	0.40
	0.1 - 0.2	3.06	7.13	0.14
	0.2 - 0.3	2.11	10.23	0.30
Orchard grass strips	0 - 0.1	3.60	5.94	0.08
	0.1 - 0.2	3.16	16.85	0.22
	0.2 - 0.3	2.06	5.89	0.22
Orchard ruts on passages of tractor	0 - 0.1	1.77	9.41	0.36
	0.1 - 0.2	1.97	10.62	0.33
	0.2 - 0.3	1.67	17.00	0.46

Table 4. Decomposition of water resistant aggregates formed from 1-3 mm fraction under the destructive water activity

Object	Depth (m)	Water resistance (%)			
		<0.25	0.25 - 0.5	0.5 - 1.0	1.0-3.0
		(mm)			
Grain crops rotation	0 - 0.1	10.2	10.4	1.0	78.4
	0.1 - 0.2	3.0	6.2	0.6	90.2
	0.2 - 0.3	26.2	31.0	26.8	16.0
Vegetable rotation	0 - 0.1	8.0	9.4	3.4	79.2
	0.1 - 0.2	5.1	6.3	2.4	86.2
	0.2 - 0.3	14.5	14.6	5.9	65.0
Orchard herbicide strips	0 - 0.1	7.4	5.2	1.3	86.1
	0.1 - 0.2	12.0	10.3	0.7	77.0
	0.2 - 0.3	16.7	10.0	6.3	67.0
Orchard grass strips	0 - 0.1	2.4	0.3	0.2	97.1
	0.1 - 0.2	4.8	1.5	0.5	93.2
	0.2 - 0.3	7.1	4.5	1.6	86.8
Orchard ruts on passages of tractor	0 - 0.1	2.6	0.7	0.3	96.4
	0.1 - 0.2	4.8	2.6	0.8	91.8
	0.2 - 0.3	10.6	10.8	2.8	75.8

destructive water action were aggregates of this fraction separated from soil under grass strips - 97.1 % of aggregates from 0-0.1 m layer were not destroyed and from 0.1-0.2 m layer 93.2 %. Similar water resistance characterized soil aggregates from tracks of wheels. As the result of decomposition of tested aggregate fraction under water action only very small quantities of other dimension fractions were found in disrupted residues of soil aggregates from grass strips. The aggregates of 1-3 mm fraction separated from the soil of grain and vegetable crops rotations, especially in the superficial soil layer, were less stable. Percentage of undistroyed granules was equal to 78.4 % in grain crops rotation and to 79.2 % in vegetable crops rotation. During the destructive water action 10.2 % of soil aggregates from grain crops field and 8 % from vegetable crops field passed to silt fraction (<0.25 mm).

Very high water resistance characterized the aggregates of 5-3 mm fraction in the soil from grass strips and from tracks of wheels. In 0-0.1 m soil layer in both objects the water resistance of granules was over 93 %.

Table 5. Decomposition of water resistant aggregates formed from 3-5 mm fraction under the destructive water activity (in %)

Object	Depth (m)	Water resistance (%)				
		<0.25	0.25 - 0.5	0.5 - 1.0	1.0 - 3.0	3.0 - 5.0
		(mm)				
Grain crops rotation	0 - 0.1	18.5	28.6	48.8	2.9	1.3
	0.1 - 0.2	22.4	25.4	32.6	16.8	2.8
	0.2 - 0.3	57.4	37.1	3.2	1.4	0.9
Vegetable rotation	0 - 0.1	13.0	37.1	44.2	3.6	2.0
	0.1 - 0.2	19.0	7.0	69.3	2.3	2.4
	0.2 - 0.3	28.7	12.0	57.0	1.4	0.8
Orchard herbicide strips	0 - 0.1	32.8	19.2	12.4	6.0	29.6
	0.1 - 0.2	24.8	14.5	52.3	5.6	2.8
	0.2 - 0.3	14.6	3.7	78.0	2.5	1.2
Orchard grass strips	0 - 0.1	3.3	1.3	0.7	1.0	93.7
	0.1 - 0.2	9.1	5.4	3.5	3.6	78.4
	0.2 - 0.3	32.6	10.6	34.4	14.2	8.2
Orchard ruts on passages of tractor	0 - 0.1	3.2	1.9	0.9	0.9	93.2
	0.1 - 0.2	11.9	8.6	8.8	10.6	60.1
	0.2 - 0.3	43.4	42.6	7.4	4.6	2.0

About 3 % of aggregates only passed to silt fraction. Distinctly law water resistance equal 1.3 to 2.8 % characterized the soil aggregates of grain and vegetable crops rotations. Much more aggregates with dimensions less than 1 mm were formed after decomposition of granules of 5-3 mm fraction than of 3-1 mm fraction. In grain crops rotation, the 1-0.5 mm aggregates made 48.9 % and 44.2 % in vegetable crops rotation. Silt fraction made 18.5 % and 12.0 % in the soils of grain and vegetable crops rotations, respectively (Table 5).

In the lower horizon of soil profile soil aggregates had less water resistance in all objects tested. The 5-3 mm fraction made from 0.8 to 2.0 % only in 0.2-0.3 m horizon.

DISCUSSION

The results of soil aggregation analysis showed a great differentiation resulting from various soil utilization. The most advantageous structural soil state was found under grass strips. High contribution of 5-1 mm aggregates of agricultural value under grass strips in related to a protective influence of green growth of grass against erosion and destructive action of atmospheric factors. The soil particles condense in the root growth zone forming a better structure. The obtained results show as well that the grass strips are acting also as a protection against heavy machinery equipment passing many times the same tracks of wheels during cultural operations. This results probably due to well developed coronal root system of grasses. The results of other experiments also proved that the grass strips ameliorate the soil structure in orchards and that their influence is reaching to the depth of 45-50 cm [2]. The comparison of soil structure state in herbicide strips and in fields of crops rotation indicates little differences among soil utilization systems. It was noted that a thin protective mulch layer was formed on the soil surface from dropped leaves and from part of cut grasses which were thrown off from interrows during mowing. This way of soil mulching was alredy mentioned in other studies [5].

The relatively small contribution of soil aggregates of agronomic value (5-1 mm) in vegetable crops rotation can be due to a number of cultural soil operations carried out before vegetable growing.

The differences in water resistance among soil aggregates in grain and vegetable crop rotations, were not significant. Much better effects were expected in the vegetable crops rotation as a result of regular applying of farm manure which was not utilized in grain crops rotation. Explanation of these relations can be found in the papers of other authors [1]. They have proved that the influence of organic matter on soil aggregation appears mainly as a formation of the persistent water aggregates at that time only when the total humus content achives a high level, what occurs in the chernozems and black earths.

CONCLUSIONS

1. Comparison of succession of many years' utilization of soil lessivé, developed from loess, in grain crops rotation, vegetable rotation and in apple orchard indicates that the most profitable effect on soil structure, expressed as the greatest contribution of water resistant aggregates and of aggregates of agricultural value, was under grass strips in orchard.

2. Different agrotechnics used in the fields of grain crops or vegetable rotations did not affect significantly the water resistance of soil aggregates of 5-1 mm fraction.

3. In apple orchard herbicide strips the thin mulch layer formed from dropped leaves and cut grass protects soil surface against destructive influence of atmospheric effects.

4. Grass strips utilized in orchard interrows protects the soil against destructive effect of heavy machinery equipment which is moving the same ruts during cultivation works in vegetation period.

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