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INDICATORS OF SOIL AGGREGATION AND THEIR CHANGES IN CONSERVATION TILLAGE FOR ONION

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Abstract. Soil structure depends on several factors, among which are farming system and soil tillage. The state of aggregation determines the water-air relations in soil and influences the thermal conductivity, porosity and density of soil, availability of nutrients, as well as biological processes, etc. In the field experiment with conservation tillage for onion we studied the influence of various methods of conventional tillage, no tillage, and disking as well as the biomass of the inter-harvest plants on the aggregation and structure of soil. *Secale cereale* and *Vicia sativa* cultivated as inter-crop cover plants favourably influenced the soil aggregation. It was expressed by greater share of valuable soil aggregates (ø 1–5 mm) and better soil structure index in comparison with conventional tillage (CT), without plant mulches. The leaving of mulches from cover plants on the surface of the soil from fall to spring and direct sowing on onion without tillage (NT) decreased soil cloddiness index. The positive influence of plant mulches on soil structure was mainly observed after wintering and in the initial period of onion vegetation. The changes in indicators of soil aggregation under the influence of mulching and simplifications of the soil tillage system for vegetables were predominantly recorded in the soil arable layer of 0–20 cm.

Key words: soil structure index, soil pulverization index, soil cloddiness index, MWD

INTRODUCTION

Soil structure is one of the basic factors of soil fertility, an important determinant of growth yield of cultivable plants. The state of soil aggregation depends on several factors, among which are farming system and soil tillage. Conservation tillage, in which the biomass of the inter-crop cover plants sown at the end of summer and left on the field until the spring is partly mixed with soil and partly remains on the surface of the soil, all the while the cultivation measures are shallower and eventually ceased, links the pro-ecological activities with economic effects. Sowing into the mulch that is mixed with the soil, or directly into the frozen or desiccated plant mass eliminates the need for applying the most energy-consuming measures, that is pre-winter tillage. It allows the ceasing of the

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spring soil cultivation or limiting it only to a shallow tillage [Kuś 1995, Wyland et al. 1996]. This is in accordance with the recommendations of organic farming, in which the traditional tillage with a mouldboard plough is discouraged, and a simplified tillage is advised.

During tillage the top layer of soil, inhabited by aerobic organisms, is placed in the bottom of the furrow, while the anaerobic organisms get to the surface. Thus, both groups of organisms die due to unfavorable conditions. After some time the biotic conditions characteristic to a given soil may restore [Carter 1986, Kuś 1995]. The soil structure is also worsened [Pagliai et al. 2004, Madari et al. 2005]. The shallow mixing of the harvest residues and organic fertilizers with soil favours the improvement of surface soil structure stability, prevents formation of soil crust, facilitates water filtration, and makes the soil less susceptible to compaction [Konopiński et al. 2001, Kęsik et al. 2007]. The plant biomass introduced into soil forms an optimal environment for development of soil micro-organisms [Dąbek-Szreniawska 2004]. The covering of the soil surface with organic matter in the form of mulch, positively influences soil structure, decreases sealing, prevents crusting, improves infiltration and water retention, limits water evaporation from soil, decreases losses of nitrogen during winter season, prevents water and air erosion, limits weed growth, positively influences biological activity of soil, etc. [Höppner et al. 1995, Wyland et al. 1996, Nyakatawa et al. 2001, Parker et al. 2002, Ding et al. 2006].

The aim of this work, which is a fragment of complex studies, was evaluation of the changes of soil structure under the influence of mulching cover plants and varied pre-winter and spring pre-sowing tillage measures applied for onion and comparison of different ways of describing the soil aggregation.

MATERIALS AND METHODS

The field experiment was conducted in years 2003–2006 in Felin Experimental Station of the University of Life Sciences in Lublin (Poland, 51°23'N, 22°56'E), on a grey-brown podzolic soil derived from loess (Orthic Luvisol), laying on chalk marl, with a grain size distribution typical for medium silt loam. The humus content in the soil studied ranged from 1.64 to 2.25%, and the reaction varied from 4.87 to 6.09 pH. In the cultivated layer of soil (0–20 cm) the following were determined (mean values): 11.59–12.79 mg P, 15.02–20.69 mg K and 8.68–10.43 mg Mg 100 g^{-1} of soil [Błażewicz-Woźniak et al. 2008].

The experimental plant was garden onion (*Allium cepa* var. *cepa* Helm.) of the Wolska variety. The experiment was set up according to the method of random sub-blocks in four replications. The following factors were included: mulching cover plants (spring rye, *Secale cereale,* and spring vetch, *Vicia sativa*); various soil tillage measures: no tillage (NT), disking during the spring (SD), and disking before the winter (WD). The cover plants: spring rye (R) in the amount of 150 $kg \cdot ha^{-1}$ and spring vetch (V) – 140 $kg \cdot ha^{-1}$, were sown in the 3rd decade of July 2003 and in the 1st decade of August 2004 and 2005, in the years preceding the onion cultivation. The produced biomass was mixed with soil according to the set scheme (in the fall or spring). During the winter the inter-crop plants left on the field froze, and in the spring the soil was covered with mulch. The tillage measures applied for onion are shown in table 1. The control treatment was conventional tillage with mouldboard plough without mulching plants (CT).

Table 1. The sequence of measures in the soil tillage systems applied in the experiment conducted
Tabela 1. Kolejność wykonywanych zabiegów w systemach uprawy roli w przeprowadzonym doświadczeniu

CT – traditional mouldboard ploughing without cover plants CT – tradycyjna uprawa pługiem lemieszowym bez roślin okrywowych	SF: 1+2+2+5; K: 2+7+8+2+9+2
NT – no tillage; cultivation with cover plants NT – uprawa zerowa; z siewem okrywowych roślin poplonowych	SF: 3+2+4+2: K: 10
SD – spring mixing of biomass with soil (spring disking); cultivation with cover plants SD – wymieszaniem zielonej masy z glebą wiosną; uprawa z siewem okrywowych roślin poplonowych	SF: 3+2+4+2; K: 6+2+9+2
WD – mixing of biomass with soil before winter (pre-winter disking); cultivation with cover plants WD – wymieszaniem zielonej masy z glebą wiosną; uprawa z siewem okrywowych roślin poplonowych	SF: 3+2+4+2+6; K: 6+2+9+2

S – summer – lato, F – fall – jesień K – spring – wiosna
1 – skimming (6–8 cm) – podorywka
2 – harrowing – bronowanie
3 – medium ploughing (15–20 cm) – orka średnia
4 – cover plant sowing – siew roślin okrywowych
5 – deep ploughing (25–30 cm) – orka głęboka
6 – disking – talerzowanie
7 – scarifying – kultywatorowanie
8 – rolling – wałowanie
9 – onion traditional sowing – tradycyjny siew cebuli
10 – onion direct sowing – bezpośredni siew cebuli

Soil samples of approximately 2 kg from the layer of 0–20 and 20–40 cm were collected for soil structure analysis in four periods: after wintering before beginning of spring tillage, at the beginning of plant growth, during full vegetation, and in the period of onion harvest. In the lab the soil was air-dried, and 500 g samples were sifted through a set of sifters with the following mesh diameters: 0.25; 0.5; 1; 3; 5; 7; 10 mm. Classification of aggregates was conducted by separating the fraction soil aggregates with diameter of 1–5 mm. The evaluation indicators of soil structure and soil aggregation were determined [Walczak and Witkowska 1976]:

1) Mean weight diameter (MWD) [Kemper and Rosenau 1986]

$$\mathrm{MWD} = \sum_{i=1}^{n} x_i w_i \tag{1}$$

where w_i is the proportion of each aggregate class in relation to the whole, x_i the mean diameter of the classes (mm)

2) soil structure index (according to Wiershynin and Revut):

$$\mathrm{W} = \frac{\%\ \text{of aggregates with}\ \phi\ 1\text{-}10\ \text{mm}}{\%\ \text{of aggregates with}\ \phi > 10\ \text{mm and}\ \phi < 0.25\ \text{mm}} \tag{2}$$

3) soil pulverization index (according to Czudnowski):

$$S = \frac{\%\ \text{of aggregates with}\ \phi > 0.25\ \text{mm}}{\%\ \text{of aggregates with}\ \phi < 0.25\ \text{mm}} \quad (3)$$

4) Index of soil cloddiness (according to Revut)

$$B = \frac{\%\ \text{of aggregates with}\ \phi > 10\ \text{mm}}{\%\ \text{of aggregates with}\ \phi < 10\ \text{mm}} \quad (4)$$

The obtained results were statistically elaborated using the variance analysis. The significance of differences was determined using the Tukey's test with P = 0.05. For selected characteristics the correlation analysis was conducted.

RESULTS AND DISCUSSION

Impact of inter-crop plants on the status of soil aggregation in arable layer (0-20 cm) is reflected in the MWD values, which in the plots under conservation tillage were lower than under traditional tillage (CT) (tab. 2). It was particularly noted at the beginning of onion vegetation, when in the no tillage treatment (NT) with mulch from spring vetch (V) MWD was 5.28 mm, with rye mulch (R) – 5.57 mm, while in the traditional tillage (CT) – 6.21 mm. The highest MWD value in both analyzed soil layers was noted after winter before conducting field works and the lowest during the full onion vegetation. During that time the differences between CT and NT in the MWD values were not so significant. Similar results were presented by Hermawan and Bomke [1997].

MWD of the arable layer (5.82 mm) was lower than the 20–40 cm layer (6.16 mm). After conventional tillage (CT) the MWD value in the 20–40 cm layer was lower (5.85 mm) than after conservation tillage (on average 6.21). Madari et al. [2005] noted that CT had significantly lower aggregation indices compared to NT, but only in the 0–5 cm layer. Higher value of MWD of the soil under NT in comparison with CT was noted also by Pinheiro et al. [2004] at depth of 0–10 cm and Franzluebbers [2002] at all soil depths. Positive influence of NT was evidenced by 50% contents of aggregates ≥ 2 mm, which was greater than under CT (30%) at a depth of 0–5 cm [Pinheiro et al. 2004]. According to Schaller and Stockinger [1953] a single size fraction such as the > 2 mm or > 1 mm can be satisfactorily used to express soil aggregation. They found correlation between the MWD and the percent of aggregates > 2 mm, > 1 mm, and > 0.25 mm. Pinheiro et al. [2004] assume that the proportion of aggregates with diameter ≥ 2 mm appeared to be a suitable indicator of the influence of tillage systems on aggregation.

The soil structure index (W) in the analyzed experiment was on average 0.64 in the arable layer and 0.71 in the 20–40 cm layer (tab. 2). It was the most positive after the wintering under the mulching plants (NT) and it was on average 0.72 in the 0–20 cm layer in comparison with traditional tillage (CT) without mulching plants (0.54). No tillage (NT) with plant mulch improved the structure index of the arable layer of soil, although with the passage of time in the plant vegetation period the W index decreased, which points to a diminishing influence of plant mulching, which gradually decomposed. Similar results were obtained by Barral et al. [2007]. The soil structure index showed reverse values in the plots where the biomass of inter-crop plants was mixed with soil before-winter disking (WD). The soil structure index in the arable layer of these plots (WD) after winter was close to control (CT) and it was 0.56, but along with the passage of time the state of soil aggregation in this combination improved, which was indicated by the increase on the structure index to 0.71 during the harvest of onion. It can be assumed that the increase of the share of the soil aggregates with diameter of 0.25–10 mm under the influence of mulch plants occurred due to decrease of the share of clay and clod fractions, which was indicated by the increase of the soil structure index [Yang et al. 2007].

The trends of changes in soil aggregation are evidenced also by the indicators of soil pulverization (S) and soil cloddiness (B) (tab. 3). The degree of pulverization is lower when the values of indicator S are higher [Walczak and Witkowska 1976]. The low value of index S (12.9) and the highest one of index B (0.92) in the arable layer of the control plot (CT) in comparison with the plots under various conservation tillage measures with mulching plants, indicates structure-forming action of these plants and their contribution to soil aggregate stability [Braunack and Dexter 1989, Yang et al. 2007]. Weill et al. [1989] noted lower pulverization of soil in case of direct sowing (NT) as compared to plough tillage (CT). Positive influence of no-tillage (NT) in comparison with plough tillage (CT) on decrease of soil dispersion is noted in many studies [Cambardella and Elliott 1993, Błażewicz-Woźniak 2002, Lenart 2004]. In the experiment the highest value of index S in topsoil was noticed after winter on plots with rye mulch (NT+R and SD+R). Soil covered with plant mulches was protected from pulverization.

Spring rye and spring vetch, as mulching plants, decreased the soil cloddiness index (B), in comparison with traditional tillage (CT) without mulching plants (tab. 3). Also, this indicates protective character of plant mulch. Soil covered with plant mulch did not undergo compaction or crust formation, as did bare soil [Nyakatawa et al. 2001]. Hevia et al. [2007] noted that aggregates formed in NT were 13 to 16% more stable than CT aggregates. Also, incorporation into the soil of plant biomass stabilized its structure [Reganold et al. 1987, Schjonning et al. 1994, Pagliai et al. 2004], decreasing the indicators of cloddiness in the arable layer of soil.

The most favorable physical characteristics show the soils with dominance of fractions with diameter of 1–10 mm, and in particular ø 1–5 mm. The content of aggregates with ø 1–10 mm proves a good soil tilth. Soil in which aggregates of 1-10 mm in diameter dominate, create optimal conditions for growth of plant root system [Dexter 2004, Lipiec et al. 2007] and their yielding [Bouma et al. 1999, Lipiec and Håkansson 2000]. From the agricultural point of view, soil aggregates with diameter of 1–5 mm are most valuable because their presence in soil assures the best air-water conditions. Aggregates with ø 1–5 mm are characterized by the greater total porosity, and aggregates with diameter of 0.25–0.5 mm – the lowest [Witkowska-Walczak et al. 2004]. Clods with diameter of < 0.5 mm do not guarantee appropriate soil aeration and decrease non-capillary porosity. Paluszek [2004] proved that increase of contribution of fractions 0.25–10 mm and in particular of fractions 5–10 mm and 1–5 mm under the influence of "hydrogel" caused substantial decrease in soil density, total porosity, and content of air pores. This was confirmed by other works [Walczak and Witkowska 1976, Witkowska-

Table 2. Influence of tillage and cover crops on MWD and soil structure index (W) in the soil layers 0–20 and 20–40 cm (mean for 2004–2006)
Tabela 2. Wpływ uprawy i roślin okrywowych na MWD i wskaźnik strukturalności gleby (W) w warstwach gleby 0–20 i 20–40 cm (średnia 2004–2006)

	Treatment Kombinacja	Meanweight Diameter (MWD) in mm Średnia ważona średnica w mm					Soil structure index (W) Wskaźnik strukturalności gleby (W)				
		after winter po zimie	begining of vegetation początek wegetacji	full of vegetation pełnia wegetacji	at harvest w czasie zbioru	mean średnia	after winter po zimie	begining of vegetation początek wegetacji	full of vegetation pełnia wegetacji	at harvest w czasie zbioru	mean średnia
0–20 cm	CT	6.28	6.21	5.70	5.87	6.02	0.54	0.56	0.62	0.69	0.60
	NT+R	6.01	5.57	5.65	5.51	5.69	0.72	0.73	0.65	0.69	0.70
	SD+R	6.00	5.83	5.97	6.37	6.04	0.73	0.65	0.62	0.55	0.64
	WD+R	6.25	6.20	5.50	5.73	5.92	0.52	0.56	0.64	0.64	0.59
	Mean (R)	6.08	5.87	5.71	5.87	5.88	0.66	0.65	0.64	0.63	0.64
	NT+V	5.84	5.28	5.44	4.90	5.36	0.72	0.60	0.58	0.80	0.68
	SD+V	5.96	5.75	5.92	6.12	5.94	0.70	0.57	0.60	0.52	0.60
	WD+V	5.94	5.88	5.40	5.78	5.75	0.59	0.61	0.71	0.78	0.67
	mean (V)	5.91	5.64	5.58	5.60	5.68	0.67	0.59	0.63	0.70	0.65
	mean – średnia	6.04	5.82	5.65	5.76	5.82	0.65	0.61	0.63	0.67	0.64
20–40 cm	CT	6.01	5.19	5.76	6.44	5.85	0.69	0.84	0.76	0.54	0.71
	NT+R	6.64	6.56	6.06	5.93	6.30	0.67	0.70	0.74	0.66	0.69
	SD+R	6.98	6.62	5.97	6.72	6.57	0.58	0.62	0.75	0.61	0.64
	WD+R	6.15	6.05	5.57	6.16	5.98	0.62	0.76	0.91	0.74	0.76
	Mean (R)	6.59	6.41	5.86	6.27	6.28	0.62	0.69	0.80	0.67	0.70
	NT+V	6.48	5.78	6.12	5.04	5.86	0.73	0.70	0.67	0.74	0.71
	SD+V	6.72	5.05	6.36	6.12	6.06	0.58	0.87	0.97	0.74	0.79
	WD+V	6.43	6.87	6.13	6.62	6.51	0.73	0.59	0.74	0.69	0.69
	mean (V)	6.54	5.90	6.20	5.93	6.14	0.68	0.72	0.79	0.72	0.73
	mean – średnia	6.49	6.02	5.99	6.15	6.16	0.66	0.73	0.79	0.67	0.71
$LSD_{0.05}$ for: $NIR_{0,05}$ dla:	treatments – kombinacji					0.52					ns
	depts – głębokości					0.17					0.04
	dates – terminów					0.32					ns

CT – conventional tillage (control): pre-winter ploughing + spring pre-sowing measures; NT – no-tillage; SD – spring disking + spring pre-sowing measures; WD – pre-winter disking + spring pre-sowing measures; Cover crops: R – spring rye *(Secale cereale)*, V – vetch *(Vicia sativa)*; ns – not significant;
CT – uprawa tradycyjna (kontrola): orka przedzimowa + uprawki doprawiające; NT – uprawa zerowa; SD – talerzowanie wiosną + uprawki doprawiające; WD – talerzowanie przed zimą + uprawki doprawiające; Rośliny okrywowe: R – żyto jare *(Secale cereale)*, V – wyka siewna *(Vicia sativa)*; ns – różnice nieistotne statystycznie

Table 3. Influence of tillage and cover crops on soil pulverization index (S) and soil cloddiness index (B) in the soil layers 0–20 and 20–40 cm (mean for 2004–2006)

Tabela 3. Wpływ uprawy i roślin okrywowych na wskaźnik rozpylenia (S) i wskaźnik zbrylenia gleby (B) w warstwach gleby 0–20 i 20–40 cm (średnia 2004–2006)

	Treatment Kombinacja	Soil pulverization index (S) Wskaźnik rozpylenia (S)					Soil cloddiness index (B) Wskaźnik zbrylenia (B)				
		after winter po zimie	begining of vegetation początek wegetacji	full of vegetation pełnia wegetacji	at harvest w czasie zbioru	mean średnia	after winter po zimie	begining of vegetation początek wegetacji	full of vegetation pełnia wegetacji	at harvest w czasie zbioru	mean średnia
0–20 cm	CT	13.1	15.6	11.4	11.6	12.9	1.02	1.08	0.78	0.79	0.92
	NT+R	16.5	10.8	11.4	10.3	12.3	0.79	0.69	0.75	0.66	0.72
	SD+R	17.0	12.8	12.0	16.8	14.7	0.78	0.75	0.84	1.03	0.85
	WD+R	13.3	12.7	8.8	10.1	11.2	1.00	0.96	0.67	0.73	0.84
	Mean (R)	15.6	12.1	10.7	12.4	12.7	0.86	0.80	0.75	0.81	0.80
	NT+V	13.7	7.1	8.3	6.4	8.9	0.73	0.62	0.68	0.48	0.63
	SD+V	13.3	11.2	10.2	10.2	11.2	0.77	0.79	0.97	0.99	0.88
	WD+V	13.2	16.2	9.1	13.2	12.9	0.81	0.80	0.63	0.75	0.75
	mean (V)	13.4	11.5	9.2	9.9	11.0	0.77	0.74	0.76	0.74	0.75
	mean – średnia	14.3	12.3	10.2	11.2	12.0	0.84	0.81	0.76	0.78	0.80
20–40 cm	CT	15.9	13.2	20.4	20.7	17.6	0.84	0.55	0.70	1.08	0.79
	NT+R	23.3	22.7	22.4	18.4	21.7	1.00	0.96	0.82	0.79	0.89
	SD+R	23.4	21.2	21.7	19.4	21.4	1.22	1.09	0.83	1.04	1.05
	WD+R	18.1	15.5	17.7	15.4	16.7	0.96	0.83	0.66	0.81	0.82
	Mean (R)	21.6	19.8	20.6	17.7	19.9	1.06	0.96	0.77	0.88	0.92
	NT+V	23.5	13.6	19.9	8.1	16.3	0.96	0.72	0.89	0.53	0.77
	SD+V	20.6	14.3	19.9	17.2	18.0	1.10	0.50	0.70	0.79	0.77
	WD+V	24.2	24.6	20.2	27.5	24.1	0.89	1.11	0.79	0.97	0.94
	Mean (V)	22.8	17.5	20.0	17.6	19.5	0.98	0.78	0.79	0.76	0.83
	mean – średnia	21.3	17.9	20.3	18.1	19.4	1.00	0.82	0.77	0.86	0.86
LSD $_{0.05}$ for: NIR $_{0,05}$ dla:	treatments – kombinacji					3.6					0.11
	depts – głębokości					2.3					ns
	dates – terminów					1.2					ns

*Denotations as in table 2 – Oznaczenia jak w tabeli 2

-Walczak et al. 2004, Shein 2004, Lipiec et al. 2007]. Aggregates with diameter of < 5 mm create optimal conditions for sprouting of plants [Braunack and Dexter 1989, Braunack 1995, Guérif et al. 2001].

In our experiment, the amount of aggregates of fraction 1–5 mm in the arable layer of soil in the spring was greater in the plots with no tillage (NT) used together with plant mulch (on average 23.5%) than in the plots with traditional cultivation (CT) (19.6%) (tab. 4). Similar results were obtained using mulches from *Vicia sativa*, *Phacelia tanacetifolia*, *Avena sativa* and *Sinapis alba* [Błażewicz-Woźniak et al. 2001]. This proves the protective role of plant mulch covering the field in the winter. In seven-year studies of Calkins and Swanson [1998] soil aggregation was substantially better and the density lower under the mulch from *Lotus corniculatus*, with *Secale cereale* and after a mixture of grasses (*Lolium perenne*, *Festuca rubra*) in comparison with herbicide fallow. In the 20–40 cm soil layer the amount of aggregates of fractions 1–5 mm was higher than in the arable layer, however, the influence of plant bedding on the amount of the most valuable soil aggregates (ø 1–5 mm) was not noticed. This can be explained with the mixing of clay particles deeper into the soil profile as well as the process of leaching present in these soils.

Table 4. Influence of tillage and cover crops on percentage of soil aggregates with diameter of 1–5 mm in the soil layers 0–20 and 20–40 cm (mean for 2004–2006)
Tabela 4. Wpływ uprawy i roślin okrywowych na udział agregatów glebowych o średnicy 1–5 mm w warstwach gleby 0–20 i 20–40 cm (średnia 2004–2006)

	Treatment Kombinacja	Aggregates 1–5 mm – Agregaty o średnicy 1–5 mm				
		after winter po zimie	begining of vegetation początek wegetacji	full of vegetation pełnia wegetacji	at harvest w czasie zbioru	mean średnia
0–20 cm	CT	19.6	18.9	20.6	21.1	20.1
	NT+R	23.2	22.3	21.4	21.7	22.2
	SD+R	23.2	20.8	20.3	19.1	20.9
	WD+R	19.0	19.5	20.9	21.7	20.3
	mean (R)	21.8	20.9	20.9	20.8	21.1
	NT+V	23.8	20.3	19.6	23.2	21.7
	SD+V	22.9	19.7	19.0	18.6	20.1
	WD+V	20.1	20.9	22.1	23.6	21.7
	mean (V)	22.3	20.3	20.2	21.8	21.2
	mean – średnia	21.7	20.3	20.6	21.3	21.0
20–40 cm	CT	23.1	24.5	22.7	18.5	22.2
	NT+R	22.6	21.6	23.8	21.7	22.4
	SD+R	20.4	20.1	23.1	19.9	20.9
	WD+R	21.9	23.6	26.2	23.1	23.7
	mean (R)	21.6	21.8	24.4	21.6	22.3
	NT+V	23.7	23.1	21.1	23.4	22.8
	SD+V	21.5	23.1	19.8	22.6	21.8
	WD+V	22.8	19.8	23.2	21.4	21.8
	mean (V)	22.7	22.0	21.4	22.5	22.1
	mean – średnia	22.3	22.3	22.8	21.5	22.2
LSD $_{0.05}$ for: NIR $_{0,05}$ dla:		treatments – kombinacji				ns
		depts – głębokości				0.8
		dates – terminów				ns

* Denotations as in table 2 – Oznaczenia jak w tabeli 2

Table 5. Correlation between all studied indicators of soil aggregation
Tabela 5. Współczynniki korelacji między badanymi wskaźnikami agregacji gleby

Indicators of soil aggregation Wskaźniki agregacji gleby		MWD	W	S	B	1–5 mm
0–20 cm	MWD średnia ważona średnica	-	-0.55**	0.77**	0.92**	-0.43*
	structure index (W) wskaźnik strukturalności (W)	- 0.55**	-	-0.09	-0.72**	0.93**
	pulverization index (S) wskaźnik rozpylenia (S)	0.77**	-0.09	-	0.57**	0.04
	index of cloddiness (B) wskaźnik zbrylenia (B)	0.92**	-0.72**	0.57**	-	-0.67**
	aggregates 1–5 mm agregaty o średnicy 1–5 mm	- 0.43*	0.93**	0.04	-0.67**	-
20–40 cm	MWD średnia ważona średnica	-	-0.61**	0.79**	0.93**	-0.65**
	structure index (W) wskaźnik strukturalności (W)	- 0.61**	-	-0.34	-0.81**	0.58**
	pulverization index (S) wskaźnik rozpylenia (S)	0.79**	-0.34	-	0.70**	-0.40*
	index of cloddiness (B) wskaźnik zbrylenia (B)	0.93**	-0.81**	0.70**	-	-0.65**
	aggregates 1–5 mm agregaty o średnicy 1–5 mm	- 0.65**	0.58**	-0.40*	-0.65**	-

Mixing of mulch matter with soil during the process of pre-winter and spring pre-sowing measures (SD or WD) did not indicate such a clear influence on the contribution of aggregates of fraction 1–5 mm, as surface mulching (NT) (tab. 4). In the spring, after the disking before winter (WD), the average value of aggregates with ø 1–5 mm in the arable layer was the same as in the control (CT) and it was 19.6%. However, in the harvest period the share of the aggregates of this fraction increased on average 22.7% in the 0–20 cm layer and it was slightly higher in the control plot (CT) (21.1%). It can be assumed that it was caused by the degradation of the biomass introduced into the soil occurring during the onion vegetation and the structure-forming activity of the products of its degradation as well as a heightened activity of soil microorganisms. Many authors note increase of biological activity of soil under conservation tillage [Epperlein and Martinez-Vilela 2001, Motta et al. 2001, Kabir and Koide 2002]. Soil organisms participating in the degradation of organic matter and in the formation of humus affect the state of soil aggregation as well as aggregate stability [Lynch and Bragg 1985, Dąbek-Szreniawska 2004, Zaller and Köpke 2004]. In studies by Höflich et al. [1999] the conservation tillage stimulated the development of bacteria in rhizosphere of winter wheat, rye, winter oats and maize. It was noted in our experiment that regardless of the treatment method of spring vetch mulch, fungi colonies dominated in the soil samples taken in the middle of June, while the total number of bacteria was the highest in plots where the rye mulch was mixed with the soil by spring disking (SD) [Pięta and Kęsik 2007]. In studies of Patkowska [1998] the introduction of after-crop of white mustard and rye into soy cultivation increased the population of bacteria and fungi. Significantly lower proportion of > 6 mm dry aggregates and higher proportion of 2–6 and 0.25–2 mm in cover cropped soil after spring tillage as compared with the bare control found Hermawan and Bomke [1997].

Many authors indicate that physical disturbance of soil structure has resulted in decreasing aggregate stability paralleled by a loss of organic matter [Beare et al. 1994, Six et al. 2000]. High correlation between mulch rate and soil mean weight diameter (MWD) has been reported by Mulumba and Lal [2008]. In the analyzed experiment no significant correlation was noted only between the soil structure index (W) and soil pulverization index (S) (tab. 5). Based on statistical analysis was a significant correlation between the other studied indicators of soil aggregation found. MWD of soil aggregates was additionally correlated with the cloddiness index (B) and the pulverization index (S). The negative dependence was noted between MWD, percentage of aggregates size class 1–5 mm, and the soil structure index (W). Positive correlation between MWD and greater number of large aggregates was confirmed by Castro Filho et al. [2002].

CONCLUSIONS

1. Spring rye and spring vetch cultivated in inter-crop periods as cover plants positively influenced the soil aggregation, expressed by the higher value of soil structure index, lower indices of cloddiness and pulverization and higher share of the most valuable soil aggregates (ø 1–5 mm) in comparison with traditional tillage (CT) without plan mulch.
2. Leaving the cover plant mulch on the soil surface (NT) positively influenced the share of soil macro-aggregates with ø 1–5 mm as well as decreased index of cloddiness in comparison with the treatments of pre-winter tillage (WD) and spring pre-sowing (SD).
3. Positive influence of plant mulch was noted in particular after wintering and in the beginning of plant vegetation and it disappeared with the passage of time.

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WSKAŹNIKI AGREGACJI GLEBY I ICH ZMIANY W UPRAWIE KONSERWUJĄCEJ POD CEBULĄ

Streszczenie. Struktura gleby zależy od szeregu czynników, wśród których ważną rolę odgrywają system gospodarowania i sposób uprawy roli. Stan agregacji determinuje stosunki wodno-powietrzne w glebie, wpływa na przewodnictwo cieplne, porowatość i gęstość gleby, dostępność składników pokarmowych, a także procesy biologiczne i in. W doświadczeniu polowym z konserwującą uprawą roli pod cebulę badano wpływ zróżnicowanych sposobów uprawy przedzimowej i przedsiewnej (tradycyjna uprawa płużna, talerzowanie, uprawa zerowa) oraz biomasy roślin międzyplonowych na stan agregacji i strukturę gleby. *Secale cereale* i *Vicia sativa* uprawiane w międzyplonach jako rośliny okrywowe korzystnie wpłynęły na agregację gleby, wyrażającą się większym udziałem najcenniejszych rolniczo agregatów glebowych (ø 1–5 mm) oraz wskaźnikiem strukturalności gleby w porównaniu z uprawą tradycyjną (CT) bez mulczów roślinnych. Pozostawienie mulczu z roślin okrywowych na powierzchni roli od jesieni do wiosny i siew bezpośredni cebuli w glebę nieuprawnioną (NT) spowodowało obniżenie wskaźnika zbrylenia gleby. Dodatni wpływ mulczów roślinnych zaznaczył się przede wszystkim po przezimowaniu i w początkowym okresie wegetacji cebuli. Zmiany agregacji gleby pod wpływem mulczujących roślin okrywowych i uproszczeń całokształtu uprawy roli pod warzywa odnotowano przede wszystkim w ornej warstwie gleby 0–20 cm.

Słowa kluczowe: wskaźnik strukturalności gleby, wskaźnik rozpylenia, wskaźnik zbrylenia gleby, MWD

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