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Influence of the EM-A preparation on the structure properties in various mineral soils

Abstract: The aim of the study was the assessment of the influence of EM-A preparation on the properties of soil structure of medium and fine texture. Soil material for the incubation experiment was collected from humus arable horizons of four mineral soils: *Gleyic Chernozem* (soils A, B and D) and *Haplic Fluvisol* (soil C). The experiment was conducted in containers of 2000 cm³, where soil material of about 3 kg was placed and three doses of EM-A were added. After a 12-month incubation, aggregates of 1 cm³ were cut out. Their basic physical properties (density, porosity) were determined, as well as the parameters which characterize the structure: dynamic and static water resistance, secondary aggregation after dynamic and static water resistance and capillary water capacity. The effect of additions of EM-A was not significant for majority of analyzed soil properties.

Key words: EM-A preparation, secondary aggregation, minimal and maximal water capacity.

INTRODUCTION

Texture is a key property that affects the parameters of soil structure. High content of colloids, characteristic to heavy soils, determines the development of permanent monolithical structure, which is not favorable from the agricultural point of view. What is especially harmful, is drying up the soils, as such conditions determine the appearance of solids (aggregates) which cannot be broken. Furthermore, when moisture is too low, such soils dry very fast, they contract and clefts which appear, break plants' roots. As a result of these processes, density grows and porosity decreases, whereas strong moisture of heavy soils results in excessive adhesiveness and lower permeability. Optimal arable moisture of these soils is very limited and therefore, the period for cultivation is short (Świątochowski et al. 1996). Colloquially, these soils are called "minute soils". The alternation of wetting – drying cycles may lead to the fall of soil microorganisms' population which may affect structure's composition negatively (Fierer et al. 2003). Nowadays, agriculture gives possibilities for the improvement of soil structure with the application of various structure forming additives. When observing development tendencies in agrotechnics, one may notice the search for alternatives for traditional agriculture such as ecological methods of soil cultivation (Kaczmarek et al. 2007). "EM" technology is believed to be such a chance (Zajaczkowski and Sowiński 2001, Higa 2003). The influence of naturally existing microor-

ganisms on soil structure has been a subject of a lot of research (Roldan et al. 1994, Schlecht-Pietsch et al. 1994). Their authors concentrated mainly on soils of coarse texture. Less interest is devoted to the influence of soil biocenoses on heavy soils (Neergaard-Bearden and Petersen 2000). The aim of this study was to reveal what impact the implementation of EM-A preparation has on the structure forming parameters on the soils of medium and fine texture.

MATERIALS AND METHODS

Soil material used for an incubation experiment was collected in May 2014 from a humus arable horizon of four mineral soils: black earths (*Gleyic Chernozem*) (soils A, B and D) and alluvial soil (*Haplic Fluvisol*) (soil C) (IUSS Working Group 2015, PSC 2011). The experiment was conducted in containers of 2000 cm³, where soil material of about 3 kg was placed, after elimination of stones and roots. Altogether, 16 containers were prepared. In case of each of the four soils, apart from control probes (A0, B0, C0, D0), an addition of EM-A cultures (EM-A preparation) was used in three doses (EM I: A1,B1,C1,D1, EM II: A2,B2,C2,D2, EM III: A3,B3,C3,D3). The EM-A preparation consists of lactic bacteria (*Lactobacillus casei*, *Streptococcus lactis*), photosynthetic bacteria (*Rhodopseudomonas palustris*, *Rhodobacter spae*), yeast (*Saccharomyces albus*, *Candida utilis*), actinomycetes (*Streptomyces albus*, *S. griseus*) and molds (*Aspergillus oryzae*, *Mucor hiemalis*) (Kacz-

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marek et al. 2008). In conversion to field conditions, the amount reflected spurting of active form concentration of 50 l (EM I), 100 l (EM II) and 300 l (EM III) of solution per hectare. EM1 preparation was produced by *Greenland Technologia EM* company (EM-A = 1 liter of EM1 concentrate + 1 liter of molasses + 20 liters of water). Incubation lasted 12 months. During the investigation following parameters were measured: soil moisture, soil temperature and air humidity. The mean soil temperature was: 20,5°C (soil A); 20,8°C (soil B); 20,7°C (soil C) and 20,4°C (soil D). The moisture of selected soils was held on a level close to field water capacity. Its average values were as follows: 24.2% v/v (soil A); 26.5%v/v (soil B); 32,1%v/v (soil C); 20,8% v/v (soil D). The average air humidity was 52%. After the incubation, cylindrical soil samples of 1 cm³ volume (diameter 11.29 mm, height 10 mm.) – further called aggregates – were cut out. Parameters which characterize soil structure were determined on air dry soil aggregates. The special methods developed in the Department of Soil Science and Land Protection at Poznań University of Life Sciences were used (Rzasa and Owczarzak 1983). The following parameters were determined: static and dynamic water resistance, secondary aggregation, maximal and minimal capillary water capacity. Specific gravity, soil bulk density and total porosity of aggregates were determined by methods widely used in soil science (Van Reeuwijk 2002). The content of total carbon was determined with a Makro Elemental Analyzer (Vario Max CNS). The statistical analysis was conducted with Duncan's test – separately for each soil – at the statistical significance of $\alpha = 0.05$. All the analysis were performed in five replications, results presented in tables represent mean values.

RESULTS AND DISCUSSION

The investigated soils showed the following texture (FAO 1977): loam (soil A), silty loam (soil B), clay (soil C) and sandy loam (soil D) (Table 1). Total carbon content (Ct) did not differ from typical values in soils of similar origin and texture (Rzasa et al. 1999). The lowest content of Ct was found in the aggregates collected from soil D, whereas the highest from soil B. The former ranged from 12 to 12.1 g·kg⁻¹, and the latter from 25.4 to 28.9 (Table 1). Application of EM-A did not have a significant impact on the content of Ct. Similar results, including combinations with the addition of various forms of organic matter, were also obtained by Schenck zu Schweinsberg-Mickan and Müller (2009) as well as by van Vliet et al. (2006). An important indicator of soils microbiological activity and,

TABLE 1. Selected physical properties of modelled aggregates

Combination	Texture acc to: FAO 1977	Total carbon Ct [g·kg ⁻¹]	Particle density [Mg·m ⁻³]	Bulk density [Mg·m ⁻³]	Total porosity [m ³ ·m ⁻³]
A0	L	23.6a	2.62a	1.34a	0.488a
A1	L	23.8a	2.62a	1.32a	0.496a
A2	L	23.7a	2.62a	1.35a	0.485a
A3	L	22.9a	2.62a	1.33a	0.492a
B0	SiL	27.2a	2.61a	1.20a	0.540b
B1	SiL	28.9a	2.61a	1.28b	0.510a
B2	SiL	25.4a	2.61a	1.24b	0.525a
B3	SiL	26.7a	2.61a	1.25b	0.521a
C0	C	21.9a	2.63a	1.34a	0.490a
C1	C	22.2a	2.63a	1.36a	0.483a
C2	C	22.9a	2.63a	1.37a	0.479a
C3	C	22.1a	2.63a	1.35a	0.487a
D0	SL	11.9a	2.64a	1.50ab	0.432a
D1	SL	12.1a	2.63a	1.46a	0.445b
D2	SL	11.2a	2.63a	1.52b	0.422a
D3	SL	11.7a	2.63a	1.53b	0.418a

Mean values with the same letter do not differ significantly (see Material and Methods).

indirectly, of organic matter mineralization, is a respiration activity of the soil. When analyzing its dynamics, Mayer et al. (2010) did not notice any stimulating influence of EM-A on soil respiration process. However, there are publications which point out a decrease of organic matter after application of EM (Valarini et al. 2003, Zydlik and Zydlik 2008, Tołoczko et al. 2009). Tołoczko et al. (2009) did calculations according to which spurting an arable field with 2×100 l (two times a year) EM-A/ha might lead to the loss of 7 tones of organic matter. The same authors claim that organic fertilization is necessary to avoid the negative effect of the EM use in the field. On the other hand, some authors inform about a reverse process, i.e. the increase of organic matter after application of EM (Ismail 2013). Probably, the key factor which determines further processes in the organic matter after the application of EM-A preparation is its quality composition and, what follows, easiness of dissolution. Climatic conditions may also have an impact on the organic matter changes. The addition of EM-A did not influence the specific gravity that ranged from 2.61 to 2.64 Mg·m⁻³ (Table 1). Usually (except of soil B) the same soil reaction after the implementation of the EM-A preparation was observed when bulk density and total porosity of aggregates were concerned (Table 1). No EM-A impact on these traits was observed. The highest bulk density and the lowest total porosity, respectively, 1.53 Mg·m⁻³ and 0.418 m³·m⁻³ were noticed in the aggregates from combination "D3", whereas the lowest bulk density and the highest porosity, respectively, 1.20 Mg·m⁻³ and 0.540 m³·m⁻³ – in the

aggregates from „B0” combination. Similar results were obtained by Ismail (2013). Variability of both properties in combinations from the same soil was very minor, usually statistically insignificant, independent from EM-A dose (Table 1).

Resistance to dynamic and static water action, as well as, most importantly, the state of secondary aggregation after the destruction of primary aggregation, are crucial traits of mineral soils (Rzasa and Owczarzak 2004). Destructive water action is connected with the energy of raindrops (dynamic action) or recurring processes of wetting and drying (static action). Both types of destructive actions often happen at the same time e.g. during heavy rain (Owczarzak 2002). Resistance to dynamic water action was between 5.08 (D3) and $38.67 \text{ J} \cdot 10^{-2}$ (B1) (Table 2), whereas to static actions – between 138 (D2 – black earths; sandy loam) and 14400 s (A – black earths, loam and B black earths; silty loam) combinations (Table 3). In the case of static water action, aggregates underwent only partial destruction in all “A” and “B” combinations. The results showed that the application of EM-A did not have a significant impact on water resistance of aggregates (Table 2 and 3). It is proved by minimal differences and randomness of the dissolution of these traits within combinations in one soil. However, different than presented in the paper conclusions were drawn by Mrugalska et al. (2009) and Feeney et al. (2006). The influence of soil microorganisms on structure stability was also the subject of research by Cosentino et al. (2006). The authors noticed a clear relationship

between the content of labile form of organic matter (which among all contains organisms’ biomass) and stability of aggregates. Nevertheless, these authors did not apply additional doses of microorganisms, yet only observed the impact of the addition of straw on microbiological activity and stability of aggregates. Resistance to both static and dynamic water actions does not determine soil’s structure forming abilities (Rzasa and Owczarzak 2004). Yet sometimes, aggregates which show lower water resistance, having been dissolved, offer much more favorable quantity and quality dissolution of secondary aggregates (the state of secondary aggregation) (Rzasa and Owczarzak 2004). The state of secondary aggregation (percentage content of aggregation $>0.25 \text{ mm}$) in different soil variants after dynamic water resistance ranged between 55.59–57.02% – soil A, 56.16–58.40% – soil B, 55.38–59.77% – soil C and 22.34 – 25.56% – soil D (Table 2). Secondary aggregation after static water action was very similar: 54.69–58.70% – soil A, 56.62–59.70% – soil B, 51.67–55.60% – soil C, 29.30–32.51% – soil D (Table 3). The results show usually insignificant, little from a practical point of view, an increase in the number of secondary aggregates. The most favorable secondary aggregation was usually observed in combinations with the highest dose of EM-A. Positive influence of effective microorganisms on the state of secondary aggregation after dynamic as well as static water action, was however observed by other authors (i.e., Mrugalska et al. 2009). According to Rzasa and Owczarzak (2004), what is important,

TABLE 2. Dynamic water resistance of the modelled aggregates, and secondary aggregation after dynamic water action

Combination	Dynamic water resistance [J·10 ⁻²]	Secondary aggregation after dynamic water action [%]						
		Aggregate fractions [mm]						Sum of the aggregates >0.25 mm [%]
		>7	7–5	5–3	3–1	1–0.5	0.5–0.25	
A0	6.98a	0.00a	0.00a	4.07c	14.78c	20.08a	16.66a	55.59a
A1	7.13a	0.00a	0.00a	4.92c	11.59a	20.85a	18.97b	56.33a
A2	6.64a	0.00a	0.00a	2.01a	13.64b	21.85b	19.52b	57.02a
A3	6.53a	0.00a	0.00a	3.38b	12.58b	21.27b	19.48b	56.71a
B0	36.54a	0.00a	3.40b	11.70a	14.46b	17.31b	9.22a	56.16a
B1	38.67b	0.00a	4.28b	10.73a	11.70a	19.02c	10.96b	56.69a
B2	34.41a	0.00a	2.19a	14.70c	14.26b	15.71a	10.62b	57.51a
B3	33.64a	0.00a	5.92c	12.97b	14.24b	15.68a	9.59a	58.40b
C0	24.48a	0.00a	0.00a	4.74a	18.99a	20.24a	11.41a	55.38a
C1	23.94a	0.00a	0.00a	5.34b	19.04ab	22.05a	11.69a	58.12b
C2	22.19a	0.00a	0.00a	4.86a	19.01a	21.21a	10.66a	55.74a
C3	21.32a	0.00a	0.00a	5.26b	18.44a	23.38b	12.69b	59.77c
D0	6.61a	0.00a	0.00a	0.00a	1.86a	7.90a	12.58a	22.34a
D1	5.59a	0.00a	0.00a	0.00a	1.78a	8.10a	13.49b	23.37a
D2	5.12a	0.00a	0.00a	0.00a	2.04a	7.77a	13.09b	22.90a
D3	5.08a	0.00a	0.00a	0.00a	1.93a	9.25b	14.38c	25.56b

Mean values with the same letter do not differ significantly (see Material and Methods).

TABLE 3. Static water resistance of the modelled aggregates and secondary aggregation after static water action

Combination	Static water resistance [s]	Secondary aggregation after static water action [%]						
		Aggregate fractions [mm]						Sum of the aggregates >0.25mm [%]
		>7	7–5	5–3	3–1	1–0.5	0.5–0.25	
A0	14400*a	0.00a	1.38a	4.04c	18.02b	19.84a	11.41a	54.69a
A1	14400*a	0.00a	1.30a	2.84b	16.58a	18.57a	16.17c	55.46a
A2	14400*a	0.00a	1.45a	2.70b	17.30a	20.58b	14.48b	56.51a
A3	14400*a	0.00a	1.32a	1.65a	16.77a	24.92c	14.04b	58.70b
B0	14400*a	0.00a	3.23b	13.32a	15.11b	15.61a	9.35a	56.62a
B1	14400*a	0.00a	3.39b	12.60a	15.69b	15.64a	9.88a	57.20a
B2	14400*a	0.00a	2.38a	15.56b	15.34b	15.74a	8.65a	57.67a
B3	14400*a	0.00a	3.57b	14.64b	13.55a	19.01b	8.93a	59.70b
C0	837a	0.00a	0.00a	0.00a	25.41a	18.88a	7.38a	51.67a
C1	910b	0.00a	0.00a	0.00a	24.47a	19.09a	8.96a	52.52a
C2	827a	0.00a	0.00a	0.00a	25.91a	19.56a	10.13b	55.60b
C3	818a	0.00a	0.00a	0.00a	26.56a	19.25a	7.72a	53.53b
D0	167b	0.00a	0.00a	0.00a	1.57a	14.64a	13.09a	29.30a
D1	178b	0.00a	0.00a	0.00a	1.95a	14.43a	13.51a	29.89a
D2	138a	0.00a	0.00a	0.00a	2.44b	14.11a	13.97a	30.52a
D3	142a	0.00a	0.00a	0.00a	1.91a	15.06a	15.54b	32.51b

*Aggregates were only partially destroyed. Mean values with the same letter do not differ significantly (see Material and Methods).

is not only a total number of secondary aggregates, but also the character of their disaggregation, i.e. percentage amount of various fractions. As a result of dynamic water action, primary aggregates disintegrated in fraction of aggregates of: 5–3 mm, 3–1 mm, 1–0.5 mm, 0.5–0.25 mm. Secondary aggregates of 7–5 mm rarely appeared, and there were no aggregates bigger than 7 mm. In case of soils A, B and C, the contribution of the aggregates of 1–0.5 mm was the largest, whereas in soil D – fraction of 0.5–0.25 mm was dominant (Table 2). Distribution of secondary aggregation after static water action was similar. Among secondary aggregates, fraction of 1–0.5 mm was usually dominant. Secondary aggregates of 5–3 mm and 7–5 mm rarely appeared, and there were no aggregates bigger than 7 mm (Table 3). Application of EM-A usually did not have a significant impact on the above-mentioned properties. A full analysis of the influence of EM-A preparation on the structure cannot omit their water properties and, most importantly – their minimal and maximal capillary water capacity. The effect of EM-A solution on these traits was also studied by Mrugalska et al. (2009). Minimal capillary water capacity ranged between 40.01% v (combination D1) – 50.84% v (combination B2) (Table 4). Maximal capillary water capacity was higher by about 3–17% v. It was also noticed that it exceeded total primary porosity by 1–11% v. It means that the collected aggregates boosted their capacity. Such a phenomenon was observed by, among others, Mrugalska et al. (2009) and Gajewski et al. (2013). A similar, triaxial

swelling of aggregates was described by Rzaşa and Owczarzak (2004). No positive effect of EM-A on the presented traits was observed. Slight variability of those parameters was statistically insignificant. However, a minor increase on capillary water capacities as a result of EM application was observed by Valarini et al. (2003). Mrugalska et al. (2009) got similar conclusions. The authors found a significant improvement of V_{kmin} and V_{kmax} .

TABLE 4. Minimum (V_{kmin}) and maximum (V_{kmax}) capillary water capacity

Combination	Capillary capacity [%v]	
	V_{kmin}	V_{kmax}
A0	43.57a	55.77a
A1	42.56a	58.43b
A2	42.01a	59.45b
A3	44.12a	58.15b
B0	50.12a	59.27b
B1	49.49a	57.14a
B2	50.84a	57.36a
B3	48.66a	58.90b
C0	46.57a	57.86a
C1	45.43a	57.54a
C2	46.34a	56.29a
C3	44.93a	57.58a
D0	41.12a	44.23a
D1	40.01a	46.02b
D2	41.22a	44.50a
D3	40.98a	44.49a

Mean values with the same letter do not differ significantly (see Material and Methods).

Most of the presented results oppose the information about a positive influence of EM-A on the state of the structure. The opposite opinion show Khaliq et al. (2006) and Valarini et al. (2003). Some authors make attempts to find out the reasons for inefficiency of microbial biopreparates (van Veen et al. 1997). They suggest that one of the basic problems which appear at the trial of implanting the soil with microorganisms which are new and not known for the ecosystem is the resistance to implanting artificial microorganisms. Pare et al. (1999) claims that the applied microorganisms cannot stand the competition of so called natural microbiocenose. Some authors (Córdor Golec et al. 2007) pay attention to the fact that the amount of the EM applied into the soil is considerably lower than the number of natural microbiocenose and the disruption of ecological balance as a result of the application of the solution – very short-term. The same authors suggest that the effect of EM application may be much more visible in soils of lower content of microorganisms, e.g. in tropical soils. It is also claimed by Mayer et al. (2010). It is definitely worth to ask: what influence can the quantity and quality of organic matter have on the applied microorganisms? What will be the reaction of soil to simultaneous application of EM-A and addition of organic matter? Would it cause a different reaction of soil? Advantages of simultaneous EM-A and organic matter addition was noticed by Khaliq et al. (2006); studies have been also carried out by Gajewski et al. (2011) and Kaczmarek et al. (2012). Their results, however, did not bring a clear answer as the effect of EM activity depended strongly on the type of the added organic matter.

SUMMARY

Presented results tackled mainly a very important soil-forming factor, i.e. microorganisms. A trial has been undertaken in order to assess the influence of an added selected “portion” of microorganisms on the total carbon content and the state of mineral soils structure. The results showed that the application of EM-A preparation usually did not have a significant impact on the analyzed properties and parameters. It is difficult to determine the reason for the lack of positive action of the solution’s application. Perhaps, effective microorganisms encountered a strong negative ecosystem. Also, it is highly possible that their number, even in high doses (from an agrotechnical point of view) was too low to cause any changes in the natural biocenosis.

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Wpływ preparatu EM-A na właściwości struktury różnych gleb mineralnych

Streszczenie: Celem pracy była ocena wpływu preparatu EM-A na właściwości struktury gleb o średnim i ciężkim uziarnieniu. Materiał glebowy wykorzystany do założenia doświadczenia inkubacyjnego pobrano z poziomów orno-próchnicznych czterech gleb mineralnych. Były to: czarne ziemie typowe (Gleyic Chernozem) (gleby A,B i D) oraz mada właściwa (Haplic Fluvisol) (gleba C). Doświadczenie przeprowadzono w pojemnikach o objętości 2000 cm³, w których umieszczono materiał glebowy o masie około 3 kg, a następnie dodano trzy dawki roztworu EM-A. Po 12-miesięcznej inkubacji, wycięto modele agregatów o objętości 1 cm³. Oznaczono dla nich podstawowe właściwości fizyczne (gęstość, porowatość) oraz parametry charakteryzujące strukturę takie, jak: dynamiczną i statyczną wodoodporność, agregację wtórną po dynamicznym i statycznym działaniu wody, pojemność kapilarną agregatów. W przypadku większości analizowanych cech wpływ preparatu EM-A był nieistotny.

Słowa kluczowe: preparat EM-A, agregacja wtórna, minimalna i maksymalna pojemność wodna.