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CHANGES OF SOME SELECTED SOIL PROPERTIES INCUBATED WITH THE ADDITION OF AGAR, STARCH AND EFFECTIVE MICROORGANISMS

ZMIANY WYBRANYCH WŁAŚCIWOŚCI GLEBY INKUBOWANEJ Z DODATKIEM AGARU, SKROBI I EFEKTYWNYCH MIKROORGANIZMÓW

Abstract: From among increasing numbers of various ecological solutions which are applied in traditional farming, considerable usefulness of the Effective Microorganism (EM) technology is frequently indicated. This preparation is believed to exhibit a wide spectrum of activities both in plant as well as in animal production. It has been demonstrated that after soil application of the discussed preparation, mineralisation and humification processes of organic compounds are accelerated. Possible changes in soil chemical properties which could occur following the application of this conditioner continue to remain debatable.

In the light of the above, investigations were undertaken with the aim to determine the impact of EM on selected physicochemical and chemical soil properties. The above tasks were realised with the assistance of an incubation experiment employing Phaeozems inoculated with EM to which increasing doses of agar or starch were added.

The obtained data revealed that the application of EM with polysaccharides can exert different effects on the examined soil properties. No statistically significant influence was observed with regards to the majority of the examined physicochemical properties. Quantitative changes of macro- and microelements depended on the type of the applied polysaccharide and its dose.

Keywords: effective microorganisms, agar, starch, physicochemical and chemical soil properties

Contemporary agriculture is looking for cheap but, at the same time, effective and environmentally-friendly methods of enhancing soil fertility and increasing yields of crop plants. That is why agricultural practice is getting increasingly interested in natural, biological preparations such as *Effective Microorganism* (EM). It is a composition of over 80 genetically unchanged microorganisms in which bacteria (photosynthetic and lactic acid), yeasts, actinomycetes and fermenting fungi dominate.

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According to Higa [1], the mastermind behind this microbiological mixture as well as Sheng et al [2] and Woodwad [3], such selection of microorganisms in practice guarantees its high and advantageous impact on the environment. With respect to soil, the argument is to improve soil fertility and health condition. This finds expression in the intensified enzymatic and biological soil activity as well as in favourable changes in its chemical and physicochemical properties. The EM impact manifests itself in a faster rate of mineralisation-humification transformations of organic matter which frequently result in increased quantities of organic carbon [4, 5].

Many experiments confirming a positive influence of EM on soils and plants were carried out in such countries as: Pakistan, Indonesia, Philippines, Thailand, China. However, the reliability of these results is frequently questioned due to the short duration of these trials as well as their local nature [6]. However, despite serious doubts, EM preparations continue to gain in popularity not only in Japan and the USA where they find many supporters but also in Europe, including Poland [7]. It is clear from the review of literature [7] on the subject that the main focus of attention of Polish researchers appears to concentrate on the determination of the influence of EM on the health and yields of crop plants. Much less attention is paid to the assessment of EM impact on soil physicochemical and chemical properties.

In order to elucidate this problem, experiments were undertaken the aim of which was to carry out investigations on changes of selected soil properties which took place following the soil incubation with EM-A preparation and two polysaccharides intended to enhance the effectiveness of microorganisms introduced into the soil.

Material and methods

The assumed research objective was realised on the basis of soil samples derived from an incubation experiment carried out for the period of 5 months in controlled conditions of temperature (± 22 °C) and air humidity (± 60 %). In the performed experiments Phaeozems was used which was sprayed with the EM-A preparation at a rate corresponding to 100 dm^3 per hectare. Since no changes were observed in soil properties before and after the treatment with the EM-A preparation, the study presents results referring only to the soil incubated with EM treating it as a control combination. The soil which was sprayed with EM-A was supplemented with three doses of agar (A) and starch (S) corresponding to 100 (dose 1), 200 (dose 2) and 1000 kg (dose 3) per hectare. Therefore, the experimental design comprised the following combinations:

K1 – Phaeozems incubated with EM-A preparation;
K2 – Phaeozems incubated with EM-A preparation and with agar at dose 1;
K3 – Phaeozems incubated with EM-A preparation and with agar at dose 2;
K4 – Phaeozems incubated with EM-A preparation and with agar at dose 3;
K5 – Phaeozems incubated with EM-A preparation and with starch at dose 1;
K6 – Phaeozems incubated with EM-A preparation and with starch at dose 2;
K7 – Phaeozems incubated with EM-A preparation and with starch at dose 3;

The following physicochemical properties were investigated in the soil samples collected from the above-presented combinations: *soil reaction* (pH), *hydrolytic acidity*

(Hh), *total base cations* (S), *cation exchange capacity* (CEC). CEC was calculated on the basis of Hh and S values using the following formula: PWK = Hh + S.

The following parameters were determined from among chemical soil properties: *content of organic carbon* (C_{org}) and *total nitrogen* (N_{tot}), amounts of available for plants macroelements (N mineral, P, K, Mg and S-SO_4) and microelements (Cu, Mn, Zn, Fe). The above properties were determined with the assistance of methods commonly applied in soil science analyses; their detailed descriptions can be found in Jakubus [8]. Data presented in this study are means of three replicates. The obtained results were subjected to formal evaluation with the assistance of the analysis of variance for single-factorial experiments using F test at the level of significance p = 0.95. The smallest significant differences were calculated using Tukey method at the level of significance of α = 0.05 and then uniform groups within the factor level were established.

Results and discussion

Literature data indicate that the application of EM resulted in the improvement of plant health condition [9–11] or led to the increase in their yields [12–15]. Reports referring to the EM impact on soil chemical and biochemical properties are less unequivocal. On the one hand, the literature on the subject corroborates such influence [4, 16] and, on the other, denies it [17, 18]. In such circumstances, Badura [19] maintains that advantageous effects of EM activities can best be seen in conditions of degraded, poor and neglected soils where microbiological balance is disturbed. The arguments of the above researcher can be referred to the performed experiment. The soil used in the trial was not degraded and, probably, this is why the obtained results failed to confirm unambiguously a positive impact of EM on properties of the examined soil. Irrespective of the applied polysaccharide, directions of changes of the examined soils were similar. As evident from Table 1, soil sorption properties described by absorbing capacity values (CEC) as well as total base cations (S) did not undergo significant changes under the influence of the applied doses of agar and starch.

Table 1

Influence of experimental factors on quantitative changes of physicochemical properties

Combinations	pH	Hh [mmol $H^+ \cdot kg^{-1}$]	S [mmol $\cdot kg^{-1}$]	CEC [mmol $\cdot kg^{-1}$]
1	6.7	4.65c ± 0.21	221.48 ± 3.34	226.13 ± 3.55
2	6.7	6.77a ± 0.25	210.52 ± 9.80	217.29 ± 10.05
3	6.8	6.22ab ± 0.32	226.47 ± 0.26	232.69 ± 0.06
4	6.8	5.66b ± 0.46	221.97 ± 3.07	227.63 ± 2.61
5	6.7	6.37ab ± 0.32	230.38 ± 20.69	236.76 ± 21.01
6	6.7	6.19ab ± 0.58	220.09 ± 6.03	226.28 ± 6.61
7	6.7	5.66b ± 0.90	221.67 ± 9.23	227.33 ± 8.34
LSD	*n.s.*	*0.961*	*n.s.*	*n.s.*

± SD

Neither was the soil reaction found to have been significantly changed by the experimental factor as its pH value remained on the same level. These results appear to contradict literature data which indicate a positive EM impact on pH value increase which was accompanied by declining soil acidification (Hh) and increased value of the soil sorption capacity (CEC) [4, 5, 20]. From among physicochemical soil properties analysed in the study, only the values of hydrolytic acidity varied. Together with the increase of agar or starch doses, soil Hh values were found reduced from 6.77 (K2) to 5.66 mmolH $\cdot$ kg^{-1} (K4) or from 6.37 (K5) to 5.66 mmol H $\cdot$ kg^{-1} (K7) (Table 1). Despite this, soil supplementation with polysaccharides led to its acidification as evidenced by higher Hh values in comparison with those found in the control soil (4.65 mmol H $\cdot$ kg^{-1}).

It is assumed that the aim of the EM introduction into the soil is, among others, to stimulate quantitative changes of humus [5, 20, 21]. Such phenomenon was confirmed also by Valarini et al [4] who reported 2.5–3.0 fold C_{org} in loamy soil following EM application. However, the reports of the above-mentioned researchers were not corroborated by the results of our investigations because neither the C_{org} nor humus content changed in a manner statistically significant after the addition of polysaccharides to the soil sprayed with EM-A. As evident from the data in Table 2, irrespective of the experimental combination, the amount of C_{org} ranged from 8.39 (K2) to 10.85 mg $\cdot$ kg^{-1} (K5) and that of humus – from 14.48 (K2) to 18.70 g $\cdot$ kg^{-1} (K5).

Table 2

Influence of experimental factors on quantitative changes of basic chemical properties

Combinations	C_{org}	Humus	N_{tot}	N-NH_4	N-NO_3
	[g $\cdot$ kg^{-1}]		[mg $\cdot$ kg^{-1}]	[mg $\cdot$ kg^{-1}]	
1	9.47 ± 1.5	16.33 ± 2.7	1165.5a ± 24.74	7.7 ± 0	4.55cd ± 0.49
2	8.39 ± 1.5	14.48 ± 2.7	1088.5c ± 4.94	7.63 ± 1.09	7.45a ± 0.63
3	9.60 ± 0.3	16.55 ± 0.5	1151.5ab ± 34.64	7.7 ± 0.99	6.30b ± 0.99
4	9.73 ± 0.3	16.77 ± 0.5	1092.0bc ± 0	8.05 ± 0.49	4.55cd ± 0.49
5	10.85 ± 0.1	18.70 ± 0.2	1144.5abc ± 64.34	7.35 ± 0.49	4.8cd ± 0.14
6	10.06 ± 0.4	17.35 ± 0.8	1148.0abc ± 9.90	7.0 ± 0.99	3.85d ± 0.49
7	9.85 ± 0.1	16.97 ± 0.3	1114.0abc ± 28.28	7.45 ± 0.35	5.45bc ± 0.21
LSD	*n.s.*	*n.s.*	*61.80*	*n.s.*	*1.102*

± SD

The chemical element closely integrated with soil humus compounds is nitrogen. According to Valarini et al [4], total nitrogen content in loamy soil treated with EM may increase even by up to 45–65 %. In our own experiments, a reverse direction of total nitrogen quantitative changes was observed. The interaction between the EM-A preparation and added polysaccharides resulted in a decline in the amount of this constituent in comparison with the content determined in the control soil (Table 2).

With respect to mineral nitrogen forms, only differences in the N-NO_3 content in the soil from the experimental combination were statistically significant. Quantitative

$N\text{-}NO_3$ changes depended on the polysaccharide added to the soil. In conditions of increasing agar doses, the content of this form of nitrogen was found to decrease from 7.45 (K1) to 4.55 $mg \cdot kg^{-1}$ (K3). At the same time, it should be stated that – against its amount determined in the control soil – agar doses of 100 and 200 kg/ha caused 1.5 fold and 38 % higher $N\text{-}NO_3$ content in soils of combination No. 2 and 3, respectively. On the other hand, in conditions of the soil incubated with EM-A and starch, quantities of the discussed form of mineral nitrogen comparable to those found in the control soil were determined (Tab. 2). Irrespective of the experimental combination, concentrations of $N\text{-}NH_4$ in soil ranged from 7.35 (K5) to 8.05 $mg \cdot kg^{-1}$ (K4) (Table 2).

From the point of view of agricultural practice, available forms of macro- and microelements are of key importance for plant nutrition and there is no agreement in the literature on the subject regarding this issue. Zydlik and Zydlik [5] reported smaller quantities of available phosphorus, potassium, magnesium as well as mineral nitrogen in the soil spread with the EM solution. On the other hand, Paschoal et al [20] failed to observe any influence of the applied EM preparation on concentrations of available macroelements.

From among the analysed macroelements, quantities of available phosphorus and magnesium were characterised by low variability in the examined experimental soil samples. A common feature of these constituents was that their quantities in the soil were found to decline together with growing agar doses, while with the increase of the starch dose, these quantities also increased (Table 3). Against this background, it is worth emphasising distinct changes in quantities of sulphur and potassium. Following the addition to the soil of growing agar doses, sulphate sulphur quantities were also found to grow, whereas increasing doses of starch were accompanied by decreasing content of this constituent. As to the content of $S\text{-}SO_4$ in the control soil (49.86 $mg \cdot kg^{-1}$), respectively 25 % more and 30 % less of this form were determined in the soil incubated with the highest doses of agar (K4) and starch (K7) (Table 3). Regardless of the type of polysaccharide added to the soil, quantities of plant available K decreased and were by 18 % lower in relation to the content of this constituent determined in the control sample (Table 3).

Table 3

Influence of experimental factors on quantitative changes of available for plants macroelements [$mg \cdot kg^{-1}$]

Combinations	K	P	Mg	S
1	282.00a ± 4.66	259.63a ± 14.83	98.61a ± 1.96	49.86b ± 5.49
2	262.21a ± 7.44	237.12a ± 1.81	91.67b ± 1.96	35.21c ± 1.86
3	230.07b ± 2.72	270.89b ± 6.15	90.28bc ± 1.96	53.54b ± 3.71
4	232.87b ± 15.54	248.63b ± 13.02	87.50c ± 1.96	62.30a ± 0.52
5	277.13a ± 3.93	216.29a ± 2.00	87.50c ± 0	49.33b ± 0
6	224.42b ± 13.99	246.33b ± 29.30	91.67b ± 1.96	37.99c ± 3.71
7	232.11b ± 29.84	239.68b ± 19.17	95.83a ± 0	35.06c ± 7.42
LSD	*28.159*	*30.374*	*3.274*	*8.047*

± SD

A direction of quantitative macroelement changes in the soil sprayed with the EM-A solution similar to that indicated above was reported by Zydlik and Zydlik [5] and, in their opinion, it should be attributed to the uptake of nutrients by plants. There was no plant factor in our own investigations and, therefore, the obtained results may point to a process of immobilisation of macroelements. Such possibility, especially with reference to biogenic components, was indicated by Freney et al [22] and Goh and Gregg [23]. According to the above researchers, in conditions of increased water content and carbon concentration, immobilisation of macroelements occurs more intensively.

From among the analysed microelements, manganese and iron quantitative changes in the examined soil were not corroborated statistically. Contents of the zinc and copper underwent similar changes under the influence of the experimental factor. As evident from data presented in Table 4, in comparison with the quantities of Zn and Cu in the control soil, in conditions of soils supplemented with agar or starch, their quantities were slightly higher. Therefore, in the case of soil incubated with EM-A and the highest dose of agar, the determined amounts of Zn and Cu were by, respectively, 46 % and 23 % lower. On the other hand, in the case of the soil incubated with EM-A and increasing quantities of starch, the determined quantities of Zn and Cu were by, respectively, 14 % and 31 % lower (Table 4). The increasing doses of starch did not differentiate the content of Cu at a simultaneous increase of zinc quantitative levels. On the other hand, increasing doses of agar were accompanied by a decline in the content of Zn (38 %) and Cu (17 %) (Table 4).

Table 4

Influence of experimental factors on quantitative changes of available for plants microelements [mg · kg^{-1}]

Combinations	Mn	Zn	Cu	Fe
1	71.70 ± 4.81	8.83a ± 1.28	1.60a ± 0.35	771.42 ± 7.82
2	75.10 ± 3.85	7.63b ± 0.43	1.48ab ± 1.17	773.80 ± 6.61
3	64.89 ± 0.96	6.37d ± 0.21	1.23ab ± 0.17	775.10 ± 6.92
4	73.06 ± 0.96	4.76e ± 2.34	1.23ab ± 0.17	773.58 ± 4.77
5	70.34 ± 0.96	6.75cd ± 0.64	1.11b ± 0	780.0 ± 0
6	74.42 ± 0.96	7.02bc ± 0.43	1.11b ± 0	780.0 ± 0
7	68.98 ± 12.51	7.62b ± 1.28	1.11b ± 0.35	780.0 ± 0
LSD	*n.s.*	*2.30*	*0.43*	*n.s.*

± SD

Conclusions

The results of our investigations prove that it is not possible to question explicitly the joint action of EM and polysaccharides on physicochemical and chemical properties of the examined soil. The incubation of soil with the EM-A preparation and polysaccharides influenced mainly its chemical properties. Their changes depended on the type of the added polysaccharide as well as on its dose. Increasing doses of agar added to the soil with the EM-A preparation reduced the content of available macro- and microelements. The joint action of the increasing quantities of starch doses and EM in the soil resulted in higher quantities of the examined components.

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ZMIANY WYBRANYCH WŁAŚCIWOŚCI GLEBY INKUBOWANEJ Z DODATKIEM AGARU, SKROBI I EFEKTYWNYCH MIKROORGANIZMÓW

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Abstract: Wśród różnych rozwiązań ekologicznych mających zastosowanie w tradycyjnym rolnictwie wskazuje się na dużą przydatność technologii Efektywnych Mikroorganizmów (EM). Preparatowi temu przypisuje się szerokie spektrum działania tak w produkcji roślinnej, jak i zwierzęcej. Wykazuje się, że po zastosowaniu doglebowym omawianego preparatu następuje przyspieszenie procesów mineralizacyjno-humifikacyjnych związków organicznych. Dyskusyjną kwestią są zmiany we właściwościach chemicznych gleb, jakie mogłyby nastąpić w konsekwencji oddziaływania tego kondycjonera.

W związku z powyższym podjęto badania mające na celu określenie wpływu EM na wybrane właściwości fizykochemiczne i chemiczne gleb. Realizacji tego zadania dokonano w oparciu o doświadczenie inkubacyjne z glebą czarna ziemia właściwą zaszczepioną EM, do której dodawano wzrastające dawki agaru lub skrobi.

Uzyskane dane świadczą o różnym wpływie EM z polisacharydami na badane właściwości gleby. W odniesieniu do większości badanych właściwości fizykochemicznych nie stwierdzono oddziaływania istotnego statystycznie. Zmiany ilościowe makro- i mikroskładników były uzależnione od rodzaju polisacharydu oraz jego dawki.

Słowa kluczowe: efektywne mikroorganizmy, agar, skrobia, właściwości fizykochemiczne i chemiczne gleby