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CHANGE AND THE INTERCONNECTEDNESS OF PHYSICAL AND MICROBIOLOGICAL PARAMETERS OF AGROCHERNOZEMS DIFFERENT DEGREES OF SOIL MOISTURE

Research article

Abstract

Research performed in Federal state budgetary institution "V. V. Dokuchaev Scientific Research Institute of Agriculture the Central of the Central-Chernozem zone" in terms of meadow soils of the South-East of the Central-Chernozem Zone in 2018-2020 biennium. The interrelation of the physical properties of soils, one of which is structural composition, with the intensity of meadow soils biological processes. The number of ammonifying more in the finer fractions, and immobilization of carbon. The size of soil aggregates determines the number of soil microorganisms developing in them. Adjusting physical properties of the soil, one of which is a structural condition, it is possible to influence the amount of soil microorganisms and enzymes that determine the intensity of soil-biological processes in the soil, and, consequently, its fertility.

Keywords: meadow soils, microbiological parameters, physical properties.

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ИЗМЕНЕНИЕ И ВЗАИМОСВЯЗЬ ФИЗИЧЕСКИХ И МИКРОБИОЛОГИЧЕСКИХ ПОКАЗАТЕЛЕЙ АГРОЧЕРНОЗЕМОВ РАЗЛИЧНОЙ СТЕПЕНИ ГРУНТОВОГО УВЛАЖНЕНИЯ

Научная статья

Аннотация

Исследования проведены в ФГБНУ «НИИСХ ЦЧП им. В.В. Докучаева» в условиях луговых почв юго-востока ЦЧЗ в 2018-2020 гг. Установлена взаимосвязь физических свойств почв, одним из которых является структурный состав, с интенсивностью почвенно-биологических процессов луговых почв. Количество аммонификаторов больше в мелких фракциях, как и иммобилизаторов углерода. Размер почвенных агрегатов определяет и количество почвенных микроорганизмов, развивающихся в них. Регулируя физические свойства почвы, одним из которых является структурное состояние, можно влиять на количество почвенных микроорганизмов, определяющих интенсивность почвенно-биологических процессов, происходящих в почве, и, как следствие этого, на её плодородие.

Ключевые слова: луговые почвы, микробиологические параметры, физические свойства.

1. Introduction

Questions of the influence of microorganisms on various spheres of soil fertility and processes occurring in the soil occupy an important place in literary sources. The role of biological factors in maintaining and reproducing soil fertility is gradually increasing. In modern conditions, this is due to a significant reduction in humus reserves in soils and the accumulation of physiologically active substances in them that have toxic properties and reduce the intensity of metabolism in the "soil – plant" system [1]. Microorganisms play an important role in soil formation and soil fertility, as well as participate in the formation of soil structure, the formation of humus and other important processes that occur in soils.

The study of soil biodynamics, which reflects the state of the soil – microorganisms – plants system, is becoming increasingly relevant.

Changes in the structure of soil cover caused by a sharp rise in ground water and increased signs of hydromorphism require solving a number of problems related to the current state of chernozems and possible negative processes caused by the transformation of steppe soils from an automorphic series to a hydromorphic one. The direct and indirect influence of elevated ground water on the functioning of steppe landscapes is significant and diverse, and therefore the issues of their study have always been and remain the most important and complex in modern soil science [2].

Also important and of interest to many researchers are issues related to the fertility of soils subject to hydromorphism, the main component of which is the composition of the soil microbocenosis.

In this regard, the establishment of the relationship between the physical properties of soils, one of which is the structural composition, and the intensity of soil-biological processes is clear and justified. Some authors have raised questions related to this problem. Studies of the Stone Steppe soils and issues related to changes in their physical and biological properties, as well as their relationship, occupy an important place in the works of many authors [3].

Thus, issues related to the relationship of physical properties of soils with the intensity of soil-biological processes occupy an important but insufficient place in scientific research. Purpose of work. Identification of the relationship of soil fertility, the indicator of which is the presence of soil microbiocenosis, with the physical properties of meadow soils in the South-East of the Central Chernozem zone as a result of agrogenesis.

2. Research methods

The objects of research were the soils of the Stone Steppe located on the upper part of the dividing slope to the beam of Talovaya: 1) meadow-chernozem soil on the convex part of the slope that is not flooded by surface waters in the spring; 2) chernozem-meadow saline slightly saline soil in a hollow depression on the concave part of the slope, subject to prolonged seasonal flooding. The structure of microbial coenosis in fractions of different sizes (1-2 mm; 2-3 mm; 3-5 mm; 5-7 mm; 7-10 mm; more than 10 mm) was studied in the considered soils in a layer of 0-20 cm. Determination of soil microbiological activity included determination of the structure of soil microbial coenosis. The number of ecological and trophic groups of microorganisms was determined by seeding on solid nutrient media. Structural composition – to N. I. Savvinov.

3. Results and discussion

Studies of the structural state of soils that differ in the degree of hydromorphism have revealed a significant decrease in the share of agronomically valuable aggregates in soils that are more susceptible to this phenomenon. The proportion of the lumpy part of the fraction (>10 mm) changed most contrastingly. Thus, in the arable horizon of the hydromorphic chernozem-meadow saline slightly saline soil of the hollow-like decrease, its share is 1.3 times greater than in the semi-hydromorphic meadow-chernozem soil on the plain increase (table 1). The content of fine-grained fraction (10-5 mm) in this the soil is also larger.

Table 1 – Structural composition of soil of Stone Steppe depending on the degree of hydromorphism (2018-2020), %

Option	Depth, cm	Size of aggregates, mm										
		>10	10-5	5-3	3-2	2-1	1-0,5	0,5-0,25	< 0,25	∑ 10-0,25	∑ > 10+ < 0,25	Cs
1	0-20	19,2	14,0	14,4	16,1	16,1	2,4	5,3	2,7	78,2	21,8	4,8
2	0-20	25,5	18,2	16,4	16,4	17,9	1,9	2,8	1,0	73,5	26,2	2,9

1 - meadow-chernozem soil on a flat rise (agrochernozem hydrometamorphized); 2 - chernozem-meadow saline slightly saline soil in a hollow-shaped depression (humus-hydrometamorphic saline soil).

As for the fraction of 5-3 mm, its amount did not differ much in the studied objects and was 14.4-16.4 %. The proportion of fractions 3-2 and 2-1 mm did not differ much in these soils. The fraction content of 1-0. 5 mm was redistributed with depth. The proportion of the dusty fraction (< 0.25 mm) was the smallest in the hydromorphic soil-1.0 % (table 1). The structural coefficient was highest in semihydromorphic meadow-chernozem soil on a flat rise and amounted to 4.8; on the contrary, its lowest value (2.9) was in the hydromorphic soil of a hollow-shaped decline.

I would like to note that the structural condition of these soils has deteriorated compared to 2018 (the coefficient of structure of semi-hydromorphic meadow-chernozem soil on a flat increase in 2018 was 7.5. The coefficient of structure in the soils of the meadow series increased with the onset of the dry phase of the climate cycle and decreased with the onset of the wet phase due to an increase in the dispersibility of soil particles.

Thus, with an increase in the degree of hydromorphism, the structural state of the soil deteriorated, the proportion of clumpy and small-clumped fractions increased, the proportion of dusty fractions decreased, the number of agronomically valuable aggregates (10-0.25 mm in size) decreased, and the structural coefficient also decreased.

Higher indicators of the structural coefficient in the soil are associated with less waterlogging in the early spring period, a higher content of exchange calcium and less-exchange sodium. The presence of sodium in the soil-absorbing complex (SAC), although in small amounts, causes increased cementation of soil particles and an increase in the proportion of the lumpy fraction.

A common pattern is a small amount of content of the fraction of the dusty fraction. It varied in the range of 1.0-2.7 %. Moreover, lower values are typical for the hydromorphic analog. This phenomenon confirms the disaggregating role of hydromorphism on the soil cover.

In soils of semihydromorphous and hydromorphic analogues, the leading position in the composition of agronomically valuable aggregates is occupied by a fraction of 1-5 mm in size. However, in relative terms, there is a significant difference between these soils. In semihydromorphic soil, structural units of 1-2; 2-3 and 3-5 mm in size accounted for approximately an equal number of aggregates. Their share was 16.1%, 16.1% and 14.4%, respectively. In total, aggregates of 1-5 mm in semihydromorphic soil accounted for 46.6 % of the total mass. In the hydromorphic analog - 50.7%.

In hydromorphic soil, despite the prevalence of mesoaggregates from 1 to 5 mm in the structure, their relative content changed significantly. A dominant fraction were aggregates with a size of 1-2 mm. On they accounted for 17.9% of the units. With the increase in the size of structural units, there is an increase in their relative content in relation to semi-hydromorphic soil. Thus, in the hydromorphic soil, the content of fine-grained fraction was 4.2% higher, and the lumpy fraction was 6.3% higher, respectively. And a few more words about the fraction with a minimum size (0.25-1.0 mm) of agronomically valuable aggregates. In semihydromorphic soil, an increase in their share is characteristic in comparison with hydromorphic soil. In the first case, the share of 0.25-1.0 mm aggregates accounted for 7.7 % of the total, in the second - almost 1.6 times less – 4.7 %.

Thus, summing up the results of the analysis of the structural state of semihydromorphic and hydromorphic analogues, it is necessary to note the following. In conditions of a greater degree of hydromorphism, the General pattern was a significant decrease in the share of agronomically valuable aggregates. Confirmation of this phenomenon is a significant decrease in the structural coefficient - 2.9 in hydromorphic soil, against 4.8 – in semihydromorphic. At the same time, despite the insignificant amount of dusty part of soil aggregates, under conditions of greater manifestation of hydromorphism, there was an almost threefold decrease in their share. Changes in the structural composition caused by the intensive manifestation of hydromorphism undoubtedly affect the nature of the orientation and relationship with other soil processes.

As a result of the research, the regularities of changes in the activity of soil microorganisms in soil aggregates of various fractions were established. The estimation of the total number of microorganisms shows significant differences, depending on the degree of hydromorphism. When the proportion of aggregates with sizes of 1-2 and 2-3 mm is close, similar values of the total number of microorganisms in these structural units are also noted (table 2).

The most noticeable differences are observed in mesoaggregates of larger size. Statistical analysis showed an inverse relationship between the size of soil aggregates and the total number of microorganisms. The coefficient of pair correlation was equal to r = -0.63±0.16, which confirms the revealed regularity of the decrease in biogenicity with an increase in the size of soil particles. An important component of the soil microbiota are microorganisms (ammonifiers) that use organic forms of nitrogen, and participate in the destruction of plant residues and dead plant roots. The total background number of ammonifiers was slightly higher in hydromorphic soil. Thus, in this soil, the number of this group of microorganisms varied in the range of 5.38-7.86×10^6 colony-forming unit (CFU) in 1 g of soil (table 2).

Table 2 – Composition of microbial coenosis in fractions of different sizes of meadow soils of the Stone Steppe (2018-2020).

Option	Fraction size, mm	MPA	SAA	The mineralizer humus	Actino-mycetes	Total number of microorganisms	SAA/MPA
		106 CFU per 1 g of absolutely dry soil					
1	1-2	7,17	18,2	8,70	3,07	37,1	2,5
	2-3	6,76	16,4	8,58	2,86	34,6	2,4
	3-5	7,39	19,5	10,3	2,90	40,1	2,6
	5-7	5,81	18,2	9,24	2,11	35,4	3,1
	7-10	5,81	15,6	9,24	2,64	33,3	2,7
	>10	5,28	14,8	8,98	2,38	31,4	2,8
2	1-2	7,53	19,9	9,14	2,96	39,5	2,6
	2-3	7,86	17,1	13,0	2,71	40,7	2,2
	3-5	6,01	18,8	9,28	2,46	36,6	3,1
	5-7	5,73	18,0	7,92	2,18	33,8	3,1
	7-10	5,46	15,6	9,01	2,46	32,5	2,9
	>10	5,38	14,3	7,80	2,69	30,2	2,6

1 - meadow-chernozem soil on a flat rise (agrochernozem hydrometamorphized); 2 - chernozem-meadow saline slightly saline soil in a hollow-shaped depression (humus-hydrometamorphic saline soil).

At the same time, the maximum number of ammonifiers, both in semihydromorphic and hydromorphic soil, is typical for aggregates with a minimum size of 1-2 mm; 2-3 mm; 3-5 mm. an Increase in the size of structural units causes a natural decrease in their activity. Moreover, the minimum activity in semihydromorphic soil was observed in aggregates of size >10 mm – 5.28×10^6 CFU, in hydromorphic-also in the fraction >10 mm – 5.38×10^6 CFU. Moreover, the trend of reducing the activity of ammonifiers is most pronounced in hydromorphic soil. Thus, we can note a fairly clear relationship between the increase in the number of microorganisms that utilize organic forms of nitrogen and the decrease in the size of soil particles. It

can be assumed that these processes are somewhat more active in small aggregates, due to their greater specific surface area and, accordingly, due to the improved possibility of using oxygen, which is necessary for the oxidation of organic substances [4]. Microorganisms growing on starch-ammonia agar (SAA) and using mineral forms of nitrogen to build their own cells, in their distribution had a clear dependence on the size of soil particles and the nature of hydromorphism. This group of microorganisms belongs to active immobilizers (table 2) readily available carbon. The higher background amount is typical for hydromorphic soils – 14.3-19.9×10^6 CFU per 1 g of soil. The activity of micro-organisms using mineral forms of nitrogen was not much different in the semihydromorphic soil-up to 14.8-19.5×10^6 CFU. A common pattern is a decrease in the number of microorganisms with an increase in the size of mesoaggregates. Apparently, small aggregates, having a larger specific surface area, activate the processes of immobilization of readily available carbon and, accordingly, due to the improved possibility of using oxygen necessary for the oxidation of organic substances [4].

The ratio of SAA:MPA shows the ratio of the total number of microorganisms using mineral nitrogen to the total number of microorganisms decomposing organic matter, reflecting the degree of participation of microflora in the process of transformation of soil organic matter. Moreover, the mineralization processes of organic matter, in these studies, are maximally expressed in aggregates of a smaller size. This is confirmed by the expansion of the ratio of microorganisms that utilize mineral forms of nitrogen to the number of microorganisms that utilize organic forms of nitrogen. At the same time, it is necessary to note the intensification of mineralization processes in semi-hydromorphic soils. The ratio of SAA:MPA in this case was 2.4-3.1, in hydromorphic soils it decreased to 2.2-3.1. This is probably due to different amounts of fresh organic matter entering the soil.

Actinomycetes belong to a large group of microorganisms that have the ability to destroy and synthesize complex organic compounds. They have a significant set of diverse enzymes. A higher number of actinomycetes is observed in agrochernozem hydrometamorphosed in fractions of a smaller size (table 2). In humus-hydrometamorphic saline soil, with a General decrease in their number, their higher activity is also characteristic of small aggregates. Statistical processing has established an average negative correlation between the number of actinomycetes and the size of soil aggregates. The pair correlation coefficient was - r = -0.58±0.12.

The content of actinomycetes in the smaller fractions was higher than in the larger fractions, which is probably due to the fact that actinomycetes are prokaryotes that require oxygen content. In smaller aggregates, the specific pore size is greater, and better aeration conditions are formed. As a result, complex organic substances are mineralized by actinomycetes to simple compounds. Thus, as the fraction size increased, the number of actinomycetes decreased.

An important component of soil biota is the number of colonies of humus mineralizers. In the soil mass, the processes of mineralization and humification of plant-root residues occur at different rates. Evaluation of the activity of humus mineralizers showed their significant variability, determined primarily by the nature of the manifestation of hydromorphism. And, second, the correlation between the structural parts of the soil aggregates. The most active mineralization processes of humus, judging by the number of relevant microorganisms, occur in semi-hydrophorphic agrochernozem hydrometamorphized. Their number varied in the range from 8.58 to 10.3×10^6 CFU in 1 g of soil (table 2). Moreover, in this case, the increase in activity is observed with the growth of the size of structural units, with the maximum value in the fraction of 3-5 mm.

In hydromorphic humus-gidrometallurgichesky saline soil there has been a General, much smaller amount of mineralizer of humus. Their number varied from 7.8 to 9.28×10^6 CFU / 1 g of soil. At the same time, the increase in the size of mesoaggregates causes a decrease in the activity of humus mineralizers. This is confirmed by the high coefficient of pair correlation, which was r = -0.94±0.21.

4. Conclusion

Different manifestations of hydromorphism in soils lead to significant changes in the structural state and associated biochemical soil processes. The conducted research allowed us to establish that the number of soil bacteria is well correlated with the degree of hydromorphism, and the resulting changes in physical parameters of fertility. The maximum number of most groups of microorganisms was found in agronomically valuable aggregates. The increase in population is observed when the size of soil structures decreases.

The results of the research allow to regulate microbiological and biochemical processes in the soil by optimizing the structural state of meadow soils. The number of ammonifiers is greater in small fractions, as well as carbon immobilizers. The size of soil aggregates also determines the number of soil micro-organisms that develop in them. In modern conditions, for the successful settlement of the corresponding fractions by agronomically significant groups of microorganisms, it is necessary to optimize the structural state by means of adaptive crop rotations with the use of perennial grasses (alfalfa). Due to the decrease in the water table on meadow soils, winter crops can be sown.

Adjusting physical properties of the soil, one of which is a structural condition, it is possible to influence the number of microorganisms inherent in determining the intensity of soil-biological processes in soil as a result of agrogenesis, and, consequently, on soil fertility.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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