

The Influence of Methods of Intensification in Agriculture on the Algal Flora of Leached Chernozem

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Abstract— Soil algae are often used as bioindicators in assessing the ecological state of the soil. The experiment with alfalfa was carried out on the basis of six-field grain-grass crop rotation in the southern forest-steppe of Western Siberia. The studies were conducted on three agrochemical backgrounds. At the biological background, only organic fertilizer was introduced (straw and cattle manure), at combined background — complex application of mineral fertilizers in a dose of N20P90, straw and cattle manure, at intensive background — full mineral fertilizer in a dose of N20P90K40 in combination with organic and plant protection products. The object of the study was the algal flora of leached chernozem: from eukaryotes - green (*Chlorophyta*), yellow-green (*Xanthophyta*), diatoms (*Bacillariophyta*), from prokaryotes – cyanobacteria (*Cyanobacteriu*) or blue-green algae. The analysis of the action of the studied factors was carried out according to the quantitative indicator, the number of cells in one gram of soil (cells/g of soil). When applying the maximum dose of mineral fertilizers, the total number of living algae cells decreased by 70% (102.4 thousand cells/g of soil). When using organic fertilizers (cattle manure, straw) on the same mineral background, the number of cells increased by 98%. The negative impact of agrochemical agents on the algal flora was manifested directly in the year of application; in subsequent years, the number of algae cells increased. Under the alfalfa of the third year of vegetation from the total number of living cells, the share of green and yellow-green accounted for 66-97%. Diatoms were more sensitive to the use of chemicals.

Keywords—microbiocenosis, algal flora, soil, agroecology, fertilizers, pesticides, plants.

I. INTRODUCTION

Soil microorganisms are an essential part of any ecosystem. In cultivated soil, their number can reach several billion in one gram of soil, and the total weight - up to 10 tons per hectare [1-3]. The importance of microorganisms in the soil formation process is invaluable, they are the most important link in the formation of the pedosphere on Earth. They are pioneers in soil formation, as they inhabited our planet during the appearance of animals and plants. In the biosphere, activity is not limited to the biologically active layer of the lithosphere, the chemical composition of air, open water sources, as well as the formation of some minerals depends on the functioning of microbiocenosis. Since biota is biochemically multifunctional, it carries out quite a large number of chemical reactions (synthesis, oxidation, reduction, decomposition of various substances), catalyzing them due to its own enzymatic system

[4-7]. It should be noted that microorganisms are autotrophs, they produce organic matter without solar energy, so we can safely assume that the pioneers in the soil-forming process were soil microorganisms. Soil microflora is usually called decomposers, whose function is to close the cycle of matter in the ecosystem, complete mineralization of plant and animal residues. The absence of this in the general cycle calls into question the formation of soil cover. Completing the process of decomposition of organic residues, there is a parallel synthesis of humus-like organic substances, the basis of soil fertility [8].

An important factor determining the homeostasis of soil biota in the agroecosystem is the use of agrochemical agents, in particular fertilizers. The stimulating effect of mineral fertilizers on the total number of microorganisms in the soil has been noted by many researchers [4, 6, 9-11]. The increase in the number of microorganisms, according to E.N. Mishustin [12] is associated with the receipt of energy material in the soil on fertilized plots: leaf litter, root-stubble remains of plants. It is also established that the activity of soil biota depends on the form, type of mineral fertilizers, combination of nutrients in them and dose. However the effectiveness of mineral and organic fertilizers in relation to the impact on the total number of microorganisms is determined by the combined influence of environmental factors: soil type, its humidity and temperature, degree of cultivation, set of crops in crop rotation [10-14].

A mandatory component of terrestrial ecosystems are soil algae. It is known that out of 1195 species of algae found in the Russian Federation, mainly native soil composition is represented by eukaryotes (green (*Chlorophyta*), yellow-green (*Xanthophyta*) and diatoms (*Bacillariophyta*) and prokaryotes – cyanobacteria (*Cyanobacteriu*) [15]. In the microbiocenosis, a special place is given to soil algae. These are single- and multicellular microorganisms with a specific pigment such as chlorophyll. The main niche of algae in the soil cover is the biologically active layer of soil 0-20 cm. Soil contamination with these microorganisms is about 300 thousand cells/g. They, like all microorganisms, are multifunctional, enrich the soil with organic matter, oxygen, fix atmospheric nitrogen, carry out chemical destruction of primary minerals. However, soil algal flora in comparison with other groups of soil microorganisms does not have a dominant role in the soil formation process, since the total value of their biomass is not more than one ton per hectare [16,17]. In virgin soils of the temperate zone of Russia algae

accumulate biological nitrogen in the amount of 17-24 kg/ha. In addition, they stimulate the activity of nitrogen-fixing bacteria, in particular azotobacter and nodule bacteria [16].

Microscopic algae are the most sensitive to exogenous influence on biogeocenosis, so according to scientists [15,18] they are bioindicators of pollutants. As indicators they have a number of advantages in comparison with other soil organisms: firstly, they are easily identified to the species, which allows to perform comparative analysis and monitoring; secondly, they react quickly to changes in abiotic and effect of anthropogenic factors; thirdly, algae and higher plants react equally to changes in soil conditions, and, fourthly, their cultivation is cheap and simple [18].

In this regard, the aim of the research was to study the reaction of the algal flora of leached chernozem on agricultural technology with different levels of application of chemicals in the grain-grass crop rotation. The tasks of the research were the following: identification of the effect and aftereffect of mineral and organic fertilizers on the algal flora of the soil, determination of the most sensitive group of algae on the agrochemical load of the soil.

II. METHODS

The object of the study was the number of algal flora of leached chernozem depending on the intensity of application of chemicals in the grain-grass crop rotation, founded on the basis of long-term stationary experience in the southern forest-steppe zone of Western Siberia. Crop rotation is deployed in time and space. The following crops were cultivated in the crop rotation: alfalfa of three years of use, wheat according to the formation of perennial herbs, second wheat according to the turnover of the formation of perennial herbs and oats. The experiment is based on the method of split plots, four-time frequency. Three factors were studied: mineral fertilizers, cattle manure and straw application. The scheme of experience is presented in the table material. Different combinations of mineral and organic fertilizers allowed the authors to assess the impact of three agricultural technologies: biological, combined and intensive on algae homeostasis in agroecosystem. From mineral fertilizers, double granulated superphosphate, ammonium nitrate and potassium chloride were applied according to the agrotechnical requirements for these fertilizers. Cattle manure at a dose of 10 t/ha of crop area was applied after harvesting oats, and straw - annually during harvesting of agricultural crops. Zoned varieties of agricultural crops were sown in the experiment. Sowing, care of crops and harvesting were carried out in the optimal time.

At the test site the soil is medium-humus medium-thick heavy loam leached chernozem. The content of mobile phosphorus is average, potassium exchange is high, the reaction of the soil solution is from slightly acidic to neutral.

To analyze the influence of the studied factors, a quantitative indicator used in Algology was used – the number of cells of cyanobacteria and soil algae, including green, yellow-green and diatoms. To do this, soil samples were taken from each variant of the experiment (sampling depth 20 cm). The number of cells was determined by direct counting on the МБИ microscope – 6 with an eyepiece of 40 [18]. The results were processed by the method of S.I. Vinogradsky in modification of E.A. Shtina with additions of K.A. Nekrasov and E.A. Busygina [19].

III. RESULTS

It is established that in leached chernozem the ecobiomorph formula has the form $Ch_5P_3H_2B_1$. In the aboriginal algal flora algae *Chlorococcum* prevail. These are mainly coccoid forms of the *Chlorococcales* order — algae of the genera *Chlorococcum*, *Chlorella*, *Actinochloris* and other algae adapted to exist in loose soils and found by individual loci on the lumpy structural units of soils of different sizes. In second place in the algocenosis there are filamentous cyanobacteria *Phormidium*-forms, two of them – *Oscillatoria brevis* and *Phormidium foveolarum*. One species of *Phormidium* is the *Phorm uncinatum* form. The third place in the number of species is occupied by algae *Hormidium*-forms. Filamentous algae *Ulothrichales* are represented by two species: *Hormidium nitens* and *Hormidium* sp. In the surface layers of the soil there are diatoms *Bacillariophyta*.

Studies conducted in the stationary experiment showed that the maximum total number of living cells (102.4 thousand cells/g of soil) was observed in the soil on a windy background of mineral nutrition (table 1). When applying mineral fertilizers at a dose of $N_{20}P_{90}$, the total number of algae decreased by 29%. In the variant $N_{40}P_{120}K_{40}$ in combination with plant protection products (treflan) from weeds and 70% compared with the control variant.

TABLE I. SPECIES AND QUANTITATIVE COMPOSITION OF SOIL ALGAL FLORA, THOUSAND CELLS/G OF SOIL

Fertilizer applied	Systematic group			General population
	green and yellow-green	blue-green	diatoms	
Biological technology				
no fertilizer	91.4	5.5	5.5	102.4
application of cattle manure ^a	96.7	—	—	96.7
straw application ^b	81.7	5.1	3.3	95.6
application of cattle manure + straw	90.5	—	5.5	96.0
Combined technology				
N ₂₀ P ₉₀	62.3	3.3	7.2	72.8
N ₂₀ P ₉₀ + application of cattle manure	70.9	—	—	70.9
N ₂₀ P ₉₀ + straw application	54.6	—	3.3	57.9
N ₂₀ P ₉₀ + application of cattle manure + straw	66.7	—	3.3	70.0
Intensive technology				
N ₄₀ P ₁₂₀ K ₄₀ + herbicides	25.6	—	5.6	31.2
N ₄₀ P ₁₂₀ K ₄₀ + herbicides + application of cattle manure	49.5	5.5	5.5	60.5
N ₄₀ P ₁₂₀ K ₄₀ + herbicides + straw application	45.6	6.2	5.5	57.3
N ₄₀ P ₁₂₀ K ₄₀ + herbicides + application of cattle manure + straw	51.3	7.2	8.8	67.3

^a. * the dose of manure-10 t/ha of crop area

^b. the dose of straw corresponds to the crop yield in this area

- dash - the absence of algae cells

Application of mineral fertilizers and plant protection products will reduce the total number of living algae cells from 102.4 to 31.2 thousand cells/g of soil. This is due to inhibition of their growth by minerals and herbicide. In addition, the powerful vegetative mass on the fertilized varieties actually obscures the soil surface, thereby reducing the photosynthetic potential of algae. According to our data,

the use of organic fertilizers (manure, straw) did not actually affect the number of living algae cells in the soil when using biological and combined technologies. However, it should be noted that the application of organic fertilizers did not remove the depressing effect of nitrogen-phosphorus fertilizers on the algal flora of the soil. Against the background of $N_{40}P_{120}K_{40}$ +

herbicides, the use of manure and straw contributed to an increase in the number of soil algae by 84-114%.

To assess the aftereffect of mineral, organic fertilizers and herbicides on the algal flora of leached chernozem, studies of the soil under the alfalfa of the third year of vegetation were performed (table 2).

TABLE II. SPECIES AND QUANTITATIVE COMPOSITION OF SOIL ALGAL FLORA, THOUSAND CELLS/G OF SOIL

Fertilizer applied	Systematic group			General population
	green and yellow-green	blue-green	diatoms	
Biological technology				
no fertilizer	63.8	9.2	19.0	92.0
application of cattle manure*	104.3	13.5	20.3	138.1
straw application**	99.9	17.6	37.2	154.7
application of cattle manure + straw	161.6	9.6	48.1	219.3
Combined technology				
N ₂₀ P ₉₀	200.1	13.4	25.0	238.5
N ₂₀ P ₉₀ + application of cattle manure	160.1	25.7	25.7	211.4
N ₂₀ P ₉₀ + straw application	188.1	—	2.9	191
N ₂₀ P ₉₀ + application of cattle manure + straw	201.2	—	14.2	215.4
Intensive technology				
N ₄₀ P ₁₂₀ K ₄₀ + herbicides	210.7	—	8.7	219.2
N ₄₀ P ₁₂₀ K ₄₀ + herbicides + application of cattle manure	102.8	—	5.9	108.7
N ₄₀ P ₁₂₀ K ₄₀ + herbicides + straw application	109.7	—	11.5	121.2
N ₄₀ P ₁₂₀ K ₄₀ + herbicides + application of cattle manure + straw	79.4	—	8.5	87.9

a. * the dose of manure-10 t/ha of crop area

b. the dose of straw corresponds to the crop yield in this area

– dash - the absence of algae cells

The seed contamination of the soil of the non-fertilized background by living algae cells was 92.0 thousand cells/g of soil. Toxicological effects from the use of agrochemical agents (application of mineral fertilizers, the use of plant protection products) on the algal flora of the soil in the aftereffect (next year) was not noted. In these variants, there was even an increase in soil biogenesis, the number of algae increased by 138-159% compared to the control variant. Comparison of the number of living cells in the soil under the alfalfa of the first year of vegetation with similar variants showed an increase of 228% in the variant $N_{20}P_{90}$ and 603% in the variant $N_{40}P_{120}K_{40}$. The aftereffect of organic fertilizers to a greater extent manifested against the background of biological technology. The use of manure and straw both separately and in a complex was quite effective. The maximum number of soil algae cells was observed in the

manure + straw variant - 219.3 thousand cells/g of soil. This is 138% higher than in the variant without fertilizers. For variants of separate application of straw and manure, the number of cells increased by 59%; 41%, respectively. On intensive ($N_{40}P_{120}K_{40}$ + herbicides) and combined ($N_{20}P_{90}$) backgrounds, the number of soil algae cells in the same variants changed slightly. Figure 1 shows the increase in the number of soil algae cells when applying manure and straw and the stimulating effect of organic fertilizers on their number in the second year of the aftereffect of agrochemical agents.

The dominant place in the total number of algogroup of chernozem soil under alfalfa of the third year of vegetation belongs to the species of green and yellow-green, their share is 66-97% of the total. The most sensitive group of algae are – diatoms.

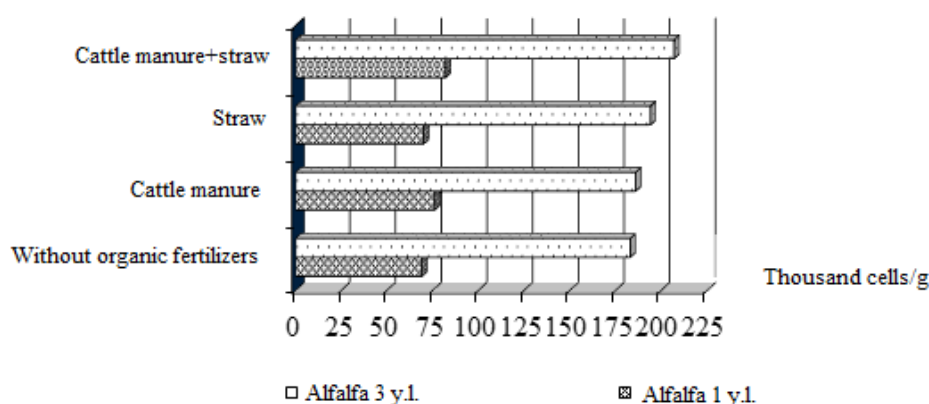


Fig. 1. Quantitative composition of soil algal flora under alfalfa of the first and third years of vegetation, thousand cells/g of soil

An integral indicator of the effectiveness of the use of agrochemical agents is the yield of agricultural crops.

Scientific-based choice of the type, dose and period of their use allows to get the maximum increase in crop produc-

tion and control the ecological state of the agrocoenosis. In our studies, a positive effect of fertilizers was established, with an increase in their total dose, the yield of dry matter of alfalfa increased by 0.24-0.58 t/ha (Fig. 2). The maximum increase in crop yield was obtained from the aftereffect of cattle manure at a dose of 10 t/ha of crop area - 0.90 t/ha of dry matter. Straw did not have a significant impact on the productivity of alfalfa. The minimal manifestation of digression of soil algogroup in the second year of the

aftereffect of agrochemical agents confirms their environmental safety, and the increase in crop yield-efficiency.

Determination of the number of soil algae allows to perform environmental monitoring of safety and targeted control of the effectiveness of mineral, organic fertilizers and plant protection products in the agrocoenosis [20-26].

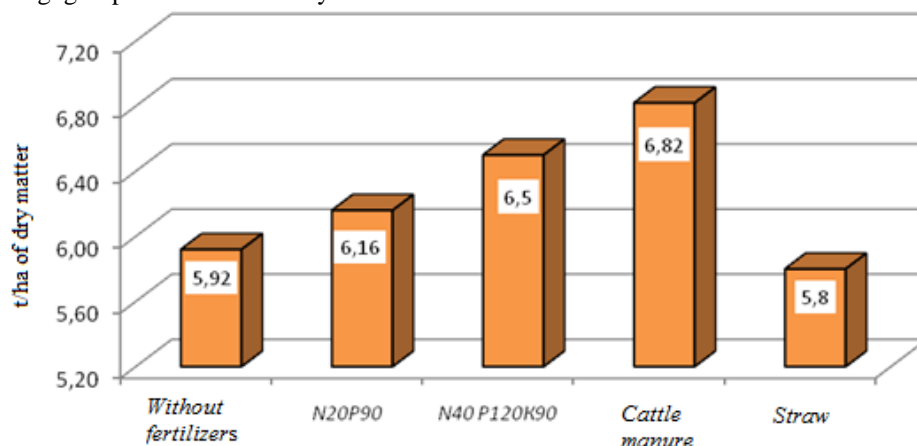


Fig. 2. Effect of mineral and organic fertilizers on the yield of alfalfa of the third year of vegetation (LSD05 of particular aver-ages - 0.21 t/ha of dry matter)

IV. CONCLUSIONS

Thus, brief description of biogenesity of leached chernozem and the available data on the impact of agrochemicals on microbial processes in the soil indicate the digression of the number of algae cells directly in the year of application; in the second and third years of alfalfa vegetation, the number of algogrouping of the soil under the crop increased significantly. It was found that the share of green and yellow-green cells accounted for 66-97% of the total number of living cells. Diatoms were the most sensitive group of algae to the use of chemicals.

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