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Dynamics of Microbiological Activity of Soils in the Natural Landscapes of the Shaulder Massif (The Mid-Stream of the Syr Darya River)

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Abstract

The microbiological properties of soils in the natural landscapes of the Shaulder Massif located in the middle course of the Syr Darya River have been considered. It has been recognized that ecological factors in the soil system consisting of the content of salts, plant residues, humus and soil moisture, influence the number of microorganisms and their qualitative composition. Zonal-landscape regularities of the distribution of microorganisms and the dynamics of microbiological activity during the vegetation period have been established. The main physiological groups of microorganisms from different soils have been identified, and their activity in the landscapes of the floodplain and supra-flooded terras of the Syr Darya River with sufficient moisture and organic substances has been revealed. It has been found that actinomycetes are active under extreme environmental conditions and dominate in the soils of the ancient alluvial plain of the extra arid zone, where the number of microorganisms such as spore-forming bacteria, Azotobacter, nitrifiers, denitrifiers, microscopic fungi and cellulose-decomposing microorganisms is sharply reduced.

Key Words: natural landscapes, soil microorganisms, the Shaulder Massif.

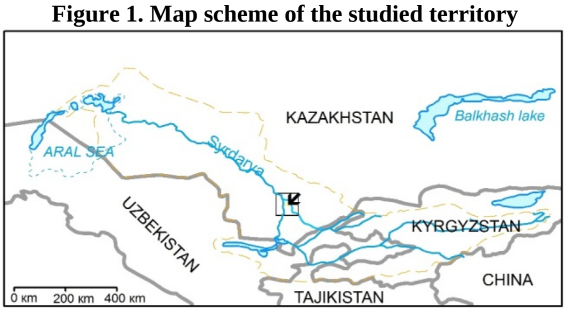
INTRODUCTION

Classical is a set of landscape components, which include soil cover, vegetation, animals, internal waters, and surface layer of air [1]. However, the landscape is not just a set of any components, but a single, regular, and interdependent system of them [2]. Accordingly, the genesis of the landscape, in addition to external factors, depends on the dynamics of its constituent components. Moreover, extremely variable phenomena occur in internal soil processes, especially in their biological component [3, 4, 5], which is difficult to imagine without soil microorganisms and their activity.

The study of microorganisms in the arid zone attracted much attention when such global environmental problems as desertification, soil degradation and pollution became available. These phenomena became extremely topical and they entered into 15 emergency situations that humanity must solve in the third millennium to protect the planet and ensure the survival of mankind [6, 7]. It is absolutely proven that microorganisms play an important role in biochemical processes that not only create the conditions for the stability of the ecosystem, but also increase the productivity of agriculture [5, 7, 8, 9]. Such studies create conditions for the emergence of new directions in the study of the microbiological component of landscapes and its changes, the features of geographical distribution, the annual dynamics of activity, etc.

This work aims to study the microbiological activity of soils in the natural landscapes of the Shaulder Massif (coordinates 68 ° 01'17 " E, 42 ° 41'06 " N, 68 ° 30'41 " E, 42 ° 54'06 " N).

Figure 1. Map scheme of the studied territory



RESEARCH OBJECTS AND METHODS

The Shaulder Massif of the Otrar steppe is typical for the mid-stream of the Syr Darya River (Figure 1).

It is located between the lowland Turan desert and desert-savannoid foothills of the western Tien Shan and it is one of the oldest agricultural areas in the territory of Kazakhstan.

According to the long-term data of Kogam weather stations (42 ° 50 'N, 68 ° 17'E) and Otrar (42 ° 55' N, 68 ° 21'E), located on the research site , the climate of the massif refers to sharply continental. The average annual temperature rises to + 15 °C and the annual precipitation is 100-200 mm/year [10].

Geomorphologically, the area of the study is a system of above-flooded terraces of the Syr Darya River, which relief is formed by the erosion-accumulative activity of the Aris river [11]. There are found 2 soil classes (Fluvisoils and Calcisol) [12], which are subdivided into 4 types of soils (Table 1).

In the floodplain and the above-floodplain terrace of the Syr Darya River there are reeds, oleaster, tamarisk, shoreweed and Kirghiz camel-thorn. On the ancient alluvial plain there are camel's-thorn and saltwart plants. On the floodplains there are narrow stretch of tugai thickets.

For the study of soils and their microbiological activity, stationary observation sites were selected and soil sections (1, 2, 3, 4) were laid, which were numbered depending on the distance from the Syr Darya River [13, 14] (Figure 2).

Soil samples were selected by genetic horizons and, then, the field humidity [15], humus content [16], root residues [17], dense residue and salt reserve in a meter layer of soil have been identified [18]. Observation of active microflora in the soil was carried out by microscopy of fouling glasses on the MBI-11 microscope with a phase contrast device KF-4 according to the technique of D. I. Nikitina [19]. It was clarified by taking into account the quantitative composition of bacteria growing on solid meat-peptone (MPA), starch-ammonia (SAA) and soil agar (SA) nutrient media by surface inoculation of soil suspension. Observation of microorganisms was introduced in dynamics in spring, summer and autumn (10th-20th days of the second month of each season).

RESULTS

Different quality of soils of the research object was established in accordance with the microbiological activity. When studying the microflora of soils, particular attention was paid to this aspect of the problem, against the background of a specific hydrothermal regime, salt content, and the stock of organic substances (Table 2).

The content of the root mass, humus, and field moisture decreases from alluvial-meadow tugai nonsaline and meadow-swamp weakly solonchakous soils to meadow-serozem weakly saline and light gypsum soils. The humus content in the upper horizons of soils decreases from 2.16% to 0.88% and also in depth. For example, in meadow-swamp weakly solonchakous soils, it decreases from 2.11% at a depth of 0-13 cm to 0.74% at a depth of 31-58 cm.

Meadow-serozem weakly saline and light gypsum solonchakous soils of zonal landscapes differ significantly in the content of water-soluble salts and in small reserves of organic matter; their hydrothermal regime is close to zonal. In light serozem soils, the salt reserve in the meter layer reaches 133 t/ha, and the volume of the dense residue reaches 0.6%.

Microbiological activity. More bacteria were detected on SA than on SAA and MPA. At the same time, in the upper horizon of alluvial-meadow tugai nonsaline soil the number of microorganisms on SA was 38.0 mln /g or 3.5 times more than SAA (10.8 mln / g) and 4.5 times more than MPA (8.4 mln / g) (Table 3).

This pattern indicates that sterilized SA is the most suitable nutrient medium for the identification of typical forms of micropopulation in soils. It was found out that 30-40% of the bacteria counted on SA extremely poorly develop on MPA. Their number decreases in the lower horizons of all studied soils.

The number of microorganisms in the soil is closely related to its moisture and humus content (Table 3). Their number decreases from alluvial-meadow tugai nonsaline soils to light serozem gypsum solonchakous virgin soils. The amount of denitrifiers decreases from alluvial-meadow tugai nonsaline soil (1.8 mln/g) to light serozem gypsum solonchakous soil (0.2 mln/g) in the upper horizons of these soils in the Shaulder Massif.

The soil formation process of the southern series often has moisture as the limiting factor where an important place is occupied by actinomycetes. According to Table 3, it can be seen that the distinguishing feature of this rather peculiar group of microorganisms is the ability to thrive with a very substantial deficit of moisture in the soil. In the upper layer of light serozems the number of actinomycetes is exactly 1.2 mln/g, and in alluvial meadow soil it is 1.6 mln/g. Even in the subsurface (0.4 mln/g) their quantity is more than in far moister soils (0.4 mln/g).

Table 1 – The virgin soils of the studied territory

Soils	Class	Location
Alluvial-meadow tugai nonsaline soil	Fluvisoils	High floodplain of the Syr Darya River
Meadow-swamp weakly solonchakous soil	Fluvisoils	High floodplain of the river
Meadow-serozem weakly saline soil	Calcisol	The first terrace of the river
Light serozem gypsum solonchakous soil	Calcisol	Ancient alluvial plain

Figure 2. The scheme of location of soil sections on the floodplain terraces of the Syr Darya River

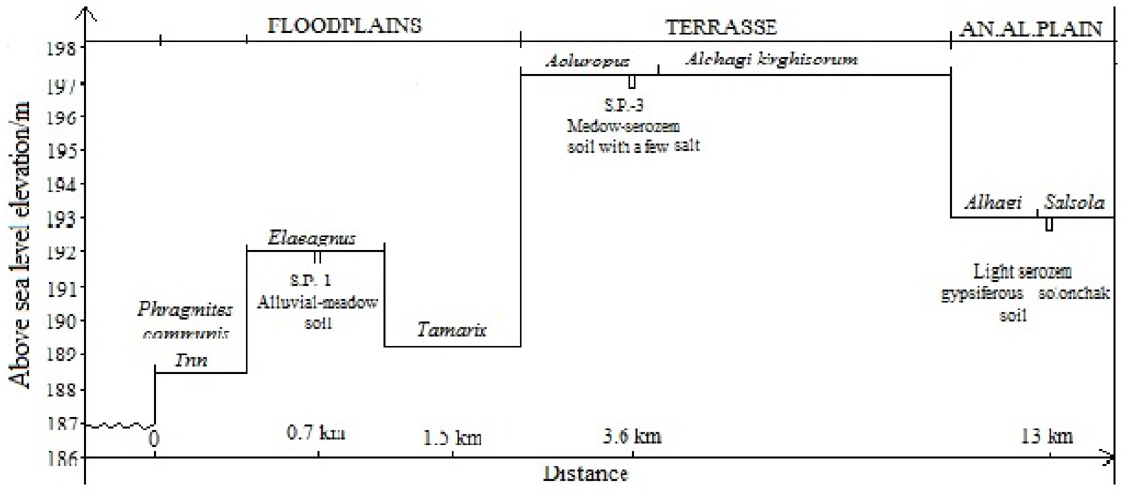


Table 2 – Characteristics of the soils of the Shaulder Massif

Soils, section (P)	Depth, cm	Dense residue,%	Salt reserve 1m, t / ha	Field soil moisture,%	Root residues, t/ha	Humus content,%
Alluvial-meadow tugai nonsaline soil, P-1	0-10	0.019	11-15	30.7	12.83	2.16
	10-21	0.038		17.5	10.56	1.85
	21-68	0.081		24.2	11.29	0.42
Meadow-swamp weakly solonchakous soil, P-2	0-13	0.120	26.7	26.2	11.0	2.11
	13-31	0.139		19.1	10.30	1.19
	31-58	0.253		18.2	8.61	0.74
Meadow-serozem weakly saline soil, P-3	0-15	0.217	30-37	16.2	-	1.61
	15-36	0.298		18.4	6.93	1.55
	36-77	0.533		22.4	3.63	0.63
Light serozem gypsum solonchakous soil, P-4	0-10	0.656	95-133	11.7	4.93	0.88
	10-30	0.190		13.6	4.64	0.59
	30-57	0.425		15.9	0.18	0.42

Table 3 – Data of microbiological analyzes of soils of the Shaulder Massif

Soils, section (P)	Depth, cm	Number of bacteria, mln / g soil			Spore-forming bacteria, thous./ g soil	Azotobacter on Ashby medium,%	Nitrifiers (zones of enlightenment),%	Denitrificators, mln./g of soil	Actinomycetes, mln / g soil	Microscopic fungi, thousand / soil	Fouling of cellulose cellulose-decomposing mimicorganisms,%
		MPA	SAA	SA							
Alluvial-meadow tugai nonsaline soil	0-10	8.4	10.8	38.0	264	100	100	1.8	1.6	9.0	100
	10-21	6.2	6.8	22.4	176	100	86	2.0	0.8	5.4	100
	21-68	3.6	4.4	16.2	132	22	28	2.0	0.2	1.5	100
Meadow-swamp weakly solonchakous soil	0-13	5.8	6.2	20.6	234	100	92	2.2	1.2	8.6	100
	13-31	4.2	5.0	12.0	184	100	80	1.4	0.4	5.2	100
	31-58	2.6	3.9	8.8	74	18	34	2.6	0.2	1.4	100
Meadow-serozem weakly saline soil	0-15	3.4	4.2	18.2	212	96	80	0.6	1.2	5.2	100
	15-36	2.2	3.4	12.8	156	70	50	0.6	0.6	0.2	72
	36-77	0.8	1.8	4.6	90	20	46	0.6	0.2	1.4	40
Light serozem gypsum solonchakous soil	0-10	2.2	2.6	10.2	134	36	50	0.2	1.6	3.1	100
	10-30	1.5	2.0	8.2	72	80	34	0.4	0.2	1.3	64
	30-57	0.4	1.2	3.6	34	14	20	0.4	0.4	0.8	20

Seasonal dynamics of the microbiological activity. The investigated soils are characterized by the seasonal dynamics of the number of microorganisms. Here we conducted observations of three types of landscapes, located at different geomorphological positions. In alluvial meadow tugai nonsaline soils the content of natural moisture was higher than in other soils throughout the growing season. Maximum moisture was detected in the upper horizon (0-10 cm) of alluvial meadow soil in spring at a rate of 30.6% moisture, however, the minimum amount of 2.3% moisture was observed in summer.

The dynamics of the abundance of Azotobacter, nitrifiers and denitrifying agents completely coincided with the field soil moisture changes over the seasons of the year. Analysis of soil samples for the content of N/NO3 during the growing season showed a direct correlation between the number of nitrifiers and the accumulation of nitrates in virgin soils. It was found that the genetic horizons of these soils were unequal to each other in their ability to accumulate nitrates.

Cellulose-destroying microorganisms are active in spring when the moisture index is high, though in autumn their activity decreases, especially in serozem soils. However, among this group of microorganisms, the number of actinomycetes increases from spring to summer and further towards autumn, i.e. a reverse picture is observed that is characteristic of other groups of soil microflora. In the middle layers (15-36 cm) of meadow-serozem soil the amount of actinomycetes increases from 0.8 mln/g to 3 mln/g from spring to autumn.

The seasonal dynamics of the development of microscopic fungi corresponds to the course of the curve of soil moisture content. Higher abundance of microflora is found in spring, reaching 8.4 thous./ha in alluvial meadow soils. The dominant are representatives of the genus Penicillium and Aspergillus. Fungi of the genus Fusarium and Trichoderma occur in a somewhat smaller number. Representatives of the genus Mucor are also found in a small number.

Spore-forming bacteria also grow rapidly in spring, but they drop sharply in their number in summer and autumn. Special changes occur on the surface of meadow-serozem weakly saline and light gypsum solonchakous soils, where the amount of spore-forming bacteria decreases due to a change in moisture. Their minimum number is 52 thous./g in the lower layer (30-57 cm) of light serozem soils in the autumn season. It has been found that not all species of these bacillary forms of bacteria are equally related to a decrease in moisture in the soil. So, Bac. Cereus and Bac. subtilis were more drought-resistant than Bac. mecentericus, Bac.megatherium and others.

Discussion

It should be noted that soils in the Shaulder Massif as the Syr Darya valley dried out from direct flooding as a result of regulation of river runoff, evolved from alluvial and bog soils to serozem soil types [20]. This predetermined a peculiar set of environmental factors that determined the quantitative and qualitative composition of the microflora of soils.

In nonsaline alluvial-meadow and meadow-swamp weak solonchakous soils located in the floodplain landscapes of the Syr Darya River, insignificant salt content, large amount of plant residues, humus and moisture create favorable conditions for the development of microorganisms. The presence of moisture is factor above the ones mentioned, which has a restraining effect on microbial diversity, community structure, and activity [3, 21, 22]. The accumulation of humic substances and nitrogen in the soil is the most important indicator of the soil-forming process and the fertility of soils, and there is close correlation between the content of humus and nitrogen. This is due to the fact that all soil nitrogen is the result of biological accumulation: about 90% of the soil nitrogen is in organic form, genetically related to humus [23].

In the studied landscapes, there is greater number of microorganisms and their high activity is noted. Soils of floodplain landscapes of the Syr Darya River contain microorganisms that actively participate in the nitrogen cycle. In such soils, the abundance of Azotobacter, nitrifiers, denitrifying agents depends on the physicochemical and microbiological properties of soil [24]. According to Ste-Maria [25], the rate of nitrification is very different among soil types due to the humus content.

The annual dynamics of the microbiological activity of alluvial-meadow nonsaline and meadow-swamp weakly solonchakous soils shows that microbiological processes are in an active state practically during the entire growing season.

Meadow-serozem weakly saline soils located in the first terrace of the Syr Darya River follow the above-mentioned soils according to the quantitative composition of microorganisms. The content of humus, field moisture, root mass and activity of microorganisms are at an average level compared with that of other soils in the studied area.

Smaller number of microorganisms, the depressivity of microbiological processes in light serozem gypsum solonchakous soils are determined by the saturation of these soils with water-soluble salts, small content of organic residues, humus and especially moisture.

In an ecosystem with arid soils, a special role belongs to cellulose-destroying microorganisms, although in our studies they did not show any particular activity rather than actinomycetes. It should be noted that actinomycetes are able to survive in extreme soil conditions, such as low humidity or high salinity [5, 16, 22]. In this case, they can reach 50% of the total microbial bacterial population [26].

Bacterial activity in soils rapidly decreases when the water potential of the soil reaches 5 bar, while many actinomycetes and fungi can withstand lower moisture potential [27]. The community of fungi forms thin crusts on the surface of the earth. They protect soil from erosion, enrich its composition, and accelerate the growth of plants. Soil crusts are one of the most important components of desert ecosystems [28].

The number of spore-forming bacteria showed little variability, although they should be the dominant microorganisms of the desert zone according to Rao [29]. In soils of the serozem series there is pronounced dynamics of the number of microorganisms and their biological activity. The sharp amplitudes of fluctuations in hydrothermal conditions undoubtedly strongly influence the composition of individual physiological groups of the microbial population of soils of this type.

CONCLUSION

1. Landscapes, alluvial-meadow tugai and meadow-swamp solonchakous soils of the Shaulder Massif containing an insignificant amount of salt, a large amount of plant residues, humus and moisture, create favorable conditions for the development of microorganisms. Meadow-serozem landscapes with weakly solonchakous properties, according to the quantitative composition of microorganisms and their biological activity, follow the above-mentioned varieties of soils.
2. Smaller number of microorganisms, weak microbiological activity in landscapes with light serozem gypsum solonchakous soils are associated with the saturation of these soils with water-soluble salts, small content of organic residues, humus and, especially, moisture.
3. Sharply expressed annual dynamics of the activity of microorganisms and their abundance are observed in landscapes with soils of the serozem series (type). In the spring mesothermic phase the proliferation of microbial cells and their activation are rapid. The result is intensive decomposition and mineralization of plant residues. With the onset of the xerothermic phase (in summer), the vast majority of soil microorganisms become latent.

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