APPLICATION OF TECHNOLOGY BASED ON CYANOBACTERIAL STRAINS TO INCREASE THE PRODUCTIVITY OF SALINATED SOILS IN THE DRYING ARAL SEA

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Abstract: *This study presents the results of scientific research conducted on the dried-up bottom of the Aral Sea, where soil samples are being tested under the project number AL-9424115044-R4. Accordingly, soil samples (№1–№67) taken from the dried-up bottom of the Aral Sea were inoculated for special experiments in stationary conditions at the Algology Laboratory of Namangan State University. For inoculation, water and algae samples were taken from several small lakes remaining on the dried-up bottom of the Aral Sea and these samples were used as optimal inoculants for the soil. The species Coelastrella cogersae, Chlorella vulgaris, Phormidium boryanum were used as inoculants. Of the species taken as inoculants, the most optimal and quickly adapted to growth conditions were Coelastrella cogersae and Phormidium boryanum. They formed a soil biofilm (BSC) on saline soils. The experiment was continued based on a local strain adapted for the island.*

Keywords: *Cyanobacteria, microalgae, soil salinity, inoculation, biofilm, bioremediation.*

ПРИМЕНЕНИЕ ТЕХНОЛОГИИ НА ОСНОВЕ ШТАММОВ ЦИАНОБАКТЕРИЙ ДЛЯ ПОВЫШЕНИЯ ПЛОДОРОДИЯ ЗАСОЛЁННЫХ ПОЧВ ВЫСОХШЕГО ДНА АРАЛЬСКОГО МОРЯ

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Аннотация: *В данном исследовании освещены результаты научных работ, проведённых на высохшем дне Аральского моря. Почвенные образцы, отобранные с данной территории, в настоящее время исследуются в рамках проекта № AL-9424115044-R4. В соответствии с этим, образцы почвы (№1–№67), собранные с высохшего дна Аральского моря, были инокулированы в лаборатории альгологии Наманганского государственного университета для проведения специальных стационарных экспериментов. Для инокуляции были отобраны образцы воды и водорослей из нескольких небольших озёр, сохранившихся на высохшем дне Аральского моря, и использованы в качестве подходящего инокулянта для почвы. В качестве инокулянтов применялись виды* Coelastrella cogersae, Chlorella vulgaris, Phormidium boryanum. *Среди использованных видов наиболее эффективными и быстро адаптирующимися к условиям роста оказались* Coelastrella cogersae *и* Phormidium boryanum, *продемонстрировавшие положительные результаты. В засолённых почвах сформировалась биологическая почвенная корка (BSC). Эксперимент был продолжен на основе местных штаммов, адаптированных к условиям Аральского региона.*

Ключевые слова: *цианобактерии, микроводоросли, засоление почв, инокуляция, биологическая почвенная корка, биоремедиация.*

INTRODUCTION

The drying of the Aral Sea has caused environmental problems in large areas of Central Asia. In particular, the rapid salinization, degradation, and desertification of soils are intensifying. Saline soils become unsuitable for plants, which leads to a decrease in agricultural productivity and a disruption of ecosystem stability.

Traditional land reclamation methods (washing, drainage systems, etc.) often require large investments and in some cases can cause additional damage to the environment. Therefore, the search for environmentally friendly and effective methods is an urgent issue. In this regard, the research work carried out by us will, to a certain extent, be used as a recommendation to reduce the salinity of the soils of the dried-up Aral Sea bottom and use them as a suitable arable land for agriculture. The main goal of the project is to organize and support soil protection measures by isolating and using strains suitable for the Aral Sea based on local strains.

The first studies on the state of the Aral Sea were conducted by L.S. Berg (1908) and L. Molchanov (1945). Many scientific studies have been conducted on the role of cyanobacteria in restoring soil fertility. In particular, Belnap and Lange (2001) emphasize in their work that biological soil crusts (Biological Soil Crusts — BSCs) are an important factor in preventing soil erosion. In their opinion, this crust strengthens the soil surface and acts as a natural protection against wind and water erosion.

According to Singh (2014), cyanobacteria not only fix atmospheric nitrogen, but also improve the physical and mechanical properties of the soil through the exopolysaccharides (EPS) they secrete. These substances bind soil particles and increase its structural stability.

A number of studies have been conducted in Uzbekistan, particularly in the Aral Sea region, to study algae and cyanobacteria living in saline soils. Studies by Sharifov (2018) and other scientists have noted a high level of adaptability of cyanobacteria belonging to the genera Nostoc and Anabaena in saline substrates.

To date, many scientific and applied studies have been focused on the algal flora of the Amu Darya basin, the bioecology of plants and animals of the Southern Aral Sea, and soil properties. However, the biodiversity, ecology, and modern systematics of hydrobionts living in the dried-up bottom of the Aral Sea have not been sufficiently studied. Unlike previous projects and scientific and applied studies, our study is devoted to the direct study of the dried-up bottom water bodies of the Aral Sea. In the course of this study, new methodologies based on scientific approaches are being developed.

Materials and methods.

1. Sample collection. Soil samples No. 1-No. 67 were collected from the designated Aral Sea area located around 45°N 60°E: 45°00`N 58°30`E. Samples were collected under sterile conditions from 3 horizons (A, B, C) according to the methods of Gollerbach and Shtina (1964).

2. Isolation and cultivation. To isolate the strain from the growing nutrient culture, a water sample was inoculated onto BG-11+ and BG-11- agar media. Subsequently, an algologically pure culture was obtained by repeated streak plating and separation of individual colonies using a Pasteur pipette [1]. The strain was then grown under standard conditions (temperature 23–25 °C, light intensity 60–75 μmol photons m^{-2} s^{-1}, photoperiod 12 h) on solid BG-11 medium (pH = 7.0; agar 1.4%) supplemented with nitrogen under climate control. The studied strain was stored in the NamDU Algology Collection (Ac.NamSU) under the numbers Ac.NamSU-1, Ac.NamSU-2, Ac.NamSU-3.

3. Light microscopy. The morphology and viability of microalgae and cyanobacterial strains were studied using light microscopy on a Levenhuk MED D25T LCD microscope (China). Observations were documented using a BestScope BLM2-274 color digital camera (China).

The observation period ranged from 1 to 12 weeks. The following diagnostic features were taken into account during morphological identification: type of thallus organization, cell shape and size, number and type of chloroplasts, presence of pyrenoid, presence and thickness of mucous layers, method of reproduction, and other relevant features.

Morphometric measurements were performed using Leica Application Suite X software. A total of 100 cells were measured to determine cell size parameters. Selected reference studies were used for both morphological and molecular-genetic identification [2,4,5,6,7].

The results obtained and their analysis.

Soil samples from the dried-up bottom of the Aral Sea were inoculated with four types of microalgae and cyanobacteria under stationary conditions in our experiment. The samples taken for the inoculation experiment were grown in appropriate nutrient media and sprinkled on the soil surface. Three identical standard samples with three strains were watered with plain water. According to this, every 6 days during the experiment, the sample containers were reweighed on a scale, the difference between the first and current weighing was covered with sterile water (so that the soil was evenly moistened). All containers were placed under the same conditions, under a light fixture at room temperature. On the 1st, 12th, 24th, 36th, 48th and 60th days, photographs were taken of each container to see the soil growing with algae, and they were subjected to physicochemical, soil moisture level determination experiments and the corresponding results were obtained (Fig. 1).

Namunalar	Quruq qoldi	Ishqoriylik		Cl	SO_4	Ca	Mg	Anion/ Kation	Na farq bilan		Komponentlar yigindisi %	Oraliq farq	Umumiy natija
		CO_3	Umumiy CO_3						mkg. ekv	%			
Coelastrella cogersae	0,590		0,024	0,029	0,336	0,071	0,040	8,81	1,94	0,045	0,533		1,16
			0,39	0,81	7,61	3,54	3,29	6,89					
Chlorella vulgaris	0,510		0,024	0,028	0,294	0,065	0,38	7,28	0,92	0,021	0,458		1,07
			0,39	0,78	6,11	3,24	3,12	6,36					
Phormidium boyanum	0,640		0,24	0,029	0,377	0,070	0,040	9,04	2,27	0,052	0,580		1,30
			0,39	0,81	7,84	3,49	3,28	6,77					
Nazorat 1	0,280		0,021	0,026	1,142	0,020	0,019	4,04	2,07	0,047	0,257		0,51
			0,34	0,73	2,29	0,99	0,98	1,97					
Nazorat 2	0,329		0,020	0,24	0,176	0,030	0,015	4,65	1,93	0,044	0,229		0,61
			0,32	0,67	3,66	1,49	1,23	2,72					
Nazorat 3	0,516		0,022	0,026	0,298	0,067	0,036	7,28	0,99	0,022	0,460		1,03
			0,36	0,73	6,19	3,34	2,95	6,29					

Figure 1. Physicochemical analyses of inoculated soil samples.

According to the results obtained, the soil samples inoculated with Phormidium and Coleastrella showed high results. Accordingly, it is recommended to isolate these two samples as local and adapted strains among the selected species and multiply them in laboratory conditions for use and introduction into the dried-up Aral Sea bottom soils.

Overall observations showed that significant differences were observed between the control and experimental options.

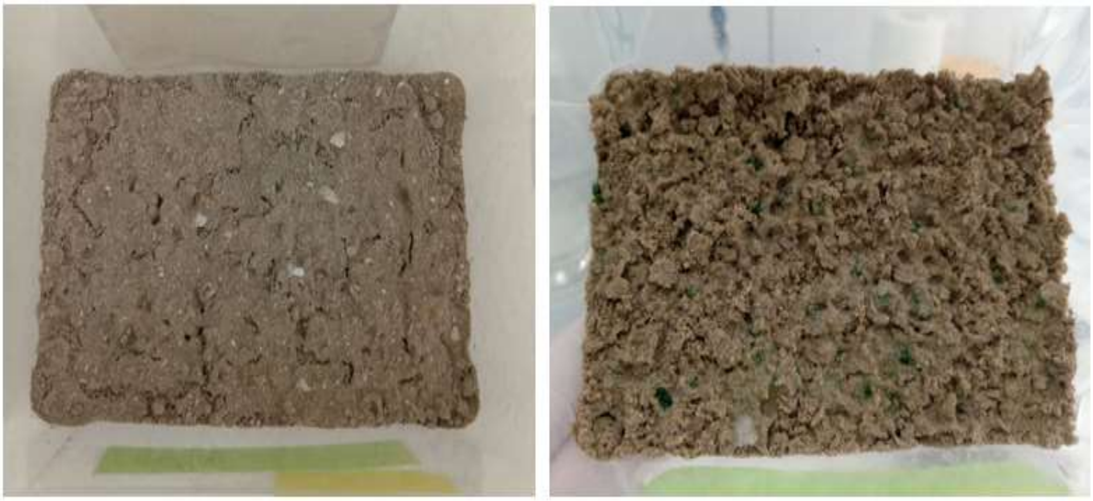
The salinization process in the control variant. Already in the first days of the experiment, after the soil was moistened, a strong mineralization process was observed in the control variants. As a result of the evaporation of moisture, white salt crystals formed on the soil surface and on the walls of the container. This process led to: hardening, compaction of the soil, and the creation of an unfavorable environment for plants[5,6,7].

In the control variant, the formation of white salt crystals in the soil was strongly manifested.

Biofilm formation: Starting from 2-3 days after inoculation, expansion of light green zones (colonization) around the inoculant was observed. This indicates that cyanobacteria and microalgae are actively multiplying in the soil substrate and forming a surface biofilm (biological soil crust) [2,4].

Reduction of salt crystallization: In the presence of cyanobacteria, the intensity of salt crystal formation was significantly reduced, unlike the control option. The soil did not harden as much as in the control option.

Along with the observations, the masses of the samples were also measured and recorded in the table in the order specified in the table. According to this, the soils inoculated on the first day differed from the soils on the second day as follows: It can be seen that the salt content decreased during the period when the cyanobacterial biomass began to increase in the saline soil, and the hardened soil became softer than before. After the cyanobacterial inoculation (after the 6th day), the formation of a green coating on the soil and a decrease in salt crystals were observed.



1 2

Figure 2. Samples selected as inoculants: 1- with microalgae; 2- with cyanobacteria, biofilms formed on the soil surface.

Discussion of results

The results obtained confirm the high efficiency of biological methods, in particular the use of cyanobacteria, in the restoration of extremely saline soils of the Aral Sea region. The strong salinization and soil hardening observed in the control variant are typical of degraded soils, in which the root system of plants cannot develop normally. Also, the active development of strains Ac.NamSU-1, Ac.NamSU-2, Ac.NamSU-3 indicates their high adaptation to the harsh climatic and saline soil conditions of the Aral Sea region [1]. This means that these strains can be used as promising biological agents in the bioremediation of saline soils.

CONCLUSION

Laboratory studies have shown that inoculation of cyanobacterial strains into saline soils is a promising and environmentally safe method of bioremediation using degraded materials. Cyanobacterial and microalgae-based inoculations reduce the migration of salts to the surface by forming a biofilm on the soil surface and soften its physical state.

The use of microalgae as biofertilizers in natural soil environments is of great importance for agriculture. The nutrients contained in microalgae make them a valuable source of organic fertilizers that improve soil health and stimulate plant growth.

A deeper scientific study and analysis of the hydrobionts of the dried-up seabed of the Aral Sea is currently underway. Extensive research is being conducted to assess the ecological state of hydrobionts in the water bodies of the studied areas. In addition, practical and innovative recommendations are being developed on the role of soil and algae in improving plant growth, soil fertility, and the overall ecological state of the soil [6,7].

The drying up of the Aral Sea, increased salinity, and ecological changes in its former seabed basins have led to profound changes in the algal flora and the formation of a new floristic composition for the basin. Scientific research in this area contributes to strengthening the regional scientific potential and creating new knowledge in the fields of hydrobiology, ecology, and sustainable economic development.

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