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Study of agrochemical properties and microbial diversity of soils of Southern Kazakhstan

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Abstract

Background and Aim. Soil is an important component of the ecosystem, providing plants with the nutrients and water resources necessary for their growth and development. The agrochemical properties, pH, and electrical conductivity of soil determine the viability and biological activity of microorganisms. The aim of this study is to investigate the agrochemical indicators (pH, electrical conductivity and nutrient content) of soil samples collected in the Sauran, Zhanakorgan, and Turkestan districts, as well as to evaluate the composition of soil microflora and the morphological, cultural and physiological-biochemical properties of microorganism strains.

Materials and Methods. During the study, the agrochemical indicators of soil samples collected in each district were determined using standard methods. The morphological, cultural, and physiological-biochemical properties of pure cultures of microorganisms isolated from the soil were examined. The ability of the strains to utilize carbohydrates, the activity of amylase and gelatinase enzymes, and their thermo- and salt tolerance were evaluated. In addition, the mutual biocompatibility of the isolated strains was assessed.

Results. The isolated microorganisms were identified at the family level and were found to belong to the genera *Bacillus* spp., *Micrococcus* spp., and *Pseudomonas* spp. Strains *Sn1, Sn5, Sn6, Jn1, Jn2, TBS583* and *TBS588* showed enzymatic activity, the ability to effectively utilise carbohydrates, and resistance to temperature and salt stress. The biocompatibility results demonstrated their ability to grow together without antagonism.

Conclusion. The studied strains are promising microorganisms for increasing soil biological fertility and producing environmentally friendly biofertilizers. Their use in agriculture may contribute to increased plant productivity and the maintenance of soil ecological balance.

Keywords: agrochemical property; biofertilizer; microorganism; soil fertility; soil microflora.

Introduction

According to a 2024 FAO report, the agrochemical properties of approximately 1.4 billion hectares of land have deteriorated, and another 1 billion hectares are at risk due to climate change and inefficient agricultural practices. Other international data and studies (e.g., the Global Saline Soil Map and regional assessments) show that more than 3% of the world's soils have lost their chemical and physical balance in the surface layer, and more than 6% in the deeper layer. Such changes are observed mainly in arid and semi-arid regions [1].

Soil is an important natural resource that ensures the sustainability of natural ecosystems. Its degradation is caused by the interaction of complex biogeochemical, environmental and anthropogenic

factors occurring on spatial and temporal scales. The main processes of soil degradation are rapid erosion, reduction of soil organic carbon (SOC), decline in biodiversity, deterioration of soil fertility, element imbalance, acidification, and salinisation. These processes can be reversed by transitioning to restorative land-use practices and applying appropriate management approaches. The main strategy is to reduce soil erosion, create a positive balance of SOC and nitrogen, increase micro-, meso-. and macro-biodiversity in the soil, and improve structural stability and pore geometry. Improving soil quality by increasing SOC, enhancing soil structure, and improving fertility reduces the risks of soil degradation (physical, chemical, biological, and environmental) and improves environmental conditions [2].

The Turkestan and Kyzylorda regions are among the most important agricultural areas of Kazakhstan, where farming and horticulture are widely developed. However, the climatic characteristics and diversity of soil structure in these regions lead to environmental problems such as salinisation, waterlogging, and wind erosion. Therefore, a comprehensive study of the agrochemical and biological properties of soils is of great importance for increasing their fertility and productivity, as well as for the efficient use of land resources. Determining the chemical composition of the soil, including pH, electrical conductivity, and nutrient levels, as well as studying the soil microflora and the morphophysiological characteristics of microorganisms, makes it possible to ensure the stability of agricultural production in these regions, maintain ecological balance, and effectively plan the agricultural development strategy. For these reasons, the study of soils in the Turkestan and Kyzylorda regions is scientifically and practically relevant and necessary. Comparing the properties of soil microflora under different natural and climatic conditions has made it possible to determine the interaction of local strains and select the most suitable ones, which will allow the development of biological fertilizers in the future [3].

Materials and Methods

The study was conducted at the Kazakh-German-Chinese International Research Laboratory of Applied Microbiology at Al-Farabi Kazakh National University. Soil samples were collected in the Turkestan and Kyzylorda regions for the study:

1. Soil sample: Sauran village. Location: Sauran district, Turkestan region. Depth: 0-30 cm. External morphological characteristics: light brown soil colour, fine-grained structure, dry surface layer, medium density, no pronounced odour, and a small amount of decaying plant remains.

2. Soil sample: Zhanakorgan district. Location: Zhanakorgan District, Kyzylorda Region. Depth: 0-30 cm. External morphological characteristics: brownish soil colour, granular structure, natural odour, and a small amount of decaying plant debris. When dry, the soil is dense; when wet, it becomes soft and homogeneous.

3. Soil sample: Turkestan. Location: Main Botanical Garden of Turkestan Region. Depth: 0-30 cm. External morphological characteristics: light brown soil colour, fine-grained structure, dry surface layer, medium density, no pronounced odour, and a small amount of decayed plant debris.

Determination of electrical conductivity. Soil samples weighing 30 g, with an accuracy of no more than 0.1 g, were mixed in a container, and placed in ten-position cassettes or conical flasks. Distilled water was added to the samples using a dispenser or measuring cylinder at a volume of 150 cm3. The soil-water mixture was srirred for 3 minutes using a shaker, rotator, or propeller mixer and then left to settle for 5 minutes. When using proportional dosing scales for the extractant, it is permissible to use a sample weighing 25-30 g. It is also permissible to proportionally adjust the mass of the soil sample and the volume of distilled water while maintaining a ratio of 1:5, with a dosing error not exceeding 2%. After 5 minutes of settling, the conductometer sensor was immersed in the suspension to determine electrical conductivity. After each measurement, the sensor was thoroughly rinsed with distilled water.

pH measurement. A portion of the soil suspension with a volume of 15-20 cm3 was transferred into a 50 cm^3 beaker and used for pH measurement. The pH meter was calibrated using three buffer solutions with pH values of 4.01, 6.86, and 9.18, prepared from standard titers. The readings were recorded no earlier than 1.5 minutes after immersing the electrodes in the solution, once the instrument readings had stabilised. During operation, the device settings were periodically checked using a buffer solution with a pH of 6.86.

Determination of mobile forms of phosphorus and potassium in soils using the Kirsanov method.

The content of mobile forms of phosphorus and potassium was determined in accordance with GOST 26207–91. The method is based on the extraction of mobile phosphorus and potassium compounds from

the soil using a 0.2 M HCl solution at a soil-to-solution ratio of 1:5 for mineral soils and 1:50 for peat soils. The extraction was carried out at a temperature of (18 ± 3) °C, followed by filtration of the extract.

Phosphorus was determined by a photocolorimetric method in the form of molybdenum blue at a wavelength of 710 nm, and potassium was determined by flame photometry using analytical lines at 766 and 700 nm. The quantitative content of phosphorus and potassium was calculated using calibration curves based on standard reference solutions and expressed in milligrams of P_2O_5 and K_2O per 1 kg of soil.

Modified determination of humus in soils according to the Tyurin method. The humus content was determined according to GOST 26213-91 using a modified Turin method with photocolorimetric detection. The method is based on the oxidation of organic matter in the soil with a potassium dichromate solution in a sulfuric acid medium when heated in a boiling water bath, followed by photocolorimetric determination of trivalent chromium, which is equivalent to the humus content. For the analysis, a soil sample (0.05-0.4 g, depending on the estimated humus content) was placed in test tubes, a chromium mixture was added, and the tubes were kept in a boiling water bath for 1 hour. After cooling, the solution was diluted with distilled water, thoroughly mixed, and allowed to settle until completely clear. The optical density of the analyzed and standard solutions was measured on a photoelectric colorimeter at a wavelength of about 590 nm. The quantitative content of humus was determined using a calibration scale constructed with Mora's salt solutions and calculated taking into account the conversion factors from carbon to humus. The results were expressed as a percentage (%). The permissible error in repeated determinations complied with GOST requirements.

Total nitrogen was determined according to GOST 26107-84 (Kjeldahl method). The method is based on the decomposition of organic matter in soil with concentrated sulfuric acid in the presence of catalysts (K_2SO_4, $CuSO_4$, Se) with the conversion of nitrogen into ammonium form. For the analysis, a soil sample (2.0-4.0 g, depending on humus content) was mineralised with sulfuric acid until the solution became completely colourless. After cooling, the ammonium nitrogen was distilled off in an alkaline medium, captured in a boric acid solution, and determined titrimetrically with a sulfuric acid solution using a mixed indicator. A control analysis was performed simultaneously. In addition, nitrogen was determined by the photometric “indophenol green” method. After mineralization of the soil sample, the optical density of the colored solutions was measured at a wavelength of 655 nm, and the nitrogen content was calculated using a calibration scale of standard solutions.

Laboratory incubation method. CO_2 determination method. The determination of CO_2 content in soil characterizes the soil's biological activity, the respiration-driven decomposition of organic matter, and microbiological processes. A known amount (e.g., 100 g) of moist soil was placed in an airtight container. An open vessel containing an NaOH solution (typically 0.1 N) was placed inside to absorb the CO_2. The jar was sealed and incubated for 5-7 days (25-30 °C). CO_2 reacts with NaOH to form Na_2CO_3. At the end of the incubation period, the excess NaOH was titrated with an HCl solution, and the amount of CO_2 absorbed was calculated [4].

During the study, the general microflora of the soil samples was examined using Koch's serial dilution method, and pure cultures of microorganisms were isolated. MPA, Sabouraud agar, Czapek agar, Simmons agar, tryptone soy agar, and Pseudomonas agar were used as differential diagnostic media. These media created favorable conditions for the growth of various groups of microorganisms and allowed their isolation. The streak method and the Drigalsky method were used to obtain pure cultures. As a result, the morphological and cultural characteristics of microorganisms grown on nutrient media, their physiological and biochemical properties, and the qualitative and quantitative composition of the microflora in the samples were comprehensively studied [5].

Carbohydrate digestion method. This method determines the ability of microorganisms to utilise carbohydrate compounds as a source of energy. During the analysis, various carbohydrates were added to the culture medium, and their enzymatic digestion was determined by the colour change of pH indicators [6].

Gelatin digestion method. The determination of gelatin hydrolysis is used to assess the proteolytic (protein-splitting) activity of microorganisms. Cultures grown in a nutrient medium containing 12-15% gelatin were incubated at a temperature of 28-30 °C for 5-7 days. If the medium remained liquid at the end of incubation, this indicates the hydrolysis of gelatin by proteases [7].

Amylase activity determination method. This method is used to determine the ability of microorganisms to break down starch. A nutrient medium containing 1% starch is inoculated, and after incubation, Lugol's solution was added to the Petri dish. A colourless zone observed around the colony indicated the breakdown of starch by amylase enzymes [8].

The *Glushanov* method was used in the study to assess the biocompatibility of the selected strains of microorganisms. During the procedure, paired combinations of pure cultures obtained from each region were prepared, and cultures from the same region were compared with each other. For each pair, the first culture was inoculated onto a solid nutrient medium in a Petri dish, and after its growth, the second culture was inoculated at a distance of 1-2 mm. The samples were incubated at a temperature of 30 °C, and after 48 hours, the biocompatibility results were evaluated [9]. Based on the results, strains demonstrating high mutual compatibility were selected.

Results and Discussion

Agrochemical properties of soil and electrical conductivity, pH indicators.

The agrochemical characteristics of soil are among the main factors determining its fertility and the availability of nutrients to plants. The acidity (pH) and ionic strength (electrical conductivity, EC) of the soil environment directly affect the vitality, composition, and dominant species of microorganisms. Therefore, analysis of the agrochemical composition of soil is an important method for predicting the distribution and functioning of microflora and for assessing the biological potential of soil.

The main elements of the agrochemical composition of the soil are key factors determining its fertility, biological activity, and ecological stability. A sufficient amount of nutrients (nitrogen, phosphorus, potassium) and humus maintains soil structure stabiliy and creates conditions for the active development of microorganisms. The balanced interaction of these elements improves plant nutrition and increases the intensity of biochemical processes in the soil. In general, the optimal level of agrochemical indicators ensures the productivity and microbiological stability of the soil ecosystem [10]. Agrochemical studies were conducted on soil samples from Turkestan, Sauran and Zhanakorgan. The results of the studies are presented in Table 1.

Table 1 – Agrochemical indicators of soil samples from Turkestan, Zhanakorgan and Sauran

Soil sample	Determined indicators, %				
	Total humus	Total indicators			CO_2
		Nitrogen	Phosphorus	Potassium	
Turkestan	0.46±	0.070±	0.120±	2.498±	5.76±
Zhanakorgan	0.49±	0.098±	0.140±	2.326±	6.32±
Sauran	0.43±	0.077±	0.116±	2.437±	5.76±

Table 1 shows the agrochemical indicators of the three soil samples studied: Turkestan, Zhanakorgan, and Sauran. These indicators included total humus content, total nitrogen, phosphorus, potassium and CO_2. The soil sample from Turkestan showed a total nitrogen content of 0.070%, while the phosphorus and potassium contents were 0.120% and 2.498%, respectively. The CO_2 level was approximately 5.76%, indicating moderate biological activity. Relatively low levels of nitrogen and humus indicate limited accumulation of organic matter and moderate soil fertility.

For comparison, the soil from Zhanakorgan showed slightly higher fertility values. The total humus content reached 0.49%, and the total nitrogen content reached 0.098%, exceeding the values observed in the Turkestan sample. The phosphorus and potassium contents were 0.140% and 2.326%, respectively. The CO_2 concentration was the highest among the soils studied (6.32%), indicating increased microbial respiration and high biological activity. These parameters suggest a more active turnover of organic matter in the soil and better availability of nutrients.

The Sauran soil showed the lowest humus content (0.43%) among the samples, reflecting a reduction in organic matter reserves. The total nitrogen content was 0.077%, phosphorus was 0.116%, and potassium was 2.437%. The CO_2 content (5.76%) was comparable to that of Turkestan, indicating similar, moderate biological activity.

A comparative analysis of the data shows that the soil in Zhanakorgan has the highest fertility potential among the samples studied. This conclusion is confirmed by its humus and total nitrogen contents, which reflect better accumulation of organic matter and nutrient reserves. In addition, the increased concentration of CO_2 indicates enhanced microbial activity and more intense biological processes in the soil, which contribute to improved nutrient cycling and availability. In contrast, the soils from Turkestan and Sauran show lower humus and nitrogen contents, indicating comparatively lower fertility and moderate biological activity.

A number of foreign studies have demonstrated a correlation between pH and electrical conductivity indicators and microbiological parameters. For example, according to *Y.C. Bai* and *Y.Y. Chang* (2020), prolonged exposure to mineral fertilizers leads to a decrease in the amount of organic matter in the soil, which, in turn, affects the structure and diversity of microbial communities [11].

Electrical conductivity is a parameter that measures the concentration of dissolved salts in the soil and reflects the ecological condition affecting plant growth by indicating the level of salinity. The study of the general microflora made it possible to determine the diversity and activity of microorganisms in the soil and served as the basis for assessing the biological fertility of the soil and the level of mineralisation of organic matter [12].

The acidity (pH) and electrical conductivity (salinity level) of soil samples from the Turkestan, Sauran, and Zhanakorgan districts were studied. Table 2 shows the pH and electrical conductivity values of the soil samples.

Table 2 – pH and electrical conductivity of soil samples

№	Soil sample	pH	Electrical conductivity
1	Turkestan	8.1±0.24	290.1±8.7ms/cm
2	Sauran	8.18±0.25	157.7±4.7 ms/cm
3	Zhanakorgan	8.61±0.25	116.5±3.4 ms/cm

As shown in Table 2, the pH and electrical conductivity of soil samples collected from the Turkestan, Sauran and Zhanakorgan districts were determined during the study. The pH level of the Turkestan soil was 8.1 ± 0.24, indicating an alkaline reaction. This pH may affect the absorption of nutrients by plants and reduce the bioavailability of certain micronutrients. The pH value of the Sauran soil was 8.18 ± 0.25, which was similar to that of Turkestan. The Zhanakorgan sample had a higher pH value of 8.61 ± 0.25, indicating that this soil was the most alkaline among the samples studied. High pH values indicate the presence of salinisation and alkalisation problems, which can negatively affect plant growth and require appropriate agrotechnical measures. A subsequent study by *Qiu Xiong* and *M. Liu* (2024) showed that small changes in pH (approximately ±1-2 units) caused significant changes in the structure of bacterial and fungal communities. The results of the study

showed that changes in acidity had a greater effect on bacteria than on fungi, altering their abundance and functional activity [13].

Electrical conductivity is an important indicator for assessing the concentration of dissolved salts in soil. In the Turkestan sample, the electrical conductivity was 290.1 ± 8.7 mS/cm, indicating a high level of salinity. This may negatively affect the physiological condition of plant roots and exacerbate the effects of water deficiency and toxic elements. In the Sauran sample, the electrical conductivity was 157.7 ± 4.7 mS/cm, which is within the normal range of salinity, indicating a relatively low concentration of salts in the soil. The electrical conductivity of the Zhanakorgan soil was the lowest, at 116.5 ± 3.4 mS/cm, indicating a minimum level of salinity and the possibility of creating a favourable environment for plant growth.

In general, the soils of the studied regions had an alkaline pH and varying degrees of salinity. While the high electrical conductivity in Turkestan indicates the severity of the salinity problem, the soils of Zhanakorgan and Sauran are relatively more suitable for agricultural use.

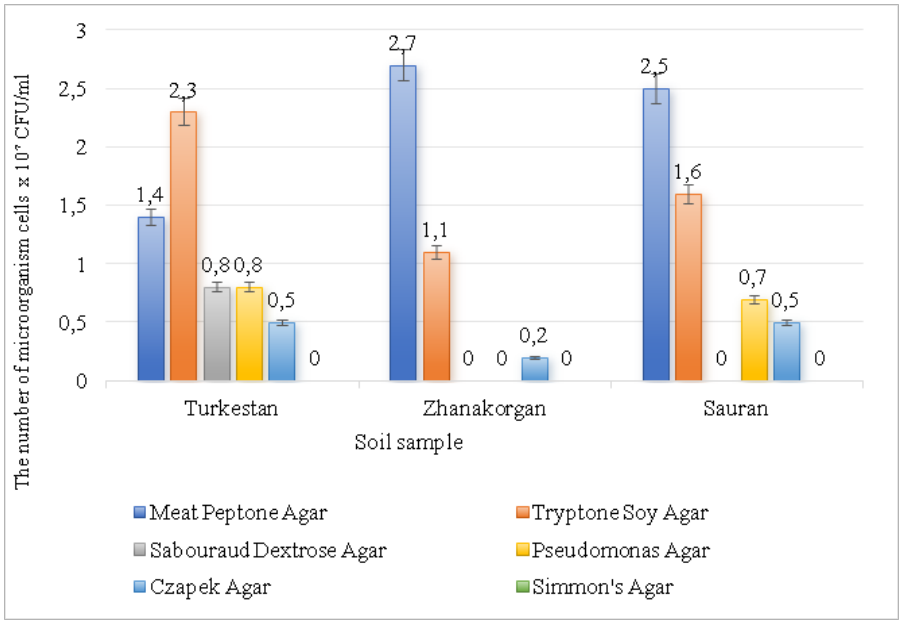


Figure 1 – Microbial community of soil samples from the Turkestan, Zhanakorgan and Sauran districts

As shown in Figure 1, the number of colonies grown on six different nutrient media from the soil microflora of Turkestan was 1.4×107 CFU/ml on the universal nutrient medium MPA. On TSA, a nutrient medium for broad-spectrum bacteria, it was 2.3×107 CFU/ml, on the Sabouraud nutrient medium for yeast and fungi, it was 0.8×107 CFU/ml, on Pseudomonas agar for *Pseudomonas aeruginosa*, it was 0.8×10^7 CFU/ml; and on Czapek medium for mould fungi, it was 0.5×10^7 CFU/ml. However, no growth of microorganisms was observed on Simmons medium used for the cultivation of representatives of the *Enterobacteriaceae* family, indicating that members of the Enterobacteriaceae family were absent in the Turkestan soil sample.

The number of colonies grown on six different nutrient media from the microflora of the Zhanakorgan soil was 2.7×107 CFU/ml on MPA nutrient medium. On TSA, it was 1.1×107 CFU/ml, and on the Czapek medium, it was 0.2×107 CFU/ml. However, no growth of microorganisms was observed on Simmons medium for culturing enterobacteria, or on Sabouraud medium and Pseudomonas agar.

Colonies grown from the Sauran soil sample showed the following values: on MPA medium - 2.5×107 CFU/ml, on TSA medium - 1.6×107 CFU/ml, on agarised Pseudomonas medium - 0.5×107 CFU/ml, on Czapek medium - 0.5×107 CFU/ml. No microbial growth was observed on Sabouraud and Simmons media. Therefore, Enterobacteriaceae and fungi were not detected in the Sauran soil samples. Microbial colonies grew well on MPA, TSA, Czapek, and Pseudomonas media.

Quantitative and qualitative composition of soil microbiocenosis.

The structure and abundance of soil microflora directly depend on agroecological conditions, soil chemical properties, and the amount of organic matter. Microorganisms play a key role in the mineralisation of organic matter and nutrient cycling in the soil, therefore, studying their composition is crucial for improving agricultural productivity. This study made it possible to identify the characteristics of soil microbiocenosis in various regions [15].

Soils from the Turkestan, Sauran, and Zhanakorgan districts were used for microbiological studies. The results are presented in Figure 2.

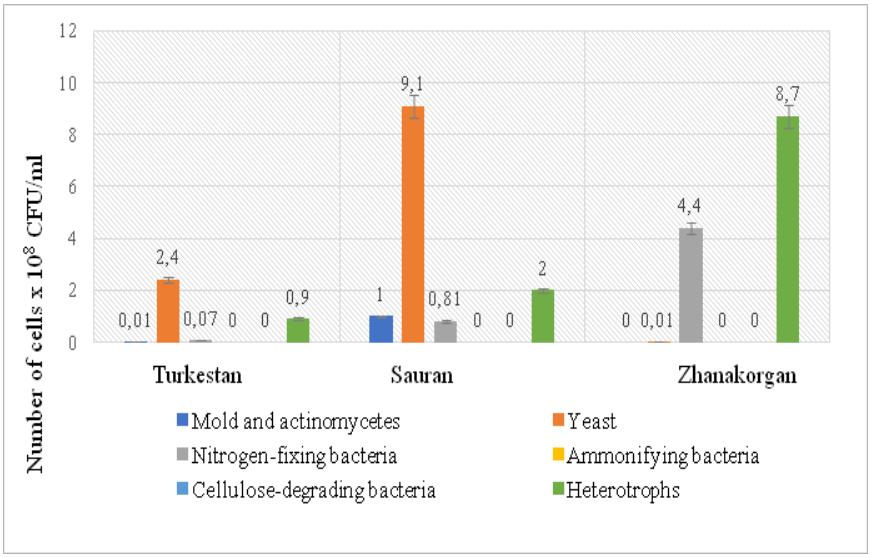


Figure 2 – Quantitative and qualitative composition of soil microbiocenosis

The results of the study presented in Figure 2 showed that the microbiomes of the soil samples from Turkestan, Sauran, and Zhanakorgan differed. In the soil from the Turkestan Botanical Garden, the quantitative composition of the microflora was low. The yeast count in this sample was 2.4×108 CFU/ml, and the heterotrophic bacteria count was 0.9×108 CFU/ml. The counts of mold fungi and actinomycetes were very low (0.01×108 CFU/ml), while nitrogen-fixing, ammonifying, and cellulose-degrading bacteria were not detected.

In the soil sample taken from the Sauran region, the yeast count reached the highest value, 9.1×108 CFU/ml. This value indicates intensive decomposition of organic matter in the soil through fermentation processes. In addition, the heterotroph count was 2.0×108 CFU/ml, while the counts of mould fungi and actinomycete were 1.0×108 CFU/ml. Nitrogen-fixing, ammonifying, and cellulose-degrading microorganisms were also not detected in this sample.

It was established that the microbiological composition of the Zhanakorgan soil was dominated by heterotrophs (8.7×108 CFU/ml) and nitrogen-fixing bacteria (4.4×108 CFU/ml). These indicators suggest high soil biological activity and intensive nitrogen turnover. However, the number of mould fungi and actinomycetes (0.01×108 CFU/ml) was extremely low, and other microbial groups (yeast, ammonifiers, and cellulose decomposers) were also not detected in this sample.

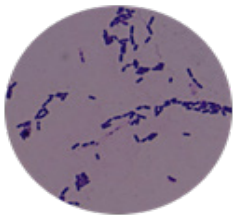
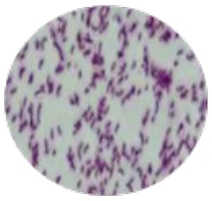
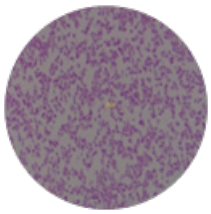
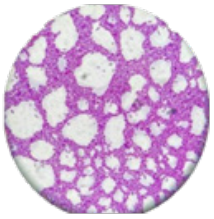
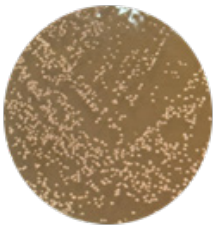
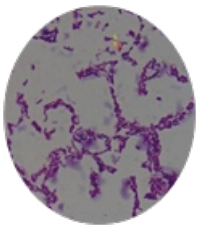
Overall, the obtained data demonstrate the specific structure of the microbiocenosis of the studied soil samples. Although microbial activity in the soils of Turkestan was limited, the high occurrence of certain groups in the Sauran and Zhanakorgan districts indicates that these soils are rich in organic matter and microbiologically active.

The streaking method was used to isolate pure cultures of microorganisms. Eight pure strains isolated from the soil samples were assigned the following conditional names: Turkestan (TBS83; TBS58), Zhanakorgan (Jn1; Jn2), and Sauran (Sn1; Sn5; Sn6; Sn9).

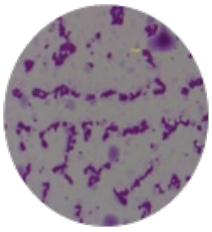
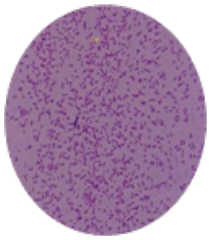
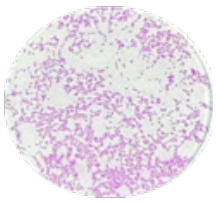
Morphological and cultural properties of pure cultures isolated from soil samples.

A study of the morphological and cultural properties of pure cultures isolated from soil samples was conducted to determine their varietal characteristics and physiological activity. The results make it possible to characterise the diversity of soil microflora and identify the most common groups of microorganisms. Morphological and cultural studies allow the determination of cell shape, size, spatial arrangement, the presence of spores and capsules, and microbial motility. The study determined the macro- and micromorphological characteristics of bacterial strains isolated from soil samples from Sauran (Sn), Zhanakorgan (Jn), and the Turkestan Botanical Garden (TBS). A total of eight strains were studied, and their morphological characteristics are described below. The results are presented in Table 3.

Table 3 – Macromorphological and micromorphological properties of pure cultures

№	Strain name	Macromorphology	Description	Cell micromorphology, ×100	Description
1	*Sn1*		Shape: round Surface: smooth Profile: smooth Transparency:matte Color: yellowish Edge: smooth Structure: uniform Consistency: soft		Shape: rod-shaped Size: 1.4 µm; Arrangement: clustered Motility: absent Nutrient: TSA Spore formation: spore-forming
2	*Sn9*		Shape: round Surface: smooth Profile: smooth Transparency: glossy Color: white Edge: smooth Structure: uniform Consistency: soft		Shape: rod-shaped Size: 1.8 µm; 3.6 µm Location: solitary Motility: mobile Nutrient medium: Czapek Spore formation: non-spore-forming
3	*Sn5*		Shape: round; Size: 5-7 mm; Surface: smooth; Side view: smooth; Transparency: transparent; Color: pigmented white; Edge: smooth; Texture: uniform; Consistency: soft.		Shape: rod Size: 1.6 µm; 3.2 µm Location: solitary; Nutrient medium: Sabouraud; Motility: absent Spore formation: spore-forming
4	*Sn6*		Shape: round Size: 4-6 mm; Surface: rough; Flatness: convex; Transparency: powdery; Color: pigmented white; Texture: smooth; Structure: uniform Consistency: soft		Shape: rod; Size: 1.15 µm; 2.3 µm; Arrangement: clustered; Nutrient medium: TSA Motility: none
5	*Jn1*		Shape: round Size: uniform Surface: rough Side view: wavy Transparency: glossy Color: pigmented white Edge: undulate Structure: homogeneous Consistency: soft		Shape: rod-shaped; Size: 1.4–4.4 µm; Arrangement: in groups; Food environment: Czapek; Motility: absent

Continuation of Table 3

6	*Jn2*		Shape: round Size: 4 mm-1 cm Surface: smooth Width: rough Transparency: shiny Color: white Edge: smooth Structure: uniform Consistency: soft		Shape: spherical; Size: 0.5 μm; Arrangement: grouped; Nutrient medium: TSA; Motility: absent
7	*TBS588*		Shape: round; Size: 5-10 mm; Surface: smooth; Side view: smooth; Transparency: transparent; Color: pigmented white; Edge: smooth; Texture: uniform; Consistency: soft.		Shape: rod-shaped Size: 1.5 μm; 3 μm Arrangement: grouped Nutrient medium: Sabouraud Motility: absent; Spore-forming
8.	*TBS583*		Shape: round; Size: 2-8 mm; Surface: smooth; Appearance: teardrop-shaped; Transparency: shiny; Color: pigmented white; Edge: smooth; Texture: uniform; Consistency: soft		Shape: rod-shaped; Size: 2 μm; 4 μm; Location: clustered; Nutrient medium: Pseudomonas; Motility: absent

As shown in Table 3, the pure cultures isolated from the Turkestan region were TBS583 and TBS588. The pure cultures isolated from the Zhanakorgan district for study were Jn1 and Jn2. The pure cultures isolated from the village of Sauran were *Sn1, Sn5, Sn*6, and *Sn9*.

Colonies of strains *Sn1, Sn5,* and *Sn6* isolated from the Sauran soil sample were round, white or yellowish, with a smooth or rough surface, a uniform structure, and a soft consistency. The cells were rod-shaped (1.15-4.2 μm), arranged singly or in groups, non-motile, and capable of sporulation. Colonies of strain *Sn9* were white, shiny, and round, with rod-shaped cells (1.8-3.6 μm) arranged singly and showing motility. This strain did not form spores.

Colonies of strain *Jn1*, isolated from a soil sample in Zhanakorgan, were white, with a rough surface, wavy edges, and a soft consistency. The cells were rod-shaped (1.4-4.4 μm), arranged in groups, and non-motile. Strain *Jn2* consists of spherical, motile cells (0.5 μm); the colonies were shiny, white, and uniform in structure.

Colonies of TBS588, isolated from a soil sample in the Turkistan Botanical Garden, were white, transparent, smooth, and soft, with rod-shaped cells (1.5-3 μm), arranged in groups; the cells were non-motile, and spore-forming. Strain TBS583 formed round, shiny colonies with rod-shaped cells (2-4 μm), which were non-motile.

Physiological and biochemical properties of promising pure cultures

The physiological and biochemical properties of promising pure cultures isolated during the study were analysed to assess their metabolic activity. The ability of microorganisms to utilise carbon and nitrogen sources, their enzymatic activity, and their resistance to stress factors were determined. These properties indicate the extent of their participation in the turnover of organic matter in the soil and their ability to stimulate plant growth [16].

Studying the growth characteristics of microorganisms at different temperatures and salt concentrations is important for determining their environmental adaptability and physiological resistance. Such studies make it possible to assess the response of microorganisms to extreme environmental factors and determine the possibility of their effective use for biotechnological or agroecological purposes. For example, according to *D. Egamberdieva* (2019), bacteria capable of surviving under high salinity conditions play an important role in the decomposition of organic waste and stimulation of plant growth [17]. In addition, studies of *S. Anjney* (2021) found that changes in temperature and NaCl concentration have a significant effect on the metabolic activity and enzyme secretion of microorganisms [18].

During the study, the tolerance of promising pure cultures isolated from different regions to temperature and salt concentrations was investigated. The growth of pure cultures under different temperature regimes and NaCl concentrations was determined, and their ability to adapt to extreme environmental conditions was assessed (Table 4).

Table 4 – Temperature tolerance and salt tolerance of the studied strains

№	Strain name	t◦ heat resistance			Growth of pure cultures at NaCl concentrations		
		28 ºC	37 ºC	45 ºC	2%	4%	6%
1	*Sn1*	+++	++	++	+++	++	+
2	*Sn9*	+++	++	+	+++	++	+
3	*Sn5*	+++	++	++	+++	++	+
4	*Sn6*	+++	++	+	+++	++	+
5	*Jn1*	+++	++	-	+++	++	++
6	*Jn2*	+++	+++	-	+++	+++	+
7	*TBS583*	+++	++	+	+++	++	-
8	*TBS588*	+++	+	+	+++	++	+

Note! +++\very good growth; ++\good growth; +\poor growth; -/no growth

As shown in Table 4, the results of the study on microbial thermostability demonstrated that all strains - *Sn1, Sn5, Sn6, Sn9, Jn1, Jn2, TBS583*, and *TBS588* - maintained a high growth rate at 28 °C. At 37 °C, the *Jn2* strain demonstrated exceptional tolerance, showing very high growth. At this temperature, the *Sn1, Sn5, Sn6, Sn9, Jn1,* and *TBS583* strains showed moderate growth, while the *TBS588* strain exhibited weak growth. At 45 °C, no growth was observed for strains *Jn1* and *Jn2*, whereas the cultures of *Sn1, Sn5, Sn6, Sn9, TBS583*, and *TBS588* showed weak or low growth.

Based on salinity tolerance indicators, all cultures maintained a high level of growth at a 2% NaCl concentration. At 4% salinity, *Jn1* and *Jn2* continued to grow well, demonstrating high tolerance. The *Sn1, Sn5, Sn6, Sn9*, and *TBS583* strains showed moderate growth, while the growth of strain *TBS588* decreased. At a 6% NaCl concentration, *Jn1* maintained a good growth rate, and strain *Jn2* also grew relatively well. The remaining strains - *Sn1, Sn5, Sn6, Sn9*, and *TBS588* - showed weak growth at high salt concentrations, while TBS583 lost its ability to grow in a 6% salt solution.

These data clearly demonstrate the levels of tolerance of the microorganisms to various temperature and salinity stresses. Strains *Jn1* and *Jn2* exhibited relatively high tolerance to elevated temperatures and saline conditions and can therefore be considered effective strains for use under agroecological conditions.

The breakdown of carbohydrates by pure cultures is necessary to meet their energy and carbon requirements. Through this process, microorganisms produce ATP (energy) and synthesize the metabolic products needed for growth and reproduction [19]. The isolated pure cultures were inoculated into media containing glucose, fructose, sucrose, lactose, and maltose. The results of the carbohydrate degradation are shown in Table 5.

Table 5 – Carbohydrate-degrading activity of pure cultures

Strain name	Glucose	Fructose	Sucrose	Maltose	Lactose
Sn1	+	+	+	+	+
Sn9	+	+	+	+	-
Sn5	+	+	+	+	-
Sn6	+	+	+	+	-
TBS583	+	+	+	+	+
TBS588	+	+	+	+	+
Jn1	+	+	+	+	+
Jn2	+	+	+	+	-

Note! +\ indicates degradation; -/ indicates no degradation

The carbohydrate utilization properties of the studied pure cultures indicate their metabolic activity and level of adaptation to the environment. All the strains - *Sn1, Sn5, Sn6, Sn9, TBS583, TBS588, Jn1* and *Jn2* - demonstrated the ability to hydrolyze glucose, fructose, sucrose, and maltose. This indicates that these microorganisms can effectively utilize major energy substrates and exhibit high adaptability Win metabolic processes. However, the ability to utilise lactose varied among the strains. Strains *Sn1, TBS583, TBS588,* and *Jn1* effectively hydrolyzed lactose, whereas this ability was not observed in strains *Sn9, Sn5, Sn6*, and *Jn2*.

Microbial amylolytic and gelatinolytic activity

Determining the amylolytic activity of microorganisms makes it possible to assess their ability to break down starch and other complex carbohydrates. This property is important for understanding the role of microorganisms in the carbon cycle and the mineralization of organic matter. In addition, strains with amylolytic activity are widely used in biotechnology, especially in the production of enzymes and biological products [8].

Gelatin degradation is used to determine the proteolytic activity of microorganisms. This property reflects their ability to enzymatically break down protein substrates. Proteolytic microorganisms make a significant contribution to the mineralization of organic residues in soil and to nitrogen cycling. In addition, such microorganisms are used in biotechnology as a source for producing protease enzymes [20]. The amylolytic activity and proteolytic potential of strains *Sn1, Sn5, Sn6, Sn9, Jn1, Jn2, TBS583,* and *TBS588*, isolated from soil samples collected in the Turkestan Botanical Garden, Sauran, and Zhanakorgan, were studied by assessing starch hydrolysis and gelatin hydrolysis. (Table 6).

Table 6 – Enzymatic activity of isolated pure cultures

Strain name	*Sn1*	*Sn5*	*Sn6*	*Sn9*	*Jn1*	*Jn2*	*TBS583*	*TBS588*
Starch	+	+	+	+	+	+	+	+
Gelatin	+	+	+	+	-	+	+	-

Note! +\ indicates degradation; -/ indicates no degradation

The study of microorganisms' amylolytic activity is shown in Figure 3.

Sn6 *Jn2*

Figure 3 – Amylolytic activity of pure cultures

The isolated pure culture strains were inoculated into an egg-peptone-gelatin (EPG) medium.

The results of the gelatin degradation are presented in Table 6.

Regarding the gelatinase activity, strains *Sn1, Sn5, Sn6, Sn9, Jn2*, and *TBS583* hydrolyzed gelatin and showed enzymatic activity. In contrast, gelatinase activity was not detected in strains *Jn1* and *TBS588*, indicating their limited potential for degrading protein substrates. Most of the microorganisms producing amylase also exhibit gelatinase activity, demonstrating broad-spectrum enzymatic potential and a high capacity for organic matter degradation.

Determining the mutual biocompatibility of prospective strains

Determining the biocompatibility of microorganism strains is important for assessing their antagonistic or cooperative interactions. The Glushanov method is based on identifying the zone of growth inhibition between microorganisms. This method is primarily used for selecting biocompatible microorganisms when establishing a consortium, since compatible strains do not inhibit each other's growth but instead may enhance their metabolic activity [9].

The biocompatibility of the pure cultures *Sn1, Sn5, Sn6, Sn9, Jn1, Jn2, TBS583*, and *TBS588,* isolated from soil samples, was investigated. The biocompatibility results of the Sn5-Sn6 isolates from the Sauran soil sample are shown in Figure 4.

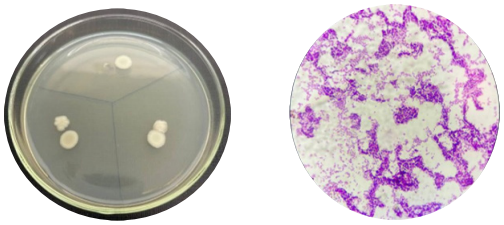


Figure 4 – Visualization of the biocompatibility of the Sn5-Sn6 cultivars

The *Sn5-Sn6* pair exhibited mutually compatible growth. Microscopic examination revealed that both strains consisted of short, rod-shaped, non-motile cells. The cells were arranged evenly and densely, and no signs of spore formation were observed. This confirms their physiological similarity and suggests a predisposition to symbiotic interaction.

When *Jn1* and *Jn2*, isolated from the soil of the Zhanakorgan district, were co-cultivated, no zone of inhibition was observed between them, however, the growth boundaries were clearly defined. This pattern indicates an interaction of mutual neutrality and was assessed as a low degree of biocompatibility. Although the cultures grew side by side, no clear signs of compatibility were observed.

Figure 5 – Overview of the biocompatibility of Jn1-Jn2 cultivars

The *TBS583* and *TBS588* cultivars, isolated from Turkestan soil, showed good compatibility and their growth boundaries merged.

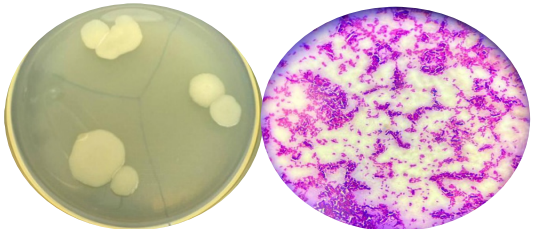


Figure 6 – Overview of the biocompatibility of the *TBS583* and *TBS588* cultivars

A positive correlation was observed between the *TBS583* and *TBS588* isolated from the Turkestan soil sample. Microscopically, both consisted of small, thin, rod-shaped cells arranged in single files. The colony density and structure were also similar, indicating their potential for symbiotic interaction.

Conclusion

An analysis of the agrochemical properties of soils from the Turkestan, Zhanakorgan, and Sauran regions revealed differences in organic and mineral content, reflecting their fertility and biological activity. The soil of Turkestan was characterised by an average level of fertility: humus - 0.46%, total nitrogen - 0.070%, phosphorus - 0.120%, potassium - 2.498%, CO_2 concentration - 5.76%, pH - 8.1, electrical conductivity - 290.1 mS/cm. These values indicate moderate biological activity and a high level of salinity, which may limit nutrient uptake by plants. The soil of Zhanakorgan had the highest fertility potential among the samples studied: humus - 0.49%, total nitrogen - 0.098%, phosphorus - 0.140%, potassium - 2.326%, CO_2 concentration - 6.32%, pH - 8.61, electrical conductivity - 116.5 mS/cm. These indicators point to high microbial activity, intensive organic matter turnover, and minimal salinity, creating favorable conditions for plants. The soil in Sauran has the lowest humus content - 0.43%, total nitrogen - 0.077%, phosphorus - 0.116%, potassium - 2.437%, CO_2 concentration - 5.76%, pH - 8.18, electrical conductivity - 157.7 mS/cm, which corresponds to moderate biological activity and a relatively low level of salinity. A comparative analysis showed that the soils of Zhanakorgan had the highest humus and nitrogen content, as well as the highest CO_2 level and lowest electrical conductivity. This reflects better accumulation of organic matter, more active microbial life, and optimal conditions for plant nutrient uptake. In contrast, the soils of Turkestan and Sauran were characterised by lower humus and nitrogen contents, moderate biological activity, and higher salinity (especially in Turkestan), which may limit their fertility.

The study of the morphological and physiological characteristics of soil microorganisms plays a special role in determining their ecological adaptability and biotechnological significance. The growth characteristics and enzyme activities of pure cultures isolated from soil samples of the Turkestan Botanical Garden and the Sauran and Zhanakorgan regions of the Turkestan and Kyzylorda oblasts reflect the influence of regional ecological factors. Such studies make it possible to assess soil microbiological indicators and to select effective strains for agricultural application.

Physiological studies revealed that all strains maintained high growth activity at 28 °C, indicating their mesophilic nature. At 37 °C, strain Jn2 exhibited exceptional tolerance, while under high-temperature stress at 45 °C, strains *Sn1, Sn5, Sn6,* and *TBS583* showed weak but stable growth. According to the salinity tolerance results, all strains grew actively at a 2% NaCl concentration, while at 4% and 6% salinity, strains Jn1 and Jn2 were distinguished by their high adaptability. This indicates that they possess halophilic or halotolerant properties and suggests that such microorganisms can be used for the biological restoration and productivity enhancement of saline soils.

In terms of metabolic activity, all of the studied strains were able to efficiently break down glucose, fructose, sucrose, and maltose. This demonstrates their ability to utilize various carbohydrates as carbon sources and confirms the high efficiency of their energy metabolism. However, the ability to hydrolyze lactose varied among the strains. While strains *Sn1, TBS583, TBS588,* and *Jn1* showed this activity, it was not observed in strains *Sn5, Sn6, Sn9,* and *Jn2*.

As a result of the study of enzymatic activity, it was determined that all strains synthesised the enzyme amylase, which means that they can hydrolyze starch and use it as a source of energy. Amylase activity plays an important role in the cycling of organic matter in soil and increases the availability of nutrients in the plant rhizosphere. In addition, gelatinase activity was observed in strains *Sn1, Sn5, Sn6, Sn9, Jn2,* and *TBS583*, indicating their ability to degrade protein substrates. However, gelatinase activity was not detected in strains Jn1 and TBS588, suggesting that these strains have limited proteolytic potential.

The results of the study showed that strains *Sn1, Sn5, Sn6, Sn9, Jn1, Jn2, TBS583*, and *TBS588,* isolated from soil samples from Sauran, Zhanakorgan and the Turkestan Botanical Garden exhibited differences in their morphological, physiological, and biochemical characteristics. Strains Sn1, Sn5, and Sn6 isolated from the Sauran soil sample, as well as strains *TBS583* and *TBS588* isolated from the Turkestan Botanical Garden, were identified as Bacillus spp. These isolates were homogeneous in colony morphology, structure, and consistency, and exhibited spore-forming ability and high adaptability.

The *Jn1* and *Jn2* strains isolated from the Zhanakorgan district were identified as *Bacillus* spp. and *Micrococcus* spp., respectively, while strain *Sn9* was identified as a representative of *Pseudomonas* spp. These microorganisms, belonging to different genera, demonstrate the biochemical diversity of the soil and the ecological adaptation of the microbiota.

Overall, the results obtained showed that most of the studied strains have high adaptability, enzymatic activity, and the ability to efficiently utilize carbon sources. These properties make strains *Sn1, Sn5, Sn6, Jn1, Jn2, TBS583,* and TBS588 promising microorganisms for biofertilizer production and for enhancing soil biological fertility.

Authors' Contributions

The authors GA, PS, and AM: contributed to the development and design of the research concept, verification of the final version of the article, quality control of experiments, participation in the discussion of the results, and scientific editing of the text. KS, MY, YI: were responsible for the organization and performance of laboratory analyses, processing of the received data, writing of the main part of the article, statistical data processing, preparation of materials, and text structuring. All authors have read, reviewed, and approved the final version of the manuscript.

References

1 Smith, P., Adhya, T., Arias-Navarro, C., Chaplot, V., Chivenge, P., Cotrufo, M.F., Engelbrecht, B., Zhang, W. (2024). Status of soils worldwide. *Annual report on environment and resources,* 49, 075629. DOI: 10.1146/annurev-environ-030323-075629.

2 Lal, R. (2015). Restoration of soil quality to curb soil degradation. *Sustainability*, 7(5), 5875-5895. DOI: 10.3390/su7055875.

3 Hu, Y., Han, Y., Zhang, Y. (2020). Land desertification and its influencing factors in Kazakhstan. *J. Arid Environ*, 180, 104203.

4 Вильдфлуш, И.Р. (2018). *Агрохимия. Учебная практика: учебно-методическое пособие*. Горки: Белорусская государственная сельскохозяйственная академия, 171.

5 Лавренчук, Л.С., Ермошин, А.А. (2019). *Микробиология: практикум.* Екатеринбург: Уральский федеральный университет, 43-47.

6 Лысак, В.В., Желдакова, Р.А., Фомина, О.В. (2015). *Микробиология. Практикум: пособие.* Минск: Белорусский государственный университет, 53, 115.

7 Li, D., Xu, J., Ju, H., Lu, Z. (2020). Screening and characterization of protease-producing bacteria for gelatin degradation from soil samples. *Frontiers in Microbiology,* 11, 578401. DOI:10.3389/fmicb.2020.578401.

8 Sharma, A., Shukla, S., Singh, S. (2021). Screening and characterization of amylase-producing bacteria from soil samples. *Journal of Applied Microbiology,* 131(3), 1122-1133. DOI:10.1111/jam.15041.

9 Глушанова, Н.А., Шендеров, Б.А. (2005). Взаимоотношения пробиотических и индигенных лактобацилл хозяина в условиях совместного культивирования i*n vitro. Журнал микробиологии, эпидемиологии и иммунологии*, 2, 56-61.

10 Xiao, X., Li, J., Lyu, J., Feng, Z., Zhang, G., Yang, H., Gao, C., Jin, L., Yu, J. (2022). Reduction of chemical fertilizer combined with bio-organic fertilizers increases cauliflower yield via regulation of soil biochemical properties and bacterial communities in Northwest China. *Frontiers in Microbiology*, 13, 922149. DOI:10.3389/fmicb.2022.922149.

11 Bai, Y.-C., Chang, Y.-Y., Hussain, M., Lu, B., Zhang, J.-P., Song, X.-B., Lei, X.-S., Pei, D. (2020). Soil Chemical and Microbiological Properties Are Changed by Long-Term Chemical Fertilizers That Limit Ecosystem Functioning. *Microorganisms*, 8(5), 694. DOI:10.3390/microorganisms8050694.

12 Liu, D., Gao, P., Niu, J., Qu, Z., Guo, S., Ding, C., Lou, Y., Yang, Q., Wang, H., Yang, Z., Di, H., Pan, H., Zhuge, Y. (2024). Assessment of microbial diversity in various saline soils driven by salt content. *Pedobiologia*, 104, 150997. DOI: 10.1016/j.pedobi.2024.150997.

13 Xiong, Q., Liu, M., Wang, Z., et al. (2024). Effects of soil pH changes on bacterial and fungal community composition in agricultural ecosystems. *Applied and Environmental Microbiology,* 01234-24. DOI: doi.org/10.1128/aem.

14 Maron, P.-A, Sarr, A., Kaisermann, A., Lévêque, J., Mathieu, O., Guigue, J., Karimi, B., Bernard, L., Dequiedt, S., Terrat, S., Chabbi, A., Ranjard, L. (2018). High microbial diversity promotes soil ecosystem functioning. *Applied and Environmental Microbiology*, 84(2), e02738-17. DOI:10.1128/AEM.02738-17.

15 Gupta, A., Singh, U.B., Sahu, P.K., Paul, S., Kumar, A., Malviya, D., Singh, S., Kuppusamy, P., Singh, P., Paul, D., Rai, J.P., Singh, H.V., Manna, M.C., Crusberg, T.C., Kumar, A., Saxena, A.K. (2022). Linking soil microbial diversity to modern agriculture practices: A review. *International Journal of Environmental Research and Public Health*, 19(5), 3141. DOI:10.3390/ijerph19053141.

16 Daunoras, J., Kačergius, A., Gudiukaitė, R. (2024). The role of soil microbiota enzymes in soil health and activity changes depending on climate change and the type of soil ecosystem. *Biology (Basel)*, 13(2), 85. DOI:10.3390/biology13020085.

17 Egamberdieva, D., Wirth, S., Bellingrath-Kimura, S.D., Mishra, J., Arora, N.K. (2019). Salt-tolerant plant growth promoting rhizobacteria for enhancing crop productivity of saline soils. *Frontiers in Microbiology*, 10, 2791. DOI:10.3389/fmicb.2019.02791.

18 Sharma, A., Singh, R.K., Singh, P., Vaishnav, A., Guo, D.-J, Verma, K.K., Li, D.-P., Song, X.-P, Malviya, M.K., Khan, N., Lakshmanan, P., Li, Y.-R. (2021). Insights into the bacterial and nitric oxide-induced salt tolerance in sugarcane and their growth-promoting abilities. *Microorganisms*, 9(11), 2203. DOI:10.3390/microorganisms9112203.

19 López-Mondéjar, R., Tláskal, V., Nunes da Rocha, U., Baldrian, P. (2022). Global Distribution of Carbohydrate Utilization Potential in the Prokaryotic Tree of Life. *mSystems*, 7(6), e00829-22. DOI:10.1128/msystems.00829-22.

20 Gudzenko, O., Varbanets, L., Avdiyuk, K., Pasichnyk, L. (2023). Proteolytic activity of Bacillus strains isolated from soil of rice agrocenosis. *Mikrobiolohichnyi Zhurnal*, 85(6), 41-47. DOI:10.15407/microbiolj85.06.041.

References

1 Smith, P., Adhya, T., Arias-Navarro, C., Chaplot, V., Chivenge, P., Cotrufo, M.F., Engelbrecht, B., Zhang, W. (2024). Status of soils worldwide. *Annual report on environment and resources*, 49, 075629. DOI: 10.1146/annurev-environ-030323-075629.

2 Lal, R. (2015). Restoration of soil quality to curb soil degradation. *Sustainability*, 7(5), 5875-5895. DOI: 10.3390/su7055875.

3 Hu, Y., Han, Y., Zhang, Y. (2020). Land desertification and its influencing factors in Kazakhstan. *J. Arid Environ*, 180, 104203.

4 Vil'dflush, I.R. (2018). *Agrohimiya. Uchebnaya praktika: uchebno-metodicheskoe posobie.* Gorki: Belorusskaya gosudarstvennaya sel'skohozyaistvennaya akademiya, 171.

5 Lavrenchuk, L.S., Ermoshin, A.A. (2019). *Mikrobiologiya: praktikum.* Ekaterinburg: Ural'skii federal'nyi universitet, 43-47.

6 Lysak, V.V., Zheldakova, R.A., Fomina, O.V. (2015). *Mikrobiologiya. Praktikum: posobie.* Minsk: Belorusskii gosudarstvennyi universitet, 53, 115.

7 Li, D., Xu, J., Ju, H., Lu, Z. (2020). Screening and characterization of protease-producing bacteria for gelatin degradation from soil samples. *Frontiers in Microbiology*, 11, 578401. DOI:10.3389/fmicb.2020.578401.

8 Sharma, A., Shukla, S., Singh, S. (2021). Screening and characterization of amylase-producing bacteria from soil samples. *Journal of Applied Microbiology*, 131(3), 1122-1133. DOI:10.1111/jam.15041.

9 Glushanova, N.A., Shenderov, B.A. (2005). Vzaimootnosheniya probioticheskih i indigennyh laktobacill hozyaina v usloviyah sovmestnogo kul'tivirovaniya *in vitro. Zhurnal mikrobiologii, epidemiologii i immunologii*, 2, 56-61.

10 Xiao, X., Li, J., Lyu, J., Feng, Z., Zhang, G., Yang, H., Gao, C., Jin, L., Yu, J. (2022). Reduction of chemical fertilizer combined with bio-organic fertilizers increases cauliflower yield via regulation of soil biochemical properties and bacterial communities in Northwest China. *Frontiers in Microbiology,* 13, 922149. DOI:10.3389/fmicb.2022.922149.

11 Bai, Y.-C., Chang, Y.-Y., Hussain, M., Lu, B., Zhang, J.-P., Song, X.-B., Lei, X.-S., Pei, D. (2020). Soil Chemical and Microbiological Properties Are Changed by Long-Term Chemical Fertilizers That Limit Ecosystem Functioning. *Microorganisms*, 8(5), 694. DOI:10.3390/microorganisms8050694.

12 Liu, D., Gao, P., Niu, J., Qu, Z., Guo, S., Ding, C., Lou, Y., Yang, Q., Wang, H., Yang, Z., Di, H., Pan, H., Zhuge, Y. (2024). Assessment of microbial diversity in various saline soils driven by salt content. *Pedobiologia*, 104, 150997. DOI: 10.1016/j.pedobi.2024.150997.

13 Xiong, Q., Liu, M., Wang, Z., et al. (2024). Effects of soil pH changes on bacterial and fungal community composition in agricultural ecosystems. *Applied and Environmental Microbiology*, 01234-24. DOI: doi.org/10.1128/aem.

14 Maron, P.-A, Sarr, A., Kaisermann, A., Lévêque, J., Mathieu, O., Guigue, J., Karimi, B., Bernard, L., Dequiedt, S., Terrat, S., Chabbi, A., Ranjard, L. (2018). High microbial diversity promotes soil ecosystem functioning. *Applied and Environmental Microbiology*, 84(2), e02738-17. DOI:10.1128/AEM.02738-17.

15 Gupta, A., Singh, U.B., Sahu, P.K., Paul, S., Kumar, A., Malviya, D., Singh, S., Kuppusamy, P., Singh, P., Paul, D., Rai, JP, Singh, H.V., Manna, M.C., Crusberg, T.C., Kumar, A., Saxena, A.K. (2022). Linking soil microbial diversity to modern agriculture practices: A review. *International Journal of Environmental Research and Public Health,* 19(5), 3141. DOI:10.3390/ijerph19053141.

16 Daunoras, J., Kačergius, A., Gudiukaitė, R. (2024). The role of soil microbiota enzymes in soil health and activity changes depending on climate change and the type of soil ecosystem. *Biology (Basel)*, 13(2), 85. DOI:10.3390/biology13020085.

17 Egamberdieva, D., Wirth, S., Bellingrath-Kimura, S.D., Mishra, J., Arora, N.K. (2019). Salttolerant plant growth promoting rhizobacteria for enhancing crop productivity of saline soils. *Frontiers in Microbiology*, 10, 2791. DOI:10.3389/fmicb.2019.02791.

18 Sharma, A., Singh, R.K., Singh, P., Vaishnav, A., Guo, D.-J, Verma, K.K., Li, D.-P., Song, X.-P, Malviya, M.K., Khan, N., Lakshmanan, P., Li, Y.-R. (2021). Insights into the bacterial and nitric oxide-induced salt tolerance in sugarcane and their growth-promoting abilities. *Microorganisms*, 9(11), 2203. DOI:10.3390/microorganisms9112203.

19 López-Mondéjar, R., Tláskal, V., Nunes da Rocha, U., Baldrian, P. (2022). Global Distribution of Carbohydrate Utilization Potential in the Prokaryotic Tree of Life. *mSystems, 7(6), e00829-22. DOI:10.1128/msystems.00829-22.*

20 Gudzenko, O., Varbanets, L., Avdiyuk, K., Pasichnyk, L. (2023). Proteolytic activity of Bacillus strains isolated from soil of rice agrocenosis. *Mikrobiolohichnyi Zhurnal*, 85(6), 41-47. DOI:10.15407/microbiolj85.06.041.

Оңтүстік Қазақстан топырақтарының агрохимиялық қасиеттері мен микробтық әртүрлілігін зерттеу

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Түйін

Алғышарттар мен мақсат. Топырақ экожүйенің маңызды құрамдас бөлігі болып табылады, өсімдіктердің өсуі мен дамуы үшін қажетті қоректік заттармен және су ресурстарымен қамтамасыз етеді. Топырақтың агрохимиялық қасиеттері, pH және электр өткізгіштігі микроорганизмдердің өміршеңдігі мен биологиялық белсенділігін анықтайды.

Бұл зерттеудің мақсаты Сауран, Жаңақорған және Түркістан аймақтарында жиналған топырақ үлгілерінің агрохимиялық көрсеткіштерін (pH, электрөткізгіштік, қоректік заттардың құрамы) зерттеу, сондай-ақ топырақ микрофлорасының құрамын және микроорганизмдер штамдарының морфологиялық-культуралдық және физиологиялық-биохимиялық қасиеттерін бағалау болып табылады.

Материалдар мен әдістер. Зерттеу барысында стандартты әдістерді қолдана отырып, әр аймақтан таңдалған топырақ үлгілерінің агрохимиялық көрсеткіштері анықталды. Топырақтан

морфологиялық-культуралдық және физиологиялық-биохимиялық қасиеттері зерттелген микроорганизмдердің таза дақылдары бөлінді. Штамдардың көмірсуларды қолдану қабілеті, амилаза және желатиназа ферменттерінің белсенділігі және олардың температураға және тұзға төзімділігі бағаланды. Сонымен қатар, оқшауланған штамдардың өзара биоүйлесімділігі зерттелді.

Нәтижелер. Оқшауланған микроорганизмдер туыс деңгейінде анықталды және *Bacillus* spp., *Micrococcus* spp. және *Pseudomonas* spp. туыстарына жатады. *Sn1, Sn5, Sn6, Jn1, Jn2, TBS583* және *TBS588* штамдары жоғары ферментативті белсенділікке, көмірсуларды тиімді сіңіру қабілетіне және температура мен тұздың әсеріне төзімділікке ие. Биоүйлесімділік нәтижелері олардың антагонизмсіз бірге өсу қабілетін көрсетті. Қорытынды. Зерттелген штамдар топырақтың биологиялық құнарлылығын арттыру және экологиялық таза биотыңайтқыштар алу үшін перспективті микроорганизмдер болып табылады. Оларды ауыл шаруашылығында пайдалану өсімдіктердің өнімділігін арттыруға және топырақтың экологиялық тепе-теңдігін сақтауға мүмкіндік береді.

Кілт сөздер: агрохимиялық қасиеттері; биотыңайтқыш; микроорганизмдер; топырақ құнарлылығы; топырақ микрофлорасы.

Изучение агрохимических свойств и микробного разнообразия почв Южного Казахстана

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Аннотация

Предпосылки и цель. Почва является важным компонентом экосистемы, обеспечивая растения питательными веществами и водными ресурсами, необходимыми для роста и развития. Агрохимические свойства, pH и электропроводность почвы определяют жизнеспособность и биологическую активность микроорганизмов. Целью данного исследования является изучение агрохимических показателей (pH, электропроводность, содержание питательных веществ) образцов почвы, собранных в Сауранском, Жанакорганском и Туркестанском районах, а также оценка состава почвенной микрофлоры и морфологических, культуральных и физиолого-биохимических свойств штаммов микроорганизмов.

Материалы и методы. В ходе исследования были определены агрохимические показатели почвенных образцов, собранных в каждом районе, с использованием стандартных методов. Были изучены морфологические, культуральные и физиолого-биохимические свойства чистых культур микроорганизмов, выделенных из почвы. Были оценены способность штаммов усваивать углеводы, активность ферментов амилазы и желатиназы, а также термо- и солеустойчивость. Кроме того, была проведена оценка взаимной биосовместимости выделенных штаммов.

Результаты. Выделенные микроорганизмы были идентифицированы на уровне семейства и принадлежат к родам *Bacillus* spp., *Micrococcus* spp. и *Pseudomonas* spp. Штамы *Sn1, Sn5, Sn6, Jn1, Jn2, TBS583* и *TBS588* обладают высокой ферментативной активностью, способностью эффективно усваивать углеводы и устойчивостью к воздействию температуры и соли. Результаты биосовместимости показали их способность расти вместе без антагонизма.

Заключение. Изученные штаммы являются перспективными микроорганизмами для повышения биологического плодородия почвы и получения экологически чистых биоудобрений. Их использование в сельском хозяйстве позволяет повысить продуктивность растений и поддерживать экологический баланс почвы.

Ключевые слова: агрохимические свойства; биоудобрение; микроорганизмы; плодородие почвы; почвенная микрофлора.