AGRICULTURAL SCIENCES

AGROCHEMICAL AND MICROBIOLOGICAL PROPERTIES OF SOILS USED FOR COTTON CULTIVATION

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АГРОХИМИЧЕСКИЕ И МИКРОБИОЛОГИЧЕСКИЕ СВОЙСТВА ПОЧВ, ИСПОЛЬЗУЕМЫХ ДЛЯ ВОЗДЕЛЫВАНИЯ ХЛОПЧАТНИКА

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Abstract
Soil fertility and plant health are main factors in achieving high crop yields. In this study, the soils used for cotton cultivation in farms located in Nishon district of Kashkadarya region and Chinoz district of Tashkent region are analyzed. Agrochemical analyses determined the levels of alkalinity, chlorine, sulfates, calcium, magnesium, as well as anion and cation concentrations, and the differences between regions are evaluated. As a result, the soils of Nishon district showed a high level of salinity, a greater amount of salts, and significantly higher concentrations of anions and cations. In contrast, the soils of Chinoz district had lower levels of water-soluble salts, forming a more favorable environment for plant growth. The findings of this research are of great importance for improving soil fertility, correctly determining agro-technical measures, and managing soil effectively.

Аннотация
Плодородие почвы и здоровье растений являются основными факторами для достижения высоких урожаев. В данном исследовании проанализированы почвы, используемые для выращивания хлопчатника на фермах, расположенных в Нишанском районе Кашкадарьинской области и Чиназском районе Ташкентской области. Агрохимический анализ определил уровень щелочности, содержание хлора, сульфатов, кальция, магния, а также концентрации анионов и катионов, и были оценены различия между регионами.

В результате было установлено, что почвы Нишанского района имеют высокий уровень засоления, большее количество солей и значительно более высокие концентрации анионов и катионов. Напротив, почвы Чиназского района содержат меньше водорастворимых солей, формируя более благоприятные условия для роста растений. Результаты данного исследования имеют важное значение для повышения плодородия почвы, правильного определения агротехнических мероприятий и эффективного управления почвенными ресурсами.

Keywords: Soil fertility, agrochemical analysis, salinization, anion, cation, humus, calcium, magnesium, pH.
Ключевые слова: плодородие почвы, агрохимический анализ, засоление, анион, катион, гумус, кальций, магний, pH.

Introduction. Soil fertility and plant health are fundamental factors in agriculture, directly influencing high productivity and the sustainability of farming activities. These processes depend on the natural environment, soil characteristics, agricultural techniques, and the physiological condition of the plants. Therefore, increasing soil fertility and protecting plants from various diseases are considered pressing issues in the field of agriculture.

Biological, agro-technical, and chemical methods are used to improve soil fertility. Enhancing the physical and chemical properties of the soil and properly regulating the amount of organic and mineral substances contribute to increased fertility. In this regard, the application of organic fertilizers, mineral fertilizers, improvement of local microflora activity, and enhancement of soil structure play a crucial role. Furthermore, the resistance of plants to diseases is essential for maintaining soil hygiene and preventing plant illnesses.

Assessing and managing soil fertility is a major concernin the agricultural sector. From this perspective, numerous studies in various scientific sources have been devoted to identifying the agrochemical properties of soil, analyzing their effects on plant growth, and determining suitable agro-technical approaches.

Nielsen and co-authors (2011) conducted an in-depth study of soil biodiversity and microbial activity. According to their research findings, microbiological activity in the soil is one of the main indicators of fertility; its high level not only improves soil structure but also ensures the adequate availability of nutrients for plants. In addition, paid special attention to the cycling of organic matter and the role of soil microflora in the ecosystem [1].

The potential to improve the physiological and chemical condition of soil through the use of microbiological preparations was demonstrated. The novelty of this research lies in the fact that biopreparations developed on the basis of micromycetes activate nutrient cycling in the soil, increasing plant growth rates and disease resistance [2].

In the book *Soil Chemistry* published by Bohn et al. (2002), the level of alkalinity in soil and its effect on the solubility of nutrients are deeply analyzed. The source indicates that high pH levels limit the solubility of phosphorus, iron, manganese, and other micronutrients, making it more difficult for plants to absorb them [3]. This conclusion is confirmed by the analysis of saline soils in the Kashkadarya region.

Scientific research has revealed both beneficial and harmful effects of chlorine on plants. The significance of this finding is that chlorine is recognized for its active role in water transport and photosynthesis processes; however, it was also noted that excessive levels of chlorine can cause stress in plants [4]. This conclusion is especially relevant for soils with salinity issues.

The role of sulfate ions in plant nutrition has been shown in relation to protein synthesis, enzyme activity, and chlorophyll formation. This research scientifically substantiates the importance of sufficient sulfate levels for nutrient-demanding crops like cotton [5].

Particular attention has been given to the role of calcium in root structure and the stability of the cell wall. It was found that the proper level of calcium in the soil influences its physical properties, especially water permeability and ion diffusion [6]. This conclusion helps in organizing the correct circulation of nutrients in the soil.

Magnesium, as the central element of the chlorophyll molecule, plays a critical role in photosynthesis, and its deficiency leads to slower plant growth and reduced yield quality [7].

Ehtaiwesh (2022) studied the impact of salinity on nutrient uptake processes and concluded that high levels of Na^+, Cl^-, and SO_4^{2-} ions have damaging effects on the plant root system [8]. In conjunction with the agrochemical analysis results of the soils in Kashkadarya, this provides a strong scientific basis for developing measures to mitigate soil salinization.

These analyses demonstrate that proper evaluation of the agrochemical condition of soil and the selection of suitable agro-technical measures are decisive factors in achieving high yields.

MATERIALS AND METHODS

2.1. Sample Collection.

During the spring and autumn seasons of 2024, soil samples were collected from the cotton fields of the "Yuksalish G'allachilik Sabzavotchilik" farm in Yuksalish MFY, Nishon district, Kashkadarya region, and the "Chinoz Turabek Imkon Plus" farm in Chinoz district, Tashkent region. Samples were taken using the envelope method from five points at depths of 0–10 cm, 10–20 cm, and 20–30 cm. Approximately 2–3 kg of soil was collected from each depth for chemical, microbiological, and physical analyses. All soil samples were transported in plastic bags to laboratories and stored at 4°C until further investigation.

2.2. Agrochemical Analyses

Chloride (Cl^-): Method: Silver nitrate ($AgNO_3$) is added to the soil extract or solution. The formation of silver chloride ($AgCl$) allows the concentration of chloride to be determined via titration.

Instruments: Titration apparatus, silver nitrate titrant. Chloride is one of the basic elements indicating the presence of salts in the soil.

Sulfates (SO_4^{2-}):Method: Turbidimetry or Gravimetry. Sulfates form a precipitate in the soil solution with the help of barium chloride ($BaCl_2$). The resulting barium sulfate ($BaSO_4$) is measured using either turbidimetry or gravimetry.Instruments: Turbidimeter or precision balance. High levels of sulfates may indicate soil salinity.

Calcium (Ca^{2+}) and Magnesium (Mg^{2+}):Method: EDTA complexometric titration. In soil extracts, calcium and magnesium ions form complexes with ethylenediaminetetraacetic acid (EDTA), which are measured by titration. Calcium is measured first, followed by the combined total of calcium and magnesium.

Instruments: Titration apparatus, indicator. Ca^{2+} and Mg^{2+} are key elements that affect soil alkalinity and structure.

Carbon (C):Method: Wet combustion (Wettig or Walkley-Black method). Soil samples are oxidized by burning or using an oxidizing agent such as potassium dichromate. The amount of CO_2 released during oxidation is measured.

Instruments**:** Calorimeter or gas measurement devices. Carbon is a key indicator of humus and is essential for assessing the organic matter content in soil.

Anions (Cl^-, NO_3^-, SO_4^{2-}, HCO_3^-, etc.):Method: Ion chromatography or spectrophotometry. Various anions in soil solutions are separated and measured using ion chromatography. Spectrophotometric methods may also be used (e.g., for nitrates).Instruments**:** Ion chromatograph or spectrophotometer. Anions reflect the nutrient content of the soil.

Cations (Ca^{2+}, Mg^{2+}, Na^+, K^+, etc.):Method: Ion exchange method. The soil solution is analyzed using special resins to determine cation content.

Instruments**:** Ion exchange columns. Cations are indicators of soil chemical balance and fertility.

RESULTS AND ANALYSIS

A significant portion of the living world that we often overlook—around 25% of all life on Earth—resides in the soil. Part of this life consists of various biosystems that are taxonomically little known [9]. By improving soil fertility, promoting plant growth, and protecting crops from diseases, microorganisms contribute to increased yield and quality of agricultural products.

Overall, soil microorganisms play a vital role in maintaining healthy soil and plants, as well as preserving the natural state of ecosystems and ensuring sustainable agriculture [10].

The agrochemical properties of soil include various parameters that determine its fertility, capacity to support plant growth, and overall productivity. Some key agrochemical properties of soil include:

- Soil pH**:** pH indicates the acidity or alkalinity of the soil environment. Different crops require specific pH ranges for optimal growth. For example, most crops grow best in a neutral to slightly acidic environment (pH 6 to 7).
- Fertility: This refers to the soil's ability to supply essential nutrients necessary for the normal growth and development of plants. Soil fertility depends on the content of primary nutrients such as nitrogen (N), phosphorus (P), and potassium (K), as well as micronutrients like iron, manganese, and zinc.
- Organic Matter Content: Organic matter plays a key role in soil fertility. It improves soil structure, enhances air permeability and moisture retention, and supports biological activity in the soil.
- Salt Content: High salt levels in the soil can negatively affect plant growth and development by causing root burn and disrupting the plant's water uptake system.
- Soil Structure: Soil structure determines its ability to retain water and air, facilitate the movement of nutrients and oxygen to plant roots, and hold both organic and mineral particles [11].

These agrochemical characteristics are crucial for evaluating soil fertility and determining the suitability of the soil for growing specific crops.

In the initial phase of the study, agrochemical analyses were conducted in the spring season—prior to cotton planting—on soil samples collected from Tashkent region (non-saline) and Kashkadarya region (saline) (Figure 1).

Figure 1. General view and sampling location of fields in Nishon district where soil samples were collected.

Soil samples were taken from fields prepared for cotton cultivation at the "Yuksalish G‘allachilik Sabzavotchilik" farm located in Nishon district, Kashkadarya region. This area has a sharply continental climate, meaning that there are significant temperature fluctuations between seasons. The average annual temperature is around 14.8°C. In winter, the average temperature can drop to as low as 0.2°C, with minimum recorded temperatures reaching approximately -15°C. In summer, temperatures rise considerably, averaging 28.8°C, with maximum temperatures reaching up to 45°C.

The region also receives relatively low annual precipitation, ranging from 180 to 220 mm, most of which occurs during the colder months, from late October through early spring. Due to this arid climate, agriculture in the area relies heavily on irrigation systems such as the Karshi main canal and the Tallimarjon reservoir.

Figure 2. General view and sampling location of fields in Chinoz district where soil samples were collected.

Soil samples were taken from fields prepared for cotton cultivation at the "Chinoz Turabek Imkon Plus" farm in Chinoz district, Tashkent region. The climate of Chinoz district is continental. The average annual temperature is 13.4°C. The average temperature in January is –3.1°C, with the minimum recorded temperature reaching –33°C. In July, the average temperature is 26.5°C, and the maximum can reach 42°C. The vegetation period lasts 210 days. Annual precipitation is about 350 mm. The Chirchiq and Syrdarya rivers flow through the district. Additionally, irrigation for agricultural crops in the area relies on canals such as Bozsuv, Kurkuldak, Northern Tashkent, and Jon.

3.2. Agrochemical Analysis of Soil Samples. Chemical elements in the soil provide essential nutrients for plants and contribute to the development of the soil's physical, chemical, and biological properties. In our research, two regions were selected for scientific comparison of saline and non-saline soil samples. Saline soil samples were taken from the fields of Nishon district, Kashkadarya region. Non-saline soil samples were taken from the fields of Chinoz district, Tashkent region. All properties were studied using a comparative method.Soil samples were collected in the spring (before cotton planting) and in autumn (after cotton harvest) to assess seasonal differences.

Spring soil samples: First, agrochemical analyses were conducted. The chemical composition of the soils from both Nishon and Chinoz districts was examined. The analysis results compared parameters such as soil alkalinity (pH), chloride (Cl), sulfates (SO_4), calcium (Ca), magnesium (Mg), and the concentrations of anions and cations. (Table 1).

Table 1

Agrochemical analyzes of soil samples

Cut	Layers, cm	Alkalinity		Cl		SO_4		Ca		Mg		Anion	Cation
		general HCO_3, %	general HCO_3, m.e.	%	Mg, equivalent	%	Mg, equivalent	%	Mg, equivalent	%	Mg, equivalent		
Nishan district	0-10	0,023	0,38	0,179	5,03	1,100	22,91	0,258	12,87	0,031	2,57	28,33	15,44
	10-20	0,022	0,36	0,371	10,46	0,976	20,33	0,294	14,67	0,036	2,96	31,15	17,63
	20-30	0,022	0,36	0,035	0,99	0,856	17,83	0,26	12,97	0,028	2,27	19,18	15,25
Chinaz district	0-10	0,032	0,52	0,007	0,20	0,029	0,60	0,007	0,35	0,002	0,20	1,32	0,55
	10-20	0,032	0,52	0,007	0,20	0,018	0,37	0,006	0,30	0,002	0,15	1,09	0,45
	20-30	0,028	0,46	0,011	0,30	0,034	0,71	0,008	0,40	0,002	0,20	1,46	0,60

Alkalinity:*Nishon District:* The alkalinity (total HCO_3) ranges between 0.022% and 0.023%, with little variation across different soil layers.*Chinoz District:* Alkalinity is relatively higher, ranging from 0.028% to 0.032%. These indicates that the soils in Chinoz district are more alkaline than those in Nishon district. Alkalinity in soil is related to the presence of dissolved carbonates and bicarbonates in water. This parameter influences the soil's pH, which determines whether it is acidic or alkaline. In alkaline soils, some nutrients such as phosphorus and lime may become less available to plants [12]. However, when alkalinity levels are within a normal range, they create a balanced environment for plant growth.

Chloride (Cl^-):*Nishon District:* Chloride content ranges between 0.099% and 0.179%, with milligram-equivalent values ranging from 0.35 to 0.99.*Chinoz District:* Chloride levels are much lower, between 0.001% and 0.003%, with milligram-equivalent values from 0.007 to 0.018.

Chloride content in Nishon district soils is significantly higher than in Chinoz. Chlorine affects water and nutrient transport as well as photosynthesis in plants. In small amounts, it is beneficial for plants, as it regulates the opening and closing of stomata [13]. However, excessive chlorine increases salinity, which can reduce crop yields.

Sulfates (SO_4^{2-}):*Nishon District:* Sulfate content is approximately 0.856% to 1.100%, with milligram-equivalent values ranging from 17.83 to 22.91. *Chinoz District:* Sulfate levels are between 0.008% and 0.013%, with milligram-equivalent values from 0.071 to 0.184. Nishon soils contain much higher levels of sulfates than Chinoz soils. Sulfates are a source of sulfur (S), which is essential for protein synthesis, enzyme production, and chlorophyll formation in plants [14]. Although beneficial, excessive sulfate levels may contribute to soil salinization.

Calcium (Ca^{2+}):*Nishon District:* Calcium content ranges from 12.87% to 14.67%, with milligram-equivalent values of 0.258 to 0.294.*Chinoz District:* Calcium content is very low — between 0.08% and 0.40%, with milligram-equivalent values from 0.007 to 0.013.

The calcium content in Nishon soils is considerably higher and above standard compared to Chinoz. Calcium improves soil's physical and chemical structure, binds soil particles, strengthens plant cell walls, and participates in many enzymatic processes. Deficiency in calcium can halt plant growth. Calcium also acts as a buffering agent against soil acidity [15]. However, excessive calcium may interfere with the uptake of micronutrients by plants.

Magnesium (Mg^{2+}):*Nishon District:* Magnesium content is between 0.028% and 0.031%, with milligram-equivalent values of 2.27 to 2.96.*Chinoz District:* Magnesium content is much lower at about 0.002%, with milligram-equivalent values ranging from 0.006 to 0.014. Magnesium levels in Nishon are significantly higher. Magnesium is one of the key micronutrients and a central element in the chlorophyll molecule. It plays a role in photosynthesis and enhances nitrogen uptake from the soil. A deficiency can cause chlorosis — yellowing of leaves and decreased photosynthesis [16]. However, excessive magnesium may also contribute to soil salinity.

Anions:*Nishon District:* Anion content ranges from 28.33 to 31.15. *Chinoz District:* Anion content is much lower, ranging from 1.32 to 1.46. Anion levels in Nishon are several times higher than in Chinoz. Anions are essential for plant nutrition, aiding in the absorption of nitrogen, phosphorus, and other nutrients [17]. Carbonates and sulfates also help buffer soil pH.

Cations:*Nishon District:* Cation content ranges from 15.44 to 17.63.*Chinoz District:* Cation content ranges from 0.45 to 0.65. Cation concentrations are much higher in Nishon compared to Chinoz. Cations influence overall soil salinity and structure. They also affect nutrient uptake by plants [18,19]. While calcium and magnesium are beneficial, high levels of sodium (Na^+) can increase soil salinity and negatively affect plant growth.

According to the results of microbiological analysis, there are significant differences in the microbial composition and abundance in soil samples collected from cotton-growing fields in Nishon district (Kashkadarya region) and Chinoz district (Tashkent region). These differences are primarily due to the moderately saline soils of Nishon and the fertile soils of Chinoz. The soils from both regions were studied based on the main microbial groups, including ammonifiers, oligotrophs, actinomycetes, micromycetes, and phosphate-solubilizing bacteria. These research results helped identify the distinct characteristics of soil microflora in each district and highlight the differences shaped by their respective environmental conditions.

Ammonifiers – In Chinoz district soils, the population of ammonifying bacteria was higher than in Nishon, especially in the upper (0–10 cm) and lower (20–30 cm) layers. The high prevalence of ammonifiers positively influences soil fertility as they are involved in the ammonification process, a key stage in the nitrogen cycle. In Nishon, the quantity of ammonifiers was very low, with *Micrococcus luteus* being most common in the 20–30 cm layer. These indicates that compared to Chinoz, the soils of Nishon are relatively poor in nitrogen-containing compounds.

Phosphate-solubilizing microorganisms – These were not found in the soils of Nishon district, while in the upper layers of Chinoz district soils, phosphate-solubilizing bacteria and fungi (particularly of the *Mucor* genus) were observed. These microorganisms have the ability to convert insoluble phosphate into a plant-available form, which indicates a higher efficiency of phosphorus availability in Chinoz soils. Such microbes are essential for enhancing phosphorus cycling and improving soil fertility[19].

Oligotrophs – Found in higher numbers in Chinoz soils and below normal levels in Nishon. Oligotrophic microorganisms contribute to soil fertility by breaking down nitrogenous organic matter. Their abundance in Chinoz indicates nitrogen-rich soils, while their lower presence in Nishon suggests a deficiency in available nitrogen. Oligotrophs also play a key role in nitrogen cycling.

Micromycetes (fungi) – More abundant in the upper and middle soil layers of Chinoz, especially in the 0–10 cm layer, where genera such as *Aspergillus*, *Trichoderma*, *Fusarium*, *Penicillium*, and *Mucor* were found. In Nishon soils, micromycetes were less common, with *Aspergillus* and *Fusarium* mostly observed in the 10–20 cm layer. Micromycetes help decompose organic matter and neutralize certain harmful compounds in the soil.

Actinomycetes – These were more prevalent in the upper soil layers in both districts. In Chinoz soils, *Streptomyces* species formed white, gray, and pink colonies. Actinomycetes have a positive effect on soil fertility and help suppress some phytopathogenic microorganisms. They were found to be more active in Chinoz than in Nishon, indicating a greater contribution to soil bioactivity[20].

In Nishonthrough fatty acid-producing bacteria and cellulose-degrading microorganisms, fatty acid-producing bacteria were found in small quantities, mainly in the 0–10 cm layer. In Chinoz, these bacteria were more widespread across all soil layers and doubled in number in the deeper layers. Cellulose-degrading microorganisms were found and isolated these colonies in both regions.

The research also revealed that Nishon soils had higher levels of water-soluble salts, including sulfates, chlorides, calcium, and magnesium, which contribute to increased soil salinity and alkalinity. The amount of anions and cations was also higher, negatively impacting crop yield and nutrient balance. In contrast, Chinoz soils had much lower levels of soluble salts, with the main elements (chloride, sulfate, calcium, magnesium) present within normal limits. Despite having a high pH (alkalinity), Chinoz soils contained significantly less salt. Nishon soils, however, are distinctly saline with elevated levels of sulfates, calcium, magnesium, and anion-cation concentrations. Chinoz soils are relatively low in salt.

Microbiological analyses conclude that Chinoz soils are biologically richer and more microbially active than those in Nishon. A higher abundance of microorganisms involved in nitrogen and phosphorus cycling supports better nutrient absorption by plants. Furthermore, the greater presence of actinomycetes and micromycetes contributes to improved resistance against soil-borne pathogens. In contrast, Nishon soils have significantly lower quantities of several microbial groups, indicating reduced fertility and nutrient availability for plants. To improve microbial balance and enhance fertility in such soils, the use of organic and biological fertilizers is recommended.

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