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BIOCHEMICAL PROCESSES IN GYPSIFEROUS SALINE SOILS: THE RELATIONSHIP BETWEEN GYPSUM CONTENT AND THE ACTIVITIES OF UREASE AND PHOSPHATASE ENZYMES

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Abstract

This study aims to assess the changes in urease and phosphatase activities under a gradient of gypsum content in irrigated gypsiferous soils in the Zarbdor district of Jizzak region. Soil samples were collected from soil profiles with different degrees of gypsum content at depths of 0–15 and 15–30 cm. The gypsum content in the soil was determined using the B.P. Machigin method, while urease and phosphatase activities were measured under laboratory conditions using generally accepted standard biochemical methods. The results showed that increasing gypsum content in the soil was accompanied by a consistent decrease in the activities of both urease and phosphatase. The obtained data confirm that these enzymes can be reliably used as bioindicators for assessing the biological condition of irrigated gypsiferous soils and the degree of development of soil degradation processes.

Keywords: Gypsiferous soils, gypsum content, soil salinity, urease, phosphatase, biological activity, soil degradation.

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Introduction

The study area is located in the south-western part of the Mirzachul Plain and is characterized by dominant arid and semi-arid climatic conditions. The regional climate is sharply continental, with hot and dry summers and a high rate of evaporation during the growing season. These conditions promote disturbances in the soil water–salt balance and create favorable environments for the formation of gypsiferous horizons and their active migration within the soil profile. These specific natural and geographical conditions have a profound impact on the formation and dynamics of biological processes, including enzymatic activity, in irrigated gypsiferous soils [7, 9, 14, 15].

Soil enzymes are biological catalysts produced by soil microorganisms, plant roots, animal metabolic products, or directly associated with abiotic soil components [1, 6, 11]. They are integral participants in key biochemical processes in soils and play a fundamental role in the decomposition of organic matter, nutrient cycling, detoxification of harmful compounds, and the formation of overall biological fertility [4,5,10].

The enzymatic activity of soils is causally interrelated with various ecological indicators, and its assessment requires an integrated approach based on systemic ecological principles. Enzyme activities are formed under the direct or indirect influence of multiple factors, including microbial abundance, organic matter reserves, soil pH, moisture, salinity level, and gypsum content [12, 13].

Among soil enzymes, the urease activity is considered one of the most important indicators for assessing the biological condition of soils. Urease is a hydrolytic enzyme that catalyzes the decomposition of urea ($\text{CO}(\text{NH}_2)_2$) into ammonia (NH_3) and carbon dioxide (CO_2). The activity of this enzyme is of primary importance for nitrogen cycling in soils, especially for the transformation and utilization of urea-based fertilizers.



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In soils, the urease is mainly synthesized by microorganisms, particularly bacteria such as *Bacillus*, *Proteus* and *Pseudomonas*, as well as by some fungi including *Aspergillus* and *Penicillium*. Among soil enzymes, urease is characterized by a rapid response, high sensitivity and strong reactivity to environmental changes, and therefore it is widely used as an indicator of soil health.

Urease activity was evaluated based on the amount of ammonia released during the enzymatic hydrolysis of urea in soil samples. Phosphatase activity was determined according to the amount of mineral phosphate released as a result of the hydrolysis of organic phosphorus substrates and was expressed in standard enzymatic activity units [2,17].

Phosphatase enzymes act as the main biocatalysts in the conversion of organic phosphorus compounds in soil into mineral forms. In particular, they play a key role in the formation of orthophosphates (Pi) that are available for plant uptake. Phosphatase activity is often directly related to the level of microbial activity, the secretion of plant roots, and nutrient deficiency in soils, especially phosphorus limitation (phosphorus stress) [3, 16]. International studies consider phosphatase activity to be one of the most sensitive indicators of soil biological fertility and phosphorus cycling, and it is widely applied as an important indicator for assessing the biological condition of degraded, saline and gypsiferous soils [4, 8].

Materials and Methods

Field investigations were carried out on irrigated gypsiferous soils in the Zarbdor district of the Jizzakh region. The soils in the study were irrigated meadow–gray soil profiles with different degrees of gypsum content. Soil samples were collected from several soil profiles at depths of **0–15 cm and 15–30 cm**, following genetic horizons, under field conditions using standard soil sampling procedures. The gypsum content of the soils was determined using the **B.P. Machigin method**, based on the extraction of gypsum with **hydrochloric acid (HCl)**.

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Results and Discussion

The study results revealed a clear relationship between gypsum content and urease activity in irrigated gypsiferous soils. The constructed graph shows that the urease activity consistently decreases with increasing gypsum content. This pattern confirms that the degree of gypsification has a significant impact on the biological activity of the soil.

The obtained data indicate that the urease activity is strongly dependent on the gypsum content of the soil. In soil profiles with a relatively low gypsum content (4.76–12%), the urease activity was comparatively high and ranged from 0.042 to 0.045 units. At intermediate gypsum contents (13.09–17.48%), a noticeable decrease in urease activity was observed. In soils with a high gypsum content (profiles 10, 9 and 6), the urease activity declined to low values, ranging from 0.027 to 0.033 units (figure 1).

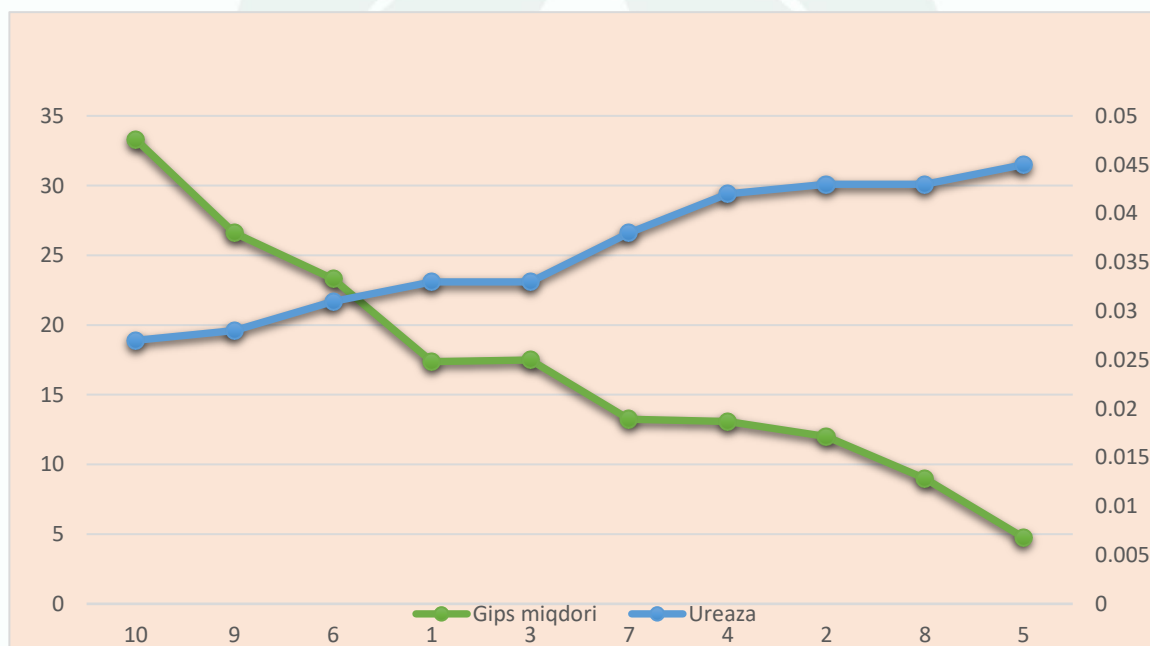


Figure 1. Changes in urease activity in the soils of the study area as a function of gypsum content

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In soil samples with a high gypsum content, the low values of urease activity can primarily be explained by the deterioration of the physicochemical properties of the soil environment. In particular, excessive accumulation of gypsum increases soil bulk density, restricts air and water regimes, and creates unfavorable conditions for microbial activity. As a result, the synthesis and activity of urease, which plays an important role in the nitrogen cycle, are reduced.

In contrast, the relatively higher urease activity was observed in the soils with lower gypsum content. This can be attributed to better preservation of organic matter reserves and a comparatively higher level of microbial activity in these soils, which promotes more intensive mineralization of organic nitrogen compounds. Overall, the obtained results demonstrate a highly reliable inverse correlation between gypsum content and urease activity ($r = -0.82$, $p < 0.05$). This confirms that the urease can be used as a sensitive and reliable bioindicator for assessing the biological condition of irrigated gypsiferous soils and the development of soil degradation processes.

In the irrigated gypsiferous soils of the Zarbdor district, a significant interaction was also observed between gypsum content and phosphatase activity. With increasing gypsum content, phosphatase activity decreased, whereas higher phosphatase activity was recorded in soils with lower gypsum content. This pattern indicates a clear negative relationship, whereby higher gypsum levels are associated with lower enzyme activity.

In the soil profiles with a high gypsum content (profiles **10, 9 and 6**), phosphatase activity was the lowest and ranged from **0.0011 to 0.013 units**. In contrast, in the intermediate layers with a gypsum content of **4.76–13.23%**, phosphatase activity was relatively higher, reaching values of approximately **0.015–0.016 units** (figure 2)

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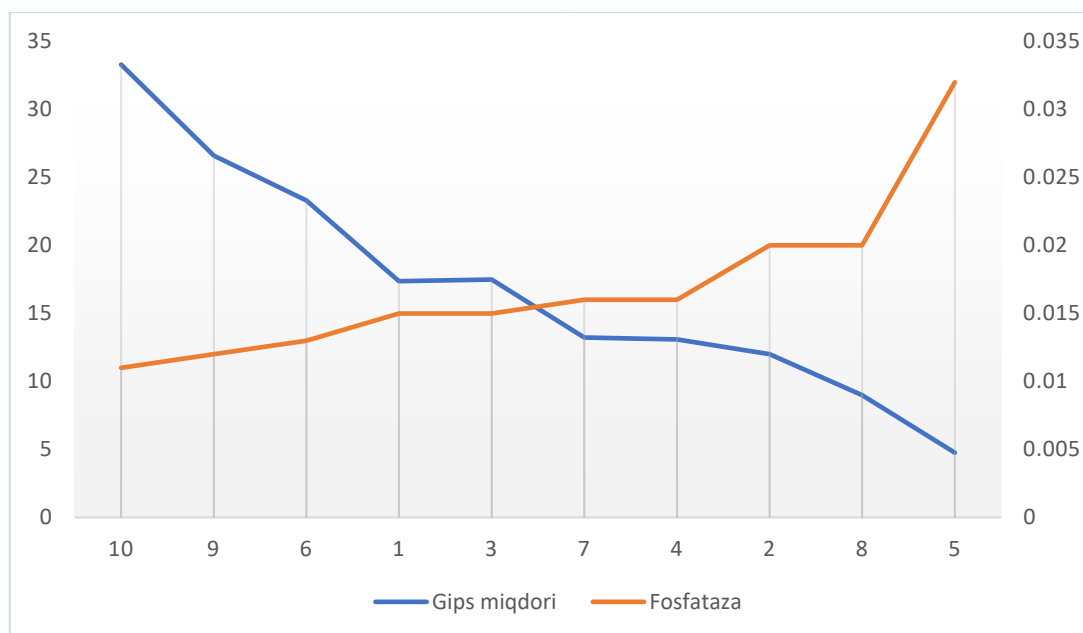


Figure 2. Changes in phosphatase activity in the soils of the study area as a function of gypsum content.

The biochemical basis for this phenomenon can be explained that once the gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) is present in the soil, the concentrations of calcium and sulfate ions increase. The increased calcium levels may suppress the activity of soil microorganisms, which in turn directly affects the activity of enzymes, particularly phosphatase and urease. In addition, the soils with a high gypsum content generally contain lower amounts of organic matter, which further limits phosphatase activity, since this enzyme functions through the hydrolysis of organic phosphate compounds.

The Pearson correlation coefficient between gypsum content and phosphatase activity was $r = -0.87$, indicating a strong negative relationship. In other words, as gypsum content increases, phosphatase activity decreases markedly.

These results are of considerable importance for evaluating biochemical and microbiological processes in soils and provide a scientific basis for determining optimal gypsum levels in irrigated gypsiferous soils.



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A consistent decrease in the activities of both urease and phosphatase was observed in gypsiferous soils with increasing gypsum content. This pattern is associated with changes in the physical properties and ionic composition of the soil under gypsiferous conditions, particularly with the high concentration of Ca^{2+} ions, as well as with disturbances in the soil water-air balance. These factors reduce the metabolic activity of microorganisms and consequently exert a negative effect on enzyme synthesis and activity.

Conclusion

This studies conducted in irrigated gypsiferous soils of the Zarbdor district, Jizzakh region, showed that the increasing gypsum content is accompanied by a consistent decrease in the activities of urease and phosphatase. Relatively higher activities of these enzymes were recorded in soil layers with low gypsum content, whereas the lowest values were observed in profiles characterized by high gypsum levels. The obtained results demonstrate that the urease and phosphatase can be considered reliable bioindicators of the biological status of nitrogen and phosphorus cycling in irrigated gypsiferous soils and can be effectively used to assess the intensity of soil degradation processes.