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ASSESSMENT OF BIOLOGICAL CONDITION OF GYPSIFEROUS SOILS BY DEHYDROGENASE ACTIVITY

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Abstract
The article deals with enzymatic activity of gypsum-bearing soils of Jizzak region, characterised by high content of gypsum (20-30 %) and diversity of its morphological forms - from fine crystalline in auxiliary horizons to coarse crystalline in groundwater zone. These soils occupy significant areas of terrace complexes of the region. It was found that enzymatic activity, in particular the activity of dehydrogenase, a sensitive intracellular enzyme, is closely correlated with the level of hypsification and type of agrocenosis. Dehydrogenase serves as an informative bioindicator reflecting the general biological state of soils and intensity of microbiological processes, especially in conditions of gypsum and saline ecosystems.

Keywords: Dehydrogenase activity, gypsiferous soil, soil biological activity, enzymatic activity,soil microorganisms, bioindication of degradation, ecological soil assessment, oxidoreductase enzymes, agroecosystems, soil salinization and gypsum content.

Introduction

One of the important criteria for assessing soil fertility and ecological well-being is its biological activity. Central to these processes is enzymatic activity, which is closely related to the functioning of soil microbiota and plant root systems. Of particular interest is dehydrogenase (DH), an intracellular enzyme involved in redox reactions and reflecting the level of respiratory and metabolic activity of microorganisms [1].

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In gypsiferous soils characterised by disturbed water-salt balance, reduced organic matter content and poor biological stability, dehydrogenase activity is considered as a reliable bioindicator of degradation or restoration of agroecosystems [2]. The assessment of DG allows monitoring not only the current biological state of the soil, but also the efficiency of agrotechnical measures, fertiliser application and the impact of climatic changes [3,4].

The enzymatic activity, particularly of oxidoreductases, varies depending on the granulometric composition of the soil, its organic saturation and abiotic conditions such as moisture and temperature. Dehydrogenase, as one of the representatives of this group, shows high sensitivity to physicochemical changes in degraded, saline and gypsiferous soils [3,4].

According to Shaaban et al (2023), application of gypsum and organic residues (manure, rice straw) on saline soils increased enzyme activity and improved mineralisation of organic matter [3]. Similar results were confirmed in more recent studies indicating the importance of adapted agricultural practices to restore enzyme activity [4,5].

Dehydrogenase activity is found in almost all types of soils, as it is provided by anaerobic and facultatively anaerobic microorganisms. However, its level varies considerably depending on the organic matter content, soil structure and aeration, as well as on the degree of anthropogenic pressure [6]. Among the key external factors affecting this enzyme are temperature, humidity, pH and ionic composition of the soil solution.

Despite the considerable interest in the problem of soil degradation, there are no comprehensive studies on the biological condition of gypsum-bearing soils in Uzbekistan, especially in Jizzak province. The available works are fragmentary and do not allow to form a holistic picture of the state of agro-ecosystems in the region. In this regard, there is a need for in-depth studies to assess dehydrogenase activity as an integral indicator of the biological state of gypsum-bearing soils, taking into account regional natural and climatic conditions and anthropogenic impacts [7].

2. Material and Methods

The objects of the study were soils of different degrees of gypsum content, distributed on the territory of Zarbdar district of Jizzak oblast, including grey soils, meadow-serozems, grey meadow-meadow, meadow, meadow-marsh soils and solonchaks. These soils are formed under conditions of sharply continental subtropical climate with duration of frost-free period 207-217 days and sum of effective temperatures 4600-6000 °C. Despite favourable conditions for heat-loving annual crops (cotton, kenaf, etc.), sharp temperature fluctuations (absolute minimum up to -40 °C) prevent the cultivation of perennial subtropical plants [8].

The studied soils have gypsum profile saturation from 20 to 30 %. Gypsum is present in various forms - from fine crystalline particles in the upper horizons to large crystals in the groundwater zone. The degree of salinity is 0.2-0.3 % toxic salts, salinisation is predominantly of sulphate type and easily soluble salts were detected at depths of 2-50 cm. Soils of the terrace zone were divided by the character of wetting into areas with periodic and permanent waterlogging, as well as with groundwater depth of 2-3 m [9].

Field studies were conducted in Mustakillik kuyoshi, Nurafshon and Tarakkiyot massifs. Soil sections were laid out and samples were taken by morphogenetic horizons (0-20 cm, 20-40 cm, 40-60 cm). To assess the biological state of soils, enzymatic activity was studied, primarily

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dehydrogenase (DH) activity, which reflects the respiratory and metabolic activity of soil microbiota and is a reliable indicator of biological processes in soil [10].

The dehydrogenase activity was determined according to the methodology described in the work of F.H. Haziev (2005). [11]. 2,3,5-triphenyltetrazolium chloride (2,3,5-TTH; $C_{19}H_{15}N_4Cl$) is a colourless compound which, accepting hydrogen mobilised by dehydrogenase, is reduced to the coloured product, 2,3,5-triphenylformazan (2,3,5-TTPH; $C_{19}H_{16}N_4$) by the equation: $C_{19}H_{15}N_4Cl + H_2 \rightarrow C_{19}H_{16}N_4 + HCl$

A suspension of soil (6 g) was placed in a conical flask, 30 mg of glucose ($C_6H_{112}O_6$), 1 ml of 3% 2,3,5-TTC solution, and 2.5 ml of distilled water were added. The mixture was mixed thoroughly, the flasks were hermetically sealed and incubated at 37 °C for 24 hours.

3 Results and Discussion

Gypsiferous content of irrigated grey-meadow soils

As a result of field and laboratory studies it was established that gypsum content in the profile of grey-meadow soils of Zarbdar district varies in a wide range - from 0.2 % to 62.4 %. On the basis of generalised data on 10 soil sections it is possible to distinguish a pronounced horizontal and vertical heterogeneity of gypsum content (Figure 1. Gypsum content (%) in the profile of irrigated grey-meadow soils of Zarbdar district (according to 10 soil sections).

Thus, in sections 1-3, gypsum is mainly accumulated in horizons 50-120 cm and rarely exceeds 20%. However, in section 6, its content sharply increases to more than 60 % in horizons from 59 to 105 cm, which indicates the presence of coarse crystalline deposits in the capillary rise zone.

A similar picture is observed in sections 9 and 10, where gypsum is concentrated mainly in deep horizons (80-100 cm), reaching 40-45 %. At the same time, in soils 5 and 8, gypsum is practically absent in the upper horizons, and its concentrations do not exceed 5-10 %.

Such heterogeneity is explained by differences in hydrogeological conditions, groundwater table depth, microrelief peculiarities and degree of agrotechnical impact. At the same time, a clear relationship between increased gypsum content and secondary salinity was revealed, which confirms the conclusions of previous researchers [9].

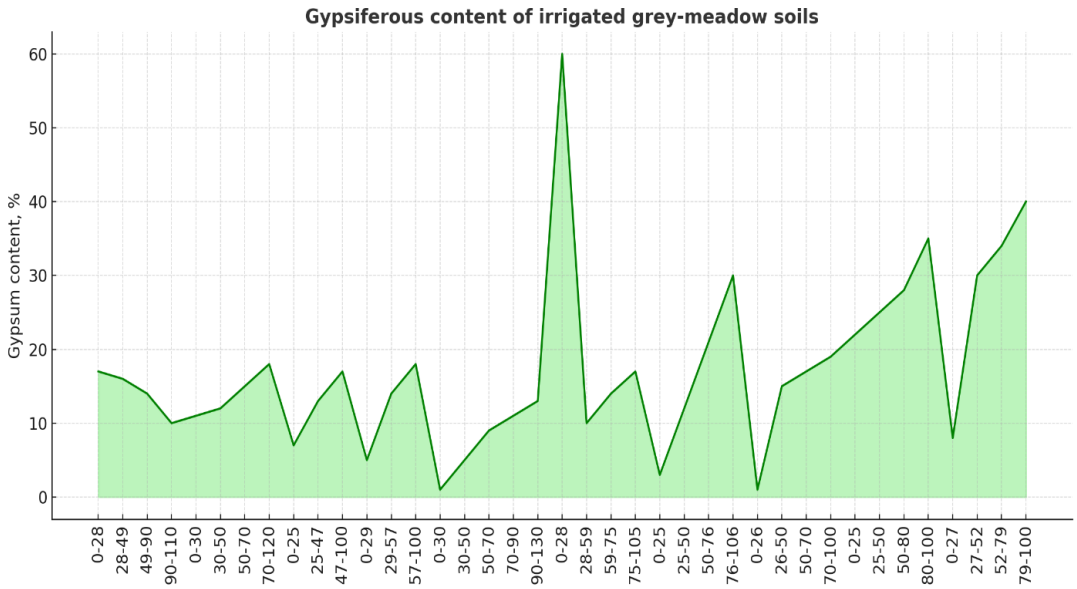

Figure 1.

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Web of Agriculture: Journal of Agriculture and Biological Sciences
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Dehydrogenase activity under conditions of different gypsiferousness

Against the background of established values of gypsum content (Fig. 1), dehydrogenase (DH) activity in soil horizons 0-15 cm and 15-30 cm was evaluated. The results presented in Figure 2 (Effect of gypsum content on dehydrogenase activity in different soil horizons) show a pronounced inverse relationship between gypsum content ($CaSO_4$-$2H_2O$) and enzymatic activity.

In the upper horizon (0-15 cm), DG activity ranges from 0.5 to 2.1 mg TPF/kg/h and gradually increases with increasing gypsum content. This may be due to increased aeration and porosity in moderately gypsiferous layers, which favours the development of anaerobic and facultative-anaerobic microorganisms.

At the same time, in the 15-30 cm horizon, DG activity is much higher - from 5.5 to 4.0 mg TPF/kg/h, but there is a tendency to decrease with increasing gypsum content. This can be explained by the disturbance of soil structure, accumulation of large gypsum crystals and deterioration of conditions for microbial communities responsible for redox processes.

Thus, an increase in gypsum content, especially above 10-12 %, has an inhibitory effect on dehydrogenase activity, especially in deep horizons. This effect is in agreement with Shaaban et al. (2023) and Wang et al. (2024), indicating the sensitivity of redox enzymes to changes in the structure and ionic composition of the soil environment.

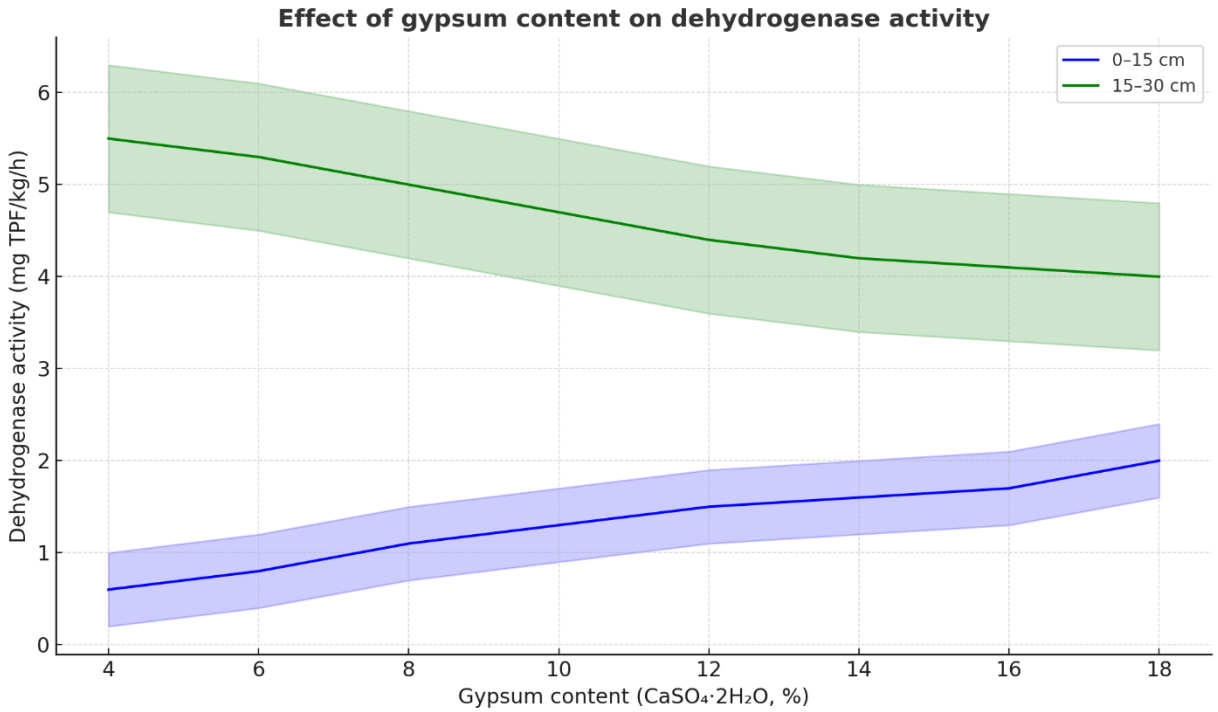

Figure 2

4 Conclusions

- In conditions of Zarbdar district of Jizzak oblast irrigated grey-meadow soils are characterised by high spatial and profile heterogeneity of gypsum content. Gypsum content varies from 0,2 % to 62,4 %, and its concentration significantly increases in horizons below 50 cm, especially in zones with close groundwater occurrence.

- It was found that dehydrogenase activity can serve as a sensitive bioindicator of the biological state of gypsum-bearing soils. The upper horizons (0-15 cm) show relatively low but stable values

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of DG (up to 2.1 mg TPF/kg/h), whereas in horizons 15-30 cm the enzymatic activity is higher but subject to decrease with increasing gypsiferousness.

- The negative correlation between gypsum level and dehydrogenase activity indicates that excess gypsum worsens conditions for microbial biota functioning and redox processes, especially in deep layers. This is due to physical compaction, disturbance of soil structure and increase in ionic load.
- The obtained data confirm the possibility of using dehydrogenase activity as an integral indicator of degradation and recovery of agroecosystems on gypsiferous soils. This indicator is particularly informative in assessing the effectiveness of ameliorative measures and agrotechnical practices aimed at stabilising biological activity.
- Integrated assessment of enzymatic activity and gypsiferousness allows to diagnose more accurately the ecological state of soils and develop scientifically based recommendations for sustainable land use in arid regions.

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