



# Magnesium Ions ( $Mg^{2+}$ ) and Calcium Cations ( $Ca^{2+}$ ) Contents in Soils of the Eastern Mirzachul District and the Soil Sorption Environment

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**ABSTRACT:** Soil samples were collected from a 40-hectare agricultural area of the Yangi Dala private farming enterprise "Ifore," located in the eastern part of the Mirzachul district, Jizzakh region. Samples were taken from different soil layers at depths of 0–5, 5–10, 10–20, 20–40, 40–60, 60–80, and 80–100 cm. Aqueous extracts were prepared, and the percentage content of  $Mg^{2+}$  ions, the pH value of the soil solution, and electrical conductivity were determined. The  $Mg^{2+}$  ion content varied among the soil layers. In the upper soil layers (0–5 and 5–10 cm), the magnesium ( $Mg^{2+}$ ) ion content was 0.39% and 0.51%, respectively. It was found that the  $Mg^{2+}$  ion content decreased with increasing soil depth from 10 to 100 cm. Additionally, the soil pH shifted from neutral to alkaline conditions with increasing depth, while electrical conductivity also showed a decreasing trend.

**KEY WORDS:** Magnesium Ions ( $Mg^{2+}$ ), Calcium Cations ( $Ca^{2+}$ ), soil water extract, distilled water, EDTA (Trilon B) solution, ammonia buffer solution, Eriochrome Black T indicator, complexometric titration, solution pH.

## I. INTRODUCTION

Over recent decades, the intensive exploitation of land resources on a global scale, including in Uzbekistan, has resulted in a substantial reduction in soil humus content and essential nutrients, along with a progressive increase in the accumulation of harmful salts. These changes have adversely affected soil fertility and crop yields [1, 2]. Consequently, soil resilience to anthropogenic pressures has significantly declined, erosion processes have been accelerated, and both physicochemical and agrochemical properties have progressively deteriorated, resulting in the disruption of agriculturally valuable soil components. These interconnected processes ultimately drive ongoing soil degradation [3-5]. Enhancing soil fertility requires, first and foremost, a comprehensive assessment of the current soil condition, differentiation of soil nutrient composition across field-level spatial variability, and the identification of high-yielding agricultural crops appropriate for each soil-climatic zone in accordance with agroecological zoning principles. Furthermore, the adoption of optimized agrotechnologies aimed at the production of high-quality and environmentally sustainable products is essential, based on an integrated analysis of crop placement and cultivation practices, together with the implementation of advanced fertilization systems, crop rotation schemes, and other agrotechnical measures within intensive farming systems [6, 7]. Mirzachol District of Jizzakh Region, located in the central part of Uzbekistan, constitutes a vast and ecologically significant area characterized by its unique climatic conditions, diverse plant species, and a variety of soil types. This region plays a vital role in maintaining Uzbekistan's ecological balance and harbors a wide range of plant and animal species adapted to its complex environmental conditions [8]. The climate of the Jizzakh Desert is characterized by hot summers and cold winters, with limited precipitation throughout the year. These climatic conditions exert a significant influence on the region's vegetation and soil composition. Soil erosion represents a serious concern in the area and is further exacerbated by unsustainable land use practices and climate change [9]. Magnesium is the third most abundant structural metal in the Earth's crust and is present in numerous rock types as well as in seawater. In soils, it occurs as  $Mg^{2+}$  ions, which are exchangeable cations in solution. Once absorbed by plant roots,  $Mg^{2+}$  is transported internally to the aerial parts of the plant. Magnesium plays a fundamental role in plant growth and development and participates in a range of processes essential for plant metabolism, including its incorporation into chlorophyll molecules and its function as a cofactor activating enzymatic activity [10]. Calcium ions ( $Ca^{2+}$ ) play a crucial role in plant growth, development, and cellular signaling. Investigating the dynamics of  $Ca^{2+}$  in the soils of Mirzachol District, Jizzakh Region, is essential for



understanding its availability and role in plant nutrition. Soil properties, including texture, cation exchange capacity, and organic matter content, influence the uptake and transport of  $\text{Ca}^{2+}$ . Understanding these processes can help improve plant growth, fruit quality, and stress tolerance within local orchard systems [11]. The aim of this study is to determine the concentrations of  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  cations, pH, and electrical conductivity in the chemical composition of saline soils in the eastern part of Mirzachol District, Jizzakh Region.

## II. METHODOLOGY

The study was conducted on a 40-hectare plot of the “Ifore” farm, located in the eastern part of Mirzachol District. Soil samples were collected by scientists from the Institute of General and Inorganic Chemistry of the Academy of Sciences of the Republic of Uzbekistan at various depths: 0–5, 5–10, 10–20, 20–40, 40–60, 60–80, and 80–100 cm. Each soil sample was weighed to 200 g using an analytical balance and subsequently air-dried at room temperature under laboratory conditions. The air-dried soil samples were ground using a porcelain mortar and pestle and subsequently sieved through laboratory sieves with mesh sizes of 1.0 mm and 0.25 mm. From each sample, 50 g of soil was accurately weighed and placed into 500 mL beakers, to which 250 mL of distilled water was added and thoroughly mixed. The resulting suspension was then filtered using filter paper. To determine  $\text{Mg}^{2+}$  concentrations, a 10 mL aliquot was taken from each prepared soil extract, to which 100 mL of distilled water and 5 mL of ammonia buffer solution were added. The ammonia buffer solution was prepared by dissolving 6.7 g of  $\text{NH}_4\text{Cl}$  in 20 mL of distilled water, diluting to 100 mL in a volumetric flask, and then adding 57 mL of 25 %  $\text{NH}_3$  solution to the mark to obtain a homogeneous solution. Thereafter, 0.1–0.2 g of eriochrome indicator powder was incorporated. Each aliquot was titrated with a Trilon B (EDTA) solution, and the volume of Trilon B consumed was recorded. To determine  $\text{Ca}^{2+}$  concentrations in the prepared soil extracts, a 10 mL aliquot was taken from each extract, to which 100 mL of distilled water and 5 mL of KOH solution were added, followed by 2–3 drops of murexide indicator (prepared by grinding 0.2 g of murexide with 40 g of  $\text{K}_2\text{SO}_4$  in a porcelain mortar for 1 h). Each aliquot was then titrated with a Trilon B (EDTA) solution, and the volume of Trilon B consumed was measured [12]. The pH and electrical conductivity of the soil extracts were measured under controlled laboratory conditions using a CHUNYE PH300 pH meter.

To determine the concentration of  $\text{Mg}^{2+}$  ions in the samples, the following formula was used.

$$\text{Mg}^{2+} = \frac{V_{\text{TB}} \cdot N(\text{TB}) \cdot E(\text{Mg}) \cdot 250 \cdot 100}{m \cdot 10 \cdot 1000} \quad (1)$$

Where:

$V_{\text{TB}}$  = volume of Trilon B (EDTA) solution used for titration (mL)

$N_{\text{TB}}$  = normality of Trilon B (EDTA) solution

$E_{\text{Mg}}$  = equivalent weight of magnesium ( $\text{g} \cdot \text{eq}^{-1}$ )

$m$  = mass of the soil sample (g)

250 – volume of the standard  $\text{MgSO}_4$  solution (mL);

100 – percent concentration (100%);

10 – volume of the aliquot taken (mL).

The results of the titrimetric analysis of  $\text{Mg}^{2+}$  ions are presented in Table 1.

To determine the concentration of  $\text{Ca}^{2+}$  ions in the samples, the following formula was used.

$$\text{Ca}^{2+} = \frac{V(\text{TB}) \cdot N(\text{TB}) \cdot E(\text{Ca}) \cdot 250 \cdot 100}{m \cdot 10 \cdot 1000}$$

Where:

$V_{\text{TB}}$  = volume of Trilon B (EDTA) solution used for titration (mL)

$N_{\text{TB}}$  = normality of Trilon B (EDTA) solution

$E_{\text{Ca}}$  = equivalent weight of calcium ( $\text{g} \cdot \text{eq}^{-1}$ )

$m$  = measured mass of  $\text{Ca}(\text{ClO}_3)_2 \cdot 2\text{H}_2\text{O}$  (g)

250 = volume of the standard  $\text{Ca}(\text{ClO}_3)_2 \cdot 2\text{H}_2\text{O}$  solution (mL)

100 = percent concentration (100%)

10 = volume of the aliquot taken (mL)

### III. RESULTS AND DISCUSSION

The titrimetric analysis results of  $Mg^{2+}$  and  $Ca^{2+}$  cations, as well as the pH and electrical conductivity of the soil extracts, are presented in Table 1.

Table 1. The percentage contents of  $Mg^{2+}$  and  $Ca^{2+}$  cations in the aqueous extracts prepared from different soil layers, as well as the pH and electrical conductivity of the aqueous extracts

No	Soil layer (cm)	$Mg^{2+}$ , (%)	$Ca^{2+}$ , (%)	pH	mv
1	0–5	0,39	0,58	6.90	5.5
2	5–10	0,51	0,61	6.69	18.3
3	10–20	0,15	0,21	6.91	5.3
4	20–40	0,09	0,10	6.95	2.9
5	40–60	0,09	0,15	7.50	- 6.2
6	60–80	0,08	0,26	7.44	- 3.1
7	80–100	0,05	0,20	7.39	- 0.8

The amounts of  $Mg^{2+}$  and  $Ca^{2+}$  cations studied within the 0–100 cm soil profile depth, as well as the soil extract pH and electrical conductivity (EC) values, exhibited significant variation in their vertical distribution. The obtained results indicate a clear differentiation between the upper and lower soil layers in terms of chemical composition and reaction of the soil environment. The highest content of the  $Mg^{2+}$  cation was recorded in the 0–5 cm layer (0.39%) and in the 5–10 cm layer (0.51%). The lowest content of the  $Mg^{2+}$  cation was recorded in the 10–20 cm layer (0.15%), 20–40 cm layer (0.09%), 40–60 cm layer (0.09%), 60–80 cm layer (0.08%), and 80–100 cm layer (0.05%). This condition is explained by the high intensity of plant residue decomposition, the accumulation of organic matter, and the biological cycling processes in the upper soil layers.  $Mg^{2+}$  ions released as a result of the mineralization of organic matter can form complex compounds with humus and may be retained in the adsorption complex. With increasing soil depth, the decrease in biological activity and the predominance of leaching processes lead to a reduction in the  $Mg^{2+}$  content. The highest content of the  $Ca^{2+}$  cation was recorded in the 0–5 cm layer (0.58%) and in the 5–10 cm layer (0.61%), whereas the lowest content of the  $Ca^{2+}$  cation was observed in the 10–20 cm layer (0.21%), 20–40 cm layer (0.10%), 40–60 cm layer (0.15%), 60–80 cm layer (0.26%), and 80–100 cm layer (0.20%). The greater accumulation of  $Ca^{2+}$  in the upper layers may be associated with carbonate compounds, organic residues, and a higher cation exchange capacity.

In addition,  $Ca^{2+}$  is one of the main cations that stabilize soil structure and plays an important role in the formation of aggregates. Its decrease with depth can be explained by leaching, the migration of carbonates, and pedogenetic processes.

The pH value of the soil extract was close to neutral in the upper layers, while an increase in alkalinity was observed with depth. This condition may be associated with the relatively higher accumulation of carbonates and bicarbonates in the lower layers. In the upper layers, organic acids produced from the decomposition of organic matter act as a factor that slightly lowers the pH. In the deeper layers, the dominance of carbonate-bearing parent materials leads to the formation of an alkaline environment. The decrease in electrical conductivity (EC) values with depth can be explained by the accumulation of soluble salts mainly in the upper soil layers. This condition may be related to capillary rise, agrotechnical practices, or fertilization processes. Along with the decrease in EC, the reduction in the amounts of  $Mg^{2+}$  and  $Ca^{2+}$  ions indicates that the total ion content of the soil decreases with increasing depth. Overall, the results confirm that chemical differentiation occurs in soil layers due to the vertical migration of cations and the influence of pedogenetic processes. The accumulation of  $Mg^{2+}$  and  $Ca^{2+}$  cations in the upper layers plays an important role in ensuring soil fertility, structural stability, and the balance of nutrient elements.

### IV. CONCLUSION AND FUTURE WORK

Based on the conducted research, the following scientific conclusions were drawn: In the upper (0–10 cm) layers of the soil profile, the amounts of  $Mg^{2+}$  and  $Ca^{2+}$  cations are higher compared to the lower layers, and their amounts consistently decrease with increasing depth. The vertical distribution of  $Mg^{2+}$  and  $Ca^{2+}$  is closely related to biological processes in the soil, the content of organic matter, as well as leaching and migration processes. The pH value of the soil extract shifts from a neutral environment to an alkaline environment with



increasing depth, which can be explained by the accumulation of carbonate compounds. The decrease in electrical conductivity values indicates a reduction in the amount of soluble salts in the soil solution with increasing depth. The identified patterns serve as an important scientific basis for assessing soil fertility, optimizing fertilization systems, and developing strategies for sustainable land use.

These results scientifically substantiate the vertical differentiation of cations and the interrelation of chemical properties in the soil profile, and they provide a methodological basis for further in-depth studies of nutrient element dynamics in the soil–plant system.

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