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Articles

Cation Exchange Capacity in the Arid Soils of the Republic of Kalmykia

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Abstract

On the basis of field research, the current state of soils in the eastern zone of the Republic of Kalmykia was studied. The predominant soil cover in this area is represented by brown saline soils and brown-desert soils in a complex with salt licks. The purpose of the study is to study the absorption complex, as well as the composition and content of exchangeable cations in the soils of the eastern zone of the Republic of Kalmykia. cations: calcium (Ca^{2+}) and magnesium (Mg^{2+}) and an assessment of the level of soil absorption capacity in 7 settlements of the Yashkul district of the Republic of Kalmykia. To conduct the research, 15 monitoring sites were placed on the borders and in the center of settlements, the background sample was taken at a distance of 500 m from the boundaries of the residential zone. The determination of the physical and chemical properties of the soils was carried out according to GOST and generally accepted methods. The results of the study showed that the level of absorption capacity of soils in the study area ranges from low to medium. The absorbent complex is saturated with the cations Ca^{2+} and $Mg^{2+,}$ and the content of exchangeable Ca^{2+} predominates over the content of Mg^{2+} in the range of 2 to 4 times.

Keywords: Republic of Kalmykia, solonets, chemical properties of soils, exchangeable cations, soil absorption complex.

1. Introduction

To date, much attention has been paid to the study of exchangeable cations, as they affect the chemical, physical and biological properties of soils, are easily absorbed by the root system of plants and are an important source of mineral nutrition (Giedroyc, 1933; Karpachevsky et al.,

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2007). The founder of the first studies on soil absorption capacity, K.K. Giedroyc (1975), who was the first to introduce the term soil absorption complex and used the term soil absorption capacity as the sum of all exchangeable cations, which can be displaced from the soil, argued that the best fertility is possessed by soils saturated with potassium and magnesium (Pinsky, 1990). The amount of magnesium absorbed should be 20-40% of the calcium absorbed (Antipova-Karataeva, Antipov-Karataev, 1940). In the soils of arid regions, such as the Republic of Kalmykia, the most important factor for diagnosing the processes of soil formation and soil fertility are the exchangeable cations of the soil absorption complex Ca^{2+}, Mg^{2+}.

Calcium is present exclusively in all soils, but in different amounts and in different ratios with other cations. It makes the soil structure loose, acts as a binder between clay and organic matter (Kershberger, Proysker, 2007). Magnesium is a concomitant element (companion) of potassium, often found in soils in the ratio of Ca^{2+} cations: Mg^{2+}=5:1, but when this ratio shifts towards Mg^{2+}, there is an increase in the alkalinity of soils due to the presence of magnesium carbonates and bicarbonates in the soil environment (Vorobyeva, Pankova, 1995; Vorobyova 2006; Okorkov, 1994). The well-known scientist G.D. Unkanzhinov et al. (2005) devoted his scientific work to the study of the dynamics of exchangeable potassium content in the soils of the Republic of Kalmykia for 1966-2013. The dynamics, based on agrochemical studies over the past 50 years, shows that the weighted average content of exchangeable potassium in the soils of arable land in the republic is at the high availability level, but there is a negative balance of this element. The monograph "Red Book of Soils and Ecosystems of Kalmykia" (Unkanzhinov et al., 2005; Okorkov, 1994) provides values of absorption capacity and composition of exchangeable cations in a number of main types of soils: solonetz, meadow-brown, light chestnut solonetz, meadow-chestnut, chestnut solonetz, chernozem, which are characteristic soils of protected natural areas of Kalmykia. Considering valuable soil and biological objects in the system of specially protected areas of the Republic of Kalmykia, (Tashninova, 2000) indicated that these objects are confined to the main natural-territorial formations. In general, modern data on the composition of exchangeable cations in the soils of the Republic of Kalmykia have not been studied sufficiently, which determines the relevance of this topic. The purpose of the study was to study the absorption complex, as well as the composition and content of exchangeable cations in the soils of the eastern zone of the Republic of Kalmykia.

2. Materials and methods

During the 2020 seasonal expedition in the Yashkul district, materials were selected based on data on the physical and chemical composition of the soils. 7 settlements in the Yashkul district were chosen as the subject of the study: Chilgir village, Ulan-Erge village, Elvg village, Ermeli village, Khogn village, Gashun village, Yashkul village (Figure 1).

Fig. 1. Sampling sites in the Yashkul district of the Republic of Kalmykia

The basis of the soil cover of this territory is a zonal group of brown saline soils and brown desert-steppe saline soils in combination with saline soils.

The structural composition of the study area is represented by brown semi-desert soils, with feather-grass-fescue, wormwood-feather grass vegetation characteristic of them. Information about the natural conditions and characteristics of this area was studied in detail in the work of A.B. Adyanova et al. (2023). The physicochemical characteristics of soils were studied using generally accepted methods: the pH of an aqueous suspension was determined by the potentiometric method with a hydrogen electrode (GOST, 2011) organic matter according to Tyurin modified by V.N. Simakov (GOST, 1993) exchange cations Ca^{+2} and Mg^{+2} according to GOST 26487-85 (GOST, 1985) trilonometrically. The level of absorption capacity was assessed using the scale given in Table 1 (Remezov, 1957).

Table 1. Assessment of the level of cation exchange capacity (CEC)

CEC	mEq/100 g soil
Low	<10
Average	10-20
High	20-40
Very high	>40

Processing of the data obtained was carried out using descriptive statistics in the Statistica v.12 program.

3. Results and discussion

In the course of studies on the extraction of water from soils in the Yashkul district of the Republic of Kalmykia, indicators such as organic carbon content, environmental reaction (pH), exchangeable cations Ca^{2+} and Mg^{2+}, as well as CEC were studied (Figures 2–7).

As a result of the work carried out, it was found that in the soils of the study area, the organic carbon in the surface layer (0–20 cm) is in the range of 0.31–1.86%, which indicates a very low content (Figure 2).

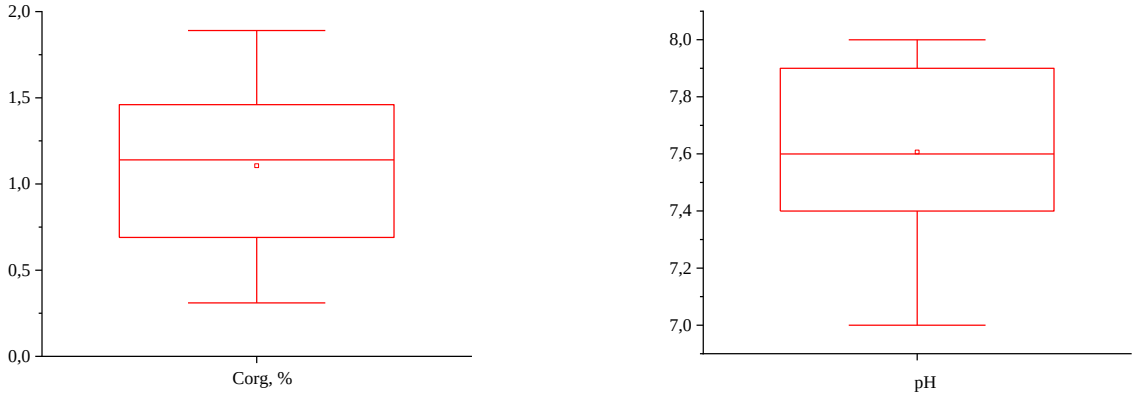

Fig. 2. Organic carbon content, %, pH in soils of the Yashkul district of the Republic of Kalmykia

The pH response of the soil environment varies from 7.0 to 8.0, which corresponds to a neutral and slightly alkaline reaction (Figure 2). The content of exchangeable cations Ca^{2+} ranges from 0.25 to 19.77 mmol(mg-eq)/100 g soil (very low to low), and for Mg^{2+} from 8.67 to 55.43 mmol(mg-eq)/100 g soil (increased to very high), it can also be concluded that the content of exchangeable calcium prevails over the exchangeable magnesium in the limit from 2 to 4 times (Figure 3).

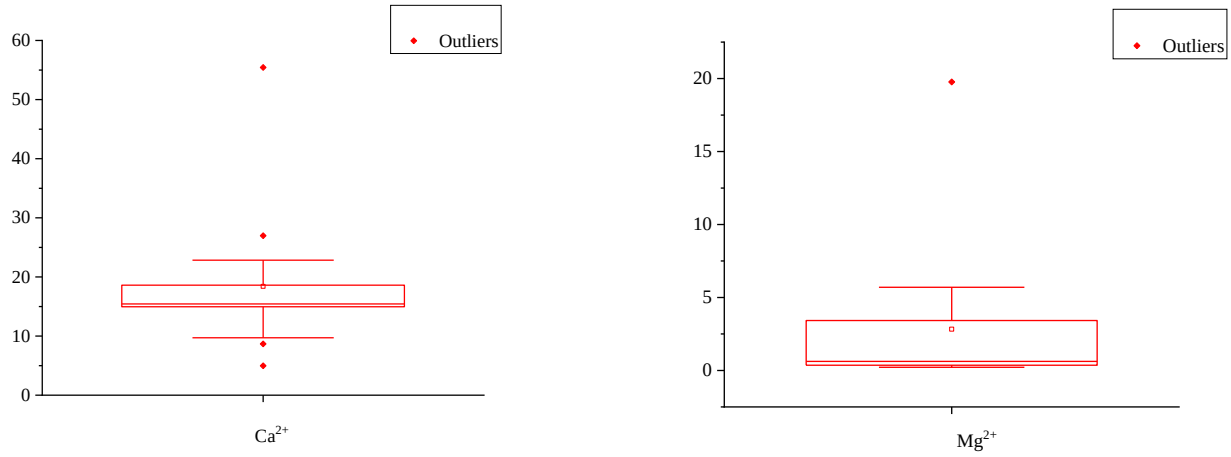

Fig. 3. Exchangeable cations Ca^{2+}, Mg^{2+} mmol (mg-eq)/100 g soil of the Yashkul district of the Republic of Kalmykia

According to the scale for assessing the level of soil absorption capacity, the CEC is in the range of 5.2–75.2 mmol (mEq)/100 g soil, indicating a variation of this indicator from low to very high, but most of the soils studied are in the medium range (Figure 4). Minimum values: pH, Corg, Ca^{2+}, Mg^{2+}, CEC are found mainly at the background sites, and this pattern is true for most of the sites studied (Figures 5–7).

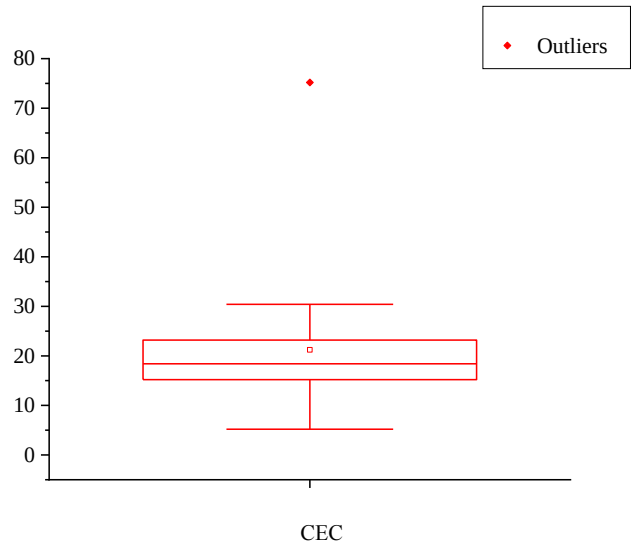

Fig. 4. CEC mmol (mg-eq)/100 g soil of the Yashkul district of the Republic of Kalmykia

Chilgir, Ermeli and Yashkul soil cover of is represented by brown desert-steppe saline soils in combination with saline soils, the pH of the soil solution varies from neutral to slightly alkaline (7.2–7.7) in terms of organic carbon content, this area varies from low-humus and medium-humus (0.31–1.89%), the saturation with exchangeable cations also varies in Mg^{2+} from very high to very low (0.56–19.77) mmol(mg-eq)/100 g soil, Ca^{2+} – changed to very low (8.67–55.43) mmol (mg-eq)/100 g, and in terms of CEC capacity there is also a variation from very high to low (10.4–75.2) mmol(mg-eq)/100 g soil (Figures 5, 6). The highest values in these settlements were found in the Yashkul settlement – for the exchange cations Mg^{2+} – 19.77 mmol(mg-eq)/100 g soil, Ca^{2+} – 55.43 mmol (mg-eq)/100 g soil and CEC – 7.52 mmol (mg-eq)/100 g soil (edge of the settlement) (Figures 3–4), and according to the pH 7.7 and Corg indices of 1.68% (background sample) (Figures 5–7).

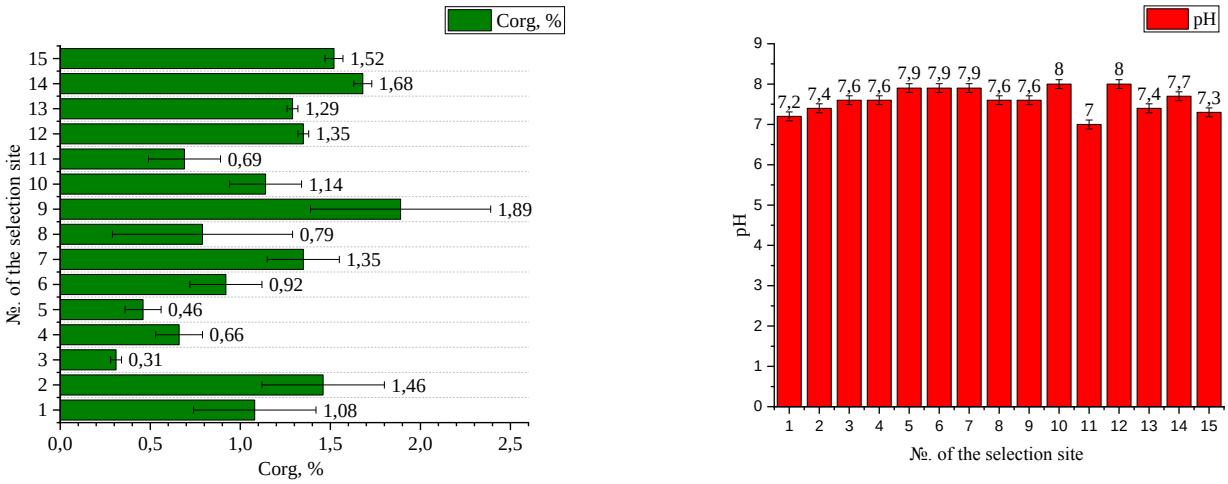

Fig. 5. Organic carbon content and pH in soils of the Yashkul district of the Republic of Kalmykia

On the territory of the villages of Khogn and the village of Gashun, brown saline soils prevail with saline soils, the reaction of the pH of the soil solution changes from neutral to alkaline (7.0 to 8.0), the variation of organic carbon within (0.69 %–1.35 %) low-humus and medium-humus soils, exchangeable cations and for Mg^{2+} 0.29–3.01 mmol (mg-eq)/100 g soil and for Ca^{2+} 9.71–22.84 mmol(mEq)/100 g soil ranges from very low to medium, with CEC within the medium to high range of 10.0–23.2 mmol(mEq)/100 g soil (Figures 5–7).

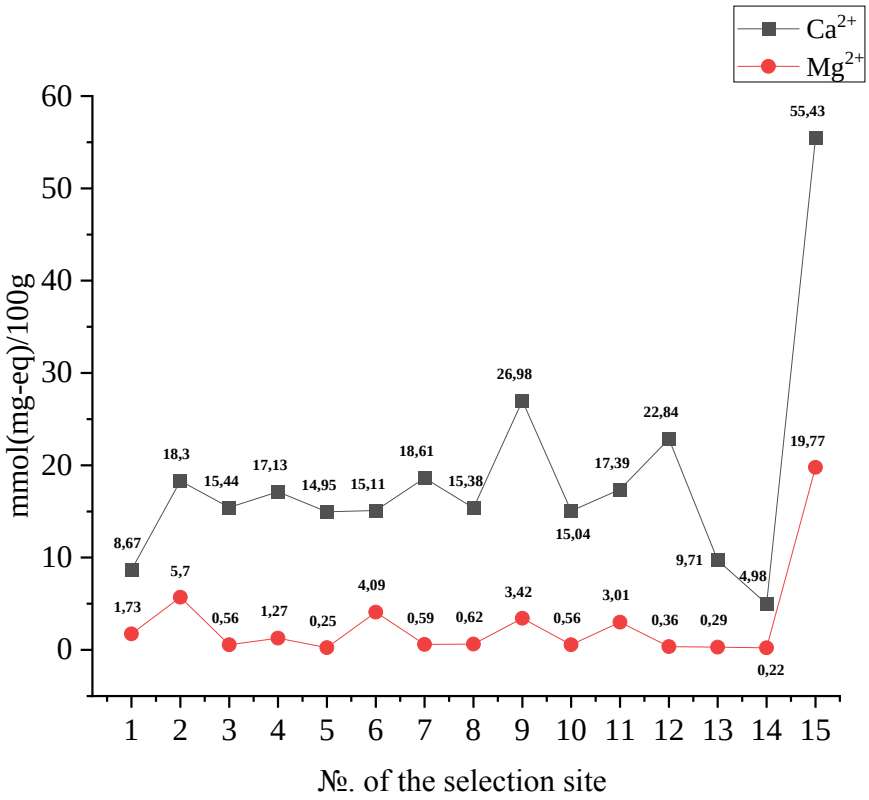

Fig. 6. Exchange cations Ca^{2+}, Mg^{2+} in the soils of the Yashkul District of the Republic of Kalmykia

The highest indicators values of were found in the village of Hogn (background) for the exchange cation Mg^{2+} 3.01 mmol (mg-eq)/100 g soil – very low (Figure 6), and in the center of the settlement the pH 8.0 alkaline and organic carbon increased (1.14%). In the village of Gashun, the values for Ca^{2+} 22.84 mmol (mg-eq)/100 g soil – average saturation and CEC 23.2 mmol (mg-eq)/100 g soil high level increased (Figure 7). The main type of soil in the village of Evlg is

meadow solonets, the pH of the soil solution is slightly alkaline (7.9), in terms of organic carbon, low-humus soil – 1.35 % (Figure 5), Mg^{2+} – 0.59 mmol (mg-eq)/100 g soil (very low), Ca^{2+} – 18.61 mmol (mg-eq)/100 g soil (low) in saturation with exchange bases, CEC – 19.2 mmol (mg-eq)/100 g soil average (Figures 5–7).

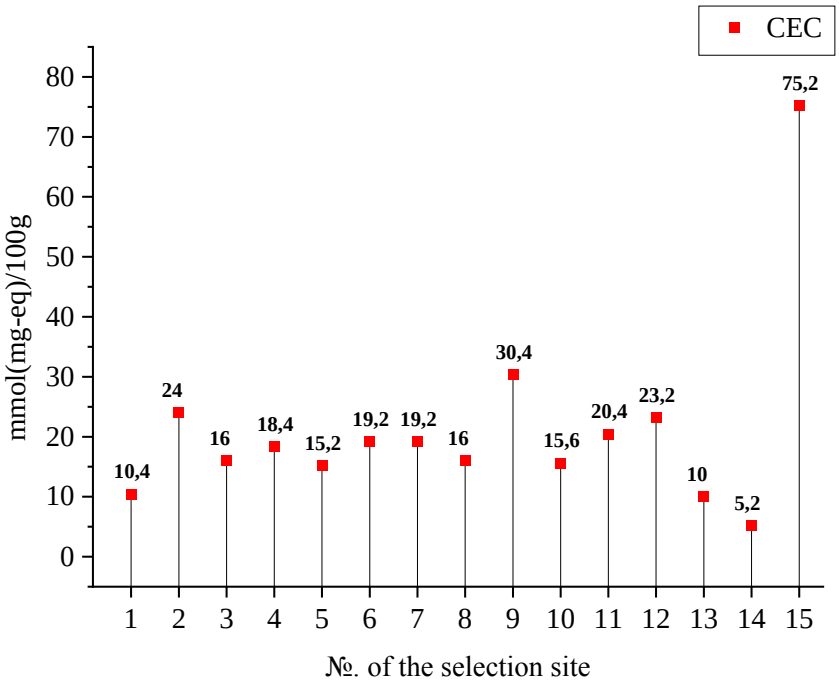

Fig. 7. Exchange cations Ca^{2+}, Mg^{2+}, CEC in the soils of the Yashkul District of the Republic of Kalmykia

The village of Ulan-Erge is represented by brown saline and saline soils, the pH of the soil solution is slightly alkaline 7.6–7.9, organic carbon is 0.46–0.92% (slightly humus to low-humus) (Figure 5), exchangeable cations at Mg^{2+} 0.25–4.09 mmol (mg-eq)/100 g soil are very low and at Ca^{2+} 14.95–17.13 mmol(mg-eq)/100 g soil low saturation, and CEC is in the range of 15.2–19.2 mmol (mg-eq)/100 g soil medium level absorption capacity (Figure 7).

4. Conclusion

Studies carried out in the Yashkul district have shown that this territory is mainly represented by a group of brown-saline to brown-semi-desert soils, which are typical for this territory. Chemical analysis of water extracts indicates that soils have a low organic carbon content (less than 2 %), which indicates low humus and low soil fertility, the pH in a larger mass of horizons (0–20 cm) is slightly alkaline (pH from 7–8 units). The saturation of the absorbing complex of metabolic Ca^{2+} and Mg^{2+}, as well as the predominance of calcium over magnesium. The content of exchange cations Ca^{2+} ranges from 0.25 to 19.77 mmol(mg-eq)/100 g soil (very low to low), and for Mg^{2+} from 8.67 to 55.43 mmol(mg-eq)/100 g soil (increased to very high). The absorption capacity of the studied soils varies from low to medium. The data obtained during the survey confirm the favorability of cultivation and cultivation of agricultural crops in the territory of the Yashkul district of the Republic of Kalmykia as an area belonging to the zone of risky farming and the correspondence exists of indicators of soil characteristics in the territory of the Republic of Kalmykia.

5. Conflict of interest information

The authors declare that there is no conflict of interest.

6. Acknowledgements

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