INTRODUCTION

The Baraba Lowland occupies 11.5 million hectares, or 65.5% of Novosibirsk oblast. It has a plain topography complicated by ridges of glacial origin. Ordinary chernozems, which are usually solonetzic, are formed on the ridges, and salt-affected soils (solonchaks, solonetzes, and solods) and their combinations with other soils occupy depressions between the ridges. Solonetzes are the most widespread soils; their area is estimated at 2530700 ha. In some districts, solonetzes occupy up to 80–82% of the agricultural lands [17].

The groundwater may have different degrees of salinity and different compositions of salts. The groundwater table lies at relatively shallow depths (45–350 cm), thus favoring the development of solonetzes from meadow-chernozemic, chernozemic-meadow, and meadow solonchakous soils. Under natural conditions, these solonetzes have a relatively high humus content and a number of adverse physical and physicochemical properties. With respect to the content of exchangeable sodium in the illuvial horizon, they are assigned to the groups of low- and medium- and high-sodium solonetzes. Low- and medium-sodium solonetzes predominate.

Numerous investigations and large-scale experiments proved that the chemical amelioration of solonetzes via the application of gypsum and phosphogypsum (a byproduct of superphosphate production) is an efficient measure to improve the fertility of solonetzes. This method was widely applied in the region in the 1970s–1980s. Thus, about 500000 ha of solonetzic soils in Omsk oblast [2] and about 30000 ha in Novosibirsk oblast [3] were ameliorated in that time.

A single application of these ameliorants increases the soil fertility for a long time and ensures high and stable crop yields. The early studies of the effect of gypsum application on the properties of solonetzes were performed by Eremchenko in Chelyabinsk oblast [8, 9]. She resumed the experiments on the chemical amelioration of solonetzes initiated by A.I. Oborin in 1932 and 1960–1963.

Eremchenko [8] showed that the positive effect of chemical amelioration on the properties of hydromorphic and semihydromorphic solonetzes subjected to long-term salinization–desalinization cycles depends on the composition of the salts and the thickness of the A horizon: on medium and shallow solonetzes with sulfate salinization, the effect of gypsum application lasts for more than 7–11 years upon noninversive tillage and for about 8 years upon moldboard plowing. A positive ameliorative effect is seen for more than 28 years on deep bicarbonate and crusty chloride–sulfate solonetzes and for more than 50 years on medium-deep bicarbonate solonetzes.

The effect of a single application of chemical ameliorants was studied in Omsk oblast by Berezin [2]. He found that the phosphogypsum applied to solonetzes of the Malinovsk Experimental Station in 1984 exerted a positive effect in the eighteenth year after the amelioration. The effect of a single application of phosphogypsum at the rate of 12 t/ha lasts for many years and becomes more pronounced with time.

The aim of our investigations was to study some properties of crusty low- and high-sodium solonetzes treated with gypsum 20 and 25 years ago and to determine the trend of anthropogenic evolution of ameliorated solonetzes.

OBJECTS AND METHODS

The investigations were performed in the northern forest steppe of the Baraba Lowland (the Kabinetnoe farm in the Chulym district) on two experimental plots located not far from one another. The chemically ameliorated chernozemic-meadow crusty hydromorphic...
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high-solonchakous solonetzes with sodium sulfate salinization were studied. These soils were slightly to moderately saline with a deeply lying calcareous horizon and different contents of adsorbed sodium in the B1 illuvial (solonetzic) horizon (low- and high-sodium solonetzes); the average thickness of the A horizon reached 4 cm.

Small-plot experiments with a single application of gypsum were set in 1981 on the low-sodium solonetz (25 years of the gypsum effect) and in 1986 on the high-sodium solonetz (20 years of the gypsum effect) [16]. The experimental plots are located on plain areas between forest groves in mesodepressions. The surface microtopography in the form of shallow saucerlike microlows is well pronounced. The groundwater level is subjected to considerable seasonal and interannual fluctuations (from 40 to 350 cm). The groundwater salinity varies from 1.5 to 2.0 g/l. In the area of the high-sodium solonetz, the groundwater level is found closer to the surface, and the groundwater salinity is somewhat higher than those in the area of the low-sodium solonetz. The plow horizons of the studied soils have light and medium clayey textures. The exchange capacity reaches 44.7 meq/100 g in the low-sodium solonetz and 35.4 meq/100 g in the high-sodium solonetz. The contents of exchangeable sodium are equal to 4.2 meq/100 g (9.5% of the CEC) in the low-sodium solonetz and 16.9 meq/100 g (47.7% of the CEC) in the high-sodium solonetz. The pH of the plow layer is 7.2–8.5 in the low-sodium solonetz and 8.0–9.3 in the high-sodium solonetz. The humus content is about 5% in both soils.

For the low-sodium solonetz, the rates of gypsum application were determined empirically and varied from 0 to 50 t/ha irrespectively of the exchangeable sodium content. For the high-sodium solonetz, the rates of gypsum application were calculated for an average sample with an interval of 0.25 of the normal rate determined according to Gedroits [5]; i.e., the experimental rates varied from 0 to 1.25 of the normal rate. The experiment was organized as follows: the experimental plot was subdivided into several trial plots with the use of pickets. The area of the trial plots was 1 m² on the low-sodium solonetz and 4 m² on the high-sodium solonetz; the distance between them was 1 m. Each plot, the 0–20-cm-deep upper soil layer (the Ap horizon) was removed onto a polyethylene film, and gypsum was applied to it and thoroughly mixed with the soil mass. The side walls of the trial plots were covered by a polyethylene film to a depth of ≈30–40 cm to prevent lateral surface and soil water flows, and the soil mixed with gypsum was placed back onto the plots. The same technology (except for the gypsum application) was applied to the control. The soil samples were taken with an auger, and the holes were filled up with paraffin to avoid additional soil drainage [4].

Before 1994, the following crop rotations were applied: fallow–wheat–oats–oats on the trial plots with the low-sodium solonetz and fallow–winter rye–wheat–oats–oats on the trial plots with the high-sodium solonetz. The plots were annually plowed by hand to a depth of 20 cm in the fall. In the spring, the soil was tilled before sowing, and cereal crops were sown by hand.

Since 1994, no crops have been sown on the plots. By the end of the experiment, lucerne was sown on all the plots. In 2006, we studied 100-cm-deep soil pits made on one of the experimental replicates. The studied variants included the control and the plots with gypsum application at the rates of 12, 18, 35, and 50 t/ha on the low-sodium solonetz and 11, 45, and 56 t/ha on the high-sodium solonetz. In the preceding years, these variants were comprehensively studied, and the obtained data made it possible to trace the changes in the properties of the ameliorated solonetzes. Soil pits were additionally set on the adjacent virgin areas in order to reveal the real effect of a single application of gypsum on the morphology and properties of the solonetzes.

The morphological features and analytic data on the studied solonetzes (the variants with different rates of gypsum application, the control variants without gypsum application, and the virgin solonetzes) were analyzed.

The soil texture was determined according to the method of Kachinskii [10]. The deviation from the mean was less than 10% at $P = 0.95$. The exchangeable sodium was determined by the Shollenberger method, and the soil pH was determined by the potentiometric method.

RESULTS AND DISCUSSION

Changes in the morphology of crusty solonetzes under the impact of gypsum application. The morphological study of the solonetzes on the experimental plots demonstrated that a columnar structure had formed in the former plow layer of the low- and high-sodium solonetzes at the control plots. Well-shaped columns were seen from a depth of 4 cm to a depth of 12 cm. Deeper, the soil acquired an angular blocky structure with shining ped faces. Effervescence was observed from the surface of the high-sodium solonetz and from a depth of 40 cm for the low-sodium solonetz. Gley features were seen in the entire profile of both soils, particularly in the lower horizons. On the control plots, plant cover was virtually absent.

Thus, after the end of the mechanical cultivation, the columnar structure in the plow horizon of the solonetzes was restored on the control plots in about 12 years. In the deeper layers, the columnar structure was gradually replaced by the angular blocky structure. In general, the initial profile of the crusty solonchak was restored on the control plots.

In the virgin solonetzes, effervescence was observed from a depth of 3 cm. It was weak in the illuvial horizon