Chemical Properties and Fertility of Solonetzes of High Exchangeable Magnesium Content

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A detailed survey of the Turgai steppe soils within the confines of the dark chestnut soil subzone of the Kustanai area has revealed low-sodium solonetzes whose exchange complex contains 40—50% exchangeable magnesium, about 50% exchangeable calcium and 10—20% exchangeable sodium.

Magnesium solonetzes are almost identical to the high-sodium ones in their morphological structure and water-physical properties. Without doubt microtopography, as the main redistributor of rainfall moisture, is decisive in the formation of the soil complex. The average annual precipitation is about 225—285 mm, which is largely evaporated.

The results of mechanical analyses show a sharp differentiation of solonetz profiles according to clay and physical clay contents. This is an important criterion of alkalinity and is quite typical of all solonetz types. The solonetz horizon B contains 2 to 2.5 times more clay than the horizon A.

Low-sodium solonetzes are saline from horizon B (0.33%) down. With depth the salt content increases and reaches 0.74%.

The maximum accumulation of salts coincides with the gypsum horizon (1.2—2.3%) that occurs in low-sodium steppe solonetzes at a depth of 45—95 cm and in the meadow-steppe average-sodium ones at about 30 cm.

Dark-chestnut soils are not salinized in the first 50 cm to 1.5 m in mellow virgin soils. However the general alkalinity of these soils is higher than in solonetzes (0.4—1.7 meq. of HCO_3).

The composition of exchangeable bases of alkali-complex soils is of interest and is shown in Table I.

The table shows that the humus horizons of the steppe solonetzes are characterized by a low content of exchangeable sodium and of the meadow steppe ones by a moderate content. Exchangeable magnesium predominates over calcium in almost all the humus horizons of the solonetz profiles.

To elucidate the reasons for the low amount of exchangeable Ca in solonetzes, comparative analyses were carried out to determine its content in various forms: exchangeable, carbonated and fixed. Results of the analyses are given in Table 2.

The fixed forms of calcium (insoluble in 0.02 n HCl) are predominant in all solonetzes, especially in horizons which overlie the solonetz horizons. In dark-chestnut soils most of the calcium is in the exchangeable form and in the form of free carbonates. The share of fixed calcium is only 10—35% in comparison with 60—70% in solonetzes.

Table 1

Exchangeable cations

N° of soil profile, agricultural land	Genetic horizon	Depth of sampling (cm)	Exchangeable in per cent of the sum		
			Ca	Mg	Na
Steppe moderate solonetzes on quaternary heavy loam					
149	A	0— 8	53	43	4
Virgin soil	B_i	12—22	37	49	14
147	A	0—15	54	35	11
Arable land	B	16—23	40	43	17
Steppe moderate solonetzes on tertiary heavy loam					
186	A	0— 5	49	51	traces
Virgin soil	B	12—22	50	41	9
Meadow-steppe solonetzes on quaternary heavy loam					
285	A	0— 4	43	42	15
Virgin soil	B_i	8—22	26	47	27
Dark-chestnut soils (analogous to solonetzes by conditions of occurrences)					
150 (149)	A	0—16	76	24	traces
Virgin soil	B	17—27	83	17	traces
148 (147)	A	0—25	71	29	traces
Arable land	B	30—40	62	38	traces
187 (186)	A	0—10	60	40	traces
Virgin soil	B	18—28	56	39	5
286 (285)	A	0—18	80	19	1
Virgin soil	A	0—18	80	19	1

Sodium mobility in solonetzes increases with a simultaneous relative decrease in its fixed compounds.

Thus the process of solonetzisation has a different effect on calcium, magnesium and sodium-containing compounds in the soils.

This process results in the fixation of calcium and a decrease in its mobility. The mobility of magnesium and especially of sodium increases during this process.

The factors influencing the degree of base mobility in solonetzes has not yet been sufficiently studied. One of the factors is, perhaps, the coating of Ca containing particles with hydrate films of Al and Fe sesquioxides of low solubility, as well as by that of organic-mineral complex compounds of Al, Fe, P and Si.

Data on the fractional composition of humus show an increased content of mobile sesquioxides in sub-solonetz horizons (Table 3).

The less exchangeable calcium and free carbonates contained in soils, the more humic substances are fixed with mobile sesquioxides.

In accordance with the data of our investigations we suppose that a change in calcium mobility (the transition of calcium carbonates into fixed low-soluble compounds and consequently a decrease in the exchangeable calcium, especially in super-solonetz horizon) as well as differentiation in

Table 2

Ratio of Ca, Mg and Na compounds in dark-chestnut soils and solonetzes

Soils types and N° of profils and genetic horizon	CaO				MgO				Na_2O			
	Total amount, %	Kinds of compounds to total supply (%)			Total content in the soil %	Compounds to total content %			Total content	Compounds %		
		fixed	exch.	carb.		fixed	exch.	carb.		fixed	exch.	carb.
Heavyloamy dark-chestnut soil 150												
A	1.13	20	60	20	1.67	83	9	8	1.54	99	—	1
B_1	3.64	10	20	70	1.76	58	7	35	1.42	99	—	1
Heavy loamy steppe solonetz 149												
A	1.04	70	30	—	1.05	83	17	—	1.60	98	2	—
B_1	1.13	50	40	10	2.52	77	17	6	1.77	90	10	—
Heavy loamy solonetzic dark-chestnut soil on non-carbonate loam 187												
A	0.79	40	50	10	0.72	72	28	—	1.28	98	—	2
B_1	0.83	40	600	—	0.80	60	30	10	1.16	97	2	1
Steppe solonetz on heavy loam 186												
A	0.99	70	30	—	0.48	75	25	—	0.94	95	—	5
B_1	1.45	60	30	10	0.99	62	28	10	1.44	90	7	3
Meadow-chestnut heavy loam 286												
A	2.02	30	20	50	2.32	94	6	—	2.08	89	—	11
Meadow-steppe heavy loamy solonetz 285												
A	1.05	60	30	10	4.56	95	5	—	1.96	96	—	4
B_1	1.33	70	20	10	2.93	75	13	12	2.66	82	12	6

the clay fraction constitute important criteria of alkalinity. There are reasons to believe that an increase in exchangeable magnesium and sodium in the solonetz horizons is the consequence of a decrease in Ca mobility, as well as changes in the conditions determining the solubility of Na and Mg compounds when a lowering of the Ca content of the soil solution occurs.

Thus, an estimation of only the exchangeable sodium influence on soil alkalinity, as has been the case, does not make it possible to correctly determine the degree of alkalinity of low-sodium solonetzes and to theoretically substainate methods of amelioration.

In the light of the above considerations we assume that there are two paths to follow in developing methods of amelioration for low-sodium solonetzes:

1. increasing the solubility of soil calcium and

Table 3

Humus substances fixed with mobile R_2O_3 in soils of solonetz complex

Soils, lands	Genetic horizon	I fraction to total C %		
		Humic acids	Fulvo-acids	Total
Heavy loamy, dark-chestnut soil, Virgin land.	A B_i	2.00 0.56	4.84 2.72	6.85 3.28
Steppe heavy loamy solonetz, Virgin land.	A B_i	6.07 2.34	10.00 4.50	16.07 6.84
Steppe solonetz on carbonate-free heavy loam, Virgin land.	A B_i	17.50 1.93	12.75 6.45	30.25 8.38
Meadow-chestnut heavy loam. Virgin land.	A	2.84	3.41	6.25
Meadow-chestnut heavy loamy solonetz. Virgin land.	A B_i	16.50 0.65	9.70 10.70	26.30 11.35
Heavy loamy dark-chestnut soil, 50 year-arable land.	A B	7.10 no	8.95 0.71	16.05 0.71
Steppe moderate heavy loamy solonetz, 50 year-arable land.	A B	11.10 9.84	7.12 no	18.22 9.84

2. applying calcium containing amendments. Both these methods are actually employed for reclaiming solonetzes but they have not been sufficiently theoretically based.

The application of sulphomaterials (sulphuric acid, sulphur, iron vitrol) may be considered as one of the methods of raising the solubility of soil calcium. The effectiveness of this method is limited by time and depends on the calcium reserve in the soils to be reclaimed. Meliorative treatments of solonetzes without the addition of carbonates and gypsum to the arable layer may be considered as physical and mechanical. They destroy hydrate films of sesquioxides and increase the solubility of soil calcium.

The application of calcium ameliorants or drawing them into the arable layer from horizons of deeper occurrence is evidently considered to be one of the methods of solonetz amelioration, especially under irrigation. In this

Table 4

Available water supply in soils of solonetz complex in spring (mm.)

Soils, lands	Depth of layer	
	0—50	0—150
Dark-chestnut	47	59
Dark-chestnut solonetzic	16	58
Meadow-chestnut	7	127
Dark-chestnut, arable land	37	80
Steppe moderate solonetz	no	no
Steppe moderate solonetz over non carbonate clay	no	7
Meadow-Steppe solonetz	no	34
Steppe deep solonetz, arable land	24	55

case the selection of chemical ameliorants is, perhaps, of no less importance, than the choice of the method of amelioration.

The water and nutrient-supplying capacity of a soil is known to be the main criterion of its fertility. Solonetzes are not nutritionally inferior to dark-chestnut soils, except for potassium its content in solonetzes being about 1/3 of that in dark-chestnut soils (26—40 mg K_2O/100 g soil). The low fertility of solonetzes is connected as a rule with an unfavourable hydroregime. Investigations have shown that dark-chestnut soils in spite of a droughty year provide plants with a certain amount of moisture accumulated during the winter-spring period.

There is an absolute absence of available moisture in the solonetz profiles during droughty years. In spring their wetted depth is limited to horizon A and amount to 5— 10 cm. Dark-chestnut soils are moistened to 110 cm and more under the same conditions.

Conclusions

The main criteria of alkalinity of low-sodium solonetzes are the differentiation of profiles according to the content of the clay fraction and calcium mobility.

An increase in exchangeable magnesium and sodium in solonetzes results from a decrease in Ca mobility and an increase in the solubility of sodium-containing compounds caused by the changes in the ionic composition of the soil solution.

One cannot judge about the degree of soil alkalinity and work out methods of low-sodium solonetz amelioration by taking into account only exchangeable sodium.

Suggestions

It is necessary to have:

1. Investigations on the selection of chemical ameliorants, that promote the dissolution of calcium compounds in the solonetz and overlying horizons;
2. The development of methods for determining the preferred rates of calcium-free and calcium-containing chemical ameliorants;
3. The study of methods for raising Ca mobility in solonetzs by mechanical and physical methods (tillage, changing of temperature and moisture regimes, etc.).