

Amelioration of Sodic Solonetz Soils in the Region East of the River Tisza

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Among the non-carbonatic solonetz soils (meadow solonetz tending to get steppified) in the southern part of the region east of the Tisza nearly all transitional forms of this type — that is from slightly acid ones with unsaturated topsoil to slightly alkaline variants (deep, medium and crusty solonetz) — can be found. The salt content of most of them consists predominantly of sulphates, or sulphates and chlorides, or sulphates and hydrocarbonates, and, in a few of them of hydrocarbonates and carbonates. Variants slightly alkaline (saturated) even in their topsoil and sodic in their upper subsoil usually occur where the chernosem and meadow zones meet, while within the chernosem zone sodic solonetz spots, i.e. calcareous and sodic from the surface down, are to be found.

A number of field experiments of long duration have been established on a wide range of such soils in the last fifteen years. Amelioration of solonetz with slightly acid or neutral topsoil by means of liming or the spreading of calcareous subsoil ("digózás") has been carried out on a large scale for about twenty years. In the course of research work conducted in the last few decades methods of amelioration have been improved and new ones have been developed. Because of the low solubility of CaCO_3 soils with slightly alkaline topsoil cannot satisfactorily be reclaimed either by means of liming or by subsoil spreading. According to my experiments, such soils can be reclaimed as follows:

1. By joint application of CaCO_3 and gypsum.
2. By spreading with calcareous subsoil along with blacksoil.
3. By spreading with calcareous subsoil containing gypsum.

pH values in the topsoil of slightly alkaline solonetz containing neutral salts in the subsoil, were about 8. On such soils any of the above methods can be applied successfully and they actually are being applied on a large scale.

The following report will deal chiefly with long duration experiments conducted on solonetz using non-carbonatic topsoil from an area with hydrocarbonates in the subsoil. The pH values of such soils generally exceed 8.0 and their upper subsoil is sodic (pH 9.0 to 9.2) and extremely sticky. The report will also deal with an experiment in which the entire profile is carbonatic-sodic (sodic solonetz). One aim of these experiments was to test various materials suitable for replacing gypsum, namely: various gypsum containing by-products, lignite dust, CaCl_2 , HCl , sludge from sulphuric acid factories, K_2SO_4 , and FeSO_4 . In experiments conducted on non-carbonatic solonetz, treatments with CaCO_3 + gypsum or of CaCO_3 + lignite dust were also applied

Table 1
Analytical data of some characteristic average profiles

Location of the experiments	Depth of the sample cm.	Fundamental analyses					Exchangeable cations					Salt composition	
		pH in H ₂ O	Total salt	Alkalinity in terms of soda	CaCO ₃	Stickiness point according to Arany	Ca ²⁺	Mg ²⁺	K ⁺	Na ⁺	S		
													me./100 g. soil
Small plots in Szelevény	0-20	8.6	0.15	0.03	in traces	57	8.6	9.8	0.7	10.0	29.1	hydrocarbonatic	
	20-30	8.9	0.17	0.08	1.0	78	7.7	11.0	0.7	14.4	33.8		
	30-40	9.0	0.17	0.10	1.0	81	7.2	10.3	0.7	14.7	32.9		
	40-60	9.1	0.17	0.12	2.3	82							
Small plots in Kónya	0-20	8.2	0.14	0.05	in traces	44	11.5	7.5	1.7	7.9	28.6		
	20-30	9.1	0.23	0.20	5.5	66	7.5	3.8	0.8	20.5	32.6		
	30-40	9.3	0.24	0.28	12.7	63	3.8	4.3	0.8	20.3	29.2		
	40-50	9.3	0.19	0.26	15.3	52	3.4	3.1	0.4	16.3	23.2		
Small plots in Székkutas	0-20	9.3	0.13	0.15	5.9	35	22.3	8.5	2.3	8.8	41.9		hydrocarbonatic-carbonatic
	20-30	9.5	0.21	0.22	6.7	34	18.4	10.2	2.1	12.6	43.3		
	30-40	9.4	0.23	0.25	7.4	37	17.7	10.0	1.7	12.2	41.6		
	40-50	9.4	0.26	0.25	8.3	39	19.3	8.0	1.2	11.5	40.0		
	50-60	9.3	0.28	0.25	9.3	39	18.9	7.8	1.1	11.4	39.2		

because of the slight alkalinity of the surface layer. These reclaiming materials were applied in various proportions. Our object was to obtain data concerning the efficiency of combined applications, as well as partial replacement of gypsum, because gypsum is in short supply.

Six of the seven field experiments were installed on noncarbonatic, slightly alkaline solonetz where pH of the topsoil is 7.0 to 8.7 and which contains no or only traces of carbonates. The upper subsoils are calcareous and sodic with pHs of 8.7 to 9.2. The salts are characterized either by hydrocarbonates or by carbonates and sulphates. Total salt content of the profile is about 0.1 to 0.2 per cent. The subsoil is generally a very heavy clay. Soil of the seventh field experiment, by contrast, is carbonatic from the surface down (sodic solonetz), and its profile, besides being frequently flooded by surface water, is exposed to the impact of sodic subsoil water. Analytical data of three characteristic profiles chosen from these experiments are presented in Table 1. They contain the results of fundamental analyses and data concerning the exchangeable cations (Table 1).

The majority of experiments were established on small plots (4 to 50 m²), but some were on medium sized ones (50 to 560 m²). They were carried out continuously, in various years (1952-1961) and on different soils. For that

reason, the plan of experiments, as well as reclaiming materials and methods applied were not always the same. The experiments were, as far as possible, operated and yield sampled for 8 to 10 years.

My starting point in determining the proper doses of reclaiming materials was the dosage applied in my other current experiments, as well as the dosage approved in general farming practice. However, higher and lower doses were also used. Doses were calculated according to active agent content, and chemically equivalent amounts given. For lignite dust applications were 3 to 5 times higher than for gypsum stone dust. At that time limestone dust was not available, so lime sludge (from sugar factories) was used instead.

Because of the vast amount of data only summary data are presented for the field experiments. For the appraisal of the effect of different materials yields of several years obtained in six experiments on non-carbonatic solonetz have been reduced to wheat units and are given in index numbers (Table 2). Yields of several years of CaCO_3 + gypsum and CaCO_3 + lignite dust experiments, respectively, are presented in separate wheat unit for each experiment (Table 3).

Results of the long term field experiments show that, of all the substances tested, those containing CaCl_2 have given the highest yield increases on all solonetz types the increases ranging from 201 to 263 per cent.

On the basis of four experiments substances containing gypsum came next with results as follows: gypsum dust 191, and gypsum sludge 151 per cent. In these experiments on non-carbonatic solonetz lignite dust, owing to its low Ca-content, produced a yield increase of only 87 per cent, but on sodic solonetz it produced increases as high as 218 per cent. On a non-carbonatic solonetz with sodic upper subsoils, spreading calcareous subsoil along with black soil have a very good result (see Table 2). On the same sort of solonetz spreading with calcareous subsoil alone increased the yield by 180 per cent.

Table 2

Effect of various reclaiming materials in field experiments of long duration presented by index number calculated from wheat units 1952-1961

a) *The average of six field experiments on non carbonatic slightly alkaline solonetz (Experiments 1-6.)*

Unre-claimed	Lime sludge from sugar factories	Spreading with calcareous subsoil	Spreading with calcareous subsoil along with black soil	Gypsum dust	Gypsum sludge	Lignite dust	Peat with CaCl_2	Number of experimental years
100	157	208	361	291	256	176	301	3-8

b) *In a field experiment on sodic-solonetz (Experiment 7.)*

Unre-claimed	Lignite dust	Peat with CaCl_2	CaCl_2	HCl	Sludge from sulfuric acid factories	K_2SO_4	FeSO_4	Number of experimental years
100	318	327	388	336	315	250	250	3

Table

Yields of long term field experiments on non carbonatic slightly alkaline solonetz soil

Location of the experiments	Un-reclaimed	Lime sludge from sugar factory	Gypsum dust			Gypsum sludge		
			50	75	100	75	110	—
Dosage q./kh.*	—	300	50	75	100	75	110	—
Medium plots in Szelevény	1.4	—	—	—	—	10.6	16.8	—
Dosage q./kh.	—	300	—	—	—	75	—	—
Large plots in Szelevény	26.6	45.2	—	—	—	62.8	—	—
Dosage q./kh.	—	—	50	75	100	75	150	225
Small plots in Kónya	17.6	—	56.2	64.2	72.3	52.0	64.8	69.7
Dosage q./kh.	—	300	—	—	—	80	160	240
Medium plots in Gyula ..	24.0	34.2	—	—	—	43.7	50.4	44.9

* kh. = kataszteri hold = 0.575 ha.

On these slightly alkaline solonetz, liming with sugar factory sludge produced an average yield increase of only 57 per cent in five experiments.

On non-carbonatic, slightly alkaline solonetz the combined method gave higher yields than either substance used by itself. Comparative increases were as follows:

1. CaCO_3 + gypsum compared to CaCO_3 alone was 57% better (2 expts);
2. CaCO_3 + lignite dust compared to CaCO_3 alone was 40% better
3. CaCO_3 + gypsum compared to gypsum sludge alone was 14% better (4 expts);
4. CaCO_3 + lignite dust compared to lignite dust alone was 85% better.

The differences above may be partly explained as follows: in (1) and (2) due to gypsum's effect in reducing alkalinity and promoting the solution of CaCO_3 ; in (3) the result may be due to the nutrient content of lime sludge rather than to any other effect.

In experiments discussed here the nutrient effect of the accessory ingredients, particularly of phosphorus, in sugar factory lime sludge and gypsum sludge probably contributed to the production of yield increases at least in the first few years after application. This must be taken into consideration when the results of these experiments are adapted to farming practice.

Two to eight years after establishing the experiments, soil samples were taken from the profiles of the experimental plots. The samples were taken from around measured fixed points, and their analytical data have indicated an increase of the salt content as a temporary effect of reclamation. In solonetz soils which are sodic in the subsurface layer and which have extremely heavy subsoil, after six years of reclamation the salts have not been leached deeper than 35

3.

containing soda in their upper subsoil presented in terms of wheat units 1952–1962

Lignite dust				Lime sludge + gypsum sludge			Lime sludge + lignite dust			Number of experimental years
—	—	250	375	—	150+	110+	—	200+	150+	
					75	110		250	375	
—	—	3.2	9.3	—	11.4	20.8	—	8.9	15.1	5
150	200	300	450	200+	—	—	200+	—	—	
				75			200			
33.8	36.4	41.7	50.6	73.4	—	—	66.1	—	—	6
—	200	300	400	200+	200+	200+	200+	200+	200+	
				50	75	100	200	300	400	
—	23.9	27.9	31.9	62.7	7.9	79.0	49.8	61.0	64.8	7
—	160	320	480	300+	300+	300+	300+	300+	300+	
				80	160	240	160	320	480	
—	34.8	30.4	38.5	51.6	53.6	54.8	44.0	45.7	51.5	5

to 40 cm, where they accumulated. At the same time, in the profiles of a sodic solonetz with lighter mechanical composition, the entire profile has been leached free of salts although it was exposed to the impact of a high water table.

The Cl^- ion in the profile of sodic solonetz with lighter mechanical composition was leached out of the soil during the first winter, even from the plot receiving the maximum dose of CaCl_2 (167 q/ha) spread in autumn. In experiments on solonetz with very heavy subsoil, Cl^- leaching removal was slower, but in the second year no harmful effect could be observed.

The properties of these solonetz soils with sodic subsoil are considerably worse than those with neutral salts in their subsoil. The penetration of roots as well as the water are greatly hindered and so, particularly in dry years, the yields are badly impaired by the very sticky, impermeable sodic layer immediately beneath the surface. Subsoiling proved to be highly effective in increasing the rate of leaching on such soils. In four subsequent years of the rotation the average yield of the various crops increased by 33.3% on medium sized reclamation plots mechanically subsoiled to a depth of 50 cm, and by 60% on small plots subsoiled manually.

On the author's suggestion a subsoil cultivator (subsoiler) with three working pieces (blades) has been devised specifically for solonetz soils and it is being used successfully in farming practice. Its loosening effect is more powerful than, and not as irregular as that of single blade subsoilers.

Reclamation of solonetz, sodic in the entire profile is practical only on sodic spots occurring in fields of good quality, where they greatly hinder uniform tillage. On such spots the use of large amounts of reclaiming material may be justified.

As sodic solonetz soils, even after reclamation, will have only a shallow fertile layer above a still sodic subsoil, only crops with considerable alkali tolerance can successfully be grown on them. From the results of my earlier subsoiling experiments on solonetz soils with slightly alkaline topsoil and sodic subsoil it may be concluded that chemical amelioration, with additional subsoiling will prove an effective way of reclaiming this type of solonetz soil.

The worst kinds of solonetz soils are eroded waste lands or pastures of very poor quality which are periodically flooded. For the time being, only a better utilization and not reclamation can be thought of for such areas. By supersowing with *Puccinellia limosa* supported by a small amount of reclaiming material and large doses of nitrogen fertilizer they can be turned into fairly good grasslands, and with additional irrigation, they may even become very good ones.

Мелиорация содовых солонцов в Затиссье

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Резюме

Среди бескарбонатных солонцовых почв области, расположенной на восток от реки Тиссы, — особенно на границе черноземной и луговой почвенной зоны, — находятся содовые луговые солонцы, насыщенные содой до самой поверхности почвы. Такие территории, встречающиеся в черноземной зоне и в поверхностных слоях содержат известь и соду, а часто являются даже солончаковатыми. Таким образом в поверхностном слое можно встретить почти все почвенные разности, начиная от слабокислой до щелочной. Проведено большое число полевых опытов с мелкими и средними делянками и большим числом вариантов. Результаты опытов показали, что средние корковые солонцы с слабо-щелочным верхним горизонтом не поддаются мелиорации путем известкования или покрытием содержащей карбонаты почвой из нижележащих горизонтов, ввиду того, что CaCO_3 даже в слабо-щелочной среде недостаточно хорошо растворяется. Почвы такого рода, — согласно результатам наших опытов, — можно улучшать путем совместного внесения CaCO_3 и CaSO_4 , или совместного расстила подпочвы, содержащей карбонаты и чернозема, или расстилом подпочвы содержащей карбонаты и гипс.

Учитывая то, что в Венгрии нет достаточных запасов гипса, мы изучали возможность использования в качестве мелиорирующих материалов различных отходов промышленности, а именно: различные отходы, содержащие гипс, отходы заводов, производящих серную кислоту, HCl , CaCl_2 , FeSO_4 , лигнитный порошок, лигнитную золу и бурый уголь. В опытах эти вещества применяли в количествах эквивалентных разному гипсу, изучались и различные дозы внесения мелиоративных веществ. На тех почвах, которые в верхнем слое не содержали CaCO_3 лучшие результаты получились в результате применения CaCO_3 и гипса в смеси с лигнитным порошком или H_2SO_4 . Опыт показал и эффективность CaCl_2 , но его применение в виде промышленного отхода, имеющемуся в нашем распоряжении, связано с трудностями. Для достижения равного эффекта лигнитного порошка требуется в четыре раза больше, чем гипса. Расстил чернозема и подпочвы, содержащей известь оказался весьма эффективным, частью и в результате того, что этим углубился верхний пахотный горизонт.

Ввиду того, что содовые солонцы и после мелиорации будут иметь только мелкий плодородный слой, под которым неизменно будет находиться подпахотный горизонт богатый содой, на них с успехом можно будет выращивать только растения хорошо переносящие щелочную реакцию почвы. Результаты проведенных ранее опытов по мелиорации солонцов с слабощелочным верхним и содержащим соду подповерхностным горизонтом показали, что их улучшение путем расстила почвы из нижележащих горизонтов может быть весьма эффективным мероприятием для мелиорации солонцов этого типа.

Худшими вариантами таких солонцов являются периодически заливаемые эродированные пустыри или пастбища низкого качества. В связи с ними пока что можно задумываться об их лучшем использовании, но не о коренном их улучшении. Если их засеять *Puccinellia limosa*, а затем внести небольшие количества мелиорирующих веществ и большие дозы азотных удобрений, они могут превратиться в приемлемые, а при орошении даже в хорошие пастбища.