The Salt Regime of Hungarian Solonetz Soils and New Amelioration Methods

G. FILEP, B. PATÓCS and I. PATÓCS

Debrecen University of Agrarian Sciences, Debrecen, and Research Institute of the Debrecen University of Agrarian Sciences, Karcag, (Hungary)

In order to study the soil forming processes of salt affected soils and to elaborate more effective soil amelioration methods, investigations have been carried out in the vicinity of Hortobágy on water and salt movements since 1971.

The equilibrium water tables of the investigated meadow solonetz soils turning into steppe formation and of deep meadow solonetz soils were 0.5—1.5 m nearer to the surface after several days than at the time of augering. The thickness of the capillary zone was about 0.9—1.5 m depending on the soil's physical and chemical properties. The water table was lower in summer (150—170 cm) than in winter (100—140 cm). It was observed that in these areas the correlation among the depth of the water table, the moisture status of the soil profile, the intensity of evaporation and the salt movements is modified by several local factors, mostly in summer (Figs. 1—3).

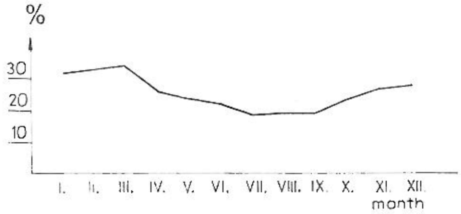

Fig. 1
Average moisture content of a 100 cm soil profile (in weight %)

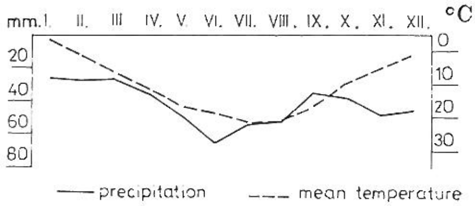

Fig. 2
Monthly mean temperature and precipitation

A) *Salt movement in salt affected soils covered by natural grassland*

Summarizing the observations on salt affected soils covered by natural grassland, it can be stated that due to the joint effect of changes in temperature, precipitation, evaporation and groundwater level in the winter period (from October to March, average of 9 years) the leaching of soluble salts, in the summer period (from April to September; average of 10 years) the accumulation of salts dominated. In the individual years, however, a deviating tendency could also be observed (Tables 1 and 2).

Table 1

Changes in the salt content of a medium meadow solonetz soil between 1971 and 1980 (global balance)

Depth, cm	Salt content in the observation period, t/ha		Salt balance (ΔS)	Salt movement quotient $h = b/a$	Change in the salt content, % $(h-1)\times 100$
	At the beginning *(a)*	At the end *(b)*			
0— 10	5.15	4.47	−0.68	0.87	−13.0
10— 20	5.10	5.19	+0.09	1.02	+2.0
20— 30	5.81	5.65	−0.16	0.97	−3.0
30— 40	7.76	7.30	−0.46	0.94	−6.0
40— 50	11.72	12.02	+0.30	1.02	+2.0
50— 60	8.14	8.35	+0.21	1.03	+3.0
60— 70	5.17	5.68	+0.51	1.10	+10.0
70— 80	4.53	4.14	−0.39	0.91	−9.0
80— 90	3.82	3.35	−0.47	0.87	−13.0
90—100	3.94	4.12	+0.18	1.05	+5.0
	61.14	60.27	−0.87	0.95	−2.2

The calculations were carried out starting from the basic principles of KOVDA [3] in the following way (1, 2):

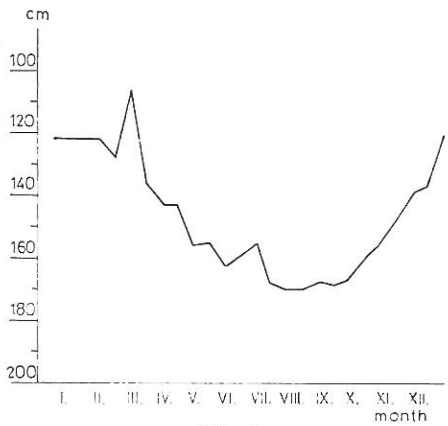

Fig. 3
Changes in the groundwater level

Symbols:

a t/ha = salt content of the soil at the beginning of the observation period;
a t/ha = $s_1 \cdot \gamma \cdot m$, where s_1 = salt content of the soil, g/100 g; γ = bulk density of the soil, g/cm^3; m = depth of soil layer, cm.

b t/ha = salt content of the soil at the end of the observation period.

The change in the salt content, i. e. the salt balance = ΔS, where

$$\Delta S = b - a \tag{1}$$

If $b > a$, the salt balance is positive, if $b < a$ the salt content decreased (negative salt balance).

The change in the salt content was expressed in percentage of the initial salt reserve, that is

$$a\% = \frac{\Delta S}{a} \cdot 100 \tag{2}$$

Table 2

Changes in the salt content of the soil according to seasons

Depth, cm	Salt content*		Salt balance (ΔS)	Salt movement quotient $h = b/a$	Change in the salt content, % $(h-1)\times 100$
	Summer period	Winter period			
	t/ha				
0— 10	5.42	4.87	−0.55	0.89	−11.0
10— 20	5.34	5.03	−0.31	0.94	−6.0
20— 30	6.09	5.86	−0.23	0.93	−7.0
30— 40	7.91	6.92	−0.99	0.87	−13.0
40— 50	12.36	13.54	+1.18	1.10	+10.0
50— 60	9.41	8.67	−0.74	0.92	−8.0
60— 70	5.92	6.03	+0.11	1.02	+2.0
70— 80	4.20	4.05	−0.15	0.96	−4.0
80— 90	4.12	3.64	−0.48	0.88	−12.0
90—100	3.69	4.10	+0.41	1.11	+11.0
	64.46	62.71	−1.75	0.96	−3.8

* Average of 10 summer periods and of 9 winter periods

or, taking into consideration equation (1),

$$a\% = \left(\frac{b}{a} - 1\right) \cdot 100 = (h - 1) \cdot 100 \tag{3}$$

where $b/a = h =$ salt movement quotient defined by KOVDA.

The periodical changes in the salt reserve are mostly equalized. Considering a longer period of time, the quantities of salts leached out of the soil and accumulating in it were nearly the same. There was a deviation of only 0.87 t/ha between the salt reserves measured at the beginning and end of the 10-year observation period.

B) *Effect of amelioration on the fertility of salt affected soils*

The precondition of increasing the fertility of solonetz soils is the improvement of their unfavourable physical and chemical properties.

Traditional surface soil amelioration (spreading of "digo earth" (marl), spreading of lime or gypsum) together with deep loosening and fertilization have played a very considerable role in increasing the fertility of solonetz soils in Hungary [7]. The existing area of salt affected soils amounts to nearly 740 000 ha. These belong to different types and subtypes. They can be ameliorated by different methods and the amendment requirement of the individual soils varies considerably.

To ameliorate the ploughed layer of the salt affected soils having acidic surface horizon, $CaCO_3$ is applied; in the case of a slightly alkaline ploughed layer, however, $CaCO_3 + CaSO_4 \cdot 2\,H_2O$ or gypsum alone is applied.

In 1975 research was begun at the Research Institute of the Debrecen Agricultural University at Karcag on the use and practical application of phosphor gypsum as a soil amendment.

On the basis of investigations it was established that:

— phosphor gypsum does not contain harmful or toxic materials from the point of view of the soil and cultivated plants. (Fluorine was present only in traces.) Regular investigations show that phosphor gypsum has no harmful, polluting effect on the environment.

— Even after storage for several years, phosphor gypsum preserved its favourable physical properties. The phosphorus content is extraordinarily favourable, and can increase the available phosphorus reserves of the ameliorated soil by 100—200 kg/ha (Table 3).

Table 3

Composition of phosphor gypsum used

$CaSO_4 \cdot 2\,H_2O$, %	70.4	MgO, %	2.4
Moisture, %	28—30	Na_2O, %	0.13
Free water, %	13.8	K_2O, %	0.01
Insoluble in acid, %	2.3	Fe_2O_3, %	0.9
		P_2O_5, %	0.8

1. *Effect of surface soil amelioration on fertility.* — The applicability of phosphor gypsum for the amelioration of the A horizon was studied in experiments set up on several subtypes of salt affected soils. Characteristic analytical data of the soil representing the experimental site are given in Table 4.

As to the effect of amelioration: sunflower, winter wheat and alfalfa, as indicator plants, showed considerable yield increases. The yield-surplus of sunflower amounts to 0.47, that of winter wheat to 0.81 and that of alfalfa to 0.79 t/ha (expressed in wheat units).

2. *Amelioration of two horizons (A + B horizon) of salt affected soils.* — In the case of surface (the upper 20—23 cm thick layer) treatment, the improvement of soil layers below the ploughed layer is very slow, and it depends on the chemical and physical properties of the B horizon. In order to increase the fertility of solonetz soils, it is necessary to increase the depth of amelioration (amelioration of the A + B horizons). Various methods and machines can be used to introduce the amendment into the B horizon:

a) One of these is the deep-ameliorating machine type TLC, which combines ploughing the 0—20 cm soil layer with the introduction of the ameliorating material into the B horizon. This machine consists of a plough, with a soil fraise attached behind the plough body on a vertical axle. The amendment is spread from a container onto the furrow sole and is mixed into the 20—40 cm soil layer by the soil fraise.

b) The amelioration of the B horizon can also be carried out using a strip-spreading, deep-loosening machine (VIMA). This machine places the ameliorating material into the loosened strips to a depth of 60 cm.

c) The third possiblity for the amelioration the B horizon is amelioration by means of twofold deep-ploughing to a depth of 40—45 cm. The first deep-ploughing brings the B horizon to the surface; the ameliorating material is then spread on the surface, after which it is worked into the soil with a soil fraise or disc tiller. Finally, the second deep-ploughing returns the ameliorated B horizon to its original position.

Table 4

Characteristic analytical data of the soil representing the experimental site

Depth, cm	pH		Total salt, %	hy_1	% of fractions under 0.01 mm	Capillary rise, mm 5 h	Adsorbed cations			
	H_2O	KCl					Ca^{2+}	Mg^{2+}	K^+	N^+
							me/100 g			
0—10	6.7	6.2	0.14	1.9	49.3	30	15.2	6.8	1.0	2.2
10—20	7.2	6.3	0.20	2.4	58.7	10	14.0	9.2	0.9	4.4
20—30	8.0	7.2	0.37	2.8	77.4	10	11.2	11.7	0.8	8.6
30—40	8.0	7.3	0.58	2.7	66.2	15	12.6	13.1	0.8	10.1
40—50	8.1	7.4	0.67	2.5	67.7	18	11.8	13.3	0.9	11.3
50—60	8.1	7.4	0.63	2.7	64.7	14	11.2	13.1	0.8	11.3
60—70	8.5	7.7	0.60	1.9	62.4	13	23.6	12.2	0.7	10.6
70—80	8.7	7.9	0.55	2.1	62.2	9	29.4	10.5	0.7	10.1
80—90	8.8	8.0	0.53	2.1	62.3	5	29.0	9.5	0.5	9.4
90—100	8.8	8.0	0.48	2.1	59.8	5	25.0	9.5	0.7	9.4
100—110	8.9	8.0	0.47	2.8	57.9	0	23.6	9.5	0.5	9.0
110—120	8.7	7.5	0.46	2.9	61.0	0	15.6	10.5	0.7	11.7

After the amelioration of the B horizon (20—40 cm) traditional surface soil (0—20 cm layer) amelioration is also carried out in the case of all three methods.

With the aim of studying the effect of A+B horizon amelioration, as well as that of phosphor gypsum, long-term experiments were set up on meadow solonetz soils turning into steppe formation. On the basis of the experimental results it was found that both traditional surface soil amelioration (0—20 cm) and the two-layer (0—20 and 20—40 cm) amelioration increased the yield of winter wheat considerably (Tables 5 and 6).

Table 5

Effect of amelioration of the B horizon with phosphor gypsum on the yield of winter wheat, t/ha

Treatments	1978	1979	1980	Average yield	%
1. Control	2.96	0.63	5.01	2.86	100
2. Surface soil (0—20) amelioration with defecation mud	4.18	1.27	5.54	3.66	128
3. Surface soil (0—20 cm) amelioration with defecation mud + B horizon (20—40 cm) amelioration with phosphor gypsum	5.27	1.35	5.93	4.18	146

With regard to the effect of two-layer amelioration (amelioration of A+B horizons) further yield surpluses were obtained (0.2—0.5 t/ha) as compared to traditional surface soil amelioration. Among the methods developed for the amelioration of A+B horizons, the twofold ploughing method proved to be the most favourable, while a slightly smaller change was caused by interventions carried out with a TLC plough or a VIMA loosener.

Table 6

Effect of amelioration methods on the yield of winter wheat, t/ha

Treatments	1977	1978	1979	1980	Average yield, $\bar{X}$	d
1. Control	2.42	2.77	1.06	3.82	2.52	—
2. A horizon ameliorated with lime	2.79	3.30	1.47	4.25	2.95	0.43
3. ad. 2 + B horizon ameliorated with TLC plough	3.36	3.56	1.70	4.61	3.31	0.79
4. ad. 2 + B horizon ameliorated by twofold ploughing	3.47	3.80	1.85	4.73	3.46	0.94
5. ad. 2 + B horizon ameliorated with VIMA loosener	2.91	3.62	1.53	4.59	3.16	0.64

The effect of amelioration methods on changes in the exchangeable cations was also investigated. As with the yield surpluses, the results prove the advantage of two-layer amelioration as compared to traditional surface soil amelioration. Changes in both the absolute and relative quantities of exchangeable Ca and Na ions after amelioration of the A+B horizons were more favourable than in the case of traditional surface soil amelioration (Fig. 4).

The correlations [5] between the exchangeable cation content of the soil and the yield were then investigated. The partial correlation coefficients to the first and second degree proved that there is a close correlation between yield and absorbed Na content (Table 7).

3. *Complex amelioration of salt affected soils.* — Under certain conditions the harmful soil processes cannot be overcome by chemical amelioration alone. On areas where there is a danger of polder formation on the surface and the water table may rise near to the surface, water regulation and soil moisture

Table 7

Correlation of yield and exchangeable cations on the basis of partial correlation coefficients
$n = 36$

Horizons, cm and variables	Averages of variables	Correlation coefficients of 0 grade	Correlation coefficients of 1 grade	Correlation coefficients of 2 grade
0—20				
x = yield kg/60 m²	$x^- = 16.72$	$r_{xy} = 0.7557$***	$r_{xy.z.} = 0.6895$***	$r_{xy.zv.} = 0.7116$***
$y = Ca^{2+}$ me/100 g	$y^- = 18.43$	$r_{xz} = -0.5015$***	$r_{xy.v.} = 0.7195$***	$r_{xz.yv.} = 0.0517$
$z = Mg^{2+}$ me/100 g	$z^- = 6.16$	$r_{xv} = -0.6560$***	$r_{xz.y.} = -0.2908$+	$r_{xv.yz.} = -0.5497$***
$v = Na^+$ me/100 g	$v^- = 4.03$		$r_{xz.v.} = -0.1599$	
			$r_{xv.y.} = -0.5996$***	
0—40			$r_{xv.z.} = -0.5083$**	
x = yield kg/60 m²	$x^- = 16.72$	$r_{xy} = 0.7066$***	$r_{xy.z.} = 0.5833$***	$r_{xy.zv.} = 0.2781$
$y = Ca^{2+}$ me/100 g	$y^- = 18.03$	$r_{xz} = -0.5459$***	$r_{xy.v.} = 0.3023$+	$r_{xz.yv.} = -0.1160$
$z = Mg^{2+}$ me/100 g	$z^- = 7.21$	$r_{xy} = -0.7868$***	$r_{xz.y.} = -0.2739$	$r_{xv.yz.} = -0.5125$**
$v = Na^+$ me/100 g	$v^- = 4.79$		$r_{xz.v.} = -0.1686$	
			$r_{xv.y.} = -0.5556$***	
			$r_{xv.z.} = -0.6876$***	

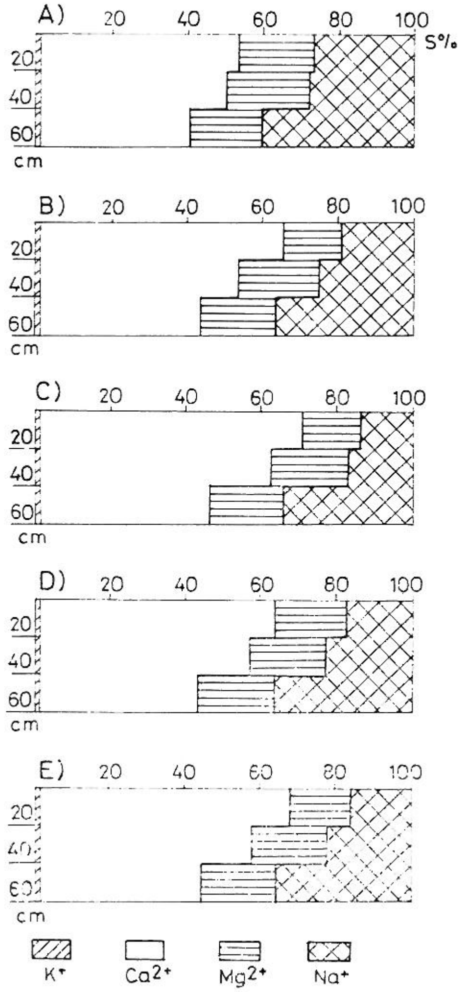

Fig. 4

Effect of amelioration methods on the value of exchangeable cations expressed in S %. A) Control; B) Surface soil ameliorated; C) Amelioration of deeper layer with a TLC plough; D) Amelioration of deeper layer by twofold deep ploughing; E) Amelioration of deeper layer with a VIMA loosener

regulation must be considered as a fundamental condition of yield stability. Consequently, complex soil amelioration necessarily includes the improvement of drainage conditions in the soil profile.

On the complex amelioration site established in an area belonging to the "Vörös Csillag" Cooperative Farm in Nádudvar in 1979, in addition to chemical and physical amelioration, the water regime of the soil was improved by controlling the water table with subsurface drainage and the conditions required for the leaching out of salts were fulfilled.

Table 8

Effect of amelioration on leaching out of sodium and yield increase

Method of chemical amelioration	No. of treatment	Drain distance, m	Removed Na in the drainage water (average), me/l	Na t/ha	Yield surplus, kg/ha
Liming of surface soil	I	15	97.6	—1.45	1085
	II	20	88.3	—2.09	1155
A + B horizon amelioration (Strip spreading)	III	15	132.8	—1.96	1425
	IV	20	120.6	—1.13	1335
A + B horizon amelioration (Twofold ploughing)	V	15	115.0	—0.42	1075
	VI	20	74.5	—1.04	1025
A + B horizon amelioration (Strip spreading)	VII	—	—	—0.87	825
Liming of surface soil	VIII	—	—	0.0	675
A + B horizon amelioration (Twofold ploughing)	X	—	—	+2.40	310

In treatments including subsurface drainage and amelioration, the process of leaching out harmful sodium salt started within a short time, as is proved by the salt reserves of the soil and the composition of the drainage water (Table 8).

After the regulation of the groundwater table and soil moisture, the salt supply of the upper 120 cm soil profile has decreased, the leaching process has started. As regards the effect of chemical amelioration combined with moisture regulation, a considerable yield increase was obtained. Significant differences between the yields of experimental plots with a drain distance of 15 and 20 m, respectively, could not be observed.

From among the chemical ameliorating methods the amelioration of A + B horizons with a VIMA loosener showed the most favourable results, amounting to a yield surplus of 1300--1400 kg/ha of wheat.

Summary

On the basis of systematic investigations carried out on solonetz soils it was found that there is a close correlation between salt movement, groundwater movement and the moisture state of the soil profile. The salt movement in meadow solonetz soils takes place in the 0.5—0.8 m layer depending on the depth of the accumulation layer and the salt maximum of the soil profile.

It was found that phosphor gypsum — a by-product of phosphorus mineral fertilizer production — can be used successfully for the amelioration of solonetz soils. In the case of traditional surface soil amelioration a yield surplus of 0.6—0.8 t/ha was achieved, which increased to 0.8—1.2 t/ha when the deeper layer (A + B horizon) was also ameliorated.

Methods adopted for introducing the ameliorating material into the deeper layer of the soil (TLC plough, twofold deep ploughing, stripwise deep reclamation with a VIMA loosener) showed favourable results.

On compacted solonetz soils with poor water conductivity, which are susceptible to stagnant water, complex amelioration is very important because it improves unfavourable soil properties and eliminates or, at least, lessens their effects. Water and salt movements in the soil become more favourable and the water, air and nutrient requirements of the plants can be better satisfied. Chemical and physical soil amelioration applied together with soil moisture regulation resulted in significant yield surpluses.

References

[1] DARAB, K.: (The salt balance and salt economy of our irrigated soils) (H, e, r) Agrokémia és Talajtan. **10.** 305—314. 1961.
[2] FILEP, GY.: (Changes of the chemical properties of irrigated soils in the region east of the River Tisza under the effect of irrigation waters of different qualities) (H, e, f, r) Agrokémia és Talajtan. **19.** 213—230. 1970.
[3] KOVDA, V. A.: (Origin and regime of saline soils) (R) Vols. I and II. Izd. Acad. Nauk. SSSR. Moscow. 1947.
[4] KURUCZ, GY.: (Reclamation and agricultural utilization of salt affected soils) (H) Gazdálkodás. **6.** 1—10. 1977.
[5] PATÓCS, I.: (Correlation between soil reclamation and yield of solonetz soils) (H) Dissertation. Karcag—Budapest. 1977.
[6] PATÓCS, B. & PATÓCS, I.: (Effect of soil reclamation on a meadow solonetz soil turning into steppe formation) (H, e, g, r) Agrokémia és Talajtan. **27.** 107—118. 1978.
[7] PRETTENHOFFER, I.: (Reclamation and utilization of Hungarian salt affected soils) (H) Akadémiai Kiadó. Budapest. 1969.
[8] SIPOS, S. & BOCSKAI, J.: (Increasing the fertility of solonetz soils by processes applied by genetic horizons) (H, e, g, r) Talajtermékenység. **3.** 91—114. 1968.

Discussion

YADAV, J. S. P.

(1) What was the content of fluorine in phosphor gypsum used in the experiment?

(2) What is the reason for differential positive accumulation of salts as a result of leaching at only two separate depths of the soil profile and not at other depths without any definite trend in relation to the depth of soil profile? Is it because of presence of impervious layers or due to the physical modification brought about by deep ploughing and turning over of the soil?

FILEP, G.

(1) The phosphor gypsum contained fluorine only in traces therefore this element as a quality influencing factor was not given in the Table.

(2) The accumulation of salts and Na ions were to be found only in the so called recycling method, some months after the reclamation. The deterioration of the upper soil layers can be explained by the fact that in this way of reclamation the salt affected B layer is mixed with the topsoil layer having a relatively better composition. After all both the chemical composition and the structure of the topsoil are getting worse, therefore the positive effect of the amelioration can be observed only later.