Humus and Nutrient (N, P, K) Status of Salt Affected Soils in Relation to Their Genesis, with Special Reference to the Soils of the Hungarian Plain

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Considerable amount of work has so far been done on chemical and physical characteristics, genesis, classification and improvement of salt affected soils, but one of the important aspects of these soils — their nutrient status has been deleted — if not fully, by the workers engaged in this line. Nonetheless, whatever work is available on the state of three major nutrients, nitrogen, phosphorus, and potassium in these soils, leads to controversy.

Many of the papers in this subject conclude that these soils are poor in fertility. This, however, does not mean that they are barren in plant nutrients. SZABOLCS [41] mentioned of some salt affected soils having ample quantities of total as well as socalled available plant nutrients. Since plants need them in aquous solution, the deficiency of available water a resultant of the deterimental influence of sodium ion, hinders their utilization by plants, he added.

Solonchaks are generally known to be poor in humus as well as in nitrogen as cited by VASIL'CHIKOVA [47], SZABOLCS [40], FEKETE [11] and many others. This is no doubt a resultant of dominant upward movement of water leading to the concentration of salts in the surface layer, which, on one hand clash with the life of growing vegetation and give rise to a poor vegetative cover and on the other hand, inorganic nitrogen, which is brought to surface along with other salts, might be subjected to volatilization losses as ammonia. However, in strongly saline solonchaks whether or not nitrogen mineralization takes place to a considerable extent, is a matter of dispute. Nonetheless, in solonetzes this process is definitely retarded due to adverse physical conditions assisted with alkalinity.

Nitrate-rich solonchaks have been reported by HEADDEN [15], STEWERT and PETERSON [37], SELYAKOV [33] and DOUGHTY et al. [10]. The later workers ascribed the high nitrate content in the surface layer to their transportation from lower layers through capillary waters.

Humus status of solonetzes is quite controversial. KONONOVA [19], ALEXENDROVA [1], CHANG [7], KAURICHEV and PANOV [18], SOLOVEV et al. [36] noted solonetzes poor in humus. On the other hand, NOSKO [27], CAIRNS [6], KOTIN [20], PANOV and KOKURINA [29], SZABOLCS [39] noted solonetzes to be moderately well supplied with humus.

Working on nitrogen availability, HARGITAI [14] found comparatively more available nitrogen in the upper horizon of a solonetz.

There are three schools of opinion concerning the state of phosphorus in salt affected soils.

1. Alkaline conditions and neutral salts depress the solubility of phosphate as observed by TEAKLE [43], MCGEORGE and BREAZEALE [24], SHAWARBI [34], LEHR and WESEMAEL [21].

2. Salts may increase or decrease the solubility of phosphorus depending on their kind, concentration, association with other ions and type of soil as was found by HIBBARD [17], LEWIS et al. [22], GAUSMANN and AWAN [12], OLSON et al. [28], TOBIA and MILAD [44].

3. Alkaline conditions and neutral salts bring about phosphorus more soluble and available to plants. In this line TRUOG [45] demonstrated that as the pH goes up to 8.5 or onward, a tendency should develop of the formation of sodium phosphate which being soluble would be readily available to plants. Similarily CHANG [7], BECKWITH and DEVRIES [4], found phosphorus to be more available to plants in salt affected soils.

Similar had been the question of state of potassium that some workers as BERNSTEIN and PEARSON [5], MELA [26], RAYCHAUDHURY and LANDEY [30], found potassium to be more available to plants in salt affected environment. GEREI et al. [13] noted increasing destruction of clay mineral with salinization process. This might increase the content of potassium in soil solution by virtue of its being freed from the fixed form during the destruction of clay. In contrary to it, MEHATA and SHAH [25] and DHAR [9] noted a linear relationship between soil pH and potassium fixation. WIKLANDER [48] found a pronounced fixation of potassium when clay was saturated with sodium.

Thus, these controversial views lead to the question that why this subject has not reached to universal understanding? The reason is the complex nature of salt affected soils and their differential genetic system. Following are two entirely different phenomena leading to the formation of solonetz soil.

Solonchak → Solonchak-solonetz → Solonetz.

Meadow soil → Solonetzic meadow soil → Meadow solonetz.

Both of these processes ultimately lead to the similar soil types but in most of the cases, the later one will be richer in humus.

In arid and semi-arid regions both the saline alkaline conditions and poor native supply of nitrogen result from the limited rainfall under which the soils have developed. Thus, the later is not a resultant of the former but merely associated with that.

Thus, while establishing any of the characteristics of this natural body of tremendous diverse nature, it is of paramount importance to take into consideration its genetic system.

There might be plenty of salt affected soils as rich in nutrients as normal fertile soils. On the other hand, many of the solonchaks can be found to be almost barren as regards to plant nutrients. If, however, the soils of the latter group are brought under reclamation, the after-reclamation phase will involve a great amount of money to enrich them adequately with plant nutrients and the whole reclamation project would be subjected to a serious economic setback. Thus, the soils having appropriate quantities of plant nutrients will involve considerably less cost of reclamation than those poor in nutrients or completely barren. This fact lays considerable emphasis to the nutrient status of salt affected soils which is usually deleted with an understanding that whatever nutrients they have, are not utilisable by plants.

The main feature of the present study is to undertake the problem involving controversy discussed in preceeding paragraphs, with an effort to study the status of humus which serves as a storehouse for the plant food, and of three major nutrients (N, P, K) in relation with the genesis of salt affected soils of two different regions of Hungary.

Materials and methods

Two important regions of Hungarian Plain, Danube valley and Tisza valley have been taken under study. The following profiles in different areas of these regions were dug for study:

I. Danube valley

1. Kiskunfélegyháza

a) *KH—1* The profile falls about 150 meters north from km stone No. 39 — on Kiskunfélegyháza — Izsák road and about 250 meters from the Duck Farm. Poor salt affected area used for sheep grazing and more or less lowest point of the territory.

Depth to ground water table: 105 cm. No sharp horizon differentiation.

Type: *Calcareous solonchak,* on calcareous loess like sand.

Sampling intervals: 0—10, 15—25, 25—30, 60—70, 90—100 cm.

b) *KH—2* The profile falls about 100 m east from the KH—1. About 20—30 cm higher and has somewhat better vegetative cover than KH—1.

Depth to ground water table: 92 cm.

Type: *Calcareous solonchak-solonetz* on loess like loamy sand.

Sampling intervals: 0—3, 5—15, 20—30, 70—80 cm.

c) *KH—3* The profile falls about 35 m north from the KH—2. Slightly higher and with a better vegetative cover than KH—2.

Depth to ground water table: 89 cm.

Type: *Calcareous solonetz* on sandy loess.

Sampling intervals: 0—4, 5—15, 25—35, 70—80 cm.

d) *KH—4* The profile falls about 200 m east from KH—3, with more or less similar features. Depth to ground water table: 97 cm.

Type: *Calcareous solonetz* on loess like sand.

Sampling intervals: 0—5, 8—18, 25—35, 70—80 cm.

2. Apaj

a) *AP—3* The profile falls 1400—1500 m south west from Dömsöd—Apaj road and 200 m south from the sweep well.

Depth to ground water table: 210 cm.

Type: *Salinized calcareous shallow meadow solonetz* on calcareous Danube alluvial sand. Sampling intervals: 0—3, 4—10, 15—25 cm.

b) *AP—4* The profile falls about 150 m north from Apaj "Lignit poros ut" and 200—250 m north from the fish pond. Very poor salt affected area with bare spots.

Depth to ground water table: 64 cm.

No sharp horizon differentiation.

Type: *Calcareous solonchak* on calcareous Danube alluvial sand.

Sampling intervals: 0—10, 12—20, 27—37 cm.

c) *AP—10* The profile falls about 30 m south west from the Apaj—Kunszentmiklós road and 300—350 m south from the farm. Poor quality pasture of no utility.

Depth to ground water table: 83 cm.

No horizon differentiation.

Type: *Calcareous solonchak* on loess like Danube deposits.

Sampling intervals: 0—10, 15—25, 30—38, 40—50 cm.

d) *AP—11* The profile falls about 50 m east from AP—10 about 20—30 cm higher point and somewhat better in vegetative cover than AP—10.

Depth to ground water table: 102 cm.

Type: *Calcareous solonchak-solonetz* on calcareous loess like Danube deposits.

Sampling intervals: 0—5, 5—15, 20—30, 35—40 cm.

3. Kunszentmiklós

KM—606 The profile falls about 300 m east from the farm, 65 m south from the electric line and about 60 m west from the pond. Poor quality pasture and slightly higher point of the area.

Depth to ground water table: 190 cm.

Type: *Calcareous solonchak-solonetz* on calcareous Danube deposits.

Sampling intervals: 0—5, 5—15, 20—30, 35—45 cm.

Note: The samples from all these profiles were taken in July, 1966.

II. Tisza valley

1. *Hortobágy*

a) *HB—2* The profile falls about 150 m north from the km stone No. 83,8, Füzesabony—Debrecen Road, and about 180 m east from the sweep-well.

Poor quality pasture.

Depth to ground water table: 230 cm.

Type: *Strongly solodized shallow meadow solonetz* on loess like clayey loam.

Sampling intervals: 0—3, 3—13, 18—28, 30—40, 40—50 cm.

Date of sampling: September, 1967.

2. *Mezőtúr*

S—43 The profile falls in the unit No. 2 of the Sallai Co-op farm, about 300 m north-east from the sheepfold and about 200 m north from the barrier on Körös river. Salt affected area having vegetative cover of medium quality. Relatively higher point of the area.

Depth to ground water table: 374 cm.

Type: *Meadow solonetz* on loess like sily clay.

Sampling intervals: 0—2, 2—13, 13—26, 26—38, 45—60, 80—90, 113—139 cm.

Date of sampling: July, 1967.

3. *Tiszaigar*

TSz—1 The profile falls about 1300 m east from the Kettős Halom, and about 1100 m north—west from the point bordering Tiszaigar, Tiszaörs, and Pusztakocs. Pasture, in somewhat medium condition and relatively higher point of the area.

Depth to ground water table: 160 cm.

Type: *Deep meadow solonetz* on calcareous slightly clayey sand.

Sampling intervals: 0—15, 15—30, 33—45, 55—70, 90—110 cm.

Date of sampling: August, 1967.

Analytical procedures: The main analytical methods employed are as follows:

1. Total organic matter: Turin's method using ferroin indicator.
2. Total nitrogen: Kjeldahl's method.
3. Aqua-regia extractable phosphorus and potassium: SIK's method[2, 3].

Phosphorus and potassium in the extract were determined by colorimeter and flame photometer, respectively.

4. Lactate extractable phosphorus and potassium:

a) For calcareous Danube valley soils ammonium lactate and for non calcareous Tisza valley soils calcium lactate were used as extracting agents in case of potassium; *b)* Ammonium lactate extraction was followed for phosphorus in the case of both regions [32].

5. Exchangeable sodium and cation exchange capacity: U.S. salinity laboratory methods [31].

Results and discussion

1. Genesis of soils

I. Danube valley soils

The present day understanding of the genesis of salt affected soils covering a great part of Danube valley has its contribution from soil scientists like 'SIGMOND [35], SZABOLCS and JASSÓ [42], HERKE [16] and VÁRALLYAY [46].

Author has also studied these soils in field as well as in laboratory and the data obtained by him closely support the theories laid by Hungarian scientists. However, his own examinations in this line are summarized as under:

1. Stratified nature of coarse textured Danube sediments [46] is clearly supported by the data on mechanical analysis, (Table 1) as in most of the cases no definite pattern of clay distribution with depth can be observed.

Table 1

Data for general chemical characterization of soils

Profile No. and Sampling Interval cm	$CaCO_3$ %	pH		Electrical conductivity of saturation extract, millimhos/cm ($EC \times 10^3$) at 25°C	CEC meq/100 g soil	ESP	Physical sand	Physical clay
		H_2O	KCl				%	
I. Danube valley:								
KH—1								
0—10	15,55	9,40	8,90	7,26	17,05	58,00	58,07	23,96
15—25	22,08	9,52	9,00	5,92	19,14	73,00	42,41	31,10
25—35	25,29	9,38	8,83	3,07	17,75	72,00	47,42	24,84
60—70	48,51	9,13	8,38	—	—	—	75,00	2,99
KH—2								
0— 2	9,50	9,09	8,48	9,12	24,62	38,00	59,23	26,02
5—15	12,39	9,47	8,75	3,30	24,88	70,00	54,31	28,68
20—30	18,17	9,37	8,65	2,46	22,09	62,00	53,49	25,08
70—80	43,78	8,70	8,37	—	—	—	48,55	9,10
KH—3								
0— 4	8,33	8,72	7,96	2,64	33,66	18,95	57,82	29,98
5—15	18,75	9,11	8,24	1,44	26,10	32,70	53,44	28,13
25—35	25,83	9,35	8,50	1,60	22,62	35,00	44,43	26,36
KH—4								
0— 5	15,82	8,40	7,77	0,92	29,58	7,80	52,66	27,03
8—18	20,57	9,22	8,30	2,64	28,71	41,00	50,33	30,33
25—35	25,00	9,47	8,80	5,35	20,07	68,00	45,78	25,46
70—80	41,00	9,10	8,48	—	—	—	45,73	12,86
AP—3								
0— 3	15,42	8,51	8,00	2,16	17,05	20,52	61,37	27,95
4—10	19,44	9,10	8,30	3,72	17,40	51,37	52,71	31,42
15—25	33,91	9.38	8,85	5,32	16,30	79,38	48,81	29,37
AP—4								
0—10	10,34	9,54	9,40	15,29	10,44	94,35	64,97	21,54
12—20	13,71	9,25	8,61	2,59	15,13	79,37	50,37	24,30
27—37	26,36	9,21	8,34	2,46	11,83	58,15	46,46	19,69
AP—10								
0—10	22,80	10,00	9,40	15,41	11,05	88,50	50.45	23,68
15—25	35,03	9,41	8,94	10,34	21,32	46,67	32,86	30,93
30—38	45,52	9,90	8,98	6,53	19,45	47,76	30,57	23,00
40—50	38.70	9,30	8,75	—	—	—	37,48	23,32
AP—11								
0— 5	11,62	8,20	8,00	2,50	13,05	7,50	70,32	15,35
5—15	16,90	9,34	8,78	2,59	14,27	75,33	51,92	28,06
20—30	34,17	9,50	9,22	7,02	14,38	74,46	37,66	25,76
35—45	49,86	9,51	9,23	—	—	—	28,96	19,42
KM—606								
0— 5	14,00	8,48	8,10	1,60	16,18	13,78	43,61	39,96
0—15	17,65	9,01	8,15	3,39	17,92	41,79	34,23	46,33
20—30	19,52	9,41	8,80	7,27	16,70	64,85	32,12	46,93
35—45	32,55	9,48	8,78	—	—	—	30,81	42,40

Profile No. and Sampling Interval cm	$CaCO_3$ %	pH		Electrical conductivity of saturation extract, millimhos/cm ($EC \times 10^3$) at 25°C	C E C meq/100 g soil	E S P	Physical sand	Physical clay
		H_2O	KCl				%	
II. Tisza valley:								
S—43								
0— 2	—	5,15	4,40	—	—	—	—	—
2—13	—	5,28	4,30	0,59	34,22	1,91	47,21	50,09
13—26	—	6,70	5,30	0,91	42,61	12,87	32,26	65,32
26—38	—	7,98	6,60	3,21	38,26	20,39	23,53	74,22
45—60	—	8,10	7,35	9,25	37,61	21,70	29,26	67,46
80—98	8,13	8,85	7,68	3,70	34,35	15,18	30,43	58,40
TSZ—1								
0—15	—	5,45	4,65	0,52	11,95	1,33	76,33	22,65
15—30	—	6,45	5,30	0,82	10,43	7,42	77,66	21,37
35—45	—	8,80	7,20	1,42	26,52	32,89	66,88	31,58
55—70	1,87	9,38	8,00	2,09	17,17	70,21	66,46	30,21
HB—2								
0— 3	—	6,32	5,08	1,47	17,39	38,76	53,60	45,81
3—13	—	7,80	6,38	3,33	20,22	47,58	43,13	55,64
18—28	—	8,75	7,42	3,57	30,87	59,95	46,38	50,57
30—40	3,14	8,90	7,90	4,56	38,17	42,34	46,44	52,25
40—50	3,55	8,92	7,90	3,08	35,13	53,83	49,65	46,14

Physical sand — Particles larger than 0,01 mm.
Physical clay — Particles smaller than 0,01 mm.

Thus, pattern of clay distribution in these soils cannot be taken confidently to help explaining the genesis of these soils.

2. An important point to be considered is the highly calcareous nature of these soils. Soda accumulation in a soil usually starts when calcium is inactivated i.e. turned to an insoluble form. The calcareous Danube sediments of loess character can be assumed to have been saturated with calcium as it is true in most of the cases. Thus, the time when soda accumulation took in, there started a tendency of the inactivation of calcium with the formation of calcium carbonate and its concomitant removal from the absorbing complex as well as from soil solution through the reactions of sodium carbonate transported from other territories as well as formed in situ to some extent, with calcium in exchangeable state and that in soluble state (mostly chlorides and sulphates) giving rise to the dominance of sodium in exchange complex as well as in soil solution (as neutral salts) on one hand, and enrichment of soil with calcium carbonate on the other hand. Thus, these reactions have also contributed at least to some extent enriching the reserve of calcium carbonate in these soils in addition to that directly inherited from the parent material.

3. Microrelief has been of tremendous significance giving rise to an association of solonchak—solonchak-solonetz—solonetz (KH-1, KH-2, KH-3, and KH-4) in Kiskunfélegyháza where all these points have been found to be with similar depth to ground water level i.e. about one meter. Though, there definitely occur seasonal fluctuation in ground water level which may influence the process of salinization and alkalinization. Solonchak (KH-1) exists on lowest position, solonchak-solonetz (KH-2) on slightly higher and solonetzes

(KH-3, KH-4) on still higher positions. If it is assumed that KH-3 and KH-4 were also solonchaks before, there existed always a tendency of the movement of salts through surface and subsurface waters towards lower position from the

Table 2

Analysis of 1 : 5 aqueous extracts

Profile No. and Sampling Interval cm	Anions						Cations			
		HCO_3^-								
	CO_3^{2-}	Alkalinity (Alkali Carbonate)	Alkalinity (Alkali Earth Carbonate)	Total Alkalinity	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
	meq/100 g soil									
I. Danube valley:										
KH—1										
0—10	1,78	3,25	0,28	3,53	0,94	0,67	0,04	0,07	5,09	0,02
15—25	2,47	4,14	0,19	4,33	0,99	0,58	0,03	0,12	6,04	0,10
25—35	1,83	3,60	0,29	3,89	0,71	0,29	0,03	0,09	4,78	0,02
60—70	0,43	1,31	—	1,31	0,29	0,07	0,01	0,06	1,63	0,04
70—100	0,03	0,50	—	0,50	0,20	0,03	0,01	0,04	0,61	0,01
KH—2										
0— 3	0,33	4,48	—	4,48	1,03	3,90	0,22	0,43	9,43	0,09
5—15	0,75	4,16	0,66	4,82	0,45	0,50	0,33	0,15	6,54	0,08
20—30	0,55	3,11	0,91	4,03	0,12	0,23	0,12	0,03	4,72	0,09
70—80	0,05	0,62	0,05	0,67	0,14	0,17	0,04	—	0,74	0,01
KH—3										
0— 4	0,10	2,79	0,13	2,92	0,37	0,49	0,04	0,11	4,28	0,04
5—15	0,18	2,54	0,37	2,91	0,25	1,44	0,06	0,01	4,04	0,04
25—35	0,95	2,48	0,90	3,38	0,15	0,10	0,10	0,14	3,78	0,04
KH—4										
0— 5	—	0,98	0,20	1,18	0,15	0,05	0,09	—	1,50	0,03
8—18	—	2,90	0,03	2,93	0,60	1,11	0,18	0,05	4,13	0,06
25—35	0,69	3,82	0,61	4,43	0,79	0,81	0,19	0,19	6,91	0,08
70—80	0,14	1,04	0,13	1,18	0,24	0,02	0,05	—	1,48	0,02
AP—3										
0— 3	0,08	1,13	0,23	1,36	0,85	2,21	0,47	1,11	2,83	0,07
4—10	—	2,99	0,36	3,35	0,42	2,00	0,14	0,15	5,43	0,05
15—25	0,29	4,61	0,74	5,34	1,01	2,18	0,20	0,49	8,04	0,06
AP—4										
0—10	2,13	4,56	2,19	6,74	2,14	3,02	0,19	0,45	10,65	0,08
10—20	—	1,66	0,71	2,37	0,91	2,79	0,53	0,12	5,43	0,03
27—37	—	0,52	0,66	1,18	0,25	2,83	0,53	0,38	3,48	0,03
AP—10										
0—10	5,07	7,80	0,41	8,21	2,83	2,55	0,12	0,23	13,74	0,06
15—25	2,03	3,72	0,44	4,17	1,31	1,06	0,07	0,13	6,13	0,07
30—38	1,99	3,72	0,29	4,01	1,08	0,74	0,03	0,10	6,00	0,03
40—50	1,56	2,73	0,25	2,98	0,70	0,39	0,03	0,73	4,09	0,01
AP—11										
0— 5	—	1,03	0,04	1,07	0,42	0,14	0,10	0,06	1,61	0,01
5—15	1,21	2,79	0,10	2,89	0,50	0,26	0,06	0,03	3,91	0,02
20—30	3,12	4,77	0,10	4,88	0,82	1,18	0,14	0,20	6,83	0,03
35—45	3,55	5,03	0,18	5,21	1,05	1,63	0,03	0,03	7,22	0,03
KM—606										
0— 5	—	0,58	0,37	0,94	0,63	0,08	0,13	0,02	1,43	0,01
5—15	—	1,47	0,34	1,81	0,96	0,52	0,23	0,09	3,09	0,01
20—30	2,30	4,80	0,30	5,10	1,05	0,25	0,02	0,02	6,78	0,03
35—45	1,77	3,17	0,54	3,71	0,90	0,15	0,02	0,02	4,65	0,01

Profile No. and Sampling Interval cm	Anions						Cations			
	CO_3^{2-}	HCO_3^- Alkalinity (Alkali Carbonate)	HCO_3^- Alkalinity (Alkali Earth Carbonate)	HCO_3^- Total Alkalinity	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
	meg/100 g soil									
II. Tisza valley:										
S—43										
0— 2	—	0,04	0,02	0,06	0,18	0,21	0,19	0,07	0,15	0,03
2— 13	—	0,20	0,08	0,28	0,20	0,21	0,03	0,02	0,63	0,03
13— 26	—	0,19	0,17	0,36	0,34	0,15	0,04	0,03	0,73	0,03
26— 38	—	0,31	0,18	0,49	1,25	1,45	0,08	0,13	2,96	0^{6}06
45— 60	—	0,21	0,16	0,36	2,22	11,85	2,28	2,39	10,21	0,17
80— 90	—	1,09	0,22	1,31	1,86	1,96	0,08	0,08	4,63	0,08
113—139	0,13	1,54	0,21	1,75	0,73	0,50	0,04	0,02	2,90	0,08
TSZ—I										
0— 15	—	0,05	0,03	0,09	0,15	0,06	0,04	0,02	0,22	0,02
15— 30	—	0,08	0,06	0,13	0,26	0,04	0,03	0,04	0,31	0,05
33— 45	—	0,54	0,04	0,58	0,28	0,05	0,03	0,06	0,73	0,05
55— 70	0,22	1,83	0,25	2,08	0,85	0,15	0,20	0,08	3,01	0,11
90—110	0,15	1,18	0,30	1,48	0,63	0,48	0,05	0,07	2,44	0,06
HB—2										
0— 3	—	0,44	0,24	0,69	0,59	1,23	0,82	0,12	1,91	0,04
4—13	—	0,44	0,13	0,58	0,53	1,11	0,16	0,08	2,57	0,03
18—20	—	0,36	0,07	0,43	0,66	1,99	0,12	0,15	3,74	0,06
28—40	—	1,25	0,03	1,28	0,65	1,34	0,07	0,08	3,78	0,02
40—50	0,42	0,24	1,96	2,30	0,63	6,39	3,63	0,22	6,96	0,04

higher ones. During the period of rains the infilterating water could easily remove the remaining salts from the higher points (KH-3, KH-4) as they were already partially removed because of relief, whereas, it could not do the same on the position of KH-1, because of the too high a quantity of salts, those already present plus those transported from the higher sites (KH-2, KH-3, KH-4). Dispersion of clay is a pre-requisite for the development of columnar structure in B horizon, characteristic of solonetzes. Electrolytes counteract the process of dispersion, whereas, soda and exchangeable sodium initiate it. However, soda if present in too high a quantity, might not act favourably for the dispersion process as postulated by Darab [8]. Thus, on KH-1 site, too high a quantity of electrolytes (neutral salts) and probably that of soda, inhibits the dispersion process initiated by exchangeable sodium unlike on KH-3, KH-4 and even on at KH-2 positions where this phenomenon could easily take place giving rise to columnar structure in B horizon. As a result, KH-1 being on the lowest position and having maximum quantity of salts, KH-2 on slightly higher position and having moderate amount of salts and KH-3, KH-4, on still higher positions with comparatively smaller amount of salts in their upper layers (Table 1), occur as solonchak, solonchak solonetz, and solonetz respectively, as is shown on the diagram (Figure 1).

Thus, fluctuations in ground water level as well as the differences in micro-relief as explained above, have brought forth the soil association of solonchak—solonchak-solonetz—solonetz in Kiskunfélegyháza.

II. Tisza valley soils

The origin and development of salt affected soils in this regions has intensively been studied by SZABOLCS [38]. Like in Danube valley soils, ground water has been the salt source in these soils too on account of basin type topography and impeded drainage. Nevertheless, the ways these soils differ to those of Danube valley are summarized as under on the basis of SZABOLCS's investigations:

1. Tisza sediments have been of finer texture and of slightly acidic in nature unlike those of Danube which have been coarser as well as calcareous.

2. Long back, most of the part of Tisza valley was a waterlogged area covered with bogs and marshes. Ground water level is relatively deeper in Tisza valley soils at most of the places on account of water regularization

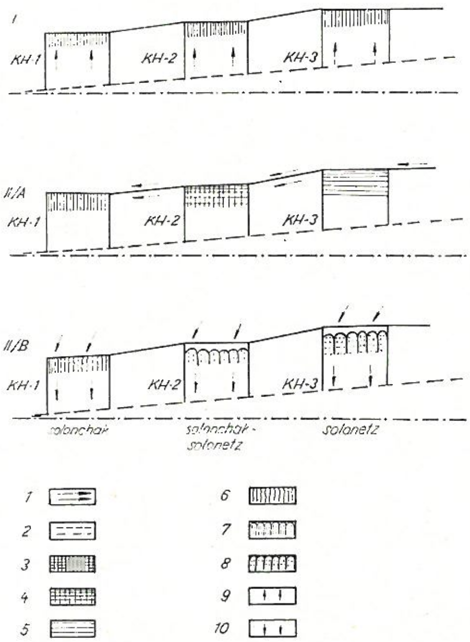

Figure 1

Diagram showing the influence of micro-relief on the processes of salinization and alkalinization in Kiskunfélegyháza

I. Salinization stage (All solonchaks). II. Alkalinization stage: A) Horizontal movement of water and salt transportation from higher sites to lower ones. B) Vertical movement of water and differentiation of soils as solonchak, solonchak solonetz and solonetz. 1. Surface and subsurface horizontal movement of water. 2. Two possibilities of ground water table due to periodic fluctuations. 3. High amount of salts. 4. Moderate amount of salts. 5. Lower amount of salts. 6. Low degree of colloid dispersion. 7. Moderate degree of colloid dispersion. 8. High degree of colloid dispersion. 9. Capillary-upward movement of water. 10 Gravitational-downward movement of water. Note: Depth to ground water table during the time of sampling was approximately one meter at all the three positions (KH—1, KH—2, KH—3) works performed in this region during last century. As a result, the main salt affected soil type in Tisza valley is meadow solonetz, whereas, solonchaks and solonchak-solonetzes cover the most of the part of Danube valley.

3. Tisza valley soils, in most of the cases, have not necessarily passed through solonchak pre-stage which has been the truth in general for salt affected soils of Danube valley. The bogs and meadows might have passed

Table 3

Status of humus and nutrients (N, P, K)

Profile No and Sampling Interval cm	Humus %	C %	N %	C : N Ratio	Phosphorus a) Aqua-regia extract-able (mg/100 g soil)	Phosphorus b) Lactate extract-able (mg/100 g soil)	Phosphorus $\frac{b}{a} \cdot 100$	Potassium a) Aqua-regia extract-able (mg/100 g soil)	Potassium b) Lactate extract-able (mg/100 g soil)	Potassium $\frac{b}{a} \cdot 100$
I. Danube valley:										
KH—1										
0—10	0,75	0,436	0,054	8,07	133,2	26,8	20,12	540,0	44,8	8,30
15—25	0,48	0,278	0,034	8,17	116,8	23,2	19,86	503,0	35,9	7,13
25—35	0,53	0,306	0,034	9,00	99,2	14,8	14,92	475,0	33,3	6,98
KH—2										
0— 3	2,90	1,683	0,192	8,76	167,2	21,0	12,56	343,0	50,6	14,71
5—15	1,33	0,773	0,076	10,17	119,2	15,6	13,08	412,0	25,3	6,14
20—30	1,24	0,719	0,075	9,61	125,6	10,0	7,96	431,0	24,0	5,56
KH—3										
0— 4	4,13	2,402	0,279	8,60	185,6	12,8	6,89	406,0	33,2	8,17
5—15	2,06	1,198	0,136	8,00	125,6	7,2	5,73	307,0	23,8	7,75
25—35	1,44	0,837	0,080	10,46	97,6	4,6	4,71	343,0	23,8	6,94
KH—4										
0— 5	3,64	2,112	0,262	8,06	155,2	8,0	5,15	268,0	19,3	5,24
8—18	2,37	1,380	0,176	7,84	131,2	7,0	5,33	412,0	23,8	5,77
25—35	1,18	0,685	0,073	9,38	102,3	4,8	4,68	524,0	23,6	4,50
AP—3										
0— 3	2,52	1,466	0,166	8,83	131,2	9,04	6,89	412,0	23,4	5,68
4—10	1,18	0,684	0,080	8,55	108,8	5,60	5,14	412,0	23,6	5,72
15—25	0,76	0,441	0,045	9,80	96,0	4,71	4,91	472,0	27,9	5,91
AP—4										
0—10	0,71	0,412	0,047	8,76	103,2	8,08	7,82	358,0	31,6	8,82
12—20	0,47	0,273	0,032	8,53	80,0	4,00	5,00	475,0	25,5	5,37
27—37	0,38	0,222	0,024	9,25	84,0	1,90	2,26	370,0	20,7	5,59
AP —10										
0—10	0,88	0,512	0,066	7,75	132,8	10,0	7,53	324,0	32,3	9,97
15—25	0,55	0,319	0,036	8,86	93,6	5,4	5,77	493,0	28,2	5,72
30—48	0,43	0,250	0,032	7,81	72,0	3,2	4,44	382,0	23,4	6,12
40—50	0,37	0,213	0,025	8,52	84,0	2,4	2,83	292,0	15,9	5,44
AP—11										
0— 5	4,00	1,745	0,221	7,68	155,0	11,6	7,09	177,0	16,6	9,37
5—15	0,95	0,552	0,051	10,88	104,8	8,5	8,11	415,0	29,4	7,08
20—30	0,60	0,349	0,032	10,90	73,6	7,0	9,51	442,0	32,9	7,44
35—45	0,35	0,204	0,022	9,27	72,0	3,4	4,72	337,0	23,6	7,00
KM—606										
0— 5	2,96	1,723	0,196	8,80	132,2	13,0	9,86	475,0	23,7	4,98
5—15	1,50	0,871	0,097	8,97	103,2	15,0	14,57	592,0	24,8	4,19
20—30	0,56	0,323	0,038	8,50	109,6	12,4	11,28	737,0	39,6	5,37
35—45	0,34	0,198	0,020	9,90	140,0	13,5	10,36	538,0	30,7	5,70

Profile No and Sampling Interval cm	Humus %	C %	N %	C : N Ratio	Phosphorus			Potassium		
					a) Aqua-regia extractable	b) Lactate extractable	$\frac{b}{a} \cdot 100$	a) Aqua-regia extractable	b) Lactate extractable	$\frac{b}{a} \cdot 100$
					mg/100 g soil			mg/100 g soil		
II. Tisza valley:										
S—43										
0— 2	—	—	—	—	396,0	18,4	4,64	840,0	53,0	6,31
2—13	7,70	4,473	0,353	12,67	316,0	14,3	4,52	753,0	41,0	5,44
13—26	2,84	1,648	0,140	11,77	182,0	5,0	2,74	1249,0	102,4	8,19
26—38	2,37	1,379	0,108	12,76	205,0	16,4	8,00	1340,0	98,8	7,37
45—60	2,06	1,197	0,101	11,85	230,0	43,7	19,00	1129,0	100,6	8,91
TSZ—1										
0—15	3,99	2,322	0,186	12,48	163,0	3,8	2,33	463,0	15,7	3,38
15—30	2,13	1,236	0,097	12,74	120,0	2,2	1,83	409,0	10,8	2,65
33—45	1,38	0,800	0,072	11,11	85,0	0,8	0,94	625,0	14,5	2,31
HB—2										
0— 3	3,75	2,178	0,198	11,00	125,0	8,0	6,40	352,0	16,9	4,79
3—13	2,61	1,519	0,127	11,96	95,0	3,8	4,00	518,0	14,5	2,79
18—28	1,04	0,607	0,064	10,04	62,0	1,2	1,93	916,0	24,1	2,63
30—40	1,08	0,630	0,052	12,11	72,0	1,7	2,36	904,0	28,9	3,20
40—50	0,60	0,350	0,026	13,30	88,0	3,2	3,58	1138,0	30,1	2,65

1. $\frac{b}{a} \cdot 100$ Lactate solubility of P and K (on percentage basis of that extractable in aqua-regia.)

through the following stages until the development of meadow solonetzes, solonetzic meadow soils and steppe meadow solonetzes of Tisza valley.

A) *Impact of lowering of water table*

1. Slightly salty bogs → solonetzic or salty meadow soils
   ↳ meadow solonetzes.
2. Swampy solonchak → swampy solonetz → meadow solonetz.
3. Swampy solonetz → meadow solonetz.
4. Meadow solonetz → steppe meadow solonetz (Ground water level lowered to 4 meters or below).
5. Bogs → meadow soils.

B) *Salt transportation from other areas*

1. Meadow soils → solonetzic or salty meadow soils → meadow solonetzes.

In Danube valley soils, however, the following process probably is of most common occurrence.

Solonchak → solonchak-solonetz → solonetz.

As it seems to author, this difference in the genesis of salt affected soil of these two regions may be of paramount importance leading to differences in many of their characteristics.

2. *Status of humus*

A general visualization of data (Table 3) clearly demonstrates that Tisza valley soils are generally richer in humus than those of Danube valley.

The following points which were closely concerned with the genesis of these soils might explain this trend:

I. Most of the part of Tisza valley was long back a waterlogged area covered with bogs and marshes which were rich in organic matter. Moreover, these soils, in most of the cases, have not passed through solonchak stage unlike Danube valley soils.

II. Tisza valley soils are fine textured, whereas, those of Danube valley – coarse textured (Table 1). As a general rule of thumb, fine textured soils are richer in humus than coarse textured ones.

III. Generally, it is true that humus decomposition process proceeds at a relatively rapid rate when the soil reaction is in a neutral to alkaline range. As a matter of fact, Tisza valley soils under study have slightly acidic reaction in their upper layers which suggests a slower rate of humus decomposition.

IV. Active calcium — water soluble and exchangeable, slows down the rate of humus decomposition, whereas, calcium carbonate hastens the process. Thus, in Danube valley soils high quantities of calcium carbonate definitely contribute towards accelerating the humus decomposition process.

V. Humus decomposition process proceeds at a relatively rapid rate when the soil is saturated with sodium. Table 1 clearly shows that the degree of sodium saturation is somewhat more in Danube valley soils than those of Tisza valley.

VI. Humus decomposition process, predominantly, is a biological one. However, chemical oxidation of organic matter also takes place to some extent, which generally is favoured by alkaline reaction of the medium – as in Danube valley soils.

Different soil types can be put in the following order with decreasing humus content.

Solonetz $>$ solonchak – solonetz $>$ solonchak.

Generally it is said that wherever the drainage is impeded, organic matter accumulates regardless of the climatic effects. However, this does not apply to solonchaks in most of the cases. Nonetheless, humus status of a soil at a given time is two dimensional one i.e. its supply through growing vegetation and the rate of its decomposition. In case of solonchaks, impeded drainage manifests itself concentrating the salts in upper soil layers which, however, clash with the life of growing plants and severely cut down the rate of the supply of organic residue to the soil. The result that all the solonchaks (KH-1, AP-4, AP-10) under study are exceptionally poor in humus. Moreover, these soils can be marked having higher values for exchangeable sodium right from the surface as well as air water regime in solonchaks is not as adverse as in solonetzes for the activity of humus decomposing microflora. This all works in the direction of leading solonchaks to a poorer status of humus.

Solonetzes (KH-3, KH-4, AP-3, Tsz-1, HB-2, S-43) as a rule have comparatively lower quantities of salts in upper horizons (Table 2) which, however, do not clash with the life of growing plants. On the other hand, in their lower horizons physical conditions are quite adverse for the life of microflora. As a result, solonetzes are comparatively richer in humus. HB-2, however, can be noted having lower status of humus in contrast to other two Tisza valley soils. This, most probably, is the resultant of solodization process, intensively going on at this site.

Solonchak-solonetzes (KH-2, AP-11, KM-606) attain an intermediary situation as regards humus status. However, it can be noticed that they attain intermediary situation as regards the vegetative cover, solonchaks and solonetz having the worst and best respectively. Because salt content in their upper horizons is not as much as in solonchaks, it does not interfere with the life of plants to the extent it does in the case of solonchaks.

Thus, this moderate vegetative cover assisted with poor physical conditions, approximating to those of solonetzes, led solonchak-solonetzes to a slightly better status of humus in contrast to solonchaks.

3. Status of nitrogen and C : N ratio

Nitrogen is closely related with humus, therefore, it has the same pattern of distribution and status as humus (Table 3). However, the depthwise trend of C : N ratio has considerably been affected by salt accumulation processes as well as by humus decomposition rate which is summarized in the following points.

I. Tisza valley soils are marked with a wider C : N ratio in contrast ot those of Danube valley which is a resultant of slower rate of humus decomposition in the case of former. Moreover, according to MATTSON [23], the higher the pH the higher the degree of oxidation of humic acid, which in turn, increases its nitrogen content. As Danube valley soils are comparatively more alkaline, especially in upper layers, this phenomenon would have contributed narrowing down the C : N ratio in these soils.

II. In solonchaks C : N ratio is the narrowest in surface layers and in solonetzes B_1 horizon has the lowest C : N ratio in most of the cases (Table 3). Thus, the dynamics of water movement has affected the C : N ratio at least to some extent — by lowering it down in the salt accumulation horizon by virtue of the deposition of nitrate salts along with others in the horizon in question. In HB-2 the narrowest C : N ratio is observed in B_2 which would have been a resultant of intense leaching. Solonchak-solonetzes do not show any definite trend of this ratio because of the considerable fluctuations in the dynamics of upward and downward movement of water though, nevertheless, it is somewhat narrower in upper layers.

III. No appreciable degree of nitrogen losses can be assumed to have taken place in all the soils under study as the drainage is impeded. But whether, after being added to ground water, all the inorganic nitrogen is again brought back to the same point of the area, is not sure because of the complex nature of under ground water movement.

IV. Nitrogen losses through volatilization of ammonia, from soil surface do not seem to have occurred to a considerable degree as the C : N ratio in the alkaline surface layers of most of the soils is rather narrow.

4. State of phosphorus

Table 3 clearly shows that Tisza valley soils are richer in phosphorus than those of Danube valley which is the resultant of higher humus content as well as heavier mechanical composition of the former.

Sodium ion has led to the mobilization of phosphorus in the profile. As a result there are no striking differences between phosphorus content of upper and lower layers. This influence of sodium ion is more pronounced in slightly solodized S-43 and strongly solodized HB-2 as in both the cases phosphorus content after falling to a minimum at a certain depth, again increases with considerable margin. However, release of fixed phosphorus during destruction of clay mineral, a resultant of solodization, has also contributed to this phenomenon. The possibility of the occurrence in these soils of phosphates and nitrates of sodium is hinted by the data on 1 : 5 water extract analysis as, in most of the cases, total cations are slightly more than total anions (Table 2).

Salts have been found to increase the solubility of phosphorus (the lactate extractable fraction of aqua-regia soluble phosphorus) as it is somewhat more in Danube valley soils in contrast to those of Tisza valley -- the soils having slightly acidic reaction in upper soil layers. All the profiles can be put as follows in decreasing order of lactate solubility of phosphorus.

$$\text{KH-1} > \text{S-43} > \text{KH-2} > \text{KM-606} > \text{AP-11} > \text{AP-10} > \text{AP-4} > \text{KH-3} > > \text{AP-3} > \text{KH-4} > \text{HB-2} > \text{Tsz-1}.$$

This order of soil types clearly demonstrates that salts increase the solubility of phosphorus only if not present in too high quantities, KH-1 which attains the first place, does not have as much salts as AP-10 and AP-4 have. Phosphorus solubility is no doubt selective to kind of salts as well. A visualization of Table 2 clearly shows the more pronounced influence of sulphates, carbonates and bicarbonates of sodium on phosphorus solubility as the minimum amount of lactate extractable phosphorus has been found in case of Tsz-1, which has chloride type salts.

The high degree of phosphorus solubility in lactate solution in the deeper layers of S-43 has been a resultant of high quantities of sulphates and somewhat neutral reaction in those layers as well as transfer of phosphorus from upper to deeper layers as the solodization process has just started. However, in the case of HB-2, the same impact of solodization process is not observed as the phosphorus released from the fixed form was either held with sesquioxides freed because of the high degree of solodization, or leached to still deeper layers because of intense leaching.

Thus, in view of the above, different soil types in a generalized way can be put as follows with decreasing order of phosphorus solubility in lactate solution.

Solonchak – solonetz > solonchak > solonetz.

To conclude, salts enhance the solubility of phosphorus depending on their concentration, kind and type of soil. Thus, author's findings are in line with the second school of opinion dealt earlier regarding phosphorus salts relationship.

5. *State of potassium*

Tisza valley soils, in general are richer in potassium than those of Danube valley (Table 3), primarily because of the heavier mechanical composition of former (Table 1). This factor is still justified as Tsz-1 — a Tisza valley profile, having light texture, KM-606 — a Danube valley soil having comparatively heavier mechanical composition, approximate to the potassium content of Danube valley soils and Tisza valley soils respectively.

Solonchaks have higher potassium content in upper soil layers, solonchak-solonetzes in B_2 and solonetzes in still deeper layers, in most of the cases. This has been the resultant, on one hand, of the high clay content in the horizons in question, and on the other hand, of dynamics of upward and downward water movement depositing the potassium salts in the salt accumulation horizon. As a matter of fact, in a soil there always exists an equilibrium between fixed, exchangeable, and water soluble potassium. Thus, appreciable quantities of it cannot be found in soil solution as is supported by the content of potassium in 1 : 5 water extract (Table 2). Moreover, almost in every soil under study, high potassium content of a layer is associated with high sodium content of it, and as a result, to some extent the latter might replace the former for satisfying the plant needs resulting to preservation of potassium in soil.

Salts contribute increasing the so-called availability of potassium, as lactate solubility of potassium is somewhat more in Danube valley soils than in those of Tisza valley, and solonchaks and solonchak-solonetzes contain more lactate soluble potassium as a percentage to that soluble in aqua-regia, than solonetzes in most of the cases.

The different profiles can be put in the following order of decreasing solubility of potassium in lactate solution:

$$\text{KH-2} > \text{AP-11} > \text{S-43} > \text{AP-10} > \text{AP-4} > \text{KH-1} > \text{KH-3}$$
$$\text{AP-3} > \text{KH-4} > \text{KM-606} > \text{HB-2} > \text{Tsz-1}.$$

This sequence can be generalized as follows:
Solonchak-solonetz > solonchak > solonetz.

Thus, this sequence headed by solonchak-solonetz clearly suggests that increasing influence of salts on potassium solubility is especially notable if they are not present in too high concentrations. S-43 is the only solonetz having appreciable quantities of lactate soluble potassium. This might have been the resultant of the beneficial influence on potassium solubility of sulphate salts wnich occur in considerable quantities in lower horizon of this soil. However, visualization of 1 : 5 water extract data (Table 2) parallel to those on lactate available potassium clearly demonstrates the association of high quantities of sulphates with high quantities of lactate soluble potasium in most of the cases and defines sulphate anion as the most favourable one enhancing the socalled potassium availability.

Conclusion

The points discussed above decisively support that state of nutrients in a salt affected soil is to a great part governed by its genetical set up. Therefore, no generalizations can be made for example "Salt affected soils are poor in nutrients" or "Rich in available phosphorus or potassium" without taking into consideration their past genetical history as well as present genetical phenomena distinguishing them into different genetical types of solonchak solonchak-solonetz and solonetz or saline, saline-alkaline and alkaline soils.

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