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HAZARDOUS IMPACT OF IRRIGATION WITH DRAINAGE WATER ON THE CHEMICAL PROPERTIES OF CLAYEY SOIL

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ABSTRACT: ***The present investigation was carried out for drawing the attention to the deteriorative effect of irrigation with drainage water on the soil chemical characteristics. Soil samples were taken from nine profiles of Al-Hamul regions. Kafr El-Sheikh governorate, long term irrigated with drainage water for chemical analysis. The obtained results manifested that application of drainage water obviously appeared the degradability in the chemical properties of the soil wherever, the EC, pH, Na^+ and SAR of the surface layer (0-30cm) for some profiles recorded, 6.34 dSm^{-1}, 8.3, 46.45 $meqL^{-1}$ and 45.2 respectively. However these characteristics in addition to some of the soluble cations and anions were evidently diminished with the depth of profile. Other chemical properties like as CEC, Exchangeable cations, ESP, EKP, ECaP and EMgP were slightly affected. Soluble chloride was the dominant anions followed by carbonate and sulphate.***

Key words: ***Clayey soils, drainage water, irrigation, chemical properties, degradation.***

INTRODUCTION

In many countries of the arid and semiarid regions as Egypt the immense need for maximizing the agricultural land so searching for a new sources of water for irrigation directed the attention to reuse the low quality water in irrigation, However this application in addition to the consequence of intensive agricultural systems, is considered one of the main causes of secondary salinization and land degradation, that represents an ever greater environmental hazard . Kandil *et al.* (2003) found that in the last few years, reuse of low quality water become part of the extension program for maximizing the use of water resources. However, the uncontrolled application of such water must have unfavorable effects on both soils and grown plants, especially in the long term use. Perez *et al.* (2003) stated that reuse of poorly purified water in semiarid areas led to progressive desertification. Hafez (2004) found in their study on Shubrakhit, El-Lowia, El-Khairy, El-Atf, El-shamasma and Idko drains along the studied locations have

salinity less than 3 ds/m and were classified as slight to moderate grade, while both El-kosor drain and toson drain more than 3 ds/m were classified as severe grade for irrigation. Seyam *et al.* (2005) reported that lack of water is an obstacles confronting development in many countries of the arid and semiarid regions as Egypt. Drainage water could be used for irrigation to partially satisfy the need of water. Also, all drains and mixed canals are considered under division of increasing salinity problems of irrigation water, as well as the main drain is considered high salinity for irrigation and classified as sever salinity problems. Abdel-Mawgoud *et al.* (2006) found that irrigation with low quality water causes increase of soil salinity (EC) Ollson *et al.* (2002) studied plots irrigated with water of electric conductivity EC = 0.1 , 0.8 , 2.5 , 4.5 and 7.5 ds/m for summer of 1991/1992 to 1994/1995. With those 4 years, soil were sodified at irrigation treatment salinities greater than 0.8 ds/m. Zein *et al.* (2002) found that soluble cations and anions were higher in the soil irrigated with drainage water than those irrigated with mixed water. Noufal (2000) studied the effect of use of drainage water on the soil. He found that the value of SAR in the sandy soil increased from 7.6 to 14.7 and from 7.9 to 10.5 in the clay soil. This indicated that SAR values in the sandy soil were higher than those in the clay one. Khater *et al.* (2002) observed that the soil pH tends to increase with increasing the salinity level of the soils irrigated with drainage water. Therefore, these soils have a marked increase in the applied soluble Na^+ leading to a pronounced increase in the exchangeable Na^+ and in turn soil pH. Walker and Lin (2008) observed that after four decades of irrigation with waste water of forested land, the soil pH has increased considerably since 1970. Ahmed (2005) found that OM in salt affected soils was reduced due to the increase of the concentration of basic ions specially Na^+ which may be resulted in more dissolution of soil organic matter. Jala Li *et al.* (2008) conducted soil columns with two soils to asses the effect of irrigation with waste water on soil quality. Upon the application of waste water, exchange occurs between solution sodium Na^+ and exchangeable cations (Ca^{2+}, Mg^{2+} and K^+), whereby these cations were released into solution. The average ESP of the soils increased during leaching from 9 to 21 and 28.8 to 29.7 after applying 5.0 and 3.5 (about 7 and 6 pore volumes) of waste water to the soil columns, respectively. Adverse effect of high Na^+ concentration in the waste water on raising ESP was less pronounced in the soils having initial high ESP than in the soils with low initial ESP. The main objective of this paper was to explore the detrimental influence of irrigation with low quality water (drainage water of the main El-Gharbia drain) on the chemical properties of the the cultivated soil in Al-Hamul regions. Kafr El-Sheikh governorate.

MATERIALS AND METHODS

Soil Sampling:

This work carried out to study the effect of irrigation with drainage water on the soil chemical properties. For this purpose, areas irrigated with drainage water were selected of Al-Hamul, Kafr El-Sheikh governorate. Nine locations were selected. These were, Timbari (60.19% clay), Ta'aween Thon (51.95% clay), Ta'aween Awal (50.82% clay) Qaryah no.7 (59.04% clay), Qaryah no.5 (58.35% clay), Qaryah no. 9 (54.22% clay), Qaryah no.8 (50.79% clay), Qaryah no.10 (52.40% clay) and Qaryah no.11 (59.80% clay). The source of irrigation water for the agricultural land of these Qaryahes is the Main El-Gharbia drain (Table 3-1).

Nine soil profiles were taken from the different nine locations respectively for each Qaryah. The depth of soil profiles was more than 100 cm, where the soil samples were taken at depths of 0 – 30 , 30 – 60 , 60 – 90 and > 90 cm. The nine studied soil profiles were located at the west of the Main El-Gharbia drain.

Soil samples were air dried and ground to pass through 2 mm sieve and kept for determination of the chemical properties.

Soil chemical analysis:

a. Soil reaction (pH) was measured in 1: 2.5 (soil: water) suspension by using compound electrode pH meter according to Cottenie *et al.* (1982).

b. The total soluble salts (EC) were determined by using electrode conductivity meter at 25^{o} C in soil paste extract as dS m^{-1} (Jackson, 1973).

c . Soluble cations (Na^{+}, K^{+}, Ca^{2+} and Mg^{2+}) and soluble anions (Cl^{-}, CO_3^{2-}, HCO_3^{-} and SO_4^{2-}) were determined and expressed as meq/L. in soil paste extract according to Jackson (1973) and Cottenie *et al.* (1982)

d. Cations exchange capacity (CEC) and exchange cations:

Cations exchange capacity was determined by using sodium acetate (CH_3COONa) at pH 8.2 and ammonium acetate ($CH3COONH_4$) at pH 7.0 .

e. Organic matter content (OM %) was determined by using Walkely and Blacks rapid titration method (Jackson, 1973).

f. Total carbonates were determined as calcium carbonate ($CaCO_3$) where its content estimated volumetrically by using the collin's calcimeter and the corrected volume of CO_2 was used to calculate the calcium carbonate percentage (Richards, 1954).

g. Sodium adsorption ration (SAR) and Exchangeable sodium percent (ESP) were calculated according to Richards (1954)

RESULTS AND DISCUSSION

Quality assessments of irrigation water:

Data in Table (1) reveal that the drainage water used for soil irrigation under study had EC value 1.50 dS/m and SAR value 6.00. This grade of irrigation water, with respect to electric conductivity and sodicity hazard, could be classified into C_3S_1 class, i.e., high salinity and low sodium hazard (Richrd, 1954).

Table (1): Some chemical analysis of irrigation water.

pH	EC dS/m	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	SAR
7.34	1.50	3.11	2.10	8.89	0.31	7.30	-	5.70	1.44	6.00

Likewise, the individual distribution of soluble cations in this water show that the soluble sodium is the dominant followed by calcium and then magnesium, while the soluble potassium is the lowest one. According to the anions, soluble chloride is the dominant soluble anion followed by soluble bicarbonate and then soluble sulphate.

Effect of irrigation by drainage water on soil chemical properties:

Total soluble salts:

When brackish water is used for several years, the chemical properties of soil may be changed. The values of electrical conductivity (EC) in the surface soil layers of the studied soil samples ranged between 0.77 – 6.35 ds/m (as shown in Tables 2,3,4). It was noticed that EC values were high due to irrigation with drainage water. This means that the salinity of irrigation water increases the soil salinity due to salt accumulation in the soil profiles. This is in agreement with Khan (1991) and Khater *et al.* (2002).

A similar conclusion was reported by Ayers and Westcot (1985) who reported that use of drainage water is considered to cause increasing salinity problems especially in heavy clay soil.

Concerning the distribution of total soluble salts in the different soil profiles under study, the presented data in Tables (2,3,4) display that the content of total soluble salts in the studied soil profiles was decreased with soil depth. Wherever the total soluble salts in the surface layers was higher than that one in the deep soil layers. This may me be due to the relatively high temperature in the arid and semi arid soils which results in accumulation of soluble salts in the soil surface layers by evaporation. This data is in agreement with those of Selem *et al.* (1989). According to values of EC in the surface soil, the studied soil can be classified as saline soils (National Soils Hand Book, 1983 and El-Samanodi *et al.,* 1991).

Table 2

Table 3

Table 4

Soluble ions (cations and anions):

The data in Tables (2,3,4) represent the content of soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (Cl^{-}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-}) as meq/L. The data show that the dominant soluble cation in the studied soil samples was Na^{+} followed by Ca^{2+} and Mg^{2+}, while the soluble K^{+} represented the lowest soluble cation. Generally, the content of soluble cations was decreasing when the soil depth increased.

It was deduced from content of soluble anions (Cl^{-}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-}) of the studied soil samples that soluble chloride (Cl^{-}) was the dominant anion followed by sulphate (SO_4^{2-}) and bicarbonate (HCO_3^{-}), i.e., the soluble anions were presented in the following order: $Cl^{-} > SO_4^{2-} > HCO_3^{-}$. Similar results were found by Khater *et al.* (2002). Soluble anions content was decreased with increasing soil depth. These results are in agreement with those found by Mohamed (2002) on the soil of Kafr El-Sheikh –Baltim who reported that the use of low quality water increases the presence of both chloride and sodium ions on the expense of the other soluble ions.

Sodium adsorption ratio (SAR):

Regarding to the calculated values of SAR of the studied soil samples as represented in Tables (2,3,4), it can be noticed that the studied soil samples were characterized by high values of SAR which resulted from the high content of soluble Na^{+} in these samples. Nevertheless values of SAR were decreased with increasing the soil depth. That may be as an obvious reflection for sodium cation which considerably decline with the depth of soil profile. These results are confirmed with those found by Mohamed (2002), who found that SAR values of the soil in Northen Kafr El-Sheikh Governorate were decreased when soil depth increased.

Soil reaction (pH):

The data in Tables (2, 3, 4) elucidate that the soil pH values of the studied soil samples were ranged between 8.0 in the soil surface layer (0 – 30 cm) and 8.5 in the soil deep layers (> 90 cm). The values of pH in the studied soil are slight alkaline (pH is around 8.0). From the same Tables, the values of pH in the soil surface layers are lower than in the deep layers. This may be due to the high content of organic matter in the surface layers (El-Maaz, 2005).

Generally, the values of pH in the studied soil samples were slightly increased as a result of use of drainage water in irrigation, which contains high concentrations of Na^{+} ions that causes an increase of soluble Na^{+} in the soil solution that lead to a pronounced promotion of the exchangeable Na^{+} and hence raising the soil pH. These results are in agreement with Bahlawan (1997).

Soil organic matter (OM) content and calcium carbonate ($CaCO_3$ %):

Data in Tables (2,3,4) manifest that the content of organic matter (OM) in the studied soil samples was ranged between 0.68 – 2.40. It can be observed that the content of OM was low. This may be due to increase of basic ions concentration, especially Na^+ ions in irrigation water (drainage water) which lead to more dissolution of organic matter. This illustration was based on the fact suggested by many authors (Kononova, 1966 and Stevenson, 1994) who reported that there is a high affinity of Na^+ salts (NaOH) on the extraction of soil organic matter.

Also, data in these Tables declare that the content of OM was higher in the soil surface layers than in the subsurface layers, this may be due to long-term cultivation of soil. These results are in agreement with those obtained by Khater *et al.* (2002) and El-Maaz (2005). Generally, the content of OM was diminished with the increase of soil depth in all studied soil samples. These findings resulted from the enrichment of the surface layer by organic residues and organic manures during agriculture processes (Anter, 2000 and Shaban, 2005). Also, data in Tables (2,3,4) indicate that the content of $CaCO_3$ % in the studied soil samples was ranged between 3.94 % in the soil surface layer (0 – 30 cm) and 0.58 % in the soil deep layer (> 90 cm). Concerning the distribution of $CaCO_3$ % with the soil profile, there was no clear trend affected by using drainage water in irrigation. Generally, the studied soil samples have a low content of $CaCO_3$ %, where this soil can be classified as non calcareous soil $CaCO_3$ % < 5 (Abo-Elelo, 2002).

4.3.6. Cation exchange capacity (CEC):

The values of cation exchange capacity (CEC) are represented in Tables (5,6,7) as meq/100 g soil. These values are ranged between 59.11 meq/100 g soil in the surface soil layer (0 – 30 cm) and 28.11 meq/100 g soil in the soil deep layer (> 90 cm). These data indicate that values of CEC were high, this may be due to increase of clay content in the soil samples under study. Also, the values of CEC in the soil surface layer were higher than that in the subsurface layer this may be attributed to the high content of OM in soil surface layers than in the soil deep layers.

Exchangeable cations and exchangeable sodium percent (ESP):

Data in Tables (5,6,7) appeared the content of exchangeable cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) as meq/100 g soil in the soils under investigation. The obtained data obviously appeared that the dominant exchangeable cations was Na^+ followed by Ca^{2+} and Mg^{2+}, while the lowest content of exchangeable cation was for K^+. In most of the studied soil profiles, the exchangeable cations were decreased with increase of soil depth. The high content of exchangeable cations was found in the soil surface layers as a result of the higher content of organic matter.

Table 5

Table 6

Table 7

The abovementioned data declared that the ESP values of soil under study were high and ranged between 37.9 – 54.3. This may be due to the soil texture and the relatively high values of the soluble sodium in both of soil and irrigation water (drainage water) as reported by Khater *et al.* (2002). Also, the results pointed out that there was no clear trend between ESP, ECaP, EMgP, and EkP values and soil depth. According to the high values of ESP in all studied soil samples (> 15 %), these soil samples are classified as sodic soils consequently, these soil are badly needed to receive its gypsum requirement and a suitable drainage net. These results are in agreement with that found by Anter (2000).

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التأثير الضار للري بمياه الصرف علي الخواص الكيميائية للأرض الطينية

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الملخص العربي

أجري هذا البحث علي الأراضي الطينية الواقعة بمنطقة الحامول بمحافظة كفر الشيخ والتي تروي لفترة طويلة بمياة الصرف من مصرف الغربية الرئيسي لجذب الإنتباه إلي التأثير الضار الناتج من الري بمياه الصرف علي خواص الأرض الكيميائية . تم اختيار تسع قطاعات من تسع قري تمثل منطقة الحامول و أخذ منها عينات أرضية لإجراء تحليل الخواص الكيميائية عليها . وقد أظهرت نتائج التحليل الكيميائي ان الري بمياه الصرف قد أدي إلي تدهور واضح في هذه الخواص حيث سجل قياس التوصيل الكهربائي و درجة الحموضة و تركيز كاتيون الصوديوم و نسبة الصوديوم المدمص في الطبقة السطحية (٣٠سم) ٦.٣٤ ديسيسيمنز/متر و ٨.٣ و ٤٦.٤٥ مللمكافيء / لتر و ٤٥.٢ علي التوالي . علي الرغم من ذلك فإنه قد حدث إنخفاض واضح في هذه القيم بالإضافة إلي قيم الكاتيونات و الأنيونات الذائبة كلما تحركنا إلي أسفل في القطاع الأرضي بينما حدث تأثر قليل لبعض الصفات الكيميائية الأخري مثل السعة التبادلية الكاتيونية والكتيونات المتبادلة والنسبة المئوية لكل من الصوديوم و البوتلسيوم والكالسيوم والمغنسيوم المتابدلين وقد أظهرت النتائج أيضا أن أنيون الكلوريد هو الأنيون السائد تبعه كل من أنيونات الكربونات ثم الكبريتات وهذا يوضح مدي التأثير الضار للري بمياه الصرف والذي يجب أن يعالج بإضافة الإحتياجات الجبسية لهذه الأراضي وعمل شبكة صرف جيدة .

Table (2): Some chemical properties of soil samples of Al-Hamul area (profiles 1 to 3).

Profile No.	Depth (cm)	EC Ds/m 1:5	PH 1:2.5	O.M (%)	$CaCO_3$ (%)	Soluble Ions (meq/L)								SAR
						Cations				Anions				
						Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	$CO3^{-}$	HCO_3^{-}	SO_4^{-2}	
1	0 – 30	6.34	8.20	2.40	1.32	4.02	1.28	55.64	0.88	53.40	00	0.96	0.46	45.20
	30 – 60	2.90	8.30	2.00	1.22	1.40	0.80	26.00	0.48	21.30	00	1.68	5.70	25.00
	60 – 90	2.50	8.30	1.96	0.93	3.55	1.05	18.85	0.45	12.50	00	2.94	8.46	12.40
	> 90	1.60	8.40	1.20	0.63	1.80	1.10	12.50	0.33	10.90	00	1.60	3.23	10.04
	Mean	3.34		1.89	1.03	2.69	1.06	28.25	0.54	24.52	00	1.79	6.21	23.25
2	0 – 30	3.60	8.00	2.35	1.02	4.68	3.16	25.91	0.73	23.50	00	1.97	9.01	13.15
	30 – 60	2.45	8.20	1.56	1.20	2.13	1.37	20.00	0.33	17.80	00	0.96	5.07	15.40
	60 – 90	2.20	8.30	0.90	0.92	3.08	1.06	17.24	0.50	16.90	00	1.28	3.70	12.06
	> 90	1.50	8.30	0.68	0.58	1.80	0.70	11.56	0.22	10.90	00	1.57	1.81	10.40
	Mean	2.44		1.37	0.93	2.92	1.57	18.68	0.44	17.27	00	1.44	4.89	12.75
3	0 – 30	4.20	8.20	2.30	1.67	5.20	3.40	31.76	1.05	35.70	00	1.33	4.38	15.30
	30 – 60	1.15	8.20	2.00	1.17	2.16	0.74	7.69	0.26	7.50	00	2.50	1.35	6.40
	60 – 90	1.10	8.10	1.12	1.20	1.50	0.90	7.11	0.26	7.00	00	1.50	1.27	6.52
	> 90	0.77	8.30	0.84	0.83	1.50	0.20	5.00	0.26	4.20	00	1.00	1.76	5.40
	Mean	1.80		1.56	1.21	2.59	1.31	12.89	0.45	13.60	00	1.45	2.19	8.40

Table (3): Some chemical properties of soil samples of Al-Hamul area (profiles 4 to 6).

Profile No.	Depth (cm)	EC Ds/m 1:5	PH 1:2.5	O.M (%)	$CaCO_3$ (%)	Soluble Ions (meq/L)								SAR
						Cations				Anions				
						Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	$CO3^{-}$	HCO_3^{-}	SO_4^{-2}	
4	0 – 30	6.11	8.10	2.24	1.25	8.70	4.80	46.45	0.85	55.80	00	0.93	4.07	17.93
	30 – 60	5.50	8.20	1.90	1.13	6.79	3.41	43.37	0.66	49.10	00	1.20	3.89	19.27
	60 – 90	4.43	8.20	1.77	1.23	6.30	1.66	35.00	0.85	40.20	00	1.26	1.95	17.58
	> 90	3.24	8.30	1.20	0.94	2.70	0.80	26.22	0.77	25.20	00	2.66	2.63	19.86
	Mean	4.82		1.77	1.14	6.12	2.66	37.76	0.78	42.65	00	1.51	3.13	18.66
5	0 – 30	5.30	8.00	2.25	2.90	5.30	2.10	44.16	1.34	50.40	00	1.14	1.36	23.00
	30 – 60	5.24	8.10	1.59	1.20	8.20	2.30	40.20	1.40	48.30	00	1.95	1.85	17.55
	60 – 90	4.30	8.10	1.16	1.94	3.50	0.64	37.08	0.96	39.90	00	0.99	1.29	25.90
	> 90	2.90	8.20	1.10	0.86	1.82	0.21	25.72	0.45	24.04	00	1.31	2.85	25.90
	Mean	4.43		1.52	1.72	4.70	1.31	36.77	1.03	40.66	00	1.34	1.83	22.90
6	0 – 30	4.14	8.20	2.20	3.94	2.70	0.44	36.54	0.53	37.60	00	1.48	1.13	29.23
	30 – 60	3.94	8.20	1.89	2.60	4.20	0.50	33.00	0.93	35.30	00	0.66	2.76	21.56
	60 – 90	3.64	8.30	1.60	1.80	2.90	0.40	31.59	1.00	33.20	00	1.14	1.55	24.68
	> 90	2.49	8.20	1.15	1.30	2.70	0.70	19.60	0.27	20.80	00	1.42	1.05	15.07
	Mean	3.55		1.71	2.41	3.12	0.51	30.18	0.68	22.40	00	1.17	1.62	22.61

Table (4): Some chemical properties of soil samples of Al-Hamul area (profiles 7 to 9).

Profile No.	Depth (cm)	EC Ds/m 1:5	PH 1:2.5	O.M (%)	$CaCO_3$ (%)	Soluble Ions (meq/L)								SAR
						Cations				Anions				
						Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	$CO3^{-}$	HCO_3^{-}	SO_4^{-2}	
7	0 – 30	6.35	8.30	2.49	1.90	4.70	1.90	54.68	2.00	58.02	00	1.03	4.23	30.20
	30 – 60	5.40	8.30	1.95	1.63	3.50	1.10	48.28	0.96	50.90	00	0.96	1.98	31.97
	60 – 90	3.00	8.40	1.62	1.12	1.50	0.35	27.36	0.43	26.50	00	1.44	1.70	28.50
	> 90	1.40	8.50	1.40	0.96	1.80	0.90	10.84	0.24	11.90	00	1.00	0.88	9.34
	Mean	4.03		1.79	1.40	2.89	1.06	35.29	0.90	36.83	00	1.10	2.19	25.01
8	0 – 30	3.76	8.20	2.50	2.47	4.50	1.10	30.08	1.08	34.50	00	1.38	0.88	18.01
	30 – 60	3.48	8.30	1.90	2.12	3.08	0.62	28.84	0.53	30.15	00	1.24	1.68	21.20
	60 – 90	3.30	8.30	1.60	2.98	2.50	1.10	27.44	0.50	28.30	00	0.92	2.32	20.47
	> 90	2.94	8.40	1.30	1.56	5.05	1.35	21.36	0.56	25.40	00	1.38	1.54	12.00
	Mean	3.37		1.82	2.28	3.78	1.04	26.93	0.66	29.58	00	1.23	1.60	17.92
9	0 – 30	4.81	8.00	2.08	2.65	3.70	2.80	40.60	0.72	44.60	00	1.02	2.20	22.55
	30 – 60	3.89	8.10	1.80	2.29	2.50	0.55	34.20	0.66	35.02	00	1.49	1.40	27.80
	60 – 90	3.60	8.20	1.20	1.63	2.30	0.30	31.66	0.66	32.10	00	1.57	1.25	27.70
	> 90	1.94	8.20	1.08	1.67	1.70	1.00	15.24	0.29	15.80	00	1.55	0.88	13.16
	Mean	3.56		1.54	2.06	2.55	1.16	30.42	0.58	31.88	00	1.40	1.43	22.80

Table (5): Soil CEC, Exchangeable Cations, ECaP, EMgP, ESP and KSP of soil samples of Al-Hamul area (profiles 1 to 3).

Profile No.	Depth (cm)	CEC (meq/100 g soil)	Exchangeable Cations (meq/100 g soil)				ECaP	EMgP	ESP	EKP
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}				
1	0 – 30	53.52	18.91	7.87	23.71	1.92	35.46	14.75	44.50	3.60
	30 – 60	48.32	16.54	6.94	22.71	1.36	34.23	14.40	46.99	2.82
	60 – 90	36.40	11.38	5.34	17.42	1.28	31.30	14.70	47.90	3.52
	> 90	39.10	12.51	6.12	18.22	1.97	31.99	15.70	46.60	5.04
	Mean	44.20	14.80	5.56	20.50	1.63	33.25	14.88	46.50	3.74
2	0 – 30	56.13	21.66	6.11	25.24	2.81	38.59	10.88	44.90	5.01
	30 – 60	53.40	22.20	4.32	23.89	1.79	41.57	8.09	44.70	3.35
	60 – 90	49.90	17.62	4.11	25.31	1.66	35.31	8.23	50.70	3.33
	> 90	35.10	9.01	4.51	17.87	2.49	25.67	12.84	50.70	7.09
	Mean	48.60	17.62	4.76	23.07	2.26	35.28	10.01	47.70	4.70
3	0 – 30	47.22	17.11	3.92	23.44	1.87	36.23	8.30	49.60	3.96
	30 – 60	44.61	13.36	4.13	22.23	1.99	29.95	9.26	54.30	4.46
	60 – 90	32.40	10.33	6.56	12.66	2.27	31.89	20.24	39.10	7.01
	> 90	32.00	9.34	6.77	14.11	1.44	29.18	21.16	43.80	4.50
	Mean	39.10	12.50	5.34	18.11	1.89	31.81	14.74	46.70	4.98

Table (6): Soil CEC, Exchangeable Cations, ECaP, EMgP, ESP and KSP of soil samples of Al-Hamul area (profiles 4 to 6).

Profile No.	Depth (cm)	CEC (meq/100 g soil)	Exchangeable Cations (meq/100 g soil)				ECaP	EMgP	ESP	EKP
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}				
4	0 – 30	58.22	21.24	9.56	24.29	2.23	36.48	16.43	41.70	3.84
	30 – 60	53.25	18.71	4.76	26.21	2.77	35.14	8.94	49.20	5.20
	60 – 90	41.20	13.74	3.98	21.15	1.43	33.35	9.66	51.30	3.47
	> 90	33.11	10.20	7.55	13.66	0.94	30.81	22.80	41.20	2.84
	Mean	46.44	15.90	6.42	21.32	1.84	33.94	14.45	45.85	3.83
5	0 – 30	59.11	22.84	7.51	25.71	2.43	38.64	12.71	43.40	4.11
	30 – 60	54.80	17.90	6.23	28.11	1.77	32.66	11.40	51.20	3.23
	60 – 90	41.40	13.10	6.55	20.26	0.93	31.64	15.82	48.90	2.25
	> 90	35.64	10.22	8.54	14.77	1.11	28.68	23.96	41.40	3.11
	Mean	47.73	16.01	7.20	22.21	1.56	32.90	15.97	46.22	3.18
6	0 – 30	45.38	17.10	6.53	18.32	2.53	37.68	14.40	40.30	5.58
	30 – 60	43.40	15.31	3.89	22.11	1.37	35.27	8.96	50.90	3.16
	60 – 90	34.04	1.22	7.44	14.11	2.06	30.02	21.86	41.50	6.06
	> 90	28.11	7.11	5.33	13.84	1.13	25.30	18.96	49.20	4.02
	Mean	37.70	12.40	5.79	17.08	1.77	32.07	16.04	45.50	4.70

Table (7): Soil CEC, Exchangeable Cations, ECaP, EMgP, ESP and KSP of soil samples of Al-Hamul area (profiles 7 to 9).

Profile No.	Depth (cm)	CEC (meq/100 g soil)	Exchangeable Cations (meq/100 g soil)				ECaP	EMgP	ESP	EKP
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}				
7	0 – 30	48.30	18.41	5.88	20.77	2.32	38.12	12.17	43.20	4.81
	30 – 60	39.15	10.66	6.23	19.78	1.24	27.23	17.19	50.50	3.17
	60 – 90	38.43	13.11	6.87	14.86	2.52	34.11	17.88	38.60	6.56
	> 90	35.04	10.87	8.87	12.64	1.84	31.02	23.31	36.07	5.26
	Mean	40.21	13.26	7.08	17.01	1.98	32.62	18.14	42.07	4.95
8	0 – 30	41.20	15.60	4.83	17.98	1.89	37.86	11.70	43.00	4.60
	30 – 60	38.90	11.77	9.89	15.11	1.23	30.26	25.42	38.80	3.16
	60 – 90	34.40	9.52	8.36	13.66	1.96	27.60	24.30	39.70	5.70
	> 90	29.30	10.45	5.74	11.12	1.04	35.67	19.60	37.90	3.55
	Mean	35.90	11.83	7.19	14.46	1.52	32.84	20.26	39.81	4.25
9	0 – 30	52.10	20.11	5.67	24.33	1.34	38.60	10.88	46.60	2.37
	30 – 60	48.64	17.33	4.01	25.11	0.99	35.63	8.25	51.60	2.04
	60 – 90	41.16	15.01	7.13	16.78	1.85	36.46	17.32	40.71	4.49
	> 90	34.20	9.91	6.41	15.22	1.76	28.91	18.74	44.50	5.15
	Mean	44.02	15.58	5.80	20.35	1.84	34.89	13.79	45.80	3.56