IMPROVING ROOT ZONE ENVIRONMENT AND PRODUCTIVITY OF A SALTY CLAY SOIL USING SUBSOILING AND GYPSUM APPLICATION

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Abstract: A field experiment (four acres) was conducted on a clay soil at graduated youth fields, El-Zawia region, Al-Hamool District, Kafer El-Shiek governorate to evaluate subsoiling combined with gypsum application for improving hydro-pedological soil properties when a surface drainage system is existed. The subsoiling treatments were 0.8 and 1.6 m spacing at 0.60 m depth and the gypsum application levels were 5.0 and 7.5 ton/fd. Sugar beet crop was grown as an indicator for soil improvement.

Salinity of soil profile was reduced by 35.10 and 12.10 % at 0.8 and 1.6 m subsoiling, respectively with adding 5.0 ton/fd of gypsum. It reduced by 24.39 and 28.88 % with applying 7.5 ton/fd of gypsum due to the corresponding treatments. Despite the gypsum treatments, the average soil salinity was decreased by 29.74 and 20.49 % when the soil was subsoiled at 0.8 and 1.6 m, respectively. In general, the decrease in the ESP values was realized in all soil layers for all treatments and diminished with soil depth giving a good indication of soil improvement. The ESP value was reduced by 41.61 and 33.59 % at 0.8 and 1.6 m subsoiling, respectively with applying 5.0 ton/fd of gypsum. It was reduced by 40.70 and 38.25 % with adding 7.5 ton/fd of gypsum due to the corresponding treatments.

The applied treatments resulted in a remarkable decrease in soil bulk density through the soil profile. The treatments gave a marked positive effect on soil porosity in the topsoil (0-50 cm). Nevertheless, such effect on soil porosity disappeared by increasing the soil depth. An increase in accumulated intake rate at the end of the elapsed time was realized in the treated soil in comparison with the untreated one. Such increase approached 58.19 and 71.77 % when the soil was subsoiled at 0.8 and 1.6 m, respectively with adding 5.0 ton/fd of gypsum. It increased by 63.64 and 61.12 % with adding 7.5 ton/fd of gypsum due to the corresponding treatments. Increasing the gypsum rate increased the accumulated intake rate by 64.98 and 62.38 % at gypsum application levels of 5.0 and 7.5 ton/fd, respectively.

The sugar beet yield increased by 26.86 and 23.27 ton/ fd over the control when the soil was subsoiled at 0.8 and 1.6 m, respectively at a gypsum application level of 5.0 ton / fd. Moreover, it increased by 28.35 and 25.25 ton/ fd at gypsum level of 7.5 ton/fd due to the corresponding treatments.

Key words: Subsoiling, Gypsum application, Clay Soil, Soil improvement.

Introduction

Saline-sodic clay soils with low permeability are mostly found in the northern part of Nile Delta. Improving such soils needs a comprehensive technique due to many contrversial factors. Subsoiling has generated considerable interest in the past few years (Moukhtar et al, 2003). Improved crop growth following subsoiling is generally considered to be the result of the physical shattering of the hardpan, which allows to increase water penetration into the subsoil. This may also accelerate the leaching of sodium from the subsoil thereby further reducing the possibility of reformation of the hardpan (Lickacz, 1993). Soil tilth represents the physical condition of the soil that is described by its bulk density, porosity, soil structure, and soil aggregate characteristics. All these have an affect on the availability and movement of water, nutrients, air and heat, as well as soil biological populations and their activity. Good soil tilth equates to sustained or increased productivity potential (Pearce et al., 1999).

Subsoiling generally improves drainage only if the operation allows water to move down through a compacted layer into a soil zone of relatively high conductivity or for disturbed soil so that water can move laterally more rapidly towards an existing underground pipe system (Ellington et al 1991). Said (2002) revealed that soil compaction influenced soil strength, bulk density, distribution and continuity of pores with consequent an adverse effect on drainage, root penetration, aeration, biological processes and nutrient uptake; all of which could have a direct bearing on crop production. Said (2003) concluded that the cumulative and basic infiltration rate of the treated soil by subsoiling markedly increased relative to the untreated one. He also, found that the treated soil resulted in a sharp decrease in the bulk density and penetration resistance in coincidence with a sharp increase in total porosity and macro pores relative to the untreated one.

Many investigators found a promising result of subsoiling technique combined with tile drainage for improving soil conditions (El-Hadidy et al., 2003). Abdel-Mawgoud (2004) clarified that the grid subsoiling caused a substantial increase in the saturated hydraulic conductivity (K_s) compared to the parallel subsoiling treatment and the positive effect of subsoiling treatments on the values of K_s persisted for more than one year. Also, he found that subsoiling resulted in a noticeable increase in macro-pores with a consequent decrease in micro-pores compared with the control treatment. Miyamoto (2006) revealed that the use of chemical amendments such as gypsum could help to reduce soil sodicity and speeds up reclamation especially in alluvial soils, which have weak structure. He also, stated that chemical amendments should be applied after subsoiling and there is no need to incorporate them into the soil.

Darryl (2004) found an increase of 192 to 248 pounds of seed cotton per acre after subsoiling a clay soil. He also, found that subsoiling dry clay soil to a depth of 30-40 cm would fracture a great volume of soil. Fracturing of the soil improved the internal soil drainage and increased water storage capacity. Henriksen et al. (2004) found that subsoiling increased potatoes yield by 14 percent. However, Jodi DeJong (2004) reported that subsoiling to a depth of 16 inches failed to increase yields for either corn or soybeans and decreased corn yield 11 bushels per acre in one of the two years.

The current study aims to evaluate the effect of subsoiling combined with gypsum application on improving some soil hydro-pedological properties when a surface drainage system exists.

Materials and Methods

A field experiment was conducted on a clay soil at graduated youth farms, El-Zawia region, Al-Hamool District, Kafer El-Shiek governorate, Egypt. Surface field drains at 20 m apart down to 0.9 m depth serve the selected area. The relevant physical and chemical properties of the studied soil profiles are shown in Table 1. An area of four acres was subjected to subsoiling and gypsum application. The subsoiling treatments were the distances between the ploughed lines (0.8 and 1.6 m at 0.60 m depth). The gypsum application levels were 5.0 and 7.5 ton/fd. The study was conducted in four plots. Each plot had an area of 200 x 20 m and was irrigated by using furrow irrigation method. Soil samples (0-20, 20-50, 50-80 and 80-120 cm) were collected from each plot before and after treatments and monitored for some physical and chemical analysis.

The particle size distribution, total calcium carbonate and organic matter were determined according to Black (1965). Also, total soluble salts, soluble ions of saturated soil extract were determined using the standard methods described by Page et al. (1982). Exchangeable sodium was determined using ammonium chloride and measured by using flame photometer according to Page et al. (1982). Soil bulk density and total porosity of the different layers of soil profile before and after the applied treatments were measured using the core sampling technique as described by Campbell (1994). Infiltration tests for the experimental plots representing the different treatment were measured using the double ring infiltrometer as described by Klute (1986).

A set of pezomiters was installed in the midway between drains to measure the water table depth through an irrigation interval. A sounder consisting of a 1.25 cm diameter copper tube and 5.0 cm in length connected with a calibrated steel tape was used to measure the water table depth. The data were measured daily and directly after irrigation. The impact of treatments on the improvement of drainage conditions could be illustrated by the parameter of water table drawdown ratio (h_t /H_o) where h_t is the measured water table head at "t" time and H_o is an initial water table head (it is taken to be equal 90 cm, drain depth) at "t" equal zero. The parameter is calculated for the different water table positions midway between drains during irrigation interval of 15 days after irrigation according to Deliman and Trafford (1976). Sugar beet (Pleno variety) crop was grown in all treated plots as well as in a control plot for comparison in November 16th, 2004 and was harvested in May 11th, 2005.

Table(1a): Particle size distribution, calcium carbonate and organic matter percentage of the investigated soil profiles before amelioration.

Profile No.	Soil Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture class	O.M. (%)	$CaCO_3$ (%)
1	0-20	19.73	33.38	46.89	Clay	1.19	3.14
	20-50	19.52	25.39	55.09	Clay	1.05	1.96
	50-80	18.25	22.81	58.94	Clay	0.75	1.86
	80-120	17.27	23.86	58.87	Clay	0.52	1.71
2	0-20	21.08	32.71	46.21	Clay	1.24	3.29
	20-50	20.84	27.23	51.93	Clay	1.19	2.13
	50-80	19.11	24.16	56.73	Clay	0.81	1.89
	80-120	18.24	23.67	58.09	Clay	0.63	1.85
3	0-20	18.95	33.91	47.14	Clay	1.35	3.34
	20-50	19.21	26.12	54.67	Clay	1.22	2.42
	50-80	19.73	21.88	58.39	Clay	0.82	1.96
	80-120	18.55	23.75	57.70	Clay	0.57	1.92
4	0-20	20.31	31.23	48.46	Clay	1.29	3.46
	20-50	20.29	25.06	54.65	Clay	1.10	2.19
	50-80	19.22	23.16	57.62	Clay	0.90	0.97
	80-120	18.36	23.53	56.11	Clay	0.73	0.84

O.M. = organic matter

Table(1b): Some physical properties of the investigated soil profiles before amelioration.

Profile No.	Soil Depth (cm)	Bulk density ($Mg\ m^{-3}$)	Total porosity (%)	Soil Infiltration			
				Elapsed time (min)	Accumulation intake (cm^3)	Rate (cm /h)	Class*
1	0-20	1.397	47.28	30	114	0.36	Slow
	20-50	1.377	48.04	75	303	0.36	Slow
	50-80	1.398	47.25	135	583	0.42	Slow
	80-120	1.403	47.06	195	708	0.18	Slow
2	0-20	1.393	47.43	30	335	0.96	Moderately slow
	20-50	1.382	47.85	75	554	0.42	Slow
	50-80	1.406	46.94	135	784	0.36	Slow
	80-120	1.411	46.75	195	914	0.18	Slow
3	0-20	1.360	48.68	30	876	2.46	Moderate
	20-50	1.353	48.94	75	990	0.24	Slow
	50-80	1.372	48.22	135	1140	0.24	Slow
	80-120	1.384	47.77	195	1210	0.12	Slow
4	0-20	1.371	48.26	30	399	1.20	Moderately slow
	20-50	1.362	48.60	75	676	0.54	Moderately slow
	50-80	1.384	47.77	135	922	0.36	Slow
	80-120	1.393	47.43	195	1142	0.36	Slow

*According to Rickard and Cossens (1965).

Table(1c): Some chemical properties of the investigated soil profiles before amelioration.

Profile No.	Soil depth (cm)	EC_e (dS/m)	Soluble anions and cations (meq./l)								ESP
			CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	
1	0-20	19.4	0.0	2.0	78.1	122.6	31.7	29.8	139.5	1.7	40.4
	20-50	16.0	0.0	1.6	93.0	64.1	11.9	11.2	134.0	1.6	59.7
	50-80	19.1	0.0	1.0	122.8	72.2	11.9	7.3	175.0	1.8	59.9
	80-120	26.7	0.0	1.0	146.0	78.4	23.8	64.6	133.5	3.5	54.5
2	0-20	12.3	0.0	2.8	73.3	36.8	7.9	11.3	92.5	1.2	16.6
	20-50	13.2	0.0	2.6	90.2	27.8	10.3	12.8	96.4	1.1	19.1
	50-80	16.7	0.0	2.6	115.8	34.7	10.8	13.5	127.5	1.3	39.6
	80-120	19.8	0.0	2.2	135.3	46.3	11.2	14.5	156.0	2.1	57.3
3	0-20	41.8	0.0	1.5	269.7	132.6	30.5	27.1	344.0	2.2	65.6
	20-50	17.3	0.0	1.5	116.3	50.1	14.9	9.2	142.0	1.8	61.2
	50-80	12.8	0.0	1.8	90.7	29.1	9.9	4.5	105.5	1.7	64.7
	80-120	13.8	0.0	2.3	97.8	30.4	14.9	5.3	108.4	1.9	69.2
4	0-20	25.3	0.0	2.6	125.3	120.7	35.5	66.6	144.0	2.5	42.9
	20-50	14.6	0.0	2.0	115.1	28.1	10.7	15.4	117.8	1.3	61.7
	50-80	15.7	0.0	1.8	134.4	19.6	9.1	4.4	141.0	1.3	62.0
	80-120	19.2	0.0	1.5	151.0	27.8	13.7	19.6	145.0	2.0	67.3

Results and Discussions

Soil salinity

Soil salinity expressed as electrical conductivity (EC) values in the studied soil profiles as affected by subsoiling and gypsum application is shown in Table 2. It is obvious that the reduction in soil salinity was more pronounced in the topsoil (0-50 cm) than the deeper layers as a consequence of subsoiling and gypsum addition (Fig.1). At average basis, the salinity of the soil was reduced by 35.10 and 12.10 % when the soil was subsoiled at 0.8 and 1.6 m, respectively, with applying gypsum at a level of 5.0 ton/fd. The reduction was 24.39 and 28.88 % with adding gypsum at a level of 7.5 ton/fd for the corresponding treatments. Regardless the subsoiling treatments, increasing the gypsum level resulted in a slight change in soil salinity, whereas the average salinity of soil profile was decreased by 23.60 and 26.63 % at gypsum application levels of 5.0 and 7.5 ton/fd, respectively. Despite the gypsum treatments, the average salinity of soil profile was reduced by 29.74 and 20.49 % when the soil was subsoiled at 0.8 and 1.6 m, respectively. It is clear that subsoiling effect was superior to gypsum application on reducing soil salinity.

Table(2): Some chemical properties of the studied soil profiles as affected by subsoiling and gypsum application**.**

Treatment: Gypsum	Treatment: Subsoiling spacing (m)	Profile No.	Soil depth (cm)	EC_e (dS/m)	Soluble anions and cations (meq./l)								ESP
					CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	
5 ton /fd	0.8	1	0-20	8.3	0.0	1.6	55.1	28.6	43.2	18.7	21.6	1.8	19.7
			20-50	10.4	0.0	1.4	83.7	18.7	29.1	10.5	62.7	1.5	25.7
			50-80	14.2	0.0	1.4	101.3	37.1	30.2	12.3	95.6	1.7	35.9
			80-120	19.8	0.0	1.2	132.5	57.7	22.7	11.4	155.5	1.8	44.6
	1.6	2	0-20	8.5	0.0	2.3	61.6	22.8	33.6	17.6	33.6	1.9	11.1
			20-50	10.9	0.0	2.0	84.9	25.5	21.7	11.5	77.9	1.3	13.8
			50-80	13.7	0.0	1.5	104.7	36.1	20.9	10.9	109.2	1.3	24.6
			80-120	21.4	0.0	1.2	123.9	76.7	17.9	10.9	171.8	1.2	36.9
7.5 ton /fd	0.8	3	0-20	13.5	0.0	1.4	99.7	41.6	63.4	31.7	45.5	2.1	23.8
			20-50	15.4	0.0	1.2	102.7	54.8	39.8	18.6	98.4	1.9	34.1
			50-80	16.7	0.0	1.2	108.4	65.8	27.6	12.5	133.7	1.6	42.7
			80-120	19.2	0.0	1.2	120.1	75.2	26.9	13.3	154.9	1.4	54.8
	1.6	4	0-20	11.4	0.0	2.0	75.1	43.7	66.9	27.6	24.1	2.2	18.2
			20-50	12.3	0.0	1.8	77.5	49.6	42.1	17.6	67.7	1.5	35.2
			50-80	13.1	0.0	1.6	80.2	56.9	28.7	13.7	94.8	1.5	39.7
			80-120	16.4	0.0	1.4	114.30	61.5	24.8	13.9	137.3	1.2	56.2

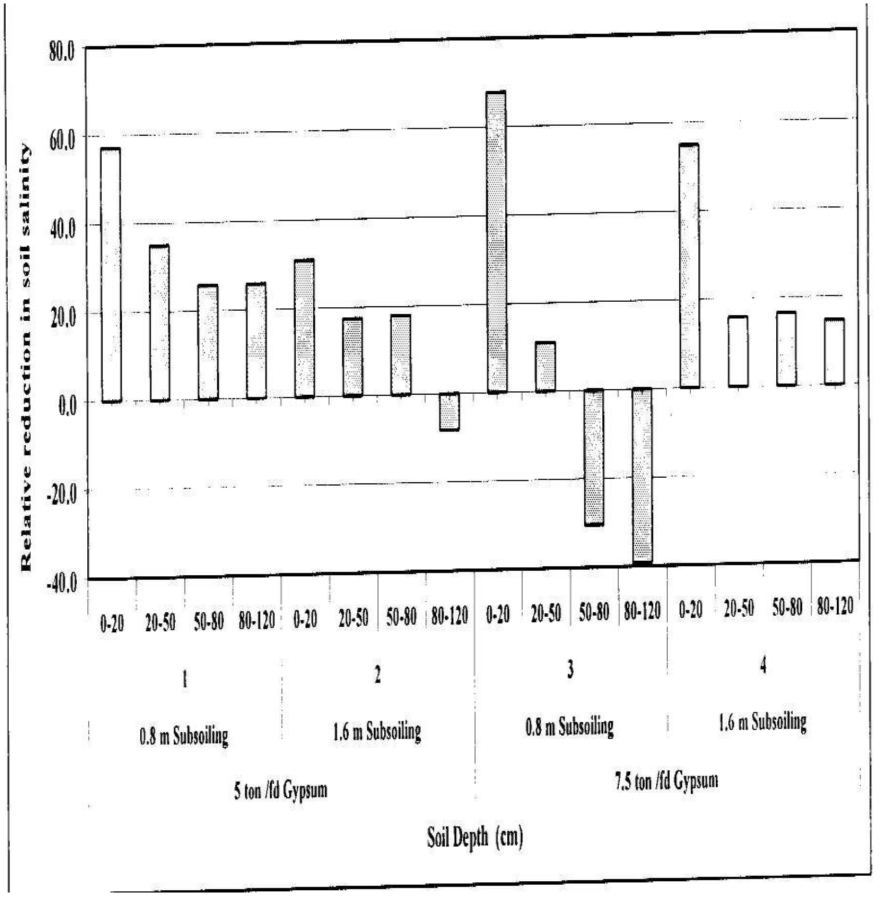

Fig.(1): The relative reduction in the salinity of the studied soil profiles as affected by subsoiling and gypsum application.

Distribution of soluble ions through soil profile:

Distribution of soluble anions and cations through the soil profiles as affected by subsoiling and gypsum application is shown in Table 2. In general, soluble ions clearly decreased as a result of subsoiling and gypsum application. Chloride and sodium were the major ions in the soil saturation extract in all treatments. Both ions as well as the EC values increased with soil depth. Calcium ions exceeded magnesium ions. It could be noticed that the 0.8 m subsoiling treatment gave a higher efficiency in leaching soluble salts through the soil profile than the other treatments.

Soil sodicty:

The obtained data of soil sodicity expressed as exchangeable sodium percentage (ESP) as affected by subsoiling and gypsum treatments is shown in Table 2. The reduction in the ESP values was realized in all soil layers for all treatments (Fig. 2). The relative reduction in the ESP values diminished with soil depth expect for profile 2, which was augmented. The ESP values in the topsoil (0-50 cm) of profile 2 became less than 15 giving a good indication of soil improvement. At average basis, the ESP was reduced by 41.61 and 33.59 % when the soil was subsoiled at 0.8 and 1.6 m, respectively with adding gypsum at a level of 5.0 ton/fd. It was also reduced by 40.70 and 38.25 % with adding gypsum at a level of 7.5 ton/fd at the corresponding treatments. Regardless the subsoiling treatments, increasing the gypsum level showed a slight change in soil sodicity, as the average ESP of soil profile was decreased by 37.60 and 39.47 % at gypsum application levels of 5.0 and 7.5 ton/fd, respectively. Despite the gypsum treatments, the average ESP of the soil profile was decreased by 41.15 and 35.92 % when the soil was subsoiled at 0.8 and 1.6 m, respectively. It is clear that the subsoiling was superior to gypsum application in reducing soil sodicity.

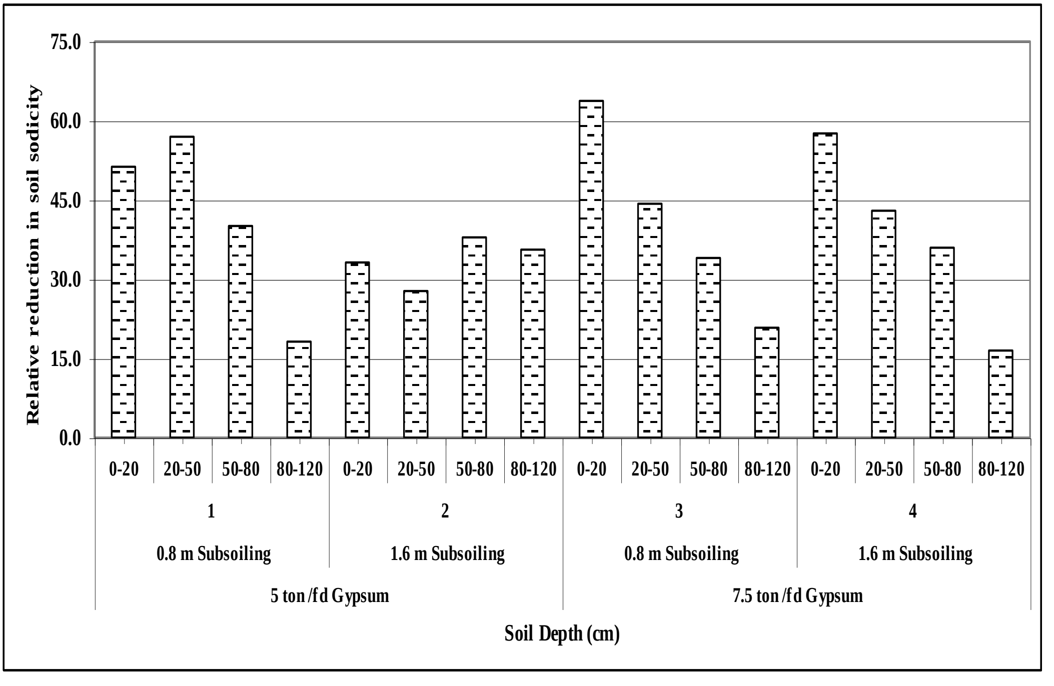

Fig.(2): The relative reduction in soil sodicity (ESP) as affected by subsoiling and gypsum application.

Soil bulk density and total porosity

The ability of plant roots to penetrate the soil is a function of its compressibility and consequently the characteristics of its porosity. Therefore, the impact of the studied treatments on bulk density and total porosity was considered. Data in Table 3 showed that the applied treatments resulted in a remarkable decrease in soil bulk density with soil depth (Fig. 3). This decrease was more obvious in the topsoil (0-50 cm) than that in subsoil (50-120 cm). In the topsoil (0-50 cm), the soil bulk density was reduced by 9.60 and 8.17 % when the soil was subsoiled at 0.8 and 1.6 m, respectively with adding gypsum at a level of 5.0 ton/fd. Moreover, it was reduced by 11.31 and 8.96 % with adding gypsum at a level of 7.5 ton/fd for the corresponding treatments. Regardless the subsoiling treatments, increasing the gypsum level resulted in a slight change in soil bulk density, whereas the average bulk density of the topsoil was decreased by 8.89 and 10.14 % at gypsum application levels of 5.0 and 7.5 ton/fd, respectively. Despite the gypsum treatments, the average bulk density of the topsoil was decreased by 10.46 and 8.57 % when the soil was subsoiled at 0.8 and 1.6 m, respectively. This means that subsoiling effect was superior to gypsum application on reducing soil bulk density. It could be attributed to the effect of subsoiling on breaking soil cods and bigger granular into smaller crumbs as well as breaking and cracking the compacted layers (Amer, 1999).

The results given in Table 3 also showed that the soil treatments gave a marked positive effect on total soil porosity in the topsoil (0-50 cm). Nevertheless, such effect on soil porosity disappeared with increasing soil depth (Fig. 4). In the topsoil (0-50 cm), the total porosity increased by 10.60 and 9.00 % when the soil was subsoiled at 0.8 and 1.6 m, respectively with adding gypsum at a level of 5.0 ton/fd. Also, it increased by 11.88 and 9.56 % with adding gypsum at a level of 7.5 ton/fd for the corresponding treatments. Regardless the subsoiling treatments, increasing the gypsum level showed a slight change in the total porosity, as the average porosity of the topsoil increased by 9.80 and 10.72 % at gypsum application levels of 5.0 and 7.5 ton/fd, respectively. Despite the gypsum treatments, the average porosity of the topsoil increased by 11.24 and 9.28 % when the soil was subsoiled at 0.8 and 1.6 m, respectively. Subsoiling was superior to gypsum application in enhancing soil porosity. Jodi DeJong (2004) stated that the theory behind subsoiling is to shatter a compacted layer deep in the soil to allow increased water movement, increased total porosity, better aeration of the root and access to additional nutrients for plant growth.

With respect to the topsoil (0-50 cm), the obtained data revealed that the applied treatments have resulted in a sharp decrease in soil bulk density in coincidence with a sharp increase in the total soil porosity compared to the untreated soil. The difference among the applied treatments were negligible concerning the subsoil layers (50-120 cm)

Table(3): Soil bulk density, total porosity and infiltration rate as affected by subsoiling and gypsum application.

Profile No.	Soil Depth (cm)	Bulk density (Mg m^{-3})	Total porosity (%)	Soil Infiltration			
				Elapsed time (min)	Accumulation intake (cm^3)	Rate (cm /h)	Class*
1	0-20	1.223	53.85	30	480	1.362	Moderate
	20-50	1.284	51.55	75	570	0.648	Moderately slow
	50-80	1.382	47.85	135	820	0.516	Moderately slow
	80-120	1.393	47.43	195	1120	0.486	Slow
2	0-20	1.251	52.79	30	730	2.064	Moderate
	20-50	1.297	51.06	75	980	1.110	Moderately slow
	50-80	1.388	47.62	135	1270	0.798	Moderately slow
	80-120	1.401	47.13	195	1570	0.684	Moderately slow
3	0-20	1.195	54.91	30	1030	2.916	Moderate
	20-50	1.211	54.30	75	1370	1.554	Moderately slow
	50-80	1.372	48.23	135	1710	1.074	Moderately slow
	80-120	1.384	47.77	195	1980	0.864	Moderately slow
4	0-20	1.221	53.92	30	750	2.124	Moderate
	20-50	1.267	52.19	75	1060	1.200	Moderately slow
	50-80	1.384	47.77	135	1420	0.894	Moderately slow
	80-120	1.392	47.47	195	1840	0.816	Moderately slow

*According to Rickard and Cossens (1965).

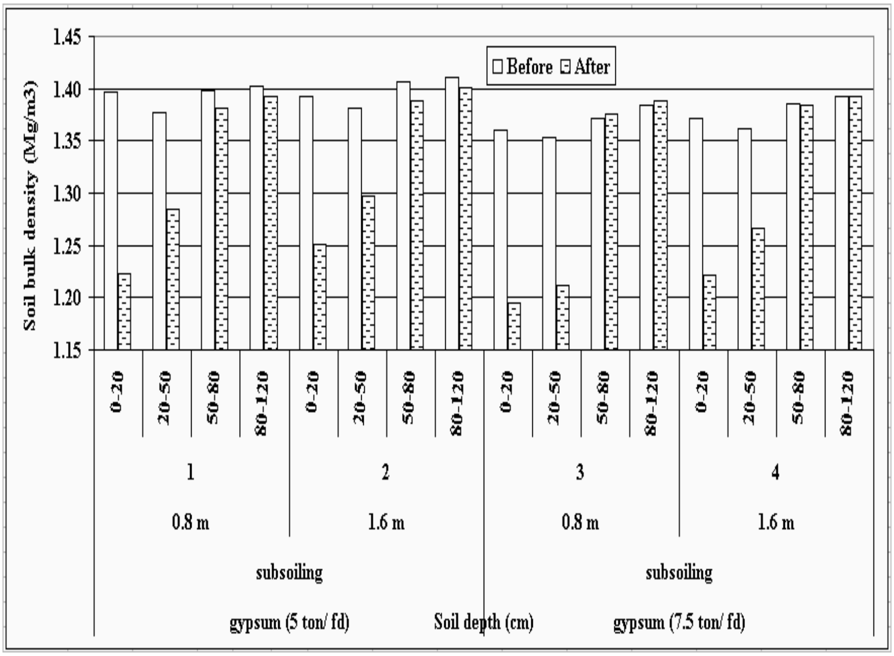

Fig.(3): Soil bulk density changes as affected by subsoiling and gypsum application.

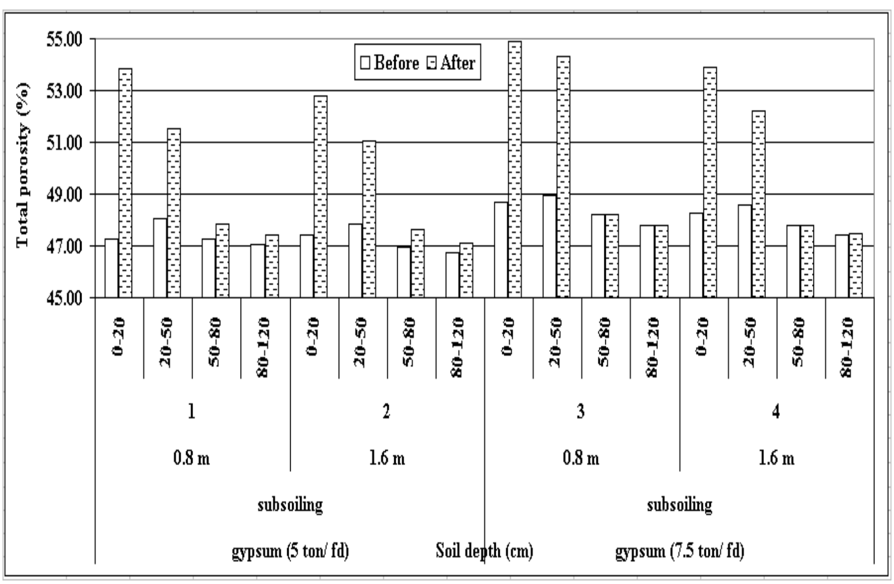

Fig.(4): Soil porosity changes as affected by subsoiling and gypsum application.

Infiltration rate

The data showed an increase in the accumulated intake rate in the treated soil at the end of the elapsed time in comparison with the untreated soil. Such increases approached 58.19 and 71.77 % when the soil was subsoiled at 0.8 and 1.6 m, respectively with adding gypsum at a level of 5.0 ton/fd. It also increased by 63.64 and 61.12 % with adding gypsum at a level of 7.5 ton/fd for the corresponding treatments. Regardless the subsoiling treatments, increasing the gypsum level affected the accumulated intake rate, whereas it increased by 64.98 and 62.38 % at gypsum application levels of 5.0 and 7.5 ton/fd, respectively. Despite the gypsum treatments, the accumulated intake rate increased by 60.92 and 66.45 % when the soil was subsoiled at 0.8 and 1.6 m, respectively. The effect of gypsum application on the accumulated intake rate was almost the same as that of subsoiling.

Since the exponent of time is negative with the intake rate (I) and positive with the accumulated intake rate (D), the former decreased while the later increased with time (Table 3). The decrease in I with time may be attributed to one or more of the following reasons, i) occurrence of a water column above the soil surface may have hindered escaping of the trapped air bubbles, ii) an inevitable decrease in the matric gradient constituting one of the main forces drowning water into the soil which usually occurs as water intake proceeds, iii) large easily accessible pores in the soil may have been filled with water before other pores, iv) fine soil particles from the surface layer may have been washed into the lower soil layers plugging up some of their pores, and v) breakdown soil aggregates due to increasing trapped air pressure in some pores (Tayel et al., 2001).

The basic infiltration rate as affected by treatments for the studied soil profile is presented in Table 3. The data pointed out that the basic infiltration rate of the treated soil markedly increased relative to the untreated soil. The increases in the basic infiltration rate reached 150 and 250 % when the soil was subsoiled at 0.8 and 1.6 m, respectively with adding gypsum at a level of 5.0 ton/fd. Also, it increased by eight and one fold with adding gypsum at a level of 7.5 ton/fd for the corresponding treatments. Regardless the subsoiling treatments, increasing the gypsum level affected the basic infiltration rate, whereas it increased two and four fold at gypsum application levels of 5.0 and 7.5 ton/fd, respectively. Despite the gypsum treatments, the basic infiltration rate increased by five and two folds when the soil was subsoiled at 0.8 and 1.6 m, respectively. Therefore, the effect of gypsum application on the basic infiltration rate was superior to that of subsoiling.

Ankeny et al. (1990) reported that infiltration of water into the soil is directly related to soil macro pores. On the other hand, shallow plowing results in a slight mixing of the soil surface above the compacted layer which obstructs water flow. In this regard, Hillel (1998) mentioned that the final infiltrability is limited by the presence of impeding layer inside the soil profile.

Water table drawdown ratio

In general, it could be said that an improvement in drainage conditions through calculating the water table drawdown ratio (h_t/H_o) was realized progressively as time proceeds, especially in the treatment having 7.5 ton/fd gypsum with soil subsoiled at 0.8 m apart (Fig. 5). The improvement is continuous with a fast rate. It may worthwhile to mention that the drawdown changes irregularly from day to anther. It might be attributed to the preferential flow through macro-pores "bypass" flow (Moustafa, 1984).

Generally, the treatments had an enhancement effect on lowering the water table, particularly under the narrow space between subsoiling. Lowering water table after irrigation gives the chance for the effective root zone to dry, shrink and form water pathways. It is worthy to mention that the drying process plays an important role in the drainage of heavy clay soils because it improves the soil structure and permeability.

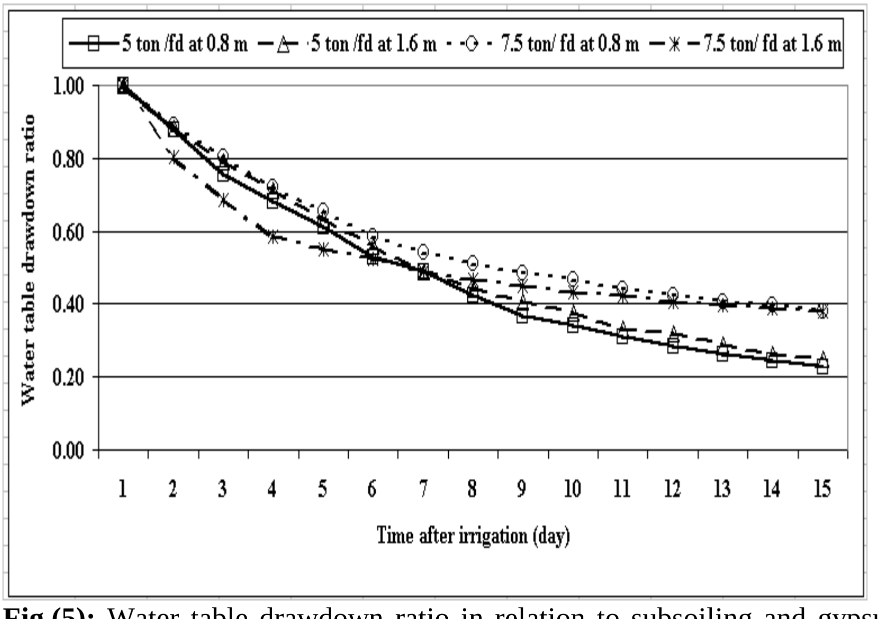

Fig.(5): Water table drawdown ratio in relation to subsoiling and gypsum application during an irrigation interval

Sugar beet yield

Data presented in Table 4 showed the effect of subsoiling and gypsum application on sugar beet yield. The obtained data revealed that the sugar beet yield increased by 26.86 and 23.27 ton/ fd over the control plot when the soil was subsoiled at 0.8 and 1.6 m, respectively using gypsum application level of 5.0 ton / fd. Moreover, it increased by 28.35 and 25.25 ton/ fd with adding gypsum at a level of 7.5 ton/fd for the corresponding treatments. Regardless the subsoiling treatments, increasing the gypsum level caused increase in the sugar beet yield, whereas it increased by 25.07 and 26.80 ton/ fd at gypsum application levels of 5.0 and 7.5 ton/fd, respectively. Despite the gypsum treatments, the sugar beet yield increased by 27.61 and 24.26 ton/ fd when the soil was subsoiled at 0.8 and 1.6 m, respectively. This means that the subsoiling was superior to gypsum application in enhancing the sugar beet yield.

Table(4): The effect of subsoiling and gypsum application on sugar beet yield (ton/fd)

Treatment		Profile No.	Root yield (ton/fd)	Yield increased (ton/ fd)	Increasing %
Gypsum	Subsoiling spacing (m)				
Control plot			8.58	0.00	0.00
5 ton /fd	0.8	1	35.44	26.86	313.05
	1.6	2	31.85	23.27	271.21
	Mean		33.65	25.07	292.19
7.5 ton /fd	0.8	3	36.93	28.35	330.42
	1.6	4	33.83	25.25	294.29
	Mean		35.38	26.80	312.35

It can be concluded that under such conditions the subsoiling and gypsum application are the most effective treatments that ameliorate saline sodic clay soil served by a surface drainage system. Moreover, the study gives evidence for the importance of subsoiling at narrow space in order to encourage the enhancement process by shattering a compacted layer deep in the soil to allow increased water movement, increased total porosity and better aeration for roots.

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تحسين بيئة منطقة الجذور وإنتاجية الأراضي الطينية الملحية باستخدام الحرث تحت التربة مع إضافة الجبس

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تم إجراء تجربة حقلية (حوالى 4 فدان) فى الأراضى الطينية لشباب الخرجيين ، بمنطقة الزاوية، مركز الحامول، محافظة كفرالشيخ بهدف تقييم أثر الحرث تحت التربة وإضافة الجبس على تحسين خواص التربة الهيدروبيدولوجية فى وجود نظام صرف سطحى. وكانت معاملات الحرث تحت التربة على مسافات 0.8، 1.6م وبعمق 0.6م وتم إضافة الجبس بمعدل 5.0، 7.5 طن / فدان. وتم زراعة محصول بنجر السكر للدلالة على مدى تحسن التربة.

وقد أظهرت النتائج أن ملوحة قطاع التربة قد انخفضت بنسبة 35.1، 12.1% عند 0.8، 1.6م مسافة حرث تحت التربة على الترتيب وذلك عند إضافة 5.0 طن جبس/ فدان. بينما انخفضت بنسبة 24.39، 28.88% عند إضافة 7.5 طن جبس/ فدان لنفس المعاملات. وبغض النظر عن معاملات الجبس فإن متوسط ملوحة التربة قد انخفضت بنسبة 29.74، 20.49% عند 0.8، 1.6م مسافة حرث تحت التربة على الترتيب. وبصفة عامة فإن النسبة المئوية للصوديوم المتبادل قد انخفضت فى كل طبقات قطاع التربة وقد تلاشى هذا النقص مع عمق التربة ليعطى مؤشراً جيداً على تحسن خواص التربة. وقد انخفضت النسبة المئوية للصوديوم المتبادل بنسبة 41.61، 33.59 % عند 0.8، 1.6م مسافة حرث تحت التربة على الترتيب عند إضافة 5.0 طن جبس/ فدان. بينما انخفضت بنسبة 40.70، 38.25 % عند إضافة 7.5 طن جبس/ فدان لنفس المعاملات.

والمعاملات المستخدمة قد نتج عنها نقص ملحوظ لقيم الكثافة الظاهرية خلال قطاع التربة، وأظهرت المعاملات أثر ايجابى ملحوظ على المسامية الكلية فى سطح التربة (0-50سم) غير أن هذا التأثيرعلى المسامية الكلية قد تلاشى بزيادة عمق التربة. وقد زاد المعدل التراكمى لدخول الماء الى التربة عند نهاية الوقت المنقضى فى الأراضى التى تم معاملتها بالمقارنة بالحالة الأولية للتربة. وقد وصلت هذه الزيادة الى 58.19، 71.77 % عند 0.8، 1.6م مسافة حرث تحت التربة على الترتيب عند إضافة 5.0 طن جبس/ فدان. بينما وصلت الى 63.64، 61.12% عند إضافة 7.5 طن جبس/ فدان لنفس المعاملات. وأدى زيادة معدل إضافة الجبس الى زيادة المعدل التراكمى لدخول الماء الى التربة بنسبة 64.98، 62.38% عند معدل إضافة 5.0، 7.5 طن جبس/ فدان على الترتيب.

وقد زاد محصول بنجر السكر بحوالى 26.86 ، 23.27 طن/ فدان عند 0.8، 1.6م مسافة حرث تحت التربة على الترتيب عند إضافة 5.0 طن جبس/ فدان. بينما زاد المحصول بحوالى 28.35 ، 25.25 طن/ فدان عند إضافة 7.5 طن جبس/ فدان لنفس المعاملات.