EFFECT OF APPLYING GYPSUM ON SOME PHYSICO-CHEMICAL AND HYDROLOGICAL PROPERTIES OF A SALINE-SODIC CLAY SOIL PROVIDED WITH A TILE DRAINAGE SYSTEM

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ABSTRACT:

Ameliorating the saline-sodic soil process represents an important target in the agricultural security program of Egypt. In this concern, a field trial was conducted for improving a salt-affected clay soil provided with a tile drainage system at Mehallet Mousa, Kafr El-Shiekh Governorate, Egypt. The main target of this work was at identifying the effective role of applied gypsum, as a soil chemical amendment, with different rates on physico-chemical and hydrological properties of such soil as well as maximizing its productivity from maize and wheat crops. The applied gypsum treatments were categorized into: i. control without applied gypsum, ii. 3.75 ton gypsum/fed ≈ 75 % of gypsum requirements (GR) for the uppermost 15 cm, iii. 5 ton gypsum/fed ≈ 100 % GR and iv. 6.25 ton gypsum/fed ≈ 125 % GR. The applied gypsum rates were uniformly spread on surface and thoroughly mixed with the soil top 15 cm, and then followed by a recycle of wetting and drying was repeated four times through a period of about two months.. A recycle of wetting and drying was repeated four times through a period of about two months. Soil samples at depths of 0-15, 15-30, 30-45 and 45-60 cm were periodically collected after 3, 6, 9 and 12 months from starting the experiment to determine soil physico-chemical, *i.e.,* ECe, ESP, salt leaching index, bulk density, infiltration rate, aggregation index and quickly drainable pores. Moreover, the shape of water table between drains, water table depth were monitored as well as the drainage intensity factor "*a*" and the rate of water drawdown were calculated.

The obtained results revealed that the reduction percentages of soil salinity after 3, 6, 9 and 12 months from starting the experiment reached 30.3, 33.1, 35.4 and 45.0 % for the applied gypsum rates 75 % GR vs 34.6, 36.9, 45.6 and 53.3 % for 100 % GR and 35.0, 66.6, 69.9 and 75.7 % for 125 % GR, respectively. That was true, since additional gypsum in excess of the requirement helped speedily soil amelioration process. In general, the soil salinity reached the safe limits of soil salinity (ECe=< 4.0 dS/m) and sodicity (ESP= < 15 %) after 6 months of applying 100 and 125 % GR. Also, the values of ECe and ESP were tended to a gradual decrease with increasing the experimental time, but the reverse was true for the values of salt leaching index that showed gradual increases.

Concerning soil physical soil properties, the obtained results showed a pronounced increase in infiltration rate, where the increase percentages ranged 42.3-56.0, 43.7-60.9 and 55.4-91.5 % at 75, 100 and 125 % GR, respectively. A similar and parallel trend was also observed for the values of quickly drainable pores. Such favourable effect refers to the released Ca^{2+} from gypsum that leading to improve soil structure, creation of friable granules and conductive pores that enhancing water penetration, and then promote a sufficient cycle of wetting and drying. Also, a parallel increase was achieved for the aggregation index values as time elapsed and increasing gypsum rates, where the corresponding relative increase percentages ranged between 18.0-89.3, 55.0-120.0 and 108.0-140.3 % at 75, 100 and 125 % GR, respectively. Moreover, a noticeable decrease was observed for soil bulk density due to adding gypsum as an amendment comparing with the control treatment.

Regarding soil hydrological properties, it was clearly showed a marked drop in water table level differs from one day to another as well as the applied gypsum rates, probably due to the nature of the stratified layering of such Nile alluvial soil. The average rate of water table drawdown after one year of gypsum application mounted 35.2, 44.8 and 95.0 % for soils treated with 75 %, 100 % and 125 % GR as compared with the initial state, respectively. In general, lowering the water table has given the top soil a chance to dry, shrink and creating water passageways. It was also noticed that the drainage intensity factor (*a*) tended to increase with increasing the applied gypsum rate, where its greatest value was achieved at 125 % GR, may be due to the increase of released Ca^{2+} and its positive action to link clay particles, and in turn enhance soil internal drainage and water movement to drains. In addition, a parallel pronounced decrease in the total water resistance was associated with increasing the applied gypsum rate, *i.e.,* 7.69, 23.07 and 30.77 % at 75, 100 and 125 % GR, respectively. This means that applied gypsum led to improve the soil structure which helped in creating a more permeable soil medium with less resistance to water flow towards tile drains.

The achieved amelioration in physico-chemical and hydrological properties of the studied soil positively reflected on the increases of grain yields of both summer maize and winter wheat, which were approached 27.8, 50.0 and 61.1 % for maize vs 25.7, 42.9 and 57.1 % over the control for wheat at 75, 100 and 125 % GR, respectively. Finally, the obtained results suggest that this work is considered as scientific and logic fundamental base for a successful agricultural development of such salt affected area as well as possible to increase unite area income.

Key words: Saline-sodic clayey soil, gypsum, tile drainage system, soil amelioration.

INTRODUCTION:

Soil salinity/sodicity is affecting crop yields badly by up-setting water and nutritional balance of the plants due to deterioration of physical and chemical properties of soil as well as by toxic effects of individual ions. To bring back these soils to their full production potential reclamation is imperative. Accumulation of salts is a major retarding factor for the successful plant growth in irrigated areas of the arid and semi-arid regions. The origin of salts in the soils of arid regions varies widely. Irrigation water always contains some salts which tend to accumulate gradually under the high rate of evaporation. The local water mismanagement practices lead the soil salinity to become 1.5 times irrigation water salinity **(El-Guindy, 1989)**. Ground water is the other source of salts under irrigated farming in arid regions.

Total salt affected area in the world about 955 Mega ha out of which 0.9 M ha in Egypt. The majority of salt-affected soils in Egypt are located in the northern-central part of the Nile Delta and on its eastern and western sides. However, fifty five percent of the cultivated lands of northern Delta region are salt-affected, twenty percent of the southern Delta and middle Egypt region and twenty five percent of the Upper Egypt region are salt-affected soils **(Elsharawy *et al.,* 2008)**. Salt-affected soils represent a large portion from the agricultural lands in the Delta and Upper Egypt. In such soils, the hydrological conditions are of a very complex nature **(Abdel-Dayem *et al.,* 1978)**.

Mostafa (2000) reported that salt affected soils include saline non-sodic, saline-sodic, and non-saline sodic soils. Generally, saline non-sodic and saline sodic soils need leaching processes in their reclamation. Reclamation of sodic soils requires the removal of most or part of the exchangeable sodium replacing it by the more favourable calcium ions in the root zone. This can be accomplished in many ways, the best are dictated by local conditions, available resources and the kind of crops to be grown on the reclaimed soils.

Reclamation of saline sodic soils includes leaching of the soluble salts and applying a proper amendment in order to improve their physical and chemical properties. The kind and amount of chemical amendments to be used for reclaiming sodic soils are based on several factors, among them are: i. Physical and chemical properties of the soil, ii. The time available for soil reclamation, iii. The final required level of exchangeable sodium percent (ESP) and iv. The costs of applied soil amendments and water application. Gypsum is the most commonly used amendment for sodic soil reclamation, because of its low cost, availability and ease of handling.

In Egypt, improving saline-sodic soils are considered as an important part in the agricultural security program. Saline-sodic soils containing excess soluble salts in quantities to interfere with the growth of most crops. It is characterized by EC of > 4.0 dS/m, ESP > 15 and pH >8.5. Such soils cause a serious problem for crop production owing to poor physical and chemical properties **(Mohamedin *et al.,* 2005)**. The improvement of these soils is usually beginning by the removal of salts by leaching may increase hydrolysis of the sodic clay soil, consequently increases pH values. Thus the application of soil amendments becomes essential. **Ali and Kahlown (2001)** mentioned that reclamation of saline-sodic and sodic soils, however, cannot be achieved by simple leaching. Reclamation of these soils is difficult, time consuming and more expensive than that of saline soils due to replacement of exchangeable sodium with calcium. Hence, it requires the addition of chemical amendments such as gypsum along with leaching. They also added that, the effectiveness of gypsum depends upon: i. Degree of fineness, ii. Way in which it is incorporated on the soil and iii. Efficiency of drainage system.

Miyamoto and Enriquez (1990) pointed out that gypsum application provided low ratios of sodicity to salinity in percolating solution and relatively uniform hydraulic gradient throughout the soil profile. **Singh and Bajwa (1991)** found that application of gypsum for the reclamation of sodic soil enhanced the removal of soluble Na^+ and decreased ESP and pH of the reclaimed soil. Additional gypsum in excess of the requirement helped speedy reclamation; when water of rather high SAR was used for leaching. **Gupta *et al*. (1988)** found that despite variation in dose and frequency of gypsum application to a sodic Vertisols under reclamation, decreases in soil pH, EC and ESP at the end of the third year did not vary much between treatments varying in dose and frequency. **Khalifa *et al.* (1994)** found that the application of gypsum decreased soil salinity, soluble ions and exchangeable Na and Mg and increased exchangeable Ca.

Baumhardt *et al*. (1992) found that application of gypsum to soil surface caused 38 % increase in water infiltration rate particularly when the soil was plowed prior to its application. **Galal *et al.* (1993)** found that soil bulk density decreased and hydraulic conductivity increased, especially after two years and two successive cultivation seasons and when gypsum requirements were added in two split does rather than one. **Koriem *et al*. (1994)** reported that gypsum treatment was superior in decreasing EC, soluble ions, ESP, exchangeable Mg percent and increasing exchangeable Ca percent as well as improving all physical properties. They found that applying gypsum requirement in a mixture of (gypsum + lime) improved soil properties but to a lower extent in comparison with the application of gypsum alone. Leaching saline sodic soils with drainage water followed by irrigation water in the presence of gypsum was more suitable for reclamation and can help to save the Nile water for irrigation purposes. **Shams**

El-Din (2001) revealed that to reveres the declining trend of agricultural productivity a combination of agro-chemical amendments and subsurface drainage, supplemented by a proper irrigation management, has to be adopted.

The aim of this investigation was to study the effect of applying gypsum as an amendment with different rates on some physico-chemical and hydrological properties in salt affected soils provided with a tile drainage system. Such work represents an attempt to study the effectiveness of subsurface drainage system combined with the additives of gypsum as a chemical amendment with different rates for reclaiming a saline-sodic soil and maximizing its productivity.

MATERIALS AND METHODS:

A reclamation process was conducted at a private farm of about 30 feddan within the area of salt-affected soils at Mehallet Mousa, Kafr El-Shiekh Governorate, Egypt. The climate is semi-arid with mean temperature of 26 ^oC and annual precipitation less than 100 mm. The studied soil is characterized by a clay texture, saline-alkali condition (average values of ECe=19.0 dS m^{-1} and ESP= 25.7), a low average of infiltration rate (0.7 m/day), a low hydraulic conductivity (0.15 m/day) and a shallow saline water table (less than 80 cm depth of ground surface and EC=10.4 dS m^{-1}). Such soil conditions are seriously hampers on growth and yield of grown plants. The main soil characteristics are presented in Table (1).

Table (1): The main soil properties of the studied area before installation of tile drains.

Soil depth cm	ECe (dS m^{-1})	ESP	Particle size distribution %			Bulk density (g cm^{-3})	K_S (m/day)
			Sand	Silt	Clay		
0-15	15.6	23.0	17.4	33.4	49.2	1.37	0.050
15-30	18.7	24.1	16.1	36.2	47.7	1.38	0.053
30-60	19.2	27.6	20.3	34.3	45.4	1.40	0.043
60-80	22.4	28.1	18.2	33.8	48.0	1.41	0.046

Tile drainage system was installed, where the equation of **Hooghoudt (1940)** was used to calculate the drain spacing, which was identified at was 30 m. The system consists of lateral and collector of PVC pipe drains ranging in size from 4 to 15 inches in diameter placed at depth of 1.25 to 1.50 m from ground surface.

Gypsum was applied as a soil amendment, its chemical characteristics are presented in Table (2). The gypsum requirements were determined according to **Schoonover's method (1952)**. The experiment was laid in a randomized complete block design, with three replicates and plot area of 25 m^2 (1/168 fed). The applied gypsum treatments were: i. Control without gypsum applied (T_1), ii. 3.75 ton/fed ≈ 75 % of gypsum requirements (GR) for the uppermost 15 cm (T_2), 5 ton/fed ≈ 100 % GR (T_3) and 6.25 ton/fed ≈ 125 % GR (T_4), Gypsum rate were uniformly spread on soil surface and thoroughly mixed in the top 15 cm, and then followed by an alternative pattern of irrigation and kept to dry. A recycle of wetting and drying was repeated four times through a period of about two months.

Maize (*Zea maize*) as a summer crop was planted in mid of May and harvested at the end of August. Also, wheat (*Triticum aestivum* L.) as a winter crop was cultivated at the beginning of November and harvested at the end of May. The plants received the recommended doses of N, P and K fertilizers as well as the normal culture practices for both crops were applied as recommended in the area under consideration

Table (2): Some chemical characteristics of the applied gypsum.

Characteristics	Values
pH (1:5 as water suspension)	4.92
Solubility product (g 100 g-1)	0.92
EC in dS m^{-1} (water extract 1:5)	2.31
Soluble cations and anions (mg kg^{-1}):	
Ca^{++}	1571
Mg^{++}	161
Na^{+}	817
K^{+}	38
Cl^{-}	1575
HCO_3^{-}	918
CO_3^{--}	0.00
SO_4^{--}	3270

Soil samples, which either were taken at the initial state (Table, 1) or periodically after 3, 6, 9 and 12 months at depths of 0-15, 15-30, 30-45 and 45-60 cm, air dried, crushed, sieved through a 2 mm sieve and then kept to subjected to the different soil analyses. The samples were subjected to determine some chemical and physical properties, *i.e.*, ECe, ESP, particle size distribution, bulk density, infiltration rate, aggregation index according to the standard methods described by **Richard's (1954)**, **Page *et al.* (1982) and Gee and Bauder (1986)**. The hydraulic conductivity was determined by the Auger Hole Method **(Van Beers (1976)**. Quickly drainable pores were calculated according to **De Leenheer and De Boodr (1965).** Salt leaching index was calculated according to **Gupta *et al.* (1998)**. The obtained data were statistically analyzed using MSTAT computer program **(Nissen, 1982)**.

As for the hydrological measurements, a set of piezometers has been installed midway between the laterals as well as just beside the trench and also in the middle of the non- drained plots. The drain outflows using volumetric methods according to **(ILRI, 1974)** have been measured simultaneously with the water table levels. Certain periods and complete observations were chosen for studying the hydrological properties under investigation.

To study the shape of water table, sets of piezometers of 1.4 m depth were installed along a line perpendicular to the direction of the laterals. One piezometer was just above the drain and the others were located at distances of 1/64, 1/32, 1/16, 1/8, 1/4 and 1/2 the spacings. Water table depth was monitored three times a week through an observation wells installed at the mid space between tile drains to calculate the drainage intensity factor "*a*" and the rate of water draw down **(Dieleman and Trafford, 1976)**.

RESULTS AND DISCUSSION:

The analytical data of saline–sodic soil treated with gypsum on the basis of 0, 75, 100 and 125 % gypsum requirement throughout the experimental times of 3, 6, 9 and 12 months are tabulated in Table (3), and then their detailed discussion should be carried out into the following items.

I. Effect of applied gypsum on soil properties:

a. Soil salinity (ECe):

The ECe values of soil samples before drainage construction were ranged between 15.6 and 22.4 dS/m with an average value of 18.98 dS/m, indicate that the studied soil was strongly saline (Table, 1). The analytical data of soil samples, that were taken after drains installation, are presented in Table (3) and showed a sharply reduction in the ECe values from 11.6 at the initial state to 6.77, 5.86 and 2.85 dS m^{-1} after one year of applied 75 , 100 and 125 % GR, respectively.

Table (3): Effect of applied gypsum rates on some physico-chemical and hydrological properties throughout the experimental time.

Treatment	Time month	ECe, dS/m	ESP %	S.L.I.	B.D., gm/cm^3	I.R., cm/ hr	Q.D.P	A.I.	W.T.D., cm/day	"a", days^{-1}
Control, T_1 0 % GR	Initial	11.60	28.18	0.39	1.38	0.80	4.10	0.38	2.58	0.043
	3	9.38	23.87	0.51	1.39	0.83	4.29	0.40	2.71	0.044
	6	8.59	20.85	0.55	1.38	0.90	4.68	0.43	2.95	0.048
	9	8.36	20.29	0.56	1.38	0.94	4.88	0.45	3.08	0.050
	12	8.12	19.73	0.57	1.37	0.96	4.99	0.46	3.15	0.051
T_2 75 % GR	Initial	12.30	29.87	0.35	1.38	0.85	4.34	0.41	2.79	0.046
	3	8.58	18.23	0.55	1.35	1.21	6.99	0.48	3.24	0.052
	6	8.23	15.94	0.57	1.34	1.22	7.60	0.53	3.34	0.060
	9	7.95	15.54	0.58	1.31	1.29	7.92	0.64	3.48	0.071
	12	6.77	14.75	0.64	1.30	1.33	8.77	0.78	3.77	0.077
T_3 100 % GR	Initial	12.55	30.47	0.34	1.38	0.87	4.21	0.40	2.90	0.048
	3	8.21	15.83	0.57	1.31	1.25	6.76	0.62	3.39	0.070
	6	7.91	14.31	0.58	1.29	1.28	7.56	0.64	3.48	0.078
	9	6.82	13.81	0.64	1.26	1.35	8.47	0.79	3.65	0.082
	12	5.86	13.51	0.69	1.24	1.40	8.87	0.88	4.20	0.090
T_4 125 % GR	Initial	11.69	28.38	0.38	1.38	0.81	4.12	0.38	2.85	0.047
	3	7.60	18.44	0.60	1.27	1.26	10.09	0.79	4.31	0.072
	6	3.90	10.80	0.79	1.24	1.42	11.88	0.86	4.74	0.081
	9	3.52	10.58	0.81	1.21	1.46	12.74	0.90	5.05	0.095
	12	2.85	10.01	0.85	1.18	1.55	14.19	0.91	5.56	0.099
L.S.D. at 0.05										
Treatment		0.283	0.229	0.021	0.005	0.017	0.158	0.022	0.073	0.140
Time		0.310	0.251	0.019	0.006	0.018	0.173	0.019	0.081	0.154

S.L.I.=Salt leaching index, B.D.-Bulk density, I.R.=Infiltration rate, Q.D.P.=Quickly drainable pores, A.I.=Aggregation index, W.T.D.=Water table drawdown and "a"=Drainage intensity factor.

Also, the obtained results revealed that the reduction percentages of soil salinity after 3, 6, 9 and 12 months from starting the experiment reached 30.3, 33.1, 35.4 and 45.0 % for the applied gypsum rates 75 % GR vs 34.6, 36.9, 45.6 and 53.3 % for 100 % GR and 35.0, 66.6, 69.9 and 75.7 % for 125 % GR, respectively. That was true, since additional gypsum in excess of the requirement helped speedily soil amelioration. In general, the soil salinity reached the safe limit of soil salinity (ECe=< 4.0 dS/m) after 6 months of applying 100 and 125 % GR. Also, the values of ECe were tended to decrease with increasing the experimental time. The reverse was true for the salt leaching index that showed a gradual increase up to a maximum value at a gypsum rate of 125 % GR. The results are in conformity with those reported by **Chaudhry *et al.* (1988) and Muhammad and Abdul Hameed (1992)**.

b. Soil sodicity (ESP):

The sodification phenomenon constitutes a highly complicated problem in the studied clay soil, which constricts its productivity. Data in Table (3) showed a gradual obvious decline in ESP value with increasing the experimental time, where its value reduced below the safe limit (< 15 %) after 6 months at the applied gypsum rate of 100 % GR. That was true, since ESP value tends a parallel decrease with increasing the gypsum rates, where it reaches a minimum value (10.01 %) at a gypsum rate of 125 % GR after one year of starting the experiment. These results are in agreement with those reported by **Prather *et al.* (1975) and Muhammad and Abdul Hameed (1992)**.

c. Infiltration rate:

The obtained data of the infiltration rate, Table (3) showed a significantly lower value in the control treatment as compared with the soils treated with the different applied gypsum rates. The average values of the infiltration rate were 0.89, 1.18, 1.23 and 1.30 cm/hr for the control treatment (0 % GR), 75, 100 and 125 % GR, respectively. That was true, since there was an obvious increase in the infiltration rate with increasing the applied gypsum rate, where the relative increase percentages were 42.3, 56.0 and 75.0 % as an average for the soils treated with 75, 100 and 125 % GR, respectively, as compared to the control treatment (3.1-20.0 %). As detailed data, the increase percentages in infiltration rate ranged between 42.3-56.0, 43.7-60.9 and 55.4-91.5 % for the soils treated with 75, 100 and 125 % GR, respectively. This could be referred to the positive effect of Ca^{2+} released from gypsum additions, and then it improves soil aggregation (soil structure), which plays an important role for creating conductive pores and helps in water penetration. These results are in accordance to those obtained by **Armestrong *et al.* (1990)**.

d. Quickly drainable pores (Q.D.P)

Drainable pores measurements are generally calculated from the water retention characteristics curve. They are describing as a main feature of soil structure, however, a good structure means a favorable condition for simultaneous aeration and storage of soil moisture. Mechanical impedance of root growth is also reduced and stable traction for farm implements is provided (**Van de Goor, 1979**).As shown in table (3), the greatest and lowest values of quickly drainable pores (> 28.8 μ**)** are more associated with soil treated with a gypsum rate of 125 % GR and the untreated one (control), respectively. The favorable condition was more attributed to the creation of the friable granules which are existed after the installation of tile drains and addition of gypsum rates. These results are in harmony with those obtained by **Amer (1999)** and **Abdel-Mawgoud (2004)**.

c) Aggregation index (A.I.):

The average values of aggregation index showed a gradual increase was taken as a parallel trend for increasing the applied gypsum rates. That was confirmed by the achieved gradual increases in aggregation index from 0.42 (as an average value) in case of untreated soil (control) to 0.57, 0.67 and 0.77 at the applied gypsum rates of 75, 100 and 125 % GR, respectively. Moreover, the obtained data showed that the A.I. values tended to increase as the experimental time elapsed. However, the relative increase percentages of A.I. were ranged between 18.0-89.3, 55.0-120.0 and 108.0-140.3 % at the applied gypsum rates 75, 100 and 125 % GR as compared with the initial value, respectively.

The abovementioned results reveal that improving soil physical properties was primarily gained by drainage installation and was also governed by gypsum applications. These findings may explained by the effect of tile drains on lowering water table level and the removal of excess soluble salts. In addition, the replacements of Ca^{2+} that are released from the applied gypsum additions with that of Na^{+}. This favorable condition reduced the harmful effect of sodicity on impedes water movements and lowers soil permeability. These results are in harmony with those previously obtained by **Amer (1999) and Abdel-Mawgoud (2004)**.

d) Soil bulk density (B.D.):

Soil bulk density is the main soil character that must be taken into consideration when improving soil physical properties, especially in such clayey soil. Data in Table (3) showed that the impact of tile drains installation and the secondary treatments of gypsum on soil bulk density were more pronounced. The soil bulk density values tendency to gradual decreases with time and increasing the applied gypsum rates. The obtained data showed that there was a reduction in soil bulk density after one year of adding gypsum as an amendment from 1.38 at the initial state to 1.30, 1.24 and 1.18 g cm^3 at the applied gypsum rates of 75, 100 and 125 % GR, respectively. The promotive effect on soil bulk density was mainly due to ameliorating soil aggregation condition and the improvement of soil structure. The obtained results coincided with **Wahdan *et al.* (1999)** who found that gypsum is more effective in reduction of bulk density than sulphur.

II. Effect of applied gypsum on soil hydrological properties:

The workability of a tile drainage system in the studied salt affected clay soil is accompanied by two considerations of the nature of flow through low permeable soil and gets rid of the harmful ions. To understand the drainage criteria in this study, the shape of water table between drains, the rates of water table drawdown and drains outflow are studied under the different gypsum treatments. The comparative and rational results collected from the different experimental trials will clarify many interesting questions raised about the flow pattern and the efficiency of tile drains in such studied salt affected clay soil.

a. Water table shape between drains:

Figure (1) illustrates the water table above drain level starting from the third day after irrigation and the successive days for different gypsum treatments. It is clearly shown that the drop of water table levels differs from one day to another. This is due to the nature of the stratified layering pattern of the studied Nile alluvial soil. The water table surfaces are mostly horizontal, and then an increasing gradient was observed when only approaching the trench backfill. The flow pattern could be considered as a one dimensional flow in horizontal direction, except in the zone close to the trench where the flow turns to be a two dimensional one. The type of flow in such soils could be considered as an interflow, *i.e.,* most of the water seeps horizontally through a pervious soil layer overlaying a soil of low permeability. When water reaches the trench backfill it converges downward to the drain tubes. The obtained data are confirmed by **Fukuda (1967) and Van der Molen (1973)** who stated that the trench backfill is acting as an open ditch or as a covered furrow in heavy clayey soils.

b. Water table drawdown:

The effect of treating the soil with gypsum could be studied by comparing the values and rates of water table drawdown from the soil surface to one meter depth in different field trials. Table (3) gives the average values of water table drawdown after 3, 6, 9 and 12 months that were amounted 3.32, 3.52 and 4.5 cm/day for soils treated with the applied gypsum rates of 75, 100 and 125 % GR, respectively, as compared to the average rate of water table drawdown for the control treatment (2.89 cm/day). Generally, it is clear that the rate of water table drawdown increases as time of the experiment elapsed, with different values from treatment to another. After one year of gypsum application, the rates of water table drawdown increased by 35.2, 44.8 and 95.0 % as compared with the initial value for soils treated with 75, 100 and 125 % GR, respectively.

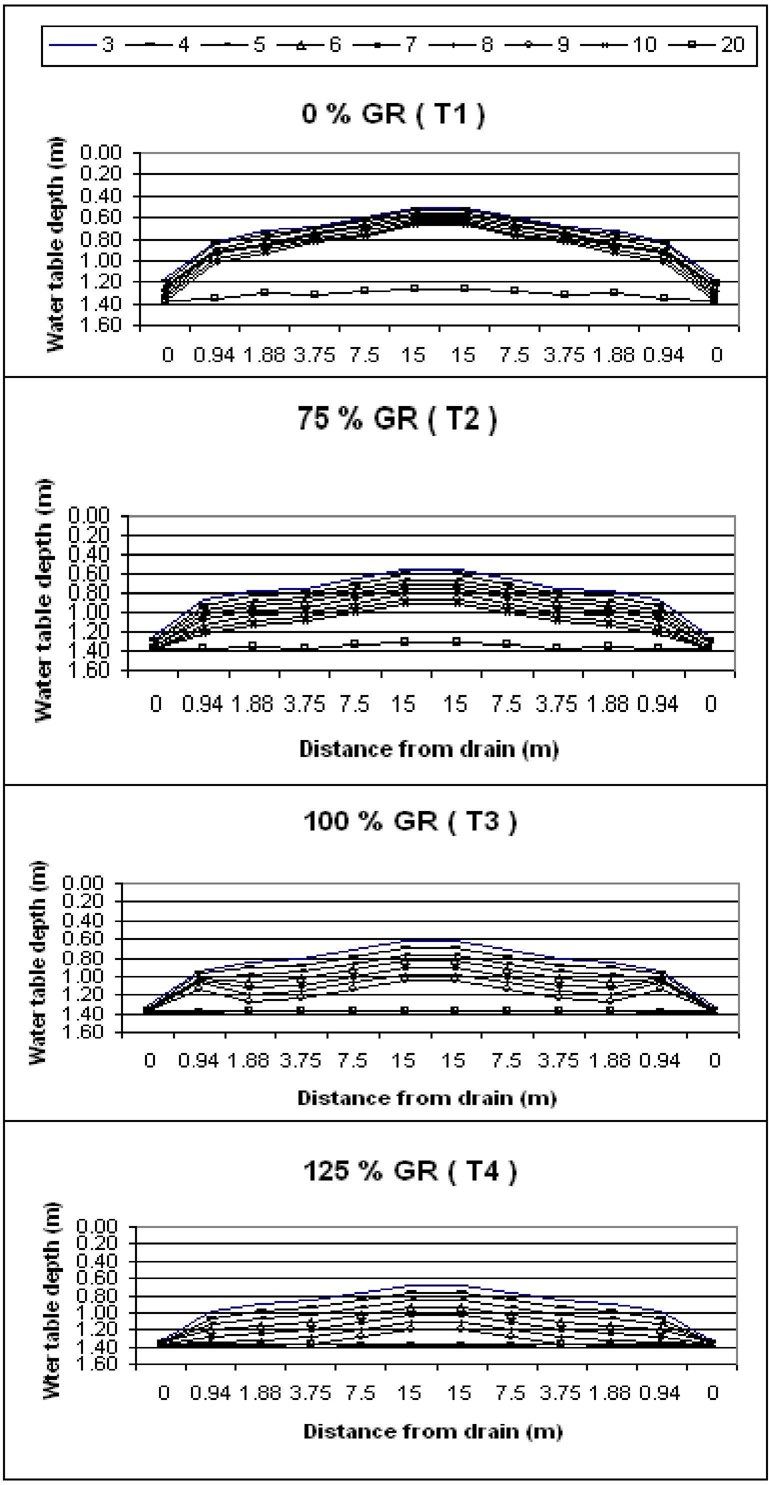

Fig. (1): Daily water table shape between drains and drawdown for the different gypsum treatments.

Lowering the water table has given the top soil a chance to dry, shrink and form water passageways. It is noteworthy to mention that the drying process and its consequences play an important role in draining heavy clayey soil since it improves the soil permeability

c. Drainage intensity factor "a":

This parameter is the most influential factor governing the ground water table depth. The obtained data in Table (3) revealed that gypsum treated soils performed better than the control one, where the greatest value of drainage intensity factor "*a*" was obtained in the case of gypsum application at 125% GR and after one year of starting the experiment. This can be explained on the basis that the action of Ca^{2+} to link the individual soil particles together, and then increasing water pass ways. Such a favorable condition enhanced the internal drainage, and consequently water movement to tile drains. These results are confirmed with that obtained by **El-Hamchary (1980) and El-Araby (2004).**

d. Water flow to drain tubes:

The relation between lateral discharge and time after irrigation cession for the different treatments of this study is illustrated in Fig. (2). Lateral discharges tended to decrease with time after cession of irrigation, whereas an increase in lateral discharge occurred for few days just after irrigation. During the first stage of water table drawdown, the relation between the hydraulic head and the discharge was linear, as shown in Fig. (3). When the water table had dropped to a certain depth from the soil surface, the relation became a non-linear one, and then the soil profile can be divided into two layers with different flow characteristics. When sub-drainage systems in clay soils are designed the depth of drain tiles, which has been experimentally adopted to be 1.4 m below the ground surface, is not necessary to be taken since the soil water moves horizontally throughout the upper more permeable soil. About 1.0 to 1.25 m is supposed to be sufficient in such soils. The capacity of a given drain pipe in draining water from soil is of great importance. A very good approximation of ground water flow to a parallel drainage system can be obtained by analyzing the flow into horizontal, vertical and radial components with corresponding resistances (**Hooghoudt, 1940 and Ernst, 1954**).

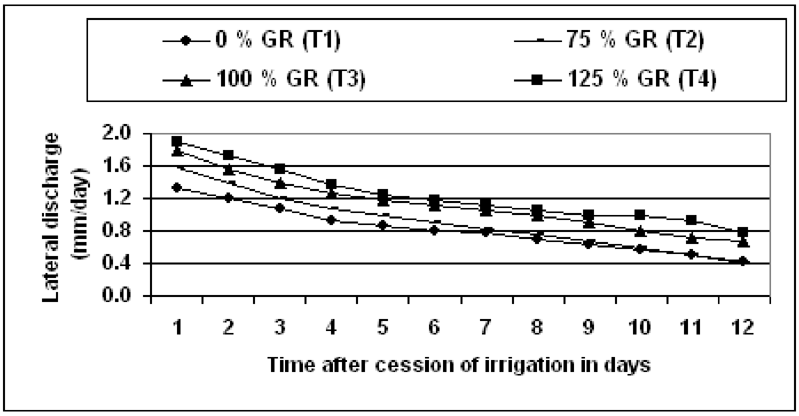

Fig. (2): Lateral discharge-time relationship for the different gypsum treatments.

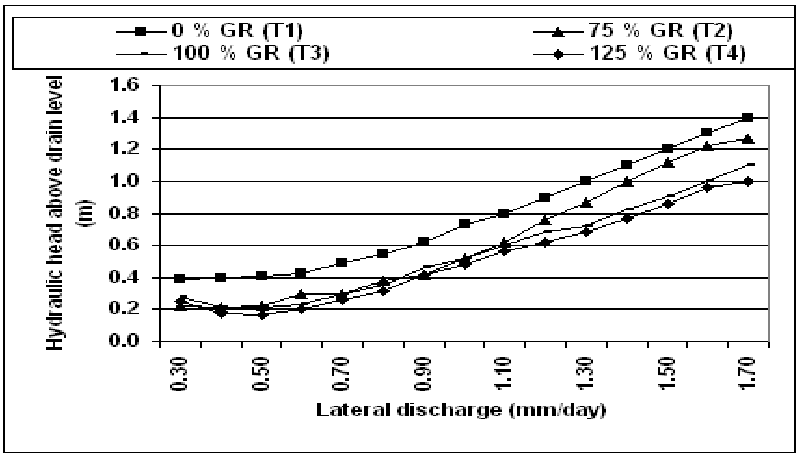

Fig. (3): Hydraulic head-discharge relationship (q-h relation) for the different gypsum treatments.

Due to the concentration of streamlines towards the joints, there will be a considerable extra flow resistance. This extra resistance was defined by **Engelund (1951)** as "entry resistance". **Ernst (1963)** has formulated the relation between the head losses which occur when water flows through a soil towards the drain tube and the amount of discharge flowing in the drain as:

$$h = QW \qquad (1)$$

Where h is the height of water table above the level of drains midway between drains, Q is the discharge of the drain and W is the total resistance of flow. the total resistance W is given by:

$$W = W_h + W_v + W_r + W_e \qquad (2)$$

Where W_h, W_v, W_r are the horizontal, vertical, radial resistances of flow through the soil and W_e is the entrance resistance. Considering a constant head h equal to 1.0 m above drain level in the four trials under this study. Then, according to equation (1):

$$Q_{T1}W_{T1} = Q_{T2}W_{T2} = Q_{T3}W_{T3} = Q_{T4}W_{T4} \qquad (3)$$

Where the subscripts $_{T1, T2, T3}$ and $_{T4}$ refer to the trial 0, 75, 100 and 125 % GR, respectively. The hydraulic head–discharge relation of Fig. (3) show that Q_{T1}, Q_{T2}, Q_{T3} and Q_{T4} amount to 1.3, 1.4, 1.6 and 1.7 mm/day, respectively. Stabilizing only the addition of 75 % gypsum requirements has decreased the total resistance by 7.69 %. On the other hand, ameliorating the top soil with 100 and 125 % GR has decreased the total resistance by 23.07 and 30.77 %, respectively. This could be due to the function of mixing gypsum with the soil that leads to improve the soil structure as well as creating a more permeable medium with less resistance to water flow towards drain tubes.

III. Effect of applied gypsum on grain yields of maize and wheat crops:

The results reveal that the grain yields (ton/fed.) of both summer maize (corn) and winter wheat are not only positively affected by tile drains installation but also to some extent by the application of gypsum rates. The grain yields are significantly increased in the treated plots, and the relative increase percentages are approached 27.8, 50.0 and 61.1 % for maize and 25.7, 42.9 and 57.1 % for wheat, respectively, under gypsum rates of 75, 100 and 125 % GR, respectively, relative to the control. This significant and positive effect of the amended soils is partly due to the gypsum applications that improve soil chemical, physical and hydrological characteristics as mentioned above, besides the beneficial effect of tile drains to accelerate leaching processes and the disposal of excess water and salts from the root zone, and in turn improving soil structure, increasing soil aeration and biological conditions.

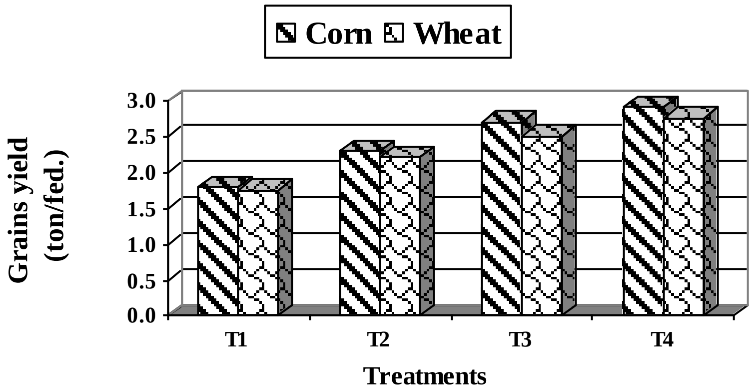

Fig. (4): Effect of the different amended treatments on grain yields of corn and wheat

From the abovementioned discussions, it could be concluded that tile drainage installation is the most important tool to conserve or reclaim the harmful effects of salty clayey soils to a feasible ones. This process must be undertaken with gypsum requirements. The results suggested that it will be possible to increase horizontally the cultivated area and to enhance unit area income.

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تأثير إضافة الجبس الزراعى على بعض الصفات الفيزيوكيميائية والهيدرولوجية لتربة طينية ملحية قلوية منفذ بها شبكة صرف مغطى

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تعتبر عملية تحسين التربة الملحية-القلوية من الأهمية فى مجال الأمن الزراعى فى مصر. ولذا، فقد تم إجراء محاولة حقلية لإصلاح تربة طينية ملحية قلوية مزودة بشبكة صرف مغطى وتقع بمنطقة محلة موسى - محافظة كفر الشيخ – مصر. وكان الهدف الرئيسى من هذه الدراسة هو تحديد الدور الفعال لتأثير إضافة الجبس الزراعى - كمحسن كيميائى - بمعدلات مختلفة على الخواص الفيزيوكيميائية والهيدرولوجية للتربة، وكذلك تعظيم إنتاجيتها من محصولى الذرة والقمح.

وقد شملت معاملات الجبس الزراعى المضاف: معاملة كونترول (بدون إضافة الجبس)، معاملة إضافة ٣.٧٥ طن/فدان تمثل ٧٥٪ من الاحتياجات الجبسية، معاملة إضافة ٥ طن/فدان تمثل ١٠٠٪ من الاحتياجات الجبسية، معاملة إضافة ٦.٢٥ طن/فدان تمثل ١٢٥٪ من الاحتياجات الجبسية، وقد خلطها جيدا بالطبقة السطحية للتربة (٠-١٥ سم)، ثم تم إجراء دورة من الترطيب والجفاف كررت أربعة مرات خلال فترة شهرين .وتم اخذ عينات دورية من التربة على أعماق ٠-١٥، ١٥-٣٠، ٣٠-٤٥، ٤٥-٦٠ سم على إمتداد أربعة فترات (٣، ٦، ٩، ١٢ شهر) من بداية التجربة لإجراء التحليلات الفيزيوكيميائية ممثلة

فى ECe، ESP، مؤشر غسيل الاملاح، الكثافة الظاهرية، معدل الرشح، مؤشر تجميع الحبيبات، مسام الصرف السريعة. كما تم دراسة شكل منسوب الماء الارضى بين الحقليات، وكذلك متابعة عمق الماء الارضى، وحساب معامل شدة الصرف ومعدل هبوط مستوى الماء الارضى تحت ظروف المعاملات المدروسة.

وقد أوضحت نتائج الدراسة أن نسب الانخفاض فى ملوحة التربة بعد مرور ٣، ٦، ٩، ١٢ شهر من بداية التجربة وصلت ٣٠.٣، ٣٣.١، ٣٥.٤، ٤٥.٠٪ عند معدل إضافة ٧٥ ٪ من الاحتياجات الجبسية، ٣٤.٦، ٣٦.٩، ٤٥.٦، ٥٣.٣٪ عند معدل إضافة ١٠٠٪ من الاحتياجات الجبسية، ٣٥.٠، ٦٦.٦، ٦٩.٩، ٧٥.٧٪ عند معدل إضافة ١٢٥٪ من الاحتياجات الجبسية على التوالى. وهذا حقيقى، حيث أن إضافة الجبس بمعدل يفوق الإحتياجات الجبسية قد أسرع من عملية التحسين. وبصفة عامة، فقد وصلت ملوحة وقلوية التربة للحد الآمن (أقل من ٤ ديسيسيمنز/م، أقل من ١٥٪) بعد مرور ٦ شهور من بداية التجربة عند إضافة ١٠٠، ١٢٥٪ من الاحتياجات الجبسية. وعموما فإن قيم ملوحة وقلوية التربة قد اتجهت إلى الإنخفاض التدريجى بمرور زمن التجربة، وعلى العكس تماما قيم مؤشر غسيل الأملاح والتى أظهرت زيادات تدريجية.

وبالنسبة إلى الخواص الطبيعية للتربة، فقد أظهرت النتائج أن هناك زيادة ملحوظة فى قيم معدل الرشح، حيث سجلت زيادة تراوحت بين ٤٢.٣-٥٦.٠، ٤٣.٧-٦٠.٩، ٥٥.٤- ٩١.٥٪ عند إضافة الاحتياجات الجبسية بمعدلات ٧٥، ١٠٠، ١٢٥٪ على التوالى. كما لوحظ إتجاه مشابه وموازى أيضا لقيم مسام الصرف السريعة. ومثل هذه النتائج الجيدة ترجع إلى التأثير الإيجابى لأيون الكالسيوم المنطلق من ذوبان الجبس والذى يؤدى الى تحسين بناء التربة وتكوين التجمعات المحببة والمصاحبة لخلق مسام موصلة تساعد على حركة وتغلغل المياه خلال التربة، والتى تشجع من دورة فعالة من الترطيب والجفاف. كما تحققت زيادة موازية فى قيم مؤشر تجميع الحبيبات بمرور الزمن وزيادة معدلات الجبس المضافة، حيث تراوحت النسب المئوية للزيادة بين ١٨.٠-٨٩.٣، ٥٥.٠-١٢٠.٠، ١٠٨.٠-١٤٠.٣ ٪ عند معدلات إضافة ٧٥، ١٠٠، ١٢٥٪ من الاحتياجات الجبسية على التوالى. بينما حدث إنخفاض ملحوظ فى قيم الكثافة الظاهرية كنتيجة لإضافات الجبس بصفة عامة مقارنة بمعاملة الكنترول (بدون إضافة جبس).

وبدراسة الخواص الهيدرولوجية، فقد إتضح من النتائج المتحصل عليها حدوث إنخفاض فى منسوب الماء الأرضى بمعدل يختلف من يوم لآخر، وهذا يرجع لطبيعة التكوين الطبقى لمثل هذه الأراضى النهرية الرسوبية. فقد وجد أن متوسط معدل هبوط مستوى الماء الارضى وصل إلى ٣٥.٢، ٤٤.٨، ٩٥.٠٪ عند معدلات إضافة ٧٥، ١٠٠، ١٢٥٪ من الاحتياجات الجبسية مقارنة بمعاملة الكنترول على التوالى. وبصفة عامة، فان هبوط مستوى الماء الارضى يعطى فرصة لجفاف سطح التربة وتشققها وخلق ممرات موصلة.كما وجد أن معامل شدة الصرف "a" يزداد بزيادة إضافة معدلات الجبس، حيث وصل إلى أعلى قيمة عند ١٢٥٪ من الاحتياجات الجبسية، وربما يرجع ذلك إلى أيونات الكالسيوم المنفردة و تأثيرها الإيجابى على تجمع حبيبات الطين، ومن ثم تحسين حالة صرف التربة الداخلى وحركة المياه إلى المصارف. بالإضافة إلى نقص ملحوظ وموازى فى مقاومة حركة المياه مصاحب لزيادة معدلات الجبس المضافة، وصلت نسبته المئوية إلى ٧.٦٩، ٢٣.٠٧، ٣٠.٧٧٪ عند معدلات إضافة ٧٥، ١٠٠، ١٢٥٪ من الاحتياجات الجبسية على التوالى. وهذا يعنى أن إضافة الجبس قد أدى إلى تحسين حالة بناء التربة والذى ساعد على خلق بيئة تربة منفذة باقل مقاومة لحركة تدفق المياه فى إتجاه المصارف المغطاه.

وقد إنعكست التأثيرات الإيجابية والمحققة من تحسين حالة صفات التربة الفيزيوكيميائية والهيدرولوجية على زيادة إنتاجية محصولى حبوب الذرة الصيفى والقمح الشتوى، حيث بلغت الزيادة فى ٢٧.٨، ٥٠.٠، ٦١.١٪ فى محصول حبوب الذرة مقابل ٢٥.٧، ٤٢.٩، ٥٧.١٪ فى محصول القمح وذلك مقارنة بمعاملة الكنترول فى حالة إضافة الجبس بمعدلات ٧٥، ١٠٠، ١٢٥٪ على التوالى. وأخيرا، فان النتائج المتحصل عليها تشير إلى أن هذه الدراسة تعتبر أساس علمى ومنطقى لأى مشروعات ناجحة فى مجال التوسع الزراعى فى مثل هذه المناطق المتأثرة بالأملاح، بالإضافة إلى زيادة العائد المحتمل من الوحدة الإنتاجية.

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