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Effectiveness of the Size of Organic Matter Used in the Reclamation of Saline Sodic Soil

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ABSTRACT

A laboratory experiment was conducted to evaluate the efficiency of (FYM) and gypsum in the reclamation of a saline sodic soil using leaching columns. Soil samples were collected from South Port Said Regional Research Station, Port Said Governorate, and Egypt at summer season 2019. Gypsum, (FYM) applied in 3 sizes, in 2 methods, soaking or mixing. The leachate samples were collected at the bottom of soil columns. The samples were analyzed for EC, pH, Na, ESP, T.P and H.C. The results of leaching increased in EC and Na compared with control. The all treatments revealed more pronounced decreased in pH compared to the control. Data showed that applications of soil amendments decreased soil pH and EC an ESP but there is an increase in the values of soil T.P and H.C. A field experiment was conducted in winter seasons 2019/2020 at the same soil. Results indicated that the highest values of H.C, T.P, by applying (FYM) at soft size with gypsum treatment compared to control and other treatments, on the other hand this treatment induced the lowest values of soil pH, EC and ESP. it can be concluded that combination of (FYM) + gypsum proved to be the best soil amendment for reducing soil EC, pH, ESP and improving T.P, H.C and A.W.

Keywords: saline sodic soil, size organic matter, soaked mixed with gypsum, washing and filtration

INTRODUCTION

Salinity is the main reason that hinders plant growth and producing an economical crop, which limits the use of much of the world's agricultural land by Yang *et al*., (2011). Soil salinity is a big problem; especially in arid and semi- arid, Characteristic Saline soil is by the presence of harmful substances of sodium and its chloride and sulphate by Rajaravindran and Natarajan, (2012). Salt causes reverse osmosis by limiting the absorption of soil water, as a result of concentrations of salts inside plant cells. We need low- cost and effective remediation strategies to reduce salt damage and improve soil properties, such as organic amendments to be applied by Shaaban *et al*., (2013). The physical and chemical properties in the soil affected by salts are improving through the use of organic a material, which leads to enhancing plant growth through, accelerating the exchange of harmful salts in the soil and removing salts in root zone by Clark *et al*., (2007). The decomposing organic matter increases the concentrate of carbon dioxide in soil, which releases H^+ which promotes the dissolution of calcium carbonate ($CaCO_3$) as the result of the lowering of the soil's acidity and releases more calcium for the exchange of sodium by Ghaffor *et al*., (2008).

Therefore, adding (FYM) to soil remediation is important for maintaining soil fertility and crop productivity by Wong *et al*., (2009) and Cha-um and Kirdmanee, (2011). To improve saline soils a large proportion of exchangeable sodium with calcium ions must be removed. This reaction can be achieved quickly using chemical modifications of the soil, such as calcium chloride or calcium sulfate (gypsum), followed by filtration to remove salts after the salts react with the modifications in an acidic environment. However, adding artificial acids to the soil is an expensive alternative for farmers. Hence, alternative and readily available acidic substances, such as manure can also help dissolve calcium compounds in the soil. However, Gypsum ($CaSO_4 2H_2O$) is the most common modification of soda soil reclamation and reduction of soil sodium has been indicated Mahmoodabadi *et al*., (2013). Gypsum is also a source of sulfur and calcium for plants it is moderately soluble in water and affordable for farmers in developing countries and this was mentioned Yildiz *et al*., (2017). Organic matter is a popular amendment of organic acids that has been shown to improve the physical properties of soil and increase dissolved calcium, both properties are required for black and saline soil reclamation by Choudhary *et al*., (2017). Prapagar *et al*., (2012) observed that adding gypsum with organic residues, cow manure and rice husk reduced the pH values of saline and soda soil compared to treating gypsum only, and this change is mainly due to the acids formed during the decomposition of the organic matter. The combination of gypsum and compost accelerated the recovery soil compared to either 5.2g of gypsum or 50g of organic matter per kg^{-1} of soil alone reported by Mahmudabadi *et al*., (2013). In northwestern India the combined use of organic and inorganic fertilizers increased the concentrations of nutrients available to plants by Manna *et al*., (2007). Cattle manure (20-40 Ton ha^{-1}) of soil organic matter, nitrogen (N) and phosphorous (P) and soil permeability increased it arrived Gupta *et al*., (2016) and Wang *et al*., (2017). The advantages of combining gypsum and organic materials have been documented around the world they include stimulating

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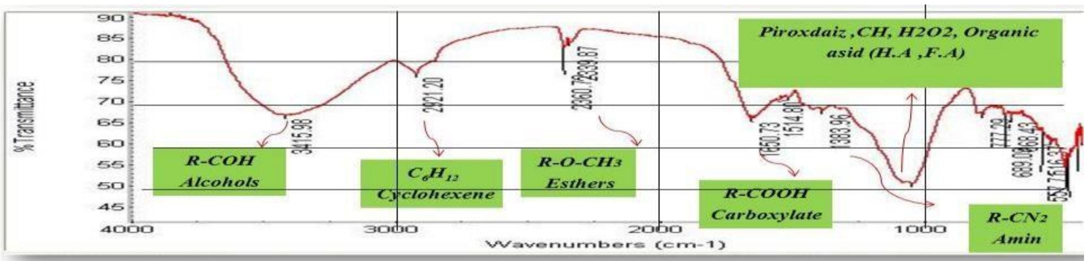
soil microbiological activity in Chile it arrived Celis *et al*., (2013), enhancing infiltration rate in arid soils in Iran by Mazahiri and Mahmoud Abadi, (2012) and reducing soil electrical conductivity (EC) and exchangeable sodium ratio (ESP).

MATERIALS AND METHODS

Materials:

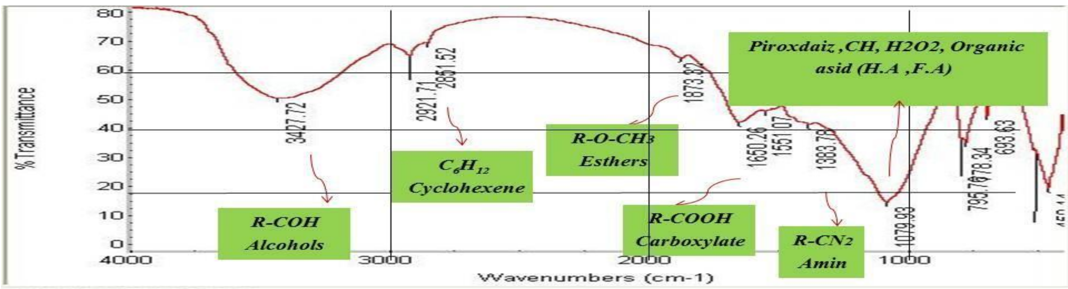
The FYM is a sensitive fraction Due to its high mobility; the movement is significant to the cycling and distribution of nutrients, such as N and P, in ecosystems. Soluble organic acids that comprise, especially carboxylic and phenolic, which participate in many chemical reactions in the soil, such as organic metal complication, increasing the ion adsorption rate. These acids make exchangeable, making it nontoxic to plants. Therefore, in tropical soils, these organic acids can compete with other ions, such as phosphate ions, for adsorption sites, increasing P availability to plants. The organic acids can also form stable organometallic complexes with Fe and Al in a wide pH range. In addition, greater soil structural quality (e.g., higher aggregate stability, soil porosity, and water retention) is positively associated to movement in the soil profile, since its movement and sorption are related to the water fluxes.

Two experiments were conducted the first is the columns experiment during summer season 2019 and the second experiment was carried out in the Research Farm of Port Saied Agricultural Research Station, Port Saied Governorate, North East Dealta, Egypt, at winter season (2019 - 2020). Concerning the columns experiment, the treatments were completely decomposed organic matter (FYM). Fully decomposed organic matter was separated into three volumes (the original volume (Coarse), smaller than 2 to 1 mm (medium), less than 1 mm micron (soft)). The rate of addition was 30 m ^{3} per fed, and the addition was adjusted according to the density of each volume single results of analysis are recorded in Fig and Table (A, B and C).



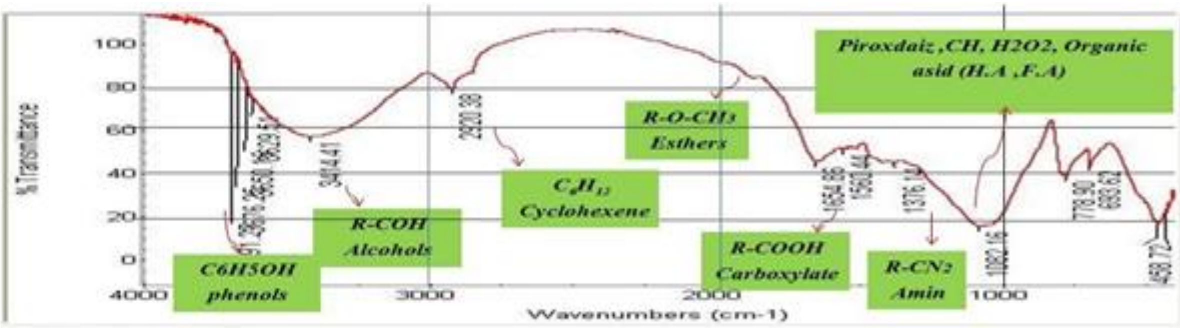
Organic physical and chemical analysis												
Material size		Weigh of Cubic (Kg m-3)		NH_4^+ (mg L $^{-1}$)	NO_3^- (mg L $^{-1}$)	Total N (%)	O.C (%)	O.M (%)	Ach (%)	C/N:R	P (%)	K (%)
Coarse Organic		560		435	30	1.46	29.9	51.54	45	1:20.5	1.15	1.23
				Soluble cations and anions (me/L)								
A.W (%)	H.C (Cm/h $^{-1}$)	T.P (%)	B.D (Mg m $^{-3}$)	PH	EC dSm $^{-1}$	Hco_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
31.8	2.0	41.3	0.56	6.55	15.38	0.0	81.6	118.38	18.2	3.58	57.4	120.8
SAR %	ESP %	Total Sugar (%)		Total phenol (%)		Total carbohydrate (%)		Total Proteins (%)			H.A (%)	F.A (%)
16.1	22.6	1.003		0.356		18.88		9.05			8.44	2.9

Fig and Table A. Coarse volume. *Diffuse reflectance Fourier transforms infrared* (FT-IR) spectra, some physical* and chemical*characteristics of the investigated original volume organic matter(FYM).



Organic physical and chemical analysis												
Material size		Weigh of Cubic (Kg m-3)		NH_4^+ (mg L $^{-1}$)	NO_3^- (mgL $^{-1}$)	Total N (%)	O.C (%)	O.M (%)	Ach (%)	C/N:R	P (%)	K (%)
Medium Organic		320		555	20	1.16	31.9	54.99	55	1:27.5	0.99	1.07
				Soluble cations and anions (me/L)								
A.W (%)	H.C (Cm/h $^{-1}$)	T.P (%)	B.D (Mg m $^{-3}$)	PH	EC dSm $^{-1}$	Hco_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
33.2	2.1	43.1	0.32	6.6	14.33	0	78.72	107.66	10.4	1.58	53.3	121.1
SAR %	ESP %	Total Sugar (%)		Total phenol (%)		Total carbohydrate (%)		Total Proteins (%)			H.A (%)	F.A (%)
20.5	29.2	0.524		0.43		13.67		7.19			8.12	2.88

Fig and Table B. Medium volume. *Diffuse reflectance Fourier transforms infrared* (FT-IR) spectra, some physical* and chemical* characteristics of the investigated original volume organic matter (FYM).



Organic physical and chemical analysis												
Material size		Weigh of Cubic (Kg m⁻³)		NH_4^+ (mg L⁻¹)	NO_3^- (mg L⁻¹)	Total N (%)	O.C (%)	O.M (%)	Ach (%)	C/N:R	P (%)	K (%)
Soft Organic		500		512	36	1.52	29.2	50.34	39.5	1:19.2	1.35	1.47
				Soluble cations and anions (me/l)								
A.W (%)	H.C (Cm/h⁻¹)	T.P (%)	B.D (Mg m⁻³)	PH	EC dSm⁻¹	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
31.8	2.0	41.3	0.5	6.65	15.22	0.0	79.68	118.2	8.32	12.66	57.4	119.5
SAR %	ESP %	Total Sugar (%)		Total phenol (%)		Total carbohydrate (%)		Total Proteins (%)			H.A (%)	F.A (%)
14.0	19.5	0.655		0.382		21.56		9.4			8.64	3.5

Fig and Table C. Soft volume. ***Diffuse reflectance Fourier transforms infrared*** **(FT-IR) spectra, some physical* and chemical* characteristics of the investigated original volume organic matter (FYM).**

The first part was added separately without gypsum and was added when filling the soil column and mixed with a 10 cm surface layer. The second part was soaked for a week in the calculated gypsum needs solution and the dissolved concentration of the gypsum solution was 25 equivalent / liter, then it was filtered, dried and mixed with a layer of 10 cm when filling the soil column, then the soaking solution was added to it. The third part was mixed with the gypsum block when filling the soil column into a 10 cm surface layer. As shown in Figures and the attached table for analyzing each volume and components it contains, which are compatible with the infrared analysis Soil was collected from South Port Said Regional Research Station, Port Said Governorate. This soil is classified as a saline sodic soil according to the Global Soil Reference Base (FAO, 2014).

We collected soil from the field in layer ranging in depth from 0 to 30 cm in depth (Rupp, 2016). During the collection, we observed that the soil showed signs of salt crusts on the surface and high concentrations of salt sodium. After collection, the soil material was air dried, crushed and sieved to pass through a 2.0 mm sieve. Some physical and chemical properties of soil which were determined according to the standard methods outlined by (Klute, 1986) and (Page, 1982) and results of analysis are recorded in Table (1).

Table 1. Some physical and chemical characteristics of the investigated soils.

Characteristics Columns initial Soil analysis													
Physical analysis													
Soil depth, (cm)		**$CaCO_3$ %**		**O.M (FYM) %**		**Particle size distribution%**						**Texture class**	
						Coarse sand%		**Fine sand%**		**Silt%**	**Clay%**		
0 - 30		5.6		0.39		9.9		15.8		15.35	58.95	Clay	
Bulk density ($g\ cm^3$)		Hydraulic Conductivity ($Cm\ h^{-1}$)			Total porosity (%)		CEC ($mq\ 100g^{-1}$)		Soil moisture content				
									F.C%		W.P%	A.W%	
1.46		1.4			30.38		32.7		37.3		17.26	19.83	
Chemical analysis ($meq\ L^{-1}$)													
PH	EC ($dS\ m^{-1}$)	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	SAR %	ESP %	Available macronutrients ($mg\ kg^{-1}$) N	P	K
8.5	42	6.08	399.3	182.5	108.4	169.5	304.9	5.2	25.8	37.16	12	3.75	44.6

Soil columns setup

Two experiments were conducted the first is the Columns experiment during summer season 2019 and the second in the Experimental Research Farm of Port Saied Agricultural Research Station, Port Saied Governorate, North East Dealta, Egypt, winter season (2019 - 2020) at was conducted at institute Soils, Water and Environment. (SWERI) Agricultural Research Center (ARC), Giza, Egypt, in the filter columns, From April to December 2019. Each column was manufactured using PVC pipes 45 cm high and 11 cm in diameter (inner diameter 10 cm). These columns were set on a wooden work table and covered underneath. To facilitate drainage, each cylinder bottom was provided with a piece of filter paper, a piece of woolen fabric and a plastic filter, all were tied tightly with a rubber string and collected the juices in 1L plastic soda bottles. Then, the filter columns are filled with soil material, already mixed and uniformly moist to avoid high bulk density up to a depth from 0- 30 cm. There was 10 cm of headspace in each column to facilitate to give a suitable water level. The account was done dose of gypsum required for soil restoration, which is sufficient to reduce the initial (ESP) of soil at (37.16), requirements (GR). A gypsum requirement (GR) was calculated so as to reduce the ESP to 15 % (U.S.S.L.S, 1954). Percentage of purity of the used agricultural gypsum was 85 % purity and its addition rate was 12.46 Mg fed-1. To compare the effectiveness of method of application of gypsum to saline sodic soils gypsum requirements were added using the following methods of application: GR= ESPi – ESPf /100 (CEC*1.72). Surface application, Gypsum was applied at the rate of half of the gypsum cycle for the field experiment and at the rate of the entire amount to test the columns on the surface of soil columns with a layer (0-10) and mixed in the field experiment in a layer (30 cm) with an amount of water. As for the organic matter, each volume was divided into three parts, and the added quantities were determined according to the density of each volume.

A- The first section is added alone without any other additives.

B- The second section, soak in the gypsum solution for a week before adding it to the columns at a concentration of 25 equivalents to a liter.

C- The third section was mixed with gypsum before adding to the columns at a rate of 12 grams per / columns.

Amount of the water volume was about 2 L. Each treatment was replicated eight months and the soil columns were subjected to leaching. Upon termination of leaching, the soil columns were divided into three layers (0 – 10, 10 - 20 and 20 – 30 cm) and the soil material was air dried then, crushed, sieved through a 2.0 mm sieve and stored in plastic bags for chemical analysis and characteristics physical, three undisturbed soil core samples were taken for measurements of bulk density (BD), hydraulic conductivity (HC) and moisture pF curve. Then a field confirmation experiment was conducted in the same study area, Statistical data analysis all experiments described were repeated independently with three replications each time. A completely randomized design was used the experimental data were analysis software (SAS) system. The differences among the mean of the treatments were recorded using LSD0.05 using COSTAT (Cary, NC, USA, version 6.3.1.1, July 11, 2001).

RESULTS AND DISCUSSION

Effect of size organic matter individually and soaking or mixing with gypsum on leachates of columns:

Leachate EC

Figure 1 shows that all treatments application either, singly or in combination caused a pronounced increased the leachate EC when compared with the control treatment untreated soil. This trend may be attributed to the movement of soluble salts and to the favorable effect of amendments on the leach ability through improving the physical properties of the soil.

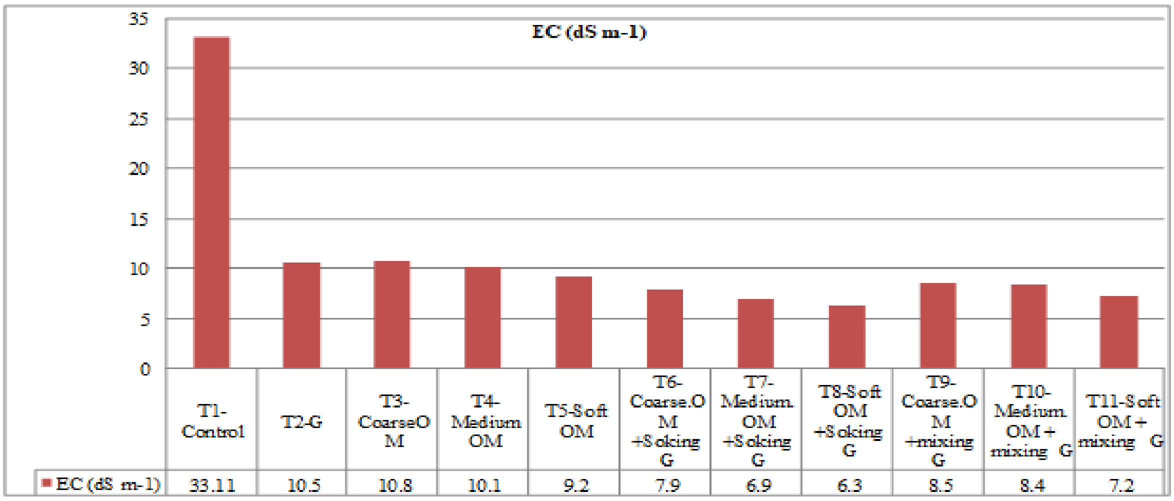


Figure 1. (EC dSm^{-1}) in leachates under different treatments

Also, all treatments were significantly higher mean leachate EC's in columns compared to the control. Treating soil with amendments increased salt removal by 237.63, 247.26, 224.75, 131.51,154.01, 121.86, 109.00, 147.58, 170.09 and 221.54% due to T2, T3, T4, T5, T6, T7, T8, T9, T20 and T11, respectively compared with control. It worth to mentioned that, the application of gypsum alone or organic matter (FYM) amendments at coarse and medium size were caused the highest values of leachate EC compared to the application of organic matter combined with gypsum. On the other hand, organic matter (FYM) mixing with gypsum recoded the higher values of leachate EC than the organic matter (FYM) soaking in gypsum. These results may be due to the benefits of dissolution rates at high sodicity followed by longer sustained release of calcium are possible, also soils were surface crusting and infiltration problems shallow mixing of organic matter (FYM) with gypsum in the surface layer is considered best For salt-affected soils, adding organic matter (FYM) can accelerate sodium leaching reduce electrostatic precipitation and electrical conductivity (EC), increase water retention capacity, and general stability Lax *et al*., (1994) and Vijayasatya *et al*., (2015), Tajada *et al*. (2006), and Mahdy, (2011).

The principle of reclamation processes can be explained by the fact that organic addition of soil can activate soil microbes to produce organic acids equivalent to alkaline soils Khorandi and Nourbakhsh, (2007). Therefore, the positive effect of (FYM) was reported by Yu *et al*., (2010) by increasing the concentrations of nutrients and organic elements while reducing salinity and sodium. The physical structure of the soil is also improved and more effective salt filtration is obtained with the addition of organic soil Meng *et al*., (2016) reported on the positive effect of (FYM) on soils who determined that applying (FYM) together with deep tillage was more effective in management.

Leachate pH

Figure 2 show that the leachates' pH decreased in all treatments compared with control and initial. Value, where the significant differences (at 0.05). The lowest pH of leachates was observed in T6 applied gypsum alone follow the T2. On the contrary the highest values were obtained in T7. Moreover, results revealed that gypsum exhibited a relatively greater effect on reducing soil pH. The decrease in soil pH due to gypsum application was probably due to, mainly the replacement of sodium by calcium and the formation of neutral salts with $SO4^{=}$. Besides, large quantities of CO_2, which evolved during leaching, process the decomposition of the organic matter such as compost by activity of microorganisms resulting increase of organic and inorganic acids pH. Similar observations were also reported by (Abdel-Fattah 2012).

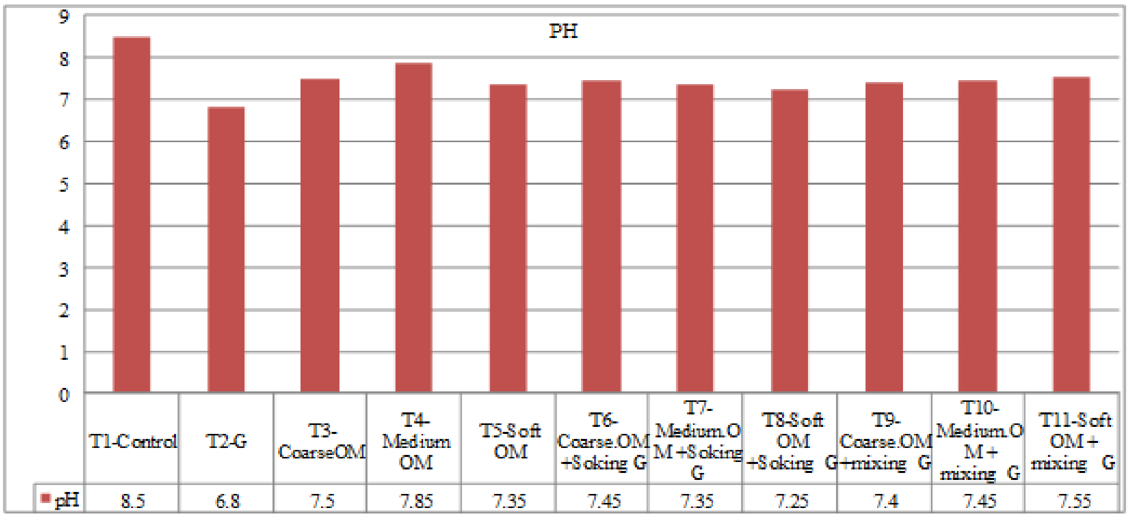


Figure 2. pH in leachates under different treatments

The concentration of Na^+ leachates:

The concentration of Na^+ leachate was higher and statistically significant in the organic matter at different particles and gypsum amended individually or combination addition in soils compared with the control. Regardless in figure 3 showed that the effect of the organic matter (FYM) application at different size, individually or combined with gypsum at different methods (soaking or mixing) the results indicate that both organic matter (FYM) at coarse size and gypsum alone gave the highest values of Na^+ leachates compared with other treatments. It seems that the presence of calcium as a competing ion in the leaching water may repel sodium in soil exchange complex, resulting to the highest concentration of sodium in the leachate solution. Conversely, the minimum Na^+ leachates were observed by control treatment. Also, mixing organic matter with gypsum recorded the higher Na^+ leachates than organic matter soaking in gypsum. These results suggest that application of organic amendments can facilitate efficient replacement of Na^+ on the exchange sites by adding significant amounts of divalent cations and may further prevent the entry of Na^+onto the exchange phases. Jalali and Ranjbar (2009) who found that application of manure caused to an increase in leaching of sodium. Addition of organic matters and gypsum, the leachate Na^+ increased. This increase in the Na^+ might be attributed to the increased gypsum dissolution in presence of organic matter which led to higher salinity (Najme and Majid 2013).

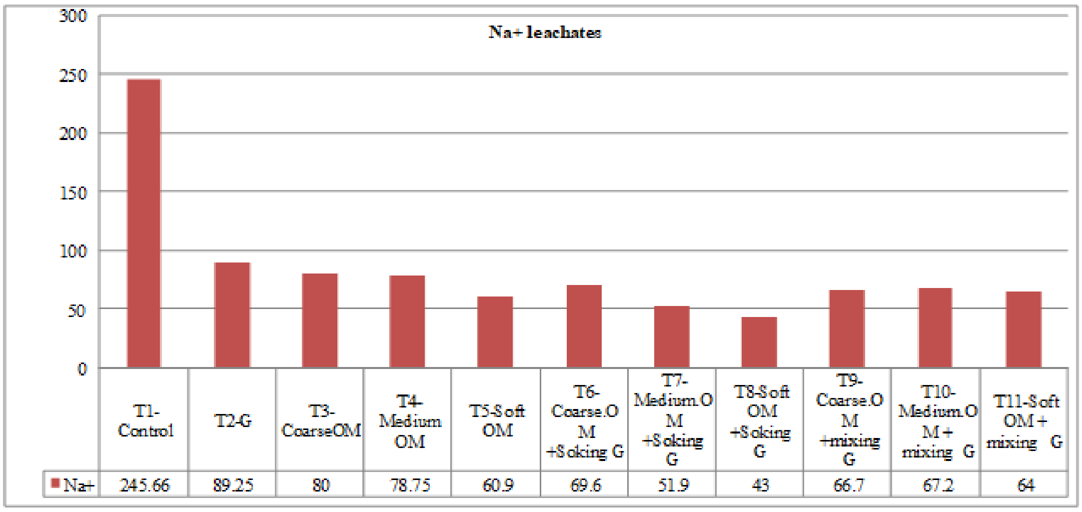


Figure 3. Concentration of Na^+ in leachates under different treatments

The effect of reclamation materials added from the organic matter in their different sizes, with or without gypsum, on the properties in three depths of the columns experiment.

Soil salinity:

The residual total soluble salts in soil in the three depths significantly affected electrical conductivity (EC dSm-1) in the end of the column experiment are shown in Table (2). Leaching was effective in decreasing soil salinity since the EC values ranged between 9.4 to 5.0 dsm-1 at end the 8 of leaching of soil in comparison with initial soil (42.0 dSm-1). It is clear that the minimum EC values were recorded with application of T11 followed by T5. The EC values were 37.0 for untreated soil, 9.94, 11.21, 6.03, 5.98, 9.51, 8.37, 6.41, 7.47, 6.34 and 5.28 dsm-1 for T2, T3, T4, T5, T6, T7, T8, T9 and T10, respectively,

Table 2. Effect of different treatments and soil depth on EC (dSm^{-1})

Treatments	Soil depth (cm)			Mean
	0-10	10-20	20-30	
T1- Control	37.0	37.5	38.7	37.73
T2- Gypsum	9.4	9.92	10.1	9.94
T3- Coarse OM	10.8	11.33	11.5	11.21
T4-Medium OM	5.25	5.96	6.9	7.03
T5- Soft OM	5.0	6.54	6.4	5.98
T6- Coarse.OM + Soaking Gypsum	8.95	9.78	9.8	9.51
T7- Medium.OM + Soaking Gypsum	7.5	8.81	8.8	8.37
T8- Soft OM + Soaking Gypsum	6.81	6.14	6.3	6.41
T9- Coarse.OM + mixing Gypsum	7.3	7.5	7.6	7.46
T10- Medium.OM + mixing Gypsum	6.45	6.47	6.1	6.34
T11- Soft OM + mixing Gypsum	5.1	6.36	6.0	5.82
L.S.D. at 0.05	2.75	2.64	2.56	

Efficiency of the treatments was, T11>T5>T4>T10>T8>T9>T7>T6>T2>T3, respectively. These results may be due to in saline or sodic soils, the addition of organic matter (FYM) can accelerate the leaching of Na+, decrease the ESP and electrical conductivity, and increase water infiltration, water-holding capacity, and aggregate stability.

Soil reaction

The soil-pH at end of the columns experiment are shown in Table (3) the data showed that different treatments significantly affected on soil-pH. The minimum pH values were recorded with application of T6 followed by T9. The initial soil-pH (having 8.5) was reduced to 8.80 for untreated soil,7.80, 7.76, 7.86, 7.93,7.48, 7.71, 7.70, 7.65, 7.86, and 7.91 for T2, T3, T4, T5, T6, T7, T8, T9, T10 and T11, respectively. The reduced in soil pH due to gypsum application was probably due to combination of more than one factor, mainly the replacement of sodium by calcium and the formation of neutral salts with SO4=. This decreasing may be due to removal of exchangeable sodium from the soil column. Moreover, gypsum solubility is also enhanced because of the increased activity coefficient of calcium and sulfate as a result of increased ionic strength of solution and the formation of the sodium sulfate ion pair. Likewise, large quantities of CO2 must have been evolved during leaching process, some of which would become soluble in soil solution giving carbonic acids.

Concerning organic matter (FYM), the decreases in soil-pH in soil this illustrates the indirect effect of decreased sodium and the direct effect of organic acids, which must have been formed during decomposition of compost. Yield (Smith et al., 1996). Additional acidifiers may be required for optimal growth. The main advantage of gypsum and cow manure is that gypsum supplies Ca2+ to substitute the adsorbed Na+ while manure increases the content of CaCO2 in the soil, also releasing more Ca2+ for the substitution of Na+ (Mohamed, 2014). Our results are similar to those of (Tiwari and Jain, 1992) and (Izhar-ul-Haq et al., 2007). These studies found that the best results came from the combined use of gypsum and manure to reduce soil pH. Wong et al (2009) determined that addition of organic materials (FYM) increased soil microbial biomass while added gypsum decreases pH.

Table 3. Effect of different treatments and soil depth on soil pH

Treatments	Soil depth (cm)			Mean
	0-10	10-20	20-30	
T1- Control	8.1	8.3	8.5	8.3
T2- Gypsum	7.8	7.85	7.75	7.8
T3- Coarse OM	7.9	7.85	7.55	7.76
T4-Medium OM	7.9	7.85	7.85	7.86
T5- Soft OM	7.95	7.9	7.95	7.93
T6- Coarse.OM + Soaking Gypsum	7.35	7.5	7.6	7.48
T7- Medium.OM + Soaking Gypsum	7.5	7.75	7.9	7.71
T8- Soft OM + Soaking Gypsum	7.45	7.75	7.9	7.70
T9- Coarse.OM + mixing Gypsum	7.7	7.75	7.5	7.65
T10- Medium.OM + mixing Gypsum	7.85	7.85	7.9	7.86
T11- Soft OM + mixing Gypsum	7.85	7.95	7.95	7.91
L.S.D. at 0.05	0.101	0.135	0.258	

Exchangeable sodium percentages (ESP%):

Exchangeable sodium percentages of different treatments are shown in Table (4) indicated that all treatments were effective in reducing the soil ESP to <15 after eight leaching in columns experiment. ESP reductions were significantly in soils amended with organic amendments (FYM) at different sizes, gypsum invidually and when the conjunction organic (FYM) and gypsum than in the control soils table 4. It is clear that conjunctive applications of organic amendment (FYM) in different size soaking and mixing with gypsum were highly effective in decreasing soil ESP compared to their individual. Also, data showed that applied organic amendment (FYM) with gypsum soaking or mixing not different.

Table 4. Effect of different treatments and soil depth on soil exchangeable sodium percentages (ESP %)

Treatments	Soil depth (cm)			Mean
	0-10	10-20	20-30	
T1- Control	35.0	34.0	36.0	35.0
T2- Gypsum	13.3	15.0	15.9	14.73
T3- Coarse OM	18.1	18.4	18.8	18.43
T4-Medium OM	16.8	13.9	14.7	13.58
T5- Soft OM	14.7	15.0	14.5	14.73
T6- Coarse.OM + Soaking Gypsum	14.4	15.1	16.2	15.23
T7- Medium.OM + Soaking Gypsum	14.1	14.5	15.3	14.63
T8- Soft OM + Soaking Gypsum	13.6	13.6	13.8	13.56
T9- Coarse.OM + mixing Gypsum	14.5	16.0	16.8	15.76
T10- Medium.OM + mixing Gypsum	14.8	15.4	15.0	15.06
T11- Soft OM + mixing Gypsum	14.2	14.4	14.5	14.36
L.S.D. at 0.05	1.87	1.85	2.09	

Higher ESP reductions seen in soils that received both gypsum and organic matter (FYM) may be attributed to the release of Ca2+ from the organic amendments supplementary Ca2+ provided by gypsum, and Ca2+contributions from the dissolution of native calcite by compost addition, which likely enhanced the Na+ - Ca2+ exchange rate between the soil solution and exchange phases. This increase in soil exchangeable Ca2+ levels by organic amendments (FYM) likely increased the displacement of Na+ from exchange sites and enhanced its leaching from the soil profile, thus helping the soils to be remediated at a much faster rate. Other similar studies also indicated that use of gypsum integrated with organic material (FYM) like water hyacinth compost and rice straw compost reduced ESP of saline-sodic soils as compared their sole application (Abay and Kasahun, 2019). Abou El-Defan et al. (2005) studied the effect of farmyard manure, gypsum and mix of them on some characteristics of soil irrigated with drainage water. They found that ESP values significantly decreased with different treatments, especially with application of farmyard manure mixed with gypsum.

Total soil porosity (%):

Data in Table 5 revealed that total porosity was significantly affected by the different treatments. However, the values of soil total porosity increased due to all tested treatments, gypsum in the absence or presence of organic matter in different sizes compared with initial value (39.24 %). With regard to the effect of method of organic matter (FYM) application with gypsum in soaking or mixing application to the saline sodic soil, Table 5 shows that values of the total porosity were higher in soils treated with organic matter in different sizes soaking in gypsum than in gypsum mixing ones. Therefore, the highest value of soil total porosity (45.85%) was registered with T8 - Soft OM + soaking in gypsum.

Table 5. Effect of different treatments and soil depth on soil total soil porosity (%)

Treatments	Soil depth (cm)			Mean
	0-10	10-20	20-30	
T1- Control	39.00	39.10	38.14	38.74
T2- Gypsum	44.7	42.45	41.85	43.00
T3- Coarse OM	40.95	41.10	39.3	40.45
T4-Medium OM	41.85	43.80	43.80	43.15
T5- Soft OM	40.8	40.65	40.04	40.49
T6- Coarse.OM + Soaking Gypsum	41.85	45.00	44.20	42.29
T7- Medium.OM + Soaking Gypsum	43.50	42.45	44.70	43.55
T8- Soft OM + Soaking Gypsum	46.05	44.85	44.40	45.10
T9- Coarse.OM + mixing Gypsum	43.95	43.80	43.80	43.85
T10- Medium.OM + mixing Gypsum	39.75	45.30	40.0	42.50
T11- Soft OM + mixing Gypsum	42.9	40.05	42.45	41.80
L.S.D. at 0.05	1.76	1.65	1.46	

On the other hand, the lowest value was (35.0 %) was observed by untreated soil. These results may be attributed to calcium accumulations on the exchange sites due to combination organic matter with gypsum have improved soil aggregation thus reduced the bulk density, as well as increased soil porosity. Hussain, et al., 2001., found that physical properties like bulk density, porosity, void ratio, water permeability and hydraulic conductivity were significantly improved when FYM (10 t ha-1) was applied in combination with chemical amendments resulting enhance in sodic soil. (Larney and Angers, 2012) who reported that combinations of organic amendments resulted in substantial flocculation and in the formation of a large number of soil aggregates. Improvements in soil structure, decreases in bulk density and increases in soil porosity.

Soil hydraulic conductivity H.C. (cm h^{-1}):

Data in Table 6 show that the values of hydraulic conductivity were increased by adding different treatments compared to the control. Data indicated that the values of hydraulic conductivity were higher when organic matter (FYM) combined with gypsum than the application gypsum alone. The highest values of hydraulic conductivity were observed by applying Soft OM + soaking with gypsum treatment compared to other treatments and control. These results may be due to Improvements in soil aggregate stability as well as saturated hydraulic conductivity was more enhanced were organic matter combined with gypsum. Similar results were obtained by Esmaeil (2018) who found that the highest values of hydraulic conductivity and total porosity were observed by applying gypsum + organic matter + sulfur treatment in compared to control and other treatments. Vijayasatya, et al. (2015) revealed that combined applications of organic amendment and gypsum produced a significant effect on soil hydraulic conductivity.

Table 6. Effect of different treatments and soil depth on soil H.C (cm h^{-1})

Treatments	Soil depth (cm)			Mean
	0-10	10-20	20-30	
T1- Control	1.1	1.2	1.1	1.15
T2- Gypsum	1.3	1.4	1.3	1.35
T3- Coarse OM	1.5	1.5	1.4	1.45
T4-Medium OM	1.5	1.5	1.5	1.5
T5- Soft OM	1.5	1.5	1.5	1.5
T6- Coarse.OM + Soaking Gypsum	1.5	1.6	1.5	1.55
T7- Medium.OM + Soaking Gypsum	1.6	1.5	1.6	1.55
T8- Soft OM + Soaking Gypsum	1.6	1.6	1.6	1.6
T9- Coarse.OM + mixing Gypsum	1.5	1.5	1.5	1.5
T10- Medium.OM + mixing Gypsum	1.4	1.5	1.5	1.45
T11- Soft OM + mixing Gypsum	1.5	1.4	1.5	1.45
L.S.D. at 0.05	0.082	0.086	0.066	

Physical and chemical soil properties of field experiment:

Data in Table 7 indicated that application of organic matter mixing with gypsum led to decrease in soil pH, EC and ESP, however the total porosity, hydraulic conductivity and available water were increasing. The highest values of hydraulic conductivity, total porosity and available water were found by applying organic matter (FYM) at soft size with gypsum treatment compared to control and other treatments, while in the same time this treatment induced the lowest values of soil pH, EC and ESP.

Table 7. Effect of organic matter at different sizes, and gypsum, the chemical and physica properties of soil.

	Chemical properties			Physical properties		
Treatments	**pH**	**EC (dS m-1)**	**ESP %**	**T.P (%)**	**H.C (Cm h-1)**	**A.W (%)**
Control	8.5	39.4	25.7	30.43	1.12	21.94
Gypsum	7.9	17.5	15.9	36.81	1.56	23.86
Coarse.OM +soaking Gypsum	7.9	13.5	12.8	38.32	1.67	25.80
Medium.OM + soaking Gypsum	7.7	11.7	12.6	41.09	1.74	26.14
Soft OM + soaking Gypsum	7.3	10.8	9.30	43.45	1.78	29.2
LSD 0.05	0.25	4.24	6.87	1.32	0.32	9.26

CONCLUSION

Generally, it can be concluded that organic matter (FYM) and gypsum application led to improve saline-sodic soil chemical and physical properties and accelerated the reclamation process of salt affected soils. An effective reclamation procedure for saline sodic soils is removal of undesirable Na^+ by addition of some $Ca2^+$ source paralleled with leaching of this Na^+. However, the combination of compost + gypsum proved to be the best soil amendment for reducing soil EC, pH, ESP and improving porosity, hydraulic conductivity and available water.

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فاعلية حجم المادة العضوية المستخدمة في استصلاح التربة الملحية الصودية

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يتطلب تحسين التربة الملحية إدارة متكاملة لتحسين خصائص التربة ، وزيادة إنتاج المحاصيل وجودتها ، وقد تم التخطيط لدراسة وتقييم الاستخدام المشترك للتعديلات العضوية وغير العضوية لتحسين خواص التربه، حيث يتم استخدام العديد من الطرق لاستصلاح التربة المالحة، التحسين المادي (الحرث العميق) والتحسين الكيميائي الجبس،كلوريد الكالسيوم ، الحجر الجيري ، حامض الكبريتيك ، الكبريت وكبريتات الحديدوز) ، وتعتمد على إزالة الصوديوم القابل للتبديل والصوديوم المذاب وتغيير التركيب الأيوني للتربة عن طريق الترشيح لأملاح الصوديوم خارج قطاع التربة. إن طرق التحسين البيولوجي باستخدام المواد العضوية الحية أو الميتة (المحاصيل ، والسيقان ، والقش ، والسماد الأخضر ، وروث الماشيه ، والسماد ، وحمأة الصرف الصحي) لها تأثيران مفيدان رئيسيان على استصلاح التربة المالحة والقلوية ، وتحسين بنية التربة ونفايتها. اولا- تم اجراء تجربيتن على ارضى مزرعه مركز البحوث الزراعيه - بجنوب مدينه بورسعيد ارض ملحيه قلويه وكان EC لهذه الارض(42 dS m-1) وكان ال (8.5 PH) ونسبة ال (ESP 37.16%) وهى ارض طينية ثقيلة . احداهما تجربة معملية فى أعمدة لتحديد كفائه المواد المستخدمه والتحكم فى أسلوب تنفيذ التجربة خلال فصل الصيف لعام ٢٠١٩من ابريل حتى ديسمبر. والتجربة الثانية كانت حقلية على نفس الأرض خلال الموسم الشتوى ٢٠١٩ / .٢٠٢٠ وتم تحديد معدل 30 م٣ من المادة العضوية حيث تم تصغير حجم الماده العضويه الى الحد الممكن ثم فصلها الى احجام من خلال مناخل الفصل وتم تعديل معدل الاضافة طبقا لكثافه كل حجم بعد الفصل: الحجم الآول استخدم المادة العضوية فى الحجم الخشن بدون فصل. الحجم الثانى تم فصل المادة العضوية الى الحجم الآقل من ٢ ملمكرون وأكبر من ١ ملمكرون. الحجم الثالث وهو الحجم الناعم حيث كان الحجم الآقل من ١ ملمكرون. تم تحديد كمية الجبس المضافة تبع (GR= ESPi – ESPf /100 (CEC*1.72) . ثانيا – تم فصل كل حجم من احجام المادة العضوية السابقة الى ثلاثه أجزاء. الجزء الأول تم اضافته منفردا بدون جبس وتم اضافته عند تعبئة عمود التربة والخلط مع طبقة ١٠ سم السطحية . الجزء الثانى تم نقعه لمدة اسبوع فى محلول الاحتياجات الجبسية المحسوبة وكان التركيز الذائب لمحلول الجبس 25 ممكافئ / لتر ثم تم ترشيحه وتجفيفه وخلطه مع طبقة ١٠ سم عند تعبئه عمود التربه ثم تم اضافة محلول النقع عليه . الجزء الثالث تم خلطه مع المقرر الجبسى عند تعبئة عمود التربه فى طبقه ١٠ سم السطحية.. ثم تم اجراء عملية الغسيل والرشح لمده 5 ايام ثم ترك التربه لتجف ويحدث التفاعل والتبادل لمدة ٢٥ يوم وهذا حدث كل شهر لمده ٩ اشهر وتم اختيار افضل التطبيقات وجرى تنفيذه فى الحقل مباشرة. ثالثا – تم اخذ عينات من التربة بعد انتهاء التجارب وتم اجراء التحليلات عليها وتم تقدير بعض الخصائص الكيماوية والفيزيائيه لتحديد أفضل المواد المستخدمة وتقيم الطرق المستخدمة وتم اجراء التحليلات الاحصائية والتى اوضحت. أفضل المواد التى زادت من الرشح وأعطت اكبر كميه مياه صرف كانت المادة العضوية فى الحجم المتوسط يليها الماده العضويه فى الحجم الناعم الذى تفوق على الحجم المتوسط فى خفض الملوحة ونسبة الصوديوم المدمص. كان للحجم الناعم الآفضلية فى تحسين خواص تربة الآعمدة المدروسة فى عمق (٠ - ١٠) فى كل المعاملات سواء كان اضافه فردية او نقع من الجبس أو خلط مع الجبس فى تعديل التوصيل الكهربائى وكذلك المسامية الكلية والتوصيل الهيدروليكى والماء الميسر، بينما تفوقت اضافة الجبس منفرد فى تعديل الصوديوم المتبادل والصوديوم المدمص. بينما فى عمق (١٠ - ٢٠) وعمق (٢٠ - ٣٠) كان هناك تبادل بين كل المعاملات رغم تفوق الحجم الناعم المنقوع فى الجبس او المضاف بصورة فردية. بالنسبة لتجربة الحقل وضح بصورة كبيره تفوق الحجم الناعم ا المنقوع مع الجبس على كل المعاملات فى كل الخصائص الكميائيه مثل التوصيل الكهربائى ونسبة الصوديوم المدمص ونسبة الصوديوم المتبادل .