Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Effect of Glauconite, Gypsum and Leaching Requirements on the Productivity of Salt affected Soils

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ABSTRACT

The application of leaching requirements and soil amendments such as glauconite and gypsum are management practices for improving the productivity of salt affected soils. A field trial was conducted at El-Hamoul District, Kafr El Sheikh Governorate during two winter seasons (2016/017 and 2017/018) to investigate the effect of irrigation with leaching requirements (LR), ie. without (I1), 5% (I2) and 10 % (I3) and some soil amendments, ie. without (A1), gypsum (A2), glauconite (A3) and gypsum combined with glauconite (A4) on improving saline-sodic soils, sugar beet yield, water productivity and economic returns. The obtained results could be summarized as follows: Irrigation with LR. 10 % (I3) received the highest amount of irrigation water applied compared to other treatments in both seasons. The application of 10 % LR (I3) and gypsum and/or glauconite decreased soil salinity, sodicity, penetration resistance and bulk density but increased basic infiltration rate and total porosity of soil. Irrigation with 5% or 10 % LR with soil amendments increased sugar beet root, top and sugar yields in both seasons. The interaction between I3 and A4 achieved the highest root yield, top yield, sugar yield, irrigation water productivity (IWP), net return, net return from water unit and economic efficiency in both seasons. It could be concluded that the interaction between I3 and A4 resulted in enhancing saline-sodic soils productivity and recorded the highest values of net return and economic efficiency for sugar beet crop.

Keywords: Glauconite, gypsum, leaching requirements, salt affected soils and sugar beet crop.

INTRODUCTION

In Egypt, nearly 33.00% of total soil is classified as saline-sodic soils. Which have poor aeration and hydraulic conductivity due to dispersion, translocation and deposition of clay platelets in the conducting pores (Hafez *et al*., 2015 and Matosic *et al*., 2018). Saline-sodic soils have an adverse influence on the growth and yield of crops due to the low fertility (Matosic *et al*., 2018). Sodic soils are generally ameliorated by adding calcium (Ca^{2+}) to replaced the excess Na^+ in the cation exchange complex (Hafez *et al*., 2015). However, saline-sodic soils might contain Ca^{2+} in the form of calcite ($CaCO_3$) at different depths (Matosic *et al*., 2018). Saline-sodic soils amelioration with physical practices such as plowing, and sub-soiling or chemical amendments such as gypsum (Hafez *et al*., 2015) are considered as valuable technologies. However, integration between irrigation and soil amendments on saline sodic soils has less attention. Sub-soiling will enhance downward movement of irrigation water carrying off excess salts from soil surface layers (Abdel-Mawgoud *et al*., 2006).

Gypsum ($CaSO_4.2H_2O$) is one of the most important and commonly used as an amendment in saline-sodic soil due to its low cost (Hafez *et al*., 2015) and availability. It improves hydraulic conductivity, bulk density and macro-porosity. However, the addition of gypsum is successfully alleviated the adverse soil properties associated with sodic soils (Saied *et al*., 2017).

Glauconite "Green Sand" ((K,Na) (Fe^{+3},Al,Mg)$_2$ (Si,Al)$_4$ O_{10} $(OH)_2$) is an iron potassium phyllosilicate mineral (mica group), green in color, with low hardness and very low weathering resistance. Also, it has been used for over 100 years as a natural source of slow release fertilizer and soil conditioner (El-Amamy *et al*., 1982). Glauconite used as a substrate for growing agricultural plants as soil amendment and source of potassium for growing crops. Egyptian glauconite has a big advantage that it has sandy loam textural, so it can be used also as a sand filter and low coast cations adsorbent agent (Eid, 2013). Glauconite improves water use efficiency and enhances the plant growth (Morsy *et al*., 2016).

The reclamation of salt-affected soils should be done by simple leaching practices to bring them as non-saline, non-sodic soils for economical crop production. Sufficient water with leaching practices should be used (Pazira and Homaee, 2010). Amirpouya *et al*., (2010) concluded that the salts leaching from the alluvial, heavy textured, saline and sodic soils of the region using the intermittent water application has been effective in decrement the soluble salts, especially in the top soil layers. Furthermore, it is worthy to use a unit depth of leaching water per unit depth of soil segment as the reclamation requirement and to leach salts gradually by irrigation (Pazira and Homaee, 2010).

Sugar beet is the second important crop for sugar production in Egypt, has ability of growing in the new reclaimed soils and can be irrigated with one fourth of the water used with sugar cane. One way of increasing production of sugar beet is proper soil management such as

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DOI: 10.21608/jssae.2020.79167

irrigation and soil amendments (El-Shahawy *et al*., 2001). Shabana (2010) reported that improving of root, top and sugar yield of sugar beet can be achieved by improving soil structure and consequently the permeability and aeration. Some physio-chemical properties of salt affected soil were improved by application of gypsum, compost and sub-soiling at Kafr El-Sheikh Governorate (Amer and Hashem., 2018).

The main objective of the present work is to evaluate the impact of leaching treatments and the use of gypsum and glauconite as soil amendments on improving some soil properties, productivity and economic returns from sugar beet.

MATERIALS AND METHODS

Study site: The field trial was conducted at North Nile Delta (Al-Hamul District, Kafr El-Sheikh Governorate, Egypt), during the two winter seasons (2016/017 and 2017/018) to evaluate the impact of irrigation with leaching requirements and some soil amendments on some soil physio-chemical properties and sugar beet productivity as well as productivity of irrigation water and economic returns. The experimental site is located at 31° 04′ 28″ N Latitude, 30° 31′ 25″ E Longitude and 6 m above mean sea level.

Experimental design: The experimental treatments were arranged in split plot design, with three replicates. Each plot was 36 m^2 (20 m length and 1.8 m width), Irrigation treatment area was (60 m length and 7.5 m width) and amendments treatment (60 m length and 1.8 m width).

The main plots were devoted for irrigation treatments with three levels (without leaching requirements I1, 5% leaching requirements I2 and 10 % leaching requirements I3). The sub plots were assigned to soil amendments treatments (without amendments A1, Gypsum A2, Glauconite A3 and gypsum combined with glauconite A4).

Soil preparation: The soil preparation started with ploughing process, Sub-soiling was established at 1.5 m spacing and 45 cm depth for all treatments. LASER soil levelling with ground surface slope of 0.1% and performing graded long furrows (60 m length).

Cultural practices: Seeds of sugar beet (Pleno Variety) were sown on August, 17th, 2016 in the 1st season and on September, 20th, 2017 in the 2nd season. The hills were thinned to one plant before the 1st irrigation. All plots received 200 Kg Ca-superphosphate/fed (15.5% P_2O_5) during land preparation. N fertilizer in the form of ammonia gas at the rate of 90 Kg N/fed was injected at 10 cm depth from soil surface before cultivation for both seasons. Potassium application in the form of potassium sulphate (48 % K_2O) at the rate of 50 kg/fed was applied with the 2nd irrigation. Soil amendments were applied before the 1st season. The gypsum and glauconite were incorporated with the upper 30 cm soil layer with ploughing. The different agricultural practices and crop were performed as recommended for the area through both seasons of study.

Gypsum requirements were determined according to U.S., salinity laboratory staff (FAO and IIASA, 2000) as follows:

$$GR = \frac{(ESP_i - ESP_f)}{100} \times CEC \times 1.72 \times \left(\frac{100}{G\ purity\ 85\%}\right)$$

Where

GR: gypsum requirement ($Mgfed^{-1}$), ESP_i: initial soil ESP, ESP_f: the required soil ESP and CEC: cation exchange capacity (cmolc kg^{-1}).

So 5.2 Mg fed^{-1} (Mg = metric tons), are sufficient to reduce the initial ESP from 18 to 10 % for 30 cm soil depth. Glauconite was applied at the rate of 1400 Kg fed^{-1} according to Boulis (2011). The analysis of the nature glauconite as reported by Agricultural Research Centre, Egypt: SiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, TiO_2 and loss on ignition (LOI) was 52.26, 11.04, 15.17, 0.05, 1.17, 4.23, 0.75, 5.40, 0.24, 0.51 and 9.18 % as wt., respectively.

Soil and water sampling: Soil samples at 0-15, 15-30 and 30-45 cm depth were collected from each plot before the experiment and after harvesting in both seasons and used for determined some soil physical and chemical analysis. Data in Tables 1 and 2 show that parameters before experiment. The type of the soil in the experimental farm was clay in texture and categorized as saline-sodic soils. The EC value of irrigation water ranges between 0.84 to 1.08 dS m^{-1} with an average of 0.96 dS m^{-1}.

Table 1. Initial soil chemical analysis and some soil properties of the experimental site.

Depth (cm)	pH	EC (dS m^{-1})	ESP	CEC (Cmol kg^{-1})	FC (%)	PWP (%)	AW (%)
0-15	8.26	7.17	17.15	31.9	44.17	25.36	18.81
15-30	8.82	9.07	18.99	30.5	40.10	22.75	18.35
30-45	8.84	10.55	20.02	29.5	38.17	20.62	17.55

EC = Electrical conductivity; ESP = Exchangeable sodium percentage; AW: Available water; CEC= Cation exchange capacity; FC: field capacity; PWP: permanent wilting point.

Table 2. Initial soil physical analysis of the experimental site.

Depth (cm)	Sand%	Silt%	Clay%	Texture	BD (Mg m^{-3})	SPR (N cm^{-2})	IR ($cmhr^{-1}$)
0-15	18.75	28.13	53.12	Clayey	1.28	450	
15-30	20.54	27.92	51.54	Clayey	1.35	365	0.68
30-45	21.73	25.49	52.78	Clayey	1.39	265	

IR = Infiltration rate; BD: soil bulk density; SPR: soil penetration resistance.

EC was determined in saturated soil paste extract and exchangeable sodium was determined using ammonium acetate and measured by using flame photometer according to Page *et al*., (1982). Infiltration rate was determined as described by Garcia (1978) using double cylinder infiltrometer. Soil bulk density was determined and total porosity was calculated for all treatments according to Campbell (1994). Soil penetration resistance (SPR) was determined by hand penetrometer device (Herrick and Jones, 2002). Soil physical traits and moisture parameters were determined in undisturbed soil samples as explained by (Klute 1986 and Delgado and Gómez 2016).

Yield and its quality: Root and top yield of sugar beet were determined for different treatments while sucrose concentration (juice sugar content) and juice purity (%) for all treatments were determined in Delta Sugar Company limited laboratories at El-Hamoul, Kafr El-Sheikh Governorate. Gross sugar yield (ton/fed or Mg fed^{-1}) was calculated by multiplying root yield (ton/fed) by sucrose and juice purity (%). Alkaline coefficient (AC) was calculated as follows: AC= [(Na+K) ⁄ (α-amino N)] according to Wieninger and kubadinow (1971) and polloch (1984).

Water measurements: Applied irrigation water: The amount of irrigation water was measured by using a rectangular sharp crested weir. The discharge was calculated using the following equation as described by (Masoud, 1969):

$$Q = CL (H)^{1.5}$$

Where:

Q = Discharge (m^3s^{-1}), L = Length of the crest (m), H = Head above the weir (m) and C= Empirical coefficient determined from discharge measurement (1.84).

Leaching Requirements (LR): Leaching requirements was based on the following equation as described by (Ayers and Westcot, 1976):

$$LR = ECw / 2 (ECe)$$

Where:

LR is the minimum amount of leaching needed to control salts.
ECw : electrical conductivity of irrigation water (0.96 dS m^{-1})
ECe: electrical conductivity for soil paste extract (initial value 8.93 dS m^{-1} as average)

Leaching requirements were added to water applied (WA) with each irrigation except for the planting irrigation:

Irrigation water productivity (IWP, kg m^{-3}): was calculated according to Ali *et al*., (2007) as follows:

$$IWP = Gy/WA,$$

Where

Gy= root and top yields, kg fed^{-1} and WA= water applied, m^3 fed^{-1}

Economic evaluation: Cash inflows and outflows for various treatments (at prices of the local market) were calculated, and some economic indicators were estimated according to the equations outlined by (FAO, 2000).

Statistical analysis: Data for root and top yields of sugar beet were recorded and were subjected to statistical analysis by ANOVA technique according to Cochran and Cox (1960). The treatments were compared to Duncan's multiple range test (Duncan, 1955). All statistical analyses were performed using analysis of variance technique by mean of cohort Computer software. Gross income per water unit and economic efficiency were calculated according to Gittinger (1982).

RESULTS AND DISCUSSION

Soil salinity (ECe) and sodicity (ESP):

The initial soil ECe and ESP values varied from 7.17 to 10.55 dSm^{-1} and from 17.15 to 20.02%, respectively (Table 1) which were higher than those after both growing seasons (5.35 to 7.67 dSm^{-1} and 12.94 to 16.86%, respectively) as shown in Table (3). This may due to the sub-soiling, leaching requirements and soil amendments led to enhancing leaching the excessive salts from surface layer. Afterwards, regular subsequent irrigations will gradually reduce the salt content in groundwater at least when it is close to soil surface (Moukhtar *et al*, 2003).

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Table 3. Soil ECe and ESP values as influenced by different treatments after the two growing seasons.

Treatments	After the 1st season				After the 2nd season			
	ECe dS m^{-1}	decrease(%)	ESP	decrease(%)	ECe dS m^{-1}	decrease(%)	ESP	decrease(%)
				Irrigation treatments (I)				
I1	7.39 a	0	15.99 a	0	7.04 a	0	15.65 a	0
I2	6.99 b	5.41	16.25 a	-1.63	6.49 b	7.81	15.78 a	-0.83
I3	6.58 c	10.96	14.14 b	11.57	5.96 c	15.34	13.50 b	13.74
F. test	**	-	*	-	**	-	**	-
LSD 0.05 %	0.098	-	0.87	-	0.199	-	0.29	-
				Soil amendments (A)				
A1	8.14 a	0	17.29 a	0	7.67 a	0	16.86 a	0
A2	6.14 c	24.57	14.33 b	17.12	5.69 c	25.81	13.84 c	17.91
A3	7.81 b	4.05	16.72 a	3.30	7.25 b	5.48	16.26 b	3.56
A4	5.85 d	28.13	13.49 b	21.98	5.35 d	30.25	12.94 d	23.25
F. test	**	-	**	-	**	-	**	-
LSD 0.05 %	0.113	-	1.002	-	0.23	-	0.35	-
				Irrigation (I) × Soil amendments (A)				
I1A1 (control)	8.59 a	0	18.29 a	0	8.3 a	0	18.01 a	0
I1A2	6.48 e	24.56	14.74 cd	19.41	6.2 e	25.30	14.44 cd	19.82
I1A3	8.25 b	3.96	17.35 ab	5.14	7.85 b	5.42	16.98 ab	5.72
I1A4	6.22 f	27.59	13.58 de	25.75	5.8 f	30.12	13.16 de	26.93
I2A1	8.16 b	5.01	17.42 ab	4.76	7.75 b	6.63	17.09 a	5.11
I2A2	6.16 f	28.29	15.34 cd	16.13	5.65 fg	31.93	14.75 c	18.10
I2A3	7.83 c	8.85	17.31ab	5.36	7.24 c	12.77	16.97 ab	5.77
I2A4	5.84 g	32.01	14.95 cd	18.26	5.32 gh	35.90	14.32 cd	20.49
I3A1	7.68 c	10.59	16.16 bc	11.65	6.97 cd	16.02	15.48 bc	14.05
I3A2	5.79 g	32.60	12.92 e	29.36	5.25 gh	36.75	12.33 ef	31.54
I3A3	7.36 d	14.32	15.51 c	15.20	6.68 d	19.52	14.84 c	17.60
I3A4	5.49 h	36.09	11.96 e	34.61	4.93 h	40.60	11.35 f	36.98
F. test	**	-	**		**		**	
LSD 0.05 %	0.197	-	1.73		0.399		1.51	

I1 = Without leaching requirements; I2 = 5% leaching requirements; I3 = 10 % leaching requirements; A1= without amendments; A2= Gypsum; A3= Glauconite. ; A4= gypsum combined with glauconite; ECe = Electrical conductivity; ESP = Exchangeable sodium percentage

Data in Table 3 showed that irrigation with leaching requirements especially 10 % were significant in reducing soil salinity and sodicity compared to plots without leaching. The mean values of soil salinity were 7.04, 6.49 and 5.96 dSm^{-1} and ESP values were 15.65, 15.78 and 13.50% in plots without LR, 5% LR and 10 % LR, respectively after the 2nd season. These results are in agreement with Pazira and Homaee (2010) and Amirpouya, *et al*., (2010), who concluded that the salts leaching from the alluvial, heavy textured, saline and sodic soils using the intermittent water application are effective in reducing the soluble salts, especially in the top soil layers. Concerning, the effect of irrigation treatments the overall mean values for ECe and ESP can be descended in order I1> I2> I3.

Soil amendments had more pronounced significant effect on salinity and sodicity reduction, especially after the 2nd season. ECe values were reduced by 25.81, 5.48 and 30.25 % for gypsum, glauconite individually or glauconite combined with gypsum, respectively compared to that without application of amendments after the 2nd season. The corresponding values of ESP reduction were 17.91, 3.56 and 23.25 %, respectively. In this context, Ali and Kahlown (2001) reported that reclamation of saline-sodic and sodic soils are more difficult than that of saline soils because it needs long time and is more expensive and it requires chemical amendments such as gypsum with salt leaching. Generally the overall mean values for ECe and ESP can be descended in order A1> A3> A2> A4 and the values are (7.67 dS m^{-1} and 16.86%), (7.25 dS m^{-1} and 16.26%), (5.69 dS m^{-1} and 13.84%) and (5.35 dS m^{-1} and 12.94%), respectively after the 2nd season.

Presented data in Tables (3) illustrated that the interaction between irrigation and amendments treatments caused significant decrease in ECe and ESP. It can be observed that (I3) with (A4) achieved the highest ECe and ESP values in the 2nd season (8.3 dS m^{-1} and 18.01%, respectively) compared to control (I1 under A1) after the 2nd season. The decreases in and ESP values with (I3) under (A4) were (36.09 and 34.61%, respectively) and (40.6 and 36.98%, respectively) after in the first and second growing seasons, respectively compared to I1 under A1 (control). Data showed that reducing salinity and sodicity were achieved with gypsum combined with glauconite under 5 or 10 % LR followed by gypsum with 5 or 10 % LR. These data were in harmony with those reported by Reda (2006) who observed that application of gypsum with leaching was successful in reclamation of sodic and saline-sodic soils having good drainage conditions. application of glauconite reduced ECe and ESP of salt affected soils under all irrigation treatments, may be attributed to that it used as a natural source of slow release fertilizer and soil conditioner

Ratios of Ca^{++}/TSS and Na^{+}/TSS:

Data in Fig (1) showed that Ca^{++}/TSS ratio before experiment was 19.7, while after conducting the treatments was varied from 19.8 to 27.2. The opposite trend was found with Na^{+}/TSS ratio, whereas it was 71.17 before experiment and decreased after application (60.30 -70.73). The increase of Ca^{++}/TSS and decrease of Na^{+}/TSS ratio after the 2nd season especially with gypsum or glauconite combined with gypsum may be due to the leaching of Na^{+} was higher than Ca^{++} and Mg^{++}. Also, irrigation treatments seem to be more favorable effective in increasing Ca^{++}/TSS ratio and decreasing Na^{+}/TSS ratio due to the leaching of soluble Na^{+}. This trend seems to be agree with Ali and Kahlown (2001) and Amer and Hashem (2018).

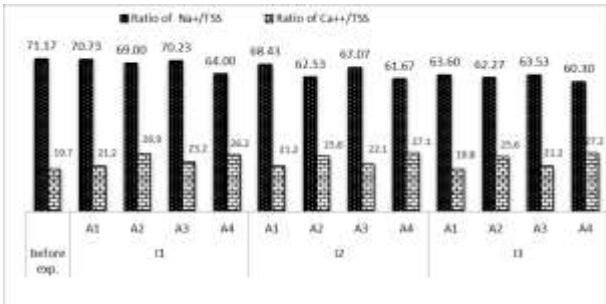

Fig. 1 Average of Ca^{++}/TSS and Na^{+}/TSS ratios as affected by the different studied treatments (after two seasons) .

Bulk density, total porosity and soil penetration resistance:

Results in Table (4) reveal that different treatments are more effective in producing relatively low values of soil bulk density and penetration resistance compared to that before experiment. The average values of soil bulk density and soil penetration resistance for all depths before conducting the experiment were 1.34 Mg m^{-3} and 360 N cm^{-2}, respectively which be decreased by the treatments after the 2nd season to 1.21 - 1.28 Mg m^{-3} and 239.5 - 320.3 N cm^{-2}, respectively. This trend could be attributed to that the soil amendments seemed to be more effective with sub-soiling on breaking soil clods and bigger granular into smaller crumbs as well as breaking and cracking the compacted layers (Abdel-Mawgoud *et al*., 2006).

Table 4. Soil bulk density, total porosity and penetration resistance as affected by different treatments during the two growing seasons.

Treatments	BD (Mg m^{-3})		Total porosity %		SPR (N cm^{-2})	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
I1A1 (control)	1.28 a	1.27a	51.7 d	52.08 e	313.3 a	320.3 a
I1A2	1.27 ab	1.25 ab	52.08 cd	52.83 cd	256.8 c	257.1 c
I1A3	1.26 bc	1.25 ab	52.45 bc	52.83 cd	296.3 b	290.3 b
I1A4	1.25 cd	1.24 b	52.83 ab	53.21 bc	242.3 c	239.5 d
Mean	1.27	1.25	52.26	52.74	277.2	276.8
I2A1	1.28 a	1.27 a	51.7 d	52.08 e	310.2 ab	319.5 a
I2A2	1.26 bc	1.24 b	52.45 bc	53.21 bc	256.3 c	252.3 cd
I2A3	1.25 cd	1.25 ab	52.83 ab	52.83cd	296.3 b	289.3 b
I2A4	1.25 cd	1.23 bc	52.83 ab	53.58 b	245.6 c	245.3 cd
Mean	1.26	1.25	52.45	52.92	277.1	276.6
I3A1	1.28 a	1.27 a	51.7 d	52.45 de	314.2 a	319.5 a
I3A2	1.26 bc	1.23 bc	52.45 bc	53.58 b	243.5 c	248.2 cd
I3A3	1.25 cd	1.24 b	52.83 ab	53.21 bc	295.8 b	296.3 b
I3A4	1.24 d	1.21 c	53.21 a	54.34 a	243.2 c	241.6 d
Mean	1.26	1.24	52.55	53.4	274.2	276.4

I1 = Without leaching requirements; I2 = 5% leaching requirements; I3 = 10 % leaching requirements; A1= without amendments; A2= Gypsum; A3= Glauconite. ; A4= gypsum combined with glauconite; BD: soil bulk density; SPR: soil penetration resistance.

Data showed that the application of gypsum and glauconite as well as their combination led to slight decrease in soil bulk density and penetration resistance. Soil bulk density and soil penetration resistance without amendments after the 2nd season recorded relatively higher values of both parameters (1.27 Mg m^{-3} and 319.5 N cm^{-2} respectively) than that with amendments (1.21 - 1.25 Mg m^{-3} and 239.5-296.3 N cm^{-2}, respectively). In almost cases, the soil porosity values take the opposite trend of that with bulk density. The decline in bulk density with the soil amendments could be probably due to loosening soil and thus temporarily forming macro-pores (Matosic *et al*., 2018). On the other hand, the data showed that irrigation treatments had no effect on the bulk density, total porosity and penetration resistance of the soil.

Basic infiltration rate (IR):

Results in Fig (2) show that BIR value before the experimental setting up was low (0.68 $cmhr^{-1}$) while after application of soil amendments, its values were higher and varied after the 2nd season from 0.93 to 1.16 $cmhr^{-1}$. This may be due to that the application of soil amendments gave the top soil layer a chance for drying and shrinkage to form passage ways for water to the drains. Similar results were obtained by Abdel-Mawgoud *et al*., (2006).

Results in Fig (2) show that application of soil amendments resulted in enhancing soil BIR. BIR in the untreated plots under different leaching rates after the 2nd season recorded approximately the same values (0.94 $cmhr^{-1}$) while, the application of gypsum and glauconite led to higher BIR values (1.1 and 0.95 $cmhr^{-1}$, respectively). The effect of soil amendments with sub-soiling practices in increasing the basic infiltration rate may be due to the lowering of water table level and swelling and shrinkage cycles as well as the charges of Ca which improve soil structure due to aggregating the clay particles (Said, 2003). He also, found that the treated soil resulted in a sharp decrease in the soil bulk density and penetration resistance in coincidence with a sharp increase in total porosity and macro pores relative to the untreated one. Also, the data indicated that LR treatments had no clear effect on infiltration rate.

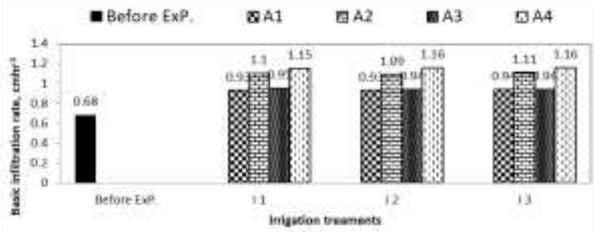

Fig (2): Basic infiltration rate ($cmhr^{-1}$) after the second seasons

Sugar beet yield:

Data in Table (5) reveal that irrigation treatments significantly affected the root, top and sugar yield of sugar beet. Whereas, the root yield was increased to 9 and 18.6%, top yield 2 and 2% and sugar yield 17.8 and 27.4 % with 5% and 10 % LR, respectively as compared to that without leaching. Therefore, it can be concluded that the amelioration of salt affected soils is more effective with the increase of LR level.

Table 5. Effect of leaching requirements and soil amendments on root and top yields of sugar beet during the two growing seasons

Treatments	Sugar beet yields (Mg fed^{-1}.)					
	1st season			2nd season		
	Root	Top	Sugar	Root	Top	Sugar
			Irrigation treatments (I)			
I1	19.9 c	5.89 b	2.92 b	20.5 c	5.93 b	2.89 c
I2	21.7 b	6.02 a	3.44 a	23.3 b	6.05 a	3.52 b
I3	23.6a	6.02a	3.72 a	25.4 a	6.05 a	3.85 a
F. test	**	**	*	**	*	**
LSD 0.05 %	0.103	0.027	0.37	0.95	0.035	0.01
			Soil amendments (A)			
A1	17.9 d	3.7 b	2.58 c	18.4 d	3.72b	2.55 d
A2	22.9 b	6.73 a	3.36 b	23.5 c	6.77 a	3.31 c
A3	22.1 c	6.73 a	3.42 b	24 b	6.77 a	3.58 b
A4	24.1 a	6.74 a	4.08 a	26.2 a	6.77 a	4.25 a
F. test	**	**	**	**	**	**
LSD 0.05 %	0.102	0.033	0.102	0.12	0.029	0.02
			Irrigation (I) × Soil amendments (A)			
I1A1 (control)	17.5 i	3.69 c	2.32 g	16.7 j	3.71 c	2.13 k
I1A2	20.5 f	6.63 b	2.82 e	20.5 g	6.67 b	2.7 j
I1A3	19.5 g	6.63 b	2.92 e	21.7 f	6.67b	3.12 h
I1A4	22.2 e	6.63 b	3.61 d	22.9 e	6.67b	3.6 f
I2A1	17.3 i	3.71 c	2.58 f	18.8 i	3.73 c	2.68 j
I2A2	22.9 d	6.78 a	3.43 d	24.4 d	6.82 a	3.5 g
I2A3	22.2 e	6.78 a	3.54 d	24.6 d	6.82 a	3.76 d
I2A4	24.4 c	6.78 a	4.2 b	25.2 c	6.82 a	4.15 b
I3A1	18.8 h	3.71 c	2.83 e	19.8 h	3.73 c	2.84 i
I3A2	25.2 b	6.78 a	3.81 c	25.6 b	6.82 a	3.71 e
I3A3	24.4 c	6.78 a	3.81 c	25.8 b	6.82 a	3.86 c
I3A4	25.8 a	6.79 a	4.42 a	30.5 a	6.82 a	5.01 a
F. test	**	*	*	**	*	**
LSD 0.05 %	0.18	0.056	0.18	0.21	0.05	0.03

I1 = Without leaching requirements; I2 = 5% leaching requirements; I3 = 10 % leaching requirements; A1= without amendments; A2= Gypsum; A3= Glauconite. ; A4= gypsum combined with glauconite

Soil amendments achieved significant increase in sugar beet root, sugar and top yields, whereas, the highest values of root, top and sugar yield were achieved with A4, followed by A2 and A3 while, the lowest values were recorded with A1. The increases in sugar beet root yield with A4, A3 and A2 were 34.6, 23.5 and 27.9%, respectively in the 1st season and 42.4, 30.4 and 27.7% in the 2nd season, respectively compared to A1. The corresponding values for sugar yield were 30.2, 32.6 and 58.1% in the 1st season and 29.8, 40.4 and 66.7% in the 2nd season, respectively. These results may be attributed to that gypsum and glauconite are the most effective amendments for ameliorating saline sodic soils. Similar results were obtained by Matosic *et al*., (2018).

The interaction between irrigation and amendments treatments caused significant increase in root, top and sugar yield of sugar beet. It can be observed that 10 % LR (I3) with gypsum combined with glauconite (A4) achieved the highest root, top and sugar yield values in the 2nd season (30.5 ,6.2 and 5.01 kg fed^{-1}, respectively) followed by 5% LR (I2) combined with A4. This may be related to the improvement of soil aeration and decreasing soil salinity which increase nutrient availability, enhancing root number, density and dry weight (Shabana, 2010) and enhancing water and nutrients uptake (Atia *et al*., 2007). The increases of sugar beet yield after the 2nd season were more pronounced than the 1st season, which may be due to that the improving of soil amelioration needs relative long time

Sugar beet purity and quality:

Data in Table (6) show significant increases in sucrose % and alkalinity coefficient but insignificant increase in purity % with irrigation treatments in the both seasons. So, the values of sucrose were 16.16, 17.16 and 17.17 % in the 1st season and 16.24, 17.24 and 17.25 % in the 2nd season with I1, I2 and I3, respectively. The corresponding values of alkalinity coefficient were 3.20, 3.61 and 3.42 in the 1st season and 3.28, 3.76 and 3.56 in the 2nd season, respectively. The purity values with all irrigation treatments ranged between 90.12 - 91.71 % in the 1st season and 90.64- 92.24 % in the 2nd season. It could observe good improves in the entire studied sugar beet components in the 2nd season; may be due to the high amounts of water applied in both seasons with the effectiveness of the amendments in decreasing soil salinity.

Table 6. Effect of leaching requirements and soil amendments on sucrose%, alkalinity coefficient, purity% of sugar beet during the two growing seasons.

Treatments	1st season			2nd season		
	Sucrose (%)	Purity (%)	Alkalinity coefficient	Sucrose (%)	Purity (%)	Alkalinity coefficient
Irrigation treatments (I)						
I1	16.16 b	90.12 a	3.2 c	16.24 b	90.64 a	3.28 b
I2	17.16 a	91.71 a	3.61 a	17.24 a	92.24 a	3.76 a
I3	17.17 a	91.54 a	3.42 b	17.25a	92.08 a	3.56 ab
F. test	*	ns	**	*	ns	*
LSD 0.05 %	0.012	10.3	0.037	0.011	10.36	0.363
Soil amendments (A)						
A1	15.99 d	89.81 b	3.16 d	16.07 d	90.33 b	3.28 c
A2	16.28 c	89.81 b	3.35 b	16.36 c	90.33 b	3.48 b
A3	16.99 b	91.35 ab	3.81 a	17.07 b	91.88 ab	3.97 a
A4	18.06 a	93.53 a	3.32 c	18.15 a	94.07 a	3.39 bc
F. test	**	*	**	**	*	*
LSD 0.05 %	0.007	2.53	0.01	0.009	2.54	0.116
Irrigation (I) × Soil amendments (A)						
I1A1 (control)	14.96 j	88.8 bc	2.61 i	15.03 j	89.31bc	2.72 f
I1A2	15.57 i	88.38 c	2.88 g	15.65 i	88.89 c	2.98 e
I1A3	16.57 g	90.42 bc	3.73 b	16.65 g	90.95 bc	3.89 b
I1A4	17.56 c	92.88 bc	3.58 d	17.65 c	93.42 abc	3.53 c
I2A1	16.45 h	90.22 bc	3.137 f	16.53 h	90.74 abc	3.3 d
I2A2	16.57 g	90.4abc	3.73 b	16.65 g	90.95 abc	3.88 b
I2A3	17.33 d	92.2 abc	3.96 a	17.42 d	92.74 abc	4.12 a
I2A4	18.29 b	94 a	3.6 c	18.38 b	94.54 a	3.73 bc
I3A1	16.57 g	90.4 abc	3.73 b	16.65 g	90.95 abc	3.83 b
I3A2	16.71 f	90.6 abc	3.45 e	16.79 f	91.15 abc	3.59 c
I3A3	17.07 e	91.4 abc	3.73 b	17.16 e	91.96 abc	3.91 b
I3A4	18.33 a	93.7 ab	2.79 h	18.42 a	94.25 ab	2.9 ef
F. test	**	ns	**	**	ns	*
LSD 0.05 %	0.011	4.38	0.018	0.015	4.41	0.202

I1 = Without leaching requirements; I2 = 5% leaching requirements; I3 = 10 % leaching requirements; A1= without amendments; A2= Gypsum; A3= Glauconite. ; A4= gypsum combined with glauconite

In addition, the data show high significant increase in sugar purity and quality due to application of the soil amendments. Therefore, A4 treatment achieved the highest values of sucrose were 18.06 and 18.15 % and purity were 93.53 and 94.07 % in the 1st and 2nd seasons, respectively. While, the highest alkalinity coefficient values in both seasons which was 3.81and 3.97, respectively were achieved with A3. The increase of these parameters may be due to the release of Ca from gypsum and K from glauconite, which considered as essential elements for cell wall structure, provides normal transport and retention of other elements and increment of Ca and reduction of Na in soil lead to healthy environment for plant growth (Hafez *et al*., 2015) and the application of glauconite can increase soil fertility (Eid, 2013).

The interaction between irrigation and soil amendments treatments caused significant effects on sucrose % and alkalinity coefficient but insignificantly effect on purity %. It can be observed that 10 % LR (I3) with A4 achieved the highest sucrose % in both seasons which was 18.33 and 18.42 %, respectively, while the highest alkalinity coefficient values was achieved by using 5 %LR (I2) combined with A3 in both seasons which was 3.96 and 4.12, respectively.

Irrigation water applied and irrigation water productivity:

The amount of irrigation water including rainfall was 7.3 and 7.7 cm for the 1st and the 2nd seasons, respectively is shown in Table (7). Data showed that, the treatment irrigated without leaching requirements (I1) received the lowest amount of irrigation water compared to other treatments. The mean values of water applied were 3088.5, 3246.5 and 3387 $m^3 fed^{-1}$ in the 1st season and

2980.5, 3140.5 and 3288.4 m^3 fed^{-1} in the 2nd season for I1, I2 and I3, respectively.

Productivity of irrigation water depends on the amount of irrigation water applied and the yield of roots or sugar. Therefore, the highest value of IWP of root and sugar yield was 9.25 kgm^{-3} and 1.40 kgm^{-3}, respectively where achieved with gypsum combined with glauconite under 10% leaching requirement in the 2nd season. While the lowest values of root and sugar yield was 5.34 kg root/m^3 and 0.75 kg sugar/m^3, respectively where achieved with 5% leaching requirement without soil amendments in the 1st season. These results may be due to the yield increase was higher than the increase of water applied with different leaching requirements. Also, glauconite improves the water use efficiency and enhances the plant growth (Morsy *et al*., 2016). Therefore, gypsum and/or glauconite caused increasing in the IWP values for root and sugar yield with each irrigation treatment may be due to the improvement of the soil physical properties such as bulk density, porosity, aggregates stability and infiltration rate that affect water-air relationships in the root zone (Doran and Parking, 1994).

Table 7. Applied water and irrigation water productivity of sugar beet during the two growing seasons.

Treatments	Water applied m^3fed^{-1}		IWP for root (Kg m^{-3})		IWP for sugar (Kgm^{-3})	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
I1A1 (control)	3088.52	2980.47	5.66 de	5.61 d	0.75 e	0.71 f
I1A2	3088.52	2980.47	6.64 bc	6.88 bc	0.91 cd	0.91 def
I1A3	3088.52	2980.47	6.30 cd	7.28 b	0.95 c	1.05 cde
I1A4	3088.52	2980.47	7.18 abc	7.69 b	1.17 b	1.21 bc
Mean	3088.52	2980.47	6.45	6.87	0.94	0.97
I2A1	3246.5	3140.5	5.34 e	6.00 cd	0.79 e	0.85 ef
I2A2	3246.5	3140.5	7.06 abc	7.78 b	1.06 b	1.11 cd
I2A3	3246.5	3140.5	6.83 abc	7.82 b	1.09 b	1.2 bc
I2A4	3246.5	3140.5	7.52 ab	8.02 b	1.29 a	1.32 b
Mean	3246.50	3140.50	6.69	7.41	1.06	1.12
I3A1	3387	3288.4	5.56d e	6.01 cd	0.84 de	0.86 ef
I3A2	3387	3288.4	7.43 ab	7.79 b	1.12 b	1.13 bc
I3A3	3387	3288.4	7.21 abc	7.85 b	1.12 b	1.17 bc
I3A4	3387	3288.4	7.60 a	9.26 a	1.3 a	1.52 a
Mean	3387.00	3288.40	6.95	7.73	1.1	1.17

I1 = Without leaching requirements; I2 = 5% leaching requirements; I3 = 10 % leaching requirements; A1= without amendments; A2= Gypsum; A3= Glauconite. ; A4= gypsum combined with glauconite

The economic evaluation:

Data in Table (8) show the values of total return, net return, net return from water unit and economic efficiency as affected by different treatments. Irrigation with 5 or 10 % LR resulted in high values of total return, net return, net return from water unit and economic efficiency compared to that without leaching. Soil amendments achieved higher net return, net return from water unit and economic efficiency than without soil amendments. The highest values of the previous economic parameters were achieved with gypsum combined with glauconite under 10 % leaching requirements in the 2nd season. This behavior may be related to the increase in yield and its components as a result of application of irrigation and soil amendment treatments. Generally, glauconite "Green Sand" is a good amendment for using in agriculture, provides beneficial microbes to grow in the soil, improves water holding capacity and increases ability to store and retain nutrients.

Table 8. Total return, Net return, Net return from water unit and economic efficiency of sugar beet crop as affected by different treatments during the two growing seasons.

Treatments	Income, root (L.E/fed)	Income, top (L.E/fed	Total return L.E/fed	Total cost L.E/fed	Net return L.E/fed	Net return from water unit (L.E/m^3)	Economic efficiency
				1st season			
I1A1 (control)	11367	332	11699	5890	5809	1.88	0.99
I1A2	15377	597	15974	6190	9784	3.17	1.58
I1A3	14585	597	15182	6009	9173	2.97	1.53
I1A4	16620	597	17217	6309	10908	3.53	1.73
I2A1	11269	334	11603	5890	5713	1.76	0.97
I2A2	17186	611	17797	6190	11607	3.58	1.88
I2A3	16620	610	17230	6009	11221	3.46	1.87
I2A4	18316	611	18927	6309	12618	3.89	2.00
I3A1	12248	334	12582	5890	6692	1.98	1.14
I3A2	18881	611	19492	6190	13302	3.93	2.15
I3A3	18316	610	18926	6009	12917	3.81	2.15
I3A4	19311	611	19922	6309	13613	4.02	2.16
				2nd season			
I1A1 (control)	10877	334	11211	5890	5321	1.79	0.9
I1A2	15377	600	15977	5890	10087	3.38	1.71
I1A3	16281	600	16881	5890	10991	3.69	1.87
I1A4	17186	600	17786	5890	11896	3.99	2.02
I2A1	12248	335	12583	5890	6693	2.13	1.14
I2A2	18316	614	18930	5890	13040	4.15	2.21
I2A3	18429	614	19043	5890	13153	4.19	2.23
I2A4	18881	614	19495	5890	13605	4.33	2.31
I3A1	12836	336	13172	5890	7282	2.21	1.24
I3A2	19221	614	19835	5890	13945	4.24	2.37
I3A3	19356	614	19970	5890	14080	4.28	2.39
I3A4	22839	614	23453	5890	17563	5.34	2.98

Net return= total cost from the total return, ($LEfed^{-1}$). - Economic efficiency: by dividing the total seasonal net return on total seasonal cost. - Net return from water unit: by dividing seasonal net return (LE fed^{-1}) on seasonal water applied ($m^3 fed^{-1}$) ; I1 = Without leaching requirements; I2 = 5% leaching requirements; I3 = 10 % leaching requirements; A1= without amendments; A2= Gypsum; A3= Glauconite. ; A4= gypsum combined with glauconite

CONCLUSION AND RECOMMENDATIONS

The application of gypsum and/or combined with glauconite with leaching requirements led to improve the saline-sodic soils productivity, crop productivity, irrigation water productivity, net return, net return from water unit and economic efficiency for sugar beet crop. These parameters may be due to release of Ca from gypsum and K from glauconite, since they are considered as essential elements for plant and cell wall structure. Also, glauconite provides normal transport and retention of other nutrient elements, increases soil fertility and decreases Na in soil which can result in healthy environment for plant growth. Nevertheless, the effect of adding these amendments applications during sub-soiling practices under irrigation with leaching requirements should be studied to investigate the impacts of different rates of these materials and with other amendments on saline-sodic soil properties and crop production.

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تاثير اضافة الجلوكونيت, والجبس الزراعي والاحتياجات الغسيليه علي انتاجية الأراضي المتاثره بالاملاح

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استخدام بعض محسنات التربه مع اضافة الاحتياجات الغسيليه يعتبر ممارسات لإدارة الاراضي المتأثره بالأملاح لتحسينها ورفع انتاجيتها. لذا أجريت تجربه حقليه في مركز الحامول – محافظة كفرالشيخ خلال موسمين شتويين 2017/2016 و2018/2017م لدراسة تأثير اضافة الاحتياجات الغسيليه (بدون و 5% و 10 %) وبعض محسنات التربه (بدون اضافة واضافة الجلوكونيت واضافة الجبس منفردا او اضافتهما معا) علي تحسين الخواص الفيزيائيه والكيميائيه للأراضي الملحيه القلويه وانتاجية محصول بنجر السكر وانتاجية مياه الري المضافه والعائد الاقتصادي. ويمكن تلخيص النتائج المتحصل عليها فيما يلي: حققت معاملة الري مع اضافة 10 % احتياجات غسيليه اعلي كميه مضافه من مياه الري مقارنة بباقي المعاملات. ادت معاملات الري مع الاحتياجات الغسيليه او معاملات اضافة محسنات التربه الي تقليل ملوحة وقلوية التربه واندماج التربه والكثافه الظاهريه وزيادة معدل التشرب والمساميه الكليه وكذلك زيادة محصول الجذور والعرش والسكر واعلي القيم لإنتاجية وحدة المياه مقارنة بالتربه الغير معامله. وكان افضل النتائج مع التفاعل بين 10 % احتياجات غسيليه مع اضافة الجبس و الجلوكونيت معا ، مما يؤكد اهمية اضافة المحسنات مع الاحتياجات الغسيليه في زياده انتاجية الأراضي المتأثره بالأملاح وتحقيق اعلي عائد اقتصادي وكفاءه اقتصاديه من محصول بنجر السكر.