EFFECTIVENESS OF GYPSUM APPLICATION AND PLOWING IN IMPROVING SEVERELY DETERIORATED CLAY SOIL CHARCTERISTICS AND WHEAT GROWTH AT QAROUN LAKE SHORE LINE, FAYOUM GOVERNORATE

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ABSTRACT

Wide areas of severely deteriorated lands at Quaroun Lake shoreline have been left bare since a long time , although many attempts were made to cultivate some parts but all failed. A field experiment was carried out in a private field during the season 2014-2015 at the north of Fayoum Governorate (about 200 m from Quaroun Lake, Sinours District).Nine treatments were tested including the control, shallow and deep plowing (20 and 60 cm), application of 50% and 100 % of estimated gypsum requirements and their combinations. Remarkable decreases were found in the values of soil bulk density, ECe values, soluble cations and anions, soil paste pH and removal sodium efficiency (RSE). Values of total porosity, hydraulic conductivity, field capacity, permanent wilting point, available water increased with soil deep plowing and gypsum application. Also, grain and straw yields of grown wheat crop were enhanced with soil deep plowing together with gypsum application and leaching with required amounts of water in comparison with those of the control treatment . Deep plowing with the application of 100 % of estimated gypsum requirements resulted in the best improvement of both soil characteristics and plant growth among all other treatments. Results of the present experiment that was conducted in a private farm has actually encouraged farmers of the studied area to start land reclamation and cultivation of their lands that were left bare since a long time.

Key words: Salt-affected soils, Saline- sodic soil, gypsum, deep plowing , clay pan, wheat crop.

INTRODUCTION

Inadequate drainage is a serious problem as nearly 33 % of the world irrigated lands is salt-affected especially in arid areas**, (Tanwar, 2003).**Soils of the northern part of Fayoum basin, adjacent to Qaroun Lake, can be considered as a problematic area. They have heavy textural soil classes mostly with shallow depths of brackish ground water which is considered, the main cause of soil properties deterioration , **(Mohamedin, 2002)**. Many agricultural soils have impermeable layers (hard pan), from clay illuviation (clay pans), or cementation by either iron oxides, calcium carbonate , or silica, **(Brady and Weil, 2002)**. Many strategies including plowing, leaching, use of chemical amendments and organic fertilization achieve improvement in soil properties and help plant growth in these salt-affected soils.

Gypsum is the most low cost source of soluble calcium to replace exchangeable sodium from exchange complex and commonly used in the reclamation of saline-sodic and sodic soils, **(Oster and Frenkel, 1980)** and **(Khan et.al., 1999)**. **Rashid et.al. (2009)** concluded that deep tillage and gypsum both in combination proved more effective in combating ill effects of salts and improving wheat yield in salt-affected soil. Also, **Abdel-Fattah, (2012)** found that application of gypsum combined with compost enhanced the reclamation process and caused more decreases in salinity as will as sodicity .Wide areas of lands at Quaroun Lake shore line have been left bare since a long time.

Objective of the present investigation was to study the effectiveness of gypsum and deep plowing and their combination in improving severely deteriorated heavy clay low permeable saline-sodic soil and their impact on wheat crop production at the north of Fayoum adjacent to Qaroun lake.

Materials and Methods

The experiment was carried out in a private farm at the north of Fayoum Governorate about 200 m from Quaroun lake, Sinours district which never received any previous gypsum applications. The morphological investigations showed that the studied soil have a blocked clay pan within the subsurface layer (30 – 60 cm) with a thickness of 10 cm (from 50 to 60 cm) and suffering from salinity and sodicity, table (1).

Treatments were distributed in a randomized complete block design with four replicates each in 20 m^2 (4 X 5 m) plots.

Treatments were as follows:

P_0 g_0 without plowing + zero gypsum
P_0 g_1 without plowing + 50% of estimated gypsum requirements
P0 g2 without plowing + 100 % of estimated gypsum requirements
P_1 g_0 shallow plowing + zero gypsum
P_1 g_1 shallow plowing +50% of estimated gypsum requirements
P_1 g_2 shallow plowing + 100 % of estimated gypsum requirements
P_2 g_0 deep plowing + zero gypsum
P_2 g_1 deep plowing +50% of estimated gypsum requirements
P_2 g_2 deep plowing + 100 % of estimated gypsum requirements

The leaching requirements were calculated to reduce soil initial ECe of (13.33 dS/ m) to the mean of ECe values of the two layers , 0 – 30 cm and 30 – 60cm. according to **Reeve equation (1975)** , as follows :

$$\frac{D_{iw}}{D_s} = \frac{EC_{ei}}{EC_{ef}} + 0.15$$

Table(1) :Initial soil physical and chemical properties of the tested soil.

Soil property	**Value**	
	Soil depth, cm	
	0 - 30	30 - 60
Physical properties		
Sand %	15.4	14.6
Silt %	24.4	22.9
Clay %	60.2	62.5
Texture class	Clay	Clay
Bulk density (Mg/m3)	1.35	1.4
Total porosity (% on weight basis)	49.06	53.90
Field capacity (% on weight basis)	43.33	43.60
Wilting point (%on weight basis)	24.60	28.80
Available water (%on weight basis)	18.73	14.80
Hydraulic conductivity (cm/h)	0.35	0.20
Chemical properties		
pH (in soil paste)	8.40	8.52
ECe (dS/m)	12.30	14.40
Soluble Cations, mmole$^+$/L		
Ca^{++}	22.40	23.40
Mg^{++}	13.30	20.20
Na^+	84.50	97.60
K^+	1.80	1.70
Soluble anions , mmole$^-$/L		
$CO3^{--}$	1.20	2.50
$HCO3^-$	4.50	4.60
Cl^-	78.50	95
$SO4^{--}$	37.80	40.80
Exchangeable Na (cmole$^+$/kg)	9.04	9.50
CEC, (cmole$^+$/kg)	41.02	41.60
ESP, %	22.04	22.80
$CaCO_3$, (g/kg)	49.30	51.10
O.M, (g/kg)	20.10	12.5
estimated gypsum requirements, (t/h)	21.057	

Where D_{iw} is the depth of leaching water in cm ,D_s is the depth of leached soil in cm , EC_{ei} and EC_{ef} are the electrical conductivity values of soil paste extract in dS/m before and after leaching, respectively.

Calculated leaching water requirements (49 cm) was divided into 7 leachates; each was 7 cm. All calculated leaching requirements were added with treatments before cultivation of wheat crop. Estimated EC of used irrigation water was 0.75 dS/m, table (2).

Table(2) : Analysis of used irrigation water.

pH	EC_w, dS/m	Soluble cations, $mmol^+/L$			Soluble anions, $mmol^-/L$				SAR
		$Ca^{++}+Mg^{++}$	Na^+	K^+	$CO3^{--}$	$HCO3^-$	Cl^-	$SO4^{--}$	1.66
7.10	0.51	2.80	1.96	0.30	-	2.80	2.05	0.20	

Wheat crop (Triticum Sativum L.), Seds-1 Varity was planted in November 20, 2014. All cultural practices for grown plants has been conducted according to the Egyptian Ministry of Agriculture recommendations. After harvest, grains and straw yields were recorded.

At the end of experiment, soil samples were collected from the two layers (0 – 30 cm and 30 – 60 cm) to determine their physical and chemical properties. Statistical analysis was recorded using SPSS statistical program.
Soil physical properties were determined according to the methods described by Klute (1986).

Soil pH was measured in soil past (Chapman and Pratt, 1961) , soil organic matter was estimated according to **Walkley and Black (1934)** and $CaCO_3$ using volumetric Calcimeter according to Allison and Moodie (1965). Electrical conductivity, soluble cations and soluble anions were measured in saturated soil paste extract **(USDA-NRCS, 2014).** Cation exchange capacity was determined after **Bower et.al. (1952)**, exchangeable sodium was extracted with buffered neutral NH_4OAC solution and measured by flame photometer, and exchangeable sodium percentage (ESP) was calculated.

The gypsum requirements was estimated as described in **USSL Staff (1954)**.

Results and Discussions

1-Initial characteristics of the studied soil

Data in table 1 indicated that soil of the studied field is saline- sodic heavy clay texture the two layers (0 – 30cm and 30 – 60 cm), soil bulk density values increased with depth. However, values of total porosity, wilting point, available water and hydraulic conductivity decreased.
Results in table 2 showed that irrigation water used is non-saline ($EC_w < 0.75$ dS/m) according to the guidelines proposed by **FAO (1992**.

2-Some soil physical properties as influenced by the applied treatments

Actually, the soil bulk density plays a vital role in the further use of farm management, machinery and the crop growth and yield, **Fayza Ahmed, (2004).**

Table(3) : Effect of applied treatments on the studied soil physical properties *

Treatment	Depth, cm	Bulk density,Mg/m^3	Total porosity,% on weight basis	Field capacity,% on weight basis	Wilting point,% on weight basis	H.C**	Available water,% on weight basis
$P_0\ g_0$	0 - 30	1.34	50.53	44.63	25.74	0.38	18.89
	30 - 60	1.39	54.52	45.00	30.05	0.22	14.95
	Mean	1.37	52.53	44.77	28.01	0.30	16.77
$P_0\ g_1$	0 - 30	1.29	51.04	45.07	25.61	0.48	19.46
	30 - 60	1.38	55.07	45.36	29.98	0.32	15.38
	Mean	1.34	53.06	45.22	27.80	0.40	17.42
$P_0\ g_2$	0 - 30	1.26	52.05	45.97	26.30	0.61	19.67
	30 - 60	1.32	56.16	46.26	30.55	0.35	15.71
	Mean	1.29	54.11	46.12	28.43	0.48	17.69
$P_1\ g_0$	0 - 30	1.38	50.98	45.03	25.74	0.49	19.29
	30 - 60	1.33	55.01	45.31	30.06	0.29	15.25
	Mean	1.36	53.00	45.17	27.90	0.39	17.27
$P_1\ g_1$	0 - 30	1.25	52.55	46.42	26.55	0.68	19.87
	30 - 60	1.33	65.70	46.71	31.00	0.40	15.71
	Mean	1.29	59.13	46.57	28.78	0.54	17.79
$P_1\ g_2$	0 - 30	1.30	51.60	45.50	25.61	0.76	19.89
	30 - 60	1.31	55.60	45.78	29.92	0.44	15.86
	Mean	1.31	53.60	45.64	27.62	0.60	17.88
$P_2\ g_0$	0 - 30	1.28	51.54	45.52	26.04	0.57	19.48
	30 - 60	1.36	55.61	45.81	30.41	0.33	15.40
	Mean	1.32	53.58	45.67	28.23	0.45	17.44
$P_2\ g_1$	0 - 30	1.23	54.08	47.75	27.11	0.84	20.64
	30 - 60	1.28	58.34	48.05	31.74	0.48	16.31
	Mean	1.26	56.21	47.90	29.43	0.66	18.48
$P_2\ g_2$	0 - 30	1.20	55.08	48.65	27.62	1.14	21.03
	30 - 60	1.25	59.43	48.95	29.66	1.10	19.29
	Mean	1.23	57.26	48.80	28.64	1.12	20.16

Each value in this table represents the mean of 4 replications*
**** Hydraulic Conductivity**

According to the above-mentioned, data (the table 3) , the differences in soil physical properties may be referred to application of gypsum and deep plowing. The application of gypsum and deep plowing resulted in considerable decreases in the bulk density values of the studied soil, in agreement with the results obtained by **Webster and Nyborg, (1986).** The maximum mean decrease percentages of bulk density as calculated on basis of values of the two soil layers were 8.03 and 10.22 % for deep plowing + 50% of gypsum requirements and deep plowing with 100% gypsum requirements , respectively, compared to the control treatment. Generally, the above mentioned results agree with those reported by **Azhar et.al., (2001)** and **Prammanee et.al. (2007)**. Deep plowing and gypsum application and their combination increased soil total porosity values in comparison to the control treatment (no plowing and no gypsum application).

Such effects has been observed in both surface and subsurface layers with the treatment (deep plowing + 100 % gypsum requirements).Also, it could be concluded from Table (3) that, field capacity, wilting point and available water were increased for the two layers (0 – 30 cm) and (30 – 60 cm) as a result of using applied treatment. The greatest increase was found with treatment (deep plowing + 100 %

gypsum requirements). Soil hydraulic conductivity was increased by gypsum application and deep plowing . The greatest hydraulic conductivity values were obtained for treatment p_2 g_2 through the two tested soil layers. Hydraulic conductivity is especially sensitive to low electrolyte concentration. Thus, mixing gypsum into the soil can potentially increase hydraulic conductivity values, **(Oster and Frenkel, 1980; Oster,1982 and Oad et.al., 2001a).**

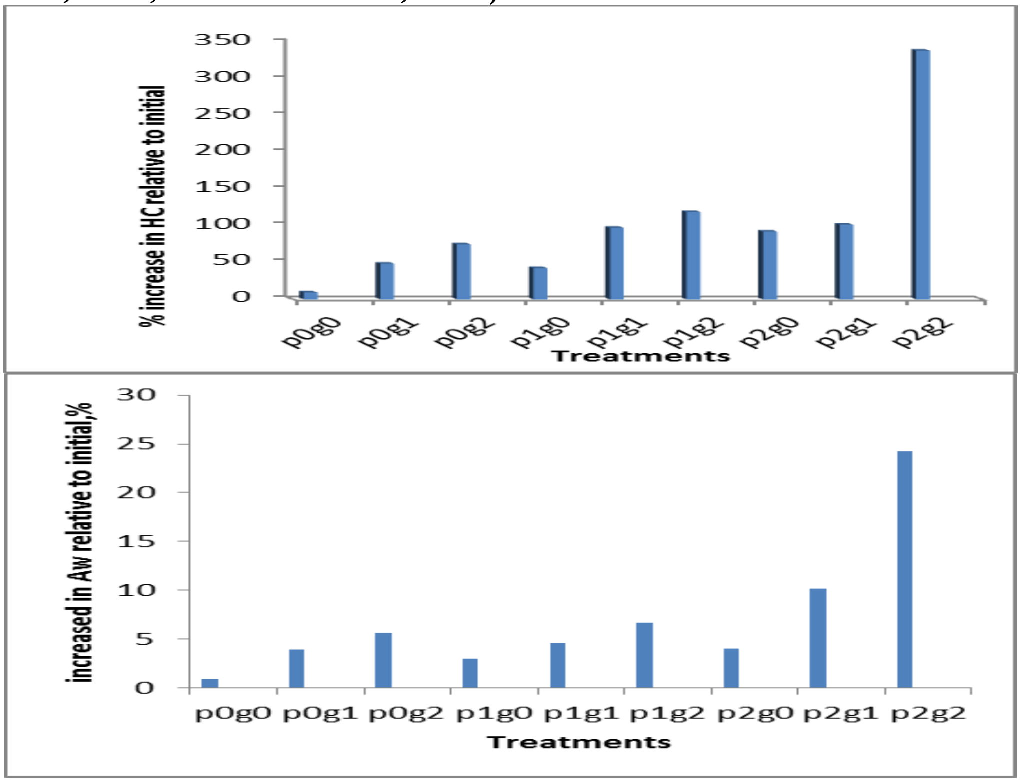

Figure (1): percent change in available water (AW) and hydraulic conductivity (HC) relative to initial at the end of experiment.

Figure (1) show the percent change in available water and hydraulic conductivity at the end of experiment. It could be concluded that the available water values relative to initial expressed as mean percent increased from 0.93 % to 24.25% for the control and p_2g_2 treatments, respectively. Hydraulic conductivity values relative to initial as percent increased from 9.29 % to 337.86 % for control and p_2g_2 treatments ,respectively, at the end of experiment . The greatest increases were observed with p_2g_2 treatment .

3- Some soil chemical properties as influenced by the applied treatments

Data presented in Table (4), indicated the reduction in soil pH due to soil deep plowing and gypsum application.

Table(4) : Effect of applied treatments on soil pH, ECe, solube cations and soluble Anions values in the tested soil.

Treatment	Soil depth, cm	pH In soil paste	ECe dS/m	Soluble cations, mmole+/L, in soil paste extract				Soluble anions, mmole-/L, in soil paste extract			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO3^{--}$	$HCO3^{-}$	Cl^{-}	$SO4^{--}$
P_0g_0	0-30	8.23	9.84	18.14	10.77	68.45	1.46	0.97	3.65	63.59	30.61
	30-60	8.34	11.52	18.25	16.36	79.06	1.37	2.03	3.73	76.95	33.03
		Mean	10.68	18.20	13.57	73.76	1.42	1.50	3.69	70.27	31.82
P_0g_1	0-30	8.22	8.80	16.15	9.59	60.96	1.30	0.86	3.25	56.63	27.26
	30-60	8.33	10.30	16.34	14.65	70.78	1.23	1.80	3.30	68.49	29.41
	Mean		9.55	16.25	12.12	65.87	1.27	1.33	3.28	62.56	28.34
P_0g_2	0-30	8.19	8.30	17.10	10.16	54.36	1.38	0.81	3.14	53.41	25.64
	30-60	8.30	9.70	15.39	13.80	66.66	1.15	1.70	3.13	64.91	27.26
	Mean		9.00	16.25	11.98	60.51	1.27	1.26	3.14	59.16	26.45
P_1g_0	0-30	8.14	7.80	14.32	8.50	54.03	1.15	0.77	2.88	50.19	24.16
	30-60	8.26	9.20	14.59	13.08	63.23	1.10	1.61	2.96	61.17	26.26
	Mean		8.50	14.46	10.79	58.63	1.13	1.19	2.92	55.68	25.21
P_1g_1	0-30	8.09	7.40	13.58	8.07	51.26	1.09	0.73.	2.73	47.62	23.65
	30-60	8.22	8.60	13.64	12.23	59.04	1.09	1.51	2.77	57.18	24.54
	Mean		8.00	13.61	10.15	55.15	1.09	1.67	2.75	52.40	24.10
P_1g_2	0-30	8.06	6.90	13.66	8.11	51.54	1.09	0.73	2.74	47.88	23.05
	30-60	8.17	8.10	14.27	12.32	59.54	1.04	1.52	2.80	57.95	24.90
	Mean		7.50	13.97	10.22	55.54	1.07	1.13	2.77	52.92	23.98
P_2g_0	0-30	8.01	5.90	10.83	6.43	40.87	0.87	0.58	2.18	37.97	18.27
	30-60	8.10	6.90	10.95	9.81	47.42	0.82	1.21	2.22	45.87	19.70
	Mean		6.40	10.89	8.12	44.15	0.85	0.90	2.20	41.92	18.99
P_2g_1	0-30	7.98	4.92	10.08	5.98	38.03	0.81	0.54	2.03	35.33	17.00
	30-60	8.09	5.76	10.53	9.09	43.92	0.76	1.12	2.07	42.75	18.36
	Mean		5.34	10.31	7.54	40.98	0.79	0.83	2.05	39.04	17.68
P_2g_2	0-30	7.56	3.69	6.72	3.99	25.35	0.54	0.30	1.35	42.85	11.40
	30-60	7.70	4.32	7.02	6.06	29.28	0.51	0.75	1.38	28.50	12.24
	Mean		4.01	6.87	5.03	27.32	0.53	0.53	1.37	35.68	11.82

The greatest decrease in soil pH was observed in deep plowing plots with the application of 100 % gypsum requirement of soil, Values of soil ECe were considerably decreased within the two layers (0 – 30) and (30 – 60 cm), from 9.84 to 3.69 dS/m and from 11.32 to 4.32 dS/m in soil surface and subsurface layers, respectively.

It is clear from table (4) that soluble cations and anions were considerably decreased in both surface and subsurface layers as a result of treatments, the greatest decrease was observed with deep plowing and the application of 100% of estimated gypsum requirements of soil.

Table(5): Values of CEC, ESP, OM and CaCO3 equivalent of the tested soil

Treatment	Soil depth, cm	CEC Cmole+/kg	Exch. Na, cmole+/kg	ESP	O.M g/kg	CaCO3 g/kg
P_0g_0	0 - 30	41.43	8.22	19.84	20.5	48.31
	30 - 60	42.02	8.62	20.51	12.75	50.08
	Mean	41.73	8.42	20.18	16.63	49.20
P_0g_1	0 - 30	41.43	7.64	18.68	20.54	48.21
	30 - 60	42.43	8.22	19.37	12.78	49.97
	Mean	41.93	7.93	19.03	16.66	49.09
P_0g_2	0 - 30	41.51	6.99	16.84	20.58	48.12
	30 - 60	42.23	7.24	17.14	12.80	49.88
P_1g_0	Mean	41.87	7.12	16.99	16.69	49.00
	0 - 30	41.64	7.56	18.16	20.56	48.17
	30 - 60	42.36	7.84	18.51	12.79	49.80
	Mean	42.00	7.70	18.34	16.68	48.98
P_1g_1	0 - 30	41.80	7.15	17.11	20.60	48.07
	30 - 60	42.44	7.41	17.45	12.81	49.60
	Mean	42.17	7.28	17.28	16.71	48.84
P_1g_2	0 - 30	41.93	6.17	14.72	20.64	47.90
	30 - 60	42.57	6.21	14.59	12.84	48.20
	Mean	42.25	6.19	14.66	16.74	48.05
P_2g_0	0 - 30	42.05	7.40	17.60	20.57	48.14
	30 - 60	42.71	7.59	17.77	12.79	47.90
	Mean	42.38	7.50	17.69	16.68	48.02
P_2g_1	0 - 30	42.25	5.75	13.60	21.11	47.14
	30 - 60	42.85	5.86	13.68	13.13	46.56
	Mean	42.55	5.81	13.64	17.12	46.85
P_2g_2	0 - 30	42.66	3.76	8.81	22.11	4637
	30 - 60	43.26	3.90	9.02	13.75	45.90
	Mean	42.96	3.83	8.92	17.93	46.14

Results of exchangeable sodium in mmmol^{+}/kg soil and ESP remarkable reductions due to all treatments in comparison with the through surface and subsurface soil layers. ESP values decreased from 19.84 % to 8.81% and from 20.51% to 9.02% within soil layers (0 – 30 cm) and (30 – 60 cm), respectively. Slight increases in O.M were observed after harvesting wheat crop as a result of applied treatment. The greatest increase was found with treatment P_2g_2. It could be concluded from data presented in Table (5) that the percentage of CaCO3 content was decreased at the end of experiment from 48.31 g/kg to 44.37 g//kg and from 50.08 g/kg soil to 45.90 g/kg soil for surface and subsurface layers, respectively. This could be attributed to subsequent leaching of soil with migration water.

Table(6) : Percent change in ESP after treatments of the tested soil.

Treatment	Depth,cm	ESP	Reduced* ESP, %	RSE**
Initial	0 – 30	22.04		
	30 – 60	22.80		
P_0g_0	0 – 30		2.20	9.98
	30 – 60		2.29	10.04
	Mean		2.25	10.01
P_0g_1	0 – 30		3.36	15.25
	30 – 60		3.43	15.04
	Mean		3.40	15.15
P_0g_2	0 – 30		5.20	23.59
	30 – 60		5.66	24.82
	Mean		5.43	24.21
P_1g_0	0 – 30		3.88	17.60
	30 – 60		4.29	18.82
	Mean		4.09	18.21
P_1g_1	0 – 30		4.93	22.37
	30 – 60		5.35	23.46
	Mean		5.14	22.92
P_1g_2	0 – 30		7.32	33.21
	30 – 60		8.21	36.01
	Mean		7.77	34.61
P_2g_0	0 – 30		4.44	20.15
	30 – 60		5.03	22.06
	Mean		4.74	21.11
P_2g_1	0 – 30		8.44	38.29
	30 – 60		9.21	40.39
	Mean		8.83	39.34
P_2g_2	0 – 30		13.23	60.03
	30 – 60		13.78	60.44
	Mean		13.51	60.24

***Reduced ESP,% = ESP_i - ESP_f**

**** RSE = Removal sodium efficiency in percentage of Na – removed from soil at the end of experiment was calculated according to Mahdy , (2011) as follows:**

RSE = ESP_i - ESP_f / ESP_i x 100

Data presented in Table (6) and figure (2) show percent change in ESP after applying treatments of the studied soil. The greatest reduction in ESP values was found with treatment P_2g_2 , RSE values greatly increased from about 9.98% with the control (no deep plowing and no gypsum) to 60.24% with the treatment (deep plowing +100% of estimated gypsum requirement.

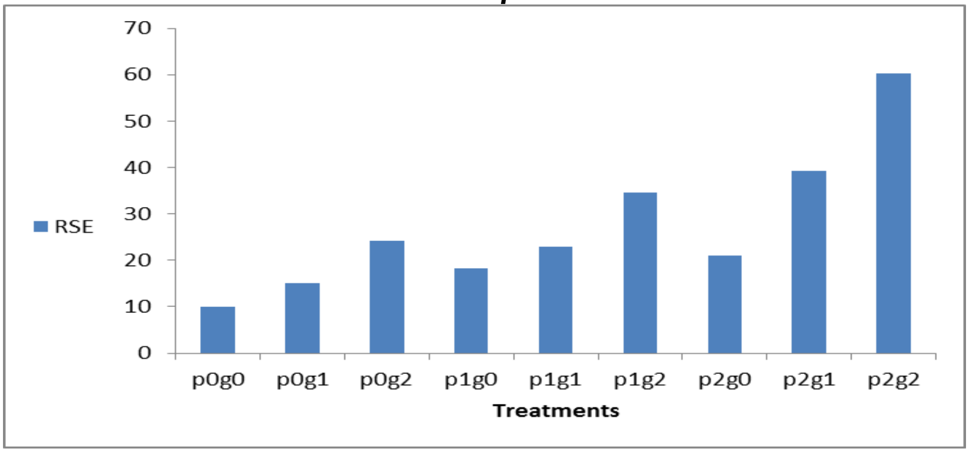

Figure (2): Removal sodium efficiency (RSE) in percentage of Na – removed from soil at the end of experiment.

4- Some plant parameters as influenced by the applied treatments

Table (7) indicate values of grain and straw yield of wheat plant as affected by the applied treatment.

Table (7): Effect of applied treatments on grain and straw yields of wheat crop.

Treatment	Wheat yield (t/he)	
	grain	straw
P_0g_0	3.738 c	4.405 f
P_0g_1	3.810 c	4.350 f
P_0g_2	4.214 bc	5.320 ef
P_1g_0	3.200 bc	4.200 def
P_1g_1	4.917 abc	4.907 cde
P_1g_2	5.476 abc	5.990 bcd
P_2g_0	3.512 abc	4.881 abc
P_2g_1	6.238 ab	6.238 eb
P_2g_2	7.024 a	6.500 a

It could be observed from statistical analysis of data presented in Table (7) that there are significant differences ($P \leq 0.05$) among treatments concerning grain and straw yields of wheat. The greatest increase in grain and straw yields of wheat plants were associated with treatment p_2g_2 , this could be due to the increase of available water % and the decrease of both soil salinity and sodicity stress through plant growth stages as a result of soil deep plowing, gypsum application and leaching with water.

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أثر اضافة الجبس الزراعي والحرث في تحسين صفات الأرض الطينية الثقليلة شديدة التدهور المتاخمة لبحيرة قارون ونمو نبات القمح بها

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الملخص

اجريت تجربة حقلية في احدي المزارع الخاصة علي ارض طينية ثقيلة وأظهرت الدراسة المورفولوجية وجود طبقة مندمجة تحت التربة و تعاني من الملوحة والصودية تبعد حوالي 200م عن بحيرة قارون لدراسة اثر كلا من الحرث السطحي والحرث العميق مع اضافة الجبس والتداخلات بينهما ، حيث اجريت اولا عملية غسيل للتربة بمعدلات الاحتياجات الغسيلية المحسوبة مقسمة علي سبع فترات ، وبعد عملية الغسيل واجراء المعاملات التسعة (بدون حرث بدون جبس، بدون حرث + 50 % من الاحتياجات الجبسية، بدون حرث + 100 % من الاحتياجات الجبسية، حرث سطحي بدون جبس، حرث سطحي + 50 % من الاحتياجات الجبسية، حرث سطحي + % من الاحتياجات الجبسية، حرث عميق بدون جبس، حرث عميق + 50 % من الاحتياجات الجبسية و حرث عميق + % من الاحتياجات الجبسية) تم زراعة محصول القمح للاستدلال علي مدي التحسن في خواص التربة الطبيعية والكيميائية وانعكاس ذلك علي انتاجية القمح من الحبوب والتبن وكان افضل المعاملات تاثيرا علي التحسن في خواص التربة المدروسة والتحسن في انتاجية محصول القمح من الحبوب والتبن هي الحرث العميق + 100% من الاحتياجات الجبسية