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IMPACT OF SOME SOIL MANAGEMENT PRACTICES ON SOME CHEMICAL PROPERTIES OF SALT AFFECTED SOILS AND SUGAR BEET PRODUCTION

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ABSTRACT

A field experiment was conducted during two successive winter seasons 2012 and 2013 in El Tina plain area, North Sinai, Egypt. It aims to study the effect of drain spacing, ploughing method and gypsum and elemental sulphur applications on some soil chemical properties and sugar beet yield. The main plots were devoted to different drain spacing, S (25, 35 and 50 m). The subplots were allocated to ploughing method, P (conventional and cross subsoiling plough). The sub-subplots were assigned for soil amendment application, A (without amendment, gypsum and elemental sulphur application). The results indicated that, decreasing of soil pH under gypsum or elemental sulphur application treatments were superior to other studied treatments. Addition of elemental sulphur was more effective in decreasing soil pH than gypsum addition treatment. The values of pH under elemental sulphur treatments were 8.14, 8.10 and 8.00 for 30-40, 40-50 and 50-60 cm soil depths as compared to 8.22, 8.20 and 8.09 for control treatments, .870respectively. The more effective treatment with respect to decreasing soil salinity was 25 m drain spacing, cross subsoiling ploughing and gypsum addition in 0-10 and 10-20 cm soil depths, which represent about 3.22 and 3.31dSm^{-1} less than control treatments, respectively. The relevant values for fourth consecutive lower soil depths were 3.62, 5.03, 3.57 and 3.05 dSm^{-1} lower than control treatments, respectively. Along more soil depths under investigation, 25 m drain spacing and cross subsoiling ploughing combined with gypsum addition treatment was the more effective treatment that sharply decreased ESP of the studied soil. The highest decrease under such conditions was 39.45% lower than control treatment in 30-40 cm soil depth. The combination of 25 m drain spacing, cross subsoiling ploughing method and gypsum addition treatment achieved the highest sugar beet roots yield. Such increment was 7.57 tons fed^{-1}, which represent about 75.85% over control treatments.

Key words: Salt affected soils, drain spacing, cross subsoiling, gypsum, sulphur, sugar beet.

INTRODUCTION

El-Tina Plain suffered from high groundwater table and high temperature that led to the salinization of the soil profile to extremely high levels. The high salinity of the groundwater table led to the formotion of salt crusts and increased soil sodium content **(Kamel and Bakry, 2009)**. The soils in the area of El-Tina plain are characterized by five texture classes namely, loamy sand, sandy loam, clay loam, clay and sandy **(Rabie *et al.,* 1991)**. The soil texture in the area varies from sand to clay; the heavy clay soil area is only located at the north-western part of the area **(DRI, 1997)**.

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The soil salinity in the most area ranged between 100 and 125 dS m^{-1} (**Sallam *et al.,* 2013**). **Ezeaku *et al.* (2015)** found that application of the soil reclamation treatments particularly gypsum at 100% (GR) and in combination with farmyard manure and chiseling decreased soil pH comparing with control treatment. **Kanwal *et al.* (2014)** found that application of gypsum, municipal compost and their combination decreased soil pH in the soils compared with control treatments. **Ahmed (2013)** revealed that soil pH decreased in the case of elemental sulphur application as a result of biologically oxidized of elemental sulphur to H_2SO_4 in the soil under aerobic conditions. Mole drain individually or combined with soil amendments (gypsum, sand and aluminum sulfate) decreased soil pH (**Farag *et al.,* 2013**).

Abdel-Fattah and El-Naka (2015) studied the desalination and desodification curves of Sahl El-Tina soils and they found that all treatments reduced soil salinity, with a superiority of calcium chloride in reducing soil salinity, increasing soil permeability and speed of reclamation. Subsoiling will enhance downward movement of irrigation water carrying of excess salts from surface soil layers **(Moukhtar *et al.,* 2002b and Moukhtar *et al.,* 2003b)**. **Ezeaku and Shehu (2012**) found that, a significant decrease in electrical conductivity (EC) was observed when gypsum at 100% GR was applied alone or combined with FYM.

The soil salinity reduced by 13.3 and 41.1% in surface layer and it reduced by 25.7 and 38.85% in the subsurface layer under 30 and 60 m drain spacing, respectively compared to the narrow one (**Abdel-Mawgoud *et al.,* 2007). Li *et al.* (2015)** found that soil ESP was declined under gypsum application, where the Ca^{++} in gypsum is sufficiently soluble to provide calcium ions (Ca^{2+}) that exchange and replace exchangeable sodium ions (Na^{+}).

Makoi and Ndakidemi (2007) stated that in the first year (Y1) farmyard manure decreased the ESP by 30.4%, gypsum by 30.3% and by 30.4% when the two amendments were combined. The mole drain filled with sand technique combined with soil amendments was more effective in reducing exchangeable sodium percentage **(Farag *et al.,* 2013 and Hussain *et al.,* 2001).**

The present study aimed at investigating the effect of some soil management practices on some soil chemical properties under cultivation of sugar beet.

MATERIALS AND METHODS

A field experiment was conducted during two successive winter seasons 2012 and 2013, at El Tina plain area, North Sinai, Egypt. The flood irrigation system was applied. The field experiment aims to study the impact of some soil management practices on some physical and chemical properties of the soil under investigation. Soil samples representing soil depths 0-10, 10-20, 20-30, 30-40, 40-50 and 50-60 cm were collected and prepared for physical and chemical analyses. The main physical and chemical properties of the studied soil under investigation are shown in Tables 1 and 2. The chemical analysis of the irrigation water is shown in Table 3. The field experiment included the following treatments:

Drain Spacing

1- 50 m drain spacing (S1), which represent the common drain distance in the study area.

2- 25 m drain spacing (S2), which represent the unsteady state (transient) flow conditions and calculated using Glover-Dumm′s formula as recommended by **Wesseling (1980)**.

3- 35 m drain spacing (S3), which represent

Table (1): Some physical properties of the studied soil under investigation

Soil depth (cm)	Particle size distribution (%)				Textural class	Particle density (Mg m^{-3})	Bulk density (Mg m^{-3})	Porosity (%)	Saturated hydraulic conductivity (K_s) (m day^{-1})
	Coarse sand	Fine sand	Silt	Clay					
0-10	29.40	32.04	21.69	16.87	Sandy loam	2.54	1.40	44.88	0.85
10-20	30.50	30.43	23.40	15.67	Sandy loam	2.56	1.38	46.09	0.65
20-30	14.87	36.07	32.49	16.57	Loam	2.63	1.24	52.85	0.33
30-40	21.91	30.63	27.05	20.42	Loam	2.62	1.26	51.91	0.36
40-50	20.08	33.84	29.57	16.52	Loam	2.61	1.25	52.11	0.27
50-60	52.17	14.74	17.43	15.66	Sandy loam	2.57	1.39	45.91	0.92

Table (2): Some chemical properties of the soil under investigation

Soil depth (cm)	pH	EC (dSm^{-1})	ESP (%)	CaCO3 (%)	O.M (%)	CEC (cmol$_c$ kg^{-1} soil)
0-10	8.13	16.61	23.31	1.73	1.42	19.35
10-20	8.15	14.65	25.08	1.22	0.78	18.25
20-30	8.06	16.46	28.33	2.05	0.61	22.25
30-40	8.30	18.71	30.14	1.94	0.35	21.16
40-50	8.27	18.08	28.16	2.11	0.26	22.05
50-60	8.14	14.33	22.38	1.31	0.11	17.64

Table (3): Some chemical properties of the irrigation water used in the current study.

pH	EC (dSm^{-1})	Cations meql^{-1}				Anions meq l^{-1}				SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	
7.62	1.43	7.62	2.77	8.40	0.18	-*	5.33	8.61	0.41	4.95

* no carbonate was detected.

the steady state flow conditions and calculated according to **Donnan (1946)** and its modification by **Hooghoudt (1952)**.

B- Ploughing method, (conventional or cross subsoiling plough)

C- Soil amendment, (without soil amendment application (control), gypsum at rate 10 Mg fed.$^{-1}$ or elemental sulphur at rate 0.5 Mg fed.$^{-1}$)

The field experiment was carried out in a spilt spilt plot design where, the drain spacing occupied the main plots, the plough method occupied the sub plots and the soil amendment treatments occupied the sub sub plots. The experimental area was cultivated by sugar beet plant *(Beta vulgaris L.*). NPK fertilizers, Leaching requirements and farmyard manure were applied as recommended in the area under investigation.

After harvesting, soil samples were collected and yield data were estimated.

Particle size distribution, Bulk density (Db), Total porosity (%), Saturated hydraulic conductivity, The electrical conductivity (EC) and total calcium carbonate ($CaCO_3$) (%), were determined according to **Klute (1986)**. Saturated soil paste was prepared and extracted according to **Richards (1954).** Soil pH in saturation soil paste according to **Richards (1954).** Organic matter content was determined according to Walkley and Black procedure **(Nelson and Sommers, 1982).** Cation exchange capacity (CEC) was determined using ammonium acetate method and exchangeable sodium was determined using ammonum acetate solution as described by **Jackson (1967)**. Gypsum requirement (GR) was calculated according to Schoonover's method **(Richards, 1954)**. The obtained data were statistically analyzed and treatment differences were evaluated using least significant difference ($LSD_{0.05}$) test using SAS software **(SAS, 1994)**.

RESULTS AND DISCUSSION

Effect of Applied Treatments on Soil Reaction (pH)

Results presented in Table 4 show that the two treatments (S_1 and S_2) are characterized by slightly decreased soil pH. Such effects were found true in all studied soil depths.

Regarding to the influence of the ploughing method on soil pH, results in the previous Table show that in all soil depths, subsoiling ploughing treatment resulted in a narrow range of decreasing soil pH relative to control treatments.

Obtained results of Table 4 also indicate to decrease of soil pH under gypsum or elemental sulphur application treatments were superior to other studied treatments. The pH values were 8.17, 8.12 and 8.04 in 30-40, 40-50 and 50-60 cm soil depths comparing to 8.22, 8.20 and 8.09 for control treatments, respectively under gypsum addition treatment. These findings are in harmony with **Rasouli *et al.* (2013)** who found that gypsum application to the soil decreased soil pH. As shown in Table 4 addition of elemental sulphur was more effective in decreasing soil pH than gypsum addition treatment. The values of pH under elemental sulphur treatments were 8.14, 8.10 and 8.00 for 30-40, 40-50 and 50-60 cm soil depths as compared to 8.22, 8.20 and 8.09 for control treatments, respectively. The decreasing of soil pH under such conditions could be due to the oxidation of elemental sulphur by soil microorganisms to sulphuric acid which in turn decrease soil pH. Such findings are in harmony with those of **El- Gala *et al.* (1990[a]), El-Gala *et al.* (1990b), El-Fakhrani *et al.* (1992) and El-Fakharani (1995 and 1996)**.

The effectiveness of studied treatments on reducing soil pH was enhanced by using narrow drain spacing treatment combined with subsoilingploughing method and soil amendments as shown in Table 4. Along studied soil depths, elemental sulphur addition combined with 35 drain spacing and cross subsoiling method caused the high decreasing in soil pH. Such decreases were 0.14, 0.10 and 0.09 units in 0-10, 10-20 and 20-30 cm soil depths lower than control treatments, respectively. The corresponding values for 30-40, 40-50 and 50-60 cm soil depths were 0.21, 0.21 and 0.08 units lower than control treatments, respectively.

Effect of Applied Treatments on Soil Salinity (EC)

Results in Table 5 reveal that soil salinity (EC) in all studied soil depths was decreased as a result of two narrow drain spacings, cross subsoiling ploughing method and soil amendements addition and their interactions. Obtained results show that 25 m drain spacing significantly decreases EC of the studied soil depths under investigation

Table (4): pH values of the investigated soil saturation extracts as affected by applied treatments

Drain space (m)	Plough (P)	Soil amendments (A)			Mean	Mean of main effects		Soil amendments (A)			Mean	Mean of main effects	
		A_o	A_1	A_2				A_o	A_1	A_2			
		Depth (0-10) cm						Depth (10-20) cm					
S_1	P_1	8.13	8.09	8.10	8.11	S_1	8.08	8.12	8.08	8.04	8.08	S_1	8.07
	P_2	8.12	8.05	7.99	8.05	S_2	8.06	8.12	8.07	8.00	8.06	S_2	8.06
Mean		8.12	8.07	8.04	8.08	S_3	8.04	8.12	8.07	8.02	8.07	S_3	8.06
S_2	P_1	8.10	8.07	8.02	8.06	P_1	8.07	8.11	8.07	8.02	8.06	P_1	8.07
	P_2	8.09	8.05	8.00	8.05	P_2	8.04	8.11	8.06	8.03	8.06	P_2	8.06
Mean		8.10	8.06	8.01	8.06	A_o	8.10	8.11	8.06	8.02	8.06	A_o	8.11
S_3	P_1	8.09	8.07	8.02	8.06	A_1	8.06	8.11	8.07	8.04	8.07	A_1	8.06
	P_2	8.08	8.04	7.99	8.03	A_2	8.02	8.10	8.04	8.02	8.05	A_2	8.02
Mean		8.08	8.05	8.00	8.04			8.10	8.05	8.03	8.06		
		Depth (20-30) cm						Depth (30-40) cm					
S_1	P_1	8.02	7.99	7.93	7.98	S_1	7.97	8.29	8.25	8.20	8.24	S_1	8.23
	P_2	8.02	7.94	7.92	7.96	S_2	7.99	8.29	8.20	8.17	8.22	S_2	8.19
Mean		8.02	7.96	7.92	7.97	S_3	7.99	8.29	8.23	8.18	8.23	S_3	8.11
S_2	P_1	8.00	7.98	7.93	7.97	P_1	7.98	8.27	8.22	8.19	8.22	P_1	8.20
	P_2	8.02	8.00	8.03	8.02	P_2	7.99	8.22	8.11	8.16	8.16	P_2	8.16
Mean		8.01	7.99	7.98	7.99	A_o	8.02	8.24	8.16	8.17	8.19	A_o	8.22
S_3	P_1	8.02	8.01	7.94	7.99	A_1	7.99	8.15	8.12	8.08	8.12	A_1	8.17
	P_2	8.03	8.02	7.93	7.99	A_2	7.95	8.13	8.10	8.08	8.10	A_2	8.14
Mean		8.02	8.02	7.94	7.99			8.14	8.11	8.08	8.11		
		Depth (40-50) cm						Depth (50-60) cm					
S_1	P_1	8.21	8.14	8.12	8.16	S_1	8.15	8.11	8.07	8.02	8.06	S_1	8.05
	P_2	8.22	8.11	8.09	8.14	S_2	8.15	8.10	8.03	8.00	8.04	S_2	8.04
Mean		8.21	8.12	8.10	8.15	S_3	8.14	8.10	8.05	8.01	8.05	S_3	8.04
S_2	P_1	8.21	8.15	8.11	8.15	P_1	8.15	8.11	8.02	8.00	8.04	P_1	8.05
	P_2	8.19	8.12	8.11	8.14	P_2	8.14	8.06	8.05	8.00	8.03	P_2	8.04
Mean		8.20	8.13	8.11	8.15	A_o	8.20	8.08	8.03	8.00	8.04	A_o	8.09
S_3	P_1	8.19	8.11	8.09	8.14	A_1	8.12	8.08	8.02	8.02	8.04	A_1	8.04
	P_2	8.20	8.11	8.09	8.13	A_2	8.10	8.09	8.03	7.98	8.03	A_2	8.00
Mean		8.20	8.12	8.10	8.14			8.09	8.02	8.00	8.04		

Notes: S1, S2 and S3=50, 25 and 35 m drain spacing, respectively. P1= conventional ploughing. P2= cross subsoilingploughing.

A0= without amendment application. A1= Gypsum application (10 Mg $fed.^{-1}$). A2= Elemental sulphur application (0.5 Mg $fed.^{-1}$).

Table (5): Electrical conductivity (EC), (dSm^{-1}) of the investigated soil saturation extracts as affected by applied treatments

Drain space (m)	Plough (P)	Soil amendments (A) A_o	A_1	A_2	Mean	Mean of main effects		Soil amendments (A) A_o	A_1	A_2	Mean	Mean of main effects	
		Depth (0-10) cm						**Depth (10-20) cm**					
S_1	P_1	14.99	13.05	14.10	14.05	S_1	13.57	12.60	11.07	11.39	11.69	S_1	11.40
	P_2	13.45	12.40	13.39	13.08	S_2	12.49	11.37	10.61	11.37	11.12	S_2	10.33
Mean		14.22	12.73	13.75	13.57	S_3	13.01	11.99	10.84	11.38	11.40	S_3	10.60
S_2	P_1	13.20	12.10	13.18	12.83	P_1	13.45	11.18	10.45	10.78	10.80	P_1	11.20
	P_2	12.38	11.57	12.50	12.15	P_2	12.59	10.17	9.29	10.09	9.85	P_2	10.36
Mean		12.79	11.84	12.84	12.49	A_o	13.50	10.68	9.87	10.43	10.33	A_o	11.19
S_3	P_1	13.97	12.99	13.47	13.48	A_1	12.32	11.36	10.82	11.13	11.10	A_1	10.28
	P_2	13.00	11.77	12.86	12.54	A_2	13.25	10.46	9.43	10.44	10.11	A_2	10.86
Mean		13.48	12.38	13.16	13.01			10.91	10.12	10.78	10.60		
		Depth (20-30) cm						**Depth (30-40) cm**					
S_1	P_1	14.80	13.08	13.95	13.94	S_1	13.38	16.58	15.35	15.89	15.94	S_1	15.09
	P_2	13.11	12.28	13.08	12.82	S_2	12.35	14.63	13.83	14.28	14.25	S_2	12.61
Mean		13.96	12.68	13.52	13.38	S_3	12.72	15.60	14.59	15.08	15.08	S_3	13.20
S_2	P_1	13.18	12.11	13.05	12.78	P_1	13.29	13.43	12.51	13.55	13.16	P_1	14.31
	P_2	12.25	11.18	12.32	11.92	P_2	12.34	12.25	11.55	12.40	12.06	P_2	12.96
Mean		12.72	11.65	12.69	12.35	A_o	13.21	12.84	12.03	12.98	12.98	A_o	13.96
S_3	P_1	13.31	12.96	13.21	13.16	A_1	12.19	14.13	13.17	14.17	13.82	A_1	13.08
	P_2	12.60	11.50	12.77	12.29	A_2	13.06	12.77	12.07	12.91	12.58	A_2	13.87
Mean		12.96	12.23	12.99	12.72			13.45	12.62	13.54	13.54		
		Depth (40-50) cm						**Depth (50-60) cm**					
S_1	P_1	16.28	14.55	15.34	15.39	S_1	14.78	12.43	11.02	12.27	11.90	S_1	11.46
	P_2	14.73	13.38	14.41	14.17	S_2	13.63	11.43	10.31	11.32	11.02	S_2	10.27
Mean		15.50	13.97	14.88	14.78	S_3	13.98	11.93	10.67	11.80	11.46	S_3	10.58
S_2	P_1	14.41	13.31	14.51	14.08	P_1	14.63	11.14	9.63	11.24	10.67	P_1	11.22
	P_2	13.26	12.71	13.59	13.19	P_2	13.63	10.19	9.38	10.03	9.87	P_2	10.32
Mean		13.84	13.01	14.05	13.63	A_o	14.56	10.66	9.50	10.63	10.27	A_o	11.13
S_3	P_1	14.97	13.68	14.63	14.42	A_1	13.42	11.23	10.66	11.39	11.10	A_1	10.08
	P_2	13.72	12.89	14.02	13.54	A_2	14.42	10.39	9.49	10.33	10.07	A_2	11.10
Mean		14.34	13.29	14.32	13.98			10.81	10.08	10.86	10.58		

	Depth (cm)	S	P	A	SP	SA	PA	SPA	Depth (cm)	S	P	A	SP	SA	PA	SPA
$L.S.D_{0.05}$	**0-10**	0.16	0.13	0.16	0.57	0.62	0.50	0.24	30-40	0.18	0.15	0.18	0.46	0.92	1.11	0.33
	10-20	0.17	0.14	0.17	0.45	0.62	0.51	0.21	40-50	0.17	0.14	0.17	0.57	0.69	0.54	0.18
	20-30	0.17	0.13	0.17	0.52	0.67	0.49	0.19	50-60	0.14	0.11	0.14	0.53	0.62	0.55	0.17

Notes: Refer to notes under Table 4.

especially in the three upper soil depths. The obtained decreases were 1.08, 1.07 and 1.03 dSm^{-1} lower than control treatments, respectively. The relevant detected values in (30-40), (40-50) and (50-60 cm) soil depths were 2.48, 1.15 and 1.19 dSm^{-1} lower than control treatments, respectively. Also, 35 m drain spacing treatment significantly reduced soil salinity comparing to control treatments.

The maximum decreasing was 1.89 dSm^{-1} which represent about 12.52% lower than control treatment was recorded in 30-40 cm soil depth. From the previous results, it could be concluded that, 25m drain spacing treatment was superior in reducing soil salinity comparing to other studied drain spacing treatments. These results could be rendered to the improvement of soil physical properties *i.e.* porosity, hydraulic conductivity… *etc* under narrow drain spacing treatment. Under such conditions, the efficiency of salt leaching from the soil will be increased. These findings are in agreement with **Abdel-Mawgoud *et al.* (2007)** who found that the decreasing in soil salinity followed the order of : 15>30>60 m drain spacing treatments.

Regarding to the effect of ploughing method treatment on soil salinity, results in Table 5 show that EC values were significantly decreased as a result of cross subsoiling method treatment. Such decreases were 6.39, 7.50 and 7.15% at three consecutive upper soil depths lower than control treatments. The corresponding values in the three consecutive lower soil depths were 9.43, 6.84 and 8.02% lower than control treatments, respectively. Such effects could be ascribed to the increase of improving soil water movement with cross subsoiling method treatment which led to increasing leaching of the salts through the soil profile. Same tendency was found by **El-Shahawy (2003)** who found that EC values decreased as a result of subsoiling operation. Data presented in Table 5 show the effect of gypsum and elemental sulphur addition treatments on soil salinity. Obtained data clear that gypsum addition was more pronounced and significantly decreasing soil salinity in all studied soil depths. Such decreases in the two upper successive soil depths were 1.18 and 0.91 dSm^{-1} lower than control treatments. The corresponding values in (20-30), (30-40), (40-50) and (50-60 cm) soil depths were 1.02, 0.88, 1.14 and 1.05 dSm^{-1} lower than control treatments, respectively. Decreasing soil salinity as a result of gypsum addition could be attributed to Ca^{2+} Ions which improve the soil physical properties by promoting flocculation, enhancing mean weight diameter, aggregate stability as well as soil hydraulic properties, all of the previous conditions increase leaching of salts through soil under studying.

These results are in agreement with **Chi *et al.* (2012)** who found that Gypsum addition significantly decreased soil salinity (EC). On the other hand, elemental sulphur addition slightly decreased soil salinity comparing to gypsum treatment. Such effect was more effective and significantly on decreasing soil salinity in the two studied surface soil depths. In this connection **El-Gamal (2015)** pointed out that sulphur addition significantly decreased soil salinity, (EC).

The triple combination of both drain spacing, ploughing method and soil amendments addition were postulated in Table 5. For three upper and three lower soil depths, which significantly exhibit reducing soil salinity. The more effective treatment with respect to decreasing soil salinity was 25 m drain spacing, cross subsoiling ploughing and gypsum addition in 0-10 and 10-20 cm soil depths, which represent about 3.42 and 3.31dSm^{-1} less than control treatments, respectively. The relevant values for fourth consecutive lower soil depths were 3.62, 5.03, 3.57 and 3.05 dSm^{-1} lower than control treatments, respectively.

Effect of Applied Treatments on Exchangeable Sodium Percentage (ESP)

Exchangeable sodium percentage or soil sodicity consider one of the important factors that used in classified salt-affected soils as well as determine the levels of their reclamation. The influence of both drain spacing and ploughing method as well as soil amendments application on exchangeable sodium percentage (ESP) are presented in Table 6.

With regard to drain spacing treatments, results in Table 6 demonstrate that, two studied narrow drain spacing treatments significantly decreased (ESP) in all studied soil depths. There was a fluctuation between two narrow drain spacing treatments with superiority of decreasing ESP through studied soil depths. Generally, in two studied upper soil depths, the 25 m drain spacing treatment was superior to another drain spacing treatments on decreasing soil ESP. On the other hand, the 35 m drain spacing treatment was the superior in decreasing soil ESP in (20-30), (40-50) and (50-60 cm) soil depths.

The highest value for decreasing ESP was detected in (50-60 cm) soil depth under 35 m drain spacing treatment. Such decreases represent about 14.25% lower than control treatment. Meanwhile, the lowest decrease for soil ESP was found in (30-40 cm) soil depth under the same previous treatment. The effect of narrow drain spacing treatment on decreasing ESP could be ascribed to that narrow lateral distance between drains improve soil hydraulic conductivity and consequently effectively removing the formed sodium soluble salts downward to the drain lines. **Wasef (2004)** found that a significant decreasing of ESP values were observed in the 20 m drain spacing than the other wide ones.

The decreasing of ESP was significantly under cross subsoiling ploughing treatment (Table 6). Such decreases were more marked in (20-30) and (30-40 cm) soil depths, which represent about 8.59 and 6.044% lower than control treatments, respectively. The effect of cross subsoiling treatment on improving desodification could be attributed to that many lines with big crack extent from soil surface to the subsoil depths and also numerous effective capillary cracks is formed. All these cracks together break the soil matrix and encourage downward of water as well as solute movement, especially soluble Na^+ salts, These findings are in good agreement with **Antar *et al.* (2008)** who found that the greatest desodification occurs after subsoiling tillage.

Regarding to soil amendments application and their effects on ESP, results in Table 6 show that both gypsum and elemental sulphur addition significantly decreased ESP values comparing to control treatments. Apparently, gypsum addition was more pronounced on decreasing soil ESP than elemental sulphur addition. The highest value for decreasing soil ESP was detected in (30-40 cm) studied soil depth under gypsum addition treatment. Such value represent about 24.00% lower than the value of control treatment. The corresponding values for two studied upper and two studied lower soil depths represent about 22.61, 22.45, 21.54 and 18.24% lower than the values of control treatments, respectively. The positive effects of gypsum on reducing ESP could be due to gypsum accelerate desaliniation and reclamation of the soil under investigation, where the Ca^{++} in gypsum is sufficiently to produce calcium ions (Ca^{++}) which exchange with and replace exchangeable sodium ions (Na^+). The sodium displaced by the Ca^{++} reacts with sulphate (SO_4^{-2}) to form sodium sulphate ($Na_2\ SO_4$). This sodium sulphate is highly water-soluble and easily leached from the soil **(Li *et al.*, 2015).** Also, the positive effect of elemental sulphur on decreasing ESP may be attributed to the enhancing effect of sulphur on form soil

Table (6): Exchangeable sodium percentage (ESP), (%) of the investigated soil as affected by applied treatments

Drain space (m)	Plough (P)	Soil amendments (A) A_o	A_1	A_2	Mean	Mean of main effects		Soil amendments (A) A_o	A_1	A_2	Mean	Mean of main effects	
		Depth (0-10) cm						**Depth (10-20) cm**					
S_1	P_1	22.75	18.65	21.82	21.07	S_1	20.52	24.00	18.14	22.75	21.63	S_1	21.39
	P_2	21.49	17.32	21.11	19.97	S_2	18.75	22.73	17.83	22.90	21.16	S_2	19.63
Mean		22.12	17.98	21.46	20.52	S_3	18.82	23.37	17.98	22.83	21.39	S_3	19.81
S_2	P_1	21.48	17.13	20.24	19.62	P_1	19.93	21.99	16.56	21.25	19.93	P_1	20.50
	P_2	19.93	13.88	19.82	17.88	P_2	18.79	20.90	16.38	20.67	19.32	P_2	20.05
Mean		20.71	15.50	20.03	18.75	A_o	21.14	21.44	16.47	20.96	19.63	A_o	22.18
S_3	P_1	20.73	16.05	20.56	19.11	A_1	16.36	22.09	16.95	20.80	19.95	A_1	17.20
	P_2	20.47	15.17	19.96	18.53	A_2	20.59	21.37	17.33	20.31	19.67	A_2	21.45
Mean		20.60	15.61	20.26	18.82			21.73	17.14	20.55	19.81		
		Depth (20-30) cm						**Depth (30-40) cm**					
S_1	P_1	26.41	22.93	24.64	24.66	S_1	23.64	28.34	23.77	25.87	25.99	S_1	24.70
	P_2	24.67	19.75	23.43	22.61	S_2	21.98	25.02	21.07	24.11	23.40	S_2	22.92
Mean		25.54	21.34	24.03	23.64	S_3	21.84	26.68	22.42	24.99	24.70	S_3	23.67
S_2	P_1	24.58	19.11	23.74	22.48	P_1	23.17	25.03	20.10	24.13	23.09	P_1	24.50
	P_2	23.55	17.72	23.16	21.48	P_2	21.18	26.04	17.16	25.08	22.76	P_2	23.02
Mean		24.06	18.42	23.45	21.98	A_o	24.56	25.53	18.63	24.61	22.92	A_o	26.17
S_3	P_1	24.44	19.48	23.19	22.37	A_1	19.42	26.06	19.96	27.28	24.43	A_1	19.89
	P_2	23.70	17.56	22.71	21.32	A_2	23.48	26.52	17.28	24.94	22.91	A_2	25.23
Mean		24.07	18.52	22.95	21.84			26.29	18.62	26.11	23.67		
		Depth (40-50) cm						**Depth (50-60) cm**					
S_1	P_1	27.47	21.71	25.71	24.96	S_1	24.08	22.94	18.17	22.33	21.15	S_1	20.49
	P_2	25.61	19.74	24.21	23.19	S_2	22.03	21.33	17.76	20.42	19.84	S_2	18.03
Mean		26.54	20.72	24.96	24.08	S_3	21.64	22.14	17.97	21.37	20.49	S_3	17.57
S_2	P_1	25.64	18.34	23.60	22.53	P_1	23.16	20.84	15.73	19.32	18.63	P_1	19.17
	P_2	24.34	16.64	23.62	21.53	P_2	22.01	18.31	15.90	18.11	17.44	P_2	18.23
Mean		24.99	17.49	23.61	22.03	A_o	25.12	19.57	15.82	18.71	18.03	A_o	20.18
S_3	P_1	24.20	18.61	23.12	21.98	A_1	18.71	18.84	16.01	18.38	17.74	A_1	16.50
	P_2	23.43	17.23	23.27	21.31	A_2	23.92	18.81	15.46	17.94	17.40	A_2	19.42
Mean		23.82	17.92	23.19	21.64			18.82	15.73	18.16	17.57		

	Depth (cm)	S	P	A	SP	SA	PA	SPA	Depth(cm)	S	P	A	SP	SA	PA	SPA
$L.S.D_{0.05}$	0-10	0.37	0.30	0.37	2.24	0.95	0.96	0.36	30-40	0.90	0.74	0.90	3.09	1.55	1.42	0.83
	10-20	0.32	0.26	0.32	2.30	0.57	0.91	0.56	40-50	0.45	0.37	0.45	2.92	0.98	1.24	0.68
	20-30	0.45	0.40	0.45	2.35	1.09	1.02	0.56	50-60	0.43	0.35	0.43	1.72	0.86	1.43	0.74

Notes: Refer to notes under Table 4.

aggregates and increasing soil hydraulic conductivity due to increasing the solubility of calcium carbonate in soil. The obtained results are similar to that obtained by **El-Hamdi *et al.* (2007)** who found that elemental sulphur addition decreased both soil salinity and sodicity.

The triple interactions of the three studied factors are presented in Table 6. Along more soil depths under investigation, 25 m drain spacing and cross subsoiling ploughing combined with gypsum addition treatment was the more effective treatment that sharply decreased ESP of the studied soil. The highest decrease under such conditions was 39.45% lower than control treatment in 30-40 cm soil depth.

Effect of Applied Treatments on Sugar Beet Yield

With respect to drain spacing treatments, results in Table 7 reveal that, 25 and 35 m drain spacing treatments significantly increased sugar beet roots yield and TSS relative to control treatments. Such increments of sugar beet roots yield were 2.19 and 1.98 tons fed.$^{-1}$ which represents about 18.85 and 17.04% over control treatments, respectively. Such results may be due to that narrow drain spacings improves soil physicochemical properties, as a direct effect on desalination and indirect on desodification and consequently, improves root zone conditions. These results stand in well agreement with those obtained by **Behairy (2007)** who found that narrow drain spacings improve root zone conditions of cotton plants, as a direct effect of desalination and faster water table recession hence, increased cotton yield. Concerning sugar beet roots yield under ploughing method treatments, results presented in Table 7 show that the cross subsoiling ploughing treatment significantly increased sugar beet roots yield by about 1.98 tons Fed.$^{-1}$ over control treatments. Such positive effects of cross subsoiling treatment may be due to the distribution and loosening of compacted subsurface layers which may cause appreciable improvement on the physical factors affecting root growth namely; soil mechanical impedance, soil aeration, soil water and soil temperature, thereby crop productivity increases. These results are quite in agreement with **Jabro *et al.* (2010) and Younesi and Navabzadeh (2007)** who found that deep plowing improves soil conditions more than shallow plowing because it loosens the soil, improving water intake rate and aeration, increasing root depth and development and allowing for deeper fertilizer movement in the soil.

Results presented in Table 7 also, show that gypsum and elemental sulphur addition significantly improved sugar beet roots yield. The increase in sugar beet yield was more pronounced under gypsum addition treatment. Such increase was 3.69 tons fed^{-1} which represent about 33.00% over control treatment. The obtained results may be due to that gypsum positively affected the soil properties such as porosity, ESP, pH and nutrients availability, which enhance plant growth. In this connection, **Chun *et al.* (2001)** found that application of flue gas desulfurization gypsum decreased Na^+ toxicity in plant cells, increased the storage capacity of soil N, and improved the availability of some other macro and micronutrients.

On the other hand, elemental sulphur had a positive effect in increasing sugar beet roots yield. Obtained findings could be attributed to the favorable effect of sulphur on reducing soil pH, improving soil conditions and increasing the availability of certain nutrients. These results are in agreement with the findings of **Sabir *et al.* (2007), Farook and Khan (2010) and Helmy *et al.* (2013)**.

The effects of triple interaction of drain spacing, ploughing method and soil amendments addition are shown in Table 7. The combination of 25 m drain spacing, cross subsoiling ploughing method and gypsum addition treatment achieved the highest sugar beet roots yield. Such increment was 7.57 tons fed^{-1}, which represent about 75.85% over control treatments.

Table (7): Sugar beet roots yield (tons/fed.) as affected by applied treatments

Drain space (m)	Plough (P)	Soil amendments (A)			Mean	Mean of the main effects	
		A_o	A_1	A_2			
		Yield (tons/fed.)					
S_1	P_1	9.98	12.00	10.77	10.92	S_1	11.62
(50 m)	P_2	10.61	13.83	12.53	12.32	S_2	13.81
Mean		10.29	12.92	11.65	11.62	S_3	13.60
S_2	P_1	10.77	14.66	12.69	12.71	P_1	12.01
(25 m)	P_2	12.65	17.55	14.54	14.91	P_2	14.01
Mean		11.71	16.11	13.62	13.81	A_o	11.18
S_3	P_1	10.48	13.84	12.92	12.41	A_1	14.87
(35)	P_2	12.60	17.33	14.42	14.78	A_2	12.98
Mean		11.54	15.58	13.67	13.60		

L.S.D$_{0.05}$	S	P	A	SP	SA	PA	SPA
	0.40	0.33	0.40	1.62	1.41	1.11	0.30

Notes: Refer to notes under Table 4.

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تأثير بعض أساليب إدارة التربة على بعض الخواص الكيميائية للأراضى المتأثرة بالأملاح وإنتاجية محصول بنجر السكر

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أجريت تجربة حقلية خلال موسمين شتويين متتاليين ٢٠١٢ و ٢٠١٣ بمنطقة سهل الطينة، شمال سيناء، مصر، لدراسة تأثير كلاً من مسافات المصارف الحقلية وطرق الحرث وايضاً إضافة محسنات التربة (الجبس أو الكبريت) على بعض الخواص الكيميائية وإنتاجية بنجر السكر، أستخدم التصميم الإحصائى نظام القطع المنشقة مرتين مع ثلاث مكررات، وضعت مسافات المصارف الحقلية (٢٥، ٣٥ و ٥٠م) فى القطع الرئيسية بينما تم وضع طرق الحرث (حرث تقليدى – حرث تحت التربة متعامد) فى القطع المنشقة الأولى، ووضعت محسنات التربة (جبس أو كبريت عنصرى) فى القطع المنشقة الثانية، ويمكن تلخيص أهم النتائج المتحصل عليها فيما يلى: وجد أن إنخفاض pH التربة تحت تأثير معاملة التربة بالمصلحات المختلفة (الجبس الزراعي والكبريت العنصري) كان أكثر وضوحا من غيره من المعاملات الأخرى، وقد وجد أن إضافة الكبريت العنصري كان أكثر تأثيرا من حيث إنخفاض رقم pH التربة مقارنة بالجبس الزراعى ، حيث وجد أن قيم رقم pH التربة تحت تأثير إضافة الكبريت كانت ٨,١٤ و ٨,١٠ و ٨,٠٠ فى أعماق ٣٠-٤٠ و ٤٠-٥٠ و ٥٠-٦٠ وذلك مقارنة بقيم الكنترول ٨,٢٢ و ٨,٢٠ و ٨,٠٩ على الترتيب، أوضحت النتائج أن التفاعل بين معاملة ٢٥ م مسافة بين المصارف ومعاملة الحرث المتعامد تحت التربة ومعاملة إضافة الجبس الزراعي كانت الأكثر تأثيرا من حيث إنخفاض قيم ملوحة التربة، حيث إنخفضت الملوحة بمعدل ٣،٤٢ و ٣،٣١ ديسي سيمنز/م في الطبقات صفر – ١٠ سم و١٠ -٢٠ سم أقل من معاملات الكنترول علي الترتيب، وكانت قيم ملوحة التربة لأعماق التربة الأربعة الأخرى المتتالية هى ٣,٦٢، ٥,٠٣، ٣,٥٧ و ٣,٠٥ ديسي سيمنز/م أقل من معاملات الكونترول على الترتيب، أوضحت النتائج أن المعاملة ٢٥م مسافة بين المصارف والحرث المتعامد تحت التربة مع إضافة الجبس الزراعي كانت أكثر تأثيرا من حيث انخفاض قيم النسبة المئوية للصوديوم المتبادل، حيث كان ٣٩,٤٥% أقل من معاملة الكنترول فى الطبقة ٣٠ – ٤٠سم، وجد أن المعاملة الأكثر تأثيراً من حيث الزيادة في محصول البنجر كانت معاملة المسافة بين المصارف (٢٥م) مع معاملة الحرث المتعامد تحت التربة وإضافة الجبس الزراعى، حيث بلغت هذه الزيادة ٧,٥٧ طن/فدان بنسبة ٧٥,٨٥ % أعلى من معاملة الكنترول.

الكلمات الإسترشادية: الأراضى المتأثرة بالأملاح، مسافات المصارف الحقلية، حرث تحت التربة المتعامد، الجبس، الكبريت، بنجر السكر.

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