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Impact of Some Soil Amendments and Different Tillage Depths on Saline Heavy Clay Soils Properties and Its Yield Water Productivity

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Soil salinity and sodicity are core limiting factors to sustainable agriculture activities in several parts of Nile Delta, Egypt. To such, we investigated the effects of combined applications of compost, gypsum and tillage practices on both soil physical, chemical properties in relation with wheat (*Triticum aestivum* L.*)* and maize (*Zea mays* L.) yields. Two field trials over two seasons (winter 2015/2016 and summer 2016) were conducted at the Experimental Farm, Sakha Agricultural Research Station, Kafr Elsheikh Governorate. Experiment was performed under split-plot design with 12 treatments and three replicates. Results showed that soil salinity, sodium adsorption ratio and exchangeable sodium percentage were highly significantly decreased due to application of gypsum and compost which recorded the lowest values under tillage depth at 60 cm. Data showed that the lowest values of soil bulk density and highest values of porosity were obtained by application of gypsum+compost, under tillage depth at 60 cm. Both of soil infiltration rate and hydraulic conductivity as well as water productivity and productivity of irrigation water took the same trend. Water application efficiency (%) and water consumptive use efficiency (%) were decreased with increasing tillage depth up to 60 cm as compared to plowing depth at 15 cm and 30 cm. Application of gypsum and compost individually or together highly significantly ($p < 0.01$) increased yield of wheat and maize, and recorded the highest values with gypsum+compost under tillage at

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60 cm depth. Total income and net income were highly significantly increased with gypsum, compost or the combined application of these amendments, the net income recorded the highest value by 50% from soil gypsum requirements +5 Mg compost $Fed.^{-1}$ (2.4 Fed.= hectare) under plowing depth at 60 cm for wheat. While the net income for maize recorded the highest values with 100% from soil gypsum requirements under the same plowing depth.

Keywords: Soil amendments; soil properties; tillage depth; water relations; wheat and maize.

1. INTRODUCTION

In arid and semi-arid regions, soil salinity and sodicity are common problems under these conditions. Moreover, in these soils, there are increased potentials for hazardous accumulation of salts and the productivity of crops and plants is severely limited under such conditions. It is worth to mention that, the salt affected soils represent 9.1% from the total area in Egypt. Saline clay soils with low permeability are mostly found in the northern part of Nile Delta [1]. Therefore, the reclamation process of salt affected soils may be achieved by using different practices such as gypsum, compost application as soil amendments. These previous practices are increasingly important tools for improving crop productivity in many regions [2,3,4]. The crop production may be adversely affected by salt toxicity, poor soil physical/chemical properties and nutritional imbalances under salt-affected soils conditions [5,6]. Application of organic amendments, such as compost, has been successfully proposed in many cases to improve soil structure and both the chemical [7]. The physical properties of heavy clay were improving by applied of gypsum, [8]. Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Exchangeable Sodium Percentage (ESP), bulk density, soil porosity, soil infiltration rate and hydraulic conductivity were clearly improved by application of gypsum under saline sodic soil, [4]. [9] reported that the application of gypsum to saline soil has successfully reduced its EC and ESP values. [10] indicated that gypsum application increased the soluble Na^+ in the top 20 cm soil. However, one year after the treatment, under crop rotation and addition of gypsum; SAR, EC, pH and Cl^- in top 20 cm of soil were significantly decreased. [11] found that the application of compost or gypsum to a salt affected soil led to the dissolution of $CaCo_3$, and increase soluble calcium; causing an effective displacement and leaching of sodium from the soil. Years shallow tillage created hardpan at about 15 cm depth. This hardpan influences bulk density and porosity of soil which directly or indirectly effects on the growth and yield of crops [12]. Hardpan due to subsoil compaction of agricultural soils is a global concern due to adverse effects on crop yield and environment [13]. The sustainable use of deep tillage breaks up high density soil layer, improves the water infiltration and movement in soil, enhance root growth, develops and increases crop production potential [14]. Deep tillage of the soil increased corn yield up to 90% [15]. There is not much research carried out on the effects of combination between gypsum and compost application on the soil and plant under different tillage depth. Thus, this research experiment was planned to evaluate the potential effect of gypsum and compost under different tillage depths on changes in some properties of saline heavy clay soils, water relations, wheat and maize productivity and economical efficiency at North Delta, Egypt.

2. MATERIALS AND METHODS

Two Field trials were conducted at Sakha Agric. Res. Station Farm, North Delta, Egypt, during two successive seasons, winter of 2015/2016 and summer of 2016 (Latitude 31°06 09.71 N and Longitude 30° 00 20.40 E). To study the effect of different tillage depths and soil amendments on some properties of saline heavy clay soils, water relations and yield of wheat and maize.

2.1 Experimental Design

The experiments were designed in split plots with three replicates. Each plot was 10x30 m (300 m^2). Main plots (tillage depths): at 15 cm depth, 30 cm and at 60 cm depth. Subplots (soil amendments): without, 100% from soil gypsum requirements (SGR), 5 Mg fed^{-1} from compost straw rice and 50% from SGR +5 Mg fed^{-1} from compost $Fed.^{-1}$. The meteorological data from Sakha station during the two growing seasons are presented in Table 1.

Soil samples were collected at the depths of (0-20, 20-40 and 40-60 cm) in the initial and after harvesting of wheat and maize. And its prepared for physical and chemical analysis according to the standard methods. Infiltration rate was determined using double ring infiltrometer as described by [16]. Soil bulk density and total porosity of the different layers of soil profile were measured after first and second seasons from treatments using the core sampling technique as described by [17]. Soil moisture characteristics curves, field capacity and wilting point were determined by using the pressure plate extractor with regulated air pressure [16]. Soil chemical and physical characteristics of the experimental site before cultivation as shown in Tables 2 and 3 and some chemical characteristics of rice straw compost as shown in Table 4.

Wheat (variety Giza 168) was sown on November 15th and harvested on May, 1st 2015/ 2016. Maize (variety Giza 129) was sown on May 20th, 2016 and harvested on September 12th, 2016. Grain, straw yield and biological yield of wheat were determined for each treatment. Wheat and maize seeds were obtained from Agronomy Research Institute, Agriculture Research Centre, Giza, Egypt.

Table 1. Climatological data for the two growing seasons 2015/2016

Seasons	Months	Air temp. C^o		Mean	Relative humidity (%)	Wind speed velocity ($kmday^{-1}$) at 2 m height	Pan evop. ($cmday^{-1}$)	Rain pain mm
		Max.	Min.					
2015	Nov.	24.4	14.42	19.41	75.6	70.30	0.319	52.24
	Dec.	19.70	8.36	14.03	77.9	57.90	0.250	25.0
2016	Jan.	18.4	6.35	12.38	74.05	69.20	0.252	46
	Feb.	22.58	9.35	15.97	69.05	58.80	0.252	0.0
	March.	24.5	11.6	18.05	69.9	63.20	0.359	13.2
	April	30.03	18.62	24.33	61.7	87.10	0.593	0.0
	May	30.4	22.8	26.6	58.4	97.0	0.647	0.0
	June	33.6	26.3	29.95	61.15	112.8	0.806	0.0
	July	33.7	26.1	29.9	69.75	105.5	0.783	0.0
	August	33.6	26.0	29.8	70.3	92.8	0.773	0.0
	Sep.	32.6	24.3	28.5	67.5	95.1	0.590	0.0

Table 2. Soil chemical characteristics of the experimental site before cultivation (over mean two seasons)

Depth (cm)	Soil pH*	EC (dSm^1) **	SAR (%)	ESP (%)	CEC ($cmolekg^1$)	Gypsum requirement (MgFed.-1)	OM (gkg^1)	$CaCO_3$%
0 – 20	8.41	8.58	15.51	17.77	37.5	9.11	10.4	3.56
20 – 40	8.55	9.32	16.16	18.42	35.4	10.24	9.56	2.82
40 – 60	8.63	10.12	16.84	19.08	34.5	11.11	8.75	1.97
Mean	-	9.34	16.17	18.42	35.80	10.15	9.57	2.78

** Soil pH in (1:2.5 soil: water suspension), ** Soil EC in soil paste extract*

Table 3. Soil physical characteristics of the experimental site before cultivation (over mean two seasons)

Depth (cm)	K, md^{-1}	IR, cmh^{-1}	Soil moisture characteristics				Particle size distribution (%)			
			F.C. (%)	WP (%)	AW (%)	BD (kgm-3)	Sand	Silt	Clay	Soil texture
0 – 20			42.6	21.25	21.35	1.40	17.72	26.67	55.61	Clayey
20 – 40			40.0	19.80	20.20	1.45	18.11	26.00	55.89	Clayey
40 – 60	0.68	0.49	39.2	18.45	20.75	1.51	18.51	24.22	57.27	Clayey
Mean			40.6	19.83	20.77	1.45	18.11	25.63	56.26	Clayey

Table 4. Some chemical characteristics of rice straw compost

EC	PH	Total N	NH_4	No_3	O.M	C/N	Total P	Total K	Fe	Zn	Mn	Moisture
(dsm^{-1})		(%)	($mgkg^{-1}$)		(%)	Ratio	(%)		($mgkg^{-1}$)			(%)
3.15	7.86	1.89	638	165	34.5	15.51	1.57	1.19	135	48	126	24.5

2.2 Some Water Relations

Amount of irrigation water applied (m^3 fed^{-1}) for each irrigation treatment was measured and then seasonal water applied was recorded by using cut-throat flume (30*90 cm) through the whole growing season and calculated as m^3 fed^{-1} according to [18].

Water consumptive use (m^3 fed^{-1}) by growing plants was calculated based on soil moisture depletion (SMD) according to [19].

$$Cu = SMD = \sum_{i=1}^{i=n} \frac{\theta_2 - \theta_1}{100} * Dbi * Di * 4200 \quad (1)$$

Where:

- Cu = Water consumptive use in the effective root zone (60 cm),
- θ2 = Gravimetric soil moisture percentage after irrigation,
- θ1 = Gravimetric soil moisture percentage before the next irrigation,
- Dbi = Soil bulk density (kg/m3) for depth, Di = Soil layer depth (20 cm) and 1 = Number of soil layers (1-3).

- Total water stored in the effective root zone (m3Fed.$^{-1}$) was calculated by using the following equation:

$$SW = \sum_{i=1}^{i=n} (\theta_2 - \theta_1 * Dbi * Di * 4200) \quad (2)$$

Irrigation application efficiency % (IAE) were calculated according to [20] as follows:

$$IAE = \frac{\text{total water stored in the effective root zone}}{\text{total water applied}} * 100 \quad (3)$$

Consumptive use efficiency (Ecu): was calculated according to [21];

$$Ecu = (ETc/Wa) * 100 \quad (4)$$

Where:

Ecu= Consumptive use efficiency (%), ETc= Total evapotranspiration ≈ consumptive use and Wa= Applied water to the field.

Water productivity (WP) is generally defined as crop yield per cubic meter of water consumption. Concept of water productivity in agricultural production systems is focused on producing more food with the same water resources or producing the same amount of food with less water resources. It was calculated according to [22]

$$WP = GY/ET \quad (5)$$

Where:

WP= Water productivity (kg grains/m3), GY= Grain yield kg fed^{-1} and ET= Total water consumption of the growing season (m^3 fed.$^{-1}$).

Productivity of irrigation water (PIW) was calculated according to [22] as kg grains/m^3 water applied.

$$PIW = Gy/I \quad (6)$$

Where: Gy = Grain yield (kg fed.$^{-1}$) and I = Irrigation water applied m^3 fed.$^{-1}$

All obtained data was statistically analyzed using [23], and revised L.S.D. test was used to compare the differences among treatment means [24].

3. RESULTS AND DISCUSSION

3.1 Some Soil Chemical Properties

3.1.1 Soil salinity (ECe)

Table 5 and Figs. 1 and 2 showed that the electrical conductivity of the soil was high significant decreased due to gypsum, compost or combined application of these amendments after harvesting of plants during the two growing seasons. Consequently, soil salinity as affected by treatments can be arranged in descending order; gypsum (g)+compost (C)+ gypsum (g) > compost (C) > without. It could be mentioned that the soil salinity was decreased due to gypsum and compost application may mitigate salt stress to plants through salt sorption. These results are supported by the data obtained by [9,10,12]. The combined application of organic matter and gypsum to salt affected soilsreduced EC more than gypsum alone, [25].

3.1.2 Soil sodicity and exchangeable sodium percentage

Table 5 and Figs. 1 and 2 pointed out that sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP) were highly significantly decreased by gypsum application and recorded the lowest values due to the combination between gypsum and compost application during two growing seasons. These results are supported by the data obtained by [4,7].

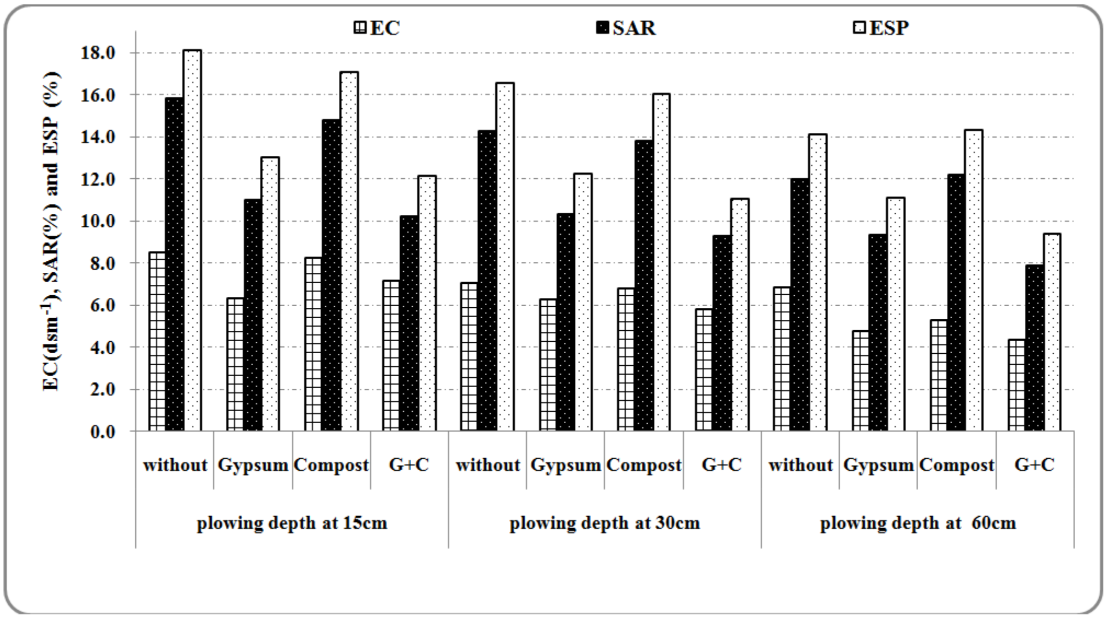

Fig. 1. Effect of tillage depth and soil amendments on soil salinity, soil sodicity and exchangeable sodium percentage after harvesting of wheat crop during winter season 2015/2016

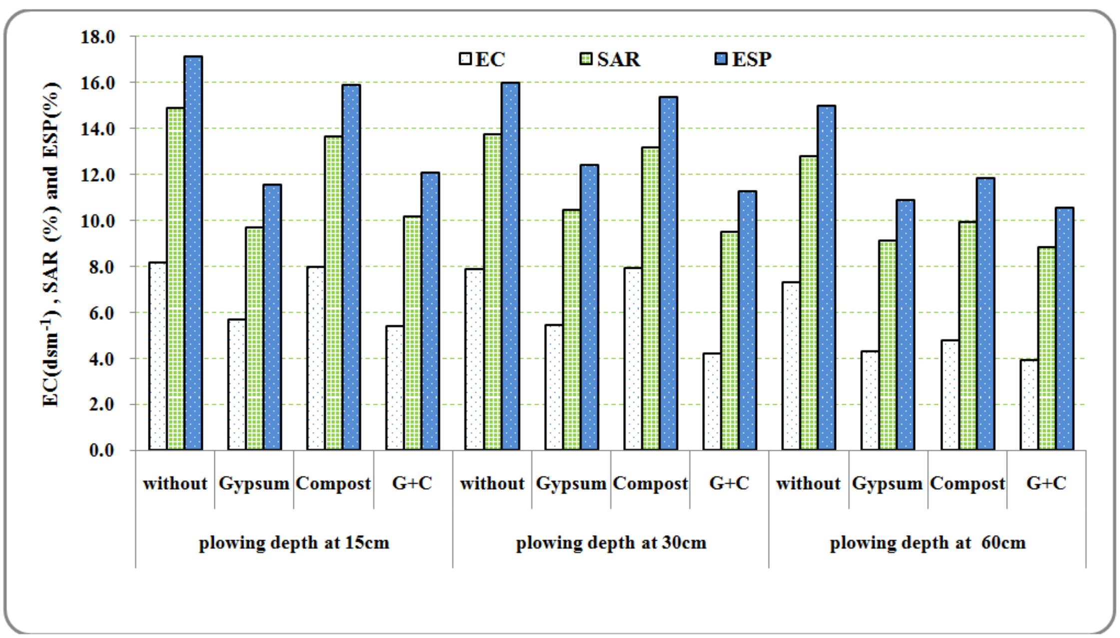

Fig. 2. Effect of tillage depth and soil amendments on soil salinity, soil sodicity and exchangeable sodium percentage after harvesting of maize crop during summer season 2016

Table 5. Mean values of soil salinity, soil sodicity and exchange sodium percentage as affected by tillage method and soil amendments after harvesting of wheat and maize crops

Treatments		After wheat			After maize		
		EC (dsm^{-1})	SAR (%)	ESP (%)	EC (dsm^{-1})	SAR (%)	ESP (%)
Tillage depth	15 cm	7.19a	12.96a	15.08a	6.82a	12.1a	14.15a
	30 cm	5.72b	11.92b	13.96b	6.37b	11.7b	13.77b
	60 cm	5.07c	10.34c	12.23c	5.07c	10.2c	12.06c
	F_{test}	**	**	**	**	**	**
	$LSD_{0.05}$	0.04	0.02	0.08	0.07	0.08	0.09
	$LSD_{0.01}$	0.08	0.04	0.11	0.11	0.11	0.11
Amendments	Without	7.47a	14.04a	16.25a	7.80a	13.8a	16.04a
	Gypsum	5.12c	10.21c	12.11c	5.14c	9.8c	11.61c
	Compost	6.77b	13.59b	15.80b	6.88b	12.3b	14.36b
	G+C (0.5:1)	4.61d	9.50d	11.3d	4.52d	9.11d	10.85d
	F_{test}	**	**	**	**	**	**
	$LSD_{0.05}$	0.06	0.02	0.04	0.07	0.09	0.03
	$LSD_{0.01}$	0.09	0.03	0.06	0.09	0.13	0.05
Interaction T*A		**	**	**	**	**	**
Standard deviation		1.24	2.43	2.75	1.15	2.10	2.23

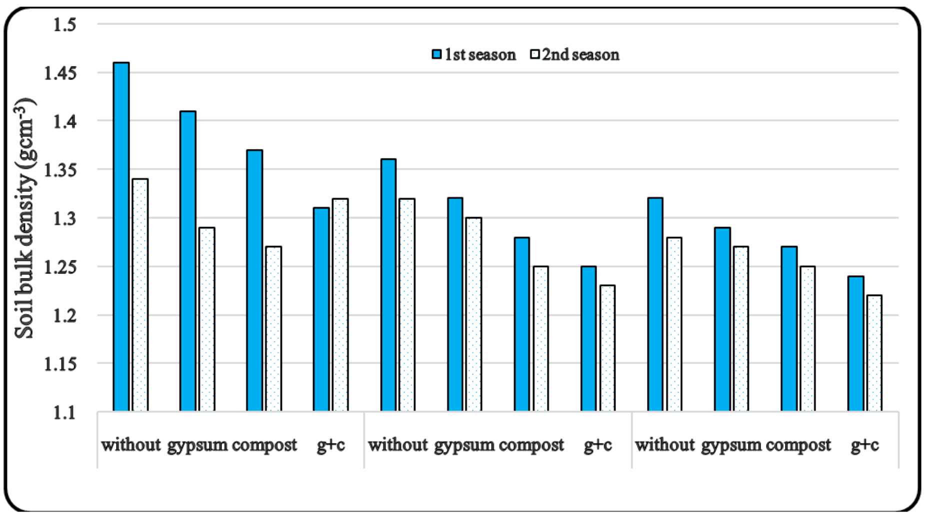

Fig. 3. Effect of tillage depth and soil amendments on soil bulk density during two growing seasons. (Standard deviation 0.07 and 0.04 for 1st and 2nd seasons)

3.2 Some Soil Physical Properties

3.2.1 Soil bulk density (BD) and its porosity

Data in Figs. 3 and 4 illustrates that the application of organic amendments as compost alone or in combination with gypsum led to increase the soil porosity and decrease BD. Data showed that the lowest values of soil bulk density and highest values of porosity were found with application of gypsum+ compost under plowing depth at 60 cm during two growing seasons. These results may be attributed to the role of compost which it had low density that helps to lower the bulk density of highly clay soils, increasing efficiency drainage and aeration. This positive effect of organic amendments on soil density has been reported by previous studies. These results are supported by the data obtained by [12,26].

3.2.2 Infiltration rate (IR), cumulative infiltration (CI) and hydraulic conductivity (K)

Data in Figs. 5, 6 and 7 showed that soil infiltration rate, cumulative infiltration and its hydraulic conductivity and were increased due to the application of gypsum, compost or combination between of gypsum and compost due to the increasing in soil porosity. Soil infiltration rate, cumulative infiltration and its hydraulic conductivity were recorded the highest values with combination between gypsum and compost application under tillage depth at 60 cm during two growing seasons. IR and K were increased by increasing tillage depth. It can be arranged in descending order; tillage depth at 60 cm> tillage depth at 30 cm> tillage depth at 15 cm, during two growing seasons. These results are in agreement with findings of [4,7,12].

3.3 Water Measurements

Data presented in Fig. 8 show that the values of seasonal water applied were increased with increasing tillage depth and recorded the highest values (2616 and 3486 m^3 fed^{-1}) under tillage depth at 60 cm during two growing seasons, respectively. Increasing the amount of seasonal water applied under 60 cm plowing depth comparing with other tillage depths treatments 15 and 30 cm is due to the effect of tillage depth on improvement of the soil infiltration and porosity. Also, the same data pointed out that the values of water consumptive use (WCU) (m^3 fed^{-1}) were increased with increasing the tillage depth and recorded the highest values up to tillage depth at 60 cm (1672 and 1978 m^3 fed^{-1}) during two growing seasons, respectively. Fig. 8 clear that the values of water stored in the effective root zone (m^3 fed^{-1}) were increased with increasing tillage depth and recorded the highest values up to tillage depth at 60 cm (1862 and 2192 m^3 fed^{-1}) during two growing seasons, respectively. Data in Fig. 9 showed that water application efficiency was decreased with increasing tillage depth up to 60 cm. It can be arranged in the descending order tillage depth 15 cm (76.06%)> tillage depth 30 cm (73.67%)> tillage depth 60 cm (71.18%) for wheat. And tillage depth 15 cm (68.97%)> tillage depth 30 cm (64.09%)> tillage depth 60 cm (62.88%) for maize. Also, results showed that consumptive use efficiency (%) was recorded lowest value due to tillage depth 60cm during two growing seasons.

3.3.1 Water productivity (WP) and productivity of irrigation water (P/W) (kg m^{-3})

Table 6 showed the effect of different tillage depth and soil amendments on water productivity (kg grains/m^3) and productivity of irrigation water (PIW) kg grains/m^3 water applied, during two growing seasons. Data showed that WP and PIW were highly significantly increased due to tillage depth; whereas the highest values for WP and PIW were achieved under tillage depth at 60 cm as compared with 30 cm and 15 cm depth. These increases in WP and PIW may be due to increase in grain yield under tillage depth at 60 cm. Whereas, the highest values average of WP and PIW (1.44 and 0.912 kg grains m^{-3}) for wheat and (1.249 and 0.709 kg. grains m^{-3}) for maize was recorded with tillage depth at 60 cm treatment. Regarding to soil amendments application data showed that there were high significant effects on increasing of WP and WIP,

Table 6. Effect of different tillage depth and soil amendments on water productivity (kg grains/m^3) and productivity of irrigation water (PIW) kg grains/m^3 water applied by wheat and maize crops

Treatment		Wheat		Maize	
		WP	WIP	WP	WIP
Tillage depth	Plowing depth at15 cm	1.285c	0.905b	1.063c	0.652b
	Plowing depth at 30 cm	1.338b	0.887c	1.146b	0.649c
	Plowing depth at 60 cm	1.44a	0.912a	1.249a	0.709a
	F_{test}	**	**	**	**
	LSD $_{0.05}$	0.002	0.001	0.002	0.0013
	$LSD_{0.01}$	0.003	0.006	0.003	0.0012
Amendments	Without application	0.796d	0.531d	0.787d	0.458d
	100% from SGR*	1.526b	1.02b	1.257b	0.730b
	5 Mg compost $Fed.^{-1}$	1.374c	0.917c	1.205c	0.699c
	50% from SGR +5 Mg compost $Fed.^{-1}$	1.720a	1.150a	1.363a	0.792a
	F_{test}	**	**	**	**
	LSD $_{0.05}$	0.002	0.005	0.001	0.006
	$LSD_{0.01}$	0.003	0.007	0.003	0.008
T*A		**	**	**	**
Standard deviation		0.36	0.24	0.24	0.14

SGR: Soil gypsum requirements*

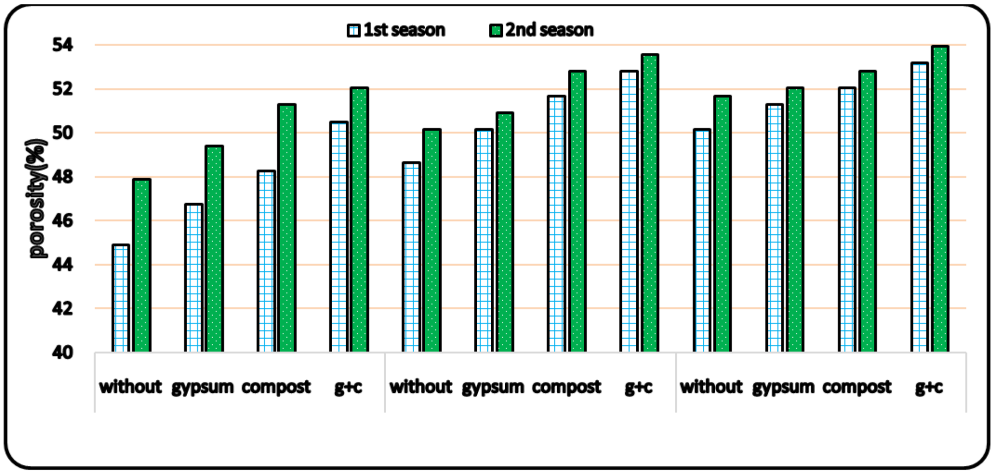

Fig. 4. Effect of tillage depth and soil amendments on soil porosity during two growing seasons. (Standard deviation 2.49 and 1.75 for 1st and 2nd seasons)

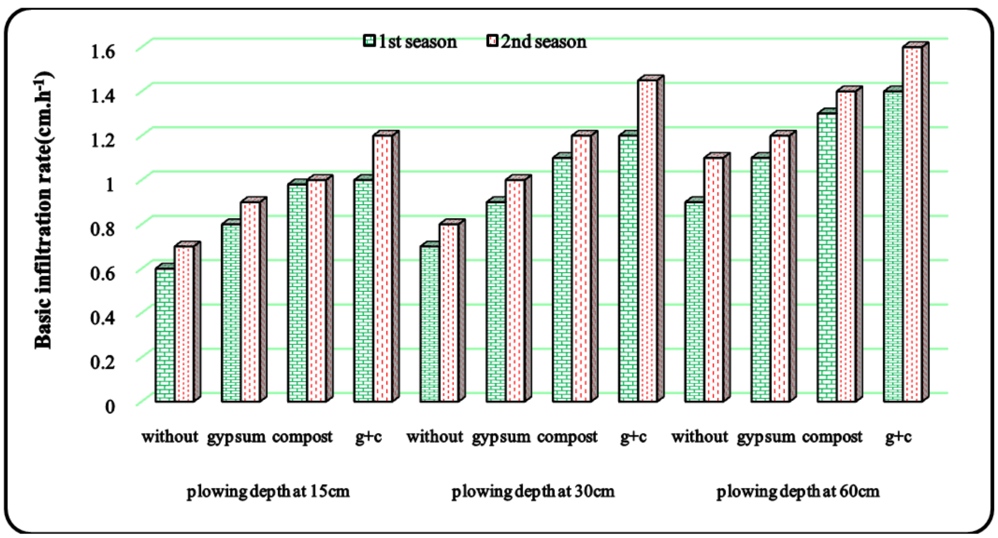

Fig. 5. Effect of tillage depth and soil amendments on infiltration rate during two growing seasons. (Standard deviation 0.27 and 0.28 for 1st and 2nd seasons)

where the highest mean value of WP and WIP (1.720 and 1.150 kg. grains m^{-3}) for wheat and (1.363 and 0.792 kg. grains m^{-3}) for maize was recorded under combination between gypsum and compost applications. Concerning the interaction between treatments, the WP and WIP were highly significantly increased due to the interaction between tillage depths and soil amendments application, during two growing seasons.

3.4 Yield of Maize and Wheat

Table 7 showed that application of gypsum, compost individually or together highly significantly increased the yield of wheat and maize. The results outlined some differences in grains and straw yield induced by gypsum, compost alone or combined application of these amendments. The treatment amended with gypsum + compost application seemed to have higher values, as compared to all other treatments. Data referred that grain, straw and biological yield of wheat and maize were highly significantly increased due to the tillage depth. And recorded highest values under tillage depth at 60 cm. Table 7 cleared that grain, straw and biological yield of wheat and maize were highly significantly increased and recorded highest values due to the interaction between tillage depth and amendments application. Application of organic amendments is considered as an effective management strategy for both amelioration of salt affected soils and improvement of plant growth. The ameliorative role of the previous amendments in salt affected soils may be attributed to soil amendments application led to improve of some chemical and physical soil properties, such decrease the soil salinity and increase the basic infiltration rate. These results are supported by the data obtained by [26].

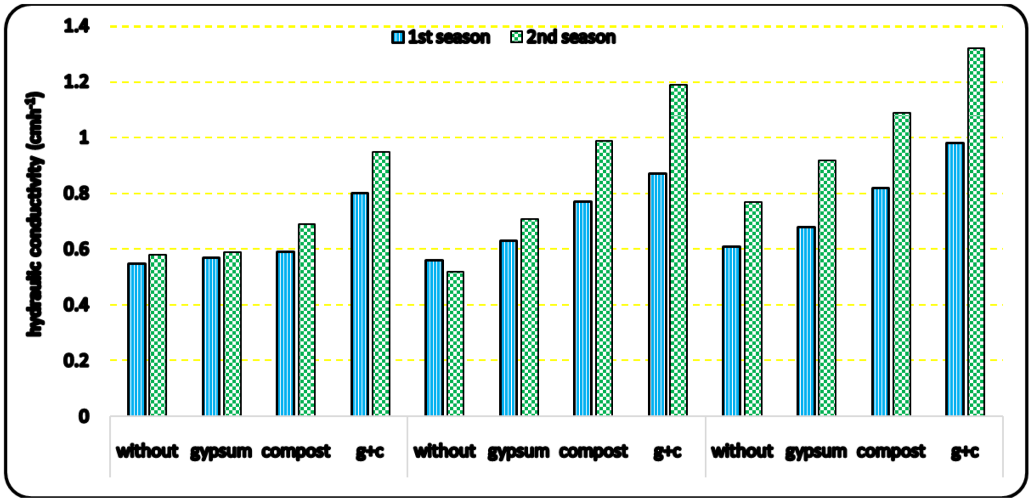

Fig. 6. Effect of tillage depth and soil amendments on hydraulic conductivity during two growing seasons. (Standard deviation 0.14 and 0.26 for 1st and 2nd seasons)

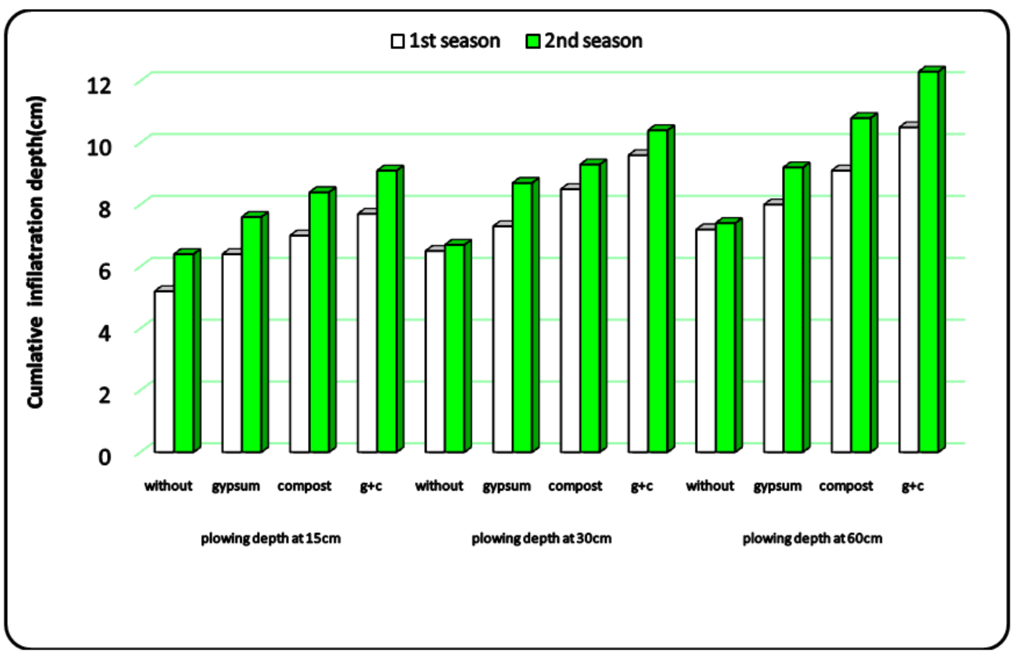

Fig. 7. Effect of tillage depth and soil amendments on cumulative infiltrated depth (cm) during two growing seasons. (Standard deviation 1.48 and 1.73 for 1st and 2nd seasons)

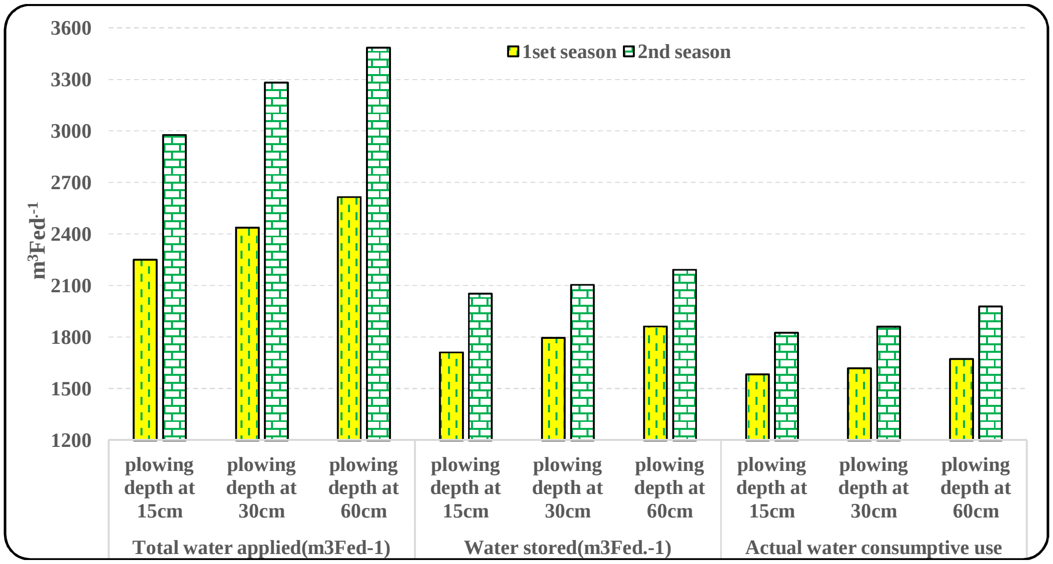

Fig. 8. Effect of tillage depth and soil amendments on water applied, water consumptive use and water stored in the effective root zone during two growing seasons

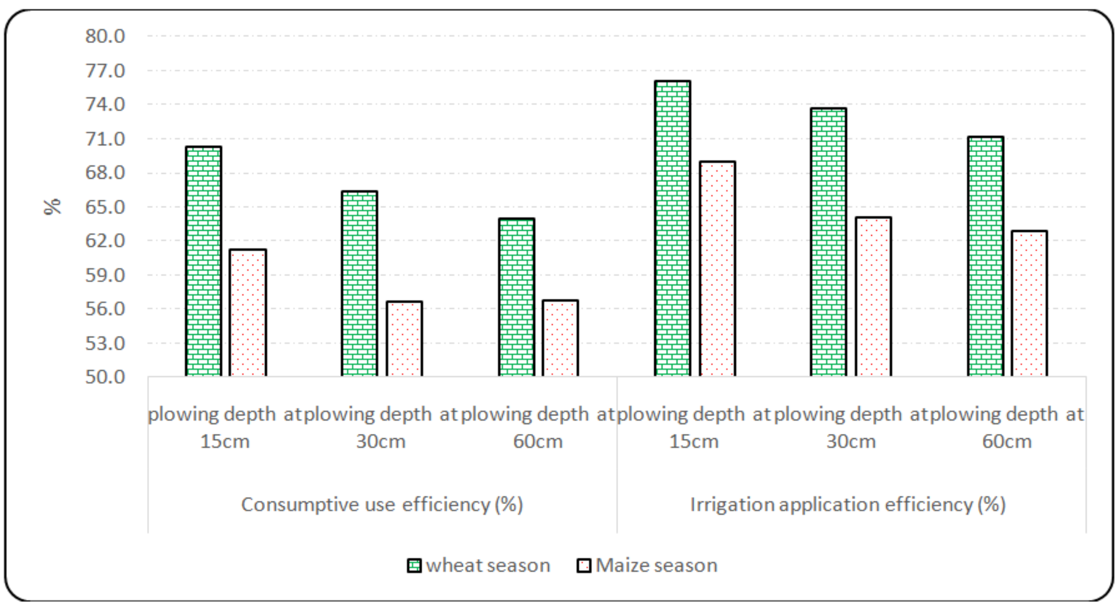

Fig. 9. Effect of tillage depth on consumptive use efficiency (%) and irrigation application efficiency (%) during two growing seasons

3.5 Economic Evaluation

Data in Figs. 5 and 6 pointed out that gypsum, compost or the combined application of these amendments highly significantly ($p < 0.01$) increased total income and net income during two growing seasons. The highest values of wheat and maize yields beside the total net income resulting from the application of gypsum, compost, gypsum + compost, which it ameliorated the saline- soils conditions for cereal crops and their production. The net income for previous treatments have recorded the highest value (6046.7LE Fed.$^{-1}$ by 50% from soil gypsum requirement +5 ton compost Fed.$^{-1}$ under tillage depth at 60 cm for wheat. While the net income for maize were 4585.5 LFed.$^{-1}$ with gypsum treatment under tillage depth at 60 cm. Also investment factor took the same trend, since it was recorded the highest values (1.39) due to combined application of these amendments under tillage depth at 60 cm for wheat and 1.15 by gypsum application under tillage depth at 60 cm for maize. Consequently, the effect of treatments on net income of wheat and maize values can be arranged in the following order; gypsum + compost > gypsum > compost > without.

Table 7. Grain, straw and biological yield (Mg Fed.$^{-1}$) for wheat and maize as affected by some soil amendments and tillage depths

Treatment		Wheat			Maize		
		Grain	Straw	Biological yield	Grain	Straw	Biological yield
Tillage depths (cm)	15 cm	2.037c	2.080c	4.117c	1.914c	1.999c	3.940c
	30 cm	2.163b	2.157b	4.321b	2.132b	2.199b	4.332b
	60 cm	2.411a	2.479a	4.890a	2.471a	2.533a	5.004a
	F_{test}	**	**	**	**	**	**
	$LSD_{0.05}$	0.001	0.007	6.52	0.003	0.003	0.002
	$LSD_{0.01}$	0.002	0.011	10.81	0.006	0.004	0.004
Amendments	Without	1.295d	1.451d	2.746d	1.488d	1.546d	3.034d
	5 Mg gypsum Fed. $^{-1}$	2.843b	2.404b	4.887b	2.378b	2.423b	4.8017b
	5 Mg compost Fed.$^{-1}$	2.239c	2.772c	4.518c	2.282c	2.354c	4.636c
	G+C	2.798a	2.821a	5.620a	2.577a	2.653a	5.230a
	F_{test}	**	**	**	**	**	**
	$LSD_{0.05}$	0.001	0.008	0.008	0.002	0.006	0.002
	$LSD_{0.01}$	0.002	0.011	0.011	0.003	0.008	0.007
T*A		**	**	**	**	**	**

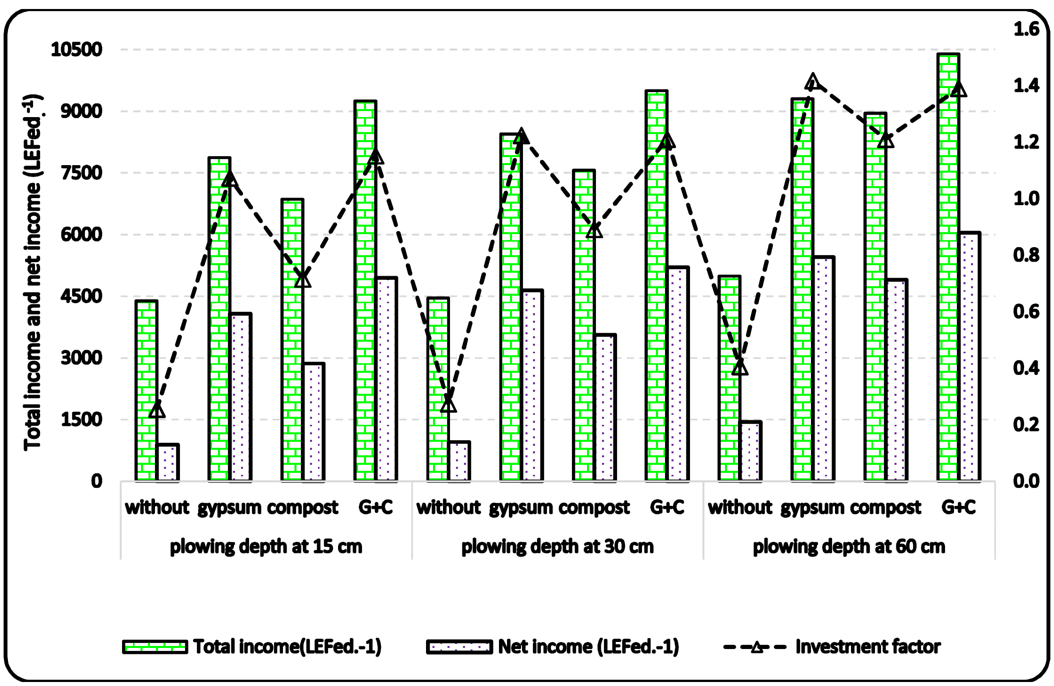

Fig. 10. Total income, net income and investment factor of wheat yield as affected by some soil amendments application under different tillage depths

Notes: 1- Total income (LE Fed. $^{-1}$) = (grain yield x price + straw yield x price)
2- Net income = total income (LE Fed. $^{-1}$) - total costs (LE Fed. $^{-1}$)
3- Investment factor= net income (LE fed.$^{-1}$) / total cost (LE fed.$^{-1}$)

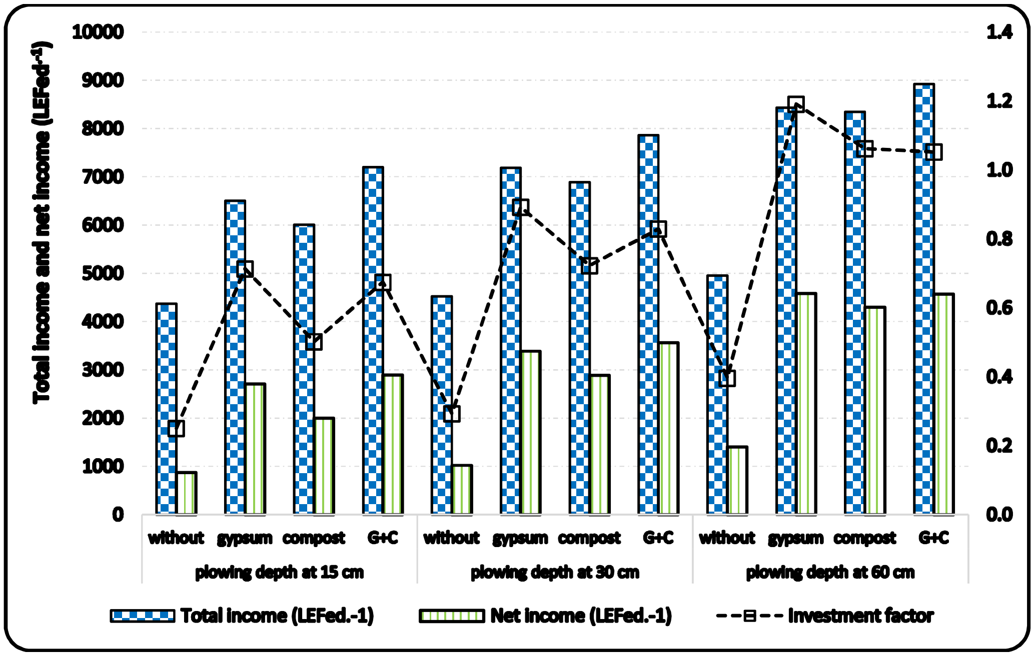

Fig. 11. Total income, net income and investment factor of maize yield as affected by some soil amendments application under different tillage depths

4. CONCLUSION

It could be concluded that the application of 50% from gypsum requirements + 5 Mg compost $Fed.^{-1}$ combined with plowing depth at 60 cm achieved economic production of wheat and maize without adverse effect under salt affected soils at North Delta, Egypt.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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