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Impact of Some Soil Amendments on Properties and Productivity of Salt Affected Soils at Kafr El-Sheikh Governorate

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TWO FIELD trials were conducted in salt affected soils at special farm Mars El-Gaml village, Kafr El-Sheikh Governorate, Egypt to study the effects of amending soils with gypsum, compost, ammonia injection and subsoiling on some soil physio-chemical properties as well as the outcome yields of barley (winter 2016/2017) and rice (summer 2017). Seven treatments were tested to attain this aim using a complete randomized block design (CRBD) with three replicates. The results showed that improving soil chemical properties such as soil salinity and soidicity took place through amending soils with gypsum requirements (SGR) combined with 4Mg. from compost fed.-1 and subsoiling in both seasons (1 feddan = 0.42 ha). Such treatments recorded a positive effect on soil Ca/Mg ratio in root zone (0-60 cm) in both seasons. It could be observed that the application of SGR combined with compost and subsoiling was superior to other treatments in decreasing of the soil bulk density and increment both of the soil porosity and soil infiltration rate. Yield of barely and rice were highly significantly increased and recorded highest values due to application of gypsum combined with ammonia and subsoiling. Economic efficiency recorded the highest values due to application of SGR and ammonia injection with subsoiling in both seasons. Consequently, application of SGR with ammonia and subsoiling treatments could be used economically to improve the yield of barely and rice. Some physio-chemical properties of salt affected were improved by application of SGR combined with compost and subsoiling at Kafr El-Sheikh Governorate..

Keywords: Ammonia injection , Subsoiling, Salt affected soils, Soil amendments, Yield.

Introduction

Salt affected soils represent about 30 % from the total cultivated area in Egypt (FAO 2005) and 37% of the total cultivated soils in Nile Delta, while the North Delta contains the highest area of saline and saline-sodic soils (46%). Poor drainage in addition to reuse of saline drainage water supports the buildup of salinity and sodicity (Negm 2016). Saline, sodic, or saline/sodic soils are originated mainly in the semi-arid areas where the evaporation rate exceeds precipitation (Qadir et al., 2008). The degradation due to salinization, intrusion of seawater and water logging are the current potential hazard in the irrigated land. It's could be considered as an important issue in the agricultural security program (Abdel-Fattah, 2012). It has been known that sodium and magnesium has a negative effect on soil physical properties when its concentration is relatively high compared to calcium. The slow drawdown rate of the excess water through soil profile after irrigation indicated that the tile drainage system in the Mars El-Gaml, Kafr El-Sheikh Governorate area is not efficient and/or the soil is compacted due to unfavorable chemical and physical (Amer et al., 2017). The infiltration rate can be restricted by poor soil management (Haghnazari et al., 2015). Moukhtar et al. (2003) reported that saline groundwater is a permanent source of soil salinzation that causes poor productivity in the irrigated areas. It is also stated that, good drainage efficiencies and proper soil management are important factors to improve soil characteristics. Rice is reclaiming crop for saline and saline-sodic soils. Rice is sensitive to salinity at different growth stages (Zeng, 2004; Moradi and Ismail, 2007), leading to a reduction in crop yield of more than 50% when exposed to 6.65 dS m^{-1} electrical conductivity (ECe) in soil (Zeng and Shannon,

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2000). The threshold of average root zone critical salinity values for barley growth is 8 dSm^{-1} and slope 5%/ dS m^{-1} and 3 dS m^{-1} and slope 12% / dSm^{-1} for rice (Rhoades et al., 1992). Winter barley is the crop of wheat soils of poorer quality. In Egypt, grain yield of barely varied between 1.8 ton fed^{-1} to 2.16 Mg fed^{-1} under normal clay soil. Horneck et al. (2007) reported that the accumulation of excessive salt in irrigated soils reduce crop yields, reduce the effectiveness of irrigation, ruin soil structure and affect other soil properties. In addition, rice which is grown under submerged conditions helps to leach down soluble salts up to a greater extent, and hence decrease ECe (Ghafoor et al., 2008). Managing salt affected soil is required during soil reclamation. The construction of mole d rain is effective in decreasing of the soil salinity, sodicity and bulk density El-Henawy et al. (2016) and it can increase soil infiltration rates Aiad (2014). Also, gypsum has become an efficient soil amendment to reclaim sodic soils of poor aggregation or soil structure (Fisher and Madeline, 2011). Application of gypsum increases of soluble Ca^{2+} in soil solution to substitute the adsorbed sodium, hence overcome the dispersion effects of Na^+ and improve the soil structure in the dispersed soils. (Shainberg et al., 1988). The decaying organic matter increases soil CO_2 concentrations and releases H^+ when it dissolves in water. The released H^+ enhances $CaCO_3$ dissolution and liberates more calcium for sodium exchange (Ghafoor et al,. 2008). However, the addition of organic matter in conjunction with gypsum has been successful in reducing adverse soil properties associated with sodic soils Abdel-Fattah and Merwad (2016) and Saied et al. (2017). The application of compost accelerated sodium leaching and reduced EC, which increased water-holding capacity and soil aggregate stability (Tejada et al., 2006). Decreased soil dispersion and reduced EC more effectively than those attained when amending soils with gypsum solely (Vance et al. 1998), beside of improving the chemical properties (EC, pH and SAR) of the saline sodic soil to the desired levels (Ghulam et al. 2011).while the dispersion of clays from soils was increased when Ca/Mg ratios in the percolating solutions were below unity with an SAR1:5 >3. (Bardhan et al., 2007) while the productivity of soil was higher when Ca/Mg ratio on the soil exchange complex was 3.2:1 (Ansari et al., 2010). High Mg^{2+} in soils creates big blocks that are hard to be broken down and thus reduces K and N efficiency(Genever, 2010). Moreover, Mg induced K deficiency (Hannan, 2011).On the other hand, Dontsova and Norton (2001) observed that availability of K and ammonium can also be affected by a soil's preference for Ca^{2+}. They suggested further study is needed to explore how distribution of K between solution, exchangeable and non-exchangeable phases is influenced by the Ca/Mg ratio. Anhydrous ammonia is one of the most efficient and widely used as source of nitrogen for plant growth. The advantages of ammonia relatively easy application and ready availability have led to its increased use as a fertilizer. In soil, ammonia reacts with water to form the ammonium ($NH4^+$) ion, which is held on clay and organic matter. Anhydrous ammonia increased gross income, net income, benefit / costs ratio and profitability of rice. Osman et al. (2013). The current study aims to evaluate the effect of some soil amendments, ammonia injection and subsoiling on improving some physio-chemical properties and productivity of salt affected soils at Kafr El-Sheikh Governorate..

Materials And Methods

Two field trials were conducted in salt affected soil at Mares El-Gamal village, Kafr El-Sheikh Governorate, North Nile Delta, Egypt, during winter (2016/2017) and summer (2017) to study the impact of some soil amendments, ammonia injection and subsoiling on soil properties and productivity of barely and rice.. The location is situated at 31° 12' 43.00" N and 30° 59' 40.00" E. The salinity of irrigation water was 0.5 dSm^{-1} and drainage water salinity was 4.64 dS m^{-1}. The area is under subsurface drainage system installed at a depth of approximately 2.0 m with 25 m laterals spacing. The water table in this area was 80 cm below the ground surface. The recommended agricultural practices were followed during both seasons. Chemical and physical characteristics of the experimental sites prior to each growing season are presented in Tables 1 and 2. Chemical characteristics of different compost plant residues are shown in Table 3. The experimental plot was 200 m^2 and treatments were arranged in a complete randomized block design (CRBD) with three replicates as follows:

1- Check treatment
2- Gypsum (G)
3- Gypsum + Ammonia (A)
4- Gypsum + Compost (C)
5- Gypsum + Subsoiling (S)
6- Gypsum + Subsoiling + Ammonia
7- Gypsum + Compost + Subsoiling

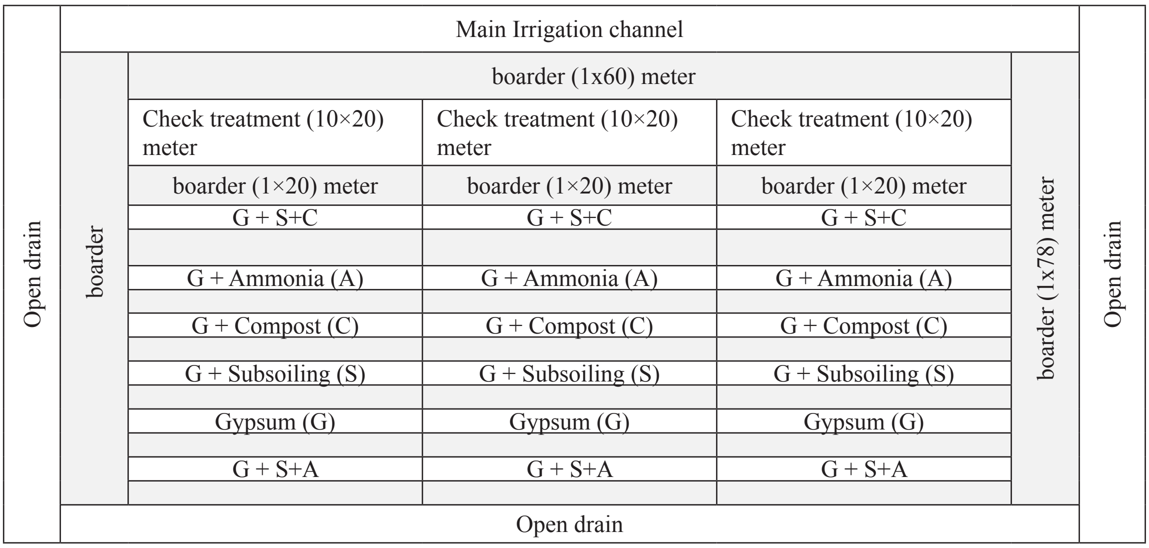

Fig.1. Layout of the experiment

TABLE 1. Soil chemical properties of the experimental site before treatments.

Depth (cm)	Soil pH*	EC (dSm^{-1}) **	Soil SAR	ESP (%)	Soluble cations $(mmol_c\ L^{-1})$				Soluble anions $(mmol_c\ L^{-1})$			CEC $(cmolekg^{-1})$	OM $(g\ kg^{-1})$	$CaCO_3$ $(g\ kg^{-1})$
					Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO^3	Cl^-	$SO4^=$			
0 – 20	7.95	10.76	16.3	23.07	70.6	0.8	16.1	21.2	5.5	49.4	53.8	31.5	9.41	3.21
20– 40	8.13	11.79	17.1	24.14	77.1	0.9	17.6	23.2	5.8	54.0	59.0	30.8	9.1	2.64
40 – 60	8.29	13.84	19.0	27.04	91.8	0.8	19.5	27.1	5.5	64.3	69.4	30.3	8.21	2.51
Mean	-	12.13	17.5	24.75	79.8	0.8	17.7	23.8	5.6	55.9	60.8	30.87	8.91	2.79

Where: *Soil pH was determined in soil water suspension (1:2.5), **soil EC was determined in saturated soil paste extract, SAR, ESP, CEC, OM and $CaCo_3$ represents sodium adsorption ratio, exchangeable sodium percentage, cation exchange capacity, organic matter and total calcium carbonate, respectively.

TABLE 2. Soil physical characteristics of the experimental site before treatments

Depth (cm)	K, (m/d)	IR, (cm/h)	Soil moisture characteristics				Particle size distribution (%)			
			FC (%)	WP (%)	AW (%)	BD $(Mg\ m^{-3})$	Sand	Silt	Clay	Texture
0 – 20	0.14	0.21	38.5	19.2	19.3	1.42	17.9	26.6	55.5	Clayey
20 – 40			39.1	19.6	19.5	1.43	18.2	25.8	56.0	Clayey
40 – 60			39.5	19.7	19.8	1.44	18.2	24.2	57.6	Clayey

Where: K, IR,FC, WP, AW, and BD represents hydraulic conductivity, infiltration rate, Field Capacity, wilting point, available water and bulk density, respectively.

TABLE 3. Some chemical characteristics of plant residuals compost

EC $(dS\ m^{-1})$	pH	C/N ratio	O.M	N	P	K	Fe	Zn	Mn	Moisture content
			$(g\ kg^{-1})$	(%)			$(mg\ kg^{-1})$			(%)
2.41	7.86	1/10	31.5	2.12	0.70	1.25	135	48	126	24.5

Before the winter season 2016/2017, subsoiling was conducted with 2 m spacing and 60 cm depth perpendicular to the open drainage. Open drain was used to collect the drainage water brought by subsoiling channels. All plots received 100 kg fed^{-1} mono-super phosphate (15.5% P_2O_5) and 50 kg $Fed.^{-1}$ potassium sulphate, (48% K_2O) during tillage (1 feddan =

0.42 ha). The recommended N for barely (45 kg Nfed^{-1}) crop was added to the plots didn't injected by ammonia or application of compost, while the recommended N for rice (80kgNFed.$^{-1}$) was added to the plots didn't injected by ammonia and application (40 kg N fed^{-1}) was added to the plots received compost. Ammonia injected (82% N) was added as N recommended for barely and rice at (10-15 cm) depth from soil surface. Before the application of treatments, the area was ploughed with chisel plough and laser land dead leveled. Leaching requirements was calculated according EC_w of irrigation and the permissible salinity of drainage water and applied with barley (about 20 %). Gypsum was ploughed during soil tillage and followed by irrigation. Compost was added before planting of barely at a rate of 4tonfed^{-1}, gypsum and compost were applied in the first season only. All soil treatments were applied one month before sowing to assure their complete decomposition except ammonia injection was done 5days before both of sowing of barely and transplanting of rice. Gypsum requirements were determined according to the methods described by U.S., salinity laboratory staff (FAO and IIASA, 2000), so 8.0 Mg fed^{-1}, (Mg = metric tons; 1 fed = 0.42 ha) are sufficient to reduce the initial ESP from 24.75 to 10% for 30-cm soil matrix as follows:

$$GR= (ESP_i – ESP_F)/100 \times CEC \times 1.72$$

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

Soil samples were collected from all plots before experiment and after the first and second seasons in three consecutive depths of 0-20, 20-40 and 40-60 cm to monitor some physical and chemical characteristics. Salinity, sodium adsorption ratio and Ca^{2+} /Mg^{2+} ratio was determined in saturated soil paste extract, exchangeable sodium was determined using ammonium chloride and measured by using flame photometer according to (Page et al., 1982). Soil bulk density and total porosity of the different layers of soil profile in all plots were measured using the core sampling technique as described by Campbell (1994). Infiltration rate was determined using double cylinder infiltrometer as described by Garcia (1978). Field capacity and wilting point were determined by using the pressure plate extractor with regulated air pressure (Garicia, 1978). Barley (*Hordeum vulgare* L.), variety Giza 126 was sown on November 20th, 2016 and harvested on May, 5th, 2017 while rice (*Oryza sativa L.*) variety Sakha101was sown May 10th, 2017 and transplanted after one month from growing seed in the nursery bed and harvested on September 30th, 2017. At physiological maturity growth stage, grain and straw yields of barley and rice (Mgfed.$^{-1}$) were determined in both seasons. All agricultural practices were carried out as recommended by the Ministry of Agriculture. Anhydrous ammonia was obtained from Soils, Water and Environment Research Institute (Ammonia Injection Unit, Kafr El-Sheikh).

Economic evaluation

Gross return (LE Fed.$^{-1}$), net return (LE Fed.^{1}) and economic efficiency were used to run the economic evaluation.

Statistical analysis

The data were analyzed statistically by analysis of variance (ANOVA) using Cohort computer program according to Gomez and Gomez (1984).

Results and Discussion

Soil chemical properties

Electrical conductivity (ECe)

Table 4 and Fig. 2 revealed that the ECe in root zone (0-60cm depth) was highly significantly decreased by application of gypsum ($P \leq 0.01$) after harvesting of barely and rice (9.22 and 6.84 dSm^{-1}, respectively), where the corresponding reduction were 23.6 % and 41.8%, respectively as compared with check treatment (Fig.2). These results are in harmony with those obtained by Shainberg et al.(1988) and Fisher and Madeline (2011). Also, data showed that the ECe in root zone was highly significantly decreased due to application of gypsum combined with ammonia in the 1st and 2nd seasons (9.25 and 6.79 dSm^{-1}, respectively) with reduction of 23.4 % and 42.3 %, respectively. However, ECe insignificantly affected by gypsum combined with ammonia as compared with gypsum only. These results may be due to gypsum plays a significant role in the providing a Ca^{2+} cation to replace the exchangeable Na^+ on the exchange positions and leaching it out into the groundwater (Sharma and Minhas, 2005).

The data showed that application of compost had positive effect on ECe due to improving the soil physical properties; hence it led to remove Na^+ fare from root zone. This finding is in agreement with Tejada et al. (2006) and Abdel-Fattah and Merwad (2016). On the other hand, application of gypsum with compost was more effective in improving the salt affected soils. Salinity level in soil amended by gypsum combined with compost was highly significantly decreased in root zone in both 1st and 2nd seasons (8.55 and 5.42 dSm^{-1}, respectively) with ECe reduction of 29.2 % and 53.9 %, respectively as compared with check treatment. The obtained results seem to agree with Abdel-Fattah and Merwad (2016) and El-Sanat et al. (2017). So, it could be observed that application of gypsum combined with compost was more effective than gypsum alone on salt leaching.

The subsoiling treatments were more effective on salt leaching, may be due to improvement of soil basic infiltration and leaching of the salts from the surfaces layers out to the drainage system (Aiad, 2014 and El-Henawy et al., 2016). Regarding to the effect of subsoiling combined with gypsum on soil salinity; the data referred to that the ECe values were highly significantly decreased due to gypsum and subsoiling with both crops (7.98 and 4.75 dSm-1, respectively), where the reductions of ECe were 33.9 % and 59.6 %, respectively as compared with check treatment. The combined application of gypsum with subsoiling was more effective than gypsum only on leaching of the salts. These results showed obvious role of the subsoiling in improving of drainage efficiency and in sequence enhances salts leaching especially with gypsum application. These observations are in agreement with El-Sanat et al. (2017).

Also, data cleared that gypsum with subsoiling and ammonia injection had a highly significant effect on decreasing ECe after the 1st and 2nd seasons (7.89 and 4.72 dSm-1, respectively), whereas the reduction of ECe were (34.6% and 59.6 %, respectively) as compared with check treatment.

Table 4 showed that the ECe was highly significant decreased due to application of gypsum with compost and subsoiling after the 1st and 2nd seasons (7.55 and 4.13 dS m^{-1}, respectively), with reduction of 37.4 % and 64.9 %, respectively as compared with check treatment. It could be observed that the soil salinity after rice crop were recorded lowest values as compared with after barely. These results may be due to during growth stages of rice, the standing water could be disposed through drainage system and replaced with fresh water. This process could reduce the salinity of both soil and ground water (Ouda and Zohry 2016).

Finally, ECe along soil profile was highly significantly affected by different treatments according the following descending order: gypsum with subsoiling and compost > gypsum with subsoiling and ammonia > gypsum with subsoiling > gypsum with compost > with ammonia = gypsum > check treatment. It could be observed that the addition of ammonia with any treatments did not have appreciable effect on soil salinity in both growing seasons. Hence, combined application of gypsum requirement with compost and subsoiling played significant role in improving of soil salinity condition.

TABLE 4. Soil salinity (dS m^{-1}) as affected by different treatments

Treatments	After first season				After second season			
	Soil depth (cm)				Soil depth (cm)			
	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
Check treatment	11.23a	11.77a	13.20a	12.07	11.11a	11.22a	12.94a	11.76
Gypsum (G)	7.74c	9.58b	10.33b	9.22	5.12b	7.25b	8.15b	6.84
G +Ammonia(A)	7.74c	9.65b	10.36b	9.25	5.02b	7.22b	8.13b	6.79
G +Compost (c)	7.82b	8.54c	9.37bc	8.55	4.10c	5.01c	7.14c	5.42
G + subsoiling (S)	6.12d	8.45d	9.36cd	7.98	3.13d	4.31d	6.81d	4.75
G + S +A	6.01e	8.36d	9.31d	7.89	3.11d	4.25d	6.80d	4.72
G +C+S	5.71f	8.01e	8.94cd	7.55	2.95e	4.10e	5.35e	4.13
F_{test}	**	**	**		**	**	**	
$LSD_{0.05}$	0.04	0.11	0.45		0.25	0.06	0.18	
$LSD_{0.01}$	0.05	0.15	0.62		0.31	0.09	0.25	

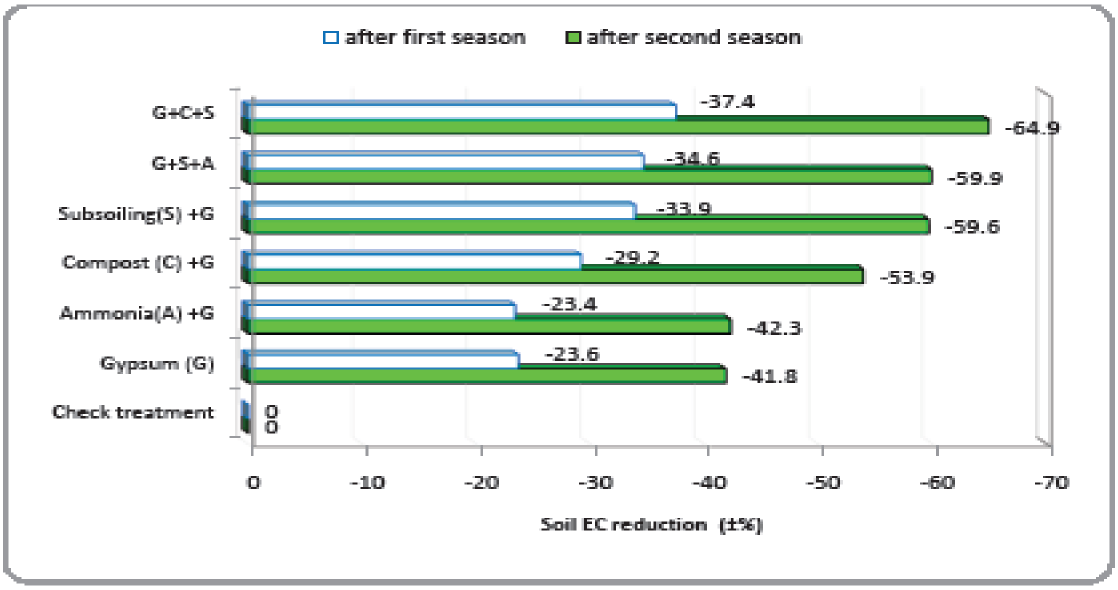

Fig. 2. Average soil EC reduction, 0-60cm depth (±%) related to check treatment in first and second growing seasons

Sodium adsorption ratio (SAR)

Data in Table 5 showed that the sodium adsorption ratio (SAR) decreased by the application of gypsum from 17.5 before treatment to 14.27 and 12.77 after the 1st and 2nd seasons, respectively, with reduction of 8.23 % and 15.5%, respectively as compared with check treatment as shown in Fig.(2). These results may be due to the role of gypsum in providing Ca^{2+} cation to replace the exchangeable Na^{+} on the exchange positions as observed by Sharma and Minhas (2005). Also, data revealed that the SAR was decreased to 14.27 and 12.79 due to application of gypsum combined with ammonia injection in the 1st and 2nd seasons, respectively, where the reductions were 8.2 % and 15.4 %, respectively as compared with check treatment.So, application of ammonia injection had no effect on SAR.

Data in Table 5 and Fig. 3 showed that SAR was positively affected by an application of gypsum and compost, where it was decreased to 13.71 and 11.98 after the 1st and 2nd seasons, respectively, with reduction of 11.8% and 20.7%, respectively as compared with check treatment. These results seem to agree with findings observed by Courtney and Harrington (2012) and El-Sanat et al.(2017). It could be observed that the application of gypsum combined with compost was more effective on SAR than gypsum only as observed also by Vance et al. (1998), Abdel-Fattah & Merwad (2016) and Ouda & Zohry (2016). The reduction in soil SAR due to application of compost may be related to release of Ca^{2+} from soil $CaCo_3$ or leaching of Na^{+} from soil (Sarwar et al., 2008). Or due to gum compounds, polysaccharides and organic acids produced from compost decomposition improved soil structure and help in leaching of soluble salts.

The application of subsoiling with gypsum or compost seems to be more effective in decreasing SAR. So, SAR was decreased due to application of subsoiling with gypsum after the 1st and 2nd seasons to 11.75 and 15.21, respectively, where the corresponding reductions were -24.4 % and 32.4 %, respectively.

Also , the data refer to that SAR values were decreased due to application of subsoiling with gypsum and ammonia injection to 11.65 and 9.74 after the 1st and 2nd seasons, with reduction of 25.1% and 35.5 %, respectively compared to the check treatment. So, it could be observed that SAR was not clearly affected by ammonia injection applied with other amendments. On the other hand, SAR were more affected by the combined application of subsoiling with gypsum and compost where it was decreased to 11.26 and 9.57 in the 1st and 2nd seasons, respectively, with corresponding reduction of 27.6 % and 36.7 %, respectively as compared with check treatment, (Table 5 and Fig. 3).

TABLE 5. Sodium adsorption ratio (SAR) as affected by different treatments

Treatments	After first season				After second season			
	Soil depth (cm)				Soil depth (cm)			
	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
Check treatment	13.23	15.63	17.79	15.55	12.91	15.1	17.31	15.11
Gypsum (G)	11.59	14.46	16.75	14.27	10.12	13	15.2	12.77
G +Ammonia(A)	11.59	14.46	16.75	14.27	10.13	13.1	15.15	12.79
G +Compost (C)	11.63	13.75	15.74	13.71	9.87	12.1	13.98	11.98
G +Subsoiling (S)	8.35	12.6	14.29	11.75	7.06	10.81	12.75	10.21
G+ S + A	8.27	12.48	14.2	11.65	6.45	10.19	12.59	9.74
G+ S + C	7.97	11.75	14.07	11.26	6.57	9.55	12.58	9.57

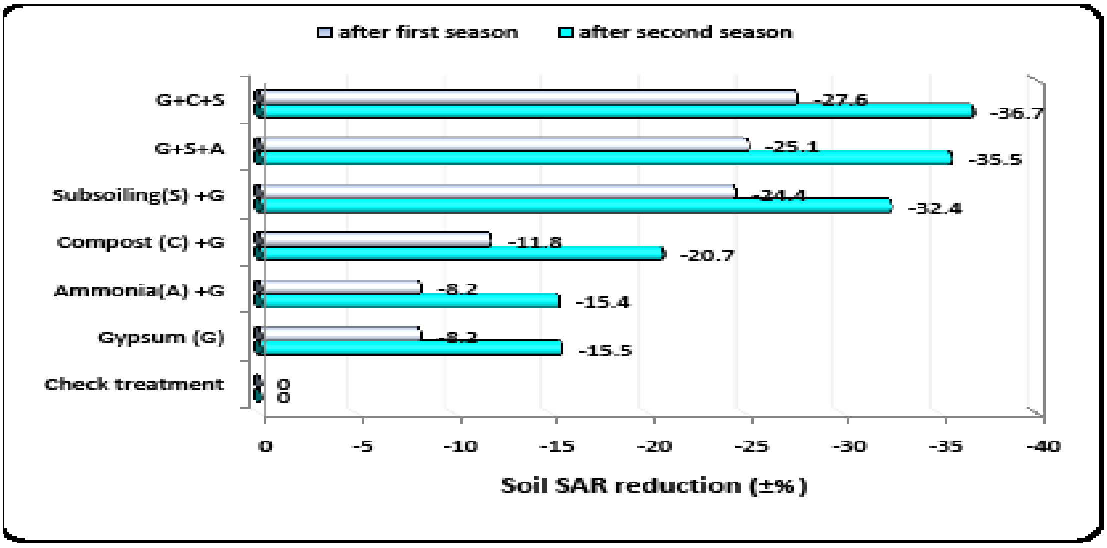

Fig. 3. Average soil SAR reduction 0-60 cm depth (±%) related to check treatment in first and second growing seasons

Ca/Mg ratio

Figure 4 showed the effect of different treatments on Ca/Mg ratio on soil surface. The obtained data indicated that Ca/Mg ratio was increased by application of gypsum from 0.76 to 0.84 and 0.98 after the 1st and 2nd seasons, respectively. Gypsum application increased Ca2+ and modifies the ratio Ca2+ to Mg2+ on the exchange complex in soil. Also, Ca/Mg ratio was slightly affected by ammonia injection when applied with gypsum, since it was increased to 0.85 and 0.98 after the 1st and 2nd seasons, respectively. The Ca/Mg ratio was appreciably affected by application of gypsum combined with compost and it was increased to 1.08 and 1.16 after the 1st and 2nd seasons, respectively. These results may be due to organic materials improve the soil physicochemical properties that accelerate exchange of cations on soil solids and leaching of salts from the root zone (Clark et al., 2007)

Regarding the effect of subsoiling combined with gypsum on Ca/Mg ratio. The data showed that it was increased to 0.97 and 1.03 after the 1st and 2nd seasons, respectively. The values of Ca/Mg ratio were decreased up to (1.17 and 1.26) after harvesting of barely and rice due to application of gypsum, subsoiling and ammonia injection. On the other hand, Ca/Mg ratio was increased due to application of gypsum with compost and subsoiling to 1.24 and 1.47 after the 1st and 2nd seasons, respectively. The removal of Mg2+ on soil complex and replaces by Ca2+ released from gypsum caused a positive increment of Ca/Mg ratio. This results seems nearly agreement with (Agar, 2012), who found that application of gypsum with sulfur are needed to remove the exchangeable Mg2+ from soil profiles and both materials together are more effective than one of them individually.

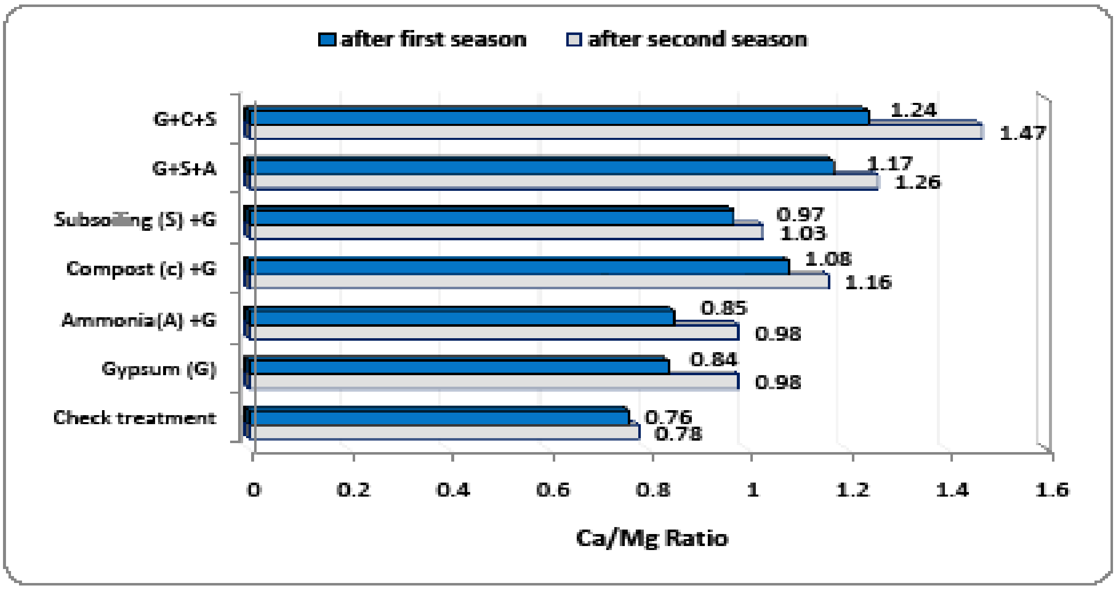

Fig. 4. Average of Ca/Mg ratio of soil layer (0-60cm depth) as affected by different treatments

Soil physical properties

Soil bulk density (BD)

Results in Table 6 revealed that treatments application seemed to be effective in producing relatively low values of soil bulk density especially in the surface layers. Soil bulk density ranged from 1.42 to 1.44 Mgm-3 before experimental installation while, after two seasons from experimental installation bulk density were reduced and varied from 1.26 to 1.42 Mgm-3

Table 6 and Fig 5 showed that soil BD decreased by the application of gypsum (1.42 and 1.40 Mg m-3) in both seasons, with reduction of 1.4 % and 2.6% , as compared with the check treatment. Also, data referred that soil BD decreased by application of gypsum combined with ammonia injection (1.39 and 1.41 Mgm-3) in both seasons, with reduction of 2.1 and 3.2% , as compared with the check treatment.

Table 6 and Fig 5 referred that the BD decreased to 1.37 and 1.34 Mg m-3 by gypsum and subsoiling treatments in both seasons, with the reduction of 4.9% and 6.7% as compared with check treatment. These results referred to the role ameliorative effect of the subsoiling on improvement of soil drainage, soil aeration and water infiltration (El-Henawy et al., 2016).

The data showed also that the BD was decreased due to application of gypsum combined with compost and mole drains from 1.49 Mg m^{-3} of the check treatment to 1.38 Mg m^{-3} and 1.31 Mg m^{-3} after the 1st and 2nd seasons, respectively, whereas the reductions were 7.4% and 12.1 % respectively. So, the effect of different treatments on soil bulk density followed the ascending order such as: G + C+ M > G + C = G +M + A > G + M> G + A = G > check treatment.

This means that gypsum +compost + mole drains effects were superior to others treatments on reducing soil bulk density. It could be attributed to the effects of mole on breaking soil clods and bigger granular into smaller crumbs as well as breaking and cracking the compacted layers (Antar et al., 2008). It could be observed that there were remarkable changes on BD by application of compost and/or subsoiling with any treatments in both growing seasons.

Soil porosity

Data in Table 6 showed that the application of gypsum increased the soil porosity from 45.66 % and 45.79% of the check treatment to 46.42% and 46.79 in growing seasons. Also, the application of gypsum combined with the compost had positive effect on the soil porosity since was increased to 48.68% and 49.69% after harvesting of barely and rice, respectively .Thus, the role of compost may be related to increase of soil granulation, increase porosity and decrease soil density and improving soil properties, (El-Henawy et al., 2016).

The data referred also that application of gypsum with subsoiling had positive effect on increasing of the soil porosity after the first and second seasons (48.30 and 49.43, respectively). The highest values of soil porosity after the first and second seasons (49.81% and 52.33%, respectively) were recorded by the application of gypsum with both compost and subsoiling as compared with the check treatment. So, it can be concluded that gypsum combined with compost and the subsoiling is the most effective treatment

TABLE 6. Soil bulk density (Mg m^{-3}) and total porosity (%) as affected by different treatments

Treatments	Soil depth (cm)	After 1st season		After 2nd season	
		BD (Mg m^{-3})	Porosity %	BD(Mg m^{-3})	Porosity %
Check treatment	0-20	1.43	46.04	1.43	46.04
	20-40	1.44	45.66	1.44	45.66
	40-60	1.45	45.28	1.44	45.66
Average		1.44	45.66	1.44	45.79
Gypsum (G)	0-20	1.40	47.17	1.37	48.30
	20-40	1.42	46.42	1.41	46.79
	40-60	1.44	45.66	1.42	46.42
Average		1.42	46.42	1.40	47.17
G+ Ammonia (A)	0-20	1.38	47.92	1.36	48.68
	20-40	1.42	46.42	1.40	47.17
	40-60	1.44	45.66	1.42	46.42
Average		1.41	46.67	1.39	47.42
G + Compost (C)	0-20	1.35	49.06	1.31	50.57
	20-40	1.36	48.68	1.34	49.43
	40-60	1.37	48.30	1.35	49.06
Average		1.36	48.68	1.33	49.69
G+ subsoiling (S)	0-20	1.36	48.68	1.33	49.81
	20-40	1.37	48.30	1.34	49.43
	40-60	1.38	47.92	1.36	48.68
Average		1.37	48.30	1.34	49.43
G+S+A	0-20	1.34	49.43	1.31	50.57
	20-40	1.36	48.68	1.33	49.81
	40-60	1.38	47.92	1.35	49.06
Average		1.36	48.68	1.33	49.81
G +C+S	0-20	1.31	50.57	1.25	52.83
	20-40	1.33	49.81	1.26	52.45
	40-60	1.35	49.06	1.28	51.70
Average		1.33	49.81	1.26	52.33

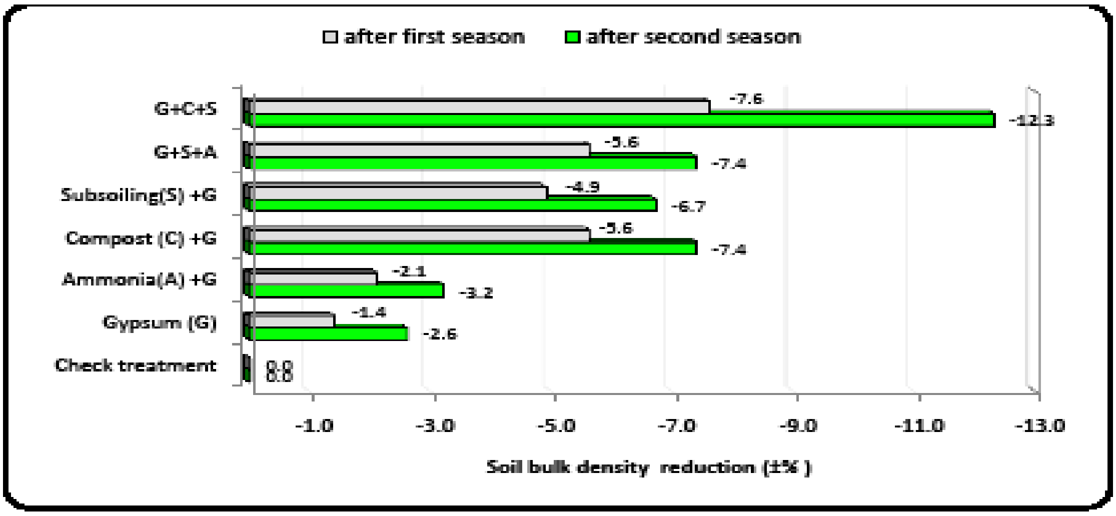

Fig. 5. Average of soil bulk density reduction 0-60 cm depth (±%) related to check treatment in first and second growing seasons

that ameliorate saline sodic clay soil.

The effect of different treatments on soil porosity can be arranged in the following ascending order: G+C+S > G+ S +A > G +C > G+ S >G +A>G > Check treatment.

Soil basic infiltration rate (IR)

Infiltration rate (IR) is the volume flux of water flowing into the profile per unit of soil surface area. Table 7 showed that the application of gypsum and/or without ammonia injection slightly increased IR from 0.32 cm/h of check treatment to about 0.33 cm/h after harvesting of barely and rice, where the increase was about 3.1%. Also, the data referred that the IR was increased to (0.51 and 0.56 cm h^{-1}) after first and second seasons, due to application of gypsum with compost, whereas the relative increase were 59.4 % and 75 %, respectively as compared with check treatment. In addition, gypsum combined with subsoiling increased IR in the 1st and 2nd seasons (about 0.45 and 0.48 cm h^{-1}, respectively. with the increase of about 40.6% and 50.0 %, respectively comparing to the check treatment. This may be due to the improved drainage under subsoiling treatments that gave the top soil layer a chance to dry and permitted for shrinkage and formation of water passage ways which allowed a rather easier movement of water through mole into net drainage (El-Henawy et al., 2016).

Addition of gypsum , subsoiling and ammonia injection increased IR in the 1st and 2nd seasons (about 0.46 and 0.49 cmh-1, respectively. with the increase of about 43.8% and 53.1 %, respectively comparing to the check treatment. On the other hand, the obtained data showed that the IR was clearly increased due to application of gypsum with compost and subsoiling (1.16 and1.21cmh^{-1}) after first and second seasons, respectively, whereas the relative increased were about 262.5% and 278.1 %, respectively compared with check treatments. Hence subsoiling can be used to improve the efficiency of drainage and an adequate auxiliary drainage treatments in clay soils of low level with a saline water table to reserve the root zone from water logging and salinity. This results may be due to increasing of root resudies through soil profile by application of organic manure and gypsum with subsoiling.

The effect of different soil amendments on soil basic IR can be arranged in the following ascending order: G+C+ S > G +C > G+ S +A ≈ G+ S >G +A= G > check treatment.

It can be observed from the results that the IR values were not clearly affected by the combination of ammonia injection with other soil amendments. The positive effect on IR may be due to that application of gypsum increases of soluble Ca^{2+} to overcome the dispersion effects of Na^+ ions and promote flocculation and structure development in dispersed soils. The permeability of clay soils is strongly dependent on the type of exchangeable cations and it decreases with increasing of the soil sodicity, (Shainberg et al., 1988). Also, the positive effect of compost on decreasing of the bulk density and increasing the soil porosity and IR values, consequently ease leaching the salts from upper soil layer and movement far by subsoiling, similar results were nearly obtained by Saied et al. (2017). This may be also due to improving drainage system in the area by subsoiling, in addition to improve soil physical properties as a result of decreasing Mg / Ca ratio in soil is less the unity which causes a increment in infiltration rate.

TABLE 7 . Soil basic infiltration rate (IR, cm h^{-1}) as affected by different treatments

treatments	1st season	Relative variation (±%)	2nd season	Relative variation (±%)
Check treatment	0.32	0	0.32	0
Gypsum (G)	0.33	3.1	0.33	3.1
G +Ammonia (A)	0.33	3.1	0.34	6.3
G +Compost (C)	0.51	59.4	0.56	75
G +Subsoiling (S)	0.45	40.6	0.48	50
G + S +A	0.46	43.8	0.49	53.1
G +C+ S	1.16	262.5	1.21	278.1

Yield of barley and rice

Table 8 showed that grain and straw yields of barely and rice were highly significantly increased by application of gypsum. These results may be due to application of Ca amendments as soil modifiers that can prevent development of sodicity which is directly related to plant growth, crop productivity and crop yields (Wong et al., 2009). And soluble Ca^{2+} released by gypsum could be a factor that alleviated the stress effect of Na^+ on rice growth (Chi et al., 2012). Also, the application of gypsum combined with compost, ammonia injection or subsoiling highly significantly increased the grain and straw yield of barely and rice, and all of them were superior to gypsum individually or the check treatment. Beneficial effects of compost applications to crops are many and varied. Most of them are due to soil quality improvement and nutrient enhancement which resulted in increases in yield of barley and rice.

Data showed that grain and straw yields of barely and rice were highly significantly increased and recorded the highest values due to application of gypsum combined with subsoiling and compost or ammonia injection. As a general, the application of gypsum with subsoiling and ammonia injection considered as an effective management strategy for amelioration of salt affected soils and achieved the highest productivity. Finally, the soil productivity as affected by different soil amendments can be arranged in the following descending order: G+ S +A > G+ S + C > G+ S >G+ C > G+ A > G > check treatment.

The beneficial effect of the ameliorative role of the previous treatments in salt affected soils may be attributed to that gypsum and compost on improvement soil properties such soil salinity and basic infiltration rate. The obtained results are supported by the data obtained by Saied et al. (2017) and El Sanat et al. (2017). The relation between soil salinity and yield were supported by Amer et al. (2017) who found that the yield potential in the parts at Kafr El-Sheikh Governorate with relative low EC soils (4.6-4.9 dSm^{-1}) was about 10 % higher than that in parts with relatively high salinity (6.8 dSm^{-1}).

TABLE 8. Yield of barley and rice ($Mgfed^{-1}$) as affected by different treatments

Treatments	Barley (Mg fed^{-1})		Rice (Mg fed^{-1})	
	Grain	Straw	Grain	Straw
Check treatment	0.788f	1.020f	0.750i	1.010i
Gypsum (G)	1.620e	1.855e	1.50f	1.80f
G +Ammonia (A)	1.650d	1.890e	1.82e	2.15e
G +Compost (C)	1.655d	1.955d	1.93d	2.20d
G + Subsoiling (S)	1.786c	1.987c	1.17c	2.37c
G + S + A	1.991a	2.250a	2.36a	2.76a
G+ S +C	1.859b	2.080b	2.32b	2.54b
Ftest	**	**	**	**
LSD0.05	0.012	0.011	0.009	0.014
LSD0.01	0.009	0.008	0.007	0.011

Economical evaluation

Data in Table 9 showed that costs of agriculture treatment materials and price yield of barely and rice according the local market. Data in Fig. 6 and 7 showed that the gross and net incomes were obviously increased by gypsum combined with subsoiling and ammonia injection or compost. The experimental plot achieved gypsum + subsoiling + ammonia together achieved the highest values of gross and net incomes of barley (5730.2 and

TABLE 9. Costs of agriculture treatment materials and price yield of barely and rice

Item	Variable cost (LE fed $^{-1}$)					Fixed cost (LE fed $^{-1}$)							Price (LE Mg^{-1})	
	Gypsum*	Compost**	subsoiling ***	Ammonia injection	N-fertilizer	Rent cost	Seed	P-K-fertilizer	Labor cost	Ploughing	Harvesting	Irrigation	Grain	Straw
Barely	450	400	30	270	300	1500	200	600	300	200	600	300	2200	600
Rice	450	400	30	480	521	1500	300	600	600	200	600	600	3750	300

Notes:

1- Total cost(LE Fed. -1) = fixed cost(LE Fed. -1) + variable cost (LE Fed. -1)
2- Gross income (LE Fed. -1) = grain yield x price + straw yield x price
3- Net income = gross income (LE Fed-1) - total costs (LE fed-1)
4- Economic efficiency (Eco. Eff.) = Gross income (LE Fed-1) /total cost (LE Fed-1)

*Total cost for gypsum (900LEFed.-1) for barely and rice
** Total cost for compost (800LEFed.-1) for barely and rice
*** Total cost for subsoiling (120LEFed.-1) for four seasons

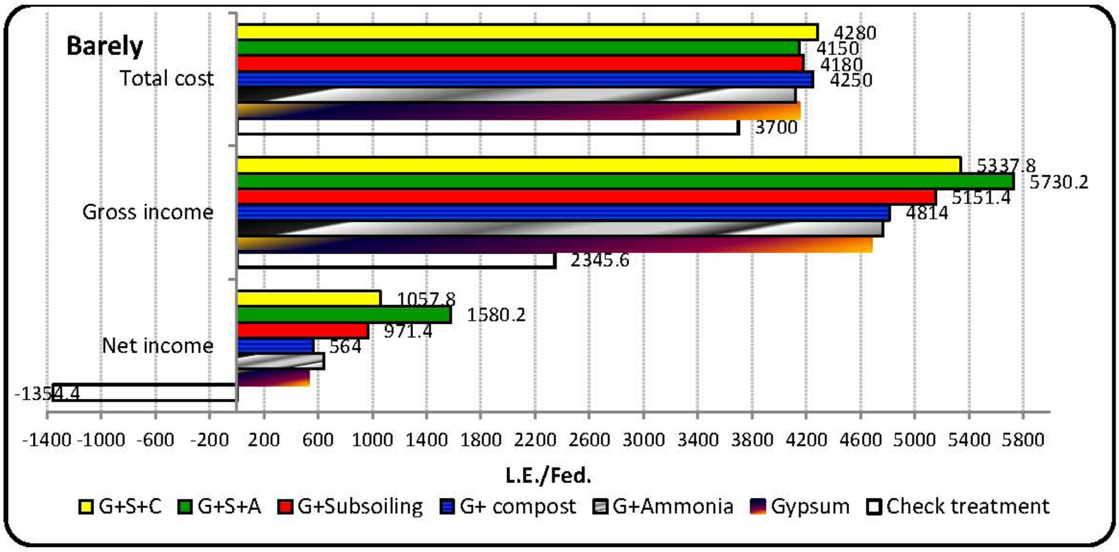

Fig. 6. Total cost, gross income and net income (LE fed^{-1}) from yield of barely as affected by different treatments

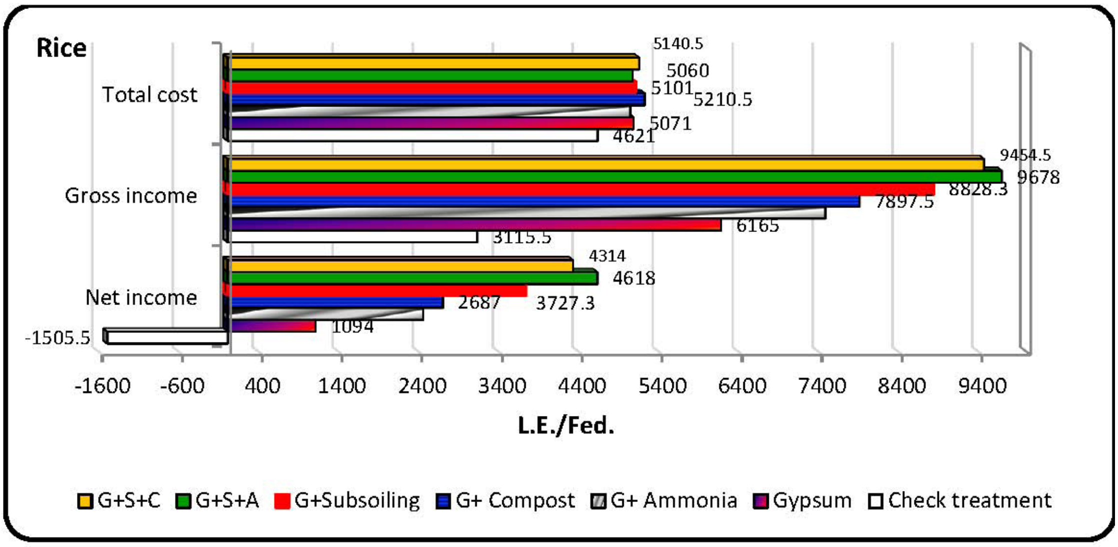

Fig.7. Total cost, gross income and net income (LE fed^{-1}) for yield of rice as affected by different treatments

1550.2 LEFed.-1, respectively) and rice (9678 LEfed.-1and 5298 LEFed.-1, respectively). Concerning the economic efficiency, the highest values 1.38 and 1.91) for barley and rice were recorded due to the combined between gypsum, subsoiling and ammonia injection. Theses results are consistent with those obtained by Osman et al. (2013) who concluded that anhydrous ammonia increased gross income, net income, benefit / costs ratio and profitability of rice.

Conclusion

It could be concluded that the application of gypsum requirements to the soil combined with ammonia gas and subsoiling could be economically used to improve the yield of cereal crops such as barley and rice. Some physio-chemical properties of salt affected soil were improved by application of gypsum, compost and subsoiling at Kafr El-Sheikh Governorate.

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تأثير إضافة بعض محسنات التربة على خواص وإنتاجية الأراضي المتأثرة بالأملاح في محافظة كفر الشيخ

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- أجريت تجربتان حقليتان في أراضى متأثرة بالأملاح بمزرعة خاصة تقع في قرية مارس الجمل - محافظة كفرالشيخ خلال موسمين نمو شتوى٢٠١٧/٢٠١٦، وصيفى ٢٠١٧ لدراسة تأثير إضافة الجبس،الكمبوست ، الحقن بالامونيا والحرث تحت التربة على خواص وإنتاجية التربة لمحصولى الشعير والأرز. تم إختبار عدد (٧) معاملات في قطاعات كاملة العشوائية في ثلاث مكررات ومن أهم النتائج:

- تبين من النتائج تحسن الخواص الكيميائية للتربة حيث لوحظ تناقص معنوى لقيم كل من ملوحة التربة ونسبة ادمصاص الصوديوم، وزيادة نسبة الكالسيوم الى الماغنسيوم خلال العمق ٠-٦٠سم نتيجة إضافة الاحتياجات الجبسية للتربة ، ٤ طن كمبوست/فدان مع الحرث تحت التربة خلال موسمى الدراسة.

- كما لوحظ تحسن الخواص الطبيعية للتربة، حيث سجلت النتائج اقل القيم للكثافة الظاهرية للتربة وأعلى قيم للمسامية ،ومعدل الرشح نتيجة اضافة كل من الجبس مع الكمبوست ، والحرث تحت التربة خلال موسمى الدراسة.

- توضح النتائج زيادة معنوية لكلا من الحبوب والقش للشعير والأرز حيث سجلت أعلى القيم نتيجة اضافة كل من الجبس والحقن بالأمونيا مع الحرث تحت التربة خلال موسمى الدراسة.

- سجل كل من العائد الكلى وصافى العائد وكذلك نسبة العائد على الاستثمار أعلى قيمة نتيجة إضافة الجبس والحقن بالأمونيا مع الحرث تحت التربة لمحصولي الشعير والأرز.

- تبين من التقييم الاقتصادى تحسن إنتاجية محصولى الشعير والأرز نتيجة إضافة الاحتياجات الجبسية للتربة والحقن بالأمونيا مع الحرث تحت التربة ، بينما تحسنت الخواص الفيزوكيمائية للتربة تحت ظروف الاراضى المتأثرة بالأملاح نتيجة إضافة كل من الجبس والسماد العضوى مع الحرث تحت التربة.