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Saline-Sodic Soils Treated with Some Soil Amendments and Foliar Application with Compost Tea and Proline for Improvement Some Soil Properties and Yield-Water Productivity of Rice

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Authors' contributions

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

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ABSTRACT

The improvement of saline and sodic soils aims to reduce the dissolved salts in the soil solution. In this context, an integrated management approach is required, which not only improves its effectiveness in improving soil properties but also increases water productivity and yields.

To mitigate the negative effects of soil salinity, improvement of soil properties and yield –water productivity of rice plant, a field trial was carried out at El-Hamoul region, Kafer El-Sheikh, Egypt, during the summer seasons of 2019 and 2020. The experiments were conducted in split plot design, with three replicates. The main plots were assigned to soil amendments (control, compost (C) 10.0 Mg ha^{-1}, gypsum (G) 100% from gypsum requirement 13.512 Mg ha^{-1} and G+C).Sub main plots were assigned to foliar application (control (tap water), compost tea (50 L ha^{-1}), proline (3.6 g ha^{-1}), and combination of compost tea + proilne).

Generally, results showed that the impacts of main plots were in the following order: compost + gypsum > gypsum > compost > control in both growing seasons. Also, soil amendments had a significant effect on decreasing some soil chemical properties i.e. pH, EC, ESP and increasing of

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CEC compared control treatment. The treatment compost +gypsum more pronounced the other treatment on soil bulk density and total porosity. Soil basic infiltration rate (IR) and hydraulic conductivity (K) high significantly increased by application of compost, gypsum and gypsum + compost and recorded the highest value by application of compost + gypsum. Chlorophyll, proline content, 1000-grain weight, straw and grain yield of rice were significant increased and recorded the highest values due to the interaction between compost + gypsum and foliar of compost tea and proline during two growing seasons. Water productivity (WP) and productivity of irrigation water (PIW) for grain yield of rice were high significantly increased and recorded the highest values due to the interaction between soil amendments, compost tea and proline. Total return, net return, benefit cost ratio and total return from water unit for rice yield were significant increased with treatment and recorded highest values due the interaction compost + gypsum and foliar application of compost tea and proline.

Keywords: Rice; compost; gypsum; salt-affected soils; total return; water productivity.

1. INTRODUCTION

Salt affected soil is occupied about 30% from Delta lands [1]. Saline–sodic soils are degraded due to the simultaneous effect of salinity and sodicity. This causes loss of soil physical structure by clay swelling, and dispersion [2, 3]. Salinization can cause yield decreases of 10–25% for many crops .Salinity affects plant growth by creating osmotic imbalances and specific ion toxicities [4]. Addressing soil salinization through improved soil, water and crop management practices is important for achieving food security and to avoid desertification [5, 6].The handling of salt-affected soils should include mobilization of Na^+ and then leaching these ions from soil profile to improve the soil properties in particular hydraulic conductivity [7]. Some soil amendments could be used to remediate and reclaim salt-affected soils such as gypsum, sulfur, and compost [8, 9]. Gypsum is the most commonly applied product for the reclamation of saline–sodic soils and can improve physical and chemical soil properties primarily by maintaining a favorable electrolyte concentration in soil solution. As adsorbed Na^+ on exchangeable sites of clay particles are considered to be responsible for soil dispersion, gypsum can prevent it by maintaining high Ca/Na ratios, and thus promoting clay flocculation and structure stability [10]. Gypsum is relatively insoluble and it has lowest solubility in water below 40ºC [11]. Salt-affected soils significant improvements soil physical, chemical, and biological characteristics with the application of compost [12]. Compost can potentially effect on improvement of the soil chemical properties and both of the rice plants growth and yields [13]. And suggest the succession of crops due to the great importance in the phytoremediation of soils [14, 15]. In this context, the rice crop is introduced during the reclamation of saline-sodic [16].The threshold of average root zone critical salinity values for rice growth is 3 dSm^{-1} and slope 12 dSm^{-1} [17]. The application of compost has a positive effect on soil salinity due to its improving soil physical properties; hence it led to remove Na^+ from root zone [7], and promotes sustainability of salt affected soils because of its long-term ameliorative effects on physical, chemical and biological properties of soil[13,18]. Compost can alleviate salinity stress in plants by improving soil fertility promoting nutrient availability and plant growth [19, 20], stimulating respiration, photosynthesis, and chlorophyll content [21], and soil chemical, physical properties and its fertility parameters were influenced [22]. Combined application of gypsum and organic amendments in sodic soils improved soil properties, resulting in decreased soil bulk density, electrical conductivity (EC), and exchangeable sodium percentage (ESP) [23]. Application of gypsum and compost tea can be used to combat salt effects on plant growth and soil properties under saline-sodic soil conditions [24]. Application of compost had positive effect on plant nutrients as well as led to remove Na^+ far from root zone [25]. Compost tea is a highly concentrated microbial solution produced by extracting beneficial microbes from compost. It is a source of foliar and soil organic nutrients, contain chelated micronutrients for easy plant absorption and the nutrients is in a biologically available form for both plant and microbial uptake. It has beneficial effects on plant growth and considered as a valuable soil amendment [26, 27]. The efficiency of salt tolerance of rice yield was improved with foliar application of proline. In crux, foliar applications of 50 Mm proline at seedling and vegetative stages significantly improved the performance of rice cultivars by improving tillering dynamics, plant water-relations, chlorophyll pigments, photosynthetic pigments, morphological and kernel yield under saline conditions [28]. Little attention has been given to the interaction effect between the type of the soil amendments and foliar application of proline and compost tea. Thus, the main objective of this study is to study the effectiveness of soil amendments (gypsum and compost) and foliar application with compost tea and proline to reduce the harmful effects of soil salinity and improve both of some soil properties and economic return as well as water productivity of rice crop.

2. MATERIALS AND METHODS

2.1 Experimental and Treatments

Field trials were carried out at El-Hamoul region, Kafr El-Sheikh, Egypt. The experiment was conducted during the two growing summer season of 2019 and 2020 to study effectiveness of gypsum and compost as soil amendments in alleviating salt-affected soils and foliar both of compost tea and proline on improvement of soil properties and yield –water productivity of rice plant.

The experiments were conducted in split plot design, with three replicates. The main plots were assigned to soil amendments (control, compost (C) 10.0 Mg ha^{-1}, gypsum (G) 100% from gypsum requirement and G+C).Sub main plots were assigned to foliar application (control (tap water), compost tea (50 L ha^{-1}), proline (3.6 g ha^{-1}), and combination of compost tea + proilne).

Gypsum was applied before transplanting of rice at of 13.512 Mg ha^{-1}, as 100% from Gypsum Requirement based on soil CEC and ESP values to lower ESP to 10. Gypsum required for reducing the initial soil ESP to the required level in the surface layer (10) were calculated according to [29], as follow:

$$GR= (ESP_i - ESP_f)/100 \times CEC \times 1.72$$

Where GR: gypsum requirement (Mg ha^{-1}), ESP_i: initial soil ESP, ESP_f: The required soil ESP (10) and CEC: cation exchange capacity (cmolc kg^{-1}).

Foliar application of compost tea and proline after 20 day and 40 day from transplanting of Rice. The required compost and gypsum were mixed with the upper soil layer before tillage. The plot area was 21 m^2. Compost tea used was produced from the Agricultural Research Center (ARC), Giza, Egypt. Chemical composition (mg kg^{-1}) of compost included N (1.45), P (0.67), K (2.19), organic matter (37.9), C/N ratio (19:1), whereas pH (7.69), EC (2.71 dS m^{-1}) and moisture content (28.21%), where the composting was from mixture of residual plants and animals. The chemical composition of compost tea: pH, EC (dS m^{-1}), NO_3, NH_4, P, K, Ca, Mg, Na, Fe, Mn, Zn were 8.01, 5.11, 65.0, 0.63, 19.0, 1.34,443, 220, 55.0, 21.1, 1.08 and 0.85 mg L^{-1}, respectively. In the first growing season, plants were transplanted with Sakha 108 rice cultivars seedlings on 17th Jun., 2019, while in the second growing season, plants were transplanted on 18th Jun., 2020. Harvesting process was occurred on 30th September in the two growing seasons. All agricultural practices and fertilization rates were performed according to the traditional recommendations in North Delta area. Also. Climatological data, potential evapotranspiration and maximum evapotranspiration during the two growing summer seasons 2019 and 2020 were showed in Table 1.

2.2 Soil Sampling Analysis

Before planting and after harvesting Rice crop, soil samples (0-20, 20-40 and 40-60 cm depth) were collected and composite (Table 2). Composite soil samples were dried, sieved through 2 mm mesh and analyzed for salinity which was determined in the saturated soil paste extract according to [30]. The bulk density was determined using core-ring method and one core per stratus of each plot was collected and the samples were oven dried for 48 h at 105^{o}C, weighed and bulk density calculated according to [31]. Also, particle size distribution was determined according to [32].

2.3 Plant Analysis

Plant samples from the measured plants for growth, chlorophyll content determination chlorophyll content (SPAD unit), was measured on ten leaves taken from each replicate by chlorophyll meter (SPAD-502, Soil- Plant Analysis Department (SPAD) section, Minolta camera Co., Osaka, Japan) by [35]. Proline content determination free proline was extracted from 200 mg of leaf sample in 3% (w/v) aqueous sulfosalcylic acid and estimated using ninhydrin reagent according to the method of [36].1000-grain weight and both of grain and straw yield of rice were calculated and recorded for each plot and calculated per hectare.

Table 1. Climatological data, potential evapotranspiration (ET_0) and maximum evapotranspiration (ET_m) for of rice during two growing summer seasons 2019 and 2020

Month	T (C	R.H. (%)	W.V. (km day^{-1})	day	P.E. period	P.E. day^{-1}	K pain	ET_0	K_c	ET_m cm	ET_m m^2
					2019						
Jun.	30.5	65.75	103.5	14	0.846	11.84	0.75	8.88	1.07	9.50	958.08
July	31.0	69.8	83.8	30	0.808	24.24	0.75	18.18	1.16	21.09	2125.75
Aug.	31.6	70.65	68.7	31	0.683	21.17	0.75	15.88	1.19	18.90	1904.81
Sept.	30.2	68.15	76.9	30	0.590	17.70	0.75	13.28	1.04	13.81	1391.64
										63.30	6380.28
					2020						
Jun.	27.6	52.15	111.8	15	0.952	14.28	0.75	10.71	1.07	11.46	1155.14
July	28.15	60.30	101.7	30	0.879	26.37	0.75	19.78	1.16	22.94	2312.54
Aug.	30.5	67.65	92.4	31	0.803	24.89	0.75	18.67	1.19	22.22	2239.46
Sept.	31.4	67.45	93.30	30	0.624	18.72	0.75	14.04	1.04	14.60	1471.85
										71.22	7179.00

** T. (C°): average of maximum and minimum temperature; R.H.: relative humidity; W.V.: wind velocity (at 2 m height); P.E.: Pan Evaporation. K pain: coefficient of evapotranspiration, ET_0, potential evapotranspiration, K_c, ET_m: maximum evapotranspiration ($m^2 ha^{-1}$). Source: Meteorological station at Sakha Agric. Res. Station.ET_0 = P.E.cm period day -1 *K pain, ETm cm =ET_0*K_c. The dimension less crop coefficient, Kc is the ratio between the water consumed by specific crop to ETo. Values of Kc were quoted from [33] and presented in Table 1*

Table 2. Some physical and chemical properties of the experimental soil

Soil depth(cm)	Soil physical properties							
	Soil moisture characteristics				Particle size distribution (g kg^{-1})			
	F.C (%)	W.P. (%)	A.W. (%)	B.D. (kgm^{-3})	Sand	Silt	Clay	Soil texture
0-20	43.10	21.55	21.55	1.39	163.0	330.0	507.0	clay
20-40	40.50	20.25	20.25	1.38	144.0	338.0	518.0	clay
40-60	38.50	19.25	19.25	1.40	128.0	342.0	530.0	clay

Soil chemical properties												
Soil depth (cm)	pH	EC dS m^{-1}	SAR	ESP (%)	Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})			
					Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^-	HCO_3^-	Cl^-	SO_4^-
0-20	8.31	8.25	14.6	17.7	58.6	7.8	19.0	13.2	0.0	4.5	46.9	47.2
20-40	8.32	8.54	14.9	18.0	60.6	8.1	19.6	13.7	0.0	5.0	48.5	48.5
40-60	8.35	9.11	15.6	18.9	65.6	8.7	21.0	14.6	0.0	4.5	52.5	52.8

Soil depth (cm)	CEC	N	P	K	OM	$CaCO_3$
	(cmol$_e$ kg^{-1})		(mg kg^{-1})		(g kg^{-1})	
0-20	39.1	25.8	9.5	245	18.1	28.1
20-40	38.0	26.9	9.3	242	16.5	27.2
40-60	36.3	23.0	9.1	241	14.6	24.1

F.C.: Field Capacity; W.P.: Wilting Point; A.W.: Available Water; B.D.: Bulk Density; pH: was determined in soil water suspension (1:2.5); EC: was determined in saturated soil paste extract; ESP: Exchangeable Sodium Percent; CEC: Cation Exchange Capacity; OM: Organic Matter; N, P, K: available nitrogen, phosphorus and potassium. According to Natural Resources Conservation Service (NRCS), Oregon State University, USA, the soil of experiment can be classified as saline-sodic soil [34]

2.4 Yield-Water Relations

Amount of water applied: the discharge through an orifice was determined from the following equation as described by [37]:

$$Q = CA\,(2Gy)^{1/2} \qquad \text{Equ.(1)}$$

Where: Q= Discharge rate, m3 sce^{-1}, C = discharge coefficient ranges from 0.6 to 0.8 A= area of orifice opening (m^2) G= accelerating of gravity (9.8msec^{-2}), Y= the head causing free flow where Y is the upstream head measured from the center of orifice opening.

Water productivity (WP) is generally defined as the ratio of yield (Y), Kg m^{-2}, to the amount of water depleted by the crop in the process of evapotranspiration (ET), m^3 m^{-2} season^{-1}. It was calculated according to [38].

$$WP= \frac{Yield\ (Kg\ ha^{-1})}{ET} \quad Equ.(2)$$

Productivity of irrigation water (PIW). It was calculated by the following equations according to [39] as follows:

$$PIW= \frac{Yield\ (Kg\ ha^{-1})}{Water\ applied\ (m^3\ ha^{-1})} \quad Equ.(3)$$

2.5 Economic Evaluation

Cash inflow and outflows for various treatments as of the local market price were calculated, and some economic indicators were also estimated such as: 1-Net return, which calculated by deducting the total cost from the total return (USD ha^{-1}), 2- Benefit Cost Ratio (BCR) calculated by dividing the total seasonal return by total seasonal cost 3- Net return from water unit, calculated by dividing the net seasonal return by water applied [40]. The data were analyzed statistically by analysis of variance (ANOVA) using M-State program according to [41]. Treatment means were compared by Duncan's Multiple Range Test at 5% and 0.01 level of significance [42].

3. RESULTS AND DISCUSSION

3.1 Soil Chemical Properties

The statistical analysis of the data shown in Table 3 revealed that the treatment of soil amendments had significant effect on decreasing both of pH, electrical conductivity (Ec_e), exchangeable sodium percent (ESP %) and increasing of cation exchange capacity (CEC) as compared without treatment. Amendments application had pronounced effect on soil chemical properties. Data in Table 3 showed that pH was significant decreased by application of soil amendments and recorded lowest values 8.22 due to compost and gypsum application after the second season.

Treatment of soil amendments (SA) had a positive significant effect on decreasing soil salinity (EC_e) and ESP (%) after harvesting of rice for both the two growing seasons Table 3. Data show that ECe and ESP (%) values (for both two seasons) were significant decreased due to application of compost and gypsum. The data showed that (ECe) and ESP (%) recorded lowest value (5.79 and 12.34) by treatment of compost and gypsum application after two seasons. Concerning the impact of the treatments on soil chemical properties as pH, EC_e and ESP (%), the impacts were in the following order: compost + gypsum > gypsum > compost > control in both growing seasons. These results supported by [13, 43] who found that application of gypsum followed by a mature municipal solid compost mix has been used to restore degraded sodic soils. Similarly, [44] reported that gypsum was effective in the reclamation of sodic soils. The application of gypsum decreases pH, electrical conductivity (EC), exchangeable sodium percentage (ESP), and bulk density and increases the hydraulic conductivity and infiltration rate [45]. The addition of organic matter in conjunction with gypsum has been successful in reducing adverse soil properties associated with sodic soils. Addition of organic matter and gypsum to the surface soil will decrease spontaneous dispersion and EC down to the subsoil, compared to the addition of gypsum alone [46].

Results presented in Table 3 also show that CEC, there is a positive significant effect due to soil amendments treatment which observed during both seasons. The same data showed that the mean CEC was recorded highest values (47.95) by application of compost and gypsum after the second season. Concerning the impact of the treatments on soil chemical properties CEC, the impacts were in the following order: compost + gypsum > compost > gypsum > control in both growing seasons. These results may be due to application of compost on improving soil physical properties, enhancement the chelation ability of $Ca^{2+}$and Mg^{2+}in soil solution to effectively replace Na^+ from the cation exchange complex particularly at alkaline pH values and reducing the exchangeable sodium percent (ESP %) of the saline soil; hence it led to remove Na^+ from root zone [10,13,25].

3.2 Soil Physical Properties

3.2.1 Soil bulk density (BD) and Total porosity

Results in Table 4 revealed that the soil amendments treatments seemed to be effective in producing relatively low values of soil bulk density. Soil bulk density (BD) ranged from 1.395 to 1.393 Mg m^{-3} without treatment for two growing seasons, while with soil amendments , bulk density values (BD) were reduced and varied from 1.365 to 1.270 mgm^{-3}.Table 4 showed that soil BD recorded lowest values due to the compost + gypsum application compared without treatment after the two growing seasons. Concerning the impact of the treatments on soil bulk density and total porosity, the impacts were in the following order: compost + gypsum > compost > gypsum > control in both growing seasons.

This may be reflected the role of compost in increasing the soil aggregation, increasing the soil porosity and decreasing soil bulk density as well as improving soil properties [7, 12], treatment of compost + gypsum was more pronounced the other treatment due the role of gypsum and compost on improvement the chemical and physical of the soil properties this results are supported by [2, 13]. With respect to the effect of foliar application of compost tea or proline on soil bulk density and total porosity after harvesting of rice yield, data pointed out that soil bulk density and total porosity were non-significant effect in both seasons as shown in Table 4.On the other hand the soil bulk density and total porosity were non-significant affected by the inter action between the all treatment.

3.2.2 Soil basic infiltration rate, IR (cm h^{-1}) and hydraulic conductivity, K (cm d^{-1})

Regarding the soil infiltration rate and hydraulic conductivity, it is found that the application of compost, gypsum and gypsum + compost high significantly increased both parameters due to the high significantly increasing in soil porosity and improving soil aggregation as shown in Table 4. It is clear that the highest value of IR and K was found with the combined application of compost + gypsum. Concerning the impact of the treatments on soil basic infiltration rate and hydraulic conductivity, the impacts were in the following order: compost + gypsum > compost > gypsum > without treatment in both growing seasons.

The benefits in the physical properties of soil possible due to that gypsum alone or combined with compost improves the hydro-physical properties such as soil bulk density, total porosity, soil aggregation and permeability which increase both of total porosity and drainable pores. Whereas the field area of study is a good drainage efficiency. Also, humic substances stabilize soil aggregates for a long term in which they are mainly involved in the micro-aggregate formation. These results are supported by [22].

3.3 Chlorophyll (SPAD) and Grain Proline Content (µmol/g of Rice)

To evaluate the effects of some soil amendments, compost tea and proline on rice yield production under saline-sodic soils, different of some soil amendments and foliar application of compost tea and proline were applied. These previous amendments may be having a role in enhancing growing plants to overcome the problems resulting from soil salinity and its sodicity. Therefore, rice plants were cultivated to evaluate these previous treatments.

Chlorophyll (SPAD) and grain proline content (µmol/g of rice) are listed in Table 5. With respect to the effect of some soil amendments and foliar application of compost tea and proline, it is pointed out that chlorophyll (SPAD) and proline content (µmol/g of rice) were highly significantly increased with application of compost, gypsum and compost+ gypsum comparing with control during both growing seasons. The highest values of chlorophyll (SPAD) (41.74 and 45.46 (SPAD) and proline content (0.421 and 0.424 µmol/g) were obtained due to application of compost + gypsum in the two growing seasons. With respect to the effect of foliar application of compost tea and proline, data pointed out that chlorophyll (SPAD) and proline content (µmol/g of rice) values were significant increased with different treatments as compared with the control in both seasons as shown in Table 5.

On the other side, it could be concluded that chlorophyll (SPAD) and grain proline content (µmol/g of rice) were highly significantly increased due to the combination between the treatment of the soil amendments, foliar of compost tea and proline. The data showed that chlorophyll (SPAD) and proline content (µmol/g of rice) were recorded the highest values by application of compost + gypsum and foliar of compost tea and proline. This result are supported by [18, 26].

3.4 Yield of Rice

Table 6 showed that 1000 GW (g), straw and grain yield of rice were significant increased by application of compost, gypsum and compost + gypsum. The data showed that 1000 GW (g), straw and grain yield of rice were recorded highest values by combined application of compost + gypsum during two growing season.1000 GW (g), and yield of rice were significant increased with foliar application of compost and proline as shown in Table 6. The previous characters were significant increased due to the interaction between the all treatments. Where the highest values 1000 GW (g), straw and grain yield of rice were obtained by application compost + gypsum, foliar of compost

Table 3. Some chemical properties as affected by compost, gypsum and foliar application both of compost tea and proline after harvesting yield of rice in 2019 and 2020 seasons

Treatment	1st season				2nd season			
	pH	EC (dSm1)	ESP (%)	CEC (cmol$_e$ kg^{-1})	pH	EC (dSm^{-1})	ESP (%)	CEC (cmol$_e$ kg^{-1})
Soil Amendments (SA)								
Control	8.29a	7.98a	17.68a	35.71d	8.30a	8.36a	18.09a	35.26d
Compost (C)	8.27b	7.97a	17.67a	41.05b	8.25b	8.26b	17.49b	41.50b
Gypsum (G)	8.26c	6.37b	14.65b	38.8c	8.24c	6.13c	14.28c	39.65c
C +G	8.24d	6.14c	12.72c	46.9a	8.22d	5.79d	12.34d	47.95a
F_{test}	*	**	**	**	**	**	**	**
$LSD_{0.05}$	0.006	0.018	0.091	0.073	0.006	0.018	0.043	0.073
$LSD_{0.01}$	0.009	0.028	0.138	0.111	0.009	0.028	0.065	0.111
Foliar Application (FA)								
Control	8.27	7.15	15.73	40.50	8.259	7.17	15.59	40.97
Proilne (Pr.)	8.26	7.08	15.65	40.70	8.255	7.11	15.52	41.16
Compost tea(CT)	8.26	7.07	15.63	40.74	8.252	7.09	15.50	41.21
Pr +CT	8.26	7.04	15.59	40.83	8.22	7.06	15.47	41.30
1F $_{test}$	ns	ns	ns	ns	ns	ns	ns	ns
Interactions								
SA*FA	ns	**	**	*	ns	**	ns	*

** indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same latter in a column are not significantly different at 0.05 level using Duncan's Multiple Range Test (DMRT)*

Table 4. Some physical properties as affected by application of soil amendments and foliar both of compost tea and proline after harvesting yield of rice in 2019 and 2020 seasons

Treatments	1st season				2nd season			
	Bd mgm^{-3}	Porosity (%)	IR (cmh^{-1})	K (md^{-1})	Bd mgm^{-3}	Porosity (%)	IR (cmh^{-1})	K (md^{-1})
Soil amendments (SA)								
Control	1.395a	47.36d	0.52d	2.254d	1.393a	47.43d	0.50d	3.24d
Compost	1.355b	48.87b	0.81b	4.137b	1.327b	49.92c	0.83b	4.15b
Gypsum (G)	1.365c	48.49c	0.67c	3.183c	1.337c	49.55b	0.69c	3.21c
C +G	1.317d	50.30a	0.96a	5.850a	1.270d	52.08a	0.99a	5.88a
F_{test}	*	**	**	**	*	**	**	**
$LSD_{0.05}$	0.007	0.292	0.004	0.004	0.008	0.312	0.004	0.005
$LSD_{0.01}$	0.011	0.443	0.005	0.007	0.012	0.474	0.006	0.007
Foliar application (FA)								
Control	1.355	48.83	0.73	3.84	1.346	49.402	0.760	3.86
Proilne (Pr.)	1.354	48.91	0.74	3.86	1.343	49.32	0.752	3.87
Compost tea (CT)	1.350	49.02	0.74	3.87	1.340	49.181	0.751	3.88
Pr. + CT	1.35	49.06	0.75	3.87	1.34	49.43	0.76	3.89
F_{test}	ns	ns	ns	ns	ns	ns	ns	ns
Interactions								
SA*FA	ns	ns	ns	ns	ns	ns	ns	*

BD, IR, and K is represented soil bulk density, soil porosity, infiltration rate and hydraulic conductivity, respectively indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same latter in a column are not significantly different at 0.05 level using Duncan's Multiple Range Test (DMRT)*

tea and proline. Finally the data showed that the combined application of organic amendments and foliar application of organic and inorganic may play a significant role in improvement yield of rice and 1000 grain weight. In addition, compost are slow release nutrients all over the growth season, moreover, compost is rich in its nitrogen and micro-nutrients content. These favorable conditions creates better nutrients absorption and favors the growth and development of root system which in true reflects better vegetative growth, photosynthetic activity and dry matter accumulation under saline condition. Consequently higher total yield of rice would be obtained by compost + gypsum application as compared without treatment. The obtained results are supported by [26, 27]. Grain and straw yield of rice were recorded highest values due to application of compost and gypsum due to successful in reducing adverse soil properties associated with sodic soils the obtained results are supported by [25, 46].

3.5 Water Productivity (WP) and Productivity of Irrigation Water (PIW)

Water applied 12122.4 and 13640.16 m^3 ha^{-1} for two growing seasons were recorded. It is well known that under saline-sodic soils, the water is the crucial factor regarding the crop production. Therefore, it is very important to evaluate the agricultural production in the point of view of the importance of water. So, rice grain yield of rice should be converted to the values of the yield produced by one m^3 water which called water productivity and PIW. Therefore, WP values for grain yield of rice as affected by different treatments were calculated under these saline-sodic soils (Fig.1a and b). Also, WP and PIW was significant increased due to application of soil amendments and recorded highest values by application of compost + gypsum as compared without treatment. The same data showed that WP was significant increased with application of compost tea as compared without treatment. With regarded the effect of the interaction between the treatment, the data showed that the water productivity for grain yield of rice were high significantly increased due to the interaction between the treatment of soil amendments, compost tea and proline. And recorded highest values (1.11 and 1.02) kg grain m^{-3} by treatment of compost + gypsum, compost tea and proline during two growing seasons. Meaningfully, one cubic meter of water applied produces 1.11 and 1.02 Kg grain yield for 1st season and 2nd season, respectively.

3.6 Economical Evaluation

Data in Table 7 showed that agricultural operations costs for rice production (USD ha^{-1}) in 2019 and 2019 summer seasons. Data in Fig. 2 (a and b) showed that total return and net return for rice were significant affected by application of soil amendment compost, gypsum and compost + gypsum. And recorded the highest values with application of compost + gypsum. The effect of application of soil amendment on total return and net return of rice values, can be arranged in the following order compost + gypsum > compost > gypsum > control. Also the same data show that application of compost tea or proline had significant effect on increasing of total return and net return for rice and recorded the highest values with foliar of compost tea or proline. Data in Fig. (2.a) pointed out that total return and net return had significant

Table 5. Chlorophyll (SPAD) and grain proline content (µmol/g of rice) as affected by application of soil amendments and foliar application both of compost tea and proline after harvesting yield of rice in 2019 and 2020 seasons

Treatments	1st season		2nd season	
	Chlorophyll (SPAD)	Proline (µmol/g)	Chlorophyll (SPAD)	Proline (µmol/g)
		Soil amendments (SA)		
Control	38.90d	0.380d	40.46d	0.386d
Compost (C)	39.89c	0.386c	42.68c	0.388c
Gypsum (G)	39.97b	0.398b	43.17b	0.401b
G+C	41.74a	0.421a	45.46a	0.424a
Ftest	**	**		**
$LSD_{0.05}$	0.16	0.001	0.18	0.001
$LSD_{0.01}$	0.24	0.002	0.28	0.002
		Foliar application (FA)		
Control	39.65	0.383	42.43	0.386
Proline(Pr)	40.60	0.410	43.45	0.413
Compost tea(CT)	40.45	0.402	43.30	0.404
Pr. +CT	40.78	0.429	43.95	0.431
Ftest	**	**	**	**
$LSD_{0.05}$	0.18	0.001	0.19	0.001
$LSD_{0.01}$	0.25	0.002	0.26	0.002
		Interactions		
SA*FA	ns	**	ns	**

** indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same latter in a column are not significantly different at 0.05 level using Duncan's Multiple Range Test (DMRT)*

Table 6. 1000-grain weight (g), straw and grain yield of rice as affected by application of soil amendments and foliar spray both of compost tea and proline in 2019 and 2020 seasons

Treatments	1st season			2nd season		
	1000GW (g)	Straw $mgha^{-1}$	Grain $mgha^{-1}$	1000GW (g)	Straw $mgha^{-1}$	Grain $mgha^{-1}$
Soil amendments (SA)						
Cont.	17.39d	4.879d	5.095d	17.65d	5.174d	4.954d
Compost (C)	17.42c	5.868c	6.002c	17.77c	6.036c	5.983c
Gypsum (G)	17.74b	5.962b	6.091b	18.09b	6.214b	6.079b
G+C	18.09a	6.410a	6.554a	18.59a	6.739a	6.590a
F_{test}	**	**	**	**	**	**
$LSD_{0.05}$	0.04	0.011	0.003	0.04	0.011	0.002
$LSD_{0.01}$	0.08	0.017	0.004	0.08	0.017	0.004
Foliar application (FA)						
Control	17.6d	5.587d	5.424d	17.96d	5.705d	5.554d
Proilne(Pr.)	17.68b	6.086b	5.976b	18.05b	6.216b	6.089b
Compost tea(CT)	17.64c	5.784c	5.592c	18.00c	5.909c	5.714c
CT +Pr.	17.73a	6.286a	6.120a	18.09a	6.420a	6.250a
F_{test}	**	**	**	**	**	**
$LSD_{0.05}$	0.02	0.007	0.003	0.02	0.008	0.003
$LSD_{0.01}$	0.03	0.010	0.005	0. 03	0.011	0.004
Interactions						
SA*FA	**	**	**	**	**	**

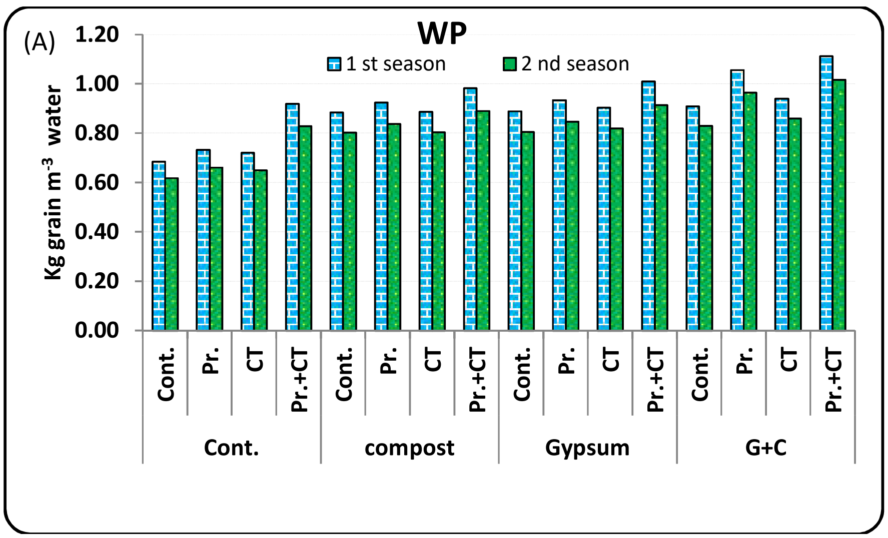
** indicate P < 0.05, P < 0.01 and not significant, respectively. Means of each factor designated by the same latter in a column are not significantly different at 0.05 level using Duncan's Multiple Range Test (DMRT)*

Table 7. Agricultural operations costs for Rice production ($\$ha^{-1}$) in 2019 and 2020 of summer season

Treatments		Fixed cost (a)* ($\$ha^{-1}$)	Variable cost (b)** ($\$ ha^{-1}$)				Total cost (a + b) ($\$ha^{-1}$)
			SA	CT	Pr.	total	
Control	without	1052.16	0	0	0	0	1052.2
	Pr.	1052.16	0	0	7.68	7.68	1059.8
	CT	1052.16	0	3.84	0	3.84	1056.0
	CT +Pr.	1052.16	0	3.84	7.68	11.52	1063.7
Compost (C)	without	1052.16	76.80	0	0	76.80	1129.0
	Pr.	1052.16	76.80	0	7.68	84.48	1136.6
	CT	1052.16	76.80	3.84	0	80.64	1132.8
	CT +Pr.	1052.16	76.80	3.84	7.68	88.32	1140.5
Gypsum(G)	without	1052.16	36.86	0	0	36.86	1089.0
	Pr.	1052.16	36.86	0	7.68	44.54	1096.7
	CT	1052.16	36.86	3.84	0	40.70	1092.9
	CT +Pr.	1052.16	36.86	3.84	7.68	48.38	1100.5
Compost (G+C)	without	1052.16	113.66	0	0	113.66	1165.8
	Pr.	1052.16	113.66	0	7.68	121.34	1173.5
	CT	1052.16	113.66	3.84	0	117.50	1169.7
	CT +Pr.	1052.16	113.66	3.84	7.68	125.18	1177.3

Fixed cost (a):cost of tillage, irrigation, seed, planting, workers, fertilizer, pesticide , harvesting and rent the soil, Variable cost (b)**: including soil amendments (SA), compost tea (CT) and proline (Pr.), costs of compost and gypsum were dividing in the two growing season* effected by all the treatment and recorded highest value due to the interaction between compost + gypsum, compost tea and proline. Also benfit costs ratio took the same trend, since it was recorded the highest values (1.62) for rice yield due to the interaction between application of soil amendments, compost + gypsum and foliar application with compost tea + proline. (Fig., 2.b).

Data in Fig. (2.c) referred that application of soil amendments had significant effect on increasing of the total return from water unit and recorded highest values (0.33 and 0.31 \$ ha^{1}) with application of compost + gypsum during 1st season and 2nd season. The same data clear that total return from water unit was significant increased due to application of compost tea and or proline as compared without treatment during two growing season. Fig. 2c showed that total return from water unit for rice yield was recorded the highest values (2.43 and 2.23 $\$m^{-3}$) due to the interaction between soil amendments and foliar both of compost tea and proline.



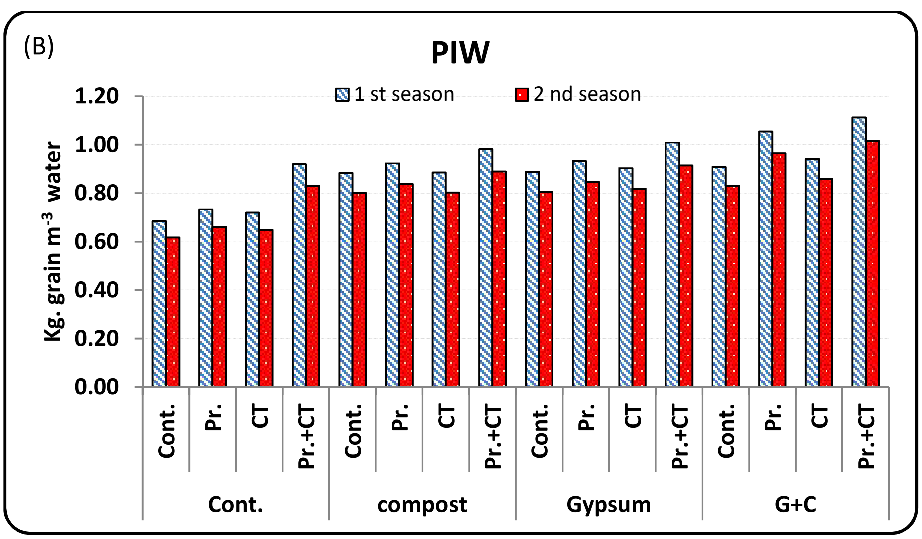


Fig. 1. (A), Water productivity (WP) and (B), productivity of irrigation water (PIW) for grain yield of rice (kg grain/m^3 of water) as affected by compost, gypsum and foliar application both of compost tea and proline in 2019 and 2020 seasons

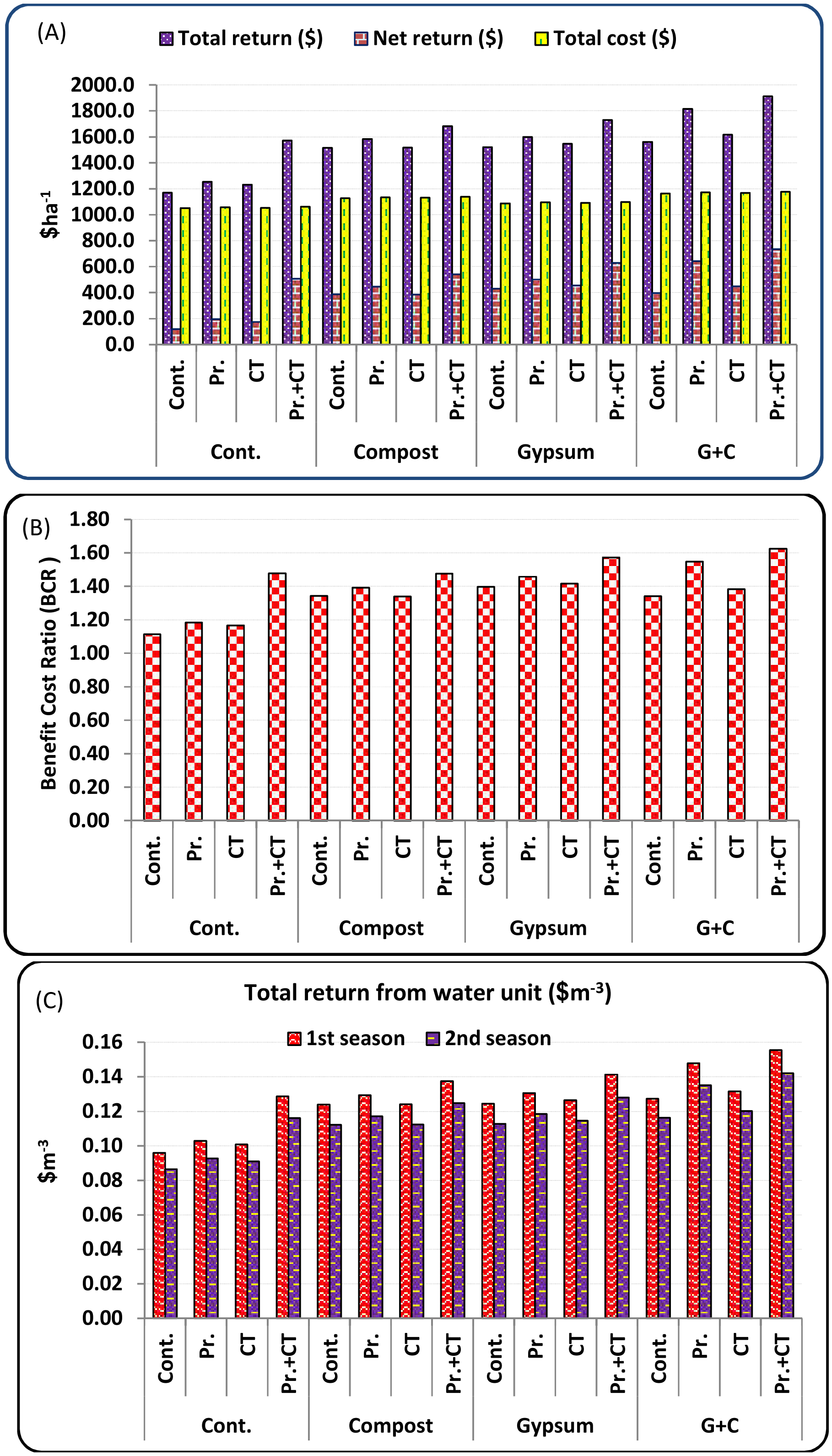


Fig. 2. Total return, net return and total cost (A), benefit cost ratio (B) and total return from water unit ($\$m^{-3}$) for rice yield (mean over both two seasons for A and B)

These results may be due to application of the soil amendments such as compost and gypsum on improvement the physical and chemical soil properties hence yield, water productivity and its economics.

4. CONCLUSIONS

Application of some soil amendments as compost + gypsum and foliar application both of compost tea and proline the most treatment on improvement the physical and chemical soil properties, yield, water productivity of rice and its economics as total return, net return and total return from water unit.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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