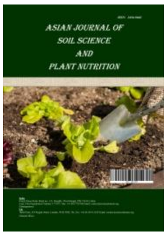

Asian Journal of Soil Science and Plant Nutrition

8(2): 1-12, 2022; Article no.AJSSPN.87415
ISSN: 2456-9682

Improving and Sustaining some Soil Properties by Application of some Soil Amendments and N-Fertilizer and its Effect on Productivity of Wheat and Rice Crops under Salt-Affected Soils

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Authors' contributions

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

Article Information

DOI: 10.9734/AJSSPN/2022/v8i230134

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/87415

Original Research Article

Received 12 March 2022
Accepted 20 May 2022
Published 21 May 2022

ABSTRACT

Two field experiments were conducted at El-Hamoul, Kafr El-Sheikh Governorate, Egypt, over two seasons, winter 2020/2021 and summer 2021, to improve and sustain some soil properties and productivity both of wheat (*Triticum aestivum L.*) and rice (*Oryza sativa L.*) by adding phosphogypsum (PG), vermicompost (VC), and different rates of nitrogen fertilizers to salt-affected soils. Split plot design was used to arrange the experimental designs. Soil amendments were used in the main plots: T1: Control, T2: PG (10.39Mg ha^{-1})equivalent to 100% gypsum requirement (GR), (Mg = 1000kg), T3:VC(10Mg ha^{-1})and T4: PG (10.39Mg ha^{-1})+ VC (5Mg.ha^{-1}). The N-fertilization subplots were N1: 50%, N2: 75% and N3: 100% of the N-recommended dose. The obtained results revealed that soil amendments significantly ($P \leq 0.01$) reduced electrical conductivity (ECe, dSm^{-1}), exchangeable sodium percentage (ESP, %), soil bulk density (kg m^3), and soil penetration resistances (Mpa), while PG + VC treatment had the lowest values afterharvesting both of wheat and rice. In addition, the combination treatment (PG + VC) showed significantly increased for cation exchange capacity (CEC), soil porosity (%), and soil basic infiltration rate (IR, cm h^{-1}) after harvesting both of wheat and rice. 1000-grain weight, grain, and straw yield of wheat and rice were highly significantly increased by application of PG , VC and increased up to 100% from N recommended and they attained the highest values due to the interaction of 100%PG + 50%VC + 100% N, which may be suggested to be applied under this circumstance.

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Keywords: Phosphogypsum; vermicompost; N- fertilizer; soil properties; rice; wheat.

1. INTRODUCTION

One of the major reasons for low productivity of crops grown on salt-affected soil is the salt toxicity and poor soil properties [1]. Increasing the concentration of soil soluble salts by more than 4 dSm^{-1} influences plant growth, quantity and quality of the many crops in many areas around the world [2]. Increase of salt concentration in the root zoon particularly ions such as Na^+, Cl^-, Mg^{2+}, SO_4^{2-} or HCO_3^- causes toxicity to plants, inhibition of biochemical and physiological processes , disrupting the metabolism and oxidation as well as reduction reactions in plant cells, thus , water and nutrients uptake, the development of crop growth and the roots spread inside the soil [3]. To reduce soil salt toxicity improve the soil propertiesand yield of wheat(*Triticumaestivum L*.) and rice (*Oryza sativa L.*) crops, low-cost, efficient treatment strategies are required.,according to the Central Agency for Public Mobilization and Statistics (CAPMAS), Egyptis one of the largest wheat importers with 80% (approximately,13 million tons) of its need is from Russia and Ukraine. Rice is the main food for more than half of the world's population [4] and provides 20% of the worldtotal calories and 31% of the Egyptian population.One of the most popular and successful techniques for decreasing Na^+ accumulation in salt-affected soils is leaching from the root zone [5]. Phosphogypsum (93% $CaSO_4$_$2H_2O$ helps to offset the dispersion acts of Na^+ and promote structure development in dispersed soils by increasing soluble Ca^{2+} to remove the exchangeable sodium, PG is commonly utilized as Ca^{2+} supply which can improve a variety of soil qualities such soil bulk density, total porosity and hydraulic conductivity and act as soil modifiers, preventing the development of sodicity, which is linked to plant growth and yields [6,7]. Vermicompost (VC) is a possible input and nutritive organic fertilizer rich in humus, macro and micro nutrients, growth hormones (auxines, gibberlins, and cytokinins), and beneficial for soil bacteria, and it's a great soil conditioner and amendment as evidenced by recent scientific studies [8]. It has been determined that indigenously prepared earthworm vermicompost is superior to conventionally prepared composts because it contains at least four times the amount of nutrients when compared to conventional cattle dung compost [9]. Vermicompost is the best organic manure management option in terms of crop processing, soil health improvement, efficiency and production enhancement, as well as microbial activity and soil characteristics [10]. Soil organic carbon status, lower bulk density, higher soil porosity and water holding capacity, enhanced dehydrogenase activity, and increased soil microorganisms, for example, are all factors to consider [11]. Worm casts contain four times more organic matter (48.2 g kg^{-1}soil), than surface soil, (11.9 g kg^{-1}soil) [12]. The released H^+ enhances $CaCO_3$ dissolution and liberates more calcium (Ca) for sodium (Na) exchange [5]. The anaerobic conditions during rice growth with VC also provided higher CO_2, which could increase the amount of soluble Ca^{2+} for soil reclamation [6]. Moreover, organic materials improve the soil physicochemical properties that accelerate exchange of cations on soil solids and leaching of salts from the root zone [13], hence preventing root from salt injuries and roots can grow more smoothly [14]. Found a mixture of 75% chemical fertilizer and 25% vermicompost produced the largest tomato plant and fruit yield. The addition of organic materials in conjunction with gypsum hastens the reclamation process and reduces the gypsum requirement [7].While it is commonlyassumed that vermicompost only provides long-term benefits, numerous research suggest otherwise. Vermicompost boosts productivity of cereals like wheat and maize [15] and legumes [16], as well as the growth and yield of fruits [17] and vegetables [18] as well as nitrogen and phosphorus [19,20]. A correlation between increased soil N from vermicompost and plant biomass has been demonstrated by [21].The combined application of inorganic, for instance gypsum, and organic amendments, like farm manure and humic acid, improves their effectiveness for increasing soil properties [22]. Based on the aforementioned facts, we prepared a short-term study to see how phosphogypsum (PG), vermicompost (VC), and 100%PG + 50%VC treatment affected on some soil properties and yields of both crops wheat (*Triticum asestivum* L.) and rice (*Oryza sativa L.*), under salt-affected soil

2. MATERIALS AND METHODS

Two field experiments were conducted at El-Hamoul, Kafr El Sheikh, Egypt, during two growing seasons (winter 2020/2021 and summer 2021) to investigate the effects of soil amendments (phosphogypsum (PG), vermicompost (VC)) and nitrogen fertilization on some soil properties and productivity of wheat and rice crops under salt-affected soils. The experimental designed were arranged in split plot design with three replicates. The main plots were occupied by soil amendments, T_1: check treatment, T_2: 100 %GR as PG (10.39 Mg ha^{-1}), T_3: VC (10Mg ha^{-1}), and T_4: 100% PG + 50% VC as (PG+VC). The sub plots were devoted to N-fertilization after standardizing the inorganic N content in the soil, N_1: 50 %, N_2: 75%, and N_3: 100% of N-recommended dose. Therefore, the experiment units were 36 plots (4 soil amendments X 3 N-dose X 3 rep.) where the area of each plot was 42 m^2 (6X 7m). Wheat Cv. Giza 171 was sown in 20^{th} Nov., 2020 and Rice Cv. Giza 178 in the 15^{th} June, 2021. The wheat plants were harvest after 160 days after sowing (DAS) and rice plants were harvested after 135 days from transplanting. All the recommended agronomic practices were applied for both crops. N-fertilizer was applied to rice as ammonium sulphate (33% N) at rate of 168 kg ha^{-1}in two equal doses at 21 and 55 DAS, respectively and 180 kg ha^{-1} to wheat as urea (46.5%N). The recommended dose of 36 Kg P_2O_5 ha^{-1} as mono phosphate (15.5% P_2O_5) and 72 Kg K_2O ha^{-1} as potassium sulfate (48% K_2O) were applied to both crops before planting. 1000- grain weight, grain and straw yields of rice and wheat plants were determined at harvesting stage. Soil samples were collected from 3 consecutive depths (0-20, 20- 40 and 40-60 cm) before experiments and after harvesting of both crops for all treatments to carry out some physical and chemical analysis. Salinity was determined in saturated soil paste extract, cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) according to [23].Organic matter (OM) content was determined using the Walkley and Black method according to [24]. Soil bulk density and total porosity of different soil layers for all treatments were measured before experiments and after harvesting using the core sampling technique as described by [25]. Particle size distribution of soil was measured using pipette method according to [26]. Infiltration rate was determined using double cylinder infiltrometer as described by [27].Soil penetration resistance is directly measured with a penetrometer. Field capacity (FC) and permanent wilting point (PWP) were determined by using pressure membrane method at 0.33 and 15 bars [28].Gypsum ($CaSO_4.2H_2O$) requirements (GR) were determined according to [29] to reduce the initial ESP for the soil matrix to 10% in the surface layer (0-30 cm) according to the following equation:

$$GR = (ESP_i - ESP_f) \times CEC \times 1.72 \times (100/purity)$$
$$= (16.92-10)/100 \times 31.07 \times 1.72 \times 100/85$$
$$= 4.35 \times 2.39 = 10.39\ Mgha.^{-1}$$

Where: GR: gypsum requirement (Mg ha^{-1}) for upper 30 cm soil, (Mg = 1000kg)

ESP_i: initial soil ESP, ESP_f: the desired soil ESP and CEC: cation exchange capacity (cmolc kg^{-1}). Accordingly, 1.72 ton is the GR to reduce 1 cmolc Na (100 $g)^{-1}$ soil. ha=2.39fed. Phosphogypsum (PG) is an industrial by-product created by wet-acid generation of phosphoric acid from rock phosphate at Abu-Zaable district (El-Sharkia governorate). PG was obtained from Soil Improvement at Sakha Station. PG is an acidic waste material (pH= 3.8) and its main components are calcium sulfate of 93.0%, oxides of calcium of 19.6%, silicon of 10.7%, aluminum of 1.15% and iron of 3.0% and some impurities such as P_2O_5 (0.5-1.4%), F, sodium silicate and organic substances. While the VC was made from rice straw and animal wastes with earthworm species *Eiseniafetida and Dendrobaenaveneta* [30]. Phosphogypsum and VC were thoroughly mixed with the surface soil layer (0-30 cm) before cultivation, and then it was ploughed twice in two ways using chisel plough. while maintaining the drainage system in the soil. Some physical and chemical properties of the experimental soil are shown in Table (1). The chemical composition of VC was listed in Table (2).The meteorological data during the two growing seasons are presented in Fig.1.

2.1 Statistical Analysis

The data were analyzed statistically by analysis of variance (ANOVA) using Cohort computer program according to [31]. Mean separation procedure was performed using LSD, at a 0.05 and 0.01 level of significance.

3. RESULTS AND DISCUSSION

3.1 Soil Chemical Properties

The impact of phosphogypsum (PG), vermicompost (VC), and their combination on some soil chemical characteristics is discussed (Table 3 and Fig.2). Electrical Conductivity (ECe), Exchangeable Sodium Percentage (ESP), and Cation Exchange Capacity (CEC) were all shown to be very significant ($P \leq 0.01$) when soil amendments were applied individually as compared with control. The mixed application of phosphogypsum and vermicompost (100%PG +

50%VC) resulted in the lowest ECe values, (9.37 and 8.44dSm^{-1}) for the first and second seasons, respectively. After harvesting wheat and rice, treatment of 100% PG + 50%VC reduced EC by approximately 32.59 % after harvesting of wheat and rice (Fig. 2.a).

By using phosphogypsum and vermicompost (100%PG + 50%VC), ESP followed the same pattern and recorded the lowest values (10.26 and 9.21 %) for the first and second seasons, respectively. After wheat and rice harvesting, ESP declined by 42.52 and 47.88 %, respectively (Fig. 2a).

These findings could be attributed to the role of phosphogypsum as industrial byproducts in the reclamation of salinesodic soils by providing Ca and enhancing chemical characteristics of the soil [6,7].

Table (3) shows that applying soil amendments has a substantial positive effect on raising CEC ($P \leq 0.01$) with the use of PG, VC, and their combination 100% PG + 50%VC. After harvesting wheat and rice, the application of VC was the most effective treatment, with the highest values (41.47 and 42.28cmolekg^{-1}), respectively. The application of VC after wheat and rice harvesting, CEC increased by around 35.57 and 36.87 %, respectively (Fig.2b). The effect of treatments can be arranged in descending order: V > (100%PG + 50%VC) > PG > control.

As stated by [5,13], this result was most likely attributable to the action of VC on increasing the specific surface and thus boosting soil exchangeable capacity soil.

EC and ESP were unaffected by nitrogen fertilizer treatment compared to control (without application) during two growth seasons, as shown in Table (3).Due to the interaction between (100%PG + 50%VC) and 50% N treatment, EC was dramatically reduced and recorded the lowest values (9.35 and 8.42dSm^{-1}) for the first and second seasons, respectively.

On the other hand, ESP was unaffected by the interaction between A and B treatments during the two growing seasons, with the lowest values for the first and second seasons 10.22 and 9.18, respectively for (100%PG + 50%VC) and 50% N treatment compared to the other treatments. Due to the interaction between (100%PG + 50%VC) and50% N, CEC was highly substantially enhanced ($P \leq 0.01$) and recorded greatest values 41.55 and 42.55 cmolekg^{-1} during the first and second seasons, respectively.

Table 1. Some physical and chemical properties of the experimental soil

Soil depth(cm)	**Soil physical characteristics**								
	Soil moisture characteristics					**Particle size distribution (%)**			
	F.C (%)	W.P. (%)	A.W. (%)	B.D. (kg m^{-3})	IR (cm/h)	Sand	Salt	Clay	Soil texture
0-20	44.11	22.01	22.10	1.30	0.55	17.31	255.1	571.8	clay
20-40	40.52	20.28	20.24	1.32		18.85	247.6	563.9	clay
40-60	38.03	19.03	19.00	1.32		19.06	251.2	558.2	clay

Soil chemical properties						
Soil depth(cm)	pH	EC (dSm^{-1})	ESP (%)	CEC (cmole kg^{-1})	OM (%)	$CaCO_3$ (%)
0-20	8.31	11.12	15.89	31.19	1.78	1.98
20-40	8.39	13.79	17.96	30.95	1.64	2.09
40-60	8.46	14.52	19.42	30.65	1.42	2.16

F.C.: Field Capacity; W.P.: Wilting Point; A.W.: Available Water; B.D.: Bulk Density; IR:soil basic infiltration rate 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.

Table 2. Some chemical composition of Vermicompost (VC)

EC	**pH (1:2.5)**	**moisture**	**Organic carbon**	**N**	**P**	**K**	**Na**	**Ca**	**Mg**	**Cu**	**Fe**	**Zn**
dSm^{-1}		%					Meq(100g)$^{-1}$			mg kg^{-1}		
3.11	7.55	25	12	1.11	0.16	0.45	0.08	14.1	8.15	2.1	1.35	9.48

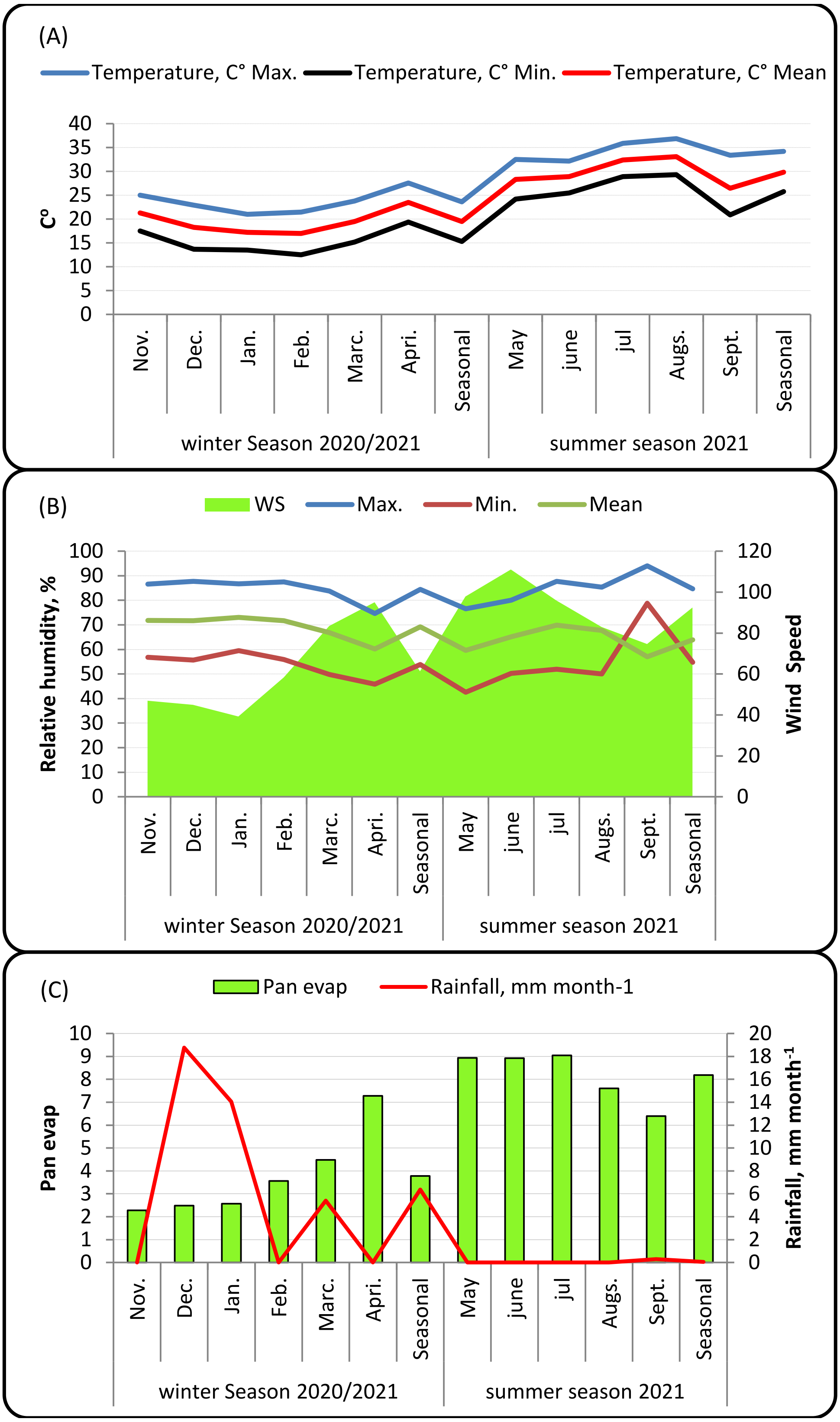

Fig. 1. Meteorological data of temperature °C (A) , and relative humidity (%) , wind speed (B) pan evaporation and rainfall (mm month^{-1}) (C) during 2020/2021 and 2021 growing seasons

3.2 Soil Physical Properties

3.2.1 Soil bulk density

Fig.(3.a) showed that soil bulk density was decreased due to individual application of phsphogypsum, vermicompost and recorded the lowest values (1.29 and 1.28kgm^{-3}) for 1st season and 2nd season with treatment of (100%PG + 50%VC) as compared to without application .

3.2.2 Soil porosity

With regarded to the soil porosity was increased with application of the soil amendmentsand recorded highest values 51.32 and 51.70% for 1st season and 2nd season with treatment of (100%PG + 50%VC) as compared to without application as shown (Fig.3.b).

In addition, the effect of soil amendments can be arranged in descending order: (100%PG + 50%VC) > VC> PG >control. Thesis results may be due to the application of phosphor-gypsum increases soluble Ca^{2+}, thus helping to overcome the dispersion acts of Na^{+} and to promote structure development in dispersed soils and the role of vermicompost on improved both soil bulk density and its porosity. These results are supported by [10].

3.2.3 Soil penetration resistances (SPRa)

Soil penetration resistance is the ability of the soil to withstand the loads above it.Soil compaction occurs due to the repeated operation of the tractor on the same track. This is indicated by an increase in the value of bulk density and penetration resistance but the porosity value decreases. This condition will cause the roots will be difficult to penetrate the soil so that root development will be disrupted Fig.(3.c) pointed out that Soil Penetration Resistances (Mpa) was decreased by application of soil amendments and recorded lowest values (1.09 and 0.89Mpa) for 1stand 2nd seasons with application of 100% PG + 50%VC as compared to the other treatments.

These results refer to positive effects of phosphogypsum and vermicompost application on decreasing of SPRa hence this condition will cause the roots will be easier to penetrate the soil so that root development will be more best uptake of some nutrients.

Table 3. Mean values of ECe (dSm^{-1}), exchangeable sodium percentage (%) and cation exchange capacity (cmolekg^{-1}) as affected by the soil amendments, nitrogen fertilizer and its interaction after harvesting of winter wheat 2020/21 and rice in summer of 2021 seasons

Treatment	**After wheat (1st season)**			**After Rice (2nd season)**		
	ECe (dSm^{-1})	**ESP (%)**	**CEC (cmolekg^{-1})**	**EC (dSm^{-1})**	**ESP (%)**	**CEC (cmolekg^{-1})**
Soil amendments (A)						
Control	13.90a	17.85a	30.59d	12.52a	17.67a	30.89d
Phosphogypsum (PG)	10.76c	11.52c	30.80c	9.70c	11.21c	31.09c
Vermicompost (VC)	13.43b	16.61b	41.47a	12.10b	16.07b	42.28a
100%PG + 50%VC	9.37d	10.26d	40.84b	8.44d	9.21d	41.18b
F_{test}	**	**	**	**	**	**
$LSD_{0.05}$	0.038	0.064	0.067	0.034	0.147	0.025
$LSD_{0.01}$	0.058	0.098	0.102	0.052	0.223	0.039
N-Fert. (B)						
N1	11.89	14.05	35.93	10.71	13.59	36.30
N2	11.84	14.06	35.89	10.66	13.53	36.34
N3	11.87	14.08	35.96	10.69	13.52	36.44
F_{test}	ns	ns	ns	ns	ns	ns
Interaction						
A x B	**	ns	*	**	ns	*

*Means of each factor followed by the same letter are not significantly different at 5 % level according to Duncan's multiple range test.*indicate significant p ≤ 0.05,** indicate significant p ≤ 0.01 and ns indicate not significant. The values mean over soil depths of (0-20, 20- 40 and 40-60cm). N1: 50% of N-recommended dose, N2: 75% of N-recommended dose and N3: 100% of N-recommended dose*

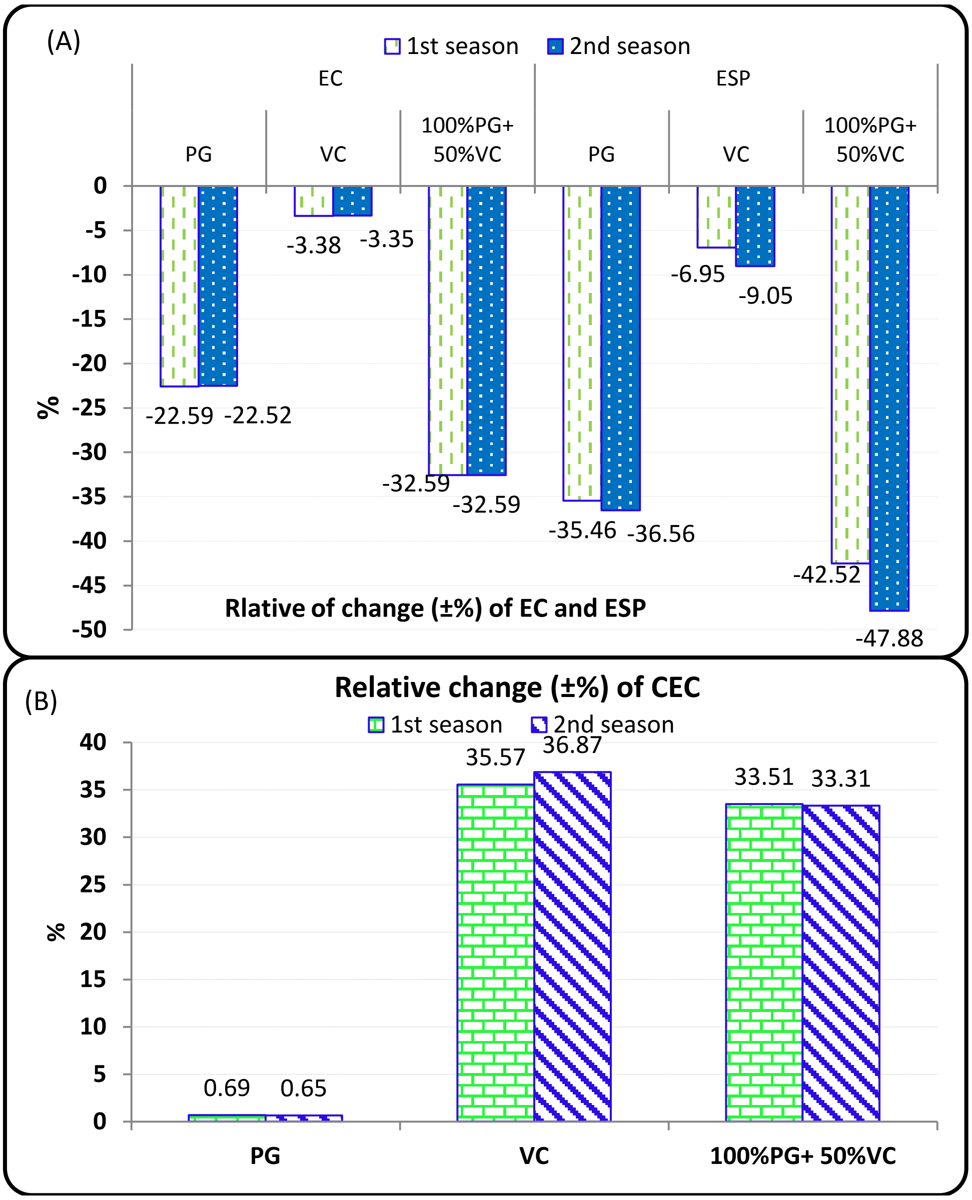

Fig. 2. Relative change (± %) mean values of EC (dSm^{-1}), exchangeable sodium percentage (ESP %) and cation exchange capacity ($cmolekg^{-1}$) as affected by the soil amendments, in 2020 and 2021 seasons

3.2.4 Soil basic infiltration rate (IR)

Individual applications of PG and VC improved soil basic infiltration rate (IR), with the highest values 1.3 and 1.38 cm/h for the first and second seasons, respectively, when compared to the other treatments (Fig. 4a and 4b). A clear improvement in the IR was also observed after the second season compared to the first season. In descending order, the effects of soil amendments are: (100%PG + 50%VC) > VC > PG > control. The beneficial effect of vermicompost and a good soil drainage system on improving soil porosity, aeration, and soil structure, and therefore soil structure [9 and 13].

3.3 Yield of Wheat

Data in Table (4) showed that mean values of 1000-grain weight, grain and straw yield of wheat were highly significantly increased by the application of the soil amendments PG, VC and recorded highest values (40.72g., 4.402$Mgha.^{-1}$ and 4.643$Mgha.^{-1}$) with application of (100%PG + 50%VC). Also the same data pointed that mean values of 1000-grain weight, grain and straw

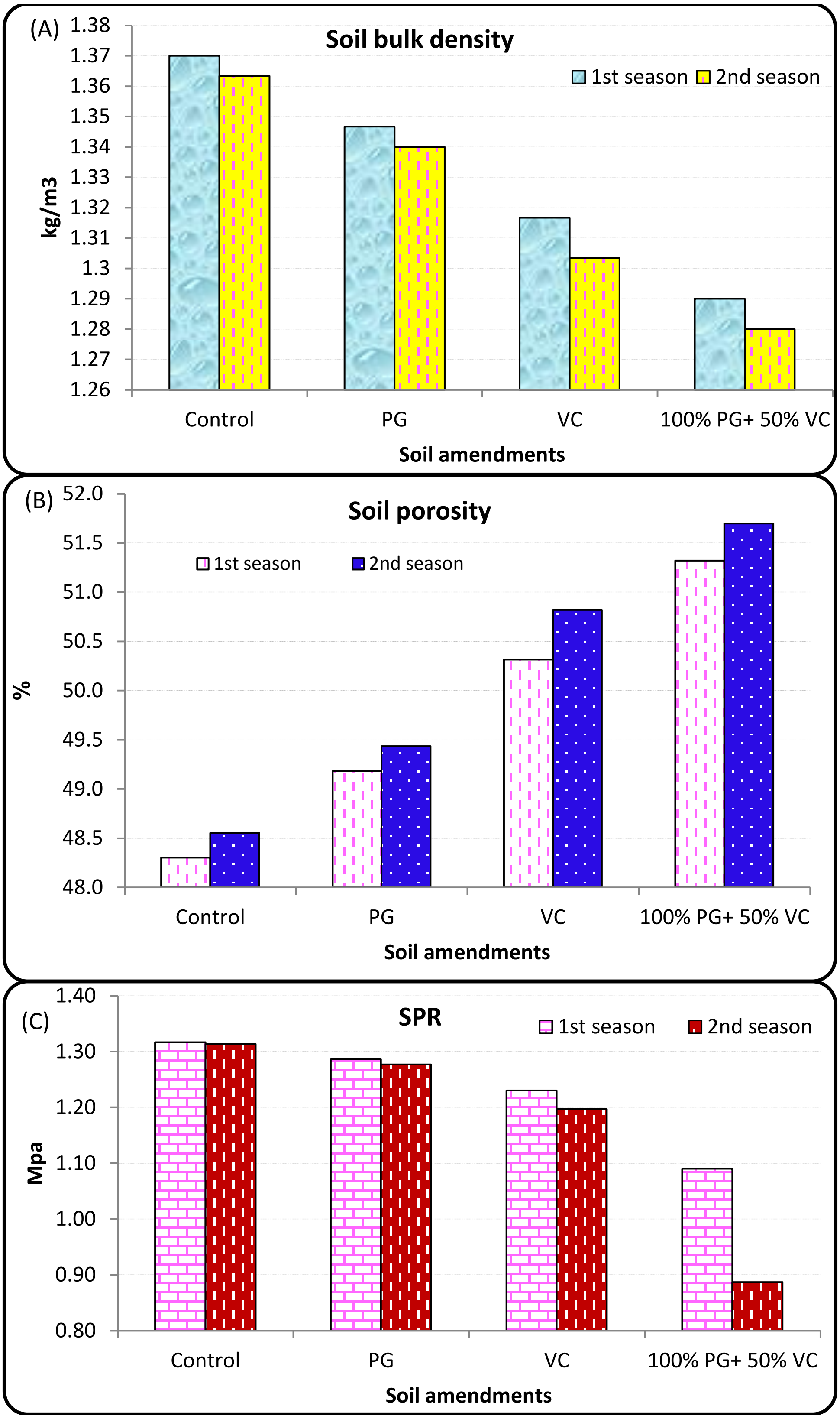

Fig. 3. Soil bulk density, soil porosity and soil penetration resistances (SPRa) as affected by the soil amendments in 2020 and 2021 seasons (The values mean over soil depths of (0-20, 20-40 and 40-60cm)

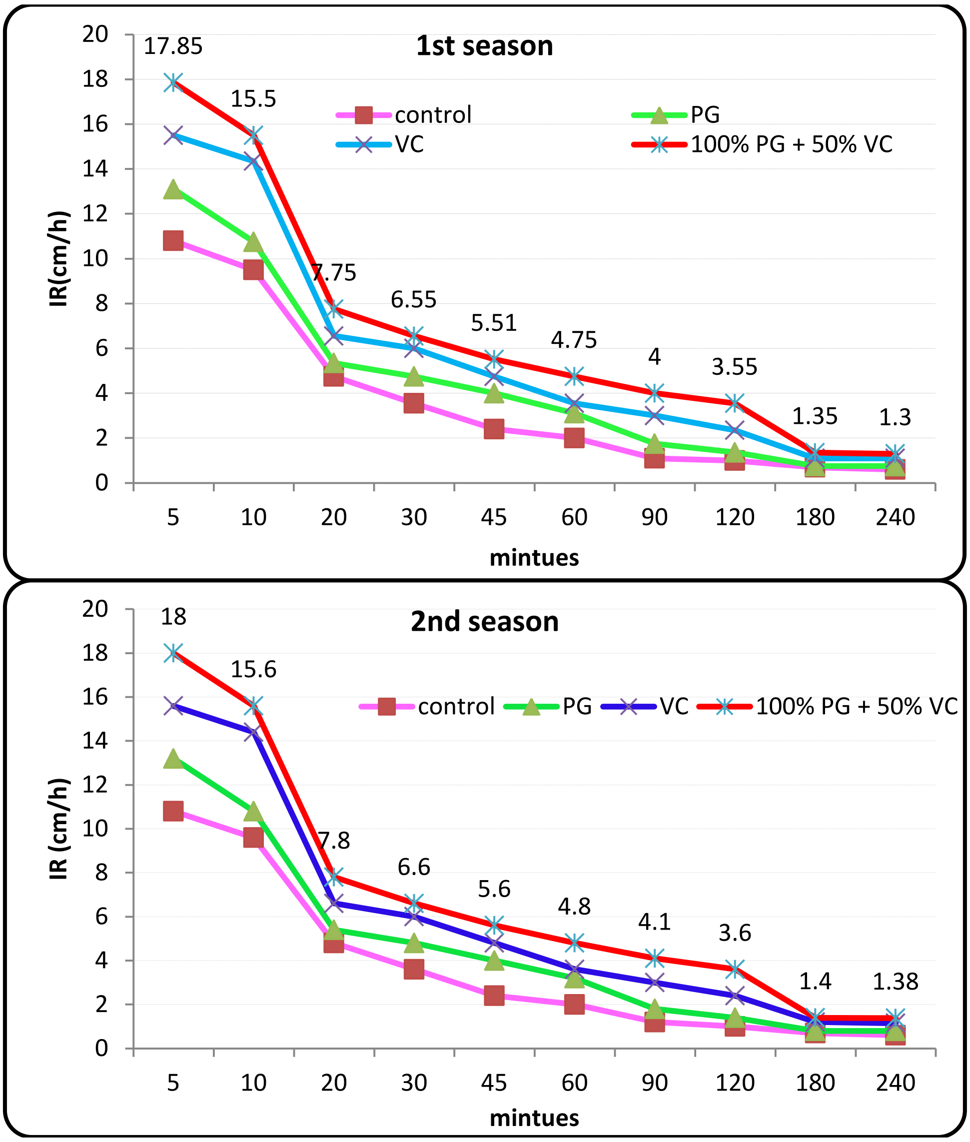

Fig. 4. Mean values of soil infiltration (IR) as affected by the soil amendments after two growing winter 2020/2021and summer 2021 seasons

yield of wheat were highly significantly increased due to application of N-fertilizer and recorded highest values (40.21g., 5.038Mgha.$^{-1}$ and 5.134Mgha.$^{-1}$) with application of 100% from N recommended. Table (4) cleared that mean values of 1000-grain weight, grain and straw yield of wheat were highly significantly increased due to the interaction between PG +VC and N and recorded highest values (41.75g., 5.038Mgha.$^{-1}$and 5.134Mgha.$^{-1}$) by application of (100%PG + 50%VC) and $N_{100.}$

3.4 Yield of Rice

The presented data in Table (4) noticed that mean values of 1000-grain weight, grain and straw yield of rice were highly significantly increased by application of the soil amendments PG,VC and recorded highest values (21.21g., 6.183Mgha.$^{-1}$and 6.324Mgha.$^{-1}$) with mixed application of 100% PG + 50%VC. Also the same data pointed that mean values of 1000-grain weight, grain and straw yield of rice were highly significantly increased due to application of N-treatment and recorded highest values (21.06 g., 5.373Mgha.$^{-1}$ and 5.660Mgha.$^{-1}$ with application of 100% from N recommended.

Table (4) pointed out that mean values of 1000-grain weight, grain and straw yield of rice were highly significantly increased due to the interaction between PG + VC xN and recorded highest values (21.55g., 6.584 $Mgha.^{-1}$ and 6.709 $Mgha.^{-1}$ with 100% PG + 50%VC and $N_{100.}$

These results may be due to the availability of macronutrients and micronutrients is generally higher in vermicompost than in the other treatments, indicating that vermicompost is a better supplement to improve both of physical and chemical properties of the soilas well as stimulate plant growth. Thus vermicompost has a huge potential for use on agricultural crops. Thesis results supported by [10,21]. Therefore, the application of Vermicompost as an organic amendment has ability to produce some essential nutrients for supporting plant growth compared with chemical fertilizers. Use of the right amounts of vermicompost as an important source of nitrogen and its replacement for N-recommended will guaranty soil quality and health for the future generations.

The role of PG as a source of Ca^{2+} to remove exchangeable Na^{+} and improve chemical soil properties and act as soil modifiers that limit the development of sodicity, which is directly related to plant growth which may be the reason for the more pronounced treatment [6].

Table 4. Mean values of 1000-GW(g.) and both of grain and straw yield of wheat and rice ($Mgha.^{-1}$) as affected by the soil amendments, nitrogen fertilizer and its interaction in 2020/21 and 2021 seasons

Treatment			Wheat			Rice		
			Grain	Straw	1000-GW	Grain	Straw	1000-GW
			$Mgha.^{-1}$		g.		$Mgha.^{-1}$	g.
Soil amendments (A)								
Control			2.490d	2.749d	39.15d	4.400d	4.620d	20.16d
Phosphogypsum (PG)			3.508b	3.659b	39.81b	5.358b	5.808b	21.18b
Vermicompost (VC)			3.295c	3.497c	39.57c	4.737c	4.919c	20.86c
100%PG + 50%VC			4.402a	4.644a	40.72a	6.183a	6.324a	21.21a
F_{test}			**	**	**	**	**	**
$LSD_{0.05}$			0.009	0.007	0.146	0.005	0.006	0.018
$LSD_{0.01}$			0.014	0.010	0.222	0.009	0.009	0.028
N-Fert. (B)								
N_1			3.112c	3.344c	39.44c	4.935c	5.196c	20.66c
N_2			3.353b	3.595b	39.78b	5.198b	5.399b	20.84b
N_3			3.807a	3.958a	40.21a	5.373a	5.660a	21.06a
F_{test}			**	**	**	**	**	**
$LSD_{0.05}$			0.003	0.003	0.036	0.004	0.004	0.019
$LSD_{0.01}$			0.005	0.006	0.050	0.006	0.008	0.027
Interaction A x B								
Control	N1		2.342l	2.665j	39.11	4.194l	4.505l	20.11i
	N2		2.524k	2.770i	39.16h	4.433k	4.601k	20.15h
		N3	2.603j	2.811h	39.17h	4.572j	4.751i	20.23g
Phosphogypsum	N1		3.143h	3.389f	39.60f	5.160f	5.648f	20.94e
(PG)	N2		3.344g	3.489e	39.71de	5.394e	5.765e	21.14c
		N3	4.039c	4.101c	40.13c	5.523d	6.016c	21.45b
Vermicompost	N1		3.105i	3.215g	39.43g	4.651i	4.680j	20.65f
(VC)	N2		3.234g	3.487e	39.48g	4.744h	4.916h	20.93e
		N3	3.552e	3.791d	39.79d	4.813g	5.160g	21.01d
100%PG+ 50%	N1		3.855d	4.106c	39.62ef	5.738c	5.949d	20.93e
VC	N2		4.316b	4.632b	40.78b	6.226b	6.314b	21.16c
		N3	5.038a	5.134a	41.75a	6.584a	6.709a	21.55a
F_{test}			**	**	**	**	**	**
$LSD_{0.05}$			0.007	0.007	0.073	0.009	0.012	0.039
$LSD_{0.01}$			0.010	0.009	0.101	0.013	0.017	0.054

indicate significant $p < 0.05$, indicate significant $p < 0.01$ and ns indicate not significant.N_1: 50% of N-recommended dose, N_2: 75% of N-recommended dose and N_3: 100% of N-recommended dose., (Mg.= 1000kg.)*

4. CONCLUSION

Under salt-affected soils, field experiments were undertaken to improve some soil parameters and productivity both of wheat and rice by applying phosphogypsum, vermicompost, and nitrogen fertilization. Individual application of soil amendments resulted in highly significant decreases ($P \leq 0.01$) in electrical conductivity (EC), exchangeable sodium percentage (ESP), soil bulk density, and soil penetration resistances, with the lowest values with from 100%PG + 50 % VC after rice and wheat harvesting. Also, cation exchange capacity (CEC), soil porosity, and soil basic infiltration rate were all significantly reduced by soil amendments, with the highest values resulting from as 100% PG + 50%VC following wheat and rice harvesting. 1000-grain weight, grain, and straw yield of wheat and rice were highly significantly increased by application of soil amendments and increased up to 100% from N recommended. Application of soil amendments significantly boosted the 1000-grain weight, grain, and straw yield of wheat and rice, with the maximum values attributable to the interaction between 100% PG + 50%VC and 100 %N - recommended.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/87415