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An Innovative Mixture of Biochar, Compost, Rock Phosphate and Phosphorene to Irrigate Wheat with Highly Saline-Sodic Water in Egypt

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Abstract

Egypt suffers from the dilemma of "absolute scarcity" of fresh water and the poor quality of available non-conventional water resources. The problem is further complicated by rapid population growth and climate changes. Available information indicates that individually and/or dual addition of soil amendments such as biochar (B), compost (C), rock phosphate (RP) and phosphorene (P) (trade name of phosphate-solubilizing bacteria) help crop plants to tolerate salinity and sodicity of soil and irrigation water. However, no data is currently available on the potential of BCRPP mixture to utilize poor quality waters for irrigation. Therefore, the aim of this study was to evaluate the potential of BCRPP mixture in mitigating salinity and sodicity stresses of irrigation water on wheat. In a pot trial, soil was amended with BCRPP mixture at four different rates (0, 2.5, 5, and 10%, w/w) while wheat (*Triticum aestivum* L.) was grown under two type of irrigation water; fresh water (EC = 0.41 dS m^{-1}; SAR = 2.03 and Adj. SAR 2.44) or highly saline-sodic water (EC = 6.23 dS m^{-1}; SAR = 37.82 and Adj. SAR 52.95). Soil properties, plant performance, and nutrient uptake were determined. Results significantly indicated improvements in most growth and development wheat parameters, i.e. Photosynthetic pigments concentration (Chlorophyll A, B, and total, and carotenoids), non-enzymatic antioxidants (Ascorbic Acid, ASA), and organic osmolytes (proline and total soluble sugars, TSS) in addition to biomass and grain yields. Contents of essential nutrients in wheat parts also increased due to applying of BCRPP mixture, while the content and proportions of Na^+ decreased. There were strong synergistic effects of the mixture components on soil quality and fertility, including decreased pH and bulk density and increased soil organic matter and plant-available nitrogen, phosphorus and potassium. However, soil salinity increased, due to the saline nature of biochar and rock phosphate and failure to apply a leaching fraction (LR) to prevent salt accumulation in the soil. Conclusively; the synergetic application of BCRPP significantly improved the growth and productivity of wheat irrigated with highly saline-sodic water, especially at the rate of 5.0 g BCRPP hg^{-1} soil. However, this conclusion is still in its early stages and needs further development.

Keywords: Biochar; Compost; Rock Phosphate; Phosphate-Solubilizing Bacteria; Saline-Sodic Water; Wheat Crop

Full length article **Corresponding Author*, e-mail: *mohamedahmedsaleh98@gmail.com*

1. Introduction

The "absolute scarcity" of fresh water and poor quality of available non-conventional water resources is the major constraints to agricultural development and food production in saline-arid environments such as Egypt. The problems are complicated with the rapid population growth, and climate change [1-2] stated that salinity and sodicity of soil and water are the critical and foremost environmental abiotic stresses to limit crops productivity in Egypt. Saline-sodic irrigation waters diminish crop yields by altering the chemical composition of soil and its solution, and hence physicochemical characteristics and microbiological activities deteriorate and worsen [3]. The high contents of Na^+, HCO_3^-, CO_3^{2-} and Cl^- ions in poor saline-sodic irrigation water are absorbed by existing plants disrupts osmotic potential and transpiration rates, hence reducing crops production[4]. Specific ion toxicity leads to dehydration, which diminishes photosynthetic and respiratory activity in plant cells [5]. “Saline Agriculture” is a modern approach based on the philosophy of “how to live with the stresses of saline-arid environments” based on nature-based solutions. One such solution to use and reuse of marginal poor-quality waters in irrigation (such as wastewater and groundwater) is treated soil with natural organic and inorganic amendments[6-7].

In addition there are several soil and water management strategies that can be applied to improve plant tolerance to salinity and sodicity stresses. Ayman et al. [8], Ayman and Fawzy. [9] Stated that organic soil amendments such as compost, farmyard manure, biochar, animal dung, and crop residues are used to alleviate the severe impacts of salinity and sodicity on plants. Biochar, often known as “agricultural black gold”, improves crop productivity and soil characteristics while sequestering more carbon in soils [1]. Biochar mitigates harmful effects of Na^+ adsorption ratio (SAR), and electrical conductivity (EC) by enhancing the physical, chemical, and biological properties of severely degraded soil [8-10-12]. Compost has been used in normal and stressed agricultural for centuries to enhance soil fertility, thereby mitigates salinity and sodicity stresses of soil and waters [1]. It comprises vital nutrients, advantageous microorganisms, and humic compounds that improve the soil's physicochemical and biological characteristics[10]. The incorporation of compost into soil significantly affects plant development, especially under stressful conditions. Cao et al. [13] indicated that under salinity stress, plants cannot absorb enough nutrients and water from the soil; nevertheless, the incorporation of compost enhances the soil's organic matter and increases the surface area for microorganisms to chelate the saline ions.

Furthermore, the abundance of functional groups and active sites in compost draws saline ions, rendering them inaccessible for plant absorption [14]. Phosphorus (P) is a limiting nutrient in the soil-plant nutrient cycle. External application of chemical P fertilizers can meet the P requirements of crops during critical growth stages. However, excessive application of P fertilizers leads to low P acquisition efficiency, which has serious environmental consequences and accelerates the depletion of mineral P reserves. Phosphate-solubilizing bacteria (PSB) have the ability to make insoluble phosphate available to plants through solubilization and mineralization, increasing crop yields while maintaining environmental sustainability. Therefore, in sustainable agriculture, the use of P bio fertilizers is a viable technique to mitigate the environmental issues linked to chemical fertilizers[15]. The very low solubility of rock phosphate (RP) restricts its direct application as a soil amendment, particularly in saline-alkaline soils. Prior research indicates that RP may enhance the physicochemical characteristics of saline soils, and that inoculation with PSB amplifies these benefits [16-17].

Also, they discovered that the integration of RP and PSB enhances P uptake in maize under salt stress, compared to the use of RP alone. Current research mostly emphasizes the synergistic use of RP and PSB to enhance plant development and ameliorate soil physicochemical qualities [18]. Following rice and maize, wheat global production is rank third, which provides 35% of the world’s total food grain [19] .Its global production comprises around 700 million tons from 200 million hectares [20]. Wheat, a predominant cereal crop worldwide, belongs to the *Poaceae* family and constitutes around 50% of global commerce and 30% of grain output [21]. Available information indicates that individually and/or dual addition of soil amendments such as biochar (B), compost (C), rock phosphate (RP) and phosphorene (P) (trad name of phosphate-solubilizing bacteria) help crop plants to tolerate salinity and sodicity of soil and irrigation water. However, no data are currently available on the potential of BCRPP mixture to utilize poor quality waters for irrigation. Therefore, the aim of this study was to evaluate the potential of BCRPP mixture in mitigating salinity-sodicity stresses of irrigation water on wheat.

2. Materials and methods

2.1. Location, experimental design and treatments

A pot experiment was conducted at the wire-house of Faculty of Technology & Development, Zagazig City, Egypt. The faculty is located at: latitude 30◦35′23.7″ N, longitude 31◦28′53.2″ E. The experiment included eight treatments representing all possible combinations between two grades of irrigation water quality, and four addition rates of BCRPP mixture. The treatments were arranged in a split-plot design (SPD) with three replications. Main plots were assigned to two saline-sodic levels of irrigation water; freshwater (EC = 0.41 dS m^{-1}; SAR = 2.03 and Adj. SAR 2.44) and highly saline-sodic water (EC = 6.3 dS m^{-1}; SAR = 37.82 and Adj. SAR 52.95). Sub plots were arranged to four rates of BCRPP mixture (0.0, 2.5, 5.0, and 10.0 g BCRPP hg^{-1} soil). Thus, the overall plots = 2 levels of water salinity × 4 rates of BCRPP mixture × 3 replicates = 24 pot.

2.2. Soil, water, biochar (B), compost (C), rock phosphate (RP), phosphorene (P), and preparation of BCRPP mixture

To conduct this pot experiment, surface soil samples (0-02 m) were collected from the research farm of the Faculty of Technology and Development, Zagazig University, Zagazig city, Egypt. Soil samples were air-dried in the laboratory, crushed, ground and sieved to pass through a 2-mm sieve. The soil used is fine in texture and generally has good physical, chemical and fertility properties as shown in Table 1. In this experiment, two types of irrigation water were used. The first was tap water to represent fresh Nile water. It is clear from the data recorded in Table 1 that it is slightly saline and not sodic water where its class is C2-S1 according to the classification of [22]. The second type of irrigation water was prepared using natural salts collected from the surface of highly saline soil in the Tina Plain area of Sinai. The natural salt was air-dried, then gradually increasing amounts were dissolved in tap water until the target salinity level of 6 dS/m^{-1} was reached. This salinity level was chosen to represent the general average of the salinity of non-conventional water resources in Egypt (agricultural drainage water, groundwater, and treated water) available for irrigating soils of new reclamation projects in/or outside the Nile Valley and Delta regions. Detailed analysis showed that this water was highly saline-sodic with class of C4-S4 [22]. Biochar (B) was produced from date palm wastes by pyrolysis technique as described in previous work of [23]. The resulting biochar crushed & ground, then sieved with a 2-mm sieve to facilitate its integration with rest ingredients of BCRPP mixture.

The compost was purchased from Zain Seeds Company, Cairo, Egypt (https://www.zainseeds.com/) where it provides in fine granules (< 2 mm), and is available under the trade name of "Vermicompost". Rock phosphate (RP) was obtained from Abu Zaabal Fertilizers and Chemicals Company, Egypt. It is available in very fine powder form. Phosphorene was procured from Biofertilizers Production Unit and Agric. Microbiology Dept., Soils, Water and Environment Res. Inst., Agric. Res. Center, Giza city, Egypt. Phosphorene is the trade name of phosphate-solubilizing bacteria "*Bacillus megatherium* var. phosphaticum" (Pure local strain) adsorbed on peat moss powder as a carrier. The amount of phosphoriene equivalent to its recommended dose under Egyptian conditions (1 kg fed.$^{-1}$, where 1 fed. ≈ 1 acre) [24] was added to fine soil to increase the homogeneity of the phosphoriene with rest components of BCRP mixture. The B, C, and RP thoroughly mixed in equal proportions (1:1:1), then inoculated with phosphoriene dose, and thoroughly mixed again. Some chemical properties and fertility status of proposed BCRP mixture recorded in Table 1.

2.3. Pot experiment setup

The BCRPP mixture was thoroughly mixed with the soils at three rates of 2.5, 5.0 and 10 g hg^{-1} soil before filling the pots. A portion of soil was left without amended with BCRPP mixture as control. Plastic pots were filled with 7 kg of soil alone or soil + BCRPP. At November 25, 2022 (the 2022/2023 winter season) wheat grains (*Triticum aestivum L.*cv. Misr1) were sown in the pots. Each pot was sowed with 15 grains at a consistent depth and spacing. Half of the pots were irrigated with fresh water (EC = 0.41 dS m^{-1}; SAR = 2.03 and Adj. SAR 2.44) and the other half irrigated with highly saline-sodic water (EC = 6.23 dS m^{-1}; SAR = 37.82 and Adj. SAR 52.95). Irrigation was done when 75% of the available water is utilized (~ one 0.8 L pot^{-1} every 1.5 -2 week). Plants were sampled at 80 and 140 days after the sowing.

2.4. Soil, water, BCRPP, and plant analysis methods

Particle size distribution was determined using a hydrometer protocol. Assessed the bulk density (BD), particle density (PD) was using the core, and pycnometer, respectively. Soil reaction (pH), water, and BCRPP were measured using a pH meter. Organic matter (OM) and calcium carbonate ($CaCO_3$) were determined by a wet oxidation method utilizing H_2CrO_7, back titration with NaOH, respectively. Available-N was extracted using KCl and distilled by the Kjeldahl method. The electrical conductivity (EC) of extracts and water were measured using an EC-meter. Soluble- K and Na were determined by a flame photometer, soluble-Ca and Mg titrated with 0.01M $EDTANa_2$, soluble HCO_3 and CO_3 titrated with 0.01M HCl, soluble-Cl was determined according to Mohr method. Cation exchange capacity (CEC) of soil and BCRPP were assessed using 1M NaOAc. Extractable-P were extracted with 1M of $NaHCO_3$ (pH=8.5), then determined by a colorimetric technique via spectrophotometer. NH_4OAc-K and Na of soil and BCRPP were quantified using a flame photometer.

Fe, Zn, Mn, and Cu were extracted with diethylene triamine pentacitic acid (DTPA) (0.005M DTPA, 0.1M triethanolamine, 0.1M $CaCl_2$), then the four micronutrients were determined using atomic absorption spectroscopy (ASS-PerkinElmer). Analytical techniques were conducted as outlined by [25]. Table 1 presents various physical and chemical parameters of the soil, biochar and water. Wheat samples were oven-dried, ground, and wet-digested using a mixture of H_2SO_4 and H_2O_2 at 420°C for chemical analyses according to [26].Total-N, P, and K levels were determined using the Kjeldahl, colourimetric, and flame-photometer techniques, respectively, according to [25]. In addition, wheat samples were prepared for various parameters such as pigments (chlorophyll a, b, total, and carotenoids), non-enzymatic antioxidants (ascorbic acid), & organic osmolytes (free proline and total soluble sugars) using a specific preparation and measurement method applied by [27].

2.5. Statistical analysis

For statistical evaluation, analysis of variance (ANOVA) was performed using the R package (V.4.3.3). The differences between means using Duncan's test significant difference test were calculated at a significant level of 5% to evaluate differences between averages of treatments. All charts were made using the Origin Lab package (V.9).

3. Results and discussion

3.1.1. Effect of application of BCRPP on some soil properties, and wheat growth parameters irrigated with fresh and highly saline – sodic water

The results obtained shown in Fig. (1A) indicate a significant improvement in soil organic matter. It ranged from 1.11 to 3.73g OM hg^{-1} of soil. The 10 g BCRP hg^{-1} rate recorded the highest value in soil organic matter. Soil bulk density (BD) decreased due to increasing application rates of BCRPP (Fig. 1B). Its values ranged from 1.02 to 1.25 g cm^{-3}, and a rate of 10 g BCRPP hg^{-1} was recorded as the lowest value compared to the control treatment. Values of EC ranged from 1.60 to 5.52dSm^{-1}, due to increasing rates of BCRPP (Fig. 1C). Soil reaction (pH) was not affected statistically significantly due to application of BCRPP (Fig. 1C). Available levels of N, P, and K increased, due to increasing BCRPP application rates, and it ranged from 28.84 to 16.39mg N kg^{-1}, 40.40 to 140.78 mg P kg^{-1}, 124.33 to 364.77 mg K hg^{-1} (Fig. 1D). According to obtained results presented in Figure (1), they emphasize a significant increase in these characters, and thus application of BCRPP contributes to enhancing soil fertility.

3.1.2. Effect of application of BCRPP on some wheat growth parameters irrigated with fresh and highly saline – sodic water

The result obtained generally showed a significant decrease in averages of some wheat growth parameters, wheat grain and straw analysis, due to irrigating wheat plant with highly saline – sodic water (Table 2). In contrast, application of BCRPP led to enhancement in some wheat growth parameters, especially at rates of 2.5, 5.0g gh^{-1}. Stem length, leaf area, spike length, grain yield, 1000-grain weight, and biomass yield ranged from 63.67 to 71.67cm, 13.14 to 29.10cm^2, 7.67 to10.83cm, 14.03 to 22.31g, 37.31 to 37.31g, and 31.26 to 47.63g, respectively. In the same order of these measurements, the 5.0g BCRPP hg^{-1} treatment recorded a better increase by 5.49% (stem length), 47.42% (leaf area), 34.04% (spike length), 14.46% (grain yield), 11.42% (1000-grain weight), 15.99% (biomass yield), respectively. This clearly confirms that irrigation with highly saline – sodic water causes a significant decrease in wheat plants and vice versa with fresh water (Fig. 2A-2H), while the rate of 5.0g BCRPP hg^{-1} causes a significant increase in most of the measured parameters.

3.1.3. Effect of application of BCRPP on photo synthetical, non-enzymatic antioxidants and organic osmolytes parameters irrigated with fresh and highly saline – sodic water

Table (3) presents wheat pigments (chlorophyll A (Ch. A), B (Ch. B), total (Ch. T), and carotenoids (CART), proline acid (PA), soluble total sugars (TSS), and ascorbic acid (ASA). All previous parameters clearly recorded significant increases due to irrigation with saline water (6.23dS m^{-1}) except for Ch. B and Ch. T, which recorded a significant decrease by 23.14%, 3.51%, respectively. In contrast, these parameters recorded significant increases with saline water by 1.90% (2.43mg g^{-1}), 6.56% (0.97mg g^{-1}), 80.19% (55.11µg g^{-1}), 11.93% (33.60 µg g^{-1}), 40.17% (0.22 µg g^{-1}), compared to irrigation with fresh water (0.41dS m^{-1}). The 5g BCRPP hg^{-1} rate recorded the highest values by 16.89%,125.56%, 32.13%, 208.57%, 162.79%, 51.44%, for Ch. A, Ch. B, Ch. T, PA, TSS, and ASA, respectively, compared to the 0.0g BCRPP hg^{-1} treatment. We noticed that irrigation with saline water in general leads to an increase in the levels of wheat tissue from these characters (Fig. 3A-3G). This increase was also evident because of the application of the BCRPP, especially at the rate of 5 g BCRPP hg^{-1}.

3.1.4. Effect of application of BCRPP on some macro-micronutrients and Na of wheat shoots and grains irrigated with fresh and highly saline – sodic water

Content of nutrients in wheat grains ranged from 2.20 to 2.55 g N hg^{-1}, 0.29 to 0.65g P hg^{-1}, 0.36 to 0.49g K hg^{-1}, 36.13 to 106.16µg Fe g^{-1} calculated based on plant dry matter, as presented in Table (4) and Figure 4A-4H. At the same scenario, nutrients of wheat straw ranged from 0.43 to 0.63 g N hg^{-1}, 0.05 to 0.23g P hg^{-1}, 1.24 to 2.56 g K hg^{-1}, 229.41 to 501.12 µg Fe g^{-1}. According to result presented in Table (4), nutrients of wheat straw and grains decreased due to highly saline – sodic water (6.23dS m^{-1}) irrigation, except for the grain K along with Fe. Consequently, the 5 g hg^{-1} rate was recorded statistically increased in plant nutrients (i.e., N, P, K, and Fe). Content of Zn in wheat straw increased by 44.72%, while in wheat grains decreased by 1.12%, due to highly saline – sodic water irrigation as presented in Table (5). In contrast, the scenario changed for Mn, Mn decreased in wheat straw by 5.95%, while Mn in wheat grain increased 28.79%. In addition, content of Cu in wheat was not affected due to difference in water salinity levels or application of BCRPP (Fig. 5A-5H). Additionally, wheat tissue affected by Na in irrigation water, Na-content in wheat straw increased by 509%, while its level in grains decreased by 32%.

In the same context, Na level at the 5g BCRPP hg^{-1} decrease in wheat straw and grain by 79%, and 51%, respectively, compared to the 0.0g BCRPP hg^{-1}. These results clearly confirm that improved Zn absorption in wheat straw, while Na absorption has decreased in all applied rates. In addition, ratios of both K/Na (Fig. 6A), P/Na (Fig. 6B), Zn/Na (Fig. 6C) and Fe/Na (Fig. 6D) increased due to irrigation with highly saline – sodic water and application of BCRPP. It is clear from this that the best rate of increase in this ratio was 5g BCRPP hg^{-1}. This proves that application of the BCRPP reduces Na absorption by wheat tissues, which helps to neutralize the effect of Na on wheat growth. In addition, the BCRPP absorbed sodium, thus reducing its absorption in the plant. Moreover, figure 7 shows the Pearson's correlation coefficient between all the studied parameters except Cu. Generally, there were significant relationships with strong positive correlations in most of the studied traits. In contrast, the relationship was in both carotenoids, manganese, and sodium. These relationships appeared more clearly in highly saline – sodic water (upper left side) than in fresh water (down right side). This demonstrates the beneficial roles of applying the BCRPP to enhancing wheat growth and productivity, as well as soil fertility.

3.2. Discussion

3.2.1. Effect of application of BCRPP on some soil properties

Salt stress is one of the major challenges for various agricultural lands all over the [2-20-28]. According to earlier studies salt stress affected the early stages of growth, physiological and biochemical processes that led to reduced wheat crops. The present study was designed to assess the salinity stress in water on different parameters of wheat with BCRPP application. Salt stress reduced growth parameters (stem length, leaf area, spike length, shoot weight, grains yield, and biomass yield) of wheat plants while BCRPP application improved all growth parameters as relative to the plants under control and stressed conditions. Similar results were observed by several scientists that all growth [9-12-20-29-32]. The reduction in growth attributes might be due to accumulation of different osmolytes, restricted cell division, changes in activity of metabolic enzymes and metabolic pathways which play a pivotal role during salt stress [2-33]. In addition, application of BCRPP led to a clear improvement in some properties of soil physical and chemical. This enhancement of soil properties can be attributed to composition of the BCRPP. The BCRPP , as we mentioned in the methods and material section, consists of biochar as described by [23]. Compost, and rock phosphate inoculated with phosphate solubilizing bacteria. Biochar improves the chemical, physical and biological characters of soil, including organic matter, phenotypes, porosity, water-holding capacity, and hold Na^{+}, because biochar has unique properties include ng high porosity, CEC, high cationic, functional groups, its ability to conserve water and nutrients.

Simultaneously, biochar-enriched compost demonstrated a higher content of functional groups such as carboxylic and phenolic hydroxyl [12-34]. Furthermore, compost also improves different soil qualities, as the positive effects of biochar with composts are largely convergent, as both are organic materials. The soil content of organic matter has a very important impact in soil characteristics and its fertility. Phosphate rock is also considered one of the most important sources of mineral phosphorous in soil, which is compost as a source of some necessary nutrients. The synergistic application of biochar with compost and rock phosphate inoculated with phosphate solubilizing bacteria increases positive role of this synergistic component together for several purposes, including improving soil properties, and improving plant growth, especially under saline stress conditions. Our study has corresponded too many study that emphasized that biochar, the compost, rock phosphate inoculated with PSB have important positive roles in improving soil properties and enhancing the wheat growth under salt stress conditions. On the other hand, irrigation with highly saline – sodic water (6.23dSm^{-1}) led to clear declines in values of some wheat growth. Undoubtedly, salinity plays a harmful role due to its negative impact on plant growth.

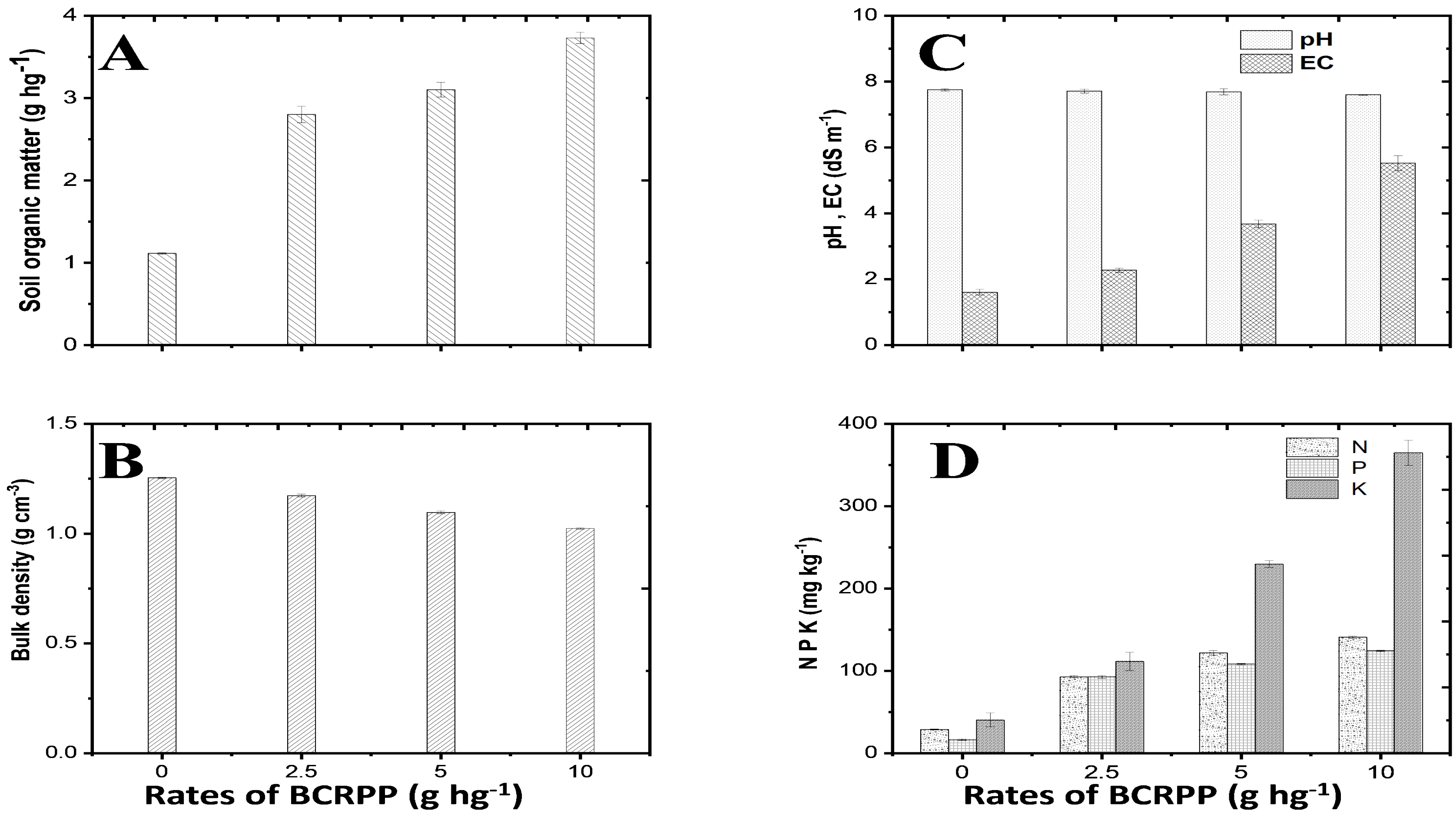

Fig. 1. Effect of soil amendments of BCRPP on soil organic matter (A), bulk density (B), soil reaction (pH) and electrical conductivity (EC) (C), and extractable-N, P and K (D).

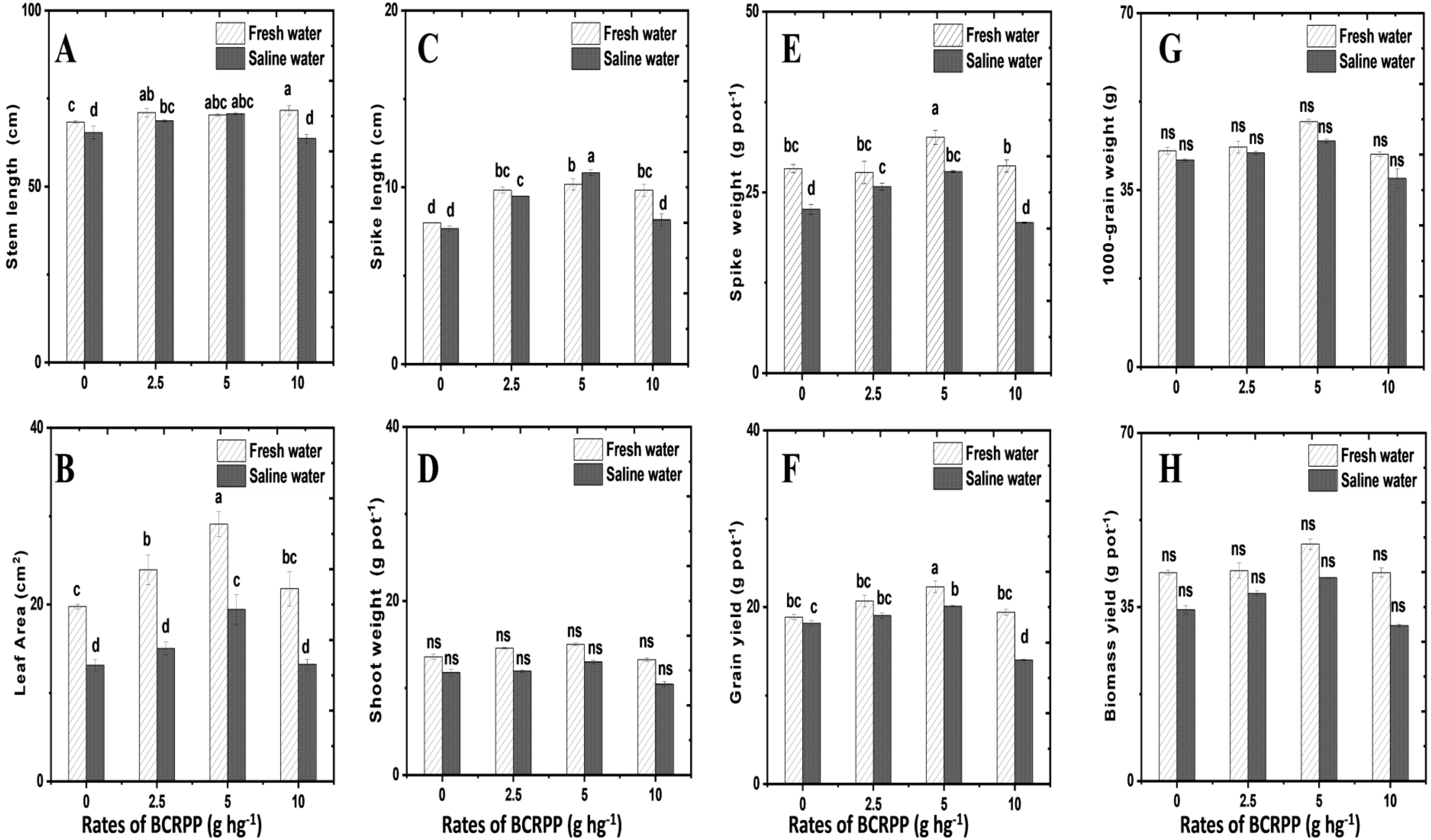

Fig. 2. Effect of soil amendments of BCRPP on stem length, leaf area, spike length, shoot weight, spike weight, grain yield, calculated 1000-grain yield, and biomass yield of wheat irrigated with fresh or highly saline – sodic water. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

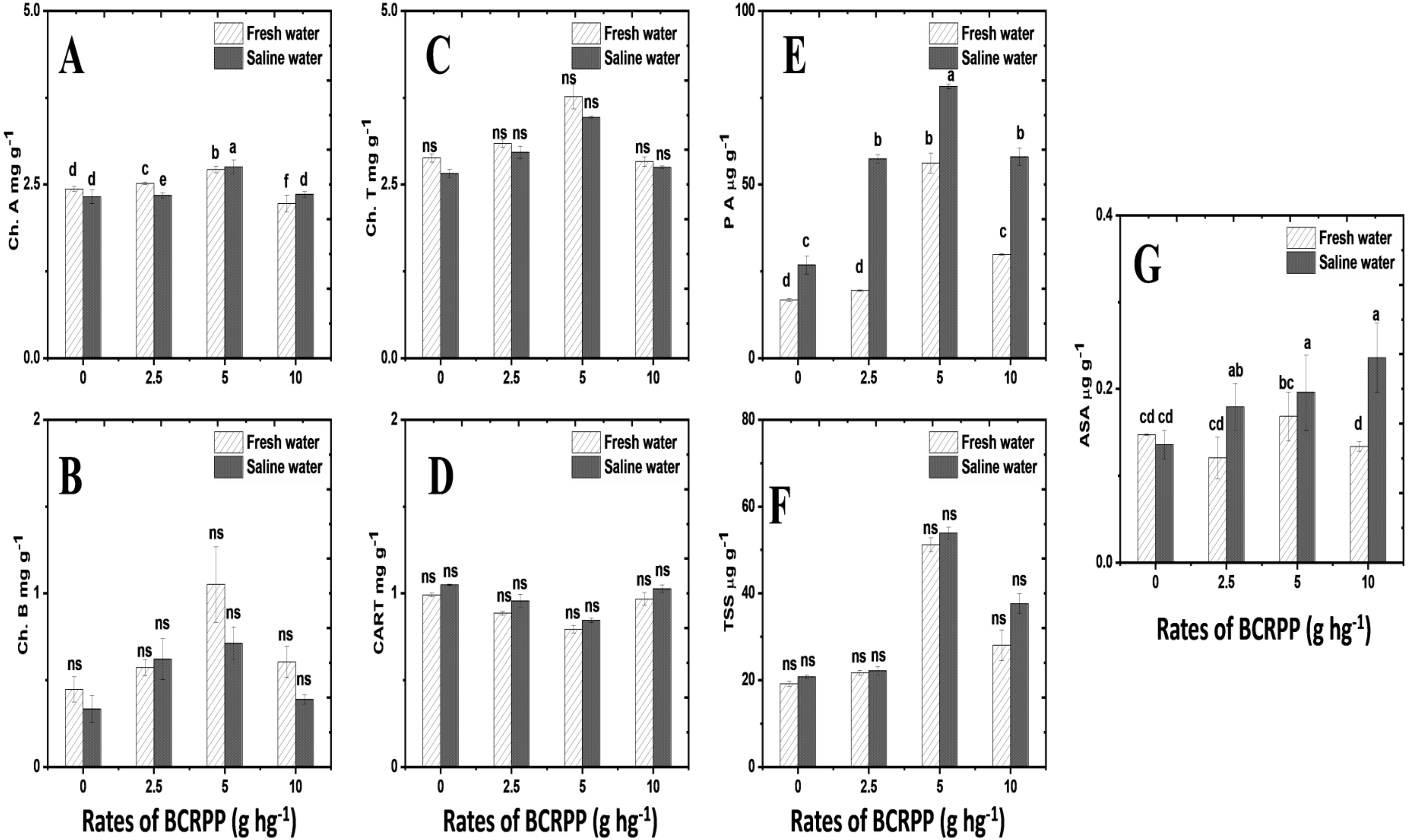

Fig. 3. Effect of soil amendments of BCRPP on content of chlorophyll A (A), chlorophyll B(B), total chlorophyll (C), carotenoids (D), proline acid (E), total soluble sugars (F) and ascorbic acid (G) of wheat irrigated with fresh or highly saline – sodic water. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

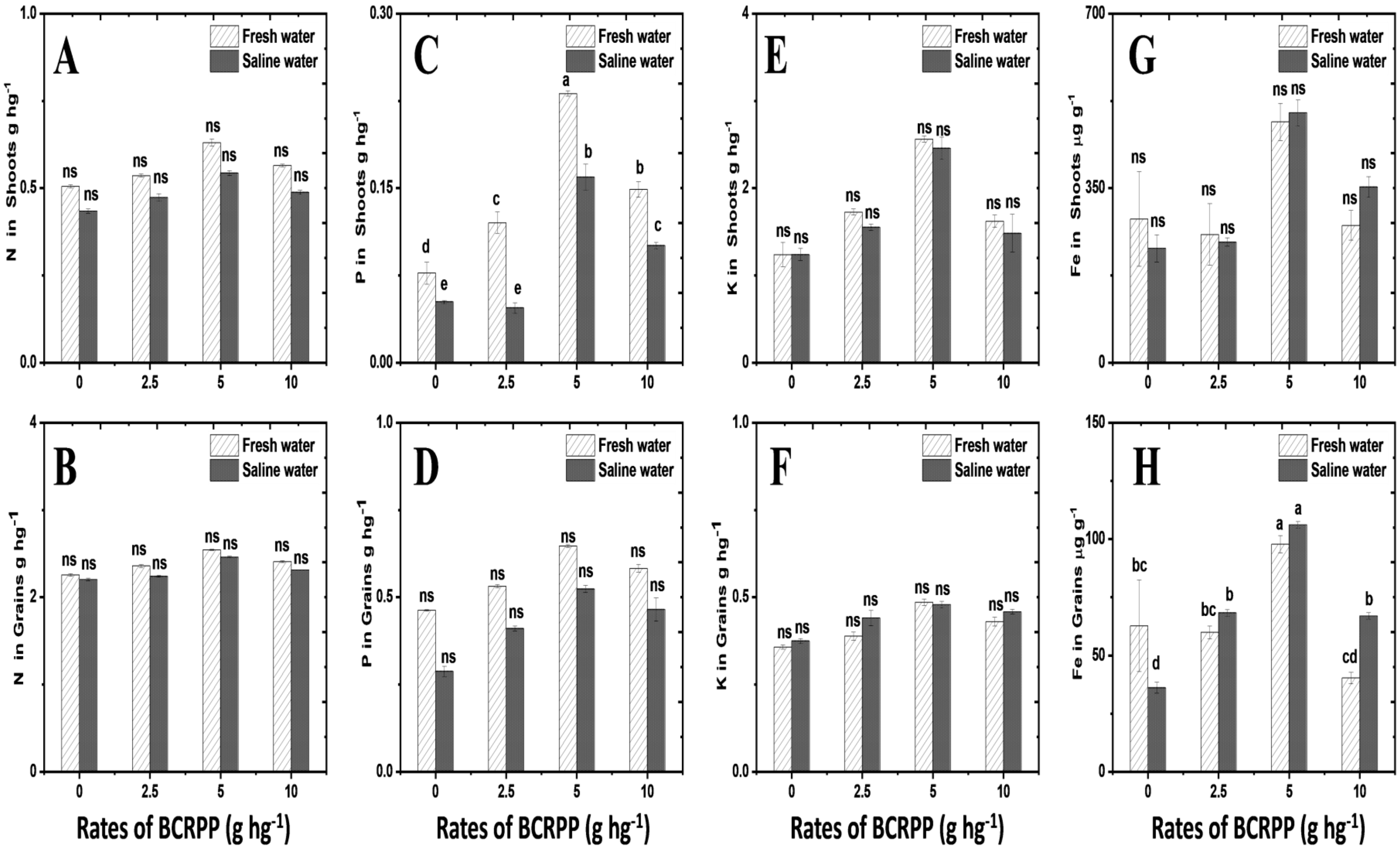

Fig. 4. Effect of soil amendments of BCRPP on content of N in shoot (A), N in grains (B), P in shoots (C), P in grains (D), K in shoots (E), K in grains (F), Fe in shoots (G) and Fe in grains (H) of wheat irrigated with fresh or highly saline – sodic water. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

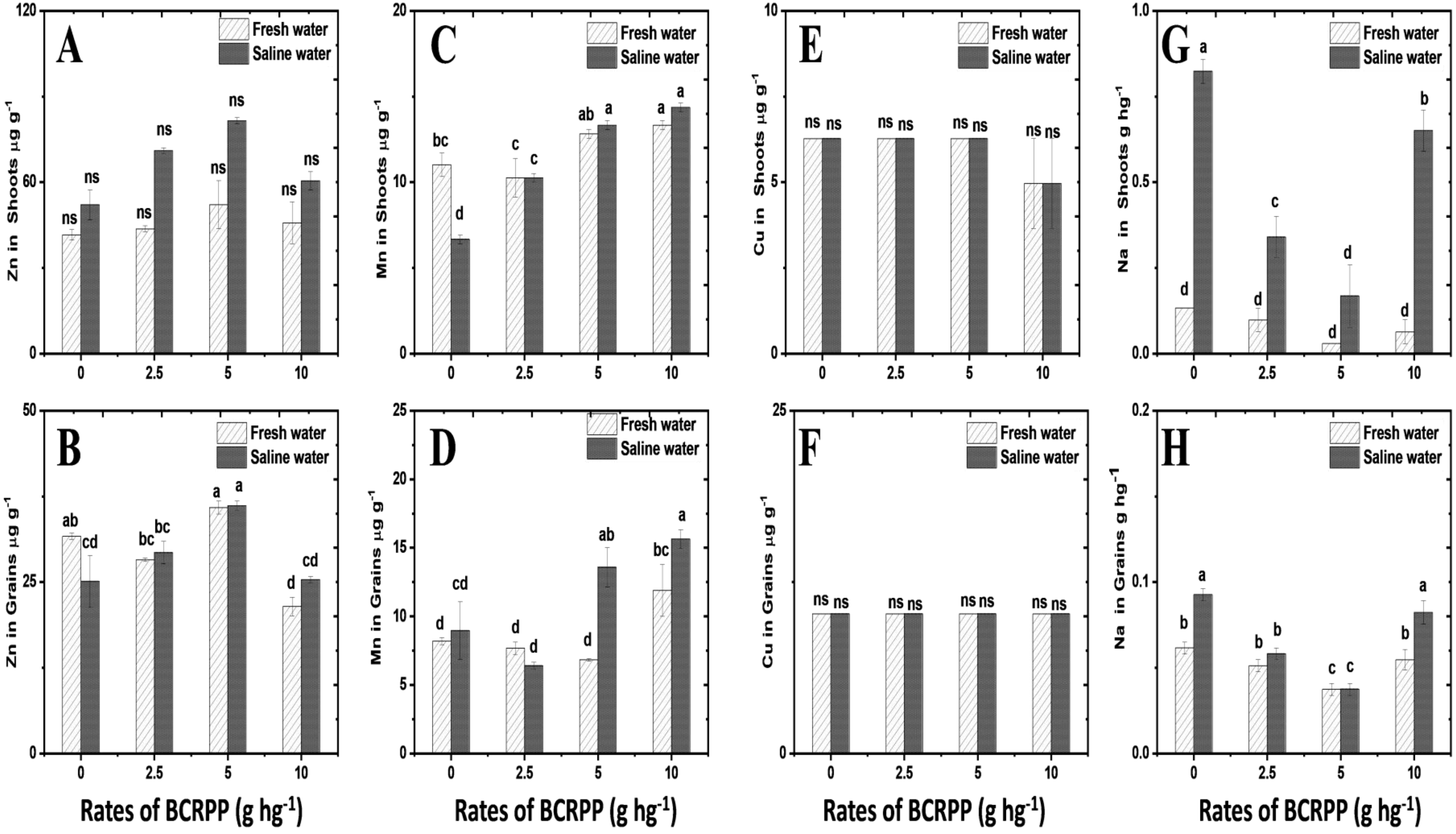

Fig. 5. Effect of soil amendments of BCRPP on content of Zn in shoot (A), Zn in grains (B), Mn in shoots (C), Mn in grains (D), Cu in shoots (E), Cu in grains (F), Na in shoots (G) and Na in grains (H) of wheat irrigated with fresh or highly saline – sodic water. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

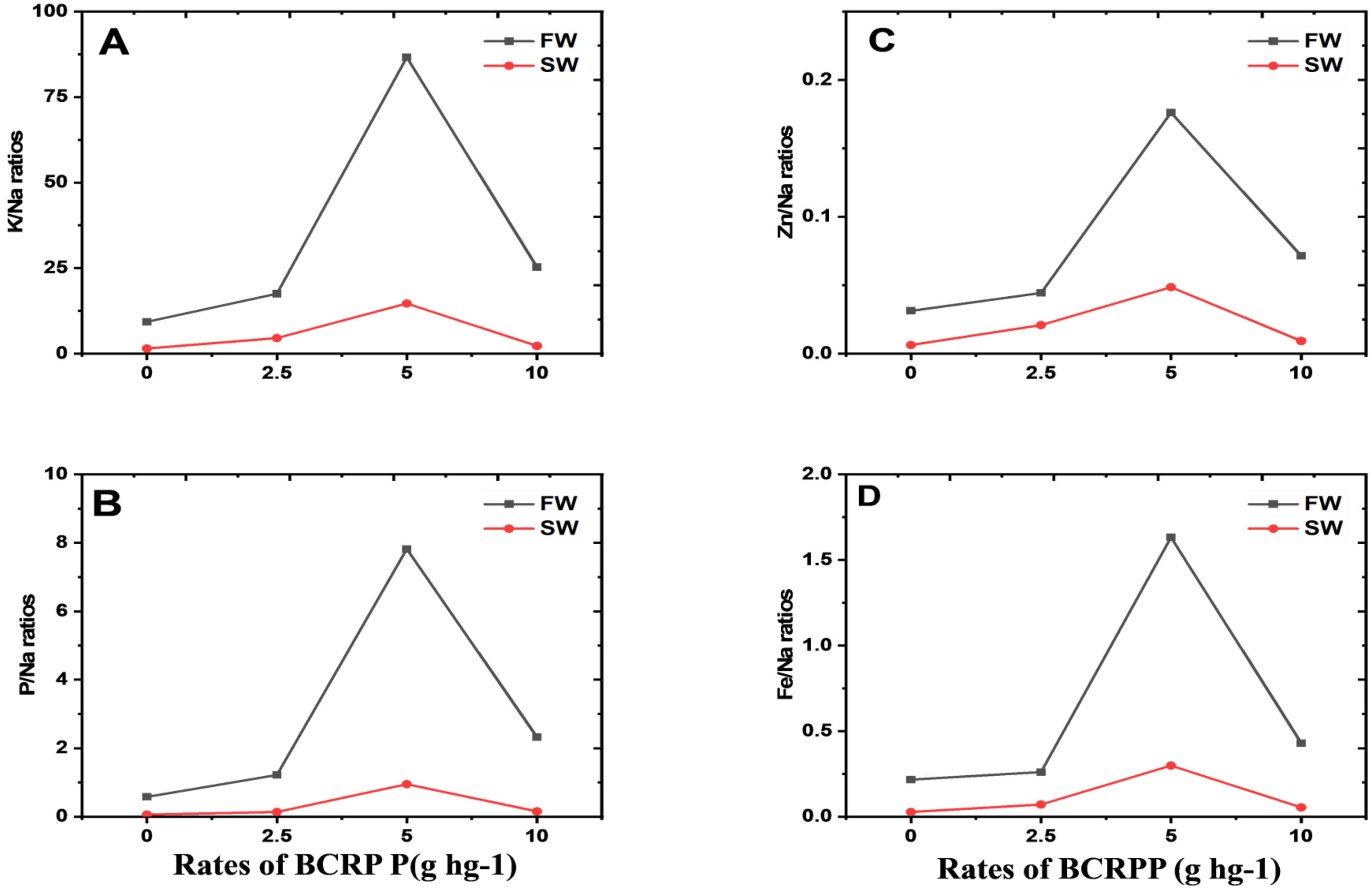

Fig. 6. Effect of soil amendments of BCRPP on K/Na (A), P/Na (B), Zn/Na (C) and Fe/Na (D) ratios of wheat irrigated with fresh or highly saline – sodic water.

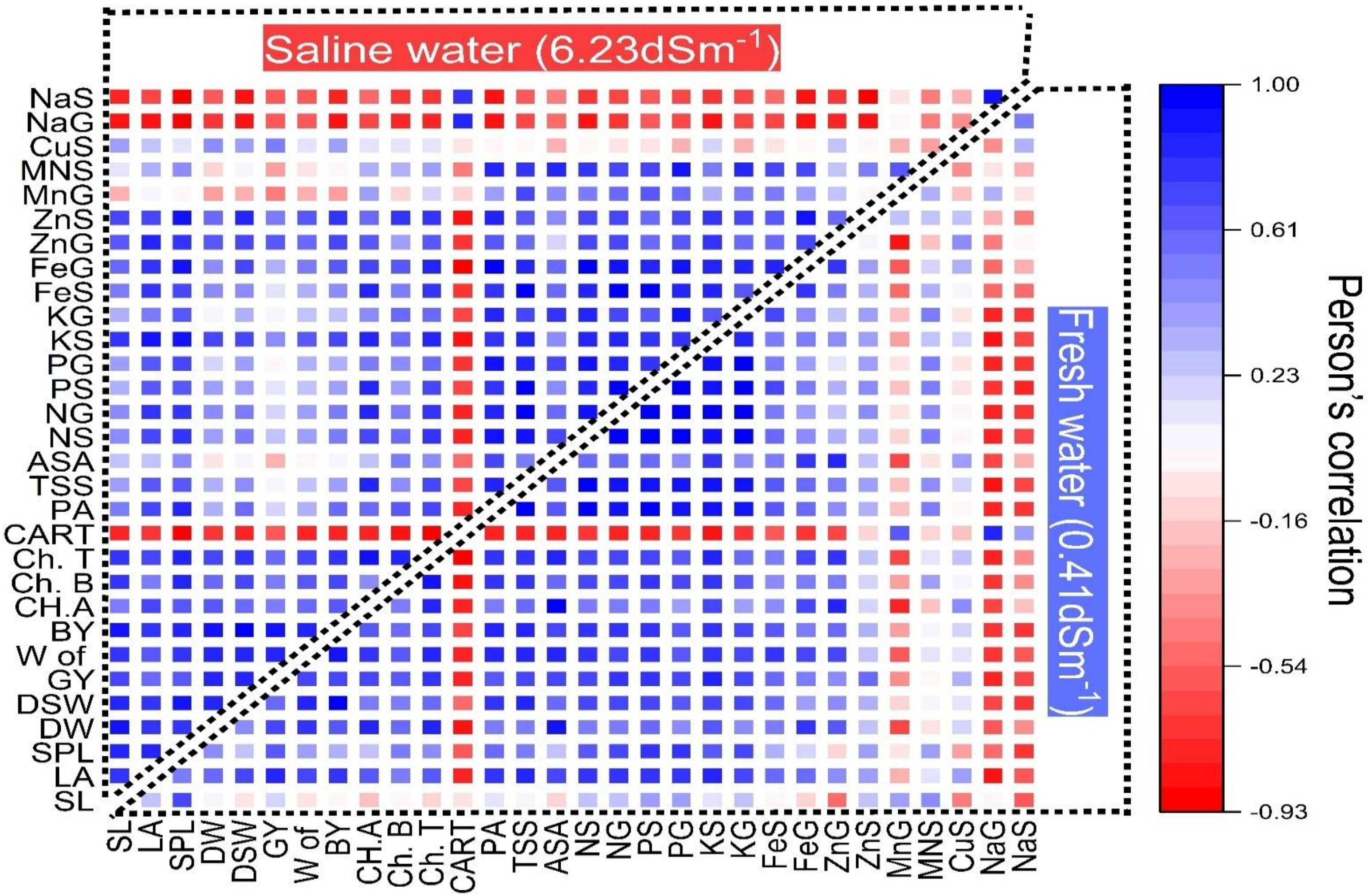

Fig. 7. Pearson's correlation coefficients for most of the studied measured parameters for wheat irrigated with fresh water (down right) or highly saline – sodic water (upper left).

Table 1. Some physical and chemical analysis of soil, water and BCRPP.

Property	***Unit***	***Soil***	***BCRPP***	***Saline water***	***Fresh water***
Bulk density (BD)	g cm-^{3}	1.24			
Particles density (PD)	g cm-^{3}	2.40			
Particle size distribution					
Sand	g hg^{-1}	20.4			
Silt	g hg^{-1}	37.50	-	-	-
Clay	g hg^{-1}	42.10			
Texture class Clay					
Water holding capacity	g hg^{-1}	69			
Field Capacity	g hg^{-1}	34			
Permanent wilting pointe	g hg^{-1}	17			
EC	(dS m^{-1})	2.19	*1.95	6.23	0.41
pH	-	7.80	**7.71	7.42	7.81
$CaCO_3$	g hg^{-1}	4.42	12.81		
Organic matter	g hg^{-1}	1.07	4.82		
CEC	cmol $_{(+)}$ kg^{-1}	40.27	72.35		
KCl-N	mg kg^{-1}	23.60	102.32		
$NaHCO_3$-P	mg kg^{-1}	13.03	578.13		
NH_4OAc-K	g kg^{-1}	0.32	5.14	-	-
NH_4OAc-Na	g kg^{-1}	0.22	1.42		
DTPA-Zn	µg g^{-1}	0.51	5.07		
DTPA-Mn	µg g^{-1}	4.92	12.10		
DTPA-Fe	µg g^{-1}	4.50	14.30		
DTPA-Cu	µg g^{-1}	0.49	1.89		
Soluble ions					
K^+		0.78	105.10	0.31	0.26
Ca^{2+}		2.84	25.30	1.50	1.06
Mg^{2+}		2.60	15.40	3.00	0.81
Na^+		15.17	45.30	54.52	1.97
Cl^-	meq. L^{-1}	15.09	146.50	50.00	1.73
HCO_3^-		1.98	13.50	1.50	1.01
CO_3^{2-}		0.00	0.00	0.00	0.00
SO_4^{2-}		4.82	31.16	7.51	1.36
SAR	-			37.82	2.03
SSP	%	-	-	92.18	48.04

Property	***Unit***	***Soil***	***BCRPP***	***Saline water***	***Fresh water***
ESP	%			35.28	1.71
ADJ SAR	-			52.95	2.44
Class	-			C4 - S4	C2 - S1

* Measured in a 1:10 extract. ** measured in a 1:10 suspension

Table 2. Effect of soil amendments of BCRPP * on some growth and yield parameters of wheat irrigated with fresh or highly saline – sodic water

Treatments	**Stem length (cm)**	**Leaf area (cm^2)**	**Shoot weight (g pot^{-1})**	**Spike length (cm)**	**Spike weight (g pot^{-1})**	**Grain yield (g pot^{-1})**	**1000-grain weight (g)**	**Biomass yield (g pot^{-1})**
Water salinity (WS)								
0.41 dS m^{-1}	70.3±0.54 a	23.7±1.22 a	14.1±0.23 a	9.5±0.28 ns	29.3±0.73 a	20.3±0.46 a	44.2±0.83 a	43.4±0.86 a
6.23 dS m^{-1}	67.1±0.96 b	15.2±1.47 b	11.8±0.30 b	9.0±0.38 ns	24.3±0.84 b	17.9±0.70 b	41.3±0.92 b	36.1±1.11 b
BCRPP * mixture rates(W/W)								
0.0%	66.8±1.08 b	16.5±1.52 b	12.7±0.46 c	7.8±0.11 d	25.5±1.32 b	18.5±0.25 c	41.9±0.53 b	38.2±1.72 bc
2.5%	69.8±0.75 a	19.5±2.15 b	13. 3±0.59 b	9.7±0.11 b	26.8±0.84 b	19.9±0.49 b	42.9±0.60 b	40.2±1.26 b
5.0%	70.5±0.22 a	24.3±2.38 a	14.0±0.47 a	10.5±0.22 a	30.3±1.15 a	21.2±0.58 a	46.6±0.89 a	44.3±1.58 a
10.0%	67.7±1.96 b	17.5±2.12 b	11.8±0.65 d	9.0±0.43 c	24.8±1.79 b	16.7±1.22 d	39.7±1.39 c	36.6±2.42 c
(WSXBCRPP)	Sig.	NS	Sig.	NS	Sig.	Sig.	NS	NS

* **BCRPP** is mixture of biochar (B), compost (C), rock phosphate (RP) and phosphorene (P); All values =means ± standard errors of triplicate values of each treatment are presented. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

T.3. Effect of soil amendments of BCRPP * on photo synthetical, non-enzymatic antioxidants and organic osmolytes parameters of wheat irrigated with fresh or highly saline – sodic water

Treatments	**Ch. A ** (mg g^{-1})**	**Ch. B ** (mg g^{-1})**	**Ch. T ** (mg g^{-1})**	**CART ** (mg g^{-1})**	**PA ** (µg g^{-1})**	**TSS ** (µg g^{-1})**	**ASA ** (µg g^{-1})**
Water salinity (WS)							
0.41 dS m^{-1}	2.4±0.07 b	0.7±0.09 ns	3.1±0.14 ns	0.9±0.03 b	30.6±4.74 b	30.0±3.90 ns	0.15±0.01 b
6.23 dS m^{-1}	2.4±0.07 a	0.5±0.06 ns	3.0±0.11 ns	1.0±0.03 a	55.1±5.60 a	33.6±4.10 ns	0.22±0.02 a
BCRPP * mixture rates(W/W)							
0.0%	2.4±0.25 b	0.4±0.05 b	2.8±0.05 bc	1.0±0.01 a	21.8±2.52 d	20.0±0.47 c	0.14±0.01 b
2.5%	2.4±0.06 b	0.6±0.06 b	3.0±0.08 b	0.9±0.02 b	38.4±8.50 c	21.9±0.52 c	0.15±0.02 a
5.0%	2.8±0.03 a	0.9±0.13 a	3.7±0.11 a	0.8±0.02 b	67.2±5.11 a	52.6±1.12 a	0.18±0.02 a
10.0%	2.2±0.06 c	0.5±0.06 b	2.8±0.05 c	1.0±0.02 a	43.9±6.38 b	32.8±2.87 b	0.18±0.03 a
(WSXBCRPP)	Sig.	NS	NS	NS	Sig.	NS	Sig.

* **BCRPP** is mixture of biochar (B), compost (C), rock phosphate (RP) and phosphorene (P).
** These parameters were determined and calculated based on fresh tissues of wheat sampled at 90 days after seeding; **Ch. A,** chlorophyll a; **Ch. B,** chlorophyll b; **Ch. T**, total chlorophyll; **CART,** carotenoids; **PA**, proline acid; **TSS**, total soluble sugars; **ASA**, ascorbic acid; All values =means ± standard errors of triplicate values of each treatment are presented. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

T.4. Effect of soil amendments of BCRPP * on some nutrients concentrations of wheat irrigated with fresh or highly saline – sodic water

Treatments	N ($g\ hg^{-1}$)		P ($g\ hg^{-1}$)		K ($g\ hg^{-1}$)		Fe ($\mu g\ g^{-1}$)	
	Shoots	**Grains**	**Shoots**	**Grains**	**Shoots**	**Grains**	**Shoots**	**Grains**
Water salinity (WS)								
0.41 dS m^{-1}	0.56±0.01 a	2.4±0.03 a	0.14±0.02 a	0.56±0.02 a	1.8±0.15 ns	0.42±0.02 ns	326.1±37.92 ns	65.2±7.59 ns
6.23 dS m^{-1}	0.48±0.01 b	2.30±0.03 b	0.09±0.01 b	0.42±0.03 b	1.7±0.15 ns	0.44±0.01 ns	331.3±34.20 ns	69.4±7.52 ns
BCRPP * mixture rates(W/W)								
0.0%	0.47±0.02 d	2.2±0.02 d	0.06±0.01 d	0.38±0.04 c	1.2±0.07 c	0.37±0.01 d	258.8±45.96 b	49.44±10.65 b
2.5%	0.50±0.01 c	2.3±0.03 c	0.08±0.02 c	0.47±0.03 c	1.6±0.04 b	0.41±0.02 c	249.7±28.05 b	64.15±2.34 b
5.0%	0.59±0.02 a	2.5±0.02 a	0.20±0.02 a	0.59±0.03 a	2.5±0.06 a	0.48±0.01 a	492.0±20.66 a	102.0±2.58 a
10.0%	0.53±0.02 b	2.4±0.02 b	0.12±0.01 b	0.52±0.03 b	1.6±0.11 b	0.44±0.01 b	314.2±23.48 b	53.6±6.08 b
(WSXBCRPP)	NS	NS	Sig.	NS	NS	NS	NS	Sig.

* **BCRPP** is mixture of biochar (B), compost (C), rock phosphate (RP) and phosphorene (P); All values =means ± standard errors of triplicate values of each treatment are presented. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

T.5. Effect of soil amendments of BCRPP * on some essential nutrients concentrations and sodium of wheat irrigated with fresh or highly saline – sodic water

Treatments	Zn ($\mu g\ g^{-1}$)		Mn ($\mu g\ g^{-1}$)		Cu ($\mu g\ g^{-1}$)		Na ($g\ hg^{-1}$)	
	Shoots	**Grains**	**Shoots**	**Grains**	**Shoots**	**Grains**	**Shoots**	**Grains**
Water salinity (WS)								
0.41 dS m^{-1}	45.8±2.70 b	29.3±1.64 ns	11.9±0.48 a	8.7±0.72 b	5.9±0.33 ns	10.2±0.00 ns	0.08±0.02 b	0.05±0.00 b
6.23 dS m^{-1}	66.3±3.59 a	29.0±1.62 ns	11.2±0.91 b	11.2±1.24 a	5.9±0.33 ns	10.2±0.00 ns	0.50±0.08 a	0.07±0.01 a
BCRPP * mixture rates(W/W)								
0.0%	46.9±3.42 b	28.4±2.25 b	8.9±1.03 c	8.6±0.96 b	6.2±0.00 ns	10.2±0.00 ns	0.48±0.16 a	0.08±0.01 a
2.5%	57.4±6.14 ab	28.8±0.78 b	10.3±0.51 b	7.1±0.37 b	6.2±0.00 ns	10.2±0.00 ns	0.22±0.06 c	0.05±0.00 c
5.0%	66.8±7.59 a	36.0±0.53 a	13.1±0.20 a	10.2±1.64 b	6.2±0.00 ns	10.2±0.00 ns	0.10±0.05 d	0.04±0.00 d
10.0%	53.2±4.86 ab	23.4±1.09 c	13.9±0.28 a	13.8±1.23 a	6.2±0.00 ns	10.2±0.00 ns	0.36±0.13 b	0.07±0.01 b
(WSXBCRPP)	NS	Sig.	Sig.	Sig.	NS	NS	Sig.	Sig.

* **BCRPP** is mixture of biochar (B), compost (C), rock phosphate (RP) and phosphorene (P).
; All values =means ± standard errors of triplicate values of each treatment are presented. Different small letters in column indicate significant differences (at $p \leq 0.05$) among treatments.

Saline stress causes many damages to the plant, including ionic imbalance, ionic toxicity, metabolic dysfunction, and oxidative stress, poor absorption of some nutrients, high reactive oxygen species, and cell division. Elongation…etc. Thus, these decreases can be attributed due to irrigation with highly saline – sodic water, which caused a decrease in some wheat growth parameters and grain yield, to these negative effects of salt stress, whether in the soil or in applied irrigation water ($6.23dSm^{-1}$). On the other hand, the application of the BCRPP led to statistically significant increases in the characteristics of some wheat growth parameters, such as grain yield and biomass, especially at the rate of 5g BCRPP hg^{-1}. This increase in the grain and biomass yield was about 11.42, 6.00%, respectively. According to these results in Table (2), and Figures (2A-2H), it can be said that the application of BCRPP led to improvements of wheat yield and its components under salt conditions, up to rate of 5g BCRPP hg^{-1}, due to application of BCRPP. These studies emphasized the beneficial effect of the BCRPP applied.

3.2.2. Effect of application of BCRPP on some physiological parameters of wheat fresh tissues

On the other hand, irrigation with highly saline – sodic water to increase the contents of fresh wheat tissue from some pigments (i.e., Ch. A, Ch. B, Ch. T, CART), PA, TSS, ASA, excluding Ch. B and Ch. T. Our results were correlated with findings of [29], and which showed reduction in chlorophyll content, and this reduction in photosynthetic pigments might be due to enhanced performance of chlorophyllase enzyme and ROS production, inhibition of photosynthesis and instability of protein compilation of photosynthetic pigments [2-35]. According to present findings BCRPP treatment increased chlorophyll, PA, TSS, ASA contents in wheat fresh tissues. The association of salt and biochar treatment increased the content of chlorophyll and carotenoid compared to stressed plant in some plants, especially wheat plant [20-29-32-36].Decrease in activity of chlorophyllase enzyme might be a possible reason for reduction in chlorophyll content [29]. Many studies have confirmed the negative effects of salt stress [2-20-37] while other studies have indicated a noticeable decrease in chlorophyll values as a result of the negative salt stress effect [8-20-29-31-32-37] .

The study of Shahzadi et al., [20] indicated an increase in contents of carotenoids, proline acid, soluble sugars, and ascorbic acid due to salt stress. The high contents of these physiological parameters are an important indicator of the plant's endurance vs. saline stress. Among compatible solutes, PA, TSS are very important, under stress conditions, their synthesis and accumulation in cell are a common way to grow. Proline acid (PA) is a vital solute for protein synthesis, metabolic activities & in immune responses under stress conditions [2-33]. The present study demonstrated proline content of leaf is highest in the stressed plant of wheat plant. Present results agreed with those obtained by Shahzadi, et al., [20] and Kanwal, et al.,[33] in wheat. Increased level of proline after exposure to salt stress could be due to decreased activity of dehydrogenase and less oxidation [2-38] .In addition, application of BCRPP improved these characteristics in plants, especially at the rate of application of 5% compared to other application transactions. This emphasizes the positive role of the mixture in promoting wheat growth under conditions of salinity and soil fertility.

3.2.3. Effect of application of BCRPP on some physiological parameters of wheat fresh tissues

Additionally, absorption of nutrients such as N, P, K, Fe, Zn and Mn in wheat straw and grains significantly increased, due to increasing BCRPP application rate. The 5g BCRPP hg-1 treatment is characterized by a significant advantage, compared to the other rates. P and Zn content of wheat grains and straw significantly increased with increasing application of BCRPP, especially at a rate of 5g BCRPP hg-1. Consequently, this has beneficial roles in increasing wheat's ability to tolerate salt stress and enhancing growth parameters and biomass yield under saline conditions. Wheat absorption of these nutrients can be attributed to the unique properties of BCRPP , including biochar [39] biochar enriched compost [40-41], P-enhanced biochar-compost [42] and rock phosphate inoculated with phosphate solubilizing bacteria and microhizal [43] .In addition to the beneficial role that phosphorene plays in promoting and releasing P from rock phosphate from BCRPP.

We also do not overlook the vital role of phosphorene and mycorrhiza in promoting soil biodiversity and promoting plant growth under saline stress. In the other hand, Na^+ levels have significantly decreased due to the synergistic application of BCRPP, while the Na^+ increased due to irrigation with highly saline – sodic water. This can be attributed to the ability of BCRPP to hold sodium, compared to the untreated treatment. In addition, ratios of nutrients/Na^+ (K/Na, P/Na, Zn/Na and Fe/Na ratios) showed Fig. (6) Confirmed that most of these percentages were higher. This proves that the application of BCRPP reduced Na^+ absorption in wheat, especially at a rate of 5g BCRPP hg^{-1}. In contrast, we can attribute the sharp decrease in the rate of 10g BCRPP hg^{-1}, compared to 5g BCRPP hg-1 to the increase in the ability of BCRPP to reserve ions, and thus this percentage decreases. Generally, it can be said that applying the BCRPP at the rate of 5g BCRPP hg^{-1} improves soil fertility and enhancing wheat growth and yield under highly saline – sodic water up to EC ($6.23dSm^{-1}$) in the clayey Egyptian soils.

4. Conclusion

In this study, salinity showed deleterious impacts on the growth and physiology of wheat plants: however, salinity caused significantly lower wheat growth parameters including stem length, leaf area, spike length, shoot weight, grains yield, 1000 grains weight, and biomass yield, due to the translocation of beneficial salts from the system or leaves. In addition, highly saline – sodic water caused significantly greater in Ch. A., CART, PA, and ASA. In contrast, BCRPP application enhanced physiological, agronomic, and biochemical attributes of wheat irrigated with highly saline – sodic water. Moreover, the rate of 5g BCRPP hg^{-1} archived greater values in most measurements of wheat irrigated with fresh and highly saline – sodic water than any other treatments. The results of this study demonstrated that the combination of biochar (B), compost (C), rock phosphate (RP) and phosphorene (P) at the rate of 5g BCRPP hg^{-1} was more efficient than any rate. Thus, the synergetic application of biochar enriched compost and rock phosphate inoculated with phosphate solubilizing bacteria could be beneficial in alleviating the deleterious impacts of salinity on the wheat plants and improving the wheat productivity in under salt stress.

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