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RESEARCH ARTICLE

The role of compost and biochar in improving saline-affected soil characteristics and total nutrient uptake of rice grains in the Mekong delta, Vietnam

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Abstract

The Mekong River Delta (MRD) in South Vietnam is one of the most favorable areas for agricultural activities. In recent years, the impact of saline water intrusion has been evident in the MRD, leading to yield losses in many rice-growing regions. This study aimed to investigate the effectiveness of compost and biochar amendment in improving some physical and chemical properties of saline-affected soil and, thus, maintaining the sustainability of rice growing systems in MRD of Vietnam. The field experiments were arranged in a completely randomized block consisting of four treatments with four replications: Triple rice crops per year, double rice crops per year, double rice crops per year applied with compost at a rate of 3 tons $ha^{-1,}$ and the double rice crops per year applied with biochar at a rate of 10 tons ha^{-1}. Soil characteristics were analyzed, including bulk density, porosity, electrical conductivity, amount of dissolved and exchangeable Na+, K+, Ca2+ cations, and soil exchangeable sodium percentage. Rice straw biomass and N, P, and K uptake were also recorded at harvest. This study demonstrated that compost and biochar amendments could decrease soil bulk density and increase soil porosity in the top soil layer (at a depth of 0-15 cm). In addition, the application of compost significantly increased exchangeable Ca^{2+} concentration and total uptake of N in rice grains. Applying biochar significantly increased exchangeable K+ concentration in soil and the total uptake of N and K in rice grains.

Keywords: Biochar; Compost; Rice Grain; Soil Bulk Density; Soil Porosity.

1. Introduction

Soil salinity is an increasing problem worldwide, especially in arid and semi-arid regions (Mahmoodabadi *et al.*, 2013). In Vietnam, the Mekong River Delta (MRD) is located downstream of the Mekong River. It is the national largest rice-producing region with the role of not only providing domestic food but also serving exports (Tuan, 2010). However, saline water intrusion has been affecting productivity, planted area and rice sowing time in the coastal areas of the MRD in recent years. Bülent and Örçen (2020) reported that salinization accumulates water-soluble salts in the soil solution. In particular, high Na^+ ion content on soil colloids causes soil disturbance (Agar, 2011; Yu *et al.*, 2010) and limits the absorption of essential nutrients for plants such as K, Ca, Mg, P, etc. Thereby, it reduces crop productivity (Abdel-Fattah and Mohamed, 2018).

Many studies have applied chemical measures to improve saline-affected soil through the cation exchange mechanism: using Ca^{2+} and Mg^{2+} to replace Na^+ on clay minerals and irrigation to wash Na^+ from the soil. In addition, Ghosh *et al.* (2010) reported that adding organic materials is an effective solution to improve the properties of

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different soil types affected by salinity. Composts have been known as soil amendments to provide Ca^{2+} and Mg^{2+} (Fricke and Vogtmann, 1994) to replace Na^+, increase pores and air exchange in the soil, promote plant growth and soil microbial activity (Rasool *et al.*, 2007) and reduce soil EC and exchangeable sodium percentage (ESP) (Qadir *et al.*, 2001). Besides composts, biochar also plays an important role in improving the physical and chemical properties of soil (Abdel-Fattah and Mohamed, 2018). Biochar amendment reduced soil compaction (Jien and Wang, 2013), promoted soil aggregation (Sun and Lu, 2014) and increased soil permeability (Jien and Wang 2013). In addition, biochar contains high K^+ content, which promotes the ion exchange process, thereby increasing the effectiveness of flushing salinity out of the soil. It was also proved that biochar amendment significantly decreased soil solution EC (EC_e), exchangeable sodium percentage (ESP), sodium adsorption rate (SAR), and some soluble and exchangeable cations in salt-affected soils (Saifullah *et al.*, 2018). Additionally, applying biochar can improve soil quality such as pH, water holding capacity, infiltration capacity, increase fertilizer use efficiency and crop productivity (Chávez-García and Christina, 2019).

Therefore, this study was conducted to investigate the effectiveness of compost and biochar in improving some physical and chemical properties of saline-affected soil and maintaining the sustainability of rice growing systems in the coastal areas of the MRD. The specific objective of this study was to evaluate changes in soil bulk density and soil porosity as well as concentrations of dissolved and exchangeable cations in saline-affected soils as being amended with compost and/ or biochar. At the same time, compost and biochar were expected to support rice growth and yield, which were investigated by the differences in rice straw biomass and total uptake of N, P, and K in rice grains. The research results are expected to help develop new soil management strategies to improve rice production in saline-affected areas of the MRD.

2. Materials and Methods

2.1. Experimental Areas

The experiment was conducted in two coastal areas in the MRD of Vietnam: Thanh Phu district, Ben Tre province (9°58’22.51” N, 106°28’51.22” E) and U Minh Thuong district, Kien Giang province (9°43’34.43” N, 105°10’55.06” E). The research areas are in a typical tropical moist climate with an average annual temperature of 27°C. There are two distinct seasons including dry season from December to April and rainy season from May to November (Phuong *et al.*, 2020). Soil classification was based on the International Union of Soil Sciences (IUSS) Working Group World Reference Base for Soil Resources (WRB) (2015), following that the soils at the experimental sites were classified as Sali-Thionic Fluvisols for Ben Tre and Sali-Gleyic Fluvisols for Kien Giang. Two experimental sites have traditionally grown the triple rice crops for more than 10 years; however, in recent years they have only been able to grow double rice crops per year due to saline intrusion in the dry season.

2.2. Experimental Materials

The rice seeds used in the study were OM5451 in Kien Giang and Tep Hanh (local variety) in Ben Tre. The sowing rate was 150 kg ha^{-1} for two locations. Inorganic fertilizers were used in the experiment, including urea (46% N), super phosphorus (16% P_2O_5), and potassium chloride (60% K_2O). Soil amendments used in the experiment, including compost, was a commercial product made from sugarcane filter cake, which was provided by PPE Company Limited, Can Tho, Vietnam; slow pyrolysis rice husk biochar processed at a maximum temperature of 700°C and was supplied from Mai Anh Co., Ltd., Dong Thap, Vietnam. Data of the leading chemical properties of the initial soils (0-20 cm), compost and biochar used in this study were reported by Phuong *et al.* (2020) (Table 1).

Table 1. Main chemical properties of initial soils (0-20 cm) in Ben Tre and Kien Giang, compost and biochar used in the study

Parameters	Compost	Biochar	Initial soil properties	
			Ben Tre	Kien Giang
pH $_{H2O\ (1:5)}$	8.7	7.7	-	-
pH $_{H2O\ (1:2.5)}$	-	-	4.64	4.65
EC$_{(1:5)}$ (mS cm^{-1})	17.1	4.1	-	-
EC$_{(1:2.5)}$ (mS cm^{-1})	-	-	1.24	1.16
ECe (mS cm^{-1})	-	-	4.50	4.10
CEC (cmol$^+$ kg^{-1})	66	6.5	14.6	15.4
Dissolved Na (cmol$^+$ kg^{-1})	1.59	0.24	3.67	2.62
Dissolved K (cmol$^+$ kg^{-1})	20	3.35	0.15	0.07
Dissolved Ca (cmol$^+$ kg^{-1})	7.79	0.15	1.70	0.96
Exchangeable Na (cmol$^+$ kg^{-1})	0.6	0.24	1.38	1.21
Exchangeable K (cmol$^+$ kg^{-1})	15	12.9	0.63	0.52
Exchangeable Ca (cmol$^+$ kg^{-1})	61.6	0.16	6.01	3.44
ESP (%)	-	-	9.64	8.00
Total porosity (%)	76.2	92.3	53.4	56.4

(-): not analyzed

2.3. Experimental Design

The field experiments were carried out in the winter-spring growing crop of 2019-2020 on long-term experiments base, which were previously done in the spring-summer crop of 2018, summer-autumn crop of 2018, winter-spring crop of 2018-2019, spring-summer crop of 2019, summer-autumn crop of 2019 as described in the study of Phuong *et al.* (2020).

The field experiments were arranged in completely randomized block design consisting of four treatments with four replications, including:

Rice-Rice-Rice (RRR): Triple rice crops per year;

Rice-Rice (RR): Double rice crops per year;

Rice-Rice+compost (RR+CP): Double rice crops per year applied with compost at a rate of 3 tons ha^{-1};

Rice-Rice+biochar (RR+BC): Double rice crops per year applied with biochar at a rate of 10 tons ha^{-1}.

Each plot had an area of 40 m^2 (8 m x 5 m). All treatments received the same amount of NPK (inorganic) fertilizers, viz. urea, superphosphate, and potassium chloride at rates of 100 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5, and 30 kg ha^{-1} K_2O. The entire amount of phosphate (P) fertilizer was applied before sowing. At 10 days after sowing, applying the first urea (N) fertilizer (20% N of the total rate of N). At 20 days after sowing, 40% nitrogen (N) mixed with 50% potassium (K) was applied. At 40 days after sowing, N and K were applied at the same rate as at day 20 after sowing. Compost and biochar were applied at the beginning of each crop in combination with soil plowing.

2.4. Data Collection and Soil Analysis Methods

Soil sampling and analysis: Soils were taken at harvest time at a depth of 0-15 cm, representing the cultivated topsoil. After sampling, the sampled soils were placed in black polythene bags, labeled with numbers, stored in cool conditions, and sealed for transporting to the laboratory. Soil properties were analyzed including: soil bulk density, porosity, EC, dissolved and exchangeable Na^+, K^+, Ca^{2+} cations, K^+/Na^+, Ca^{2+}/Na^+ ratios and ESP.

Agronomic data collection: At harvest, agronomic data were collected in the winter-spring crop of 2019-2020 including rice straw biomass and harvested plant samples at the time of harvesting and processing to analyze total uptake N, P_2O_5, K_2O in rice grains.

2.5. *Analyses of Soil Parameters:*

Bulk density was calculated as the oven-dry soil weight (105°C) of undisturbed soil sample per bulk volume unit using the core method (Grossman and Reinsch, 2002). Total soil porosity was calculated from bulk density and particle density, which were determined using the pycnometer method (Blake and Hartge, 1986).

Soil pH and EC were analyzed by adding deionized water to mix with soil in a 1:5 ratio (soil : water, w:v) and the mixture was shaken for 1 hour at 120 rpm. Measurements were performed using pH and EC meters. Dissolved Na^+, K^+, Ca^{2+} concentrations were measured using the soil extract 1:5 (soil : water, w:v) after passing through filter paper. Ions in the filtrate were determined by Atomic Absorption Spectrophotometric (AAS). Exchangeable Na^+, K^+, Ca^{2+} cations were obtained by subtracting dissolved cations from the extractable cations. Extractable cations were analyzed by extracting soil sample (2.5 g) three times with 0.1 M $BaCl_2$ extracting (30 ml each time) and shaking for 1-h and determined with AAS. The exchangeable sodium percentage (ESP) was calculated according to the equation:

$$ESP\ (\%) = \frac{[\mathrm{Na}^+]}{\mathrm{CEC}}\ x\ 100$$

Where Na^+ is the exchangeable sodium content and CEC is the cation exchange capacity.

The aboveground parts of rice plants were separated into straw and grain, then were oven-dried at 105°C, and the rice straw was weighted for biomass.

2.6. *Data analysis*

All presented data were the average from four replicates. Significant differences among treatments were analyzed by one-way analysis of variance and then expressed as the least significant difference (LSD 0.05) using SPSS V.22 software.

3. Results and Discussion

3.1. *Effects of biochar and compost amendments on soil physical properties*

Soil bulk density

Research results at the Ben Tre experimental site showed that bulk density in the top-soil layer (0-15 cm) was lowest in RR+CP and RR+BC, significantly different from RRR treatment but not different from RR treatment (Table 2). At Kien Giang, similar results were recorded as soil bulk density in the top soil layer (0-15 cm) was lowest in RR+CP and RR+BC (Table 2). According to Mukherjee and Lal (2013), biochar application reduced soil bulk density because of the high porosity of biochar. When being applied to soil, biochar significantly reduced soil density by increasing pore volume.

There were no differences between treatments in the sub-soil layer (15-30 cm) for two sites (Table 2). This result is similar to the study of Major *et al.* (2012), who recorded that an application of 20 tons ha^{-1} biochar had no significant difference in soil bulk density in the sub-soil layer (15-30 cm).

3.1.1. *Soil porosity*

The analysis of porosity of the top-soil layer (0-15 cm) at Ben Tre showed that applying RR+CP, RR+BC significantly increased soil porosity by 54.53% and 54.52%, respectively as compared to that from the RRR treatment, but not significantly different from the RR treatment (Table 2). At Kien Giang, soil porosity increased with the highest values of 59.27% and 59.08% with respect to the RR+BC and RR+CP treatments, significantly different from the RRR and RR treatments (Table 2).

There was no difference in soil porosity between treatments in the sub-soil layer (15-30 cm) at the two sites (Table 2).

According to the study conducted by Masulili *et al.* (2010), the total increase in soil porosity was recorded after applying 10 tons ha^{-1} and 15 tons ha^{-1} of rice husk was up to 50% in all amended plots.

Table 2. Changes in soil bulk density and soil porosity at 0-15 cm and 15-30 cm depth as treatment effects at Ben Tre and Kien Giang sites in winter-spring crop 2019-2020

Treatments	**Soil bulk density (g cm^{-3})**		**Soil porosity (%)**	
	0-15cm	**15-30cm**	**0-15cm**	**15-30cm**
Ben Tre				
RRR	1.18 ^{a}	1.37	51.67 ^{b}	47.14
RR	1.14 ^{ab}	1.38	53.48 ^{ab}	47.19
RR+CP	1.12 ^{b}	1.37	54.53 ^{a}	47.26
RR+BC	1.12 ^{b}	1.37	54.52 ^{a}	47.35
P-value	*	*ns*	*	*ns*
Kien Giang				
RRR	1.14 ^{a}	1.29	54.56 ^{b}	50.57
RR	1.13 ^{a}	1.30	57.58 ^{b}	50.54
RR+CP	1.05 ^{b}	1.29	59.27 ^{a}	50.65
RR+BC	1.05 ^{b}	1.29	59.08 ^{a}	51.28
P-value	**	*ns*	**	*ns*

*Different letters indicate a significant difference ($p<0.05$) among treatments, * $p<0.05$; ** $p<0.01$; ns: not significant.*

3.2. Effects of biochar and compost amendments on soil chemical properties

Electrical conductivity of soil (EC)

Results showed that soil $EC_{(1:5)}$ values ranged from 0,83 to 0,91 mS cm^{-1} in Ben Tre and from 0,42 to 0,48 mS cm^{-1} in Kien Giang. There was no significant difference in soil EC among treatments at two sites (Table 3).

Table 3. Change in soil EC as treatment effects at Ben Tre and Kien Giang sites in winter-spring crop 2019-2020

Treatment	**$EC_{(1:5)}$ (mS cm^{-1})**	
	Ben Tre	**Kien Giang**
RRR	0.89	0.42
RR	0.83	0.43
RR+CP	0.91	0.48
RR+BC	0.83	0.47
P-value	*ns*	*ns*

ns: not significant.

3.2.1. Concentration of dissolved and exchangeable cations in soil

Sodium concentration is an important parameter of saline-affected soils. In Ben Tre, the results illustrated that RR+BC treatment removed the highest amount of dissolved Na^{+} from saline-affected soil and was significantly different from the RRR, RR and RR+CP treatments.

Meanwhile, the amount of exchangeable Na in RRR treatment increased significantly as compared to the RR, RR+CP and RR+BC treatments. However, there were no significant differences in dissolved and exchangeable Na^+ concentrations between treatments in Kien Giang (Table 4).

Research results showed that the treatment with biochar had the highest dissolved and exchangeable K^+ amounts as well as a statistically significant difference as compared to RRR, RR and RR+CP treatments in both Ben Tre and Kien Giang sites (Table 4). This may be due to the increased availability of K^+ cation from the initial biochar. In addition, the exchangeable K^+ content in the treatment with also increased significantly as compared to the RRR and RR treatments in Kien Giang. This result was consistent that an increased K^+ availability facilitates the efficient exchange of adsorbed Na^+ into soil solution.

It was also recorded that the treatment with compost had the highest amount of exchangeable Ca^{2+} cation and had a statistically significant difference as compared to RRR, RR and RR+BC treatments in Ben Tre and Kien Giang sites. This was due to the fact that compost contains a significant amount of Ca, which led to higher amount of exchangeable Ca^{2+} in treatment RR+CP when compost was amended into soil. Meanwhile, the amounts of dissolved Ca^{2+} in the other treatments were not statistically different. Chaganti and Crohn (2015) reported that increased availability of divalent cations facilitates efficient exchange of adsorbed Na^+ into soil solution and increased exchangeable Na^+ concentrations in the soil.

Table 4. Change in soil dissolved and exchangeable cations as treatment effects at Ben Tre and Kien Giang sites in winter-spring crop 2019-2020

Treatment	**Dissolved cations**			**Exchangeable cations**		
	Na^+	**K^+**	**Ca^{2+}**	**Na^+**	**K^+**	**Ca^{2+}**
Ben Tre						
RRR	3.46 b	0.11 b	0.13	2.35 a	0.69 b	2.92 b
RR	3.46 b	0.11 b	0.11	1.47 b	0.72 b	2.86 b
RR+CP	3.44 b	0.11 b	0.13	1.67 b	0.76 b	4.42 a
RR+BC	3.74 a	0.13 a	0.16	1.56 b	1.18 a	3.06 b
P-value	*	**	*ns*	**	***	***
Kien Giang						
RRR	1.81	0.06 b	0.08	1.23	0.62 c	2.01 b
RR	1.94	0.06 b	0.08	1.19	0.59 c	1.98 b
RR+CP	1.94	0.07 b	0.09	1.32	0.67 b	2.26 a
RR+BC	1.86	0.17 a	0.09	1.12	1.45 a	2.01 b
P-value	*ns*	***	*ns*	*ns*	***	**

*Different letters indicate a significant difference ($p<0.05$) among treatments, * $p<0.05$; ** $p<0.01$; *** $p<0.001$; ns: not significant.*

The results of analyzing the K^+/Na^+ ratio showed that the treatment with biochar had the highest K^+/Na^+ ratio and was statistically different from the RR+CP, RR and RRR treatments for two sites (Figure 1A, 1B). Yan *et al.* (2023) reported that the relatively higher concentrations of K^+ to Na^+ in saline water were more beneficial to soil aggregate stability, reducing the risk of macropores reduction due to sodium contamination. Marchuk and Marchuk (2018) showed that potassium cations also could increase soil hydraulic conductivity to some extent when applied to a soil with high sodium content by substituting the Na^+ on exchange sites. The results of the Ca^{2+}/Na^+ ratio analysis showed that the treatment with compost had the highest

Ca^{2+}/Na^{+} ratio and was statistically different from the RR+BC and RRR treatments in Ben Tre (Figure 1C). However, there was no significant difference in the Ca^{2+}/Na^{+} ratio among treatments in Kien Giang (Figure 1D). Tsai *et al.* (2012) reported that soil calcium (Ca^{2+}) can alleviate soil dispersibility by replacing Na^{+} in soil colloids, the outer layers of the Ca^{2+} containing colloidal particles do not adsorb water molecules, turning Na^{+} qualitative hydrophilic colloid into Ca^{2+} hydrophobic colloids. According to McKenna *et al.* (2019), colloidal particles move closer together, promoting soil particles to form stable aggregates in water, thereby improving soil structural stability.

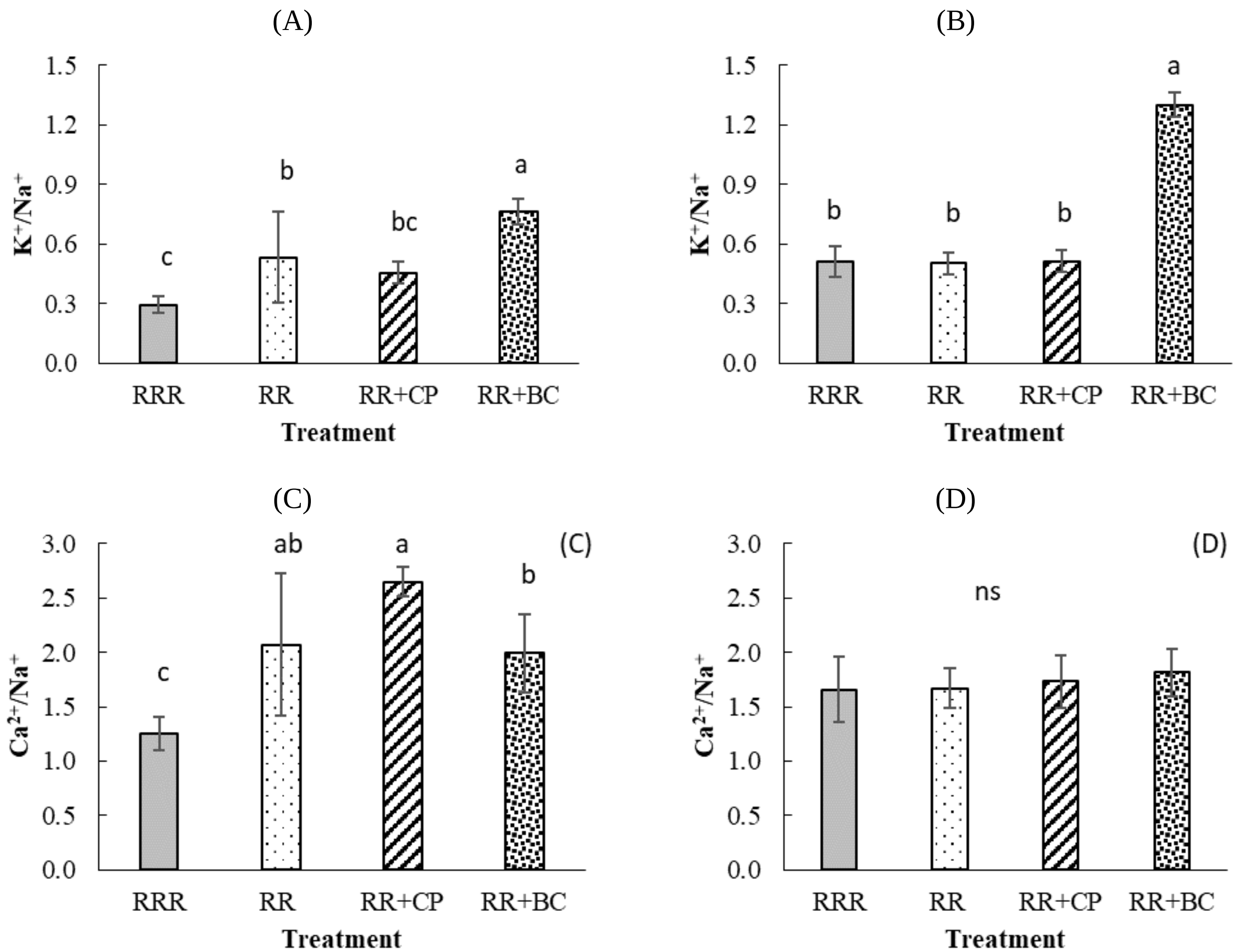

Figure 1. Changes in K^{+}/Na^{+} and Ca^{2+}/Na^{+} ratio in soil as treatment effects at Ben Tre (A,C) and Kien Giang (B,D) with data from winter-spring 2019-2020 crop.
Different letters indicate a significant difference ($p < 0.05$) among treatments; ns: not significant. Error bars indicate the standard deviation of four replicates ($n = 4$) for each treatment.

3.2.2. Soil exchange sodium percentage (ESP)

The results of analyzing ESP values in Ben Tre showed that the ESP value of the RRR treatment was highest and significantly different from the RR, RR+CP and RR+BC treatments. There were no significant differences between RR, RR+CP and RR+BC treatments (Figure 2A). However, the results from the study in Kien Giang showed that there were no differences in ESP values between compost and biochar addition as compared to the RRR and RR treatments (Figure 2B).

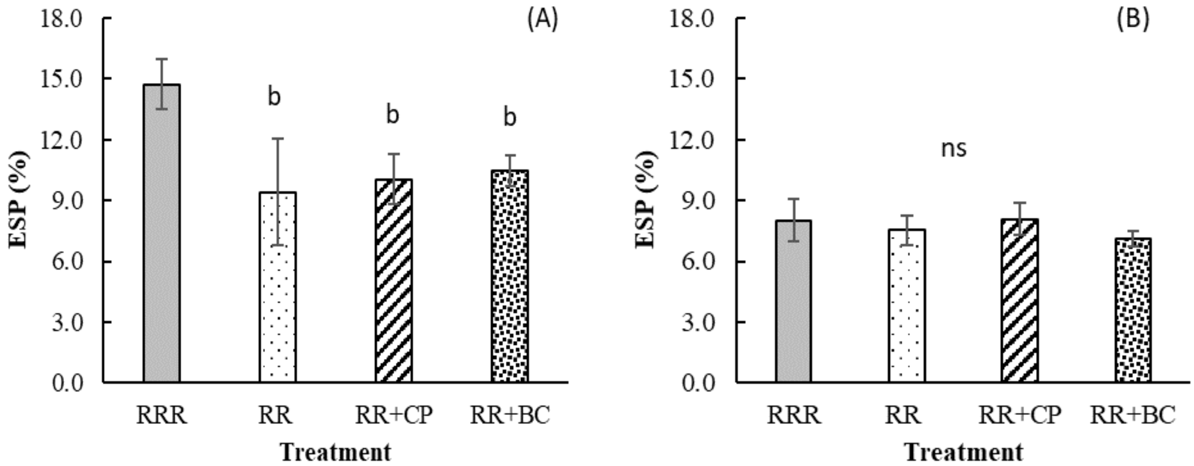

Figure 2. Changes in soil exchang sodium percentage as treatment effects at Ben Tre (A) and Kien Giang (B) with data from winter-spring 2019-2020 crop.

Different letters indicate a significant difference ($p < 0.05$) among treatments; ns: not significant. Error bars indicate the standard deviation of four replicates (n = 4) for each treatment

3.3. Effects of biochar and compost amendments on rice straw biomass and total uptake of N, P, and K in rice grains grown on saline-affected soils

3.3.1. Rice straw biomass

Results of rice straw biomass analysis showed that there was no significant difference in rice straw biomass when adding compost and biochar as compared to RRR and RR treatments at Ben Tre and Kien Giang (Figure 3A, 3B).

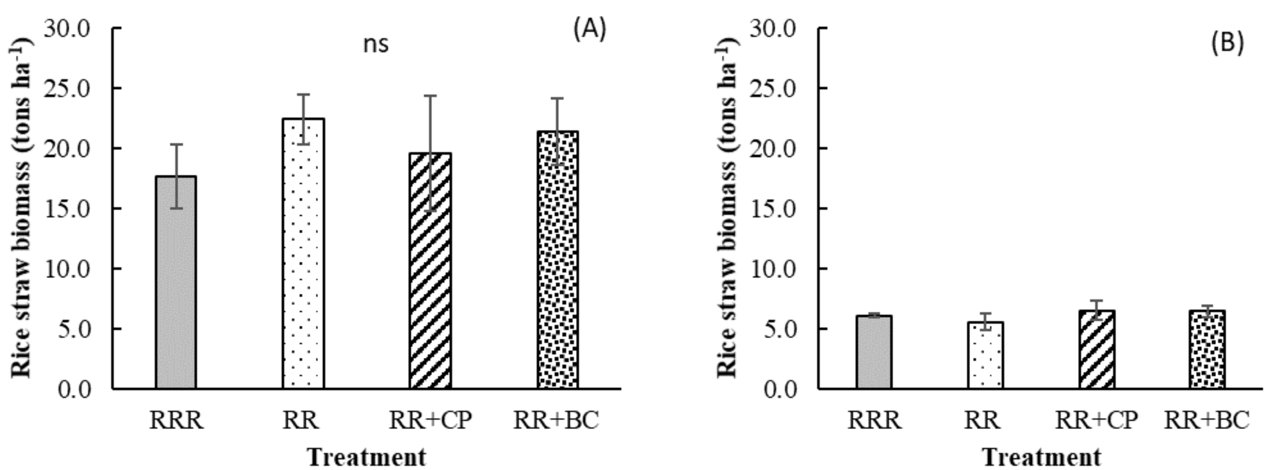

Figure 3. Effects of soil amendments on rice straw biomass at Ben Tre (A) and Kien Giang (B) with data for winter-spring 2019-2020 crop.

Letter ns: not significant. Error bars indicate the standard deviation of four replicates (n = 4) for each treatment.

3.3.2. Total uptake of N, P, and K in rice grains

Total uptake N, P, and K in rice grains at Ben Tre and Kien Giang were shown in Table 5. The results of analyses of total uptake of N, P, and K in rice grain showed that compost and biochar amendments increased the total uptake of N, P, and K in rice grains significantly different as compared to RR and RRR treatments in Ben Tre (Table 5).

In Kien Giang, the results also showed that the treatments with compost and biochar amendment had high total uptake of N, significantly different from the RR and RRR treatments. Meanwhile, the total uptake of K in rice grains was highest in the treatment with biochar, which was statistically different from the RR+CP, RR and RRR treatments. However, there was no significant difference in total uptake of P in rice grains between treatments (Table 5).

Applying biochar to soil contributes to improve water and air spaces, creating favorable conditions for microorganisms to grow and enhancing the activity of nutrient mineralization process. In addition, with its surface adsorption properties, biochar also has useful adsorption capacity and reduces the rates of N evaporation and leaching. Biochar amendment had been shown to be effective in improving available P content in the soil, thereby increasing the amount of phosphorus uptake in rice grains, with a statistically significant difference as compared to the treatment without biochar amendment as recorded in Ben Tre. The reason to explain for this advantage may come from the fact that applying biochar to the soil helps improve soil structure, porosity, creating many pores and thus, a favorable environment for microorganisms to hide. According to Deb *et al.* (2016), biochar mediated changes to the soil environment, altered microbial community structure and thus affected the processes of P solubilization and mineralization. The intial biochar source contained high levels of available K; as a result, biochar amendment increased total uptake of K in rice grains to the highest level, statistically significant difference as compared to the remaining treatments in two experimental sites.

Rice yields in this study were reported by Linh *et al.* (2023). Biochar amendment significantly increased rice grain yield as compared with no amendment at both sites. Rice yield of the RR+BC significantly increased by 0.68 Mg ha^{-1} and 0.76 Mg ha^{-1} compared with RR in Ben Tre and Kien Giang, respectively. Githinji (2013) reported that the significant increase in rice yield when applying biochar may be due to the effect of biochar in improving soil nutrient content, helping to enhance plant growth. According to Azeez *et al.* (2011), increased crop yields may be related to the addition of biochar which improved soil quality and enhanced nutrient supply to crops was reported by Gaskin *et al.* (2010), while increasing the biomass and activity of microorganisms in the soil was reported by Gunes *et al.* (2014). According to Brandstaka *et al.* (2010), the increase in yield after biochar application may be due to the better water holding capacity of the soil when using biochar. Besides, the beneficial effects of biochar addition in production may be due to changes in soil properties that provide useful nutrients to plants (Sohi *et al.,* 2010).

Table 5. Total uptake of N, P, K in rice grain in the treatments at Ben Tre and Kien Giang sites in winter-spring 2019-2020 crop

Treatment	**Ben Tre**			**Kien Giang**		
	Total uptake of N, P, K in rice grain (kg ha^{-1})					
	%N	**%P_2O_5**	**%K_2O**	**%N**	**%P_2O_5**	**%K_2O**
RRR	49.43 ^{b}	25.67 ^{b}	12.73 ^{b}	50.99 ^{b}	37.87	19.30 ^{b}
RR	46.44 ^{b}	24.39 ^{b}	12.63 ^{b}	49.54 ^{b}	39.37	19.89 ^{b}
RR+CP	59.60 ^{a}	31.21 ^{a}	16.76 ^{a}	59.75 ^{a}	42.79	21.08 ^{b}
RR+BC	61.69 ^{a}	33.52 ^{a}	18.49 ^{a}	59.74 ^{a}	45.81	23.99 ^{a}
P-value	**	***	***	**	*ns*	**

*Different letters indicate a significant difference ($p<0.05$) among treatments, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns: not significant.*

The use of organic matter from biochar helps improve soil productivity, increase carbon content, promote soil microbial activity, improve soil structure and soil nutrient status as well as crop productivity (Beckman, 1973). In addition, plant growth is due to changes in the soil physical properties as well as biochar's ability to retain nutrients in fertilizers and reduce leaching losses (Chan and Xu, 2009).

4. Conclusion

This study evaluated the importance of compost and biochar amendments in improving soil physical and chemical properties of saline-affected soils. This study proved that compost and biochar amendment could improve soil physical properties by decreasing soil bulk density and increasing soil porosity in the top soil layer (0-15 cm). In addition, application of compost significantly increased exchangeable Ca^{2+} concentration and total uptake of N in rice grain. Application of biochar significantly increased exchangeable K^{+} concentration in soil and total uptake of N and K in rice grain. However, adding compost and biochar has not significantly changed the physical and chemical properties of the sub-soil layer (15-30 cm) and rice straw biomass.

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Authors' Contributions

All authors are contributed in this research

Funding

There is no funding for this research.

Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest.

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