Original Research Article

Effect of Integrated Use of Organic and Inorganic Fertilizers on Salinity Tolerance in Rice

ABSTRACT

Salinity is a serious problem for soil and water in Bangladesh. It limits normal year round crop production. To reduce this problem, this experiment was conducted in farmers' field of two locations at south coastal region of Bangladesh for two consecutive years. Six treatments viz., T_1: Control (no organic material and chemical fertilizer), T_2: 100% recommended chemical fertilizer, T_3: 2 t ha^{-1} rice husk biochar + 100% recommended chemical fertilizer, T_4: 3 t ha^{-1} poultry manure + chemical fertilizer with IPNS basis, T_5: 3 t ha^{-1} vermicompost + chemical fertilizer with IPNS basis, T_6: 3 t ha^{-1} Mazim organic fertilizer + chemical fertilizer with IPNS basis were used in this experiment. The design of the experiment was randomized complete block design (RCBD) with 3 replications. The T. Aman rice (var. BRRI dhan52) was used as test crop. The results revealed that the maximum yield and yield contributing parameters were found in T_3 treatment. Results also revealed that all the organic amendments integrated with chemical fertilizers were capable to increase soil fertility level by reducing salinity. Among them, T_3 treatment was best because highest organic carbon, total nitrogen, available sulphur, available phosphorus, exchangeable potassium and lowest electrical conductivity, exchangeable sodium of post-harvest soils were found in this treatment. Therefore, integrated use of rice husk biochar and chemical fertilizers could be the better approach for enhancing food security through increasing crop production in southern saline region as well as whole Bangladesh.

Keywords: Salinity tolerance, T. Aman rice, Organic and inorganic fertilizers, food security.

1. INTRODUCTION

Bangladesh is one of the most climate vulnerable countries in the world. Soil and water salinity is a hot issue that is growing at an alarming rate in coastal areas of Bangladesh. The coastal areas of Bangladesh account for more than 30% of the country's arable land [1]. Salinity increases in the coastal area in winter when the soil is dry [2]. During rabi season, large areas remain fallow due to lack of irrigation water and higher salinity. Salinity causes adverse environmental and hydrological conditions, increases nutrient mining, and limits regular year-round agricultural production [3]. The primary crops (cereals, potatoes, legumes, oil seeds, vegetables, species, and fruit crops) in the saline-prone coastal zone suffered a significant yield loss, averaging 20–40% [4]. To stop exploiting nutrients by salinity, organic sources of plant nutrients, namely rice husk biochar, poultry manure, vermicompost, and standard organic fertilizers etc. should be properly taken into account. It can play an important role in maintaining soil fertility and crop productivity even in saline soil. Although the proportion of nutrients in inorganic fertilizers is high compared to organic fertilizers, the presence of growth stimulants in organic fertilizers can make them important in improving soil fertility [5]. Organic fertilizers act as a source of nutrients and are beneficial for soil improvement [6]. Organic matter serves as a reservoir for plant nutrients, mainly N, P and S, and improves the cation exchange capacity of the soil [7]. Rice husk biochar, poultry manure, vermicompost and compost are good sources of organic fertilizers. Poultry manure, vermicompost and compost are the most commonly used fertilizers, but rice husk biochar is not commonly used fertilizer in Bangladesh. Currently, there are many poultry farming industries developed across the country. Therefore, a large amount of poultry manure is discharged and, if not utilized properly, will become a great burden and pollute the environment.

The rice husk biochar, vermicompost and organic fertilizers are prepared by different organizations for agricultural research purposes in Bangladesh. This study is significant because organic fertilizers such as rice husk biochar, poultry manure and vermicompost are cheap and locally available alternative materials used to improve productivity of rice and other crops. On the other hand, the application of integrated nutrient management practices is more necessary to achieve higher crop productivity, quality and yield. The impact of integrated use of manure and chemical fertilizers on different crops has been reported in Bangladesh [8]. The present situation of Bangladesh requires in-depth research on integrated crop nutrition system with various organic improvement measures on rice crop in the coastal saline zone.

2. MATERIALS AND METHODS

The experiment was carried out at Nilgonj and Latachapli unions of Kalapara upazila in Patuakhali district. The experimental field was located in the floodplain of the Ganges between 21°48' and 22°05' North latitude and between 90°05' and 90°20' East longitude [9]. The experimental area was located in the subtropical climate zone and was characterized by high rainfall during the months of April to September (Kharif season) and low rainfall during the remaining periods in the year. The variety of T. Aman rice was BRRI dhan52. Six treatments such as T_1 = Control (no organic matter or chemical fertilizers), T_2 = 100% recommended chemical fertilizers (NPKS), T_3 = 2 t ha^{-1} rice husk biochar + 100% recommended chemical fertilizers (NPKS), T_4 = 3 t ha^{-1} poultry manure + chemical fertilizers (NPKS) with IPNS basis, T_5 = 3 t ha^{-1} vermicompost + chemical fertilizers (NPKS) with IPNS basis, T_6 = 3 t ha^{-1} Mazim organic fertilizer + chemical fertilizers (NPKS) with IPNS basis were used in this experiment. The experiments were arranged in a randomized complete block design with 3 replications. Plot size was 4m × 5m. Chemical fertilizers were adjusted with nutrients supplied from organic manures in different treatments on the basis of IPNS. All organic materials and chemical fertilizers were applied during the final land preparation. Urea was applied in three equal splits at final soil preparation, 20 and 40 days after transplanting. Twenty-five-days old seedlings were transplanted with a spacing of 20 cm×20 cm. Two times of weeding were carried out at 25 and 45 days after transplanting to keep the soil weed-free. Irrigation was provided whenever necessary particularly during tellering and grain filling stages. Harvesting was carried out according to the full maturity of the crop. Harvest maturity was determined when 90% of the grains turn golden yellow. Yield and yield contributing data such as plant height, effective tillers $hill^{-1}$, filled grains $panicle^{-1}$, thousand grain weight of T. Aman rice were recorded according to standard procedures. The plant height was measured from the ground level to the top of the leaves and panicle. From each plot, the plant heights of ten hills were measured and averaged. The number of effective tillers hill^{-1} was counted from the sample hills. The panicle that had at least one grain was considered an effective tiller. Presence of any food materials in the spikelet was considered as a grain and total number of grains present panicle^{-1} from the sample hills was counted and averaged. One thousand cleaned dried grains (14% moisture content) were counted from seed stock obtained from sample hills of each plot, weighed in gram by using an electric balance. Ten hills were harvested from the center of each plot to estimate grain yield. After threshing and cleaning, the fresh weight of grains was recorded and then the grain yield was recorded by adjusting at 14% grain moisture content of the grain using the following formula:

$$\text{Grain yield at 14\% MC} = \left(\frac{100-\text{Sample MC \%}}{100-14}\right) \times \text{Fresh weight of grains at harvest.}$$

The T. Aman rice straw samples were collected after each harvest and analyzed for Na and K uptake according to standard procedures [10]. The soil samples after each harvest of T. Aman rice were collected and analyzed for EC, organic C, total N, available P, available S, exchangeable K and exchangeable Na following standard protocol [11]. Statistical computer program STAR (Statistical Tools for Agricultural Research) was used to analyze the soil and crop data [12]. Analysis of variance (ANOVA) was used to determine the significant treatment effects and 5% significance level was used to compare the treatment means by Duncan's multiple range test (DMRT).

3. RESULTS

3.1 Plant height

The tested treatments significantly influenced the plant height in both the years and sites. In the first year (2019), the highest plant height was recorded in treatment T_3 (2 t ha^{-1} rice husk biochar with 100% recommended chemical fertilizer), which was statistically similar with treatment T_5 at Nilgonj site and treatments T_4, T_5 and T_6 at Latachapli site. In the second year (2020), the highest plant height was also recorded in treatment T_3, which was statistically similar to other tested treatments except for treatment T_1. The lowest plant height was recorded in T_1 (control) treatment in both the years and sites (Table 1).

Table 1 Effect of different organic materials integrated with chemical fertilizers on plant height

Treatments	Nilgonj		Latachapli	
	Plant height (cm)		Plant height (cm)	
	2019	2020	2019	2020
T_1	91.43 c	85.93 b	89.93 c	85.87 b
T_2	99.05 bc	99.13 ab	95.43 bc	94.00 ab
T_3	110.15 a	112.17 a	105.90 a	106.60 a
T_4	101.25 b	102.77 a	99.13 ab	101.63 a

T_5	103.85 ab	103.27 a	100.93 ab	104.83 a
T_6	98.90 bc	99.93 ab	97.27 abc	98.47 ab
CV (%)	5.93	5.41	6.09	5.13
Level of Significance	***	**	**	**
SE (±)	2.53	4.66	2.60	4.34

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.2 Effective tillers hill^{-1}

Different tested treatments significantly affected the number of effective tillers hill^{-1} in both the years and the sites. The T_3 treatment, which was statistically equivalent to the T_5 treatment at both sites, had the largest number of effective tillers hill^{-1} in the first year (2019). The T_3 treatment, which was statistically equivalent to the T_4, T_5, and T_6 treatments at the Nilgonj site and to the T_5 treatment at the Latachapli site, likewise produced the best results in the second year (2020). The T_1 (control) treatment was found to have the lowest effective tillers hill^{-1} at both sites (Table 2).

Table 2 Effect of different organic materials integrated with chemical fertilizers on effective tillers hill^{-1}

Treatments	Nilgonj		Latachapli	
	Effective tillers hill^{-1}		Effective tillers hill^{-1}	
	2019	2020	2019	2020
T_1	6.80 d	6.13 c	6.73 d	6.18 d
T_2	8.15 c	8.50 b	8.03 c	7.97 c
T_3	11.65 a	12.03 a	10.73 a	11.23 a
T_4	10.28 b	10.17 ab	9.70 b	10.00 b
T_5	11.05 ab	11.40 a	9.90 ab	10.17 ab
T_6	10.13 b	10.17 ab	9.47 b	9.77 b
CV (%)	5.20	6.78	6.93	6.55
Level of Significance	***	***	***	***
SE (±)	0.33	0.62	0.29	0.34

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.3 Filled grains panicle^{-1}

The quantity of filled grains panicle^{-1} was significantly affected by the various tested treatments in both the years and the sites. The highest number of filled grains panicle^{-1} was recorded in T_3 treatment, which was statistically similar to the T_4 and T_5 treatments in the first year at both sites but in second year it was similar to the T_2, T_3, T_4, T_5 and T_6 treatments at Nilgonj site and to the T_4, T_5 and T_6 treatments at Latachapli site. The T_1 (control) treatment had the lowest results in both years and sites (Table 3).

Table 3 Effect of different organic materials integrated with chemical fertilizers on filled grains panicle^{-1}

Treatments	Nilgonj	Latachapli

	Filled grains panicle^{-1}		Filled grains panicle^{-1}	
	2019	2020	2019	2020
T_1	95.45 c	90.80 b	92.39 d	89.71 d
T_2	108.98 b	108.57 a	102.70 c	101.11 c
T_3	118.83 a	119.10 a	116.13 a	118.20 a
T_4	112.88 ab	112.83 a	110.67 ab	112.44 ab
T_5	114.90 ab	115.40 a	111.80 ab	113.47 ab
T_6	109.20 b	109.97 a	107.47 bc	108.24 b
CV (%)	5.79	6.56	5.23	5.13
Level of Significance	***	***	***	***
SE (±)	0.51	0.08	0.95	0.86

Different letters in a column represents significant difference at p< 0.05, CV = Coefficient of variation, SE (±) = Standard error.

3.4 Thousand grain weight

There was no statistically significant effect was found on thousand grain weight by different tested treatments but the grain weight was increased for using the treatments over control in both the years and sites. The highest thousand grain weight was recorded in the T_3 treatment and the lowest weight was recorded in the T_1 (control) treatment in both the years and sites (Table 4).

Table 4 Effect of different organic materials integrated with chemical fertilizers on thousand grain weight

Treatments	Nilgonj		Latachapli	
	Thousand grain weight (g)		Thousand grain weight (g)	
	2019	2020	2019	2020
T_1	24.10	24.07	24.07	24.03
T_2	24.18	23.87	24.23	24.17
T_3	24.88	24.90	24.87	24.89
T_4	24.30	24.30	24.37	24.38
T_5	24.53	24.60	24.47	24.50
T_6	24.23	24.20	24.30	24.37
CV (%)	6.21	6.70	6.23	5.82
Level of Significance	NS	NS	NS	NS
SE (±)	0.24	0.34	0.64	0.56

NS = Not Significant

3.5 Grain yield

The various tested treatments had a substantial impact on the grain yield in both the years and the sites. The highest grain yield was recorded in the T_3 treatment (2 t ha^{-1} rice husk biochar along with 100% recommended chemical fertilizer) which was statistically similar to the T_2, T_4, T_5 and T_6 treatments in all cases except second year of the Nilgonj site where it was statistically similar to the T_4 and T_5 treatments. The lowest grain yield was recorded in the T_1 (control) treatment in both the years and sites (Table 5).

Table 5 Effect of different organic materials integrated with chemical fertilizers on grain yield

Treatments	Nilgonj	Latachapli

	Grain yield (t ha^{-1})		Grain yield (t ha^{-1})	
	2019	2020	2019	2020
T_1	2.90 b	2.45 c	2.51 b	2.41 b
T_2	3.26 ab	3.32 bc	2.95 ab	3.13 ab
T_3	4.16 a	4.43 a	3.36 a	3.76 a
T_4	3.43 ab	3.44 abc	3.15 ab	3.32 ab
T_5	3.57 ab	3.57 ab	3.19 a	3.41 a
T_6	3.31 ab	3.38 bc	3.12 ab	3.29 ab
CV (%)	6.73	5.78	5.64	6.97
Level of Significance	*	**	*	*
SE (±)	0.27	0.30	0.19	0.29

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

In Nilgonj site, the T_2, T_3, T_4, T_5 and T_6 treatments increased the grain yield by 12.41%, 43.45%, 18.28%, 23.10% and 14.14%, respectively in the first year, whereas 35.51%, 80.82%, 40.41%, 45.71% and 37.96%, respectively in the second year over control treatment (Fig. 1). In Latachapli site, the T_2, T_3, T_4, T_5 and T_6 treatments increased the grain yield by 17.53%, 33.86%, 25.50%, 27.09% and 24.30%, respectively in the first year whereas 29.88, 56.02%, 37.76%, 41.49% and 36.51%, respectively in the second year over control treatment (Fig. 2). The results clearly indicated that the T_3 treatment increased the highest amount grain yield and the T_2 treatment (100% recommended chemical fertilizer) gave the lowest result over the T_1 (control) treatment in both the years and sites.

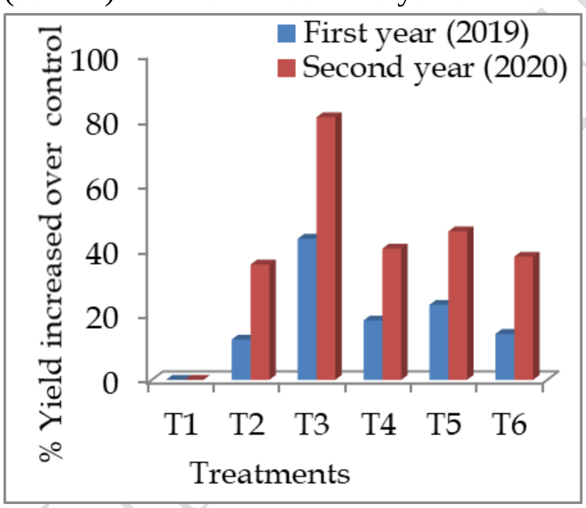

Fig. 1 Grain yield increased by different tested treatments over control

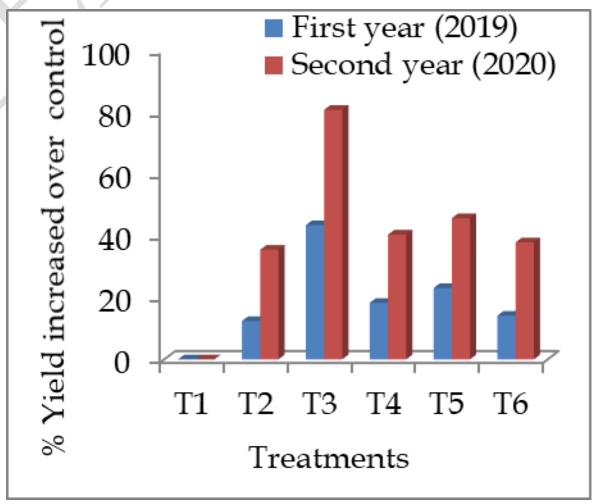

Fig. 2 Grain yield increased by different tested treatments over control

3.6 Na uptake

The Na uptake by straw was significantly varied due to the different tested treatments in both the years and sites. In Nilgonj site, the highest Na uptake was in T_2 treatment, which statistically identical to the other tested treatments except the T_1 (control) treatment in both the years. In Latachapli site, the Na uptake was highest in the T_6 treatment which statistically identical to the T_1, T_2, T_4 and T_5 treatments in the first year. In the second year, the highest Na uptake was found in T_2 treatment, which was statistically identical to the T_4, T_5 and T_6 treatments. The lowest Na uptake of straw was recorded in the T_1 treatment in both the years and sites (Table 6).

Table 6 Effect of different organic materials integrated with chemical fertilizers on straw Na uptake

Treatments	Nilgonj		Latachapli	
	Na uptake (kg ha^{-1})		Na uptake (kg ha^{-1})	
	2019	2020	2019	2020
T_1	75.63 b	69.67 b	72.24 ab	65.00 bc
T_2	87.20 a	86.09 a	77.77 ab	78.42 a
T_3	81.00 ab	76.41 ab	64.29 b	64.14 c
T_4	79.96 ab	73.97 ab	80.18 a	76.96 ab
T_5	80.78 ab	73.09 ab	77.49 ab	76.45 ab
T_6	80.95 ab	72.94 ab	82.92 a	77.46 a
CV (%)	3.95	2.25	2.61	1.82
Level of Significance	*	*	*	**
SE (±)	2.61	3.85	4.09	3.47

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.7 K uptake

The K uptake of straw influenced significantly by different tested treatments in both the years and sites. In Nilgonj site, the highest K uptake by straw was recorded in the T_3 treatment, which was statistically not identical to the other tested treatments in both the years. In Latachapli site, the highest K uptake by straw was recorded in the T_3 treatment, which was statistically identical to the T_4, T_5 and T_6 treatments in the first year whereas in second year it was statistically identical to the T_5 treatment. The lowest K uptake of straw was recorded in the T_1 (control) treatment in both the years and sites (Table 7).

Table 7 Effect of different organic materials integrated with chemical fertilizers on straw K uptake

Treatments	Nilgonj		Latachapli	
	K uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	2019	2020	2019	2020
T_1	10.40 c	9.45 d	8.88 b	7.64 c
T_2	18.11 bc	18.72 cd	13.54 b	15.69 bc
T_3	47.18 a	56.57 a	38.91 a	46.90 a
T_4	24.92 b	27.19 bc	20.54 ab	24.02 bc
T_5	31.20 b	32.68 b	25.69 ab	28.24 ab
T_6	22.85 bc	23.91 bc	19.30 ab	21.11 bc
CV (%)	3.53	2.48	2.46	2.59
Level of Significance	***	***	*	**
SE (±)	4.11	3.78	6.98	12.74

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.8 Straw Na and K ratio

The lowest Na and K ratio of straw was found in treatment T_3 and the highest Na and K ratio was recorded in the T_1 treatment in both the years and sites (Fig. 3-4). Treatment T_5, receiving 3 t ha^{-1} vermicompost along with chemical fertilizer with IPNS basis had the second lowest Na and K ratio in straw. The Na and K ratio of straw recorded from different tested treatments followed the order as $T_1>T_2>T_6>T_4>T_5>T_3$ in both the years and sites. Hence, treatment T_3 was the best treatment for making T. Aman rice more salt tolerance among all the tested treatments.

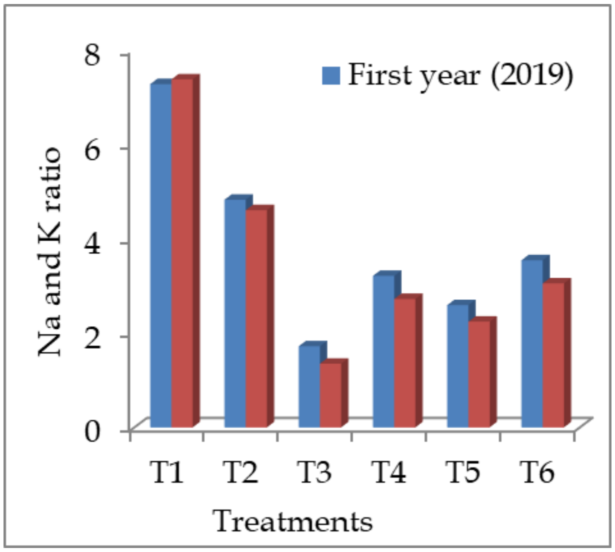

Fig. 3 Effect of different tested treatments on straw sodium and potassium ratio at Nilgonj site

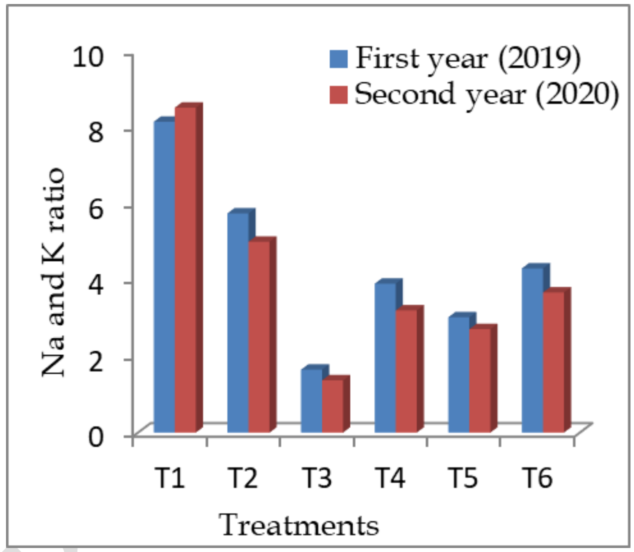

Fig. 4 Effect of different tested treatments on straw sodium and potassium ratio at Latachapli site

3.9 Soil EC

The various tested treatments had a significant impact on the EC of the post-harvest soil in both the years and the sites. The T_1 (control) treatment had the highest EC of post-harvest soil, and it was statistically similar to the T_2, T_4, T_5, and T_6 treatments across both years at the Nilgonj site, as well as to the T_2, T_4 and T_6 treatments across the first year at the Latachapli site, but only to the T_2 treatment across the second year. The T_2 treatment, which uses 100% recommended chemical fertilizer, had the second-highest soil EC measurement. The T_3 treatment had the lowest EC of post-harvest soil and was statistically different from all other tested treatments in both the years and sites (Table 8).

Table 8 Effect of different organic materials integrated with chemical fertilizers on post-harvest soil EC

Treatments	Nilgonj EC (dS m^{-1})		Latachapli EC (dS m^{-1})	
	2019	2020	2019	2020
T_1	5.12 a	5.21 a	5.40 a	5.46 a
T_2	4.78 a	4.72 a	4.97 ab	5.01 ab
T_3	3.44 b	3.34 b	3.73 c	3.60 c
T_4	4.71 a	4.66 a	4.85 ab	4.74 b
T_5	4.66 a	4.61 a	4.77 b	4.70 b
T_6	4.72 a	4.69 a	4.88 ab	4.82 b

CV (%)	2.42	3.01	3.16	2.69
Level of Significance	***	***	***	***
SE (±)	0.20	0.22	0.16	0.14

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

In the Nilgonj site, the EC of post-harvest soil reduced by 6.64%, 32.81%, 8.01%, 8.98% and 7.81% in first year whereas, 9.40%, 35.89%, 10.56%, 11.52% and 9.98% in second year in the T_2, T_3, T_4, T_5 and T_6 treatments, respectively over control treatment (Fig. 5). In the Latachapli site, the soil EC reduced by 7.96%, 30.93%, 10.19%, 11.67% and 9.63% in the first year, whereas 8.24%, 34.07%, 13.19%, 13.92% and 11.72% in second year in the T_2, T_3, T_4, T_5 and T_6 treatments, respectively over control treatment (Fig. 6). The highest reduction of post-harvest soil EC was recorded in the T_3 treatment and the lowest reduction was in the T_2 treatment (100% recommended chemical fertilizer) over the T_1 (control) treatment among all the tested treatments in both the years and sites. The highest reduction of post-harvest soil EC was in the rice husk biochar treated plots because of its highest capacity of Na^+ adsorption from soil solution than other tested organic and inorganic fertilizers. The continuous application of organic fertilizers results in the higher reduction of soil salinity in second year than first year (Fig. 5-6)

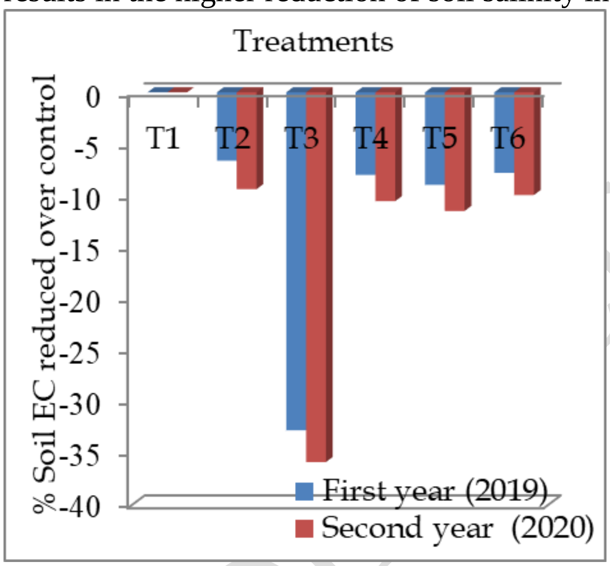

Fig. 5 Soil EC reduced by different tested treatments over control

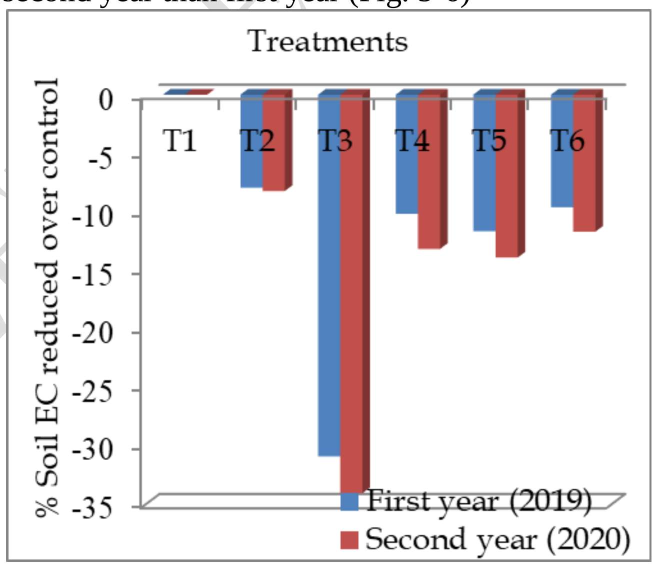

Fig. 6 Soil EC reduced by different tested treatments over control

3.10 Organic C

The post-harvest soil organic carbon considerably changed in response to the various tested treatments across both the years and the sites. The T_3 treatment (2 t ha^{-1} rice husk biochar together with 100% recommended chemical fertilizer) was found to have the highest organic C content of the post-harvest soil across both the years and sites. This treatment was statistically identical to the T_5 treatment, with the exception of the second year at the Latachapli site. In both the years and the sites, the T_1 (control) treatment had the lowest organic C content of post-harvest soil. The porous nature of rice husk biochar and its high chemically stable carbon content make it effective for carbon sequestration in soil, as evidenced by the greatest organic C levels discovered in the plots treated with rice husk biochar in both the years and sites. (Table 9).

Table 9 Effect of different organic materials integrated with chemical fertilizers on post-harvest soil organic C

Treatments	Nilgonj		Latachapli	
	Organic C (%)		Organic C (%)	
	2019	2020	2019	2020
T_1	0.68 c	0.59 c	0.65 c	0.64 c
T_2	0.67 c	0.64 c	0.64 c	0.65 c
T_3	0.87 a	0.89 a	0.85 a	0.88 a
T_4	0.77 b	0.79 b	0.73 b	0.75 b
T_5	0.82 a	0.83 a	0.79 a	0.78 b
T_6	0.76 b	0.79 b	0.70 b	0.74 b
CV (%)	4.05	3.66	2.67	3.26
Level of Significance	**	**	*	*
SE (±)	0.06	0.11	0.09	0.11

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.11 Total N

The total N content of the post-harvest soil was significantly impacted by the various tested treatments in both the years and sites. The T_3 treatment, which was statistically identical to the T_2, T_4, T_5, and T_6 treatments, had the highest total N content of post-harvest soil in both the years and sites. The T_5 treatment had the second-highest soil total N concentration. The T_1 (control) treatment had the lowest total N content of post-harvest soil in both the years and the sites (Table 10).

Table 10 Effect of different organic materials integrated with chemical fertilizers on post-harvest soil total N

Treatments	Nilgonj		Latachapli	
	Total N (%)		Total N (%)	
	2019	2020	2019	2020
T_1	0.06 b	0.06 b	0.04 b	0.05 b
T_2	0.07 ab	0.07 ab	0.05 ab	0.06 ab
T_3	0.08 a	0.09 a	0.07 a	0.08 a
T_4	0.07 ab	0.07 ab	0.05 ab	0.06 ab
T_5	0.08 a	0.08 ab	0.06 a	0.07 a
T_6	0.07 ab	0.07 ab	0.06 a	0.06 ab
CV (%)	3.34	3.14	2.96	2.97
Level of Significance	*	*	**	**
SE (±)	0.01	0.01	0.01	0.01

Different letters in a column represents significant difference at p< 0.05, CV = Coefficient of variation, SE (±) = Standard error.

3.12 Available P

The various tested treatments had a significant impact on the available P content of the post-harvest soil in both the years and the sites. The T_3 treatment had the highest post-harvest soil available P content and was statistically identical only to the T_5 treatment in both years at Nilgonj site whereas it was statistically identical to the T_2, T_4, T_5, and T_6 treatments in both years at Latachapli site. The T_1 (control) treatment had the lowest soil available P level across both the years and sites (Table 11).

Table 11 Effect of different organic materials integrated with chemical fertilizers on post-harvest soil available P content

Treatments	Nilgonj		Latachapli	
	Available P (mg kg^{-1})		Available P (mg kg^{-1})	
	2019	2020	2019	2020
T_1	14.63 c	13.97 c	14.00 c	13.80 b
T_2	15.07 c	15.15 bc	14.85 b	15.07 ab
T_3	16.85 a	17.33 a	16.37 a	16.93 a
T_4	15.20 bc	15.27 bc	15.25 b	15.40 ab
T_5	16.08 ab	16.13 ab	15.49 b	16.00 ab
T_6	15.07 c	15.17 bc	15.04 b	15.19 ab
CV (%)	2.08	3.16	2.49	3.03
Level of Significance	***	**	***	*
SE (±)	0.26	0.53	0.18	0.76

Different letters in a column represents significant difference at p< 0.05, CV = Coefficient of variation, SE (±) = Standard error.

3.13 Available S

The different tested treatments in both the years and the sites considerably affected the available S content of the post-harvest soil. The highest available S content of the post-harvest soil was found in T_3 treatment (2 t ha^{-1} rice husk biochar along with 100% recommended chemical fertilizer), and was statistically similar to the T_4 and T_5 treatments in both years of the Nilgonj site but not statistically similar to any treatment in the first year of the Latachapli site, and statistically similar to the T_2, T_4, T_5 and T_6 treatments in the second year of the Latachapli site. In both the years and the sites, the T_1 (control) treatment had the lowest available S content of post-harvest soil (Table 12).

Table 12 Effect of different organic materials integrated with chemical fertilizers on post-harvest soil available S content

Treatments	Nilgonj		Latachapli	
	Available S (mg kg^{-1})		Available S (mg kg^{-1})	
	2019	2020	2019	2020
T_1	13.85 c	13.33 b	12.91 d	11.87 b
T_2	14.50 bc	14.57 b	13.58 c	13.70 ab

T_3	15.78 a	17.23 a	15.24 a	15.90 a
T_4	14.78 abc	15.20 ab	14.36 b	14.43 ab
T_5	15.00 ab	15.23 ab	14.44 b	14.78 ab
T_6	14.31 bc	14.50 b	14.13 b	14.68 ab
CV (%)	2.72	3.87	2.26	3.44
Level of Significance	**	**	***	*
SE (±)	0.33	0.60	0.14	0.98

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.14 Exchangeable K

In both the years and the sites, the impact of the several tested treatments on the exchangeable K content of the post-harvest soil was statistically significant. The T_3 treatment had the highest exchangeable K content of the post-harvest and it was statistically equivalent to the T_4, T_5, and T_6 treatments in both the years of Nilgonj site and first year of Latachapli site. The T_3 treatment was also statistically identical to the T_2, T_4, T_5, and T_6 treatments in second year of Latachapli site. The T_1 (control) treatment had the lowest exchangeable K content of post-harvest soil in both the years and sites (Table 13).

Table 13 Effect of different organic materials integrated with chemical fertilizers on post-harvest soil exchangeable K content

Treatments	Nilgonj		Latachapli	
	Exchangeable K (meq $100g^{-1}$ soil)		Exchangeable K (meq $100g^{-1}$ soil)	
	2019	2020	2019	2020
T_1	0.30 b	0.28 b	0.23 c	0.22 b
T_2	0.31 ab	0.33 ab	0.28 bc	0.30 ab
T_3	0.37 a	0.38 a	0.35 a	0.37 a
T_4	0.33 ab	0.33 ab	0.32 ab	0.32 a
T_5	0.34 ab	0.35 a	0.33 ab	0.34 a
T_6	0.32 ab	0.32 ab	0.31 ab	0.32 a
CV (%)	3.79	2.65	3.14	2.78
Level of Significance	*	*	***	**
SE (±)	0.02	0.02	0.02	0.02

Different letters in a column represents significant difference at $p < 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.15 Exchangeable Na

The exchangeable Na content of the post-harvest soil varied significantly due to different tested treatments in both the years and sites. The T_1 (control) treatment had the highest exchangeable Na content of post-harvest soil and was statistically similar to the T_2 treatment in the both the years and sites except second year at Latachapli site. The T_3 treatment had the lowest exchangeable Na content of post-harvest soil and was statistically identical to the T_4, T_5, and T_6 treatments in both sites except second year at Latachapli site (Table 14).

Table 14 Effect of different organic materials integrated with chemical fertilizers on post-harvest soil exchangeable Na content

Treatments	Nilgonj		Latachapli	
	Exchangeable Na (meq $100g^{-1}$ soil)		Exchangeable Na (meq $100g^{-1}$ soil)	
	2019	2020	2019	2020
T_1	12.09 a	12.49 a	14.12 a	14.74 a
T_2	10.04 ab	10.15 ab	12.36 ab	12.61 b
T_3	6.71 c	6.44 c	8.80 c	8.16 d
T_4	8.23 bc	8.06 bc	10.47 bc	10.40 c
T_5	8.13 bc	8.03 bc	10.12 bc	10.07 c
T_6	8.32 bc	8.12 bc	11.00 bc	10.72 c
CV (%)	2.09	2.89	3.36	2.79
Level of Significance	***	**	**	***
SE (±)	0.73	0.94	0.85	0.44

Different letters in a column represents significant difference at $p< 0.05$, CV = Coefficient of variation, SE (±) = Standard error.

3.16 Correlation matrix between yield and yield parameters

The correlation matrix of grain yield and yield contributing parameters was done to find out the interrelationship between them. The values of correlation coefficient (r) with their level of significance are given in Table 15. The plant height, effective tillers $hill^{-1}$, filled grains $panicle^{-1}$, and thousand grain weight was positively and significantly correlated with grain yield in both the years and sites.

Table 15 Correlation between yield and yield parameters

Variables	Grain yield (t ha^{-1})			
	Nilgonj		Latachapli	
	2018-19	2019-20	2018-19	2019-20
Plant height	0.98***	0.99***	0.95**	0.96**
Effective tillers $hill^{-1}$	0.87*	0.91*	0.98***	0.97**
Panicle length	0.89*	0.93**	0.98***	0.98***
Filled grains $panicle^{-1}$	0.90*	0.92**	0.99***	0.97**
Thousand grain weight	0.97**	0.78^{NS}	0.85*	0.90*

* = Significant at 5% level, ** =Significant at 1% level, *** =Significant at 0.1% level, NS = Not significant.

4. DISCUSSION

The highest yield and yield contributing parameters were found in T_3 treatment and the lowest results of these parameters were found in T_1 treatment. It might be because rice husk biochar boosted salt tolerance in rice plant and nutrient supplying capacity in soil compared to other tested manures. Additionally, by lowering oxidative stress and boosting the activities of antioxidant enzymes, rice husk biochar could promote plant growth and biomass under salt stress. Different researchers came to similar conclusions. According to Chen *et al.* [13], the use of biochar increased the number of filled grain, productive panicle number, seed setting rate, and grain yield while also promoting the growth of tillers and plant height. According to Hossain *et al.* [14], the use of both organic and inorganic fertilizer together resulted in the best grain yield.

The T_3 treatment resulted in the lowest Na^+ and highest K^+ uptake of T. Aman rice straw. It might be due to using rice husk biochar increased the highest quantity of soil exchangeable K among the studied manures by lowering soil salinity. Therefore, the application of rice husk biochar boosted K^+ uptake because the greater K in soil effectively competed with soil Na for plant uptake. Numerous researchers came to similar conclusions. According to Olasekan *et al.* [15], applying rice husk biochar increased soil K. The T_3 treatment had the lowest Na^+ and K^+ ratio of any of the investigated treatments for T. Aman rice straw. The considerable decrease in Na^+ uptake, rise in K^+ uptake, and drop in the Na^+: K^+ ratio in rice plants could be attributed by the application of rice husk biochar. According to Ran *et al.* [16], adding biochar to rice plants considerably boosted K^+ concentration while decreasing Na^+ concentration and Na^+: K^+ ratio.

The application of manures integrated with chemical fertilizers resulted in an improvement in organic C, total N, exchangeable K, available S, and available P of soil. On the other hand, application of manures integrated with chemical fertilizers resulted in a drop in soil EC and exchangeable Na. The highest and the lowest soil EC and exchangeable Na were recorded in the T_1 and T_3 treatments, respectively. It might be because using rice husk biochar reduced soil salinity and soil Na by adsorbing Na^+. Akthar *et al.* [17] also demonstrated that the use of biochar decreased soil salinity and soil Na. The Organic C, total N, exchangeable K, available P, and available S values of post-harvest soil were highest and lowest in the T_3 and T_1 treatments, respectively. Several researchers reported the similar outcomes. Malik and Chauhan [18] noted that the soil N, P, and K concentrations were higher when organic and inorganic fertilizers were used in integrated way. Haefele *et al.* [19] observed that application of rice husk biochar enhanced total organic C, total N, C: N ratio, and available P and K in soil.

5. CONCLUSION

The effectiveness of integrated application of rice husk biochar, poultry manure, vermicompost and Mazim organic fertilizer with chemical fertilizers was studied through the field trials in T. Aman rice cultivation. The rice husk biochar integrated with chemical fertilizers performed better than other tested treatments in terms of T. Aman rice production and nutrient content. Besides these, 2 t ha^{-1} rice husk biochar integrated with 100% recommended chemical fertilizers provided the highest positive effects on post-harvest soil nutrient status than other tested treatments. The experiment's findings showed that the ability of rice husk biochar to reduce salinity by adsorbing sodium (Na^+) ions made it the most effective soil amendment for boosting soil fertility and crop productivity in saline soil. Therefore, rice husk biochar combined with chemical fertilizers is a novel method to promote crop productivity in saline soil that improves food security in Bangladesh.

REFERENCES

1. Salehin M, Chowdhury MMA, Clarke D, Mondal S, Nowreen S, Jahiruddin M, Haque A. Mechanisms and Drivers of Soil Salinity in Coastal Bangladesh. *Ecosystem Services for Well-Being in Deltas*, Nicholls R, Hutton C, Adger W, Hanson S, Rahman M and Salehin M (eds.). Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-319-71093-8_18. 2018.
2. Masum MR, Naher N, Paul AK, Alam AKMM. Effects of salinity on soil properties of coastal areas of (Babuganj, Bakerganj, Gournadi and Kalapara) in Bangladesh. International Journal of Bio-resource and Stress Management. 2017; 8(5):684-691.
3. Haque SA. Salinity problems and crop production in coastal regions of Bangladesh. Pakistan Journal of Botany. 2006; 38(5):1359-1365.
4. Miah MY, Kamal MZU, Salam MA, Islam MS. Impact of salinity intrusion on agriculture of SouthwestBangladesh- A review. International Journal of Agricultural Policy and Research. 2020; 8 (2):40-47.
5. Sanwal SK, Lakminarayana K, Yadav RK, Rai N, Yadav DS, Mousumi B. Effect of organic materials on soil fertility, growth, physiology, yield and quality of turmeric. Indian Journal of Horticulture. 2007; 64(4):444-449.
6. Jeptoo A, Aguyoh JN, Saidi M. Improving carrot yield and quality through the use of bio-slurry manure. Sustainable Agriculture Research. 2013; 2(1):164-172.
7. Brady NC, Weil RC. The Nature and Properties of Soils. 15th Edition, Pearson, New York. 2017.
8. Haque MA, Jahiruddin M, Islam MS, Rahman MM, Saleque MA. Effect of bioslurry on the fertility and productivity of wheat for wheat-rice cropping system. Agricultural Research. 2018; 7(4):432-442.
9. Bangladesh Population Census 2001. Bangladesh Bureau of Statistics; Cultural survey report of Kalapara Upazila. 2007.
10. Al-Karaki G. Growth, sodium, and potassium uptake and translocation in salt stressed tomato. Journal of Plant Nutrition. 2000; 23:369-379.
11. Hossin MS, Paul AK, Hoque MF, Mukta MA, Hossain MD. Estimation of fertility status of coastal soils for agricultural planning in Bangladesh. Haya: The Saudi Journal of Life Science. 2022; 7(5):142-150.
12. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research-An International Rice Research Institute Book. Second Edition. A Wiley-Inter Science Publication, John Wiley & Sons, New York. 1984.
13. Chen X, Yang S, Ding J, Jiang Z, Sun X. Effects of biochar addition on rice growth and yield under water-saving irrigation. Water. 2021; 13:209.
14. Hossain MN, Sarker UK, Uddin MR, Rehana S, Hoque MMI, Islam MA. Effects of bio-slurry with chemical fertilizer on the performance of some high yielding varieties of boro rice (*Oryza sativa* L.). Archives of Agriculture and Environmental Science. 2018; 3(2):109-115.

15. Olasekan AA, Agbede TM, Aboyeji C, Dunsin O, Simeon VT. Effects of biochar and poultry manure on soil characteristics and the yield of radish. Scientia Horticulturae. 2019; 243:457-463.

16. Ran C, Gulaqa A, Zhu J, Wang X, Zhang S, Geng Y, Guo L, Jin F, Shao X. Benefits of biochar for improving ion contents, cell membrane permeability, leaf water status and yield of rice under saline-sodic paddy field condition. Journal of Plant Growth Regulation. 2020; 39:370-377.

17. Akthar SS, Andersen M, Liu F. Biochar mitigates salinity stress in potato. Journal of Agronomy and Crop Science. 2015; 21(5):368-378.

18. Malik SS, Chauhan RC. Impact of organic farming on soil chemical properties. Journal of International Academic Research for Multidisciplinary. 2014; 2(7):349-360.

19. Haefele SM, Konboon Y, Wongboonm W, Amaranthe S, Maarifat AA. Effects and fate of biochar from rice residues in rice-based systems. Field Crops Research. 2011; 121(3):430-440.