

## **Improving Salinity Tolerance in Rice by Integrated Use of Organic and Inorganic Fertilizers for Enhancing Food Security in Bangladesh**

### **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<sub>1</sub>: Control (no organic material and chemical fertilizer), T<sub>2</sub>: 100% recommended chemical fertilizer, T<sub>3</sub>: 2 t ha<sup>-1</sup> rice husk biochar + 100% recommended chemical fertilizer, T<sub>4</sub>: 3 t ha<sup>-1</sup> poultry manure + chemical fertilizer with IPNS basis, T<sub>5</sub>: 3 t ha<sup>-1</sup> vermicompost + chemical fertilizer with IPNS basis, T<sub>6</sub>: 3 t ha<sup>-1</sup> 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<sub>3</sub> 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<sub>3</sub> 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. To stop exploiting nutrients, 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. 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 [3]. Organic fertilizers act as a source of nutrients and are beneficial for soil improvement [4]. Organic matter serves as a reservoir for plant nutrients, mainly N, P and S, and improves the cation exchange capacity of the soil [5]. 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 [6]. 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 [7]. 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 BRR1 dhan52. Six treatments such as T<sub>1</sub> = Control (no organic matter or chemical fertilizers), T<sub>2</sub> = 100% recommended chemical fertilizers (NPKS), T<sub>3</sub> = 2 t ha<sup>-1</sup> rice husk biochar + 100% recommended chemical fertilizers (NPKS), T<sub>4</sub> = 3 t ha<sup>-1</sup> poultry manure + chemical fertilizers (NPKS) with IPNS basis, T<sub>5</sub> = 3 t ha<sup>-1</sup> vermicompost + chemical fertilizers (NPKS) with IPNS basis, T<sub>6</sub> = 3 t ha<sup>-1</sup> 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. 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. Two times of weeding were carried out at 25 and 45 days after transplanting to keep the soil weed-free. 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<sup>-1</sup>, filled grains panicle<sup>-1</sup>, thousand grain weight of T. Aman rice were recorded according to standard procedures. The T. Aman rice straw samples were collected after each harvest and analyzed for Na and K uptake according to standard procedures [8]. 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 [9]. Statistical computer program STAR (Statistical Tools for Agricultural Research) was used to analyze the soil and crop data [10]. 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<sub>3</sub> (2 t ha<sup>-1</sup> rice husk biochar

with 100% recommended chemical fertilizer), which was statistically similar with treatment T<sub>5</sub> at Nilgonj site and treatments T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> at Latachapli site. In the second year (2020), the highest plant height was also recorded in treatment T<sub>3</sub>, which was statistically similar to other tested treatments except for treatment T<sub>1</sub>. The lowest plant height was recorded in T<sub>1</sub> (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 <sub>1</sub>	91.43 c	85.93 b	89.93 c	85.87 b
T <sub>2</sub>	99.05 bc	99.13 ab	95.43 bc	94.00 ab
T <sub>3</sub>	110.15 a	112.17 a	105.90 a	106.60 a
T <sub>4</sub>	101.25 b	102.77 a	99.13 ab	101.63 a
T <sub>5</sub>	103.85 ab	103.27 a	100.93 ab	104.83 a
T <sub>6</sub>	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<sup>-1</sup>

Different tested treatments significantly affected the number of effective tillers hill<sup>-1</sup> in both the years and the sites. The T<sub>3</sub> treatment, which was statistically equivalent to the T<sub>5</sub> treatment at both sites, had the largest number of effective tillers hill<sup>-1</sup> in the first year (2019). The T<sub>3</sub> treatment, which was statistically equivalent to the T<sub>4</sub>, T<sub>5</sub>, and T<sub>6</sub> treatments at the Nilgonj site and to the T<sub>5</sub> treatment at the Latachapli site, likewise produced the best results in the second year (2020). The T<sub>1</sub> (control) treatment was found to have the lowest effective tillers hill<sup>-1</sup> at both sites (Table 2).

**Table 2** Effect of different organic materials integrated with chemical fertilizers on effective tillers hill<sup>-1</sup>

Treatments	Nilgonj		Latachapli	
	Effective tillers hill <sup>-1</sup>		Effective tillers hill <sup>-1</sup>	
	2019	2020	2019	2020
T <sub>1</sub>	6.80 d	6.13 c	6.73 d	6.18 d
T <sub>2</sub>	8.15 c	8.50 b	8.03 c	7.97 c
T <sub>3</sub>	11.65 a	12.03 a	10.73 a	11.23 a
T <sub>4</sub>	10.28 b	10.17 ab	9.70 b	10.00 b
T <sub>5</sub>	11.05 ab	11.40 a	9.90 ab	10.17 ab
T <sub>6</sub>	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 ( $\pm$ )	0.33	0.62	0.29	0.34
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Different letters in a column represents significant difference at  $p < 0.05$ , CV = Coefficient of variation, SE ( $\pm$ ) = Standard error.

### 3.3 Filled grains panicle<sup>-1</sup>

The quantity of filled grains panicle<sup>-1</sup> was significantly affected by the various tested treatments in both the years and the sites. The highest number of filled grains panicle<sup>-1</sup> was recorded in T<sub>3</sub> treatment, which was statistically similar to the T<sub>4</sub> and T<sub>5</sub> treatments in the first year at both sites but in second year it was similar to the T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments at Nilgonj site and to the T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments at Latachapli site. The T<sub>1</sub> (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<sup>-1</sup>

Treatments	Nilgonj		Latachapli	
	Filled grains panicle <sup>-1</sup>		Filled grains panicle <sup>-1</sup>	
	2019	2020	2019	2020
T <sub>1</sub>	95.45 c	90.80 b	92.39 d	89.71 d
T <sub>2</sub>	108.98 b	108.57 a	102.70 c	101.11 c
T <sub>3</sub>	118.83 a	119.10 a	116.13 a	118.20 a
T <sub>4</sub>	112.88 ab	112.83 a	110.67 ab	112.44 ab
T <sub>5</sub>	114.90 ab	115.40 a	111.80 ab	113.47 ab
T <sub>6</sub>	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 ( $\pm$ )	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 ( $\pm$ ) = 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<sub>3</sub> treatment and the lowest weight was recorded in the T<sub>1</sub> (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 <sub>1</sub>	24.10	24.07	24.07	24.03
T <sub>2</sub>	24.18	23.87	24.23	24.17
T <sub>3</sub>	24.88	24.90	24.87	24.89
T <sub>4</sub>	24.30	24.30	24.37	24.38
T <sub>5</sub>	24.53	24.60	24.47	24.50
T <sub>6</sub>	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 ( $\pm$ )	0.24	0.34	0.64	0.56

NS = Not Significant

### 3.5 Grain yield

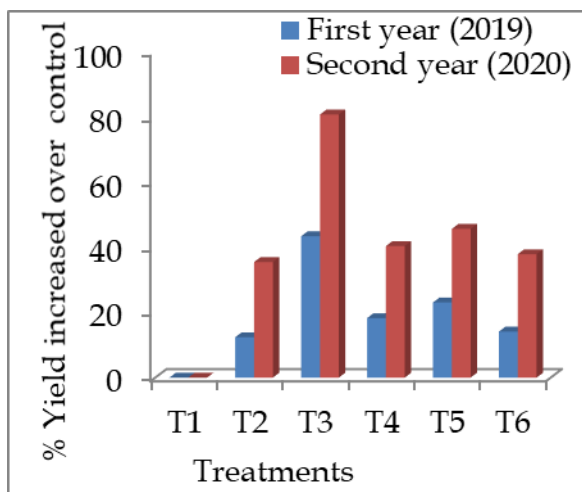
The various tested treatments had a substantial impact on the grain yield in both the years and the sites. The highest grain yield was recorded in the T<sub>3</sub> treatment (2 t ha<sup>-1</sup> rice husk biochar along with 100% recommended chemical fertilizer) which was statistically similar to the T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments in all cases except second year of the Nilgonj site where it was statistically similar to the T<sub>4</sub> and T<sub>5</sub> treatments. The lowest grain yield was recorded in the T<sub>1</sub> (control) treatment in both the years and sites (Table 5).

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

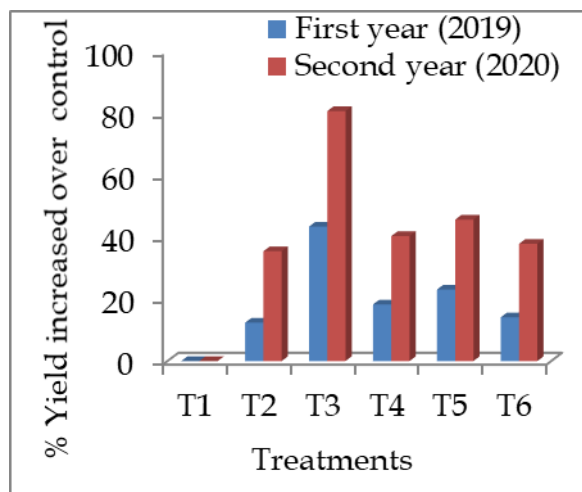
Treatments	Nilgonj		Latachapli	
	Grain yield (t ha <sup>-1</sup> )		Grain yield (t ha <sup>-1</sup> )	
	2019	2020	2019	2020
T <sub>1</sub>	2.90 b	2.45 c	2.51 b	2.41 b
T <sub>2</sub>	3.26 ab	3.32 bc	2.95 ab	3.13 ab
T <sub>3</sub>	4.16 a	4.43 a	3.36 a	3.76 a
T <sub>4</sub>	3.43 ab	3.44 abc	3.15 ab	3.32 ab
T <sub>5</sub>	3.57 ab	3.57 ab	3.19 a	3.41 a
T <sub>6</sub>	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 ( $\pm$ )	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 ( $\pm$ ) = Standard error.

In Nilgonj site, the T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> 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<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> 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<sub>3</sub> treatment increased the highest amount grain yield and the T<sub>2</sub> treatment (100% recommended chemical fertilizer) gave the lowest result over the T<sub>1</sub> (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<sub>2</sub> treatment, which statistically identical to the other tested treatments except the T<sub>1</sub> (control) treatment in both the years. In Latachapli site, the Na uptake was highest in the T<sub>6</sub> treatment which statistically identical to the T<sub>1</sub>, T<sub>2</sub>, T<sub>4</sub> and T<sub>5</sub> treatments in the first year. In the second year, the highest Na uptake was found in T<sub>2</sub> treatment, which was statistically identical to the T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments. The lowest Na uptake of straw was recorded in the T<sub>1</sub> 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 <sup>-1</sup> )		Na uptake (kg ha <sup>-1</sup> )	
	2019	2020	2019	2020
T <sub>1</sub>	75.63 b	69.67 b	72.24 ab	65.00 bc
T <sub>2</sub>	87.20 a	86.09 a	77.77 ab	78.42 a
T <sub>3</sub>	81.00 ab	76.41 ab	64.29 b	64.14 c
T <sub>4</sub>	79.96 ab	73.97 ab	80.18 a	76.96 ab
T <sub>5</sub>	80.78 ab	73.09 ab	77.49 ab	76.45 ab
T <sub>6</sub>	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<sub>3</sub> 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<sub>3</sub> treatment, which was statistically identical

to the T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments in the first year whereas in second year it was statistically identical to the T<sub>5</sub> treatment. The lowest K uptake of straw was recorded in the T<sub>1</sub> (control) treatment in both the years and sites (Table 7).

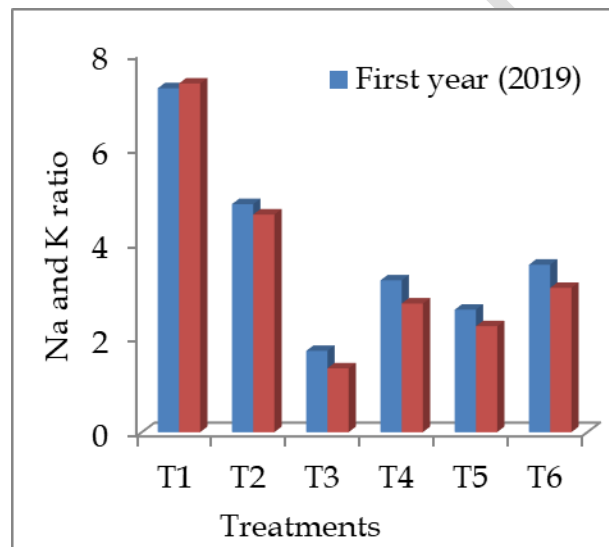
**Table 7** Effect of different organic materials integrated with chemical fertilizers on straw K uptake

Treatments	Nilgonj		Latachapli	
	K uptake (kg ha <sup>-1</sup> )		K uptake (kg ha <sup>-1</sup> )	
	2019	2020	2019	2020
T <sub>1</sub>	10.40 c	9.45 d	8.88 b	7.64 c
T <sub>2</sub>	18.11 bc	18.72 cd	13.54 b	15.69 bc
T <sub>3</sub>	47.18 a	56.57 a	38.91 a	46.90 a
T <sub>4</sub>	24.92 b	27.19 bc	20.54 ab	24.02 bc
T <sub>5</sub>	31.20 b	32.68 b	25.69 ab	28.24 ab
T <sub>6</sub>	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

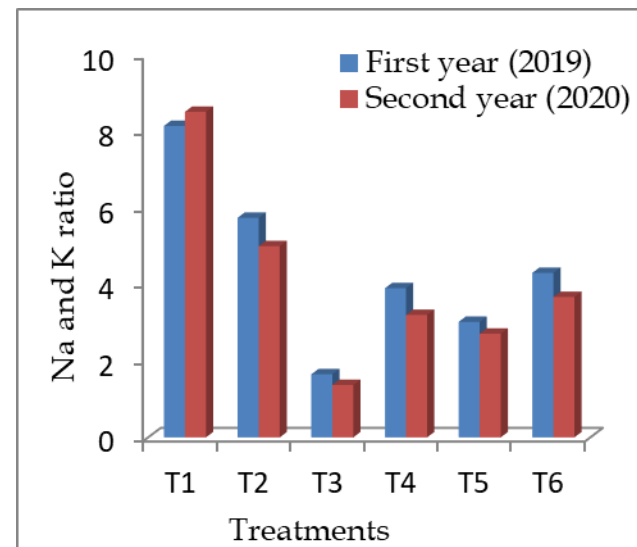
Different letters in a column represents significant difference at  $p < 0.05$ , CV = Coefficient of variation, SE (±) = Standard error.

### 3.8 Straw Na and K ratio

The lowest Na and K ratio of straw was found in treatment T<sub>3</sub> and the highest Na and K ratio was recorded in the T<sub>1</sub> treatment in both the years and sites (Fig. 3-4). Treatment T<sub>5</sub>, receiving 3 t ha<sup>-1</sup> 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<sub>1</sub>>T<sub>2</sub>>T<sub>6</sub>>T<sub>4</sub>>T<sub>5</sub>>T<sub>3</sub> in both the years and sites. Hence, treatment T<sub>3</sub> 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

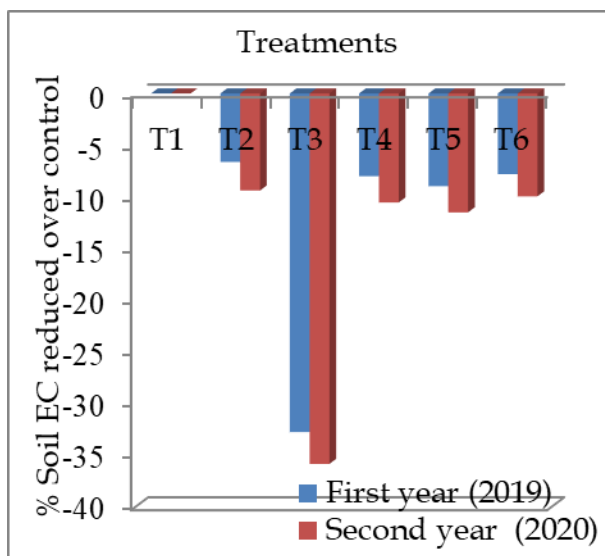
The various tested treatments had a significant impact on the EC of the post-harvest soil in both the years and the sites. The T<sub>1</sub> (control) treatment had the highest EC of post-harvest soil, and it was statistically similar to the T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, and T<sub>6</sub> treatments across both years at the Nilgonj site, as well as to the T<sub>2</sub>, T<sub>4</sub> and T<sub>6</sub> treatments across the first year at the Latachapli site, but only to the T<sub>2</sub> treatment across the second year. The T<sub>2</sub> treatment, which uses 100% recommended chemical fertilizer, had the second-highest soil EC measurement. The T<sub>3</sub> 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

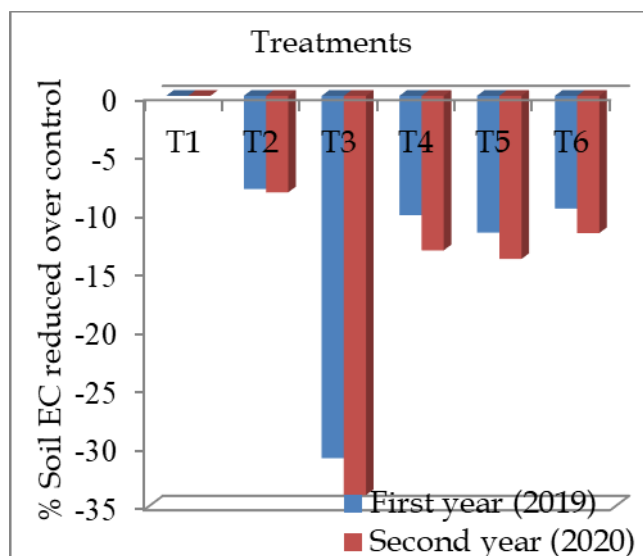
Treatments	Nilgonj		Latachapli	
	EC (dS m <sup>-1</sup> )		EC (dS m <sup>-1</sup> )	
	2019	2020	2019	2020
T <sub>1</sub>	5.12 a	5.21 a	5.40 a	5.46 a
T <sub>2</sub>	4.78 a	4.72 a	4.97 ab	5.01 ab
T <sub>3</sub>	3.44 b	3.34 b	3.73 c	3.60 c
T <sub>4</sub>	4.71 a	4.66 a	4.85 ab	4.74 b
T <sub>5</sub>	4.66 a	4.61 a	4.77 b	4.70 b
T <sub>6</sub>	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<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> 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<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments, respectively over control treatment (Fig. 6). The highest reduction of post-harvest soil EC was recorded in the T<sub>3</sub> treatment and the lowest reduction was in the T<sub>2</sub> treatment (100% recommended chemical fertilizer) over the T<sub>1</sub> (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<sup>+</sup> 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<sub>3</sub> treatment (2 t ha<sup>-1</sup> 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<sub>5</sub> treatment, with the exception of the second year at the Latachapli site. In both the years and the sites, the T<sub>1</sub> (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 <sub>1</sub>	0.68 c	0.59 c	0.65 c	0.64 c
T <sub>2</sub>	0.67 c	0.64 c	0.64 c	0.65 c
T <sub>3</sub>	0.87 a	0.89 a	0.85 a	0.88 a
T <sub>4</sub>	0.77 b	0.79 b	0.73 b	0.75 b
T <sub>5</sub>	0.82 a	0.83 a	0.79 a	0.78 b

T <sub>6</sub>	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<sub>3</sub> treatment, which was statistically identical to the T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, and T<sub>6</sub> treatments, had the highest total N content of post-harvest soil in both the years and sites. The T<sub>5</sub> treatment had the second-highest soil total N concentration. The T<sub>1</sub> (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 <sub>1</sub>	0.06 b	0.06 b	0.04 b	0.05 b
T <sub>2</sub>	0.07 ab	0.07 ab	0.05 ab	0.06 ab
T <sub>3</sub>	0.08 a	0.09 a	0.07 a	0.08 a
T <sub>4</sub>	0.07 ab	0.07 ab	0.05 ab	0.06 ab
T <sub>5</sub>	0.08 a	0.08 ab	0.06 a	0.07 a
T <sub>6</sub>	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<sub>3</sub> treatment had the highest post-harvest soil available P content and was statistically identical only to the T<sub>5</sub> treatment in both years at Nilgonj site whereas it was statistically identical to the T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, and T<sub>6</sub> treatments in both years at Latachapli site. The T<sub>1</sub> (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 <sup>-1</sup> )		Available P (mg kg <sup>-1</sup> )	
	2019	2020	2019	2020

T <sub>1</sub>	14.63 c	13.97 c	14.00 c	13.80 b
T <sub>2</sub>	15.07 c	15.15 bc	14.85 b	15.07 ab
T <sub>3</sub>	16.85 a	17.33 a	16.37 a	16.93 a
T <sub>4</sub>	15.20 bc	15.27 bc	15.25 b	15.40 ab
T <sub>5</sub>	16.08 ab	16.13 ab	15.49 b	16.00 ab
T <sub>6</sub>	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<sub>3</sub> treatment (2 t ha<sup>-1</sup> rice husk biochar along with 100% recommended chemical fertilizer), and was statistically similar to the T<sub>4</sub> and T<sub>5</sub> 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<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments in the second year of the Latachapli site. In both the years and the sites, the T<sub>1</sub> (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 <sup>-1</sup> )		Available S (mg kg <sup>-1</sup> )	
	2019	2020	2019	2020
T <sub>1</sub>	13.85 c	13.33 b	12.91 d	11.87 b
T <sub>2</sub>	14.50 bc	14.57 b	13.58 c	13.70 ab
T <sub>3</sub>	15.78 a	17.23 a	15.24 a	15.90 a
T <sub>4</sub>	14.78 abc	15.20 ab	14.36 b	14.43 ab
T <sub>5</sub>	15.00 ab	15.23 ab	14.44 b	14.78 ab
T <sub>6</sub>	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<sub>3</sub> treatment had the highest exchangeable K content of the post-harvest and it was statistically equivalent to the T<sub>4</sub>, T<sub>5</sub>, and T<sub>6</sub> treatments in both the years of Nilgonj site and first year of Latachapli site. The T<sub>3</sub> treatment was also statistically identical to the T<sub>2</sub>, T<sub>4</sub>, T<sub>5</sub>, and T<sub>6</sub> treatments in second year of Latachapli

site. The T<sub>1</sub> (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 <sup>-1</sup> soil)		Exchangeable K (meq 100g <sup>-1</sup> soil)	
	2019	2020	2019	2020
T <sub>1</sub>	0.30 b	0.28 b	0.23 c	0.22 b
T <sub>2</sub>	0.31 ab	0.33 ab	0.28 bc	0.30 ab
T <sub>3</sub>	0.37 a	0.38 a	0.35 a	0.37 a
T <sub>4</sub>	0.33 ab	0.33 ab	0.32 ab	0.32 a
T <sub>5</sub>	0.34 ab	0.35 a	0.33 ab	0.34 a
T <sub>6</sub>	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<sub>1</sub> (control) treatment had the highest exchangeable Na content of post-harvest soil and was statistically similar to the T<sub>2</sub> treatment in the both the years and sites except second year at Latachapli site. The T<sub>3</sub> treatment had the lowest exchangeable Na content of post-harvest soil and was statistically identical to the T<sub>4</sub>, T<sub>5</sub>, and T<sub>6</sub> 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 <sup>-1</sup> soil)		Exchangeable Na (meq 100g <sup>-1</sup> soil)	
	2019	2020	2019	2020
T <sub>1</sub>	12.09 a	12.49 a	14.12 a	14.74 a
T <sub>2</sub>	10.04 ab	10.15 ab	12.36 ab	12.61 b

T <sub>3</sub>	6.71 c	6.44 c	8.80 c	8.16 d
T <sub>4</sub>	8.23 bc	8.06 bc	10.47 bc	10.40 c
T <sub>5</sub>	8.13 bc	8.03 bc	10.12 bc	10.07 c
T <sub>6</sub>	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<sup>-1</sup>, filled grains panicle<sup>-1</sup>, 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 <sup>-1</sup> )			
	Nilgonj		Latachapli	
	2018-19	2019-20	2018-19	2019-20
Plant height	0.98***	0.99***	0.95**	0.96**
Effective tillers hill <sup>-1</sup>	0.87*	0.91*	0.98***	0.97**
Panicle length	0.89*	0.93**	0.98***	0.98***
Filled grains panicle <sup>-1</sup>	0.90*	0.92**	0.99***	0.97**
Thousand grain weight	0.97**	0.78 <sup>NS</sup>	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<sub>3</sub> treatment and the lowest results of these parameters were found in T<sub>1</sub> 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.* [11], 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.* [12], the use of both organic and inorganic fertilizer together resulted in the best grain yield.

The T<sub>3</sub> treatment resulted in the lowest Na<sup>+</sup> and highest K<sup>+</sup> 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<sup>+</sup> 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.* [13], applying rice husk biochar increased soil K. The T<sub>3</sub> treatment had the lowest Na<sup>+</sup> and K<sup>+</sup> ratio of any of the investigated treatments for T. Aman rice straw. The considerable decrease in Na<sup>+</sup> uptake, rise in K<sup>+</sup> uptake, and drop in the Na<sup>+</sup>: K<sup>+</sup> ratio in rice plants could be attributed by

the application of rice husk biochar. According to Ran *et al.* [14], 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.* [15] 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 [16] noted that the soil N, P, and K concentrations were higher when organic and inorganic fertilizers were used in integrated way. Haefele *et al.* [17] 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,  $2 \text{ t ha}^{-1}$  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.

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