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Use of organic amendment for amelioration of salinity stress in transplanted aman rice cv. BRRI dhan41

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ABSTRACT

Salinity causes unfavorable environment that restricts normal growth, development and yield of crops. Application of organic amendments is one of the agronomic practices to ameliorate salt stress in plants. An experiment was carried out at the net house of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh during July to December 2013 to minimize the adverse effects of soil salinity in transplanted Aman rice cv. BRRI dhan41 through application of organic amendments. The sodium chloride induced salinity levels of 0, 25 and 50 mM were imposed at tillering stage of the crop. Four organic amendments viz. cowdung, compost, green manure (*Sesbania rostrata*) and poultry manure @ 10 t ha^{-1} were applied to ameliorate the salinity stress effect. The experiment was conducted in chari and laid out in completely randomized design. Results reveal that the different levels of salinity showed significant adverse effect on plant height, number of tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length, number of total spikelets panicle^{-1}, 1000-grain weight, grain yield, biological yield and harvest index (HI). All the plants were affected badly when they were exposed salinity level of 50 mM NaCl. The highest grain yield (4.93 t ha^{-1}) and straw yield (5.47 t ha^{-1}) were obtained from the control condition where no salinity was imposed. Grain yield decreased gradually with the increase in level of salinity stress. The salinity stress of 50 mM NaCl yielded the lowest grain yield (4.18 t ha^{-1}). Application of organic amendments helped to ameliorate salinity stress compared to those without organic amendments. Grain yield reduction at 50 mM salinity level was 32.72% compared to control, which was reduced to only 5.31, 9.41, 9.41 and 26.18% by the application of poultry manure, compost, green manure and cowdung, respectively @ 10 t ha^{-1}. Similar amelioration effect was also observed in case of straw yield. The results of the study conclude that salinity stress condition for growing BRRI dhan41 could successfully be ameliorated to some extent through application of organic amendments like poultry manure, green manure and cowdung. However, no substantial ameliorative effect of salinity stress was found with the application of compost.

Keywords: Salinity**,** organic amendments, aman rice.

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INTRODUCTION

In Bangladesh, rice dominates over all other crops and covers 77% of the total cropped area and 93% farmers grow rice (BBS, 2012). To meet the consequently increasing demand, food production must be increased either by increasing arable land or by increasing yield of crops. However, the arable land in the densely populated countries of South and Southeast Asia like Bangladesh is very limited. So, food production must be increased by increasing per unit area yield in order to meet the food demand of ever increasing population.

Soil salinity, drought, high and low temperatures, heavy metals and oxidative stress are serious threats to agriculture, resulting in deterioration of the environment. Salinity stress in nature is caused from the accumulation of soluble salts in the root zone of plants. A soil is said to be saline when electrical conductivity of the soil is more than 4 dSm^{-1} (deci Siemens meter^{-1}). Soil salinity causes direct harms in plants by osmotic stress (high salt in soil makes it harder for plant roots to extract water) and ionic toxicity mostly of sodium and chloride. Thus, salinity stress affects the

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metabolism of plant cells, leading to severe crop damage and productivity. Every year more and more lands become nonproductive owing to salt accumulation. Salinization plays a major role in land degradation. It affects 19.5% of irrigated land and 2.1% of dry land agriculture in the world (Jaleel et al., 2007).

The coastal areas of Bangladesh cover about 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity (Haque, 2006; Uddin et al., 2011). According to salinity survey findings and salinity monitoring information, about 1.02 million hectares (about 70%) of the cultivated lands in coastal areas are affected by varying degrees of soil salinity. About 0.282, 0.297, 0.191, 0.450 and 0.087 million hectares of lands are affected by very slight, slight, moderate, strong and very strong salinity respectively (Haque, 2006). According to SRDI (Soil Resource Development Institute) 750380 hectares of land was identified as salt-affected in 1973 and the amount of salt-affected land stood at 1000056 hectares in 2010. The upward trend in salinity intrusion has been hampering crop production, particularly *Boro* rice in the dry season.

Soil salinity is a major process of land degradation that decreases soil fertility and crop productivity. There is a report that coastal regions of Bangladesh are quite low in soil fertility (Haque, 2006). Appropriate management strategies and techniques with suitable varieties having higher yield potential could contribute to the improvement of crop production in the coastal areas of Bangladesh. Both the organic and inorganic amendments are found to be effective in the amelioration of saline soils. The best means of maintaining soil fertility, productivity and salt tolerance could be through addition of organic manures. Various organic amendments such as farmyard manure, compost, poultry manure and mulch can be used for the amelioration of saline soils. Organic amendments improve physical, chemical and biological properties of soils under saline conditions. There are evidences that soil amendments with organic manures reduce the toxic effects of salinity in various plant species (Idrees et al., 2004; Abou El-Magd et al., 2008; Leithy et al., 2010; Raafat and Thawrat, 2011).

There exists tremendous variation for salt tolerance within species in rice (Sabouri and Biabani, 2009). In general, rice shows variability in sensitivity towards excess salinity at various developmental stages during its life cycle. It is considered relatively tolerant to salinity at the germination stage while the young seedling stage and early reproductive stages, i.e. panicle initiation and pollination are the most salinity-sensitive growth stages, directly affecting the crop yield (Heenan et al., 1988; Khatun et al., 1995; Zeng et al., 2001). So to feed the world, there is a need to re-engineer rice to harvest better yields (Surridge, 2002).

To improve the yield of transplanted *Aman* rice in the salinity affected coastal areas of the country, BRRI has developed some salinity tolerant rice cultivars such as BRRI dhan40, BRRI dhan41, BRRI dhan53, BRRI dhan54 and BRRI dhan55 (BRRI, 2010). However, soil salinity management did not receive proper attention in the past, but recently emphasis has been given on this issue. Sustainable and profitable productions of crops in salt-affected areas are possible if appropriate soil management practices are followed. Therefore, the present study was undertaken with the following objectives:

- To evaluate the yield of transplanted *Aman* rice cv. BRRI dhan41 under salinity stress.
- To improve the yield of transplanted *Aman* rice cv. BRRI dhan41 under salinity stress through application of organic amendment.
- To suggest an approach for the improvement of production of transplanted *Aman* rice under salinity stress condition through application of appropriate organic amendment.

MATERIALS AND METHODS

Study area

The research work was carried out at the net house of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh. Experimental site is located at 24^0 N latitude and 94^0 E longitude of 18 meter high from the sea level. The experimental site belongs to the non-calcareous dark grey flood plain soil under the agro-ecological region of the Old Brahmaputra

Floodplain, AEZ 9 (UNDP and FAO, 1998). The soil was collected within 6 cm from the top of soil

The experimental soil was loamy in texture having a soil pH value of 6.43, moderate in organic matter content. After collection, the soil was sun dried and loosened and all the inert matter was removed. After that the *Chari* (concrete pots) was filled with the soil.

The climate of the experimental area is under the sub-tropical climate which is characterized by high temperature, high humidity and heavy precipitation with occasional gusty wind from April to September and scanty rainfall associated with moderately low temperature during October to March. Weather data of experimental site during the period (July to December) have been presented in Table 1.

Table 1
Average monthly air temperature, rainfall, relative humidity, sunshine and solar radiation in June 2013 to December 2013.

Month	Monthly Average air temperature (^oC)			Monthly Average Rainfall (mm)	Monthly Average Humidity (%)	Average Sunshine Hours/Day	Solar Radiation (w/m^2)
	Maximum	Minimum	Average				
June	33.1	26.5	29.8	236.2	82.1	145.9	11795.80
July	32.3	26.8	29.5	338.8	84.1	120.7	11452.31
August	31.7	26.2	29.0	317.4	85.7	113.3	5835.25
September	32.4	26.2	29.3	131.6	85.5	132.0	10137.32
October	30.5	23.7	27.1	262.6	86.9	140.9	9693.28
November	29.6	16.1	23.1	0.0	81.6	218.1	10633.62
December	25.1	13.6	19.4	0.6	64.5	97.5	7772.72

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh

Treatments

Treatment includes five organic amendments namely compost @ 10 t ha^{-1} (A_1), cowdung @ 10 t ha^{-1} (A_2), green manure @ 10 t ha^{-1} (A_3), poultry manure @ 10 t ha^{-1} (A_4), no organic amendment (A_5). Three level of salinity were used viz. no salinity (S_1), salinity level 25 mM (S_2) and salinity level 50 mM (S_3).

Experiment

The experiment was conducted in *Chari* (concrete pots). The radius of each *Chari* was 30 cm and its area was 2463.02 cm^2. The experiment was laid out in completely randomized design (CRD) with three replications. The total number of *Chari* was 45 (5×3×3). Considerable spacing was maintained among the *Chari* for convenience of cultural operations.

BRRI dhan41

The variety used for the experiment was BRRI dhan41. It was developed by the Bangladesh Rice Research Institute (BRRI) from the cross between BR23 and BR1185-2B-16-1. It was released in 2003 as transplanted *Aman* rice and named as BRRI dhan41. Its original breeding line name is BR5828-11-1-4. It is photosensitive, salt tolerant, tall, bold grain type rice. This variety can tolerate 8-10 dSm^{-1} salinity when they are tender and 6-8 dSm^{-1} salinity in rest of the living period. The cultivar BRRI dhan41 matures within 150 days after transplanting. It attains a plant height of about 115 cm. The average yield of BRRI dhan41 is 4.5 t ha^{-1} (BRRI, 2007).

Crop Cultivation

Seeds were collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur.

Seeds of BRRI dhan41 were dipped into water in buckets for 24 hours and then taken out of water and packed in the gunny bags for sprouting. The seeds sprouted after 72 hours of steeping. Seedling nursery for the variety was prepared by puddling the soil. Sprouted seeds of the variety were sown on 29 June 2013 and after sowing the seeds, proper care was taken for normal growth and development of the seedlings in the nursery bed. All weeds and stubble were removed and beds were properly leveled.

Chari was selected for the experiment to check the loss of saline water. The size of the *Chari* was 30 cm diameter on top and 40cm in height. The total number of *Chari* was 45 (5×3×3). Then each of the *Chari* was filled with the collected soil and fertilized with recommended dose for the variety BRRI dhan41 considering the soil type used for the experiment.

Fertilizer application

Each *chari* was filled up with 22 kg soil and leveled well. The applied fertilizer dose of the variety BRRI dhan41 were urea 150 kg ha^{-1}, TSP 90 kg ha^{-1}, MoP 70kg ha^{-1}, gypsum 60 kg ha^{-1}, and zinc sulphate ($ZnSO_4$) 12 kg ha^{-1}. The total amount of TSP, MoP, gypsum and zinc sulphate ($ZnSO_4$) and one-third of the urea were applied during the final *Chari* preparation and rest of the urea was top dressed in two equal splits. One at 20 days after transplanting (DAT) and another one at 40 days after transplanting (DAT). All the fertilizers were incorporated in the top most soil within 6 inch of the *Chari* soil.

Organic amendments

Organic amendments viz., control, compost, cowdung, green manure (*Sesbania rostrata)* and poultry manure were applied @ 10 t ha^{-1} in the respective *Chari*. The organic amendments were applied during *Chari* preparation for well decomposing.

Transplantation

Nursery beds were made wet by application of water both in the morning and the evening in the previous day before uprooting the seedlings. Without causing any major injury to the roots, the seedlings were uprooted. Seedlings were uprooted from the nursery bed on 1 August 2013. Transplanting was done on 1 August 2013. Three seedlings were transplanted in each hill and six hills were transplanted in each *chari*. Transplanting was done as early as possible after uprooting.

Intercultural operations

Seedlings of some hills died off and those were replaced by gap filling (after 1 week of transplanting) with the seedlings from same sources and same aged. The *Charis* were kept weed free (by hand weeding) from very beginning of transplanting up to the harvesting of the crop.

Plant protection measures

Plants were infested with Rice stem borers which were successfully controlled by the application of Basudin 10G @ 20kg ha^{-1}. The roof of the net house was covered with thin polythene sheet to protect the *Charis* from rain water.

Imposition of salinity stress

Commercial salt (NaCl) was used for developing salinity. For treatments of S_1, S_2 and S_3, 0g, 52.85g and 105.89g of salts were added respectively in the respective *Chari*. These amounts of salts were dissolved in 1000 ml of water and the solutions were then poured uniformly into the *Chari* at tillering stage.

Harvesting and processing

The crop was harvested *Chari*-wise at full maturity on 1 December 2013. After harvesting, the crop of each *Chari* was bundled separately and tagged properly. The bundles were sun dried properly before recording data on various plant characteristics and yield.

Collection of data

Data were recorded at harvest for plant height at harvest (cm), number of total tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of non-effective tillers hill^{-1}, number of panicles hill^{-1}, panicle length (cm), number of total spikelets panicle^{-1}, number of grains panicle^{-1}, number of sterile spikelets panicle^{-1}, weight of 1000 grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%). The data were recorded as per procedure described elsewhere.

Statistical Analysis

The recorded data were tabulated and the "Analysis of Variance" was done using computer package MSTATC program. The means were evaluated with Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of salinity stress and organic amendments

Plant height

The effect of salinity on plant height was found statistically significant (Table 2). Result shows that plant height decreased with increasing salinity level. The highest plant height (131.05 cm) was recorded in control (Table 2) and the lowest plant height (129.21 cm) was observed at 50 mM salinity level (S_3). Khan et al. (1997) also observed decreased plant height of rice due to salinity stress. On the other hand the highest plant height (146.78 cm) was recorded in compost and the lowest plant height (110.34 cm) was recorded at control (Table 3). The effect of organic amendments on plant height was found statistically significant.

Number of total tillers hill^{-1}

The effect of salinity on number of total tillers hill^{-1} was found statistically significant (Table 2). It was observed that number of total tillers hill^{-1} decreased with increasing salinity level. The highest number of total tillers hill^{-1} (8.00) was recorded in control and the lowest number of total tillers hill^{-1} (7.00) was recorded at 50 mM NaCl (Table 2). Aoki and Ishikawa (1971) also reported the similar phenomenon due to salinity stress. The effect of organic amendments on number of total tillers hill^{-1} was found statistically significant Table 2 (Table 3). The highest number of total tillers hill^{-1} (8.44) was recorded in poultry manure and the lowest number of total tillers hill^{-1} (6.62) was recorded at cowdung.

Number of effective tillers hill^{-1}

The effect of salinity on number of effective tillers hill^{-1} was found statistically significant (Table 2). It was observed that number of effective tillers hill^{-1} decreased with increasing salinity level. The highest number of effective tillers hill^{-1} (6.68) was recorded in control and the number of the lowest effective tillers hill^{-1} (4.76) was recorded at 50 mM NaCl (Table 2). Murty and Rao (1968) also reported similar results. The effect of organic amendments on number of effective tillers hill^{-1} was found statistically significant. It was observed that the highest number of effective tillers hill^{-1} (6.81) was recorded in poultry manure and the number of the lowest effective tillers hill^{-1} (4.98) was recorded at control (Table 3).

Number of non effective tillers hill^{-1}

The effect of salinity on number of non-effective tillers hill^{-1} was found statistically significant (Table 2). The highest number of non-effective tillers hill^{-1} (2.24) was recorded in 50 mM NaCl and the number of the lowest non-effective tillers hill^{-1} (1.32) was recorded at control (Table 2). After harvesting it was found that, the number of non-effective tillers hill^{-1} increased with decreasing salinity level.

The effect of organic amendments on number of non-effective tillers hill^{-1} was found statistically significant (Table 3). The highest number of non-effective tillers hill^{-1} (2.20) was recorded in control and the number of the lowest non-effective tillers hill^{-1} (1.63) was recorded at poultry manure (Table 3).

Number of panicles hill^{-1}

The effect of salinity on number of panicle hill^{-1} was found statistically significant (Table 2). It was observed that number of panicles decreased with increasing salinity level.

Effect of salinity stress on yield and yield contributing characteristics of transplanted *Aman* rice cv. BRRI dhan41.

Salinity level	S_1	S_2	S_3	CV (%)	Level of sig
Plant height (cm)	131.05a	129.54b	129.21b	5.28	**
No. of total tillers hill^{-1}	8.00a	7.34ab	7.00b	7.25	**
No. of effective tillers hill^{-1}	6.68a	5.36b	4.76c	13	**
No. of non-effective tillers hill^{-1}	1.32c	1.98b	2.24a	2.75	**
No. of panicles hill^{-1}	6.20a	5.25b	4.99c	10.25	**
Length of panicle (cm)	22.97a	21.09ab	20.91b	5.05	**
No. of total spikelets panicle^{-1}	112.33a	110.80b	103.27c	6.88	**
No. of grains panicle^{-1}	90.87a	81.27b	70.93c	7.51	**
No. of sterile spikelets panicle^{-1}	21.47c	29.53b	32.33a	8.89	**
1000- grain weight (g)	18.6	18.39	18.86	6.07	NS
grain yield (t ha^{-1})	4.93a	4.75b	4.18c	4.56	**
strw yield (t ha^{-1})	5.47	5.25	5.34	7.58	NS
Biological yield (t ha^{-1})	10.39a	10.01b	9.52c	5.56	**
HI%	47.12ab	47.53a	43.89b	6.58	**

In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letters differ significantly (as per DMRT).
*= Significant at 5% level of probability, **= Significant at 1% level of probability, NS= Not significant
S_1=No salinity, S_2= 25 mM SalinityS_3= 50 mM Salinity

The highest number of panicles (6.20) was recorded in control and the number of the lowest panicles (4.99) was recorded at 50 mM NaCl (Table 2). The effect of organic amendments on number of panicles was found statistically significant (Table 3).The highest number of panicle (6.62) was recorded in poultry manure and the number of the lowest panicle (4.91) was recorded at control (Table 3).

Panicle length

The effect of salinity on panicle length was found statistically significant (Table 2). It was observed that panicle length decreased with increasing salinity level. The highest panicle length (22.97 cm) was recorded in control (Table 2) and the lowest panicle length (20.91 cm) was recorded in 50 mM salinity level. Hossain (2002) and Islam (2004) also reported that panicle length was significantly decreased with rising of salinity level.

The effect of organic amendments on panicle length was found statistically significant (Table 3). The highest panicle length (22.79 cm) was recorded in compost and the lowest panicle length (20.92 cm) was recorded at control (Table 3).

Number of total spikelets panicle^{-1}

The effect of salinity on number of total spikelets panicle^{-1} was found statistically significant (Table 2). It was observed that number of total spikelets panicle^{-1} decreased with increasing salinity level. The highest number of total spikelets panicle^{-1} (112.33) was recorded in control and the number of the lowest total spikelets panicle^{-1} (103.27) was recorded at 50 mM NaCl (Table 2). The results of the present study are similar to the findings of Islam (2004). The effect of organic amendments on number of total spikelets panicle^{-1} was found statistically significant (Table 3). The highest number of total spikelets panicle^{-1} (115.33) was recorded in compost and the number of the lowest total spikelets panicle^{-1} (96.67) was recorded at control (Table 3).

Table 3
Effect of organic amendments on yield and yield contributing characteristics of transplanted *Aman* rice cv. BRRI dhan41.

Manure	A_1	A_2	A_3	A_4	A_5	CV (%)	Level of sig.
Plant height (cm)	146.78a	134.29ab	129.67b	128.60b	110.34c	5.28	**
No. of total tillers hill^{-1}	7.82b	6.62c	7.17c	8.44a	7.18c	7.25	**
No. of effective tillers hill^{-1}	6.13b	4.79c	5.29c	6.81a	4.98c	13	**
No. of non-effective tillers hill^{-1}	1.69	1.83	1.87	1.63	2.2	2.75	**
No. of panicles hill^{-1}	5.42b	4.96c	5.49b	6.62a	4.91c	10.25	**
Length of panicle (cm)	22.79a	22.24ab	21.30b	21.01b	20.92b	5.05	**
No. of total spikelets panicle^{-1}	115.33a	109.29b	109.63b	119.00a	96.67c	6.88	**
No. of grains panicle^{-1}	80.00bc	82.44b	77.11c	94.44a	71.11d	7.51	**
No. of sterile spikelets panicle^{-1}	35.33a	22.00b	31.44a	24.56b	25.56b	8.89	**
1000- grain weight (g)	18.72	18.59	18.64	18.5	18.62	6.07	NS
grain yield(t ha^{-1})	4.14d	4.68c	4.93b	5.15a	4.20d	4.56	**
straw yield(t ha^{-1})	4.82b	5.54a	5.47a	5.40a	5.54a	7.58	**
Biological yield(t ha^{-1})	8.96c	10.22a	10.40a	10.55a	9.74b	5.56	**
HI%	46.01b	45.74b	47.34ab	48.76a	43.04c	6.58	**

In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letters differ significantly (as per DMRT).

*= Significant at 5% level of probability; **= Significant at 1% level of probability; NS= Not significant
A_1= Compost @ 10 t ha^{-1}; A_2= Cowdung @ 10 t ha^{-1}; A_3= Green manure (*Sesbania rostrata)* @ 10 t ha^{-1};A_4= Poultry manure @ 10 t ha^{-1};A_5= No organic amendment

Number of grains panicle^{-1}

The effect of salinity on number of grains panicle^{-1} was found statistically significant (Table 2). It is observed that number of grains panicle^{-1} decreased with increasing salinity level. The highest number of grains panicle^{-1} (90.87) was recorded in control and the number of the lowest grains panicle^{-1} (70.93) was recorded at 50 mM NaCl (Table 2). The effect of organic amendments on number of grains panicle^{-1} was found statistically significant (Table 3). The highest number of grains panicle^{-1} (94.44) was recorded in poultry manure and the number of the lowest grains panicle^{-1} (71.11) was recorded at control (Table 3).

Number of sterile spikelets panicle^{-1}

The effect of salinity on number of sterile spikelets panicle^{-1} was found statistically significant (Table 2). The highest number of sterile spikelets panicle^{-1} (32.33) was recorded in 50 mM NaCl and the number of the lowest sterile spikelets panicle^{-1} (21.47) was recorded at control (Table 2). After harvest it was found in case of salinity effect on number of sterile spikelets panicle^{-1} that number of sterile spikelets panicle^{-1} increased with increasing salinity level. Murty and Rao (1968) reported that sterile spikelets increased by increasing salinity level.

Table 4a
Interaction effects of organic amendments and salinity stress on yield of transplanted Aman rice cv. BRRI dhan41 under salinity stress.

	S_1A_1	S_1A_2	S_1A_3	S_1A_4	S_1A_5	S_2A_1	S_2A_2	S_2A_3
Plant height (cm)	136.27	137.93	129	127.73	124.33	158.87	129.8	117.87
No. of total tillers hill^{-1} (total)	7.20c-g	7.27c-f	8.27abc	9.20a	8.07a-d	9.20a	6.74efg	6.27fg
No. of effective tillers hill^{-1}	6.06cd	5.50de	7.09b	8.03a	6.75bc	6.53bc	4.40f	4.27f
No. of non-effective tillers hill^{-1}	1.14e	1.77b-e	1.18e	1.17e	1.32de	2.67ab	1.60cde	2.00a-e
No. of panicles hill^{-1}	5.87c	5.20cd	6.80b	7.60a	5.54c	5.13cd	5.20cd	5.40c
Length of panicle (cm)	22.93	23.19	22.1	23.45	23.15	22.92	21.26	20.48
No. of total spikelets panicle^{-1}	112.67b	112.33b	112.33b	121.67ab	102.67c	119.00ab	115.33ab	115.33ab
No. of grains panicle^{-1}	85.33b	85.67b	88.00b	113.00a	82.33b	87.00b	89.67b	68.33cd
No. of sterile spikelets panicle^{-1}	27.33cde	26.67de	24.33def	8.67g	20.33ef	32.00bcd	25.67de	47.00a
1000- grain weight (g)	18.58	19.07	18.67	18.33	18.33	18.2	18.18	18.41
grain yield (t ha^{-1})	4.55fg	5.27bc	5.49ab	5.71a	4.89de	4.59efg	4.33gh	4.86def
straw yield (t ha^{-1})	5.11bc	5.49ab	5.88a	5.56ab	5.29ab	4.66c	5.32ab	5.49ab
Biological yield (t ha^{-1})	9.66def	10.76ab	11.38a	11.28a	8.89g	9.25fg	9.65def	10.35bcd
HI%	47.12bc	48.95ab	48.30ab	50.66a	40.60e	49.53ab	44.93cd	46.97bc

The effect of organic amendments on number of sterile spikelets panicle^{-1} was found statistically significant (Table 3). The highest number of sterile spikelets panicle^{-1} (35.33) was recorded in compost and the number of the lowest sterile spikelets panicle^{-1} (22.00) was recorded at cowdung (Table 3).

Grain weight

The effect of salinity on 1000-grain weight was not found statistically significant (Table 2).

Grain yield

The effect of salinity on grain yield was found statistically significant (Table 2). It was observed that grain yield decreased with increasing salinity level The highest grain yield (4.93 t ha^{-1}) was recorded in control and the lowest grain yield (4.18 t ha^{-1}) was recorded at 50 mM NaCl (Table 2). Farah and Anter (1978) reported that grain yield decreased with the increasing of salinity level. The effect of organic amendments on grain yield was found statistically significant (Table 3). The highest grain yield (5.15 t ha^{-1}) was recorded in poultry manure and the lowest grain yield (4.20 t ha^{-1}) was recorded at control (Table 3). The grain yield obtained from applying compost, cowdung and green manure were 4.14, 4.68 and 4.93 t ha^{-1} respectively (Table 3).

Straw yield

The effect of salinity on straw yield was found statistically not significant (Table 2). The effect of organic amendments on straw yield was found statistically significant (Table 3). The highest straw yield (5.54 t ha^{-1}) was recorded in cowdung and the lowest straw yield (4.82 t ha^{-1}) was recorded at compost. The straw yield obtained from applying compost, cowdung and green manure were 4.82, 5.54 and 5.47 t ha^{-1} respectively (Table 3).

Table 4b
Interaction effects of organic amendments and salinity stress on yield contributing characteristics of transplanted Aman rice cv. BRRI dhan41 under salinity stress.

	S_2A_4	S_2A_5	S_3A_1	S_3A_2	S_3A_3	S_3A_4	S_3A_5	CV (%)	Level of sig
Plant height (cm)	134.73	104.8	145.2	135.13	142.13	123.33	101.9	5.28	NS
No. of total tillers hill^{-1} (total)	8.51ab	6.73efg	7.07d-g	6.60efg	6.97d-g	7.62b-e	6.00g	7.25	**
No. of effective tillers hill^{-1}	7.40ab	4.20f	5.80cde	4.47f	4.52f	5.00ef	4.00f	13	**
No. of non-effective tillers hill^{-1}	1.11e	2.53ab	1.27de	2.13a-d	2.44abc	2.62ab	2.74a	2.75	**
No. of panicles hill^{-1}	5.53c	5.00cde	5.27cd	4.47de	4.27e	6.73b	4.20e	10.25	**
Length of panicle (cm)	20.5	19.37	22.52	22.26	21.32	20.24	19.1	5.05	NS
No. of total spikelets panicle^{-1}	112.00b	92.33de	114.33ab	82.00e	97.00cd	123.33a	95.00cd	6.88	**
No. of grains panicle^{-1}	88.00b	73.33cd	67.67d	72.00cd	75.00c	82.33b	57.67e	7.51	**
No. of sterile spikelets panicle^{-1}	24.00def	19.00ef	46.67a	13.67fg	23.00def	41.00ab	37.33abc	8.89	**
1000- grain weight (g)	18.43	18.71	19.38	18.51	18.85	18.76	18.82	6.07	NS
grain yield (t ha^{-1})	5.11cd	4.12h	3.61i	4.43gh	4.43gh	4.63efg	3.29j	4.56	**
straw yield (t ha^{-1})	5.25abc	5.55ab	4.69c	5.81a	5.04bc	5.37ab	5.79a	7.58	**
Biological yield (t ha^{-1})	10.36bcd	10.43bc	7.98h	10.24bcd	9.46efg	10.01cde	9.91c-f	5.56	**
HI%	49.29ab	46.92bc	41.37e	43.35de	46.76bc	46.34bcd	41.62e	6.58	**

Biological yield

The effect of salinity on biological yield was found statistically significant (Table 2). It was observed that biological yield decreased with increasing salinity level The highest biological yield (10.39 t ha^{-1}) was recorded in control and the lowest biological yield (9.52 t ha^{-1}) was recorded at 50 mM NaCl (Table 2). The effect of organic amendments on biological yield was found statistically significant (Table 3). The highest biological yield (10.55 t ha^{-1}) was recorded in poultry manure and the lowest biological yield (8.96 t ha^{-1}) was recorded at compost (Table 3).

Harvest index

The effect of salinity on harvest index (%) was found statistically significant (Table 2).The highest harvest index (47.53%) was recorded in 25 mM NaCl and the lowest harvest index (43.89%) was recorded at 50 mM NaCl (Table 2). The effect of organic amendments on harvest index (%) was found statistically significant (Table 3).The highest harvest index (48.76%) was recorded in poultry manure and the lowest harvest index (43.04%) was recorded at control (Table 3).

Table 5
Amelioration of salinity stress on grain yield and straw yield by interaction of organic amendments application.

Interaction (SxA)	Grain yield ($t\ ha^{-1}$)	% increase or decrease of grain yield over control	Straw yield ($t\ ha^{-1}$)	% increase or decrease of straw yield over control
S_1A_5	4.89	0.00	5.29	0.00
S_1A_4	5.71	16.77	5.56	5.10
S_1A_3	5.49	12.27	5.88	11.15
S_1A_2	5.27	7.77	5.49	3.78
S_1A_1	4.55	-6.95	5.11	-3.40
S_2A_5	4.12	-15.75	5.55	4.91
S_2A_4	5.11	4.50	5.25	-0.76
S_2A_3	4.86	-0.61	5.49	3.78
S_2A_2	4.33	-11.45	5.32	0.56
S_2A_1	4.59	-6.13	4.66	-11.91
S_3A_5	3.29	-32.72	5.79	9.45
S_3A_4	4.63	-5.31	5.37	1.51
S_3A_3	4.43	-9.41	5.04	-4.73
S_3A_2	4.43	-9.41	5.81	9.82
S_3A_1	3.61	-26.18	4.69	-11.34

S_1= 0 salinity, S_2= 25 mM Salinity, S_3= 50 mM Salinity, A_1= Compost @ 10 t ha^{-}, A_2= Cowdung @ 10 t ha^{-1}, A_3= Green manure (*Sesbania rostrata)* @ 10 t ha^{-1}, A_4= Poultry manure @ 10 t ha^{-1}, A_5= No organic amendment

Interaction effects of organic amendments and salinity stress

Plant height

The interaction effect between salinity levels with organic amendments application on plant height was found statistically not significant (Table 4). The highest plant height (158.87 cm) was recorded in 25 mM NaCl salinity level (S_2) × 10 t ha^{-1} compost (A_1). The lowest plant height (101.95 cm) was obtained from 50 mM salinity (S_3) × no organic amendment application (A_5). Plant height decreased with increasing salinity level and varied with different organic amendments. Islam et al. (2011) on hybrid rice and Miah (1992) on two rice varieties also found that plant height decreased with increasing salinity. Leithy et al. (2010) on peanut, Abou El-Magd et al. (2008) on sweet funnel and Raafat and Tharwat (2011) on rice have shown that organic amendments increased plant height at different levels of soil salinity.

Number of total tillers hill^{-1}

The influence of interaction between organic amendments application and salinity level had significant effect on number of total tiller $hill^{-1}$ (Table 4b). The highest number of tillers $hill^{-1}$ (9.20) was recorded in the interaction of no salinity level (S_1) × poultry manure @ 10 t ha^{-1} (A_4). The lowest number of tillers $hill^{-1}$ (6.00) was recorded in the interaction of 50 mM salinity level (S_3) × no organic amendment (A_5). Momayezi et al. (2010) also showed that number of effective tillers $hill^{-1}$ was decreased by increasing salt level in rice.

Number of effective tillers hill^{-1}

From Table 4, it can be seen that there was significant effect between organic amendments application and salinity level in relation to number of effective tillers $hill^{-1}$. Maximum number of effective tillers $hill^{-1}$ (8.03) was recorded in the interaction of no salinity level (S_1) × poultry manure @ 10 t ha^{-1} (A_4).The lowest number of effective tillers $hill^{-1}$ (4.00) was recorded in the interaction of 50 mM salinity level (S_3) × no organic amendment (A_5). Haq et al. (2001) reported that combined application of gypsum, pressmud and FYM produced the maximum number of effective tillers in a saline-sodic soil.

Number of non-effective tillers hill^{-1}

The data on table 4 revealed that the number of non-effective tillers hill^{-1} varied significantly due to different treatment combinations. The minimum number (1.17) of non-effective tillers hill^{-1} was obtained from the interaction of no salinity level (S_1) × poultry manure @ 10 t ha^{-1} (A_4) and the maximum number (2.74) was obtained from the interaction of 50 mM salinity level (S_3) × no organic amendment (A_5).

Panicle length

Interaction effect between salinity levels with organic amendments application on panicle length was found statistically not significant (Table 4).

Number of total spikelets panicle^{-1}

The significant variation was observed in number of total spikelets panicle^{-1} due to interaction of salinity levels and organic amendments application. The highest number (123.33) of total spikelets panicle^{-1} was found in 50 mM salinity level (S_3) × 10 t ha^{-1} poultry manure (A_4). The lowest number (82.00) of total spikelets panicle^{-1} was found in 50 mM salinity level (S_3) × 10 t ha^{-1} cowdung (A_2).

Number of grains panicle^{-1}

The data on Table 4 showed that the number of grains panicle^{-1}varied significantly due to different treatment combinations. The highest number of grains panicle^{-1} (113) was obtained from the interaction of no salinity level (S_1) × poultry manure @ 10 t ha^{-1} (A_4) and the lowest number of grains panicle^{-1} (57.67) was obtained from the interaction of 50 mM salinity level (S_3) × no organic amendment (A_5).

Number of sterile spikelets panicle^{-1}

Interaction effect between salinity levels with organic amendments application on numbers of sterile spikelets panicle^{-1} was found statistically significant (Table 4). The highest numbers of sterile spikelets panicle^{-1} (46.67) was recorded in 50 mM salinity level (S_3) × 10 t ha^{-1} compost (A_1). The lowest numbers of sterile spikelets panicle^{-1} (8.67) was obtained from no salinity (S_1) × poultry manure @ 10 t ha^{-1} (A_4).

Grain weight

The interaction effect between salinity levels with organic amendments application on thousand grain weight was not found statistically significant (Table 4).

Grain yield

The data on Table 4 showed that the grain yield varied significantly due to different treatment combinations. The highest grain yield (5.71 t ha^{-1}) was obtained from the interaction of no salinity level (S_1) × poultry manure @ 10 t ha^{-1} (A_4) and the lowest grain yield (3.29 t ha^{-1}) was obtained from the interaction of 50 mM salinity level (S_3) × no organic amendment (A_5).

Straw yield

The interaction effect between salinity levels with organic amendments application on straw yield was found statistically significant (Table 4). The highest straw yield (5.88 t ha^{-1}) was obtained from the interaction of no salinity level (S_1) × green manure @ 10 t ha^{-1} (A_3) and the lowest straw yield (4.66 t ha^{-1}) was obtained from the interaction of 25 mM salinity level (S_2) × compost @ 10 t ha^{-1} (A_1).

Biological yield

The interaction effect of salinity levels and organic amendments application on biological yield was found statistically significant (Table 4). The highest biological yield (11.38 t ha^{-1}) was obtained from the interaction of no salinity level (S_1) × green manure @ 10 t ha^{-1} (A_3) and the lowest biological yield (7.98 t ha^{-1}) was obtained from the interaction of 50 mM salinity level (S_3) × compost @ 10 t ha^{-1} (A_1).

Harvest index

The interaction effect of salinity levels and organic amendments application on harvest index was found statistically significant (Table 4). The highest harvest index (50.66%) was found in the interaction of no salinity level (S_1) × poultry manure @ 10 t ha^{-1} (A_4). The lowest harvest index (41.37%) was found in the interaction of 50 mM salinity level (S_3) × compost @ 10 t ha^{-1} (A_1).

Amelioration of Salinity Stress on Grain and Straw Yields by Organic Amendments

Table 5 showed reduction of grain and straw yields of transplanted A*man* rice cv. BRRI dhan41 under various levels of salinity stress over control and under application of organic amendments. It is perceived from the table that application of organic amendments in terms of poultry manure @ 10 t ha^{-1} increased grain yield by 16.77% over control when no salinity was imposed. On the other hand salinity stress @ 25 mM NaCl and 50 mM NaCl decreased grain yield by 15.75% and 32.72%, respectively. Over control, the grain yield reduction of 15.75% was turned into an increased yield of 4.50% and that of 32.72% to 5.31% by application of poultry manure @ 10 t ha^{-1}. In case of straw yield, application of organic amendments increased straw yield by 11.15% over control when there is no salinity imposed. Again, imposition of salinity stress @ 25 mM NaCl and 50 mM NaCl decreased straw yield by 11.91% and 11.34%, respectively. The straw yield reduction of 11.91% was turned into an increased yield of 3.78% and that of 11.34% to 9.82% by application of organic amendments. The results revealed that the ameliorative effect of organic amendments were more effective at the both salinity levels used in the study.

From the above observation it can be concluded that application of organic amendments were effective in ameliorating salinity stress. The application of poultry manure @ 10 t ha^{-1} was more effective than the other organic amendments. Crop cultivation in saline areas might be profitable with organic amendment of soils. To validate the result, however, similar experiment needs to be conducted under natural occurrence of salinity stress.

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