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MITIGATION OF THE ADVERSE EFFECTS OF SALT STRESS ON MAIZE (*Zea mays* L.) THROUGH ORGANIC AMENDMENTS

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Abstract

Salinity is a major limiting factor for crop production in coastal areas of Bangladesh. Organic amendments could contribute to the improvement of crop production in coastal areas. BARI Hybrid Maize-5 and Hybrid Maize Pacific-987 were grown in pots to mitigate the adverse effects of salt stress in maize by organic amendments. Farmyard manure (FYM) and poultry manure (PM) were mixed with soils before seed sowing. Salinity stress (25 mM and 50 mM) was induced at vegetative stage. Salt stress caused a significant reduction in growth and yield of both the maize cultivars. Higher NaCl (50 mM) stress caused a drastic decrease in growth and yield of both maize cultivars. Salinity also decreased reproductive growth, chlorophyll content and K^+/Na^+ ratio in both maize cultivars. Organic amendments with FYM and PM improved salt tolerances of maize that were associated with increased yield components, chlorophyll content and K^+/Na^+ ratio. Hybrid Maize Pacific-987 grown in low salinity with FYM or PM amendments produced higher yield than control condition. On the contrary, BARI Hybrid Maize-5 conferred tolerance to high salinity, when soils were amended with FYM or PM. Furthermore, organic amendments improved electrical conductivity, exchangeable Na and organic matter status under salinity condition. The present study suggests that organic amendments with FYM or PM confer tolerance to salinity in maize by increasing chlorophyll content and K^+/Na^+ ratio.

Key words: Salt stress, organic amendments, farmyard manure, poultry manure, maize

Introduction

Soil salinity is a major concern in agriculture all over the world because it affects almost all plant functions. More than 6% of the world's land and more precisely, one third of the world's irrigated land are significantly affected by soil salinity (Flowers and Yeo, 1995; FAO, 2008). Moreover, soil salinization due to irrigation is becoming increasingly detrimental to agriculture.

Agriculture is one of the most important sectors of Bangladesh's economy. Physiological stress in plants due to salinity is the major factor reducing crop yields in coastal areas of Bangladesh. Usually 30-50% yield losses occur depending on the level of soil salinity. Out of 2.86 million ha of coastal and offshore lands, about 1.06 million ha are affected by varying degrees of salinity (SRDI, 2010). The area under salinity is increasing with time (from 0.83 to 1.056 million ha in 36 years, SRDI, 2010) due to rise in sea water level with increased global temperature. Increased soil salinity due to climate change would significantly reduce food grain production.

Salinity imposes both ionic toxicity and osmotic stress to plants (Hasegawa *et al.,* 2000; Zhu, 2003). Salt stress disturbs cytoplasmic K^+/Na^+ homeostasis, causing an increase in Na^+ to K^+ ratio in the cytosol (Zhu, 2003). Accumulation of excess Na^+ and Cl^- causes ionic imbalances that may impair the selectivity of root membranes and induce K^+ deficiency (Gadallah, 1999) that are often associated with a decrease in photosynthetic electron transport activities in photosynthesis (Kirst, 1989). There is a report that the deficiency of K^+ initially leads to chlorosis and then causes necrosis (Gopal and Dube, 2003).

Soil salinization is a major process of land degradation that decreases soil fertility and crop productivity. It has been reported that coastal regions of Bangladesh are quite lower in soil fertility (Haque, 2006). Appropriate management strategies and techniques with suitable genotypes having higher yield potential could contribute to the improvement of crop production in the coastal areas of Bangladesh. 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 (FYM), compost, poultry manure (PM) 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).

Rice is mainly grown in the salinity affected areas of Bangladesh, but the average yield is very low due to lack of salt-tolerant high yielding variety and inappropriate management practices. However, about 20% peoples of Bangladesh are seriously affected by soil and water salinity in the coastal belt. Maize in Bangladesh is becoming an important crop in the rice based cropping system. Among the cereals grown in Bangladesh, maize is the third most important crop after rice and wheat. Maize can contribute significantly towards solving food problem and thereby play its gainful role in the agro-economy of the country. In Bangladesh, maize can be grown in different agro-climatic zones round the year. With the increase in demand from poultry and other feed industries, more area is expected to divert from rice to hybrid maize in coming years. There is a great possibility to bring saline areas under maize cultivation with proper reclamation and management.

There is no systematic information in Bangladesh about the role of organic amendments in the mitigation of soil salinity in crop plants. Considering abovementioned facts, the present study was undertaken for the improvement of salinity tolerance and economic crop production through organic amendments in the coastal areas of Bangladesh.

Materials and Methods

Soil collection and pot preparation

Two pot experiments were carried out at the net house of the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh. Soil was collected from the Soil Science Field Laboratory, BAU. A total of 88 equal size plastic pots were filled with 8 kg soils each. Characteristically, the soil was silt loam having pH 6.15, EC 0.17 dS/m, exchangeable Na 0.35 meq/100 g soil, total nitrogen 0.11% and organic matter 1.90%.

Plant materials and treatments

BARI Hybrid Maize 5 and Hybrid Maize Pacific 987 were used as test crops. Eleven treatment combinations *viz.* control (no salt added), 25 mM NaCl, 50 mM NaCl, 25 mM NaCl + 5 t/ha FYM, 25 mM NaCl + 10 t/ha FYM, 50 mM NaCl + 5 t/ha FYM, 50 mM NaCl + 10 t/ha FYM, 25 mM NaCl + 4 t/ha PM, 25 mM NaCl + 8 t/ha PM, 50 mM NaCl + 4 t/ha PM, 50 mM NaCl + 8 t/ha PM were used for the two maize varieties. Three maize seeds were sown into each pot. One plant was kept in each pot and others were uprooted after emergence. FYM and PM were mixed with soils as per treatment before seed sowing. FYM contained 0.45% N, 0.30% P, 1.13% K and 0.102% S, and PM contained 0.84% N, 0.93% P, 1.28% K and 0.21% S. Plants were exposed to different concentrations of NaCl (0-50 mM) at vegetative stage. The experiment was laid out in a completely randomized design with four replications.

Management practices, crop harvesting and data recording

Fertilization and other management practices were performed as and when required. The crops were harvested at full maturity. Root growth, yield attributes, and grain and straw yields were recorded.

Determination of chlorophyll content

Chlorophyll content was measured using the method described by Porra *et al.* (1989). An aliquot amount of green leaf of maize was suspended in 10 mL of 80% acetone, mixed well and kept at room temperature in the dark for 7 days. The supernatant was collected after centrifugation at 5000 rpm and the absorbance was recorded at 645 and 663 nm in a spectrophotometer.

Chemical analysis of plant and soil samples

Soil pH, EC, exchangeable Na and organic carbon content were measured using standard methods. Grain and straw samples were analyzed for N, P, K, S and Na content using the methods described by Khanam *et al.* (2001).

Statistical analysis

Data were statistically analyzed by ANOVA. The significant differences between mean values were compared by Duncan's Multiple Range Test (DMRT). Differences at $p < 0.05$ were considered significant.

Results and Discussion

Root and plant growth

Salt stress caused a significant reduction in root length, root weight, plant height and plant weight of both BARI Hybrid Maize-5 and Hybrid Maize Pacific-987 (Fig. 1A, B, C, D). Higher salt stress caused drastic reductions of these growths. Organic amendments with FYM and PM significantly increased the root length, root weight, plant height and plant weight of both maize varieties at 25 mM NaCl stress. High doses of FYM or PM showed better performances over low doses in producing vegetative growth at 25 mM NaCl stress. Addition of organic manures increased vegetative growth of BARI Hybrid Maize-5 at 50 mM NaCl stress but these increases were not apparent in Hybrid Maize Pacific-987. However, FYM performed better in producing plant growth than PM at different salt stresses. Leithy *et al.* (2010) on Peanut, Abou El-Magd *et al.* (2008) on sweet funnel and Raafat and Tharwat (2011) on rice also found that organic amendments increased the vegetative growth of plant at different levels of soil salinity.

Reproductive growth

Significant reduction in cob length, cob diameter, number of grains column^{-1}, total number of grains cob^{-1}, 100-grain weight and total grain weight of both BARI Hybrid Maize-5 and Hybrid Maize Pacific-987 was observed under salt stress (Table 1 and 2). Neither BARI Hybrid Maize-5 nor Hybrid Maize Pacific-987 could produce grains when plants were treated with 50 mM NaCl stress. Organic amendments with FYM or PM increased the recorded parameters of both the maize varieties when exposed to 25 mM NaCl stress. At 50 mM NaCl stress, FYM and PM contributed to the remarkable production of cob of BARI Hybrid Maize-5 (Table 1) but no cob was produced in Hybrid Maize Pacific-987 plants (Table 2). Abou El-Magd *et al.* (2008) on sweet funnel, Raafat and Tharwat (2011) and Idrees *et al.* (2004) on sugarcane also showed that organic amendments increased the reproductive growth under different salt stress conditions.

Chlorophyll contents

Salt stress inhibits photosynthetic capacity, leading to a decrease in crop production (Pitman and Läuchli, 2004). A significant decrease in chlorophyll (chl) content of both maize varieties was observed in response to salt stress (Table 3). Salinity causes a reduction in chl content due to suppression of specific enzymes that are responsible for the synthesis of photosynthetic pigments. Neither FYM nor PM increased chl content in BARI Hybrid Maize 5 treated with 25 mM NaCl stress although both manures significantly increased chl contents at 50 mM NaCl stress condition. On the other hand, both manures FYM and PM resulted in significant increases in chl content in Hybrid Maize Pacific 987 (Table 3). Niazi *et al.* (2002) reported that improvement of plant growth in saline soils was associated with increased chl contents.

K^+/Na^+ ratio

Intracellular K^+/Na^+ homeostasis is crucial for cell metabolism and is considered to be a key component of salinity tolerance in plants (Hasegawa *et al.,* 2000). Organic compounds might have beneficial effects to plants in their adaptation to salinity by maintaining K^+/Na^+ homeostasis. Salinity significantly reduced K^+/Na^+ ratio in both varieties (Table 4). Both FYM and PM improved K^+/Na^+ ratio in both maize varieties induced by NaCl stress. No differences were observed in K^+/Na^+ ratio between FYM and PM amendments. As no grains were formed in plants of both varieties exposed to 50 mM NaCl stress, K and Na contents could not be detected. However, organic manures have been shown to increase K^+/Na^+ ratio in sweet fennel (Abou El-Magd *et al.,* 2008).

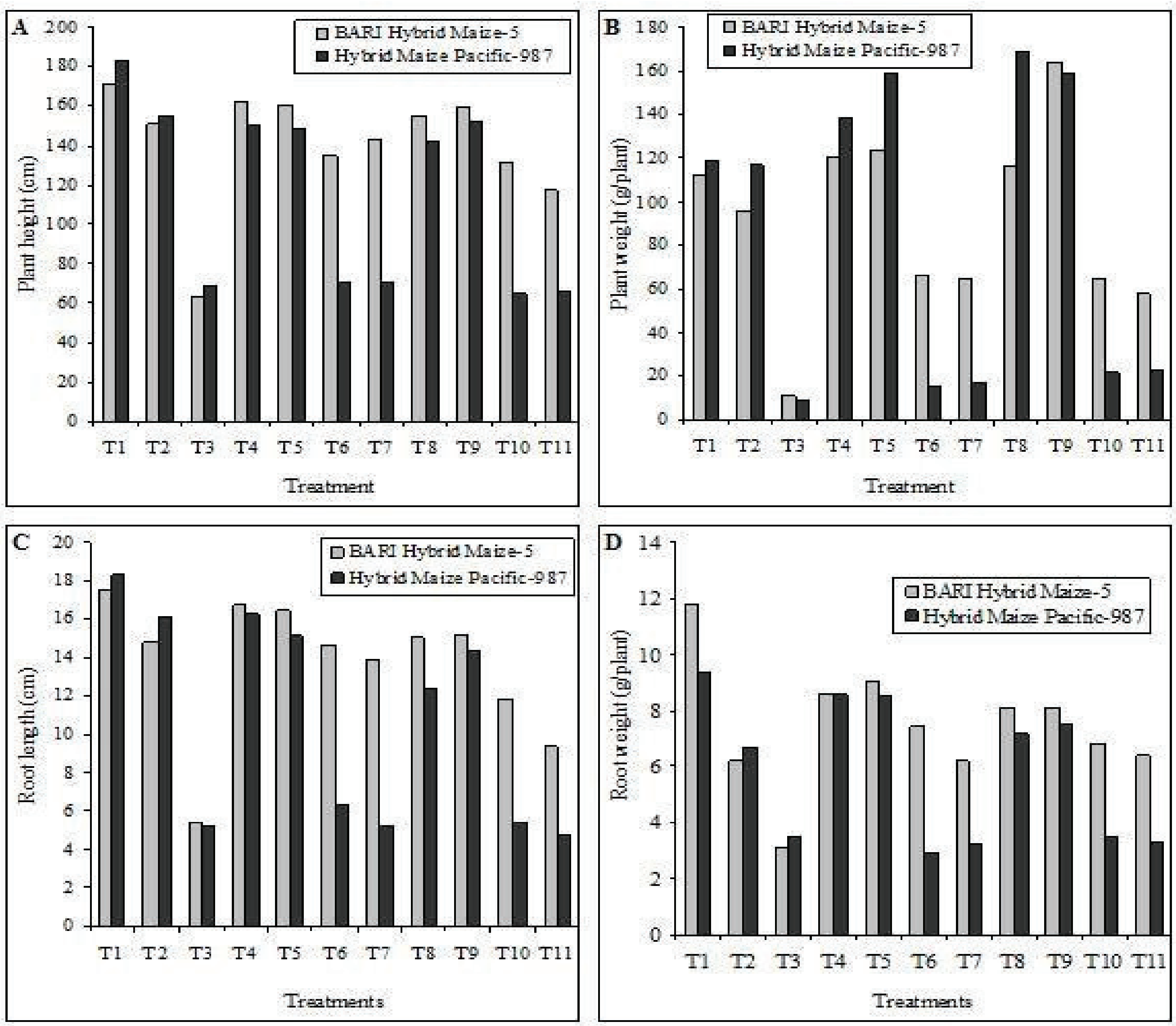

Fig. 1: Effects of organic manures on root and plant growth of maize under salt stress. Values represent the mean of four replications.

Treatments: T1 = control, T2 = 25 mM NaCl, T3 = 50 mM NaCl, T4 = 25 mM NaCl + FYM (5 t/ha), T5 = 25 mM NaCl + FYM (10 t/ha), T6 = 50 mM NaCl + FYM (5 t/ha), T7 = 50 mM NaCl + FYM (10 t/ha), T8 = 25 mM NaCl + PM (4 t/ha), T9 = 25 mM NaCl + PM (8 t/ha), T10 = 50 mM NaCl + PM (4 t/ha), T11 = 50 mM NaCl + PM (8 t/ha).

Table 1: Effects of organic manures on yield attributes and grain yield of BARI Hybrid Maize-5 under salt stress

Treatments	Cob length (cm)	Cob diameter (cm)	No. of grains $column^{-1}$	No. of grains cob^{-1}	100-grain weight (g)	Grain yield $plant^{-1}$ (g)
Control	18.0a	13.3b	27a	327a	26.9ab	85.7a
25 mM NaCl	14.7c	12.4bc	21c	263c	21.7d	54.1e
50 mM NaCl	ND	ND	ND	ND	ND	ND
25 mM NaCl + FYM (5 t/ha)	14.4c	12.9bc	19cd	284b	25.2b	63.3cd
25 mM NaCl + FYM (10 t/ha)	16.5ab	13.6b	24b	323a	23.5c	65.1c
50 mM NaCl + FYM (5 t/ha)	9.0f	8.0d	12f	138e	13.5fg	11.5i
50 mM NaCl + FYM (10 t/ha)	10.3e	11.7c	16e	205d	15.1ef	13.9h
25 mM NaCl + PM (4 t/ha)	15.7b	16.7a	20c	264c	25.0b	66.5c
25 mM NaCl + PM (8 t/ha)	15.4bc	13.3b	15e	264c	27.3a	73.5b
50 mM NaCl + PM (4 t/ha)	12.3d	10.8cd	18d	273bc	14.0f	19.5f
50 mM NaCl + PM (8 t/ha)	10.3e	10.5cd	14ef	280b	6.30g	10.0g
SE (±)	0.47	0.38	0.73	8.14	1.05	4.26
CV (%)	3.46	3.12	3.91	3.11	5.31	9.19

Values represent the mean of four replications. In some cases, 100-grain weight was obtained from the multiplication of 50 grains with 2. ND (not detected) indicates no plants survived during the data recording. Same letter in a column represents insignificant difference at $p < 0.05$.

Table 2: Effects of organic manures on yield attributes and grain yield of Hybrid Maize Pacific-987 under salt stress

Treatments	Cob length (cm)	Cob diameter (cm)	No. of grains $column^{-1}$	No. of grains cob^{-1}	100-grain weight (g)	Grain yield $plant^{-1}$ (g)
Control	20.3b	12.9ab	24a	283c	27.3b	59.0d
25 mM NaCl	20.2b	12.4b	22b	237d	27.4b	52.1f
50 mM NaCl	ND	ND	ND	ND	ND	ND
25 mM NaCl + FYM (5 t/ha)	21.0a	12.3b	25a	274cd	28.5a	56.1de
25 mM NaCl + FYM (10 t/ha)	20.5ab	13.8a	24a	294bc	28.1a	71.4c
50 mM NaCl + FYM (5 t/ha)	ND	ND	ND	ND	ND	ND
50 mM NaCl + FYM (10 t/ha)	ND	ND	ND	ND	ND	ND
25 mM NaCl + PM (4 t/ha)	19.0bc	13.8a	25a	341a	25.8c	79.6a
25 mM NaCl + PM (8 t/ha)	18.3c	13.9a	24a	332a	25.0c	74.1b
50 mM NaCl + PM (4 t/ha)	ND	ND	ND	ND	ND	ND
50 mM NaCl + PM (8 t/ha)	ND	ND	ND	ND	ND	ND
SE (±)	0.31	0.25	0.41	5.71	0.25	1.60
CV (%)	1.56	1.90	1.72	1.94	0.92	2.45

Values represent the mean of four replications. ND (not detected) indicates no plants survived during the data recording. Same letter in a column represents insignificant difference at $p < 0.05$.

Nutrient uptake

Salinity decreases nutrient uptake and transport to the shoot, thus inducing a nutrient imbalance in the plant (Evelin ***et al.***, 2009). We also investigated whether manures influenced NPS uptake by maize under different salt stresses (data not shown). Salinity decreased N accumulation in grain of both varieties but this uptake increased by straw of BARI Hybrid Maize-5. Overall, salinity decreased P and S uptake by straw and grain of both varieties. In most cases, addition of FYM and PM increased NPS uptake by maize under salt stress. No differences in nutrient uptake were observed between FYM and PM amendments. Similar results on nutrient uptake influenced by manures under salt stress have been observed by Zaki *et al.* (2009) and Abou El-Magd *et al.* (2008).

Changes in soil properties by organic manures

We investigated the changes in soil properties such as pH, EC, exchangeable Na and organic matter status in post harvest soils (Table 5). An increase in soil pH, EC and exchangeable Na was observed when NaCl was added to the soils. Addition of FYM or PM considerably decreased EC and exchangeable Na, and increased organic matter status in soils under salt stress condition. No remarkable changes in soil pH were observed by the addition of manures to the soils treated with NaCl (Table 5). Raafat and Tharwat (2011) have observed that organic amendments improve soil properties and nutritional status even under soil salinity. There are also increasing evidences that soil amendments with manures improve physical and chemical properties of soils under saline conditions such as bulk density, EC and exchangeable sodium percentage and increase the availability of NPK (Tejada *et al.,* 2006; Amanullah *et al.,* 2007; Mohamed *et al.*, 2007).

Conclusion

It can be concluded that soil amendments with FYM and PM improve soil properties, increase chlorophyll content and K^+/Na^+ ratio, and thereby confer tolerance to salinity. However, crop cultivation in saline areas might be profitable with organic amendment of soils. Extensive field research work is needed to test the result under actual field condition since organic manures like FYM and PM are easily available and cheap and hence could be a nice option for growing maize in saline areas.

Table 3: Chlorophyll (chl) contents in maize influenced by organic manures under salt stress

Treatments	BARI Hybrid Maize-5			Hybrid Maize Pacific-987		
	Chl-a (μg ml^{-1})	Chl-b (μg ml^{-1})	Total chl (μg ml^{-1})	Chl-a (μg ml^{-1})	Chl-b (μg ml^{-1})	Total chl (μg ml^{-1})
Control	7.17a	4.55a	11.70a	6.49ab	2.99c	9.48cd
25 mM NaCl	6.66bc	3.51cd	10.20cde	5.66c	2.01d	7.67e
50 mM NaCl	6.03d	2.36e	8.39f	ND	ND	ND
25 mM NaCl + FYM (5 t/ha)	6.53bcd	4.21abc	10.70bc	5.80b	2.26cd	8.06d
25 mM NaCl + FYM (10 t/ha)	7.05ab	4.40ab	11.50ab	6.87ab	3.80a	10.70b
50 mM NaCl + FYM (5 t/ha)	5.53e	3.83abc	9.36e	ND	ND	ND
50 mM NaCl + FYM (10 t/ha)	6.13cd	3.54cd	9.67ef	ND	ND	ND
25 mM NaCl + PM (4 t/ha)	6.91ab	3.77bcd	10.70bc	6.55ab	3.20b	9.75c
25 mM NaCl + PM (8 t/ha)	6.54bcd	4.07abc	10.60bcd	7.57a	3.89a	11.50a
50 mM NaCl + PM (4 t/ha)	6.50bcd	3.06d	9.56e	ND	ND	ND
50 mM NaCl + PM (8 t/ha)	6.79ab	3.47cd	10.30cde	ND	ND	ND
SE (±)	0.08	0.11	0.16	0.11	0.12	0.21
CV (%)	1.28	2.96	1.58	1.68	3.87	2.26

Values represent the mean of four replications. ND (not detected) indicates no plants survived during the estimation of chl. Same letter in a column represents insignificant difference at $p < 0.05$.

Table 4: K^+/Na^+ ratio in maize influenced by organic manures under salt stress

Treatment	BARI Hybrid Maize-5		Hybrid Maize Pacific-987	
	K^+/Na^+ (in straw)	K^+/Na^+ (in grain)	K^+/Na^+ (in straw)	K^+/Na^+ (in grain)
Control	2.18a	1.14b	1.82a	1.32a
25 mM NaCl	1.08c	0.85c	1.12e	0.94d
50 mM NaCl	0.46f	ND	0.58g	ND
25 mM NaCl + FYM (5 t/ha)	1.16b	1.13b	1.22d	1.17b
25 mM NaCl + FYM (10 t/ha)	1.16b	1.10b	1.23d	1.20b
50 mM NaCl + FYM (5 t/ha)	0.53e	0.80c	0.61f	ND
50 mM NaCl + FYM (10 t/ha)	0.55e	0.75c	0.68f	ND
25 mM NaCl + PM (4 t/ha)	1.11bc	1.14b	1.50b	1.11c
25 mM NaCl + PM (8 t/ha)	1.18b	1.30a	1.30c	1.13bc
50 mM NaCl + PM (4 t/ha)	0.78d	0.75c	0.61f	ND
50 mM NaCl + PM (8 t/ha)	0.72d	0.78c	0.66f	ND
SE (±)	0.07	0.03	0.06	0.02
CV (%)	7.11	3.24	6.04	1.66

Values represent the mean of four replications. ND indicates data not detected. Same letter in a column represents insignificant difference at $p < 0.05$.

Table 5: Changes in soil properties by organic manures under salt stress

Treatment	Soil properties			
	Soil pH	EC (dS m^{-1}) (soil:water = 1:5)	Exchangeable Na (me/100g)	Organic matter (%)
Control	6.10	0.150	0.33	1.90
25 mM NaCl	6.48	0.592	0.59	1.87
50 mM NaCl	6.55	1.971	1.23	1.87
25 mM NaCl + FYM (5 t/ha)	6.48	0.391	0.43	2.08
25 mM NaCl + FYM (10 t/ha)	6.46	0.394	0.34	2.14
50 mM NaCl + FYM (5 t/ha)	6.21	1.215	0.83	2.03
50 mM NaCl + FYM (10 t/ha)	6.32	1.405	0.94	2.24
25 mM NaCl + PM (4 t/ha)	6.27	0.528	0.44	2.24
25 mM NaCl + PM (8 t/ha)	6.32	0.529	0.46	2.32
50 mM NaCl + PM (4 t/ha)	6.31	1.169	0.87	2.24
50 mM NaCl + PM (8 t/ha)	6.39	1.294	1.01	2.41

Values represent the mean from four replications. Data of soil properties were not analyzed statistically.

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