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Salinity Stress Mediated by Organic Amendments of Winter Pulses

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Abstract

A pot experiment was conducted in the month of December 2017 to March 2018 following RCB design to investigate the mitigating effects of poultry manure and rice husk biochar on salinity stress in BARI Masur- 4, BARI Khesari- 2, BARI Felon-1 and BU Chola-1. Poultry manure and rice husk biochar were mixed in soil of pot @ 10 t/ha of both. Saline treated pots were irrigated with salt solution (100 mM) from 14th days after sowing (DAS) to maturity and control plants were irrigated with tap water. The treatments were i) control (no saline+ no organic matter) ii) saline (100 mM NaCl solution) iii) saline (100 mM NaCl) + poultry manure @ 10 t/ha iv) saline (100 mM NaCl) + rice husk biochar @ 10 t/ha. Data on leaf chlorophyll and proline content were collected at flowering stage. Growth and yield parameters like plant height, total dry matter accumulation, number of pods/plant, 100 seed weight and seeds yield/plant were measured at harvest. Results revealed that salinity decreased the height, accumulation of dry matter, leaf chlorophyll content and yield but increased leaf proline content of winter pulses. Application of poultry manure and rice husk biochar was found to mitigate the negative effects of salinity stress in winter pulses. Among the organic amendments used, rice husk biochar @ 10 t/ha performed better than poultry manure. It was also found that among the winter pulses, BARI Felon -1 was more responsive to rice husk biochar under saline condition.

Keywords: Poultry manure, biochar, salinity mitigation, winter pulses

1. Introduction

Soil salinity is a major concern to agriculture all over the world because it affects almost all plant functions. Millions of hectares of land throughout the world are salt affected which involved to reduce the crop production. More lands are becoming non-productive each year by salinity buildup. About 7% of the world's land area, 20% of the world's cultivated land and nearly half of the irrigated land are affected by soil salinity (Mali *et al.*, 2012). Agriculture is the most important sector of Bangladesh's economy. Usually 30-50% yield losses occur depending on the level of soil salinity. Over 30% of the cultivable area of Bangladesh lies in the coastal and offshore zones. Out of 2.86 million hectares of coastal and offshore lands, about 1.06 million hectares are affected by varying degrees of salinity (SRDI, 2010). Soil salinization 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 lower in soil fertility (Kibria *et al*., 2015). Appropriate management strategies and techniques with suitable crop genotypes having higher yield potential could contribute to the improvement of crop production in the coastal

areas of Bangladesh. There are evidences that soil amendments with various organic substances such as farmyard manure, poultry manure and mulch can be used for reduce the toxic effects of salinity in various plant species (Raafat and Thawrat, 2011).

Organic amendments have mitigated salt stress in plants by improving antioxidant enzyme synthesis in plants (Tartoura *et al*., 2014). Organic amendments improve physical, chemical and biological properties of soils under saline conditions. Chowdhury *et al*. (2019) suggested that soil amendments with farm yard manure and poultry manure improve salt tolerance in rice by increasing K^+/Na^+ ratio and nutrient uptake."Biochar" is pyrolysed organic material intended for use as a soil amendment to-sustainably sequesters C and concurrently improves soil function, while avoiding any adverse effects, on both the short and long terms (Lehmann and Joseph, 2015). Soil salinity management did not receive proper attention in the past, but now emphasis has been given on this issue. Sustainable and profitable productions of crops in salt-affected areas are possible if appropriate soil management is made. There is no systematic information in Bangladesh about the role of organic amendments in the mitigation of salinity in crop cultivation. Therefore, the study was carried out to assess the effectiveness of organic amendments to alleviate the salinity tolerance of winter pulses.

2. Materials and Methods

2.1. Experimental site and soil

The experimental site is in the center of Madhupur Tract (24.09^o N latitude and 90.26^o E longitude) at 8.4 m above the sea level. The experiment was carried out in the month of December 2017 to March 2018. The experimental soil was a sandy loam with pH (6.93), organic carbon (0.61%), total N (0.07%), available P (8.00 μg g^{-1}), exchangeable K (0.79 $cmol_c$ kg^{-1} dry soil), available S (10 μg g^{-1}), CEC (13.05 $cmol_c$ kg^{-1} dry soil) and EC 0.4 dS m^{-1}. Plastic pots (30 cm length and 24 cm diameter) were used in the experiment which was filled with mixture of soil and cowdung at a ratio of 4:1 and each pot contain 12 kg soil. The soil of the pot (where BARI Masur-4 was grown) was fertilized uniformly with 143, 124 and 180 mg urea, triple super phosphate and muriate of potash corresponding to 11-10-18 kg urea, triple super phosphate and muriate of potash per hectare, respectively. The soil of the pot (where BU Chola-1 was grown) was fertilized uniformly with 182, 124 and 120 mg urea, triple super phosphate and muriate of potash corresponding to 14-10-12 kg urea, triple super phosphate and muriate of potash per hectare, respectively. The soil of the pot (where BARI Khesari-2 was grown) was fertilized uniformly with 221, 100 and 100 mg urea, triple super phosphate and muriate of potash corresponding to 17-8-10 kg urea, triple super phosphate and muriate of potash per hectare, respectively. The soil of the pot (where BARI Felon-1 was grown) was fertilized uniformly with 221, 100 and 100 mg urea, triple super phosphate and muriate of potash corresponding to 17-8-10 kg urea, triple super phosphate and muriate of potash per hectare, respectively. Half amount of urea and all other fertilizers were applied in pot before seed sowing, rest of the urea was applied before flowering.

2.2 Treatments, layout and design

Four winter pulses i) BARI Masur- 4 ii) BARI Khesari- 2 iii) BARI Felon-1 and iv) BU Chola-1 were used as test crop. Two types of organic amendments i) poultry manure ii) rice husk biochar were mixed in soil of pot @ 10 t/ha of both. The rice husk biochar was with pH (7.15), N (2.57%), P (0.21%), exchangeable K (0.23 $cmol_c$ k g^{-1} dry biochar), Ca (1.02%), Mg (0.45%), S (0.33%) and EC 1.32 mS cm^{-1}. Plants were grown in two conditions: control (no saline) and saline. Saline treated pots were irrigated with 100 mM NaCl salt solution from 14th days after sowing (DAS) to maturity and control plants were irrigated with tap water. Salinity of the pot soil was 7-9 dS m^{-1} in whole growing season. There were four treatments namely: i) control (no saline + no organic matter)

ii) saline (100 mM NaCl solution) iii) saline (100 mM NaCl) + poultry manure @ 10 t/ha iv) saline (100 mM NaCl) + rice husk biochar @ 10 t/ha. The experiment was laid down in randomized complete block design with three replications.

2.3 Data collection

Seeds of the four pulses were sown 5 December, 2017. Data on leaf chlorophyll and proline content were collected at flowering stage. Crops were harvested 1-7 March, 2018. Growth and yield parameters like plant height, total dry matter accumulation, number of pods/plant, 100 seed weight and seeds yield/plant were measured at harvest.

2.4. Statistical analysis

The data of all parameters were subjected analyzed statistically by using software Statistix 10 (Analytical software, 2018). All the recorded data were analyzed using analysis of variance (ANOVA) and means were compared by using Least Significant Difference (LSD) test at a significance level of $P \leq 0.05$.

3. Results and Discussion

3.1 Plant height

Soil salinity caused a significant decrease in plant height of four winter pulses viz. BARI Masur-4 ii) BARI Khesari-2 iii) BARI Felon-1 and iv) BU Chola-1. Application of organic amendments increased the plant height of all the pulses (Table 1). Relative (per cent of control) plant height of the pulses ranged from 42.12% to 66.40% under saline condition. Plant height reduction due to salinity was lower in BARI Khesari-2 (33.46%), while that was higher in BARI Felon-1 (57.53%). Highest relative plant height (72.73%) was recorded in BARI khesari-1 when soil was treated with rice husk biochar @ 10 t/ha and the lowest height (49.43%) was observed in BARI Felon-1 when soil was treated with poultry manure @ 10 t/ha. Salinity induced reduction in plant height is a common phenomenon and was also reported earlier for different crops, e.g., mungbean, cowpea and soybean (Egeh and Zamora, 1992). The reduction in plant height was probably resulted from a slow growth caused by osmotic stress imposed by a high concentration of salts in the rooting zone.

Leithy *et al.* (2010) and Raafat and Tharwat (2011) have shown that different organic amendments increased plant height at different levels of soil salinity on peanut, sweet funnel and rice. Abubakar and Ali (2018) conducted a research to screen the effect of organic manure (poultry manure & cowdung) on the vegetative growth of maize and observed that plant height increased by increasing the application of both manure and that was better than that of inorganic fertilizer application.

Table 1. Effect of organic amendments on plant height of winter pulses under saline condition (Mean ± SE, n=3)

Pulses	Plant height (cm)			
	Control	Saline	Saline + poultry manure	Saline+ rice husk biochar
BARI Masur- 4	32.83±3.22	17.23±1.53 (52.49)	20.00±1.53 (60.91)	21.50±1.75 (65.48)
BARI Khesari-2	52.93±6.79	35.17±3.61 (66.40)	35.83±3.97 (67.70)	38.50±3.55 (72.73)
BARI Felon-1	46.93±2.45	19.77±1.39 (42.12)	23.27±1.73 (49.57)	28.80±1.70 (61.36)
BU Chola-1	47.20±1.34	23.33±2.02 (47.44)	23.33±2.18 (49.44)	25.70±2.16 (54.45)
LSD (5%)			7.95	
CV (%)			15.50	

Values presented in parentheses indicate percent values to the control.

3.2. Dry matter accumulation

Soil salinity caused a significant effect in dry weight (stem + leaf) of winter pulses. At saline soil relative (per cent of control) dry weight of the pulses ranged from 35.94% to 47.69% at 100 mM salinity. Dry weight reduction due to salinity was lower in BARI Masur-4 (52.31%), while that was higher in BU Chola-1 (64.06%) (Table 2). Organic amendments significantly increased the dry matter accumulation of pulses under saline condition. Rice husk biochar improved the highest dry weight (64.13%) was recorded in BARI Felon-1 and the lowest relative height (45.97%) was observed in BU Chola-1 when soil was treated with poultry manure @ 10 t/ha. Reduction in dry matter production under saline condition was also reported by Patil *et al.* (1992) and Raptan *et al*. (2001) in mungbean. Reduction in total dry matter under saline condition resulted in significant reductions of stem and leaf biomass (data not shown). Under salinity, incorporation of biochar increased shoot biomass reported by Akhtar *et al*. (2015).

Table 2. Effect of organic amendments on dry matter accumulation of winter pulses under saline condition (Mean ± SE, n=3)

Pulses	Dry matter (g/plant)			
	Control	Saline	Saline+poultry manure	Saline+ rice husk biochar
BARI Masur- 4	0.68±0.05	0.32±0.01 (47.69)	0.35±0.03 (51.92)	0.39±0.07 (57.67)
BARI Khesari-2	2.39±0.48	0.98±0.31 (41.04)	1.20±0.03 (50.24)	1.47±0.06 (61.21)
BARI Felon-1	4.16±0.77	1.93±0.19 (46.29)	2.27±0.22 (54.56)	2.67±0.04 (64.13)
BU Chola-1	2.71±0.58	0.97±0.09 (35.94)	1.25±0.19 (45.97)	1.31±0.06 (48.33)
LSD (0.5%)			0.91	
CV (%)			15.90	

Values presented in parentheses indicate percent values to the control.

Table 3. Effect of organic amendments on total chlorophyll content of winter pulses under saline condition (Mean ± SE, n=3)

Pulses	Total chlorophyll (mg/g fresh weight of leaf)			
	Control	Saline	Saline+ poultry manure	Saline+ rice husk biochar
BARI Masur-4	3.39±0.63	1.82±0.31 (53.59)	2.02±0.42 (59.69)	2.17±0.42 (64.11)
BARI Khesari-2	3.60±0.42	2.18±0.07 (60.50)	1.60±0.35 (44.40)	1.97±0.37 (54.76)
BARI Felon-1	2.75±0.50	1.12±0.03 (40.66)	1.34±0.20 (48.79)	1.81±0.06 (65.90)
BU Chola-1	3.74±0.20	1.41±0.11 (37.73)	1.50±0.11 (40.14)	1.69±0.11 (45.32)
LSD (0.5%)			1.74	
CV (%)			19.00	

Values presented in parentheses indicate percent values to the control.

3.3 Chlorophyll in leaf

Total chlorophyll of winter pulses also was reduced significantly at salinity stress. Leaf chlorophyll was increased after amendment of organic amendments in different pulses under saline conditions (Table 3). The highest chlorophyll increased was (65.90%) in BARI Felon-1 when biochar was added 10 t/ha and the lowest relative total chlorophyll (40.14%) was observed when poultry manure was applied @ 10 t/ha in BU Chola-1. Under saline conditions, photosynthetic activity decreases leading to reduced plant growth, leaf area, chlorophyll content and chlorophyll fluorescence reported by Muhammad *et al.* (2007). Das *et al*. (2013) found that organic amendments with farm yard manure or poultry manure confer tolerance to salinity in maize by increasing chlorophyll content. Ferdous *et al*. (2018) found water hyacinth compost and rice husk biochar had positive effects to mitigate negative effects of salinity on chlorophyll content in soybean.

Table 4. Effect of organic amendments on leaf proline content of winter pulses under saline condition (Mean ± SE, n=3)

Pulses	Proline (µ mole/g fresh weight of leaf)			
	Control	Saline	Saline+ poultry manure	Saline+ rice husk biochar
BARI Masur- 4	1.36±0.63	2.03±0.31 (149.02)	1.82±0.48 (134.07)	1.65±0.42 (121.32)
BARI Khesari-2	1.64±0.42	2.12±0.07 (129.33)	2.12±0.37 (129.33)	2.04±0.35 (124.64)
BARI Felon-1	1.35±0.50	1.97±0.03 (145.81)	1.57±0.06 (115.76)	1.53±0.20 (113.30)
BU Chola-1	1.36±0.20	1.88±0.11 (138.82)	1.79±0.11 (131.94)	1.69±0.11 (124.82)
LSD (0.5%)			0.67	
CV (%)			23.30	

Values presented in parentheses indicate percent values to the control.

Table 5. Effect of organic amendments on number of pod per plant of winter pulses under saline condition (Mean ±SE, n=3)

Pulses	Number of pod/plant			
	Control	Saline	Saline+ poultry manure	Saline+ rice husk biochar
BARI Masur-4	192.33±21.91	76.00±7.24 (39.51)	101.00±2.08 (52.51)	105.00±2.89 (54.59)
BARI Khesari-2	20.33±1.45	7.33±0.88 (36.07)	9.00±0.58 (44.26)	12.67±1.45 (62.30)
BARI Felon-1	15.00±1.16	7.33±0.88 (48.89)	8.00±0.58 (53.33)	10.00±1.16 (66.67)
BU Chola-1	41.66±4.41	19.67±1.45 (47.20)	21.67±3.53 (52.00)	23.33±2.41 (56.00)
LSD (0.5%)			17.43	
CV (%)			25	

Values presented in parentheses indicate percent values to the control.

3.4 Proline content

Proline content of winter pulses was increased significantly at salinity stress condition. In saline condition the highest relative proline content was measured in leaf of BARI Masur- 4 (149.01%) and the lowest was in BARI Khesari-2 (129.32%). Proline content was decreased in leaf of pulses after organic amendment application under saline condition (Table 4). Decreasing trend of leaf proline in winter pulses after incorporation of organic compounds indicated that organic amendments relief the pulses from salinity stress. Highest relative proline content was recorded in BARI Masur-4 (134.07%) when soil was treated with poultry manure and it was lowest in BARI Felon-1 (113.30%) when rice husk biochar was applied as soil amendment. Lower accumulation of proline under saline condition after organic amendment indicates that organic amendments reduce the salinity effects on winter pulses.

3.5 Number of pod

Winter pulses exposed to salinity caused a significant reduction in number of pods/plant, the reduction was higher in BARI Khesari-2 (63.93%) and it was lowest in BARI Felon-1 (51.11%) (Table 5). Organic amendments with poultry manure and rice husk biochar increased the number of pods/plant under salinity. Due to organic amendment application the number of pods/plant was increasing than salinity condition. Highest relative number of pods/plant was observed in BARI Felon-1 (66.67%) when rice husk biochar was added @ 10 t/ha and it was 44.26% when poultry manure was added @ 10 t/ha under saline condition in BARI Khesari-2. Ferdous *et al*. (2018) reported that soybean plants exposed to salinity caused a significant reduction in number of pods/plant. Organic amendments with water hyacinth compost and rice husk biochar increased number pods/plant at 50 mM and 100 mM NaCl salinity stress.

3.6 100-seed weight

Salt stress caused a significant decrease in 100-seed weight of winter pulses. Organic amendments with both poultry manure and biochar significantly increased the 100-seed weight of pulses under salt stress condition (Table 6). Application of 10 t/ha rice husk biochar better than poultry manure. Highest relative 100-seed weight (70.76%) was observed in BARI Felon-1 when biochar was added @ 10 t/ha and it was 59.21% when poultry manure was added at the same dose. Salinity induced reduction of 100- seed weight reported by Rashid *et al*. (2005) in lentil. Abou El-Magd *et al*. (2008) on sweet funnel showed that organic amendments increased 100- grains weight on different salt stress condition.

Table 6. Effect of organic amendments on 100- seed weight of winter pulses under saline condition (Mean ±SE, n=3)

Pulses	100 seed weight (g)			
	Control	Saline	Saline + poultry manure	Saline + rice husk biochar
BARI Masur-4	1.67±0.12	0.76±0.03 (45.40)	0.77±0.03 (46.11)	0.95±0.06 (56.88)
BARI Khesari-2	5.00±0.29	2.30±0.12 (46.00)	2.81±0.18 (56.13)	3.00±0.35 (60.00)
BARI Felon-1	9.23±0.51	4.67±0.44 (50.54)	5.47±0.52 (59.21)	6.53±0.32 (70.76)
BU Chola-1	14.67±1.45	6.00±1.16 (40.91)	7.33±0.44 (50.00)	8.17±0.44 (55.68)
LSD (0.5%)		1.65		
CV (%)		20.0		

Values presented in parentheses indicate percent values to the control.

Table 7. Effect of organic amendments on grain yield of winter pulses under saline condition (Mean ±SE, n=3)

Pulses	Grain yield (g/plant)			
	Control	Saline	Saline+ poultry manure	Saline+ rice husk biochar
BARI Masur-4	4.43±0.31	0.81±0.11 (18.29)	1.28±0.03 (28.78)	1.26±0.05 (29.18)
BARI Khesari-2	3.49±0.45	0.58±0.08 (16.52)	0.86±0.06 (24.55)	1.31±0.27 (37.46)
BARI Felon-1	14.51±1.14	3.52±0.14 (24.25)	4.54±0.17 (31.27)	7.45±0.33 (51.34)
BU Chola-1	7.40±1.21	1.38±0.17 (18.59)	1.89±0.29 (25.51)	2.31±0.37 (31.24)
LSD (0.5%)			1.39	
CV (%)			23.5	

Values presented in parentheses indicate percent values to the control

3.7 Seed yield

Salt stress caused a significant decrease in seed yield of winter pulses (Table 7). Organic amendments with both poultry manure and biochar significantly increased the yield of pulses under salinity. Both poultry manure and rice husk biochar also showed a considerable yield in winter pulses. Highest relative yield (51.34%) was observed when rice husk biochar was added @ 10 t/ha at BARI Felon-1 and it was 24.55% in BARI Khesari-2 when poultry manure was added @ 10 t/ha under saline condition. Addition of biochar may improve plant growth and yield by mitigating the negative effect of salinity through its high sorption ability. Application of FYM alone or in combination with organic compounds increases yield of wheat as well as improves quality of wheat grain under salt stress (Raafat and Thawrat, 2011). Amanullah *et al*. (2007) have shown that organic and inorganic amendments enhanced the yield of rice against soil salinity. There are evidences that organic manures reduce the adverse effects of various stresses on plants by affecting the uptake and accumulation of inorganic nutrients (Zaki *et al*., 2009. Abou El-Magd *et al*., 2008).

4. Conclusions

From the results it could be concluded that salinity decreased plant the height, dry matter accumulation, chlorophyll content and yield but increased leaf proline content of winter pulses. Applications of poultry manure and rice husk biochar were found to mitigate the negative effects of salinity stress. Among the organic amendments used, rice husk biochar @ 10 t/ha performed better than poultry manure. Among the winter pulses studied BARI Felon -1 was more responsive to rice husk biochar under saline condition.

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