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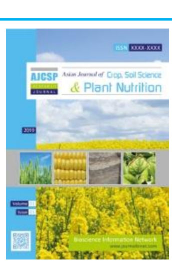

Amelioration of salinity stress in transplant Aman rice through application of gypsum

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ABSTRACT

The experiment was carried out at the farmyard of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from August 2017 to January 2018 to investigate the ameliorative effect of gypsum application on plant characteristics and yield, under various levels of salinity stress, of transplant Aman rice cv. Binadhan-10. The experiment was designed with three salinity levels such as control (M_0), 5 dSm^{-1} (M_1) and 10 dSm^{-1} (M_2) NaCl, two gypsum levels such as control (G_0) and 150 kg ha^{-1} (G_1). To ameliorate the salinity stress t, gypsum was applied. Results revealed that the different levels of salinity had a significant adverse effect on plant height, the total number of tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, panicle length, number of sterile spikelets $panicle^{-1}$, 1000-grain weight, number of grains $panicle^{-1}$, grain yield, straw yield, biological yield and harvest index. All the plants were affected badly when they were exposed to 10 dSm^{-1} salinity level. At salinity level of 5 dSm^{-1} grain yield reduction was 37%, which could be minimized to 14% by the application of gypsum. In case of straw yield, A similar amelioration effect was also observed. At 5 dSm^{-1} the grain yield was more improved from 3.46 t ha^{-1} to 3.93 t ha^{-1} when gypsum was applied. The grain yield reduction could further be improved at salinity level of 10 dSm^{-1} from 65% to 36% with the application of gypsum. At 10 dSm^{-1} the grain yield was more improved from 1.95 t ha^{-1} to 2.55 t ha^{-1} when gypsum was applied. The results of the study conclude that salinity stress could be ameliorated through the application of gypsum @ 150 kg ha^{-1} in transplant Aman rice cv. Binadhan-10.

Key Words: *Ameliorative effect, Gypsum, Soil salinity and Transplant Aman rice*

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I. Introduction

Rice (*Oryza sativa*), provides the primary source of food and calories for about half of mankind and one of the most essential cereal crops of the world (Khush, 2005). Word wide it is annually cultivated on an area of 163.2 million hectares with a total production of 503.8 million tones (FAO, 2017). In Bangladesh, Agriculture is dominated by rice cultivation where it is staple food also. Bangladesh is one of the most important rice growing countries in the world. 11.39 million hectares land is used for rice production in the country and annual production of rice is 34.71 million metric tons (BBS, 2017). About 30% of cultivable lands of the country are under the coastal area from which salinity affected area is nearly 53% (Haque, 2006; Uddin et al., 2011). According to salinity survey findings and salinity monitoring information, the total area of cultivated lands, in coastal areas, are affected by varying degrees of soil salinity is about 70% (1.02 million hectares). The lands are affected by very slight, slight, moderate, strong and very strong salinity are about 0.282, 0.297, 0.191, 0.450 and 0.087 million hectares, respectively (Haque, 2006). The salinity level of 4 dSm^{-1} is considered as a critical level for rice though rice exhibits considerable intra-specific variability in tolerance to salinity (Flowers and Yeo, 1981). Salinity can limit growth and plant yield in three ways including reducing osmotic potential, creating ion toxicity and causing disarrangement and imbalance of ion uptake leading to disorders in enzyme activities and membrane and metabolic activities in the plant (Hasegawa et al., 2000). To improve the yield of transplant 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). Binadhan-10 is a salt-tolerant variety for Boro season which can tolerate up to 12 dSm^{-1} of salinity, released in 2012 developed by Bangladesh Institute of Nuclear Agriculture (BINA). Gypsum is a source of calcium ion which can replace the sodium ion to reduce salinity. Gypsum is the most extensively used amendment for the reclamation of saline sodic soils because of its low cost, general availability, and rich supply of Ca^{2+} followed by leaching can ameliorate saline-sodic soils (Murtaza et al., 2009).

The present work aimed to study the amelioration of salinity stress in transplant *Aman* rice cv. Binadhan-10 through the application of gypsum. To achieve the aim, the objectives of this work were to investigate the effect of various salinity levels on yield and plant characters of transplant *Aman* rice cv. Binadhan-10 and to assess the ameliorative effect of gypsum and on plant characters and yield of transplant *Aman* rice cv. Binadhan-10 under various salinity levels.

II. Materials and Methods

Site and soil

The experiment was carried out at the farmyard of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during the period from August 2017 to January 2018. The site of the experiment is located at 24° 75' N latitude and 90° 50' E longitude at a mean elevation of 18 m above the sea level. It belongs to the Sonatala series of Old Brahmaputra Flood Plain under Agro-Ecological Zone-9 (AEZ-9) having non-calcareous Dark Grey floodplain soils (UNDP and FAO, 1988).

Treatments

Two sets of treatments included in the experiment were:
Factor A: Salinity level (a) Control (no salinity; M_0); (b) 5 dSm^{-1} (M_1); (c). 10 dSm^{-1} (M_2) and
Factor B: Level of gypsum (a) Control (no gypsum; G_0); (b) 150 kg ha^{-1} (G_1)

Design and layout of the experiment

The experiment was laid out in a Completely Randomized Design (CRD) with 3 (three) replications. Each pot contained one hill and denotes a replication. The total number of pots used in this study was 36 (2 x 2 x 3x 3).

Procedure for crop cultivation

Seeds were collected from the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Seeds of Binadhan-10 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. Plastic pot was selected for the experiment to check the loss of saline water. The total number of pots was 36 (2 x 2 x 3 x 3). The size of the pot was 23 cm in height and 30 cm in diameter. Then each of the pot was filled with the collected soil (8 kg/pot) and fertilized with recommended doses for the variety Binadhan-10 considering the soil type used for the experiment. Fertilizers were applied in the soil as per the recommendation of Bangladesh Institute of Nuclear Agriculture (BINA) with 10-ton cowdung, 217 kg urea, 110 kg triple superphosphate, 70 kg muriate of potash, 45 kg gypsum and 4.5 kg zinc sulphate ha^{-1} as basal dose (BINA, 2013). The fertilizers were broadcast and incorporated into the soil at final land preparation. Urea was applied in 3 equal splits at 30, 50 and 70 days after sowing (DAS). Transplanting was done on 30 August, 2017. Three seedlings were transplanted in each hill. Transplanting was done soon after uprooting of the seedlings. The pots were kept weed free (by hand weeding) from the very beginning of transplanting up to harvesting of the crop. Water was supplied as and when needed to ensure sufficient moisture for the normal growth of the crops. Plants were infested with leafhopper and rice yellow stem borer which was successfully controlled by Diazinon at 25 DAT. Rice bug at the milk stage was controlled by spraying Malathion, and bacterial leaf blight (BLB) was controlled by spraying Cupravit. By using a net, crops were protected from birds and animals. The crop was harvested pot-wise at full maturity on 4 January 2018. After harvesting, the crop of each pot was bundled separately and tagged properly. The bundles were sun dried properly before recording data on various plant characters and yield.

Collection of data

Plant height at harvest (cm), number of total tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length (cm), grains panicle^{-1}, sterile spikelets panicle^{-1} (no), weight of 1000 grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}), harvest index was recorded on different intervals.

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).

III. Results and Discussion

Effect of salinity stress on yield and plant characters of transplant *Aman* rice cv. Binadhan-10

The effect of salinity stress on yield and yield attributes of transplant Aman rice var. BINA dhan10 was statistically significant (Table 01). It was observed that the plant height, number of total tillers hill^{-1}, effective tillers hill^{-1}, panicle length, grains panicle^{-1}, 1000 grain weight, grain yield, straw yield, biological yield and harvest index decreased with the increasing salinity level. The highest, plant height (92.25 cm), no. of total tillers hill^{-1} (12.58), effective tillers hill^{-1} (11.08), panicle length (23.6 cm) , grains panicle^{-1} (52.07), 1000 grain weight (26.18 g), grain yield (5.59 t ha^{-1}), straw yield (6.88 t ha^{-1}), biological yield (12.47 t ha^{-1}) and harvest index (45.17%) were observed at the control (no salinity). On the other hand, the lowest no. of total tillers hill^{-1} (9.75), no. of effective tillers hill^{-1} (8.08) and grain yield (2.25 t ha^{-1}) were recorded at the 10 dSm^{-1} salinity level. The no. of sterile spikelet panicle^{-1} increased with the increasing salinity levels. The highest no. of sterile spikelet panicle^{-1} (32.33) was observed at the 10 dSm^{-1} salinity level and the lowest no. of sterile spikelet's panicle^{-1} (15.65) was observed at control salinity level. So, the salinity stress 10 dSm^{-1} had significant negative impact on transplant Aman rice.

Following the present result (Ntia and Binang, 2007) revealed that plant height, panicle length, with salt concentration, biomass and yield are affected and salinity markedly reduced agronomic attributes (plant height) in all genotypes. Asch et al. (2000) also reported that salinity in the reproductive stage reduces the number of filled panicles, fertile panicles, weight of 1000 grains and percentage of fertile grains, but increases fertile tiller. By modifying plants morphological, anatomical and physiological traits, chloride and sodium sulphates in high concentration, affects plant growth (Muscolo et al., 2003).

Effect of gypsum on yield and plant characters of transplant *Aman* rice cv. Binadhan-10

A significant variation also observed when only effect of gypsum evaluated. Highest plant height (81.0 cm), tillers hill^{-1} (11.94), number of effective tillers hill^{-1} (10.06), panicle length (20.65 cm), number of grains panicle^{-1} (42.15), 1000-grain weight (25.56g), grain yield (4.12 t ha^{-1}), straw yield (4.90 t ha^{-1}), biological yield (9.02 t ha^{-1}) was recorded in 150 kg ha^{-1} gypsum as compared to no gypsum application (Table 02). The lowest plant height (77.28 cm), total tillers hill^{-1} (10.39), number of effective tillers hill^{-1} (8.94), panicle length (19.59 cm), number of grains panicle^{-1} (38.89), 1000-grain weight (24.77 g), grain yield (3.57 t ha^{-1}), straw yield (4.75 t ha^{-1}), biological yield (8.32 t ha^{-1}) was recorded in 0 kg ha^{-1} gypsum.

Table 01. Effect of salinity level on yield and plant characters of transplant *Aman* rice cv. Binadhan-10

Salinity level (dSm^{-1})	Plant height (cm)	Total tillers hill^{-1}(no.)	Effective tillers hill^{-1}= (no.)	Panicles length (cm)	Grains panicle^{-1}(no.)	Sterile spikelet's panicle^{-1}(no.)	1000 grain weight(g)	Grain yield (g hill^{-1})	Grain yield (t ha^{-1})	Straw Yield (g hill^{-1})	Straw yield (tha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Control (no salinity)	92.25 a	12.58 a	11.08 a	23.6 a	52.07 a	15.65 c	26.18 a	16.92 a	5.59 a	20.86 a	6.88 a	12.47 a	45.17 a
5	78.75 b	11.17 b	9.33 b	20.74 b	42.55 b	22.55 b	24.75 b	11.20 b	3.70 b	13.91 b	4.59 b	8.29 b	44.49 a
10	66.417 c	9.75 c	8.08 c	16.03 c	26.94 c	32.33 a	24.57 b	6.34 c	2.25 c	9.07 c	2.99 c	5.24 c	42.14 b
LSD $_{0.05}$	2.16	0.88	0.55	0.66	1.72	1.25	0.76	0.75	0.37	0.41	0.14	0.35	3.31
Level of sig.	**	**	**	**	**	**	**	**	**	**	**	**	*

In a column, figures with similar letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT LSD = least significant difference, ** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Table 02. Effect of gypsum on yield and plant characters of transplant *Aman* rice cv. Binadhan-10

Gypsum rates (kg ha^{-1})	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicles Length (cm)	Grains panicle^{1} (no.)	Sterile spikelet's panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (g hill^{-1})	Grain yield (t ha^{-1})	Straw yield (g hill^{-1})	Straw yield (tha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Control(no gypsum)	77.28 b	10.39 b	8.94 b	19.59 b	38.89 b	25.03 a	24.77 b	10.82 b	3.57 b	14.38 b	4.75 a	8.32 b	42.61
150	81.0 a	11.94 a	10.06 a	20.65 a	42.15 a	21.99 b	25.56 a	12.16 a	4.12 a	14.85 a	4.90 b	9.02 a	45.26
Level of sig	**	**	**	**	**	**	**	**	**	**	**	**	NS

In a column, figures with similar letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT
** = Significant at 1% level of probability, * = Significant at 5% level of probability, NS = Not significant

Table 03. Interaction effect of salinity and gypsum on yield and plant characters of transplant *Aman* rice cv. Binadhan-10

Salinity × gypsum	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Panicles length (cm)	Grains panicle^{-1} (no.)	Sterile spikelet's panicle^{-1} (no.)	1000-grain Weight (g)	Grain yield (g hill^{-1})	Grain yield (t ha^{-1})	Straw yield (g hill^{-1})	Straw yield (t ha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
M_0 G_0	89.83 b	12.00 a	10.67 b	23.33 a	50.77 b	17.50 d	25.97 ab	16.08 b	5.31b	20.50 b	6.76 b	12.07 b	44.79 ab
M_0 G_1	94.67 a	13.17 a	11.50 a	23.87 a	53.37 a	13.80 e	26.39 a	17.77 a	5.86 a	21.23 a	7.00 a	12.87 a	45.55 a
M_1 G_0	77.33 c	10.33 b	8.50 c	19.82 c	41.07 d	23.33 c	24.25 cd	10.48 d	3.46 c	13.91 c	4.54 c	8.05 c	42.88 ab
M_1 G_1	80.17 c	12.00 a	10.17 b	21.67 b	44.03 c	21.77 c	25.24 bc	11.93 c	3.93 c	13.91 c	4.59 c	8.53 c	46.11 a
M_2 G_0	64.67 e	8.83 c	7.67 d	15.63 d	24.83 f	34.25 a	24.10 d	5.90 e	1.95 e	8.73 e	2.88 e	4.53 e	40.15 b
M_2 G_1	68.17 d	10.67 b	8.50 c	16.43 d	29.04 e	30.41 b	25.05 bcd	6.77 e	2.55 d	9.41 d	3.12 d	5.66 d	44.12 ab
LSD $_{0.05}$	3.05	1.25	0.77	0.93	1.4	1.76	1.08	1.06	0.53	0.58	0.50	0.50	4.68
Level of sig.	*	*	*	*	*	*	*	*	*	*	*	*	*

M_0 = Control (no salinity); M_1 = Salinity @ 5 dSm^{-1}; M_2 = Salinity @ 10 dSm^{-1}, G_0 = Control (no gypsum); G_1 = Gypsum @ 150 kg ha^{-1}
In a column, figures with similar letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT
LSD = least significant difference, ** = Significant at 1% level of probability, * = Significant at 5% level of probability

Moreover, the result revealed that number of sterile spikelets panicle^{-1} increased in control (G_o) than gypsum supplemented group (G_1) the lower number of sterile spikelets panicle^{-1} (21.99) was recorded in 150 kg ha^{-1} gypsum. The higher harvest index (45.26%) was recorded at 150 kg ha^{-1} gypsum (G_1) as compared to control (42.61%) (Table 02).

Similar result was found from the study of Siam et al. (2014) who investigated the ameliorative effect of gypsum on the yield of transplant Aman rice variety BRRI dhan40 under salinity stress and suggested that salinity stress in transplant Aman rice var. By applied gypsum, BRRI dhan40 could successfully be ameliorated. Shaaban et al. (2013) also reported that gypsum increased root length and paddy yield under various levels of salinity and decreased soil pH, electrical conductivity and sodium adsorption ratio.

Interaction effect of salinity levels and gypsum on yield and plant characters of transplant *Aman* rice cv. Binadhan-10

The interaction effect of salinity levels and gypsum rates on plant height was found statistically significant ($p<0.01$) (Table 03). Plant height increased with increasing gypsum level and control salinity interaction. The highest plant height (94.67 cm), total tillers hill^{-1} (13.17), effective tillers hill^{-1} (11.50), panicle length (23.87), grains panicle^{-1} (53.37), 1000-grain weight (26.39), grain yield (5.86 t ha^{-1}), straw yield (7.00 t ha^{-1}) and biological yield (12.87 t ha^{-1}) was recorded in 150 kg ha^{-1} gypsum (G_1) and control salinity (M_0) interaction. On the flip side, the lowest plant height (64.67cm), total tillers hill^{-1} (8.83), effective tillers hill^{-1} (7.67), panicle length (15.63), grains panicle^{-1} (24.83), 1000-grain weight (24.10), grain yield (1.95 t ha^{-1}), straw yield (2.88 t ha^{-1}), biological yield (4.53 t ha^{-1}) was recorded in higher salinity 10 dSm^{-1} (M_2) and control gypsum (G_0) interaction (Table 03). Furthermore, the highest sterile spikelets panicle^{-1}(34.25) was recorded in higher salinity 10 dSm^{-1} (M_2) × no gypsum (G_0) application (Table 03). The lowest sterile spikelets panicle^{-1}(13.80) was recorded in 150 kg ha^{-1} gypsum (G_1) and control salinity (M_0) interaction ($G_1 \times M_0$). The highest harvest index (46.11%) obtained from 5 dSm^{-1} (M_1) × 150 kg ha^{-1} gypsum (G_1) application and the lowest harvest index (40.15%) obtained from 10 dSm^{-1} (M_2) × 0 kg ha^{-1} gypsum (G_0) application.

Amelioration of salinity stress on grain and straw yields of transplant *Aman* rice cv. Binadhan-10 by gypsum

Table 04 shows the reduction of grain and straw yields of transplant *Aman* rice cv. Binadhan-10 under various levels of salinity stress over control and under application of gypsum. It is evident from the table that the application of gypsum @150 kg ha^{-1} increased grain yield by 10.35% over control when no salinity was imposed. On the other hand, imposition of salinity stress @5 dSm^{-1} and 10 dSm^{-1} NaCl decreased grains yield by 34.83% and 63.27%, respectively. Over control, the grain yield reduction of 34.83% due to salinity stress @5 dSm^{-1} was minimized to 25.98% and that of 63.27% due to salinity stress @5 dSm^{-1} was minimized to 51.97% by applying gypsum @150 kg ha^{-1}. In case of straw yield, application of gypsum @ 150 kg ha^{-1} increased straw yield by 3.55% over control when no salinity was imposed. On the other hand, imposition of salinity stress @5 dSm^{-1} and 10 dSm^{-1} NaCl decreased straw yield by 32.84% and 57.39%, respectively over control. However, the straw yield reduction of 32.84% was minimized to 32.10% and that of 57.39% to 53.84 % by applying gypsum @ 150 kg ha^{-1}. The results reveal that the ameliorative effect of gypsum at 150 kg ha^{-1} was effective at both salinity levels used in the study.

Table 04. Amelioration of salinity stress on grain and straw yields of transplant *Aman* rice cv. Binadhan-10 by gypsum application

Interaction (Salinity × gypsum)	Grain yield (t ha^{-1})	% increase or decrease over control	Straw yield (t ha^{-1})	% increase or decrease over control
$M_0 G_0$	5.31b	-	6.76 b	-
$M_0 G_1$	5.86 a	10.35	7.00 a	3.55
$M_1 G_0$	3.46 c	-34.83	4.54 c	-32.84
$M_1 G_1$	3.93 c	-25.98	4.59 c	-32.10
$M_2 G_0$	1.95 e	-63.27	2.88 e	-57.39
$M_2 G_1$	2.55 d	-51.97	3.12 d	-53.84

M_0= Control (no salinity); M_1= Salinity @5 dSm^{-1}; M_2= Salinity @10 dSm^{-1}, G_0= Control (no gypsum); G_1= Gypsum @150 kg ha^{-1}. In a column, figures with similar letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT

V. Conclusion

The effect of gypsum was significant over all the parameters. It was observed that plant height, total of tillers hill^{-1}, number of effective tillers hill^{-1}, panicle length, grains panicle^{-1}, 1000- grain weight, grain yield and straw yield increased with the increasing gypsum level. Gypsum ameliorated salinity remarkably in case of grain yield and straw yield. Grain yield reduction was 37% at salinity level of 5 dSm^{-1}, which could be minimized to 19% by the application of gypsum. The grain yield reduction could further be improved at salinity level of 10 dSm^{-1} from 65% to 53% and 36% with the same application. From the present study, it can be concluded that gypsum at 150 kg ha^{-1} alone showed better salinity amelioration in terms of yield of transplant *Aman* rice cv. Binadhan-10. To reduce the salinity problem for cultivation of transplant Aman rice cv. Binadhan-10, gypsum @ 150 kg ha^{-1} can be recommended on this agro climatic zone.

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