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EFFECTS OF ORGANIC AND INORGANI C AMENDMENTS ON BORO RICE (BINA DHAN-8) IN SALINE SOILS

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ABBREVIATIONS

AEZ	- Agro-ecological zone
Agril.	- Agricultural
BARC	- Bangladesh Agricultural Research Council
BAU	- Bangladesh Agricultural University
BBS	- Bangladesh Bureau of Statistics
BINA	- Bangladesh Institute of Nuclear Agriculture
BRRI	- Bangladesh Rice Research Institute
CV	- Coefficient of variation
cv.	- Cultivar
DAT	- Days after Transplanting
et al.	- And others
FAO	- Food and Agriculture Organization
J.	- Journal
LSD	- Least Significant Difference
MoP	- Muriate of Potash
Res.	- Research
Sci.	- Science
Soc.	- Society
SRDI	- Soil Resource Development Institute
TSP	- Triple Super Phosphate
Var.	-Variety
Viz.	-Namely
%	-Percentage

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EFFECTS OF ORGANIC AND INORGANIC AMENDMENTS ON BORO RICE (Binadhan -8) IN SALINE SOILS

ABSTRACT

A field experiment was conducted with Boro rice (cv Binadhan-8) from January 2019 to April 2019 at Char Alahi, Companigonj, Noakhali to investigate the effects of organic and inorganic amendments on growth and yield of Boro rice (Binadhan-8) in saline soils. The experiment was laid out in a split-plot design with three replications, where main plots comprised of four levels of organic amendments viz. A_0: no soil amendment, A_1: farm yard manure (5.0 t ha^{-1}), A_2: crop residue (5.0 t ha^{-1}), A_3: rice husk (4.0 t ha^{-1}) and sub-plots had four gypsum doses viz. G_1: control, G_2: 160 kg ha^{-1}, G_3: 200 kg ha^{-1}, G_4: 240 kg ha^{-1}. Each treatment was also received recommended dose of chemical fertilizers such as using in control treatment. Organic amendment had significant effect on the yield and yield components of Boro rice (Binadhan-8). The results indicated that the highest plant height (100.9 cm), panicle length (27.23 cm), number of plants hill^{-1} (9.616) and harvest index (47.98%) were recorded in crop residue A_2 (5.0 t ha^{-1}) while the highest 1000-grain weight (24.41 g), grain yield (6.210 t ha^{-1}), straw yield (7.123 t ha^{-1}) and biological yield (13.32 t ha^{-1}) were obtained from farm yard manure A_1 (5.0 t ha^{-1}). The impact of different organic sources over control was statistically similar. Rates of gypsum significantly influenced all of the parameters except biological yield and harvest index. The highest plant height (100.6 cm) and harvest index (47.63%) were obtained from (G_4) 240 kg ha^{-1}; the highest panicle length (27.39 cm), number of plants hill^{-1} (9.868), 1000-grain weight (24.38 g), grain yield (6.165 t ha^{-1}), straw yield (6.858 t ha^{-1}) and biological yield (13.02 t ha^{-1}) were obtained from (G_2) 160 kg ha^{-1}. The impact of different rates of gypsum was statistically similar in almost all cases. The interaction of organic amendments and gypsum significantly manipulated the yield and yield attributes. Due to interaction of organic amendments and gypsum, the highest growth and yield was observed in farm yard manure with 160 kg ha^{-1} soil (A_1G_2). The S uptake by plants was significantly influenced by the both types of treatments. The results indicated that Boro rice can be grown successfully in a saline area by applying the farm yard manure as organic amendments and 160 kg ha^{-1} of gypsum as an inorganic amendment.

CHAPTER 1
INTRODUCTION

Rice is the most important staple food in Asia, providing an average of 32% of total calorie uptake (Maclean *et al.,* 2002). This staple food ranked first position by production (28931 thousand metric tons) during the year 2007-08 among all cereals in Bangladesh (BBS, 2009). In Bangladesh, rice dominates over all other crops and covers 77% of the total cropped area and 93% farmers grow rice. The total area and production of rice in Bangladesh are about 11.7 m ha and 31.98 million metric tons, respectively (BBS, 2011). This crop is being cultivated in at least 95 countries throughout the world (FAO, 2004). About 90% or more of the population of Bangladesh, Myanmar, Sri Lanka, Vietnam, and Cambodia depend on rice for their major food intake (IRRI, 1997). To meet the projected demand for rice, it has been estimated that global annual rice production needs to be increased from the present 560 million to 860 million tons by 2025 (Khush, 1997). In Bangladesh, production needs to be increased by more than 50% in the next 15 years to keep up with the population growth. However, Bangladesh has 8.76 million hectares of arable land, of which 75% is devoted to rice cultivation (BBS, 2005).

Salinity causes reduction in crop yield on about 10 m ha of worlds irrigated land (Rhoades and Loveday, 1990). In general, soil salinity is believed to be mainly responsible for low land use as well as cropping intensity in the area (Rahman and Ahsan, 2001). Salinity is an environmental challenge affecting crop production seriously all over the world. Over 800 million hectares of land throughout the world are salt-affected, either by salinity (397 million ha) or the associated condition of sodicity (434 m ha) (FAO, 2005). Out of 2.85 million hectares of coastal land and off-shores land of Bangladesh, about 1.056 million hectares are affected by different degrees of salinity (SRDI, 2010). The coastal

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saline soils are distributed unevenly in 64 Thanas of 13 Districts covering portions of eight agroecological zone (AEZ) of the country (Seraj and Salam, 2000). Salinity largely reduces the yield of rice in the coastal areas of the country mainly in Khulna, Jessore, Bagerhat, Barguna, Satkhira, Patuakhali, Noakhali, and Chittagong districts and in the Islands of Bay of Bengal like Bhola, Hatia and Swandip. Bangladesh has a mammoth population. Food security has been and will remain as a major concern for Bangladesh. To meet the consequent increased demand, food production must be increased either by increasing arable land or by increasing yield per hectare. The arable land in the densely populated country like Bangladesh is very limited. In this situation, it is essential to explore the possible alternatives that are economically feasible for Bangladesh. It could be achieved either by bringing the salt affected areas under cultivation and/or by developing salt tolerant crop species or varieties.

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.

Many attempts have been undertaken to counteract the adverse effects of salt stress by using organic and inorganic amendments. 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).

One of the major reasons for low productivity of crops grown on salt-affected soil is the salt toxicity and poor soil properties (Gao *et al.,* 2008). A need, therefore, exists for low-cost, efficient treatment strategies to reduce the salt toxicity of soils and to improve the soil properties. Leaching of sodium from the root zone is one of the most common and effective methods for controlling sodium accumulation in salt affected soils (Ghafoor *et al.*, 2008). Gypsum is typically used as a source of calcium to remove the exchangeable sodium. The application of calcium can improve various soil properties and act as soil modifiers that prevent the development of sodicity which is directly related to plant growth, crop productivity and crop yields (Muhammad and Khattak, 2011).

Considering these points, the current study was designed with the following objectives:

i) to observe the effects of organic and inorganic amendments on boro rice (Binadhan-8) in saline soils,

ii) to know the interaction effects of organic and inorganic amendments on boro rice (Binadhan-8) in saline soils.

CHAPTER 2
REVIEW OF LITERATURE

Salinity is one of the major abiotic stresses which adversely affect the growth and yield of plant. Rice that grows under saline condition faces different stresses, especially ion toxicity and low water availability. Resear ches on rice have been performed extensively in south Asia for improvement of its yield and quality. Recently Bangladesh Rice Research Institute (BRRI), Bangladesh Institute of Nuclear Agriculture (BINA) and Bangladesh Agricultural University (BAU), Mymensingh has started extensive research on varietal development on salinity tolerance of rice. Research efforts on the development of salt tolerant genotypes are very little. To justify the present study, attempts have been made to incorporate some of the important findings of renowned scientists and research workers in this country and elsewhere of the world. The most relevant studies, which have been conducted in the recent past related to the present research work, are presented below-

Effect of organic and inorganic amendments for rice production

Kandeshwari M (2014) conducted a field experiment during rabi (August, 2010-January, 2011) season in Wetland Farms of Tamil Nadu Agricultural University, Coimbatore, to evaluate the integrated nutrient management practices under system of rice intensification. The main objective of the study was to optimize the use of different sources of nutrients under SRI. The experiment was laid out in a randomized block design with three replications. It is evident from the present investigation that application of 75% inorganic N + 12.5% N through FYM + 12.5% N through well decomposed PM is found to be a better option for getting higher productivity and economic returns of rice under system of rice intensification.

Sujatha *et al.,* (2014) conducted a field experiment at the Agricultural College

Farm, Bapatla, during *kharif* 2012-13 to find out the residual soil fertility and productivity of rice as influenced by different organic sources of nutrients viz., poultry manure, FYM, neemcake and vermicompost. The experimental results indicated that maximum yield of rice was recorded with recommended dose of fertilizers which was on a par with 50% RDN as basal +50% at 10 days before PI stage through poultry manure. Among different organic manure treatments, application of 100% RDN through FYM recorded highest amount of NPK in soil after harvest, followed by application of 50% RDN as basal +50% at 10 days before PI stage through FYM which were however, on a par with each other.

Linlin W *et al.,* (2014) reported that the ability of the following four organic amendments to ameliorate saline soil in coastal northern China was investigated from April 2010 to October 2012 in a field experiment: green waste compost (GWC), sedge peat (SP), furfu ral residue (FR), and a mixture of GWC, SP and FR (1:1:1 by volume) (GSF). Compared to a non-amended control (CK), the amendments, which were applied at 4.5 kg organic matter m23, dramatically promoted plant growth; improved soil structure; increased the cation exchange capacity (CEC), organic carbon, and available nutrients; and reduced the salt content, electrical conductivity (EC), and exchangeable sodium percentage (ESP). At the end of the experiment in soil amended with GSF, bulk density, EC, and ESP had decreased by 11, 87, and 71%, respectively, and total porosity and organic carbon had increased by 25 and 96% respectively, relative to the CK.

Tilahun *et al.,* (2013) conducted a field experiment to assess the effects of combined application of farm yard manure (FYM) and inorganic NP fertilizers on soil physico-chemical properties and nutrient balance in a rain-fed lowland rice production system in Fogera plain, northwestern Ethiopia. Results showed that application of 15 t·FYM·ha^{-1} significantly increased soil organic matter and available water holding capacity but decreased the soil bulk density, creating a

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good soil condition for enhanced growth of the rice crop. Application of 15·t ha^{-1}·FYM and 120 kg·N·ha^{-1}resulted in 214.8 kg·ha^{-1}·N positive balance while application of 15 t·ha^{-1}·FYM and 100 kg·P_2O_5·ha^{-1} resulted in a positive balance of 69.3 kg·P2O5·ha^{-1} available P. From the results of this experiment, it could be concluded that combined application of FYM and inorganic N and P fertilizers improved the chemical and physical properties, which may lead to enhanced and sustainable production of rice in the study area.

Fakhrul Islam *et al.,* (2013) conducted an experiment in the Sher-e-Bangla Agricultural University research farm, Dhaka, Bangladesh du ring December 2010 to April 2011 to study the effect of fertilizer and manure with different water management on the growth, yield and nutrient concentration of BRRI dhan28. There were 2 irrigation levels (I0= Alternate wetting and drying, I1= Continuous flooding) and 8 fertilizer treatment (T0: control, T1: 100% RDCF, (N100P15K45S20Zn2), T2: 10 ton cowdung/ha, T3: 50% RDCF + 5 ton cowdung/ha, T4: 8 ton poultry manure/ha, T5: 50% RDCF + 4 ton poultry manure/ha, T6: 10 ton vermicompost/ha, T7: 50% RDCF + 5 t on vermicompost/ha). The T5 (50% RDCF + 4 ton poultry manure/ha) showed the highest effective tillers/hill, plant height, panicle length, 1000 grain wt., grain yield (5.92 kg/plot) and straw yield (5.91 kg/plot). The higher grain and straw yields were obtained organic manure plus inorganic fertilizers than full dose of chemical fertilizer and manure.

Shaaban *et al.,* (2013) reported that combined application of organic and inorganic amendments was known to play a significant role in improvement of soil properties. A field experiment was conducted to explore the effects of gypsum, farmyard manure and commercial humic acid application on the amelioration of salt affected (saline sodic) soil. During this study, soil pH, electrical conductivity, sodium adsorption ratio, responses of root length and rice paddy yield were examined. Application of gypsum with or without farm manure and commercial humic acid decreased soil pH (8.26%), electrical conductivity (from 6.35 dS/m to

2.65 dS/m) and sodium adsorption ratio (from 26.56 to 11.60), and increased root length (from 9.17 cm to 22.6 cm) and paddy yield (from 695.7 kg/ha to 1644 kg/ha).

Zhang *et al.,* (2013) reported that Careful soil management is important for the soil quality and productivity improvement of the reclaimed coastal tidal flat saline land in northern Jiangsu Province, China. Farmyard manure (FYM) and mulch applications, which affect soil characteristics and plant significantly, are regard as an effective pattern of saline land improvement. The experiment, laid out in a randomized complete block design with three replications. Result showed that capillary water holding capacity (CHC), saturated water content (SWC), saturated hydraulic conductivity (*Ks*) and bulk density (BD), cone index (CI) were affected significantly by the FYM and mulch application, especially in the 0–10 cm soil layer. FYM and mulch management increased of CHC, SWS and *Ks* over all soil depth in the order FYM + SM>FYM + PM>FYM>SM>PM>CK. With the contrary sequence, BD and CI decreased significantly; however, FYM and mulch application affected BD and CI only in the upper soil layers. The combined management of farmyard manure and straw mulch was recommend to be an effective method for the melioration of reclaimed coastal tidal flat saline soil.

Khotabaei *et al.* (2013) reported that the application of organic amendments can be an appropriate solution to reclaim and improve physical properties of saline-sodic soils. In this research, an experiment was performed under greenhouse conditions to study the effect of amendments to the physical properties of loamy saline-sodic soil. The five treatments were control (without amendment), municipal solid waste compost (MC), vermicomposting (VC), poultry manure (PM), and gypsum powder (G). They were carried out in a completely randomized design with three replications. Each treatment comprised 10 ton/ha of the specified soil added to the soil. The results showed that soil amendments decreased bulk density ($p<0.05$) and increased mean weight diameter of aggregates (MWD) ($p<0.05$) over the

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control. The positive effects of the amendments showed that the application of organic and/or inorganic amendments can be recommended for saline-sodic soil to improve soil physical quality.

Mohamed Abdel-Fattah (2012) reported that a leaching experiment using columns technique was carried out to evaluate the efficiency of gypsum, water hyacinth compost "WHC", rice straw compost "RSC" and their different combinations on reclamation of clay saline-sodic soils. Soils were collected from Sahl El-Hossinia, El-Sharkia Governorate, Egypt. The results of the study indicated that all the used amendments either, singly or in combination showed a pronounced decreased in EC, pH, SAR, and ESP compared with control. The results showe d that combined treatments more efficient than single one. Increase the rate of gypsum used leads to an increase in decrease salinity as well as sodicity. This study suggests that application of gypsum combined with WHC or RSC enhanced reclamation and caused more decreases in salinity as well as sodicity.

Thamaraiselvi *et al.,* (2012) reported that in recent investigations, the addition of organic amendments is a best and cheapest source for the soil to counteract the toxicity of soil. During this work, it was explained briefly about how the organic manures provide benefits for the soil. The experiments were conducted with three soils each treated with four treatments of organic amendments representative samples were drawn on 0, 10, 20 and 30 days after incubation analyzed for pH, EC, organic carbon N, P & K . Instead of chemical fertilizer using organic amendments prevents hazards in soil Environment; improve soil multiplication protection of human being from environmental pollution.

Behzad *et al.,* (2011) reported that with more pressing demands for non-agricultural sectors, availability of good-quality water is falling short of the crop water requirement, particularly in arid and semi-arid regions of the world, like Pakistan. Studies were conducted at three sites following randomized complete block design (RCBD) with three replications. The treatments employed were:

Tube well water (TW) alone; TW + Gypsum @ 50% soil gypsum requirement (TW + G50); TW –Canal water (CW) + G50; TW –CW + farm manure (FM) @ 25 Mg ha −1 (TW –CW + FM) before sowing wheat. There was maximum and significant decrease in ECe and SAR with TW –CW + FM at all the three sites. Maximum decrease in ECe (72.65%) at 0 –15 cm soil depth was at site 2, while maximum decrease in ECe (77.62%) at 15 –30 cm soil depth was at site 1. Maximum percent decrease in SAR was 75.76% at 0 –15 cm followed by 63.93% at15 –30 cm at sites 2 and 3, respectively, with TW –CW + FM.

Walpola *et al.,* (2010) reported that as it is believed that soil salinity can alter the organic matter turnover process, the present study discussed the influence of soil salinity on the decomposition of organic matter and nitrogen mineralization in animal manure amended soils. A factorial combination of two soil types (saline and non-saline soils) with three types of animal manure (i.e. poultry manure, goat manure and cow dung) was used to assess the C and N mineralization. The amount of CO2-C released from both soils was not significant ($P \leq 0.05$) until day 2 of incubation. However, saline soil showed significantly ($P \leq 0.05$) low NH4+ –N content compared to the non-saline soil. Though, the nutritional composition of applied manures was different, no significant ($P \leq 0.05$) differences were found among the treatments in terms of N mineralization. However, the content of NO3 – –N was found to be dominated in non-saline soil throughout the incubation. Results could be concluded that the response pattern of C and N mineralization to salinity stress depended on the type of animal manure incorporate to the soil and duration of incubation.

Abdel *et al.,* (2009) reported that Soil degradation and salinization are two of the utmost threat affecting agricultural areas, derived from the increasing use of low quality water and inappropriate cultural practices. The problem of low productivity of saline soils may be ascribed not only to their salt toxicity or damage caused by excess amounts of soluble salts but also arising from the lack of organic matter and available mineral nutrients especially N, P, and K. Concerns about salinization risk and environmental quality and productivity of agro-ecosystems have emphasized the need to develop management practices that maintain soil resources. However, their application could be also a promising alternative to alleviate the adverse effects caused by soil salinization. MSW compost, with high organic matter content and low concentrations of inorganic and organic pollutants allow an improvement of physical, chemical and biochemical characteristics and constitute low cost soil recovery.

Abdul *et al.,* (2008) reported that the effect of organic matter in improving the properties of saline soils. A laboratory study was conducted to determine the effect of adding farm yard manure (manure), Egyptian clover hay (clover hay), and wheat straw, at 1 and 3% of soil weight on water stability of soil aggregates (WSA), water -holding capacity (WHC), pH, and electrical conductivity of soil extract (ECe) of a normal, saline, and saline sodic soil. After 90 and 180 days, WSA and WHC increased, while pH and ECe decreased. Soil properties improved most by adding 3% manure to all the soils. Organic matter added to these soils increased WSA and WHC and decreased pH and Ece. It is concluded that manure ameliorated salt affected soils and promoted wheat growth better than clover hay and wheat straw.

Bajwa and Josan (2003) conducted a field experiment to examine the influence of different amounts of gypsum, applied either at each irrigation or in one dose, on the amelioration of deteriorating effects of sodic water irrigations under a fixed rice-wheat cropping cycle. Application of gypsum decreased pH, SAR and ESP of the top 0-60 cm soil and hence increased yields of crops. Increase in levels of gypsum progressively decreased the Na saturation of the soil. In rice, small amounts of gypsum applied in one dose were less beneficial. Gypsum, to supply 5 meq Ca/l of sodic irrigation water for rice crops was sufficient to maintain high yields.

Sharma (2001) reported that, the application of gypsum could alleviate the adverse effects of salinity and increase tolerance to salinity in rice plants. Addition of gypsum (10mM) showed significant promotion in the total chlorophyll contents at higher levels too.

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Abdullah *et al.* (2001) reported that supplemental Ca^{2+} significantly ameliorated the detrimental effects of salinity on the growth and root nutrient of rice plants. The shoot length of plants grown in a saline environment (100 mM NaCl) at a high (10 mM) Ca^{2+} level was not significantly different from control plants (grown at 1 mM NaCl). At the same time, the root length of those plants grown at 100 mM NaCl with 10 mM Ca^{2+} was only 30% of the control value.

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CHAPTER 3
MATERIALS AND METHODS

This chapter describes the experimental aspects of the study. The field experiment was conducted at Char Alahi, Companigonj, Noakhali to determine the effects of organic and inorganic amendments on boro rice (Binadhan-8) for better crop production. This section, for ease of presentation, has been divided into various sub-sections such as experimental site and soil, collection and preparation of soils, short description of the variety (Binadhan-8) under study, land preparation, treatments, experimental design, fertilizer application, transplanting of rice seedlings, intercultural operations, harvesting, data collection and recording, soil analysis, plant analysis and statistical analysis.

Experimental site and soil

The experiment was conducted at Char Alahi, Companigonj, Noakhali during Boro season of 2019. The land belongs to AEZ 18 i.e. Young Meghna Estuarine Floodplain. The land type was medium high land and the general soil type was Calcareous Alluvium. The experimental area has sub-tropical humid climate and is characterized by high temperature accompanied by moderately low rainfall during August-November. Weather information regarding temperature, relative humidity and rainfall, prevailed at the Weather Yard, Feni during the study period are presented in the Appendix I.

Collection and preparation of soils

The soil samples were collected at a depth of 0-15 cm from 10 different spots of the experimental field. The samples were put together to make a composite soil sample. The unwanted materials like stones, gravels, pebbles, plant roots, etc. were removed from the soil. Then, the soil samples were air-dried and the clods were broken, ground to pass a 2-mm (10- mesh) sieve, mixed up thoroughly and about 500g of the mixed soil was kept in a plastic bottle for analysis the physical and chemical properties. The data are presented in Table 3.1.

Table 3.1 Physical and chemical characteristics of the experimental field soil

Characteristics	Value
Physical characteristics	
% Sand (2-0.05 mm)	14
% Silt (0.05-0.002 mm)	45
% Clay (<0.002 mm)	9
Textural class	Silt loam
Chemical characteristics	
pH	6.00
EC (dS m^{-1})	3.66
Total N (%)	0.13
Available P (mg kg^{-1})	2.94
Exchangeable K ($cmol_c$ kg^{-1})	0.43
Available S (mg kg^{-1})	15.6

Short description of the variety under study

Binadhan-8

The variety used for the experiment was Binadhan-8. It was developed by the Bangladesh Institute of Nuclear Agriculture. It was released in 2010 as transplant Boro rice and named as Binadhan-8. This variety can tolerate 12-14 dS m^{-1} salinity when they are tender and 8-10 dS m^{-1} salinity in rest of the living period. The cultivar Binadhan-8 matures within 130 days after transplanting. It attains a plant height of about 66 cm. The average yield of Binadhan-8 is 4.5 t ha^{-1}.

Land Preparation

Land preparation was started in the last week of January 2019. Before tilling, the whole field was sprayed with 'round up' herbicide to destroy all kinds of weed.

Then, ploughing and cross-ploughing with were made a power tiller. After leveling, the experimental plots were laid out as per treatments and design.

Treatments

This was a 2-factorial experiment - Organic amendments and Gypsum doses.

Factor A: Organic amendment

A_0: No soil amendment

A_1: Farm yard manure (5.0 t ha^{-1})

A_2: Crop residue (5.0 t ha^{-1})

A_3: Rice husk (4.0 t ha^{-1})

Factor B: Gypsum doses

G_1: Control (No gypsum)

G_2: 160 kg ha^{-1}

G_3: 200 kg ha^{-1}

G_4: 240 kg ha^{-1}

Experimental design

The experiment was laid out in a split- plot design with three replications. Each replication represented a block. Each block was partitioned into one main-plot and each main plot was partitioned into four sub-plots. Main plots represented four amendments and sub-plots represented four gypsum doses. The size of the individual plot was 3 m x 4 m (12 sq. meters). The block to block and plot to plot distance was maintained as 1.0 m and 0.5 m, respectively. The gypsum doses were randomly distributed to unit plots in each main plot. A border area of 1m on all four sides of the experimental field was also maintained using the same crop. A complete layout of the experiment is presented in the Fig. 3.1.

Fertilizer application

The full amounts of TSP, MoP and Gypsum were added as broadcast during final land preparation. Urea was applied in three equal splits - the 1st split (50%) of urea application was made after three days of transplanting, the second split after 28 days of transplanting (tillering stage) and the third split after 50 days of transplanting (panicle initiation stage). Recommended doses of chemical fertilizer viz. urea (@75g/plot), triple super phosphate (@148g/plot), muriate of potash (@3g/plot), Gypsum (162g/plot) as per treatment were applied to each individual plot.

Transplanting of rice seedlings

The seedlings of Binadhan-8 was uprooted carefully from the seed bed in the morning and transplanted on the same day. Thirty-day old healthy seedlings were transplanted in the experimental plots on 25 January 2019. Three seedlings were transplanted in each hill with a spacing of 20 cm × 20 cm.

Intercultural operations

Different intercultural operations such as weeding and irrigation were done to ensure normal growth of the crop. 'Round up' herbicide was sprayed over the field before tilling. 'Rifit' (Pratilaclor) herbicide was applied three days after transplanting in the all plots. Hand weeding was once done for all plots. Irrigation was provided five times over the growth period. Insecticide 'Brifer 5G' and 'Agriginion' were used to control stem borer (insect) attack.

Harvesting

The crop was harvested at full maturity which required three months from the date of transplanting. The crop was harvested on 30 April 2019. The harvested crop of each plot was bundled separately and brought to threshing floor for threshing. The bundles from each plot were threshed, cleaned and processed.

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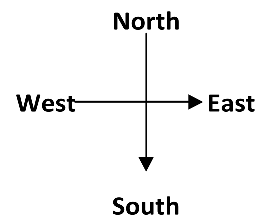

G_3	G_2	G_1
G_1	G_3	G_4
G_2	G_4	G_3
G_4	G_1	G_2
G_3	G_1	G_3
G_2	G_3	G_2
G_4	G_2	G_4
G_1	G_4	G_1
G_4	G_1	G_1
G_2	G_2	G_4
G_3	G_4	G_2
G_1	G_3	G_3
G_3	G_4	G_4
G_2	G_2	G_3
G_4	G_1	G_1
G_1	G_3	G_2

Plot to plot = 50 cm, Block to block = 1 m

Fig. 3.1 Layout of the experiment

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Data Collection and Recording

The following plant data were collected and recorded:

Plant height

The height of the plant in cm was measured from the ground level to the top of the panicle. From each plot, plants of ten hills were measured and averaged.

Number of plants hill^{-1}

Number of plants hill^{-1} was counted. It includes productive plants.

Panicle length

Panicle length in cm was measured from basal node of the rachis to apex.

1000-grain weight

Thousand rice grains from each plot were counted and weighed. It was expressed in g.

Grain yield

After harvesting of the crop, grain yield from each unit plot was dried and weighed. The result was expressed as t ha^{-1} on 14% moisture basis.

Straw yield

After harvesting of the crop, straw yield from each unit plot was dried and weighed. The result was expressed as t ha^{-1}.

Biological yield

Grain yield and straw yield were altogether considered as biological yield. Biological yield was calculated with the following formula:

$$\text{Biological yield (t ha}^{-1}) = \text{Grain yield (t ha}^{-1}) + \text{Straw yield (t ha}^{-1})$$

Harvest index (HI)

It is the ratio of grain yield to biological yield and was calculated with the following formula:

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Soil analysis

Soil samples were analyzed for both physical and chemical characteristics. The soil samples were analyzed following the standard methods as follows:

Textural class: Mechanical analysis of soil was done by hydrometer method (Buoyocos, 1927) and the textural class was determined by fitting the values for % sand, % silt and % clay to the Marshall's triangular co -ordinate following USDA system.

Soil pH: Soil pH was measured with the help of a glass electrode pH meter, the soil-water ratio being maintained at 1: 2.5 (Jackson, 1962).

Electrical conductivity (EC): The electrical conductivity (EC) was measured in 1:5 (soil : water) suspension with a glass electrode EC meter as described by Jackson (1988). The results were expressed in dS m^{-1}.

Organic matter content: Organic carbon content of soil was determined following wet oxidation method (Nelson and Sommers , 1982). The amount of organic matter was calculated by multiplying the per cent organic carbon with the van Bemmelen factor, 1.73 (Piper, 1950).

Total nitrogen: Total N content in soil was determined by Kjeldahl method. The soil was digested with 30% H_2O_2, conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 100:10:1). Nitrogen in the digest was determined by distillation with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01 N H_2SO_4 (Bremner and Mulvaney, 1982).

Available phosphorus: Available P content extracted from soil with 0.5M $NaHCO_3$ solution at a pH 8.5. The P in the extract was then determined by developing blue colour with $SnCl_2$ reduction of phosphomolybdate complex and measuring the colour by spectrophotometer at 660 nm wavelength (Olsen and Sommers, 1982).

Exchangeable potassium: Exchangeable K content of soil was determined by extraction with 1M NH_4OAc, pH 7.0 solution followed by measurement of extractable K by flame photometer (Knudsen *et al.*, 1982).

Available sulphur: Available S content was determined by extracting soil sample with $CaCl_2$ (0.15%) solution, as described by Tabatabai (1982). The S content in the extract was determined turbidimeterically and the turbid was measured by spectrophotometer at 420 nm wavelength.

Plant analysis

Preparation of samples: The plant samples were dried in an oven at 60^0C for about 48 hours and then ground by a grinding mill to pass through a 20-mesh sieve. The ground plant materials (grain and straw) in paper bags were stored into a desiccator. The grain and straw samples were analyzed for determination of S concentrations. The method was as follows:

Digestion of plant samples for sulphur determination: Plant samples weighing 0.5 g were transferred into 100 ml digestion flasks. Ten ml of diacid mixture (HNO_3: $HC1O_4$ = 2: 1) were added into the flask. After leaving for a while, the flasks were heated to raise the temperature slowly to 200°C. Heating was stopped when the dense white fume of $HC1O_4$ occurred. After cooling, the contents were taken into a 50 ml volumetric flask and the volume was made with distilled water. The digests were used for the determination of S.

Determination of Sulphur: Sulphur in extract was determined by using 5 ml digest, after that sulphur content was measured by developing turbidity by adding 1 ml acid seed solution (20 ppm S as K_2SO_4 in 6N HC1) and 0.5 gm. $BaCl_2$

crystal. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelength.

Statistical analysis

The analysis of variance for various crop characters and for S concentration and uptake was done following the F-statistics. Mean comparisons of the treatments were made by the Least Significant Difference (LSD).

CHAPTER 4

RESULTS

Rice is a salt-sensitive cereal crop. Growth and development as well as productivity of rice are severely affected by salinity. In the present study, four organic amendments viz. no soil amendment , farm yard manure (5.0 t ha^{-1}), crop residue (5.0 t ha^{-1}), rice husk (4.0 t ha^{-1}) and four gypsum doses viz. control, 160 kg ha^{-1}, 200 kg ha^{-1}, 240 kg ha^{-1} were imposed in Boro rice cv. Binadhan-8. The results obtained from the study have been presented in this chapter.

Effect of organic amendments on yield and yield contributing characters ofBoro rice

Plant height

The effect of organic amendments on plant height was found statistically significant (Table 2). The highest plant height (100.9 cm) was recorded in rice husk (A_3) and the lowest (96.10 cm) was recorded at farm yard manure (A_1). Result revealed that plant height at A_3 and A_2 are statistically similar.

Panicle length (cm)

The effect of organic amendments on panicle length was statistically significant (Table 2). The highest panicle length (27.23 cm) was recorded in rice husk (A_3) and the lowest (26.37 cm) was recorded at control (A_o). Result revealed that panicle length at A_3, A_2 andA_1 are statistically similar.

Number of plants hill $^{-1}$

The number of plants $hill^{-1}$ was not significantly affected by organic amendments (Table 2). The highest number of plants $hill^{-1}$ (9.616) was observed in crop residue (A_2), and the lowest (8.565) was recorded in rice husk (A_3).

Table 2. Mean effect of organic amendments on yield contributing characters of Boro rice cv. Binadhan-8

Organic amendments	Plant height (cm)	Panicle length (cm)	Number of plants hill^{-1}	1000 grain weight (g)
A_0 No soil amendment	97.73b	26.37b	9.267	23.30
A_1 Farm yard manure (5.0 t ha^{-1})	96.10b	26.74ab	9.350	24.41
A_2 Crop residue (5.0 t ha^{-1})	99.87a	27.22a	9.616	23.31
A_3 Rice husk (4.0 t ha^{-1})	100.9a	27.23a	8.565	23.99
$LSD_{0.05}$	2.05	0.628	1.38	0.885

Values in a column having common letters do not differ significantly at 5% level of significance.

1000-grain weight (g)

The effect of organic amendments on 1000-grain weight (g) was not statistically significant (Table 2). The highest 1000-seed weight (24.41 g) was observed in farm yard manure (A_1), the lowest (23.30 g) was observed in control (A_0).

Grain yield

The effect of organic amendments on grain yield (t ha^{-1}) was statistically significant (Table 3 and Fig.1). The highest grain yield (6.210 t ha^{-1}) was observed in crop residue (A_2) where the lowest (5.63 t ha^{-1}) was observed in no soil amendment (A_0). Result revealed that grain yield at A_3, A_2 and A_1 are statistically similar.

Straw yield

Straw yield was significantly affected by organic amendments (Table 3 and Fig. 1). The highest straw yield (7.123t ha^{-1}) was observed in farm yard manure (A_1) and the lowest (6.284 t ha^{-1}) was recorded in control (A_0). The performance of straw yield was $A_1>A_2>A_3>A_0$. Result revealed that straw yield at A_3 and A_2 are statistically similar.

Biological yield

Organic amendments had significant effect on the biological yield (Table 3). The highest biological yield (13.32 t ha^{-1}) was obtained from farm yard manure (A_1). The lowest biological yield (11.92 t ha^{-1}) was obtained from control (A_0).

Harvest index (%)

The effect of organic amendments on harvest index was statistically significant (Table 3). The highest HI (47.98%) was recorded in crop residue (A_2) and the lowest HI (46.54%) was observed in farm yard manure (A_1).

Table 3. Mean effect of organic amendments on yield of Boro rice cv. Binadhan-8

Organic Amendments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
A_0 No soil amendment	5.63b	6.28c	11.92c	47.27ab
A_1 Farm yard manure (5.0 t ha^{-1})	6.19a	7.12a	13.32a	46.54b
A_2 Crop residue (5.0 t ha^{-1})	6.21a	6.73b	12.95ab	47.98a
A_3 Rice husk (4.0 t ha^{-1})	6.09a	6.66b	12.76b	47.76a
$LSD_{0.05}$	0.173	0.313	0.512	0.993

Values in a column having common letters do not differ significantly at 5% level of significance.

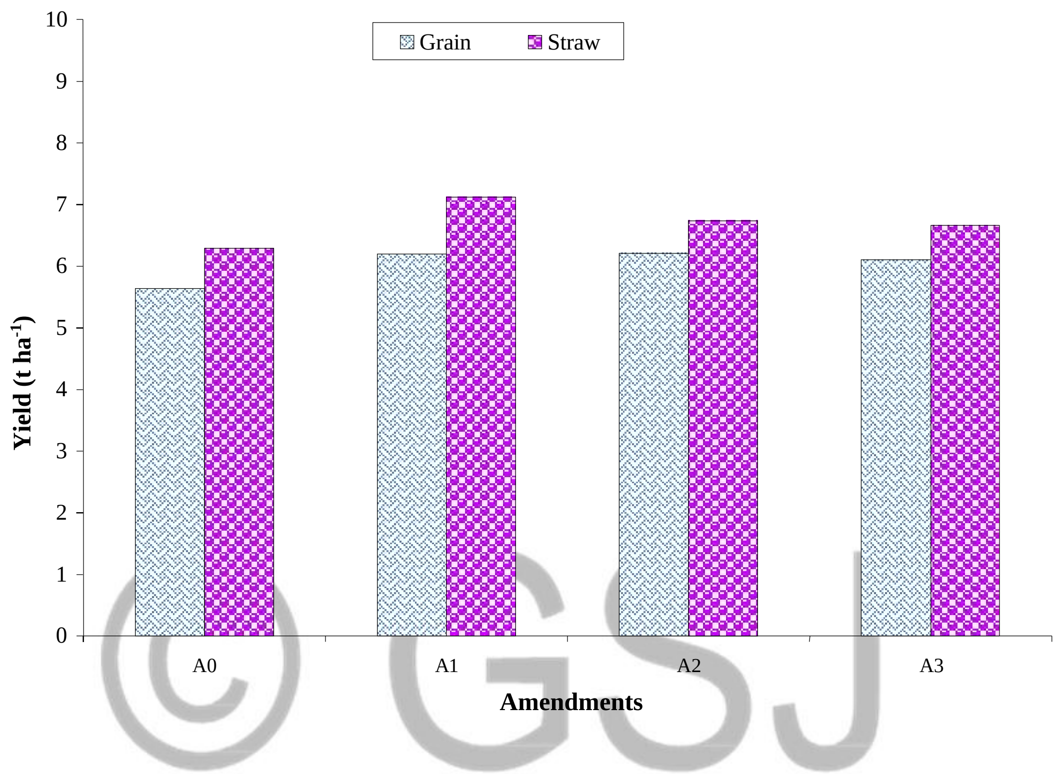

Fig. 4.1 Effect of organic amendments on grain and straw yield

Legend:

A_0 = No soil amendment

A_1 = Farm yard manure (5.0 t ha^{-1})

A_2 = Crop residue (5.0 t ha^{-1})

A_3 = Rice husk (4.0 t ha^{-1})

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Effect of different gypsum doses on yield and yield contributing charactersof Boro rice

Plant height

The effect of inorganic amendment was significant in terms of plant height (Table 4). The highest plant height (100.6 cm) was observed from 240 kg ha^{-1} gypsum (G_4). The lowest plant height (97.08 cm) was produced from 160 kg ha^{-1} gypsum (G_2). Result revealed that plant height at G_1 and G_4 are statistically similar.

Panicle length (cm)

Rate of gypsum had significant effect on panicle length (Table 4). The longest panicle (27.39 cm) was found from control (G_1) and the shortest (26.47 cm) was obtained from 240 kg ha^{-1} of gypsum (G_4). Result showed that panicle length at G_1 and G_2 are statistically similar.

Number of plants hill^{-1}

The effect of inorganic amendment was significant in terms of the production of plants hill^{-1} (Table 4). The highest number of plants hill^{-1} (9.868) was obtained from 160 kg ha^{-1} of gypsum (G_2) and the lowest number of plants hill^{-1} (8.499) found from 200 kg ha^{-1} of gypsum (G_3). Result revealed that number of plants hill^{-1} at G_1 and G_2 are statistically similar.

1000-grain weight (g)

Rate of gypsum on 1000-grain weight (g) was found significant. The highest 1000-grain weight (24.38 g) was recorded from 160 kg ha^{-1} soil (G_2) and the lowest 1000-grain weight (23.34 g) was found in 200 kg ha^{-1} of gypsum (G_3). Result showed that 1000-grain weight (g) at G_1 and G_2 are statistically similar.

Table 4. M ean effect of different gypsum doses on yield contributing characters of Boro rice cv. Binadhan-8

Gypsum doses	Plant height (cm)	Panicle length (cm)	Number of plants hill^{-1}	1000 grain weight (g)
G_1 Control	99.22ab	27.39a	9.73a	23.80ab
G_2 160 kg ha^{-1}	97.08c	27.16a	9.86a	24.38a
G_3 200 kg ha^{-1}	97.65bc	26.55b	8.49b	23.34b
G_4 240 kg ha^{-1}	100.6a	26.47b	8.69b	23.49b
$LSD_{0.05}$	1.72	0.538	0.759	0.748

Values in a column having common letters do not differ significantly at 5% level of significance.

Grain yield

Inorganic amendment had significant effect on grain yield (Table 5 and Fig. 2). The highest grain yield (6.165 t ha^{-1}) was obtained from 160 kg ha^{-1} soil (G_2) which was statistically similar to the yields obtained from (G_3) and (G_4).The lowest grain yield (5.789 t ha^{-1}) was found in control condition (G_1). Application of gypsum (G_2) 160 kg ha^{-1} showed good performance in grain yield.

Straw yield

Rate of gypsum was significant in terms of straw yield (Table 5). The highest straw yield (6.858 t ha^{-1}) was observed from 160 kg ha^{-1} gypsum (G_2) and the lowest straw yield (6.518 t ha^{-1}) was produced in control treatment (G_1). In case of straw yield application of gypsum (G_2) 160 kg ha^{-1} also showed better performance than control condition (G_1). Result revealed that straw yield at G_2, G_3 and G_4 are statistically similar.

Biological yield

Inorganic amendment had not significant effect on the biological yield. The highest biological yield (13.02 t ha^{-1}) was obtained from 160 kg ha^{-1} gypsum (G_2) and the lowest biological yield (12.31 t ha^{-1}) was obtained from control treatment (G_1).

Harvest index (%)

The influence of inorganic amendment on harvest index was not significant (Table 5). The highest value (47.63%) was obtained from 240 kg ha^{-1} gypsum (G_4) and the lowest value (47.09%) was obtained fro m control treatment of gypsum (G_1).

Table 5. Mean effect of different gypsum doses on yield of Boro rice cv. Binadhan-8

Gypsum doses	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
G_1: Control	5.789b	6.518b	12.31	47.09
G_2: 160 kg ha^{-1}	6.165a	6.858a	13.02	47.34
G_3: 200 kg ha^{-1}	6.045a	6.681ab	12.72	47.49
G_4: 240 kg ha^{-1}	6.140a	6.749a	12.89	47.63
$LSD_{0.05}$	0.183	0.220	0.840	0.641

Values in a column having common letters do not differ significantly at 5% level of significance.

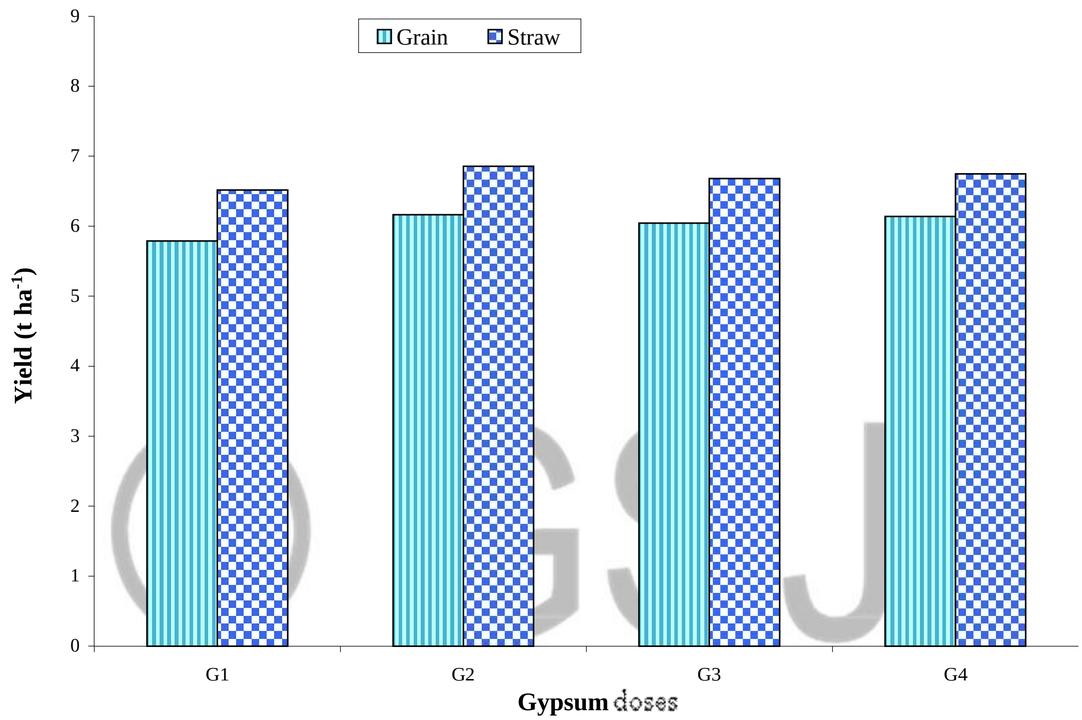

Fig. 4.2 Effect of different gypsum doses on grain and straw yield

Legend:

G_1 = Control

G_2 = 160 kg ha^{-1} Gypsum

G_3 = 200 kg ha^{-1} Gypsum

G_4 = 240 kg ha^{-1} Gypsum

Interaction effect of organic amendments and gypsum on yield and yield contributing characters of Boro rice

Plant height

The interaction between organic amendments and gypsum at harvest had significant effect on plant height (Table 6). The highest plant height (101.6 cm) was observed rice husk with gypsum 240 kg ha^{-1} (A_3G_4) which was statistically similar with A_3G_1, A_3G_2, A_3G_3, A_3G_4, A_2G_1 and A_2G_4. The lowest plant height (95.27 cm) was observed in control with 200 kg ha^{-1} (A_1G_2).

Table 6. Interaction effect of organic amendments and different gypsum doses on plant height (cm) of Boro rice cv. Binadhan-8

Organic amendments x gypsum doses	G_1	G_2	G_3	G_4
A_0	98.12bcde	98.60bcde	95.27ef	98.93bcde
A_1	97.07de	92.47f	96.7de	98.07bcde
A_2	101.3abc	96.73de	97.50cde	104.00a
A_3	100.4abcd	100.5abcd	101.1abc	101.6ab
$LSD_{0.05}$:		3.45		

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1} Gypsum
G_3 = 200 kg ha^{-1} Gypsum
G_4 = 240 kg ha^{-1} Gypsum

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Panicle length (cm)

The experimental results showed that the interaction effect level of organic amendments and gypsum was significant on panicle length (Table 7). However, statistically the longest panicle (28.13 cm) was obtained from crop residue with control (A_2G_1) whereas the shortest panicle was (25.27 cm) obtained from control with 240 kg ha^{-1} gypsum (A_0G_4).

Table 7. Interaction effect of organic amendments and different gypsum doses on panicle length (cm) of Boro rice cv. Binadhan-8

Organic amendments x gypsum doses	G1	G2	G3	G4
A_0	27.40abcd	27.07abcd	25.73ef	25.27f
A_1	26.37def	27.83ab	26.33def	26.43cdef
A_2	28.13a	27.00abcd	26.45cdef	27.30abcd
A_3	27.67abc	26.73bcde	27.67abc	26.87bcde
$LSD_{0.05}$:	1.08			

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1}
G_3 = 200 kg ha^{-1}
G_4 = 240 kg ha^{-1}

Number of plants hill $^{-1}$

The interaction effect between organic amendments and gypsum for plants hill^{-1} was also significant (Table 8). Results revealed that the height number of plants hill^{-1} (11.53) was obtained from crop residue with control (A_2G_1). The lowest number of plants hill^{-1} (7.930) was observed in rice husk with 200 kg ha^{-1} of gypsum (A_3G_3).

Table 8. Interaction effect of organic amendments and different gypsum doses on number of plants hill^{-1} of Boro rice cv. Binadhan-8

Organic amendments x gypsum doses	G1	G2	G3	G4
A_0	9.870bc	10.20ab	8.47bcd	8.53bcd
A_1	9.40bcd	9.73bc	8.67bcd	9.60bcd
A_2	11.53a	10.07ab	8.93bcd	7.93d
A_3	8.13cd	9.47bcd	7.93d	8.73bcd
$LSD_{0.05}$:	1.52			

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1} Gypsum
G_3 = 200 kg ha^{-1} Gypsum
G_4 = 240 kg ha^{-1} Gypsum

1000-grain weight (g)

The interaction effect between organic amendments and gypsum for 1000-grain weight (g) was statistically significant (Table 9). The highest 1000 -seed weight (25.23 g) was observed in farm yard manure with 160 kg ha^{-1} soil (A_1G_2) and the lowest (22.40 g) was observed in control with 240 kg ha^{-1} of gypsum (A_0G_4).

Table 9. Interaction effect of organic amendments and different gypsum doses on 1000 grain weight (g) of Boro rice cv. Binadhan-8

Organic amendments x gypsum doses	G1	G2	G3	G4	Mean
A_0	23.00cdef	24.17a-e	23.65a-f	22.40f	23.31
A_1	24.67abc	25.23a	23.47b-f	24.26abcd	24.41
A_2	22.50ef	23.46bcdef	22.89def	24.39abcd	23.31
A_3	25.05ab	24.65abc	23.37bcdef	22.90def	23.99
Mean	23.81	24.38	23.35	23.49	23.75
$LSD_{0.05}$:	1.49				

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1} Gypsum
G_3 = 200 kg ha^{-1} Gypsum
G_4 = 240 kg ha^{-1} Gypsum

Grain yield

The interaction effect between amendments and gypsum in relation to grain yield was statistically significant (Table 10 and Fig. 3). The highest grain yield (6.360 t ha^{-1}) observed in farm yard manure with 160 kg ha^{-1} soil (A_1G_2) and the lowest (4.467 t ha^{-1}) was observed in control with no application of gypsum (A_0G_1).

Table 10. Interaction effect of organic amendments and different gypsum doses on grain yield (t ha^{-1}) of rice cv. Binadhan-8

Organic amendments x gypsum doses	G_1	G_2	G_3	G_4	Mean
A_0	4.467d	6.18abc	5.82c	6.07abc	5.63
A_1	6.26ab	6.36a	6.28ab	5.89bc	6.20
A_2	6.24ab	5.97abc	6.30ab	6.33a	6.21
A_3	6.19abc	6.15abc	5.78c	6.27ab	6.10
Mean	5.79	6.17	6.05	6.14	6.03
$LSD_{0.05}$:		0.365			

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1} Gypsum
G_3 = 200 kg ha^{-1} Gypsum

G_4 = 240 kg ha^{-1} Gypsum

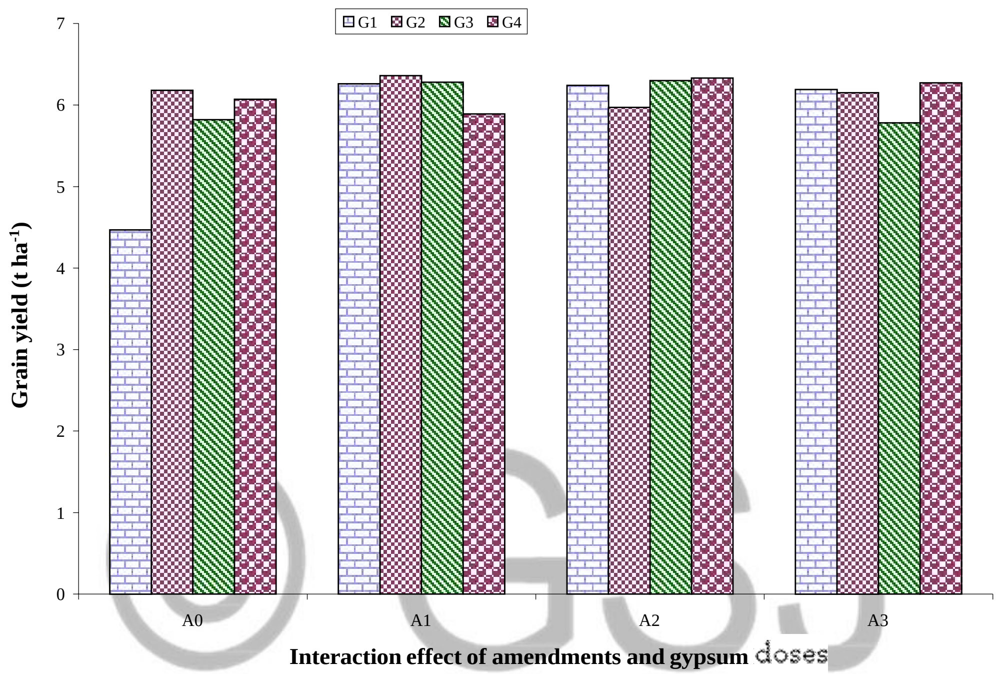

Fig. 4.3 Interaction effect of organic amendments and different gypsum doses on grain yield

Legend:

A_0 = No soil amendment

A_1 = Farm yard manure (5.0 t ha^{-1})

A_2 = Crop residue (5.0 t ha^{-1})

A_3 = Rice husk (4.0 t ha^{-1})

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Straw yield

The interaction effect between amendments and gypsum in relation to straw production was also significant (Table 11 and Fig. 4). The highest straw yield (7.43 t ha^{-1}) observed in farm yard manure with control (A_1G_1) and the lowest (4.95 t ha^{-1}) was observed in control with no application of gypsum (A_0G_1).

Table 11. Interaction effect of organic amendments and different gypsum doses on straw yield (t ha^{-1}) of rice cv. Binadhan-8

Organic amendments x gypsum doses	G_1	G_2	G_3	G_4	Mean
A_0	4.95e	7.13ab	6.50cd	6.55cd	6.28
A_1	7.43a	7.16ab	6.94abc	6.96abc	7.12
A_2	7.00abc	6.327d	6.74bcd	6.89bc	6.74
A_3	6.69bcd	6.813bcd	6.540cd	6.597cd	6.66
Mean	6.52	6.86	6.68	6.75	6.70
$LSD_{0.05}$:			0.439		

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1} Gypsum
G_3 = 200 kg ha^{-1} Gypsum
G_4 = 240 kg ha^{-1} Gypsum

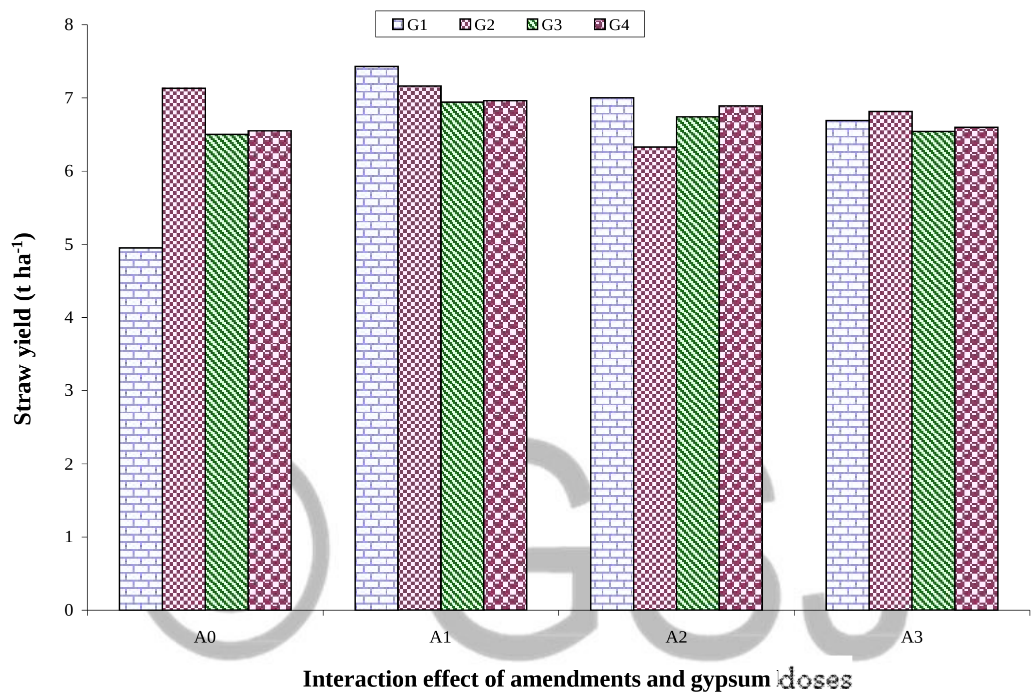

Fig. 4.4 Interaction effect of organic amendments and different gypsum doses on straw yield

Legend:

A_0 = No soil amendment

A_1 = Farm yard manure (5.0 t ha^{-1})

A_2 = Crop residue (5.0 t ha^{-1})

A_3 = Rice husk (4.0 t ha^{-1})

Biological yield

Interaction of amendments and gypsum significantly influenced the biological yield (Table 12). The highest biological yield (13.69 t ha^{-1}) was recorded from farm yard manure with control (A_1G_1) and the lowest biological yield (9.417 t ha^{-1}) was observed in control with no application of gypsum (A_0G_1).

Table 12. Interaction effect of organic amendments and different gypsum doses on biological yield (t ha^{-1}) of rice cv. Binadhan-8

Organic amendments x gypsum doses	G_1	G_2	G_3	G_4	Mean
A_0	9.417b	13.31a	12.32a	12.61a	11.91
A_1	13.69a	13.52a	13.21a	12.85a	13.32
A_2	13.24a	12.30a	13.04a	13.22a	12.95
A_3	12.88a	12.96a	12.32a	12.86a	12.76
Mean	12.31	13.02	12.72	12.89	12.73
$LSD_{0.05}$:	1.67				

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment

A_1 = Farm yard manure (5.0 t ha^{-1})

A_2 = Crop residue (5.0 t ha^{-1})

A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control

G_2 = 160 kg ha^{-1} Gypsum

G_3 = 200 kg ha^{-1} Gypsum

G_4 = 240 kg ha^{-1} Gypsum

Harvest index (%)

The interaction effect between amendments and gypsum in relation to HI was also statistically significant (Table 13). The highest HI (48.72%) was observed in rice husk with 240 kg ha^{-1} gypsum (A_3G_4). The lowest HI (45.73%) was observed in farm yard manure with control (A_1G_1).

Table 13. Interaction effect of organic amendments and different gypsum doses on harvest index (%) of rice cv. Bina dhan-8

Organic amendments x gypsum doses	G_1	G_2	G_3	G_4	Mean
A_0	47.44abcd	46.34def	47.22bcde	48.09abc	47.27
A_1	45.73f	47.05cdef	47.55abcd	45.84ef	46.54
A_2	47.18bcde	48.56ab	48.30abc	47.88abc	47.98
A_3	48.00abc	47.42abcd	46.91cdef	48.72a	47.76
Mean	47.09	47.34	47.50	47.63	47.39
$LSD_{0.05}$:	1.28				

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1} Gypsum
G_3 = 200 kg ha^{-1} Gypsum
G_4 = 240 kg ha^{-1} Gypsum

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Effects on Sulphur uptake by Boro rice

Effect of organic amendments S uptake by grain

The effect of organic amendments on grain yield (kg ha^{-1}) was statistically significant (Table14). The highest grain yield (11.12 kg ha^{-1}) was observed in farm yard manure (A_1) where the lowest (9.029 kg ha^{-1}) was observed in control (A_0). Result revealed that grain yield at A_1, A_2 and A_3 are statistically similar. Reduced grain yield under salinity condition might be due to the production of lower number of grains $panicle^{-1}$.

Effect of organic amendments S uptake by straw

Straw yield was significantly affected by organic amendments (Table 14). The highest straw yield (12.92 kg ha^{-1}) was observed in farm yard manure (A_1) and the lowest (10.23 kg ha^{-1}) was recorded in control (A_0). Reduced straw yield under salinity condition might be due to inhibited photosynthesis under salinity stress that causes less amount of nutrient uptake by the plant.

Effect of organic amendments total S uptake by Boro rice

The effect of organic amendments on total S uptake (kg ha^{-1}) was statistically significant (Table 14). The highest total S uptake (24.03 kg ha^{-1}) was observed in farm yard manure (A_1) where the lowest (19.25 kg ha^{-1}) was observed in control (A_0). Reduced total S uptake under salinity condition might be due to the production of lower number of grains $panicle^{-1}$.

Table 14. Mean effect of organic amendments on S uptake by Boro rice cv. Binadhan-8

Organic amendments	S uptake (kg ha^{-1})		
	Grain	Straw	Total
A_0 No soil amendment	9.02c	10.23d	19.25d
A_1 Farm yard manure (5.0 t ha^{-1})	11.12a	12.92a	24.03a
A_2 Crop residue (5.0 t ha^{-1})	10.74ab	11.80 b	22.54b
A_3 Rice husk (4.0 t ha^{-1})	9.95bc	10.97c	20.92c
$LSD_{0.05}$	1.00	0.637	1.06

Values having common letters do not differ significantly at 5% level of significance.

Effect of gypsum S uptake by grain

Inorganic amendment had significant effect on grain yield (Table 15). The highest grain yield (10.79 kg ha^{-1}) was obtained from 160 kg ha^{-1} gypsum (G_2) and the lowest grain yield (9.637 kg ha^{-1}) was found in 200 kg ha^{-1} gypsum (G_3).

Effect of gypsum S uptake by straw

Rate of gypsum was significant in terms of straw yield (Table 2). The highest straw yield (12.10 kg ha^{-1}) was observed from 160 kg ha^{-1} gypsum (G_2) and the lowest straw yield (10.78 kg ha^{-1}) was produced in 200 kg ha^{-1} gypsum (G_3).

Effect of gypsum total S uptake by Boro rice

Inorganic amendment had significant effect on total S uptake (Table 15). The highest total S uptake (22.88 kg ha^{-1}) was obtained from 160 kg ha^{-1} gypsum (G_2) and the lowest total S uptake (20.40 kg ha^{-1}) was found in 200 kg ha^{-1} gypsum (G_3).

Table 15. Mean effect of different gypsum doses on S uptake by Boro rice cv. Binadhan-8

Gypsum doses	S uptake (kg ha^{-1})		
	Grain	Straw	Total
G_1 Control	9.95bc	11.41b	21.36bc
G_2 160 kg ha^{-1}	10.79a	12.10a	22.88a
G_3 200 kg ha^{-1}	9.64 c	10.78 c	20.40c
G_4 240 kg ha^{-1}	10.47ab	11.63ab	22.10ab
$LSD_{0.05}$	0.530	0.496	1.40

Values having common letters do not differ significantly at 5% level of significance.

Interaction effect of organic amendments and gypsum S uptake by grain

The interaction effect between organic amendments and gypsum in relation to grain yield was statistically significant (Table 16). The highest grain yield (12.02 kg ha^{-1} observed in farm yard manure with control (A_1G_1) and the lowest (6.523 kg ha^{-1}) was observed in control with no application of gypsum (A_0G_1).

Interaction effect of organic amendments and gypsum S uptake by straw

The interaction effect between organic amendments and gypsum in relation to straw production was also significant (Table 16). The highest straw yield (14.47 kg ha^{-1}) observed in farm yard manure with control (A_1G_1) and the lowest (7.377 kg ha^{-1}) was observed in control with no application of gypsum (A_0G_1).

Interaction effect of organic amendments and gypsum total S uptake byBoro rice

The interaction effect between organic amendments and gypsum in relation to total S uptake was statistically significant (Table 16). The highest total S uptake (26.49 kg ha^{-1}) observed in farm yard manure with control (A_1G_1) and the lowest (13.90 kg ha^{-1}) was observed in control with no application of gypsum (A_0G_1).

Table 16. Interaction effect of organic amendments and different gypsum doses on S uptake by rice cv. Binadhan-8

Organic amendments x gypsum doses	S uptake (kg ha^{-1})		
	Grain	Straw	Total
A_0G_1	6.523g	7.377g	13.90g
A_0G_2	10.11de	11.86cd	21.96bcde
A_0G_3	8.930f	10.19f	19.09ef
A_0G_4	10.55bcde	11.48cde	22.04bcde
A_1G_1	12.02a	14.47a	26.49a
A_1G_2	11.73ab	13.25b	24.97ab
A_1G_3	10.23de	11.38de	21.57cdef
A_1G_4	10.52cde	12.57bc	23.09bcd
A_2G_1	11.54abc	13.12b	24.66abc
A_2G_2	10.99abcd	11.73cde	22.71bcd
A_2G_3	10.76bcde	11.69cde	22.45bcd
A_2G_4	9.686ef	10.65ef	20.34def
A_3G_1	9.733ef	10.66ef	20.40def
A_3G_2	10.33de	11.56cde	21.89bcde
A_3G_3	8.630f	9.850f	18.48f
A_3G_4	11.11abcd	11.81cd	22.92bcd
$LSD_{0.05}$	1.06	0.993	2.81

Values having common letters do not differ significantly at 5% level of significance.

Legend:

Organic amendments

A_0 = No soil amendment
A_1 = Farm yard manure (5.0 t ha^{-1})
A_2 = Crop residue (5.0 t ha^{-1})
A_3 = Rice husk (4.0 t ha^{-1})

Gypsum doses

G_1 = Control
G_2 = 160 kg ha^{-1} Gypsum
G_3 = 200 kg ha^{-1} Gypsum
G_4 = 240 kg ha^{-1} Gypsum

CHAPTER 5

DISCUSSION

Rice is a major food of Bangladesh. Among the various factors limiting rice yield, salinity is one of the most serious environmental problems in the world (Mcwilliam, 1986). In Bangladesh, over thirty percent of the net cultivable area is in the coastal area. Out of 2.85 million hectare of the coastal and off-shore areas, about 1.056 million hectares are arable lands, which constitute about 52.8 percent of the net cultivable area in 64 thanas of 13 districts (SRDI, 2010). In the present study, four organic amendments viz. no soil amendment, farm yard manure (5.0 tha^{-1}), crop residue (5.0 t ha^{-1}), rice husk (4.0 t ha^{-1}) and four gypsum doses viz. control (0), 160 kg ha^{-1}, 200 kg ha^{-1}, 240 kg ha^{-1} were imposed on Boro rice cv. Binadhan-8.

It was observed that different types of organic amendments had significant effect on the yield and yield components over no amendment. Organic matter application is considered effective management for salt affected soil amelioration and crop growth (Bhatti *et al.,* 2005; Pang *et al.,* 2010). Organic manures, such as farmyard manure, green manure, organic amendment and municipal solid waste, have been used as a source of plant nutrients and organic matter to improve fertility conditions of agricultural lands for a long time (Dao and Cavigelli, 2003). Generally, the physical, chemical, and biological properties were improved when manures incorporated into soils (Ould Ahmed *et al.,* 2010). Haynes and Naid u (1998) reviewed that addition of organic manures into soil results in increased water holding capacity, porosity, infiltration capacity, hydraulic conductivity and water stable aggregation and decreased bulk density and surface crusting.

Application of different doses of gypsum showed a significant response to Binadhan-8 over control. Gypsum is typically used as a source of calcium to remove the exchangeable sodium. The application of calcium amendments can improve various soil properties and act as soil modifiers that prevent the development of sodicity which is directly related to plant growth, crop productivity and crop yields

(Muhammad and Khattak, 2011). The conjunctive uses of farm manure with gypsum significantly improve soil physicochemical properties of sodic soils as compared to their alone application (Ullah and Bhatti, 2007). In addition to osmotic adjustment, genotypic differences in inorganic ions uptake under salinity have implications for maintaining adequate nutrition and for optimizing nutrients related salinity tolerance mechanisms.

Results showed that the interaction effect between organic amendments and different gypsum doses had significant effect in respect of all parameters. S uptake showed significant variation. The maximum S uptake by grain, straw and total was recorded in the treatment Farm yard manure (A_1). 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 rice 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 Abou El-Magd *et al.,* (2008).

It can be concluded that the farm yard manure (A_1) and 160 kg ha^{-1} gypsum (G_2) were more effective than other treatments to produced better growth, higher yield and greater enhancement of different nutrient content and uptake by grain, straw and total due to its proper nutrient supplying in soil.

CHAPTER 6

SUMMARY

The field experiment was conducted at Char Alahi, Companigonj, Noakhali to determine the effect of organic and inorganic amendments on boro rice (Binadhan-8) for better crop production in saline soil during the period from January 2013 to April 2013. The experiment was laid out in a split- plot design with three replications, where main plots comprised of four levels of organic amendments viz. A_0: no soil amendment, A_1: farm yard manure (5.0 t ha^{-1}), A_2: crop residue (5.0 t ha^{-1}), A_3: rice husk (4.0 t ha^{-1}) and sub-plots had four gypsum doses viz. G_1: control, G_2: 160 kg ha^{-1}, G_3: 200 kg ha^{-1}, G_4: 240 kg ha^{-1}. Each replication represented a block. Each block was partitioned into one main-plot and each main plot was partitioned into four sub-plots. Main plots represented four amendments and sub-plots represented four gypsum doses. The size of the individual plot was 3m x 4 m (12 sq. meters). The block to block and plot to plot distance was maintained as 1.0 m and 0.5 m, respectively. The gypsum rates were randomly distributed to unit plots in each main plot. A border area of 1m on all four sides of the experimental field was also maintained using the same crop. The data were recorded on yield and yield components. The crop was harvested whe n about 90% of the grains became golden yellow in color. Data on yield contributing characters including plant height, panicle length, plants $hill^{-1}$, 1000-grain weight, grain yield and straw yield were recorded from each plot. The collected data were analyzed statistically and the mean differences were adjudged by Least Significant Difference (LSD) at 1% and 5% level of significance.

Different levels of organic amendments had significant effect on the yield and yield components of Boro rice cv. Binadhan-8. The highest plant height (100.9 cm), panicle length (27.23 cm) and number of plants $hill^{-1}$ (9.616) were recorded in crop residue A_2 (5.0 t ha^{-1}) while the highest 1000-grain weight (24.41 g), grain yield

(6.210 t ha^{-1}), straw yield (7.123 t ha^{-1}), biological yield (13.32 t ha^{-1}) were obtained from farm yard manure A_1 (5.0 t ha^{-1}) and the highest harvest index (47.98%) was recorded from crop residue A_2 (5.0 t ha^{-1}).

Rates of gypsum significantly influenced all of the parameters except biological yield and harvest index. The highest plant height (100.6 cm) and harvest index (47.63%) were obtained from (G_4) 240 kg ha^{-1}; the highest panicle length (27.39 cm), number of plants $hill^{-1}$ (9.868), 1000-grain weight (24.38 g), grain yield (6.165 t ha^{-1}), straw yield (6.858 t ha^{-1}), biological yield (13.02 t ha^{-1}) were obtained from (G_2) 160 kg ha^{-1}.

Results revealed that the interaction between levels of organic amendments and gypsum had significant effect in respect of all parameters. The highest values (6.360 t ha^{-1}) for yield and yield components were given by the treatment farm yard manure with 160 kg ha^{-1} soil (A_1G_2), although for some parameters, some other combination had similarities with this combination. The lowest values (4.467 t ha^{-1}) for parameters under study were mostly from control with no application of gypsum (A_0G_1).

Total S uptake by organic amendments had significant effect on the yield and yields components of Boro rice. The highest total S uptake (24.03 kg ha^{-1}) was observed in farm yard manure (A_1) and the lowest (19.25 kg ha^{-1}) was observed in control (A_0).

Results also assumed that total S uptake by gypsum significantly influenced all of the parameters. The highest total S uptake (22.88 kg ha^{-1}) was obtained from 160 kg ha^{-1} gypsum (G_2) and the lowest total S uptake (20.40 kg ha^{-1}) was found in 200 kg ha^{-1} gypsum (G_3).

Thus this study implies that the yield and yield contributing characters of Boro rice cv. Binadhan-8 were drastically affected by organic amendments and gypsum. The organic and inorganic amendments could be applied in growing rice in saline soil in proper dose.

CHAPTER 7

CONCLUSION

Binadhan-8 is a salt tolerant rice variety. Additional production of rice is possible by proper organic and inorganic amendments. Since farm yard manure, crop residues are given in the field for growing successful rice crop. Similarly the proper doses of gypsum help in leaching of soluble salt consequently reducing soil salinity and gave more production. However an indication that, this Boro rice variety can be grown successfully in a saline area by applying the farm yard manure as organic amendments and 160 kg ha^{-1} of gypsum as an inorganic amendment.

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APPENDICES

APPENDIX I. Monthly record of air temperature, relative humidity and rainfall during the period from January 2013 to May 2013

Month	Temperature(°C)			Humidity (%)	Rainfall (mm)
	Maximum	Minimum	Average		
January	24.11	12.1	18.10	77	5.1 (1 day)
February	27.18	15.62	21.4	81	Nil (0 day)
March	34.12	18.0	26.06	76	4.4 (2 days)
April	35.32	24.44	29.88	77.12	31.0 (5 days)
May	35.40	27.30	31.35	86.67	170.0 (6 days)

Source: Weather Yard, Feni

APPENDIX II. ANOVA for interaction effect of organic amendments and different gypsum doses on plant height (cm), panicle length (cm), number of plants hill $^{-1}$ and 1000 grain weight (g) of Boro rice cv. Binadhan-8

Source of variation	df	Plant height (cm)	Panicle length (cm)	Number of plants hill $^{-1}$	1000 grain weight (g)
Replication	2	4.207	0.036	1.646	0.710
Organic amendments (A)	3	55.669**	2.087*	2.413NS	3.534NS
Error	6	4.208	0.395	1.922	0.785
Gypsum doses (B)	3	30.876**	2.491**	5.892**	2.515*
A x B	9	10.348*	1.505**	1.936*	2.015*
Error	24	4.208	0.408	0.812	0.790

** = Significant at 1% level of probability

* = Significant at 5% level of probability

NS = Not significant

APPENDIX III. ANOVA for interaction effect of organic amendments and different gypsum doses on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of Boro rice cv. Binadhan-8

Source of variation	df	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.084	0.059	3.027	0.007
Organic amendments (A)	3	0.886**	1.421**	4.222**	4.868*
Error	6	0.030	0.098	0.263	0.988
Gypsum doses (B)	3	0.354**	0.243*	1.161NS	0.654NS
A x B	9	0.629**	0.946**	2.984**	2.076**
Error	24	0.047	0.068	0.993	0.579

** = Significant at 1% level of probability
* = Significant at 5% level of probability
NS = Not significant

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APPENDIX IV . ANOVA for interaction effect of organic amendments and different gypsum doses on grain yield (t ha^{-1}), straw yield (t ha^{-1}) S uptake by Boro rice cv. Binadhan-8

Source of variation	df	S uptake (kg ha^{-1})		
		Grain	Straw	Total
Replication	2	1.342	0.032	6.453
Organic amendments (A)	3	10.333**	15.971**	51.017**
Error	6	1.012	0.407	1.132
Gypsum doses (B)	3	3.183**	3.613**	13.470**
A x B	9	4.677**	6.419**	21.562**
Error	24	0.395	0.347	2.765

** = Significant at 1% level of probability
* = Significant at 5% level of probability
NS = Not significant

SYMBOLS USED

SV = Sources of variation

Df = Degrees of freedom

** = Significant at 1% level

* = Significant at 5% level

NS = Not significant

ANOVA = Analysis of variance