Project ID 656

Competitive Research Grant

Sub-Project Completion Report

on

Enhancing the crop productivity through adoption of climate smart technologies in the salinity areas of Bangladesh

Project Duration

July 2017 to September 2018

Department of Agronomy
Bangladesh Agricultural University
Mymensingh 2202

Submitted to

Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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The execution of CRG sub-project entitled "Enhancing the crop productivity through adoption of climate smart technologies in the salinity area of Bangladesh" has successfully been completed by the Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202 using the research grant of USAID Trust Fund and GoB through Ministry of Agriculture. We would like to thank World Bank for arranging the grantsupport and supervising the CRGs by BARC. We highly appreciate the cooperation and quick responses of PIU-BARC, NATP 2, in respect of field implementation of the sub-project in different locations in the coastal district Noakhali. We gratefully acknowledge the help and cooperation of the respondent farmers for our Benchmark Survey in the study area who gave their time, thought and valuable information regarding the crop cultivation practices they follow. We are very highly grateful to our cooperator farmers who were always very helpful for the implementation of our interventions in their field and who were always keen about the improved agricultural practices we followed there. Our thanks are due to the Director PIU-BARC, NATP 2 and his team who have given their whole hearted support to prepare this document. We believe and hope that the information and the technologies we generated through the study and published in the report would be very helpful to the agricultural scientists and extension workers who are working in the salinity affected coastal area for designing their future research projects in order to technology generation as well as increasing production and productivity for sustainable food and nutrition security in Bangladesh. The document may also be useful to guide the farmers in the salinity affected area for increasing their crop production by adopting the technologies for the amelioration of salinity and drought stress and thus increase crop production.

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Acronyms

BARI	: Bangladesh Agricultural Research Institute
BBS	: Bangladesh Bureau of Statistics
BINA	: Bangladesh Institute of Nuclear Agriculture
BRAC	: Building Resources Across Communities
BRRI	: Bangladesh Rice Research Institute
BARC	: Bangladesh Agricultural Research Council
Co-PI	: Co- Principal Investigator
DMRT	: Duncan’s Multiple Range Test
GDP	: Gross Domestic Product
HI	: Harvest Index
LSD	: Least Significant Difference
NATP	: National Agriculture Technology Project
PI	: Principal Investigator
SRDI	: Soil Resource Development Institute
T. *aman*	: Transplant *aman*

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Executive Summary

Agricultural productivity in the coastal area of Bangladesh is very low due to unfavorable condition. The situation is getting aggravated in the area day by day because of global warming and climate change. The farmers in the area are marginal and landless usually cultivating one crop in a year. During *kharif*-II the farmers primarily grow low-yielding and late-maturing transplant *aman* rice varieties and most of the lands remain fallow during the dry period of the year. The constraints of low agricultural productivity in the coastal area include prolonged submergence/ water logging during and after the monsoon (*kharif*-II season) and increasing soil salinity and lack of fresh irrigation water during the dry season (both *Rabi* and *kharif*-I seasons). Thus, the levels of cropping intensity, crop diversity and crop yield in the area are much lower than the other parts of the country. This research program was designed with a view to increasing crop productivity in the coastal area of Noakhali district by adopting climate smart technologies. The objectives of the study include: i) to identify the existing cropping systems being practiced by the farmers in the coastal area of Noakhali district and the reasons liable to poor yields and ii) to increase the yield of *boro* and transplant *aman* rice, sesame, sunflower and maize through varietal selection and adopting salinity stress ameliorative agronomic practices. Three research sites were selected in two Upazilas of Noakhali district namely Hatiya and Subornochar. A benchmark survey was done with a semi-structured questionnaire in the area covering 141 farmers in both the Upazilas. The survey results indicate that most of the sample farmers are illiterate but belonging to the middle age working group. Most of the farmers are found to be either small or medium or large category of farmers with the most dominant as medium farmers (41.48%). The major cropping patterns identified in the area include transplant *aman* rice with fallow either in *rabi* or in *kharif*-I season. Salinity and drought are the major problems in the area causing lower crop yields. As the respondents opined, 30 to 60% of the crop yield is generally lost due to either salinity or drought. In addition, some of biotic stresses like diseases and insects, unavailability of quality seeds, lack of information about advanced technologies and appropriate training are the other reasons that decrease crop yield in the area. Most of the respondent farmers under survey areas stated that introduction of salinity and drought tolerant crop species/ varieties, development of irrigation facilities, supply of good quality seeds, training of the farmers and interest free credit facilities may improve the crop productivity in the area. For improving the crop productivity in the study areas season-specific field trials have been designed. A field trial on transplant *Aman* rice was conducted in two selected locations of Hatiya and one selected location in Subornochar with a view to increase rice yield through varietal selection (Shawrna, BR11, BRRI dhan52 and Binadhan-7) and gypsum fertilizer application. In *Rabi* season experiments on *Boro* rice (BRRI dhan 28 and Binadhan-10), sunflower (Hysun-33 and BARI Surjamukhi-2) and maize (NK-40 and BARI Hybridbhutta-9) were done in the selected areas, which included stress tolerant varieties and improved management practices to ameliorate the stress effects. Irrespective of variety, application of gypsum fertilizer increased the yield of transplant *aman* rice nearly 10% in both the research locations. Effect of gypsum fertilizer was more pronounced in *rabi* crops like maize and sunflower. In combination with mulching, gypsum fertilizer increased maize and sunflower yields more than 50% as compared to no mulch and no gypsum fertilizer application. Furrow transplanting in *boro* rice along with gypsum fertilizer application appeared as very promising technology increasing the grain yield by more than 2 t ha^{-1}in Binadhan-10 and by more than 1.5 t ha^{-1} in BRRI dhan28.During *Kharif*-I season a field trial was conducted in the selected area on sesame, a known salt tolerant crop. But the experiment of sesame was failed due to heavy rainfall at that time in the area.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project**: Enhancing the crop productivity through adoption of climate smart technologies in the salinity areas of Bangladesh

2. **Implementing organization**: Department of Agronomy, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

3. **Name and full address with phone, cell and E-mail of PI/Co-PI (s)**:

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4. **Sub-project budget (Tk)**:
4.1 Total: 1841627.00 (Eighteen lac forty one thousand six hundred twenty seven taka)
4.2 Revised (if any): 1485225.00 (Fourteen lakh eighty five thousand two hundred twenty five)

5. **Duration of the sub-project**:
5.1 Start date (based on LoA signed): 12 July 2017
5.2 End date: : 30 September 2018

6. **Justification of undertaking the sub-project**:
Agriculture is the mainstay of the economy of Bangladesh. The sector contributes about 14.23 % to the total Gross Domestic Product (GDP) of the country and also accommodates around 48.1% of labour force (BBS, 2019). Recently, the country has reached nearly to its self-sufficiency in rice production but remained far behind from the food security. According to the

State of Food Insecurity in the World, about 27% (41.7 million) of the people in Bangladesh are still undernourished.

Agriculture of Bangladesh is characterized by major influence of climatic and physical environmental factors including natural hazards such as floods, drought, salinity, cyclonic storms etc. Agricultural productivity in the country is under a big challenge due to the climatic vulnerability. Because of its geographical position, there is little doubt that Bangladesh is likely to be one of the worst affected nations in the face of climate change (Harmeling, 2014). The most vulnerable area of the country under climate change is the coastal region which covers about 20% of the country's total land area and over 30 percent of the net cultivable area (Haque, 2006). About 53% of the coastal areas are affected by salinity. Agricultural land use in these areas is very poor, which is much lower than country's average cropping intensity (Rahman, 2012). According to the World Bank (2013), the coastal belt of the countryis among the highly food insecure areas in the country. One of the main obstacles in attaining self-sufficiency in food production in the coastal area of the country is the low productivity of crops due to increased salinity problem. Moreover, salt-affected areas in the coastal region of Bangladesh increased by 26.71% in 2009 from 1973 (SRDI, 2010). The salinity level of the major rivers in the country's south-western region has also increased in recent years. Thus, the increasing levelof salinity in the coastal area poses a serious threat for crop production.

The agricultural productivity in the coastal area of Bangladesh is very low due to adverse conditions such as salinity and drought. The farmers in the coastal area are marginal and landless who usually cultivate one crop in a year (Rashid *et al*., 2014; Sarangi*et al*., 2015). During *Kharif*-II the farmers primarily grow low-yielding and late-maturing transplant *aman*rice varieties and most of the lands remain fallow during the dry period of the year (Mainuddin*et al*. 2014; Schulthess*et al*., 2015). The causes of low agricultural productivity in the coastal areas include prolonged submergence/ water logging during and after the monsoon (*Kharif*-II season) and increasing soil salinity and lack of fresh irrigation water during the dry season (both *Rabi* and *Kharif*-I seasons). Almost 65% of the coastal zone of Bangladesh is affected by various levels (low to high) of salinity during dry season (SRDI, 2010). Moreover, the area is also highly vulnerable to various environmental hazards like cyclone affecting the agricultural productivity.For this reason, the levels of cropping intensity, crop diversity and crop yield in the area are much lower than the other parts of the country. As such the productivity of different crops can be put under trial with high yielding varieties and improved management packages for increasing the yield and livelihood improvement of the resource poor farmers living in the coastal area of the country.

7. **Sub-project goal**: To improve the crop productivity through adoption of climate smart technologies in the salinity areas of Bangladesh

8. **Sub-project objective (s)**:

   i) To identify the existing cropping patterns being practiced by the farmers in the coastal area of Noakhali district and the reasons liable to poor yields.

   ii) To increase the yield of *Boro* and Transplant *Aman* rice, sesame, sunflower and maize through varietal selection and adopting salinity stress ameliorative agronomic practices.

9. **Implementing location (s)**: Farmers field in Subornachar and HatiyaUpazila of Noakhali District
10. **Methodology in brief**:

    Site Selection: After visitingthe district physically and discussing with various stakeholders **t**hree research sites were selected within greater Noakhali district representing the typical coastal ecosystem. Two sites were selected in Uttar Jotekhali of Horoni Union under HatiyaUpazila and one in MaddhayaCharbhata village of Charbhata Union under SubornocharUpazila.

Photograph 1. The team is visiting the research area and discussing with the farmers

Benchmark Survey: A benchmark survey was done in two Upazillas namely Hatiya and Subornachar of Noakhali district to analyze the existing cropping practices and socio-economic conditions of the farmers. One hundred forty one farmers from the three research sites were interviewed with a semi-structured questionnaire. Farmers were selected randomly from each of the farmers' group: large, medium, small, marginal and landless.

Selection of Cooperator farmers

Three farmers (one from each of the research sites) were selected to execute the research programs in their fields. They were selected based on their land availability, interests to cooperate with us to adopt new technologies and their social position. Name of farmers are: Mst. RubinaAkter and Mr. JaherMajhi in Uttar Jotekhali and Mst. ParvinAkter in Uttar Charbhata.

Conduction of experiment in *Kharif*-II season: Effects of gypsum fertilization on T. *Aman* rice

An experiment with two sets of transplant *Aman* rice varieties (BR11, BRRI dhan52 and Binadhan-7 in Hatiya and Shorna, BRRI dhan52 and Binadhan-7 in Subornochar) and three levels of gypsum (0, 75 and 150 kgha^{-1}) application were conducted in all three research sites. Standard experimental procedure was followed. The experiments were laid out in randomized complete block design with four replications. Individual plot size was 10 m^2. Thirty day old seedlings of the varieties were transplanted on August 10, 2017. Fertilizers except gypsum were applied as per recommendation of BARC (2012). All management practices including weeding, irrigations and pest control were done as per recommendation of BRRI (2017). At maturity the crop was harvested on November 1, 2017 for Binadhan-7 and November 7, 2017for the other varieties and data were collected on various plant characters including grain and straw yields as per the plan.

Photograph 2. Pictorial views of the experimental fields of transplant *aman* rice inHatiya and Subornochar

Conduction of experiments in *Rabi* season

Yield performance of Sunflower as influenced by variety, mulching and gypsum fertilization

The experiment was conducted in the field of Mst. RubinaAkter of Uttar Jotekhali village of HatiyaUpazilla, Noakhali. The experiment included two sunflower varieties namely BARI Surjomukhi-2 (an inbred variety) and Hysan-33 (a hybrid variety from BRAC), two mulching (no mulching and mulching with water hyacinth) and four levels of gypsum fertilizer *viz.* 0, 50, 100 and 150 kg gypsum per hectare. The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. Individual plot size used was 10 m^2 (4 m × 2.5 m). The crop was sown on 29th December 2017 maintaining the recommended spacing. Gap-filling and thinning were performed in due time. Fertilizers except gypsum were applied as per the recommendation of BARI (2017). All intercultural operations including pest control were done as and when necessary. At maturity the crop was harvested and data were collected on various plant characters including seed and stover yields as per the plan.

Photograph 3. Pictorial view of the experiment in sunflower at vegetative stage in Jotekhali village of HatiyaUpazila

Photograph 4. Pictorial view of the experiment in sunflower at reproductive stagein Jotekhali village of HatiyaUpazila

Improving yield of maize varieties through mulching and gypsum fertilization

This experiment was carried out in the field of Mr. JaherMajhi of Uttar Jotekhali Village of Horoni Union, Hatiya, Noakhali. Two maize varieties namely BARI Hybrid Bhutta-9 and NK-40 (a hybrid variety from Syngenta), two mulching treatments (no mulching and mulching with water hyacinth) and four levels of gypsum fertilizer *viz.* 0, 50, 100 and 150 kg gypsum per hectare were included in the experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. Individual plot size used was 10 m^2 (4 m × 2.5 m). The crop was sown on 31^{st} December 2017 maintaining the recommended spacing. Gap-filling and thinning were performed in due time. All intercultural operations were done as and when necessary. At maturity the crop was harvested, threshed and dried and then data were collected on various plant characters including grain and stover yields as per the plan.

Photograph 5 Pictorial view of the experiment in maizein Uttar Jotekhali Village of Horoni Union, Hatiya, Noakhali

Improving the yield of *Boro* rice through furrow transplanting and gypsum fertilization

To improve the yield of *Boro* rice in the salinity affected area of Noakhali district the experiment was conducted in the field of Mst. ParvinAkter of Uttar Charbhata Village of Charbhata Union, Subornachar, Noakhali. Two *Boro* rice varieties namely BRRI dhan28 and Binadhan-10, two transplanting methods *viz.* conventional and furrow, and four levels of gypsum fertilizer *viz.* 0, 50, 100 and 150 kg gypsum per hectare were included in the experiment. Under furrow transplanting method, furrow (15 cm width) and ridge (10 cm width with 15 cm height) were prepared and seedlings were transplanted in the furrows.Line to line distance (furrow to furrow) was 25 cm and hill to hill distance was 15 cm. In case of conventional transplanting method, seedlings were transplanted on flat bed maintaining the spacing of 25 cm x 15 cm. In both transplanting methods, three seedlings were transplanted in each hill. The experiment was laid out in Split-split plot design with 3 replications. Individual plot size used was 10 m^2 (4 m × 2.5 m). Thirty-five days old seedlings were transplanted on 20^{th} January 2018 in the well puddled plot. Fertilizers except gypsum were applied as per recommendation of BARI (2017). All intercultural operations were done as and when necessary. At maturity the crop was harvested and data were collected on various plant characters including grain and straw yields as per the plan.

Furrow transplanting

Photograph 6. Pictorial view of the experiment in *Boro* rice in Uttar Charbhata Village of Charbhata Union, Subornachar, Noakhali

\Measurement of soil salinity

The soil samples were taken from the experimental fields as per treatment specifications of three replications at a depth of 0-15 cm (by using auger from the middle portion of the soil 0-15 cm) of top layer. These soil samples were kept in shade for air dry. After drying samples were crushed to pass through 2 mm screen and stored in an air tight polythene bag prior to salinity analysis. Soil salinity was determined as EC of a 1:5 soil: water extract method (Blakemore *et al*., 1987).

Procedure

For determining soil salinity, soil sample of 20 g was taken in a beaker and 100 ml distilled water was added into the beaker. The soil and water sample were kept for overnight for mixing well. In the next day, the soil solution was shaken for 1 minute and kept 30 minutes after shaking. This shaking and rest procedure was done for three times. Then the solution was filtered with filter paper in another beaker for extraction. EC5 was measured by a conductivity meter (HI8733). The EC5 (EC of soil at 1:5 ratio) value was converted to ECe (EC of soil saturation extract) by using the following equation: ECe= 3.768 x EC5 – 0.0145 (Mondal, 1997).

Analysis of the information/data:

All the data collected through benchmark survey were cleaned, coded and analyzed in accordance with the objective of the baseline study. The survey data were analyzed by Excel. The mean value of the collected experimental data were analyzed statistically using the analysis of variance technique with the help of computer package MSTAT-C.

11. Results and discussion:

Findings of the Baseline Study

Age Distribution of Sample Farmers

Distribution of the sample farmers according to their age category is shown in Table 1. The table shows that 82.20 percent sample farmers are in middle age category (between 36 to 50 years) and 1.42 percent sample farmers are old age (more than 50 years) and 15.60 percent are in young age (18 to 35 years) group. Thus, the majority of the sample farmers in the study area were in the working age group (36-50).

Table 1: Age distribution of sample farmers

Age group	Farmers	
	No.	Percent
Young (18-35)	22	15.60
Middle aged (36-50)	116	82.20
Old >50	3	1.42
Total	141	100

Source: Benchmark Survey, 2017

Educational Status of the Family Members

The level of literacy is generally considered as an index of social advancement of a community. It makes a man more capable to manage scare resources and hence to earn maximum profit. On the basis of educational qualification, the educational status of the respondent farmers can be categorized into four groups: Illiterate, up to primary, up to secondary and up to higher secondary. Table 2 shows that 56.03 percent farmers are illiterate and 26.24, 12.77 and 4.96 percent are in primary, secondary and higher secondary categories, respectively. So, more than half of the sample farmers in the study area illiterate. It is necessary to increase awareness among the people in the study area to get education and be capable of making right decision regarding farm businesses and to obtain new information. Since literacy has its own merit and contributes to economic and social development, it has s significant impact on decision making process of agricultural production.

Table 2: Education levels of respondent farmers

Level of literacy	No. of farmers	Percent
Illiterate	79	56.03
Primary	37	26.24
Secondary	18	12.77
Higher secondary	7	4.96
Total	141	100

Source: Field Survey, 2016 & 2017

Average Farm Size of the Farmers

The farmers were classified into five categories on the basis of farm size. Farmers having 0.002 to 0.02 ha of land were included in the group of landless farmers, 0.021 to 0.2 ha of land as marginal farmers, 0.21 to 0.99 ha as small farmers, 1.0 to 3.0 ha as medium farmers and above 3.0 ha as large farmers. Table 3 shows distribution of land area according to farm size among the sample farmers. It is to be noticed that 5.67 percent of sample farmers belonged to the category of marginal farmers, 22.70 percent were small farmers, 41.48 percent were medium farmers and remaining 29.79 percent were large farmers. It is interesting to note that majority of the sample farmers were small, medium and large farmers group.

Table 3: Categories of farmers according to farm size

Farmers Category	Farm size (ha)	No	Percentage (%)
Landless	0.002 -0.02	0	0.00
Marginal	0.021 – 0.2	8	5.67
Small	0.21–0.99	32	22.70
Medium	1.0-3.0	59	41.84
Large	above 3.0	42	29.79
Total		141	100

Source: Field Survey, 2016 & 2017

Major Cropping Patterns

Table 4 shows the major cropping pattern in the study areas. In *Kharif*-I season, 94.33 % sample farmers keep their lands fallow while only 4.96 % farmers cultivate *Aus* rice. Another only one crop bottle gourd was reported to grow by the sample farmers. Understandably transplant *Aman* rice is the major crop in *Aman* season which is grown by 92.91% of the sample farmers. Apart from transplant *Aman* rice farmers were also found to grow bean and some vegetables in a very limited scale. A number of crops were found to grow during *Rabi* season which dominantly includes chilli, bean, groundnut, *Boro* rice and soybean. Sweet potato, grasspea, felon dal and water melon, lentil, sesame etc. were also found to grow to a limited scale. However, a significant portion of the sample farmers were also found to keep their lands fallow during *Rabi* season. Thus, the table clearly indicates that the dominant cropping pattern practiced in the area is transplant *Aman* rice based and include one to two crops in most of the cases.

Table 4: Major cropping patterns in the surveyed area

***Kharif*-I**	***Kharif*-II**	***Rabi***
Fallow (94.33%)	T. *Aman* rice (92.91)	Fallow (36.25)
Aus rice (4.96)	Fallow (4.96)	Chilli (10.57)
Bottle gourd (0.71)	Bean (1.42)	Soybean (9.86)
	Vegetable (0.71)	Groundnut (7.54)
		Boro rice (6.38)
		Bean (5.45)
		Sweet potato (5.32)
		Grasspea (4.18)
		Falon dal (4.32)
		Water melon (4.36)
		Lentil (3.42)
		Sesame (1.68)
		Others (0.67)

Problems liable to poor crop yield in the area

Salinity and drought are the major problems in the area causing lower crop yields. Table 5 illustrates that 30 to 60% of the crop yield may be lost due to either salinity or drought. In addition, some of biotic stresses like diseases and insects, unavailability of quality seeds, lack of information about advanced technologies and appropriate training are the other causes that decreases crop yield in the area.

Most of the farmers interviewed stated that introduction of salinity and drought tolerant crop species/ varieties, development of irrigation facilities, supply of good quality seeds, training of the farmers and interest free credit facilities may improve the crop productivity in the area.

Table 5. Salinity and drought problems causing crop yield loss in the surveyed area

Stress situation		**Crop yield loss (%)**	**Farmers' opined (%)**
Salinity	Low	10-25%	14.18
	Medium	30-45%	58.16
	High	50-60%	21.28
	Very high	65-100%	6.38
Drought	Low	10-25%	9.93
	Medium	30-45%	58.16
	High	50-60%	29.79
	Very high	65-100%	9.22

Findings of the experiment with transplant *Aman* rice

Experiment in Hatiya

Yield and major yield contributing characters of transplant *Aman* rice differed significantly (Table 6). BR11 produced the highest grain yield, which was statistically similar to that of BRRI dhan52. On the other hand, Binadhan-7 produced the lowest grain yield. Field duration of the varieties might play a significant role in the yield differences among the varieties with the shortest field duration of Binadhan-7 and longest field duration of BRR11.

Table 6. Effect of variety on yield and yield contributing characters of *Aman* rice

Variety	No. of total tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	Panicle length (cm)	No. of grains $panicle^{-1}$	Grain yield ($t\ ha^{-1}$)	Benefit Cost Ratio
V_1	8.742b	8.383b	24.70a	76.90a	5.506 a	1.34
V_2	8.328c	7.840c	24.77a	72.20b	5.346 a	1.31
V_3	9.914a	8.844a	23.44b	58.69c	4.698b	1.15
$LSD_{0.05}$	0.369	0.170	0.824	0.559	0.336	-
$S\bar{x}$	0.117	0.045	0.261	0.178	0.107	-
Level of significance	**	**	**	**	**	
CV (%)	4.05	3.43	5.72	1.74	7.52	

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);
** =Significant at 1% level of probability;
V_1 = BR11; V_2 = BRRI dhan52; V_3 = Binadhan-7.

Grain yield and the major yield contributing characters varied significantly also due to gypsum fertilizer (Table 7). Application of gypsum fertilizer increased the grain yield of transplant *Aman* rice as compared to control (no gypsum application). Application of 75 kg gypsum/ ha produced the highest yield and further increase in the level of gypsum did not increase grain yield significantly. Gypsum fertilizer supplies Ca^{2+} which replaces Na^{+} from soil particles (clay) and thus Na^{+}may be leached out from soil reducing salinity stress. As a result, grain yield might have beed increased in rice by the application of gypsum fertilizer. The yield contributing characters and grain yield of transplant *Aman* rice were also influenced by the interaction of variety and gypsum fertilizer application (Table 8). Higher grain yield was obtained under gypsum fertilizer application as compared to no gypsum. However, BR11 and BRRI dhan52 responded better to gypsum fertilizer application in comparison to Binadhana-7 @75 kg gypsum ha^{-1}. But at higher dose of gypsum Binadhan-7 responded better than BR11 and BRRI dhan52. Under the interaction of variety and gypsum fertilizer, no difference in grain yield was observed between BR11 and BRRI dhan52.

Table 7. Effect of level of gypsum fertilizer on yield and yield contributing characters of transplant *Aman*rice

Level of gypsum	No. of total tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	Panicle length (cm)	No. of grains $panicle^{-1}$	Grain yield (t ha^{-1})	Benefit Cost Ratio
G_0	8.566b	7.844b	0.7233a	24.26ab	68.83b	4.987b	1.16
G_1	9.198a	8.528a	0.6700b	23.59b	69.14ab	5.164ab	1.21
G_2	9.219a	8.696a	0.5267c	25.06a	69.83a	5.399a	1.31
$LSD_{0.05}$	0.248	0.195	0.053	0.946	0.822	0.265	-
$S\bar{x}$	0.086	0.067	0.018	0.327	0.285	0.092	-
Level of significance	**	**	**	**	*	**	-
CV (%)	5.54	2.27	13.07	4.57	1.09	8.74	-

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);
** =Significant at 1% level of probability, * =Significant at 5% level of probability;
G_0 = Gypsum @ 0 Kg ha^{-1}; G_1 = Gypsum @ 75 kg ha^{-1}; G_2 = Gypsum @ 150 kg ha^{-1}.

Table 8. Interaction effects of variety and level of gypsum on yield and yield contributing characters of *Aman* rice

Interaction (variety x level of gypsum)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	No. of grains panicle^{-1}	Grain yield (t ha^{-1})	Benefit Cost ratio
G_0 xV_1	8.40 de	8.03d	0.370 e	75.02c	5.393a	1.25
G_0 xV_2	8.10e	7.40e	0.700 c	73.93cd	5.348a	1.21
G_0 xV_3	9.197b	8.10d	1.10 a	57.53g	4.218b	1.13
G_1 xV_1	9.117bc	8.633bc	0.480 d	78.87a	5.625a	1.32
G_1 xV_2	8.36de	8.000d	0.370 e	69.85e	5.200a	1.21
G_1 xV_3	10.11a	8.950b	1.160 a	58.69fg	4.668b	1.16
G_2 xV_1	8.70cd	8.483c	0.230f	76.81b	5.498a	1.28
G_2 xV_2	8.51de	8.120d	0.40 de	72.82d	5.490a	1.28
G_2 xV_3	10.43a	9.483a	0.9500b	59.85f	5.208a	1.21
$LSD_{0.05}$	0.430	0.337	0.091	1.42	0.459	-
$S\bar{x}$	0.148	0.117	0.032	0.492	0.159	-
Level of sig.	**	**	**	**	*	-
CV (%)	4.05	3.43	12.10	1.74	7.52	-

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);
** =Significant at 1% level of probability, * =Significant at 5% level of probability;
G_0 = Gypsum @ 0 kg ha^{-1}; G_1 = Gypsum @ 75 kg ha^{-1}; G_2 = Gypsum @ 150 kg ha^{-1};
V_1 = BR11; V_2 = BRRI dhan52; V_3 = Binadhan-7.

Experiment in Subornochar

Variety exerted significant differences in the Subornochar location in terms of all of the yield parameters and grain yield of transplant *Aman* rice (Table 9). Among the three varieties used, local variety Shorna produced the highest grain yield (5.44 t/ha), followed by BRRI dhan52 (5.30 t/ha) and Binadhan-7 (4.69 t/ha). The highest grain yield in Shorna might be due to its better adaptability with the local agro-ecological condition, especially higher tolerance to salinity.

Table 9. Effect of variety on yield and yield contributing characters of *Aman* rice

Variety	No. of total tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	No. of non-effective tillers $hill^{-1}$	No. of grains $panicle^{-1}$	Grain yield ($t\ ha^{-1}$)
V_1	8.533b	8.217b	0.3167c	76.30a	5.443a
V_2	8.323b	7.893c	0.4300b	71.51b	5.307b
V_3	9.997a	8.937a	1.060a	61.03c	4.690c
$LSD_{0.05}$	0.234	0.160	0.072	1.50	0.131
$S\bar{x}$	0.059	0.041	0.018	0.383	0.033
Level of significance	**	**	**	**	**
CV (%)	2.18	2.00	7.43	2.61	3.25

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);
** =Significant at 1% level of probability, * =Significant at 5% level of probability;
V_1 = Shorna (Local); V_2 = BRRI dhan52; V_3 = Binadhan-7.

Table 10. Effect of level of gypsum on yield and yield contributing characters of *Aman*rice

Level of gypsum	No. of total tillers $hill^{-1}$	No. of effective tillers $hill^{-1}$	Panicle length (cm)	No. of grains $panicle^{-1}$	Grain yield ($t\ ha^{-1}$)
G_0	8.510b	7.817b	22.87b	68.24b	4.917b
G_1	9.190a	8.560a	23.36ab	70.08ab	5.203a
G_2	9.153a	8.670a	23.47a	70.52a	5.320a
$LSD_{0.05}$	0.200	0.172	0.499	1.87	0.172
$S\bar{x}$	0.065	0.056	0.162	0.606	0.056
Level of significance	**	**	*	*	**
CV (%)	2.00	1.47	3.38	1.65	1.94

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);
** =Significant at 1% level of probability, * =Significant at 5% level of probability;
G_0 = Gypsum @ 0 Kg ha^{-1}; G_1 = Gypsum @ 75 Kg ha^{-1}; G_2 = Gypsum @ 150 kg ha^{-1}.

The results also show that gypsum application improved transplant *Aman* rice yield either alone or in combination with variety (Tables 10 & 11). Grain yield gradually increased with the increasing level of gypsum fertilizer and the highest grain yield was recorded by the application of 150 kg gypsum/ ha. On the other hand, 75 kg/ ha gypsum was sufficient enough to produce the highest grain yield in case of local variety Shorna, but the amount was 150 kg gypsum /ha for both BRRI dhan52 and Binadhan-7. Increased grain yield with gypsum application was probably attributed by the amelioration of salinity stress by removing Na+ from soil (replacement of Na^+ by Ca^{2+} and then subsequent leaching)

Table 11. Interaction effects of variety and level of gypsum on yield and yield contributing characters of *Aman* rice

Interaction (variety x level of gypsum)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	No. of grains panicle^{-1}	Grain yield (t ha^{-1})	Benefit Cost Ratio
$G_0 x V_1$	8.130ef	7.810e	0.320f	73.23bc	5.13c	1.21
$G_0 x V_2$	8.070f	7.390f	0.680d	71.38cd	5.26bc	1.24
$G_0 x V_3$	9.330b	8.250cd	1.080b	60.10e	4.36e	1.12
$G_1 x V_1$	8.870c	8.470c	0.400e	80.23a	5.69a	1.35
$G_1 x V_2$	8.43def	8.120d	0.310fg	68.97d	5.19bc	1.23
$G_1 x V_3$	10.27a	9.090b	1.180a	61.03e	4.73d	1.16
$G_2 x V_1$	8.600cd	8.370cd	0.230g	75.43b	5.51ab	1.31
$G_2 x V_2$	8.470de	8.170cd	0.300fg	74.17bc	5.47ab	1.30
$G_2 x V_3$	10.39a	9.470a	0.920c	61.97e	4.98cd	1.19
$LSD_{0.05}$	0.347	0.297	0.080	3.23	0.297	-
$S\bar{x}$	0.113	0.097	0.026	1.05	0.096	-
Level of significance	*	*	**	**	*	-
CV (%)	2.18	2.00	7.43	2.61	3.25	-

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT);
** =Significant at 1% level of probability, * =Significant at 5% level of probability;
G_0 = Gypsum @ 0 kg ha^{-1}; G_1 = Gypsum @ 75 kg ha^{-1}; G_2 = Gypsum @ 150 kg ha^{-1};
V_1 = Shorna (Local); V_2 = BRRI dhan52; V_3 = Binadhan-7.

Findings of the experiments conducted in *Rabi* season

Experiment with sunflower: Yield performance of Sunflower as influenced by variety, mulching and gypsum fertilization

Variety significantly influenced the yield and yield contributing characters of sunflower. All the yield contributing characters and seed yield (1.87 t ha^{-1}) were higher for the hybrid BRAC Hysun-33 (V_2) (Table 12).

Yield contributing characters and yield of sunflower were significantly influenced by mulching. Mulching with water hyacinth (M_1) produced the higher seed yield (1.98 t ha^{-1}) than no mulching (M_2) (Table 13).

Levels of gypsum fertilizer also significantly influenced all the yield contributing characters and yield of sunflower. The results revealed that, as the level of gypsum increased the yield contributing characters and yield of sunflower were also increased gradually (Table 14). The highest seed yield (2.04 t ha^{-1}) was found for 150 kg gypsum ha^{-1} (G_3).

Table 12. Effect of variety on yield and yield contributing characters of sunflower

Variety	Girth of single flower (cm)	Number of filled seeds $head^{-1}$	Weight of total seeds $head^{-1}$ (g)	Weight of 100-seeds	Seed yield (t ha-1)	Stover yield (t/ha)
V_1	35.35 b	439.7 b	31.89 b	7.31 b	1.79 b	3.41 b
V_2	37.98 a	499.7 a	34.43 a	7.51 a	1.87 a	3.56 a
Level of significance	**	**	**	**	**	**
LSD value	0.13	0.58	0.23	0.03	0.03	0.03
CV (%)	0.54	0.18	0.98	0.78	2.58	1.23

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per LSD);
** = Significant at 1% level of probability, * = Significant at 5% level of probability;
V_1 = BARI Surjomukhi-2, V_2 = BRAC Hysun-33.

Table 13. Effect of mulching on yield and yield contributing characters of sunflower

Mulching	Girth of flower (cm)	Number of filled seeds head^{-1}	Weight of total seed per flower head (g)	Weight of 100-seeds	Seed yield (t ha-1)	Stover yield (t/ha)
M_0	36.07 b	406.0 b	28.20 b	6.96 b	1.68 b	3.32 b
M_1	37.26 a	533.5 a	38.12 a	7.86 a	1.98 a	3.65 a
Level of significance	**	**	**	**	**	**
LSD value	0.13	0.58	0.23	0.03	0.03	0.03
CV (%)	0.54	0.18	0.98	0.78	2.58	1.23

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per LSD);
**= Significant at 1% level of probability;
M_0 =Without mulching, M_1 =With mulching (Water hyacinth).

Table 14. Effect of gypsum levels on yield and yield contributing characters of sunflower

Gypsum Level	Girth of flower (cm)	Number of filled seeds head^{-1}	Weight of total seeds head^{-1} (g)	Weight of 100-seeds	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})
G_0	34.38 d	359.0 d	24.72 d	6.40 d	1.58 d	3.22 d
G_1	36.59 c	443.1 c	31.04 c	7.24 c	1.77 c	3.42 c
G_2	38.75 a	524.5 b	36.64 b	7.86 b	1.94 b	3.54 b
G_3	36.93 b	552.1 a	40.24 a	8.14 a	2.04 a	3.74 a
Level of significance	**	**	**	**	**	**
LSD value	0.16	0.67	0.27	0.04	0.03	0.03
CV (%)	0.54	0.18	0.98	0.78	2.58	1.23

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per LSD);
**= Significant at 1% level of probability;
G_0 = 0 kg gypsum ha^{-1}, G_1 = 50 kg gypsum ha^{-1}, G_2 = 100 kg gypsum ha^{-1}, G_3 = 150 kg gypsum ha^{-1}.

The results of this study also showed that, all the yield contributing characters and yield of sunflower were significantly influenced by the interactions among varieties, mulches and gypsum fertilizer levels. The hybrid variety BRAC hysun-33 under mulched condition applied with 100 kg gypsum ha^{-1} (V_2×M_1×G_2) produced the highest number of filled seeds head^{-1} (704), weight of total seeds head^{-}

[1](48.68 g) and 100-seed weight (8.67 g) those leaded to highest seed yield (2.35 t ha^{-1}) for this treatment interaction. For both the varieties, the respective lowest values of these parameters were found when no mulching and no gypsum were applied (Table 15). Irrespective of variety, mulching and gypsum fertilizer application increased grain yield of sunflower. Mulching reduces the evaporation of soil moisture and thus minimizes the upward movement of salty water from the sub-surface soil layers. As a result, accumulation of salt under mulching condition may remain lower than that of no mulch condition. Application of gypsum fertilizer removes Na^+ from the soil through replacement by Ca^{2+} and then subsequently by leaching. Application of mulching and gypsum fertilizer thus provide better benefit cost ratio of the crops compared to no mulching and no gypsum application.

Table 15. Effect of interactions among varieties, mulches and gypsum fertilizer levels on the yield and yield contributing characters of sunflower

Interaction	Girth of flower (cm)	Number of filled seeds head^{-1}	Weight of total seeds head^{-1} (g)	Weight of 100-seeds	Seed yield (t ha-1)	Stover yield (t/ha)	Benefit Cost Ratio
$V_1 \times M_0 \times G_0$	32.00 l	323.7 o	22.20 l	6.06 o	1.52 h	3.11 i	1.76
$V_1 \times M_0 \times G_1$	36.33 h	365.5 m	25.77 j	6.62 m	1.61 g	3.18 hi	1.79
$V_1 \times M_0 \times G_2$	36.27 h	426.7 k	29.84 h	7.34 i	1.73 f	3.21 h	1.80
$V_1 \times M_0 \times G_3$	37.80 e	475.0 g	35.60 e	7.88 f	1.91 d	3.69 d	2.21
$V_1 \times M_1 \times G_0$	35.47 i	358.5 n	24.93 k	6.45 n	1.60 g	3.24 gh	1.83
$V_1 \times M_1 \times G_1$	35.67 i	452.1 h	32.25 g	7.52 h	1.81 e	3.35 f	1.94
$V_1 \times M_1 \times G_2$	36.67 g	521.7 e	39.07 d	8.24 d	1.99 c	3.63 d	2.14
$V_1 \times M_1 \times G_3$	32.60 k	594.7 c	45.44 b	8.42 c	2.21 b	3.87 bc	2.30
$V_2 \times M_0 \times G_0$	32.87 k	318.7 p	22.08 l	6.10 o	1.51 h	3.19 h	1.87
$V_2 \times M_0 \times G_1$	38.60 d	390.3 l	26.30 j	6.81 l	1.63 g	3.34 f	1.94
$V_2 \times M_0 \times G_2$	40.27 c	445.7 i	28.98 i	7.19 j	1.72 f	3.31 fg	1.92
$V_2 \times M_0 \times G_3$	34.40 j	502.0 f	34.87 f	7.72 g	1.87 de	3.52 e	2.08
$V_2 \times M_1 \times G_0$	37.20 f	435.3 j	29.67 h	7.01 k	1.71 f	3.37 f	1.96
$V_2 \times M_1 \times G_1$	35.74 i	564.5 d	39.85 c	8.02 e	2.03 c	3.81 c	2.28
$V_2 \times M_1 \times G_2$	41.80 b	704.0 a	48.68 a	8.67 a	2.35 a	4.03 a	2.58
$V_2 \times M_1 \times G_3$	42.93 a	636.9 b	45.04 b	8.56 b	2.19 b	3.90 b	2.31
Level of significance	**	**	**	**	**	**	-
LSD value	0.32	1.34	0.54	0.09	0.07	0.07	-
CV (%)	0.54	0.18	0.98	0.78	2.58	1.23	-

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per LSD) ;
** = Significant at 1% level of probability, * = Significant at 5% level of probability;
V_1 = BARI Surjomukhi-2, V_2 = BRAC Hysun-33;
M_0 = Without mulching, M_1 = With mulching (Water hyacinth);
G_0 = 0 kg gypsum ha^{-1}, G_1 = 50 kg gypsum ha^{-1}, G_2 = 100 kg gypsum ha^{-1}, G_3 = 150 kg gypsum ha^{-1}.

Experiment with maize: Improving yield of maize varieties through mulching and gypsum fertilization

Yield and most of the yield contributing characters were significantly influenced by variety, mulching, gypsum levels and their corresponding interactions. For variety, higher number of grain lines cob^{-1} (13.34), number of grains line^{-1} (35.14), 100-grain weight (32.03 g) and grain yield (7.59 t ha^{-1}) were obtained from NK-40 compared to BARI hybrid bhutta-9 (Table 16). Mulching with water hyacinth produced higher 100-grain weight (32.09 g) and grain yield (7.59 t ha^{-1}) as compared to no mulching irrespective of variety (Table 17). For the interactions among varieties, mulching and gypsum fertilizer levels, the highest number of grains line^{-1}, 100-grain weight and grain yield were 38.02, 34.33 g and 8.96 t ha^{-1} for $V_2M_1G_2$ (NK-40, water hyacinth and 100 kg gypsum ha^{-1}) treatment combination (Table 19). On the other hand, the lowest values for the same parameters were 30.51, 28.67 g and 5.41 t ha^{-1} for $V_1M_0G_0$ (BARI hybrid bhutta-9 with no mulching and no gypsum application), respectively. The results revealed that mulching with water hyacinth alone increased 10.64% grain yield as compared to no mulching and application of gypsum fertilizer @ 150 kg ha^{-1}increased 33.66% grain yield compared to no gypsum application at salinity level (8.21 dSm^{-1}). In case of the interactions among varieties, gypsum levels and mulching, grain yield increased by 65.61% in the variety NK-40 when cultivated with mulched condition along with the application of gypsum fertilizer @ 100 kg ha^{-1}at salinity level (8.21 dSm^{-1}).Therefore, it may be concluded that the yield of maize in the saline area of Noakhali, Bangladesh can be increased by adopting mulching technique and gypsum fertilizer application. Mulching minimizes the evaporation of water from the sub-surface of soil and thus reduces the upward movement of salt and its subsequent accumulation on the soil surface. Thus, salinity at soil surface under mulch application remains lower than that of no mulch condition. Gypsum fertilizer may also help reduce salinity level in soil by replacing Na^+ ions from soil particles by Ca^{2+}, which may then be leached out from soil surface.

Table 16. Effect of varieties on the yield and yield contributing characters of maize

Variety	Cob length (cm)	Cob weight (g)	No. of grains cob^{-1}	Total grain weight cob^{-1} (g)	100- grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
V_1	14.86b	216.9b	430b	133.0b	30.82b	6.87b	12.44b
V_2	15.40a	221.3a	469a	143.5a	32.03a	7.59a	13.03a
$S\bar{x}$	0.026	1.254	0.041	1.319	0.016	0.008	0.016
Level of Significance	**	**	**	**	**	**	**
CV (%)	0.68	2.29	1.27	3.82	0.20	0.52	0.52

In a column, figures without letter do not differ significantly whereas figures with dissimilar letters differ significantly (as per DMRT); ** = Significant at 1% level of probability,V_1 = BARI hybrid bhutta-9, V_2 = NK-40.

Table 17. Effect of mulching on the yield and yield contributing characters of maize

Mulching	Cob length (cm)	Cob weight (g)	No. of grains cob^{-1}	Total grain weight cob^{-1} (g)	100-grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
M_0	14.83b	217.0b	427b	134.2b	30.76b	6.86b	12.19b
M_1	15.43a	221.2a	474a	142.3a	32.09a	7.59a	13.28a
$S\bar{x}$	0.026	1.254	0.041	1.319	0.016	0.008	0.016
Level of significance	**	**	**	**	**	**	**
CV (%)	0.68	2.29	1.27	3.82	0.20	0.52	0.52

In a column, figures without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability;M_0 = Without mulching, M_1 = With mulching (water hyacinth).

Table 18. Effect of levels of gypsum fertilizer on the yield and yield contributing characters of maize

Gypsum level	Cob length (cm)	Cob weight (g)	No. of grains cob^{-1}	Total grain weight cob^{-1} (g)	100-grain weight (g)	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})
G_0	14.89 c	211.8 b	397 c	120.0 c	29.39 d	6.03 d	11.15 d
G_1	15.19 b	222.3 a	450 b	136.2 b	30.71 c	6.99 c	12.29 c
G_2	15.56 a	222.6 a	475ab	148.9 a	32.53 b	7.85 b	13.89 a
G_3	14.88 c	219.8 a	480 a	147.9 a	33.07 a	8.06 a	13.60 b
$S\bar{x}$	0.0302	1.447	0.047	1.524	0.018	0.009	0.018
Level of significance	**	**	**	**	**	**	**
CV (%)	0.68	2.29	1.27	3.82	0.20	0.52	0.52

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability;
G_0 = 0 kg gypsum ha^{-1}, G_1 = 50 kg gypsum ha^{-1}, G_2 = 100 kg gypsum ha^{-1}, G_3 = 150 kg gypsum ha^{-1}.

Table 19. Effect of interactions among varieties, mulches and gypsum fertilizer levels on the yield and yield contributing characters of maize

Interaction	Cob length (cm)	Cob weight (g)	No. of grains cob^{-1}	100-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Benefit Cost Ratio
$V_1 \times M_0 \times G_0$	13.62 i	235 g	361n	28.67m	5.41 n	9.910 n	1.05
$V_1 \times M_0 \times G_1$	14.15 h	241ef	391 l	29.25 k	6.34 l	11.65 l	1.26
$V_1 \times M_0 \times G_2$	15.40bcd	240 f	419 h	30.33gh	7.17 h	12.81 h	1.47
$V_1 \times M_0 \times G_3$	14.54 g	242 de	426 g	32.67 f	7.30 g	12.90 h	1.51
$V_1 \times M_1 \times G_0$	15.17 e	243 cd	393 k	29.76 j	6.31 l	12.12 j	1.28
$V_1 \times M_1 \times G_1$	15.51 bc	243 cd	421 h	30.41 g	7.04 i	12.38 i	1.39
$V_1 \times M_1 \times G_2$	15.54 b	245 b	433 f	32.79 e	7.63 f	14.52 a	1.58
$V_1 \times M_1 \times G_3$	14.91 f	243 d	443 e	32.68 f	7.79 e	13.24 g	1.62
$V_2 \times M_0 \times G_0$	15.44 bc	240 f	367 m	29.03 l	5.88 m	10.64 m	1.14
$V_2 \times M_0 \times G_1$	15.23 de	235 g	398 i	30.23 h	6.69 j	11.75 l	1.35
$V_2 \times M_0 \times G_2$	15.32cde	245 b	435 f	32.65 f	7.63 f	13.82 e	1.58
$V_2 \times M_0 \times G_3$	14.91 f	243 d	460 c	33.26 c	8.52 c	14.04 d	1.81
$V_2 \times M_1 \times G_0$	15.33cde	244bc	387 j	30.11 i	6.52 k	11.93 k	1.44
$V_2 \times M_1 \times G_1$	15.87 a	245 b	452 d	32.95 d	7.90 d	13.40 f	1.66
$V_2 \times M_1 \times G_2$	15.97 a	250 a	488 a	34.33 a	8.96 a	14.40 b	1.97
$V_2 \times M_1 \times G_3$	15.17 e	25 a	467 b	33.67 b	8.63 b	14.23 c	1.85
$S\bar{x}$	0.060	0.0408	0.037	0.037	0.018	0.037	-
Level of Significance	**	**	**	**	**	**	-
CV (%)	0.68	0.47	0.19	0.20	0.52	0.52	-

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); ** = Significant at 1% level of probability;
V_1 = BARI hybrid bhutta-9, V_2 = NK-40;
M_0 = Without mulching, M_1 = With mulching (Water hyacinth);
G_0 = 0 kg gypsum ha^{-1}, G_1 = 50 kg gypsum ha^{-1}, G_2 = 100 kg gypsum ha^{-1}, G_3 = 150 kg gypsum ha^{-1}.

Experiment with *Boro* rice: Improving the yield of *Boro* rice through furrow transplanting and gypsum fertilization

There was significant variation on yield contributing characters and yield of *Boro* rice due to the effect of transplanting methods. Grain yield including all the yield improving traits were higher in case of furrow transplanting method as compared to conventional transplanting method.

Variety significantly influenced the yield contributing characters and yield of *Boro* rice. Grain yield and all the yield contributing characters except number of sterile spikelets panicle^{-1} were higher for Binadhan-10 than that of BRRI dhan28 (Table 21).

Yield contributing characters and yield of *Boro* rice were significantly influenced by the gypsum levels. Results revealed that, yield contributing characters and yield of *Boro* rice were increasing gradually with the increasing levels of gypsum. Highest values of these parameters were found for 150 kg gypsumha^{-1} (G_3)and the respective lowest values were found for no gypsum application (G_0) (Table 22).

Table 20. Effect of transplanting method on the yield and yield contributing characters of *Boro*rice

Transplanting Method	No. of effective tillers hill^{-1}	Grains panicle^{-1}	No. of sterile spikelets panicle^{-1}	1000-grains weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Furrow Transplanting	11.81 a	84.95 a	10.53 b	22.89 a	5.66 a	7.23 a
Conventional Transplanting	9.19 b	78.65 b	13.43 a	22.47 b	4.90 b	6.42 b
Level of significance	**	**	**	**	**	**
LSD value	0.0481	0.502	0.920	0.4053	0.083	0.152
CV (%)	0.31	0.41	5.05	1.17	1.04	1.46

In a column, figures without letter do not differ significantly whereas figures with dissimilar letters differ significantly (as per LSD);
** = Significant at 1% level of probability.

Table 21. Effect of variety on the yield and yield contributing characters of *Boro*rice

Variety	No. of effective tillers hill^{-1}	Grains panicle^{-1}	No. of sterile spikelets panicle^{-1}	1000-grains weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
V_1	9.87 b	80.39 b	12.98 a	22.58 b	5.06 b	6.57 b
V_2	11.14 a	83.21 a	10.98 b	22.79 a	5.49 a	7.08 a
Level of significance	**	**	**	**	**	**
LSD value	0.062	0.279	0.503	0.116	0.069	0.062
CV (%)	0.61	0.35	4.27	0.52	1.34	0.93

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per LSD);** = Significant at 1% level of probability;
V_1 = BRRI dhan28, V_2 = Binadhan-10.

Table 22. Effect of gypsum fertilizers levels on the yield and yield contributing characters of*Boro*rice

Gypsum level	No. of effective tillers hill^{-1}	Grains panicle^{-1}	No. of sterile spikelet panicle^{-1}	1000-grains weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
G_0	8.32 d	77.13 d	13.10 a	22.31 c	4.72 d	6.18 c
G_1	10.18 c	81.35 c	11.79 b	22.59 b	5.19 c	6.65 b
G_2	11.73 b	83.10 b	11.90 b	22.86 a	5.49 b	7.27 a
G_3	11.80 a	85.62 a	11.12 c	22.96 a	5.74 a	7.23 a
Level of significance	**	**	**	**	**	**
LSD value	0.046	0.241	0.338	0.235	0.038	0.046
CV (%)	0.56	0.35	3.29	1.23	0.91	0.86

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per LSD);
**= Significant at 1% level of probability;
G_0 = 0 kg gypsum ha^{-1}, G_1 = 50 kg gypsum ha^{-1}, G_2 = 100 kg gypsum ha^{-1}, G_3 = 150 kg gypsum ha^{-1}.

Results of the study also revealed that, yield and major yield contributing characters of Boro rice were significantly influenced by the interaction among transplanting method, variety and gypsum levels(Table 23).The highest grain yield (6.63 t ha-1) was found from the combination of furrow transplanting method, Binadhan-10 and gypsum fertilizer application @ 150 kg ha^{-1}. On the other hand, the lowest grain yield (4.26 t ha^{-1}) was obtained from the variety BRRI dhan28 under conventional transplanting method and no gypsum fertilizer application. The result clearly indicates that furrow transplanting method and gypsum fertilizer application increased the grain yield of *Boro* rice irrespective of variety. Under furrow transplanting method and gypsum fertilizer application @ 150 kg ha^{-1}, grain yield increase in Binadhan-10 was 30.32% and in BRRI dhan28 was 26.68% as compared to their respective conventional transplanting method and no gypsum fertilizer application. A similar increase in straw yield under furrow transplanting method with gypsum fertilizer application was also observed. The findings of the study thus conclude that the yield of *Boro* rice in the salinity affected area of Noakhali district can be improved substantially following furrow transplanting method, Binadhan-10 and gypsum fertilizer application @150 kg ha^{-1}.

Table 23. Effect of interaction among transplanting method, variety and gypsum levels on the yield and yield contributing characters of *Boro*rice

Interaction	No. of effective tillers $hill^{-1}$	Grains $panicle^{-1}$	No. of sterile spikelets $panicle^{-1}$	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Benefit Cost Ratio
$T_1 \times V_1 \times G_0$	8.070 m	76.71 k	11.88 d	4.83 k	6.26 j	1.17
$T_1 \times V_1 \times G_1$	11.17 g	82.33 f	11.75 d	5.37 f	6.99 fg	1.20
$T_1 \times V_1 \times G_2$	12.63 d	85.49 d	11.93 d	5.59 e	7.07 ef	1.21
$T_1 \times V_1 \times G_3$	13.13 c	88.73 b	11.08 e	5.81 c	7.40 c	1.23
$T_1 \times V_2 \times G_0$	10.12 i	79.15 h	10.29 f	5.15 h	6.93 g	1.19
$T_1 \times V_2 \times G_1$	12.14 e	87.83 c	9.157 g	5.71 d	7.09 e	1.23
$T_1 \times V_2 \times G_2$	13.53 b	89.16 b	10.11 f	6.21 b	8.14 a	1.29
$T_1 \times V_2 \times G_3$	13.73 a	90.21 a	8.037 h	6.63 a	7.97 b	1.34
$T_2 \times V_1 \times G_0$	7.370 p	76.14 l	16.11 a	4.26 m	5.61 l	1.17
$T_2 \times V_1 \times G_1$	7.830 n	76.76 k	14.02 b	4.65 l	5.98 k	1.21
$T_2 \times V_1 \times G_2$	9.040 l	77.65 j	13.71 bc	4.91 j	6.59 i	1.24
$T_2 \times V_1 \times G_3$	9.770 j	79.35 h	13.32 c	5.12 h	6.73 h	1.24
$T_2 \times V_2 \times G_0$	7.720 o	76.52 kl	14.12 b	4.62 l	5.90 k	1.17
$T_2 \times V_2 \times G_1$	9.580 k	78.48 i	12.23 d	5.03 i	6.53 i	1.24
$T_2 \times V_2 \times G_2$	11.71 f	80.09 g	11.85 d	5.23 g	7.26 d	1.18
$T_2 \times V_2 \times G_3$	10.57 h	84.20 e	12.05 d	5.40 f	6.82 h	1.31
Level of significance	**	**	**	**	**	-
LSD value	0.092	0.483	0.663	0.075	0.092	-
CV (%)	0.56	0.35	3.29	0.91	0.86	-

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per LSD);
** = Significant at 1% level of probability;
T_1 = Furrow Transplanting, T_2 = Conventional Transplanting;
V_1 = BRRI dhan28, V_2 = Binadhan-10;
G_0 = 0 kg gypsum ha^{-1}, G_1 = 50 kg gypsum ha^{-1}, G_2 = 100 kg gypsum ha^{-1}, G_3 = 150 kg gypsum ha^{-1}.

Amelioration of salinity stress by mulching

Mulching is known to lower the accumulation of salts in the surface soil as it minimizes evaporation of water from the surface and thus reduces the upward capillary movement of salty water. In the study, soil salinity in the surface soil in maize without mulching was 8.5 dSm^{-1}, which was 5.1dSm^{-1} when the crop field was mulched with water hyacinth (Fig. 1). A similar accumulation of salts in the surface soil was also found in sunflower where salinity was 8.3dSm^{-1} in no mulch field but 5.3dSm^{-1} in mulched condition. The results of the study clearly indicates that mulching reduces the salinity level in the surface soil which might have influenced positively on the better yield of the crops under mulched condition than the no mulch condition.

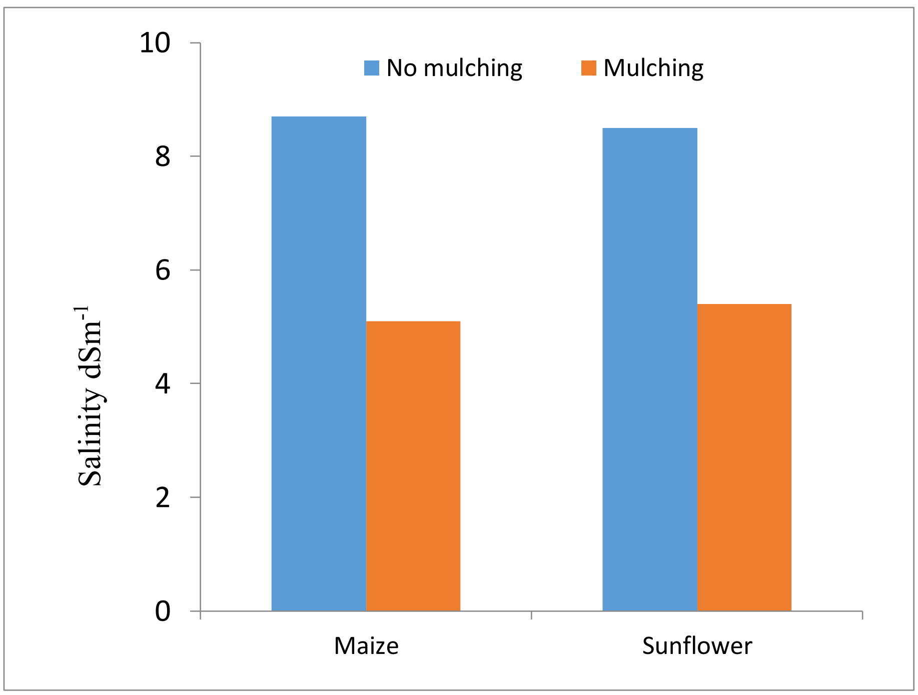

Fig. 1 Salinity level as measured in the root zone soils (0-15 cm) of plots with and without mulching (water hyacinth mulch). Soil samples were collected immediately after harvesting the crop.

Amelioration of salinity stress by gypsum fertilizer application

Application of gypsum in saline soil is beneficial in the way that it supplies a divalent Ca^{2+} ion, which replaces the monovalent Na^{+} from its binding with the soil. When Na^{+} becomes free ion, it is leached out from the root zone of the crop particularly if irrigation is given afterwards. Average soil salinity as measured in April and May from the fields of *boro* rice, maize and sunflower indicates that soil salinity was more than 8 dSm^{-1} in the plots of sunflower and maize that received no gypsum fertilizer. On the other hand, application of gypsum fertilizer @ 50, 100 and 150 $kgha^{-1}$ lowered the salinity in the surface soil to a considerable extent, which was lesser than 6 dSm^{-1}in most of the cases (Fig. 2). Salinity in *Boro* rice field was a bit lower as compared to sunflower and maize, which was lesser than 8.0 dSm^{-1} under no gypsum fertilizer application. The level of salinity decreased further substantially with the application of gypsum fertilizer at the rates of 50, 100 and 150 $kgha^{-1}$. The results of the study clearly reveal that application of gypsum fertilizer in the salinity affected field reduces the level of salinity in the surface soil, which eventually ameliorates the salinity stress in crops and thus improves the crop yield as better yield of *boro*rice, maize and sunflower were obtained in the study.

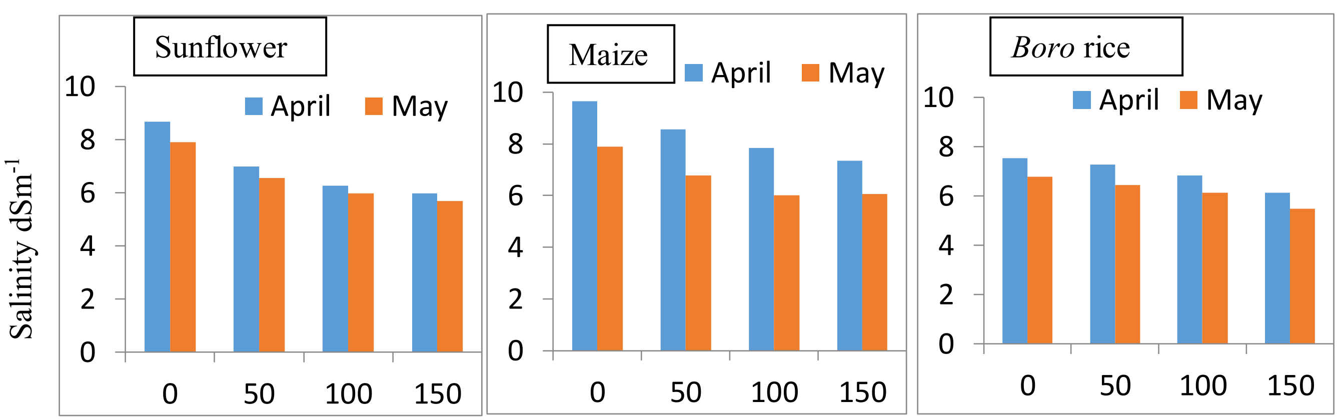

Fig. 2 Salinity level as measured in the root zone soils (0-15 cm) of plots (sunflower, maize and *Boro* rice) with and without gypsum fertilizer application at variable rates. Soil samples were collected once in April and once in May.

Amelioration of salinity stress in *boro* rice by furrow transplanting

Furrow transplanting in rice is advocated for the salinity affected area, as the method facilitates the accumulation of salts mostly on the ridges and thus keeps the furrow with lesser salt. The measurement of soil salinity from the furrow and ridge of the *boro* rice field in the study reveals the similar findings. Salinity level in the surface soil under conventional transplanting (flat area) was found as nearly 7 dSm^{-1} (Fig. 3). But under furrow transplanting the salinity in the soil of furrow was found only arounfd3 dSm^{-1}. On the other hand, the salinity in the soil on the ridge was more than 10 dSm^{-1}. Therefore, it can be concluded that under furrow transplanting of *boro* rice majority of the salt gets accumulated on the ridge keeping the furrow with lesser salt. Therefore, rice transplanted only within the furrow could avoid the harmful effect of salinity, though much more salinity was on the ridge.

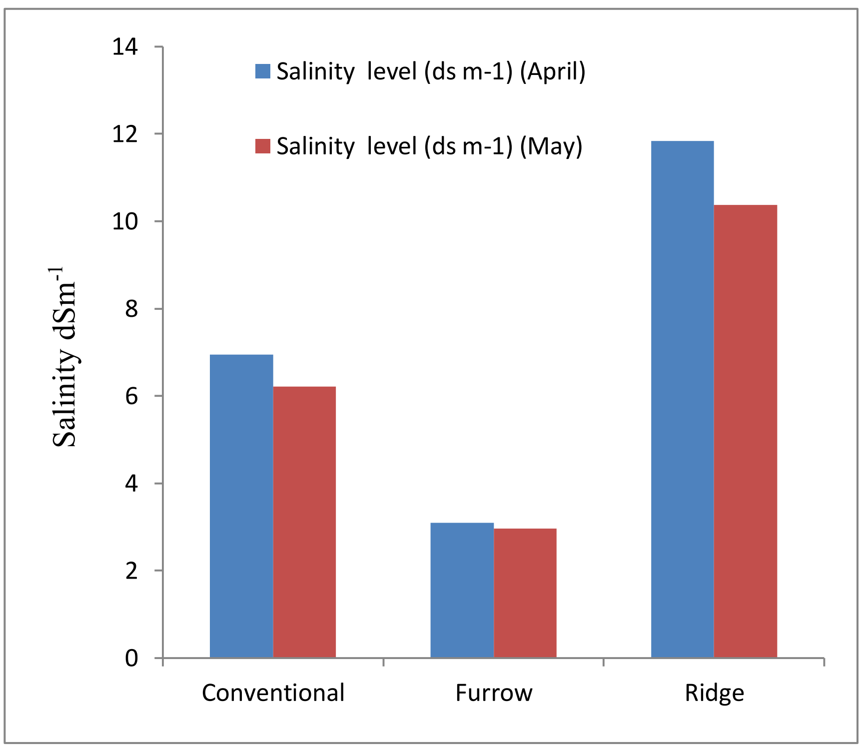

Fig. 3 Salinity level as measured in the soils (0-15 cm) of furrow and ridge of *boro* rice field (furrow transplanting) along with the soils from flat field (conventional transplanting). Soil samples were collected once in April and once in May (immediately after harvesting the crop).

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12. Research highlight/findings (Bullet point – max 10 nos.):

- Cropping patterns being practiced by the farmers in the study area are Transplant *aman* rice dominated and more than 95% of the cultivable lands remain fallow during *Kharif* I season and 25% of the cultivable lands remain fallow during *Rabi* season.
- Major existing cropping patterns as identified in the study area is Fallow – T. *aman* rice – chilli/ bean/ groundnut/ *boro* rice.
- Salinity and drought are ranked as the most important stresses causing significant crop yield loss in the area during *rabi* season.
- Irrespective of variety, application of gypsum fertilizer increased the yield of transplant *aman* rice nearly 10% in both the research locations (Hatiya and Subarnachar).
- Effect of gypsum fertilizer was more pronounced in *rabi* crops like maize and sunflower. In combination with mulching gypsum fertilizer improved maize and sunflower yields more than 50% as compared to no mulch and no gypsum fertilizer application.
- Furrow transplanting in *Boro* rice along with gypsum fertilizer application appeared as very promising technology increasing the grain yield more than 2 t ha^{-1} in Binadhan-10 and more than 1.5 t ha^{-1} in BRRI dhan28.
- Application of mulching and gypsum in maize and sunflower, and furrow transplanting method in *boro* rice reduce salinity levels within the root zone soil and thus increase crop yield.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP target		Achievement		Remarks
	Phy(#)	Fin(Tk)	Phy(#)	Fin(Tk)	
(a) Office equipment					
Laptop computer	One	60000	One	60000	
Laser printer	One	20000	One	20000	
Scanner	One	10000	One	10000	
Digital camera	One	25000	One	25000	
(b) Lab.& field equipment					
EC Meter	One	50000	One	50000	
(c) Other capital items					
Computer table	One	5000	One	5000	
Executive table	One	20000	One	20000	
Executive chair	One	10000	One	10000	
	Total	200000	**Total**	200000	

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target (Tk)	Achievement	PP Target (Tk)	Achievement	
Repair and renovation of Lab.	-	-	35000	100%	

3. Training/study tour/ seminar/workshop/conference organized: NOT APPLICABLE

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation*
A. Contractual Staff Salary	416627	416627	396627	20000	95	
B. Field Research / Lab expenses and supplies	655000	655000	530000	125000	81	
C. Operating Expenses	210000	207723	179698	28025	87	
D. Vehicle Hire and Fuel, Oil & Maintenance	175000	135000	129000	6000	96	
E. Training/Workshop/Seminar etc.	70000	0	0	0	0	
F. Publications and printing	80000	70000	14900	55100	21	
G. Miscellaneous	35000	35000	35000	0	100	
H. Capital Expenses	200000	200000	200000	0	100	
Total	**1841627**	**1719350**	**1485225**	**234125**	86	

- The experiment in *Kharif* I season with sesame was damaged due to heavy rainfall in the area. Therefore, the costs of all of the activities in relation to the experiments remained unspent.

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
i) To identify the existing cropping systems being practiced by the farmers in the coastal area of Noakhali district and the reasons liable to poor yields.	Benchmark survey was done. One hundred forty one farmers were interviewed with a semi-structured questionnaire.	Major Patterns: Fallow – T. aman rice – Fallow Fallow – T. aman rice – Chilli Fallow – T. aman rice – Soybean Fallow – T. aman rice – Groundnut Fallow – T. aman rice – Cowpea Fallow – T. aman rice – water melon Major problems: Salinity and drought	Information on the major cropping patterns being practiced in the area and the reasons liable to poor yield of crops for the future use
ii) To increase the yield of *Boro* and Transplant *Aman* rice, sesame, sunflower and maize through varietal selection and adopting salinity stress ameliorative agronomic practices.	i) Field trials with transplant *aman* rice including variety and gypsum fertilizer application as treatments. ii) Field trial with Sunflower using variety, mulching and gypsum fertilizer as treatments. iii) Field trial with maize using variety, mulching and gypsum fertilizer as treatments. iv) Field trial with*Boro* rice with variety, transplanting method and gypsum fertilizer. application as treatments v) Field trial with sesame including variety and gypsum fertilizer application as treatments.	i) Yield of T. aman rice increased significantly by the application of gypsum fertilizers irrespective of variety. ii) Application of gypsum fertilizer, and mulching increasedyield of sunflower significantly (47 to 56%). iii) Application of gypsum fertilizer and mulching increased yield of maize significantly (nearly 50%). iv) Furrow transplanting andgypsum fertilizer increased grain yield of boro rice by 36-44% depending on varieties. v) Sesame was damaged due to heavy shower at seedling stage	Selection of appropriate variety and improved agronomic management practices like mulching, gypsum fertilizer application, rice transplanting methods etc. would increase crop productivity in the salinity and drought affected area of Noakhali district

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication			
Information development			
Other publications, if any **MS Thesis**		1. Enhancing the crop productivity through adoption of climate smart technologies in the salinity area of Bangladesh 2. Improving yield of transplant *aman* rice in the salinity affected area of Noakhali district through gypsum application 3. Yield of *boro* rice as influenced by method of transplanting and gypsum fertilizer application in the salinity affected area of Noakhali district 4. Effect of mulching and gypsum fertilizer application on the yield of maize in salinity affected area of Noakhali district 5. Effect of mulching and gypsum fertilizer application on the yield of sunflower in salinity affected area of Noakhali district	Proceedings of Annual Workshop on BAU Research Progress (2017-18)* Department of Agronomy, Bangladesh Agricultural University, Mymensingh

***The presentation made in the workshop has been awarded as the BEST Presentation.**

F. Technology/Knowledge generation/Policy Support (as applied):

i. **Generation of technology (Commodity & Non-commodity)**

Selection of appropriate crop species/ varieties along with improved agronomic management practices like gypsum fertilizer application in T. aman rice, gypsum fertilizer application and mulching in maize and sunflower; and furrow transplanting of *boro* rice appeared as promising technology for improved crop production in the salinity and drought affected coastal area of Noakhali district.

ii. **Generation of new knowledge that help in developing more technology in future**

Gypsum fertilizer application can substantially reduce the level of salinity in soil and thus increase crop production.
Mulching minimizes the level of salinity on the surface soil and thus increase crop yield.
Furrow transplanting in *boro* rice accumulates most of the salt on the ridge and less salt within the furrow, which ultimately favors the yield of *boro* rice grown in the furrows.

iii. **Technology transferred that help increased agricultural productivity and farmers' income**

The technology of increasing yield of a number of crops viz. T. aman rice, Boro rice, Maize and Sunflower has been developed through the project. The technology can now be taken into consideration to transfer in the farmers' field by the concerned authority such as Department of Agricultural Extension.

iv. **Policy Support**

The technology generated by the research project can be incorporated into the policy for increasing crop productivity in the salinity and drought affected coastal area of the country.

G. Information regarding Desk and Field Monitoring

i) **Desk Monitoring[description & output of consultation meeting, monitoring workshops/seminars etc.):**

Desk monitoring was done by BARC Team and the report was satisfactory.

ii) **Field Monitoring (time& No. of visit, Team visit and output):**
Frequent field monitoring was done by the Research Team during the experiments in the field. The activities of the project were monitored by BARC Team at BAU Campus. No field monitoring in Noakhali area was done by BARC.

I. Lesson Learned/Challenges (if any)

i) The research areas were heavily showered during end of April to beginning of May 2018. As a result, the experiment with sesame was not successful.

J. Challenges (if any): Did not have any challenge.

Signature of the Principal Investigator
Date ………………………….
Seal

Counter signature of the Head of the organization/authorized representative
Date …………………………..
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