

Competitive Research Grant (CRG)

Sub-Project Completion Report

on

Increasing Productivity of Cropping System in Some Coastal Areas of Bangladesh

Project Duration

May 2017 to September 2018

Department of Agronomy
Patuakhali Science and Technology University



Submitted to
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Acronyms

BARC-Bangladesh Agricultural Research Council
BARI- Bangladesh Agricultural Research Institute
BCR-Benefit Cost Ratio
BRRI- Bangladesh Rice Research Institute
DAE-Department of Agricultural Extension
DAS-Days After Sowing
DAT-Days After Transplanting
dSm⁻¹– Desisimens per meter
et al. – And others
etc. –Etcetera
FAO-Food and Agriculture Organization of the United Nations
Fig. – Figure
HYV- High Yielding Varieties
Kg – Kilogram
LSD – Least Significant Difference
m² – Meter squares
NS – Non-Significant
REY-Rice Equivalent Yield
t ha⁻¹ – Ton per hectare
T. Aman –Transplanted Aman
T.Aus-Transplanted Aus
TVC-Total Variable Cost
UNDP-United Nations Development Program
Viz. – Namely
AEZ-Agro Ecological Zone

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Executive Summary

Salinity and late drainage are two major constraints for crop production in the coastal belt of Bangladesh. The productivity and economic performances of five cropping patterns under different tillage methods/mulching conditions were evaluated in farmers' fields (medium high land) of Dumki (non-saline) and Kalapara (saline) upazilas of Patuakhali district. The objective was to study the agro-economic performance of the new cropping systems in saline and non-saline tidal ecosystems. The designed cropping patterns were Fallow-T. Aman rice-Mungbean (for non-saline)/Fallow (for saline) (Farmers' practice), T. Aus rice-T. Aman rice-Cowpea (for non-saline)/Soybean (for saline), T. Aus rice-T. Aman rice-Mungbean, T. Aus rice-T. Aman rice-Maize, T. Aus rice-T. Aman rice-Sunflower. T. Aus rice (Var. BRRI dhan55), T. Aman rice (Var. Moulata and BRRI dhan77 in non-saline and Swarnamushuri in saline ecosystem) and *Rabi* crops were raised during *kharif I* 2017, *Kharif II* 2017 and *Rabi* season 2017-18, respectively in both sites. Tillage treatments (strip tillage and conventional tillage) and mulching treatments (mulching and no mulching) were imposed on the selected *Rabi* crops viz. mungbean, cowpea/soybean, maize and sunflower to observe their effects. Farmers were directly involved in conducting the trials. The major activities were selection of project location and farmers, baseline survey, training of farmers on production technology of *Aus* rice, *Aman* rice and *Rabi* crops, raising *Aus* and *Aman* rice and *Rabi* crops with tillage and mulching treatments. Among the tested cropping systems, T. Aus rice (Var. BRRI dhan55)-T. Aman rice (Var. BRRI dhan77)-Sunflower (Var. Pacific Hysun33) cropping pattern with strip tillage or mulching of sunflower was found most profitable with respect to gross margin, rice equivalent yield (REY) and benefit-cost ratio (BCR) for non-saline ecosystem. The REY of this cropping system was 21.08-21.35 t ha⁻¹ year⁻¹ with net return of Tk. 199950-229651 and BCR of 1.77-1.98 depending on tillage or mulching treatments imposed. T. Aus rice (BRRI dhan55)-T. Aman rice (BRRI dhan73)-Sunflower (Pacific Hysun33) cropping pattern with strip tillage or mulching of sunflower was found most profitable for saline ecosystem. The REY of this cropping system was 19.57-19.60 t ha⁻¹ year⁻¹ with net return of Tk. 181990-191835 and BCR of 1.74-1.82 depending on tillage or mulching treatments used. There is an ample scope of substantial improvement of the productivity of the farmers' practice with the cultivation of high yielding T. Aus rice, T. Aman rice and sunflower in medium high land either by strip tillage or mulching.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: Increasing Productivity of Cropping System in Some Coastal Areas of Bangladesh

2. Implementing organization: Department of Agronomy, Patuakhali Science and Technology University

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: **34,99,745.00**

4.2 Revised (if any): **34,99,745.00**

5. Duration of the sub-project: 8 May 2017 to 30 September 2018

5.1 Start date (based on LoA signed): 8 May 2017

5.2 End date: 30 September 2018

6. Justification of undertaking the sub-project:

The coastal area of Bangladesh has less cropping intensity due to dry season salinity of soil and water along with other severe constraints like tidal flood, late drainage, heavy clay basin, scarcity of quality irrigation water, late rainfall, low fertility status etc. Total saline area has increased to about 1.056 million hectares from 0.833 million hectares in about the last four decades (SRDI, 2010). The present land use in this areas consists mainly of growing one T. *Aman* rice (Traditional) and occasionally in some places *Rabi* crops like mungbean

(Var. BARI Mung-6), sunflower (Var. Pacific Hysun 33), grass pea (Var. Local), cowpea (Var. Local), sesame (Var. Local), groundnut (Var. Local) with poor management practices (Traditional tillage, no irrigation, no weeding, etc.). About 53% of arable land remains fallow in seven coastal districts during *Kharif-1* season and 34% in *Rabi* season (BARC, 2008).

There are different cropping patterns prevailing in the coastal districts. Some of them are: Fallow-Fallow-T. Aman rice, Fallow-T. Aman rice-Rabi crops, Fallow-T. Aus rice-T. Aman rice, Fallow-T. Aman rice-Boro rice. Inclusion of short duration and salt or flood tolerant HYV *Aus* and *Aman* rice, heat and or salt tolerant late *Rabi* crops may be an agronomic option towards increasing productivity and cropping intensity in coastal ecosystem.

The surface soils of most of the coastal areas dries out quickly in the dry season during land preparation due to heavy consistency of soil and causes germination failure of seeds in many cases. These necessitate minimum tillage and mulching. Strip tillage is a conservation option and involves tillage of a targeted area (not more than 30% of the soil surface), whilst leaving crop residues on the surface, retaining moisture, organic matter and vastly increasing worm activity and fertility. Therefore, this type of tillage may be a good technology for sustainable intensive farming in coastal Bangladesh.

7. Sub-project goal: The goal of the project is to ensure household and local food security through cropping system approach.

8. Sub-project objective (s):

- i. To develop sustainable production technology of selected *Rabi* crops for improved cropping system in saline and non-saline tidal ecosystem
- ii. To evaluate the agro-economic performance of the designed cropping systems in saline and non-saline tidal ecosystem.

9. Implementing location (s):

- i. Sreerampur, Dumkiupazilla (non-saline)
- ii. Tajepara, Kalaparaupazilla (saline)

10. Methodology in brief:

Experimental site

Two sites (non-saline and saline ecosystem) were selected on the basis of base line survey and in consultation with DAE personnels. The site of non-saline ecosystem was at Sreerampur village situated in the central side of Dumkiupazila of Patuakhali district. The experimental field was located at 22° 27′/37.85" N latitude and 90° 23′/06.80" E longitude at an altitude of 03 meters above the sea level. The site of saline ecosystem was at Tajepara village, 4 kilometers east from Kuakataseabeach of Kalaparaupazilla. The experimental field was located at 21°49′/41.05" N latitude and 90° 12′/ 31.14" E longitude at an altitude of 1.5 meters above the sea level. The experimental sites were the representatives of non-saline and saline ecosystem of coastal area. The experimental area belongs to the non-calcareous soil under Agro-ecological Zone of the Ganges Tidal Floodplain (AEZ-13). The region covers several river borne sediments of silt (UNDP and FAO, 1988).

Soil

The soil of the experimental land belongs to the Barisal series of non-calcareous clay soil but they become more silty in the east and usually have a buried peat layer in the west under the Ganges Tidal Floodplain (AEZ-13). The experimental field was medium high land with poor drained condition. Initial soil was collected from each farmer's field of each location and their physical and chemical properties were analyzed following the standard procedure. The physical and chemical properties of experimental soils are presented in Table 1 and Table 2, respectively.

Table 1. Textural class of experimental soil

Location	Sand	Silt	Clay	Texture
Dumki	21.03	60.00	18.97	Silt loam
Kalapara	35.20	32.50	32.30	Clay loam

Table 2. Average concentration of N, P, K, Na and S in initial soil sample of Dumki and Kalapara sites, May 2017

Soil	Salinity	p ^H	OM	Total	Olsen	Ava. K	Ava. Na	Ava. S	Ava.	Ava.
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	level (dSm ⁻¹)		(%)	N (%)	P (ppm)	(me/100g)	(me/100g)	(ppm)	Zn (ppm)	B (ppm)
Dumki	1.32	5.55	1.42	0.11	6.35	0.12	0.02	15.58	0.47	0.25
Kalapara	6.25	4.81	1.92	0.13	5.25	0.14	0.09	11.46	0.48	0.22

Climate and weather

The experimental area was located under the sub-tropical climate which is specialized by moderately high temperature and heavy rainfall during the *Kharif* season (April-September) and low rainfall with moderately low temperature during *Rabi* season (October to March). The monthly total precipitation, average maximum and minimum temperature and humidity during the study period have been presented in Appendix 1 and 2.

Experimental treatment, design and layout

In Dumkiupazila (non-saline ecosystem), Fallow-T. Aman rice-Mungbean and T. Aus rice -T. Amanrice-Fallow are the major cropping patterns. Fallow-T. Aman rice-Grasspea/Cowpea/Groundnut/Sweet potato/Chilli/Sunflower/Sesame are followed in some areas. Grasspea is cultivated as a relay crop with T. Aman rice. BRR1 dhan48 and BRR1 dhan55 are grown in Aus season. Lalmota, Sadamota, Motamota and Moulata are the main varieties cultivated as T. Aman rice. In saline system of Kalaparaupazila, Fallow-T. Aman rice-Fallow is the major cropping pattern. Fallow-T. Aman rice-Water melon/Cowpea/ Groundnut/Chilli are the minor cropping patterns. Cowpea is relayed with T. Aman rice in some areas. Swarnamushuri is widely cultivated in this area during *Aman* season.

The following experiments were conducted in farmers' field (medium high land) of Dumki and Kalaparaupazila, Patuakhalibased on the existing cropping patterns during May 2017 to May 2018.

Experiment 1. Evaluation of cropping pattern potential under different tillage practices of Rabi crops

Treatment

A. Tillage method for *Rabi* crops: 2 (strip tillage and conventional tillage)

B. Cropping pattern: 5

Fallow-T. Aman rice-Mungbean(for non-saline)/ Fallow (for saline) (Farmers' practice)
Aus rice-T. Aman rice -Cowpea(for non-saline)/Soybean (for saline) (proposed)
Aus rice-T. Aman rice-Mungbean(proposed)
Aus rice-T. Aman rice-Maize(proposed)
Aus rice-T.Aman rice-Sunflower(proposed)

Experimental design: Split-plot (Tillage method in the main plot and cropping pattern in the sub-plot).

Experiment 2. Evaluation of cropping pattern potential under mulching practices in

Rabi crops

Treatment

A. Mulching for *Rabi* crops: 2 (mulching and no mulching)

B. Cropping pattern: 5 (as in expt. 1)

Experimental design: Split-plot (Mulching in the main plot and cropping pattern in the sub-plot).

Thus a total of 10 cropping systems combinations were compared in both experiments of non-saline ecosystem. Since land remained fallow in the *Rabi* season in the farmers' pattern in saline ecosystem, there was no tillage or mulching treatments imposed. Thus a total of 9 cropping systems combinations including the farmers' one were compared in saline ecosystem.

Three farmers having medium high land were selected for conducting each experiment in Dumki upazila and four farmers having same type of land for each experiment for Kalapara upazila of Patuakhali district. Farmers were selected on the basis of base line survey and in consultation with DAE personnel, BARI and BRRI scientists. Each farmer was treated as one replication. The unit plot of each experiment was of same size. The unit plot size of tillage experiment was 12-x2.5m and that of mulching experiment was 5-x2.5m. Each farmer was trained for conducting the experiments. Sub-plot to sub-plot distance was 0.50 m for both experiment. The main plot to main plot distance of tillage experiment was wide enough (2.0 m) to enable turning of power tiller while it was 1.0m for mulching experiment.

Selection of variety

The varieties selected are presented in Table 3 with their short description.

Table 3. Varietal description of different Rabi crops used in the experiments

Location	Kharif 1 season	Varietal description	Kharif II season	Varietal description	Rabi season	Varietal description
Dumki	BRRIdhan55	HYV, short duration and salt tolerant, released by BRRIdhan55	BRRIdhan77 (For IP)	HYV, long duration and tidal flood resistant, released by BRRIdhan77	BARI Mung-6 (For IP)	Photo insensitive, Yellow mosaic virus resistant, Pod matures at nearly same stage
			Moulata (For FP)	Popular local cultivar, tall and long duration	Cowpea (Patuakhali local) (For IP)	Popular tall cultivar
					Hybrid maize-DON 111 (For IP)	Hybrid variety large cob
					Hybrid Sunflower-Pacific Hysun33 (For IP)	Medium tall and good germination
Kalapara	BRRIdhan55	Short duration and salt tolerant	BRRIdhan73 (For IP)	HYV, short duration and salt tolerant	BARI Mung-6 (For IP)	Photo insensitive, Yellow mosaic virus resistant, Pod matures at same stage
			Swarnamushuri (For FP)	Popular traditional dwarf cultivar, dark green leaf and medium duration, introduced from India by the farmers themselves	BARI Soybean-6 (For IP)	Tolerant to yellow mosaic virus
					HYbrid maize-DON 111 (For IP)	Hybrid variety, large cob
					Hybrid Sunflower-Pacific Hysun33 (For IP)	Medium tall and good germination

FP= Farmers' pattern, IP= Improved pattern

Crop establishment and management

Implementation of this study involved active participation by farmers who applied routine management under the facilitation of the researcher.

T. Aus rice

Aus rice was raised during *Kharif 1* season 2017 in both sites. BRRRI dhan55 was used in all options. Puddling was done using irrigation water by power tiller with 3 passes. Transplanting dates were same in both sites. Fertilizers were applied on soil test basis with high yield goal as per Fertilizer Recommendation Guide (BARC, 2012). In saline ecosystem, the crop was fertilized with 66-20-30-8-1 kg N, P, K, S and Zn per ha, respectively. All of P, K, S and Zn were applied as basal during final land preparation through TSP, Mop, Gypsum and $ZnSO_4$, respectively. N was applied through urea super granule (USG) at 7-10 days of transplanting at 7-10 cm soil depth at the centre of every 4 hills. Two weedings were required in saline ecosystem but one weeding was needed in non-saline ecosystem due to presence of very few weeds caused by high depth of water in early stage of crop. Agrifuran @ 10 kg ha^{-1} was applied at 20 days after transplanting to control stem borer. All other cultural practices were followed as per BRRRI (2017). During the growing period of Aus rice in saline ecosystem, salinity level was low, ranging from 1.80 to 2.75 dSm^{-1} . Agronomic practices followed in T. Aus rice in non-saline ecosystem are shown in Table 4.

T. Aman rice

T. Aman rice was grown in *Kharif II* season 2017 in both sites. The most popular variety traditional Moulata was selected for Dumki upazilla based on survey of the experimental site and BRRRI dhan77, a recently released long duration tidal flood resistant Aman rice variety was used for growing in this season. A salinity tolerant variety BRRRI dhan73 was selected along with conventional variety Swarnamushuri for Kalapara upazila. Puddling was done with power tiller with 3 passes. The varieties were transplanted in separate plots in each site. Transplanting dates were same in both sites. Fertilizers were applied on soil test basis with high yield goal for each crop as per Fertilizer Recommendation Guide (BARC, 2012). In saline ecosystem, the crop was fertilized with 77-15-44-11-1 kg N, P, K, S and Zn per ha, respectively. The source and method of fertilizer application were same as the Aus rice. All

other cultural practices were followed as per BRR (2017). Farmers in coastal region used pyrazosulfuron-ethyl, a new pre-emergence herbicide to control weed in T. Aman rice. Therefore, no manual weeding was required to control weeds in Swarnamushuri. The same insecticide as used in T. Aus was applied at 30 days after transplanting for controlling stem borer in all varieties except Moulata in both site. The traditional variety Moulata is stem borer resistant and hence did not require any insecticide. The crop was harvested at maturity on different dates depending on varieties starting from November to December. During the growing period of Aman rice, salinity level was also low, ranging from 1.85 to 2.28 dSm⁻¹. Cultural operations done in T. Aman rice of non-saline ecosystem are presented in Table 4.

15-20 cm anchored residue was retained for strip tillage treatment in Rabi crops.

Rabi crops

After final harvest of T. Aman rice, tillage and mulching treatments were imposed at joe condition in both sites. Agronomic practices followed in tillage and mulching experiments are more or less same in both sites. Therefore, agronomic practices followed in only one experiment (Tillage experiment) in one site (Dumki) are shown in Table 4. The exceptions are presented here along with description of some important operations. Strip tillage was done with a power tiller in a single operation. In case of conventional method, tillage operation was accomplished by a power tiller with 3 passes ploughing for line sowing and 2 passes for broadcasting (farmers' practice). Seeds of all Rabi crops were sown on 20-21 January 2018 in Dumki upazila and on 27-28 January 2018 in Kalapara upazila. Seeds were sown manually in furrow made by a tine in line sowing method. Depth of sowing was around 4 to 5 cm for all crops.

Table 4. Agronomic practices followed in different cropping patterns under strip and conventional tillage methods at Dumki, Patuakhali

Items	C ₁ =Fallow/T.Aus C ₂ =T.Aman C ₃ =Rabi crop	FP	IP ₁	IP ₂	IP ₃	IP ₄
Variety	C ₁	Fallow	BRR dhan55	BRR dhan55	BRR dhan55	BRR dhan55
	C ₂	Moulata	BRR dhan77	BRR dhan77	BRR dhan77	BRR dhan77
	C ₃	BARI Mung-6	Cowpea Local	BARI Mung-6	DON 111	Pacific Hysun33

Items	C ₁ =Fallow/T.Aus C ₂ =T.Aman C ₃ =Rabi crop	FP	IP ₁	IP ₂	IP ₃	IP ₄
Land preparation with power tiller	C ₁	-	3 full	3 full	3 full	3 full
	C ₂	3 full	3 full	3 full	3 full	3 full
	C ₃ (Strip tillage)	Strip	Strip	Strip	Strip	Strip
	C ₃ (Conventional tillage)	2 full	2 full	2 full	2 full	2 full
Sowing / Transplanting date	C ₁	-	May 26-27/17	May 26-27/17	May 26-27/17	May 26-27/17
	C ₂	August 21-22/17	August 21-22/17	August 21-22/17	August 21-22/17	August 21-22/17
	C ₃	20-21 January/18	20-21 January/18	20-21 January/18	20-21 January/18	20-21 January/18
Seed rate (kg/ha)	C ₁	-	30	30	30	30
	C ₂	50	35	35	35	35
	C ₃	30	50	45	30	10
Planting method	C ₁	-	Line transplanting	Line transplanting	Line transplanting	Line transplanting
	C ₂	Uneven transplanting	Line transplanting	Line transplanting	Line transplanting	Line transplanting
	C ₃	Broadcasting	Line sowing	Line sowing	Line sowing	Line sowing
Spacing (cm)	C ₁	-	20×20	20×20	20×20	20×20
	C ₂	30×30	20×20	20×20	20×20	20×20
	C ₃	Broadcasting	30×15	30×10	60×25	60×25
Seedling age (Days)	C ₁	-	25	25	25	25
	C ₂	45	35	35	35	35
	C ₃	-	-	-	-	-
Seedling no. hill ⁻¹	C ₁	-	2-3	2-3	2-3	2-3
	C ₂	12-15	3-4	3-4	3-4	3-4
	C ₃	-	-	-	-	-
Fertilizer (N-P-K-S-Zn-B)	C ₁	-	71-15-38-7-1-0	71-15-38-7-1-0	71-15-38-7-1-0	71-15-38-7-1-0
	C ₂	30-0-0-0-0-0	84-15-50-9-1	84-15-50-9-1	84-15-50-9-1	84-15-50-9-1

Items	C ₁ =Fallow/T.Aus C ₂ =T.Aman C ₃ =Rabi crop	FP	IP ₁	IP ₂	IP ₃	IP ₄
	C ₃	NO	14-15-15-6-0-0	18-27-29-14-2-1	237-74-98-39-4-1	124-32-60-16-2-1
Weed control(DA T/DAS)	C ₁	-	1 (20) weeding	1 (20) weeding	1 (20) weeding	1 (20) weeding
	C ₂	No	1 (20) weeding	1 (20) weeding	1 (20) weeding	1 (20) weeding
	C ₃ (Strip tillage)	No	Chemical + 1 (25) weeding	Chemical + 1 (25) weeding	Chemical + 2 (25,50) weeding	Chemical + 2 (25, 50) weeding
	C ₃ (Conventional tillage)	No	1 (25) weeding	1 (25) weeding	1 (25) weeding	1 (25) weeding
Irrigation no.(DAS)	C ₁	-	No	No	No	No
	C ₂	No	No	No	No	No
	C ₃	No	1 (25)	1(25)	3(25,50,70)	2(25,50)
Pest Control	C ₁	-	Chemical	Chemical	Chemical	Chemical
	C ₂	No	Chemical	Chemical	Chemical	Chemical
	C ₃	No	Chemical	Chemical	Chemical	Chemical
Date of maturity	C ₁	-	August 9-11/17	August 9-11/17	August 9-11/17	August 9-11/17
	C ₂	December 7-9/17	December 9-11/17	December 9-11/17	December 9-11/17	December 9-11/17
	C ₃ (Strip tillage)	April 11-13/18	April 24-26/18	April 11-13/18	May 9-11/18	April 27-29/18
	C ₃ (Conventional tillage)	April 8-10/18	April 22-24/18	April 8-10/18	May 5-7/18	April 24-26/18

FP=Farmers' pattern, IP₁=Improved pattern 1,IP₂=Improved pattern 2,IP₃=Improved pattern 3,IP₄=Improved pattern 4

Farmers of the experimental area generally use low seed rate of mungbean, about 30-35 kg ha⁻¹ in broadcasting method, therefore 30 kg ha⁻¹ of seed was used to maintain similarity with the farmer's practice. In mulching experiment, straw mulch was applied @ about 5 t ha⁻¹ in between two rows immediately after sowing.

Crops were germinated using residual soil moisture in strip tillage and conventional tillage treatments. Fertilizers were calculated on the basis of soil test with high yield goal for each *Rabi* crop sown in both sites as per Fertilizer Recommendation Guide (BARC, 2012). The amount of fertilizers applied in different *Rabi* crops in saline ecosystem were:N-P-K-S-Zn-B=15-27-26-16-2-1 kg ha⁻¹for mungbean, N-P-K-S-Zn-B=21-30-44-14-2-1kg ha⁻¹ for soybean,N-P-K-S-Zn-B=218-75-88-47-4-1kg ha⁻¹ for maize and N-P-K-S-Zn-B=110-32-44-19-2-

1 kg ha⁻¹ for sunflower and. The whole amount of all fertilizers was broadcast basally during final land preparation in all pulse crops with conventional tillage and line sowing (3 passes). In case of strip tillage for pulse crops, whole amount of all fertilizers were broadcast throughout the field before tillage operation. In case of strip tillage for maize and sunflower required amount of basal urea, TSP, Mop, zinc sulphate, gypsum and boric acid were broadcast throughout the field before tillage operation. In all cases, seeds were sown manually. Top dressing of urea fertilizer for maize and sunflower was done at 25 and 50 DAS and mixed thoroughly with the soil. No fertilizers, irrigation and weeding were done in case of broadcast sowing with conventional tillage (2 passes). Same kind of fertilizers were applied on the basis of soil test in case of mulching experiment in both sites. Earthing up was done at 50 DAS in maize and sunflower. Since farmers in coastal region use low seed rate and do not commonly use fertilizer and any weed control method this was the control treatment representing the farmers' practice.

In the experimental site of non-saline ecosystem, one manual weeding was done in all pulse crops with conventional tillage and line sowing treatments while 2 weedings were required in maize and sunflower with the same treatment. In saline ecosystem, one weeding was required in conventional tillage and line sowing treatments for all crops due to less prevalence of weed population. In strip tillage treatment, non-selective herbicide glyphosate (Round up) was applied @ 5L ha⁻¹ one week before sowing of seeds to avoid soil disturbance and moisture loss after sowing in both sites. Further one weeding was needed at 25 DAS as some weeds were emerged. However, no weeding was required for mulching treatment in both sites. All other cultural practices were followed as per BARI (2000). Harvesting of all crops was done at maturity by the farmers in presence of the researcher.

All *Rabi* crops except soybean were infested by pests in both sites. Voliam flexi @ 250ml ha⁻¹ was sprayed to control thrips (a major pest of mungbean in coastal area) during flower initiation stage of mungbean and cowpea and Carbendazim @ 500g ha⁻¹ to control powdery mildew during pod formation stage in mungbean. Carbendazim (500g ha⁻¹) was also sprayed to control stem rot of sunflower before flower initiation. Reliance @ 4 L ha⁻¹ was sprayed to control stem borer of maize before tasseling stage.

Data collection and evaluation

The following data were recorded

i. Soil moisture: Soil moisture was determined using a digital soil moisture meter (Model: PMS-714) in the experimental fields of *Rabi* crops at 15 day interval during the experimental period. Readings were taken on three spots in each plot at 10 cm depth.

ii. Soil salinity: Soil salinity was measured in the experimental fields of *Rabi* crops at 15 day interval during the experimental period. Soil samples were taken from each plot at 15 cm depth. The soil salinity of experimental plots were determined electrometrically (soil water ratio was 1:5) by a conductivity meter (WTW LF 521; Germany) as described by Petersen(2002). 100 grams of air-dried soil was taken in a 1000 ml glass bottle and 500 mL of distilled water was added to it. The bottle was closed with screw cap and shaken in a shaker for 15 minutes. Then the shaker was stopped and left it for one hour. The suspension was shaken for 5 minutes. The bottle was removed from the shaker and filtered on a dry Whatman No. 42 filter. Then the electrical conductivity was determined by an electrical conductivity meter (Calibrated with 0.01 N KCl solution). The results of EC were expressed in desisimens per meter (dSm^{-1}).

iii. Tidal water depth: Daily high and low tidal water depth was recorded in the experimental field of *Aus* and *Aman* rice in both sites. In *Aus* season, water depth in the crop field of non-saline ecosystem of Dumkiupazila ranged from 0 to 33cm and in saline ecosystem of Kalaparaupazila, it ranged from 0 to 38cm during the growing period. In *Aman* season, it ranged from 0 to 35cm in Dumkiupazila and from 0 to 25 cm in Kalaparaupazila during the period from August to October.

iv. Plant population: Plant population of *Rabi* crops was counted at harvest from central four rows of 1 meter length for line sowing methods and from 1×1m area for broadcast method of sowing.

v. Seed and straw yields: Grain and straw yields of rice were determined from a 10m^{-2} area in the center of each farmer's field. Two central rows of 10 m length each were harvested for measuring seed and stover yields of all *Rabi* crops in tillage experiment. Two central rows of 4 m length each were harvested for measuring the same in mulching experiment. Seed yield was adjusted at a moisture content of 15.5% for maize, 13% for sunflower and 12% for mungbean, cowpea and soybean and converted to ton per hectare. Straw/stover weight was recorded after sun drying for 2-3 days.

vi. Economic analysis: Economic analysis of each cropping system was calculated. Total variable cost of cultivation, gross return, net return and finally the benefit-cost ratio of each cropping system was calculated to evaluate the profitability of a cropping system. The amount of different inputs required per hectare was calculated and the cost of input for different options was estimated based on their local market price. The local price of paddy and *Rabi* crops was used for calculating return.

vii. Rice equivalent yield: The equivalent yield of *Rabi* crop was calculated into T. *Aus* and T. *Aman* rice equivalent yield (REY) based on the price of the products as follows.

REY (t ha⁻¹) of *Rabi* crop

$$= \frac{\text{Yield (t ha}^{-1}\text{) of } Rabi \text{ crop} \times \text{Price (Tk. t ha}^{-1}\text{) of } Rabi \text{ crop}}{\text{Price (Tk. t ha}^{-1}\text{) of rice}}$$

REY of the cropping pattern = Yield (t ha⁻¹) of rice (*Aus* + *Aman*) + REY (t ha⁻¹) of *Rabi* crop

Statistical analysis

The collected data were compiled and tabulated in proper form. Rice equivalent yield (REY) and BCR of the cropping system was subjected to statistical analysis. Data on seed yield, straw yield and days to maturity were not statistically analysed due to different crop species. Data on rice equivalent yield and benefit-cost ratio were statistically analyzed using the 'Analysis of variance' technique with the help of computer package MSTAT-C and difference among treatments means were adjudged with least significant difference (LSD) as outlined by Gomez and Gomez (1984).

11. Results and Discussion:

Yield performance of T. *Aus* and T. *Aman* rice

T. *Aus* rice

The data of *Aus* rice (Variety BRRI dhan55) is given Table 5. The average yield of *Aus* rice in Dumkiupazila was 3.77 t ha⁻¹ and that of Kalaparaupazila was 3.89 t ha⁻¹. The yield variation might be due to salt stress at earlier stage and climatic variation particularly the ambient temperature prevailed during reproductive stage.

T. Aman Rice

Different varieties were used in two ecosystems. The tidal submergence resistant variety BRR1 dhan77 used in non-saline tidal ecosystem gave average grain yield of 5.33 t ha⁻¹ while Moulata (traditional variety) grown in the same ecosystem produced 3.78 t ha⁻¹ grain yield. About 100% plants of Moulata were lodged at dough stage while BRR1 dhan77 being a tall variety did not lodge at all. However, the yield of BRR1 dhan77 was 41% higher than Moulata.

Table 5. Grain yield of T. Aus and T. Aman rice of experimental field

Location	T. Aus rice			T. Aman rice		
	Variety	Grain Yield (t ha ⁻¹)	Days to maturity	Variety	Grain Yield (t ha ⁻¹)	Days to maturity
Dumki	BRR1 dhan55	3.77	101	BRR1 dhan77	5.33	146
				Moulata	3.78	154
Kalapara	BRR1 dhan55	3.89	103	BRR1 dhan73	4.75	113
				Swarnamushuri	5.58	128

In saline ecosystem, the salt tolerant variety BRR1 dhan73 produced 4.75 t ha⁻¹ average grain yield which is satisfactory as described by BRR1 (2017) but this yield is much lower than the yield produced by BRR1 dhan77. The major cause of lower yield in BRR1 dhan73 might be due to shorter life span as compared to BRR1 dhan77 as shown in Table 5. However, the most popular conventional dwarf variety Swarnamushuri produced 5.58 t ha⁻¹ average grain yield which is 17.47% higher than BRR1 dhan73. Certainly, the yield of Swarnamushuri is very surprising and needs to be further investigated for final conclusion.

Days to maturity of T. Aus and T. Aman rice

T. Aus rice (BRR1 dhan55) required 101-103 days to attain at maturity (from sowing to harvesting) depending on the sites. The traditional variety Moulata in Dumki upazila had total life span of 154 days while it was 146 days for BRR1 dhan77. The conventional variety Swarnamushuri in Kalapara upazila took 128 days to attain at maturity while BRR1 dhan73 took 113 days (Table 5).

Soil Moisture

Soil moisture data at different days after sowing is shown in Fig.1, Fig. 2, Fig. 3 and Fig. 4. From Fig. 1 and Fig. 3 it is seen that strip tillage always maintained higher soil moisture after seeding under strip tillage method compared to conventional tillage in saline and non-saline ecosystem. The higher soil moisture content under strip tillage could be due to less soil disturbance, minimum expose to air and sun for evaporation and partially soil surface covered by rice crop residues than conventional tillage. Hossain *et al.* (2013) also observed that the higher soil moisture was maintained under strip tillage than full tillage treatments. The maximum soil moisture content at 0-10 cm soil depth was observed at sowing time under both strip tillage and conventional tillage technique in saline and non-saline ecosystem. Soil moisture gradually decreased from sowing time onwards with slight increase after irrigation at 50 DAS. In non-saline ecosystem, soil moisture ranged from 16.01 to 22.3% in strip tillage and from 12.28 to 22.3% in conventional tillage. In saline ecosystem, it was 17.8 to 21.89% in strip tillage and 15.4 to 21.89% in conventional tillage. Mulching also maintained higher soil moisture relative to nomulching treatment throughout the study period (Fig.2 and Fig.4). Soil moisture content declined onwards from sowing in both the treatments under saline and non-saline ecosystem. In non-saline ecosystem, soil moisture varied from 14.6 to 22.7% under mulching condition and from 12.07 to 22.7% under no mulching condition. In saline ecosystem, it was 14.68 to 22.1% under mulching condition and 12.34 to 22.1% under no mulching condition.

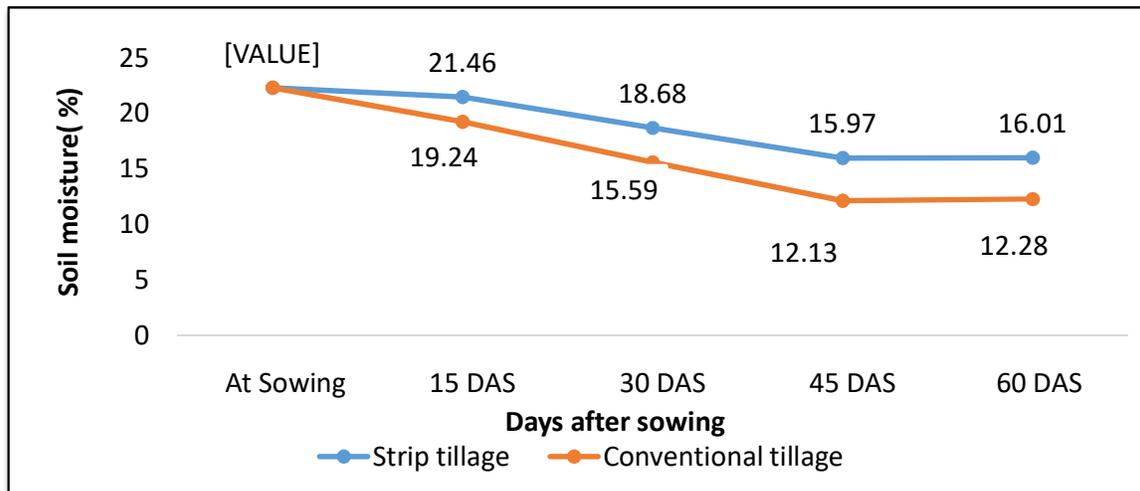


Fig.1. Soil moisture variation in Rabi crop field after seeding in non-saline ecosystem of Patuakhali district under strip tillage (ST) and conventional tillage (CT)

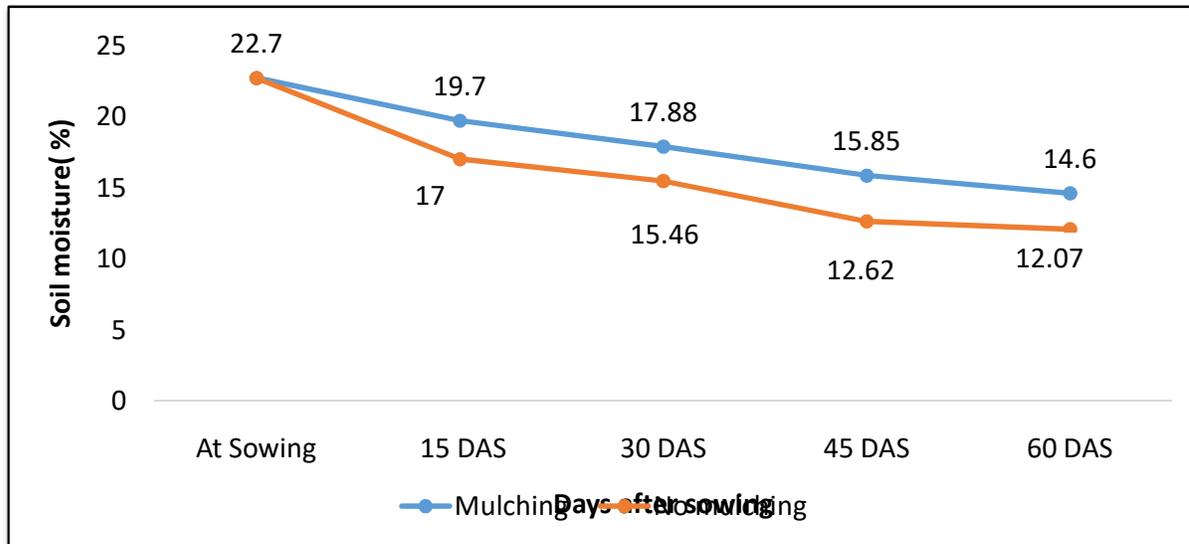


Fig.2. Soil moisture variation in Rabi crop field after seeding in non-saline ecosystem of Patuakhali district under mulching (M) and nomulching (NM) conditions

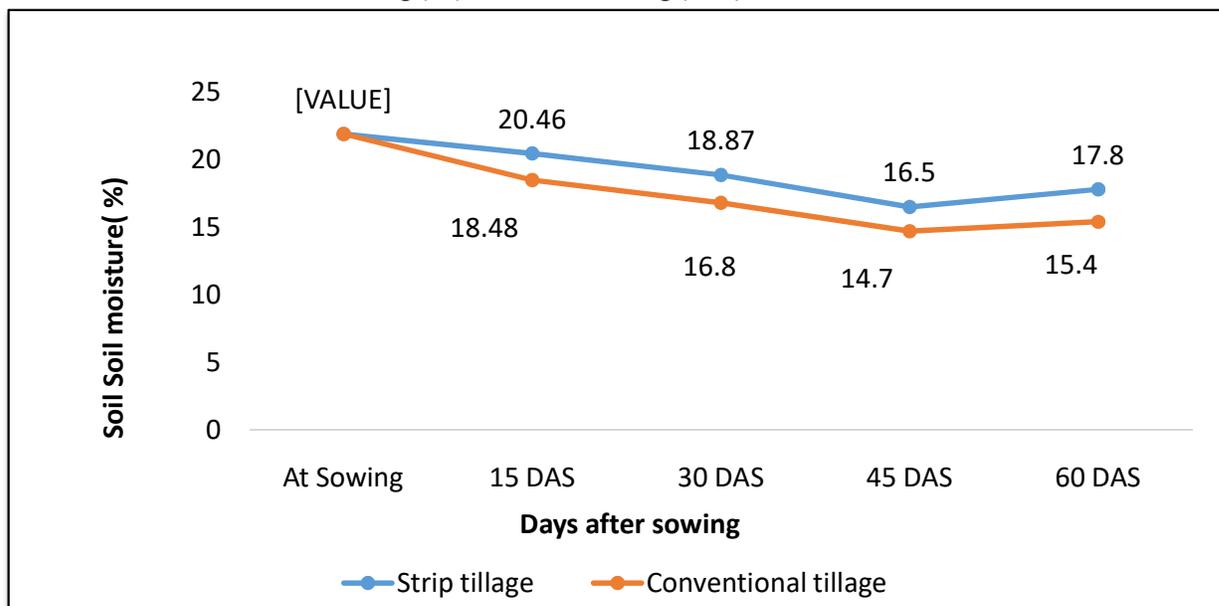


Fig.3. Soil moisture variation in Rabi crop field after seeding in saline ecosystem of Patuakhali district under strip tillage (ST) and conventional tillage (CT)

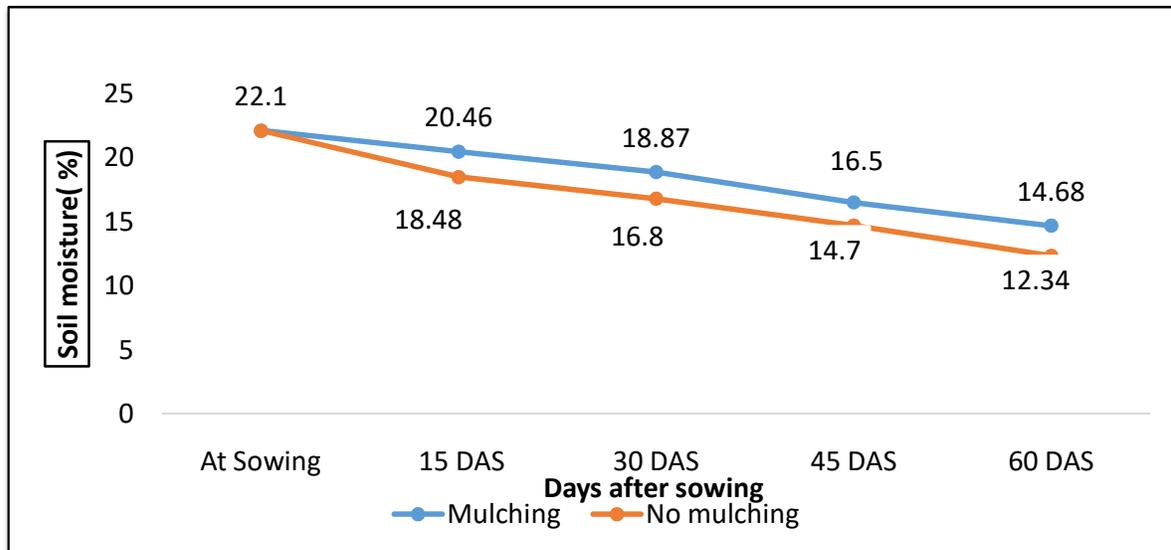


Fig.4. Soil moisture variation in Rabi crop field after seeding in saline ecosystem of Patuakhali district under mulching (M) and nomulching (NM) condition

Soil salinity

Soil salinity levels at different days after sowing is shown in Fig. 5 (Tillage experiment) and Fig. 6 (Mulching experiment). Soil salinity was higher in conventional tillage relative to strip tillage (Fig. 5). Likewise, no mulching treatment had higher soil salinity compared to nomulching treatment (Fig.6). This might be due to more evaporation loss of water in no mulching treatment resulting lower soil moisture content and higher soil salinity. Soil salinity gradually increased from sowing time onwards due to less soil moisture prevailed in the soil as shown in Fig.4. Soil salinity ranged from 1.48 dSm^{-1} at sowing time to 5.81 at 90 DAS under conventional tillage while corresponding value ranged from 1.48 to 5.16 dSm^{-1} under strip tillage (Fig.5). In mulching experiment, salinity value ranged from 1.60 at sowing time to 6.33 dSm^{-1} at 90 DAS under no mulching treatment while it ranged from 1.60 to 5.86 dSm^{-1} under mulching treatment.

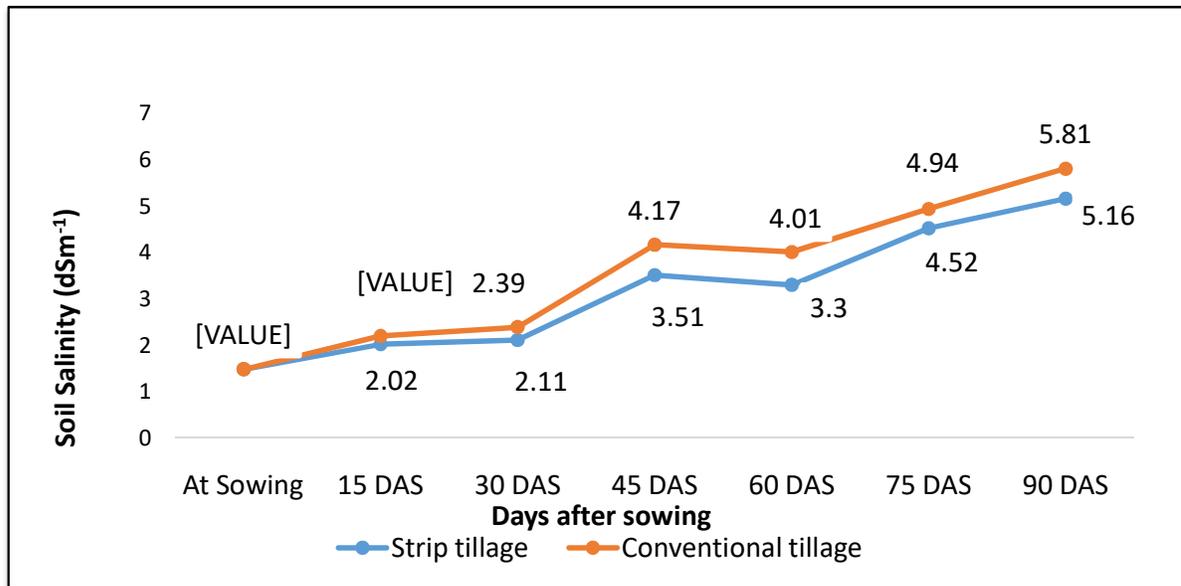


Fig.5. Soil salinity (dSm⁻¹) in Rabi crop field at different days (DAS) after sowing in saline ecosystem of Patuakhali district under strip tillage (ST) and conventional tillage (CT)

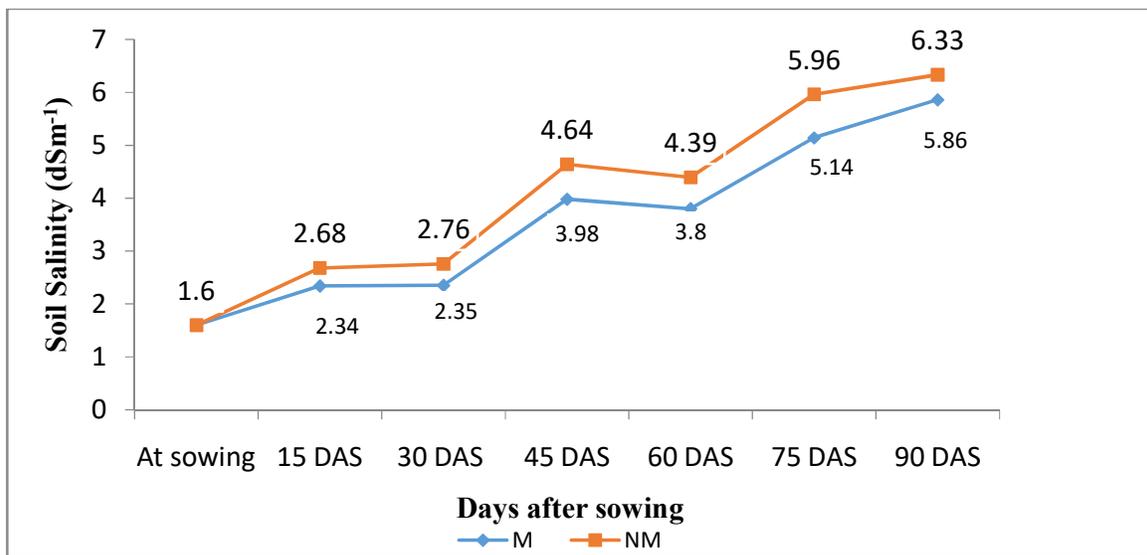


Fig.6. Soil salinity (dSm⁻¹) in Rabi crop field at different days after sowing (DAS) in saline ecosystem of Patuakhali district under mulching (M) and no mulching (NM) condition

Plant population

Plant population of mungbean, cowpea and soybean at harvest was higher in strip tillage technique as compared to conventional tillage in both experiments under saline and non-saline ecosystems due to favourable environment prevailed in the soil. Strip tillage ensured higher soil moisture and loose soil surrounding root zone enhancing better root

development. This might have caused less seedling mortality and higher plant population of these crops. Plant population m^{-2} of maize and sunflower was equal in both experiment at both sites (Fig. 7-10).

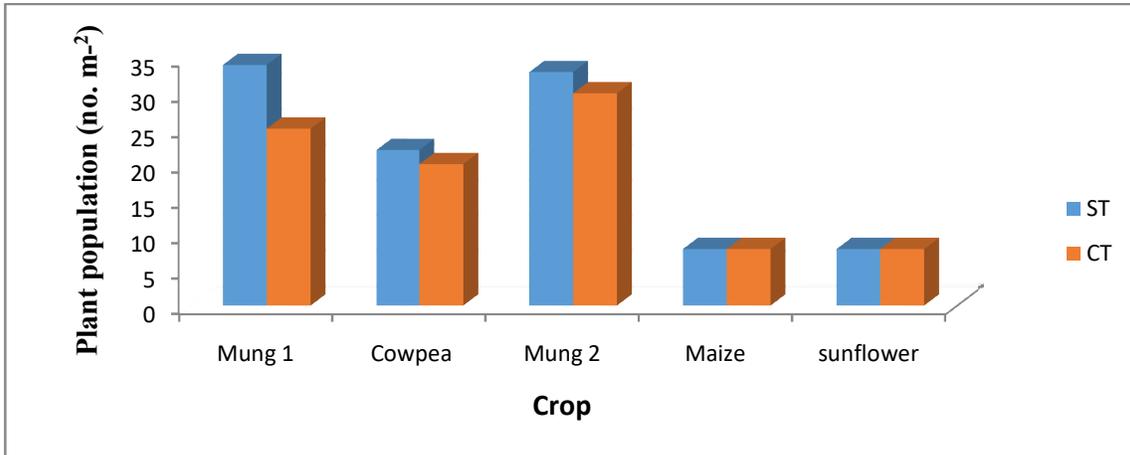


Fig.7. Plant population m^{-2} at harvest of different Rabi crops at harvest in non-saline ecosystem of Patuakhali district under strip tillage (ST) and conventional tillage (CT)

Mung1= Mungbean after Moulata rice cultivation

Mung 2= Mungbean after BRR1 dhan77cultivation

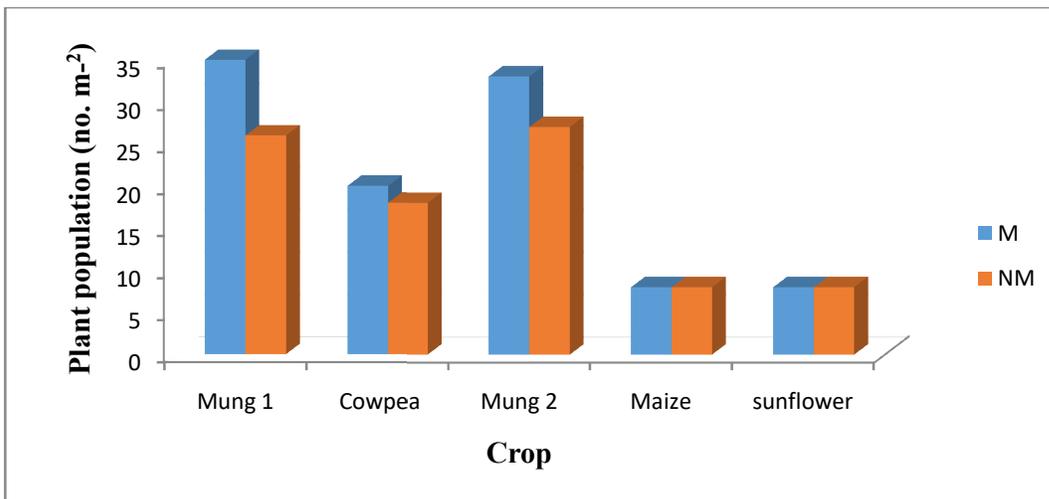


Fig.8. Plant population m^{-2} of different Rabi crops at harvest in non-saline ecosystem of Patuakhali district under mulching (M) and nomulching (NM) condition

Mung1= Mungbean after Moulata rice cultivation

Mung 2= Mungbean after BRR1 dhan77cultivation

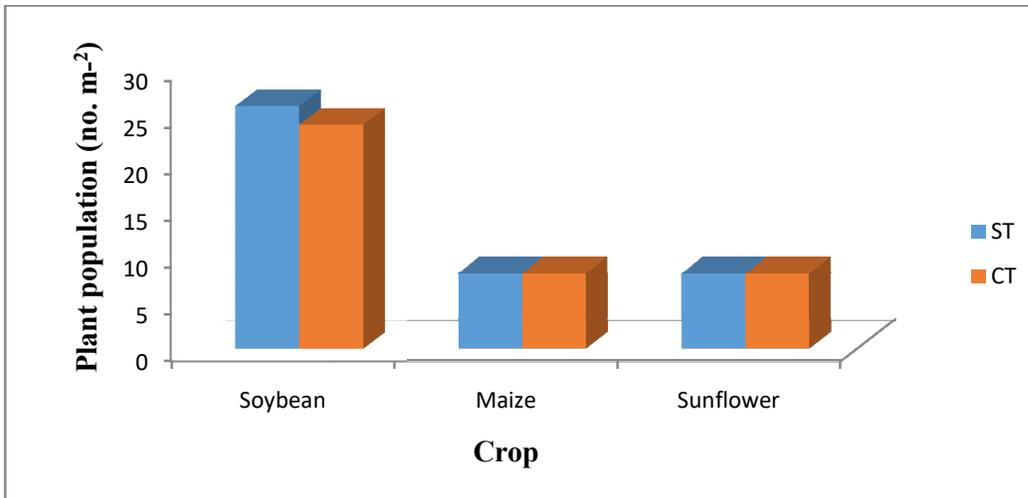


Fig.9. Plant population m⁻² of different Rabi crops at harvest in saline ecosystem of Patuakhali district under strip tillage (ST) and conventional tillage (CT)

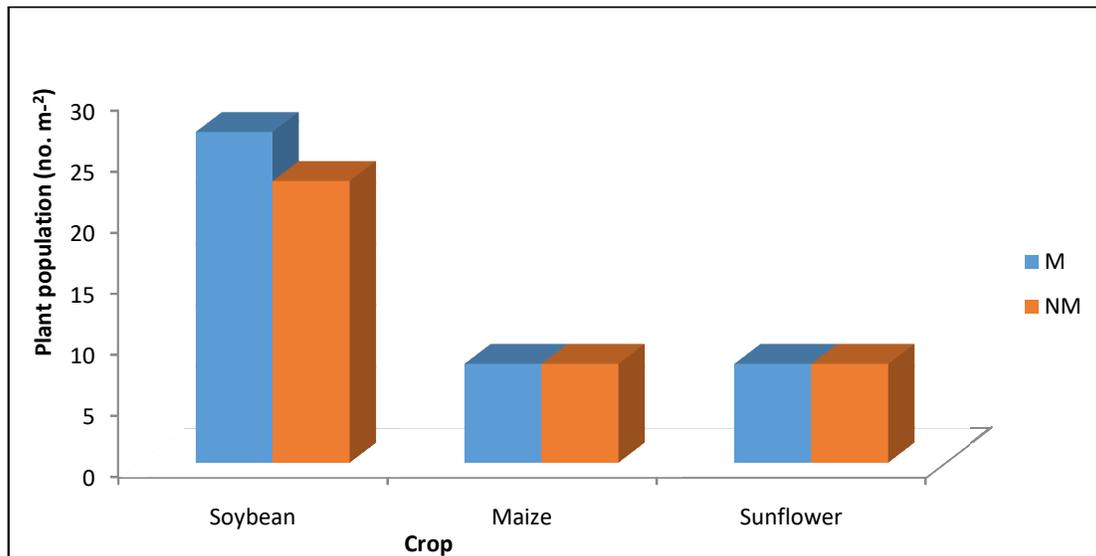


Fig.10. Plant population m⁻² of different Rabi crops at harvest in saline ecosystem of Patuakhali district under mulching (M) and nomulching (NM) condition

Yield performance of Rabi crops under different tillage methods

Yield performance of mungbean, cowpea, soybean, maize and sunflower grown after T.Aman rice harvest is presented in Table 6 and 7. A great variation was observed in seed yields of different Rabi crops under different tillage methods in both ecosystems. In general, higher crop yield was achieved under strip tillage than conventional tillage method.

In non-saline ecosystem, mungbean grown after Moulata with strip tillage and line sowing method produced higher seed yield (1.12 t ha^{-1}) compared to mungbean grown after Moulata with conventional tillage and broadcasting method (0.65 t ha^{-1}) (Table 6). Cowpea, maize and sunflower also gave higher yields (1.52 t ha^{-1} , 10.30 t ha^{-1} and 3.57 t ha^{-1} , respectively) in strip tillage than conventional tillage. The higher crop yields under strip tillage could be due to better crop establishment (Fig.7), uniform crop stand, higher soil moisture content (Fig.1) and better performance of yield components than conventional tillage. Treviniet *al.* (2013) reported that strip tillage is a conservation technique widespread overseas with recognized environmental and agronomical benefits. It offers improved soil organic matter, better root establishment and growth and better water holding capacity of soil. However, Fallow-T. Aman rice (Moulata)-Mungbean (BARI Mung-6) cropping pattern resulted in 72.30% higher mungbean yield in strip tillage than in conventional tillage with broadcast method of sowing. T. Aus rice (BRRRI dhan55) -T. Aman rice (BRRRI dhan77)-Mungbean (BARI Mung-6) cropping pattern resulted in 16.85% higher mungbean yield in strip tillage than in conventional tillage with line sowing method. T. Aus rice (BRRRI dhan55)-T. Aman rice (BRRRI dhan77)-Cowpea (Local) cropping pattern resulted in 24.59% higher cowpea yield in strip tillage than in conventional tillage with line sowing. Likewise, T. Aus rice (BRRRI dhan55)-T. Aman rice (BRRRI dhan77)-Maize (DON 111) cropping pattern gave 14.32% higher maize yield in strip tillage than in conventional tillage with line sowing method. T. Aus rice (BRRRI dhan55)-T. Aman rice (BRRRI dhan77)-Sunflower (Pacific Hysun 33) cropping pattern gave 17.05% higher sunflower yield in strip tillage than in conventional tillage with line sowing method. Straw yield also followed the similar trend as the grain yield.

In saline ecosystem, all the crops sown by both tillage methods germinated properly but after 45 DAS mungbean plants starts to die and completely died within 55 days of sowing due to increase in salt stress as shown in Fig. 5. Soybean was also affected severely by salt stress but the severity was less as compared to the mungbean plots. The seed yield of soybean was only 0.56 t ha^{-1} with strip tillage as against 0.47 t ha^{-1} with conventional tillage (Table 7). But the seed yields of maize and sunflower were satisfactory, 6.10 t ha^{-1} and 3.19 t ha^{-1} , respectively under strip tillage as against 5.42 t ha^{-1} and 2.89 t ha^{-1} , respectively under conventional tillage. Maas and Grattan (1999) reported that mungbean is sensitive to salt

stress, soybean and sunflower are moderately tolerant and maize is moderately sensitive. Though the soybean is moderately tolerant, it could not show good performance while sunflower falling under same rating group showed good performance. Similarly maize being the moderately sensitive also gave average performance. The other factors like soil temperature, soil moisture etc. might have interacted with salt stress and plant growth of sunflower resulting lower salinity effect on the yield. Baiet *al.* (2017) concluded that high soil temperature aggravates salt damage to drip-irrigated rice seedlings. Shoot and root Na⁺ concentrations, shoot and root Na⁺ uptake and the Na⁺ distribution ratio in shoots were all the greatest when moderate salt stress was combined with high temperature. Comparing with non-saline ecosystem, maize produced 40.78% less yield in saline ecosystem. On the other hand, sunflower gave only 10.64% less yield in saline ecosystem as compared to non-saline ecosystem. It is remarkable that the same variety of maize under saline ecosystem produced 2-3 cobs plant⁻¹ while it was 1 cob plant⁻¹ in non-saline ecosystem (Photograph 28 and 29). The cause is unknown and needs to be explored. However, Bothmungbean and soybean showed tip burning and necrosis of young leaves which are supposed to be salt-induced injury symptoms (Maas and Grattan (1999). Maize and sunflower did not exhibit any injury symptoms. T. Aus rice (BRRi dhan55)-T. Aman rice (BRRi dhan73)-Soybean (BARI Soybean-6) cropping pattern resulted in 19.15% higher soybean yield in strip tillage than in conventional tillage method. Likewise, T. Aus rice (BRRi dhan55)-T. Aman rice (BRRi dhan73)-Maize (DON 111) cropping pattern gave 12.55% higher maize yield in strip tillage than in conventional tillage method. T. Aus rice (BRRi dhan55)-T. Aman rice (BRRi dhan73)-Sunflower (Pacific Hysun 33) cropping pattern gave 10.38% higher sunflower yield in strip tillage than in conventional tillage method. Our results were consistent with the findings of Onyariet *al.* (2010) who observed that strip tillage was superior to conventional tillage in chickpea. Similar results were also reported by Gathalaet *al.* (2015) in maize and rice maize system.

Days to maturity of *Rabi* crops under different tillage methods

Variation of days to maturity of different *Rabi* crops due to tillage method was not wide in both ecosystems. In general, strip tillage required slightly higher number of days for maturity than conventional tillage. This might be due to higher soil moisture which inhibits the senescence of leaves of the plant. Vyn and Raimbault (1992) observed that plant growth with strip tillage tended to be delayed compared with mould board plow treatment.

Maize took the highest days to attain at maturity and mungbean took the lowest. In non-saline ecosystem, the life span of mungbean ranged from 87 to 90 days, cowpea ranged from 101 to 103 days, maize from 114 to 118 days and sunflower from 103 to 106 days depending on tillage methods (Table 6). In saline ecosystem, soybean took 103-106 days to attain at maturity depending on tillage methods. Maize and sunflower required 113-117 and 103-107 days, respectively for maturity (Table 7).

Table 6. Seed yield, stover yield and days to maturity of Rabi crops under strip and conventional tillage after T. Aman rice cultivation in non-saline ecosystem

Tillage method	Crop				
	Seed yield (t ha ⁻¹)				
	Mungbean*	Cowpea	Mungbean**	Maize	Sunflower
Strip tillage	1.12 (72.30%)	1.52 (24.59%)	1.04 (16.85%)	10.30 (14.32%)	3.57 (17.05%)
Conventional tillage	0.65	1.22	0.89	9.01	3.05
Stover yield (t ha ⁻¹)					
Strip tillage	1.48	2.51	1.25	10.50	6.21
Conventional tillage	0.67	2.31	1.16	9.65	5.42
Days to maturity					
Strip tillage	90	103	90	118	106
Conventional tillage	87	101	87	114	103

*= Mungbean cultivation following traditional T. Aman rice (Moulata)

**= Mungbean cultivation following HYV T. Aman rice (BRRI dhan77)

Figures in parentheses indicate percent increase over conventional tillage

Table 7. Seed yield, stover yield and days to maturity of Rabi crops under strip and conventional tillage after T. Aman rice cultivation in saline ecosystem

Tillage method	Crop		
	Seed yield (t ha ⁻¹)		
	Soybean	Maize	Sunflower
Strip tillage	0.56 (19.15%)	6.10 (12.55%)	3.19 (10.38%)
Conventional tillage	0.47	5.42	2.89
Stover yield (t ha ⁻¹)			
Strip tillage	1.30	6.57	3.68
Conventional tillage	1.20	5.95	3.07
Days to maturity			
Strip tillage	106	117	107
Conventional tillage	103	113	103

Figures in parentheses indicate percent increase over conventional tillage

Yield performance of *Rabi* crops under mulching and no mulching conditions

All the *Rabi* crops exhibited better performance with straw mulching relative to no mulching in non-saline ecosystem (Table 8). Mungbean grown after BRRi dhan77 with straw mulching and line sowing method produced higher seed yield (0.92 t ha^{-1}) compared to mungbean grown after BRRi dhan77 with no mulching and line sowing method (0.81 t ha^{-1}) in non-saline ecosystem. Cowpea produced 2.19 t ha^{-1} seed yield, maize produced 8.97 t ha^{-1} seed yield and sunflower produced 3.53 t ha^{-1} seed yield under mulching condition grown after BRRi dhan77 in line sowing method as against corresponding yields of 1.60, 8.11 and 2.97 t ha^{-1} under no mulching condition (Table 8). The higher crop yields under mulching condition might be due to better crop establishment (Fig. 8), higher soil moisture content (Fig. 2) and better growth performance than no mulching condition. However, Fallow-T. *Aman* rice (Moulata)–Mungbean (BARI Mung-6) cropping pattern (Farmers' practice) resulted in 8.93% higher mungbean yield with broadcasting method of sowing in mulching treatment than in no mulching treatment. T. Aus rice (BRRi dhan55)-T. *Aman* rice (BRRi dhan77)–Mungbean (BARI Mung-6) cropping pattern resulted in 13.58% higher mungbean yield with line sowing method of sowing in mulching treatment than in no mulching treatment. T. Aus rice (BRRi dhan55)-T. *Aman* rice (BRRi dhan77)–Cowpea (Local) cropping pattern resulted in 36.88% higher cowpea yield in mulching treatment than in no mulching treatment. Likewise, T. Aus rice (BRRi dhan55)-T. *Aman* rice (BRRi dhan77)-Maize (DON 111) cropping pattern gave 10.60% higher maize yield in mulching treatment than in no mulching treatment. T. Aus rice (BRRi dhan55)-T. *Aman* rice (BRRi dhan77)-Sunflower (Pacific Hysun 33) cropping pattern gave 18.86% higher sunflower yield in mulching treatment than in no mulching treatment (Table 8). It is noticeable here that sunflower was more responsive to mulch than maize.

The same phenomenon of mungbean and soybean plant death as observed in tillage experiment was observed in mulching experiment under both mulching and no mulching treatments in saline ecosystem. Seed yields of maize and sunflower were 6.96 t ha^{-1} and 3.22 t ha^{-1} , respectively under mulching condition as against 5.37 t ha^{-1} and 2.95 t ha^{-1} , respectively under no mulching condition (Table 9).

T. Aus rice (BRRi dhan55)-T. *Aman* rice (BRRi dhan73)–Soybean (BAR Soybean-6) cropping pattern resulted in 29.27% higher soybean yield in mulching treatment than in no mulching treatment under saline ecosystem. Likewise, T. Aus rice (BRRi dhan55)-T. *Aman* rice (BRRi

dhan73)-Maize (DON 111) cropping pattern gave 29.61% higher maize yield in mulching treatment than in no mulching treatment. T. Aus rice (BRRRI dhan55)-T. Aman rice (BRRRI dhan73)-Sunflower (Pacific Hysun 33) cropping pattern gave 9.15% higher sunflower yield in mulching treatment than in no mulching treatment (Table 9). Here, maize was more responsive to mulch than sunflower. Mupangwaet *al.* (2016) reported that mulching materials produced higher grain yield in maize.

Days to maturity of *Rabi* crops under mulching and no mulching conditions

There was little variation of days to maturity in different *Rabi* crops due to mulching in both ecosystems (Table 8 and 9). In general, mulching treatment required slightly more number of days for maturity than no mulching condition. Perhaps higher soil moisture inhibits the senescence of leaves of the plant as in the strip tillage. Like tillage experiment, maize took the highest days to attain at maturity and mungbean took the lowest. In non-saline ecosystem, the life span of mungbean ranged from 88 to 91 days, cowpea ranged from 101 to 104 days, maize from 114 to 119 days and sunflower from 102 to 105 days depending on mulching conditions (Table 8). In saline ecosystem, soybean took 104-108 days to attain at maturity depending on mulching condition. Maize and soybean required 114-118 and 104-108 days, respectively for maturity (Table 9).

Table 8. Seed yield, stover yield and days to maturity of *Rabi* crops under mulching and no mulching condition after T. Aman rice cultivation in non-saline ecosystem

Mulching condition	Crop				
	Seed yield (t ha ⁻¹)				
	Mungbean*	Cowpea	Mungbean**	Maize	Sunflower
Mulching	0.61 (8.93%)	2.19 (36.88%)	0.92 (13.58%)	8.97 (10.60%)	3.53 (18.86%)
No mulching	0.56	1.60	0.81	8.11	2.97
Stover yield (t ha ⁻¹)					
Mulching	0.83	3.08	1.08	9.50	5.80
No mulching	0.74	2.37	0.99	9.13	5.50
Days to maturity					
Mulching	91	104	90	119	105
No mulching	88	101	88	114	102

*= Mungbean cultivation following traditional T. Aman rice (Moulata)

**= Mungbean cultivation following HYV T. Aman rice (BRRRI dhan77)

Figures in parentheses indicate percent increase over no mulching

Table 9. Seed yield, stover yield and days to maturity of Rabi crops under mulching and no mulching condition after T. Aman rice cultivation in saline ecosystem

Tillage method	Crop		
	Seed yield (t ha ⁻¹)		
	Soybean	Maize	Sunflower
Mulching	0.53 (29.27%)	6.96 (29.61%)	3.22 (9.15%)
No mulching	0.41	5.37	2.95
Stover yield (t ha ⁻¹)			
Mulching	1.21	7.35	3.77
No mulching	1.13	5.56	3.23
Days to maturity			
Mulching	108	118	108
No mulching	104	114	104

Figures in parentheses indicate percent increase over no mulching

Economic performance of cropping system under different tillage methods of Rabi crops

The economics of the cropping systems clearly revealed that the improved cropping systems tested in the study appreciably enhanced the gross return and benefit-cost ratio over the farmers' cropping system in non-saline ecosystem (Table 10 and 11). The gross margin was increased by 92 to 901% in improved cropping systems compared to the existing cropping system. Analysis of cost and return revealed that the highest gross return (Tk. 464900 ha⁻¹), gross margin (Tk. 235249 ha⁻¹) and BCR (1.98) were obtained from the cropping system T. Aus rice (BRRI dhan55)-T. Aman rice (BRRI dhan77)-Sunflower (Pacific Hysun 33 sown with strip tillage). The higher gross margin and BCR was due to minimum energy expenditures for tillage, higher yield and price of output (seed) by sunflower with strip tillage method (Table 10 and 11). Hossain *et al.* (2016) obtained 231% higher gross margin in improved cropping pattern (Garlic-Maize-T. Aman rice) compared to farmers' pattern (Fallow-Boro rice-T. Aman rice). Hossain *et al.* (2013) reported that the strip tillage achieved higher grain yield (wheat 4.96 t ha⁻¹, lentil 1.40 t ha⁻¹, mungbean 1.50 t ha⁻¹) in all three crops with a net saving in cost of sowing 3050/- ha⁻¹ than conventional tillage. The farmers' practice Fallow-T. Aman rice

(Moulata)-Mungbean (BARI mung-6 with conventional tillage and broadcasting of seed) showed the lowest cost (Tk. 98128 ha⁻¹) but failed to show higher gross return (Tk. 121080 ha⁻¹), gross margin (Tk. 22952 ha⁻¹) and BCR (1.23). The lowest cost in farmers' practice was due to lower use of fertilizer, no weeding and insecticide use in traditional rice as well as no fertilizer use, no irrigation and weeding in mungbean.

In saline ecosystem, all the cropping systems did not perform well. Since total damage of mungbean occurred due to salt stress, a total of 9 cropping systems were obtained for comparison in non-saline ecosystem (Table 12). The alternative cropping systems except cropping system 2 and 3 gave 31 to 340% higher gross margin over the farmers' practice. However, the best results were obtained from the cropping system T. Aus rice (BRRI dhan55)-T. Aman rice (BRRI dhan73)-Sunflower (Pacific Hysun 33 sown with strip tillage (Table 12 and 13). The lowest gross margin (Tk. 31277) was obtained from the cropping system T. Aus rice (BRRI dhan55)-T. Aman rice (BRRI dhan73)-Soybean (BARI Soybean-6) sown with conventional tillage and line sowing) (cropping system 3). Cropping system 2 and 3 gave 1% higher and 28% lower net return, respectively than farmers' practice. The lowest gross margin was due to the lowest seed yield of soybean. Benefit-cost ratio was lowest in the cropping system 3 (1.17).

Table 10. Agro-economic performance of different cropping systems under different tillage methods of Rabi crops in non-saline ecosystem

Sl. No.	Cropping System	Seed yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	TVC (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)
1	Fallow	-	-	-	-	-
	T. Aman rice (Moulata)	3.75	6.12	87240	66903	20337
	Mungbean (BARI Mung-6) *	1.12	1.48	58960	35280	23680
	Total			146200	102183	44017
2	Fallow	-	-	-	-	-
	T. Aman rice (Moulata)	3.75	6.12	87240	66903	20337
	Mungbean (BARI Mung6) *** (Farmers' practice)	0.65	0.67	33840	31225	2615
	Total			121080	98128	22952
3	T. Aus rice (BRRI dhan55)	3.80	4.29	103580	74581	28999
	T. Aman rice (BRRI dhan77)	5.36	6.62	99000	67103	31897
	Cowpea (Local)*	1.52	2.51	58220	32650	25570
	Total			260800	174334	86466

Sl. No.	Cropping System	Seed yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	TVC (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)
4	T.Aus rice (BRRRI dhan55)	3.80	4.29	103580	74581	28999
	T.Aman rice(BRRRI dhan77)	5.36	6.62	99000	67103	31897
	Cowpea(Local) **	1.22	2.31	47320	37880	9440
	Total			249900	179564	70336
5	T.Aus rice (BRRRI dhan55)	3.80	4.29	103580	74581	28999
	T.Aman rice (BRRRI dhan77)	5.36	6.62	99000	67103	31897
	Mungbean(BARI Mung-6) *	1.04	1.25	54500	35280	19220
	Total			257080	176964	80116
6	T.Aus rice (BRRRI dhan55)	3.80	4.29	103580	74581	28999
	T.Aman rice (BRRRI dhan77)	5.36	6.62	99000	67103	31897
	Mungbean(BARI Mung-6) **	0.89	1.16	46820	42320	4500
	Total			249400	184004	65396
7	T.Aus rice (BRRRI dhan55)	3.80	4.29	103580	74581	28999
	T.Aman rice (BRRRI dhan77)	5.36	6.62	99000	67103	31897
	Maize (DON 111)*	10.30	10.50	227000	106468	120532
	Total			429580	248152	181428
8	T.Aus rice (BRRRI dhan55)	3.80	4.29	103580	74581	28999
	T.Aman rice (BRRRI dhan77)	5.36	6.62	99000	67103	31897
	Maize(DON 111) **	9.01	9.65	199500	123598	75902
	Total			402080	265282	136798
9	T.Aus rice (BRRRI dhan55)	3.80	4.29	103580	74581	28999
	T.Aman rice (BRRRI dhan77)	5.36	6.62	99000	67103	31897
	Sunflower(Pacific Hysun 33) *	3.57	6.21	262320	93565	168755
	Total			464900	235249	229651
10	T.Aus rice (BRRRI dhan55)	3.80	4.29	103580	74581	28999
	T.Aman rice (BRRRI dhan77)	5.36	6.62	99000	67103	31897
	Sunflower(Pacific Hysun 33) **	3.05	5.42	224340	112935	111405
	Total			426920	254619	172301

*= Strip tillage and line sowing.

**= Conventional tillage (3 ploughing) and line sowing

*** = Conventional tillage (2 ploughing) and broadcast sowing

TVC= Total variable cost

Price of inputs

Price of outputs

Aus rice seed= Tk.40 kg⁻¹
 Aman rice seed (Moulata)= Tk.35 kg⁻¹
 Aman rice seed (BRRl dhan77)= Tk.35 kg⁻¹
 Mungbean seed= Tk. 80 kg⁻¹
 Cowpea seed = Tk. 70 kg⁻¹
 Maize seed= Tk. 450 kg⁻¹
 Sunflower seed= Tk.1350 kg⁻¹
 Urea= Tk.20 kg⁻¹
 TSP= Tk.30 kg⁻¹
 MoP= Tk.20 kg⁻¹
 Zinc sulphate= Tk.180 kg⁻¹
 Boric acid= Tk.260 kg⁻¹
 Gypsum = Tk.30 kg⁻¹
 Labourer= Tk.450.00 labourer⁻¹

Aus rice nonseed= Tk.25 kg⁻¹
 Aman rice nonseed (Moulata)= Tk.20 kg⁻¹
 Aman rice nonseed (BRRl dhan77)= Tk.16 kg⁻¹
 Mungbeannonseed= Tk. 50 kg⁻¹
 Cowpea nonseed = Tk. 35 kg⁻¹
 Maize nonseed= Tk. 20 kg⁻¹
 Sunflower nonseed= Tk.70 kg⁻¹
 Straw/stover= Tk.2 kg⁻¹

Rice equivalent yield of cropping systems under different tillage methods of *Rabi* crops

Rice equivalent yield (REY) of different cropping systems are presented in Table 11 and 13. In non-saline ecosystem, all the proposed cropping systems (Table 11) resulted in substantially higher REY (22-297%) than the farmers' cropping system. Among the *Rabi* crops, maize and sunflower with strip tillage contributed to the higher REY of the cropping system. Sunflower contributed the highest to the REY of the cropping system followed by *Aman* rice and *Aus* rice in the same cropping system. Razzakqueet *al.* (2005) reported that REY depends not only upon the sole contribution of any one component but also upon the contribution of both T. *Aman* and mustard.

In non-saline ecosystem, the highest REY (21.35 t ha⁻¹year⁻¹) was obtained from T. *Aus* (BRRl dhan55)-T. *Aman* rice (BRRl dhan77)-Sunflower (Pacific Hysun 33 sown with strip tillage) cropping system. In contrast, the lowest REY (5.38 t ha⁻¹year⁻¹) was recorded from the farmers' cropping system viz. Fallow-T. *Aman* rice (Moulata)-Mungbean (sown with conventional tillage and broadcasting) cropping system (Table 11).

In saline ecosystem, the best result (REY-19.57 t ha⁻¹year⁻¹) was recorded from the cropping system T. *Aus* (BRRl dhan55)-T. *Aman* rice (BRRl dhan73)-Sunflower (Pacific Hysun 33 sown with strip tillage) and the lowest (5.60 t ha⁻¹year⁻¹) from the farmers' practice Table (Table 13). However, the proposed cropping system increased the REY of 76 to 249% over the farmers' cropping system.

Table 11. REY and BCR of different cropping systems under different tillage methods of *Rabi* crops in non-saline ecosystem

Sl. no.	Cropping system	REY (t ha ⁻¹ year ⁻¹)	Component wise contribution (%) to REY	BCR of the component crop	BCR of the system
1	Fallow T.Amanrice (Moulata) Mungbean(BARI Mung-6) *	6.55	- 57 43	- 1.30 1.67	1.43
2	Fallow T.Amanrice (Moulata) mungbean(BARI Mung-6) *** (Farmers' practice)	5.38	- 70 30	- 1.30 1.08	1.23
3	T.Aus rice (BRRIdhan55) T.Aman rice (BRRIdhan77) Cowpea (Local)*	11.76	32 46 22	1.39 1.48 1.78	1.50
4	T.Aus rice (BRRIdhan55) T.Aman rice (BRRIdhan77) Cowpea (Local)**	11.24	34 48 18	1.39 1.48 1.25	1.39
5	T.Aus rice (BRRIdhan55) T.Aman rice (BRRIdhan77) Mungbean(BARI Mung-6) *	11.70	32 46 22	1.39 1.48 1.54	1.45
6	T.Aus rice (BRRIdhan55) T.Aman rice (BRRIdhan77) Mungbean (BARI Mung-6) **	11.33	34 47 19	1.39 1.48 1.11	1.35
7	T.Aus rice (BRRIdhan55) T.Aman rice (BRRIdhan77) Maize (DON 111)*	19.21	20 28 52	1.39 1.48 2.13	1.73
8	T.Aus rice (BRRIdhan55) T.Aman rice (BRRIdhan77) Maize (DON 111)**	17.95	21 30 49	1.39 1.48 1.61	1.52
	T.Aus rice (BRRIdhan55)		18	1.39	

Sl. no.	Cropping system	REY (t ha ⁻¹ year ⁻¹)	Component wise contribution (%) to REY	BCR of the component crop	BCR of the system
9	T.Aman rice (BRRRI dhan77)	21.35	25	1.48	1.98
	Sunflower(Pacific Hysun 33) *		57	2.80	
10	T.Aus rice (BRRRI dhan55)	19.57	19	1.39	1.67
	T.Aman rice (BRRRI dhan77)		27	1.48	
	Sunflower(Pacific Hysun 33)**		54	1.99	
LSD (0.05)	-	1.20	-	-	-
CV(%)	-	5.10	-	-	-

*= Strip tillage and line sowing.

**= Conventional tillage (3 ploughing) and line sowing

*** = Conventional tillage (2 ploughing) and broadcast sowing, REY= Rice equivalent yield,

BCR= Benefit- cost ratio

Table 12. Agro-economic performance of different cropping systems under different tillage methods of Rabi crops in saline ecosystem

Sl. no.	Cropping System	Seed yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	TVC (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)
1	Fallow	-	-	-	-	-
	T. Aman rice (Swarnamushuri)	5.6	8.18	105960	62500	43640
	Fallow (Farmers' practice)	-	-	-	-	-
	Total			105960	62500	43640
2	T.Aus rice (BRRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRRI dhan73)	4.90	6.43	91260	68500	22760
	Soybean (BARI Soybean-6) *	0.56	1.3	30600	35877	-5277
	Total			225400	181320	44080
3	T.Aus rice (BRRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRRI dhan73)	4.90	6.43	91260	68500	22760
	Soybean (BARI Soybean 6) **	0.47	1.2	25900	43980	-18080
	Total			220700	189423	31277
4	T.Aus rice (BRRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRRI dhan73)	4.90	6.43	91260	68500	22760
	Mungbean (BARI Mung-6)*	-	-	-	-	-
	Total			194800	145443	49357
5	T.Aus rice (BRRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRRI dhan73)	4.90	6.43	91260	68500	22760
	Mungbean (BARI Mung-6)**	-	-	-	-	-
	Total			194800	145443	49357

Sl. no.	Cropping System	Seed yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	TVC (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)
	Total			194800	145443	49357
6	T.Aus rice (BRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRI dhan73)	4.90	6.43	91260	68500	22760
	Maize (DON 111)*	6.10	6.57	135140	98748	36992
	Total			329940	244191	85749
7	T.Aus rice (BRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRI dhan73)	4.90	6.43	91260	68500	22760
	Maize (DON 111)**	5.42	5.95	120300	112498	7802
	Total			315100	257941	57159
8	T.Aus rice (BRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRI dhan73)	4.90	6.43	91260	68500	22760
	Sunflower (Hysun33)*	3.19	3.68	230660	88182	142478
	Total			425460	233625	191835
9	T.Aus rice (BRRI dhan55)	3.78	4.52	103540	76943	26597
	T.Amanrice (BRRI dhan73)	4.90	6.43	91260	68500	22760
	Sunflower (Hysun33)**	2.89	3.07	208440	99932	108508
	Total			403240	245375	157865

*= Strip tillage and line sowing.

**= Conventional tillage (3 ploughing) and line sowing

TVC= Total variable cost

Price of inputs

Aus rice seed= Tk.40 kg⁻¹
Aman rice seed (Swarnamushuri)= Tk.35 kg⁻¹
Aman rice seed (BRRI dhan73)= Tk.35 kg⁻¹
Maize seed= Tk. 450 kg⁻¹
Sunflower seed= Tk.1350 kg⁻¹
Soybean seed= Tk. 80 kg⁻¹
Urea= Tk.20 kg⁻¹
TSP= Tk.30 kg⁻¹
MoP= Tk.20 kg⁻¹
Zinc sulphate= Tk.180 kg⁻¹
Boric acid= Tk.260 kg⁻¹
Gypsum = Tk.30 kg⁻¹
Labourer= Tk.500.00 labourer⁻¹

Price of outputs

Aus rice nonseed= Tk.25 kg⁻¹
Aman rice nonseed ((Swarnamushuri)=Tk.16 kg⁻¹
Aman rice nonseed(BRRIdhan73)=Tk.16 kg⁻¹
Maize nonseed= Tk. 20 kg⁻¹
Sunflower nonseed= Tk.70 kg⁻¹
Soybean nonseed= Tk.50 kg⁻¹
Straw/stover= Tk.2 kg⁻¹

Table 13. REY and BCR of different cropping systems under different tillage methods of Rabi crops in saline ecosystem

Sl. no.	Cropping system	REY (t ha ⁻¹ year ⁻¹)	Component wise contribution (%) to REY	BCR of the component crop	BCR of the system
1	Fallow T. Aman rice (Swarnamushuri) Fallow(Farmers' practice)	5.6	- 100 -	- 1.70 -	1.70
2	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Soybean (BARI Soybean 6) *	10.05	38 49 13	1.35 1.33 -0.85	1.24
3	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Soybean (BARI Soybean 6) **	9.83	38 50 12	1.35 1.33 -0.54	1.17
4	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Mungbean (BARI Mung-6)*	8.68	43 57	1.35 1.33	1.34
5	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Mungbean (BARI Mung-6)**	8.68	43 57	1.35 1.33	1.34
6	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Maize (DON 111)*	14.63	26 33 41	1.35 1.33 1.37	1.35
7	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Maize (DON 111)**	13.97	27 35 39	1.35 1.33 1.07	1.22
8	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Sunflower (Pacific Hysun33)*	19.57	19 25 56	1.35 1.33 2.62	1.82
9	T.Aus rice (BRRRI dhan55) T.Amanrice (BRRRI dhan73) Sunflower (Pacific Hysun33)**	18.54	20 26 54	1.35 1.33 2.09	1.64
LSD (0.05)	-	0.15			-
CV(%)	-	0.64			-

*= Strip tillage and line sowing.

**= Conventional tillage (3 ploughing) and line sowing

REY= Rice equivalent yield

BCR= Benefit- cost ratio

Cropping system 1 was not included in statistical analysis because of no Rabi crops and tillage treatment.

Economic performance of cropping system under mulching and no mulching conditionsof Rabi crops

Cost and return analysis (Table 14) of the cropping systems in non-saline ecosystem showed that the improved cropping systems appreciably enhanced the gross return and benefit-cost ratio over the farmers' cropping system. The highest gross return (Tk. 458550 ha⁻¹), gross margin (Tk. 258600 ha⁻¹) and BCR (1.77) were obtained from the cropping system T. Aus rice (BRRI dhan55) -T. Aman rice (BRRI dhan77)-Sunflower (Pacific Hysun 33 sown with mulching) due to higher yield and price of output (seed) by sunflower with mulching. The improved cropping systems produced 129 to 757% higher gross margin over the control. The farmers' practice Fallow-T. Aman (Moulata)-Mungbean (BARI Mung-6 with no mulching and broadcasting of seed) had the lowest cost (Tk. 94750 ha⁻¹) but failed to show higher gross return (Tk. 118080 ha⁻¹), gross margin (Tk. 23330 ha⁻¹) and BCR (1.25) due to lower yield.

In saline ecosystem, all the cropping systems did not exhibit good economic performance (Table 16). The alternative cropping systems except cropping system 2 and 3 gave 44 to 326% higher gross margin over the farmers' practice. The highest gross return (Tk. 429440 ha⁻¹), gross margin (Tk. 181990 ha⁻¹) and BCR (1.74) were obtained from the cropping system T. Aus rice (BRRI dhan55)-T. Aman rice (BRRI dhan73)-Sunflower (Pacific Hysun 33 sown with mulching) due to higher yield and price of output (seed) by sunflower with mulching (Table 16). Cropping system 2 and 3 each gave 21% lower gross margin than farmers' practice. The farmers' practice Fallow-T. Aman rice (Swarnamushuri)-Fallow had the lowest cost (Tk. 62500 ha⁻¹) but failed to show higher gross return (Tk. 105240 ha⁻¹) and gross margin (Tk. 42740 ha⁻¹) due to cultivation of one rice crop in a year only (Table 16).

Table 14. Agro-economic performance of different cropping systems under mulching and nomulching conditions of Rabi crops in non-saline ecosystem

Sl. no.	Cropping System	Seed yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	TVC (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)
1	T.Aus rice (BRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Amanrice(Moulata)	3.81	6.20	89400	65850	23550
	Mungbean(BARI Mung-6)****	0.61	0.83	32160	30500	1660
	Total			223410	170000	53410

Sl. no.	Cropping System	Seed yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	TVC (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)
2	Fallow	-	-	-	-	-
	T.Amanrice (Moulata)	3.81	6.20	88600	65850	22750
2	Mungbean(BARI Mung-6)	0.56	0.74	29480	28900	580
	*** (Farmers' practice)					
	Total			118080	94750	23330
3	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Aman rice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Cowpea (Local)*	2.19	3.08	82810	38850	43960
	Total			282660	178670	103990
4	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Aman rice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Cowpea (Local)**	1.60	2.37	60740	34680	26060
	Total			260590	174500	86090
5	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Amanrice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Mungbean(BARI Mung-6) *	0.92	1.08	48160	32710	15450
	Total			248010	172530	75480
6	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Amanrice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Mungbean(BARI Mung-6)**	0.80	0.99	41980	30100	11880
	Total			241830	169920	71910
7	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Aman rice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Maize (DON 111)*	8.97	9.50	198400	126564	71836
	Total			398250	266384	131866
8	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Aman rice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Maize (DON 111)**	8.11	9.13	180460	121332	59128
	Total			380310	261152	119158
9	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Aman rice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Sunflower (Pacific Hysun 33)*	3.53	5.80	258700	118780	139920
Total			458550	258600	199950	
10	T.Aus rice (BRRRI dhan55)	3.73	4.30	101850	73650	28200
	T.Aman rice(BRRRI dhan77)	5.30	6.60	98000	66170	31830
	Sunflower (Pacific Hysun 33)**	2.97	5.50	218900	113460	105440
	Total			418750	253280	165470

*= Mulching and line sowing.

**= No-mulching and line sowing

*** = No-mulching and broadcast sowing

****= Mulching and broadcast sowing

TVC= Total variable cost

Price of inputs

Aus rice seed= Tk.40 kg⁻¹
 Aman rice seed (Moulata)= Tk.35 kg⁻¹
 Aman rice seed (BRRI dhan77)= Tk.35 kg⁻¹
 Mungbean seed= Tk. 80 kg⁻¹
 Cowpea seed = Tk. 70 kg⁻¹
 Maize seed= Tk. 450 kg⁻¹
 Sunflower seed= Tk.1350 kg⁻¹
 Urea= Tk.20 kg⁻¹
 TSP= Tk.30 kg⁻¹
 MoP= Tk.20 kg⁻¹
 Zinc sulphate= Tk.180 kg⁻¹
 Boric acid= Tk.260 kg⁻¹
 Gypsum = Tk.30 kg⁻¹
 Labourer= Tk.450.00 labourer⁻¹

Price of outputs

Aus rice nonseed= Tk.25 kg⁻¹
 Aman rice nonseed (Moulata)= Tk.20 kg⁻¹
 Aman rice nonseed (BRRI dhan77)= Tk.16 kg⁻¹
 Mungbeannonseed= Tk. 50 kg⁻¹
 Cowpea nonseed = Tk. 35 kg⁻¹
 Maize nonseed= Tk. 20 kg⁻¹
 Sunflower nonseed= Tk.70 kg⁻¹
 Straw/stover= Tk.2 kg⁻¹

Table 15. REY and BCR of different cropping systems under mulching and non-mulching conditions of Rabi crops in non-saline ecosystem

Sl. no.	Cropping system	REY (t ha ⁻¹ year ⁻¹)	Component wise contribution (%) to REY	BCR of the component crop	BCR of the system
1.	T.Aus rice (BRRI dhan55) T.Amanrice(Moulata) Mungbean(BARI Mung-6)****	8.90	42 43 15	1.38 1.36 1.05	1.31
2.	Fallow T.Amanrice (Moulata) Mungbean(BARI Mung-6)*** (Farmers' practice)	5.21	- 73 27	- 1.35 1.02	1.25
3.	T.Aus rice (BRRI dhan55) T.Aman rice(BRRI dhan77) Cowpea (Local)*	12.77	29 41 30	1.38 1.48 2.13	1.58
4.	T.Aus rice (BRRI dhan55) T.Aman rice(BRRI dhan77) Cowpea (Local)**	11.76	32 45 23	1.38 1.48 1.75	1.49
5.	T.Aus rice (BRRI dhan55) T.Amanrice(BRRI dhan77) Mungbean(BARI Mung-6) *	11.27	33 47 20	1.38 1.48 1.47	1.43
6.	T.Aus rice (BRRI dhan55)		34	1.38	

	T.Amanrice(BRRI dhan77) Mungbean(BARI Mung-6)**	10.98	48 18	1.48 1.39	1.42
7.	T.Aus rice (BRRI dhan55) T.Aman rice(BRRI dhan77) Maize (DON 111)*	17.78	21 30 49	1.38 1.48 1.57	1.49
8.	T.Aus rice (BRRI dhan55) T.Aman rice(BRRI dhan77) Maize (DON 111)**	16.94	22 31 47	1.38 1.48 1.49	1.46
9.	T.Aus rice (BRRI dhan55) T.Aman rice(BRRI dhan77) Sunflower (Pacific Hysun 33)*	21.08	18 25 57	1.38 1.48 2.22	1.77
10.	T.Aus rice (BRRI dhan55) T.Aman rice(BRRI dhan77) Sunflower(Pacific Hysun 33) **	19.17	19 28 53	1.38 1.48 1.92	1.65
LSD (0.05)		0.83			-
CV(%)		3.52			-

*= Mulching and line sowing, **= No-mulching and line sowing, *** = No-mulching and broadcast sowing
****= Mulching and broadcast sowing, REY= Rice equivalent yield, BCR= Benefit- cost ratio

Table 16. Agro-economic performance of different cropping systems under mulching and no mulching conditions of Rabi crops in saline ecosystem

Sl. no.	Cropping System	Seed yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Gross return (Tk. ha ⁻¹)	TVC (Tk. ha ⁻¹)	Gross margin (Tk. ha ⁻¹)
1	Fallow	-	-	-	-	-
	T. Aman rice (Sornomusuri)	5.56	8.14	105240	62500	42740
	Fallow (Farmers' practice)	-	-	-	-	-
	Total			105240	62500	42740
2	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770
	Soybean (BARI Soybean 6) *	0.53	1.21	28920	52610	-23690
	Total			225420	191560	33860
3	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770
	Soybean (BARI Soybean 6) **	0.41	1.13	22760	47713	-23953
	Total			219260	186663	33597
4	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770
	Mungbean (BARI Mung-6)*	-	-	-	-	-
	Total			196500	138950	57550
5	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770

	Mungbean (BARI Mung-6)**	-	-	-	-	-
	Total			196500	138950	57550
6	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770
	Maize (DON 111)*	6.96	7.35	153900	120345	33555
	Total			350400	259295	91105
7	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770
	Maize (DON 111)**	5.37	5.56	118520	114535	3985
	Total			315020	253485	61535
8	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770
	Sunflower (Pacific Hysun 33)*	3.22	3.77	232940	108500	124440
	Total			429440	247450	181990
9	T.Aus rice (BRRI dhan55)	4.00	4.64	109480	75700	33780
	T.Amanrice(BRRI dhan73)	4.60	6.71	87020	63250	23770
	Sunflower (Pacific Hysun 33)**	2.95	3.23	212960	104375	131685
	Total			409460	243325	166135

*= Mulching and line sowing.

**= No-mulching and line sowing

TVC= Total variable cost

Price of inputs

Aus rice seed= Tk.40 kg⁻¹

Aman rice seed (Swarnamushuri)= Tk.35 kg⁻¹

Aman rice seed (BRRI dhan73)= Tk.35 kg⁻¹

Maize seed= Tk. 450 kg⁻¹

Sunflower seed= Tk.1350 kg⁻¹

Soybean seed= Tk. 80 kg⁻¹

Urea= Tk.20 kg⁻¹

TSP= Tk.30 kg⁻¹

MoP= Tk.20 kg⁻¹

Zinc sulphate= Tk.180 kg⁻¹

Boric acid= Tk.260 kg⁻¹

Gypsum = Tk.30 kg⁻¹

Labourer= Tk.500.00 labourer⁻¹

Price of outputs

Aus rice nonseed= Tk.25 kg⁻¹

Aman rice nonseed(Swarnamushuri)= Tk.16 kg⁻¹

Aman rice nonseed (BRRI dhan73)= Tk.16 kg⁻¹

Maize nonseed= Tk. 20 kg⁻¹

Sunflower nonseed= Tk.70 kg⁻¹

Soybean nonseed= Tk.50 kg⁻¹

Straw/stover= Tk.2 kg⁻¹

Rice equivalent yield of cropping systems under mulching and nonmulching conditions of Rabi crops

Rice equivalent yield (REY) of different cropping systems under saline and non-saline ecosystems are presented in Table 15 and 17. In non-saline ecosystem, improved cropping systems resulted in higher (73-305%) rice equivalent yield than the farmers' cropping system.

Among different *Rabi* crops, maize and sunflower with straw mulching contributed to the higher REY of the cropping system where sunflower contributed to the highest REY followed by *Aman* rice and *Aus* rice in the same cropping system.

In non-saline ecosystem (Table 15), the highest REY (21.08 t ha⁻¹year⁻¹) was obtained from T.Aus (BRRI dhan55)-T.Aman (BRRI dhan77)–Sunflower (Pacific Hysun 33 sown with strip tillage) cropping system. In contrast, the lowest REY (5.21t ha⁻¹year⁻¹) was recorded from the farmers’ cropping system viz. Fallow- T.Aman rice (Moulata)–Mungbean (BARI Mung-6 sown with no mulching and broadcasting) cropping system. Bhattacharya *et al.* (2015) also recorded higher REY (13.9-19.3 t ha⁻¹ year⁻¹) with the inclusion of maize or sunflower with mulching in rice based cropping system.

In saline ecosystem, REY ranged from 5.56t ha⁻¹year⁻¹ in farmers’ practice to 19.60t ha⁻¹year⁻¹ in improved cropping system T. Aus (BRRI dhan55)-T.Aman (BRRI dhan73)- Sunflower (Pacific Hysun 33 sown with mulching)(Table 17). The improved cropping systems increased REY of 73 to 253% over farmers’ practice.

Table 17. REY and BCR of different cropping systems under mulching and nomulching conditions of Rabi crops in saline ecosystem

Sl. no.	Cropping system	REY (t ha ⁻¹ year ⁻¹)	Component wise contribution (%) to REY	BCR of the component crop	BCR of the system
1	Fallow T. Aman rice (Swarnamushuri) Fallow (Farmers’ practice)	5.56	- 100 -	- 1.68 -	1.68
2	T.Aus rice (BRRI dhan55) T.Amanrice (BRRI dhan73) Soybean (BARI Soybean-6) *	9.89	40 47 13	1.45 1.37 0.55	1.18
3	T.Aus rice (BRRI dhan55) T.Amanrice (BRRI dhan73) Soybean (BARI Soybean-6) **	9.60	42 48 10	1.45 1.37 0.48	1.17
4	T.Aus rice (BRRI dhan55) T.Amanrice(BRRI dhan73) Mungbean (BARI Mung-6)*	8.60	47 53	1.45 1.38	1.41
5	T.Aus rice (BRRI dhan55)		47	1.45	

	T.Amanrice(BRR dhan73) Mungbean (BARI Mung-6)**	8.60	53	1.38	1.41
6	T.Aus rice (BRR dhan55) T.Amanrice (BRR dhan73) Maize (DON 111)*	15.39	26 30 44	1.45 1.37 1.28	1.35
7	T.Aus rice (BRR dhan55) T.Amanrice (BRR dhan73) Maize (DON 111)**	13.84	29 33 38	1.45 1.37 1.08	1.24
8	T.Aus rice (BRR dhan55) T.Amanrice (BRR dhan73) Sunflower (Pacific Hysun 33)*	19.60	20 23 57	1.45 1.37 2.15	1.74
9	T.Aus rice (BRR dhan55) T.Amanrice (BRR dhan73) Sunflower (Pacific Hysun 33)**	18.67	21 25 54	1.45 1.37 2.04	1.68
LSD (0.05)		0.05			-
CV(%)		0.26			-

*= Mulching and line sowing.

**= No-mulching and line sowing

REY= Rice equivalent yield

BCR= Benefit- cost ratio

Cropping system 1 was not included in statistical analysis because of no Rabi crops and tillage treatment.

12. Research highlight/findings:

- i. Strip tillage or mulched treatment was found better for higher yield, gross margin and BCR of all *Rabi* crops in non-saline ecosystem. In saline ecosystem, all *Rabi* crops except mungbean and soybean showed better performance under the same tillage or mulched treatments. Sunflower was the best in respect of yield, gross margin and BCR in both tillage and mulching experiment.
- ii. Most of the improved cropping systems tested in the study enhanced gross margin, REY and BCR over the farmers' practice.
- iii. In non-saline ecosystem, the highest gross margin (Tk.229651 t ha⁻¹), REY (21.35t ha⁻¹ year⁻¹) and BCR (1.98) were obtained from T. Aus rice (BRR dhan55)- T. Aman rice (BRR dhan77)-Sunflower (Pacific Hysun 33) cropping pattern with strip tillage of

sunflower. This pattern also produced highest gross margin (Tk. 199950), REY (21.08 t ha⁻¹ year⁻¹) and BCR (1.77) under mulching condition of sunflower.

iv. In saline ecosystem, the highest gross margin (Tk.191835), REY (17.87t ha⁻¹ year⁻¹) and BCR (1.82) were obtained from T. Aus rice (BRRI dhan55)-T. Aman rice (BRRI dhan73)–Sunflower (Pacific Hysun33) cropping pattern with strip tillage of sunflower. The same pattern also produced highest gross margin (Tk.181990), REY (19.6t ha⁻¹ year⁻¹) and BCR (1.74) under mulching conditions of sunflower.

v. The farmers' practice Fallow-T. Aman rice (Moulata)-Mungbean (BARI Mung-6 with conventional tillage and broadcast sowing) in non-saline ecosystem produced the lowest grossmargin, REY and BCR.The cropping system including mungbean and soybean in saline ecosystem showed the poor performance.

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B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk.)	Phy (#)	Fin (Tk.)	
(a) Office equipment	<p>Computer and computer accessories</p> <p>a) Desktop Computer-01 No. b) Laptop-02 No. c) UPS -01 No. d) Scanner-01 No. e) Digital Camera-01 No.</p> <p>Furniture</p> <p>a) Computer table-02 No. b) Book-self-01 No. c) Steel Almira-01 No. d) Executive Table-02 No. e) Executive Chair-02 No. f) Visitor/Front Chair-08 No. g) Computer Chair-02 No.</p>	369500	<p>Computer and computer accessories</p> <p>a) Desktop Computer-01 No. b) Laptop-02 No. c) UPS -01 No. d) Scanner-01 No. e) Digital Camera-01 No.</p> <p>Furniture</p> <p>a) Computer table-02 No. b) Book-self-01 No. c) Steel Almira-01 No. d) Executive Table-02 No. e) Executive Chair-02 No. f) Visitor/Front Chair-08 No. g) Computer Chair-02 No.</p>	369500	
(b) Lab & field equipment	<p>Lab equipments</p> <p>a) Digital soil moisture meter-02 No. b) Digital Soil temperature meter-02 No. c) Seed moisture meter-02 No. d) pH meter-01 No. e) EC meter-01 No. f) Electric Balance-02 No.</p> <p>Field equipments</p> <p>a) Irrigation pump and pipe-02 set b) Power tiller-01 No. c) Strip tillage tool-02 No. d) USG applicator-02 No. e) Sprayer-02 No. f) Pedal thresher-02 No.</p>	667000	<p>Lab equipments</p> <p>a) Digital soil moisture meter-02 No. b) Digital Soil temperature meter-02 No. d) pH meter-01 No. e) EC meter-01 No. f) Electric Balance-02 No.</p> <p>Field equipments</p> <p>a) Irrigation pump and pipe-02 set b) Power tiller-01 No. c) Strip tillage tool-02 No. d) USG applicator-02 No. e) Sprayer-02 No. f) Pedal thresher-02 No.</p>	667000	
(c) Other capital items	-	-	-	-	-

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
Repair and renovation of implement shed (WD1)	-	-	Tk. 100000.00	Tk. 100000.00	-
Repair and renovation of implement shed (WD2)	-	-	Tk. 322590.00	00	This work was not done due to no release of fund

3. Training/study tour/ seminar/workshop/conference organized:

Description	Number of participant			Duration (Days/weeks / months)	Remarks
	Male	Female	Total		
(a) Training					
Training of farmers and project personnels on Aus and Aman rice production, Date:15 July 2017,Location: Agronomy Lab,PSTU.	13	2	15	01	
Training of farmers and project personnels on Aman rice production, Date: 11 August 2017,Location: Kalapara	15	-	15	01	
Training of farmers and project personnels on Rabi crop production, Date: 3 December 2017, Location: PSTU Innovation Center.	13	2	15	01	
Training of farmers and project personelson growing 3 crops in a same land in southern region of Bangladesh,Date: 21 September 2018, Location: PSTU Innovation Center.	29	2	31	01	
(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	830370	830370	830370	00	100%	-
B. Field research/lab expenses and supplies	825575	600000	502985	97015	90%	No release of fund
C. Operating expenses	349879	349879	349879	00	100%	-
D. Vehicle hire and fuel, oil & maintenance	133433	133433	133433	00	100%	-
E. Training/workshop/seminar etc.	119200	119200	119200	00	100%	-
F. Publications and printing	144138	83665	64500	19165	45%	No release of fund
G. Miscellaneous	60650	60650	60650	00	100%	-
H. Capital expenses	1036500	1036500	1036500	00	100%	-

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)
To develop sustainable production technology of selected Rabi crops for improved cropping system in saline and non-saline tidal ecosystem	<ul style="list-style-type: none"> i. Selection of sites for on-farm trials ii. Selection of farmers for on-farm trials i.Training of farmers and project personnels on Rabi crop production in two sites viz. saline and non-saline ecosystems. ii. Trials on late Rabi crops with different tillage methods and mulching conditions in saline and non-saline ecosystem and calculation of economic return. 	<ul style="list-style-type: none"> i.30 farmers from each site and project personnels were trained. ii. Suitable Rabi crop with high net return and BCR was selected iii.Improved producton technology of Rabi crops in respect of tillage and mulching was developed 	i.About 50 farmers in two sites are following this improved technology of <i>Rabi</i> crop production and meet their vegetable oil demand
To evaluate the agro-economic performance of the designed cropping systems in saline and non-saline tidal ecosystem.	<ul style="list-style-type: none"> i.Training of farmers and project personnels on Aus and Aman rice production in saline and non-saline ecosystems. ii. Raising Aus and Aman rice in saline and non-saline ecosystems and calculation of economic return. 	i.Improved cropping systems with high net return , BCR and REY was developed	About 50 farmers are following the improved cropping system and increased their income

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 leaflet		2	1. mgy`a DcK~jxqGjvKvqAvDkGesAvgbav#biDrcv`b cÖhyw ³ 2. mgy`a DcK~jxqGjvKvqavbwfwËK km`` web`v#mm~h©gyLxiDrcv`b cÖhyw ³
Journal publication	-	-	-
Information development	-	-	-
Other publications, if any (Souvenir)	-	2	1. Evaluation of cropping pattern potential under different tillage methods of Rabi crops in non-saline ecosystem. An Abstract Published in Souvenir of 17 th Conference, Bangladesh Society of Agronomy 2. Evaluation of cropping pattern potential under different tillage practices of Rabi crops in saline ecosystem. An Abstract Published in Souvenir of 17 th Conference, Bangladesh Society of Agronomy

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

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

- a. Improved production technology was developed in respect of tillage and mulching of late *Rabi* crops (maize, sunflower, mungbean and cowpea in non-saline ecosystem and maize and sunflower in saline ecosystem).
- b. Improved cropping system with high gross return, BCR and REY was developed for both saline and non-saline ecosystems.

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

The information on tillage methods and mulching conditions generated through research will strengthen the knowledge of researchers and will help in developing proper technology to suit under low management and saline soils in future.

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

The technology dissemination through community participation and farmer to farmer diffusion increased agricultural productivity and farmers' income.

Researchers of this project faced many problems during cropping system development and explored its solution. The policy makers would get practical and exact feedback from project findings if they need modification of agricultural policy for coastal belt of Bangladesh.

G. Information regarding Desk and Field Monitoring

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

Monitoring team of PIU-BARC, NATP-2 visited on 17/02/2018. and observed the project activity through power point presentation. They observed the Lab and field equipments, verified the cash book, leisure book, check registrar and stock book and gave some advices regarding the improvement of record keeping and followed accordingly.

ii) Field Monitoring (time& No. of visit, Team visit and output):

Monitoring team	Date of field visit	Total visit till date (No.)	Remarks
PIU-BARC, NATP-2	17/02/2018	01	
Internal Monitoring	02/05/2018	01	
NUMAN Project team(Australian)	20/02/2018	01	

H. Lesson Learned (if any)

i) Conduct complex experiments in farmers' field

The research project is a complex one consisting of two factors. Implementation of 2 factor experiment in the farmers' field was very difficult in respect of cultural operations. In the future, 2 factor experiment is to be avoided.

ii) Selection of mungbean as rabi crops in saline ecosystem

Mungbean is a saline sensitive crops. It is widely and successfully grown in non-saline ecosystem of Patuakhali. But all plants were died within 55 days of sowing in saline ecosystem. So in the future, trials on mungbean crop should be avoided.

iii) Selection of *Rabi* crops requiring different cultural operations

In this project, maize (cereal), sunflower and soybean (oil seeds), mungbean and cowpea (pulses) were selected as test crops which requires different sowing times and soil moistures. All *Rabi* crops were sown at the same date and at same soil moisture content. Mungbean and cowpea does not need high soil moisture for germination while maize and sunflower needs enough soil moisture. High soil moisture particularly in mungbean and cowpea plots caused wilting of some plants. So in the future, crops requiring different sowing time and soil moisture should be avoided.

I. Challenges (if any)

j) Lack of fresh water for irrigation in *Rabi* crops was a serious constraint faced in saline area. In the later stages of crops there was little water in the nearby pond which was the source of irrigation water for the *Rabi* crops. Without minimum fresh water it is quite impossible to grow maize and sunflower. Therefore, availability of fresh water is a big challenge for *Rabi* crop production in the saline zone.

ii) In the coastal area, maize and sunflower are not grown in a vast area. Area coverage is very low. Marketing facilities is not so developed. Therefore, good marketing facilities for both maize and sunflower seed is a great challenge for increasing their area in coastal belt of Bangladesh.

iii) There was a serious crisis of labour during harvesting period of T. Aman rice in the coastal area, particularly in Kalaparaupazila. Generally, labour demand is met up by the outside labour come from Rangpur district. In *Rabi* season labour crisis was also acute. Therefore, availability of skilled manpower for adoption of the technology is a big challenge.

iv) Farmers' negative attitude towards receiving the new improved technology requiring more inputs is a great challenge to disseminate the technology generated among the farmers.

Signature of the Principal Investigator
 Date
 Seal

Counter signature of the Head of the
 organization/authorized representative
 Date
 Seal

Appendix

Appendix 1. Monthly record of air temperature, rainfall and relative humidity of the experimental site (Sreerampur, Dumki) during the period from May 2017 to May 2018.

Months	Air temperature (⁰ C)		Relative humidity (%)	Total Rainfall(mm)
	Maximum	Minimum		
May, 2017	39	27	61	222.5
June, 2017	37	28	69	320.6
July, 2017	35	27	76	491.9
August, 2017	36	28	72	390.1
September, 2017	34	28	71	484.6
October, 2017	32	25	74	422
November, 2017	30	21	61	4
December, 2017	29	20	54	16.3
January, 2018	26	17	43	0
February, 2018	31	21	38	1
March, 2018	36	24	35	14.8
April, 2018	36	26	51	150.2
May, 2018	36	27	63	377.7

Source: <https://www.worldweatheronline.com/patuakhali-weatheraverages/bd.asp>

Appendix 2. Monthly record of air temperature, rainfall and relative humidity of the experimental site (Tajepara, Kalapara) during the period from May 2017 to May 2018.

Months	Air temperature (⁰ C)		Relative humidity (%)	Total Rainfall(mm)
	Maximum	Minimum		
May, 2017	39	28	63	193.9
June, 2017	36	28	75	371.2
July, 2017	35	27	78	482.2
August, 2017	35	28	75	415.8

September, 2017	34	28	74	480.9
October, 2017	33	26	71	281.9
November, 2017	32	24	55	13.7
December, 2017	29	22	57	64.3
January, 2018	27	18	43	0
February, 2018	32	22	40	1.4
March, 2018	37	25	43	55.5
April, 2018	36	27	55	337.9
May, 2018	35	28	67	642.2

Source: <https://www.worldweatheronline.com/patuakhali-weather-averages/bd.asp>

Appendix 3. Some photographic views of the project activities



Photograph 1. Farmers' training on T. Aus rice cultivation in Kalaparaupazila



Photograph 2. T.Aus rice field in Dumkiupazila



Photograph 3. T. Aman rice field in Kalaparaupazila



Photograph 4. Field day of T. Aman rice in Dumkiupazila



Photograph 5. Field visit by BARC monitoring team



Photograph 6. Farmers’ training on Rabi crop cultivation in Dumkiupazila



Photograph 7. Strip tillage by PTOS in Dumkiupazila



Photograph 8. Maize with strip tillage



Photograph 9. Maize with conventional tillage



Photograph 10. Sunflower with strip tillage



Photograph 11. Sunflower with conventional tillage

Non-saline ecosystem



Photograph 12. Maize with mulching



Photograph 13. Maize with no mulching



Photograph 14. Sunflower with mulching



Photograph 15. Sunflower with no mulching

Non-saline ecosystem



Photograph 16. Mungbean with mulching



Photograph 17. Mungbean with no mulching



Photograph 18. Soybean with strip tillage



Photograph 19. Soybean with conventional tillage

Saline ecosystem



Photograph 20. Maize with strip tillage



Photograph 21. Maize with conventional tillage



Photograph 22. Sunflower with strip tillage **Photograph 23. Sunflower with conventional tillage**

Saline ecosystem



Photograph 24. Maize with mulching



Photograph 25. Maize with no mulching



Photograph 26. Sunflower with mulching



Photograph 27. Sunflower with no mulching

Saline ecosystem



Photograph 28. Maize plant with 1 cob plant⁻¹ in non-saline ecosystem



Photograph 29. Maize plant with 2-3 cobs plant⁻¹ in saline ecosystem



Photograph 30. Field day of Rabicrop in Dumkiupazila