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Competitive Research Grant

Sub-Project Completion Report

on

Conservation Agricultural Practices for the Improvement of Soil Health, Cropping System Productivity and Farmers' Income

Project Duration:

May 2017 to September 2018

Soil Science Division, Bangladesh Agricultural Research Institute (BARI),Gazipur

Submitted to

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

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Acronyms

AEZ	Agro-Ecological Zone
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
CA	Conservation Agriculture
CD	Cow dung
CF	Chemical fertilizer
Co-PI	Co- Principal Investigator
CRG	Competitive Research Grant
CRI	Crown Root Initiation
CT	Conventional Tillage
CV	Co-efficient of Variation
DAS	Days After Sowing
DAT	Days After Transplanting
FP	Farmer's Practice
FRG	Fertilizer Recommendation Guide
HI	Harvest Index
MoP	Muriate of Potash
MT	Minimum Tillage
NATP	National Agricultural Technology Program
NM	Nutrient Management
NR	Net Return
PCR	Project Completion Report
PI	Principal Investigator
PIU	Project Implementation Unit
PRC	Pulse Research Centre
PTOS	Power Tiller Operated Seeder
RARS	Regional Agricultural Research Station
REY	Rice Equivalent Yield
RND	Recommended Nitrogen Dose
SOM	Soil Organic Matter
ST	Strip Tillage
STB	Soil Test Basis

Table of Contents

Executive Summary

The present project was undertaken to observe the effects of conservation agriculture (CA) on the improvement of soil organic matter, physico-chemical properties of soil and crop productivity. Three field trials were conducted in 4 locations (Gazipur, Jashore, Ishurdi and Rajbari). Three cropping patterns (Wheat- Mungbean-T. aman; Mustard-Boro- T. aman and Onion-Jute-T. aman) were studied under minimum tillage, strip tillage (ST) and crop residue retention and nutrient management. Total of 56 nos. of initial, 240 nos. of post-harvest soil samples and 80 plant samples were collected and analyzed. Some stationary goods, research and capital items were procured as per provision of the project. Up to September 2018, received Tk. 2520458.00 and total of Tk. 2451010.00 spent. The rest money Tk. 69448.00 have been refunded to PIU-BARC.

At Joydebpur, ST with residue retention conserved higher soil moisture at spike initiation and grain filling stages of wheat compared to CT practice. Though, tillage and residue had no significant effect on the yield attributes of wheat at Joydebpur, however, higher grain yield (4.08 t ha^{-1}) found in STover CT practice (3.81 t ha^{-1}). On the other hand, at RARS, Jashore, increased available soil moisture content was recorded at CRI, spike initiation and grain filling stage of wheat in ST and residue retention. Statistically higher grain yield of wheat (3.91 t ha^{-1}) was found in STas compared to that of CT practice (3.0 t ha^{-1}). Tillage practices and residue retention had no significant effect on T. aman rice and mungbean at both locations. Statistically higher REY was observed in ST than CT at RARS, Jashore. After 1-year, increased residue retention showed increased all nutrient contents and microbial population in soil over residue removal.

The single effect of N fertilizer on T. aman rice was significant at both the locations (Joydebpur and Ishurdi). The yield under 125% of RND (5.10 & 6.24 t ha^{-1}) and 100% of RND (4.98 & 5.87 t ha^{-1}) outperformed 75% of RND (4.27 & 5.47 t ha^{-1}) at Joydebpur and RARS, Ishurdi, respectively. In case of mustard, due to unexpected rain during winter, excessive soil moisture was recorded in CT over ST practice at 20, 50 and 70 DAS at Joydebpur that has led to the increased moisture under CT reduced mustard growth and yield significantly lower (0.69 t ha^{-1}) compared to ST practice (1.12 t ha^{-1}). Considering the N-fertilizer dose, the highest seed yield (1.05 & 1.30 t ha^{-1}) was obtained in N_3, followed by N_2 (0.93 & 1.29 t ha^{-1}) and the lowest yield (0.74 & 1.05 t ha^{-1}) was noted in N_1 at Joydebpur and RARS, Ishurdi, respectively. The highest grain yield of Boro rice was recorded in N_3 level (5.81 t ha^{-1}& 5.88 t ha^{-1}) and the lowest value being recorded in N_1 level (4.69 t ha^{-1}& 4.59 t ha^{-1}) at Joydebpur and at Ishurdi, respectively. Significantly higher REY was observed in N_3 level followed by N_2 and N_1 level. It was observed that seed yield of mustard under ST increased with the increased rates of N fertilizer at both the locations, while yield under CT decreased even under highest rate of N application (125% of RND).

Different nutrient management showed significant variations on fibre yield of jute; grain yield of T. aman rice and onion bulb yield at farmer's field of Rajbari. On the other hand, the yield attributes of jute, T. aman rice and onion responded similarly to tillage methods. The higher fibre yield (3.64 t ha^{-1}) was recorded from NM_3 (125% CF of STB) andNM_2 (100% CF of STB, 3.16 t ha^{-1}) compared to lower yield from NM_1 (FP, 2.96 t ha^{-1}) and NM_4 (80% CF + 20% CD, 3.23 t ha^{-1}). The highest grain yield of T. aman was produced in NM_4 (6.02 t ha^{-1}), which was statistically similar to NM_3 (5.93 t ha^{-1}) and NM_2 (5.72 t ha^{-1}). The NM_4 produced the highest onion bulb yield (16.0 t ha^{-1}) followed by NM_3 (14.6 t ha^{-1}). It is evident that residual nutrient from 20% nutrient supplement by CD to chemical fertilizer and successive use of CD outperformed 125%, 100% CF and farmers' practice. Regardless of tillage methods, the nutrient management practices had significant effects on system productivity (REY). Higher REY was not in NM_4 (33.6 t ha^{-1}) and NM_3 (32.31 t ha^{-1}) treatments compared to NM_2 (30.55 t ha^{-1}) and NM_1(28.64 t ha^{-1}).

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: Conservation Agricultural Practices for the Improvement of Soil Health, Cropping System Productivity and Farmers' Income
2. Implementing organization: Bangladesh Agricultural Research Institute (BARI)
3. Name and full address with phone, cell and E-mail of PI/Co-PI (s):

Principal Investigator: **Dr. Nazmus Salahin**
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&

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4. Sub-project budget (Tk):
   - 4.1 Total: 2607095.00
   - 4.2 Revised (if any): 2451010.00
5. Duration of the sub-project:
   - 5.1 Start date (based on LoA signed): 09 May 2017
   - 5.2 End date: 30 September 2018
6. Justification of undertaking the sub-project:

Soil organic matter (SOM) is the most important property which is directly correlated with the nutrient content of soil and represents 90–95% of the N, 40% of the P and 90% of S in soil, as well as considerable amounts of other soil nutrients (Smith *et al*., 1993) and determines soil health because of its great influence on the physical, chemical and biological properties of soil (Roose *et al*., 2006; Diaz-Zorita and Grove, 2002). SOM and nutrient stocks are the important indicators of sustainable long-term agricultural production practice (Bell *et al.,* 2012). Thus, among the soil properties, maintenance of SOM deserves special attention.

Nitrogen is the most limiting nutrient element in Bangladesh soils because of low soil organic matter content. In the rice-rice system, the level of soil N has little increased and in the wheat-rice system, the N level has rather slightly decreased (Jahiruddin *et al.*, 2009). Under conservation tillage, nitrogen mineralization rate tends to be lower since the soil is not as greatly disturbed and the organic residues remain on the surface where decomposition is slower (Jahiruddin et al., 2009). Under CA practice, a lower amount of nitrogen is available for crop growth due to lower mineralization, so it may be necessary to apply more N fertilizer in the first years of CA. Karmaker *et al*. (2014) indicated that the N requirement of transplanting rice was more for non-puddled soil following strip tillage than for puddled rice.

Unfortunately, soil fertility is gradually declining over in Bangladesh due to conventional system of excessive tillage and residue removal that degraded soil quality accelerating decomposition of soil organic carbon. Most of the soils of Bangladesh contain less than 1.5% SOM, and some soils have even less than 1% SOM (BARC, 2012). The cropping systems in Bangladesh are mainly rice-based with an average cropping intensity of 191% (BBS, 2012). In addition, the sub-tropical humid climate is one of the major causes of rapid breakdown of SOM in presence of heterotrophic microbes; consequently, loss of nutrients occurs from soils through different processes, viz. leaching, volatilization, runoff etc. The low SOM is a cause of low productivity and is considered as one of the serious threats to the sustainability of agriculture in Bangladesh (Jahiruddin and Satter, 2010). Organic matter (OM) depletion occurs in high land and medium high land soils (WRC, 2008-2009) while OM content has little increased in low land soils with rice-rice cropping pattern (BRRI, 2008). Intensification of agricultural land use with high expansion of modern crop varieties has increased remarkably which exhausts higher amount of nutrients from soil. Thus, with advancement of time, soil fertility has declined (Islam, 2008) and chronologically the deficiency of N, P, K, S, Zn and B has arisen in the soils (Jahiruddin and Satter, 2010). Decline in SOM poses serious agricultural and environmental drawbacks by reducing nutrient concentrations (Ashagrie *et al*., 2007). Most agricultural soils have become vulnerable to tillage-stimulated rapid loss of SOM in the coarse texture soils (Stewart *et al.*, 2007).

In these situations, the idea of conservation agriculture (CA) through employing minimal soil disturbance, crop residue retention with suitable crop rotations (Hobbs *et al*., 2008; Kassam *et. al*., 2009) has emerged as a holistic alternate agricultural system for its production sustainability, economic viability and environment friendly approach. Minimum or zero tillage practice increases SOM levels (Busari and Salako, 2013), water retention capacity (Aziz *et al.* 2013), and decreases production costs by reducing fuel costs for intensive tillage and irrigation requirements (Johansen *et al*., 2012). Research on zero and minimum tillage has been proven as a greater opportunity to increase SOM, microbial activity, total N, and extractable P, S, Zn and B at the soil surface compared to conventional tillage (Vu *et al*., 2009). But, conservation agriculture (CA) is inadequately developed for intensive upland-rice cropping system widely practiced in Bangladesh (Alam *et al.,* 2016) and the effects of CA practices on soil properties along with crop yields of rice-based triple cropping systems have not been adequately assessed in Bangladesh (Salahin *et al*., 2017). Moreover, no data are available to assess the requirement for nitrogen fertilizer under conservation tillage systems in Bangladesh. With a view to address such issue, the present project is intended to be undertaken to observe the effects of CA (minimum tillage and crop residue retention) on the improvement of soil organic matter, physico-chemical properties of soil and crop productivity along with determination of nitrogen requirement of crops under CA practice for the intensive rice-based cropping system.

7. Sub-project goal: Improvement and conservation of soil fertility and crop productivity with generation of sustainable higher crop production and income for the farmers.

8. Sub-project objective (s):
   i. To monitor the changes in SOM and soil physico-chemical properties as governed by CA practice;
   ii. To assess the cropping system productivity under intensive rice- based agriculture and
   iii. To observe economic benefits of CA over traditional practice.
9. Implementing location (s): Joydebpur; RARS, Jessore; RARS, Ishurdi and Rajbari.
10. Methodology in brief:

Survey work and site selection

For background information about existing cropping practices of the proposed 4 locations, survey work was conducted interrogating farmers and scientists of the concerned areas about the prospects, feasibility and potentiality of the area for conservation agricultural practices. Upon discussion, 4 sites were selected taking 1 from each location for field experimentation.

Assessment of baseline soil properties of the experimental sites

The experiment was started at Joydebpur Central Farm, Gazipur; RARS, Jashore; RARS, Jashore and farmer's field of Rajbari district during 2017-2018.The study areas were under the agro-ecological zone "Madhupur Tract (AEZ-28)" and "High Ganges River Floodplain (AEZ-11)" and "Low Ganges River Floodplain (AEZ-12)". There are three major cropping seasons in the study area viz. Rabi, Kharif-I and Kharif-II. Rabi season extends from middle October to middle March, Kharif-I season from middle March to the end of June and Kharif-II season from early July to middle October.

Major cropping patterns at Gazipur (AEZ-28) are Boro-fallow-T. aman, Boro-fallow-fallow, mustard-Boro-T. aman, wheat/maize-fallow-T. aman, Boro-T. aus- T. aman etc., at Jashore and ishurdi (AEZ-11) are wheat/maize/potato-mungbean-T. aman, Boro/wheat/lentil/maize-fallow-T. aman, Boro/potato -T. aus-T. aman, Boro/onion -jute- T. aman, wheat/mustard/lentil-jute-T. aman, wheat -sasame- T. aman, mustard-Boro rice- T. amanetc., at Rajbari district (AEZ-12) are onion/garlic/lentil/pea/wheat/mustard-jute- T.aman, wheat-sesame-T.aman, Boro/wheat-fallow-T. aman, wheat/onion/grasspea/mustard-jute-fallow, year round sugarcane (FRG, 2012).

Initial soil properties of the experimental field were determined and information of soil texture, bulk density, soil pH, organic matter, total N, exchangeable K, available P, S, Zn, and B contents at 0-15 and 15-30 cm depthsof Joydebpur, Jashore, Ishurdi and Rajbari experimental field are presented in Tables 1(a-b), 2(a-b), 3(a-b) & 4(a-b), respectively.

Table 1a Particle size distribution, textural class and bulk density of initial soil of the experimental field, Joydebpur

Soil depth (cm)	Particle size distribution			Textural class	Bulk density (g cm^{-3})
	Sand%	Silt%	Clay%		
0-15	51.00	23.48	25.52	Sandy clay loam	1.39
15-30	46.00	24.48	29.52	Sandy clay loam	1.41

Table 1b Initial soil pH, SOM, total N, available K, P, S, Zn and B contents of the experimental field, Joydebpur

Soil depth (cm)	pH	SOM	Total N	Available other nutrients				
		(%)		K	P	S	Zn	B
				(c mol kg^{-1} soil)	(mg kg^{-1})			
0-15	6.3	1.02	0.055	0.12	8.0	15.0	0.90	0.15
15-30	6.4	0.99	0.052	0.11	7.4	13.4	0.85	0.13
Composite	Slightly acidic	Low	Very Low	Low	Low	Low	Low	Very low

Table 2a Particle size distribution, textural class and bulk density of initial soil of the experimental field, Jashore

Soil depth (cm)	Particle size distribution			Textural class	Bulk density (g cm^{-3})
	Sand%	Silt%	Clay%		
0-15	53.00	24.28	22.72	Sandy clay loam	1.42
15-30	55.00	23.28	21.72	Sandy clay loam	1.44

Table 2b Initial soil pH, SOM, total N, available P, K, S, Zn and B contents of the experimental field, RARS, Jashore

Soil depth (cm)	pH	SOM	Total N	Available other nutrients				
		(%)		K	P	S	Zn	B
				(c mol kg^{-1} soil)	(mg kg^{-1})			
0-15	7.6	1.27	0.065	0.18	13.0	14	0.56	0.16
15-30	7.7	1.25	0.062	0.16	12.0	13	0.53	0.14
Composite	Slightly alkaline	Low	Very Low	Low	Low	Low	Low	Low

Table 3a Particle size distribution, textural class, bulk density and soil moisture content of initial soil of the experimental field, RARS, Ishurdi

Soil depth (cm)	Particle size distribution			Textural class	Bulk density (g cm^{-3})	Soil moisture (%)
	Sand%	Silt%	Clay%			
0-15	56.00	24.28	19.72	Sandy loam	1.43	13.8
15-30	57.00	25.28	17.72	Sandy loam	1.45	13.3

Table 3b Initial soil pH, SOM, total N, available K, P, S, Zn and B contents of the experimental field, RARS, Ishurdi

Soil depth (cm)	pH	SOM	Total N	Available other nutrients				
		(%)		K	P	S	Zn	B
				(c mol kg^{-1} soil)	(mg kg^{-1})			
0-15	7.3	1.25	0.065	0.30	16.2	16	0.57	0.17
15-30	7.2	1.22	0.061	0.28	14.5	14	0.54	0.15
Composite	Neutral	Low	Very Low	Optimum	Medium	Medium	Low	Low

Table 4a Particle size distribution, textural class and bulk density of initial soil of the experimental field, Rajbari district

Soil depth (cm)	Particle size distribution			Textural class	Bulk density (g cm^{-3})
	Sand%	Silt%	Clay%		
0-15	58.00	27.48	14.52	Sandy loam	1.53
15-30	60.00	26.48	13.52	Sandy loam	1.55

Table 4b Initial soil pH, SOM, total N, available K, P, S, Zn and B contents of the experimental field of Rajbari district

Soil depth (cm)	pH	OM	Total N	Available other nutrients				
		%		K	P	S	Zn	B
				(c mol kg^{-1} soil)	(mg kg^{-1})			
0-15	8.1	1.09	0.060	0.15	7.2	13	0.25	0.15
15-30	8.2	1.03	0.056	0.14	7.0	12	0.21	0.13
Composite	Slightly alkaline	Low	Very Low	Medium	Low	Medium	Very Low	Low

Implementation:

Experiment No. 01. Effect of minimum tillage and crop residue retention on soil physico-chemical properties and crop yields under a rice-based cropping system

Objectives:

The present study was undertaken in context of the following objectives:

i. To observe the effects of tillage and crop residue retention on soil physico-chemical properties and crop yields in the rice–based cropping system.

ii. To find out the better combination in tillage system with residue retention levels for higher crop yield and better soil health.

iii. To assess the system productivity in rice-based cropping system.

Materials and practices

Description of experimental site

The experiment was initiated at Joydebpur Central Farm, Gazipur and RARS, Jashore in 2017-18.The study area was under the agro-ecological zone "Madhupur Tract" (AEZ-28) and "High Ganges River Floodplain" (AEZ-11).

Treatments and design

The unit experimental plot area was 7.2 m × 3.5 m at Joydebpur and 7.2 m × 5.0 m at Jashore and the design of the experiment was split-plot with four replications. Two tillage practices, such as, T_1: conventional tillage (CT) and T_2: strip tillage (ST) were assigned in main plot and two levels of crop residue retention was distributed as R_1: 30 cm crop residue retention and R_0: removal of crop residue (farmers' practice) in sub-plot.

Land preparation, fertilizer application, seedling transplantation and intercultural operations

At the initiation of the experiment, the plots were separated from each other according to the layout. Strip tillage was done by power tiller operated seeder (PTOS) with one pass whereas conventional tillage was by power tiller with two passes followed by two laddering.

The rates of application of chemical fertilizers at Joydebpur and Jashore sites were $N_{68}P_8K_{48}S_7Zn_1$ and $N_{66}P_7K_{33}S_8Zn_1$ for T. aman rice, $N_{136}P_{25}K_{80}S_{10}Zn_{1.5}B_{1.0}$ and $N_{131}P_{16}K_{60}S_{11}Zn_2B_1$ kg ha^{-1} for wheat whereas $N_{20}P_{22}K_{32}S_{12}Zn_1B_1$ and $N_{20}P_{14}K_{24}S_{13}Zn_2B_1$ for mungbean, respectively according to STB following FRG (BARC, 2012. Urea, TSP, MoP, Gypsum, $ZnSO_4$ and H_3BO_3 fertilizers were applied as the sources of N, P, K, S, Zn and B, respectively.

For T. aman rice, all fertilizers except urea were applied as basal dose and urea was applied at 3 equal splits at 6 days after transplanting (DAT), 28 DAT and 46 DAT. In case of wheat, whole amount of the fertilizers except urea was applied as basal dose whereas urea was applied in three equal splits at 7, 29 and 52 days after sowing (DAS). For mungbean, whole amount of fertilizers was applied as basal dose.

Varieties of the tested crops used in the experiments were BRRIdhan 72 of T. aman for Joydebpur and BRRIdhan 57 of T. aman for RARS, Jashore, BARI Gom 30 of wheat and BARI Mung 6 of mugbean. The T. aman seedlings were transplanted on 07 & 06 August 2017 maintaining 20 cm × 20 cm spacing, wheat seeds were sown on 17 & 27 November of 2017 at 20 cm apart from rows continuously, whereas mungbean seeds were sown on 25 and 28 March 2018 at Joydebpur and Jashore, respectively. Wheat and mungbean seeds were sown by using PTOS machine.

After that hand weeding in wheat (just uprooting the weeds by hand, therefore, no soil pulverization occurred in ST practice) was done once only at 28th DAS. No pesticide or insecticides were applied.

Crop harvesting and data collection

T. aman rice was harvested on 15 November 2017 at both locations, wheat was harvested on 15 & 21 March of 2018 at Joydebpur and Jashore, respectively and due to heavy rainfall, the mungbean was damaged at Joydebpur and first picking of mungbean was started on 25 May 2018 at Jashore. Two square meter area from each plot was selected for data collection. Ten plants of each plot were selected randomly for recording yield contributing data. Thousand grains weight was measured plot wise. The whole plant was cut at ground level from R_0 plots whereas 30 cm of wheat straw was retained in the R_1 plots. The grain and straw was separated, sun-dried and weighed from 1.0 m^2 area of each plot. The amount of residue retained in the R_1 plots was collected from 1.0 m^2 area. Finally, the grain and straw were converted into t ha^{-1}.

Statistical analysis

All the crop data and soil properties at selected depths were statistically analyzed using a split-plot design. Treatment effects on measured variables were tested by analysis of variance (ANOVA), and comparisons among treatment means were made using the least significant difference (LSD) multiple range test calculated at 5% level of probability ($P \leq 0.05$). Statistical procedures were carried out with the software program Statistix 10™.

11. Results and Discussion

1st Crop: T. aman rice

Effect of tillage practices and residue retention on the yield of T. aman rice (BRRIdhan 72) at Joydebpur

Tillage practices and crop residue retention levels showed no significant variations on the yields of T. aman grain and straw with harvest index. However, numerically but not significantly higher yields (4.60 t ha^{-1} grain & 5.08 t ha^{-1} straw) were recorded in ST practice and lower yields (4.41 t ha^{-1} grain & 4.71 t ha^{-1} straw) was recorded in CT practice (Table 5). Similar finding was found by Salahin et al. (2017) who noted that grain and straw yield did not vary ($p > 0.05$) among the tillage practices.

Statistically similar grain and straw yield was noted in both residue retention (4.60 t ha^{-1} grain & 4.98 t ha^{-1} straw) and residue removal treatment (4.41 t ha^{-1} grain & 4.81 t ha^{-1} straw), shown in Table 5.

The harvest index showed insignificant differences between two tillage practices and crop residue retention levels (Table 5). Under the residue retention treatment, 2.66 t ha^{-1} residue of T. aman was retained on the soil over removal.

Table 5 Effects of tillage practices and residue retention on grain and straw yields with harvest index and amount of retained residue of T. aman at Joydebpur

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Residue retained (t ha^{-1})
Tillage practices				
Conventional tillage (CT)	4.41	4.71	48.4	1.40
Strip tillage (ST)	4.60	5.08	47.5	1.26
$LSD_{0.05}$ value	1.24^{ns}	1.05^{ns}	1.7^{ns}	0.27^{ns}
Residue retention levels				
Residue retention (R_1)	4.60	4.98	48.0	2.66 a
Residue removal (R_0)	4.41	4.81	47.8	0.00 b
$LSD_{0.05}$ value	0.62^{ns}	0.47^{ns}	1.6^{ns}	0.18**
CV (%)	11.23	7.90	2.66	11.13

Effect of tillage practices and residue retention on yield of T. aman rice (BRRIdhan 57) at RARS, Jashore

Tillage practices and crop residue retention levels showed no significant variations on the yields of T. aman grain and straw with harvest index. However, numerically but not significantly higher yields (5.24 t ha^{-1} grain & 5.28 t ha^{-1} straw) were recorded in ST practice and lower yields (4.98 t ha^{-1} grain & 5.15 t ha^{-1} straw) was recorded in CT practice (Table 6).

Statistically similar grain and straw yield was obtained in both residue retention (5.20 t ha^{-1} grain & 5.13 t ha^{-1} straw) and residue removal treatment (5.02 t ha^{-1} grain & 5.30 t ha^{-1} straw), shown in Table 6.

The harvest index showed insignificant differences between two tillage practices and crop residue retention levels (Table 6). Under the residue retention treatment, 2.17 t ha^{-1} T. aman residue was retained on the soil over removal.

Table 6 Effects of tillage practices and residue retention on grain and straw yields with harvest index and amount of retained residue of T. aman at RARS, Jashore

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Residue retained (t ha^{-1})
Tillage practices				
Conventional tillage (CT)	4.98	5.15	49.0	1.19
Strip tillage (ST)	5.24	5.28	49.8	0.98
$LSD_{0.05}$ value	1.28^{ns}	0.89^{ns}	6.0^{ns}	0.49^{ns}
Residue retention levels				
Residue retention (R_1)	5.20	5.13	50.3	2.17 a
Residue removal (R_0)	5.02	5.30	48.6	0.00 b
$LSD_{0.05}$ value	0.74^{ns}	0.50^{ns}	5.4^{ns}	0.30**
CV (%)	11.86	7.91	8.95	22.87

2^{nd} Crop: Wheat

Effect of tillage practices and residue retention on weed biomass in wheat field

Prior to the first wheat crop, *glyphosate (*trade name 'round up'*),* apost-emergence herbicide, was applied throughout the plots. Tillage practices had significant effects on weed infestation at RARA, Jashore but not at Joydebpur. Higher weed biomass (53 g m^{-2}) was observed in strip tilled plots over conventional tilled plots (36 g m^{-2}) at Jashore (Table 7).

Previous crop residue retention/incorporation showed significant variations in weed biomass at both locations. Higher amount of weed biomass (79 g m^{-2} at Joydebpur and 49 g m^{-2} at Jashore) was recorded under the residue retention/incorporation plots over residue removal (R_1) plots (51 g m^{-2} at Joydebpur and 41 g m^{-2} at Jashore), as shown in Table 7.

Table 7 Effects of tillage practices and residue retention on weed biomass (g m^{-2}) of wheat at Joydebpur and RARS, Jashore

Treatments	At Joydebpur	At RARS, Jashore
Tillage practices		
Conventional tillage (CT)	62	36 b
Strip tillage (ST)	68	53 a
$LSD_{0.05}$ value	22^{ns}	9**
Residue retention levels		
Residue retention (R_1)	51 b	41 b
Residue removal (R_0)	79 a	49 a
$LSD_{0.05}$ value	15**	4**
CV (%)	18.78	6.61

Effects of tillage practices and residue retention on the dry root weight of wheat

Root weight of wheat at Joydebpur was not significantly influenced by tillage practices and residue retention at Joydebpurand at Jashore (Table 8).

Table 8 Effects of tillage practices and residue retention on dry root weight (g $plant^{-1}$) of wheat at Joydebpur and at RARS, Jashore

Treatments	At Joydebpur	At RARS, Jashore
Tillage practices		
Conventional tillage (CT)	3.60	3.91
Strip tillage (ST)	3.96	4.28
$LSD_{0.05}$ value	0.53^{ns}	0.6^{ns}
Residue retention levels		
Residue retention (R_1)	3.82	4.12
Residue removal (R_0)	3.74	4.07
$LSD_{0.05}$ value	0.07^{ns}	0.2^{ns}
CV (%)	1.60	3.54

Effect of tillage and residue retention on the yield of wheat

The different tillage practices showed significant variations on the grain yield of wheat at RARS, Jashore (Table 10) but not at Joydebpur (Table 9). Significantly higher grain yield (3.91 t ha^{-1}) was observed in ST practice than CT (3.00 t ha^{-1}) at RARS, Jashore, as presented in Table 10. On the otherexperimental site at Joydebpur, numerically higher grain yield (4.08 t ha^{-1}) was noted in ST treatment and lower grain yields (3.81 t ha^{-1}) was recorded in CT practice (Table 9).

Residue retention levels showed insignificant variations in the grain yield at both locations. However, residue retention treatment gave the numerically higher grain yield than residue removal treatment.Similar results found by Sidhu and Hur (1993)who stated that the residue management treatments had non-significant effects on the succeeding crop yield in all the years.

Statistically similar straw yield of 4.47 & 4.21 t ha^{-1}at Joydebpur and 4.38 & 4.20 t ha^{-1} at Jashore wererecorded under ST practice and CT practices, respectively (Table 9& Table 10).

The harvest index (HI) showed significant differences between two tillage practices at RARS, Jashore (Table 10) and higher HI was recorded in ST (48.2%) than CT (41.7%).

The amount of wheat residue retained by weight significantly varied due to variation of residue retention levels. Higher amount of residue was retained in R_1 treatment where 30 cm of residue was kept on the soil (2.55 & 2.10 t ha^{-1} at Joydebpur & Jashore, respectively), as presented in Table 9& 10.

Table 9 Effects of tillage practices and residue retention on grain and straw yields with harvest index of wheat at Joydebpur

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Straw retained (t ha^{-1})
Tillage practices				
Conventional tillage (CT)	3.81	4.38	46.5	1.22
Strip tillage (ST)	4.08	4.47	47.7	1.33
$LSD_{0.05}$ value	0.49^{ns}	0.91^{ns}	6^{ns}	0.41^{ns}
Residue retention levels				
Residue retention (R_1)	3.96	4.59	46.3	2.55 a
Residue removal (R_0)	3.92	4.25	48.0	0.00 b
$LSD_{0.05}$ value	0.56^{ns}	0.46^{ns}	5^{ns}	0.40^{**}
CV (%)	11.62	8.53	8.91	25.87

Table 10 Effects of tillage practices and residue retention on grain and straw yields with harvest index of wheat at Jashore

Treatments	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest index (%)	Straw retained ($t\ ha^{-1}$)
Tillage practices				
Conventional tillage (CT)	3.00 b	4.20	41.7 b	0.98
Strip tillage (ST)	3.91 a	4.21	48.2 a	1.12
$LSD_{0.05}$ value	0.53*	0.52^{ns}	2.7*	0.29^{ns}
Residue retention levels				
Residue retention (R_1)	3.68	4.37	45.7	2.10 a
Residue removal (R_0)	3.23	4.04	44.4	0.00 b
$LSD_{0.05}$ value	0.56^{ns}	0.72^{ns}	3.8^{ns}	0.26^{**}
CV (%)	13.34	14.00	6.83	20.40

Effects of tillage practices and residue retention on soil moisture content (%) during the wheat growing season

Soil moisture was determined at wheat sowing, at 20, 50, 70 days after sowing (DAS) and at the harvesting time. Initially, soil moisture content was 27.6% in ST, 27.8% in CT and 28.0% in residue retained plot and 27.4% in residue removal plot at Joydebpur. Soil moisture content did not varyremarkably due to the variation of tillage practices throughout the growing season of wheat but it varied considerably at 50 and 70 DAS by keeping the residue. Higher soil water was recorded in the residue retained plots than residue removal plots (Table 11).Salahin et al. (2017) found the similar results thatthe moisture content increased due to previous crop residue retention.

On the other hand, initially, soil moisture content was 19.4% in ST, 19.1% in CT, 19.5% in residue retained and 19.0% in residue removed plot at RARS, Jashore. Soil moisture varied by residue retention levels at 20, 50 and 70 DAS whereas at 50 and 70 DAS by tillage practices. Higher soil water content was recorded in ST (23.8 & 21.6%) and lower values were in CT practice (19.9 & 17.7%) at 50 and 70 DAS, respectively. Residue retention conserved more moisture content than residue removal at 20, 50 and 70 DAS (Table 12). Hartwig & Ammon (2002) stated that when cover crop residues left on the surface, conserve soil moisture by reducing evaporation. Results obtained from the works of Rahman et al. (2005) showed that rice straw mulching had a significant effect on moisture conservation in minimum or no-till wheat fields.

Several authors have mentioned that water storage capacity (WSC) in soil increased under minimum/conservation tillage practices compared to CT due to lower evaporation loss from the ground surface with increased residue retention (Brady and Weil, 2008; Singh and Kaur, 2012).

Table 11 Effects of tillage and residue retention on soil moisture content (%) in wheat field at Joydebpur

Treatment	At 20 DAS (07 Dec. 2017)	At 50 DAS (06 Jan. 2018)	At 70 DAS (25 Jan. 2018)	At harvest (15 March 2018)
Tillage practices				
Conventional tillage (CT)	38.5	22.0	17.6	12.3
Strip tillage (ST)	37.4	21.8	18.8	13.0
$LSD_{0.05}$ value	15^{ns}	5.1^{ns}	3.3^{ns}	2.0^{ns}
Residue retention levels				
Residue retention (R_1)	39.2	23.0 a	19.1 a	12.7
Residue removal (R_0)	36.6	20.7 b	17.3 b	12.6
$LSD_{0.05}$ value	3.0^{ns}	1.4**	1.5*	1.5^{ns}
CV (%)	6.41	5.19	6.64	9.95
Initial soil moisture	ST = 27.6% & CT = 27.8% and R^+ = 28.0% & R^- = 27.4%			

Table 12 Effects of tillage and residue retention on soil moisture content (%) in wheat field at RARS, Jashore

Treatment	At 20 DAS (17 Dec. 2017)	At 50 DAS (16 Jan. 2018)	At 70 DAS (05 Feb. 2018)	At harvest (21 March 2018)
Tillage practices				
Conventional tillage (CT)	15.6	19.9 b	17.7 b	22.8
Strip tillage (ST)	16.6	23.8 a	21.6 a	22.4
$LSD_{0.05}$ value	3.2^{ns}	3.0*	3.6*	8.6^{ns}
Residue retention levels				
Residue retention (R_1)	16.4 a	22.5 a	20.2 a	22.4
Residue removal (R_0)	15.7 b	21.2 b	19.1 b	21.7
$LSD_{0.05}$ value	0.3**	0.7**	0.6**	1.2^{ns}
CV (%)	1.69	2.60	2.47	4.40
Initial soil moisture	ST = 19.4% & CT = 19.1% and R^+ = 19.5% & R^- = 19.0%			

3rd Crop: Mungbean

Effects of tillage practices and residue retention on grain and green biomass yields of mungbean during 2017 at Joydebpur

Due to unexpected rainfall during mungbean growing period at Joydebpur, mungbean crop was damaged.

Effects of tillage practices and residue retention on grain and green biomass yields of mungbean during 2018 at RARS, Jashore

Tillage practices and residue retention had no significant effect on grain and green biomass yields of mungbean during 2018 at RARS, Jashore (Table 13).

Table 13 Effects of tillage and residue retention on grain and green biomass yields of mungbean during 2018 at RARS, Jashore

Treatments	Seed yield (kg ha^{-1})	Green biomass yield (t ha^{-1})
Tillage practices		
Conventional tillage (CT)	800	9.9
Strip tillage (ST)	885	9.2
$LSD_{0.05}$ *value*	125^{ns}	1.3^{ns}
Residue retention levels		
Residue retention (R_1)	869	9.9
Residue removal (R_0)	816	9.2
$LSD_{0.05}$ *value*	57^{ns}	1.0^{ns}
CV (%)	5.50	8.94

Effects of tillage practices and residue retention on cropping system productivity

Cropping system productivity refers to the total yields of the crops grown in sequence in the same piece of land in a year, expressed as, rice equivalent yield (REY). Tillage practices showed significant variations in REY at RARS, Jashore. Higher REY was observed in strip tillage (12.1 t ha^{-1}) than that of conventional tillage (10.5 t ha^{-1}) at RARS, Jashore, shown in Table 14.

Table 14 Effects of tillage practices and residue retention on cropping system productivity, REY (t ha^{-1})

Treatments	At Joydebpur	At RARS, Jashore
Tillage practices		
Conventional tillage (CT)	9.50	10.5 b
Strip tillage (ST)	9.85	12.1 a
$LSD_{0.05}$ *value*	0.42^{ns}	1.4*
Residue retention levels		
Residue retention (R_1)	9.75	11.8
Residue removal (R_0)	9.60	10.8
$LSD_{0.05}$ *value*	1.09^{ns}	1.0^{ns}
CV (%)	9.24	7.05

Note: Market prices of rice was Tk. 20.00 kg^{-1}, wheat was Tk. 25.00 kg^{-1}& mung bean was Tk. 45.00

Total residue retained in the plots under different tillage and residue retention treatment

Due to heavy rainfall, mungbean was damaged at Joydebpur. From two crops (T. aman and wheat), 2.62 and 2.59 t ha^{-1} residues were retained in CT and ST practice, respectively. On the other hand, three crops were grown at RARS, Jashore during 2017-18 year and total 12.7 and 14.2 t ha^{-1} residues was retained in CT and ST practice, respectively (Table 15). The total amount of residue retention was significantly higher in increased residue retention treatment (5.21 t ha^{-1} at Joydebpur and 16.1 t ha^{-1} at RARS, Jashore) over residue removal treatment, shown in Table 15.

Table 15 Retention of residues by the component crops in the wheat –mungbean-T. aman rice cropping system

Treatments	Amount of residues retained (t ha^{-1})	
	At Joydebpur – 2 crops (T. aman and wheat)	At RARS, Jashore – 3 crops (T. aman, wheat & mungbean)
Tillage practices		
Conventional tillage (CT)	T. aman: 1.40 t ha^{-1} Wheat: 1.22 t ha^{-1} ***Total: 2.62 t ha^{-1}***	T. aman: 1.19 t ha^{-1}, Wheat: 0.98 t ha^{-1} Mungbean green biomass: 10.5 t ha^{-1} ***Total: 12.7 t ha^{-1}***
Strip tillage (ST)	T. aman: 1.26 t ha^{-1} Wheat: 1.33 t ha^{-1} ***Total: 2.59 t ha^{-1}***	T. aman: 0.98 t ha^{-1}, Wheat: 1.12 t ha^{-1} Mungbean green biomass: 12.1 t ha^{-1} ***Total: 14.2 t ha^{-1}***
Residue retention levels		
Residue retention (R_1)	T. aman: 2.66 t ha^{-1} Wheat: 2.55 t ha^{-1} ***Total: 5.21 t ha^{-1}***	T. aman: 2.17 t ha^{-1}, Wheat: 2.10 t ha^{-1} Mungbean green biomass: 11.8 t ha^{-1} ***Total: 16.1 t ha^{-1}***
Residue removal (R_0)	0	0

Effect of tillage practices and residue retention on soil microbial population

Soil microbial population was determined after wheat harvest at Joydebpur and RARS, Jashore. The total number of microbes varied due to tillage practices and crop residue retention. The highest microbial population in soil was recorded under ST with residue retention followed by CT with residue retention, ST with residue removal and the lowest microbial population in soil was recorded under CT with residue removal at both the locations (Table 16 and Table 17).

Under strip tillage system, plant residues left at or near the soil surface encourage fungal growth and the temporary immobilization of nutrients (Pankhurst *et al.*, 2002). An increase in the proportion of microbial biomass attributable to fungi was found in reduced tillage (Frey *et al.*, 1999). It was observed that microbial population in soil directly related to organic matter and total N accumulation in soil. Our results are similar to Sumpam *et al.* (2009) who stated that **s**oil organic C and total N concentration had correlation with the microbial colony forming units. On the other hand, soil organic matter is a resource for soil biota and there is a strong relationship between the abundance of soil organisms and the content of organic matter and many soil organisms receive benefits because of a reduction in soil disturbance and an increase in surface crop residues (Nakamoto et al., 2006).

Table 16 Effect of tillage and residue retention on soil microbial population at Joydebpur

Treatment	Mycorrhizal spore (per 100g soil)	Rhizobium	PSB	Azotobacter
		cfu/ g soil		
CT × R_1	62 ± 10.16	1.6×10^4	8.8×10^4	1.8×10^5
CT × R_0	37 ± 6.78	2.5×10^3	8.7×10^4	7.1×10^4
ST × R_1	64 ± 9.05	2.8×10^4	8.2×10^5	7.2×10^5
ST × R_0	54 ± 5.14	3.8×10^3	9.6×10^4	1.1×10^5

Table 17 Effect of tillage and residue retention on soil microbial population at RARS, Jashore

Treatment	Mycorrhizal spore (per 100g soil)	Rhizobium	PSB	Azotobacter
		cfu/ g soil		
CT × R_1	83 ± 6.5	5.0×10^3	2.5×10^4	1.7×10^5
CT × R_0	75 ± 8.9	1.5×10^3	5.2×10^4	3.8×10^4
ST × R_1	92 ± 6.8	1.8×10^4	1.7×10^4	3.0×10^5
ST × R_0	82 ± 15.4	4.3×10^3	1.5×10^5	4.2×10^4

Effects of tillage practices and residue retention on soil bulk density (BD)

At both the locations, tillage practices and residue retention levels had no significant effect on soil bulk density (BD) after 1-year and soil BD value remained unchanged at 0-15 cm soil depth (Table 18).

Table 18 Effects of tillage and residue retention on soil bulk density (g cm^{-3}) after 1-year

Treatments	At Joydebpur	At RARS, Jashore
Tillage practices		
Conventional tillage (CT)	1.41	1.42
Strip tillage (ST)	1.42	1.44
Residue retention levels		
Residue retention (R_1)	1.41	1.42
Residue removal (R_0)	1.42	1.44
$LSD_{0.05}$ value	Tillage = 0.06^{ns} and residue = 0.01^{ns}	Tillage = 0.03^{ns} and residue = 0.03^{ns}
CV (%)	0.63	1.62

Effect of tillage practices and residue retention levels on chemical properties of post-harvest soil

After 1- crop cycle, regardless of tillage practices, crop residue retention showed significant variations in chemical properties of post-harvest soil at both the locations. Previous crop residue retention treatment gave higher values of SOM, TN, available P, K, S, Zn, B contents over residue removal treatment, presented in Table 19 and Table 20.

Higher available nitrogen content with application of rice residues could be attributed to addition of crop residue and reduction of nitrogen loss in residues incorporated plots by forming organo-mineral complexes (Das et al., 2003). Some studies also found improvement in soil nitrogen with the addition of crop residues as compared to crop residue removal (Kharub et al., 2004).

Table 19 Effects of tillage practices and residue retention levels on SOM, total N, available P, K, S, Zn and B contents of the post-harvest soil of Joydebpur

Treatments	OM	TN	Available other nutrients				
			K	P	S	Zn	B
	(%)		(c mol kg $^{-1}$soil)	(µg ml^{-1})			
Tillage practices							
Conventional tillage	1.11	0.060	0.17	8.8	17.9	1.02	0.18
Strip tillage	1.18	0.063	0.18	9.4	18.8	1.06	0.22
$LSD_{0.05}$ value	0.09^{ns}	0.003^{ns}	0.01^{ns}	1.3^{ns}	1.08^{ns}	0.06^{ns}	0.05^{ns}
Residue retention levels							
Residue retention	1.17 a	0.064 a	0.19 a	9.5 a	19.1 a	1.08 a	0.22 a
Residue removal	1.12 b	0.059 b	0.17 b	8.7 b	17.6 b	0.99 b	0.18 b
$LSD_{0.05}$ value	0.02^{**}	0.001^{**}	0.004^{**}	0.7^{*}	0.7**	0.04^{**}	0.01**
CV (%)	1.63	1.13	1.98	6.12	3.04	2.83	4.48
Initial	1.02	0.055	0.12	8.0	15.0	0.90	0.15

Table 20 Effects of tillage practices and residue retention levels on SOM, total N, available P, K, S, Zn and B contents of the post-harvest soil of RARS, Jashore

Treatments	OM	TN	Available other nutrients				
			K	P	S	Zn	B
	(%)		(c mol kg $^{-1}$ soil)	(µg ml^{-1})			
Tillage practices							
Conventional tillage	1.25	0.064	0.21	13.3	16.5	0.67	0.21
Strip tillage	1.29	0.070	0.23	13.9	17.2	0.79	0.23
$LSD_{0.05}$ value	0.24^{ns}	0.014^{ns}	0.07^{ns}	1.3^{ns}	1.1^{ns}	0.04^{ns}	0.04^{ns}
Residue retention levels							
Residue retention	1.35 a	0.072 a	0.25 a	14.0 a	17.4 a	0.78 a	0.23 a
Residue removal	1.19 b	0.062 b	0.20 b	13.2 b	16.3 b	0.67 b	0.21 b
$LSD_{0.05}$ value	0.10**	0.005^{**}	0.05^{*}	0.7**	0.5**	0.04^{**}	0.09^{**}
CV (%)	6.47	6.15	16.69	4.10	2.41	4.84	3.42
Initial	1.27	0.065	0.18	13.0	14.0	0.56	0.16

Rainfall occurred during the growing period of wheat at Joydebpur

In October, 2017 a considerable amount of rainfall (74 mm) occurred. Wheat seeds were sown on 17 November, 2017 followed by heavy rainfall of 11 mm. In December, 2017 a total amount of 32 mm rainfall was recorded (Table 21). There was no rainfall in January 2018 but 15 mm rainfall was noted in February, 2018 and thereafter there was no rainfall till the harvest of wheat.

Table 21 Rainfall data (mm) in the wheat growing period at Joydebpur

Month	Rainfall (mm)	Month	Rainfall (mm)
October 2017	74	07 Jan-18	0
05 Nov-17	1	14 Jan-18	0
12 Nov-17	0	21 Jan-18	0
19 Nov-17	1	28 Jan-18	0
26 Nov-17	9	04 Feb-18	0
03 Dec-17	8	11 Feb-18	0
10 Dec-17	22	18 Feb-18	0
17 Dec-17	2	25 Feb-18	15
24 Dec-17	0	04 Mar-18	0
31 Dec-17	0	11 Mar-18	0

Profitability of growing crops under different tillage practices and residue retention levels in the wheat - mungbean - T. aman rice cropping pattern

Relative profitability of T. aman rice, wheat and mungbean production is presented in Table 22, 23 and 24. The net returns (NR) were highest for ST with crop residue retention combinations than the other treatment combinations. On the other hand, the highest BCR was found in ST× residue retention combinations and the lowest BCR was recorded in CT× residue removal combinations in both locations.

Table 22 Profitability of T. aman rice production under different tillage practices and residue retention levels

Particular	Joydebpur				Jashore			
	ST		CT		ST		CT	
	Residue retention	Residue removal	Residue retention	Residue removal	Residue retention	Residue removal	Residue retention	Residue removal
Gross return (Tk. ha^{-1})	99545	97625	97475	95340	112215	110535	109645	107710
Total input cost (Tk. ha^{-1})	65552	65552	66000	65440	68887	68327	68215	68215
Net return (Tk. ha^{-1})	33993	32073	31475	29900	43328	42208	41430	39495
BCR	1.52	1.49	1.48	1.46	1.63	1.62	1.61	1.58

Table 23 Profitability of wheat production under different tillage practices and residue retention levels

Particular	Joydebpur				Jashore			
	ST		CT		ST		CT	
	Residue retention	Residue removal	Residue retention	Residue removal	Residue retention	Residue removal	Residue retention	Residue removal
Gross return (Tk. ha^{-1})	105030	104360	101740	101070	99290	93380	87790	81620
Total input cost (Tk. ha^{-1})	66021	66581	67029	67589	63541	63541	64549	64549
Net return (Tk. ha^{-1})	39009	37779	34711	33481	35749	29839	23241	17071
BCR	1.59	1.57	1.52	1.50	1.56	1.47	1.36	1.26

Table 24 Profitability of mungbean production under different tillage practices and residue retention levels

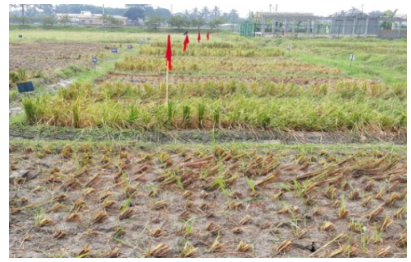
Particular	Jashore			
	ST		CT	
	Residue retention	Residue removal	Residue retention	Residue removal
Gross return(Tk. ha^{-1})	84975	82225	82425	79800
Total input cost(Tk. ha^{-1})	44116	44676	44340	44900
Net return(Tk. ha^{-1})	40859	37549	38085	34900
BCR	1.93	1.84	1.86	1.78

Conclusions:

At RARS, Jashore, ST and residue retention conserved more soil moisture content at 20 DAS (CRI), 50 DAS (spike initiation) and 70 DAS (grain filling) in soils in wheat field at dry condition. With this synergistic effect of strip tillage, longer spike length and higher number of spikelets spike^{-1} of wheat were obtained than conventional tillage. Consequently, statistically higher grain yield of wheat (3.91 t ha^{-1}) was found over CT practice (3.0 t ha^{-1}) at RARS, Jashore. But tillage and residue retention had no significant influence on the yield and yield attributes of wheat at Joydebpur. On the other hand, tillage practices and residue retention had no significant effect on the previous crops mungbean and T. aman. Statistically higher REY was observed in strip tillage than conventional tillage at RARS, Jashore. After 1-year, tillage practices and residue retention had no significant effect on soil bulk density but increased residue retention showed increment of all nutrient contents and microbial population in soil over residue removal treatment.

Pictorial view of the experiment regarding to experiment No. 01 (Effect of minimum tillage and crop residue retention on soil physico-chemical properties and crop yields under a rice-based cropping system)

Locations: BARI Central Farm, Gazipurand RARS, Jashore

BARI Central Farm, Gazipur-T. aman rice

BARI Central Farm, Gazipur-Wheat

At RARS, Jashore

Evaluation team of BARI visited the wheat field

Monitoring team of BARC visited the wheat field

Prof. R. W. Bell, MU, Australiavisited the wheat field

Experiment No. 02. Effect of tillage and nitrogen on the Mustard- Boro- T. aman rice cropping system under conservation agriculture practice

Objectives:

The present study was carried out to fulfill the following objectives:

i). to determine the optimum rate of nitrogen fertilizer for the intensive Mustard- Boro- T. aman cropping system under minimum tillage practice,

ii). to evaluate the effects of tillage and nitrogen fertilizer on soil physico-chemical properties and crop yields in the rice–based cropping system, and

iii). to assess the system productivity in the intensive rice-based cropping system.

Materials and practices

Description of experimental site

The experiment was conducted at BARI Central Research Farm, Joydebpur and RARS, Ishurdi in 2017-2018.The study area was under the agro-ecological zone "Madhupur Tract" (AEZ-28) and "High Ganges River Floodplain" (AEZ-11).

Treatments and design

The unit experimental plot area was 7.2 m × 3.5 m at Joydebpur and 7.2 × 4.0 m at RARS, Ishurdi and the design of the experiment was split-plot with three replications. Two tillage practices such as, T_1: conventional tillage (CT) and T_2: strip tillage (ST) were assigned in main plot and three levels of N fertilizer, such as N_1: 75% of recommended N-fertilizer dose (RND), N_2: 100% of recommended N-fertilizer dose (RND) and N_3: 125% of recommended N-fertilizer dose (RND) was allotted in sub-plot.

Sowing/transplanting

At initiation of the experiment, the plots were separated from each other according to the layout. Strip tillage was done by power tiller operated seeder (PTOS) with one pass whereas conventional tillage was by power tiller with two passes followed by two laddering.

Thirty days aged T. aman rice seedlings (cv. BRRIdhan 72) were transplanted on 02 & 10 August 2017, maintaining 20 cm × 20 cm spacing, mustard seeds (cv. BARI Sharisha 14) were sown on 16th and 29th November 2017 at 30 cm apart from rows continuously and forty days aged Boro rice seedlings (cv. BRRIdhan 28) were transplanted on 14 & 20 March 2018 maintaining 20 cm × 20 cm spacing at Joydebpur and Ishurdi, respectively. The rates of chemical fertilizers were $N_{68}P_8K_{48}S_7Zn_1$ kg ha^{-1} for T. aman, $N_{102}P_{22}K_{54}S_{10}Zn_1B_{0.5}$ kg ha^{-1} for mustard and $N_{153}P_{13}K_{72}S_{12}Zn_1$ kg ha^{-1} for Boro at Joydebpur, whereas the rates were $N_{66}P_7K_{33}S_8Zn_1$kg ha^{-1} for T. aman, $N_{131}P_{21}K_{64}S_{19}Zn_3B_1$kg ha^{-1} for mustard and $N_{148}P_8K_{56}S_{15}Zn_2$kg ha^{-1} for Boro at RARS, Ishurdi according to STB following FRG (BARC, 2012).

For T. aman rice, all fertilizers except urea were applied as basal dose and urea was applied at 3 equal splits at 5 DAT, 30 DAT and 48 DAT. In case of mustard, whole amount of the fertilizers with half amount urea of respective N-levels was applied as basal dose whereas rest half amount of urea was applied at 25 days after sowing (DAS). After that, hand weeding in mustard (just uprooting the weeds by hand, therefore, no soil pulverization occurred in ST practice) was done once only at 24th DAS. For Boro rice, all fertilizers except urea were applied as basal dose and urea was applied at 3 equal splits at 6 DAT, 35 DAT and 52 DAT.

Crop harvesting and data collection

T. aman rice was harvested on 13 & 16 November 2017, mustard was harvested on 19 Feb. & 01 March 2018 and Boro was harvested on 06 & 11 June 2018 at Joydebpur and Ishurdi, respectively. Two square meter area from each plot was selected for data collection. Ten (10) plants of each plot were selected for yield contributing characters. Thousand seed weights was determined plot wise. The plants were cut, then threshed, cleaned, sun-dried and weighed of grain and straw separately from 2.0 m^2 area of each plot. Finally, the grain and straw were converted into t ha^{-1}.

Results and Discussion

1st Crop: T. aman rice

Effect of tillage and N-levelson the yield of T. aman riceduring 2017 at Joydebpur

Tillage practices showed no significant variations on the yields of T. aman grain and straw with harvest index during 2017 at Joydebpur. However, numerically but not significantly higher grain yield (4.95 t ha^{-1}) was recorded in CT practice as compared to the grain yield (4.61 t ha^{-1}) recorded in ST practice On the other hand, vice-versa result was observed in straw yield (Table 25).

Different N-levels showed significant variations in grain and straw yield of T. aman rice at Joydebpur. Statistically the highest grain (5.10 t ha^{-1}) and straw yield (6.09 t ha^{-1}) were found in 125% of RND which was statistically identical 100% of RND (4.98 t ha^{-1} grain & 5.83 t ha^{-1} straw) and the lowest grain (4.27 t ha^{-1}) and straw (5.28 t ha^{-1}) were obtained in 75% of RND, as shown in Table 25.Jisan et al. (2014) found the highest grain (5.64 t ha^{-1}) yield in the increasing N dose was applied @ 75 kg ha^{-1} and observed 31.77 % and 15.92 % higher grain and straw yield over control treatment.

Harvest index showed insignificant differences between tillage practices and N-levels (Table 25).

Table 25 Effects of tillage practices and N-levels on grain and straw yield with harvest index of T. aman rice during 2017 at Joydebpur

Tillage practices	Grain yield (t ha^{-1})				Straw yield (t ha^{-1})				HI (%)			
	N-Levels											
	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*
CT	4.41	5.19	5.26	4.95	5.21	5.87	5.93	5.67	45.8	46.9	47.0	46.6
ST	4.13	4.77	4.93	4.61	5.34	5.80	6.25	5.80	43.6	45.1	44.1	44.3
Mean	4.27 b	4.98 a	5.10 a	-	5.28 b	5.83 a	6.09 a	-	44.7	46.0	45.6	-
$LSD_{0.05}$ value	Tillage=0.43^{ns}, N-level=0.15** and Tillage × N-level = 0.45^{ns}				Tillage = 0.50^{ns}, N-level=0.29** and Tillage × N-level =0.58^{ns}				Tillage = 4.2^{ns}, N-level = 1.7^{ns} and Tillage × N-level = 4.4^{ns}			
CV (%)	2.32				3.85				2.82			

Effects of tillage and N-levels on the yield of T. aman rice during 2017 at RARS, Ishurdi

Grain and straw yields of T. aman rice varied significantly due to different N-levels but not by tillage practices. The highest grain (6.24 t ha^{-1}) and straw (6.76 t ha^{-1}) were found in 125% of RND which was statistically identical to 100% of RND (5.87 t ha^{-1} grain & 6.44 t ha^{-1} straw). The lowest grain (5.47 t ha^{-1}) and straw yield (5.99 t ha^{-1}) were recorded in 75% of RND. The harvest index showed insignificant variations due to tillage practices and N-levels (Table 26).

Table 26 Effects of tillage practices and N-levels on grain and straw yield with harvest index (HI) of T. aman rice during 2017 at RARS, Ishurdi

Tillage practices	Grain yield (t ha^{-1})				Straw yield (t ha^{-1})				Harvest index (%)			
	N-Levels											
	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*
CT	5.33	5.88	6.09	5.77	6.01	6.51	6.57	6.36	47.0	47.5	48.0	47.5
ST	5.61	5.87	6.40	5.96	5.98	6.37	6.96	6.43	48.4	47.9	47.9	48.1
Mean	5.47 b	5.87 a	6.24 a	-	5.99 b	6.44 a	6.76 a	-	47.7	47.7	48.0	-
$LSD_{0.05}$ value	Tillage=0.59^{ns}, N-level=0.37** and Tillage × N-level = 0.7^{ns}				Tillage=0.35^{ns}, N level=0.42** and Tillage × N-level =0.57^{ns}				Tillage = 1.3^{ns}, N-level = 0.8^{ns} and Tillage × N-level =1.5^{ns}			
CV (%)	4.74				4.89				1.18			

2nd Crop: Mustard

Effects of tillage practices and N-levels on weed biomass (g m^{-2}) of mustard

Tillage practices did not show remarkable variations in weed biomass but different N-levels showed significant influences on weed biomass in mustard field during Rabi season of 2017-18 at both locations (Joydebpur and RARS, Ishurdi), as shown in Table 28. The highest weed infestation (140 g m^{-2} at Joydebpur and 144 g m^{-2} at Ishurdi) was recorded in N_3 treatment where 125% of recommended N fertilizer was applied followed by N_2 treatment (127 g m^{-2} at Joydebpur and 128 g m^{-2} at Ishurdi) and the lowest infestation (110 g m^{-2} at Joydebpur and 116 g m^{-2} at Ishurdi) was noted in N_1 treatment where 75% of recommended N fertilizer was applied (Table 28).

Table 28 Effects of tillage practices and N-levels on weed biomass (g m^{-2}) of mustard

Tillage practices	At Joydebpur				At RARS, Ishurdi			
	N-Levels							
	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*
CT	98	109	120	109	109	120	131	120
ST	122	144	159	142	123	137	157	139
Mean	110 b	127 b	140 a	-	116 b	128 b	144 a	-
$LSD_{0.05}$ value	Tillage = 57^{ns}, N-level = 13** and Tillage × N-level = 18 ^{ns}				Tillage = 33^{ns}, N-level = 10** and Tillage × N-level = 14^{ns}			
CV (%)	7.45				5.63			

Effects of tillage practices and N-levels on plant population of mustard

The different tillage practices had significant variations on the number of plants m^{-2} of mustard at Joydebpur but not at RARS, Ishurdi. Higher plant population (45 nos. m^{-2}) was found in ST and less number of plants was recorded in CT practice (36 nos. m^{-2}) at Joydebpur (Table 29). Previous studies indicated that plant density is an important factor affecting mustard yield (Sing and Verma, 1993).

The various N-levels and the interaction of tillage and N-levels had no remarkable influence on plant population of mustard at both the locations (Table 29).

Table 29 Effects of tillage practices and N-levels on plant population of mustard m^{-2}

Treatments	At Joydebpur	At RARS, Ishurdi
Tillage practices		
CT	36 b	64
ST	45 a	71
$LSD_{0.05}$ value	8*	8^{ns}
N- levels		
N_1 ($N_{75\%}$)	40	61
N_2 ($N_{100\%}$)	43	66
N_3 ($N_{125\%}$)	40	75
$LSD_{0.05}$ value	6^{ns}	11^{ns}
CV (%)	11.77	12.70

Effects of tillage practices and N-levels on dry root weight (g plant^{-1}) of mustard

Dry root weight of mustard was significantly influenced by tillage practices and different N-levels. At Joydebpur, higher root weight of mustard (1.98 g $plant^{-1}$) was observed in ST practice compared to that found in CT (1.31 g $plant^{-1}$). On the otherhand, higher amount of mustard root (1.86 g $plant^{-1}$) was found in CT practice and lower value (1.74 g $plant^{-1}$root) being documented in ST practice at Ishurdi (Table 30).

Considering the N-levels, the mean highest root mass of mustard (1.80 and 1.90 g $plant^{-1}$) was observed under the highest level of N application (125% of recommended N dose) being followed by N_2 level (1.68 and 1.80 g $plant^{-1}$) where 100% of recommended N dose was used. The minimum root mass (1.46 and 1.70 g $plant^{-1}$) was observed in N_1 treatment where 75% of recommended N dose used at Joydebpur and Ishurdi (Table 30).

Table 30 Effects of tillage practices and N-levels on root weight (g plant^{-1}) of mustard

Treatment	At Joydebpur	At RARS, Ishurdi
Tillage practices		
CT	1.31 b	1.86 a
ST	1.98 a	1.74 b
$LSD_{0.05}$ value	0.23**	0.08*
N- levels		
N_1 ($N_{75\%}$)	1.46 b	1.70 c
N_2 ($N_{100\%}$)	1.68 a	1.80 b
N_3 ($N_{125\%}$)	1.80 a	1.90 a
$LSD_{0.05}$ value	0.14**	0.04**
CV (%)	6.53	1.54

Effects of tillage practices and N-levels on seed yield (t ha^{-1}) of mustard

Tillage practices had significant differences on seed yield of mustard at Joydebpur but not at RARS, Ishurdi. At Joydebpur, significantly higher grain yield (1.12 t ha^{-1}) was found in ST practice compared to that recorded in CT practice (0.69 t ha^{-1}) (Table 31). The higher seed yield in ST treatment might be due to the combination of higher plant population m^{-2}, number of branches plant^{-1}, siliqua plant^{-1} and siliqua length (Ali *et al*., 2007). At Ishurdi, numerically but not statistically higher grain yield (1.23 t ha^{-1}) was also found in ST treatment and lower amount of grain (1.19 t ha^{-1}) was recorded in CT practice (Table 31).

Different N-levels showed significant variation on seed yield at both locations. The highest seed yield (1.05 & 1.30 t ha^{-1}) was obtained in N_3 treatment (125% RND), followed by N_2 treatment (0.93 & 1.29 t ha^{-1} in 100% RND) and the lowest amount of seed (0.74 & 1.05 t ha^{-1}) was recorded in N_1 treatment (75% RND) (Table 31). Nitrogen increased yield by influencing different growth parameters and by producing more vigorous growth and development as reflected via increasing plant height, number of flowering branches, total plant weight, leaf area index and number of siliqua and seeds per plant (Alien and Morgan, 1972). Investigations showed that nitrogen fertilizers gave increased seed yield(Siadat *et al*., 2010). Reddy and Sinha (1989) showed that seed yield has increased linearly by increasing nitrogen consumption. The application of increased rate of N fertilizer might be led to more seed yield by preventing flower and siliqua abscission, increasing the number of siliquae per unit area and affecting 1000 seed weight (TSW). Higher seed yield with increasing rate of nitrogen was also reported by Mankotish and Sharma (1997) and Bani-Saeedi (2001).

Almost all investigations showed that nitrogen fertilizers gave substantial seed yield increase (Siadat *et al*., 2010). Reddy and Sinha (1989) showed that seed yield has increased linearly by increasing nitrogen consumption. Higher seed yield with increasing rate of nitrogen was also reported by Mankotish and Sharma (1997) and Bani-Saeedi (2001).Yousaf et al. (2016) found that oilseed rape yield was significantly higher in N fertilized plots. Interaction effect of tillage practices and N-levels on seed yield was not significant.

Table 31 Effects of tillage practices and N-levels on seed yield (t ha^{-1}) of mustard

Tillage practices	At Joydebpur				At RARS, Ishurdi			
	N-Levels							
	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*
CT	0.56	0.78	0.73	0.69 b	1.00	1.32	1.26	1.19
ST	0.93	1.08	1.36	1.12 a	1.09	1.27	1.34	1.23
Mean	0.74 b	0.93 b	1.05 a	-	1.05 b	1.29 a	1.30 a	-
$LSD_{0.05}$ *value*	Tillage = 0.28*, N-level = 0.15** and Tillage × N-level = 0.31^{ns}				Tillage = 0.06^{ns}, N-level = 0.10^{**} and Tillage × N-level = 0.13^{ns}			
CV (%)	12.13				6.12			

Effects of tillage practices and N-levels on soil moisture content

During the mustard growing period at Joydebpur, soil moisture was monitored at 30-day interval and found that tillage practices had significant impact on soil moisture content at 0-15 cm soil depth but different N-levels could not create any significant variations in soil moisture content (Table 32). Significantly higher soil moisture was recorded in CT practice (44.0, 32.6 & 22.4%) over ST practice (35.0, 21.8 & 17.1%) at 25, 55 and 85 DAS, respectively. Due to excess moisture in CT practice, mustard plants became stunted in some extent and gave lower seed yield.

At RARS, Ishurdi, tillage practices and N-levels had no significant variation in soil moisture content at 0-15 cm soil depth at harvest of the mustard (Table 32).

Table 32 Effects of tillage practices and N-levels on soil moisture content (%) after mustard harvest

Treatments	Joydebpur			RARS, Ishurdi
	25 DAS (11 Dec. 2017)	55 DAS (10 Jan. 2018)	At Harvest, 85 DAS (09 Feb. 2018)	At Harvest, 92 DAS (01 March 2018)
Tillage practices				
CT	44.0 a	32.6 a	22.4 a	15.7
ST	35.0 b	21.8 b	17.1 b	15.5
$LSD_{0.05}$ *value*	0.8**	4.0**	2.6*	0.8^{ns}
N- Levels				
N_1	39.8	26.9	19.5	15.3
N_2	39.5	27.1	19.7	16.2
N_3	39.2	27.6	20.1	15.2
$LSD_{0.05}$ *value*	2.0^{ns}	2.6^{ns}	2.4^{ns}	1.1^{ns}
CV (%)	3.71	7.12	9.19	5.40

Rainfall distribution during the growing period of mustard

Before starting the growing season of mustard, considerable amount of rainfall occurred. On 1st October of 2017, there was 64 mm rainfall and it was continued following a couple of days and total 74 mm rainfall was recorded in October month. The mustard was sown on 16 November 2017 in a cloudy day and after sowing similar rainfall pattern was observed and a total of 11 mm rainfall was recorded in November month and a total of 32 mm rainfall was recorded in December month (Fig. 1). Consequently, the mustard plants became stunted in some extent and the crop performance was better in strip tilled plots compared to conventional tilled plots.

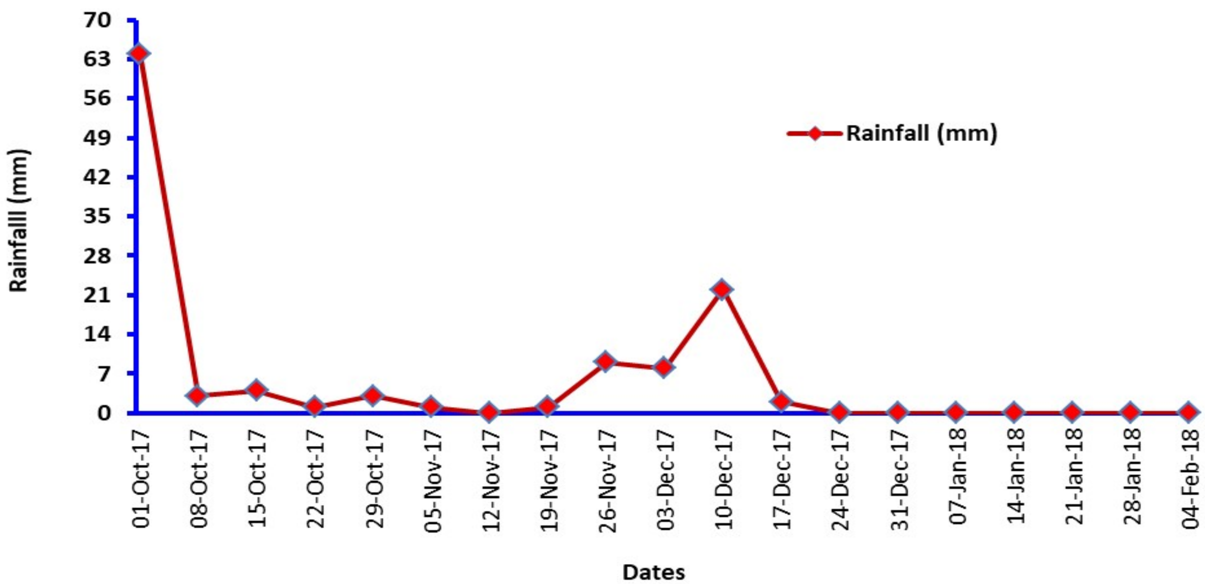


Fig. 1 Rainfall data (mm) in the mustard growing period (from October 2017 to February 2018)

3rd Crop: Boro

Effect of tillage practices and N-levels on yield of Boro rice (cv. BRRIdhan 28) during 2018 at Joydebpur

Tillage practices showed no significant variations on the yields of Boro grain and straw with harvest index. However, numerically but not significantly higher yields (5.43 t ha^{-1} grain & 5.89 t ha^{-1} straw) were recorded in CT practice and lower yields (5.22 t ha^{-1} grain & 5.89 t ha^{-1} straw) was recorded in ST practice (Table 33).

Grain and straw yield of Boro rice was significantly varied by different N-levels. The highest grain yield was recorded in N_3 level (5.81 t ha^{-1}) which was statistically identical to N_2 treatment (5.48 t ha^{-1}) and the lowest value was recorded in N_1 level (4.69 t ha^{-1}). On the other hand, the highest straw yield was recorded in N_3 level (6.34 t ha^{-1}) which was statistically identical to N_2 treatment (6.16 t ha^{-1}) and the lowest straw was recorded in N_1 level (5.12 t ha^{-1}), as shown in Table 33. Yousaf et al. (2016) found that rice yield was significantly higher in N fertilized plots.

Table 33 Effects of tillage practices and N-levels on grain and straw yield with HI of Boro rice during 2018at Joydebpur

Tillage practices	Grain yield (t ha^{-1})				Straw yield (t ha^{-1})				Harvest index (%)			
	N-Levels											
	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*
CT	5.02	5.38	5.90	5.43	5.30	6.10	6.15	5.85	48.9	46.6	49.1	48.2
ST	4.37	5.58	5.72	5.22	4.93	6.22	6.53	5.89	46.8	47.3	46.8	47.0
Mean	4.69 b	5.48 a	5.81 a	-	5.12 b	6.16 a	6.34 a	-	47.8	47.0	48.0	-
$LSD_{0.05}$ value	Tillage=0.42^{ns}, N-level=0.52** and Tillage × N-level = 0.71^{ns}				Tillage = 2.99^{ns}, N-level=0.97** and Tillage × N-level =3.09^{ns}				Tillage = 11^{ns}, N-level = 6.3^{ns} and Tillage × N-level = 13^{ns}			
CV (%)	7.34				12.36				9.98			

Effect of tillage practices N-levels on yield of Boro rice (cv. BRRIdhan 28) during 2018 at RARS, Ishurdi

Tillage practices could not create any significant variations on the Boro grain and straw yields with harvest index. However, numerically but not significantly higher yields (5.23 t ha^{-1} grain & 5.83 t ha^{-1} straw) were recorded in CT practice and lower yields (5.07 t ha^{-1} grain & 5.70 t ha^{-1} straw) was recorded in ST practice (Table 34).

Grain and straw yield of Boro rice was significantly varied by different N-levels. The highest grain was recorded in N_3 level (5.88 t ha^{-1} grain & 6.50 t ha^{-1} straw) which was statistically identical to N_2 treatment (5.00 t ha^{-1} grain & 5.70 t ha^{-1} straw) and the lowest grain (4.59 tha^{-1}) and straw (5.09 t ha^{-1}) was recorded in N_1 level.

The harvest index showed insignificant differences due to both tillage practices and N-levels (Table 34).

Table 34 Effects of tillage practices and N-levels on grain and straw yield with HI of Boro rice during 2018at RARS, Ishurdi

Tillage practices	Grain yield (t ha^{-1})				Straw yield (t ha^{-1})				Harvest index (%)			
	N-Levels											
	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*
CT	4.55	5.05	6.09	5.23	5.17	5.68	6.64	5.83	46.9	47.1	47.9	47.3
ST	4.62	4.94	5.66	5.07	5.01	5.71	6.37	5.70	48.0	46.4	47.1	47.2
Mean	4.59 b	5.00 b	5.88 a	-	5.09 b	5.70 ab	6.50 a	-	47.4	46.8	47.5	-
$LSD_{0.05}$ value	Tillage = 1.2^{ns}, N-level =0.65** and Tillage × N-level = 1.34^{ns}				Tillage = 1.72^{ns}, N-level =0.78** and Tillage × N-level = 1.86^{ns}				Tillage =1.72^{ns}, N-level =2.0^{ns} and Tillage × N-level = 2.8^{ns}			
CV (%)	9.54				10.23				3.24			

Effects of tillage practices and N-levels on cropping system productivity

Regardless of tillage practices, different N-levels showed significant variations in REY in both locations. The maximum REY was observed in N_3 level (13.5 t ha^{-1}) which was significantly identical to N_2 level (12.8 t ha^{-1}) and the minimum REY was recorded in N_1 level (10.8 t ha^{-1}) at Joydebpur. Similarly, at RARS, Ishurdi, the highest REY was found in N_3 level (15.4 t ha^{-1}) which was significantly higher than N_2 level (14.1 t ha^{-1}) and N_1 level (12.7 t ha^{-1}), shown in Table 35.

Table 35 Effects of tillage practices and N-levels on cropping system productivity (REY, t ha^{-1})

Tillage practices	At Joydebpur				At RARS, Ishurdi			
	N-Levels							
	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*	N_1 ($N_{75\%}$)	N_2 ($N_{100\%}$)	N_3 ($N_{125\%}$)	*Mean*
CT	10.8	12.5	13.0	12.1	12.4	14.2	15.3	14.0
ST	10.8	13.1	14.1	12.6	13.0	14.0	15.4	14.1
Mean	10.8 b	12.8 a	13.5 a	-	12.7 c	14.1 b	15.4 a	-
$LSD_{0.05}$ value	Tillage = 0.7^{ns}, N-level = 0.7^{**} and Tillage × N-level = 1.1^{ns}				Tillage = 1.9^{ns}, N-level = 1.0** and Tillage × N-level = 2.1^{ns}			
CV (%)	4.49				5.07			

Note: Market prices of the crops were: Tk. 20.00 kg^{-1} for rice and Tk. 50.00 kg^{-1} for mustard seed

Effects of tillage practices on the N_2O emission rate and total N_2O flux during mustard season

Static close chamber was used for collection of N_2O gas and emission was measured by Gas Chromatograph (GC-2014). Results indicated that strip tillage reduced about 50% total N_2O flux than that of conventional tillage might be due to less microbial activities (Fig. 2 & 3). It was observed that strip tillage could be a good management option to reduce N_2O and global warming potential (GWP), is a relative measure of how much heat a greenhouse gas traps in the atmosphere.

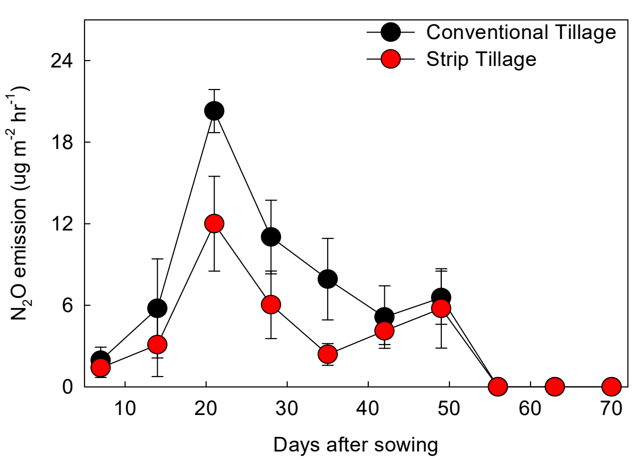


Fig. 2 Effects of tillage practices on the N_2O emission rate

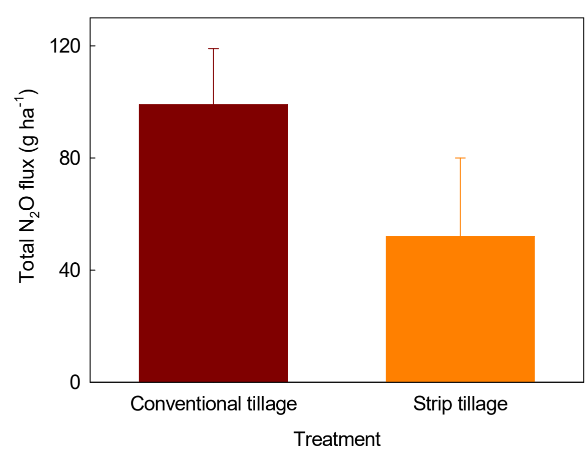


Fig. 3 Effects of tillage practices on total N_2O flux

Effects of tillage practices and N-levels on soil bulk density

Bulk density (BD) of soil did not vary significantly with tillage practices and N-levels after 1-year and soil BD value remained unchanged at 0-15 cm soil depth (Table 36).

Table 36 Effects of tillage and N-levels on soil bulk density (g cm^{-3}) after 1-year

Treatments	Joydebpur	RARS, Ishurdi
Tillage practices		
CT	1.41	1.42
ST	1.43	1.45
$LSD_{0.05}$ value	0.13^{ns}	0.04^{ns}
N- Levels		
N_1	1.42	1.43
N_2	1.42	1.44
N_3	1.42	1.45
$LSD_{0.05}$	0.03^{ns}	0.03^{ns}
CV (%)	1.50	1.17

Effects of tillage practices and N-levels on the chemical properties of post-harvest soil

After 1-crop cycle, there were no significant variations in chemical properties of post-harvest soil due to adoption of tillage practices and application of different N fertilizer doses at Joydebpur and at RARS, Ishurdi. However, there was an increasing trend of nutrient contents under minimum tillage system compared to conventional tillage system (Table 37&38).

Table 37 Effects of tillage practices and N-levels on OM, total N, available P, K, S, Zn and B contents of post-harvest soil of Joydebpur

Treatments	SOM	TN	Available other nutrients				
			K	P	S	Zn	B
	(%)		(c mol kg^{-1} soil)	(µg ml^{-1})			
Tillage practices							
CT	1.04	0.057	0.14	9.0	17.0	1.01	0.17
ST	1.10	0.059	0.18	9.7	18.4	1.03	0.21
$LSD_{0.05}$ value	0.10^{ns}	0.008^{ns}	0.07^{ns}	0.8^{ns}	3.8^{ns}	0.11^{ns}	0.06^{ns}
N- Levels							
N_1	1.06	0.057	0.15	9.2	17.5	1.01	0.18
N_2	1.07	0.058	0.16	9.5	17.6	1.02	0.20
N_3	1.09	0.059	0.18	9.3	17.9	1.04	0.21
$LSD_{0.05}$ value	0.06^{ns}	0.003^{ns}	0.03^{ns}	1.6^{ns}	0.8^{ns}	0.04^{ns}	0.03^{ns}
CV (%)	3.90	4.18	11.86	12.96	3.52	3.27	9.02
Initial value	1.02	0.055	0.12	8.0	15.0	0.90	0.15

Table 38 Effects of tillage practices and N-levels on OM, total N, available P, K, S, Zn and B contents of post-harvest soil of RARS, Ishurdi

Treatments	SOM	TN	Available other nutrients				
			K	P	S	Zn	B
	(%)		(c mol kg^{-1} soil)	(µg ml^{-1})			
Tillage practices							
CT	1.20	0.063	0.34	16.6	17.8	0.53	0.17
ST	1.28	0.066	0.40	18.1	19.5	0.66	0.23
LSD$_{0.05}$ value	0.20^{ns}	0.004^{ns}	0.06^{ns}	5.6^{ns}	18.5^{ns}	0.13^{ns}	0.12^{ns}
N- Levels							
N_1	1.26	0.064	0.37	17.8	18.1	0.62	0.18
N_2	1.22	0.065	0.36	17.7	19.7	0.59	0.23
N_3	1.24	0.065	0.38	16.6	18.2	0.58	0.20
LSD $_{0.05}$	0.17^{ns}	0.003^{ns}	0.04^{ns}	2.3^{ns}	0.04^{ns}	0.04^{ns}	0.04^{ns}
CV (%)	10.09	3.68	8.91	10.05	9.28	5.42	15.61
Initial value	1.25	0.065	0.30	16.2	16.0	0.57	0.17

Profitability of growing crops under different tillage and nitrogen levels in the mustard-Boro-T.aman rice cropping pattern

From T. aman rice cultivation, the highest net return (NR) and BCR was recorded from ST and 125%RND combination at RARS, Ishurdi and the lowest net return and BCR was in CT and 75% RND combination. On the other hand, CT and 100% RND combination gave the highest net return and BCR whereas ST and 75% RND combination gave the lowest net return as well as BCRat Joydebpur (Table 39).

In case of mustard cultivation, the highest net return and BCR was found in ST and 125% RND combination at Joydebpur, but CT and 100% RND combination gave the highest net return and BCR at RARS, Ishurdi. The CT and 75% RND combination gave the lowest net return as well as BCR at both locations (Table 40).

In case of Boro cultivation, the highest net return and BCR was found in CT and 125% RND combination at Joydebpur where as CT and 100% RND combination gave the highest net return and BCR at RARS, Ishurdi. The CT and 75% RND combination and ST and 75% RND combination gave the lowest net return as well as BCR at Joydebpur and RARS, Ishurdi, respectively (Table 41).

Table 39 Profitability of T. aman rice production under different tillage and nitrogen levels

Particular	Joydebpur						RARS, Ishurdi					
	ST			CT			ST			CT		
	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND
Gross return (Tk. ha^{-1})	87940	101200	104850	93410	109670	111130	118180	123770	134960	112610	128370	124110
Total input cost(Tk. ha^{-1})	63996	66112	67781	65228	68016	69909	75301	77399	80055	74293	78599	76951
Net return (Tk. ha^{-1})	23944	35088	37069	28182	41654	41221	42879	46371	54905	38317	49771	47159
BCR	1.37	1.53	1.55	1.43	1.61	1.59	1.57	1.60	1.69	1.52	1.63	1.61

Table 40 Profitability of mustard production under different tillage and nitrogen levels

Particular	Joydebpur						RARS, Ishurdi					
	ST			CT			ST			CT		
	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND
Gross return (Tk. ha^{-1})	67840	78680	98640	40980	56520	53540	79040	92100	97220	72500	95440	91440
Total input cost (Tk. ha^{-1})	48115	49666	51219	46659	48210	49203	52727	54561	56954	51831	54785	55498
Net return (Tk. ha^{-1})	19725	29014	47421	-5679	8310	41221	26313	37539	40266	20669	40655	35942
BCR	1.41	1.58	1.93	0.88	1.17	1.59	1.50	1.69	1.71	1.40	1.74	1.65

Table 41 Profitability of Boro rice production under different tillage practices and nitrogen levels

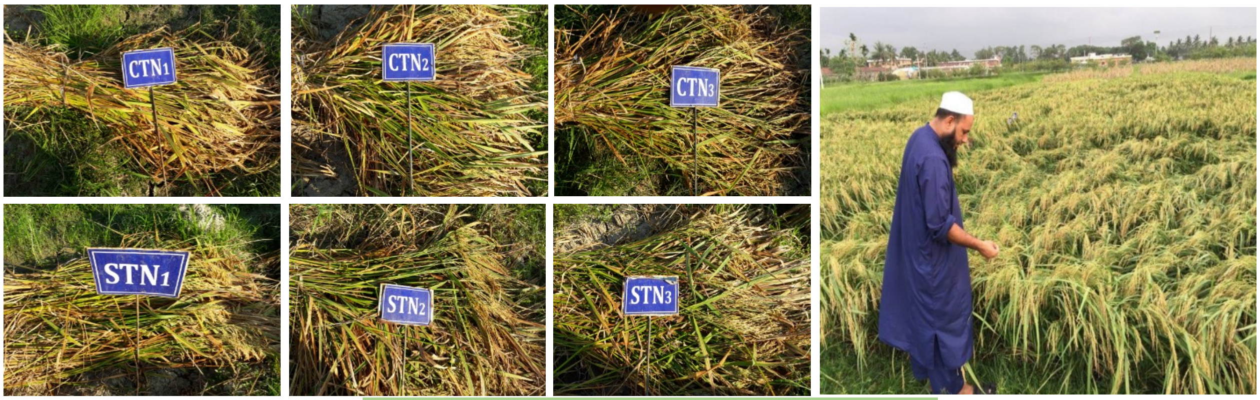
Particular	Joydebpur						RARS, Ishurdi					
	ST			CT			ST			CT		
	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND	75% RND	100% RND	125% RND
Gross return (Tk. ha^{-1})	97410	104510	119570	96170	106680	128440	87940	101200	104850	93410	109670	111130
Total input cost(Tk. ha^{-1})	71183	74350	76957	72751	76478	80205	66572	68912	70693	68700	71600	73381
Net return (Tk. ha^{-1})	26227	30160	42613	23419	30202	48235	21368	32288	34157	24710	38070	37749
BCR	1.37	1.41	1.55	1.32	1.39	1.60	1.32	1.47	1.48	1.36	1.53	1.51

Conclusions:

The single effect of N fertilizer on T. aman yield was significantly different at both the locations, while the yield under 125% of RND (5.10 t ha^{-1} Joydebpur and 6.24 t ha^{-1} at Ishurdi) and 100% of RND (4.98 t ha^{-1} at Joydebpur and 5.87 t ha^{-1} at Ishurdi) outperformed 75% of RND (4.27 t ha^{-1} at Joydebpur and 5.47 t ha^{-1} at Ishurdi). In case of mustard, due to unexpected rain during dry winter, lower soil moisture was measured in ST over CT practice at Joydebpur and crop performance was better in ST practice, consequently, significantly higher seed yield was observed in ST (1.12 t ha^{-1}) relative to CT (0.69 t ha^{-1}) under increased moisture condition. The highest seed yield (1.05 & 1.30 t ha^{-1}) was obtained in N_3 treatment, followed by N_2 treatment (0.93 & 1.29 t ha^{-1}) and lowest seed (0.74 & 1.05 t ha^{-1}) was obtained in N_1 treatment at Joydebpur and RARS, Ishurdi, respectively. Regardless of tillage practices, different N-levels had significant effects on grain and straw yields of Boro rice at Joydebpur and RARS, Ishurdi during 2018. The highest grain yield was recorded in N_3 level (5.81 t ha^{-1} at Joydebpur and 5.88 t ha^{-1} at Ishurdi) and the lowest grain was recorded in N_1 level (4.69 t ha^{-1} at Joydebpur and 4.59 t ha^{-1} at Ishurdi). Accordingly, different N-levels showed significant variations in REY and the maximum REY was observed in N_3 level (13.5 & 15.4 t ha^{-1}) followed by N_2 level (12.8 & 14.1 t ha^{-1}) and N_1 level (10.8 & 12.7 t ha^{-1}), respectively at Joydebpur and RARS, Ishurdi. Soil bulk density and the chemical properties of post-harvest soil did not vary significantly due to tillage and different N fertilizer doses after harvest of 3rd crop. It was observed that the crop yield under ST increased with the increased rates of N fertilizer at both the locations, while yield under CT decreased with increased rate of N (125% of RND) in the upland condition.

Pictorial view of the experiment regarding to experiment No. 02 (Effect of tillage and nitrogen on the Mustard-Boro-T. aman rice cropping system under conservation agriculture practice)

Locations: BARI Central Farm, Gazipur & RARS, Ishurdi



BARI Central Farm, Gazipur—T. aman rice

BARI Central Farm, Gazipur -- Mustard

Evaluation team of BARI visited the mustard experiment field

Monitoring team of BARC visited the mustard experiment field


Dr. Mohammad Hossain, Director (PRC, BARI) visited the field



RARS, Ishurdi

Experiment No. 03. Effect of tillage methods and nutrient management on the soil properties and crop productivity of onion-jute-T. aman rice cropping system

Objectives:

The present study was carried out to fulfill the following objectives:

i). To observe the effects of tillage and nutrient management on the improvement of soil properties under onion- jute- T. aman rice cropping system,

ii). To find out the suitable combination of tillage method and nutrient management for maximizing the crop yield in the pattern, and

iii). To evaluate the system productivity and economic profitability of the onion- jute - T. aman rice cropping system.

Materials and methods

Description of experimental site

The experiment was conducted at farmer's field of Rajbari district during 2017-18.The study area was under the agro-ecological zone "Low Ganges River Floodplain (AEZ-12).

Treatments and design

The unit experimental plot area was 7.2 m × 2.5 m and the design of the experiment was split-plot with three replications. Two tillage methods such as, T_1: conventional tillage (CT) and T_2: minimum tillage (MT)/strip tillage (ST) was assigned in main plot and four nutrient management system such as NM_1: farmer's practice (FP), NM_2: 100% recommended fertilizer dose (RFD) on STB as per FRG, all from chemical fertilizer, NM_3: 125% RFD on STB as per FRG, all from chemical fertilizer and NM_4: 80% of RFD from chemical fertilizer + 20% of RFD from cow dung was allotted in sub-plot in a split-plot design with three replications.

Land Preparation by tillage methods

The strip tillage (ST) was accomplished by power tiller operated seeder (PTOS) using rotating blades maintaining 20 cm spacing from row to row for preparing the strip and a narrow furrow opener by one pass around 18-24 hours before transplanting rice seedlings. For sowing jute seeds, ST was done by one pass with power tiller operated seeder (PTOS) using rotating blades maintaining 25 cm spacing from row to row. For onion seedling transplanting, minimum tillage (MT) was done by one pass with power tiller operated seeder (PTOS).

Conventional tillage (CT) was done by power tiller with three passes followed by two laddering for jute and onion seed sowing. In case of rice cultivation under CT method, at first, irrigation was done in the plots up to saturation condition, and then soil was puddled with three passes by the power tiller followed by two times laddering and then 30-day old rice seedlings were transplanted.

Sowing/transplanting

Jute seed (cv. Nabin) was sown on 11 May, 2017 maintaining 25 cm × 7-10 cm spacing, T. aman rice seedlings (cv. BRRIdhan 72) were transplanted on 10 August 2017 maintaining 20 cm × 20 cm spacing and onion seedlings (cv. King) were transplanted on 23 January 2018 at 15 cm apart from rows to row and 10 cm apart from plant to plant.

Fertilizer dose and application method

The rates of chemical fertilizers were $N_{153}P_{13}K_{72}S_{12}Zn_1B_{0.5}$ kg ha^{-1} for jute, $N_{100}P_{13}K_{47}S_9Zn_2B_{0.5}$ kg ha^{-1} for T. aman and $N_{100}P_{46}K_{94}S_{23}Zn_4B_{1.5}$ kg ha^{-1} for onion according to STB followed by FRG-2012. The farmer's practice regarding fertilizers application was $N_{180}P_{10}K_{45}S_8$ kg ha^{-1} for jute, $N_{120}P_{10}K_{40}S_6Zn_1$ kg ha^{-1} for T. aman and $N_{140}P_{30}K_{60}S_{16}$ kg ha^{-1} for onion.

For jute, full amount of fertilizers except urea was applied as basal and urea was applied in two equal splits at 25 and 50 days after sowing (DAS). At farmer's practice treatment, ½ urea was applied with all other fertilizers during final land preparation and ½ urea was at 30 DAS.

For rice, all other fertilizers except urea, was applied during final land preparation. Urea was applied in three equal splits- the 1/3rd applied at 4 DAT, the second split at tillering stage (32 DAT) and the third split at 5-7 days before PI stage (47 DAT). At farmer's practice treatment, ½ urea was applied with all other fertilizers during final land preparation and the rest ½ urea applied at 36 DAT.

In case of onion, all required fertilizers in full dose and ½ urea and MoP was applied as basal dose, the rest urea and MoP applied in 2 equal splits at 25 and 50 days after transplanting (DAT). At farmer's practice treatment, ½ urea was applied with all other fertilizers during final land preparation and ½ urea applied at 35 DAT. Organic manure (cow dung) was applied before land preparation.

Crop harvesting and data collection

Jute was harvested on 31 July 2017, T. aman was harvested on 03 Dec. 2017 and onion was harvested on 08 April 2018. Two m^2 area from each plot was selected for data collection. Ten plants of each plot were selected for recording data on yield attributes. 1000- seed weight of T. aman was measured plot wise. The plants were cut, then threshed, cleaned, sun-dried and weighed of grain and straw separately from 2.0 m^2 area of each plot. Finally, the grain and straw were converted into t ha^{-1}.

Results and Discussion

1st Crop: Jute

Effects of tillage and nutrient management on plant population, plant height and fibre yield of jute during 2017

Tillage and different nutrient methods and its interactions had no significant effect on plant population of jute. Regardless of tillage methods, different nutrient management showed significant variations on the plant height as well as fibre yield of jute (Table 42). The highest plant height (229 cm) was recorded in NM_3 treatment which was statistically identical to NM_4 treatment and different from NM_1 treatment and NM_2 treatment. The highest fibre yield was obtained from NM_3 treatment (3.64 t ha^{-1}) which was different from NM_1 treatment (2.96 t ha^{-1}), NM_2 treatment (3.16 t ha^{-1}) and NM_4 treatment (3.23 t ha^{-1}), as presented in Table 42.

Table 42 Effects of tillage and nutrient management on plant population, plant height and fibre yield of jute

Treatments	Plant population (nos. m^{-2})	Plant height (cm)	Fibre yield (t ha^{-1})
Tillage methods			
Conventional tillage (CT)	37	218	3.29
Strip tillage (ST)	36	216	3.21
$LSD_{0.05}$ value	1.3^{ns}	5^{ns}	1.10^{ns}
Nutrient management			
NM_1 (FP)	38	203 b	2.96 b
NM_2 (100% CF of STB)	37	210 b	3.16 b
NM_3 (125% CF of STB)	39	229 a	3.64 a
NM_4 (80% CF + 20% CD)	32	225 a	3.23 b
$LSD_{0.05}$ value	7^{ns}	12**	0.39*
CV (%)	14.76	4.34	9.58

NM= nutrient management, CF = chemical fertilizers, STB = soil test basis, CD = cow dung, LSD = least significant difference at P>0.05, ns= non-significant, * = P<0.05, ** = P<0.01

2nd Crop: T. aman

Effects of tillage and nutrient management on theyield of T. aman rice (cv. BRRIdhan 72)

Different nutrient management create significant impact in the grain and straw yield of T. aman rice but tillage methods could not create any significant variations on the yields of grain and straw of T. aman rice. during 2017 at the farmer's field of Rajbari district (Table 43). The highest grain yield was produced in NM_4 treatment (6.02 t ha^{-1}) which was statistically similar with NM_3 treatment (5.93 t ha^{-1}) and NM_2 treatment (5.72 t ha^{-1}). The lowest grain yield was recorded in NM_1 (5.43 t ha^{-1}). Similar pattern was observed in case of straw yield, showing the sequence as, NM_4>NM_3>NM_2>NM_1(Table 43).Many studies have reported increased productivity of intensive rice-based systems under conservation tillage with integrated nutrient management (Munda et al., 2009), but effects vary with regions due to differences in climatic and edaphic factors (Sun et al., 2010).

Table 43 Effects of tillage and nutrient management on yields of grain and straw and harvest index of T. aman rice

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (HI)
Tillage methods			
Conventional tillage (CT)	5.59	6.21	47.4
Strip tillage (ST)	5.96	6.94	48.4
$LSD_{0.05}$ value	1.34^{ns}	0.28^{ns}	4.8^{ns}
Nutrient management			
NM_1 (FP)	5.43 b	5.79 c	48.3
NM_2 (100% CF of STB)	5.72 ab	6.12 bc	48.3
NM_3 (125% CF of STB)	5.93 a	6.46 ab	47.8
NM_4 (80% CF + 20% CD)	6.02 a	6.71 a	47.2
$LSD_{0.05}$ value	0.42*	0.39**	1.4^{ns}
CV (%)	5.80	4.91	2.31

NM= nutrient management, CF = chemical fertilizers, STB = soil test basis, CD = cow dung, LSD = least significant difference at P>0.05, ns= non-significant, * = P<0.05, ** = P<0.01

Effects of tillage methods and nutrient management on yield and yield attributes of onion

Tillage methods did not show any significant influence on the number of bulbs m^{-2}, bulb diameter and bulb yield of onion. However, numerically higher bulb diameter and fresh as well as sundry bulb yield of onion was recorded in MT than CT methods. Tayel et al. (2017) recorded increased bulb volume and yield under minimum tillage practices, while under conventional tillage; increased moisture stress resulted in decreased onion volume and yield.

Different nutrient management had significant effect on the bulb diameter and fresh as well as sundry bulb yield of onion (Table 44). The highest bulb diameter of onion was found in NM_4 treatment which was statistically identical to NM_3 treatment and the lowest bulb diameter was found in NM_1 treatment. Similarly, the highest bulb yield (16.0 t ha^{-1} fresh and 13.9 t ha^{-1} sundry) was recorded in NM_4 treatment followed by NM_3 (14.6 t ha^{-1} fresh and 12.5 t ha^{-1} sundry), NM_2 (14.2 t ha^{-1} fresh and 12.0 t ha^{-1} sundry). The lowest bulb yield (12.7 t ha^{-1} fresh and 10.6 t ha^{-1} sundry) was noted in NM_1 treatment.

Integrated nutrient management is one of the most important factors that greatly influence the quality and yield of onion (Mahanthesh et al., 2009). Singh et al. (1997) reported that combined doses of organic and inorganic fertilizer (FYM 25 t ha^{-1} + NPK 100:25:25 kg ha^{-1}) increased marketable yield. Bagali et al. (2012) noted that the combination of higher levels of inorganic with higher levels of organic fertilizers recorded higher bulb yield and the market value.

Table 44 Effects of tillage and nutrient management on the number of bulb, bulb diameter, fresh and sundry bulb yield of onion at farmer's field of Rajbari

Treatments	No. of bulb (nos. m^{-2})	Bulb diameter (cm)	Fresh bulb yield (t ha^{-1})	Sundry bulb yield (t ha^{-1})
Tillage methods				
Conventional tillage (CT)	62	3.74	13.6	11.4
Minimum tillage (MT)	60	3.84	15.1	13.1
$LSD_{0.05}$ value	18^{ns}	0.11^{ns}	2.8^{ns}	2.0^{ns}
Nutrient management				
NM_1 (FP)	63	3.67 b	12.7 c	10.6 c
NM_2 (100% of STB)	61	3.75 b	14.2 b	12.0 b
NM_3 (125% CF of STB)	61	3.87 a	14.6 b	12.5 b
NM_4 (80% of CF + 20% CD)	60	3.88 a	16.0 a	13.9 a
$LSD_{0.05}$ value	6^{ns}	0.09**	1.1**	1.1**
CV (%)	7.75	1.97	5.88	7.36

NM= Nutrient management, CF = Chemical fertilizers, STB = soil test basis, LSD = least significant difference at P>0.05, ns = non-significant, ** = P<0.01

Effects of tillage methods and nutrient management on cropping system productivity

Within the tillage practices, ST practice was found to be better in REY than CT practice. Among the different nutrient management, the maximum REY (33.55 t ha^{-1}) was recorded in NM_4treatment, where 80% of RFD was supplied through chemical fertilizers and the rest 20% was supplemented through cow dung application which was statistically identical to NM_3 treatment (32.31 t ha^{-1}), where 125% CF on STB. The minimum REY (28.64 t ha^{-1}) was recorded in NM_1 (FP), as presented in Table 45.

Yadav et al. (2017) put forward that adoption of minimum tillage and integrated nutrient management can enhance the system productivity of the rice-based cropping system in Indo-Gangetic plains.

Table 45 Effects of tillage methods and nutrient management on rice equivalent yield (t ha^{-1})

Treatments	Rice equivalent yield (t/ha)
Tillage methods	
Conventional tillage (CT)	30.21
Minimum tillage (MT)	32.31
$LSD_{0.05}$ value	2.84^{ns}
Nutrient management	
NM_1 (FP)	28.64 c
NM_2 (100% CF of STB)	30.55 b
NM_3 (125% CF of STB)	32.31 a
NM_4 (80% CF + 20% CD)	33.55 a
$LSD_{0.05}$ value	1.44**
CV (%)	3.66

NM= nutrient management, CF = chemical fertilizers, STB = soil test basis, LSD = least significant difference at P>0.05,ns= non-significant, ** = P<0.01

Note: Market prices of the crops were: Tk. 20.00 kg^{-1} for rice, Tk. 25.00 kg^{-1} for onion (fresh) and Tk. 45.00 kg^{-1} for jute fibre

Effects of tillage methods and nutrient management on soil bulk density

After 1 cropping year, soil bulk density was not significantly influenced by tillage methods and different nutrient management in the Onion-Jute-T. aman rice cropping system (Table 46). However, strip or minimum tillage and 80% CF of STB + 20% CD (NM_4) showed decreasing tendency of soil bulk density than conventional tillage (CT) and other nutrient management practices compared to initial soil bulk density.

Table 46 Effects of tillage methods and nutrient management on soil bulk density

Treatments	Soil bulk density (g cm^{-3})
Tillage methods	
Conventional tillage	1.51
Strip Tillage (ST)/Minimum Tillage (MT)	1.54
$LSD_{0.05}$ value	0.13^{ns}
Nutrient management	
NM_1 (FP)	1.54
NM_2 (100% CF of STB)	1.52
NM_3 (125% CF of STB)	1.53
NM_4 (80% CF + 20% CD)	1.49
$LSD_{0.05}$ value	0.05^{ns}
CV (%)	2.76

NM= nutrient management, CF = chemical fertilizers, STB = soil test basis, LSD = least significant difference at P>0.05, ns= non-significant

Effects of tillage methods and nutrient management on the chemical properties of post-harvest soil

After 3rd crop harvest, different nutrient management practices showed significant variations in chemical properties of post-harvest soil but tillage methods varied insignificant at farmer's field of Rajbari district. The highest amount of SOM, TN, available P, K, S and Zn contents was found in NM_4 treatment followed by NM_3, NM_2 and NM_1 treatment. However, minimum or strip tillage showed an increasing trend of nutrient contents in soil compared to conventional tillage (CT), as shown in Table 47.

The introductory year of conservation agriculture practice is a transition year which can change soil chemical properties in either (positive or negative) ways (Salahin, 2017). However, the present study found soil properties improving which can be attributed to combined use of strip/minimum tillage/non-puddling of rice with organic amendment (Alam, 2018).

Table 47 Organic matter, total N, available P, K, S, Zn and B contents of post-harvest soil of farmer's field

Treatments	OM	TN	Available other nutrients				
			K	P	S	Zn	B
	(%)		(c mol kg^{-1} soil)	(μg ml^{-1})			
Tillage practices							
Conventional tillage	1.18	0.062	0.22	8.0	13.2	0.27	0.20
Strip Tillage/Min. Tillage	1.25	0.066	0.24	8.9	14.4	0.29	0.23
$LSD_{0.05}$ value	0.04^{ns}	0.020^{ns}	0.08^{ns}	4.04^{ns}	3.9^{ns}	0.16^{ns}	0.04^{ns}
Nutrient management							
NM_1 (FP)	1.09 b	0.055 c	0.21 c	7.2 c	12.8 b	0.23 b	0.21
NM_2 (100% CF of STB)	1.20 b	0.063 b	0.22 b	8.0 b	13.4 b	0.28 a	0.21
NM_3 (125% CF of STB)	1.21 b	0.064 b	0.24 b	9.0 a	13.6 b	0.30 a	0.22
NM_4 (80% CF + 20% CD)	1.37 a	0.072 a	0.26 a	9.7 a	15.4 a	0.32 a	0.24
$LSD_{0.05}$ value	0.13^{**}	0.007^{**}	0.01^{ns}	0.7^{ns}	1.7^{ns}	0.05^{ns}	0.03^{ns}
CV (%)	8.48	8.66	4.97	6.97	10.42	14.02	9.43
Initial value	1.09	0.060	0.15	7.2	13.0	0.25	0.15

NM= nutrient management, CF = chemical fertilizers, STB = soil test basis, LSD = least significant difference at P>0.05, ns= non-significant, ** = P<0.01

Profitability of growing crops under different tillage methods and nutrient management in the onion-jute-T.aman rice cropping pattern

From jute cultivation, the highest net return (NR) and BCR was recorded from ST and 125% CF combination and the lowest net return and BCR was in CT and FP combination (Table 48).

In case of T. aman cultivation, the highest net return (NR) and BCR was found in NM_4 (80% CF + 20% CD) with ST combination and CT and 125% combination gave the lowest BCR (Table 49). It was due to the use of higher rate of costly chemical fertilizers requirements.

In case of onion cultivation, the highest net return (NR) and BCR was found in ST and 80% CF + 20% CD combination whereas farmers' tillage and nutrient practice gave the lowest net return (Table 50). It was due to lower yield obtained with the farmers' practice.

Table 48 Profitability of jute production under different tillage methods and nutrient management at Rajbari

Particular	ST				CT			
	NM_1 (FP)	*NM_2 (100% CF of STB)*	*NM_3 (125% CF of STB)*	*NM_4 (80% CF + 20% CD)*	*NM_1 (FP)*	*NM_2 (100% CF of STB)*	*NM_3 (125% CF of STB)*	*NM_4 (80% CF + 20% CD)*
Gross return (Tk. ha^{-1})	127120	131620	141450	132750	128910	133010	142820	134420
Total input cost(Tk. ha^{-1})	72989	75218	77144	75190	74781	77010	78936	76982
Net return (Tk. ha^{-1})	54131	56402	64306	57560	54129	56000	63884	57438
BCR	1.74	1.75	1.83	1.77	1.72	1.73	1.81	1.75

Table 49 Profitability of T. aman rice production under different tillage methods and nutrient management at Rajbari

Particular	ST				CT			
	NM_1 (FP)	*NM_2 (100% CF of STB)*	*NM_3 (125% CF of STB)*	*NM_4 (80% CF + 20% CD)*	*NM_1 (FP)*	*NM_2 (100% CF of STB)*	*NM_3 (125% CF of STB)*	*NM_4 (80% CF + 20% CD)*
Gross return (Tk. ha^{-1})	120370	123330	125700	126630	116200	119370	121540	122660
Total input cost(Tk. ha^{-1})	75227	76869	79686	77416	78699	80341	83158	80888
Net return (Tk. ha^{-1})	45143	46461	46014	49214	37501	39029	38382	41772
BCR	1.60	1.60	1.58	1.64	1.48	1.49	1.46	1.52

Table 50 Profitability of onion production under different tillage methods and nutrient management at Rajbari

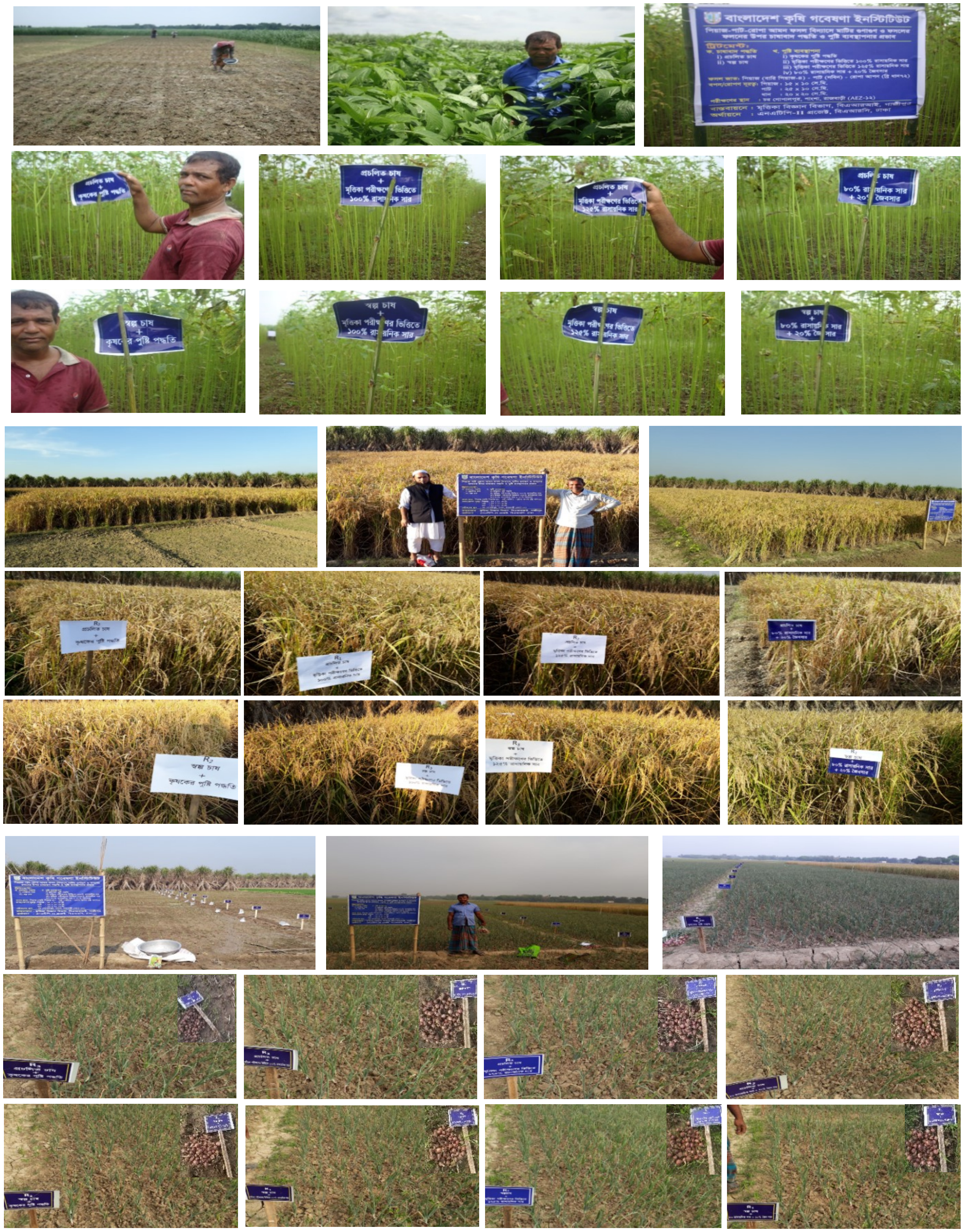
Particular	ST				CT			
	NM_1 (FP)	*NM_2 (100% CF of STB)*	*NM_3 (125% CF of STB)*	*NM_4 (80% CF + 20% CD)*	*NM_1 (FP)*	*NM_2 (100% CF of STB)*	*NM_3 (125% CF of STB)*	*NM_4 (80% CF + 20% CD)*
Gross return (Tk. ha^{-1})	266000	298000	308000	340000	242000	270000	276000	300000
Total input cost(Tk. ha^{-1})	114802	122492	128455	122762	109874	117004	123527	116714
Net return (Tk. ha^{-1})	151198	175508	179545	217238	132126	152996	152473	183286
BCR	2.32	2.43	2.40	2.77	2.20	2.31	2.23	2.57

Conclusions:

Different nutrient management showed significant variations on fibre yield of jute; grain and straw yields of T. aman rice as well as the bulb diameter and bulb yield of onion at the farmer's field of Rajbari district. On the other hand, the yield and yield attributes of jute, T. aman rice and onion responded similarly to tillage methods. In case of jute, the highest fibre yield (3.64 t ha^{-1}) was obtained from NM_3 . In case of T. aman rice, the highest grain yield was produced in NM_4 (6.02 t ha^{-1}), which was statistically similar to NM_3 (5.93 t ha^{-1}) and NM_2 (5.72 t ha^{-1}). In case of onion, NM_4 produced the highest bulb yield (16.0 t ha^{-1} fresh and 13.9 t ha^{-1} sundry) followed by NM_3 (14.6 t ha^{-1} fresh and 12.5 t ha^{-1} sundry), NM_2 (14.2 t ha^{-1} fresh and 12.0 t ha^{-1} sundry) and the lowest bulb yield (12.7 t ha^{-1} fresh and 10.6 t ha^{-1} sundry) was found in NM_1. Regardless of tillage methods, the different nutrient management practices had significant effects on system productivity (REY). The statistically highest REY was recorded in NM_4 (33.6 t ha^{-1}) having no significant difference with NM_3 (32.31 t ha^{-1}) but had difference with NM_2 (30.55 t ha^{-1}) and NM_1 (28.64 t ha^{-1}). It is evident that residual nutrient from 20% nutrient supplemented by CD to chemical fertilizer and successive use of CD outperformed 125%, 100% CF and farmers' practice.

Pictorial view of the experiment regarding to experiment No. 03 (Effect of tillage methods and nutrient management on the soil properties and crop productivity of Onion-Jute-T. aman rice cropping system)

Location: Farmer's field of Rajbari district



12. Research highlight/findings:

- Strip tillage with residue retention conserved more available soil moisture relative to conventional practices which resulted strip tillage (ST) gave higher grain yield of wheat compared to CT practice, giving statistically higher REY in strip tillage than conventional tillage at RARS, Jashore.
- The single effect of N on the yields of T. aman, mustard and Boro rice was significant, the yield under 125% RND and 100% of RND outperformed 75% of RND. Accordingly, different N-levels showed significant variations in REY and the maximum REY was observed in 125% RND followed by 100% RND and 75% RND.
- Seed yield of mustard under ST increased with the increased rate of N fertilizer (125% of RND).
- The highest fibre yield of jute was obtained from 125% CF of STB treatment and100% CF of STB compared to FP and 80% CF + 20% CD treatment. The highest grain yield of T. aman and onion bulb yield was recorded in 80% CF + 20% CD treatment which was statistically similar to 125% CF of STB and 100% CF of STB.
- After 1-year, crop residue retention showed increase of all nutrient contents and microbial population in soil over residue removal treatment under wheat-mungbean-T.aman rice cropping pattern, but soil bulk density and the chemical properties of soil remained unchanged due to tillages and different N fertilizer doses under mustard-Boro-T.aman rice cropping pattern.
- The nutrient management practices had significant effects on system productivity (REY). Higher REY was produced by 80% CF + 20% CD treatment (33.6 t ha^{-1}) and 125% CF treatment (32.31 t ha^{-1}) compared to 100% CF(30.55 t ha^{-1}) and FP (28.64 t ha^{-1}).Similar trends were observed in OM, TN, available P, K, S and Zn contents in post-harvest soil.

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B. Implementation Position

1. Progress of Procurement:

Description of equipment and capital items	PP Target			Achievement			Remarks
	Phy (#)		Fin (Tk)	Phy (#)		Fin (Tk)	
	Unit	Quantity		Unit	Quantity		
Office equipment's			**185000.00**			**185000.00**	100% of achievements
a) Laptop Computer	No.	01	60000.00	No.	01	60000.00	
b) Desktop Computer	No.	01	60000.00	No.	01	60000.00	
c) Camera	No.	01	25000.00	No.	01	25000.00	
d) Laser Printer	No.	01	20000.00	No.	01	20000.00	
e) Scanner	No.	01	10000.00	No.	01	10000.00	
f) UPS	No.	01	10000.00	No.	01	10000.00	

Office furniture			98,500.00			98,500.00	100% of achievements
a). Executive Table	No.	01	20,000.00	No.	01	20,000.00	
b). Executive Chair	No.	01	10,000.00	No.	01	10,000.00	
c). File Cabinet	No.	01	20,000.00	No.	01	20,000.00	
d). Steel Almira	No.	01	24,000.00	No.	01	24,000.00	
e). Front Chair	No	04	16,000.00	No	04	16,000.00	
f). Computer Table	No.	01	5,000.00	No.	01	5,000.00	
g). Computer Chair	No.	01	3,500.00	No.	01	3,500.00	
Lab/Field Equipments (Package 1)			3,30,000.00			3,30,000.00	100% of achievements
a). Soil Moisture Meter	No.	01	1,00,000.00	No.	01	1,00,000.00	
b). Hand Soil Penetrometer	No.	01	1,00,000.00	No.	01	1,00,000.00	
c). Pycnometer	No.	01	40,000.00	No.	01	40,000.00	
d). Sand Bath	No.	01	50,000.00	No.	01	50,000.00	
e). Dispersion cup	No	01	20,000.00	No	01	20,000.00	
f). Mechanical Stirrer	No.	01	20,000.00	No.	01	20,000.00	
Lab/Field Equipments (Package 2)			70000.00			70000.00	100% of achievements
a) Field equipment: Power Tiller Operated Seeder	No.	01	700000.00	No.	01	**700000.00**	
Other capital items:			56000.00			56000.00	100% of achievements
a) Hydraulic Conductivity Meter	No.	01	20000.00	No.	01	20000.00	
b) Root Sampler	No.	02	6000.00	No.	02	6000.00	
c) Irrigation flow meter	No.	01	15000.00	No.	01	15000.00	
d) Core sampler	No.	02	8000.00	No.	02	8000.00	
e) Core	No	20	5000.00	No	20	5000.00	
f) Soil Moisture Cup	No.	20	2000.00	No.	20	2000.00	
Lab Chemicals:			355000.00			355000.00	100% of achievements
Sodium Hexametaphosphate	1 kg	2 kg	15000.00	1 kg	2 kg	15000.00	
Hydrogen Peroxide	1 L	2 L	4200.00	1 L	2 L	4200.00	
Ammonium acetate	1 kg	2 kg	15000.00	1 kg	2 kg	15000.00	
Azomethin - H	10 g	10 g	8500.00	10 g	10 g	8500.00	
Phosphoric acid 85%	2.5 L	2.5 L	7800.00	2.5 L	2.5 L	7800.00	
Sulphuric acid	2.5 L	2.5 L	6200.00	2.5 L	2.5 L	6200.00	
Salicylic Acid	500 g	500 g	6500.00	500 g	500 g	6500.00	
Potassium sulfate	1 kg	1 kg	9500.00	1 kg	1 kg	9500.00	
Copper sulfate	1 kg	1 kg	6500.00	1 kg	1 kg	6500.00	
Acetic acid	2.5 L	2.5 L	2750.00	2.5 L	2.5 L	2750.00	
Hidrochloric acid (HCL)	2.5 L	2.5 L	5500.00	2.5 L	2.5 L	5500.00	
Nitric acid	2.5 L	2.5 L	8500.00	2.5 L	2.5 L	8500.00	
Ferrous sulphate	1 kg	1 kg	5500.00	1 kg	1 kg	5500.00	
Sodium bicarbonate	1 kg	1 kg	4900.00	1 kg	1 kg	4900.00	
Phenol	1 kg	1 kg	37500.00	1 kg	1 kg	37500.00	
Ammonium oxalate	500 g	500 g	5500.00	500 g	500 g	5500.00	
Ammonium molybdate	500 g	500 g	17500.00	500 g	500 g	17500.00	
Zinc sulphate Mono hydrate	1 kg	2 kg	15000.00	1 kg	2 kg	15000.00	
Calcium chloride	1 kg	1 kg	7700.00	1 kg	1 kg	7700.00	
Boric acid	1 kg	1 kg	4500.00	1 kg	1 kg	4500.00	
Sodium hydroxide	1 kg	1 kg	4200.00	1 kg	1 kg	4200.00	
Buffer solution	1 L	1 L	2400.00	1 L	1 L	2400.00	
Perchloric acid	2.5 L	2.5 L	35000.00	2.5 L	2.5 L	35000.00	
Barium chloride	1 kg	1 kg	4500.00	1 kg	1 kg	4500.00	
DTPA	100 g	100 g	25000.00	100 g	100 g	25000.00	
Ascorbic acid	250 g	500 g	14000.00	250 g	500 g	14000.00	
Lanthanum oxide	100 g	100 g	15700.00	100 g	100 g	15700.00	
Magnesium chloride	1 kg	1 kg	8500.00	1 kg	1 kg	8500.00	
EDTA	1 kg	1 Kg	5200.00	1 kg	1 Kg	5200.00	
Filter paper No. 1, 12.5 cm Whatman	1 pack.	17 Packs	27200.00	1 pack.	17 Packs	27200.00	
Filter paper No. 42, 12.5cm Whatman	1 pack.	5 packets	19250.00	1 pack.	5 packets	19250.00	

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
-	-	-	-	-	-

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

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training	23	07	30	02 Days	Successfully executed
(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	242595	242595	242595	0	100.00	-
B. Field research/lab expenses and supplies	865000	865000	865000	0	100.00	-
C. Operating expenses	280000	255915	255915	0	91.40	Due to not release of required fund timely.
D. Vehicle hire and fuel, oil & maintenance	220000	198000	198000	0	90.00	
E. Training/workshop/Field day etc.	130000	106500	100000	(-) 6500	76.92	A field day was not possible to arrange in the 1st year.
F. Publications and printing	80000	62948	0	(-) 62948	0.00	PCR will be printed by PIU-BARC.
G. Miscellaneous	50000	50000	50000	0	100.00	-
H. Capital expenses	739500	739500	739500	0	100.00	-

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 monitor the changes in SOM and soil physico-chemicalproperties as governed by CA practice	-Assessment of baseline soil properties of the experimental sites. -Three (03) field experimentswere conducted at four sites (Joydebpur, RARS, Jashore, RARS, Ishurdi and farmer's field of Rajbari district) and assessment of initial and post-harvest soil properties have been done.	- Increased residue retention showed increased soil organic matter and other nutrient contents as well as microbial population in soil over residue removal. - Increased available soil moisture content was recorded in ST and residue retention which resulted ST gave higher grain yield of wheat. - Different nutrient management practices showed significant variations in chemical properties of post-harvest soil at Rajbari district. The highest amount of SOM and plant nutrients was found in NM_4 treatment (80% CF + 20% CD) and the lowest contents were recorded in NM_1 treatment (FP).	- Enrichment of soil fertility. - Greater soil moisture retention in minimum tillage than conventional tillage. - Facilitate further research to innovate new technologies.

To assess the cropping system productivity under intensive rice-based agriculture	- Field experimentation and estimation of REY.	- Statistically higher REY was observed in ST than CT at RARS, Jashore in wheat-mungbean-T. aman cropping pattern. - Significantly higher REY was observed in 125% RND followed by 100% RND and 75% RNDlevel in mustard-Boro-T. aman cropping pattern at Joydebpur and Ishurdi. - At Rajbari, higher REY was produced by NM_4 (33.6 t ha^{-1}) and NM_3 (32.3t ha^{-1}) compared to NM_2 (30.6 t ha^{-1}) and NM_1(28.6 t ha^{-1}) in onion-jute-T. aman cropping pattern.	Higher crop productivity.
To observe economic benefits of CA over traditional practice	- Field experimentation and estimation of BCR.	- Strip tillage with crop residue retention gave the higher net returns (NR) and BCR in wheat-mungbean- T. aman cropping pattern (Expt. 1). - The highest NR and BCR was recorded from ST and 125% RND combination at RARS, Ishurdi whereas CT and 100% RND combination at Joydebpur in T. aman and mustard cultivation. On the other hand, in Boro cultivation, the highest NR and BCR was found in CT and 125% RND combination at Joydebpur, whereas CT and 100% RNDcombination at RARS, Ishurdi (Expt. 2). - At Rajbari, the highest NR and BCR was noted from ST and 125% CF combination in jute cultivation. On the other hand, the highest NR and BCR was found in 80% CF + 20% CD with ST combination in case of T. aman and onion cultivation (Expt. 3).	Higher income of farmers.

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 reparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	-	-	-
Journal publication	-	-	-
Information development	-	-	-
Other publications, if any	-	-	-

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

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

- Strip tillage (ST) for upland crops and non-puddling for rice crop as crop establishment practices to fit CA in rice-based cropping systems which previously was a challenge. Increased residue retention added extra benefits to these practices.
- In terms of nutrient management for novel CA practices, 125% RND for upland crops under strip planting and 100% RND for rice crops under non-puddling perform well in rice-based cropping systems.

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

- Strip planting for upland crops and non-puddling for rice crop establishment are well fitted techniques of CA. Seed yield of mustard under strip tillage (ST) increased with the increased rate of N fertilizer (125% of RND).
- Crop residue retention increased all nutrient contents and microbial population in soil over residue removal under wheat-mungbean-T. aman rice cropping pattern.
- Other soil properties show improving trends under the novel CA practices which in the long-term might results in improved soil health, climate change mitigation and sustainable crop production.

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

- The highest REY, NR and BCR were recorded from ST and 125% RND combination at RARS, Ishurdi but CT and 100% RND combination at Joydebpur in T. aman and mustard cultivation. On the other hand, in Boro cultivation, the highest REY, NR and BCR was found in CT and 125% RND combination at Joydebpur whereas CT and 100% RND combination at RARS, Ishurdi.
- At Rajbari, the highest NR and BCR was obtained from ST and 125% CF combination in jute cultivation. On the other hand, the highest NR and BCR was found in 80% CF + 20% CD with ST combination in case of T. aman and onion cultivation.
- There is a great scope to improve the overall economic condition of farmers through adopting conservation agriculture practice.
- Strip tillage and non-puddling with crop residue retention performed well in yield and economic return in wheat-mungbean- T. aman cropping system can be applied for other double or triple-crop cropping systems practiced at different locations in Bangladesh.

iv. Policy Support

- Recently the Ministry of Agriculture (MoA), Peoples Republic of Bangladesh has incorporated conservation agriculture (CA) in the policies of agriculture and crop production. The findings of the present project may assist the policy makers of the agricultural sectors for planning and setting their future research directions in order to technology generation as well as increasing production and productivity for sustainable food and nutrition security in Bangladesh. It is important that policy makers come to a better understanding of the implications of CA.
- CA is considered as a more sustainable and environmentally friendly management system for cultivating crops. Crop production in the next decade needs to be increased tremendously from less land by making more efficient use of natural resources and with minimal impact on the environment.
- The study concludes that conservation agriculture as a new resource saving farming practice appreciated and successfully adopted by the farmers in the study areas though lower profit was experienced in the first cropping year, it was expected that profit will be higher within next three or four year.

G. Information regarding Desk and Field Monitoring

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

Monitoring workshop	Date(s) of workshop	Remarks
NRM Unit, BARC & PIU-BARC, NATP-2	15/05/2018	There were some suggestions givenby experts for attaining better achievement of the sub-project activities and during final reporting, necessary steps were taken according to these suggestions.

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

Monitoring team	Date(s) of visit	No. of visit	Remarks
Technical Division/Unit, BARC	14/03/2018	1	Satisfactory
PIU-BARC, NATP-2	17/01/2018 &14/03/2018	2	Satisfactory
Internal Monitoring (BARI)	06/02/2018	1	Satisfactory

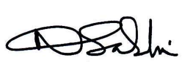
H. Lesson Learned (if any)

- Cultivation of rice is possible without puddling.
- Previous crop residue retention and strip/minimum tillage improves soil physical, chemical and biological properties.
- The seed yield of mustard increased with the increased rates of N fertilizer (125% RND) under strip tillage in the upland condition.

- Statistically higher REY was observed in strip tillage than conventional tillage in wheat-mungbean-T. Aman cropping system.
- The maximum REY was observed in 125% RND followed by 100% RND and 75% RND tillage in mustard-Boro-T. Aman cropping system.
- The highest REY was recorded in 80% chemical fertilizer + 20% cow dung and 125% chemical fertilizer of STB in the onion-jute -T. aman cropping system.

I. Challenges (if any)

- Due to unexpected rainfall during dry winter season followed by kharif-I season, crop establishment was difficult. Mustard sowing time was delay and mustard plants became stunted in some extent and T. aman rice was lodging down at ripening stage and mung bean was damaged at Joydebpur in 2018 year.
- In the last week of March/2018 (onion growing period), a heavy thunderstorm occurred in some parts of the country, especially at the experimental site, Rajbari. Therefore, onion plants were badly affected by rainstorm and the onion was harvested at least 2 weeks ago before getting full physiological maturity.
- Delayed fund release hampered project activities.
- While conservation agriculture (CA) can increase yields in the long-term, farmers may need to wait 3 to 7 years to see such increases.



Signature of the Principal Investigator
Date: 21.07.2019
Seal

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