Sub-project ID-064

Program Based Research Grant (PBRG)

Sub-project Completion Report

On

Design and development of fertilizer deep placement mechanism for existing rice transplanter

Sub-project Duration

14 February, 2018 to15 November, 2021

Coordinating Organization

Farm Machinery and Postharvest Technology Division
Bangladesh Rice Research Institute (BRRI)
Gazipur-1701

Project Implementation Unit
National Agricultural Technology Program-Phase-II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

September 2021

Ministry of Agriculture

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Program Based Research Grant (PBRG)

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Design and development of fertilizer deep placement mechanism for existing rice transplanter

Implementing Organization

Farm Machinery and Postharvest Technology (FMPHT) Division

&

Soil Science Division

Bangladesh Rice Research Institute (BRRI)

Gazipur-1701

Project Implementation Unit

National Agricultural Technology Program-Phase-II Project

Bangladesh Agricultural Research Council

Farmgate, Dhaka-1215

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Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
New Airport Road, Farmgate, Dhaka - l2l5
Bangladesh

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Abbreviation and Acronyms

AAO	:	Additional Agricultural Officer
AEO	:	Agriculture Extension Officer
AFC	:	Actual Field Capacity
ATS	:	Active Tillering Stage
BARC	:	Bangladesh Agricultural Research Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BCR	:	Benefit Cost Ratio
BINA	:	Bangladesh Institute of Nuclear Agriculture
BRRI	:	Bangladesh Rice Research Institute
CH_4	:	Methane
CO_2	:	Carbon Dioxide
DAE	:	Departmental of Agricultural Extension
DAP	:	Di-ammonium Phosphate
DAT	:	Days After Transplanting
FAPAD	:	Foreign Aided Project Audit Directorate
FDP	:	Fertilizer Deep Placement
FDR	:	Fertilizer dispensing rate per rotation of the driving wheel (g/rotation)
FMPHTD	:	Farm Machinery and Postharvest Technology Division
FPM	:	Farm Power and Machinery
GC	:	Gas chromatography
GHG	:	Greenhouse Gas Emission
GWP	:	Global Warming Potential
HQ	:	Head Quarter
HYV	:	High Yielding Variety
LoS	:	Level of Significance
LSD	:	Least Significant Difference
MoA	:	Ministry of Agriculture
MoP	:	Muriate of Potash
MTS	:	Maximum Tillering Stage
N_2O	:	Nitrous Oxide
NATP	:	National Agricultural Technology Program
NECB	:	Net Ecosystem Carbon Budget
NRM	:	Natural Resource Management
PBRG	:	Program Based Research Grant
PCR	:	Project Completion Report
PIU	:	Project Implementation Unit
PVC	:	Polyvinyl Chloride
R/S	:	Regional Station
RCBD	:	Randomized Complete Block Design
RD	:	Recommended Dose
RTFA	:	Rice Transplanter cum Fertilizer Applicator
TFC	:	Theoretical Field Capacity
TSP	:	Triple Super Phosphate
UAO	:	Upazila Agriculture Officer
UMG	:	Urea Mega Granule
USG	:	Urea Super Granule
ZnSo4	:	Zinc Sulphate

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Executive Summary

"Design and development of fertilizer deep placement mechanism for existing rice transplanter", a program based research grants, received fund from NATP-2, Bangladesh Agricultural Research Council (BARC) and officially launched on 14 February, 2018 through the signing of letter of agreement. Walking and Riding type rice transplanter are modified under the sub-project. Mixed fertilizer deep placement mechanism was incorporated in the walking (ARP-4UM) and riding type (S3-680) rice transplanter. Both the technology improved based on problems identified during field trials in Boro 2018-19 and Aman 2019 seasons. In both type rice transplanters, spiral type mechanism was incorporated as metering device to receive and dispense desired amount of mixed fertilizer. In case of walking type rice transplanter, engine power available at high rpm (more than 1800 rpm of the walking type rice transplanter) was conveyed to the applicator with the arrangement of a belt-pulley, worm gearing, shaft-bearing, chain-sprocket and bevel gear with engage-disengage facility resulting 23 rpm of the applicator main shaft.

Spiral conveying mechanism was designed and connected with the main shaft of the applicator to collect and dispense fertilizer mixture to the output channel of the applicator at desired rate based on variety and seasons. A measuring scale mentioning 1 to 8 number was used for ease of fertilizer rate control. Fertilizer dispensing rate increased with the increase of number of the lever position. Developed rice transplanter cum fertilizer applicator (RTFA) was evaluated in the laboratory, soil bin, research field and farmer's field also. In the lab test, it was found that fertilizer control lever can control fertilizer dispensing rate according to pre-calibration. In the soil bin test, it was observed that mixture fertilizer dispensed uniformly in the furrow and covered effectively. Agitator, which was used in the fertilizer hopper, rotated smoothly to prevent the bonding of fertilizer mixture. Power transmission from engine to the applicator main shaft through different stages was also found smooth, safe and heavy duty. In Aman 2019 and Aman 2020 seasons, the developed walking type rice transplanter was evaluated in 14 (07 in each season) different locations of the country while it was evaluated in 03 locations during Boro 2018-19 season and in 07 locations during Boro 2019-20 seasons. RCB design was followed in both the seasons with three replications. Treatments of the studies were mechanical transplanting along with mixed fertilizer deep placement simultaneously (T_1), mechanical transplanting and hand broadcasting of fertilizer (T_2) and traditional transplanting and hand broadcasting of fertilizer (T_3).

In Boro 2018-19 season, average dispensing rate of fertilizer in lever position 4 was calibrated 67.94 g/rotation of the rice transplanter driving wheels based on recommended dose of fertilizer while average deviation of fertilizer dispensing rate was about +3.72% due to clog of the dispensing channel of the transplanter during operation. Average of two trials, theoretical field capacity, actual field capacity and field efficiency of the RTFA were found 0.20 ha/h, 0.0.12 ha/h and 58.95% while it was 0.20 ha/h, 0.13 ha/h and 64.10% of the rice transplanter without fertilizer deep placement mechanism respectively. During field trials in Aman 2019 season, average dispensing rate of fertilizer in lever position 3 was calibrated 37.8 g/rotation of the rice transplanter driving wheels based on recommended dose of fertilizer while average deviation of fertilizer dispensing rate was about -4.86% due to slippage of the wheels during operation. Average of seven trials, theoretical field capacity, actual field capacity and field efficiency of the RTFA were found 0.19 ha/h, 0.23 ha/h and 82.2% while it was 0.21 ha/h, 0.26 ha/h and 80.3%

of the rice transplanter without fertilizer deep placement mechanism respectively. In Boro 2019-2020 season, average dispensing rate of fertilizer in lever position 4 was calibrated 68.6 g/rotation of the rice transplanter driving wheels based on recommended dose of fertilizer while average deviation of fertilizer dispensing rate was about +1.18% due to clog of the dispensing channel of the transplanter during operation. Average of 07 trials, theoretical field capacity, actual field capacity and field efficiency of the RTFA were found 0.25 ha/h, 0.20 ha/h and 79.74% while it was 0.27 ha/h, 0.22 ha/h and 80.24% of the rice transplanter without fertilizer deep placement mechanism respectively. In Aman 2020 season, only yield data were collected.

BRRI dhan58 was cultivated in Boro 2018-19 season in Kushtia and Habiganj. Higher yield was observed for machine transplanting along with fertilizer deep placement in both locations (7.9 and 6.2 t/ha, respectively) followed by mechanical transplanting (6.8 and 5.5 t/ha, respectively). During field trials in different 07 locations in Aman 2019 season, it was observed that rice yield varied with the mode and rate of fertilizer application. Mechanical transplanting along with mixed fertilizer deep placement (80% of the recommended dose of urea) gave significantly higher yield compared to the mechanical and manual transplanting along with hand broadcasting of fertilizers while rice variety was BRRI dhan71 in Rangpur, Gazipur, Netrakona and Habiganj, BRRI dhan75 in 01 locations of Kushtia and BRRI dhan87 in 02 locations in Kushtia. In Boro 2019-20, rice variety was BRRI dhan89 in 04 locations (Gazipur, Kushtia-1 and Kushtia-2 and Netrakona), BRRI dhan58 in 02 locations (Rangpur and Habiganj) and BRRI dhan28 in Kushtia-3. Similar result was observed in Aman 2020 in 7 trials while rice variety was BRRI dhan80 in Rangpur, Gazipur, Habiganj and BRRI dhan87 in Kushtia (3 trials) and Netrakona. Average across the variety, locations and years, rice yield was 6.8, 5.9 and 5.6 t/ha for mechanical transplanting along with fertilizer deep placement, only mechanical transplanting and traditional transplanting in Boro seasons while it was 5.3, 4.7 and 4.4 t/ha in Aman season. Mechanical transplanting along with mixed fertilizer deep placement also gave higher BCR compared to the other two treatments. A total of three hands on training (one-day-long) on the developed technology were conducted at Netrakona, Kushtia and Rangpur. Farmers showed their interest on the developed technology for its multifunctional use of the machine.

Methane (CH_4), Carbon dioxide (CO_2) and Nitrous oxide (N_2O) emissions from rice fields are intensified during rice cultivation, but its emission is generally analyzed based on hand or manual transplanting system. It needs to know how CH_4, CO_2 and N_2O emission patterns are affected when rice crops are grown in the same field in a year at different regions of Bangladesh. Research experiment was conducted to incorporate the fertilizer deep placement mechanism (FDP) with greenhouse gas emission (GHG) determination under different management at Kushtia and Gazipur region. Different static greenhouse gas chambers were made for collected and analysis of GHG during study period under existing and modified fertilization systems during Boro and T. Aman rice cultivation at Kushtia and Gazipur region. Static greenhouse gas chamber were installed at Kushtia and Gazipur fields for collection of GHG during Boro and T. Aman season. RCB design with three replications were applied to evaluate the machine. Treatments of the trials were T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Hand transplanting and T_3 = Mechanical transplanting along with mixed fertilizer deep placement. The mechanical transplanting along with mixed fertilizer minimized CH_4 emission compared to hand transplanting, but enhanced its emission than mechanical transplanting with hand broad casting fertilizer. It was found that mechanical transplanting along with mixed fertilizer treatment significantly reduced the total CH_4 flux by

22-38% and 7-12% compared to hand transplanting in Boro and T. Aman season at different regions of Bangladesh. Mechanical transplanting along with mixed fertilizer reduced about 6-41% and 4-20% global warming potential than hand transplanting. During T. Aman season, total nutrient uptake increased by 40-44%, 2-4%, 7-17% of N, P, K with mechanical transplanting along with mixed fertilizer than others treatments. In Boro season, mechanical transplanting along with mixed fertilizer increased by 16-32%, 13-33%, 11-24% of N, P, K total nutrient uptake compared to hand transplanting. Rice yield also significantly higher with mechanical transplanting along with mixed fertilizer than other treatments under both seasons. In conclusion, mechanical transplanting along with mixed fertilizer could be useful technique for higher rice yield, nutrient uptake, reduction in CH_4 emission and global warming potential during Boro- T. Aman rice cultivation.

Keywords: Machine design, Mechanical transplanting, Fertilizer deep placement, nutrient use efficiency, Nutrient uptake and Greenhouse gas emission.

PBRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the PBRG sub-project:

Design and development of fertilizer deep placement mechanism for existing rice transplanter (ID: 064)

2. Implementing organization(s):

Component-1:
Farm Machinery and Postharvest Technology (FMPHT) Division
Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh

Component-2:
Soil Science Division
Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh

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

a. Coordinator:

1. Dr. Md. Ansar Ali (14 February, 2018 to 29 August, 2019)
Director (Administration and Common Service), BRRI, Gazipur-1701
Mobile: 01925-053582 and Email:maalibrri@yahoo.com
2. Dr. Mohammad Abdur Rahman (01 September, 2019 to 23 September, 2021)
Head and Chief Scientific Officer, FMPHT Division, BRRI, Gazipur-1701
Mobile: 01714-236911 and Email: abrahman42@gmail.com

b. Principal Investigator (Component-1):

Dr. Md. Anwar Hossen
Senior Scientific Officer, FMPHT Division, BRRI, Gazipur-1701
Cell No.: +88-01712675130 and Email: ahossenbrri@gmail.com

c. Co-Principal Investigator (Component-1):

Dr. Md. Golam Kibria Bhuiyan
Senior Scientific Officer, FMPHT Division, BRRI, Gazipur-1701
Cell No.: +88-01717902516 and Email: kibria_1971@yahoo.com

d. Principal Investigator (Component-2):

Dr. Md. Mozammel Haque
Senior Scientific Officer
Soil Science Division, BRRI, Gazipur-1701
Cell No.: +88-01718133016 and Email: mhaquesoil@yahoo.com

4. Sub-project budget (Tk):

4.1 Total:(in Tk as approved): 1,10,00000/- (One core and ten lakh taka only)
4.2 Latest Revised (if any): Revised within same amount

5. Duration of the sub-project: From 14 February, 2018 to 15 November, 2021

5.1 Start date (based on LoA signed): From 14 February, 2018
5.2 End date:15 November, 2021

6. Background of the sub-project:

Rice is the most dominant field crop in Bangladesh covering 75% of the total cultivated area and consumes 80% of the total fertilizers alone. Urea deep placement (UDP) or fertilizer (Urea, TSP, MoP and Gypsum) deep placement (FDP) is an effective management practices for wetland transplanted rice by increasing its productivity (Misra *et al*., 1999 and Bowen *et al*., 2005). Rice yields with FDP compared with broadcasting are almost 30 present more (1.2 metric tons per hectare) (IFDC, 2015). Most of the farmers of Bangladesh do not follow the judicious nutrient management strategies on rice production. As a result, farmers cannot get maximum benefits of fertilizer application on rice yields. Hence, mixed fertilizer deep placement mechanism was incorporated in the existing rice transplanter. Incorporation of mixed fertilizer deep placement mechanism in the existing rice transplanter: design, fabrication and evaluation were the parts of this study. Spiral type metering mechanism was used to develop the technology. Fertilizer deep placement mechanism is added with the imported walking and riding type rice transplanter (Model: ARP-4 UM and S3-680, South Korea). Power transmission from rice transplanter engine to the applicator, fertilizer dispensing mechanism, frame, skid, hopper, agitator, furrow opener and closer were designed and incorporated to the rice transplanter for developing the technology using locally available materials. The mechanism incorporated in such way that the farmers can use the technology with fertilizer deep placement mechanism or without fertilizer deep placement mechanism. It is suitable to apply either single or mixed fertilizers during operation. In addition, research was conducted to observe greenhouse gas emission under deep placements of prilled urea/mixing of prilled urea, TSP, MoP, Gypsum along with farmers' practices. Finding will be helpful to mitigate the greenhouse gas emission from rice soil.

7. Sub-project general objective (s):

- To incorporate fertilizer deep placement (FDP) technology in the existing walking and riding type rice transplanter for simultaneous application of fertilizer mixture with rice seedlings transplanting.

8. Sub-project specific objectives (component wise):

8.1 Component-1: FMPHT Division, BRRI

- To design and development of power transmission mechanism from engine to the applicator for both walking and riding type rice transplanter
- To design and attach adjustable type fertilizer dispensing mechanism in the rice transplanter
- To design skid, furrow opener and covering mechanism for fertilizer deep placement
- To test, evaluate and validate the technology in laboratory, research field and farmers' field
- To save energy, cost and time of separately seedling transplanting and deep placement of fertilizer application

8.2 Component-2: Soil Science Division, BRRI

- To determine fertilizer use efficiency and recovery of different application methods
- To compare the yield and yield contributing characters under varying methods of fertilizer application
- To identify the CH_4, CO_2 and N_2O emission under varying methods of fertilizer application in rice soils of Bangladesh
- To mitigate the global warming potential in rice soils under varying methods of fertilizer application
- To find out changes of soil chemical properties

9. Implementing location (s):

Rice transplanter cum mixed fertilizer applicators were designed, fabricated and modified in the FMPHT divisional research workshop to incorporate the mixed fertilizer deep placement mechanism. Some of the components were fabricated in the local workshop according to the design. Developed technology were evaluated in the divisional soil bin, BRRI research farm and different sub-project locations of the country namely Sadar, Rangpur; Sadar, Gazipur; Mirpur, Kushtia; Kumarkhali, Kushtia; Purbadhala, Netrakona and Shaistaganj, Habiganj during sub-project period.

10. Methodology in brief (with appropriate pictures): Component-1:

10.1 Incorporation of mixed fertilizer applicator in the rice transplanter

10.1.1 Rice transplanter selection

Power operated walking type and riding type rice transplanter was used for design and development. The major specification of the transplanter is given in Table 1 and 2. The photographic view of the transplanter is also shown in figure 1 and 2.

Table 1. Specifications of the walking type rice transplanter

Country of origin and Model		South Korea and ARP-4UM
Type		Walk behind type
Dimensions	Overall length × width × height (mm)	23505×1480×800
	Overall weight (kg)	175
	Maximum output kW rpm^{-1}	3/1800
	Starting method	Recoil
Travelling Section	Steering	Hydraulic power steering mode
	Wheel type	Rubber lug wheel (Dia.: 60 cm)
	Gearshift: Forward× Reverse	2 speeds and 1 speed
Transplanting Section	Transplanting mechanism	Rotary
	Number of rows	4
	Row to row distance (mm)	300 (fixed)
	Plant to plant distance (mm)	110 to 150
	Transplanting speed, m s^{-1}	0.3 to 0.7

Table 2.Specifications of the riding type rice transplanter

Description of items			
	Overall length, width & height (mm)		3120, 2140 and 1655
	Overall weight (kg)		620
	Type		4-stroke, air-cooled OHV gasoline
Dimensions	Displacement (CC)		437
	Maximum output kW/rpm		10.5/3600
	Fuel tank capacity (L)		15 – 20
	Starting method		Electric motor start mode
	Steering		Hydraulic power steering mode
Traveling		Diameter (mm)	650
Section		Rear	Solid rubber
		Diameter (mm)	900

	Gearshift	Forward	2 speeds
		Reverse	1 speed
	Transplanting mechanism		Rotary type
	Number of rows		6
	Row to row distance (mm)		300
Transplanting Section	Plant to plant distance (mm)		140,160, 180, 200 (4 setting)
	Planting pitch control		Adjustable
	Planting depth control		Adjustable
	Planting depth, cm		0.8 – 4.4 (adjustable)
	Number of spare seedling rack		6
	Transplanting speed, m s^{-1}		0 to 1.36

Fig. 1. Walking type rice transplanter (South Korea and ARP-4UM)

Fig. 2. Riding type rice transplanter (South Korea and S3-680)

10.1.2 Design considerations

- Fertilizer deep placement (FDP) should be in between two rows and before the rotary picker
- FDP technology should be operated with the existing power of the transplanter
- Depth of fertilizer placement should be in between 80 to 100 mm
- Uniformity of fertilizer dispensing should be maintained to keep the desired dose of fertilizer
- Power transmission system should be simple with engage and disengage facility
- Locally available materials should be used to minimize the fabrication cost.

10.1.3 Design steps

- Belt-pulley arrangement with tension pulley was designed to transmit power from engine shaft to an additional shaft attached in the same axis with engage and disengage facility.
- A simple gear box incorporating worm and bevel gears was designed and attached to the rice transplanter to reduce rpm at the ratio of 35:1 and transmit at 90^0 directions.
- Spiral type fertilizer metering device was designed and attached in front of seedling holding tray to collect and dispense fertilizer at desired rate.
- Skid in between two rotary pickers was attached with variable depth control mechanism to place the dispensed fertilizer in the furrow and covered properly,
- All components of the mixed fertilizer deep placement mechanism were fabricated and attached in the transplanter as per design.

10.1.4 Fabrication

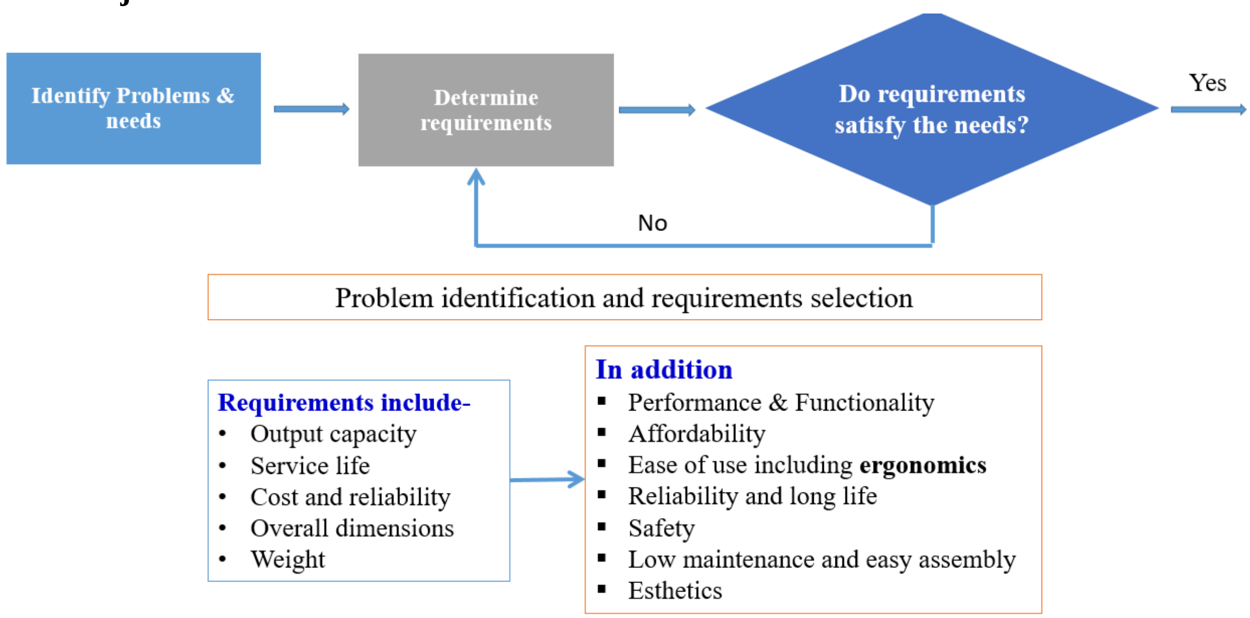
Mechanism was used based on basic principle of machine design and drawing was done using AutoCAD tools. A Prototype was fabricated in FMPHT divisional research workshop. Existing facility of the workshop was used to develop the rice transplanter cum mixed fertilizer applicator. Some of components were fabricated in the private workshop according to design.

10.2 Field evaluation of the rice transplanter cum mixed fertilizer applicator

This study was conducted to evaluate the performance of BRRI developed rice transplanter cum mixed fertilizer applicator (RTFA) in the farmers' field as well as BRRI regional station.

10.2.1 Objectives of the field operation

Main objective



Specific objectives

- To observe the field performance of the developed technology in different locations and seasons
- To identify the field problems for further improvement
- To compare the different transplanting and fertilizer application methods
- To analyze the economics of the developed technology

10.2.2 General information

Season-wise variety, location and area covered is presented in Table 3. A total of 24 trials were conducted during the project period during Boro and Aman seasons in project locations. A total of 13.4 ha area were covered under these study.

Table 3. Season-wise variety, location, area covered and date of cultivation.

No	Place	Variety	Area[1]	D/S	D/T	D/H
Boro, 2018-19						
1	Gazipur	BRRI dhan58	32	16-12-18	10-01-19	28-05-19
2	Kushtia	BRRI dhan58	105	06-12-18	15-01-19	15-05-19
3	Habiganj	BRRI dhan58	73	10-01-19	15-02-19	25-05-19
Aman, 2019						
1	Rangpur	BRRI dhan71	82	11-07-19	27-07-19	31-10-19
2	Gazipur	BRRI dhan71	64	20-07-19	02-08-19	04-11-19
3	Kushtia (1)	BRRI dhan87	82	20-07-19	07-08-19	27-11-19
4	Kushtia (2)	BRRI dhan75	72	20-07-19	07-08-19	07-11-19
5	Mirpur	BRRI dhan87	122	21-07-19	06-08-19	19-11-19
6	Netrakona	BRRI dhan71	88	10-08-19	22-08-19	06-12-19
7	Habiganj	BRRI dhan71	64	12-08-19	23-08-19	25-11-19
Boro, 2019-20						
1	Gazipur	BRRI dhan89	65	27-12-2019	28-01-2020	23-05-2020
2	Kushtia 1	BRRI dhan89	200	07-01-2020	09-02-2020	31-05-2020
3	Kushtia 1	BRRI dhan28	200	07-01-2020	10-02-2020	16-05-2020
4	Mirpur	BRRI dhan89	130	07-01-2020	08-02-2020	29-05-2020
5	Netrakona	BRRI dhan89	160	30-12-2019	02-02-2020	26-05-2020
6	Rangpur	BRRI dhan58	160	11-01-2020	15-02-2020	28-05-2020
7	Habiganj	BRRI dhan58	65	10-01-2020	18-02-2020	14-05-2020
Aman, 2020						
1	Rangpur	BRRI dhan80	100	29-07-2020	16-08-2020	10-12-2020
2	Gazipur	BRRI dhan80	80	28-07-2020	12-08-2020	08-12-2020
3	Kushtia (1)	BRRI dhan87	400	04-07-2020	29-07-2020	09-11-2020
4	Kushtia (2)	BRRI dhan87	400	04-07-2020	30-07-2020	10-11-2020
5	Mirpur	BRRI dhan87	130	11-07-2020	28-07-2020	15-11-2020
6	Netrakona	BRRI dhan87	650	07-07-2020	05-08-2020	12-11-2020
7	Habiganj	BRRI dhan80	73	03-07-2020	08-08-2020	14-11-2020

Note: [1]Area in decimal, D/S-Date of seeding, D/T-Date of transplanting and D/H-Date of harvesting

10.2.3 Experimental design and treatments

The experiment was laid out in a randomized complete block (RCB) design with three replications. About half meter of buffer spacing was maintained among the sub-plots. The treatments were

Treatments

T_1= Mechanical transplanting along with mixed fertilizer deep placement

T_2= Mechanical transplanting and hand broadcasting of fertilizer and

T_3= Manual transplanting and hand broadcasting of fertilizer

10.2.4 Seed bed preparation

Seedlings were raised on plastic tray (280×580×25 mm) both in BRRI, Gazipur and farmers' field for mechanical and manual transplanting at the same date. Thirty (30) days old seedling in

Boro (Fig. 3) and 18 days old seedlings in Aman (Fig. 4) season were used in mechanical transplanting while 45 and 35 days old seedling were used in hand transplanting respectively.

10.2.5 Transplanting

Walking type mechanical rice transplanter (model:ARP-4 UM) was modified and successfully incorporated mixed fertilizer deep placement mechanism. The developed rice transplanter cum mixed fertilizer applicator was used to transplant the rice seedling in treatments T_1 and T_2 whereas treatment T_3 was transplanted manual using seedling raised in farmers' seed bed (Fig.5-9).

Fig. 3. Seedling raising on tray in Boro 2018-19 season (BRRI dhan58)

Fig. 4. Seedling raised in Aman 2019 season (BRRI dhan71)

Fig. 5. Field operation of the RTFA in Boro season, 2018-19 (Habiganj and Kushtia)

Fig. 6. Uniform covering of dispensed fertilizer in Boro 2018-19 season (Kushtia)

Fig. 7. Fertilizer re-filling during operation in Boro 2018-19 season (BRRI Gazipur)

Fig. 8. Field operation of the RTFA in Aman, 2019 (M. Kushtia)

Fig. 9. Field operation of the RTFA in Aman, 2019 (Netrakona)

10.2.6 Mixed fertilizer deep placement

Urea fertilizer along with TSP, MoP and Gypsum fertilizer were placed in non-oxidized zone during mechanical transplanting with the same machine. Before field operation of the BRRI rice transplanter cum mixed fertilizer applicator, it was calibrated to maintain the pre-designed dose of fertilizer (Table 4). BRRI recommended urea fertilizer dose was considered 280 kg ha^{-1} for BRRI dhan29 and BBRI dhan58 for Boro 2018-19 season. At 80% of the recommended dose, 224 kg ha^{1} was used in the study. TSP, MoP and Gypsum fertilizer were 100, 165 and 112 kg ha^{-1} as recommended dose, respectively. In Boro 2019-2020 season, BRRI recommended urea fertilizer dose was considered 300 kg ha^{-1} for BRRI dhan89. At 80% of the recommended dose, 240 kg ha^{1} was used in the study. TSP, MoP and Gypsum fertilizer were 105, 150 and 112 kg ha^{-1} as recommended dose, respectively.

In Aman season, urea 167 kg ha^{-1} (20% less in T_1:134 kg ha^{-1}), TSP 62 kg ha^{-1}, MoP 83 kg ha^{-1} and Gypsum 56 kg ha^{-1} were applied based on Aman yield about 5.0 t/ha and lower fertility class of land (BRRI 2019). To maintain the desired rate of fertilizer, fertilizer dispensing rate per rotation of the driving wheel was calculated using the following formula (Hossen et al., 2019). This formula was developed for easy calibration of the applicator.

$$FDR = \frac{\pi D \times 2L \times RoF}{10^5}$$

Where,

FDR = Fertilizer dispensing (from each channel) rate per rotation of the driving wheel (g/rotation)
D = 60 cm, wheel diameter of the rice transplanter
L = 30 cm, line to line spacing of the transplanted rice
RoF = Desired rate of fertilizer application, kg ha^{-1}

All fertilizer was placed in non-oxidized zone during mechanical transplanting with the same machine. Before operation of the developed rice transplanter cum fertilizer applicator in the field, it was calibrated to maintain the pre-designed dose of fertilizer (Table 4).

Table 4. Calibration of mixed fertilizer (g/rotation)

Season	Urea[1] (kg ha^{-1})	TSP (kg ha^{-1})	MoP (kg ha^{-1})	Gypsum (kg ha^{-1})	Total (Urea, TSP, MoP and Gypsum) (kg ha^{-1})	FDR (g/rotation)
Boro/2018-19	224	100	165	112	601	67.94
Aman 2019	134	62	83	56	335	37.87
Boro/2019-20	240	105	150	112	607	68.6
Aman/2020	134	62	83	56	335	37.87

Note: [1]Urea-80% of the RD, RD-Recommended dose, TSP-Triple Super phosphate, MoP-Muriate of Potash and FDR-Fertilizer dispensing (from each channel) rate per rotation of the driving wheel (g/rotation)

Theoretical dispensing rate of mixture fertilizer was calculated 67.94 and 68.6 g/rotation of the driving wheels from each channel in Boro 2018-19 and Boro 2019-2020 season whereas it was 37.87 g/rotation in Aman seasons.

10.2.7 Fertilizer management

Recommended dose of fertilizers were broadcasted manually in T_2 and T_3 according to farmers' practices. Urea fertilizer (80% of RD) along with triple super phosphate (TSP), muriate of potash (MoP) and gypsum fertilizer were applied at transplanting using the developed machine in T_1.

10.2.8 Weed and pest management

Herbicides Saathi (Pyrazosulfuron Ethyl 10% WP) applied after 4 days of transplanting at the rate of 150g/ha (20 g/bigha). One hand weeding was done at 40 days after transplanting (DAT) to keep the fields weed free. Insect infestation was not observed in the field.

10.2.9 Irrigation water management

Experimental plots were irrigated as and when needed. During transplanting, minimum standing water was maintained in the field to reduce the floating hills as well as missing hills. Bunds around the individual plots were repaired as and when necessary to control the water flow between the plots. Water management cost was taken in consideration for BCR analysis.

10.2.10 Field capacity of the machine

Field capacity of the rice transplanter was measured with and without mixed fertilizer deep placement mechanism along with seedling transplanting. Machine operation time included time required during turning of the transplanter, feeding of seedling, fertilizer refilling in the hopper, operator's personal time, adjustment time etc. were summed to calculate the actual field capacity of the rice transplanter cum mixed fertilizer applicator, which is transplanting and fertilizing area covered (ha) divided by the time of operation (hrs). Field efficiency was measured based on actual field capacity and theoretical field capacity. Field operation of the rice transplanter cum mixed fertilizer applicator in different locations is presented in figure 5-9.

10.2.11 Actual amount of fertilizer application

Actual amount of mixed fertilizer dispensing vary from calibrated amount of fertilizer due to slippage of the wheels, variation of wheel penetration, irregular speed of operation, vibration of the machine, fertilizer loss during turning etc. Deviation percentage of fertilizer dispensing from calibration was calculated dividing the actual dispensing rate of fertilizer by the recommended rate of fertilizer of the respective area followed by subtracting from 100.

10.2.12 Yield and yield contributing character

Tiller number and plant height was counted from 12 hills per plot at 15-day intervals. Crops were harvested when 85-90% of the rice became golden. The harvested crop of each plot bundled separately, tagged and carried to a clean threshing floor. Sample bundles were then dry, threshed and then seeds were cleaned. Rice yield per plot were recorded from a pre-selected 10 m^2 harvest area and was determined with the adjustment to 14 % moisture content. For computing above ground biomass and yield attributes, samples from 1 m^2 quadrates were collected from outside of the pre-selected 10 m^2 area of each plot. Straw yield (above ground biomass), plant height, panicle length, number of tillershill^{-1} and number of panicleshill^{-1}, filled and unfilled spikelets panicle^{-1} and 1000 grains weight recorded from these quadrates.

10.2.13 Labor requirement

Number of human labor involved in each operation from seedling raising to processing is measuring to calculate the benefit-cost ratio under different treatments.

10.2.14 Operating cost calculation

Operating cost (Tk hr^{-1}) of the RTFA was calculated considering the fixed cost (Tk hr^{-1}) and variable cost (Tk hr^{-1}) using the method mentioned in Hunt (1995). Depreciation, interest on investment, tax, insurance and shelter are the components of fixed cost and calculated using the following equations.

a) Annual depreciation, $D = \frac{P - S}{L}$

Where,

D = depreciation, Tk yr^{-1}

P = purchase price of the RTPUA, Tk

S = salvage value, Tk

L = working life of the RTPUA, yr

b) Interest on Investment, $I = \frac{P + S}{2} xi$

Where, i = rate of interest

c) Tax, insurance and shelter cost, T = 3 % of purchase price.

Total fixed cost per year, FC = (a + b + c)

In variable cost calculation, the cost of fuel, lubrication, daily service, power and labor were considered. These costs increase with the increase of machine use and vary to a large extent in direct proportion to days of use per year.

d) labor cost per hour, L = Tk hr^{-1}

e) Fuel cost per hour, L = Tk hr^{-1}

f) Lubrication oil cost per hr, O = 3 % of fuel cost

g) Repair and maintenance cost (Tk hr^{-1}), RPM = 3.5% of purchase price (Tk yr^{-1}) * average annual use (hr yr^{-1})

Total variable cost = (d + e + f + g)

10.2.15 Economic analysis

Cost of rice production in different transplanting and fertilizer management practices were calculated based on total production and cost of production. Rental charge of the land and input costs were the components of production cost. Seedling raising, land preparation, fertilizer, labor, herbicides, weeding, transplanting, intercultural operation, irrigation, harvest and post-harvest costs were the components of input cost. Price of the product and production costs were used to calculate gross return, gross margin and benefit-cost ratio. The benefit-cost ratio (BCR) was computed as the gross return divided by production cost. Gross margin was also calculated by subtracting the total inputs from gross return. The total production cost was calculated by summing up the costs in individual operation. Costs of material, labor and machine were considered under respective operations.

10.3 Evaluation of different growing media for mat type rice seedling raising

Mat type seedling is a type of rice seedling that was made necessary by the introduction of mechanical transplanters, in which established seedlings eventually form a dense root mat and can be rolled into a cylindrical shape for transportation and later transplanting.

10.3.1 Weather condition during study period

This study is conducted in Sylhet to represent the cold area. Boro season represent the cold condition to raise seedling. The temperature and humidity during the seedling growing period were collected from local weather station and presented in the fig. 10 and 11, respectively. Study period for rising mat type seedling was 12 December, 2018 to 12 January, 2019.Different studies have shown that the impact of genotype, temperature, and their interactions on germination characteristics is important, with significant reductions in rice germination at temperatures below 16°C and above 30°C.

10.3.2 General information

Different information regarding season, variety, seed quality and soaking, sowing and germination percentage are presented in Table 5. All the parameters are very important and influence the seedling quality.

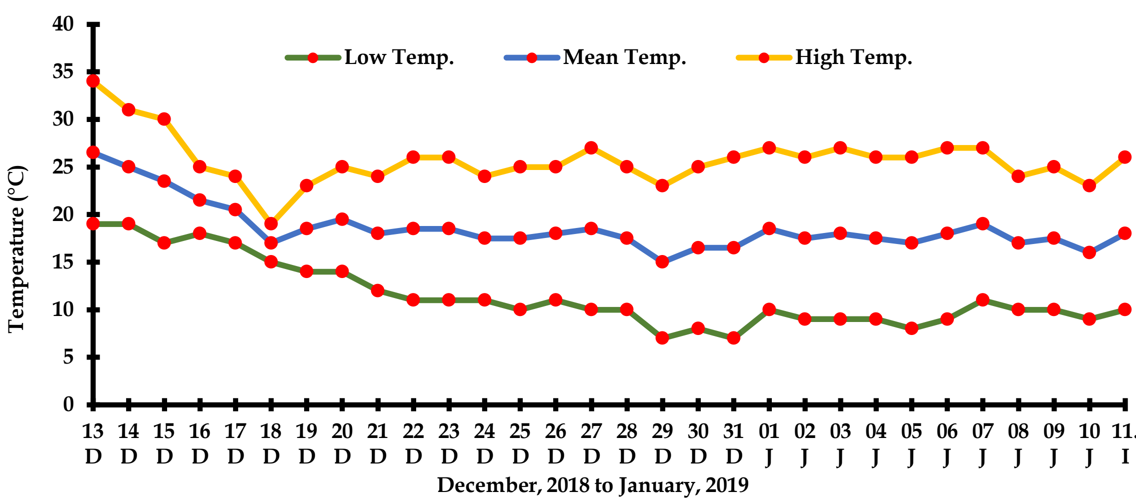


Fig. 10. Temperature during seedling growing period

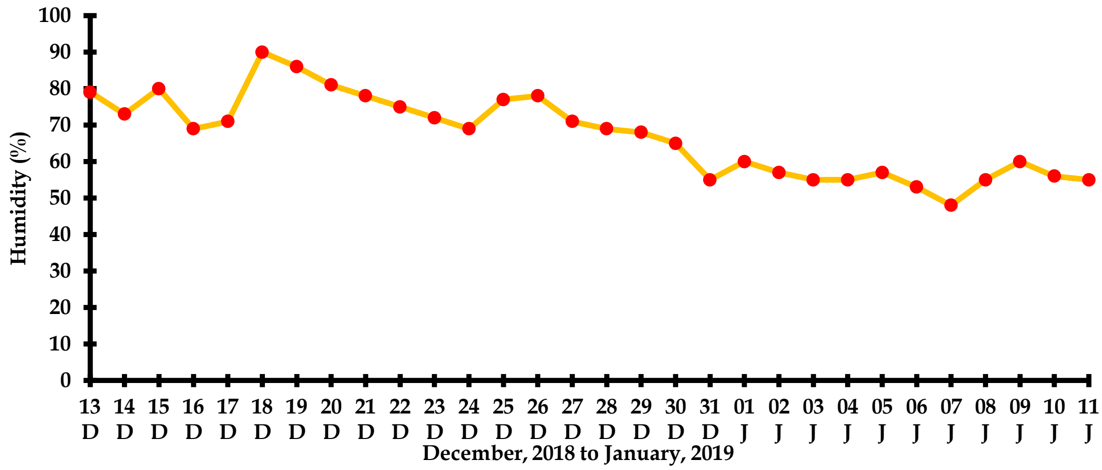


Fig. 11. Air humidity during seedling growing period

Table 5 General information of the experiment

Season	Variety	Soaking date	Sowing date	Germination (%)
Boro/2018-19	BRRIdhan28	08 Dec, 2018	12 Dec, 2018	86

10.3.3 Components of seedling growing media

Components used for preparing different growing media (Figure 12). Cow dung, rice bran, rice husk and tea wastage were used as components of seedling growing media. Rice bran and rice husk were a by-product of rice processing. Sandy clay loam and sandy clay soil were collected to use as major component for seedling growing media. Tea wastage was collected from local tea stall and used in the study.

10.3.4 Data collection

Data were collected on seedling height, number of leaf, leaf length, stem length, and stem thickness were collected at 15 and 30 days after sowing while seedling density, scoring of pest and disease incidence, number of normal and abnormal seedlings and mat characteristics were measured at 30 days after sowing. Field day was conducted at 30 days after sowing.

The data of seedling height, number of leaf, leaf length, stem length, and stem thickness were measured by slide calipers in millimeter. Seedling density was measured by a metal sheet made frame (100×100 mm^2) in number of plant per unit area. Scoring of pest and disease incidence, number of normal and abnormal seedlings and mat rolling up characteristics were measured in terms of scored 10 to 1 (10 for excellent, 8 for good, 6 for medium, 4 for bad, 2 for very bad and 1 for not possible to roll up in any way) and as number of infected plants and expressed in percentage respectively.

10.3.5 Physical properties of the seedling growing media

The components of growing media (cow dung, rice bran, rice husk and tea wastage)were air dried and passed through 2 mm sieve. A representative amount of soil sample was used for analyzing to identify the physical characteristics of the soil. Soil samples were analyzed in the SRDI (Soil Resource Development Institute) lab at Bypass road, Chondipul, Pirojpur, Sylhet and presented in the Table 6.

Table 6. Physical characteristics of the two different type of soil used as based materials for growing seedling

Properties	Value	
	Soil type-1	**Soil type-2**
Fine sand (%)	59.2	49.2
Silt (%)	14	12
Clay (%)	26.08	38.08
Texture class	Sandy clay loam	Sandy clay

10.3.6 Preparation of growing media

Sandy clay loam and sandy clay soil were used as major substance for seedling growing media. Cow dung, rice bran, rice husk and tea wastage (0%, 5%, 10%, 15% and 20% of each) were used as additional substances to mix with soil at the desired ratio (Fig. 12).

Fig. 12. Additional substances of growing-media mixed with based soil

Note: (Tray-1: Cow dung mixed with both type of soil, Tray-2: Rice bran mixed with both type of soil, Tray-3: Rice husk mixed with both type of soil and Tray-4: Tea wastage mixed with both type of soil).

10.3.7 Design of the experiment

A two-factor factorial design along with three replications was applied to identify the suitable rice seedling growing media as well as appropriate combination of base soil and additional substance. Organic substance was used as factor A and percentage of soil mixture was used as factor B for both type of soil separately (Table 7).

Table 7. Experimental arrangement

Soil type	Organic substance (Factor A)	Percentage of soil (Factor B)
Sandy clay loam	Cow dung	100% soil (Control)
Sandy clay	Rice bran	95% soil
	Rice husk	90% soil
	Tea wastage	85% soil
		80% soil

This arrangement was applied for both sandy clay loam and sandy clay soil separately. In all cases, mixture of base soil and additional substance were used as covering media. The treatments arrangement is given in Table 8.

10.3.8 Seedling tray preparation

All additional substance (cow dung, rice bran, rice husk and tea wastage) were mixed with sandy clay loam and sandy clay soil manually on volume basis and filled up the trays at desired depth. Seedling trays were filled up with mixed soil at a thickness of 20 mm which is 3/4th of the trays. Seeds @ 140 g per tray were spread uniformly on the mixed soil of the trays (Fig. 13).After sowing, respective soil mixture of each tray was spread over the seeds (3 - 4 mm thick) to cover the seeds.

Fig. 13. Seeds sowing on tray

10.3.9 Agronomic characteristics

Seedling height, number of leaf, leaf length, stem length and stem thickness were measured at 15 and 30 days after sowing whereas seedling density was measured at 30 days after sowing.

Table 8. Treatments arrangement of the study

Treatments	Factor A: Organic substance	Factor B: Percentage of soil
T_1	-	100% Soil (Control)
T_2	Cow dung	95% Soil (5% Cow dung)
T_3	Cow dung	90% Soil (10% Cow dung)
T_4	Cow dung	85% Soil (15% Cow dung)
T_5	Cow dung	80% Soil (20% Cow dung)
T_6	Rice bran	95% Soil (5% Rice bran)
T_7	Rice bran	90% Soil (10% Rice bran)
T_8	Rice bran	85% Soil (15% Rice bran)
T_9	Rice bran	80% Soil (20% Rice bran)
T_{10}	Rice husk	95% Soil (5% Rice husk)
T_{11}	Rice husk	90% Soil (10% Rice husk)
T_{12}	Rice husk	85% Soil (15% Rice husk)
T_{13}	Rice husk	80% Soil (20% Rice husk)
T_{14}	Tea wastage	95% Soil (5% Tea wastage)
T_{15}	Tea wastage	90% Soil (10% Tea wastage)
T_{16}	Tea wastage	85% Soil (15% Tea wastage)
T_{17}	Tea wastage	80% Soil (20% Tea wastage)

Note: All the treatments replicated thrice for both type of soil. The experiment was conducted separately for two different type of soil.

10.3.10 Mechanical characteristics (Rolling quality)

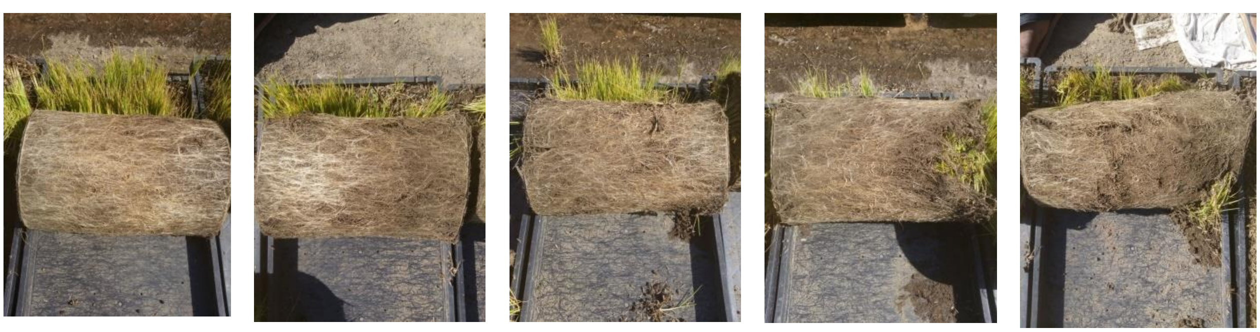
Rolling quality of the seedling mat and seedling strength were also measured at 30 days after seeds sowing. Rolling quality of the seedling mat were measured in terms of scored 10 for excellent (no crack during rolling), 8 for good (single and minor crack), 6 for medium (more than one crack but possible to roll up: medium crack), 4 for bad (more than one crack and difficult to roll up: major crack), 2 for very bad (more than one and large size crack and very difficult to roll up: extreme crack) and 1 for not possible to roll up in any way. Rolling quality of the seedling block under different growing media is shown in Figures 14-21.

1: 100% soil (zero cow-dung) | 2: 95% soil (5% cow-dung) | 3: 90% soil (10% cow-dung) | 4: 85% soil (15% cow-dung) | 5: 80% soil (20% cow-dung)

Fig. 14. Effect of sandy clay loam soil on rolling quality of seedling mat while mixing with cow-dung at different ratio

1: 100% soil (zero rice bran) | 2: 95% soil (5% rice bran) | 3: 90% soil (10% rice bran) | 4: 85% soil (15% rice bran) | 5: 80% soil (20% rice bran)

Fig. 15. Effect of sandy clay loam soil on rolling quality of seedling mat while mixing with rice bran at different ratio



1: 100% soil (zero rice husk) | 2: 95% soil (5% rice husk) | 3: 90% soil (10% rice husk) | 4: 85% soil (15% rice husk) | 5: 80% soil (20% rice husk)

Fig. 16. Effect of sandy clay loam soil on rolling quality of seedling mat while mixing with rice husk at different ratio

1: 100% soil (zero tea wastage) | 2: 95% soil (5% tea wastage) | 3: 90% soil (10% tea wastage) | 4: 85% soil (15% tea wastage) | 5: 80% soil (20% tea wastage)

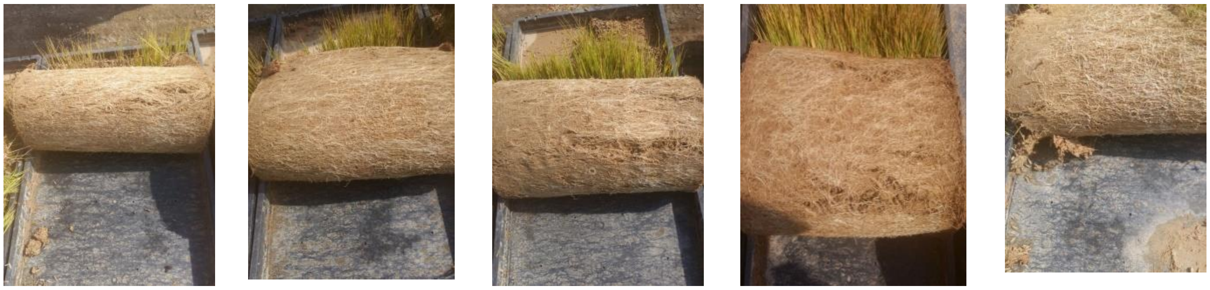
Fig. 17. Effect of sandy clay loam soil on rolling quality of seedling mat while mixing with tea wastage bran at different ratio

1: 100% soil (zero cow-dung) | 2: 95% soil (5% cow-dung) | 3: 90% soil (10% cow-dung) | 4: 85% soil (15% cow-dung) | 5: 80% soil (20% cow-dung)

Fig. 18. Effect of sandy clay soil on rolling quality of seedling mat while mixing with cow-dung at different ratio

1: 100% soil (zero rice bran) | 2: 95% soil (5% rice bran) | 3: 90% soil (10% rice bran) | 4: 85% soil (15% rice bran) | 5: 80% soil (20% rice bran)

Fig. 19. Effect of sandy clay soil on rolling quality of seedling mat while mixing with rice bran at different ratio



1: 100% soil (zero rice husk)	2: 95% soil (5% rice husk)	3: 90% soil (10% rice husk)	4: 85% soil (15% rice husk)	5: 80% soil (20% rice husk)

Fig. 20. Effect of sandy clay soil on rolling quality of seedling mat while mixing with rice husk at different ratio

1: 100% soil (zero tea wastage)	2: 95% soil (5% tea wastage)	3: 90% soil (10% tea wastage)	4: 85% soil (15% tea wastage)	5: 80% soil (20% tea wastage)

Fig. 21. Effect of sandy clay soil on rolling quality of seedling mat while mixing with tea wastage bran at different ratio

10.3.11 Scoring for pests and diseases

The pest and disease incidence were also observed at 30 days after seeds sowing (Fig. 22). It was measured as number of infected plants and expressed in percentage.

Healthy seedling **Fungal infected seedling**

Fig. 22. Healthy and fungal infected seedling

10.4 Mitigation of biotic and abiotic stress in mat type seedlings raising for mechanical rice transplanting

Healthy and vigorous seedlings are the most important factors for mat type seedling raising especially in low temperature the possibilities of fungal attack. This study was aimed to mitigate the biotic and abiotic effect on germination and mat type seedling growing during Boro season for mechanical rice transplanting. Different fungicides available in the market and MoP fertilizer along with covering by two different graded of white polythene sheet were used as treatments to mitigate biotic and abiotic stresses on mat type rice seedling. BRRI dhan28 was used as study material. Sandy clay loam soil was used to prepare the seedling tray (Fig. 23).

Fig.23. Soil sample preparation

10.4.1 Treatments and design

The experiment was being conducted in a two-factor design with three repetitions to control the biotic and abiotic stress on mat type rice seedling. The main factor was the covering mechanism (day-night time, night time only and uncovered) of the seedling tray by white polythene of different thickness (0.04 and 0.08mm) available in the markets while treating seeds as well as spray on young seedling immediate after emergence considered as sub-factor of the study. Main and sub-factors were considered to observe the effect of covering and treating mechanism on abiotic and biotic stress, respectively. The treatments arrangement is mentioned as follows-

Seedling covering mechanism used as main factor

P_1=Covering by 0.04 mm thickness polythene (day and night time)
P_2=Covering by 0.04 mm thickness polythene (night time only)
P_3=Covering by 0.08 mm thickness polythene (day and night time)
P_4=Covering by 0.08 mm thickness polythene (night time only)
P_5=Control (uncovered)

Seeds and seedling treating mechanism used as sub-factor

F_1= Seeds treated by fungicide-1
F_2= Seeds treated by fungicide-2
F_3= Fungicide-1spraying on infant seedling
F_4= Fungicide-2 spraying on infant seedling
F_5= MoP @ 8-10g/tray
F_6= Control

Seeds were treated using the fungicide (F_1 and F_2) before 10-12 hours of germination. Fungicide was spread on young seedling immediate after seedling emergence (F_3 to F_4). Seedling trays of treatments P_1 (0.04 mm thickness polythene) and P_3 (0.08 mm thickness polythene) were kept day and night time under the polythene shed during the growing periods while P_2 (0.04 mm thickness polythene) and P_4 (0.08 mm thickness polythene) were kept day time only under the polythene shed. Other management were same for all treatments. The agronomic and mechanical parameters of the raised seedling were assessed at 15 and 30 days after sowing. Sprinkler irrigation was used to irrigate regularly throughout the seedling growing period. Description of the fungicide applied as biotic stress control agent is presented in Table 9.

Table 9. Description of the fungicide applied as biotic stress control agent

Fungicide Treatments	Brand name	Group	Active ingredient (AI)	Recommended dose	Manufacturer
F_1	Atavo 75 WDG(Water Dispersible Granule)	Carbendazim	Imidacloprid 250 gm+ Carbendazim 250 gm + thriam 250 per kg	5 g per 10 liter water	Annodata Limited
F_2	Autostin 50 WDG	Carbendazim	Carbendazim 500 per kg	2-3 g. per liter of water	Auto crop care limited

10.4.2 Seedling quality

Seedling height, number of leaf, leaf length, stem length, stem thickness, seedling density and disease incidence were measured at 15 and 30 days after sowing to assess the seedling quality. All physical data are collected through digital slide calipers.

Height of plants was measured in mm from collar region to the tip of the seedling. Stem length was also measured in mm from the bottom of the first leaf to the bottom of the stem. Digital slide caliper was used to measure the stem thickness. A metal sheet box of (200×100 mm^2 size) was used to determine the seedling density from each tray as well as other seedling quality parameters. Fungal infection on seedling are measured which is roughly visible in terms of percentage affected. Pathogenic test or other parameters are not taken in this study.

10.4.3 Characteristics

Rolling quality of the seedling mat was measured to assess the mat quality. Rolling quality of the seedling mat were measured in terms of scored 10 for excellent (no crack during rolling), 8 for good (single and minor crack), 6 for medium (more than one crack but possible to roll up: medium crack), 4 for bad (more than one crack and difficult to roll up: major crack), 2 for very bad (more than one and large size crack and very difficult to roll up: extreme crack) and 1 for not possible to roll up in any way.

Componet-2

10.5 Determination of fertilizer use efficiency along with identifying CH_4, CO_2, and N_2O emission under varying methods of fertilizer application in rice soils of Bangladesh

10.5.1 Design and fabrication of gas chamber

Design

- The Chamber size: 62 x 112 cm
- Acrylic glass (2 mm)was used to minimize the fabrication cost
- Fan was used at least 6 hour/day for move air in the chamber
- Locally available materials were used to minimize the fabrication cost.

Fabrication

Designed gas chamber has been fabricated in research lab of FMPHT Division, BRRI (Fig. 24 and 25). Existing facility of the lab was used to develop the GHG chamber. Some of components were fabricated in the other lab/workshop according to design.

10.5.2 Static close chamber for measuring greenhouse gas emission

Different types of static chamber have made for determination of greenhouse gas emission from Boro and T. Aman rice cultivation under different management with different locations (Fig. 24).

Fig. 24. Methane gas chamber

Fig. 25. Carbon dioxide and nitrous oxide gas chamber

10.5.3 Methods for CH_4, CO_2 & N_2O determination

A closed-chamber method (Rolston, 1986; Ali et al., 2008, 2009; Haque et al., 2013) was used to estimate CH_4, CO_2 and N_2O emission rates. A round type of acrylic column chambers which have diameter 20 cm and height 20 cm was placed in inner soil surface between plants to collect air gas samples during the fallow season. In comparison, two different types of closed chambers were installed at different position during rice cultivation. A type of transparent glass chambers which have surface area 62 cm x 62 cm and height 112 cm was placed permanently in the flooded soil after rice transplanting for monitoring CH_4 and N_2O emission rates. Eight rice plants were enclosed in a chamber. In addition acrylic column chambers which have diameter 20 cm and height 20 cm and used for the fallow season was placed inner soil surface between rice plants for evaluating CO_2 emission rates during rice cultivation (Lou *et al.*, 2004, Xiao *et al.*, 2005, Iqbal *et al.*, 2008). There are 2-4 holes in the bottom of the chambers to maintain the water level 5-7 cm above the soil water interface during rice cultivation. All chambers were kept open in the field throughout the investigation period except during the gas sampling. The chamber was equipped with a circulating fan for gas mixing and a thermometer inside to monitor the temperature during the sampling time.

Air gas samples were collected by using 50 ml gas-tight syringes at 0 and 30 min after chamber placement. Gas samplings were carried out at three times (8:00–12:00–16:00) in a day to get the average GHGs emission rates. Three gas samples in each replicate of each treatment was then drawn off from the chamber headspace using 50ml plastic syringes equipped with 3-way stop cock. Collected gas samples were immediately transferred into 30-ml air-evacuated glass vials sealed with a butyl rubber septum for gas analysis.

Three GHGs concentrations in the collected air samples were measured by Gas Chromatography (Shimadzu, GC-2010, Japan) with Porapak NQ column (Q 80–100 mesh). A flame ionization detector (FID), thermal conductivity detector (TCD) and ^{63}Ni electron capture detector (ECD) was used for quantifying CH_4, CO_2 and N_2O concentration, respectively. The temperatures of the column, injector and detector were adjusted at 100, 200, and 200°C for CH_4, 45, 75, and 270°C for CO_2, and 70, 80, and 320°C for N_2O, respectively. Helium and H_2 gases were used as the carrier and burning gases, respectively.

Methane, CO_2 and N_2O emission rates were calculated from the increase in CH_4, CO_2 and N_2O concentrations per unit surface area of the chamber for a specific time interval. A closed-chamber equation (Rolston, 1986; Lou *et al.*, 2004**)** was used to estimate seasonal fluxes from each treatment (Haqueet al., 2017).

$F = \rho \times (V/A) \times (\Delta c/\Delta t) \times (273/T)$

Where

F is the CH_4 and CO_2 (mg m^{-2} hr^{-1}), and N_2O flux (µg N_2O m^{-2} hr^{-1})

ρ is the gas density of CH_4, CO_2, and N_2O under a standardized state (mg cm^{-3})

V is the volume of chamber (m^3)

A is the surface area of chamber (m^2)

$\Delta c/\Delta t$ is the rate of increase of CH_4, CO_2, and N_2O gas concentrations in the chamber (mg m^{-3} hr^{-1}) and

T (absolute temperature) is 273 + mean temperature in (°C) of the chamber. The seasonal CH_4, CO_2, or N_2O flux for the entire crop period was computed as reported by Singh et al., (1999):Seasonal CH_4, CO_2 and N_2O flux = $\sum_i^n (R_i \times D_i)$

Where

R_i is the rate of CH_4,

CO_2 and N_2O flux (g m^{-2} d^{-1}) in the ith sampling interval,

D_i is the number of days in the ith sampling interval, and on the number of sampling intervals.

10.5.4 Estimation of NECB (CO_2)

Findings of Ciais et al. 2010; Smith et al. 2010; Jia et al. 2012; Ma et al. 2013; Haque et al. 2015a for determination of Net Ecosystem Carbon Budget (NECB)already summarised as follows:

$$NECB = GPP – R_e – Harvest − CH_4 + Green\ manure \quad (1)$$

$$GPP = NPP + R_a \quad (2)$$

$$R_e = R_a+R_h \quad (3)$$

Where GPP, NPP, R_e, R_a and R_h represent gross primary production, net primary production, ecosystem respiration, autotrophic respiration and heterotrophic respiration, respectively. The Harvest includes rice straw and grains and fertilizer.

Equation (1) was converted to equation (4) by using equations (2) and (3) as:

$$NECB = NPP – R_h – Harvest – CH_4 + Fertilizer \quad (4)$$

The NPP was estimated according to Smith et al., 2010.

Net GWP

The net Global Warming Potential (GWP) was estimated according to Ma et al. 2013, Haque et al. 2015a and IPCC, 2014.

Net GWP (kg CO_2 eq. ha^{-1}) = $CH_4 \times 28 + N_2O \times 265 + NECB\ (CO_2) \times 1$

10.5.5 Methods of soil and plant analysis

Soil pH was measured by glass electrode pH meter method using soil water ratio 1:2:5 (McLean, 1982). Organic carbon content of soil samples was estimated by wet oxidation method (Nelson and Sommers, 1982). The total N of soil sample was determined following micro-Kjeldahl method (Bremner and Mulvaney, 1982) Available soil phosphorus was measured by Olsen method (Olsen and Sommers, 1982) and available Zn was determined by DTPA extraction method. Exchangeable K of soils was determined by flame photometer on the neutral ammonium acetate extract (Barker and Surh, 1982).

The collected grain and straw samples from each plot was dried in an oven at 65 ^{0}C for 24 hours. After drying, the samples were crushed by a grinding mill. Later the crushed samples were sieved through a 20-mesh sieve. The prepared samples was then be chemically analyzed for N, P and K following diacid digestion procedure (Jones and Case, 1990; Watson and Issac, 1990).

10.5.6 Plant sample collection and analysis

Rice straw and rice sample were collected from the experimental plot of Gazipur and Kushtia. Dried rice and straw were crushed and to pass through a 0.5-mm sieve for quantifying nutrient contents. Total N content was analyzed by micro-Kjeldahl method, and a ternary solution (HNO_3:H_2SO_4:$HClO_4$, 10:1:4 v v^{-1}) was used for the determination of total P, K, S and Zn contents of plants.

10.5.7 General Information of the field trials

Season-wise variety, location and area covered is presented in Table 10. A total of 7 trials were conducted during the sub-project period in Boro and Aman seasons in sub-project locations.

Table 10. Season-wise variety, location, area covered and date of cultivation.

No	Place	Variety	Area[1]	D/S	D/T	D/H
Boro, 2018-19						
1	Kushtia	BRRI dhan58	0.425	06-12-18	15-01-19	15-05-19
Aman, 2019						
1	Gazipur	BRRI dhan71	0.259	20-07-19	02-08-19	04-11-19
2	Kushtia	BRRI dhan87	0.332	20-07-19	07-08-19	27-11-19
Boro, 2019-20						
1	Gazipur	BRRI dhan89	0.263	27-12-2019	28-01-2020	23-05-2020
2	Kushtia	BRRI dhan89	0.810	07-01-2020	09-02-2020	31-05-2020
Aman, 2020						
1	Gazipur	BRRI dhan80	0.324	28-07-2020	12-08-2020	08-12-2020
2	Mirpur	BRRI dhan87	0.526	11-07-2020	28-07-2020	15-11-2020

Note: [1]Area in hectare, D/S-Date of seeding, D/T-Date of transplanting and D/H-Date of harvesting

10.5.8 Experimental design and treatments

The experiment was laid out in a randomized complete block (RCB) design with three replications. About half meter of buffer spacing was maintained among the sub-plots. The treatments were

Treatments

T_1 = Mechanical transplanting and broadcast of fertilizer
T_2 = Farmers' practice
T_3 = Mechanical transplanting along with mixed fertilizer deep placement

10.5.9 Greenhouse gas collection and analysis

Static close chamber were used for collection of CH_4, N_2O and CO_2 from rice fields at different location with different management. The Gas chromatography (GC) was used for analysis of gases (Fig. 26).

Fig. 26. CH_4, N_2O and CO_2 collection from rice fields

10.5.10 Fertilizer management

Recommended dose of fertilizers were broadcasted manually in T_1 and T_2 according to farmers' practices. Urea fertilizer (80% of RD) along with triple super phosphate (TSP), muriate of potash (MoP) and gypsum fertilizer were applied at transplanting using the developed machine in T_3.

10.5.11 Weed and pest management

Herbicides Saathi (Pyrazosulfuron Ethyl 10% WP) was applied after 4 days of transplanting at the rate of 150 g/ha (20 g/bigha). One hand weeding was done at 40 days after transplanting (DAT) to keep the fields weed free.

10.5.12 Yield and yield contributing character

Tiller number and plant height were collected from 12 hills per plot at 15-day intervals. Crops were harvested when 85-90% of the rice became golden. The harvested crop of each plot bundled separately, tagged and carried to a clean threshing floor. Sample bundles were then dried, threshed and then seeds were cleaned. Rice yield per plot was recorded from a pre-selected 10 m^2 harvest area and was determined with the adjustment to 14 % moisture content. For computing above ground biomass and yield attributes, samples from 1 m^2 quadrates were collected from outside of the pre-selected 10 m^2 area of each plot. Straw yield (above ground biomass), plant height, panicle length, number of tillershill^{-1} and number of panicleshill^{-1}, filled and unfilled spikelets panicle^{-1} and 1000 grains weight were recorded from 1 m^2 quadrates.

10.5.13 Statistical analysis

Data were analyzed as a single factorial design according to Gomez and Gomez (1984) using Statistix 10 program (Statistix 10 software, 2013). Means were compared with the least significant difference (LSD) test. Simple correlation analysis was carried out with Excel 2010 to determine the relationship of grain yield to yield attributes.

11. Results and discussion (with appropriate pictures):

Component-1

11.1. Incorporation of mixed fertilizer applicator in the rice transplanter

Fertilizer deep placement mechanism was fabricated in the FMPHT divisional research laboratory and improved based on the laboratory, research field and farmers field trials. Pictorial views of the final version of the developed rice transplanter is presented as follows (fig. 27-28).

Fig. 27. Rice transplanter cum fertilizer applicator (Walking type)

Fig. 28. Rice transplanter cum fertilizer applicator (Riding type)

11.1.1 Power transmission from engine to the mixed fertilizer applicator

Necessary modification of the rice transplanter was done to receive engine power for FDP technology. Engine power available at high rpm (more than 1800 rpm of the walking type rice transplanter) was transported to the applicator with the arrangement of a belt-pulley, worm gearing, shaft, bevel gear and universal joint mechanism with engage-disengage facility resulting 23 rpm of the main shaft of the applicator (Fig. 29). For engage-disengage facility, farmers can choose the transplanter either for both operation or only for seedling transplanting. Power transmission mechanism is shown in following flow chart.

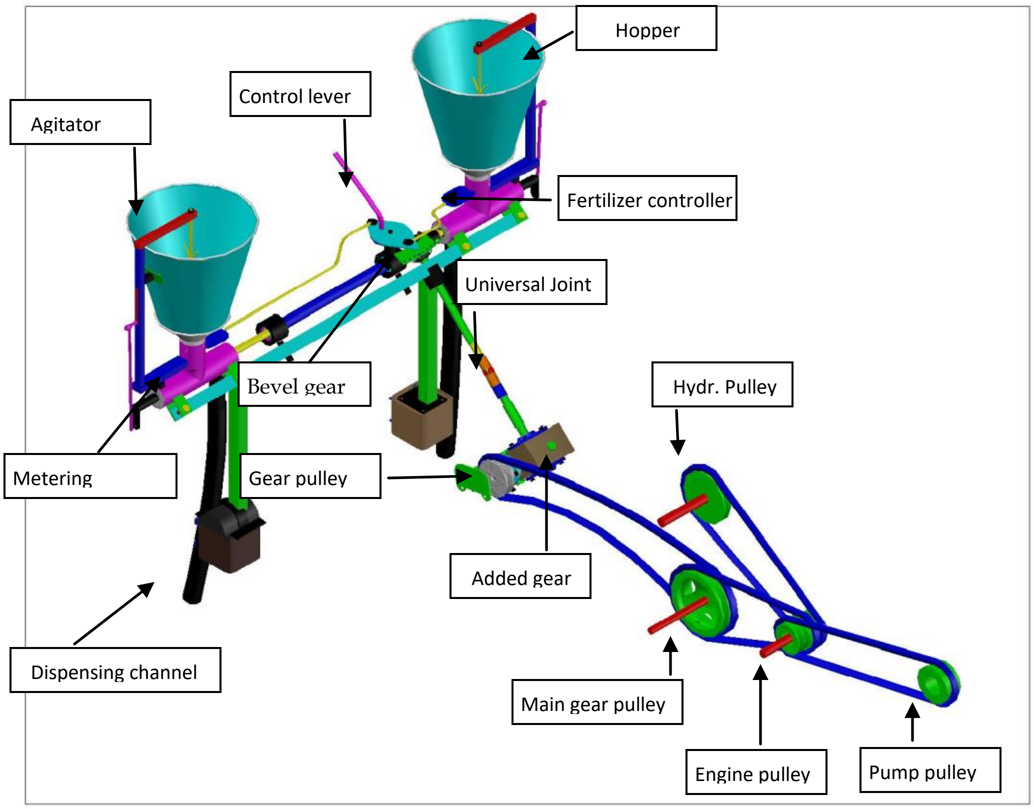


Fig. 29. Power transmission from engine to the mixed fertilizer applicator

Engine power of the selected transplanter transmitted to the hydraulic pump, driving wheels & rotary picker and water pump of the transplanter with the belt-pulley arrangement. To convey the engine power to the applicator, engine pulley and main gear pulley were modified by adding one additional grove to the main gear pulley. This is the first stages of power reduction from 1800 rpm to 810 rpm. From main gear pulley, power transmitted to the worm gear to reduce rpm at a ratio of 1:35. Bevel gear also used in the applicator shaft to change the direction of power at 90 degree intersecting shaft at the same velocity ratio. In the 2^{nd} stage, power reduced from 810 to 23 rpm. From output shaft of the gear box, power transmitted to the main shaft of the applicator using universal joint shaft.

11.1.2 Power transmission flow chart

In walking type rice transplanter, power conveyed to the applicator from engine while it was conveyed in the riding type rice transplanter from rear wheel. Flow chart of power transmission is presented below:

Prime mover : 1800 rpm ↓ RT Main gear shaft : 810 rpm ↓ Gear output shaft : 23 rpm ↓ Applicator main shaft : 23 rpm	Rear wheel: Synchronized with transplanting speed ↓ Additional shaft: (1:1) ↓ Applicator shaft: (1:1) ↓ Metering shaft: (3:1)
Power transmission flow chart of WRT	Power transmission flow chart of RRT

11.1.3 Worm and bevel gearing

Worm gears are widely used for transmitting power at high velocity ratio between non-intersecting shafts that are generally at right angles. In the developed rice transplanter cum mixed fertilizer applicator, straight face single start worm gear was used to reduce engine rpm at the velocity ratio of 20:1. Number of teeth of the worm wheel-20, circular pitch was assumed 10 mm during design and actual was found 10.21 mm. Worm and worm wheel was fabricated using high carbon and phosphorus bronze materials. Size of the gear box is 140 × 85 × 120 mm, material-cast iron and thickness-4 mm. Detail design of the worm gears is given in figure 30, 32, 33, 34.

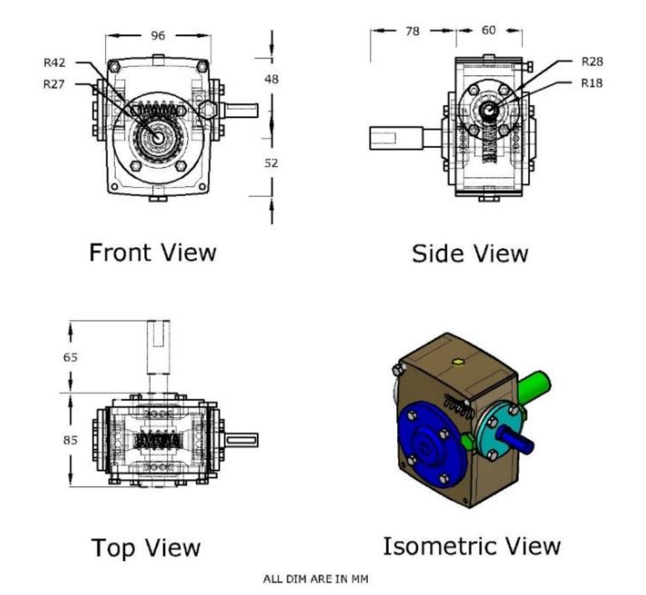


Fig. 30. Single start worm gear

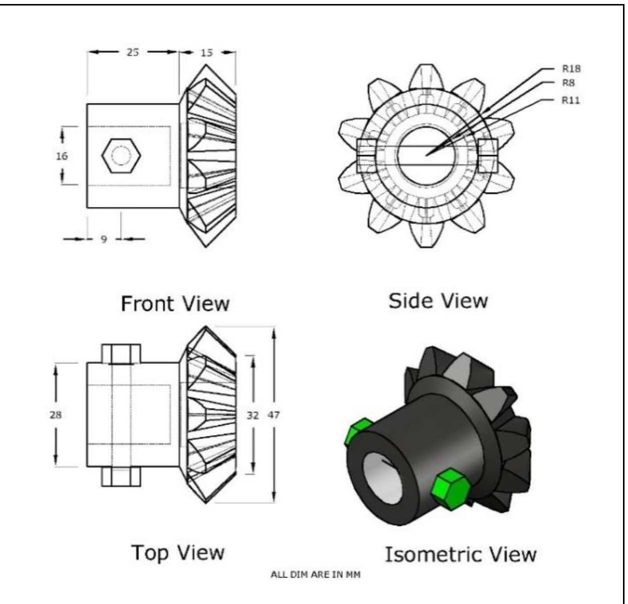


Fig. 31. Bevel gear

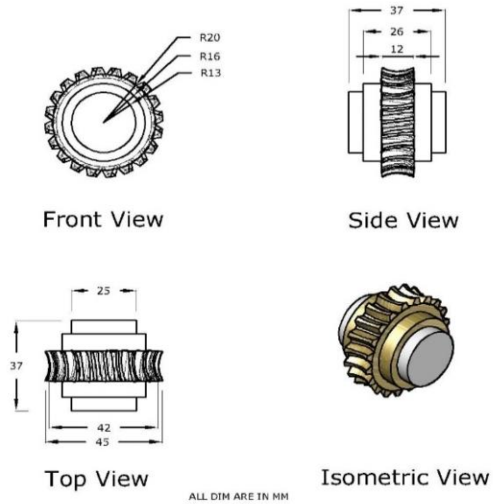


Fig. 32. Worm wheel

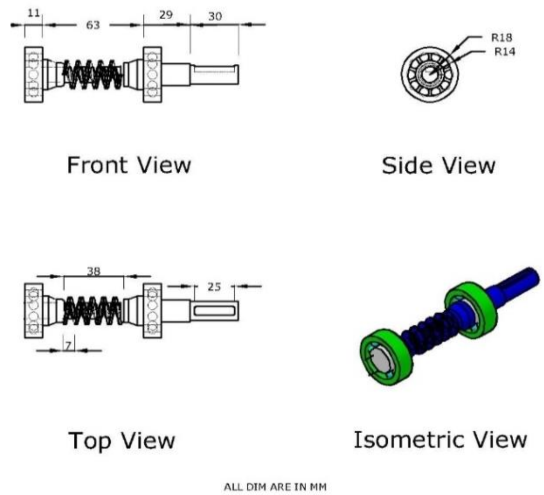


Fig. 33. Worm screw

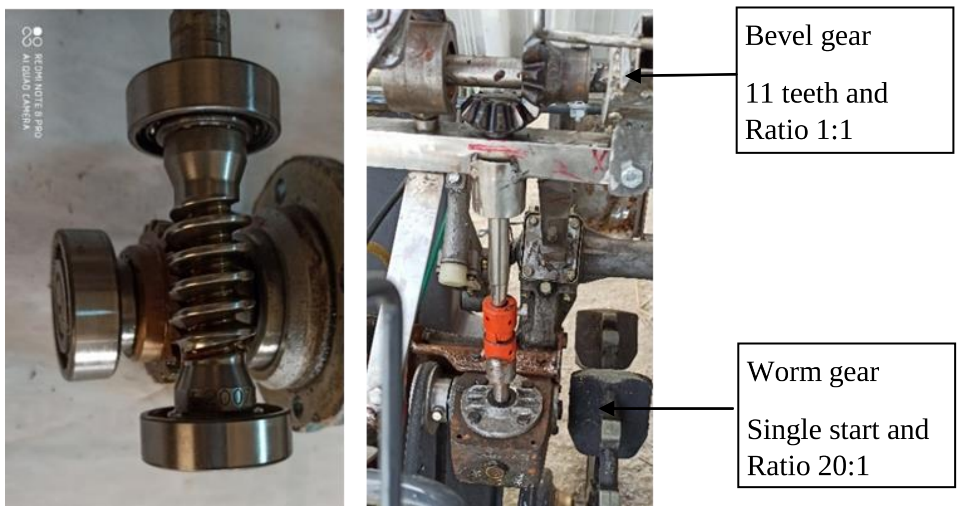


Fig. 34. Gear box incorporating with warm gearing

Bevel gear was also used in the gear box to convert the rotation at 90 degree to the intersecting shaft. The bevel gears, made of cast steel material (untreated), were used for transmitting power at a constant velocity ratio between shafts whose axes at a same angle. Bevel gears were used to transmit power to the intersecting shaft. In the developed rice transplanter cum mixed fertilizer applicator, bevel gear of equal teeth was used in the gear box. Because of compact design, 11 teeth were used for both pinion and gear, speed ratio-1:1, pressure and shaft angle-20 and 90^0, circular pitch (assumed)-10 mm and modeul-3.25 (Fig. 31).

11.1.4 Universal joint shaft

A universal joint is a mechanical device that allows one or more rotating shafts to be linked together, allowing the transmission of torque and/or rotary motion. It also allows for transmission of power between two points that are not in line with each other. In the developed rice transplanter, universal joint shaft was used to transmit power and rotation from incorporated gear output shaft to the applicator shaft (Fig. 35).

Fig.35. Universal joint shaft

11.1.5 Metering device

Spiral conveying type metering device was used in the developed rice transplanter cum mixed fertilizer applicator. Mixed fertilizer dispensed to the inner chamber of the metering device due to continuous agitation of the agitator (Fig. 36). Spiral conveyor of the metering device conveyed fertilizer mixture from inner chamber to the outlet pipe connected with the chamber (fig. 37-41). Fertilizer dispensing rate increased with the increase of opening in between fertilizer hopper and fertilizer metering chamber which can be control by a lever (Fig. 42). Rate of fertilizer dispensing can be controlled by adjusting the lever based on season and variety. Details of spiral screw is as follows:

Spiral screw

Pitch length: 75 mm, total length: 105 mm, height: 4.5 mm, root width: 11.5 mm and distance from hopper center to outlet pipe center: 35 mm.

Explode view of the fertilizer dispensing mechanism is shown in fig. 36-42.

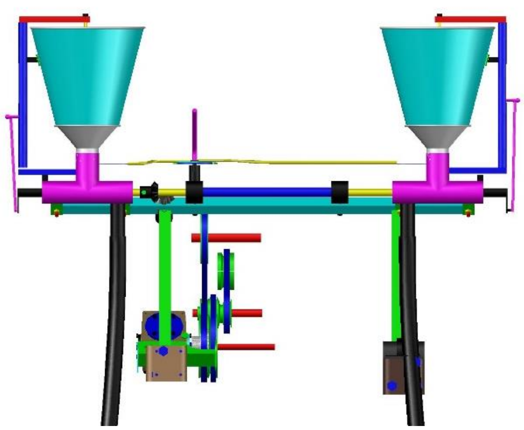


Fig. 36. Schematic view of metering device and agitator

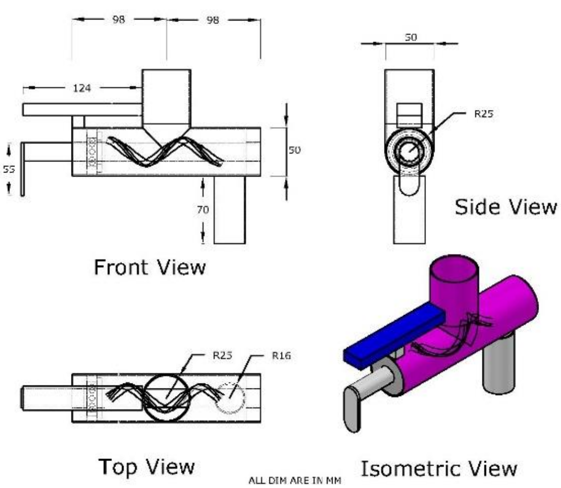


Fig. 37. Isometric view of metering device assembling

Fig. 38. Spiral screw type metering device

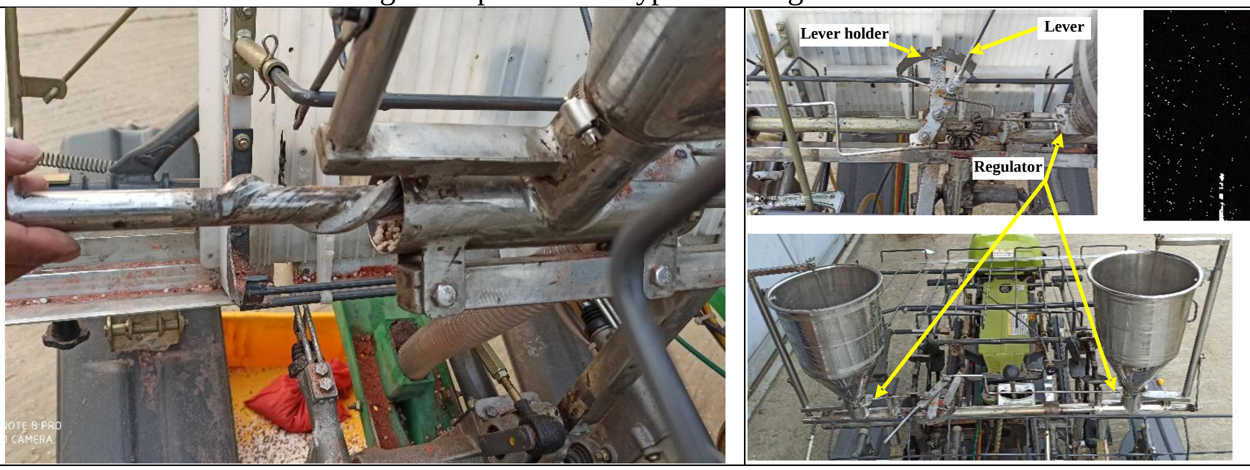


Fig. 39. Spiral screw attached in the metering chamber

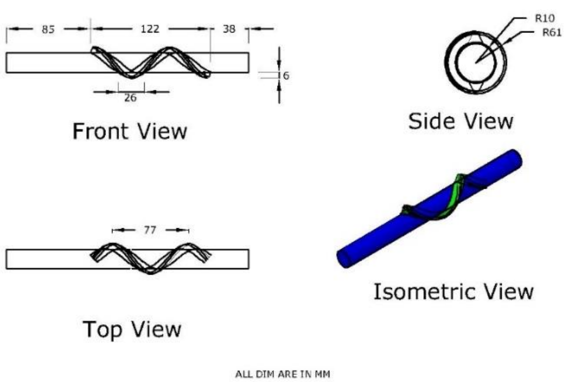


Fig. 40. Spiral conveyor

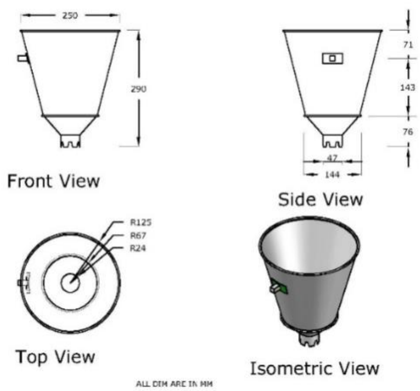


Fig. 41. Fertilizer chamber

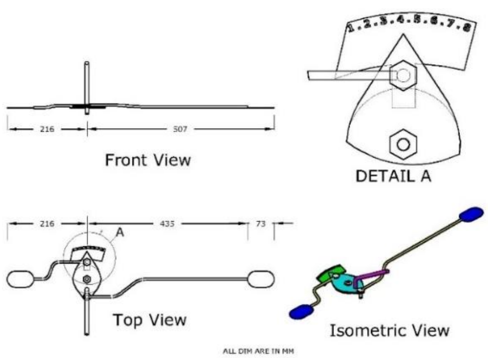


Fig. 42. Fertilizer control lever

11.1.6 Skid

Skid was designed considering space in between two rows of the transplanter and maximum depth of penetration of the transplanter skids during field operation. The bottoms of the applicator and transplanter skids were maintained same height horizontally. Depth of fertilizer placement and covering mechanism was taken in consideration to design the skids. Complete view of mixed fertilizer applicator is shown in following figure along with skid arrangement in figure 43-44.

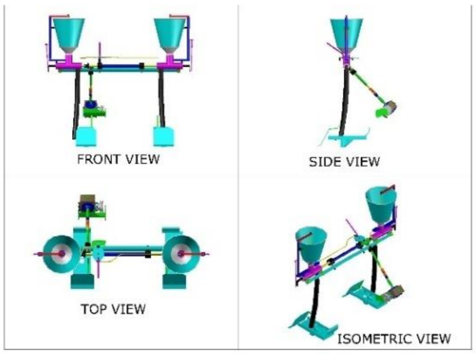
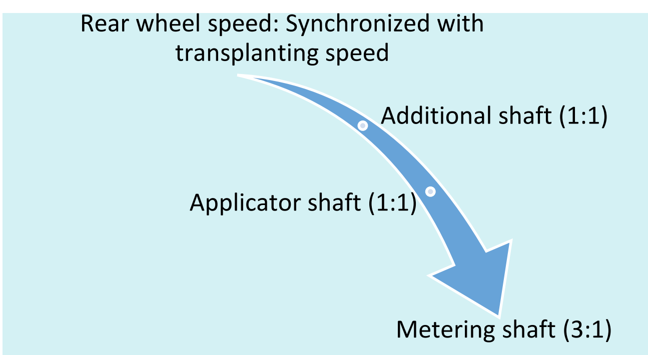


Fig. 43. Schematic view of skid and accessories	Fig. 44. Attachment of skid in the transplanter

Power transmission system and mixed fertilizer dispensing mechanism also designed, fabricated and assembled to the riding type rice transplanter successfully. Mixed fertilizer dispensing mechanism of the riding type transplanter is same as the walking type rice transplanter. On the contrary, power transmission and fertilizer dispensing mechanism of riding type rice transplanter is different from walking type transplanter. In riding type rice transplanter, power received for applicator from driving wheels.



- Power conveyed from rear wheel (RW).
- Picker rotation and spacing of seedling synchronized with RW rotation
- Power conveyed from RW to an additional shaft: Ratio 1 : 1,
- From additional shaft to applicator shaft: Ratio 1:1,
- Applicator shaft to fertilizer metering shaft: Ratio: 3:1

Stage-1: Rear wheel to an additional shaft using tine and casing type coupling
Stage-2: From 1st additional shaft to 2nd additional shaft using chain-sprocket
Stage-3: From 2nd additional shaft to applicator shaft using chain sprocket mechanism

11.1.7 Operational procedure

The walking type rice transplanter was modified to incorporate mixed fertilizer deep placement mechanism. During transplanter operation, the following procedure needs to follow for successful placement of mixed fertilizer.

- Disengage the power of the applicator gear box before start engine and transplanting.
- Lubricant and grease need to be checked of the applicator gear and chain-sprocket before operation.
- Tension of the belts also needs to be checked before operation.
- Power of the applicator gear box engaged with the start of seedling transplanting.
- At the end of field, during turning, again disengage the power of the applicator gear box for avoiding un-necessary loss of fertilizer.
- Time to time re-filled the hopper by mixed fertilizer.
- Some amount of mixed fertilizer need to be carried like seedling mat for re-filing in the field as and when necessary.

11.2 Field evaluation of the rice transplanter cum mixed fertilizer applicator (RTFA)

11.2.1 Field performance of the RTFA

11.2.1.1 Boro 2018-19 season

Field capacity of the developed rice transplanter cum mixed fertilizer applicator was measured with and without fertilizer deep placement mechanism in 02 locations during Boro 2018-19 (Table 11). Theoretical field capacity varied with forward speed of machine operation whereas actual field capacity varied with forward speed, turning time loss, seedling and fertilizer re-filling time etc. Average of locations and replications, actual field capacity of the rice transplanter was found 0.12 and 0.13 ha hr^{-1} with and without fertilizer deep placement mechanism in Boro season, respectively while field efficiency was obtained 58.95 and 64.10% with and without fertilizer deep placement mechanism, respectively. Field capacity and field efficiency was higher to some extent without fertilizer deep placement mechanism during transplanting due to extra fertilizer re-filling time and slower of operation.

Table 11. Field performance of the RTFA in Boro 2018-19 Season

Locations	Treat.	Area (Decimal)	Operation time (min)	FS (km/h)	AFC (ha/h)	TFC (ha/h)	Efficiency (%)
Kushtia	T_1	33	73.0	1.5	0.11	0.19	57.9
	T_2	40	81.0	1.62	0.12	0.19	63.2
	T_3	32	-		0.003	-	
Habiganj	T_1	20	40.5	1.63	0.12	0.20	60.0
	T_2	26	48.6	2.69	0.13	0.20	65.0
	T_3	27	-		0.0025	-	
			Average: T1	1.57	0.12	0.20	58.95
			T2	2.16	0.13	0.20	64.10

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. FDP-Fertilizer deep placement, ACF-Actual field capacity, TFC-Theoretical field capacity and FS-Forward speed

11.2.1.2 Aman 2019 season

Field capacity of the developed rice transplanter cum mixed fertilizer applicator was measured with and without fertilizer deep placement mechanism in seven locations during Aman 2019 seasons (Table 12). Average of locations and replications, actual field capacity of the rice transplanter was found 0.19 and 0.21 ha hr^{-1} with and without fertilizer deep placement mechanism in Aman 2019 season, respectively whereas field efficiency was obtained 80.66 and 80.60%, respectively. Actual and theoretical field capacity as well as field efficiency of the developed rice transplanter cum fertilizer applicator was found higher in Aman season compare to Boro season due to improvement of the technology, good seedling and field quality. Field capacity and field efficiency was higher to some extent without fertilizer deep placement mechanism during transplanting due to extra fertilizer re-filling time and slow of operation.

Table 12. Field performance of the RTFA in Aman 2019 Season

Locations	Treatments	Area (Decimal)	Operation time (min)	FS (km/h)	AFC (ha/h)	TFC (ha/h)	Efficiency (%)
Rangpur	T_1	22	26	1.92	0.21	0.23	89.18
	T_2	40	44	2.1	0.22	0.25	87.60
	T_3	20	-		0.003		
Gazipur	T_1	18	27	1.79	0.16	0.21	75.36
	T_2	20	23	1.92	0.21	0.23	91.64
	T_3	28	-		0.0025		
Mirpur	T_1	22	32	1.7	0.17	0.20	81.83
	T_2	80	98	1.85	0.20	0.22	89.29
	T_3	20	-		0.003		
Kushtia 1	T_1	20	24	2.1	0.20	0.25	80.30
	T_2	40	44	2.6	0.22	0.31	70.75
	T_3	22	-		0.003		
Kushtia 2	T_1	22	26	2.2	0.21	0.26	77.83
	T_2	30	32	2.4	0.23	0.29	79.04
	T_3	20	-		0.003		
Netrakona	T_1	28	36	2.1	0.19	0.25	74.94
	T_2	40	51	2.2	0.19	0.26	72.14
	T_3	20	-		0.003		
Habiganj	T_1	13	16	1.93	0.20	0.23	85.19
	T_2	26	32	2.23	0.20	0.27	73.73
	T_3	25	-		0.0025		
			Average: T_1	1.96	0.19	0.23	80.66
			T_2	2.19	0.21	0.26	80.60

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. FDP-Fertilizer deep placement, ACF-Actual field capacity, TFC-Theoretical field capacity and FS-Forward speed

11.2.1.3 Boro 2019-2020 season

Field capacity of the developed rice transplanter cum mixed fertilizer applicator was measured with and without fertilizer deep placement mechanism in 02 locations during Boro 2019-20 (Table 13). Average of locations and replications, actual field capacity of the rice transplanter was found 0.20 and 0.22 ha hr^{-1} with and without fertilizer deep placement mechanism in Boro season, respectively while field efficiency was obtained 79.74 and 80.24% with and without fertilizer deep placement mechanism, respectively. Field capacity and field efficiency was higher to some extent without fertilizer deep placement mechanism during transplanting due to extra fertilizer re-filling time and slower of operation.

Hossen et al. (2018) obtained field capacity of the 04 rows walk behind type rice transplanter 0.16 hector per hour in 60 trails during Aus, Aman and Boro season in diverse locations of Bangladesh. However, Tamanna et al. (2018) obtained field capacity 0.2052 hectors per hour for DP480 model and 0.1801 hectors per hour for ARP-4UM model in Aman season.

Table 13. Field performance of the RTFA in Boro 2019-20 Season

Locations	Treat.	Area (Decimal)	Time of operation (min)	FS (km/h)	AFC (ha/h)	TFC (ha/h)	Efficiency (%)
Gazipur	T_1	30	40	1.85	0.18	0.22	82.0
	T_2	20	24	1.93	0.20	0.23	87.4
	T_3	15	-		0.0025		
Kushtia 1	T_1	100	110	2.11	0.22	0.25	87.2
	T_2	70	72	2.47	0.24	0.30	79.6
	T_3	30	-		0.003		
Kushtia 2	T_1	100	123	2.19	0.20	0.26	75.1
	T_2	70	82	2.27	0.21	0.27	76.1
	T_3	30	-		0.003		
Mirpur	T_1	70	75	2.21	0.23	0.27	85.5
	T_2	30	32	2.11	0.23	0.25	89.9
	T_3	30	-		0.003		
Netrakona	T_1	100	128	2.25	0.19	0.27	70.3
	T_2	30	32	2.69	0.23	0.32	70.5
	T_3	30	-		0.003		
Rangpur	T_1	100	137	1.95	0.18	0.23	75.7
	T_2	30	32	2.51	0.23	0.30	75.6
	T_3	30	-		0.003		
Habiganj	T_1	30	37	1.99	0.20	0.24	82.4
	T_2	20	29	1.69	0.17	0.20	82.6
	T_3	15	-		0.0025		
			Average: T_1	2.08	0.20	0.25	79.74
			T_2	2.24	0.22	0.27	80.24

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. FDP-Fertilizer deep placement, ACF-Actual field capacity, TFC-Theoretical field capacity and FS-Forward speed

11.2.2 Actual amount of fertilizer dispensed

11.2.2.1 Boro 2018-19 season

Before field operation of the machine, it was calibrated to apply desired amount of fertilizer based on recommended dose of mixture fertilizer. During field operation, actual amount of fertilizer dispensed was calculated to determine percentage of deviation (Table 14). In Boro season, calibrated rate of fertilizer was 67.94 g/rotation of the rice transplanter driving wheels for Kushtia and Habiganj while actual rate was 67.39 and 63.56 g/rotation, respectively. Fertilizer dispensing rate was found less compared to calibrate rate in both locations during Boro season due to frequent clogging of the output channel of fertilizer. It was improved based on field problems in Boro season.

Table 14. Percent of deviation from calibrated amount of fertilizer as affected by soil condition and location in Boro 2018-19 season

Location	[1]Area in Deci	Amount of fertilizer (Kg/Transplanting area)				Calculated amount of dispensed (Kg)	Calculated Total fertilizer (Kg/ha)	Dispensing rate (g/rotation)		Actual fertilizer (Kg/ha)	% of deviation
		Urea (80%)	TSP	MOP	Gyp			Calibrated	Actual		
Kushtia	33	29.9	13.4	22.1	14.9	80.3	601.0	67.94	67.39	596.16	-0.81
Habiganj	20	18.1	8.1	13.4	9.1	48.7			63.56	562.27	-6.4

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m. [1]Area of mechanical transplanting along with fertilizer deep placement (T_1) is presented only.

11.2.2.2 Aman 2019 season

Developed machine again calibrated to apply desired amount of fertilizer based on recommended dose of mixture fertilizer before field operation in Aman 2019 season. During field operation, actual dispending amount of fertilizer was calculated to determine percentage of deviation (Table 15). Calibrated rate of fertilizer was 37.72 g/rotation while actual dispensing rate was 39.62, 40.51, 38.73, 39.11, 38.73, 40.81 and 39.54 g/rotation in Rangpur, Gazipur, Mirpur-Kushtia, Kumarkhali-Kushtia (1), Kumarkhali-Kushtia (2), Purbadhala-Netrakona and Habiganj, respectively. Vibration of the machine, turning losses of fertilizer and slippage of the driving wheels might be the causes of more dispensing rate of fertilizer compared to calibration in Aman season.

Table 15. Percent of deviation from calibrated amount of fertilizer as affected by soil condition and location in Aman 2019 season

Location	[1]Area in Deci	Amount of fertilizer (Kg/Transplanting area)				Calculated amount of dispensed (Kg)	Calculated Total fertilizer (Kg/ha)	Dispensing rate (g/rotation)		Actual fertilizer (Kg/ha)	% of deviation
		Urea (80%)	TSP	MOP	Gyp			Calibrated	Actual		
Rangpur	22	11.9	5.5	7.4	5.0	29.7	335.0	37.72	39.62	350.50	4.63
Gazipur	18	9.7	4.5	6.1	4.1	24.3			40.51	358.37	6.98
Mirpur, Kushtia	22	11.9	5.5	7.4	5.0	29.7			38.73	342.62	2.28
Kushtia1	20	10.8	5.0	6.7	4.5	27.0			39.11	345.98	3.28
Kushtia2	22	11.9	5.5	7.4	5.0	29.7			38.73	342.62	2.28
Netrakona	28	15.1	7.0	9.4	6.3	37.9			40.81	361.02	7.77
Habiganj	13	7.0	3.3	4.4	2.9	17.6			39.54	349.79	4.41

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m. [1]Area of mechanical transplanting along with fertilizer deep placement (T_1) is presented only.

11.2.2.3 Boro 2019-20 season

Rice transplanter cum mixed fertilizer applicator again evaluated during Boro 2019-20 season. During field operation, actual dispending amount of fertilizer was calculated to determine percentage of deviation (Table 16). Calibrated rate of fertilizer based on total calculated amount of fertilizer was 68.6 g/rotation while actual dispensing rate was 69.12, 70.04, 71.01, 68.24, 69.31, 71.06 and 67.24 g/rotation in Gazipur, Kushtia 1, Kushtia 2, Mirpur, Netrakona, Rangpur and Habiganj respectively. Insignificant amount of variation was observed during field operation. Vibration of the machine, turning losses of fertilizer and slippage of the driving wheels might be the causes of more dispensing rate of fertilizer compared to calibration.

Table 16. Percent of deviation from calibrated amount of fertilizer as affected by soil condition and location in Boro 2019-20

Location	[1]Area in Deci	Amount of fertilizer(Kg/Transplanting area)				Calculated amount of dispensed (Kg)	Calculated Total fertilizer (Kg/ha)	Dispensing rate (g/rotation)		Actual fertilizer (Kg/ha)	% of deviation
		Urea (80%)	TSP	MOP	Gyp			Calibrated	Actual		
Gazipur	30	29.1	12.7	18.2	13.6	73.7	607.0	68.6	69.12	611.5	0.74
Kushtia 1	100	97.1	42.5	60.7	45.3	245.6			70.04	619.6	2.08
Kushtia 2	100	97.1	42.5	60.7	45.3	245.6			71.01	628.2	3.49
Mirpur	70	68.0	29.7	42.5	31.7	172.0			68.24	603.7	-0.55
Netrokona	100	97.1	42.5	60.7	45.3	245.6			69.31	613.1	1.01
Rangpur	100	97.1	42.5	60.7	45.3	245.6			71.06	628.6	3.56
Habiganj	30	29.1	12.7	18.2	13.6	73.7			67.24	594.8	-2.00

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m. [1]Area of mechanical transplanting along with fertilizer deep placement (T_1) is presented only. Recommended rate of fertilizer (Kg/ha): Urea: 300, TSP: 105, MoP: 150 and Zypsum: 112

11.2.3 Transplanting cost under different methods of seedling transplanting

Transplanting cost of the transplanter depends on machine life, annual operating use, field capacity, operator cost and fuel-oil and maintenance cost. Transplanting cost of the walking type rice transplanter with and without fertilizer deep placement mechanism as well as manual transplanting cost of different seasons is presented in the Table 17-19.

Table 17. Transplanting cost under different methods during Boro 2018-19

	Transplanting cost (Tk/h)			Time of transplanting (h/ha)			Transplanting cost (Tk/ha)		
Locations	T1	T2	T3	T1	T2	T3	T1	T2	T3
Kushtia	339.8	335.2	50.0	9.1	8.3	333.3	3092.2	2782.2	16665.0
Habiganj	349.1	340.7	50.0	8.3	7.7	400.0	2897.5	2623.4	20000.0
Average	344.5	338.0	50.0	8.7	8.0	166.7	2994.9	2702.8	18332.5

Table 18. Transplanting cost under different methods during Aman 2019 season

	Transplanting cost (Tk/h)			Time of transplanting (h/ha)			Transplanting cost (Tk/ha)		
Locations	T1	T2	T3	T1	T2	T3	T1	T2	T3
Rangpur	333.3	270.3	50.0	4.8	4.5	333.3	1599.8	1216.4	16665.0
Gazipur	342.6	335.2	50.0	6.3	4.8	400.0	2158.4	1609.0	20000.0
Mirpur	333.3	324.0	50.0	5.9	5.0	333.3	1966.5	1620.0	16665.0
Kushtia-1	330.5	325.9	50.0	5.0	4.5	333.3	1652.5	1466.6	16665.0
Kushtia-2	325.9	321.3	50.0	4.8	4.3	333.3	1564.3	1381.6	16665.0
Netrakona	330.5	325.9	50.0	5.3	5.3	333.3	1751.7	1727.3	16665.0
Habiganj	339.8	337.0	50.0	5.0	5.0	333.3	1699.0	1685.0	16665.0
Average	333.7	319.9	50.0	5.3	4.8	342.8	1770.3	1529.4	17141.4

Table 19. Transplanting cost under different methods during Boro 2019-20

Locations	Transplanting cost (Tk/h)			Time of transplanting (h/ha)			Transplanting cost (Tk/ha)		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
Gazipur	337.0	335.2	50.0	5.6	5.0	400.0	1887.2	1676.0	20000.0
Kushtia 1	325.9	325.9	50.0	4.5	4.2	333.3	1466.6	1368.8	16665.0
Kushtia 2	325.9	321.3	50.0	5.0	4.8	333.3	1629.5	1542.2	16665.0
Mirpur	331.5	325.9	50.0	4.3	4.3	333.3	1425.5	1401.4	16665.0
Netrakona	330.5	325.9	50.0	5.3	4.3	333.3	1751.7	1401.4	16665.0
Rangpur	325.9	324.0	50.0	5.6	4.3	333.3	1825.0	1393.2	16665.0
Habiganj	339.8	337.0	50.0	5.0	5.9	400.0	1699.0	1988.3	20000.0
Average	330.9	327.9	50.0	5.0	4.7	352.4	1669.2	1538.8	17617.9

Note: 1. Average annual use of rice transplanter (assumed) 70 days considering Aus (15 days), Aman (20 days) and Boro (35 days). Considering 8 working hours per day, average annual use in h/yr is 560; 2. Labor cost as operator, Tk/hr=75 and helper cost, Tk/hr=50. Total cost, Tk/hr=125, and Agricultural labour cost, Tk/h=50.0; 3. Fuel cost, Tk/lit=90.00 (Octan) and 4. Treatments T_1 - Mechanical transplanting along with mixed fertilizer deep placement, T_2 - Mechanical transplanting and hand broadcasting of fertilizer and T_3 - Manual transplanting and hand broadcasting of fertilizer

11.2.4 Crop performance

Plant height and number of tiller were measured at every 15 days after transplanting to evaluate the crop performance under different methods of transplanting and fertilizer application.

11.2.4.1 Boro 2018-19 season

Plant height -Plant height did not vary significantly for the treatment of mechanical transplanting along with fertilizer deep placement (Fig. 45).

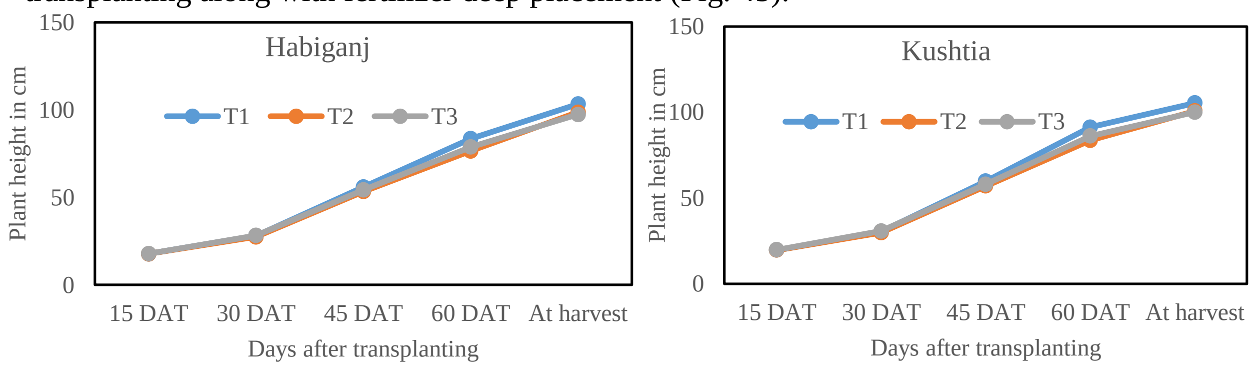


Fig. 45. Plant height at different date after transplanting in Boro 2018-19

Number of tiller – Number of tiller at different date after transplanting is presented in figure 46 and 47. At Kushtia, T_1 gave significantly higher number of tiller followed by T_2 whereas T_3 gave significantly lower number of tillers per hill.

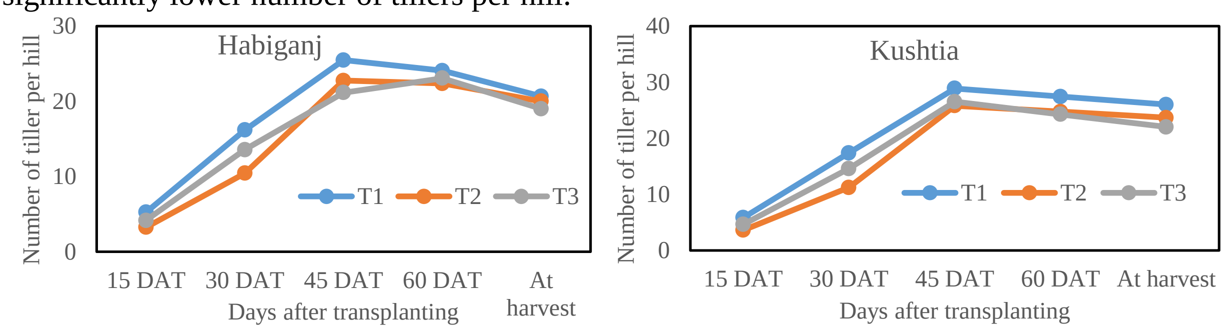


Fig. 46. Number of tiller at different date after transplanting in Boro 2018-19

Fig. 47. Crop performance of the experimental field in Boro 2018-19 season as affected under different treatments (Kushtia)

11.2.4.2 Aman 2019 season

Plant height-Plant height did not vary significantly for the treatment of mechanical transplanting along with fertilizer deep placement except Gazipur, Netrakona and Habiganj where T_1 gave significantly higher plant height compare to T_3 (Fig. 48). Plant height of T_2 and T_3 did not varied with the method of transplanting and fertilizer application irrespective of locations and varieties.

Number of tiller - Number of tiller at different date after transplanting is presented in figure 49 and 50. T1 gave significantly higher number of tiller at Gazipur and Habiganj whereas mechanical transplanted treatments gave higher number of tiller in all locations except Rangpur compared to the traditional treatments.

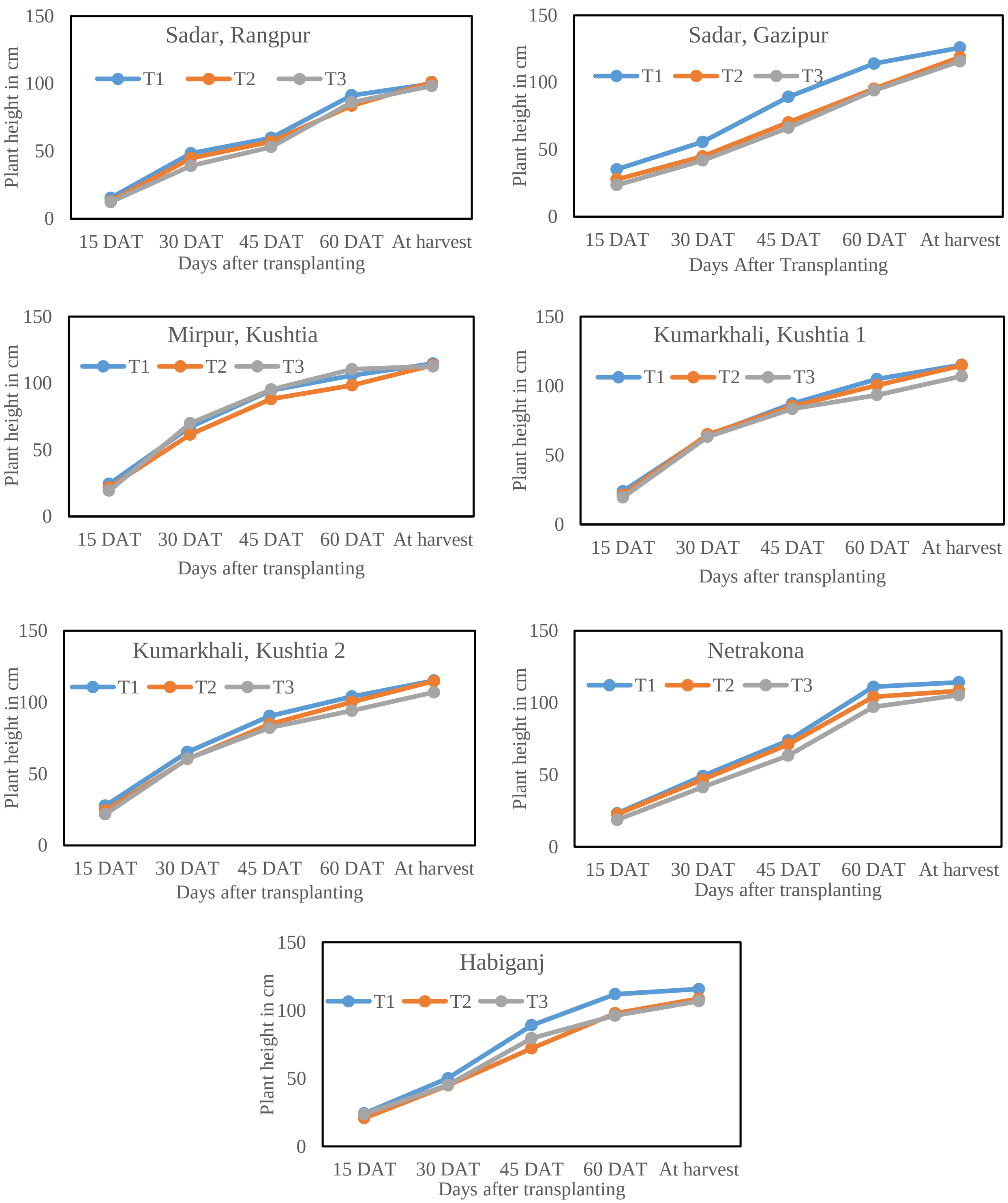


Fig. 48. Plant height at different date after transplanting in Aman 2019

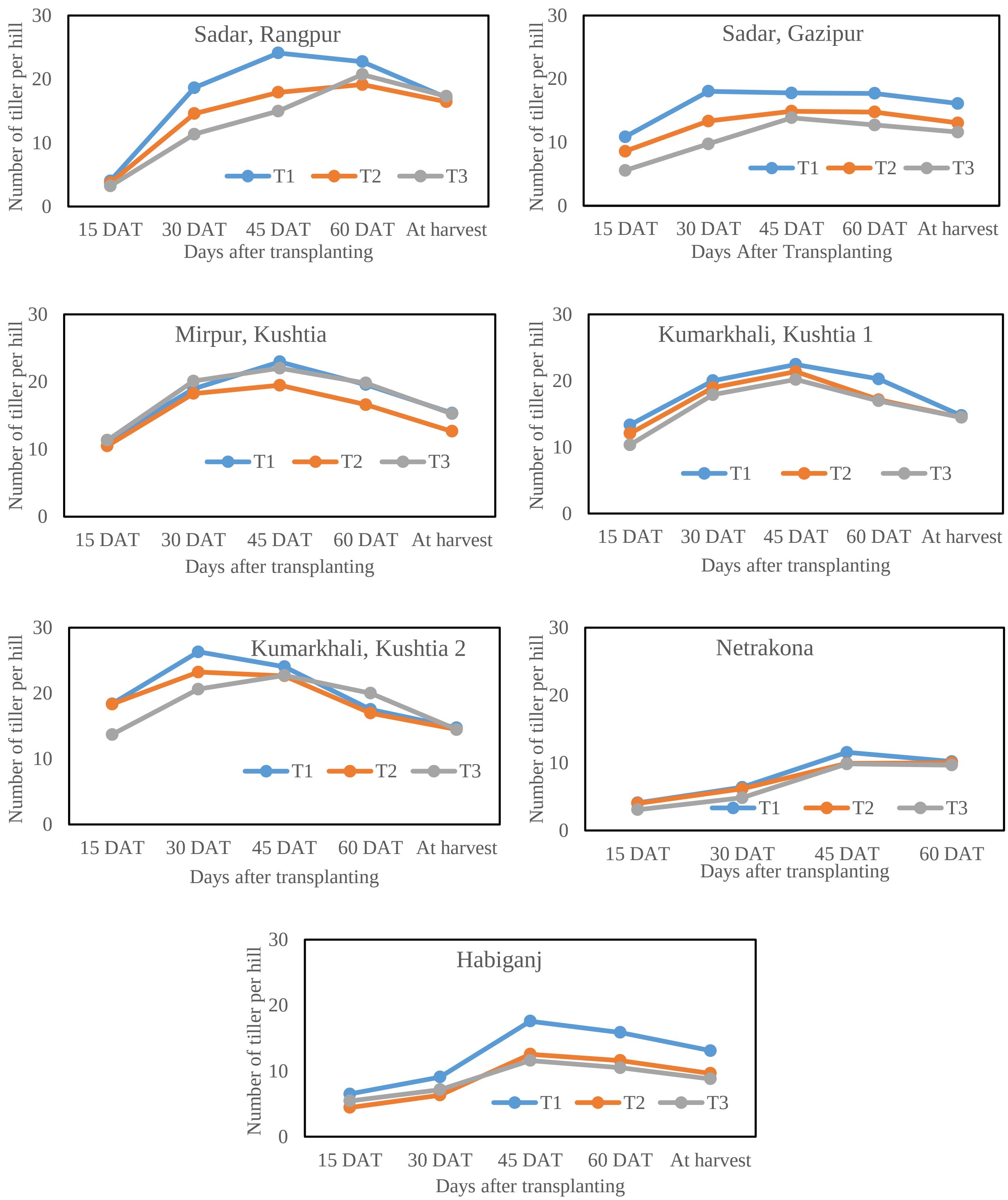
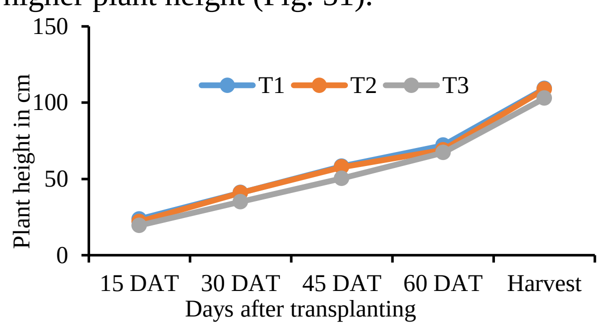


Fig. 49. Number of tiller at different date after transplanting in Aman 2019

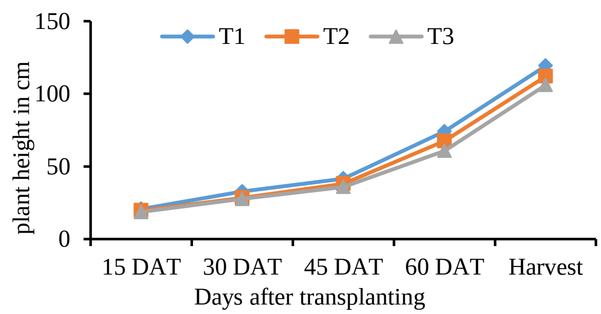
Fig. 50. Crop performance of the experimental field in Aman 2019 as affected under different treatments (Kushtia)

11.2.4.3 Boro 2019-20 season

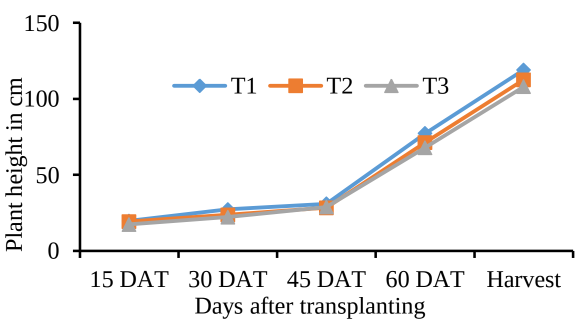
Plant height-Plant height did not vary significantly for the treatment of mechanical transplanting along with fertilizer deep placement in all locations except Kushtia where T_1 gave significantly higher plant height (Fig. 51).



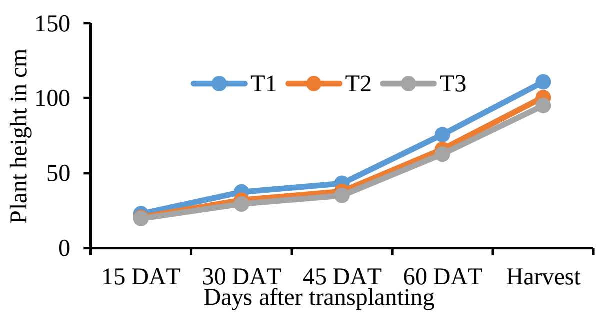
Sadar, Gazipur



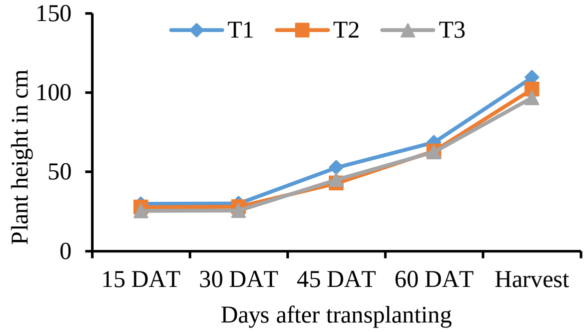
Kumarkhali, Kushtia 1



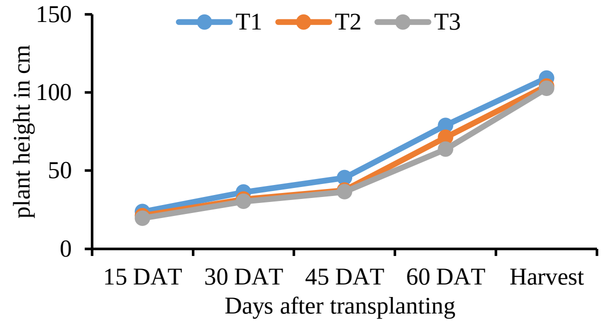
Kumarkhali, Kushtia 2



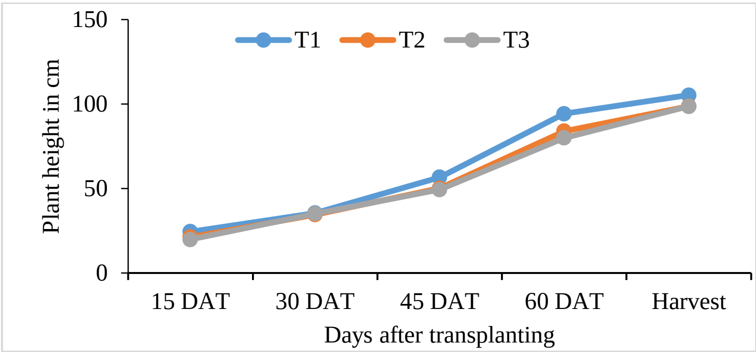
Mirpur, Kushtia



Sadar, Netrakona



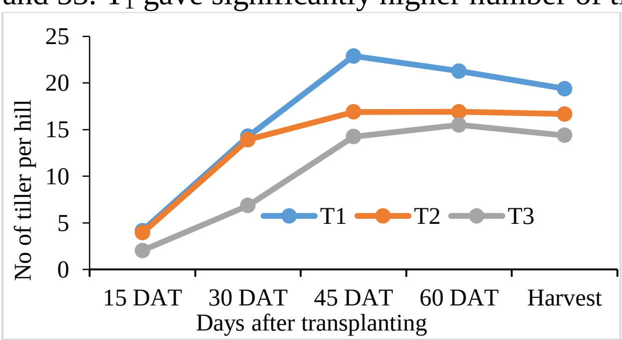
Sadar, Rangpur



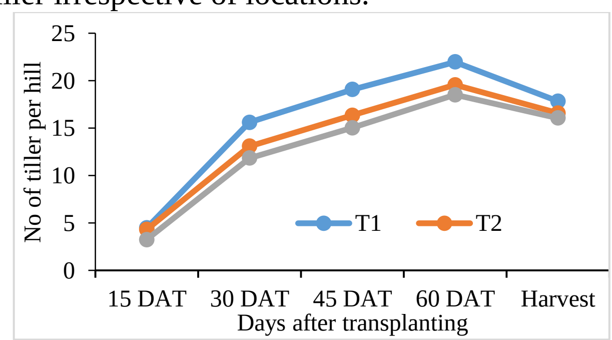
Shaestagonj, Habiganj

Fig. 51. Plant height at different date after transplanting in Boro 2019-20

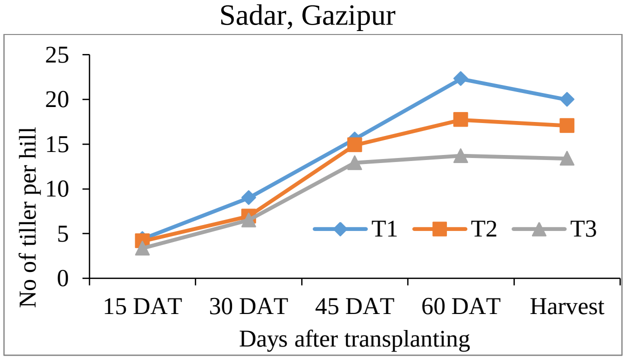
Number of tiller-Number of tiller at different date after transplanting is presented in figure 52 and 53. T_1 gave significantly higher number of tiller irrespective of locations.



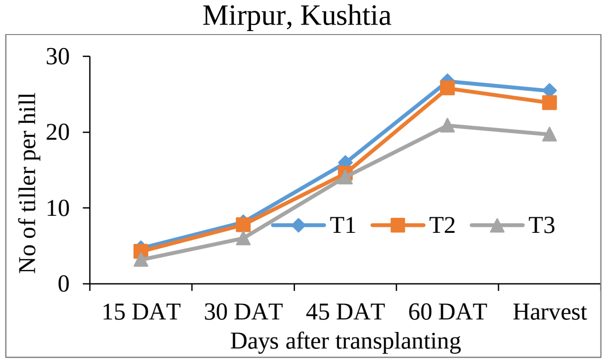
Sadar, Gazipur



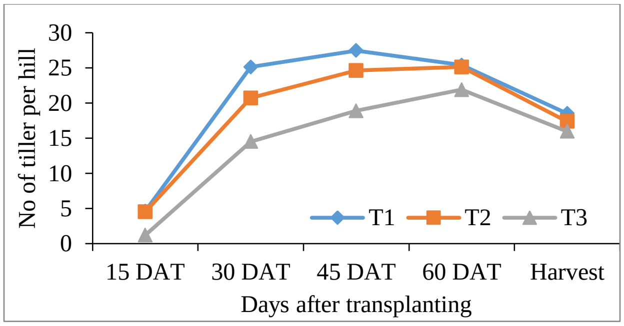
Mirpur, Kushtia



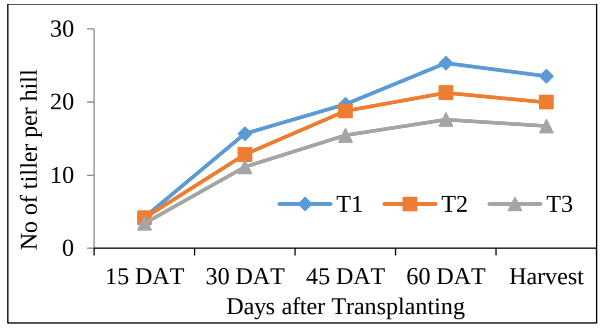
Kumarkhali, Kushtia-1



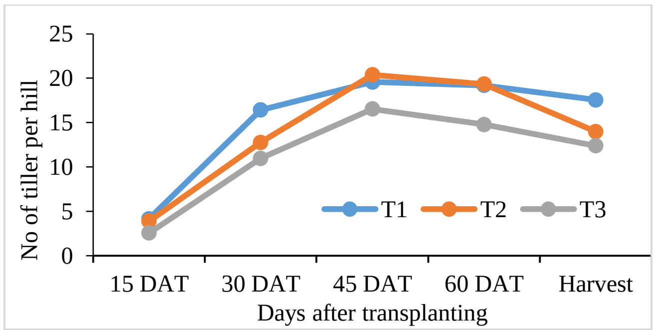
Kumarkhali, Kushtia-2



Sadar, Netrakona



Sadar, Rangpur



Shaestagonj, Hobigonj

Fig. 52. Number of tiller at different date after transplanting in Boro 2019-20

Fig. 53. Crop performance of the experimental field in Boro 2019-2020 season as affected under different treatments (Gazipur)

11.2.5 Yield performance

11.2.5.1 Boro 2018-19 Season

Rice and straw yield-Transplanting and fertilizer application methods influenced significantly on rice and straw yields in both locations during Boro season. (Table 20). In both locations, mechanical transplanting along with fertilizer deep placement (T_1) gave significantly higher yield (Kushtia: 7.96 t/ha and Habiganj: 6.15 t/ha) compared to other two treatments (T_2 and T_3) while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method (Kushtia: 6.68 t/ha and Habiganj: 5.05 t/ha) (T_3).

Table 20. Riceand Straw yield performance as affected under different transplanting and mode of fertilizer application (Boro 2018-19)

Treat	Rice yield @ 14% m.c (t/ha)		Straw yield (t/ha)	
	Kushtia	Habiganj	Kushtia	Habiganj
T_1	7.96 a	6.15 a	9.90 a	8.17 a
T_2	6.81 b	5.52 b	9.27 b	6.94 b
T_3	6.68 b	5.05 c	8.79 c	6.40 c
LoS	*	**	**	**
CV (%)	1.75	1.57	1.70	3.30
$LSD_{0.05}$	0.28	0.20	0.36	0.54

11.2.5.2 Aman 2019 Season

Rice yield-Transplanting and fertilizer application methods also influenced significantly on rice yields in all seven locations during Aman season (Table 21). In all locations, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method except Habiganj (Fig. 54).

Table 21. Rice yield performance as affected under different transplanting and mode of fertilizer application (Aman 2019)

Treat	Yield @ 14% m.c (t/ha)						
	Rangpur	Gazipur	Mirpur	Kushtia 1	Kushtia 2	Netrakona	Habiganj
T_1	4.89 a	4.83 a	5.77 a	5.94 a	6.12 a	4.52 a	4.77
T_2	4.51 b	3.66 b	4.91 b	4.89 b	5.64 b	3.92 b	3.94
T_3	4.14 c	3.81 b	4.44 c	4.84 b	5.05 c	3.67 b	4.02
LoS	**	**	**	*	**	**	ns
CV (%)	3.39	4.23	1.46	5.14	3.38	3.03	8.34
$LSD_{0.05}$	0.35	0.39	0.17	0.61	0.43	0.28	0.80

Straw yield-Straw yield varied significantly with the transplanting and fertilizer application methods in all seven locations during Aman season. (Table 22). In all locations, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method except Habiganj and Mirpur, Kushtia.

Table 22. Straw yield performance as affected under different transplanting and mode of fertilizer application (Aman 2019)

Treat	Dry straw yield (t/ha)						
	Rangpur	Gazipur	Kushtia	Kushtia 1	Kushtia 2	Netrakona	Habiganj
T_1	5.20 a	4.99 a	7.79	4.71 a	5.04 a	4.45 a	5.45
T_2	4.44 b	4.35 ab	7.61	4.67 a	4.67 b	3.88 b	4.16
T_3	4.05 c	3.85 b	6.81	4.21 b	3.67 c	3.04 c	4.11
CV (%)	2.28	6.92	5.55	3.67	3.29	5.96	14.25
$LSD_{0.05}$	0.2361	0.69	-	0.38	0.33	0.51	-

Fig. 54. Crop condition during harvesting in Aman 2019 (Habiganj)

11.2.5.3 Boro 2019-20 season

Rice yield - Transplanting and fertilizer application methods influenced significantly on rice and straw yields in all locations during Boro season (Table 23). In all cases, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method (Fig. 55).

Table 23. Rice yield performance as affected under different transplanting and mode of fertilizer application (Boro 2019-20)

Treat	Yield @ 14% m.c (t/ha)						
	Gazipur	Mirpur	Kushtia-1	Kushtia-2	Netrakona	Rangpur	Habiganj
T_1	5.89	7.05	7.12	7.14	6.25	7.04	6.99
T_2	4.35	6.24	6.22	6.44	5.72	5.98	6.13
T_3	4.65	6.10	5.49	6.11	5.37	5.59	5.42
CV (%)	2.75	0.8	0.71	1.4	2.2	2.42	2.17
$LSD_{0.05}$	0.26	0.12	0.10	0.21	0.29	0.34	0.30

Straw yield-Straw yield varied significantly with the transplanting and fertilizer application methods in all seven locations during Boro 2019-20 season (Table 24). In all locations, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments.

Table 24. Straw yield performance as affected under different transplanting and mode of fertilizer application (Boro 2019-20)

Treat	Dry straw yield (t/ha)						
	Gazipur	Mirpur	Kushtia-1	Kushtia-2	Netrakona	Rangpur	Habiganj
T_1	6.5	7.8	7.8	7.9	6.9	7.7	7.7
T_2	4.8	6.9	6.8	7.1	6.3	6.6	6.7
T_3	5.1	6.7	6.0	6.7	5.9	6.1	6.0
LoS	*	*	*	*	*	*	*
CV (%)	3.75	4.8	6.71	6.4	8.2	5.42	9.17
$LSD_{0.05}$	0.86	0.42	0.90	0.71	0.43	1.03	0.90

Fig. 55. Crop condition before harvesting in Aman 2020

11.2.5.4 Aman 2020 season

Rice yield - Transplanting and fertilizer application methods influenced significantly on rice and straw yields in all locations during Aman season (Table 25a). In all cases, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method.

Table 25 (a). Rice yield performance as affected under different transplanting and mode of fertilizer application (Aman 2020)

Treat	Yield @ 14% m.c (t/ha)						
	Gazipur	Mirpur	Kushtia-1	Kushtia-2	Netrakona	Rangpur	Habiganj
T_1	5.74	5.90	5.98	5.82	5.25	4.35	4.35
T_2	4.66	4.80	5.49	5.50	5.10	4.30	4.15
T_3	4.26	4.34	5.35	5.10	5.07	4.14	4.00
CV (%)	3.35	2.45	0.71	1.4	2.2	2.42	2.17
$LSD_{0.05}$	1.12	0.78	0.45	0.68	-	0.12	0.24

Straw yield - Straw yield varied significantly with the transplanting and fertilizer application methods in all seven locations during Aman 2020 season. (Table 25b). In all locations, mechanical transplanting along with fertilizer deep placement gave significantly higher straw yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method except Habiganj and Kushtia-1.

Table 25 (b). Straw yield performance as affected under different transplanting and mode of fertilizer application (Aman 2020)

Treat	Dry straw yield (t/ha)						
	Gazipur	Mirpur	Kushtia-1	Kushtia-2	Netrakona	Rangpur	Habiganj
T_1	5.85	5.17	5.10	6.42	5.34	4.44	4.25
T_2	4.26	4.94	5.02	5.38	5.01	4.18	4.85
T_3	4.12	4.82	5.12	5.13	4.82	4.09	4.35
LoS	*	ns	ns	*	*	*	ns
CV (%)	7.20	8.82	9.12	9.12	3.29	8.82	12.13
$LSD_{0.05}$	1.25	-	-	1.12	0.42	0.32	-

11.2.6 Economic analysis

11.2.6.1 Boro 2018-19 season

Cost-analysis of rice production is shown in Table (26-28) as affected under different rice seedling transplanting and fertilizer application methods during Boro2018-19, Aman2019 and Boro 2019-20 season. During Boro/2018-19 season, T_1 gave the highest BCR in both Kushtia (1.72) and Habiganj (1.32) whereas T_2 followed by T_3 gave lower BCR in both the locations (Table 26). Averaged for locations, BCR of T_1 (1.52) was higher compared to T_2 (1.31) and T_3 (1.20). Variation of BCR was observed due to yield effect on gross margin and to some extent from input costs (e.g., labor, fuel, time, etc.).

Table 26. Cost analysis of rice production as affected under different transplanting and fertilizer application methods during Boro/2018-19 season.

Locations	Input cost, Tk ha^{-1}			Gross return, Tk ha^{-1}			Gross margin, Tk ha^{-1}			BCR			Avg. BCR
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	
Mirpur	99978	101658	105113	171575	147788	144588	71597	46130	39475	1.72	1.45	1.38	1.52
Habiganj	100576	101740	106163	133213	119075	109000	32636	17335	2837	1.32	1.17	1.03	1.17
Average	100277	101699	105638	152394	133431	126794	52117	31732	21156	1.52	1.31	1.20	1.34

11.2.6.2 Aman 2019 season

In Aman 2019 season, T_1 gave the highest BCR in all locations compared to T_2 and T_3 whereas lower BCR was observed in T_3. Averaged of 7 locations, BCR of T_1, T_2 and T_3 were found 1.42, 1.24 and 1.10, respectively (Table 27).

Table 27. Cost analysis of rice production as affected under different transplanting and fertilizer application methods during Aman/2019 season.

Locations	Input cost, Tk ha^{-1}			Gross return, Tk ha^{-1}			Gross margin, Tk ha^{-1}			BCR			Avg. BCR
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	
Rangpur	77798	79026	84307	97800	96700	88350	20002	17674	4043	1.26	1.22	1.05	1.18
Gazipur	78379	78887	84281	101663	79438	81638	23283	551	-2643	1.30	1.01	0.97	1.09
Mirpur	76772	77862	83756	120213	107938	98313	30076	14557	51283	1.57	1.39	1.17	1.38
Kushtia-1	76029	76929	82181	127313	103688	102638	51283	26759	20457	1.67	1.35	1.25	1.42
Kushtia-2	77026	77470	82968	127663	119100	106838	50637	41630	23869	1.66	1.54	1.29	1.49
Netrakona	76120	76754	81341	94988	83963	78250	18867	7208	-3091	1.25	1.09	0.96	1.10
Habiganj	78440	79505	84800	99200	85613	85600	20760	6107	800	1.26	1.08	1.01	1.12
Average	77224	78062	83376	109834	96634	91661	30701	16355	13531	1.42	1.24	1.10	1.25

11.2.6.3 Boro 2019-20 season

In Boro 2019-20 season, T_1 gave the highest BCR in all locations compared to T_2 and T_3 whereas lower BCR was observed in T_3. Averaged of 7 locations, BCR of T_1, T_2 and T_3 were found 1.70, 1.47 and 1.21, respectively (Table 28).

Table 28. Cost analysis of rice production as affected under different transplanting and fertilizer application methods during Boro 2019-20 season.

Locations	Input cost, Tk ha^{-1}			Gross return, Tk ha^{-1}			Gross margin, Tk ha^{-1}			BCR			Avg.
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3	BCR
Rangpur	85447	87084	98091	150551	129219	120018	65103	42135	21927	1.76	1.48	1.22	1.49
Gazipur	85512	86839	101564	125552	95037	99043	40040	8198	-2522	1.47	1.09	0.98	1.18
Mirpur	83642	85517	97539	147398	134494	130514	48977	32975	67453	1.76	1.57	1.34	1.56
Kushtia-1	83264	84668	95964	150717	134185	118353	67453	49518	22388	1.81	1.58	1.23	1.54
Kushtia-2	84522	85478	96752	150283	138613	131121	65760	53135	34369	1.78	1.62	1.36	1.58
Netrakona	83536	84310	95124	133340	122923	115260	49804	38614	20136	1.60	1.46	1.21	1.42
Habiganj	85855	87686	102084	147250	132150	116824	61394	44464	14740	1.72	1.51	1.14	1.46
Average	84540	85940	98160	143584	126660	118733	56933	38434	25499	1.70	1.47	1.21	1.46

Overall BCR was higher in Boro season due to higher yield. Different cost calculation is presented in the Appendices (1 to 9).

11.3 Evaluation of different growing media for mat type rice seedling raising

The research was conducted with 20 growing media for each type of soil (sandy clay loam and sandy clay) where four levels of organic substance (cow dung, rice bran, rice husk and tea wastage) were mixed with soil at the desired rate as per design of the treatments. Potential outcomes of utilizing diverse media as an option in contrast to regular soil media have been concentrated by several studies (Ko, et al., 2005; Shiratsuchi et al., 2008; Ikeura et al., 2012). Soil collection and seedling tray filled with soil (around 5-6 kg/tray) is the major problem of seedling raising for mechanical transplanting. On the off chance that dirt medium can be supplanted by any lightweight, ease, and effectively accessible materials that would be extraordinary assistance to the rice ranchers. Rice husk, a result of the rice processing industry, was discovered to be a reasonable model for soilless culture because of the properties of good air circulation and lightweight (Islam, 2008). Also it can be overcome by rolling up the seedling as seedling mat to carry easily (Hossen et al, 2018a). The results of the research are discussed in this chapter involving different parameters of the seedling and seedling mat for the studied rice variety.

11.3.1 Agronomic characteristics

11.3.1.1 Seedling height(Soil type I)

Insignificant effect of organic substance and percentage of soil mixture was observed on seedling height while single effect of both organic substance and soil mixture percentage showed significant effect (Table 29 and fig. 56 & 57). Rice bran along with 85% soil mixture showed mathematically higher seedling height followed by 90 to 80% soil mixture with cow dung, 90% soil mixture with rice bran and 85% soil mixture with rice husk whereas 80% soil mixture with tea wastage exposed lower seedling height at 30 days.

Table 29. Interaction effect of organic substance and percentage of soil mixture (Type I) on seedling height (mm)

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	94.99	93.19	95.93	89.83	93.48
95	100.79	98.41	94.03	89.60	95.70
90	108.16	107.64	97.89	87.39	100.27
85	107.64	111.74	102.54	92.02	103.48
80	104.22	97.98	97.86	85.15	96.30
Mean	103.16	101.79	97.65	88.80	-
CV, %	6.60				
LoS	O = **, S = ** and O × S = NS				
LSD $_{0.05}$	O = 4.77 and S = 5.34				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Among the organic substance, mean seedling height in soil and cow dung mixture scored significantly higher value followed by rice bran whereas tea wastage gave lower value (Fig. 56). On the other hand, 85% soil mixture with organic substance scored significantly higher value followed by 90% soil mixture with organic substance. Significantly lower value was observed for 100% soil followed by 95 and 80% of soil mixture with organic substance (Fig. 57).

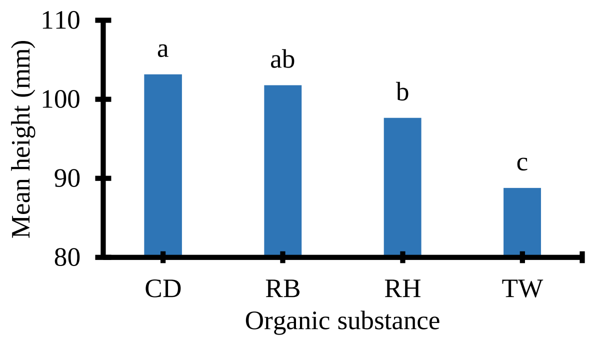


Fig. 56. Effect of organic substance on seedling height

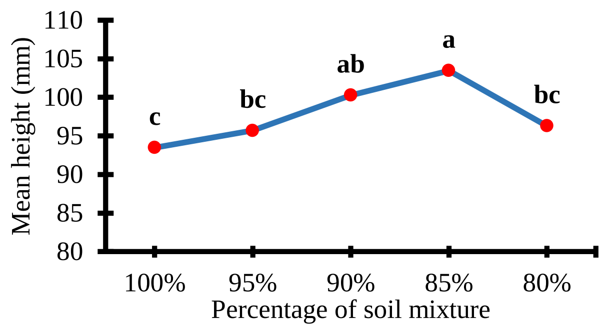


Fig. 57. Effect of percentage of soil mixture with additional substance on seedling height

11.3.1.2 Seedling height (Soil type II)

Significant effect of organic substance and percentage of soil was observed on seedling height as were single effect of both organic substance and soil mixture percentage(Table 30 and fig. 58 & 59). Cow dung along with 80% soil mixture gave significantly higher seedling height followed by cow dung along with 85% soil mixture whereas 90 and 95% soil mixture with rice husk, 95% with tea wastage and 100% soil gave significantly lower seedling height at 30 days after sowing.

Table 30. Interaction effect of organic substance and percentage of soil mixture (Type II) on seedling height (mm)

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	77.68	82.71	81.16	84.01	81.39
95	81.38	89.91	76.59	77.63	81.38
90	93.64	89.79	76.87	81.92	85.56
85	97.85	87.04	89.22	82.16	89.07
80	104.03	91.25	86.52	80.25	90.51
Mean	90.91	88.14	82.07	81.20	-
CV, %	6.82				
LoS	O = **, S = ** and O × S = **				
LSD $_{0.05}$	O = 4.32, S = 4.83 and O × S = 9.65				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Mean seedling height in soil and cow dung mixture and rice bran mixture scored significantly higher value while rice husk and tea wastage mixture gave significantly lower value (Fig. 58). On the other hand, 80% soil mixture with organic substance scored significantly higher value followed by 85% soil mixture with organic substance. Significantly lower value was observed for 100% soil and 95% soil mixture followed by 90% of soil mixture with organic substance (Fig. 59). Seedling height increased with the decrease of soil mixture percentage with organic substances. According to Mamun et al. (2013), the suitable seedling height of 120 mm could be achieved from 12-16 days old seedlings for mechanical transplanting in rice. This is in affirmation with the current examination. Number of leaf per plant was not significant at 15 and 30 DAS for both type of soil.

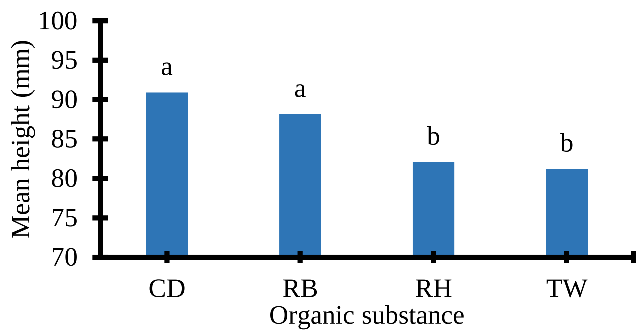


Fig. 58. Effect of organic substance on seedling height

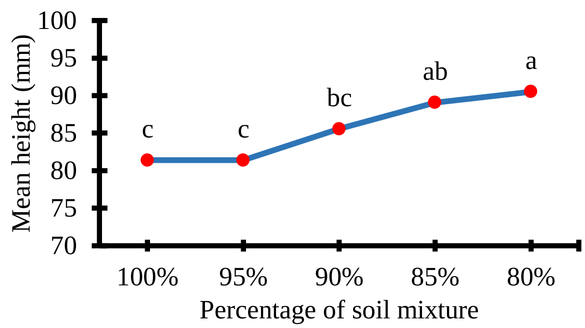


Fig. 59. Effect of percentage of soil mixture with additional substance on seedling height

11.3.1.3 Stem thickness (Soil type I)

Two-way interaction of organic substance and percentage of soil mixture did not show significant effect on stem thickness as were as single effect of both organic substance and soil mixture percentage (Table 31 and fig. 60 & 61).

Table 31. Interaction effect of organic substance and percentage of soil mixture (Type I) on stem thickness of seedlings (mm)

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	0.94	1.12	1.09	1.00	1.04
95	1.19	1.08	1.13	1.10	1.12
90	1.21	1.15	1.07	1.10	1.13
85	1.27	1.21	1.12	0.98	1.15
80	1.20	1.19	1.08	1.10	1.14
Mean	1.16	1.15	1.10	1.06	-
CV, %	12.87				
LoS	O = NS, S = NS and O × S = NS				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Mean stem thickness among the organic substance, cow dung scored higher values (Fig. 60) while 85% soil mixture with organic substance scored mathematically higher value than others percentage (Fig. 61).

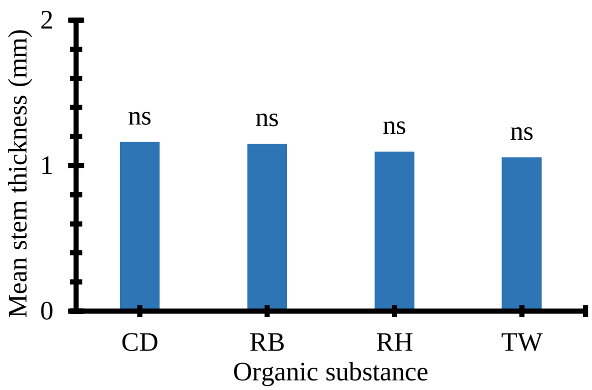


Fig.60. Effect of organic substance on stem thickness

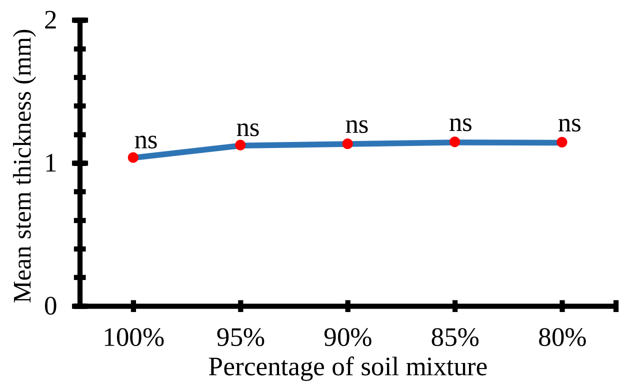


Fig.61. Effect of percentage of soil mixture with additional substance on stem thickness

11.3.1.4 Stem thickness (Soil type II)

Insignificant effect of interaction of organic substance and percentage of soil mixture was observed on stem thickness. On the other hand, single effect of both organic substance and soil mixture percentage showed significant effect on stem thickness (Table 32 and fig. 62 & 63). Cow dung along with 95% soil mixture and rice husk along with 85% soil mixture gave higher stem thickness whereas tea wastage along with 80% soil mixture gave lower stem thickness.

Table 32. Interaction effect of organic substance and percentage of soil mixture (Type II) on stem thickness of seedlings (mm)

Percentage of soil mixture	Organic substance				Mean (mm)
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	0.94	0.97	1.00	1.06	0.99
95	1.11	1.05	1.04	0.75	0.99
90	0.99	1.01	0.94	0.89	0.96
85	1.08	1.04	1.09	1.07	1.07
80	0.93	0.96	0.92	0.65	0.87
Mean (mm)	1.01	1.01	1.00	0.88	-
CV, %	12.08				
LoS	O = *, S =** and O × S = NS				
$LSD_{0.05}$	O = 0.09 and S = 0.10				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Single effect of cow dung, rice bran and rice husk scored significantly higher value of mean stem thickness while tea wastage gave significantly lower value (Fig. 62). On the other hand, 85% soil mixture with organic substance scored significantly higher values of mean stem thickness followed by 100 to 95% of soil mixture. Significantly lower value was observed for 80% soil mixture with organic substance (Fig. 63).

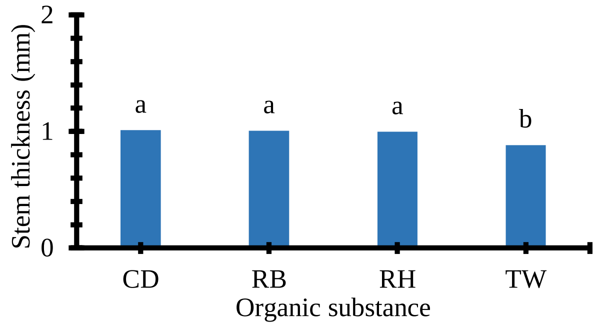


Fig. 62. Effect of organic substance on stem thickness

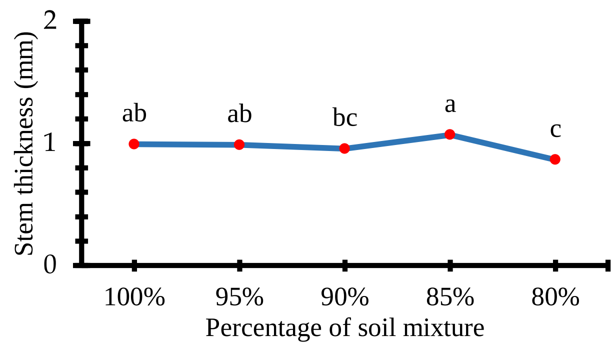


Fig. 63. Effect of percentage of soil mixture with additional substance on stem thickness

11.3.1.5 Seeding density (Soil type I)

Interaction effect of organic substance and percentage of soil mixture showed significant effect on seedling density as were significant of single effect of soil mixture percentage. Organic substance did not show significant effect on seedling density (Table 33 and fig. 64 & 65). Rice bran and rice husk along with 90 and 80% soil mixture gave significantly higher seedling density respectively whereas 80% soil mixture with rice bran gave significantly lower seedling density.

Table 33. Interaction effect of organic substance and percentage of soil mixture (Type I) on density of seedlings (cm^{-2})

Percentage of soil mixture	Organic substance				Mean ($No./cm^2$)
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	16.33	9.00	10.67	12.33	12.08
95	15.67	17.67	12.67	16.00	15.50
90	11.67	18.00	15.33	16.67	15.42
85	11.00	13.33	12.67	15.00	13.00
80	10.00	6.00	18.00	17.67	12.92
Mean (No/cm^2)	12.93	12.80	13.87	15.53	-
CV, %	23.74				
LoS	O = NS, S = * and O × S = **				
$LSD_{0.05}$	S = 2.70 and O × S = 5.41				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Among the organic substance, tea wastage scored mathematically higher values followed by rice husk while cow dung and rice bran gave lower value (Fig. 64). On the other hand, 95 and 90% soil mixture with organic substance scored significantly higher value followed by 85 and 80% soil mixture with organic substance while 100% soil gave significantly lower value (Fig. 65).

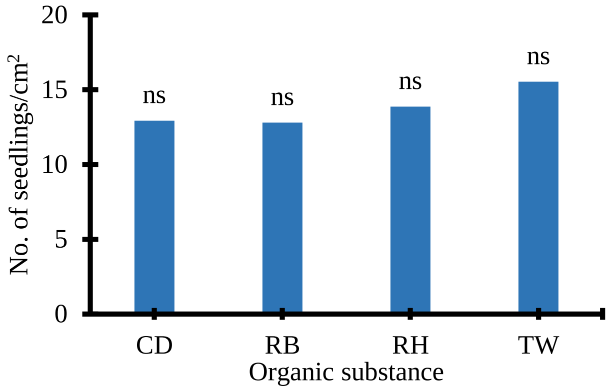


Fig. 64. Effect of organic substance on seedling density

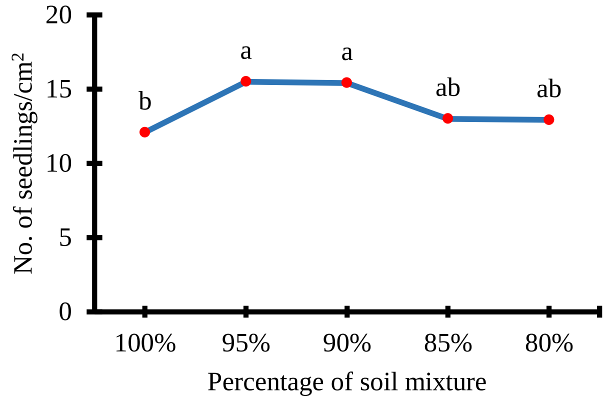


Fig. 65. Effect of percentage of soil mixture with additional substance on seedling density

11.3.1.6 Seeding density (Soil type II)

Interaction as well as single effect of organic substance and percentage of soil mixture showed significant effect on seedling density (Table 34 and fig. 66 & 67).Tea wastage along with 90% soil mixture gave significantly higher seedling density whereas 85% soil mixture with rice bran gave significantly lower seedling density.

Table 34. Interaction effect of organic substance and percentage of soil mixture (Type II) on density of seedlings (cm^{-2})

Percentage of soil mixture	Organic substance				Mean ($No./cm^2$)
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	16.00	12.67	11.00	12.00	12.92
95	12.33	14.00	12.67	12.33	12.83
90	16.33	7.33	13.33	18.67	13.92
85	13.00	6.67	12.00	9.33	10.25
80	10.33	10.33	7.67	8.67	9.25
Mean($No./cm^2$)	13.60	10.20	11.33	12.20	-
CV, %	25.73				
LoS	O = *, S = ** and O × S = *				
$LSD_{0.05}$	O = 2.25, S = 2.52 and O × S = 5.03				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Single effect of cow dung scored significantly higher values followed by tea wastage while rice bran and rice husk gave significantly lower value (Fig. 66). On the other hand, 100 to 90% soil mixture with organic substance scored significantly higher value while 85 and 80% soil mixture with organic substance gave significantly lower value (Fig. 67).

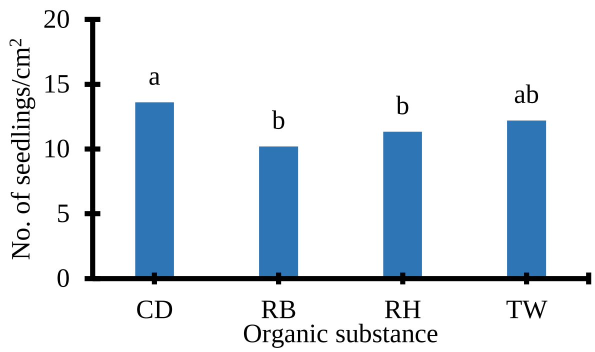


Fig. 66. Effect of organic substance on seedling density

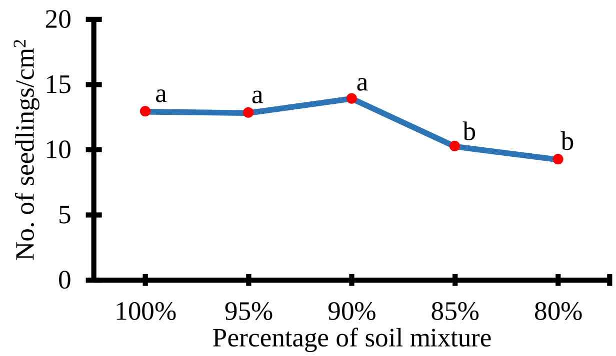


Fig. 67. Effect of percentage of soil mixture with additional substance on seedling density

11.3.2 Mechanical characteristics

11.3.2.1 Rolling quality of mat (Soil type I)

Observation scored was not varied significantly with the interaction effect of organic substance and percentage of soil mixture while scored varied significantly with the single effect of the both factor (Table 35 and fig. 68 & 69). Soil without any organic substance scored higher values on rolling quality followed by cow dung and rice bran along with 95% soil mixture whereas rice husk along with 85 to 80% soil mixture showed lower scored on rolling quality. Single effect of Cow-dung scored significantly higher value followed by rice bran while rice husk gave significantly lower value (Fig. 68). On the other hand, 100% soil scored significantly higher value. Significantly lower value was observed for 80% soil mixture with organic substance (Fig. 69). Rolling quality decreased with the increase of organic substance with sandy clay loam soil.

Table 35. Interaction effect of organic substance and percentage of soil mixture (Type I) on rolling quality of mat

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	10.00	8.67	8.00	8.00	8.67
95	8.67	8.67	6.00	8.00	7.83
90	8.00	8.00	6.00	7.33	7.33
85	8.00	6.00	4.67	7.33	6.50
80	6.67	6.67	4.67	6.67	6.17
Mean	8.27	7.60	5.87	7.47	-
CV, %	13.01				
LoS	O = **, S = ** and O × S = NS				
LSD $_{0.05}$	O = 0.70 and S = 0.79				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

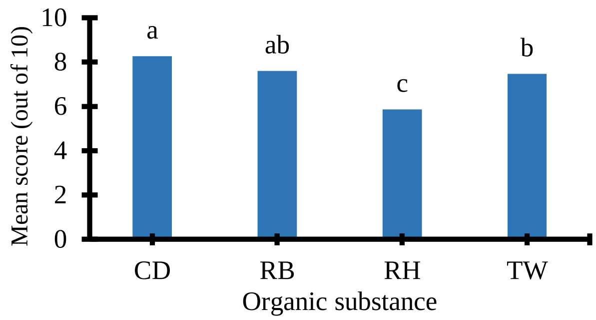


Fig. 68. Effect of organic substance on rolling quality

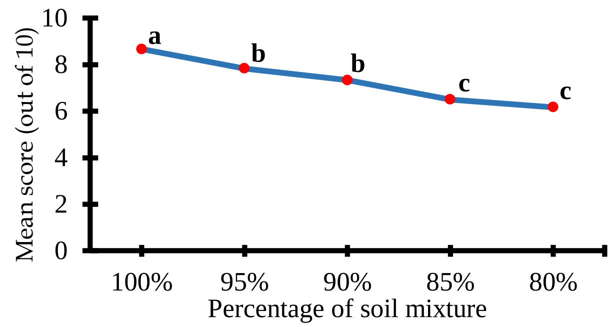


Fig. 69. Effect of percentage of soil mixture with additional substance on rolling quality

11.3.2.2 Rolling quality of the seedling mat (Soil type II)

Two-way interaction of organic substance and percentage of soil mixture did not show significant effect on rolling quality of the seedling mat. On the other hand, single effect of both organic substance and soil mixture percentage showed significant effect on rolling quality (Table 36 and fig. 70 & 71). Soil without any organic substance mathematically showed higher score on rolling quality followed by cow dung along with 95% soil mixture and tea wastage along with 95 to 90% whereas rice husk along with 80% soil mixture showed lower score on rolling quality.

Table 36. Interaction effect of organic substance and percentage of soil mixture (Type II) onrolling quality of mat

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	9.33	8.67	7.33	8.00	8.33
95	8.67	7.33	6.67	8.00	7.67
90	7.33	6.67	6.67	8.00	7.17
85	6.67	7.33	5.33	6.00	6.33
80	6.00	5.33	4.00	6.00	5.33
Mean	7.60	7.07	6.00	7.20	-
CV, %	16.29				
LoS	O = **, S = ** and O × S = NS				
LSD $_{0.05}$	O = 0.84 and S = 0.94				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Single effect of cow dung, rice bran and tea wastage scored significantly higher value while rice husk gave significantly lower value on rolling quality (Fig. 70). On the other hand, 100% soil scored significantly higher value followed by 95% soil mixture. Significantly lower score on rolling quality was observed for 80% soil mixture with organic substance (Fig. 71).

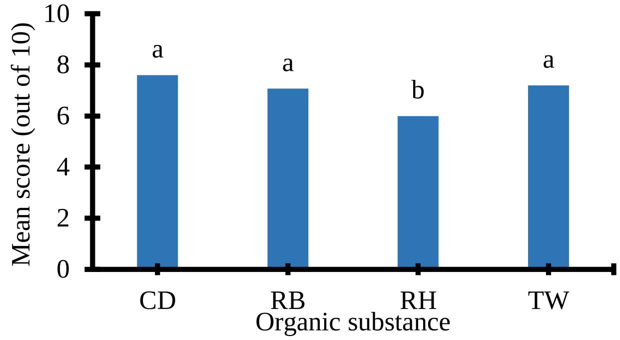


Fig. 70. Effect of organic substance on rolling quality

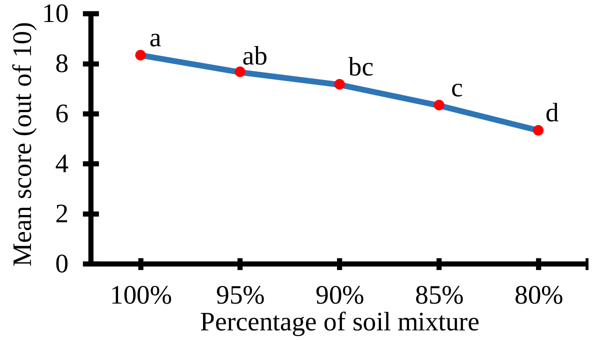


Fig. 71. Effect of percentage of soil mixture with additional substance on rolling quality

11.3.3 Fungal infection

11.3.3.1 Fungal infection (Soil type I)

Interaction effect of organic substance and percentage of soil mixture showed significant effect on intensity of fungal infection as were both the single effect of organic substance and soil mixture percentage (Table 37 and fig. 72 & 73).Rice bran along with 80% soil mixture gave significantly higher fungal infection followed by cow dung and tea wastage along with 90 to 80% soil mixture and 100% soil whereas 95% soil mixture with rice bran gave significantly lower fungal infection followed by soil without any substance.

Table 37. Interaction effect of organic substance and percentage of soil mixture (Type I) on fungal infection of seedlings (%)

Percentage of soil mixture	Organic substance				Mean (%)
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	3.33	6.67	1.67	3.33	3.75
95	5.00	0.00	3.33	5.00	3.33
90	6.67	3.33	3.33	6.67	5.00
85	5.00	3.33	3.33	5.00	4.17
80	8.33	28.33	5.00	11.67	13.33
Mean (%)	5.67	8.33	3.33	6.33	-
CV, %	60.85				
LoS	O = **, S = ** and O × S = **				
LSD $_{0.05}$	O = 2.66, S = 2.98 and O × S = 5.95				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Fungal infection was observed significantly higher for rice bran followed by tea wastage while rice husk gave significantly lower value followed by cow dung (Fig. 72). On the other hand, 80% soil mixture with organic substance scored significantly higher value of fungal infection while 100 to 85% soil mixture with organic substance gave significantly lower value (Fig. 73).

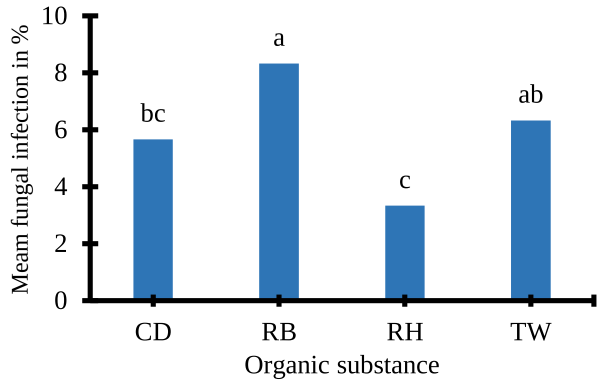


Figure 72. Effect of organic substance on fungal infection

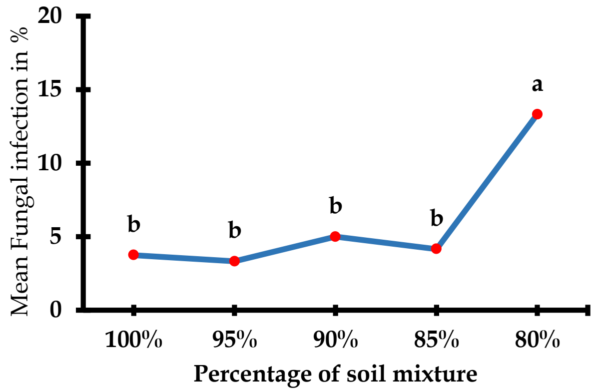


Figure 73. Effect of percentage of soil mixture with additional substance on fungal infection

11.3.3.2 Fungal infection (Soil type II)

Interaction effect of organic substance and percentage of soil mixture showed significant effect on fungal infection as were both the single effect of organic substance and soil mixture percentage (Table 38 and fig. 74 & 75).Rice bran along with 80% soil mixture gave significantly higher fungal infection followed by cow dung along with 80% soil mixture whereas 90% soil mixture with cow dung and soil without organic substance gave significantly lower fungal infection.

Table 38. Interaction effect of organic substance and percentage of soil mixture (Type II) on fungal infection of seedlings (%)

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	10.00	5.00	3.33	8.33	6.67
95	5.00	5.00	6.67	5.00	5.42
90	3.33	6.67	5.00	5.00	5.00
85	8.33	10.00	6.67	6.67	7.92
80	18.33	20.00	6.67	15.00	15.00
Mean	9.00	9.33	5.67	8.00	-
CV, %	35.07				
LoS	O = **, S = ** and O × S = **				
$LSD_{0.05}$	O = 2.07, S = 2.32 and O × S = 4.64				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Among the organic substance, cow dung, rice bran and tea wastage scored significantly higher value while rice husk gave significantly lower value (Fig. 74). On the other hand, 80% soil mixture with organic substance scored significantly higher value while 95 to 90% soil mixture with organic substance gave significantly lower value followed by soil without organic substance (Fig. 75).

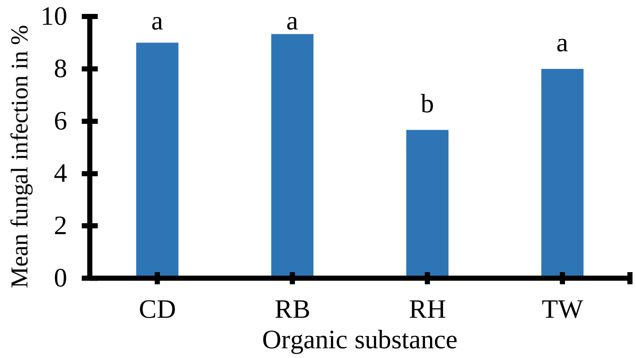


Figure 74. Effect of organic substance on fungal infection

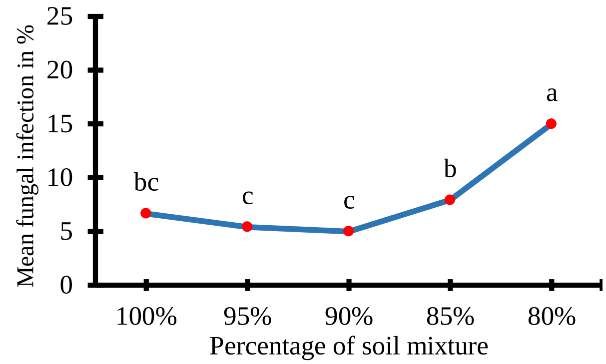


Figure 75. Effect of percentage of soil mixture with additional substance on fungal infection

11.3.4 Field demonstration

11.3.4.1 Field demonstration (Soil type I)

Observation value of the observers on seedling quality varied significantly with the interaction effect of organic substance and soil mixture as were varied with the single effect of organic substance as well as percentages of soil mixture (Table 39 and fig. 76 & 77). Observers gave significantly higher values for cow dung with 95% of soil mixture followed by 90% of soil mixture with cow dung and 100 to 90% of soil mixture with rice bran. Rice bran scored significantly lower values along with 80% soil mixture.

Table 39. Interaction effect of organic substance and percentage of soil mixture (Type I) on observation value of seedling quality (out of 10)

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	7.67	8.53	5.40	5.60	6.80
95	9.53	8.60	6.07	7.00	7.80
90	8.40	8.33	7.07	6.67	7.62
85	5.67	6.60	7.07	6.53	6.47
80	5.67	3.53	7.53	6.00	5.68
Mean	7.39	7.12	6.63	6.36	-
CV, %	6.43				
LoS	O = **, S = ** and O × S = **				
$LSD_{0.05}$	O = 0.33 , S = 0.37 and O × S = 0.73				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Cow dung and rice bran scored significantly higher value followed by rice husk and tea wastage as single effect (Table 39 and Fig. 76). On the other hand, 95 and 90% soil mixture with organic substance scored significantly higher value. Significantly lower value was observed for 80% soil mixture followed by 85 and 100% of soil mixture with organic substance (Table 39 and Fig. 77).

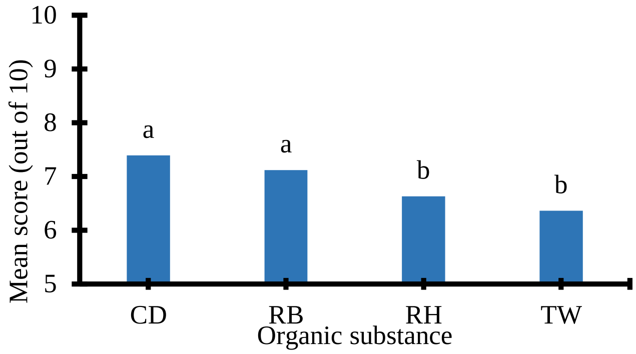


Fig. 76. Effect of organic substance on observation value of seedling quality

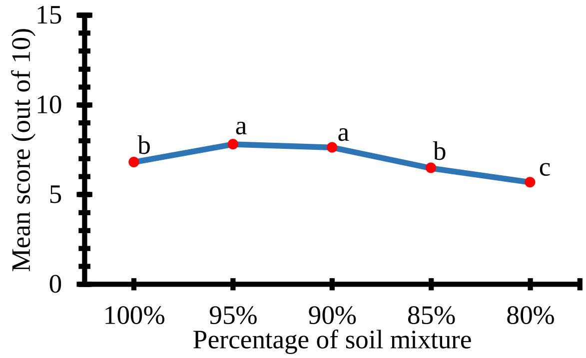


Fig. 77. Effect of percentage of soil mixture with additional substance on observation value of seedling quality

11.3.4.2 Field demonstration (Soil type II)

Observation value of the observers on seedling quality varied significantly with the interaction effect of organic substance and soil mixture as were varied significantly with the single effect of organic substance but did not show significant effect on percentages of soil mixture (Table 40 and fig. 78 & 79). Significantly higher values were observed for cow dung with 85% of soil mixture followed by 100 to 80% of soil mixture with cow dung and 90% of soil mixture with rice husk and tea wastage. Significantly lower value was scored for rice bran along with 85% soil mixture.

Table 40. Interaction effect of organic substance and percentage of soil mixture (Type II) on observation value of seedling quality (out of 10)

Percentage of soil mixture	Organic substance				Mean
	Cow dung	Rice bran	Rice husk	Tea wastage	
100	4.93	4.47	4.20	4.27	4.47
95	5.53	4.47	4.33	4.40	4.68
90	5.60	3.47	4.93	5.07	4.77
85	5.8 0	3.20	4.60	3.53	4.28
80	5.47	3.47	4.27	4.07	4.33
Mean	5.47	3.81	4.47	4.27	-
CV, %	11.73				
LoS	O = **, S = NS and O × S = *				
$LSD_{0.05}$	O = 0.39 and O × S = 0.87				

Note: NS- Not significant, *- significant at 5 %, **- significant at 1 %, LoS- Level of significance, O-Organic substance and S-Soil mixture in percentage.

Among the organic substance, cow dung scored significantly higher value (Table 40 and Fig. 78). On the other hand, 90% soil mixture with organic substance scored significantly higher value followed by 100 and 95% soil mixture with organic substance. Significantly lower value was observed for 85 and 80% soil mixture with organic substance (Table 40 and Fig. 79).

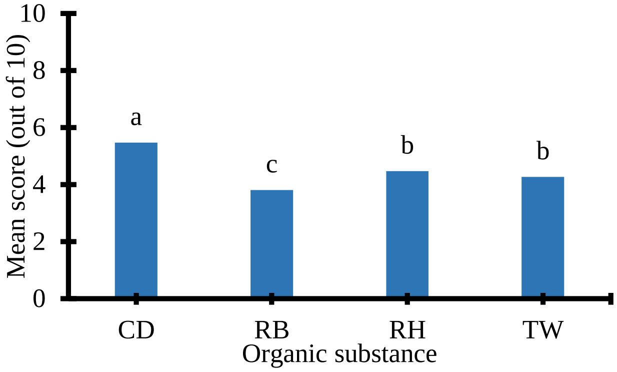


Fig. 78. Effect of organic substance on observation value of seedling quality

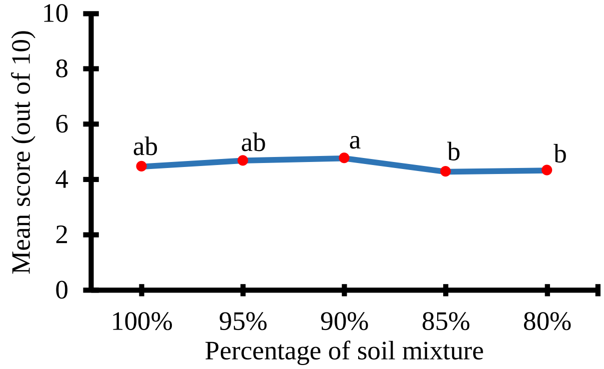


Fig. 79. Effect of percentage of soil mixture with additional substance on observation value of seedling quality

11.4 Mitigation of biotic and abiotic stress in mat type seedlings raising for mechanical rice transplanting

11.4.1 Ambient temperature and relative humidity

Temperature is an important factor for the growth of rice seedling raised in plastic tray. Ambient temperature during seedling raising period is presented in Fig. 80. The highest atmospheric temperature was observed 34^{o} C and the lowest temperature was 7^{o} C during seedling growing period. The relative humidity during growing period collected from local weather station which is presented in Fig: 81.

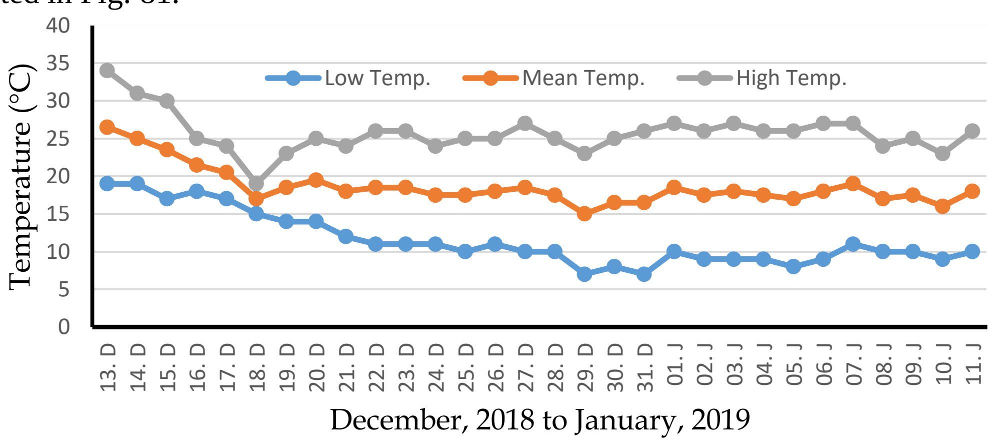


Fig. 80. Ambient temperature during study period (December 2018 to January 2019)

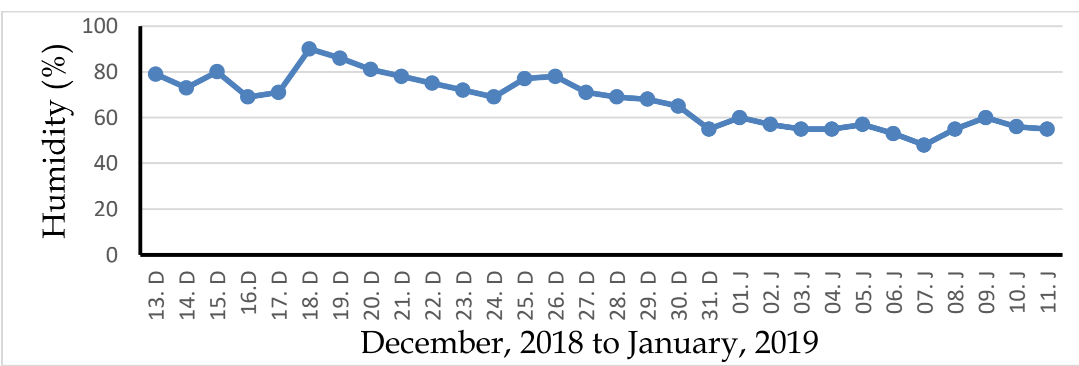


Fig. 81.Ambient air humidity during seedling growing period

11.4.2 Inside temperature of the polythene shed

For protecting the seedling from low temperature, seedling trays were covered by two different thickness (0.04 and 0.08 mm) of white polythene sheet. Inside temperature of the two different thickness of polythene shed is provided in figure 82 and 83. As for abiotic stress control, the seedling trays which are covered by polythene 0.08 mm thickness showed significantly better performance than uncovered trays. In different study, it was proved that the effect of genotype, temperature and their interactions on germination characteristics is significant and significant reductions in the germination of rice at temperature less than 16 0C and upper than 30 0C. Fungal infection and seedling density were high in covered trays than uncovered trays.

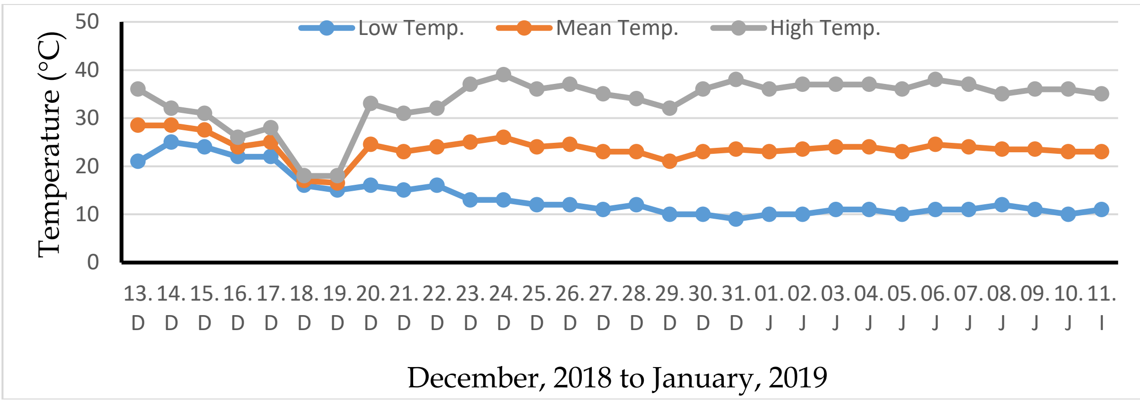


Fig. 82. Inside temperature of 4 grade (0.04 mm thickness) polythene

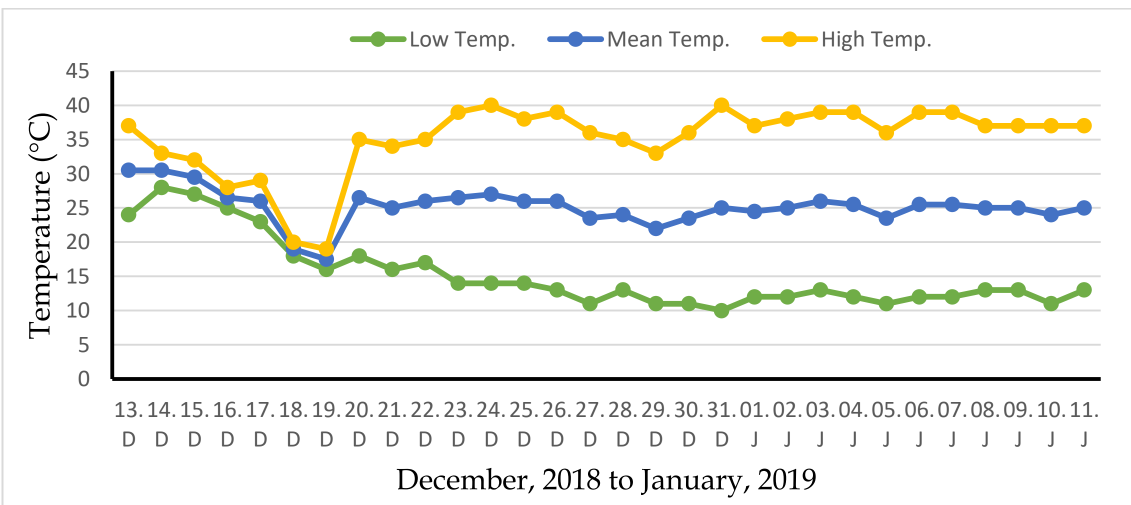


Fig. 83. Inside temperature of 8 grade (0.08 mm thickness) polythene

11.4.3 Field demonstration on seedling quality

Observation values of the observers on seedling quality varied significantly with the interaction effect of abiotic stress factor (mode and method of covering) and biotic stress factor (seeds and seedling treatment) as were varied significantly with the single effect of abiotic as well as biotic stress factor (Table 41 and fig. 84 & 85). Significantly higher values were observed for the interaction of F_3 to F_6 with P_1 (8.9 to 9.4), F_1 to F_6 with P_2 (9.2 to 9.6), F_3 to F_5 with P_3 (9.0 to 9.1) and F_1 to F_6 with P_4 (9.3 to 9.6) whereas significantly lower values were observed for the interaction of F_1 to F_2 with P_1 (8.6 to 8.8), F_1, F_2 and F_6 with P_3 (7.8 to 8.7), F_1 to F_6 with P_5 (3.7

to 7.9). However, only day time coverage by both thickness of polythene produced poor quality of seedling when seeds were treated by two different fungicides of F_1 and F_2.

Table 41. Seedling quality based on observation values of the observers during demonstration

Biotic stress control factors (Seeds and seedling treatment)	Abiotic stress control factors (Mode and method of covering)					Mean
	P_1	P_2	P_3	P_4	P_5	
F_1	8.8	9.2	8.3	9.5	3.7	7.9
F_2	8.6	9.4	7.8	9.4	6.4	8.3
F_3	9.4	9.2	9.0	9.6	6.8	8.8
F_4	9.3	9.4	9.1	9.6	7.5	9.0
F_5	9.1	9.6	9.1	9.6	7.5	9.0
F_6	8.9	9.3	8.7	9.3	7.9	8.8
Mean	9.0	9.3	8.7	9.5	6.6	-
% of cv	5.78					
LoS	A = *, B = * and A × B = *					
$LSD_{0.05}$	A = 0.33, B = 0.36 and A × B = 0.81					

Note: NS-Not significant, **-significant at 5 %, *-significant at 1 %, LoS-Level of significance, A-Abiotic stress factor, B-Biotic stress factor,P_1= 0.04mm polythene 24 hr cover (day and night time), P_2= 0.04mm polythene 12 hr cover(night time only), P_3= 0.08mm polythene 24 hr cover (day and night time), P_4= 0.08mm polythene 12 hr cover(night time only), P_5= no cover(uncovered),F_1= seed treatment by fungicide 1 (Atavo 75), F_2= seed treatment by fungicide 2 (Autostin 50), F_3= spray by fungicide 1 (Atavo 75), F_4= spray by fungicide 2 (Autostin 50), F_5= spray of MoP, F_6= no action.

Seedling quality varied significantly with the covering of polythene sheet while uncovered trays produced poor quality of seedling (Table 41). Among the abiotic stress factor (mode and method of covering) P_4 (9.3) and P_2 (9.5) scored significantly higher values while significantly lower value was observed for P_5 (6.6) (Table 41 and Fig. 84). On the other hand, significantly higher and similar values were observed among the biotic treatments of F_3 to F_6 whereas significantly lower value was observed for F_1 (Table 41 and Fig. 85).

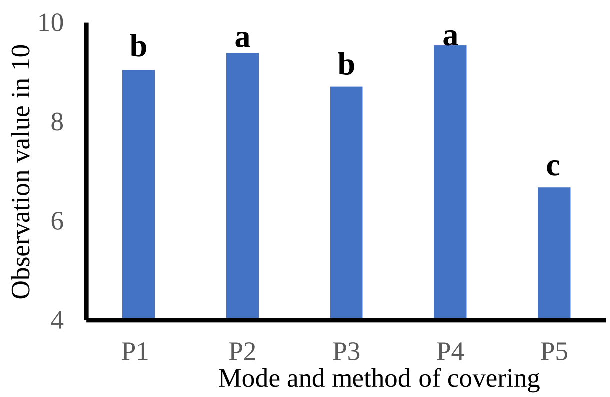


Fig. 84. Effect of abiotic stress control factors on observation values of seedling quality

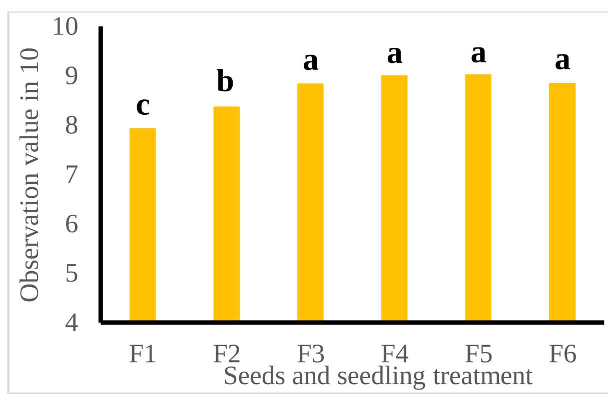


Fig. 85. Effect of biotic stress control factor on observation values of seedling quality

11.4.4 Seedling height

Interaction effect of abiotic (mode and method of covering) and biotic stress control factors (seeds and seedling treatment) showed significant effect on seedling height as were single effect of abiotic stress factor and biotic stress factor (Table 42 and fig. 86 & 87). Significantly higher values was observed for the interaction of F_5 with P_4 (142.87 to 196.63). On the other hand significantly lower values were observed interaction of F_1 to F_6 with P_1 (112.08 to 143.27), F_1 to F_6 with P_2 (128.92 to 162.36), F_1 to F_6 with P_3 (99.4 to 123.11), F_1 to F_6 with P_5 (92.79 to 103.87).After 30 days, seedling height showed remarkable value with 0.08 mm thickness polythene shed covered 24 hours (day and night) which was treated with MOP spray. Whereas other treatments did not show desired result at all.

Table 42. Effect of abiotic and biotic stress control factors on seedling height (mm)

Biotic stress control factors	Abiotic stress control factors (mode and method of covering)					Mean (mm)
	P_1	P_2	P_3	P_4	P_5	
F_1	134.91	140.55	123.11	142.87	90.24	126.34
F_2	115.96	162.36	112.42	147.05	94.77	126.51
F_3	112.08	152.66	117.16	158.81	85.61	125.27
F_4	126.79	148.18	114.33	155.96	95.55	128.16
F_5	143.27	162.01	122.66	196.63	103.87	145.69
F_6	129.64	128.92	99.4	151.68	92.79 op	120.49
Mean (mm)	127.11	149.12	114.85	158.84	93.81	
% of cv	9.22					
LoS	A = *, B = * and A × B = *					
$LSD_{0.05}$	A = 7.9161, B = 8.6716 and A × B = 19.39					

Among the abiotic stress control factors (mode and method of covering), P_4 scored significantly higher value where significantly lower value was observed for P_5 (Table 42 and Fig. 86). F_5 showed significantly higher values followed by all others treatment as biotic stress control factor (Table 42 and Fig. 87).

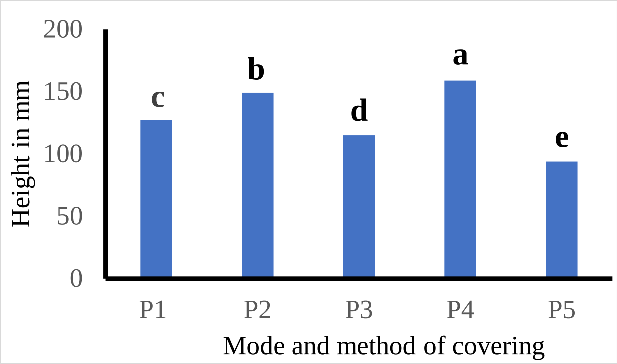


Fig. 86. Effect of abiotic stress control factors on seedlings height

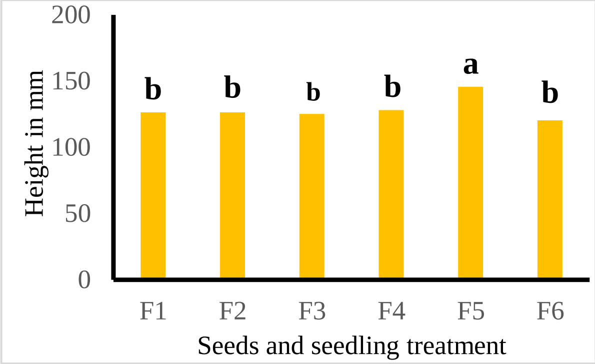


Fig. 87. Effect of biotic stress control factors on seedlings height

11.4.5 Stem thickness

Effect of abiotic stress control factor (mode and method of covering) and biotic stress factor (seed and seedling treatment) did not show significant effect on stem thickness along with the single effect of biotic stress control. Although the single effect of abiotic stress showed significant effect. (Table 43 and fig. 88 & 89). Significantly higher values were observed for F_6 with P_1 (1.1), F_1, F_3 and F_6 with P_5 (1 to 1.25). Whereas lower values were observed for F_1 to F_5 with P_1 (0.78 to 0.94), F_1 to F_6 with P_2 (0.82 to 0.97), F_1 to F_6 with P_3 (0.68 to 0.94), F_1 to F_6 with P_4 (0.75 to 0.90), F_2, F_4 to F_5 (0.95 to 1.0).After 30 days uncovered seedlings showed significant performance in stem thickness when seed treated with fungicide 1 (Atavo).

Table 43. Effect of abiotic and biotic stress control factors on stem thickness in mm at 30 days after seeds sowing

Biotic stress control factor	Abiotic stress control factor (mode and method of covering)					Mean (mm)
	P_1	P_2	P_3	P_4	P_5	
F_1	0.94	0.91	0.94	0.78	1.25	0.96
F_2	0.91	0.94	0.87	0.77	0.95	0.89
F_3	0.88	0.82	0.68	0.90	1.10	0.87
F_4	0.78	0.97	0.94	0.75	0.98	0.88
F_5	0.91	0.87	0.86	0.86	1.00	0.90
F_6	1.1	0.84	0.68	0.84	1.00	0.91
Mean (mm)	0.93	0.89	0.83	0.82	1.05	
% of cv	16.27					
$LSD_{0.05}$	A = 0.098					

Note: NS-Not significant, **-significant at 5 %, *-significant at 1 %, LoS-Level of significance, A-Abiotic stress factor, B-Biotic stress factor,P_1= 0.04mm polythene 24 hr cover (day and night time), P_2= 0.04mm polythene 12 hr cover(night time only), P_3= 0.08mm polythene 24 hr cover (day and night time), P_4= 0.08mm polythene 12 hr cover(night time only), P_5= no cover(uncovered),F_1= seed treatment by fungicide 1 (Atavo 75), F_2= seed treatment by fungicide 2 (Autostin 50), F_3= spray by fungicide 1 (Atavo 75), F_4= spray by fungicide 2 (Autostin 50), F_5= spray of MoP, F_6= no action.

Among the abiotic stress control factors (mode and method of covering), P_5 (1.05) scored significantly higher value and P_4 (0.82) scored significantly lower value (Table 43 and Fig. 88).In case of biotic stress control factor (seed and seedling treated) F_1 to F_6 scored significantly higher value (Table 43 and Fig. 89). K. Zaman et al. (2014) found that he highest and the lowest temperatures were observed at 0.04 mm thick black polythene shed during day-night and 0.08 mm thick black polythene shed during day-night respectively. They also observed that the highest stem thickness was found where seedling trays were put in 0.04 mm thick white polythene shed during night.

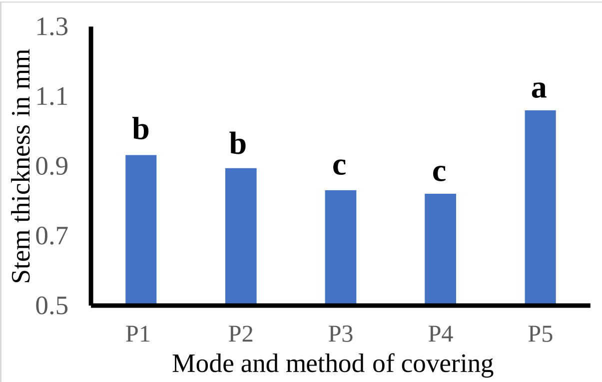


Fig. 88. Effect of abiotic stress control factors on stem thickness in mm at 30 days after seeds sowing

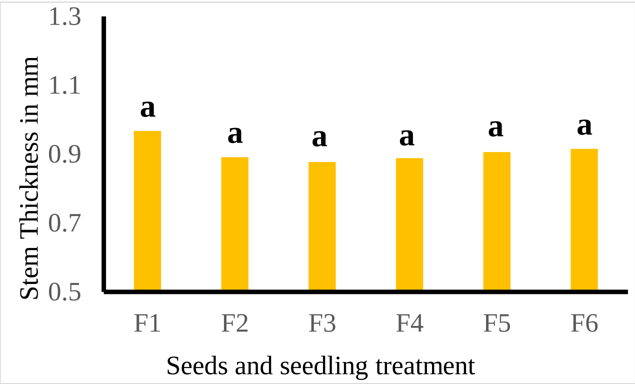


Fig. 89. Effect of biotic stress control factors on stem thickness at 30 days after seeds sowing

11.4.6 Seedling density

Two way interaction effect of abiotic and biotic stress control factor did not show significant effect on seedling density (seedling/cm^2) accompanied by the single effect of biotic stress factor. However the single effect of abiotic stress showed significant effect on seedling density. (Table 44 and fig. 90 & 91). Mathematically higher values was observed for F_1 to F_4 with P_1 (14 to 15), F_3 to F_4 with P_3 (14.3 to 15.3), F_1 to F_5 with P_4 (14.3 to 18). On the other hand mathematically lower value was scored for F_5 to F_6 with P_1 (a2.6 to 13), F_1 to F_6 with P_2 (10 to 13), F_1 to F_2, F_5 to F_6 with P_3 (12 to 13.6 and 11 to 13.3), F_6 with P_5(12.6), F_1 to F_6 with (9 to 13.6).Seedling density showed better performance when seedling were covered 24 hour by 0.08 mm thickness polythene shed and sprayed by MoP. In case of seedling in uncovered trays showed poor growth.

Table 44. Interaction effect of abiotic and biotic stress control factors on seedling density (Number/cm^2)

Biotic stress control factors	Abiotic stress control factors (mode and method of covering)					Mean (No./cm^2)
	P_1	P_2	P_3	P_4	P_5	
F_1	15.0	10.0	12.0	16.3	9.6	12.6
F_2	14.0	11.0	13.6	16.0	13.6	13.6
F_3	15.3	13.0	14.3	14.3	13.3	14.0
F_4	14.6	12.3	15.3	15.6	9.0	13.4
F_5	13.0	11.6	13.3	18.0	9.3	13.0
F_6	12.6	11.0	11.0	12.6	12.6	12.0
Mean(No./cm^2)	14.1	11.5	13.2	15.5	11.2	
% of cv	18.98					
LoS	A = * , B = NS and A × B = NS					
LSD $_{0.05}$	A = 1.66					

Among the abiotic stress control factors (mode and method of covering), P_4 (15.5) scored significantly higher value followed by P_1 (14.11). Meanwhile, P_5 (11.2) andP_2 (11.2) scored significantly lower value (Table 44 and Fig. 90). F_3 (14.06) as biotic stress control factors (seeds and seedling treatment) scored significantly higher value followed by F_1 to F_2 (12.6 to 13.66) and F_4 to F_5 (13.0 to 13.4). Significantly lower value was observed for F_6 (12) (Table 44 and Fig. 91).

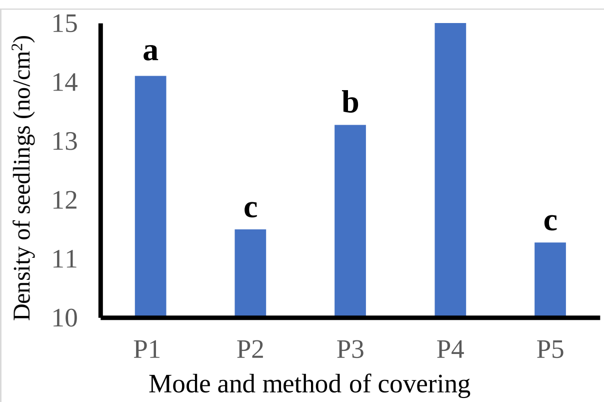


Fig. 90. Effect of abiotic stress control factors on seedling density at 30 days after seeds sowing

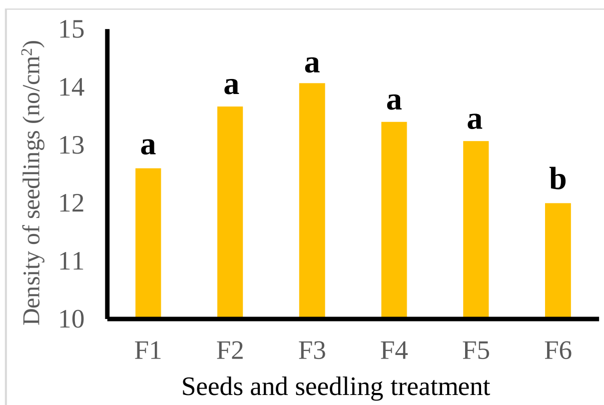


Fig. 91. Effect of biotic stress control factors on seedling density at 30 days after seeds sowing

11.4.7 Fungal infection

Interaction effect of abiotic stress factor (mode and method of covering) and biotic stress factor (seed and seedling covering) did not show significant effect on seedling density. On the contrary the single effect of abiotic stress and biotic stress factor showed significant effect on fungal infection (Table 45 and fig. 92 & 93). Significantly higher value was observed for F_6 with P_5 (28.3). Significantly lower value was scored for F_1 to F_6 with P_1 (1.6 to 8.3), F_1 to F_6 with P_2 (0 to 6.6), F_1 to F_6 for P_3 (3.3 to 16.6), F_1 to F_6 with P_4 (0 to 5), F_1 to F_5 with P_5 (10 to 18.3). Fungal infection was severe in uncovered tray where no treatment was provided. On the other hand seedling covered both thickness (0.04 mm and 0.08 mm) of polythene and pretreated seed with both fungicide (Atavo and Autostin) showed noticeable result against fungal attack.

Table 45. Effect of abiotic and biotic stress control factors on fungal infection on seedling

Biotic stress control factors	Abiotic stress control factors (mode and method of covering)					Mean
	P_1	P_2	P_3	P_4	P_5	
F_1	1.6	1.6	5	0	10	3.6
F_2	1.6	0	3.3	1.6	10	3.3
F_3	5	3.3	5	3.3	18.3	7
F_4	5	1.6	8.3	3.3	16.6	7
F_5	5	5	10	5	16.6	8.3
F_6	8.3	6.6	16.6	5	28.3	13
Mean	4.4	3.0	8.0	3.0	16.6	
% of cv	48.63					
$LSD_{0.05}$	A = 2.28 and B = 2.50					

Among the abiotic stress control factors (mode and method of covering), P_5 (16.6) scored significantly higher percentage of infection. Meanwhile P_4 (3.0) scored significantly lower percentage followed by P_1 (4.4) andP_2 (3.0) (Table 45 and Fig. 92). Significantly higher and lower percentage of plants were infected for biotic stress control factors F_6 and F_1 to F_6, respectively. On the other hand F_6 (13) biotic stress factor (seed and seedling treated) scored significantly higher value. Significantly lower value was observed for biotic stress F_1 to F_5 (3.33 to 8.33) (Table 45 and Fig. 93).

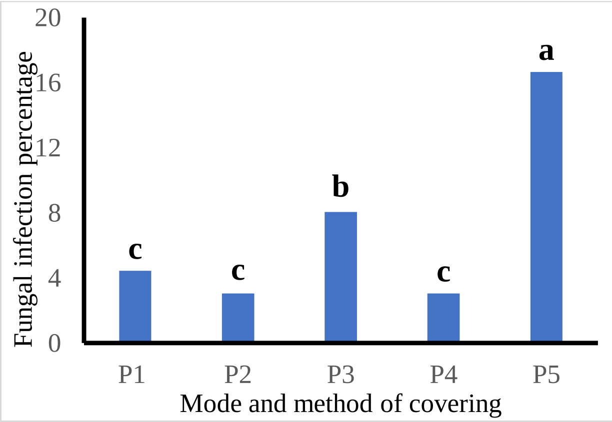


Fig. 92. Effect of abiotic stress control factors on fungal infection at 30 days after seeds sowing

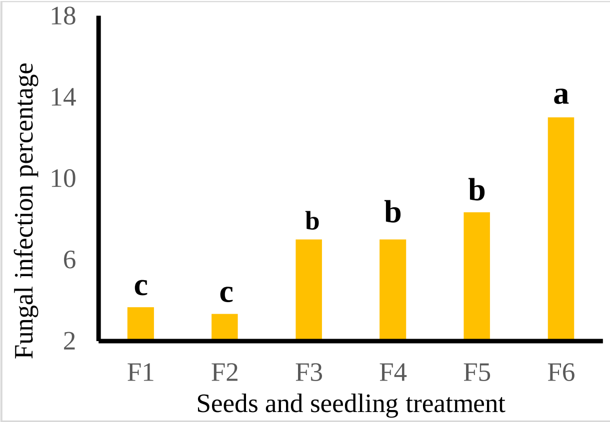


Fig. 93. Effect of biotic stress control factors on fungal infection at 30 days after seeds sowing

Note: NS-Not significant, **-significant at 5 %, *-significant at 1 %, LoS-Level of significance, A-Abiotic stress factor, B-Biotic stress factor,P_1= 0.04mm polythene 24 hr cover (day and night time), P_2= 0.04mm polythene 12 hr cover(night time only), P_3= 0.08mm polythene 24 hr cover (day and night time), P_4= 0.08mm polythene 12 hr cover(night time only), P_5= no cover(uncovered),F_1= seed treatment by fungicide 1 (Atavo 75), F_2= seed treatment by fungicide 2 (Autostin 50), F_3= spray by fungicide 1 (Atavo 75), F_4= spray by fungicide 2 (Autostin 50), F_5= spray of MoP, F_6= no action.

Componet-2

11.5 Determination of fertilizer use efficiency along with identifying CH_4, CO_2, and N_2O emission under varying methods of fertilizer application in rice soils of Bangladesh

11.5.1 Field evaluation for GHG and yield under different management at Kushtia

In Boro and T. Aman season, rice transplanter with mixed fertilizer showed lower CH_4 and N_2O emission than other treatments during Boro and T. Aman rice cultivation during 2018-2019. However, CO_2 emission was not big different among the treatments (Figure 94, 95, 96).

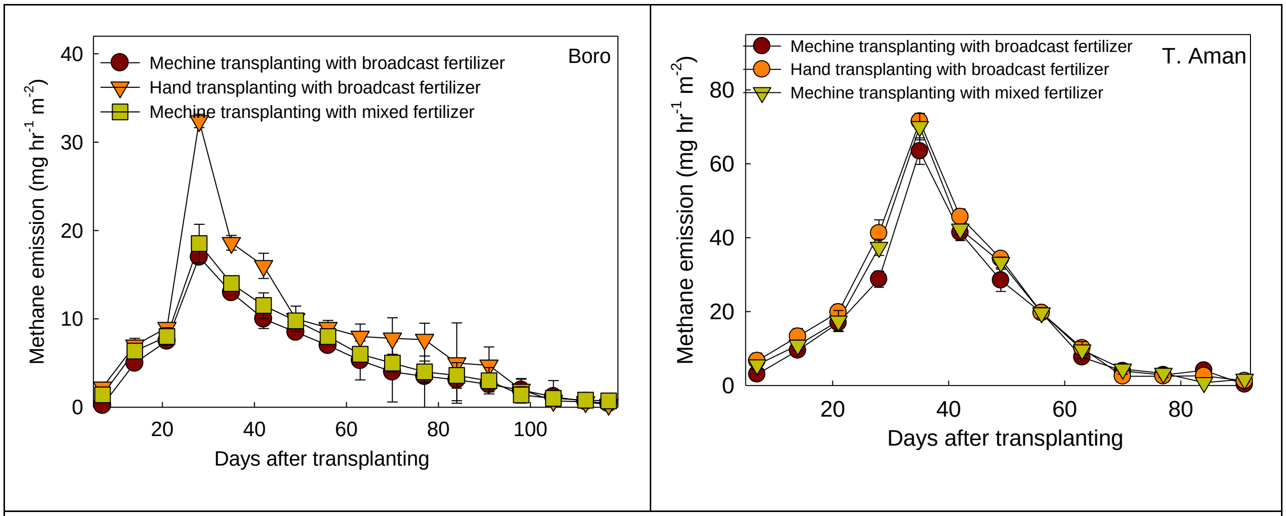


Fig. 94. Changes of CH_4 emission with Boro and T. Aman rice cultivation under Hand and machine transplanter at Kushtia region during 2018-2019.

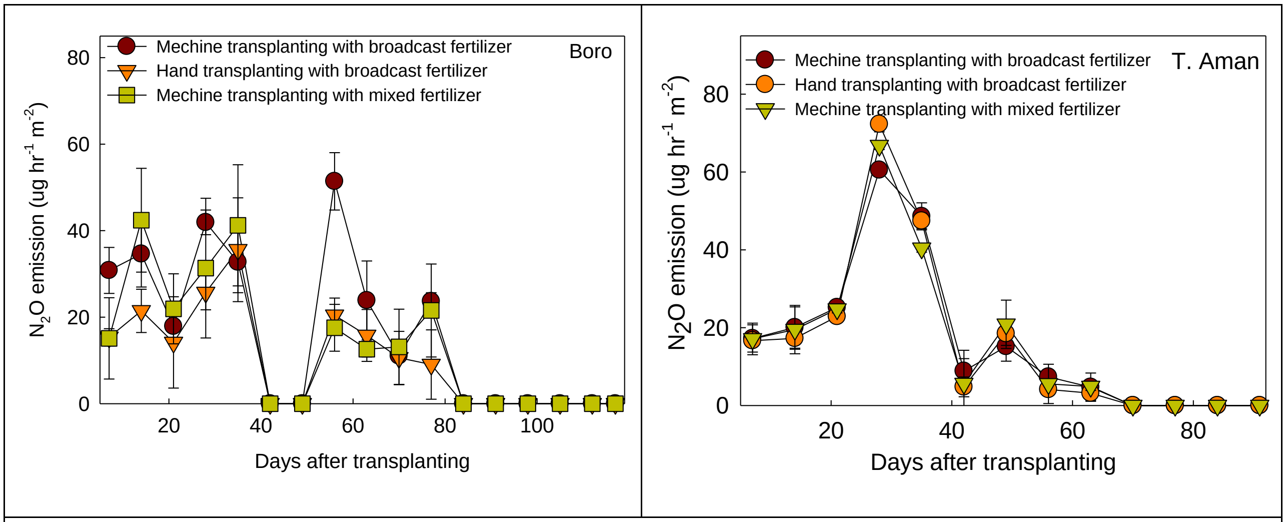


Fig. 95. Changes of N_2O emission with Boro and T. Aman rice cultivation under Hand and machine transplanter at Kushtia region

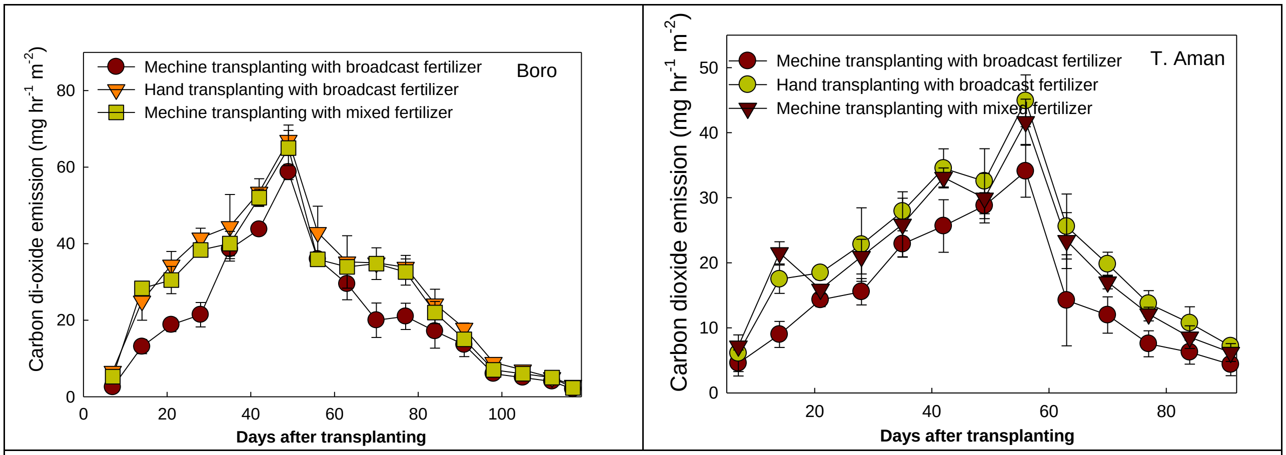


Fig. 96. Changes of CO_2 emission under Hand and machine transplanter at Kushtia

11.5.2 Field evaluation for GHG and yield under different management at Gazipur

Machine transplanter with mixed fertilizer showed lower CH_4, N_2O and CO_2 emission than that of other treatments (fig. 97, 98 and 99) during T. Aman rice cultivation during 2019 in BRRI, Gazipur

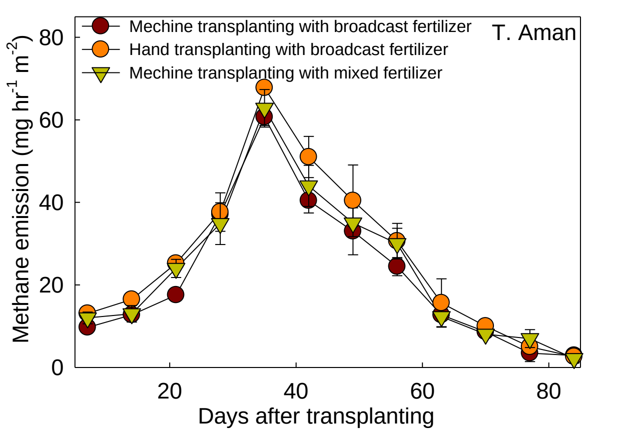


Fig. 97. Changes of CH_4 emission under hand and machine transplanter

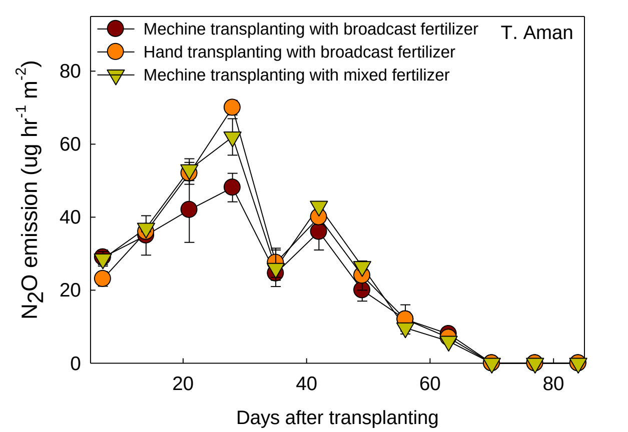


Fig. 98. Changes of N_2O emission under hand and machine transplanter

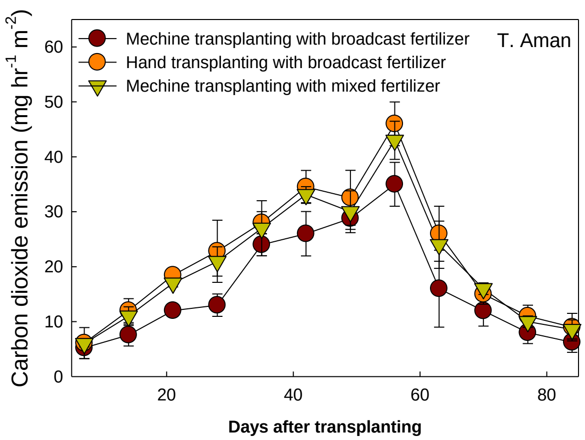


Fig. 99. Changes of CO_2 emission under hand and machine transplanter

11.5.3 Greenhouse gas (GHG) emission under different management at Kushtia and Gazipur during Boro season, 2020

In Boro season, rice transplanter with mixed fertilizer showed lower CH_4, N_2O and CO_2 emission than other treatments during Boro rice cultivation during 2020 at Kushtia and Gazipur field site (fig. 100,101 and 102).

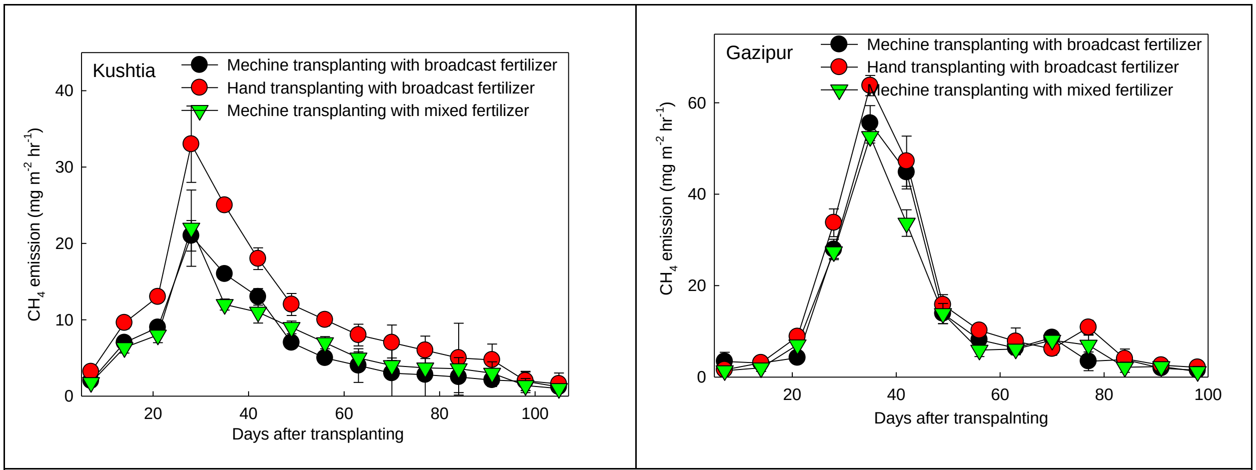


Fig. 100. Changes of CH_4 emission under hand and rice transplanter at Kushtia and Gazipur

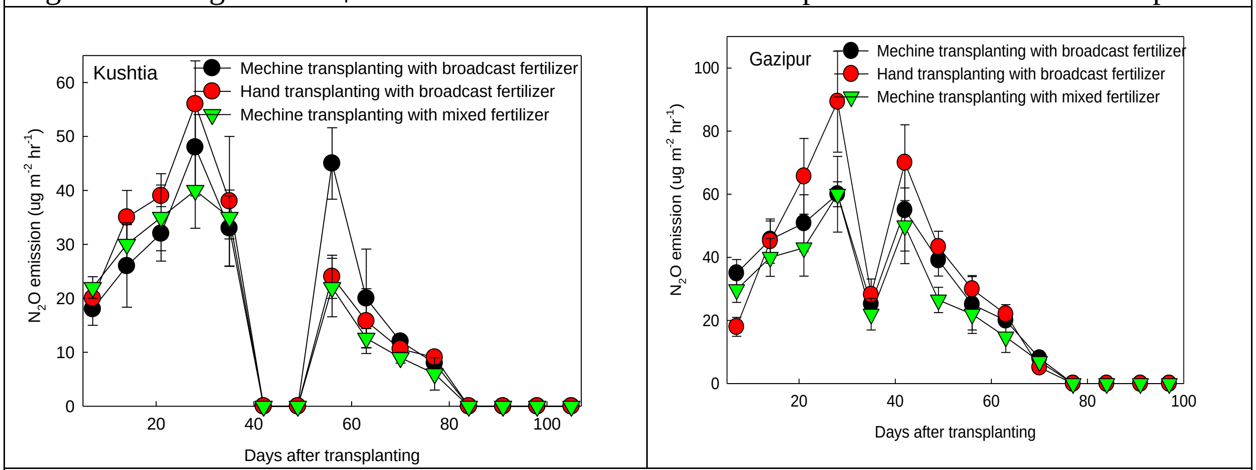


Fig. 101. Changes of N_2O emission under hand and machine transplanter at Kushtia and Gazipur

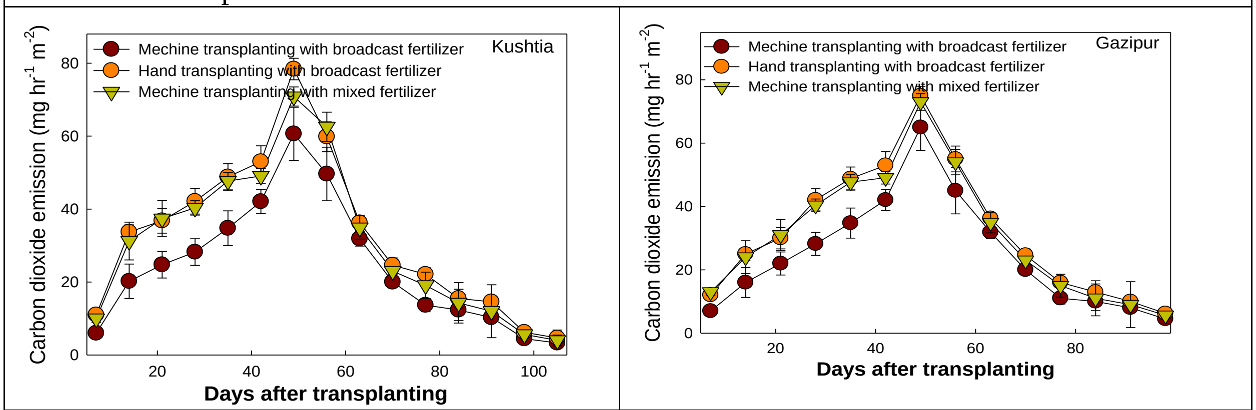


Fig. 102. Changes of CO_2 emission under hand and rice transplanter at Kushtia and Gazipur

11.5.4 Greenhouse gas (GHG) emission under different management options at Kushtia and Gazipur during T. Aman season, 2020

In T. Aman season, rice transplanter with mixed fertilizer showed lower CH_4, N_2O and CO_2 emission than other treatments during T. Aman 2020 at Kushtia and Gazipur field site (fig. 103, 104 and 105).

11.5.5 Total CH_4, N_2O and CO_2 flux during 2018-19 to 2019-2020 at Kushtia and Gazipur

During Boro and T. Aman season, rice transplanter with mixed fertilizer showed significantly lower CH_4 flux than others treatment (Table 46 and 47). Rice transplanter with mixed fertilizer reduce about 22-38% and 7-12% total CH_4 than hand transplanting during Boro and T. Aman season. However, the total N_2O flux was also varied among the treatments during study periods. In contrast, CO_2 flux also varied among the treatments.

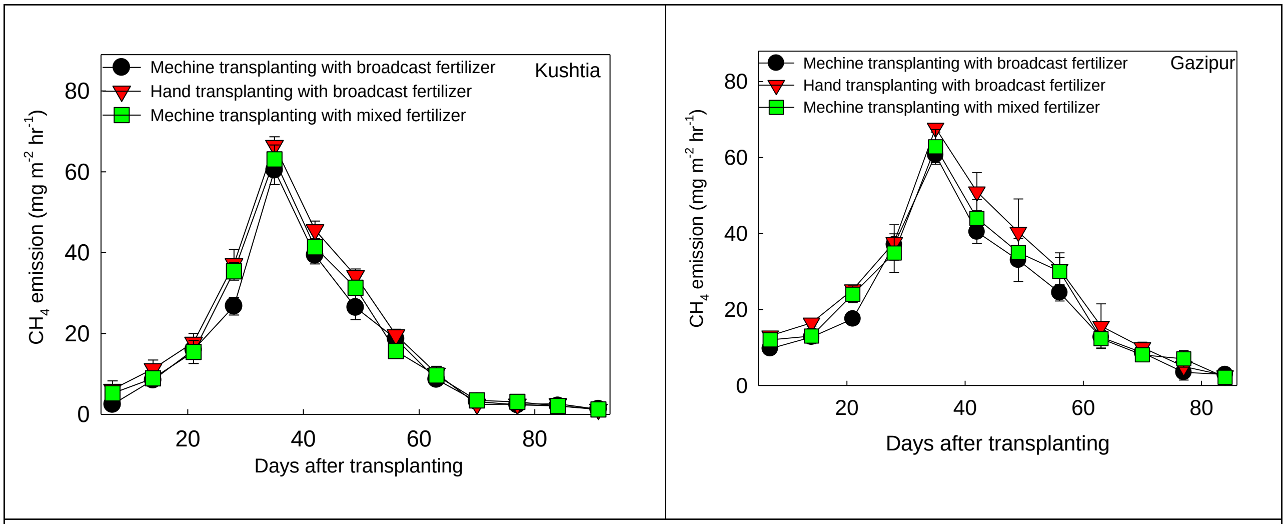


Fig. 103. Changes of CH_4 emission under Hand and rice transplanter at Kushtia and Gazipur

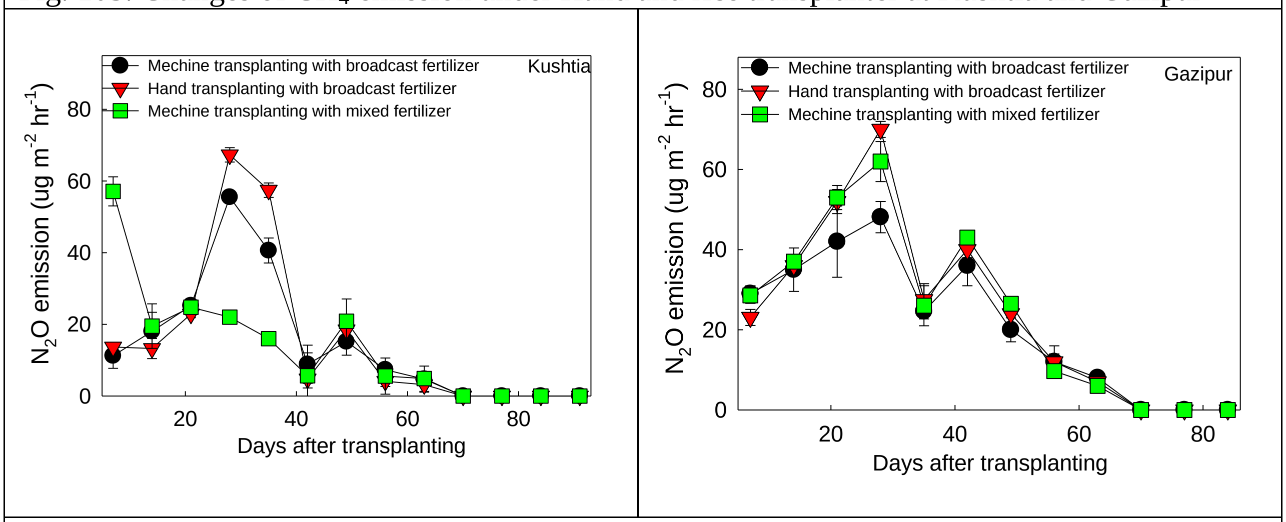


Fig. 104. Changes of N_2O emission under Hand and rice transplanter at Kushtia and Gazipur

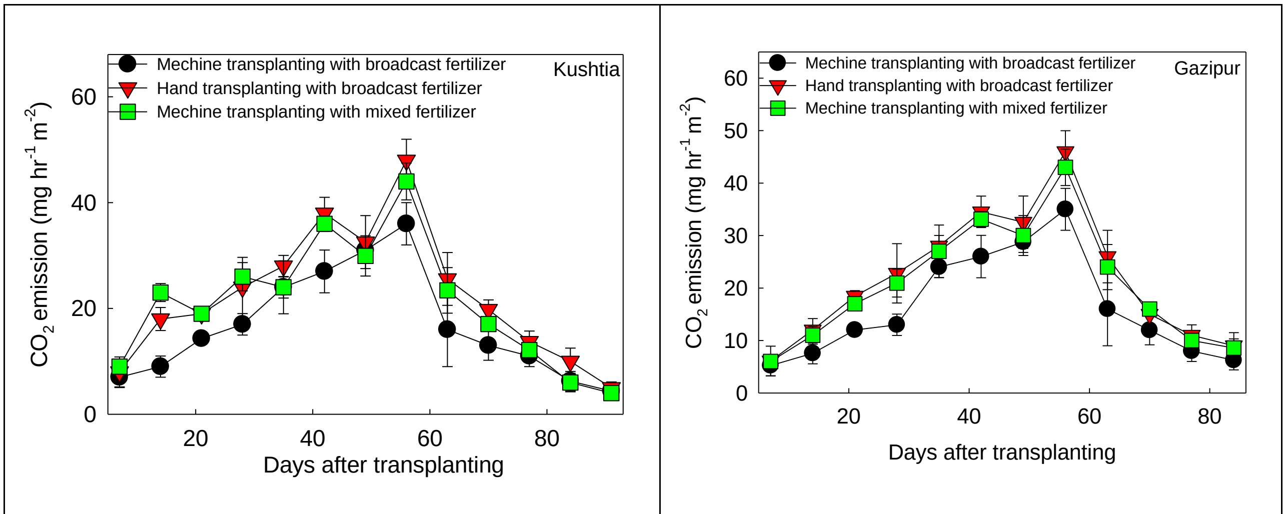


Fig. 105. Changes of CO_2 emission under hand and rice transplanter at Kushtia and Gazipur

Table 46. Total CH_4, N_2O and CO_2 during Boro season at different locations during 2018-19 and 2019-2020

Location	GHG (kg ha^{-1})	2018-2019			2019-2020		
		Treatments					
		T_1	T_2	T_3	T_1	T_2	T_3
Kushtia	CH_4	153c	237a	173b	164b	266a	166b
	N_2O	0.450a	0.282c	0.364b	0.406a	0.415a	0.355b
	NECB (CO_2)	1811c	3038a	2758b	1554b	2736a	1549b
Gazipur	CH_4	-	-	-	313b	366a	287c
	N_2O	-	-	-	0,611b	0.699a	0.529c
	NECB (CO_2)	-	-	-	1220c	1676b	1737a

Note: T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Hand transplanting and T_3 = Mechanical transplanting along with mixed fertilizer deep placement.

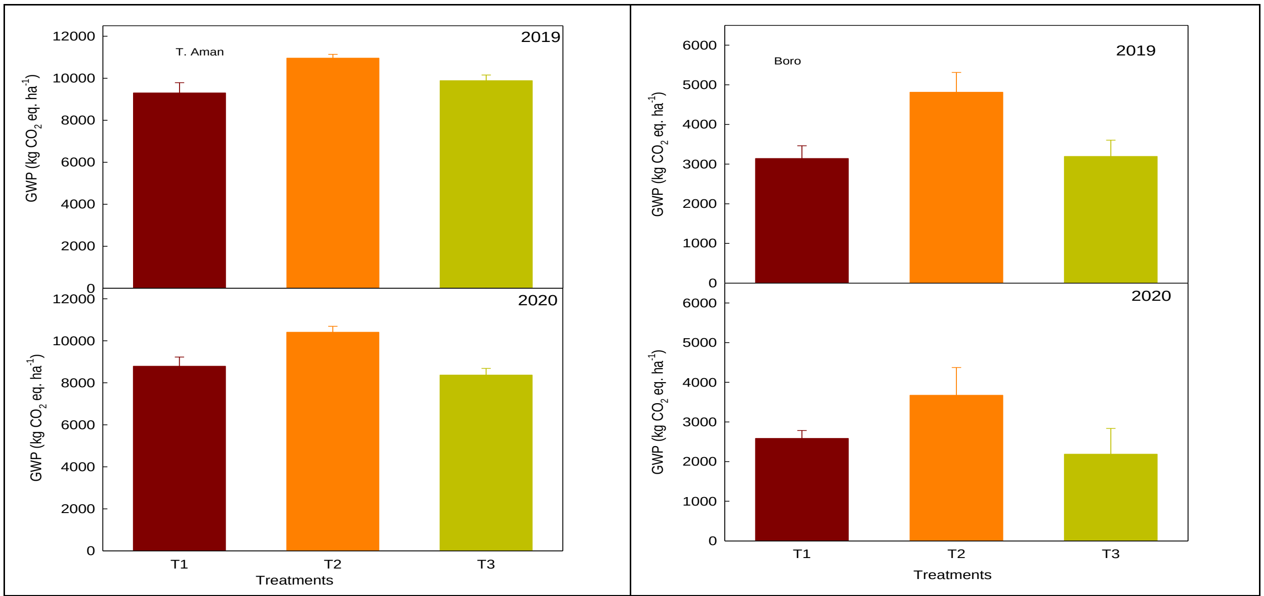


Fig. 106. Global warming potential during T. Aman and Boro season at Kushtia location

Global warming potential also varied with the treatments during T. Aman and Boro season at both locations (Table 106 and 107)

Table 47. Total CH_4, N_2O and CO_2 during T. Aman season at different location during 2018-19 and 2019-2020

Location	GHG (kg ha^{-1})	2018-2019			2019-2020		
		Treatments					
		T_1	T_2	T_3	T_1	T_2	T_3
Kushtia	CH_4	386c	465a	431b	363c	433a	396b
	N_2O	0.348a	0.348a	0.345a	0.313a	0.344a	0.296b
	NECB (CO_2)	1611c	1884b	2275a	1459b	1798b	2801a
Gazipur	CH_4	389b	447a	395b	442b	529a	479b
	N_2O	0.406a	0.409a	0.398a	0.427b	0.489a	0.490a
	NECB (CO_2)	1124b	1439b	2439a	1230c	1509b	2574a

Note: T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Hand transplanting and T_3 = Mechanical transplanting along with mixed fertilizer deep placement.

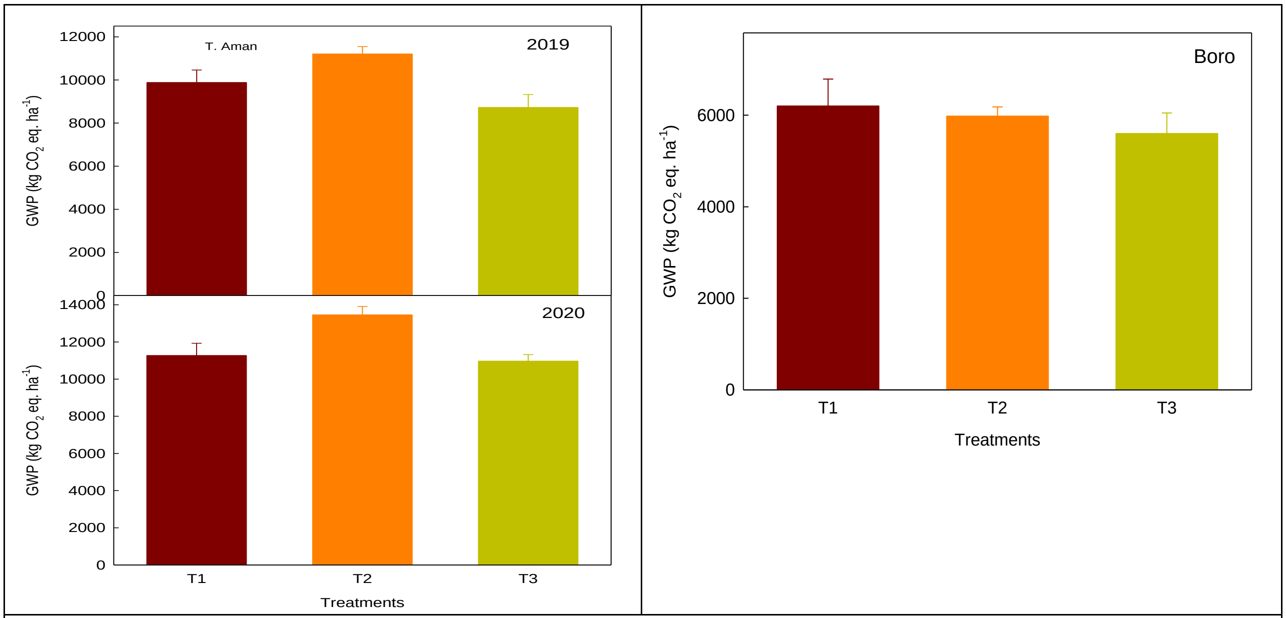


Fig. 107. Global warming potential during T. Aman and Boro season at Gazipur location

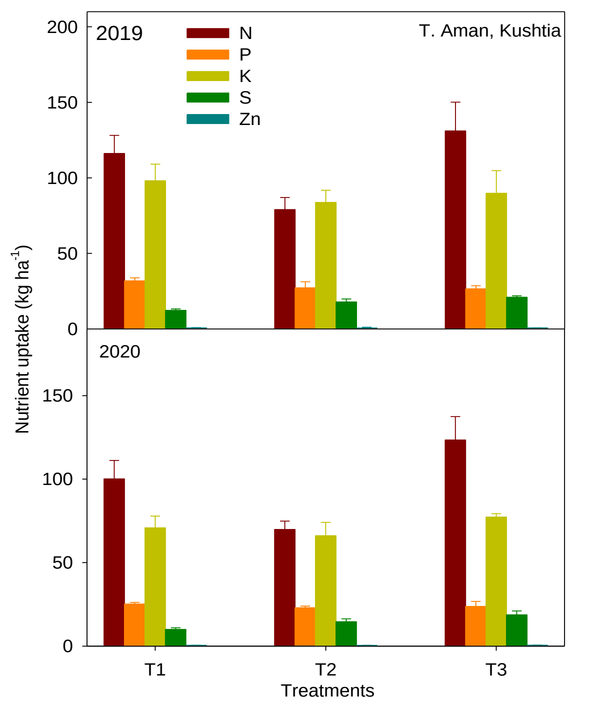
Note: T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Hand transplanting and T_3 = Mechanical transplanting along with mixed fertilizer deep placement.

11.5.6 Total nutrient uptake at different region during T. Aman and Boro season under study period

Among the fertilizer methods, transplanter with mixed fertilizer showed higher N, P, K, S and Zn nutrient uptake than transplanter with broadcast fertilizer method (fig. 108,109,110 and111).

11.5.7 Rice and straw yield performance during Boro season

Transplanting and fertilizer application methods influenced significantly on rice and straw yields in both locations during Boro season (Table 48). In both locations, rice transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method.



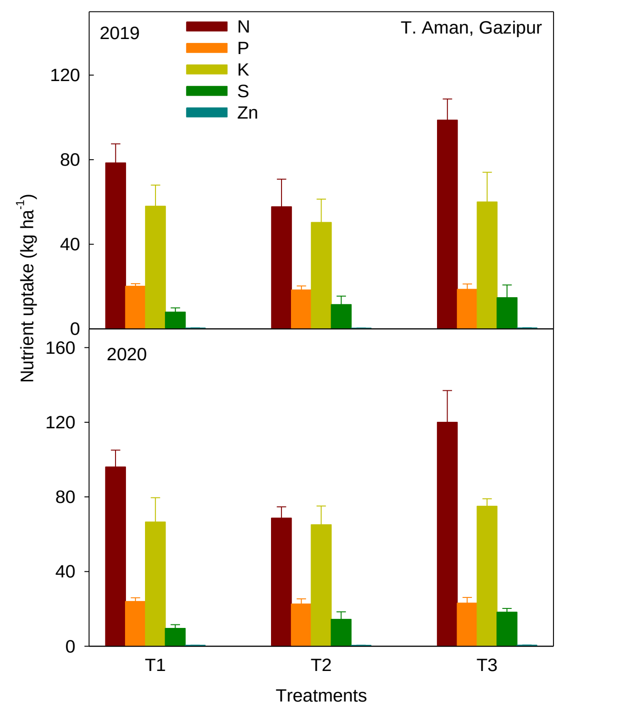
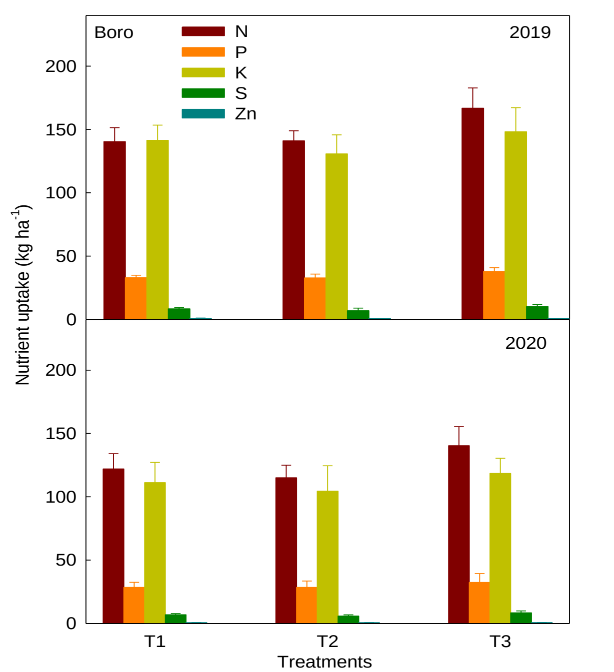


Fig. 108. Total nutrient uptake of N, P, K, S and Zn in T. Aman at Kushtia	Fig. 109. Total nutrient uptake of N, P, K, S and Zn in T. Aman at Gazipur



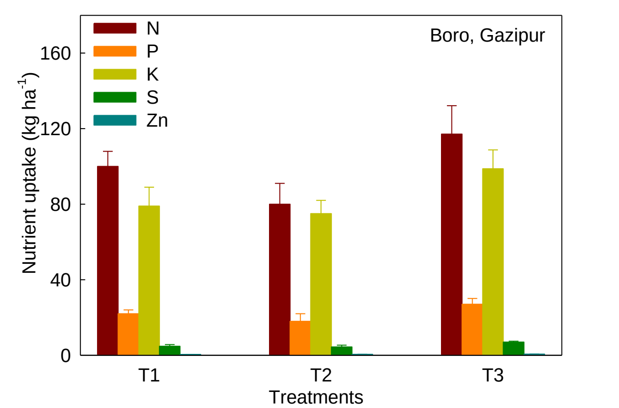


Fig. 110. Total nutrient uptake of N, P, K, S and Zn in Boro season at Kushtia	Fig. 111. Total nutrient uptake of N, P, K, S and Zn in Boro season at Gazipur

Note: T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Hand transplanting and T_3 = Mechanical transplanting along with mixed fertilizer deep placement.

Table 48. Yield and yield contributing parameters of the trail during Boro season at Kushtia

Treat	Plant height, cm	No. of tillers/ hill	No. of panicles/ hill	Straw Yield (t/ha)	riceyield (t/ha)
T_1	100.67	25.67	22.00	9.27	6.81
T_2	100.00	25.00	20.67	8.79	6.68
T_3	105.33	28.00	25.33	9.90	7.96
$LSD_{0.05}$	1.31	1.51	1.85	0.68	0.28
CV (%)	0.57	2.54	3.60	1.48	1.75

11.5.8 Rice and straw yield during T. Aman season, 2019

Transplanting and fertilizer application methods also influenced significantly on rice and straw yields at different locations during Aman season (Table 49). In two locations, mechanical transplanting along with fertilizer deep placement gave significantly higher rice and straw yield compared to other two treatments while lower rice and straw yield was found for manual transplanting along with fertilizer hand broadcasting method.

Table 49. Rice and straw yield performance as affected under different transplanting and mode of fertilizer application (T. Aman 2019)

Treat	Rice yield (t/ha)		Straw yield (t/ha)	
	Kushtia	Gazipur	Kushtia	Gazipur
T_1	4.91	3.66	7.61	4.35
T_2	4.44	3.81	6.81	3.85
T_3	5.77	4.83	7.79	4.99
CV (%)	4.23	1.46	5.55	6.92
$LSD_{0.05}$	0.39	0.17	0.56	0.69

11.5.9 Rice and straw yield during Boro 2019-2020

Transplanting and fertilizer application methods influenced significantly on rice and straw yields in all locations during Boro season (Table 50). In all cases, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method. Straw yield varied significantly with the transplanting and fertilizer application methods in all seven locations during Boro 2019-20 season (Table 50). In all locations, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments. Yield data of Gazipur and Kushtia are same for both components.

Table 50. Rice yield performance as affected under different transplanting and mode of fertilizer application (Boro 2019-20)

Treat	Rice yield (t/ha)		Straw yield (t/ha)	
	Gazipur	Kushtia	Gazipur	Kushtia
T_1	4.35	6.24	4.8	7.1
T_2	4.65	6.10	5.1	6.9
T_3	5.89	7.05	6.5	7.8
CV (%)	2.75	0.8	3.75	6.71
$LSD_{0.05}$	0.26	0.12	0.86	0.90

11.5.10 Rice and straw yield during T. Aman season, 2020

Rice yield - Transplanting and fertilizer application methods influenced significantly on rice and straw yields in all locations during Boro season (Table 51). In all cases, mechanical transplanting along with fertilizer deep placement gave significantly higher yield compared to other two treatments while lower rice yield was found for manual transplanting along with fertilizer hand broadcasting method.

Table 51. Rice yield performance as affected under different transplanting and mode of fertilizer application (T. Aman 2020)

Treat	Rice yield (t/ha)		Straw yield (t/ha)	
	Gazipur	Kushtia	Gazipur	Kushtia
T_1	4.66	4.80	4.90	5.25
T_2	4.26	4.34	5.12	5.20
T_3	5.74	5.90	6.30	6.50
CV (%)	3.35	2.45	4.42	5.56
$LSD_{0.05}$	0.23	0.21	0.43	0.53

11.5.11 Soil Properties at Kushtia and Gazipur

Soil chemical properties are not affected under different fertilizer application methods during study periods (Table 52 and 53).

Table 52. Initial soil properties at Gazipur and Kushtia region

Locations	Total N (g kg^{-1})	Organic carbon (g kg^{-1})	Avai. P (mg kg^{-1})	Exchang. K (mg kg^{-1})	Avai. S (g kg^{-1})	Avai. Zn (g kg^{-1})	Bulk density (g cm^{-3})
Gazipur	0.11	12.3	20	65	22	4	1.39
Kushtia	0.11	12.6	21	70	18	3	1.38

Table 53. Post-harvest soil properties at Gazipur and Kushtia region

Locations	Treatments	Organic carbon (g kg^{-1})	Total N (g kg^{-1})	Avai. P (mg kg^{-1})	Exchang. K (mg kg^{-1})
Gazipur	T_1	12.3	0.11	21	64.7
	T_2	12.2	0.11	22	64.6
	T_3	12.3	0.12	22	64.8
Kushtia	T_1	12.6	0.11	22	69.6
	T_2	12.6	0.11	22	69.4
	T_3	12.58	0.13	22	69.8

Note: T_1 = Mechanical transplanting and top dressing of fertilizer, T_2 = Hand transplanting and T_3 = Mechanical transplanting along with mixed fertilizer deep placement.

12. Research Highlight (title of the sub-project, background, objectives, methodology, key findings, and key words):

Sub-project title: Design and development of fertilizer deep placement mechanism for existing rice transplanter

Background:

Manual transplanting is tedious and time consuming which often the causes of delayed planting. As a result, mechanized rice transplanting is seen as a solution of labour problems. In other hand, several literatures revealed that deep placement of fertilizer reduces the losses and gave higher yield. It was hypothesized that the incorporation of the fertilizer deep placement (FDP) technology with the existing mechanical rice transplanter (both the walking and riding type) might help to harvest the benefit of both mechanical transplanting and deep placement of fertilizer application. As well, methane (CH_4), Carbon dioxide (CO_2) and Nitrous oxide (N_2O) emissions from rice fields are intensified during rice cultivation. Hence, its emission was analyzed based on different mode and method of transplanting and fertilizer application for knowing the CH_4, CO_2 and N_2O emission pattern.

General objective:

- To incorporate fertilizer deep placement (FDP) technology in the existing walking and riding type rice transplanter for simultaneous application of fertilizer mixture with rice seedlings transplanting.

Objectives:

Component-1: FMPHT Division, BRRI

- To design and development of power transmission mechanism from engine to the applicator for both walking and riding type rice transplanter
- To design and attach adjustable type fertilizer dispensing mechanism in the rice transplanter
- To design skid, furrow opener and covering mechanism for fertilizer deep placement
- To test, evaluate and validate the technology in laboratory, research field and farmers' field
- To save energy, cost and time of separately seedling transplanting and deep placement of fertilizer application.

Component-2: Soil Science Division, BRRI

- To determine fertilizer use efficiency and recovery of different application methods
- To compare the yield and yield contributing characters under varying methods of fertilizer application
- To identify the CH_4, CO_2 and N_2O emission under varying methods of fertilizer application in rice soils of Bangladesh
- To mitigate the global warming potential in rice soils under varying methods of fertilizer application
- To find out changes of soil chemical properties

Methodology:

Mixed fertilizer deep placement mechanism was incorporated in the walking (ARP-4UM) and riding type (S3-680) rice transplanter. In both type rice transplanters, spiral type mechanism was incorporated as metering device to receive and dispense desired amount of mixed fertilizer. In case of walking type rice transplanter, engine power available at high rpm (more than 1800 rpm of the walking type rice transplanter) was conveyed to the applicator with the arrangement of a belt-pulley, worm gearing, shaft-bearing, chain-sprocket and bevel gear with engage-disengage facility resulting 23 rpm of the applicator main shaft.

In Aman 2019 and Aman 2020 seasons, the developed walking type rice transplanter was evaluated in 14 (07 in each season) locations of the country while it was evaluated in 03 locations during Boro 2018-19 season and in 07 locations during Boro 2019-20 seasons. RCB design was followed with three replications. Treatments of the studies were mechanical transplanting along with mixed fertilizer deep placement simultaneously (T_1), mechanical transplanting and hand broadcasting of fertilizer (T_2) and traditional transplanting and hand broadcasting of fertilizer (T_3). In Boro 2018-19 season, average deviation of fertilizer dispensing rate from calibration was about +3.72% due to clog of the dispensing channel of the transplanter during operation while it was about -4.86% in Aman 2019 season. In Boro 2019-2020 season, it was about +1.18% after improving the power transmission system.

Key findings:
BRRI dhan58 was cultivated in Boro 2018-19 season in Kushtia and Habiganj. Higher yield was observed for mechanical transplanting along with fertilizer deep placement in both locations (7.9 and 6.2 t/ha, respectively) followed by mechanical transplanting (6.8 and 5.5 t/ha, respectively). In Aman 2019 season, it was observed that rice yield varied with the mode and rate of fertilizer application. Mechanical transplanting along with mixed fertilizer deep placement (80% of the recommended dose of urea) gave significantly higher yield compared to the mechanical and manual transplanting along with hand broadcasting of fertilizerswhile rice variety was BRRI dhan71 in Rangpur, Gazipur, Netrakona and Habiganj, BRRI dhan75 in 01 locations of Kushtia and BRRI dhan87 in another 02 locations in Kushtia. In Boro 2019-20, rice variety was BRRI dhan89 in 04 locations (Gazipur, Kushtia-1 and Kushtia-2 and Netrakona), BRRI dhan58 in 02 locations (Rangpur and Habiganj) and BRRI dhan28 in Kushtia-3. Similar result was observed in Aman 2020 while rice variety was BRRI dhan80 in Rangpur, Gazipur, Habiganj and BRRI dhan87 in Kushtia (3 trials) and Netrakona. Average across the variety, locations and years, rice yield was 6.8, 5.9 and 5.6 t/ha for mechanical transplanting along with fertilizer deep placement, only mechanical transplanting and traditional transplanting in Boro seasons while it was 5.3, 4.7 and 4.4 t/ha in Aman season. Mechanical transplanting along with mixed fertilizer deep placement also gave higher BCR (T_1:1.67) compared to the other two treatments (T_2:1.57 and T_3: 1.21).

On the other hand, mechanical transplanting along with mixed fertilizer minimized CH_4 emission compared to hand transplanting system, but enhanced its emission than mechanical transplanting with broad cast fertilizer. It was found that mechanical transplanting along with mixed fertilizer treatment can significantly reduce total CH_4 flux by 22-38% and 7-12% compared to hand transplanting under Boro and T. Aman at different regions of Bangladesh. It also reduce about 6-41% and 4-20% global warming potential than hand transplanting. During T. Aman season total nutrient uptake increased by 40-44%, 2-4%, 7-17% of N, P, K with mechanical transplanting along with mixed fertilizer than others treatments. In Boro season, mechanical transplanting along with mixed fertilizer increased by 16-32%, 13-33%, 11-24% of N, P, K total nutrient uptake compared to hand transplanting. Rice yield also significantly higher with mechanical transplanting along with mixed fertilizer than other treatments under both seasons. In conclusion, mechanical transplanting along with mixed fertilizer could be useful technique for higher rice yield, nutrient uptake, reduction in CH_4 emission and global warming potential during Boro- T. Aman rice cultivation.

Keywords: Machine design, Mechanical transplanting, Fertilizer deep placement, nutrient use efficiency, Nutrient uptake and Greenhouse gas emission.

B. Implementation Status

1. Procurement (Component wise)
1.1. Component-1

Description of equipment and capital items	PP Target		Achievements		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment					
GD-01	**05**	**47000.00**	**05**	**46900.00**	
File cabinet	01	20000.00	01	19960.00	
Computer Chair	02	7000.00	02	6980.00	
Executive chair	02	20000.00	02	19960.00	
GD-02	**04**	**150000.00**	**04**	**149900.00**	
Desktop	01	60000.00	01	60000.00	
Laptop	01	60000.00	01	60000.00	
Laser printer	01	20000.00	01	19900.00	
Scanner	01	10000.00	01	10000.00	
(b) Lab & field equipment					
GD-03	**01**	**215000.00**	**01**	**215000.00**	
Motor cycle was procured	01	215000.00	01	215000.00	
GD-04	**04**	**1600000.00**	**04**	**1540004.00**	
Walking type rice transplanter	04	1600000.00	04	1540004.00	
(c) Other capital items					

1.2 Component-2

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment					
Furniture (Table-1 and Chair-1)	02	8500.00	02	8500.00	
Computer-1 and Scanner-1	02	70000.00	02	70000.00	

2. Establishment/renovation facilities: N/A

Description of facilities	Newly established Upgraded/refurbished		Upgraded/refurbished		Remarks
	PP Target	Achievements	PP Target	Achievements	

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

3.1 Component-1

Description	Number of participants			Duration (Days)	Remarks
	Male	Female	Total		
Training (03 hands on training and 20 participants in each training)	49	11	60	03	
Workshop-01	90	13	103	01	

3.2 Component-2

Description	Number of participant			Duration	Remarks
	Male	Female	Total		
(a) Training	60	20	80	4 days	
(b) Workshop	-	-	-	-	-

C. Financial and physical progress (Combined & Component wise)

C.1. Component-1

Items of expenditure/activities	Total approved budget (Tk.)	Fund received (Tk.)	Actual expenditure (Tk.)	Balance/ unspent (Tk.)	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	1649250.00	1537309.00	1537309.00	0.00	100%	
B. Field Research / Lab expenses and supplies	3170000.00	3327439.00	3327439.00	0.00	100%	
C. Operating Expenses	780000.00	780969.00	780969.00	0.00	100%	
D. Vehicle Hire and Fuel, Oil & Maintenance	700000.00	738318.00	738318.00	0.00	100%	
E. Training/Workshop/ Seminar etc.	423700.00	441080.00	441080.00	0.00	100%	
F. Publications and printing	185000.00	148000.00	148000.00	0.00	100%	
G. Miscellaneous	111787.00	103338.00	103338.00	0.00	100%	
H. Capital Expenses	2012000.00	1951804.00	1951804.00	0.00	100%	
Total	**9031737.00**	**9028257.00**	**9028257.00**	**0.00**	**100%**	

C.2. Component-2

Items of expenditure/activities	Total approved budget (Tk.)	Fund received (Tk.)	Actual expenditure (Tk.)	Balance/ unspent (Tk.)	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	321863.00	321863.00	321863.00	0.00	100%	This deviation will be balanced after providing last payment
B. Field Research / Lab expenses and supplies	1050000.00	1049475.00	1049475.00	0.00	100%	
C. Operating Expenses	212500.00	212200.00	212200.00	0.00	100%	
D. Vehicle Hire and Fuel, Oil & Maintenance	140000.00	140000.00	140000.00	0.00	100%	
E. Training/Workshop/ Seminar etc.	80400.00	80400.00	80400.00	0.00	100%	
F. Publications and printing	20000.00	15000.00	15000.00	0.00	100%	
G. Miscellaneous	65000.00	64490.00	64490.00	0.00	100%	
H. Capital Expenses	78500.00	78500.00	78500.00	0.00	100%	
Total	**1968263.00**	**1961928.00**	**1961928.00**	**0.00**	**100%**	

C.3. Component-1 and 2 (Combined)

Items of expenditure/activities	Total approved budget (Tk.)	Fund received (Tk.)	Actual expenditure (Tk.)	Balance/ unspent (Tk.)	Physical progress (%)	Reasons for deviation
A. Contractual Staff Salary	1971113.00	1859172.00	1859172.00	0.00	100%	This deviation will be balanced after providing last payment
B. Field Research / Lab expenses and supplies	4220000.00	4376914.00	4376914.00	0.00	100%	
C. Operating Expenses	992500.00	993169.00	993169.00	0.00	100%	
D. Vehicle Hire and Fuel, Oil & Maintenance	840000.00	878318.00	878318.00	0.00	100%	
E. Training/Workshop/ Seminar etc.	504100.00	521480.00	521480.00	0.00	100%	
F. Publications and printing	205000.00	163000.00	163000.00	0.00	100%	
G. Miscellaneous	176787.00	167828.00	167828.00	0.00	100%	
H. Capital Expenses	2090500.00	2030304.00	2030304.00	0.00	100%	
Total	**11000000.00**	**10990185.00**	**10990185.00**	**0.00**	**100%**	

D. Achievement of Sub-project by objectives (Tangible form): Technology generated/ developed

D.1. Componet-1

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)
1. To design and development of power transmission mechanism from engine to the applicator for both walking and riding type rice transplanter	1.1. Purchase of rice transplanter (RT), equipment, tools and transports	1. Rice transplanter cum fertilizer applicator was developed (both walking and riding type) that is suitable for rice seedlings transplanting and fertilizer deep placement simultaneously. 2. Farmers can apply prilled urea fertilizer or mixing of Urea, TSP, MoP and Gypsum fertilizer along with seedlings transplanting using the same machine. 3. Losses of fertilizer in different form (Leaching, ammonia	1. A rice transplanter cum fertilizer deep placement technology was developed (both walking and riding type) 2. Deep placement of prilled urea fertilizer/ mixed fertilizer application and seedlings transplanting could be mechanized in study area by up scaling. 3. Saved fertilizer as well as cost of rice production and hence, farmers' income increased for more yield of the facilitated farmers.
	1.2. Design of power transmission system, mechanism selection, incorporation of fertilizer applicator with 4-row walking type rice transplanter (model-1)		
	1.3. Design of power transmission system, mechanism selection, incorporation of mixed fertilizer applicator with riding type rice transplanter (model-2)		
2. To design and attach adjustable type fertilizer dispensing mechanism in the rice transplanter	2.1. Design and incorporation was completed for both walking and riding type of rice transplanter		
3. To design skid, furrow opener and covering mechanism for fertilizer deep placement	3.1. Skid was designed and fabricated for both type of transplanter and incorporated as per design.		
4. To test, evaluate and validate the technology in laboratory, research field and farmers' field	4.1. Performance test of model-1 in soil bin was conducted for problems identification		
	4.2. Field test (research farm) of the model-1 was conducted for preliminary evaluation		

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)
	4.3. Improvement of the model-1 based on laboratory and field test result and conducted 3 trails during Boro 2018-19 season and 7 trails in Aman 2019 season	volatilization, de-nitrification and surface runoff) reduced during study. 4. Farmers can save time and costs for simultaneous transplanting and fertilizer deep placement as well as increased riceyield.	
	4.4. Fabrication another three (3) rice transplanter cum fertilizer applicator (model-1) for validation at different location		
	4.5. Newly fabricated machines were tested in lab, soil bin and farmers field in 7 locations during Boro 2019-2020 season.		
	4.6. Laboratory and field test of the model-2 was conducted for improvements		
	4.7 A total of 07 trials were conducted in Aman 2020 season		
5. To save energy, cost and time of separately seedling transplanting and deep placement of fertilizer application	5.1. Machine capacity, cost of rice production under different methods, yield and yield parameters were assessed in different season. 5.2. Mechanical transplanting along with fertilizer deep placement gave higher gross margin, higher BCR and less cost compare to the other treatments.		

D.2. Component-2

General/ 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 determine fertilizer uptake of different application methods	Fertilizer uptake efficiency was measured for different mode of application.	Increased nutrient uptake	A significant amount of fertilizer can be saved by deep placement.
To compare the yield and yield contributing characters under varying methods of fertilizer application	Yield and yield component were measured under fertilization application at different region	Increased rice yield	Farmers' income increased.
To identify the CH_4, CO_2 and N_2O emission under varying methods of fertilizer application in rice soils of Bangladesh	Static close chamber were used for measuring CH_4, N_2O and CO_2 emission	Reduce about 15-25% of total CH_4 and about 17-23% of N_2O flux	Environmental pollution was reduced through CH_4 and N_2O emission.

General/ 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 mitigate the global warming potential in rice soils under varying methods of fertilizer application	Greenhouse gas data were used for estimating of GWP	Mitigate about 4-40% GWP	Global warming was reduced under varying methods of fertilizer application

E: Information/knowledge generated/policy generated

E.1. Component-1

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output	Outcome (short term effect of the research)
1. To design and development of power transmission mechanism from engine to the applicator for both walking and riding type rice transplanter	1.1. Purchase of rice transplanter (RT), equipment, tools and transports	1.1Four (04) rice transplanter were purchased under the project for incorporation of mixed fertilizer applicator. 1.2.Power transmission system analyzed and modified for incorporating the fertilizer dispensing mechanism. 2.0 Rice transplanter cum mixed fertilizer was developed. 3.0 Skid increased the machine stability and ensured proper fertilizer deep placement. 4.1 Mechanical transplanting along with fertilizer deep placement gave higher yield than traditional transplanting. 4.2 Biotic and abiotic stress for mat type seeding raising can be minimized by covering 0.08 mm polythene in day time only during Boro season.	**1.** Mechanical transplanting along with fertilizer deep placement mechanism was developed. 2. Mat type seedling raising techniques was developed for Boro season
	1.2. Design of power transmission system, mechanism selection, incorporation of fertilizer applicator with 4-row walking type rice transplanter (model-1)		
	1.3. Design of power transmission system, mechanism selection, incorporation of mixed fertilizer applicator with riding type rice transplanter (model-2)		
2. To design and attach adjustable type fertilizer dispensing mechanism in the rice transplanter	2.1. Design and incorporation was completed for both walking and riding type of rice transplanter		
3. To design skid, furrow opener and covering mechanism for fertilizer deep placement	3.1. Skid was designed and fabricated for both type of transplanter and incorporated as per design.		
4. To test, evaluate and validate the technology in laboratory, research field and farmers' field	4.1. Performance test of model-1 in soil bin was conducted for problems identification		
	4.2. Field test (research farm) of the model-1 was conducted for preliminary evaluation		
	4.3. Improvement of the model-1 based on laboratory and field test result and conducted 3 trails during Boro 2018-19 season and 7 trails in Aman 2019 season		
	4.4. Fabrication another three (3) rice transplanter cum fertilizer		

Specific objectives of the sub-project	**Major technical activities performed in respect of the set objectives**	**Output**	**Outcome (short term effect of the research)**
	applicator (model-1) for validation at different location	4.3 Rice husk, cow-dung and tea wastage can be used with sandy clay loam soil at the rate of 15-20% for quality mat type seedling raising. 5.1Farmers income increased significantly.	
	4.5. Newly fabricated machines were tested in lab, soil bin and farmers field in 7 locations during Boro 2019-2020 season.		
	4.6. Laboratory and field test of the model-2 was conducted for improvements		
	4.7 A total of 07 trials were conducted in Aman 2020 season		
5. To save energy, cost and time of separately seedling transplanting and deep placement of fertilizer application	5.1. Machine capacity, cost of rice production under different methods, yield and yield parameters were assessed in different seasons. 5.2. Mechanical transplanting along with fertilizer deep placement gave higher gross margin, higher BCR and less cost compare to the other treatments.		

E.2. Component-2

General/ specific objectives of the sub-project	**Major technical activities performed in respect of the set objectives**	**Output**	**Outcome (short term effect of the research)**
To determine fertilizer uptake of different application methods	Fertilizer uptake efficiency was measured for different mode of application.	Increased nutrient uptake	Fertilizer inputs can be saved as well as reduced about 16-24% of GHG and about 4-40% of global warming potential.
To compare the yield and yield contributing characters under varying methods of fertilizer application	Yield and yield component were measured under fertilization application at different region	Increased rice yield	
To identify the CH_4, CO_2 and N_2O emission under varying methods of fertilizer application in rice soils of Bangladesh	Static close chamber were used for measuring CH_4, N_2O and CO_2 emission	Reduce about 15-25% of total CH_4 and about 17-23% of N_2O flux	
To mitigate the global warming potential in rice soils under varying methods of fertilizer application	Greenhouse gas data were used for estimating of GWP	Mitigate about 4-40% GWP	

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

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer	-	Booklet (1st and 2nd edition)	Name: Rice transplanter cum fertilizer applicator, Publishers: SM Printers, Gazipur, pp-40. Number-2000 copy.
Journal publication	01	03	1. Development of mixed fertilizer deep placement technology into soil simultaneously with mechanical rice seedling transplanting, J. Sci. Technol. Environ. Inform. 09(02): 649-664 | Hossen et al. (2020) EISSN: 2409-7632, Journal home: www.journalbinet.com Crossref: https://doi.org/10.18801/jstei.090220.66 2. Effect of Mat Type Rice Seedling Growing Media on Block Formation and Fungal Infection, Journal of Bangladesh Agril Univ 18(4): 1073–1082, 2020, DOI: 10.5455/JBAU.127431 3. Impact of organic substance on growth attributes of mat type rice seedlings in the trays for machine transplanting, J. Sci. Technol. Environ. Inform. 10(01): 694-708 | Shahed et al. (2020) EISSN: 2409-7632, Journal home: www.journalbinet.com Crossref: https://doi.org/10.18801/jstei.100120.70
Video clip/TV program	-	01	My TV (Date: 09-02-2020)
News Paper/Popular Article	-	-	-
Other publications,	-	-	-

G. Description of generated Technology/knowledge/policy:

i. Technology Fact Sheet (title of the technology, introduction, description, suitable location/ecosystem, benefits, name and contact address of author):

Title of the technology: Rice transplanter cum mixed fertilizer applicator

Introduction:

The farmers of Bangladesh normally apply urea fertilizer as prilled formed by hand broadcasting method. Deep placement of urea (either granule or prilled form) in transplanted rice is an agronomically efficient and environmentally safe as compared with the traditional application method of prilled urea. Based on this concept, BRRI has been developed a push type prilled urea applicator. It was found suitable during field trials in different soil conditions and seasons though laborious to operate manually. In addition, farmers need additional one machine for fertilizer application. This is also not suitable for other basal fertilizer (TSP, MoP and Gypsum). Under this condition, mixed fertilizer deep placement technology has been incorporated (suitable for either urea alone or combination of urea, TSP, MoP and Gypsum together) to the existing mechanical rice transplanter (walking type) without sacrificing the merit of transplanting to ensure both the mechanized rice transplanting and fertilizer deep placement simultaneously.

Description of the technology

- Mixed fertilizer deep placement mechanism was incorporated successfully in the walking and riding type with proper design of power transmission, fertilizer calibration, smooth dispensing mechanism and uniform covering during operation in the field.
- Mechanical transplanting along with mixed fertilizer deep placement (70% of the recommended dose of urea) gave significantly higher yield compared to the mechanical and manual transplanting along with hand broadcasting of fertilizers.
- Mechanical transplanting along with mixed fertilizer deep placement also gave higher BCR (1.41) compared to the other two treatments (1.24 and 1.11).
- Urea fertilizer along with TSP, MoP and Gypsum fertilizer can be placed and covered in 6-8 cm soil depth during mechanical transplanting.
- The capacity of machine is 35-40 decimal/h and fuel consumption is 1.0 ~ 1.25 litter/hour.
- Transplanting and fertilizing can be done in one operation which is suitable for all over the country.

Suitable location/ecosystem

Suitable in all rice cultivable area except sandy soil.

Benefits

Save 30% urea fertilizer and gave about 10% higher yield of rice as well as higher.

Name and contact address of author

Dr. Md. Anwar Hossen
Senior Scientific Officer
FMPHT Division, BRRI
Gazipur-1701
Cell phone no.: +880-1712675130

ii. Effectiveness in Policy Support (if applicable):

Upselling and popularization of the rice transplanter will enhance the adaptability of the developed technology or vice-versa. In mechanization policy of Bangladesh, rice transplanter one of the prioritized technology.

H. Technology/(knowledge generation/Policy Support (as applied):

i. Immediate impact on generated technology (commodity & non-commodity):

Farmers of the sub-project area are interested to purchase the technology. Users of the technology in the sub-project area are getting benefits by reducing the amount of fertilizer as well harvesting more rice.

ii. Generation of new knowledge that help in developing more technology in future:
Knowledge and findings of the sub-project that will help to the farmers for increasing rice yield as sustainable manner of rice transplanting mechanization as well as to reduce GHG from rice field that will be also help to the policy maker

iii. Technology transferred that help increased agricultural productivity and farmers' income:
Up scaling of the generated technology in the farming field is needed for popularization.

iv. Policy Support
Deep placement of fertilizer might be suggested for more efficient use of fertilizer, more yield as well as less environmental pollution.

I. Information regarding Desk and Field Monitoring

i. Field Monitoring (date& no. of visit, name and addresses of team visit and output)
1. Field monitoring team comprises of Dr. Monowar Karim Khan, Member Director, BARC, Dhaka; Md. Ashequr Rahaman, Assistant Manager (Accounts), PIU-BARC, NATP-2, Dhaka had monitored the sub-project activities on 23/03/2019.

J. Sub-project auditing (covers all types of audit performed)

Types of audit	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Govt	No objection	3639504.00	-	
Govt.	No objection	3310627.00	-	

K. Lessons Learned:
- Deep placement of fertilizer mixture along with mechanical transplanting increase fertilizer use efficiency, reduce losses and gave yield advantages
- Reduce of greenhouse gas emission
- Mitigation of GWP options
- Nutrient loss reduce

L. Challenges (if any):
- It was challenges to run the activities during Covid-19 pandemic situation. But finally implemented all activities timely with the devotion of the all related personnel.

M. Suggestions for future planning (if any):
- The developed technology need to up scaling
- Multi location based research is needed under different soil type

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Signature of the Coordinator
Date:……………………..
Seal

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

Appendices

Appendix 1: Seedling raising cost (Tk/ha) in Boro season, 2018-19

Items	Boro 2018-19 season		
	Amount per ha	Unit price, Tk	Total, Tk/ha
Seeds	40 kg	65.00	2600.00
Soil for 260 tray preparation	1.00 m3	1500.00	1500.00
Net for fencing	140 m	5.00	700.00
Labor for soil preparation	2 nos	400.00	800.00
Labor for seed soaking, incubation etc	0.5 nos	200.00	200.00
Labor for tray preparation, seed sowing, covering etc.	3 nos	400.00	1200.00
Labor for Irrigation, management, uprooting and others	5 nos	400.00	2000.00
Seeds and seedling treatments	LS	LS	1000.00
Total cost (Tk/ha)			10000.00

Appendix 2: Fixed cost of walking type rice transplanter operation, Boro 2018-19 season

Sl. No.	Items	Tk.
1	Purchase price (p), Tk	350000.00
2	Salvage value (S), Tk (10% of p)	35000.00
3	Working life (L), yr	8.00
4	[1]Average annual use (Au), h/yr	560.00
5	Annual depreciation, D=(P-S)/L	39375.00
6	Interest on investment, I=(P+S)/2*I, where rate of interest is 10%	19250.00
7	Tax, insurance, T=3% of P	10500.00
8	Total fixed cost (D+I+T), Tk/yr	69125.00
9	*Total fixed cost, Tk/h*	123.40

Appendix 3: Variable cost of walking type rice transplanter operation, Boro 2018-19 season

Sl. No.	Total variable cost	Kushtia			Habiganj		
		T_1	T_2	T_3	T_1	T_2	T_3
1	[2]Labour cost per hour, L (Tk/h)	125	125	50	125	125	50
2	Fuel used, lit/h	0.75	0.70	0.00	0.85	0.76	0.00
3	Fuel cost, Tk/h	68	63	0	77	68	0
4	Lubricant cost , (Tk/h) (3% of fuel cost)	2	2	0	2	2	0
5	RPM/h =3.5 % of purchase price	22	22	0	22	22	0
6	Total Variable cost (Tk/h)	216	212	50	226	217	50
7	Total operating cost Tk/h (Fixed cost+ Variable cost)	340	335	50	349	341	50
8	Field capacity of rice transplanter, ha/h	0.11	0.12	0.01	0.12	0.13	0.01
9	Time for transplanting, h/ha	9.09	8.33	166.67	8.33	7.69	333.33
10	Operating Cost for transplanting, Tk/ha	3089	2793	8333	2909	2621	16667

Appendix 4: Seedling raising cost (Tk/ha) in Aman season 2019

Items	Aman 2019		
	Amount per ha	Unit price, Tk	Total, Tk/ha
Seeds	40 kg	65.00	2600.00
Soil for 260 tray preparation	1.00 m3	1500.00	1500.00
Net for fencing	140 m	5.00	700.00
Labor for soil preparation	2 nos	400.00	800.00
Labor for seed soaking, incubation etc	0.5 nos	200.00	200.00
Labor for tray preparation, seed sowing, covering etc	3 nos	400.00	1200.00
Labor for Irrigation, management, uprooting, etc	4 nos	400.00	1600.00
Seeds and seedling treatments	LS	LS	0.00
Total cost (Tk/ha)			8600.00

Appendix 5: Variable cost of walking type rice transplanter operation, Aman 2019 season

Sl. No.	Total variable cost	Sadar, Rangpur			Sadar, Gazipur		
		T_1	T_2	T_3	T_1	T_2	T_3
1	[2]Labour cost per hour, L (Tk/h)	125	125	50	125	125	50
2	Fuel used, lit/h	0.68	0.00	0.00	0.78	0.70	0.00
3	Fuel cost, Tk/h	61	0	0	70	63	0
4	Lubricant cost , (Tk/h) (3% of fuel cost)	2	0	0	2	2	0
5	RPM/h =3.5 % of purchase price	22	22	0	22	22	0
6	Total Variable cost (Tk/h)	210	147	50	219	212	50
7	*Total operating cost Tk/h (Fixed cost+Variable cost)*	333	270	50	343	335	50
8	*Field capacity of rice transplanter, ha/h*	0.21	0.22	0.003	0.16	0.21	0.003
9	*Time for transplanting, h/ha*	4.76	4.55	333.33	6.25	4.76	400.00
10	*Operating Cost for transplanting, Tk/ha*	1587	1229	16666.7	2141	1596	20000.0

Appendix 5: Continuation…..

Sl. No.	Total variable cost	Mirpur, Kushtia			Kumarkhali, Kustia-1		
		T_1	T_2	T_3	T_1	T_2	T_3
1	[2]Labour cost per hour, L (Tk/h)	125	125	50	125	125	50
2	Fuel used, lit/h	0.68	0.58	0.00	0.65	0.60	0.00
3	Fuel cost, Tk/h	61	52	0	59	54	0
4	Lubricant cost , (Tk/h) (3% of fuel cost)	2	2	0	2	2	0
5	RPM/h =3.5 % of purchase price	22	22	0	22	22	0
6	Total Variable cost (Tk/h)	210	201	50	207	202	50
7	*Total operating cost Tk/h (Fixed cost+ Variable cost)*	333	324	50	331	326	50
8	*Field capacity of rice transplanter, ha/h*	0.17	0.20	0.003	0.20	0.22	0.003
9	*Time for transplanting, h/ha*	5.88	5.00	333.33	5.00	4.55	333.33
10	*Operating Cost for transplanting, Tk/ha*	1961	1620	16666.7	1653	1481	16666.7

Appendix 5: Continuation…..

Sl. No.	Total variable cost	Kushtia-2			Netrakona			Habiganj		
		T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
1	[2]Labour cost per hour, L (Tk/hr)	125	125	50	125	125	50	125	125	50
2	Fuel used, lit/hr	0.60	0.55	0.00	0.65	0.60	0.00	0.75	0.72	0.00
3	Fuel cost, Tk/hr	54	50	0	59	54	0	68	65	0
4	Lubricant cost , (Tk/hr) (3% of fuel const)	2	1	0	2	2	0	2	2	0
5	RPM/hr =3.5 % of purchase price	22	22	0	22	22	0	22	22	0
6	Total Variable cost (Tk/hr)	202	198	50	207	202	50	216	214	50
7	*Total operating cost Tk/hr (Fixed+ Variable cost)*	326	321	50	331	326	50	340	337	50
8	*Field capacity of rice transplanter, ha/hr*	0.21	0.23	0.003	0.19	0.19	0.003	0.20	0.20	0.003
9	*Time for transplanting, hr/ha*	4.76	4.35	333.33	5.26	5.26	333.33	5.00	5.00	333.33
10	*Operating Cost for transplanting, Tk/ha*	1552	1397	16666	1740	1715	16666.7	1699	1685	16666.7

Appendix 6. Actual field capacity (ha/hr) of transplanting, Boro 2019-2020 season

Treat	Rangpur	Gazipur	Mirpur	Kushtia-1	Kushtia-2	Netrakona	Habiganj
T1	0.18	0.18	0.23	0.22	0.2	0.19	0.2
T2	0.23	0.2	0.23	0.24	0.21	0.23	0.17
T3	0.003	0.0025	0.003	0.003	0.003	0.003	0.0025

Appendix 7. Fuel cost (lit/hr) of transplanter operation in different locations, Boro 2019-2020 season

Treat	Rangpur	Gazipur	Mirpur	Kushtia-1	Kushtia-2	Netrakona	Habiganj
T1	0.600	0.720	0.660	0.600	0.600	0.650	0.750
T2	0.580	0.700	0.600	0.600	0.550	0.600	0.720
T3	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Appendix 8. Operating time (hr/ha) of transplanter operation in different locations, Boro 2019-2020 season

Treat	Rangpur	Gazipur	Kushtia-1	Kushtia-2	Kushtia-3	Netrakona	Habiganj
T1	5.556	5.556	4.348	4.545	5.000	5.263	5.000
T2	4.348	5.000	4.348	4.167	4.762	4.348	5.882
T3	333.333	400.000	333.333	333.333	333.333	333.333	400.000

Appendix 9. BCR calculation for Boro 2019-2020

Inputs	Rangpur			Gazipur			M. Kushtia			Kushtia 1		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
Seedling preparation including seeds	11300	11300	6025	11300	11300	6500	11300	11300	6500	11300	11300	6500
Land preparation (Tillage)	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500	6500
Ridge making, leveling, canal making etc.	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Transplanting	1811	1409	16667	1872	1676	20000	1441	1417	16667	1481	1358	16667
Weeding	16250	17250	17750	16250	16750	17250	14900	15750	16750	14500	15000	15250
Fertilizer	10118	11078	11078	10118	11078	11078	10118	11078	11078	10118	11078	11078
Herbicide and pesticide	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200	2200
Irrigation cost	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Harvesting, carrying, threshing and winnowing	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000	14000
Land rent	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Total input cost	81379	82937	93420	81440	82704	96728	79659	81445	92895	79299	80636	91395
Interest on investment at the rate of 10%	4069	4147	4671	4072	4135	4836	3983	4072	4645	3965	4032	4570
Gross total input cost	85447	87084	98091	85512	86839	101564	83642	85517	97539	83264	84668	95964
Rice, t/ha	7.0	6.0	5.6	5.9	4.3	4.7	7.1	6.2	6.1	7.1	6.2	5.5
Straw, t/ha	7.7	7.7	6.6	6.1	6.5	4.8	5.1	7.8	6.9	6.7	7.8	6.8
Return from rice	140866	119534	111800	117866	86934	93066	141000	124800	121934	142334	124400	109800
Return from straw	9685	9685	8218	7686	8103	5977	6398	9694	8580	8383	9785	8553
Gross return, Tk/ha	150551	129219	120018	125552	95037	99043	147398	134494	130514	150717	134185	118353
Gross margin, Tk/ha	65103	42135	21927	40040	8198	-2522	63756	48977	32975	67453	49518	22388
BCR	1.76	1.48	1.22	1.47	1.09	0.98	1.76	1.57	1.34	1.81	1.58	1.23

Continuation…………….

	Kushtia 2			Netrakona			Habiganj		
Inputs	T1	T2	T3	T1	T2	T3	T1	T2	T3
Seedling preparation including seeds	11300	11300	6500	11300	11300	6500	11300	11300	6500
Land preparation (Tillage)	6500	6500	6500	6500	6500	6500	6500	6500	6500
Ridge making, leveling, canal making etc.	1200	1200	1200	1200	1200	1200	1200	1200	1200
Transplanting	1629	1530	16667	1740	1417	16667	1699	1982	20000
Weeding	15550	15600	16000	14500	14600	14450	16750	17250	17745
Fertilizer	10118	11078	11078	10118	11078	11078	10118	11078	11078
Herbicide and pesticide	2200	2200	2200	2200	2200	2200	2200	2200	2200
Irrigation cost	3000	3000	3000	3000	3000	3000	3000	3000	3000
Harvesting, carrying, threshing and winnowing	14000	14000	14000	14000	14000	14000	14000	14000	14000
Land rent	15000	15000	15000	15000	15000	15000	15000	15000	15000
Total input cost	80497	81408	92145	79558	80295	90595	81767	83510	97223
Interest on investment at the rate of 10%	4025	4070	4607	3978	4015	4530	4088	4176	4861
Gross total input cost	84522	85478	96752	83536	84310	95124	85855	87686	102084
Rice, t/ha	7.1	6.4	6.1	6.2	5.7	5.4	7.0	6.1	5.4
Straw, t/ha	6.0	7.9	7.1	6.7	6.9	6.3	5.9	7.7	6.7
Return from rice	142734	128800	122266	124934	114334	107400	139866	122534	108400
Return from straw	7549	9813	8855	8406	8589	7860	7384	9616	8424
Gross return, Tk/ha	150283	138613	131121	133340	122923	115260	147250	132150	116824
Gross margin, Tk/ha	65760	53135	34369	49804	38614	20136	61394	44464	14740
BCR	1.78	1.62	1.36	1.60	1.46	1.21	1.72	1.51	1.14

Appendix 10: Training details with pictorial views

Title	Target	Actual	Participants	Locations
Rice transplanter cum fertilizer applicator-"Field operation, repair and maintenance."	03	03	60	Netrakona, Rangpur and Kushtia
				
Training at Kushtia	Training at Rangpur		Training at Netrakona	