

Fertilizers application simultaneously with mechanical rice transplanting in Bangladesh

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Abstract: A research was conducted to evaluate the Bangladesh Rice Research Institute (BRRI) developed rice transplanter cum prilled urea applicator (RTPUA) during Boro 2017-2018. Urea fertilizer deep placement mechanism successfully incorporated in the walk behind type rice transplanter (ARP-4UM). 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 22 rpm of the applicator main shaft. Impellor type mechanism was connected with the main shaft of the applicator to dispense the prilled urea fertilizer to the output channel. Field experiments were conducted on a silty loam soil in Gopalganj, clay loam soil in Kushtia, silty clay loam soil in Gazipur and on a clay soil in Netrakona. Four transplanting and urea fertilizer treatments were T₁ = Mechanical transplanting (MT) along with urea deep placement together (70% urea), T₂ = MT + hand broadcasting of urea (UHB) at three equal split, T₃ = Hand transplanting (HT) and UHB at three equal split and T₄ = Control (-N). In four locations, theoretical and actual field capacity of the rice transplanter was found higher to some extent without fertilizer deep placement mechanism during transplanting due to the extra fertilizer re-filling time and slow of operation. Field capacity was found more in clay and clay loam soil. Average of four locations and three replications, actual field capacity of the rice transplanter was found to be 0.119 ha h⁻¹. In the field, saving percentage of urea fertilizer varied from 25.1% to 28.5% against the calibration of 30% of urea saving due to the variation of the machine, operational speed and more penetration of the driving wheel in the field during operation etc. It was also observed that grain yield varied with the mode and rate of urea fertilizer application. Mechanical transplanting along with urea fertilizer deep placement (70% of recommended dose) gave significantly higher yield compared to manual transplanting and hand broadcasting of urea as well as higher benefit-cost ratio (BCR). Mechanized transplanting along with urea fertilizer deep placement in wet land rice establishment is thus a promising technology for rice farmers in Bangladesh as well as in Asia.

Keywords: Mechanical transplanting, urea fertilizer, rice yield, soil type and economics

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1 Introduction

Manual transplanting is tedious and time consuming, and is often the cause of delayed planting. As a result,

mechanized rice transplanting is seen as a solution of labor problems. Likewise, using mechanized rice transplanting ensures uniform plant spacing (both the line to line and plant to plant) as well as fast and efficient planting. It has potentiality and gains popularity in Bangladesh due to the intervention of different private and government programs.

The BRRI (Bangladesh Rice Research Institute) conformed a good scope for adoption of transplanter.

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However, deep placement of fertilizer has been proven as an efficient technology in terms of yield increase, fertilizer saving, cost reduction and environmental friendliness. BRRI developed a prilled urea applicator which has been evaluated in different soil conditions and was proven as a suitable technology in terms of fertilizer saving with yield advantages. This technology is used by many farmers in Bangladesh.

However, manual operation of the applicator is laborious and time consuming but relies on access to cheap readily-available labor. Besides being costly and time consuming, deep placement of fertilizer needs right placing in desired depth. To overcome the present problems of the deep placement technology, yield increase, fertilizer save and production cost reduction of rice are urgent needs. Mechanical transplanting of rice and fertilizer deep placement in the rice field is of considerable interest but is unknown of the simultaneous mechanical seedling transplanting and fertilizer deep placement. Therefore, systematic study need to be designed and prilled urea fertilizer deep placement technology should be developed to incorporate with the rice transplanter. On the basis of above discussion, it was hypothesized that effective and efficient incorporation of prilled urea fertilizer deep placement technology with rice transplanter would enhance the productivity and profitability of rice production by accelerating the adoption of the technologies to the end users. On the basis of the above hypothesis, BRRI developed rice transplanter cum prilled urea applicator were evaluated in different locations of the country with the following objectives-

- To test and evaluate the field performance of rice transplanter cum prilled urea applicator that developed by BRRI.
- To observe the yield and yield contributing attributes and
- To analyze the economics of rice production using the technology

2 Materials and methods

2.1 Rice transplanter cum prilled urea applicator (RTPUA)

Power-operated walking-type rice transplanter was used to incorporate urea fertilizer deep placement

mechanism. The major specification of the transplanter with prilled urea applicator is given as shown in Table 1. The photographic view of RTPUA is shown in Figure 1.

Table 1 Description of the rice transplanter

Country of origin and Model	South Korea and ARP-4UM
Type	Walk behind type
Overall length × width × height (mm)	2350×1480×800
Dimensions	Overall weight (kg)
	175
	Maximum output kW rpm ⁻¹
	3/1800
	Starting method
	Recoil
Traveling section	Steering
	Hydraulic power steering mode
	Wheel type
	Rubber lug wheel
	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
Urea fertilizer deep placement section	Position of urea placement
	In between two alternative lines
	Depth of placement (mm)
	65 to 150
	Rate of displacement
	Adjustable
	Controlling
	By engage-disengage lever of belt
	Uniformity of displacement
	95% to 99%
	Option
	Either both or only rice seedling can be transplanted



Figure 1 Waking type rice transplanter cum prilled urea applicator

2.2 Field evaluation of the rice transplanter cum prilled urea applicator

This study was conducted to evaluate the performance of RTPUA in the farmer's field at the village of Chadgaw under Modan upazila of Netrakona district; Bahirbag under Muksudpur upazila of Gopalganj district; Tarapur under Kumarkhali upazila of Kushtia district and Vararur under Sadar upazila of Gazipur district, Bangladesh during the irrigated dry season 2017-2018. Soil samples from the experimental field was collected and analyzed in the soil science laboratory, BRAC, Gazipur to identify the textural classes and fertility status (Table 2).

Table 2 Soil conditions of the experimental fields

Characteristics	Muksudpur, Gopalganj	Kumarkhali, Kushtia	Madan, Netrakona	Sadar, Gazipur
Soil texture	Silty loam	Clay loam	Clay	Silty clay loam
pH	6.4	5.6	6.8	5.4
Organic carbon in % (OC)	1.5	1.4	1.8	1.3
Total N (%)	0.19	0.15	0.23	0.13

2.3 Experimental design and treatments

The experiment was laid out in a randomized complete block (RCB) design with three replications. About one meter of buffer spacing was maintained among the sub-plots whereas experimental plot area was 75, 82, 105 and 54 decimal in Netrakona, Gopalganj, Kushtia and Gazipur respectively. The treatments were-

Treatments:

T₁: Mechanical transplanting (MT) with urea deep placement together (70% urea)

T₂: MT + hand broadcasting of urea (UHB) at three equal split

T₃: Hand transplanting (HT) and UHB at three equal split

T₄: Control (N)

2.4 Seed bed preparation

Seedlings were raised both on plastic tray and farmers' seed bed for mechanical and manual transplanting at the same date. Manual transplanting was done after 15 days of mechanical transplanting. Thirty (30) and 45 days old of seedling were used in mechanical and hand transplanting plots, respectively. Control plots (T₄) were transplanted mechanically using the mat type seedling.

2.5 Seedling raising

Plastic tray (280 × 580 × 25 mm) was used for raising seedlings. Clod-free sandy loam soil was mixed with organic fertilizer and filled up the trays to a depth of 20 mm. 130 g of pre-germinated seeds (radicals and coleoptiles elongate to 1/3 of seed length) were spread uniformly on each tray. After sowing, fine and loose soil was spread over the seeds to 3-4 mm depth and irrigated to saturate the soil and allowed to drain the excess water. About 30 days older seedling with 3-4 leaves was used in experiment. Date of soaking, incubation and tray preparation is shown in Table 3.

Table 3 Basic information of the experiments regarding seedling raising and transplanting

Parameters	Netrakona	Gopalganj	Kushtia	Gazipur
Variety	BRR1 dhan28	BRR1 dhan28	BRR1 dhan58	BRR1 dhan28
Date of soaking	29/11/2017	5/12/2017	11/12/2017	25/12/17
Date of sowing and tray preparation	2/12/2017	8/12/2017	14/12/2017	27/12/17
Date of mechanical transplanting	31/12/2017	17/01/2018	18/01/2018	2/2/2018
Date of hand transplanting	15/01/2018	02/02/2018	03/02/2018	16/02/2018
Experimental Plot area in decimal	75	82	105	54
Date of harvesting	12/04/2018	18/04/2018	23/05/2018	05/05/2018

2.6 Land preparation

Rice was the previous crop of the experimental field. Average 20-25 mm height of rice straw kept in the field during land preparation. A rotary tiller powered by 2-WT was used for land preparation. Three rotary tillage passes in saturated soil, followed by two leveling were the operations for land preparation.

2.7 Rice variety

Rice variety of BRR1 dhan28 and BRR1 dhan58 was taken as test crop to conduct the study. The growth duration of BRR1 dhan28 and BRR1 dhan58 are 140 and 150 days (BRR1, 2016a).

2.8 Operational procedure of the developed rice transplanter cum prilled urea applicator

The walking type rice transplanter was modified to

incorporate prilled urea deep placement mechanism. During transplanting operation, the following procedure needs to follow for successful placement of the briquette.

- Disengage the power of the applicator gear box before start the engine and transplanting.
- Lubricant and grease need to be checked of the applicator gear and chain-sprocket before operation.
- Tension of the belt also needs to be checked before operation.
- Power of the applicator gear box engaged with the start of transplanting.
- At the end of field, during turning, again disengage the power of the applicator gear box for avoiding un-necessary loss of granule.

- Time to time re-filled the hopper by prilled urea fertilizer.
- Some amount of urea fertilizer need to be carried like seedling mat for re-filing in the field as and when necessary.

2.9 Transplanting

Walk behind type mechanical rice transplanter (model:



Figure 2 Field operation of the RTPUA



Figure 3 Fertilizer dispensing patter in the furrow (uncovered condition)



Figure 4 Fertilizer re-filling during operation

2.10 Urea deep placement

Urea fertilizer was placed in non-oxidized zone during mechanical transplanting. Before field operation, the RTPUA was calibrated to maintain the pre-designed dose of fertilizer (Table 4). BRRI recommended urea fertilizer dose was considered as 260 kg ha⁻¹ for BRRI dhan28 and BBRI dhan58 except Madan, Netrakona where urea fertilizer dose was considered as 225 kg ha⁻¹ for haor area (BRRI, 2016b). At 70% of the recommended dose, the rate of urea fertilizer is 158 and

ARP-4 UM) was modified and successfully incorporated prilled urea deep placement mechanism. The RTPUA was used to transplant the rice seedling in the treatments T₁, T₂ and T₄ whereas treatment T₃ was transplanted manual using seedling raised in farmers' seed bed (Figures. 2, 3 and 4). Basic information of the experiments is shown in Table 3.

182 kg ha⁻¹, respectively. The fertilizer dispensing rate per rotation of the driving wheel was calculated using the following formula:

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

where, FDR = Fertilizer dispensing (from each channel) rate per rotation of the driving wheel (g/rotation); D = Wheel diameter of the applicator, cm (about 60 cm); L = Line to line spacing of the transplanted rice, cm; RoF = Desired rate of fertilizer application, kg ha⁻¹.

Table 4 Calibrated rate of urea fertilizer

Location	Variety	Recommended rate of urea fertilizer	Deep placement of urea fertilizer (70% of recommended dose)	Urea dispensing rate per rotation of the driving wheel (g/rotation/channel)
Madan, Netrakona	BRRI dhan28	225	158	18
Muksudpur, Gopalganj	BRRI dhan28	260	182	21
Kumarkhali, Kushtia	BRRI dhan58	260	182	21
Sadar, Gazipur	BRRI dhan28	260	182	21

2.11 Fertilizer management

Recommended dose of urea fertilizer was applied in

the hand broadcasted plots (T₃) whereas 70% of the recommended dose in the treatment T₁. Triple super

phosphate (TSP), muriate of potash (MoP), zinc sulphate ($ZnSO_4$) and gypsum fertilizer were applied at sowing. Urea fertilizer was broadcast in three equal applications at 7 days after transplanting, vegetative stage and before panicle initiation stage in the treatment T₃. The rate of fertilizer except urea was the same for all treatments (Table 5).

Table 5 Fertilizer application rate as basal and top dressing fertilizer

Basal dose (kg ha ⁻¹)					Urea top dose (kg ha ⁻¹)		
TSP	MoP	Gypsum	Znso ₄	Urea (recommended dose, kg ha ⁻¹)	1 st top dose	2 nd top dose	2 nd top dose
120	150	112	12	260 (225*)	95 (85)	85 (75)	80 (65)

Note: * Urea application rate in Madan, Netrakona is 225 kg ha⁻¹.

2.12 Field capacity of the transplanter

Field capacity of the rice transplanter was measured with and without fertilizer deep placement mechanism along with seedling transplanting. Machine operation time included time required during turning of the transplanter, feeding of seedling, fertilizer refill in the hopper, operator's personal time, adjustment time etc. were considered to calculate the actual field capacity of the rice transplanter cum prilled urea applicator, which is transplanting and fertilizing area covered (ha) divided by the time of operation (hs). Field efficiency was measured based on the actual field capacity and calculated theoretical field capacity. Field operations of the rice transplanter cum prilled urea applicator in different locations are presented in Figure 13, 14 and 15.

2.13 Actual saving percentage of fertilizer

Actual percentage of saving was calculated to divide the actual dispensing rate of fertilizer by the recommended rate of fertilizer of the respected area of operation.

2.14 Labor requirement

The number of human labor involved in each operation from seedling raising to processing were measured to calculate the benefit-cost ratio under different treatments.

2.15 Operating cost of the transplanter cum prilled urea applicator

Transplanter operating cost (Tk h⁻¹) of the RTPUA was calculated from the fixed cost (Tk h⁻¹) and variable costs (Tk h⁻¹) using the method of Kepner et al. (1978). 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 y⁻¹; P = purchase price of the RTPUA, Tk; S = salvage value, Tk; L = working life of the RTPUA, y.

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 (Tk y⁻¹), $FC = (a + b + c)$

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

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

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

f) Lubrication oil cost per hour, $O = 3\%$ of fuel cost

g) Repair and maintenance cost (Tk h⁻¹), $RPM = 3.5\%$ of purchase price (Tk y⁻¹) × average annual use (hr y⁻¹)

Total variable cost (Tk y⁻¹) = (d + e + f + g)

2.16 Weed and pest management

Herbicides Sathi (Pyrazosulfuron Ethyl 10% WP) applied after 3-6 days of transplanting at the rate of 20 g/bigha. One hand weeding was done at 45 days after transplanting (DAT) to keep the fields weed free. Insect infestation was not severe in crop season. Only one application of Virtako (chlorantraniliprote 20% + thiamethoxam 20%) pesticide was applied to control stem borer infestation.

2.17 Irrigation water management

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 necessary to control the water flow between the plots. Excess water was drained out of the plots before 15 days of harvest to enhance maturity of the crop.

2.18 Yield and yield contributing character

Tiller number and plant height were assessed from

12 hills per plot at 15-day intervals. Crops were harvested when 85%-90% of the grains become golden. It was threshed, cleaned, dried weighed to collect necessary data on various crop characters. The harvested crop of each plot was bundled separately, tagged and carried to a clean threshing floor. Sample bundles were then dried in sunshine, threshed and then seeds were cleaned. Rice grain yield per plot was recorded from a pre-selected 10 m² harvest area and was determined with the adjustment to 14% moisture content. For computing above ground biomass and yield attributes, samples from 1 m² quadrates were collected from outside of the pre-selected 10 m² area of each plot. Straw yield (above ground biomass), plant height, panicle length, number of tillers per hill and number of panicles per hill, filled and unfilled spikelets panicle⁻¹ and 1000 grains weight were recorded from these quadrates.

2.19 Harvest index (HI)

The term 'harvest index' is used in agriculture to quantify the yield of a crop species versus the total amount of biomass that has been produced. Harvest index can apply equally well to the ratio of yield to total plant biomass (shoots plus roots) but above-ground biomass is more common because root mass is so difficult to obtain. Harvest index is defined as the yield of grains divided by the total yield of above ground biomass (straw plus grain).

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

where, Biological yield (t ha⁻¹) = Straw yield (t ha) + Grain yield (t ha⁻¹).

2.20 Gross margin

Cost of rice production in different urea fertilizer management practices was calculated based on the 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. Market price of crop was collected from local markets. 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.

2.21 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.

3 Results and discussion

3.1 RTPUA performance

3.1.1 Field capacity

Field capacity of the developed rice transplanter cum prilled urea applicator (RTPUA) was measured with and without prilled urea fertilizer deep placement mechanism in four studied locations (Table 6). Theoretical and actual field capacity of the rice transplanter was found higher to some extent without fertilizer deep placement mechanism during transplanting due to extra fertilizer re-filling time and slow of operation in the studied areas. Both the capacity was found more in Netrakona and less in Kushtia due to soil condition. Field efficiency varied from 53% to 62% irrespective of soil and locations. Average of four locations at three replications, actual field capacity of the rice transplanter was found 0.119 ha h⁻¹. Incorporation of prilled urea applicator with mechanical rice transplanter did not reduce the field capacity of the rice transplanter. However, the actual field capacity of a self-propelled rice transplanter varies with the operator's skill, field nature, soil type, puddling depth and hard pan depth (Mousavi and Hashemi, 2008). Hossen et al. (2018) found 0.108-0.133 ha h⁻¹ in Boro season and 0.101-0.141 ha h⁻¹ in Aman season in Gazipur and Kushtia reason of Bangladesh.

3.1.2 Theoretical and actual saving of urea fertilizer by the RTPUA

Before field operation of the machine, it was calibrated to save 30% of urea fertilizer from recommended dose. In the field, saving percentage varied

from 25.1% to 28.5% against the calibration of 30% of urea saving (Table 7). It might be due to the variation of operational speed, more penetration of the driving wheel in the field during operation etc. Maximum deviation was observed in Netrakona and Gopalganj. High vibration of the machine, turning losses of the fertilizer, uniform and fine prilled urea size might be the causes of more

dispensing rate of fertilizer compared to calibration. Hossen et al. (2017) found 34% and 24% of urea fertilizer saving against the calibration of 30% and 20% of urea saving using BRRI prilled urea applicator. Dissemination of the developed technology will help the farmers' to save fertilizer with sacrificing the field capacity of the machine.

Table 6 Field performance of the RTPUA

Condition of RTPUA operation	Forward speed of operation (km h ⁻¹)	Actual field capacity (ha h ⁻¹)	Theoretical field capacity (ha h ⁻¹)	Field efficiency (%)
Netrakona				
With UFDP	1.89	0.132	0.227	58.2
Without UFDP	1.93	0.139	0.232	59.9
Gopalganj				
With UFDP	1.76	0.112	0.211	53.1
Without UFDP	1.8	0.122	0.216	61.1
Kushtia				
With UFDP	1.62	0.104	0.194	53.6
Without UFDP	1.63	0.113	0.196	62.8
Gazipur				
With UFDP	1.71	0.117	0.205	57.1
Without UFDP	1.75	0.119	0.210	56.7
Average	With UFDP	1.75	0.12	55.50
	Without UFDP	1.78	0.12	60.13

Note: Average value of three replications, width covered per pass of the applicator is 1.2 m. UFDP-Urea fertilizer deep placement

Table 7 Percent of fertilizer saving as affected by soil condition and location

Location	Area (m ²)	Urea dispensed (kg)	Urea dispensed rate (kg ha ⁻¹)	Theoretical rate of dispensed at 30% saving (kg ha ⁻¹)	Recommended dose (kg ha ⁻¹)	% of saving
Netrakona	1180	18.5	156.8	158	225	25.1%
Gopalganj	1200	23.2	193.3	182	260	25.7
Kushtia	1404	26.1	185.9	182	260	28.5
Gazipur	965	18.4	190.7	182	260	26.7

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m.

3.2 Crop performance

3.2.1 Plant height

Netrakona: Plant height at different date after transplanting varied with the mode of fertilizer application which is presented in Figure 5. At 60 days after transplanting, plant height was observed more for T₁ (75.1 cm) which is equal to T₂ (74.2 cm) whereas plant height at harvest was found higher for T₃ (94.9 cm) which is equal to T₁ (90.2 cm).

Gopalganj: Plant height with different date after transplanting varied with the mode of fertilizer application and method of transplanting which is shown in Figure 5. From the date of transplanting to the date of harvesting, plant height of T₁ and T₂ was found more compared to T₃ and T₄.

Kushtia: Plant height at different date after

transplanting also varied with the mode and method of fertilizer application and seedling transplanting, respectively which is shown in Figure 5. In all cases, T₁ gave higher plant height compared to other treatments. At harvest, T₁ (100.3 cm), T₂ (98.2 cm) and T₃ (97.6 cm) gave similar plant height which was higher compared to T₄ (77.9 cm). In all cases, T₄ gave significantly lower plant height compared to T₁.

Gazipur: Plant height with different date of transplanting at Gazipur is shown in Figure 5. It was varied significantly at different days after transplanting. Plant height of T₁ and T₂ was found significantly higher compared to T₃ and T₄ whereas it was not varied between T₁ and T₂. Significantly lower plant height was observed for T₄ at the date of transplanting. Potential plant height of BRRI dhan28 and BRRI dhan58 is 90 and 100 cm,

respectively (BRRI, 2016a).

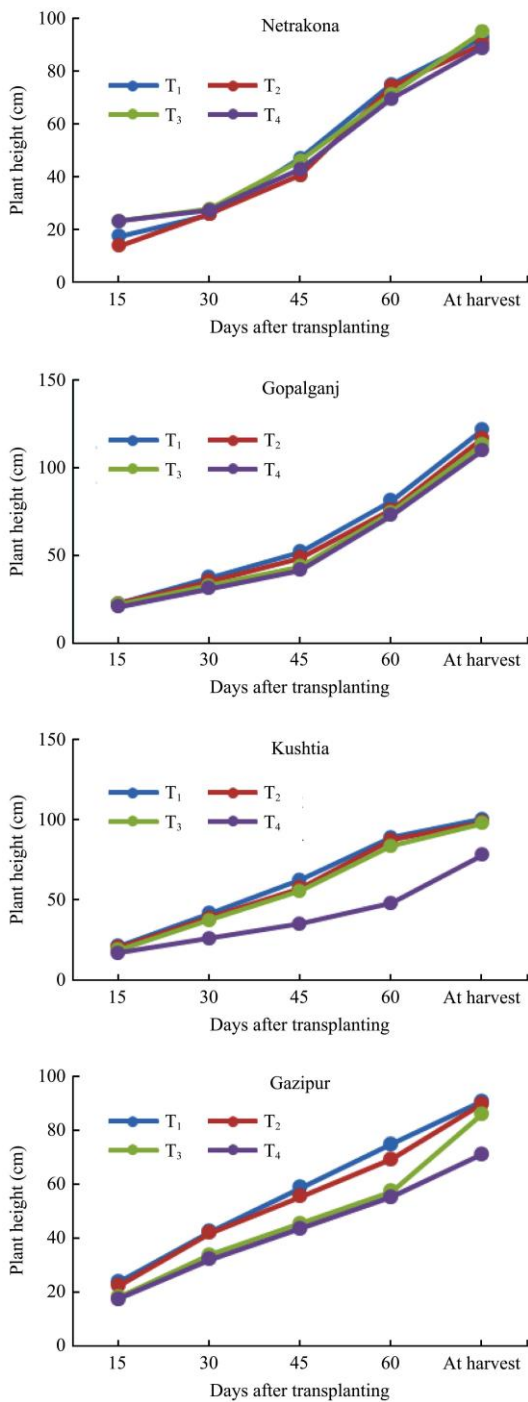


Figure 5 Plant height with respect to days after transplanting as affected by rate and application methods of urea fertilizer

3.2.2 Number of tiller

Netrakona: Number of tiller per hill at different date after transplanting varied with the mode of fertilizer application which is presented in Figure 6. At 60 days after transplanting and at harvest, tiller numbers of T₁, T₂ and T₃ were observed similar while it was significantly higher from T₄.

Gopalganj: Number of tiller per hill at different date after transplanting varied with the mode of fertilizer

application which is presented in Figure 6. At different date after transplanting, mechanical transplanting plots with fertilizer deep placement or without fertilizer deep placement gave higher number of tiller per hill compared to manual transplanting and fertilizer control plots whereas at harvest, there was no significant difference among T₁ (20.2), T₂ (17.0) and T₃ (14.2).

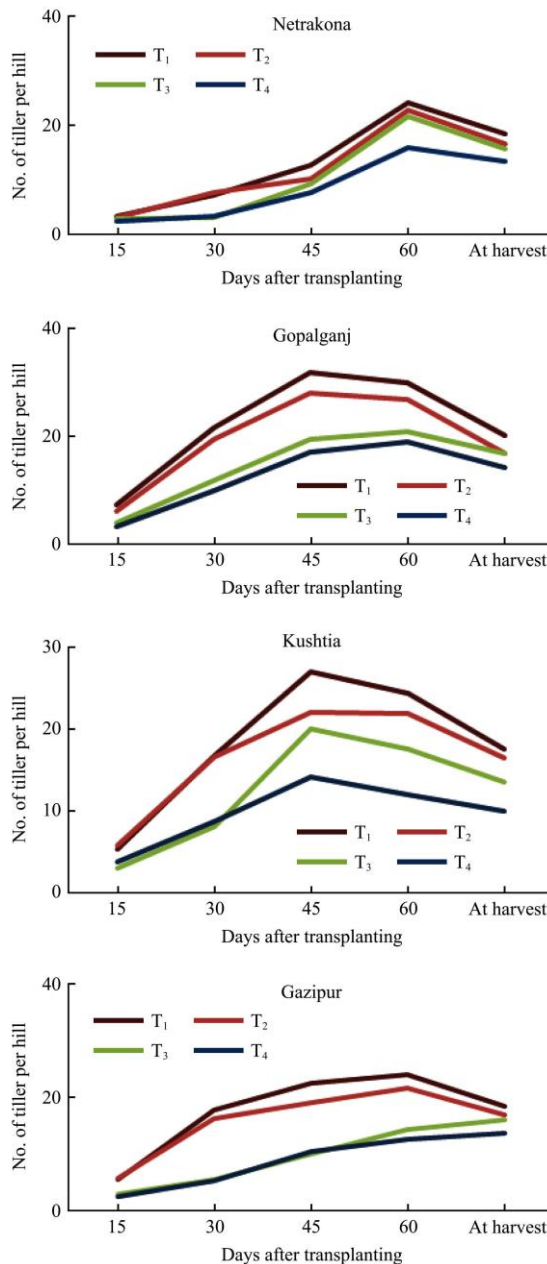


Figure 6 Plant population with respect of date after transplanting as affected by rate and application methods of urea fertilizer

Kushtia: Number of tiller per hill at different date after transplanting varied with the mode of fertilizer application which is presented in Figure 6. At 15 days after transplanting and at harvest, mechanical transplanting plots either fertilizer deep placement or without fertilizer deep placement gave similar number of

tiller per hill which was significantly higher than T₃ and T₄. At 30 and 45 days after transplanting, all the treatment varied significantly where T₁ gave higher number of tiller and T₄ gave fewer number of tiller.

Gazipur: Tiller number per hill with different date of transplanting at Gazipur is shown in Figure 6. It varied significantly at different date after transplanting. Significantly higher number of tiller was observed for T₁ and T₂ compared to T₃ and T₄. At harvest, only T₁ (18.4) gave significantly higher number of tiller from T₄ (13.7) whereas T₂ (16.8) and T₃ (16.1) gave similar number of tiller. Mechanical transplanting along with 70% of recommended dose of urea fertilizer deep placement gave similar number of tiller with mechanical transplanting along with full dose urea fertilizer broadcasting at three equal split.

3.3 Yield and yield contributing parameters

3.3.1 Grain yield performance

Grain yield varied with the mode and rate of urea fertilizer application (Table 8). Mechanical transplanting along with deep placement of urea fertilizer (70% of

recommended dose) gave significantly higher yield compared to manual transplanting and hand broadcasting of urea except Kumarkhali, Kushtia. In Madan, Netrakona and Bahirbhag, Gopalganj, mechanical transplanting along with 70% urea fertilizer deep placement gave significantly higher yield compared to the mechanical transplanting where recommended dose of urea fertilizer broadcasted manually at three equal split. In Kumarkhali, Kushtia and Sadar, Gazipur, yield of mechanical transplanting did not varied with amount and mode of urea fertilizer application. In Madan, Netrakona, yield of manual transplanting with traditional seedling and mechanical transplanting without fertilizer gave similar yield. It might be the cause of signal crop area. Deep placement of urea fertilizer as briquette form also gave higher yield compared to hand broadcasting method (Hossen, 2013). Average yield potential of BRRRI dhan28 and BRRRI dhan58 is 6.0 and 7.2 t ha⁻¹ (BRRRI, 2016a). Alizadeh (2011) reported that a 30% increase in yield in mechanical transplanting compared to the manual transplanting method.

Table 8 Yield performance as affected by mode and rate of urea fertilizer application

Treatments	Yield of BRRRI dhan28 and BRRRI dhan58 at different location (t ha ⁻¹ @ 14% m.c)			
	Modan, Netrakona (BRRRI dhan28)	Bahirbhag, Gopalganj (BRRRI dhan28)	Kumarkhali, Kushtia (BRRRI dhan58)	Sadar, Gazipur (BRRRI dhan28)
T ₁	5.74	8.27	7.37	5.51
T ₂	5.07	6.97	7.22	4.73
T ₃	3.97	5.92	6.80	4.06
T ₄	3.65	4.39	3.07	3.27
Level of significance	**	**	**	**
% of CV value	3.5	9.26	8.24	8.69
LSD	0.322	1.1825	1.0065	0.783

Note: T₁: Mechanical transplanting (MT) along with urea deep placement together (70% urea), T₂: MT + hand broadcasting of urea (UHB) at three equal split, T₃: Hand transplanting (HT) and UHB at three equal split and T₄: Control (-N). CV: Coefficient of Variation.

3.3.2 Straw yield performance

Grain yield varied with the mode and rate of urea fertilizer application (Table 9). Straw yield of machine transplanted field with or without urea fertilizer deep placement did not vary significantly. Significantly lower straw yield was observed in fertilizer control plots. In Gopalganj, Sadar and Gazipur, manual transplanted plots gave significantly lower straw yield compared to mechanical transplanting plots.

3.3.3 Harvest Index

Harvest index of the experimental crop under

different treatments were presented in Table 10. It did not vary with the rate and mode of fertilizer application over the locations and varieties. Khatun et al. (2016) observed 0.43 to 0.48 harvest index of BRRRI dhan28 for different N management in top dressing.

3.3.4 Yield contributing parameters

Yield contributing parameters influenced the grain yield directly. Hills per unit area and 1000 grain weight did not vary significantly. However, panicles per hill and filled grains per panicle did also not vary significantly with the mode and rate of urea application while it was

significantly higher than that of the control (Table 11 to 14).

Table 9 Straw yield performance as affected by mode and rate of urea fertilizer application

Treatments	Straw yield			
	Modan, Netrakona (BBRI dhan28)	Bahirbhag, Gopalganj (BBRI dhan28)	Kumarkhali, Kushtia (BBRI dhan58)	Sadar, Gazipur (BBRI dhan28)
T ₁	4.29	5.25	5.57	4.97
T ₂	4.44	4.93	5.12	4.22
T ₃	3.56	4.39	4.88	3.07
T ₄	2.72	3.31	2.06	2.45
Level of significance	*	**	**	**
% of CV value	15.56	9.26	10.81	11.79
LSD	1.17	0.83	0.95	0.87

Table 10 Harvest index (%) as affected by mode and rate of urea fertilizer application

Treatments	Harvest Index			
	Modan, Netrakona (BBRI dhan28)	Bahirbhag, Gopalganj (BBRI dhan28)	Kumarkhali, Kushtia (BBRI dhan58)	Sadar, Gazipur (BBRI dhan28)
T ₁	57.5	61.1	57.0	52.6
T ₂	53.6	58.5	59.7	52.8
T ₃	52.7	57.7	57.1	57.1
T ₄	57.3	57.0	59.6	60.4
Level of significance	NS	NS	NS	NS
% of CV value	5.56	4.36	3.78	7.02

Table 11 Yield contributing parameters as affected by mode and rate of urea fertilizer application at Netrakona

Treatments	Hills (m ²)	1000 gain wt (g at 14% mc)	Panicle (hill)	Filled grains (panicle)
T ₁	18.7	20.8	15.0	111.2
T ₂	18.7	21.6	12.6	106.4
T ₃	18.9	21.2	11.4	94.1
T ₄	18.6	22.6	8.3	99.2
% of CV	6.5	3.3	5.9	7.3
Level of significance	NS	NS	**	*
LSD	-	-	1.4	11.3

Table 12 Yield contributing parameters as affected by mode and rate of urea fertilizer application at Gopalganj

Treatment	Hills (m ²)	1000 gain wt (g at 14% mc)	Panicle (hill)	Filled grains (panicle)
T ₁	21.0	20.9	19.3	110.6
T ₂	20.9	20.6	16.6	99.2
T ₃	18.7	21.1	14.5	98.3
T ₄	18.1	21.5	12.9	89.8
% of CV	6.7	6.3	15.8	11.2
Level of significance	NS	NS	*	*
LSD	-	-	5.0	12.1

Table 13 Yield contributing parameters as affected by mode and rate of urea fertilizer application at Kushtia

Treatment	Hills (m ²)	1000 gain wt (g at 14% mc)	Panicle (hill)	Filled grains (panicle)
T ₁	21.2	21.6	16.9	98.7
T ₂	21.6	21.6	15.8	99.7
T ₃	18.2	22.2	13.1	105.1
T ₄	18.5	22.5	9.8	80.6
% of CV	9.3	2.0	11.8	11.5
Level of significance	NS	NS	**	**
LSD	-	-	3.3	21.8

Table 14 Yield contributing parameters as affected by mode and rate of urea fertilizer application at Gazipur

Treatment	Hills (m ²)	1000 gain wt (g at 14% mc)	Panicle (hill)	Filled grains (panicle)
T ₁	20.8	21.3	17.7	73.8
T ₂	21.4	22.1	15.8	74.5
T ₃	19.3	21.9	14.0	71.6
T ₄	18.8	22.0	12.8	66.0
% of CV	15.0	1.9	11.3	19.9
Level of significance	NS	NS	*	
LSD	-	-	3.4	8.4

3.4 Economic performance

Operation cost of rice transplanter (RT) and BBRI rice transplanter cum prilled urea applicator is presented in Table 15. RTPUA accounted the highest BCR of 1.55, 1.67, 1.79 and 1.49 at Netrakona, Gopalganj, Kushtia and Gazipur, respectively for 70% of the recommended urea fertilizer application in non-oxidize zone followed by mechanical transplanting plots along with hand broadcasting of urea fertilizer (1.35, 1.38, 1.70 and 1.25) as presented in Table 15.

Table 15 Benefit-cost ratio as affected by mode and rate of urea fertilizer application

Treatments	Input cost (Tk ha ⁻¹)	Gross return (Tk ha ⁻¹)	Gross margin (Tk ha ⁻¹)	BCR
Netrakona				
T ₁	78446	121235	42789	1.55
T ₂	80130	108060	27930	1.35
T ₃	83160	84740	1580	1.02
T ₄	81278	77080	-4198	0.95
Gopalganj				
T ₁	78940	131925	52985	1.67
T ₂	80836	111945	31109	1.38
T ₃	83866	95385	11519	1.14
T ₄	81278	70815	-10463	0.87
Kushtia				
T ₁	78940	141015	62075	1.79
T ₂	80836	137640	56804	1.70
T ₃	83866	129720	45854	1.55
T ₄	81278	58350	-22928	0.72
Gazipur				
T ₁	78940	117655	38715	1.49
T ₂	80836	100930	20094	1.25
T ₃	83866	85805	1939	1.02
T ₄	81278	69075	-12203	0.85

4 Conclusions

Mechanical rice transplanter is a promising technology considering the present labor crisis in Bangladesh. Prilled urea deep placement technology successfully incorporated with the walking type rice transplanter and evaluated in different locations of Bangladesh. Grain and straw yield was found more for mechanical transplanting along with fertilizer deep placement while BCR was also found more for 70% of urea fertilizer application in non-oxidize zone simultaneous with mechanical transplanting over the traditional practices. Prilled urea deep placement in the field simultaneously with the rice seedling transplanting reduce the fertilizer cost as well as production cost over traditional practices and increase the productivity of rice.

5 Recommendations

- Extensive field evaluation under different soil conditions is needed for the adaptation of the machine
- Incorporate the technology to the riding type rice transplanter

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