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# Development of mixed fertilizer deep placement technology into soil simultaneously with mechanical rice seedling transplanting

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***Key Words:***
*Design, Power transmission, Calibration, Fertilizer dispensing and Field evaluation.*

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## ABSTRACT

*A mixed fertilizer deep placement technology was designed and incorporated in the walking type rice transplanter (ARP-4UM) to place fertilizers into the soil (non-oxidized zone) and evaluated in the irrigated dry season (Boro) 2018-19 and the non-irrigated wet season (Aman) 2019 season. A spiral screw was used in the fertilizer chamber as a metering device to receive and dispense the desired amount of fertilizer during field operation. Engine power of the rice transplanter(1800 rpm) was conveyed to the metering device of the applicator with the arrangement of a belt-pulley, worm gearing, shaft-bearing, universal joint and bevel gear with engage-disengage facility resulting 23 rpm of the metering device of the applicator. Spiral screw type metering device was connected with the main shaft of the applicator to collect mixed fertilizer from hopper and dispense to the output channel of the applicator at a desired rate based on variety and seasons. A measuring scale mentioning 1 to 8 numbers 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 mixed 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 the 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 or clogging of mixed fertilizer during dispensing in operation. Power transmission from engine to the metering device of the applicator through different stages was also found smooth, safe and heavy duty. In Aman 2019 season, the developed walking type rice transplanter was evaluated in 07 different locations of the country while it was evaluated in 02 locations during Boro 2018-19 season. 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 clogging of the dispensing channel of the transplanter during operation. In an average of two trials, theoretical and actual field capacity and field efficiency of the RTFA was 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. In an average of seven trials, theoretical and actual field capacity and field efficiency of the RTFA was 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.*

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## I. Introduction

Rice, a dominant and staple food crop, plays an important role in food security of about 160 million people in Bangladesh. Nearly 48% of rural employment, about two-third of total calorie supply and one-half of the total protein consumption of the country's people depend on rice (BRKB, 2018). Rice cultivation area, overall production, per unit yield, and cropping intensity expanded appreciably over the last 45 years. Except for those, employed labor in the agricultural sector decreased remarkably due to increasing rural to urban migration with the growth of non-farm employment opportunities, inflicting rural labour shortages (Ziauddin and Ahmed, 2010). Half of agricultural GDP and one-sixth of rural household income depends on rice (Rahman et al., 2016). Modernization of rice production is the utmost need to feed the growing population of the country from gradually decreasing land. It mostly depends on the promotion of agricultural mechanization that helps to enhance the agricultural and food production of the country (Hossen, 2019). Nevertheless, agricultural mechanization is played a key function within the agro-food value chain system for sustainable production augmentation (Breuer et al. 2015). As we know, agriculture plays an extremely important role in Bangladesh's economy as well as agricultural mechanization which has been accelerated in Bangladesh in recent years. Its degree of overall development remains rather low as compared to different South Asian countries. Over the last twenty years, farm power increased rapidly due to adoption of agricultural machinery. Raising more production with high productivity is one of the ways to fulfill future food demand (Singh et al. 2019). Development, popularization to the end-user and adoption of suitable, precision, reliable and cost-effective machinery is the critical need for conservation and realistic use of production inputs.

Irrigation, tillage, threshing and some intercultural operation mechanized significantly in Bangladesh over the last two decades, while transplanting and harvesting mechanization is still low. Manual transplanting is tedious and time consuming which frequently causes delayed rice transplanting because of labour crisis. One month delayed of transplanting reduces yield about 25% while two months delayed reduces yield about 70% (Rao and Pradhan, 1973). A total of 156.2 man-days is required for rice production in one hectare of land from which 44.5 man-days (28.24% of total labor requirement) are consumed by seedling raising and transplanting (Rahman, 1997). Thus, mechanized rice transplanting is seen as an answer to the present labour crisis. However, rice seedling transplanting using mechanical rice transplanter ensures uniform plant spacing as well as fast and efficient planting also. Mechanized transplanting is gaining popularity in Bangladesh due to its potentiality and different private and governmental intervention. Multifunctional use of rice transplanter could accelerate the popularity of the end users. With this point of view, mixed fertilizer (Urea, TSP, MoP and Gypsum) deep placement (FDP) mechanisms incorporate with the existing walking type rice transplanter. Deep placement of either urea fertilizer or NPK fertilizer significantly increased grain yields and net economic return across all the rice-growing seasons and years compared to traditional practices (Miah et al., 2016) because only 30 to 50% N used effectively by the plant from top dressing of urea fertilizer (Savant and Stangel, 1990). The performance of N use is low due to ammonia volatilization, denitrification, leaching, and surface runoff. Ammonia volatilization from a wetland rice field as N losses is greater than 50% of the applied N (Dong et al., 2012). Topdressing prilled urea fertilizer produced higher amounts of ammonium N in floodwater compared to deep placement of urea (Kapoor et al., 2008). The higher amount of ammonium N in floodwater leads to a higher amount of ammonia volatilization loss (Rochette et al., 2013). However, broadcast application of N, P, and K fertilizers increases nutrients concentration in floodwater (Kapoor et al., 2008) that leads to significant losses with surface runoff. Urea fertilizer deep placement (UDP) or fertilizer (Urea, TSP, MoP and Gypsum) deep placement (FDP) is an effective management practice for wetland transplanted rice by increasing its productivity and reducing fertilizer losses (Misra et al., 1995 and Bowen et al., 2005). Fertilizer losses to the atmosphere, groundwater and waterways are drastically reduced by applying into soil at non-oxidized zone. By using UDP technology, yield also increased significantly with less use of urea about 10-20 as compared to prilled urea (OFRD, 2009).

To apply fertilizer into soil at non-oxidized zone, BRRI has been developed a push type prilled urea applicator (BRRI, 2018). It was found suitable during field trials in different soil conditions and seasons though it is laborious to operate manually. In addition, farmers need an additional one machine for fertilizer application and only urea fertilizer can be placed into soil at non-oxidized zone. Hence, an endeavor has been undertaken to attach the fertilizer deep placement technology (suitable for either urea alone or combination of urea, TSP, MoP and Gypsum together) to the prevailing mechanical rice transplanter (both the walking and riding) without sacrificing the merit of transplanting to confirm both the mechanized rice transplanting and mixed fertilizer deep placement simultaneously.

## II. Materials and Methods

Mixed fertilizer deep placement technology added with the walking type rice transplanter (Model: ARP-4 UM, South Korea). Power transmission from engine to the applicator, fertilizer dispensing mechanism including spiral screw type metering device, frame, skid, fertilizer hopper, agitator for continuous mixing of the mixed fertilizer, furrow opener in between consecutive lines of transplanted rice seedling and furrow closer incorporated to the rice transplanter using locally available materials. The fertilizer dispensing and cover mechanism incorporated in such a way that the farmers can use the technology with the mixed fertilizer deep placement mechanism or without the mixed fertilizer deep placement mechanism. Single or mixed fertilizer can be applied during operation with pre-calibration.

**Location of the study:** Mixed fertilizer deep placement mechanism was designed, fabricated and modified in the Farm Machinery and Post-harvest Technology divisional research workshop of BRRI to incorporate with the walking type rice transplanter (RT). Developed technology was evaluated in the divisional soil bin, BRRI research farm and different project locations of the country. In Boro 2018-19 season, developed technology was evaluated at Kushtia and Habiganj, respectively whereas it was evaluated at Sadar, Rangpur; Sadar, Gazipur; Mirpur, Kushtia, Kumarkhali, Kushtia; Purbadhala, Netrakona; Shaistaganj, Habiganj in Aman 2019 season.

### Mixed fertilizer deep placement technology design, development and combined with the rice transplanter

**Rice transplanter selection:** Power-operated walking-type rice transplanter was used for design and development. The major specification of the transplanter is given in Table 01.

**Design considerations:**

- Mixed fertilizer deep placement (FDP) should be done into soil in between two rows and before the rotary picker of the transplanter,
- Existing power of the RT should be used to operate the FDP technology,
- Depth placement of mixed fertilizer should be done in between 80 to 100 mm,
- Uniformity of fertilizer dispensing should be maintained during operation,
- Power transmission system should be simple to engage and disengage facility,
- Locally available and low cost materials should be used to minimize the fabrication cost.

**Table 01. Description of the walking type of rice transplanter (RT)**

| Country of origin and Model | | South Korea and ARP-4UM |
|---|---|---|
| Dimensions | Overall length × width × height (mm) | 23505 × 1480 × 800 |
| | Overall weight (kg) | 175 |
| | Maximum output kW $rpm^{-1}$ | 3/1800 |
| Travelling 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 |

**Design steps:**

- Engine power transmitted using belt-pulley arrangement with tension pulley to transmit power from the engine shaft to an additional shaft attached in the same axis with engage and disengage facility.
- A simple gearbox including single start worm gearing was designed and attached to the rice transplanter to reduce rpm at the ratio of 20:1.
- A pair of bevel gear was attached in the applicator shaft to change the rotational direction at $90^0$ at the ratio of 1:1.
- Spiral type fertilizer metering device was designed and attached in front of mat type rice seedling holding tray of the RT to collect and dispense fertilizer at desired rate.
- Skid in between two rotary pickers was attached with a 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.

**Fabrication:** Mixed fertilizer deep placement mechanism was designed based on basic principle of machine design and drawing was done using AutoCAD tools. A Prototype was fabricated in FMPHT divisional research workshop. The existing facility of the workshop was used to develop the transplanter.

**Power transmission from engine to the mixed fertilizer applicator:** Walking type of rice transplanter was modified to receive engine power for FDP technology. Engine power available 1800 rpm of the walking type rice transplanter was conveyed to the applicator with the arrangement of a belt-pulley, worm gearing, bevel gear and universal joint mechanism with an engage-disengage facility resulting 23 rpm of the main shaft of the applicator (Figure 01). For whom, farmers can choose the transplanter either for both operations or only for seedling transplanting.

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 groove to the main gear pulley. In these stages, power reduced from 1800 rpm to 810 rpm. From main gear pulley, power transmitted to the worm gear pulley at the ration of 1:1.7 ratio to reduce from 810 rpm to 460 rpm. Power again reduced in the worm gearing mechanism at the ratio of 1:20 to reduce the rpm from 460 to 23. From output shaft of the worm gear, power transmitted to the applicator's main shaft using the universal joint. Bevel gear also used in the applicator shaft to change the direction of power at 90 degrees intersecting shaft at the same velocity ratio.

**Power transmission:** In walking type rice transplanter, power conveyed to the applicator from engine reducing in different stages. Power reduction states as Prime mover rpm 1800 (engine shaft rpm)>Rice transplanter main gear rpm 810 (using belt pulley arrangement at a ratio of 1:2.2)>Worm gear input shaft rpm 460 (using belt pulley at the ratio of 1:1.76)> Worm gear output shaft rpm 23 (using worm

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gearing which speed ratio: 1:20)>Universal joint shaft rpm 23 (received power from output shaft of the worm gear)>Applicator shaft rpm at $90^0$ rotation 23 (bevel gear used at the ratio of 1:1).

**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 circular pitch was found 10.21 mm. Worm and worm gear wheel was fabricated using high carbon and phosphorus bronze materials. Size of the gearbox is 140 x 85 x 120 mm, material-cast iron and thickness-4 mm. Detail design of the worm gears is given in Figure 02, Figure 04 and Figure 05.

Bevel gear was also used in the applicator shaft to convert the rotation at 90 degrees to the intersecting shaft (Figure 03). It was made of untreated cast steel material to transmit power at a velocity ratio of 1:1 between shafts. In the developed rice transplanter cum mixed fertilizer applicator, bevel gear of equal teeth were used. 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 module-3.25.

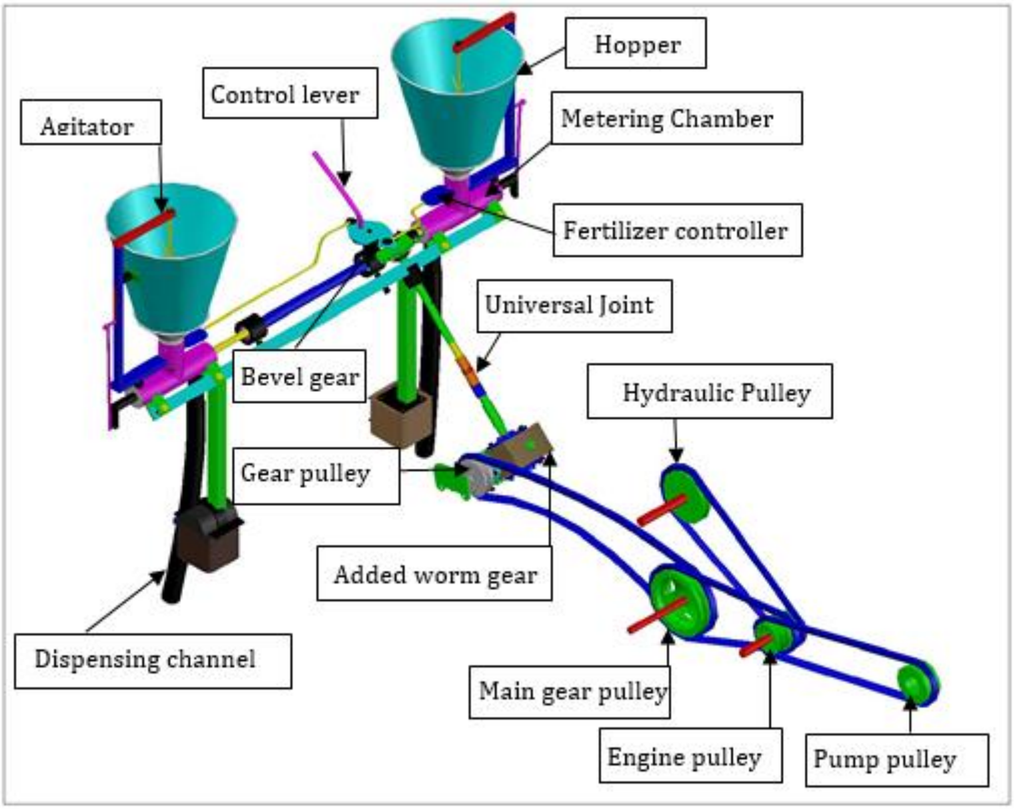


**Figure 01. Isometric drawing view of power transmission from engine to the mixed fertilizer applicator**

**Metering device:** Spiral conveying type metering device was used in the developed rice transplanter. Mixed fertilizer dispensed to the inner chamber of the metering device due to continuous agitation of the agitator (Figure 06). Spiral conveyor of the metering device conveyed fertilizer mixture from inner chamber to the outlet pipe connected with the chamber (Figure 07, Figure 08 and Figure 09). Fertilizer dispensing rate increased with the increase of opening in between fertilizer hopper and fertilizer metering chamber which can be controlled by a lever (Figure 10). Rate of fertilizer dispensing can be controlled by adjusting the lever based on rice growing season and variety.

**Fertilizer control lever:** Fertilizer control lever was attached to control the opening of the fertilizer hopper to maintain desire rate of fertilizer dispensing. Two link mechanisms were attached to close and open the opening channel. There have measuring scale marking from points 1 to 8. With the increase of the lever point, the opening of the dispensing channel also increases (Figure 10).

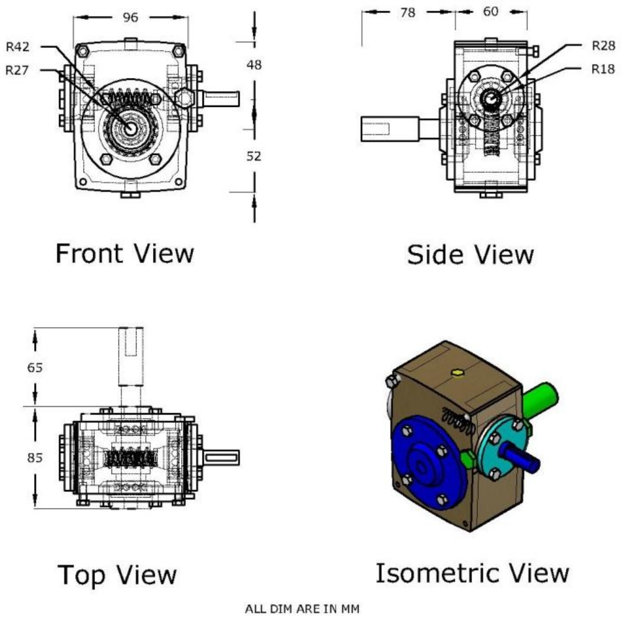


**Figure 02. Single start worm gear**

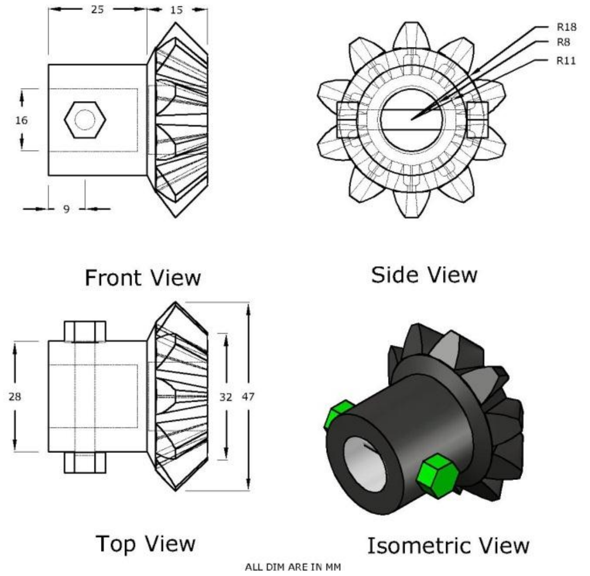


**Figure 03. Bevel gear**

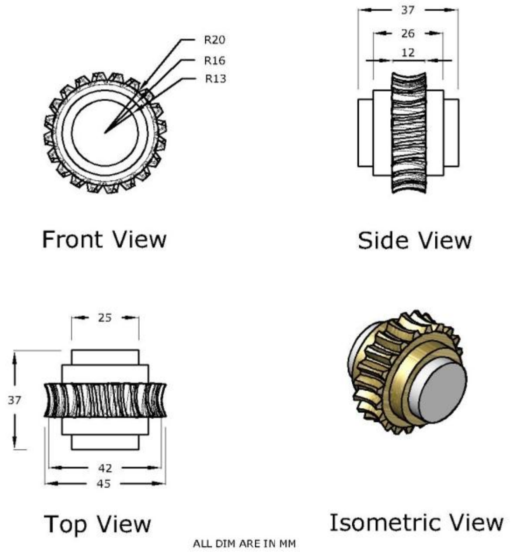


**Figure 04. Worm wheel**

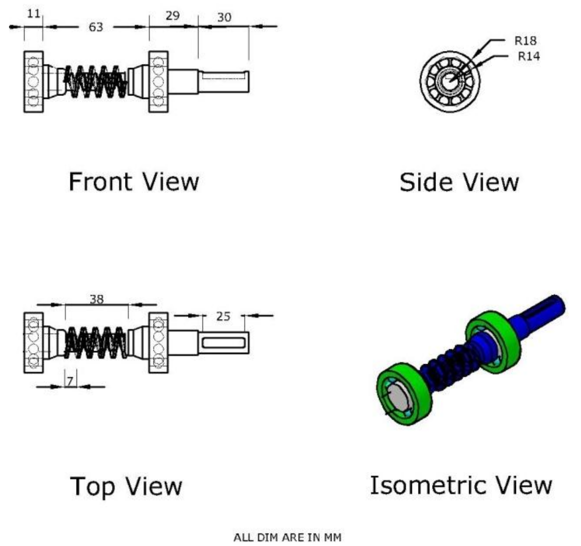


**Figure 05. Worm screw**

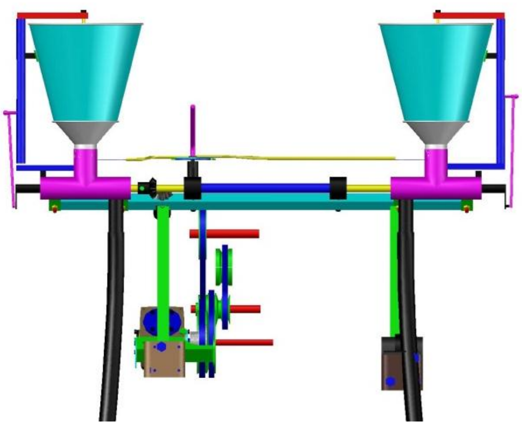

**Figure 06. Schematic view of metering device assembling along with agitator**

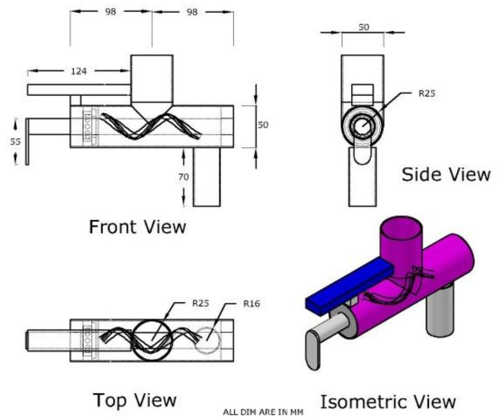


**Figure 07. Isometric view of metering device assembling**

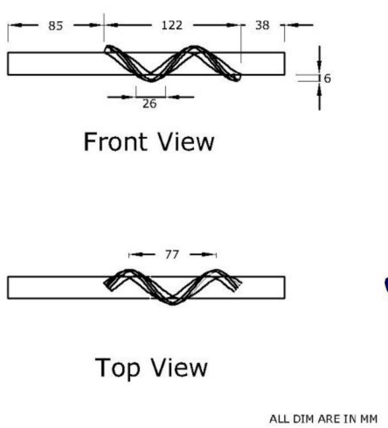


**Figure 08. Spiral conveyor**

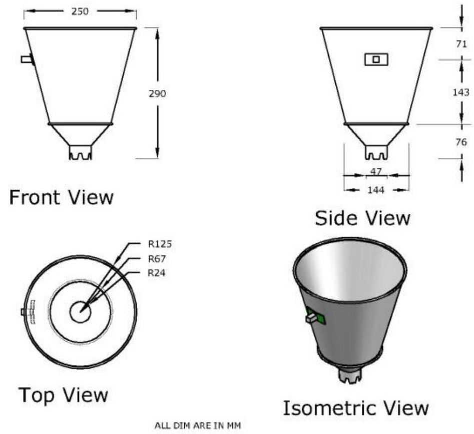


**Figure 09. Fertilizer chamber**

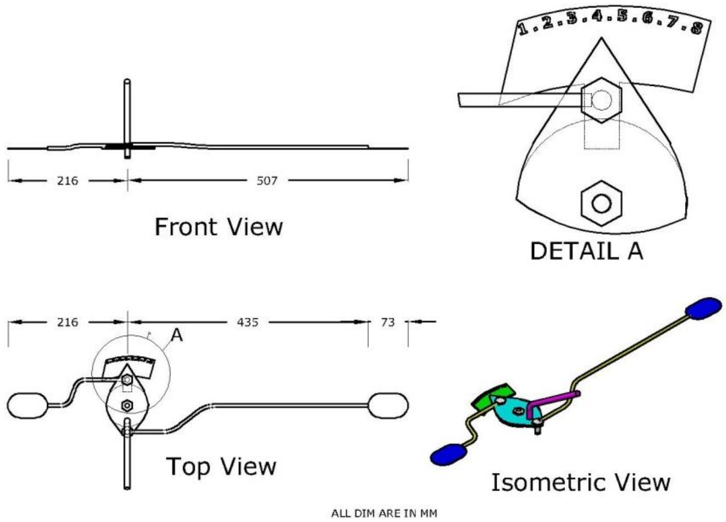


**Figure 10. Fertilizer control lever**

**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 were taken into consideration to design the skids. A complete view of mixed fertilizer applicator is shown in following figure along with skid arrangement in Figure 11.

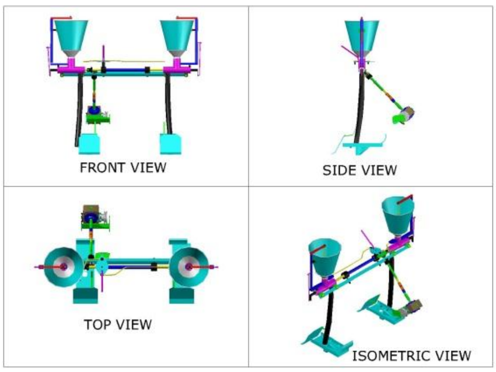


**Figure 11. Schematic view of skid along with other accessories**

**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 at Kushtia and Habigonj during irrigated dry Boro season 2018-

2019. It was also evaluated in different 07 locations (Sadar, Rangpur-BRRI dhan71; Sadar, Gazipur-BRRI dhan71; Mirpur, Kushtia-BRRI dhan87, Kumarkhali, Kushtia 1-BRRI dhan75; Kumarkhali, Kushtia 2-BRRI dhan87; Purbadhala, Netrakona-BRRI dhan71; Shaistaganj, Habiganj-BRRI dhan71) during Aman 2019 season.

**Experimental design and treatments:** Randomized complete block (RCB) design was applied to experiment with three replications. Sufficient spacing (about half meter) was allowed as buffer spacing to keep the plots isolated from each other. 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

**Mixed fertilizer deep placement:** Urea fertilizer along with TSP, MoP and Gypsum fertilizer was 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 02). A total of 280 kg ha$^{-1}$ urea fertilizer was allowed as BRRI recommended dose for BRRI dhan29 and BBRI dhan58 (BRRI, 2017) where 224 kg ha$^{-1}$ urea fertilizer (80% of the recommended dose) was only applied into soil at non-oxidized zone. TSP, MoP and Gypsum fertilizer were 100, 165 and 112 kg ha$^{-1}$ as recommended dose, respectively. All fertilizer was placed in non-oxidized zone during mechanical transplanting with the same machine. Before operation of the BRRI rice transplanter cum fertilizer applicator in the field, it was calibrated to maintain the pre-designed dose of fertilizer (Table 02).

On 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, 2018). Fertilizer dispensing rate per rotation of the driving wheel of the rice transplanter was determined using the following formula (Hossen et al., 2019) to maintain the desired rate of fertilizer.

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

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 = Line to line spacing of the transplanted rice, cm
RoF = Desired rate of fertilizer application, kg ha$^{-1}$

**Table 02. Calibration of mixed fertilizer (g/rotation)**

| Urea fertilizer (80% RD) (kg ha$^{-1}$) | TSP fertilizer (kg ha$^{-1}$) | MoP fertilizer (kg ha$^{-1}$) | Gypsum fertilizer (kg ha$^{-1}$) | Total amount 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 |

Note: RD-Recommended dose; The theoretical dispensing rate of mixture fertilizer was calculated 67.94 and 37.87 g/rotation of the driving wheels from each channel in Boro and Aman seasons, respectively.

**Field performance of the developed rice transplanter**

**Field capacity:** Rate of area coverage (field capacity) of the rice transplanter was measured during field operation with and without mixed fertilizer deep placement into soil at non-oxidized zone with seedling transplanting. Machine operation time included time required during turning of the transplanter, feeding of seedling, fertilizer refilling in the hopper, operator’s 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.

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**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.

**Operating cost of the transplanter cum prilled urea applicator:** 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, 1973). 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 )

**Statistical analysis:** Data will be analyzed as a single factorial design according to Gomez and Gomez (1984) using Statistics 10 program (Statistics 10 software, 2013). Means will be compared with the least significant difference (LSD) test. Simple correlation analysis will be carried out with Excel 2010 to determine the relationship of the machine performance.

## III. Results and Discussion

**Rice transplanter cum fertilizer applicator design, development and fabrication:** 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 are presented in Figure 12.

**Figure 12. Rice transplanter cum mixed fertilizer applicator**

**Worm and bevel gearing:** Worm gearing was designed to reduce rpm of the prime mover at a ratio of 20:1 (Figure 13). Therefore, velocity ratio of the worm gearing is (VR) 20. Circular pitch, $P_a$ = $P_C$ =10 mm (assumed). Thus, module, m = $P_C/\pi$ = 10/3.14 = 3.18 mm. Standard values of module (m) near to the calculated value is 3.25 mm. Based on the standard module (m=3.25 mm), actual circular pitch, $P_c$ = $P_a$ = 10.21 mm. Calculated worm gear speed, $N_G$ = 23 rpm and number of teeth of worm gear, $T_G$ = 20 for $N_W$=460 and VR=20. Standard number of teeth for designing, $T_G$=20 was taken for single start worm. Bevel gear was used for same velocity ratio to transmit the power at $90^0$ direction where shaft angle $20^0$. Circular pitch assumed 10 mm and standard module 3.25. Mild steel materials were used to fabricate the bevel gear (Figure 13).

| Gear box | Worm gear | Bevel gear |
|---|---|---|
| Size: 140mm × 85mm × 120 mm | Worm: Single start | Pinion: 11 teeth |
| Material: Cast iron | Worm gear: 20 teeth | Gear: 11 teeth |
| Thickness: 4 mm | Speed ratio: 20:1 | Speed ratio: 1:1 |
| | Shaft: 12 mm | Shaft: 12 mm |

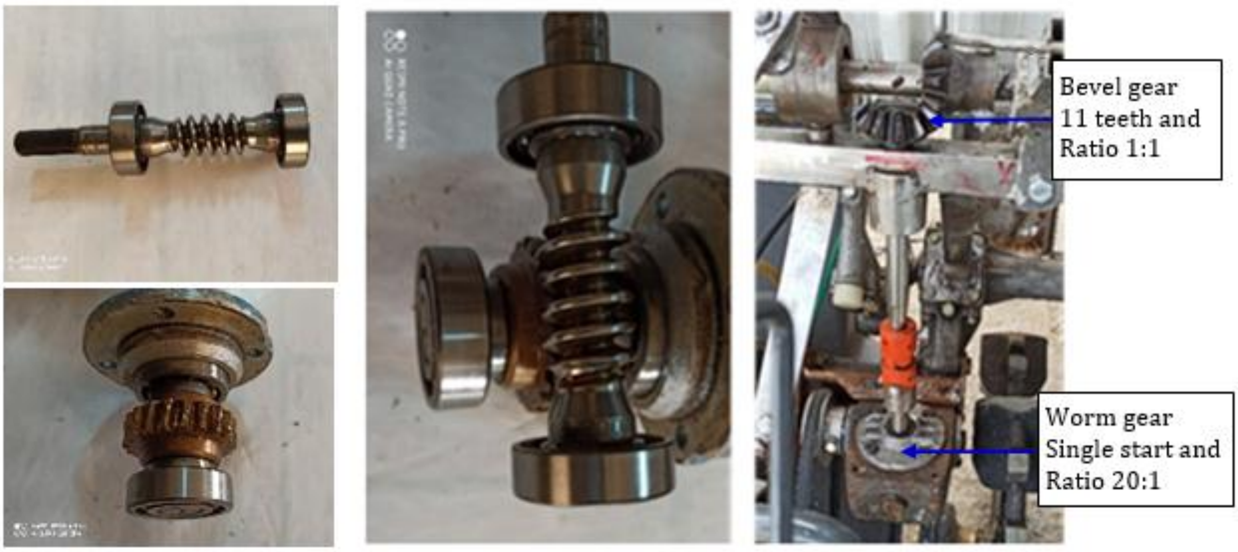


**Figure 13. Gear box incorporating with warm gearing and bevel gearing**

**Universal joint shaft:** One or more rotating shafts can be linked by a universal joint together. It allows to transmit torque and/or rotary motion as a mechanical device. It also allows transmitting power between two shafts that are not in the same line with each other. In the developed rice transplanter, a universal joint shaft was used to transmit power and rotation from incorporated gear output shaft to the applicator shaft (Figure 14).

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**Figure 14. Universal joint shaft**

**Metering device:** Stainless steel materials were used to fabricate spiral conveying type metering device (Figure 15). Details of spiral screw (Figure 16) are as follows:

| | | | |
|---|---|---|---|
| Pitch length | : 75 mm | Height | : 4.5 mm |
| Total length | : 105 mm | Root width | : 11.5 mm |

Distance from hopper center to outlet pipe center: 35 mm

**Figure 15. Spiral screw type metering device**

**Figure 16. Spiral screw attached in the metering chamber**

**Fertilizer control lever:** Fertilizer rate control mechanism was connected using two link cross connected mechanism. Opening of the dispensing channel controlled with the changing of position of the lever (Figure 17).

There have 1 to 8 marks scale to determine the desired rate of fertilizer based on season and variety. Before field operation of the machine, it is essential to calibrate the fertilizer application rate based on season and variety. Calibrated doses of fertilizer are 67.94 g/rotation in Boro season and 37.87 g/rotation in Aman season based on the total amount of fertilizer (Urea, TSP, MoP, Gypsum) 601 and 335 Kg/ha. In laboratory tests, the calibrated amount of fertilizer dispensed at lever positions 4 and 3 for Boro and Aman season, respectively (Table 03). Dispensing rate can be adjusted between two lever positions based on desired rate.

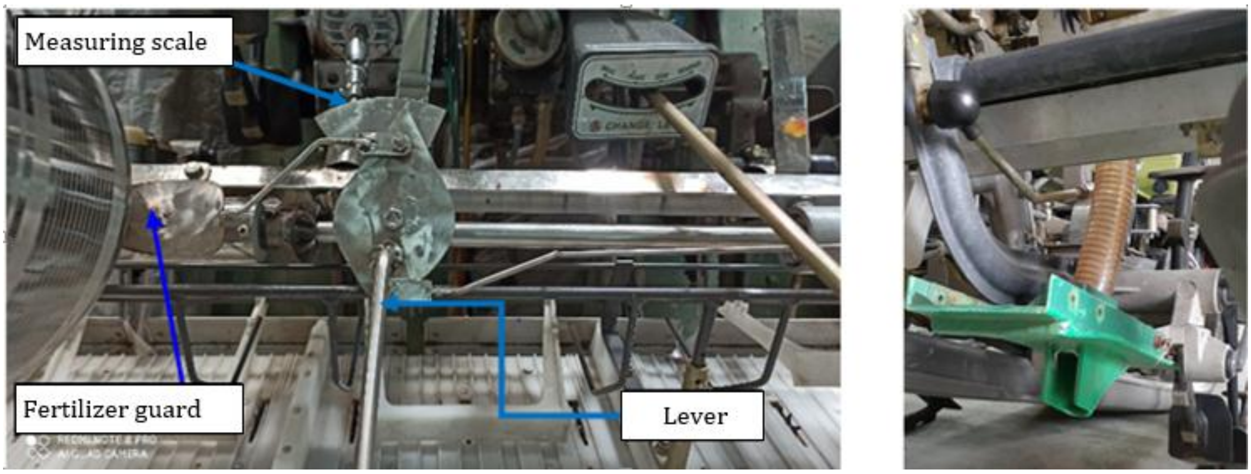


**Figure 17. Fertilizer control lever and skid along with furrow opener and closer**

**Skid:** Metallic dies were prepared to mold plastic skid as per design. Skid was build based on space in between two rows of the transplanter and maximum of 10 cm depth of penetration of the skids during field operation. The bottoms of the applicator and transplanter skids were maintained same height horizontally. The depth of fertilizer placement can be adjusted easily considering field conditions. A complete view of the fabricated view of the skid is shown in following Figure 17.

**Table 03. Fertilizer dispensing rate per rotation (g/rotation) of the driving wheel of the transplanter under different position of the lever**

| Season | Total amount of fertilizer (Kg/ha) | Lever position | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Boro | 601 | 18.25 | 28.50 | 37.90 | **67.94** | 75.80 | 82.65 | 95.25 | 105.75 |
| Aman | 335 | 18.20 | 28.47 | **37.87** | 67.90 | 75.75 | 82.25 | 95.00 | 105.67 |

Note: Mixing ratio of urea, MoP, Gypsum and TSP in Boro season: 2.24: 1.65: 1.12: 1 and in Aman season: 2.16: 1.34: 0.9: 1 while total amount of fertilizer is 601 and 335 kg/ha considering 80% urea of the recommended dose. Average of 5 trails are presented in the table.

**Operational procedure:** The walking type of rice transplanter was modified by incorporating mixed fertilizer deep placement mechanism. During transplanter operation, the following procedure needs to be followed for successful placement of mixed fertilizer into soil.

- Before the engine start of the rice transplanter and field operation, power of applicator should be disengaged.
- Lubricant and grease need to be checked off the applicator gear box before the operation.
- Proper tension of the belts also needs to be checked before the operation.
- Power of the fertilizer applicator should be engaged as soon as the start of seedling transplanting.
- Power of the applicator again disengaged at the end of field during turning to avoid unnecessary loss of fertilizer.
- Re-filled the hopper of mixed fertilizer from time to time before whole fertilizer dispensed.
- Additional amount of mixed fertilizer needs to be carried like seedling mat for re-filing the hopper in the field as and when necessary.

**Field evaluation of the rice transplanter cum fertilizer applicator**

**Field capacity of the RTFA:** 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 and in 07 locations during Aman 2019 seasons (Table 04 and Table 05). 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 whiles it was 0.19 and 0.21 ha $hr^{-1}$ in Aman 2019 season, respectively. 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 04. Field performance of the RTFA in Boro 2018-19 Season**

| Treat. | Area (Decimal) | Operation time (min) | Forward speed (km/h) | Actual field capacity (ha/h) | Theoretical field capacity (ha/h) | Efficiency (%) |
|---|---|---|---|---|---|---|
| **Mirpur, Kushtia** | | | | | | |
| $T_1$ | 33 | 73 | 1.5 | 0.11 | 0.19 | 57.9 |
| $T_2$ | 40 | 67 | 1.62 | 0.12 | 0.19 | 63.2 |
| $T_3$ | 32 | - | | 0.006 | | |
| **Shaistaganj, Habiganj** | | | | | | |
| $T_1$ | 20 | 67 | 1.63 | 0.12 | 0.20 | 60.0 |
| $T_2$ | 26 | 62 | 2.69 | 0.13 | 0.20 | 65.0 |
| $T_3$ | 27 | - | | 0.006 | | |
| | Average | | | | | |
| | | $T_1$ | 1.57 | 0.12 | 0.20 | 58.95 |
| | | $T_2$ | 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

However, field efficiency was obtained 58.95 and 64.10% with and without fertilizer deep placement mechanism in Boro season whereas it was 80.66 and 80.60 in Aman season, 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 due to improvement of the technology, good seedling and field quality. Field capacity and field efficiency were higher to some extent without fertilizer deep placement mechanism during transplanting due to extra fertilizer re-filling time and slow of operation.

**Table 05. Field performance of the RTFA in Aman 2019 Season**

| Treatments | Area decimal (Decimal) | Time of operation (min) | Forward speed (km/h) | AFC (ha/h) | TFC (ha/h) | Efficiency (%) |
|---|---|---|---|---|---|---|
| **Sadar, 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 | - | | 0.006 | | |
| **Sadar, 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 | - | | 0.006 | | |
| **Mirpur, Kushtia** | | | | | | |
| $T_1$ | 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 | - | | 0.006 | | |
| **Kumarkhali, 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 | - | | 0.006 | | |
| **Kumarkhali, 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 | - | | 0.006 | | |
| **Purbadhala, 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 | - | | 0.006 | | |
| **Shaistaganj, 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 | - | | 0.006 | | |
| | | 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 and TFC-Theoretical Field Capacity

**Actual amount of fertilizer application:** 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 dispending amount of fertilizer was calculated to determine percentage of deviation (Table 06). In Boro season, calibrated rate of fertilizer was 67.98 and 68.03 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 and again evaluated in Aman season. In Aman season, 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-Kushtua (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.

**Table 06. Percent of deviation from calibrated amount of fertilizer as affected by soil condition and location in Boro 2018-19 and Aman 2019 season**

| Treat. | *Area in Deci | Recommended amount of fertilizer(Kg/ha) | | | | | Actual amount of dispensed (Kg) | Dispensing rate (g/rotation) | | % of deviation |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Urea** | TSP | MOP | Gyp | Total | | Calibrated | Actual | |
| | | | | | Boro 2018-19 season | | | | | |
| Kushtia | 33 | 29.9 | 13.4 | 22.1 | 14.9 | 80.3 | 79.6 | 67.98 | 67.39 | +0.87 |
| Habiganj | 20 | 18.1 | 8.1 | 13.4 | 9.1 | 48.7 | 45.5 | 68.03 | 63.56 | +6.57 |
| | | | | | Aman 2019 season | | | | | |
| Rangpur | 22 | 11.9 | 5.5 | 7.4 | 5.0 | 29.7 | 31.2 | 37.72 | 39.62 | -5.05 |
| Gazipur | 18 | 9.7 | 4.5 | 6.1 | 4.1 | 24.3 | 26.1 | 37.72 | 40.51 | -7.41 |
| Mirpur, Kushtia | 22 | 11.9 | 5.5 | 7.4 | 5.0 | 29.7 | 30.5 | 37.72 | 38.73 | -2.69 |
| K. Kushtia1 | 20 | 10.8 | 5.0 | 6.7 | 4.5 | 27.0 | 28.0 | 37.72 | 39.11 | -3.70 |
| K. Kushtia2 | 22 | 11.9 | 5.5 | 7.4 | 5.0 | 29.7 | 30.5 | 37.72 | 38.73 | -2.69 |
| Netrakona | 28 | 15.1 | 7.0 | 9.4 | 6.3 | 37.9 | 40.9 | 37.72 | 40.81 | -7.92 |
| Habiganj | 13 | 7.0 | 3.3 | 4.4 | 2.9 | 17.6 | 18.4 | 37.72 | 39.54 | -4.55 |

Note: Average value of three replications, width of covered per pass of the machine is 1.2 m. *Area of mechanical transplanting along with fertilizer deep placement ($T_1$) is presented only; **Urea- 80% of the recommended dose for $T_1$.

**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 is presented in Table 07.

**Table 07. Transplanting cost under different methods**

| Locations | Transplanting cost (Tk/h) | | | Time of transplanting (h/ha) | | | Transplanting cost (Tk/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ |
| | | | | Boro Season 2018-19 | | | | | |
| Kushtia | 339.8 | 335.2 | 50.0 | 9.1 | 8.3 | 166.7 | 3089.1 | 2793.0 | 8333.3 |
| Habiganj | 349.1 | 340.7 | 50.0 | 8.3 | 7.7 | 166.7 | 2908.9 | 2621.0 | 8333.3 |
| | | | | Aman Season 2019 | | | | | |
| Rangpur | 333.3 | 270.3 | 50.0 | 4.8 | 4.5 | 166.7 | 1587.2 | 1228.5 | 8333.3 |
| Gazipur | 342.6 | 335.2 | 50.0 | 6.3 | 4.8 | 166.7 | 2141.1 | 1596.0 | 8333.3 |
| Mirpur | 333.3 | 324.0 | 50.0 | 5.9 | 5.0 | 166.7 | 1960.7 | 1620.2 | 8333.3 |
| Kushtia-1 | 330.5 | 325.9 | 50.0 | 5.0 | 4.5 | 166.7 | 1652.7 | 1481.3 | 8333.3 |
| Kushtia-2 | 325.9 | 321.3 | 50.0 | 4.8 | 4.3 | 166.7 | 1551.9 | 1396.8 | 8333.3 |
| Netrakona | 330.5 | 325.9 | 50.0 | 5.3 | 5.3 | 166.7 | 1739.6 | 1715.2 | 8333.3 |
| Habiganj | 339.8 | 337.0 | 50.0 | 5.0 | 5.0 | 166.7 | 1699.0 | 1685.1 | 8333.3 |

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 hr/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/hr=40;
3. Fuel cost, Tk/lit=90.00 (Octan) and 4. Manual transplanting capacity, 1.5 decimal/hr including seedling uprooting.

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## IV. Conclusion

Mechanical rice transplanter is a promising technology considering the present labor crisis in Bangladesh. Mixed fertilizer deep placement technology successfully incorporated with the walking type rice transplanter with proper design and found suitable in operation under laboratory, research field and farmers' field condition. Farmers would be able to place mixed fertilizer into soil at desired depth along with mechanized transplanting.

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