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EFFECT OF UREA FERTILIZER DEEP PLACEMENT DAYS AFTER TRANSPLANTING USING BRRI PRILLED UREA APPLICATOR ON TRANSPLANTED BORO RICE YIELD

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Abstract

Rice is the most important crop in the developing countries of Asia. In the south and south-east Asia, rain-fed and irrigated transplanted rice occupies nearly two-thirds of the rice-growing area and produces more than 80% of the rough rice. In these areas, prilled urea conventionally applied by farmers is very insufficient in the transplanted rice field, where severe losses occur (up to 60% of applied N) via NH_3volatilization, denitrification, leaching, and runoff. Considering loss minimization, an experiment was conducted during the Boro season at Bangladesh Agricultural Development Corporation (BADC) in Sylhet to evaluate the performance of BRRI Prilled Urea Applicator (BPUA) at the different periods after transplanting BRRI dhan28. The results reveal that the field performance of the BPUA was suitable on first day after seedling transplanting under sandy clay loam soil compared to the third day after transplanting (DAT). At the 105 DAT, the height of the crop was found to be 104.3, 104.3, and 95.7 cm for urea deep placement by BPUA on first, second, and third day after seedling transplanting respectively. The maximum grain and straw yield was found at 6.8 t ha^{-1} and 5.2 t ha^{-1}, respectively which varied with the date of applicator operation after seedling transplanting. The benefit-cost ratio was found 1.63 at first DAT, whereas it was lower on the third days after seedling transplanting. Farmer can apply urea fertilizer in the non-oxidized zone by the BPUA after the first and second day of seedling transplanting in the sandy clay loam soil for maximum yield.

Key words: Field capacity, Fertilizer saving, Labor requirement, Benefit-cost ratio.

Introduction

Rice is the staple food of Bangladesh, although the command area is decreasing gradually. Soil, cultivar, season, environment, planting time, water management, weed control, cropping pattern, source, form, rate, and time and method of fertilizer application can ordain the use efficiency for rice during cultivation (Datta, 1978).

Nitrogen is the essential nutrient required for plant growth. For maximizing the yield of rice, nitrogenous fertilizer is widely used in rice farming. Therefore, lower level of N-utilization efficiency by crops and increased N-release to the environment, resulting atmosphere and water systems pollution, makes excessive nitrogen (N) fertilization the major concerns in sustainable agriculture. The nitrogen use efficiency (NUE), specifically in terms of urea fertilizer, is very low (30-35%) in the rice cropping system (IFDC, 2007; Hossen et al., 2017 and Dong et al., 2012). In Bangladesh, level of nitrogen fertilizer severely affects the amount of rice production. Low tilling in rice fields on the central high tableland is mainly due to nitrogen deficiency. Fertilizers, which are imported, have a high-cost price owing to the distance from producer countries and transportation difficulties on the island itself. Therefore, the main prime concern is to improve the effectiveness of fertilizers.

Many solutions have been found to reduce nitrogen losses, such as broadcasting and mechanical method, which are done by prilled urea applicator (PUA) and USG applicator. In this regard, prilled urea is a nitrogen fertilizer manufactured by the reaction of ammonia and carbon dioxide. It is the material that contain a small amount of organic

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material as a conditioner or anti-caking agent and which is white with free-flowing prilled solid. The use of prilled urea in the field can easily save nitrogen losses. However, vegetative growth, development, and yield of rice depend on the application of Urea-N. Different types of N losses are involved, including ammonia volatilization, denitrification, and leaching losses, causing environmental pollution problems (Choudhury and Kennedy, 2005). Most of the farmers of Bangladesh apply urea in the rice field by the broadcasting method. The efficiency of Urea-N is 30-40% which is very low or can even lower (Choudhury and Khanif, 2004). The yearly demand of urea in Bangladesh is 2.9 million tons (MT), of which 80% (2.3 MT) is used for rice alone. When it is applied at the desired depth, its application efficiency was increased up to 60% as well as 1.15 MT of urea could be saved. Consequently, 0.05 MT urea needs to be imported (BADC, 2011). Moreover, a large quantity of urea production can be reduced, which successively would save lots of natural gas use. The saved natural gas may well be accustomed to generating electricity (Bowen *et al.*, 2005). The application of PUA reduces the effectiveness of fertilizer which causes up to 70% loss. The losses occur by fertilizers converting into gaseous form and blending with air and dissolved with rain or irrigation transcends the foundation zone of the rice plants (NAP, 2009).

In the present (prilledor acceptable type of urea) broadcasting technique of application, only 40% of the applied urea is used by the plant, and the remaining 60% is lost through the air, water, or leaching under the ground (Iqbal, 2009). Statistics indicate that about 80% of urea in total production is employed for rice production. If the urea fertilizers are applied at the desired depth, a large amount of urea production could be reduced. Based on this concept BRRI Prilled Urea Applicator (BPUA) can play a vital role in deep placement of prilled urea in between two rows of plants.

The applicator made of locally available iron and plastic materials, applies prilled urea at 6 cm to 7 cm depth below the soil surface in the middle of four bunches of rice seedlings. The manual urea placements take 28 hours, whereas the device takes only 10 hours per hectare. Therefore, the most significant advantage of the applicator is the diminishing of drudgery and the cost of chemical application is also proportionally reduced. Furthermore, the low-cost (TK 5000-6000), lightweight machine allows farmers to be ergonomic and user-friendly. Seventy farmers in twelve districts have purchased this machine within four months of its development (Hossen et al., 2017). International Fertilizer Development Corporation (IFDC) has been trying to popularize PUA technology in different countries.

Considering the aforementioned advantages of the machine, the BPUA need to be studied more from its field performance aspects. The field performance results could enhance the chance for further modification as well as its root level application among the farmers. Therefore, the aim of this study was to investigate the machine performance on different days after seedling transplanting and to find the cost-benefit ratio based on different transplanting periods.

Materials and Methods

Experimental Site and Land Preparation

The study was conducted at BADC research field in Sylhet, Bangladesh, during the irrigated dry Boro season 2019,

based on different land configurations and cropping intensity. The field size was 203.4m ×3m. It is under Agro-ecological Zone named Eastern Surma Kushiara Floodplain. Soil samples from the experimental field were collected and analyzed was found in sandy clay loam at Soil Resources Development Institute, Sylhet, Bangladesh. The soil textural classes and fertility status of the experimental field are shown in Table 1.

Table 1. Soiltextural classes and fertility status of the field

Characteristics	Percentage	Type
Sand	59.92%	Sandy Clay Loam
Silt	15.00%	
Clay	25.08%	

The plot was prepared accordingly, along with a drainage canal. BRRI dhan28 was grown in all the experimental plots. After the first rotation, the field was flooded with water and kept for seven days, and then the second rotation was done on the eighth day. During final land preparation, all care was taken for uniform land leveling and leveling. Puddled soil or poached soil in which the soil structure was given a flat surface and raised to 5-10 cm height. To increase seed vigor and allows easier uprooting for transplanting, Organic manure (decompose) and a tiny amount of inorganic fertilizer were applied as basal dressing. The variety of BRRI dhan 28 was taken as the test crop to conduct the study. Forty days old, seedlings were transplanted manually in the study field. Row-to-row spacing was maintained at 20cm. However, plant-to-plant spacing was varied due to manual transplanting.

BPUA Calibration

BRRI prilled applicator was designed considering the line-to-line spacing of 20 cm (Hossen et al. 2017). Large granule prilled urea was used in the laboratory trial and field trial. Drive wheels were rotated by pouring large granules in the hopper. After one revolution of the drive wheel, the amount of urea dispensed in both the hoppers was almost 24.80gshown in Table 2, which satisfied the amount of urea displacement during the Boro season. Fertilizer rate was varied in Aus and Aman seasons due to changes in fertilizer requirement in rice crops. Before field operation, the applicator was calibrated, and urea dispensed was set to 24.80g in one revolution of the drive wheel for Boro season Figure 1. Another fertilizer dose for all treatments was the same.

Table 2. Rate of Urea for calibration

Method of application	Recommended rate (kg ha^{-1})	Rate (kg ha^{-1})	Dispensing rate (g/rotation)*
Machine application (20% saving)	270	216	24.80

**Note: Urea dispensing rate per rotation of the driving wheel of the applicator*

Figure 1. BPUA calibration

BRRI recommended urea fertilizer was considered 270 $kgha^{-1}$ (BRRI, 2016) for Boro season. Fertilizer-dispensing rate per rotation of the driving wheel was estimated by using the following formula (Hossen *et al.* 2020) to maintain the desired rate of fertilizer

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

Where,

FDR = Fertilizer dispensing rate per rotation of the driving wheel (g/rotation)
D = Wheel diameter of the applicator, cm
L = Line to line spacing of the transplanted rice, cm
RoF = Desired rate of fertilizer application, $kgha^{-1}$

Variety selection

Rice variety of BRRI dhan28 was taken as a test crop to conduct the study. Forty days old seedlings were transplanted manually in the study field. Line-to-line and plant-to-plant spacing was maintained to 20 cm and 15 cm, respectively. Three to four plants of seedlings were transplanted manually on each hill.

Design of the Experiment:

The experiment was laid out in a randomized complete block (RCB) design with three replications. The treatments were-

T_1= Urea deep placement by BPUA on first day after seedling transplanting.

T_2 = Urea deep placement by BPUA on second day after seedling transplanting

T_3 = Urea deep placement by BPUA on third day after transplanting.

Performance of applicator

To calculate actual field capacity, actual time requirement can be estimated by including the turning time of the applicator, fertilizer refill time, operator’s time, adjustment time etc. Field efficiency was measured based on the actual field capacity and theoretical field capacity. Then, the actual saving of the fertilizer is deviated from the designed saving rate due to slippage, variation of wheel penetration and irregular speed of operation. The actual percentage of saving was calculated by dividing the actual dispensing rate of fertilizer by the recommended rate of fertilizer of the respected area of operation.

Economic analysis

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

Calculation of uncovered length

The efficacy of urea fertilizer depends on proper furrow coverage of the deeply placed fertilizer. Furrow coverage also depends on soil condition and settlement period after transplanting. Losses of Urea fertilizer in different way in the uncovered furrow are same as hand broadcasting urea fertilizer. Under the present study, the percentage of furrow coverage during machine operation was calculated after different days of seedling transplanting.

Results and Discussions

Machine performance

Field capacity of BPUA

The field capacity of BPUA varied with the time of operation of the machine after seedling transplanting. Actual field capacity was found0.065, 0.062, and 0.058 hah^{-1} for operating the machine on first, second, and third day after seedling transplanting, respectively (Table 3). Both actual and theoretical field capacity was observed less for the operation of the machine on the third day after seedling transplanting due to the soil settlement.

Table 3. Field performance of the BPUA

Treatments	Forward speed of operation (km hr-1)	Actual field capacity (ha hr-1)	Theoretical field capacity (ha hr-1)	Field efficiency (%)
T1	3.2	0.065	2.56	39.38
T2	2.75	0.062	2.2	35.48
T3	2.65	0.058	2.12	36.55

Note: Average value of three replications, area covered per pass of the applicator is 0.8 m

Field efficiency of the machine was found to be 39.38, 35.48, and 36.55% for operating on first, second, and third days after seedling transplanting, respectively. It was varied with the field size and shape, length of the field, number of turns, and forward speed (Hossen, 2016). Minimum field efficiency of the machine was observed due to small area and frequent turning of the machine. The field efficiency of BPUA is obtained at 64-65% in two locations in the farmer's field (Islam *et al.* 2015).

Actual saving percentage of fertilizer

Before field operation of the machine, it was calibrated first to save 20% of fertilizer from the recommended dose. In the field, saving percentage was observed at 21.9%, 18.5% and 16.7% against the calibration of 20% urea saving (Table 4). It might be due to the difference in operational speed, more penetration of the driving wheel in the field during operation, etc., and soil settlement with the time after seedling transplanting. More deviation was observed after the third-day of seedling transplanting due to low operational speed and frequent interruptions of operation for more frictional force for more soil settlement.

Table 4. Percent of fertilizer saving as affected by days of operation after transplanting

Treatments	Area (m^2)	Urea dispensed in the studied field (kg)	Recommended dose (kg ha^{-1})	Recommended dose at 20% saving (kg ha^{-1})	Actual Urea dispensed dose (kg ha^{-1})	% of saving	% of deviation (±)
T1	150	3.17	270	216	211	21.85	-1.85
T2	180	3.96	270	216	220	18.52	1.48
T3	195	4.39	270	216	225	16.67	3.33

Note: Average value of three replications, area covered per pass of the applicator is 0.8 m

Percentage of furrow coverage

The percentage of uncovered length varied with the date of machine operation after seedling transplanting (Table 5). The uncovered length was zero on the first day after seedling transplanting, whereas it was 16.96 and 59.73% on the second and third days after seedling transplanting, respectively.

Table 5. Uncovered length as affected by days of operation after seedling transplanting

Treatment	Total length (m)	Total uncovered length (m)	% of uncovered length
T1	203.4	0	0
T2	203.4	34.496	16.96
T3	203.4	121.491	59.73

Note: Average value of three replications.

Crop performance

Plant height

Plant height with a different date of transplanting is shown in Figure-2. After transplanting, it was not varied up to 30 days. Significant plant height variation was observed from 45 days after transplanting (DAT) to the harvest. From 45 DAT to harvest, a lower height of the plant was observed for T3.

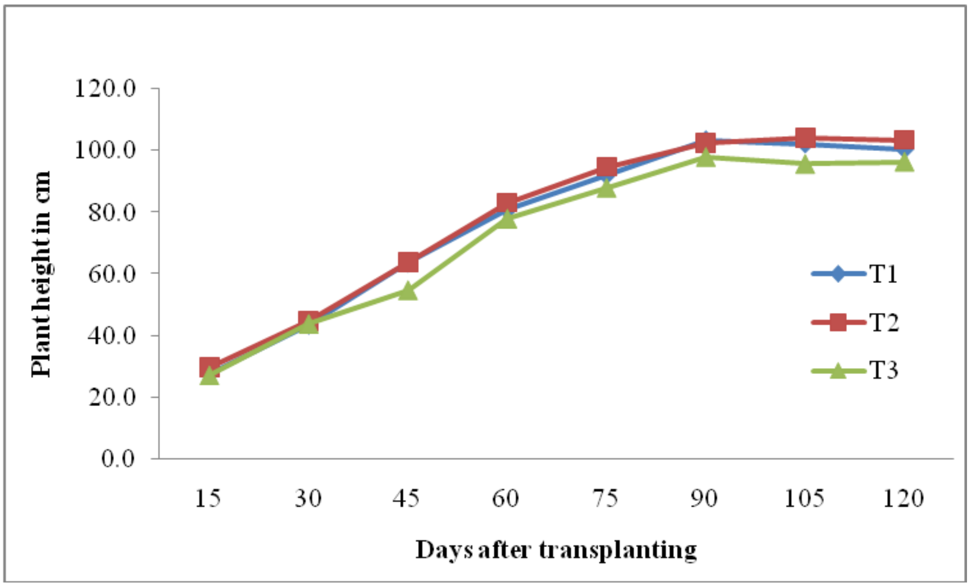

Figure 2. Plant heights with respect to days after transplanting as affected by BPUA operation after seedling transplanting

Number of tillers

The number of tillers hill^{-1} with different periods of transplanting is shown in Figure-3. There was no variation up to 30 DAT, whereas the variation of tiller number per hill was observed at 45 DAT. Tiller number varied significantly from 45DAT to the harvesting period. From 45 DAT to the harvest, a significantly lower tiller number of the plant was found in T3.

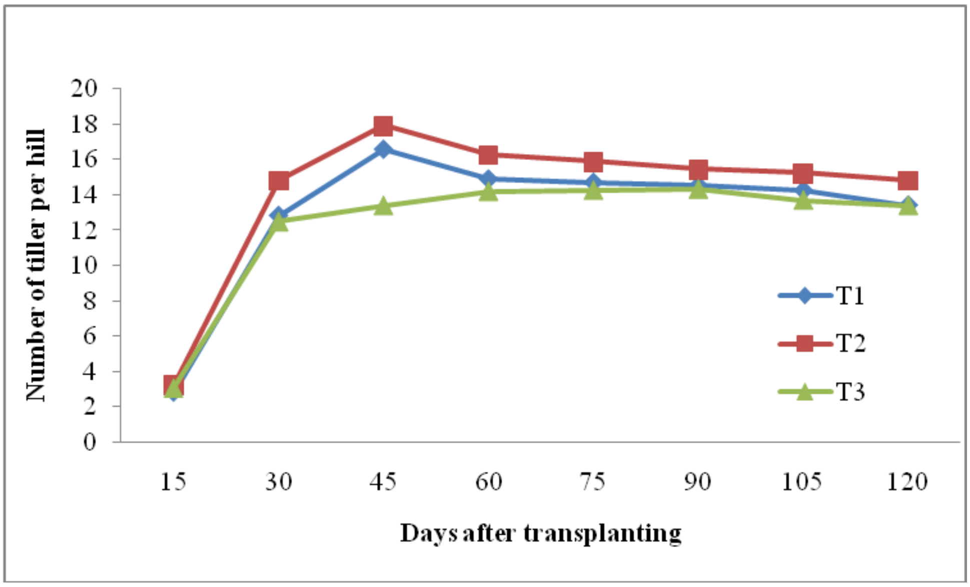

Figure 3. Plant populations with respect of date after transplanting as affected by BPUA operation after seedling transplanting

Yield Performance

Grain and straw yield Figure-4 varied with the time of operation of the BPUA after seedling transplanting (Table 6). T1 gave a higher yield compared to T2 and T3. Straw yield also varied with the time of operation of the applicator. Deep placement of urea fertilizer as briquette form also paid a higher yield compared to the hand broadcasting method (Hossen, 2013).

Figure 4. Plant populations with respect of date after transplanting as affected by BPUA operation after seedling transplanting

Table 6. Yield performance as affected by BPUA operation at different days after seedling transplanting

Treatments	Grain yield at 14% moisture content (Dry basis)	Straw yield (ton ha-1)
T1	6.8	5.2
T2	6.7	6.0
T3	6.1	6.3

Note: Average value of three replications.

Economic performance

Economic analysis, including the cost of production and return, is presented in Table 7. BPUA is accounted for the highest BCR (1.63 and 1.60) for first and second-day deep placement of urea fertilizer by BPUA after seedling transplanting. Lower BCR was observed for T3.

Table 7. 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
T1	82813	135000	52187	1.63
T2	82315	131800	49485	1.60
T3	83169	121450	38281	1.46

Conclusion

Field performance of the BPUA was found suitable on first day after seeding transplanting under sandy clay loam soil conditions. The maximum grain and straw yield was found at 6.8 tha^{-1} and 5.2 t $ha^{-1,}$ which varied with the date of applicator operation after seedling transplanting.

Benefit-cost ratio (BCR) was found to be 1.63 on the first day after seedling transplanting, whereas it was lower on the third day after seedling transplanting. Farmer can apply prilled urea fertilizer in sandy clay loam soil on the first day after seedling transplanting. This study suggested that the BRRI prilled urea applicator discussion needs to be conducted in different soil conditions and cropping patterns.

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