Improvement and evaluation of BARI USG applicator

M. A. Hoque*, M. A. Wohab, M. A. Hossain, K. K. Saha, M. S. Hassan

(*Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh*)

Abstract: Urea Super Granule (USG) placement in 6-10 cm depth in wet land rice field can save 30% of nitrogen than broadcasted prilled urea. But, deep placement by hand is more time consuming, labor expensive and also hazardous to health. To solve the problems of USG placement, a manually operated push type two-row fertilizer applicator for puddled rice field has been developed in Farm Machinery and Postharvest Process Engineering (FMPE) Division of Bangladesh Agricultural Research Institute (BARI) in 2009. The applicator was modified for variable row spacing (17-25 cm) reducing weight from 9 to 6 kg by changing the construction material of skid and drive wheel from steel to plastic. To reduce the moving resistance, the length of the skid was reduced from 760 to 610 mm. Based on farmers' demand; the hoppers were modified to hold 1 kg of USG in each hopper instead of 0.5 kg. Field performance of BARI USG applicator was evaluated in four different location of the country during the boro season (January-April) of 2011-12. Average field capacity and efficiency of the applicator were found to be 0.139 hah^{-1} and 81% respectively. Considering custom hiring, the net income per year was US$ 915 (Tk 75, 000) and the payback period was 3 days. The price of the applicator is US$ 43 (Tk 3,500). Use of the applicator ensured similar yield of rice to hand application of USG in all locations. Higher yield of rice was obtained from USG applied plot than granular urea. This improved USG applicator may be used for application of USG in puddled rice field in the rice growing countries.

Keywords: field capacity, efficiency, payback period, USG

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1 Introduction

Urea has emerged as an important nitrogen fertilizer for rice cultivation. About 2.9 million tons of urea is used for rice production in Bangladesh. Statistics indicates that about 80% of urea is used for rice production. But only 15% to 35% of the total applied nitrogen is used by the rice plant (Prasad and Datta, 1979). The low level of nitrogen recovery by rice plant is generally caused by huge losses of the soil-water-plant complex. Nitrogen loss processes are due to ammonia volatilization, denitrification, runoff, seepage and leaching. Thus, there is a great need to improve nitrogen use efficiency for rice production. Due to excessive loss of nitrogen, farmers in Bangladesh have not been able to make more effective use of fertilizer to boost their rice yields. The nature and degree of loss depends upon soil, climatic conditions, nitrogen fertilizer and water management practices. Much effort has been made to improve fertilizer use efficiencies in lowland rice production. Deep placement of nitrogen fertilizer into the anaerobic soil zone is an effective method to reduce volatilization loss. Urea in the form of USG (Urea Super Granule) has been proved to be superior to granular urea in all aspects. It is applied in the rice field only for one time after 7 to 10 days of plantation of seedlings and it contributes for the whole growing period of rice. Instead

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***Corresponding Author: Muhammad Arshadul Hoque,** Senior Scientific Officer, Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh. Cell Phone: 8801712635503. Email: arshadul@bari.gov.bd.

of normal does of 247 kg of granular urea, only 160 kg ha^{-1} of USG is required (35% less) and it increases rice yield up to 20% (Hoque, 2008 and Hossain, 1998). Depending on agroclimate and nitrogen use, deep-placed USG can save of urea fertilizer of up to 65% with an average of 33% and increase grain yields up to 50% with an average of 15% to 20% over the same amount of split-applied nitrogen as prilled urea, especially in the lower range of nitrogen rates (Savant and Stangel, 1990).

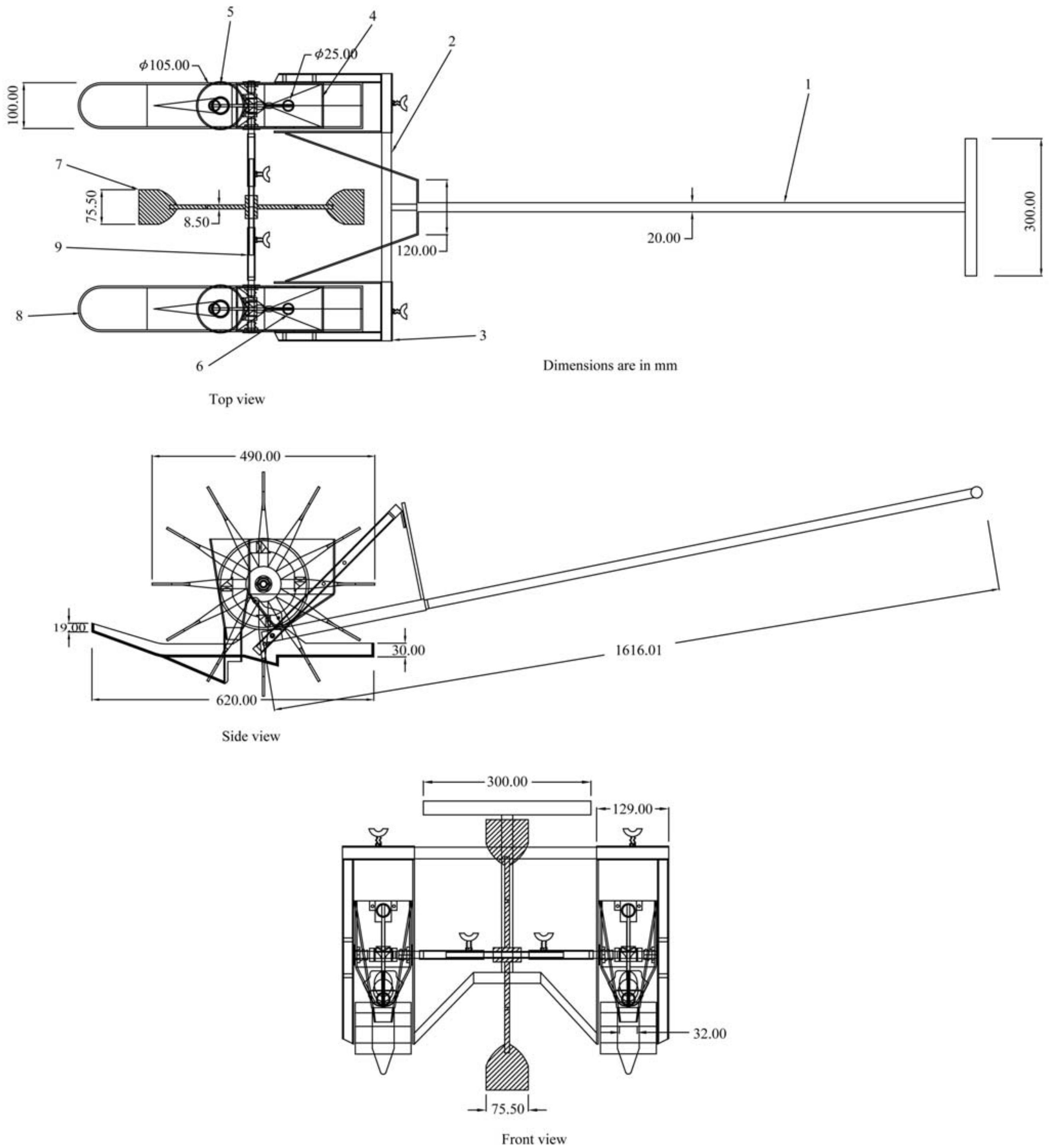
At present, USG has been started to be used in puddled rice field and found to be economic and effective method of urea fertilizer application in rice field. It is reported that USG placement in 6-10 cm depth in wet land rice field can save 30% of nitrogen than broadcasted prilled urea. Hand placement of USG of 1.8 g to 2.7 g sizes into flood soil has been resulted less loss of nitrogen, higher nitrogen recovery and higher yield than conventional nitrogen application method (Diamond, 1985). USG is presently applied manually just like transplanting of rice seedlings in the field. It is placed at a depth of 8 cm to10 cm under the soil at the center of 4 consecutive hills of 2 adjacent rows. The hand placement of USG is labor intensive and very slow i.e. 0.07 to 0.12 ha/workday (Savant et al., 1992). Savant et al., (1991) conducted field test in the Philippines and India during 1989 and 1990 seasons and found that the IFDC applicator-placed urea briquettes increased grain yields over the split-applied prilled urea, and the additional yields ranged from 0.23 to 1.48 t ha^{-1} (5 to 83%) for 25 to 63 kg N ha^{-1}. Agronomic responses of transplanted rice to the urea briquettes placed by the applicator and by hand were statistically equal.

Unfortunately, farmers have not been able to be benefited from these findings, primarily because they have no suitable fertilizer placement equipment. But, cost of fertilizer is increasing day by day. Efforts should be made to develop a low cost, efficient fertilizer application machine for placing the fertilizer at required depths for different crops. Thus, fertilizer use efficiency will be high, resulting in higher yield and lower production cost. To minimize nitrogen loss, USG application may be a good technology to increase rice yield as well as the reduction of production cost. Minimum effort has been made in Bangladesh and elsewhere in the world to develop a fertilizer applicator machine for improving fertilizer use efficiency. To solve the problem of USG placement by hand, a manually operated push type fertilizer applicator for puddled rice field has been developed in Farm Machinery and Postharvest Process (FMP) Engineering Division of Bangladesh Agricultural Research Institute (BARI) (Wohab et al., 2009). During the use of BARI developed USG applicators in the farmers' field, some problems were faced such as variability of row spacing, heavier in weight etc. To solve the problems this study was undertaken to improve the performance of the machine that suits the farmers' desire.

2 Materials and methods

A fixed row USG applicator was designed and fabricated in F M P Engineering Division of BARI in 2009 (Wohab et al., 2009). But when the USG applicator was operated in farmer's field, it could not be used in different row spacing. Based on field feedback, the applicator was modified for using the applicator in variable row spacing (17-25 cm). The operator can adjust the applicator according to requirement during its use in the field. The original applicator was reported as heavier than the farmer's expectation. Therefore, the applicator was modified by reducing weight from 9 kg to 6 kg by changing the construction material from steel to plastic of skid and drive wheel of the applicator. To reduce the contact area, the length of the skid was reduced from 760 mm to 610 mm. Based on farmer's demand; the hoppers were modified to hold 1 kg USG in each hopper instead of 0.5 kg.

Finally overall dimension of the developed applicator was 1,920 mm in length, 620 mm in width and 520 mm in height. The main functional parts are metallic handle, plastic cup type metering device, plastic fertilizer box, plastic hopper, plastic drive wheel, plastic skid, metallic parallel bar, metallic adjustable frame and metallic drive shaft. Views from top, side and front of the BARI USG applicator is shown in Figure 1. The descriptions of different parts are given below.



1. Handle 2. Parallel bar 3. Frame 4. Fertilizer box 5. Hopper 6. Metering device 7. Drive wheel 8. Skid 9. Shaft

Figure 1 Views from top, side and front of the BARI USG applicator

1) Handle: This part is made of steel rod, flat bar and square box. Its length is 1,600 ±100 mm. There are two flat bars welded at the end of the handle which is attached with the main frame by three nut and bolts. Another important feature provided with this part is the height control mechanism by adjusting the upper nut and bolt in different positions according to the height of the operator.

2) Parallel bar: This part is made of mild steel square box and flat bar. Its length is 610 mm and a flat bar is welded at the middle of the bar. The main function of this part is to hold two sets of frame and fertilizer box.

3) Frame: This part is also made of mild steel square box and flat bar. It is 445 mm in height. One flat bar and one mild steel square box were welded with another mild steel square box vertically. The horizontal square

box can be moved over the parallel bar. This provided a provision of applicator adjustment according to the distance between two rows of the rice plants. An adjusting screw is placed at the top of the frame to fix the position of the frame.

4) Fertilizer box: There are two plastic fertilizer boxes placed on the metallic shaft. The dimension being 190 mm, 100 mm and 190 mm in length, width and height respectively. The box can hold 1 kg USG fertilizer. The bottom of the box has a conical shape. There is an oval shaped hole at the bottom of the box. A flexible rubber patch is attached with screws that cover the hole. This rubber sheet acts as a valve which allows entering the USG inside the box, but does not allow the USG fertilizer to go outside through the hole.

5) Hopper: It is a hollow and plastic made conical part with diameter 105 mm at the top but at the other end the diameter decrease to 32 mm and the height is 222 mm. There are two hopper fitted in front of fertilizer boxes. The hopper is attached with the fertilizer box by screw and metering device rotates inside the hopper. The lower part of the hopper is attached vertically on the skid.

6) Metering device: The diameter of the device is 145 mm. Four numbers of cups are attached at the periphery of the device. The diameter of the cup is 25 mm having a depth of 7 mm. The device rotates on the shaft and takes up one piece of USG fertilizer and drops it in the hopper that is buried in the soil. Metering device was made of plastic.

7) Drive wheel: It is plastic made with diameter of 490 mm consisting 12 numbers of spade type traction part at the ends. Main function of the wheel is to convert the traction force to rotating force to rotate the metering device and USG fertilizer is dropped at equal interval.

8) Skid: It is plastic part having length and width of 620 mm and 100 mm, respectively. The front portion of the skid is inclined upside with 20 degree. It has a hole at the middle and the hopper vertically attached to it. A furrow opener and a furrow closer is present underneath the skid. The furrow opener opens the puddle soil like a furrow. USG fertilizers drop and then the furrow closer cover the fertilizer with soil. This part also carries the weight of the applicator on the soil.

9) Shaft: The length of the shaft is 210 mm and diameter is 12.50 mm. The shaft is made of mild steel. It holds the drive wheel and connects the connecting shaft. The connecting shaft is made of mild steel rod which is welded with stainless steel pipe. The main function of the part is to convey the rotating force to the metering device. There is an adjusting screw on the frame to adjust the row to row distance.

2.1 Operation of the USG applicator

A photographic view of BARI USG applicator and its operation is shown in Figure 2 and Figure 3, respectively. The skids of the applicator were placed in two rows of rice plants. Two third of the fertilizer hoppers were filled with USG. The applicator was pushed forward. Then the cage wheel and the metering devices were rotated. During rotation of the metering device, it carries USG into the pockets and delivers them to the furrow openers. During forward movement of the applicator, the skids help to float the machine. Fertilizer applicator drops the USG at 20 cm row spacing, at about 40 cm spacing along the row and at 5-6 cm depth. Furrow closers close the furrows providing anaerobic condition for the USG The total width of application is adjustable (70 cm to100 cm).

Figure 2 BARI USG applicator

Figure 3 BARI USG applicator in field operation

2.2 Field performance test

The field performance test of the applicator was done in the experimental field of Farm Machinery and Postharvest Process Engineering division, Gazipur; Agricultural Research Station (ARS), Pabna; Regional Agricultural Research Station, Rahmatpur, Barisal and Regional Spices Research Centre, Magura during *boro* season of 2011-12. The USG applicator was operated at 10 days after transplanting of rice seedlings. Singh et al., (1989) recommended applying USG at 10 days after transplanting rice to get better yield. The applicator was used in 2 cm to5 cm of standing water. The machine was operated at an average speed of 1.50 km h^{-1}. One operator could comfortably run the machine. The experiment was laid out in randomized complete block (RCB) design with the following treatments and three replications.

T_1= Application of USG by the machine /165 kg ha^{-1}

T_2= Application of USG by hand /165 kg ha^{-1}

T_3= Application of prilled urea at farmers' dose

T_4= Application of prilled urea at USG rate /165 kg ha^{-1}

According to farmers' practice, doses of urea were 265 kg ha^{-1} in Gazipur, 225 kg ha^{-1} in Pabna, 180 kg ha^{-1} in Barisal and 202 kg ha^{-1} in Magura. Each plot size was 5.5 × 5 m in Gazipur, 10 × 8 m in Pabna, 17.5 m × 12.5 m in Barisal and 14.0 m × 6.5 m in Magura. The soil type was clay loam, loam, sandy loam and clay loam in Gazipur, Pabna, Barisal and Magura respectively. The rice variety planted in Gazipur, Pabna and Barisal was BRRI Dhan-28 (*Oryza sativa*) and in Magura it was *Kazol Lota* (Aromatic rice). The ages of seedlings were 35, 30, 40 and 36 days in Gazipur, Pabna, Barisal and Magura respectively. The date of planting of seedlings in Gazipur was 12 February, in Pabna was 14 February, in Magura was 4 February and in Barisal was 29 April 2012. Row to row and hill to hill distance was 20 cm. Triple super phosphate (TSP) 51 kg ha^{-1}, murate of potash (MP) 70 kg ha^{-1}, Zinc 50 kg ha^{-1} and Boron 5 kg ha^{-1} were applied as basal dose before final land preparation. Full dose of USG was applied at 10 DAS (days after transplanting). One third of prilled urea was applied on 8^{th} day after transplanting and another one third urea was applied 40 DAS. Rest one third urea was applied at 55-60 DAS. Weeding was done manually at 35 DAS. Irrigation was applied when the soil moisture content became below the saturation condition.

3 Results and discussion

Performance of USG applicator at different location is shown in Table 1. Average operating time, field capacity and operation efficiency of USG applicator were 7.21 h ha^{-1}, 0.139 ha h^{-1}, 81% respectively. Saving of urea of farmer's practice of prilled urea was 53 kg ha^{-1}. In case of hand application of USG, operating time per hector was 36 hr. USG applicator can save 80% operation time and 78% cost of operation than hand application of USG. During field operation missing of USG dropping was very low as 1.0%.

The yield and yield contributing factors of different urea application methods in *boro* rice in Gazipur is shown in Table 2. There were no significant differences of plant height and length of panicle among the treatments. There was no significant difference in yield of treatments T_1 and T_2. The highest yield of rice was obtained from treatment T_1 followed by T_2 and T_3 and the lowest yield was found from treatment T_4. This may be due to significantly higher number of grain per panicle and 1,000 grain weight in treatment T_1 and T_2 than treatment T_3 and T_4.

Yield and yield contributing factor for different urea application method in *boro* rice in Pabna is given in Table 3. It is observed from the table that there were no significant differences of numbers of grain per panicle of rice among the treatments. Length of panicle and 1,000 grain weight were significantly lower in treatment T_4 than other treatments. The reason might be that due to more vegetative growth for more application of urea, the grains became healthy. It is also observed from the table that significantly highest yield was found for USG application than that of prilled urea. There was no significant difference of grain yield between machine and hand application of USG.

Table 4 shows the yield and yield contributing factors for different area application method in *boro* rice in Barisal. Significantly the highest plant height was observed for treatment T_1 than other treatments. But the plant heights of other treatments (T_2, T_3 and T_4) were statistically alike. There were no significant differences of length of panicle, number of grain per panicle, 1000 grain weight and grain yield among the treatments. The highest yield of rice was obtained from treatment T_4 and T_3 followed by T_1 and the lowest yield was found from treatment T_4. But, there was no significant difference among the treatments. These results indicate that there were no effects of USG and prilled urea applied in recommended dose. Also, there was non-significant effect of machine and hand application of USG, but machine application method saved time about 80% and cost of application about 77.84%.

Table 1 Performance of USG applicator at different locations

Parameter	Gazipur	Pabna	Barisal	Magura	Mean
USG Applicator:					
Operating time /h ha^{-1}	7.05	7.48	7.26	7.05	7.21
Field capacity / ha h^{-1}	0.142	0.134	0.138	0.139	0.139
Operation efficiency /%	83	80	81	80	81
USG used /kg ha^{-1}	165	165	165	165	165
USG saved over prilled urea / kg ha^{-1}	100	60	15	37	53
Missing of USG dropping /%	0.98	1.2	1.3	0.52	1.0
Cost / US$ ha^{-1}	4.27	3.05	4.29	3.35	3.66
Hand Application:					
Operating time /h ha^{-1}	33.33	39.16	35.42	36.46	36.09
Cost / US$ h^{-1}a	17.78	14.93	17.55	15.28	16.39
Comparison:					
Time saved over hand application / %			80		
Cost saved over hand application / %			78		

Table 2 Yield and yield contributing factors for different urea application method in *boro* rice in Gazipur

Treatment	Plant height /cm	Length of panicle /cm	Number of grain per panicle	1,000 grain weight /g	Grain yield /t ha^{-1}
T_1=Application of USG by machine @165 kg ha^{-1}	80.40	20.83	80.3a	21.43a	5.63a
T_2=USG application by hand @165 kg ha^{-1}	81.60	20.00	74.13a	21.03a	5.60a
T_3=Prilled urea at farmers practice @265 kg ha^{-1}	78.37	20.46	63.90b	20.60ab	5.23b
T_4=Prilled urea at USG rate @165 kg ha^{-1}	81.73	20.58	60.80b	19.93b	4.60c

Note: Common letter in the same column does not differ from each other by DMRT.

Table 3 Yield and yield contributing factors for different urea application method in *boro* rice in Pabna

Treatment	Plant height /cm	Length of panicle /cm	Number of grain per panicle	1,000 grain weight /g	Grain yield /t ha^{-1}
T_1=Application of USG by machine @165 kg ha^{-1}	94.33a	21.36a	111.9	22.67a	4.73a
T_2=USG application by hand @165 kg ha^{-1}	95.25a	22.26a	110.40	22.00ab	5.07a
T_3=Prilled urea at farmers practice @225 kg ha^{-1}	91.46ab	21.36a	99.83	21.33b	3.77b
T_4=Prilled urea at USG rate @165 kg ha^{-1}	87.23b	19.50b	91.20	20.00c	3.59b

Note: Common letter in the same column does not differ from each other by DMRT.

Table 4 Yield and yield contributing factors for different urea application method in *boro* rice in Barisal

Treatment	Plant height /cm	Length of panicle /cm	Number of grain per panicle	1,000 grain weight /g	Grain yield /t ha^{-1}
T_1=Application of USG by machine @165 kg ha^{-1}	103.33a	24.05	148.67	23.13	3.24
T_2=USG application by hand @165 kg ha^{-1}	99.67ab	24.33	145.67	22.97	3.32
T_3=Prilled urea at farmers practice@180 kg ha^{-1}	96.00ab	23.63	133.48	22.93	3.33
T_4=Prilled urea at USG rate @165 kg ha^{-1}	92.45b	24.21	134.33	23.43	3.24

Note: Common letter in the same column does not differ from each other by DMRT.

Yield and yield contributing factor for different urea application methods in *boro* rice in Magura is given in Table 5. It can be observed from the table that there were no significant differences of plant heights of rice among the treatments. Significantly the highest length of panicle was obtained for prilled urea applied at recommended dose than other treatments. But the lengths of panicles for other treatments were statistically alike. This might be due to that more vegetative growth of plants was observed for the recommended dose than other treatments. Numbers of grains per panicle for all treatments were statistically alike. Significantly higher 1,000 grain weights were obtained from treatments T_1, T_2 and T_3 than treatment T_4 but there were no significant differences of 1,000 grain weights among the treatments T_1, T_2 and T_3. The reason might be that due to more vegetative growth for more application of urea, the grains became healthier. It can also be observed from the table that significantly highest yield was found for USG application than that of prilled urea. There was no significant difference of grain yield between machine and hand application of USG. Significantly higher yield was obtained from recommended dose than the USG rate of prilled urea. This is because the length of panicle as well as 1,000 grain weight of the treatment T_3 was higher than treatment T_4.

Table 5 Yield and yield contributing factors for different urea application method in *boro* rice in Magura

Treatment	Plant height /cm	Length of panicle /cm	Number of grain per panicle	1,000 grain weight /g	Grain yield /t ha^{-1}
T_1=Application of USG by machine @165 kg ha^{-1}	82.67	27.89b	102.33	26.33a	3.67a
T_2=USG application by hand @165 kg ha^{-1}	82.67	34.33b	103.33	25.00a	3.63a
T_3=Prilled urea at farmers practice @202 kg ha^{-1}	87.67	38.00a	101.67	24.33a	2.98b
T_4=Prilled urea at USG rate @165 kg ha-1	88.00	28.33ab	102.67	20.33b	2.56c

Note: Common letter in the same column does not differ each other by DMRT.

Economic performance and payback period of the USG applicator is given in Table 6. If one person is engaged in custom hiring of USG applicator, then the net income per year will be US$ 915 (Tk 75,000). The payback period of the USG applicator in custom hiring is 3 days.

Table 6 Economic performance of the USG applicator

Parameters	Cost
Price of the USG applicator /US$	43 (Tk 3,500)
Operating area / ha yr^{-1}	
Aus	05
Aman	15
Boro	20
Total Operating time / d yr^{-1}	40
Custom hire rate / US$ ha^{-1}	23(Tk 1,875)
Gross income per year /US$	915 (Tk 75,000)
Repair and maintenance cost / US$ yr^{-1}	3 (Tk 250)
Net income / US$	871(Tk 71,750)
Payback period / d	3

4 Conclusion

Use of the applicator ensured similar yield to hand application of USG in all locations. USG applicator was easy to operate as its weight is 6 kg. It saved about 80% of USG application time and saved application cost to about 78% than hand application. About 19% higher yield was found from USG applied rice than that of the granular urea application method. The payback period of the applicator is 3 days. The modified version of BARI developed USG applicator is recommended for application of USG in Bangladesh as well as other rice growing countries of the world.

References

Diamond, R. B. 1985. Status of N deep placement research in Asia. *Proceedings of the technical session, Fertilizer N Deep Placement for Rice. BARC.*

Hoque, N. 2008. Saving of taka 250 crores and increasing yield by 20% by using Goti Urea (Bangla). The Daily Ittefaq, 20 May, 2008. P. 15-16.

Hossain, M. T. 1998. USG demonstration result for 1996-97 and 1997-98. *Paper presented at the national workshop on Urea Super Granule Technology (USG).* BARC, Dhaka, Bangladesh, 25 June.

Prasad, R., and S. K. Datta. 1979. Increasing fertilizer N efficiency in wet land rice. Nitrogen and rice. IRRI, Philippines.

Savant, N. K., and P. J. Stangel. 1990. Deep placement of urea super granules in transplanted rice: Principles and practices. *Nutrient Cycling in Agroecosystems*, 25 (1): 1-83. Savant, N. K., P. S. Ongkingco, F. D. Garcia, S. S. Dhane, R. R. Khadse, S. A. Chavan, and K. S. Rao. 1992. Agronomic performance of urea briquette applicator in transplanted rice. *Nutrient Cycling in Agroecosystems*, 32(2): 139-142.

Savant, N. K., P. S. Ongkingco, I. V. Zarate, F. M. Torrizo, and P. J. Stangel. 1991. Urea briquette applicator for transplanted rice. *Nutrient Cycling in Agroecosystems*, 28 (3): 323-331.

Singh, S., R. Prasad, and S. N. Sharma. 1989. Growth and yield of rice as affected by spacing, time and depth of placement of urea briquettes. ***Nutrient Cycling in Agroecosystems***,19 (2): 99-101.

Wohab, M. A., M. S. Islam, M. A. Hoque, M. A. Hossain, and S. Ahmed. 2009. Design and development of a urea super granule applicator for puddled rice field. *Journal of Agricultural Engineering*, 37/AE: 57-62.