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Field Evaluation of BRRI USG Applicator in Dry and Wet Season of Rice Cultivation

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ABSTRACT

BRRI (Bangladesh Rice Research Institute) USG (Urea super granule) applicator was developed to apply USG in non-oxidized zone at 6-10 cm depth from surface at desired spacing to maintain the recommended USG fertilizer doses of 118 and 168 kg ha^{-1} during Aman and Boro season, respectively that could be maintained with the adjustment of the applicator for 20 × 20 cm transplanting spacing. It was designed and fabricated with an adjustable facility for two rows operation in the rice field at spacing of 18 × 20, 20 × 20 and 22 × 20 cm. The modified USG applicator tested in the BRRI regional stations (RS) during Aman 2011 and the farmers' fields during Boro 2012 season. Walking speed directly influenced the field capacity of the applicator. Walking speed during field operation of the applicator depends on the soil type, USG placement time and puddled condition of the soil and it was varied 2.46-3.72 km hr^{-1}. Field capacity was observed 0.13 and 0.14 ha hr^{-1} during Boro and Aman season, respectively whereas manual USG application capacity was observed about 0.02 ha hr^{-1}. The depth of USG placement by the applicator (6.01-6.32 cm) was found more compared to manual application (5.61-5.75 cm). The yield performance of USG plots was identical in all locations during both the seasons either applied by hand or by machine. However, in some cases, USG gave significantly higher grain yield compared to prilled urea applied by hand broadcasting method.Modified BRRI USG applicator saved urea fertilizer, ensured proper placement of USG in subsurface zone and reduced drudgery without sacrificing grain yield.

Key words: Field capacity, placement depth, grain yield

INTRODUCTION

Urea is one of the major essential elements of plant. The plant takes nutrient available in the root-zone as food for growth and increase of yield. The ultimate aim of applying fertilizer at the root-zone is to meetup the deficiency of the plant. Farmers of Bangladesh use urea as a source of nitrogen of which major portion is imported at the expense of hard earning foreign currency. In 2008-09, Bangladesh government imported 137.5 million tons of urea (BBS, 2015). The field efficiency of urea is very low and the main nitrogen loss processes are: Ammonia volatization, nitrification, denitrification, leaching and run off. Other important nitrogen transformations are biological immobilization, ammonia fixation by clay minerals, and soil organic matter. In this way loss of about 20-30% of the total applied fertilizer occurred (Craswell and Vlek, 1979). The most attractive practice to a farmer in terms of application is to broadcast prilled urea on the top soil in which farmer can fertilize two hectares in one day. However, with the ever increasing demand of fertilizer, the practice of surface broadcasting is uneconomical and wasteful since 20% of the broadcast fertilizer is lost by ammonium volatilization alone in the surface water (De Datta, 1978).

On the other hand, the efficiency of granular urea is more than prilled urea. Moreover, farmers can get 20% more yield using granular urea (AIS, 2008). Deep placement of urea super granules in transplanted rice is an agro-nominally efficient and environmentally safe as compared with the traditional application method of prilled urea. The proper deep placement of USG decreases urea-N losses, improves N availability to rice plants and eventually helps to increase grain

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yields significantly, especially at N rates that small rice farmers can afford. Granular urea is to be placed at 8-10 cm deep at the center of four consecutive hills of two adjacent rows at 10-15 days after transplanting (Bhuiyan *et al.*, 1998).

On the basis of size and weight, granular urea becomes different. A 90 milligram weight granule is known as urea super granule (USG). Three USG are used in one place for Boro rice and two for Aus and Aman rice. Another two types of USG granules (1.8 and 2.7 g) are known as urea mega granule (UMG). For Aus and Aman rice cultivation, one USG of 1.8 and 2.7 g are used in one place respectively (Huda and Khan, 2014).

However, the deep placement of USG by hand after transplanting is a slow field operation thus requiring much labour. This labour intensiveness and drudgery of placing USG manually have seriously limited USG adoption by rice farmers in South and Southeast Asia (Savant *et al.*, 1992). About 6-8 work day ha^{-1} is required for manual placement of USG in rice transplanted field. Hence, a mechanical device is necessary to improve the work efficiency of labour. Applicators of IFDC, IRRI and Chinese model have been tested at BRRI in 1998. All these are not found effective in the field and do not push the USG inside the soil surface. On the other hand, metering device and skidding mechanism do not work properly and leads to miss the pickup of USG from the hopper resulting missing placement in the field. BRRI designed and developed a push type manually operated USG applicator overcoming those problems (Hossen *et al.*, 2013). Initially, the applicator was designed for 20 × 20 cm spacing. The applicator was modified for 18, 20 and 20 cm line to line spacing with adjustable mechanism (Hossen *et al.*, 2013). Both models were evaluated only in BRRI research farm, Gazipur. Therefore, there is a need to evaluate the modified USG applicator in different locations. Therefore, the present study was undertaken to evaluate the modified BRRI USG applicator in the farmers' field and BRRI RS during the Boro and Aman seasons for large scale validation.

OBJECTIVES

The objectives of the study were to:

- Observe the field performance of the applicator using 1.8 and 2.7g size granule during Aman and Boro season, respectively.
- Compare the yield performance with traditional application of prilled and USG fertilizer

METHODOLOGY

USG applicator was designed for two rows application of fertilizer in a single pass using AutoCAD drawing tools. According to the design, prototype was fabricated in the research workshop and tested in the laboratory and BRRI research fields. During the test, problems regarding USG dispensing efficiency, USG clogging, furrow opening and covering and depth of placement of USG were collected for further improvement of the applicator. After rectification of the problems, field trials were conducted in the farmers' field during Aman 2011 and Boro 2012 seasons.

Performance test of the applicator

BRRI USG applicator was tested using urea mega granules (2.7 gm size of USG) in both laboratory and field condition to observe the performance. During the test, following data were collected:

- USG dispensing efficiency (%)
- Depth of placement (cm)
- Accuracy of placement between rows (%)
- Walking speed (km hr^{-1})
- Field capacity (ha hr^{-1})

Applicator operation

There are three options to adjust the spacing of the applicator considering the line to line distance of the transplanted rice. Two nuts of the main axle, four nuts of the frame and two nuts of the handle have to be adjusted among the three options of 18, 20 or 22 cm considering the existing line spacing of the transplanted rice before field operation (Fig. 1).

Fig. 1. Adjusting mechanism of the applicator with line spacing.

Handle height also have to be adjusted in such way that the operator feels comfort to operate the applicator and covering device remain in contact with the soil horizontally (Fig. 1). It is always operated by pushing force. During pulling, muddy soil blocked the dispensing channel and restricted the flow of granules.

Field trials of the USG applicator during Aman 2011 and Boro 2012

BRRI dhan49 was cultivated in all the regional stations and BRRI dhan33 was cultivated only in the farmer's field of Netrokona district in Aman season. BRRI dhan29 were cultivated in all the locations in Boro season. Thirty-five to 40-day-old seedlings were transplanted manually. In Both the seasons, 20 × 20 cm spacing were maintained. Sizes of USG were 1.8 g (mega size) for Aman and 2.7 g (mega size) for Boro season. Table 1 and Table 2 present the general information of the experiments.

Design

The following treatments were arranged in a randomized complete block (RCB) design with three replications.

- T_1 = USG application by USG applicator
- T_2 = Manual application of USG
- T_3 = Hand broadcasting of prilled urea

Fertilizer dose in terms of USG was same for T_1 and T_2. Prilled urea was broadcast in T_3 by hand on the basis of BRRI recommended dose. Other fertilizer and management practices were the same for all treatments.

Data were collected on

- Time required to apply urea in the field (hr ha^{-1}) for all treatments
- Capacity of BRRI USG applicator and manual application of USG
- Plant height and tiller number at different days after transplanting
- Yield and yield components

Location in Aman season

Total number of six field trials was conducted in BRRI research farm, Gazipur and BRRI regional stations of Kushtia, Rajshahi, Rangpur, Comilla and one in farmer's field, Netrakona to observe the field performance of the applicator (Table 1).

Location in Boro season

Eleven field trials were conducted in different locations of the country during Boro 2011 season (Table 2). The locations were (i) Baria, sadar upazila, Kushtia (Kushtia-1), (ii) Tarapur,

Table 1. General information of the experimental plots, Aman 2011.

Location	Fertilizer rate (kg ha^{-1})						D/T	D/USG App	Date of harvesting
	TSP	MoP	Gyp.	$ZnSO_4$	PU	USG			
BRRI RS, Kushtia	52	60	35	5	210.0	118.0	24/07/10	03/08/10	29/11/10
BRRI RS, Rajshahi	62	80	45	5	172.0	118.0	05/08/10	16/08/10	15/11/10
BRRI, Gazipur	76	90	45	5	172.0	118.0	10/08/10	22/08/10	25/11/10
Purbadhala, Netrakona	65	70	40	10	170.0	118.0	10/08/10	23/08/10	10/11/10
BRRI RS, Comilla	75	100	60	10	210.0	118.0	20/08/10	30/08/10	01/12/10
BRRI RS, Rangpur	80	100	60	10	175.0	118.0	14/08/10	25/08/10	30/11/10

Table 2. General information of the experimental plots, Boro 2012.

Location	Fertilizer rate (kg ha^{-1})						D/T	D/USG App	Date of harvesting
	TSP	MoP	Gyp.	$ZnSO_4$	PU	USG			
Kushtia-1	100	120	70	15	285	168	30/12/10	10/01/10	07/05/11
Kushtia-2	100	120	70	15	285	168	04/01/11	11/01/11	15/05/11
Habiganj-1	90	100	60	12	280	168	10/01/11	19/01/11	15/05/11
Habiganj-2	90	100	60	12	280	168	02/02/11	14/02/11	09/05/11
Habiganj-3	90	100	60	12	280	168	10/01/11	20/01/11	10/05/11
Comilla-1	110	125	75	18	340	168	28/01/11	15/02/11	18/05/11
Comilla-2	110	125	75	18	340	168	27/01/11	09/02/11	19/05/11
Rangpur-1	100	120	65	15	280	168	24/01/11	06/02/11	21/05/11
Netrakona-1	100	120	70	15	285	168	13/01/11	25/01/11	27/05/11
Netrakona-2	100	120	70	15	285	168	25/01/11	05/02/11	01/05/11
Rajshahi-1	100	120	75	18	300	168	12/02/11	24/02/11	12/05/11

Note: 1 hectare = 247.16 decimal, D/T=Date of transplanting, D/USG App.=Date of USG application and PU=Prilled urea, TSP-Tripple super phosphate, MoP-Murate of potash, Gyp.-Gypsum and $ZnSO_4$-Zinc Sulphate.

Kumarkhali upazila, Kushtia (Kushtia-2), (iii) Richi, sadar upazila, Habiganj (Habiganj-1), (iv) Churango-rayer-para, Baniachang, Habiganj (Habiganj-2), (v) BRRI RS, Habiganj (Habiganj-3), (vi) Kharataiya, Burhichang upazila, Comilla (Comilla-1), (vii) Narpati, Laksam upazila, Comilla (Comilla-2), (viii) Akkelpur, sadar upazila, Rangpur (Rangpur-1), (ix) Challisha, sadar upazila, Netrokona (Netrokona-1), (x) Gohalakanda, Purbadhala upazila, Netrokona (Netrokona-2) and (xi) Khasba, Paba upazila, Rajshahi (Rajshahi-1).

Fig. 2. BRRI USG applicator.

RESULTS

As per design of the applicator, it was fabricated in the FMPHT research workshop. Figure 2 shows the complete view of the fabricated applicator.

Laboratory test of the applicator

During test, applicator was setup at upper position in such a way that the drive wheel moves easily. Two-third portion of the tank was filled with granule. The drive wheel was rotated for 20 times continuously at normal speed and then the dispensed granules were collected from the bottom of the output channel. Dispensing efficiency was calculated by counting the number of dispensed granule. In laboratory test conditions, dispensing efficiency was found around 99%. Table 3 presents the result of the laboratory test.

Field test of the applicator

BRRI USG was operated in BBRI, Gazipur research plot to observe the performance and compare with tradition placement method of USG. During field operation of the applicator, the walking speed of the operator was found 1.95 km hr^{-1}. Field capacity were about 32.5 decimal hr^{-1} whereas manual USG

Table 3. Laboratory test results of the applicator, 2012.

No. of trial	No. of rotation	No. of USG dispensed	% of dispensed USG
1	20	102	100
2	20	100	100
3	20	97	97
4	20	98	98
5	20	99	99
6	20	100	100
Average			99

Table 4. Field performance of the improved Applicator, 2012.

Item	BRRI USG applicator	Traditional application
Walking speed (km hr^{-1})	1.95	-
Field capacity (ha hr^{-1})	0.13	0.018
Depth of placement (cm)	5-6	4-5
Wt. of dispensed USG (kg ha^{-1})	165	165

application capacity was found 4.5 decimal hr^{-1}. The depth of placement of the granule was 5-6 cm for applicator and 4-5 cm for manual placing (Table 4).

Amount of dispensed granules

Fertilizer dose was varied with different adjustments. Normally 168 kg urea for Boro and 112 kg urea for Aman season is recommended as USG form. Design rate of USG dispensing in Boro season is 187, 168 and 153 kg ha^{-1} for the arrangement of line to line spacing 18, 20 and 22 cm whereas it is 125, 112 and 102 kg ha^{-1} in Aman season (Table 5).

Field trials of USG applicator during Aman 2011

Applicator performance. During field operation of the applicator, the walking speed of the operator was found 3.72 km hr^{-1} and field capacity was about 36 decimal hr^{-1} (0.146 ha hr^{-1}) whereas manual USG application capacity was found 4.5 decimal hr^{-1} (0.018 ha hr^{-1}). The depth of placement of the granule was around 6.32 cm (Table 6).

Yield performance. There was no significant yield variation observed in different N fertilization method in studied six locations except Kushtia (Table 7). In Kushtia, yield was significantly higher when N was applied as USG applying by USG applicator than other treatments. In all the cases, USG gave higher yield than prilled urea. Although there

Table 5. Amount of dispensed granules for three different adjustment of the applicator.

Season	Recommended size of granules (g)	Amount of USG dispensed (kg)		
		Spacing 18 × 20 cm	Spacing 20 × 20 cm	Spacing 22 × 20 cm
Boro	2.7	187	168	153
Aman	1.8	125	112	---

Table 6. Field performance of the BRRI USG applicator during Aman 2011.

Place	Walking speed (km hr^{-1})	Field capacity (ha hr^{-1})		Depth of of placement (cm)		Wt of dispensed USG (kg ha^{-1})	
		App.	Hand	App.	Hand	App.	Hand
BRRI, Gazipur	3.45	0.134	0.018	6.8	5.8	118.5	112
BRRI RS, Kushtia	3.95	0.157	0.015	6	5.4	119.5	115.5
BRRI RS, Rajshahi	3.55	0.139	0.021	6	5.9	118	110
BRRI RS, Rangpur	3.87	0.152	0.019	6	5.5	116.7	112.5
BRRI RS, Comilla	3.9	0.157	0.017	6.6	5.7	119.5	116
Netrakona	3.6	0.136	0.02	6.5	6.2	120	114
Average	3.72	0.146	0.018	6.32	5.75	118.7	113.33

Table 7. Yield performance of BRRI varieties in different locations as affected by different methods of N fertilization.

Treat	Yield (t ha^{-1})						Av. yield (t ha^{-1})	
	BRRI RS Kushtia	BRRI RS Rajshahi	BRRI Gazipur	Netrakona	BRRI RS Comilla	BRRI RS Rangpur	BRRI dhan49	BRRI dhan33
	BRRI dhan49	BRRI dhan49	BRRI dhan49	BRRI dhan33	BRRI dhan49	BRRI dhan49		
T_1	5.75	4.96	4.97	4.85	4.93	5.05	5.13	4.85
T_2	5.34	5.58	4.63	4.98	4.66	5.24	5.09	4.98
T_3	4.80	4.67	4.45	4.17	4.51	4.75	4.64	4.17
% CV	3.5	6.6	7.2	6.6	10.5	8.5	-	-
$LSD_{0.05}$	0.82	ns	ns	ns	ns	ns	-	-

was no significant difference in studied three treatments but USG gave around 0.5 t ha^{-1} more yield than prilled urea. It might be due to the USG produced higher effective tiller m^{-2} as well as higher grains m^{-2} resulted in higher yield (Tables 8-13).

Yield parameters

BRRI RS, Kushtia. Tiller number at 55 DAT and at harvest was found statistically similar in both T_1 and T_2 applying USG by hand and machine respectively whereas it was found significantly less in T_3 applying prilled urea by broadcasting method. But plant height was found 105.5, 103.5 and 105.2 cm for three treatments respectively. Average panicle length was 20.93, 20.32 and 21.42 cm and grains per panicle were 97, 95 and 98 nos. for T_1, T_2 and T_3, respectively. But plant height, grains per panicle and percent of sterility were found statistically identical in all treatments. Number of effective tillers per m^2 was 293, 278 and 248 and 1000 g was 20.35, 20.52 and 20.05 g for T_1, T_2 and T_3, respectively. Number of effective tiller was statistically identical in the both T_1 and T_2 whereas it was significantly less in T_3. Yield (t ha^{-1}) was found 5.75, 5.34 and 4.80 for T_1, T_2 and T_3 respectively. Yield of T_2 was statistically similar with T_1 and T_3 was similar with T_2. Moreover, yield in T_1 was significantly more than T_3 (Table 8).

BRRI RS, Rajshahi. Yield and yield contributing parameters for T_1, T_2 and T_3 were found statistically identical at BRRI RS, Rajshahi. The panicle length was 19.03, 19.40 and 19.13 cm and grain panicle^{-1} was 96, 96 and 99 for T_1, T_2 and T_3 respectively. Number of effective tillers per m^2 was 261, 295 and 235 and 1000 grain weight was 19.75, 19.55 and 19.68 g for T_1, T_2 and T_3 respectively. Yield (t ha^{-1}) was found 4.96, 5.58 and 4.67 for T_1, T_2 and T_3, respectively (Table 9).

BRRI HQ, Gazipur. Yield and yield contributing parameters for T_1, T_2 and T_3 were found statistically identical at BRRI HQ, Gazipur. Average panicle length was 20.13, 20.70 and 20.30 cm and grains per panicle were 92, 96 and 98 for T_1, T_2 and T_3, respectively. Number of effective tillers per m^2 was 285, 254 and 245 and 1000 grain weight (TGW) was 19.20, 19.14 and 18.80 g for T_1, T_2 and T_3, respectively. Yield (t ha^{-1}) was found 4.97, 4.63 and 4.45 for T_1, T_2 and T_3, respectively (Table 10).

Farmer's field in Netrakona. Tiller number at 25 and 55 DAT was significantly higher in T_2 compared to T_3. Tiller number of T_2 and T_3 at 25 and 55 DAT was statistically similar with T_1. Tiller number at harvest was found statistically identical in all treatments. Moreover plant height and panicle length was found identical for all the treatments. Grains panicle^{-1} were 109, 111 and 99 for T_1, T_2 and T_3 and both of T_1 and T_2 was significantly higher than T_3. Panicles per m^2 were found 230, 232 and 217 for T_1, T_2 and T_3 and all was statistically identical. Percent of sterility was found significantly higher in T_3 compared to T_1 and T_2 whereas it was higher in T_1 compared to T_2. TGW was 19.26, 19.42 and 19.31 g for T_1, T_2 and T_3 respectively. TGW was statistically identical for all treatments. Yield (t ha^{-1}) was found 4.85, 4.98 and 4.17 for T_1, T_2 and T_3 respectively which was statistically identical (Table 11).

Table 8. Performance of yield and yield contributing parameters, BRRI RS, Kushtia.

Treat.	No. of tillers per m² at			Plant height (cm)	Panicle length (cm)	Grain per panicle	No. of effective tillers per m²	Sterility (%)	TGW at 14% m.c. (g)	Yield at 14% m.c. (t ha^{-1})
	25 DAT	55 DAT	harvest							
T_1	318	399	366	105.5	20.93	97	293	19.85	20.35	5.750
T_2	278	362	341	103.5	20.32	95	278	16.55	20.52	5.343
T_3	232	320	308	105.2	21.43	98	248	17.56	20.05	4.803
% CV	5.96	5.24	3.90	1.02	4.50	3.70	3.68	16.85	0.55	4.97
$LSD_{0.05}$	ns	42.74	29.91	ns	ns	ns	22.74	ns	ns	0.59

Table 9. Performance of yield and yield contributing parameters, BRRI RS, Rajshahi.

Treat.	No. of tillers per m² at			Plant height (cm)	Panicle length (cm)	Grain per panicle	No. of effective tillers per m²	Sterility (%)	TGW at 14% m.c. (g)	Yield at 14% m.c. (t ha^{-1})
	25 DAT	55 DAT	harvest							
T_1	248	387	362	103.0	19.03	96	261	10.13	19.75	4.96
T_2	249	400	388	103.3	19.40	96	295	12.97	19.55	5.58
T_3	226	346	329	101.9	19.13	99	235	12.63	19.68	4.67
% CV	7.54	8.33	7.11	1.02	4.55	9.27	9.95	29.30	1.83	15.73
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 10. Performance of yield and yield contributing parameters, BRRI HQ, Gazipur.

Treat.	No. of tillers per m² at			Plant height (cm)	Panicle length (cm)	Grain per panicle	No. of effective tillers per m²	Sterility (%)	TGW at 14% m.c. (g)	Yield at 14% m.c. (t ha^{-1})
	25 DAT	55 DAT	harvest							
T_1	256	346	334	97.97	20.13	92	285	9.970	19.20	4.973
T_2	260	328	311	98.27	20.70	96	254	12.59	19.14	4.633
T_3	241	309	296	96.80	20.30	98	245	9.793	18.80	4.450
% CV	14.11	9.60	8.72	2.91	4.62	11.29	11.26	32.23	2.00	9.42
$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

Table 11. Performance of yield and yield contributing parameters, farmer's field at Netrakona.

Treat.	No. of tillers per m² at			Plant height (cm)	Panicle length (cm)	Grain per panicle	No. of effective tillers per m²	Sterility (%)	TGW at 14% m.c. (g)	Yield at 14% m.c. (t ha^{-1})
	25 DAT	55 DAT	harvest							
T_1	220	291	279	106.7	23.07	109	230	16.15	19.26	4.85
T_2	231	298	283	101.4	23.37	111	232	13.92	19.42	4.98
T_3	212	274	274	101.2	21.83	99	217	18.57	19.31	4.17
% CV	2.84	2.76	4.06	9.12	5.77	2.65	6.24	5.45	3.19	9.53
$LSD_{0.05}$	14.3	17.9	ns	ns	ns	6.4	ns	2.0	ns	ns

BRRI RS, Comilla. Yield and yield contributing parameters for T_1, T_2 and T_3 was found statistically identical at BRRI RS, Comilla except grains per panicle. Average panicle length was 21.17, 20.40 and 20.13 cm and grains per panicle were 88, 86 and 42 for T_1, T_2 and T_3, respectively. Grain panicle^{-1} was significantly higher in T_1 compared to T_3 and statistically similar with T_2 whereas T_3 also statistically similar with T_2. Number of effective tillers per m^2 was 299, 297 and 297 and TGW was 19.33, 19.03 and 19.32 g for T_1, T_2 and T_3 respectively, which was statistically identical in all treatments. Yield (t ha^{-1}) was found 4.927, 4.657 and 4.510 for T_1, T_2 and T_3 respectively (Table 12).

BRRI RS, Rangpur. Yield and yield contributing parameters for T_1, T_2 and $T_3$was found statistically identical at BRRI RS, Rangpur. Average panicle length was 20.17, 18.63 and 19.67 cm and grains per panicle was 96, 97 and 106 for T_1, T_2 and T_3, respectively. Number of effective tillers per m^2 was 273, 286 and 244 and TGW was 19.50, 19.34 and 18.77 g for T_1, T_2 and T_3, respectively. Yield (t ha^{-1}) was found 5.05, 5.24 and 4.75 for T_1, T_2 and T_3 respectively (Table 13).

Field trials of USG applicator in Boro 2012

Applicator performance. BRRI USG was operated in different 11 locations of the country to evaluate the field performance of the applicator. During field operation of the applicator average walking speed of the operator was found 2.46 km hr^{-1} and average field capacity was 32.97 decimal hr^{-1} whereas manual USG application capacity was found 4.94 decimal hr^{-1}. Average depth of placement of the granule was around 6.01 cm (Table 14). Average 162 kg of USG fertilizer was dispensed per hectare during applicator operation whereas 169.25 kg of USG fertilizer for hand application.

Yield performance. There were significant yield variation observed in different N fertilization method in studied locations

Table 12. Performance of yield and yield contributing parameters, BRRI RS, Comilla.

Treat.	No. of tillers per m^2 at			Plant height (cm)	Panicle length (cm)	Grain per panicle	No. of effective tillers per m^2	Sterility (%)	TGW at 14% m.c. (g)	Yield at 14% m.c. (t ha^{-1})
	25 DAT	55 DAT	harvest							
T_1	250	349	322	99.63	21.17	88	299	14.67	19.33	4.927
T_2	244	352	320	100.1	20.40	86	297	13.33	19.03	4.657
T_3	238	343	317	95.54	20.13	82	297	16.00	19.32	4.510
% CV	2.90	4.02	1.57	2.37	3.16	2.98	2.41	7.87	1.35	5.48
$LSD_{0.05}$	ns	ns	ns	ns	ns	5.8	ns	ns	ns	ns

Table 13. Performance of yield and yield contributing parameters, BRRI RS, Rangpur.

Treat.	No. of tillers per m^2 at			Plant height (cm)	Panicle length (cm)	Grain per panicle	No. of effective tillers m^{-2}	Sterility (%)	1000 grains weight at 14% m.c. (g)	Yield at 14% m.c. (t ha^{-1})
	25 DAT	55 DAT	harvest							
T_1	244	313	303	87.73	20.2	96	273	14.61	19.50	5.05
T_2	257	308	290	82.60	18.6	97	286	16.02	19.34	5.24
T_3	242	293	286	84.27	9.7	106	244	3.33	18.77	4.75
% CV	2.97	3.24	3.80	5.96	2.9	7.01	8.31	10.87	0.91	7.60
$LSD_{0.05}$	ns	ns	ns	ns	1.3	ns	ns	ns	0.40	ns

Table 14. Field performance of the BRRI USG applicator operated in different places during Boro 2012.

Place	Time of operation[1] (min)		Area (decimal)		Walking speed (km hr^{-1})	Field capacity (ha hr^{-1})		Depth of of placement (cm)		Wt. of dispensed USG (Kg ha^{-1})	
	App	Hand	App	Hand	App	App	Hand	App	Hand	App	Hand
Kushtia	65	418	35	35	2.4	0.13	0.02	6.0	5.5	165.0	169.0
Kumarkhali	62	265	30	20	2.2	0.12	0.02	5.9	5.2	169.0	172.0
Habiganj	47	114	25	10	2.8	0.13	0.02	5.8	5.8	162.0	169.0
Baniachang	48	53	25	5	2.8	0.13	0.02	6.0	5.8	158.0	165.0
BRRI, Habiganj	26	51	16	4	2.2	0.15	0.02	6.2	6.0	162.0	167.0
Burhichang	50	42	25	5	2.5	0.12	0.03	6.0	5.5	160.0	169.0
Laksam	51	49	25	5	2.2	0.12	0.02	6.2	5.6	162.0	169.0
Rangpur	50	50	25	5	2.9	0.12	0.02	5.9	5.1	156.0	172.0
Netrakona	46	49	25	5	2.3	0.13	0.02	6.1	5.4	160.0	170.0
Purbadhala	47	51	25	5	2.2	0.13	0.02	6.2	6.0	162.0	168.0
Rajshahi	36	92	20	8	2.3	0.13	0.02	6.0	6.0	165.0	170.0
Average					2.46	0.13	0.02	6.01	5.61	162	169.25

except BRRI RS, Habiganj; Burhichang, Akkelpur, Rangpur (Table 15). In kushtia (Sadar and Khumarkhali), Habiganj (Sadar and Baniachang), Laksam, Comilla; Netrakona (Sadar and Purbadhala) and Paba, Rajshahi, yield was significantly higher when N was applied as USG using both traditional method and USG applicator than prilled urea. In all the cases, USG gave higher yield than prilled urea. Although the performance of USG applied by USG applicator and hand was not consistent. In some locations, hand applied USG gave higher yield than applicator applied USG or vice versa. Considering the average yield of 12 locations; USG gave around 0.75 t ha^{-1} more yield than prilled urea. It might be due to the USG produced higher effective tiller m^2 as well as higher grains per m^2 resulted of higher yield.

DISCUSSION

Urea fertilizer is one of the most essential chemical fertilizers for growing rice all over the world (Prashad *et al.*, 1979). The urea application method in the rice fields depends on the types of urea fertilizer. In Bangladesh, USG applicators are being developed and improved by BRRI, Bangladesh Agricultural Research Institute (BARI) and International Fertilizer Development Center (IFDC) (Kshirode, 2010). BRRI developed USG

Table 15. Yield performance of BRRI varieties in different locations as affected by different methods of N fertilization.

Treat	Yield (t ha^{-1})											Av. yield (t ha^{-1})
	Sadar, Kushtia	Kumar., Kushtia	Sadar, Habi.	Bania-chang	BRRI Habi	Burirchang	Laksam	Sadar, Rang.	Netrakona	Purbadhala	Paba Raj.	
T_1	8.50	9.96	7.68	7.97	8.08	8.25	7.58	6.83	7.52	7.33	8.56	8.02
T_2	8.62	10.2	7.94	8.22	8.28	8.23	7.71	6.55	7.59	7.47	8.60	8.13
T_3	8.03	9.38	6.82	6.63	8.11	7.79	6.44	6.20	6.64	6.64	7.99	7.33
% CV	0.99	2.10	0.81	2.65	3.61	3.08	4.01	4.42	2.76	3.04	2.14	-
$LSD_{0.05}$	0.45	0.52	0.22	1.25	ns	ns	0.92	ns	0.74		0.38	-

Note: Kumar=Kumarkhali, Habi=Habiganj, Rang=Rangpur, Raj=Rasjshahi

applicator was used to apply USG in non-oxidized zone at 6-10 cm depth from surface at desired spacing to maintain the recommended USG fertilizer doses of 118 and 168 kg ha^{-1} during Aman and Boro season respectively (Hossen *et al.,* 2013). Recommended dose of fertilizer could be applied only maintaining the standard line to line spacing 20 cm. There are possibilities of under and over dose of fertilizer for 18 and 22 cm adjustment of the applicator, respectively. Therefore, it is recommended to use the applicator for standard 20 cm line to line spacing. However, 20 × 20 cm line to line spacing gave higher grain yield (Das *et al.,* 2013). In laboratory condition, dispensing percentage was observed about 99%. The capacity of BRRI model was high, but breakage percentage was more than 10% (Ahamed *et al.,* 2014).

Field performance of any wetland machine depends on machine maneuverability, field pattern, shape and size, soil condition and system limitation (Hunt, 1995). Field capacity of BRRI USG applicator also varied soil to soil, season to season and research field to farmers' field. Walking speed directly influenced the field capacity of the applicator. Walking speed during field operation of the applicator was observed 1.95 km hr^{-1} in research field Gazipur whereas average walking speed of operation in different locations and different soil conditions was 3.72 and 2.46 km hr^{-1} in Aman and Boro season, respectively. Clay muddy soil without ploughpan hindered the walking speed during operation in Gazipur. However, optimum softness and depth of plough in Aman season due to prolonged submergence of soil by rain water influenced the field operation of the applicator resulting more walking speed. Contrary to, insufficient depth of plough in Boro season reduced the walking speed of the applicator operation.

Depth of USG placement and proper covering improve the efficiency of USG application. Effect of depth USG in depth placing significantly influenced the grain yield as well as yield contributing parameters (Das *et al.,* 2013) and 5 to 10 cm depth of placement was found optimum for higher grain yield (Jing Xiang *et al.*, 2013). In this study, it was observed that the average depth of placement of mechanical application varied from 6.01 to 6.32 cm in Aman and Boro seasons whereas it was less in manual application: 5.61 to 5.75 cm. Depth of placement was apparently more in Aman season compared to that of the Boro season in both mechanical and manual application.

The yield performance of USG was applied by USG applicator or by hand was not consistent. In all locations during both the seasons, grain yield was identical of USG plots either applied by hand or machine. However, in some cases, USG gave significantly higher grain yield compared to prilled urea applied by hand broadcasting method. Although there was no significant difference found in some studied areas, USG gave around 0.5 t ha^{-1} and 0.75 t ha^{-1} higher grain yields than prilled urea. It might be due to the USG produced higher effective tillers per m^2 as well as higher grains m^2 resulted in higher yield. The result is coincided with the findings Bandaogo *et al*. (2014). However, Bhuiyan *et al.,* 1988 and Mohonty *et al*., 1990 noticed that the deep placement of USG gave significantly higher grain yield of rice than split application of prilled urea. Islam *et al*. (2015) observed in two locations that the deep placement of USG and prilled urea by USG applicator (4.91 t ha^{-1}) and prilled urea applicator (4.84 t ha^{-1}), respectively gave higher grain yield compared to the hand broadcasting of prilled urea fertilizer (4.67 t ha^{-1}) while both the applicators saved 30% of urea fertilizer.

CONCLUSION

BRRI USG applicator was found suitable as proper placing of urea briquette fertilizer and labour saving technology in both the Boro and Aman seasons. The operation of USG applicator is easier and has less drudgeries. Response of deep placement of USG fertilizer was more in Boro season compared to Aman season. The yield performance of USG applied by USG applicator or by hand was significantly

higher compared to prilled urea applied by hand broadcasting method whenever there was no difference between hand and manual application of USG on grain yield and yield contributing parameters.

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